

## Defining Objectives Checklist

| <b><i>Checklist Item</i></b>   | <b><i>Status</i></b> |
|--|----------------------|
| <i>Project kick-off and stakeholders defined</i>   |                      |
| <i>Clearly enumerate and define objectives</i>   |                      |
| <i>Define how wireless will support objectives</i>   |                      |
| <i>Define how wireless performance will be measured and how wireless performance directly correlates to enterprise objectives.</i> |                      |
| <i>Define how wireless in general will grow over time within the factory enterprise.</i>   |                      |
| <i>Develop a security management plan for the operation.</i>   |                      |
| <i>Conduct a preliminary spectral occupancy survey within the factory.</i>   |                      |
| <i>Establish or update the spectrum management plan.</i>   |                      |

## Factory Survey Checklist

| <i>Checklist Item</i>   | <i>Status</i> |
|---|---------------|
| <i>Review the role that wireless technology will take in meeting enterprise objectives.</i>   |               |
| <i>Review how wireless performance will be measured and how wireless performance directly correlates to enterprise objectives.</i>  |               |
| <i>Review the security risk level.</i>  |               |
| <i>Update the security plan for the operation.</i>  |               |
| <i>Conduct a thorough spectral occupancy survey</i> <ul style="list-style-type: none"> <li>• <i>Identify existing wireless devices and operating bands</i></li> <li>• <i>Identify sources of EMI</i></li> </ul>   |               |
| <i>Update the spectrum management plan.</i>   |               |
| <i>Update security management plan.</i>   |               |
| <i>Assess the existing physical factory design. Obtain factory inventory to include the following: Physical layout, operational model, measurement points, control points, machines, materials, monitoring systems, and databases</i>   |               |
| <i>Select points in which wireless will be used to monitor or control the operation</i>   |               |
| <i>Identify mobile devices and uses</i>   |               |
| <i>Determine signal specifications</i>  |               |
| <i>Determine technical requirements to meet the performance constraints of downstream data analysis, monitoring, and control applications.</i> <ul style="list-style-type: none"> <li>• <i>Number of Devices</i></li> <li>• <i>Latency</i></li> <li>• <i>Reliability</i></li> <li>• <i>Throughput</i></li> <li>• <i>Sensitivity analysis</i></li> <li>• <i>Future growth potential</i></li> </ul> |               |
| <i>Identify power sources that may be leveraged</i>   |               |
| <i>Identify safety issues</i>   |               |

## Candidate Selection Checklist

| <b><i>Checklist Item</i></b>  | <b><i>Status</i></b> |
|---|----------------------|
| <i>Review the role wireless technology will take in meeting enterprise objectives.</i>  |                      |
| <i>Review how wireless performance will be measured and how wireless performance directly correlates to enterprise objectives.</i>  |                      |
| <i>Review the security management plan and objectives.</i>  |                      |
| <i>Develop a security plan for the operation.</i>   |                      |
| <i>Conduct a thorough spectral occupancy survey</i> <ul style="list-style-type: none"> <li>• <i>Identify existing wireless devices</i></li> <li>• <i>Identify existing operating bands</i></li> <li>• <i>Identify sources of EMI</i></li> </ul>   |                      |
| <i>Update the spectrum management plan.</i>   |                      |
| <i>Update security management plan.</i>   |                      |
| <i>Assess the existing physical factory design. Obtain factory inventory to include the following: physical layout, operational model, measurement points, control points, machines, materials, monitoring systems, and databases</i>   |                      |
| <i>Select points in which wireless will be used to monitor or control the operation</i>   |                      |
| <i>Identify mobile devices and uses.</i>  |                      |
| <i>Determine signal specifications.</i>   |                      |
| <i>Determine technical requirements to meet the performance constraints of downstream data analysis, monitoring, and control applications.</i> <ul style="list-style-type: none"> <li>• <i>Number of Devices</i></li> <li>• <i>Latency</i></li> <li>• <i>Reliability</i></li> <li>• <i>Throughput</i></li> <li>• <i>Sensitivity analysis</i></li> <li>• <i>Future growth potential</i></li> </ul> |                      |
| <i>Identify power sources that may be leveraged.</i>  |                      |
| <i>Identify safety issues.</i>  |                      |
| <i>Identify needs of regulatory approval to operate for each candidate</i>  |                      |
| <i>Define cost targets</i>  |                      |
| <i>Define past-performance evaluation criteria and compare to the candidates</i>  |                      |
| <i>Assess requirements compliance for each candidate.</i>   |                      |

## Candidate Scoring Checklist

| <i>Requirement</i>               | <i>Weight</i> | <i>Specification</i> | <i>Candidate 1</i> | <i>Candidate 2</i> | <i>...</i> | <i>Candidate N</i> |
|----------------------------------|---------------|----------------------|--------------------|--------------------|------------|--------------------|
| <i>RF Operating Band</i>         | 1             | 902 to 928 MHz       | 1                  | 1                  |            | 1                  |
| <i>Range</i>                     | 1             | 30 meters            | 1                  | 1                  |            | 1                  |
| <i>Latency</i>                   | 1             | 100 milliseconds     | 1                  | 0                  |            | 1                  |
| <i>Data Delivery Reliability</i> | 1             | 99%                  | 1                  | 1                  |            | 1                  |
| <i>Reboot to Operation Time</i>  | 1             | < 30 seconds         | 1                  | 1                  |            | 0                  |
| <i>Over-the-air re-keying</i>    | 0.75          | Yes/No               | 0                  | 1                  |            | 0                  |
| <i>Number of Devices</i>         | 0.8           | 100                  | 1                  | 1                  |            | 1                  |
| <i>Power source</i>              | 0.6           | 24 VDC               | 1                  | 1                  |            | 1                  |
| <i>Battery Life</i>              | 1             | 1 year               | 1                  | 1                  |            | 1                  |
| <i>Interoperation</i>            | 1             | OPC-UA               | 1                  | 1                  |            | 1                  |
| <i>Maintainability</i>           | 0.75          | Qualitative          | 0.8                | 0.9                |            | 0.5                |
| <i>Security Compliant</i>        | 1             | Yes/No               | 1                  | 1                  |            | 1                  |
| <i>Regulatory Compliant</i>      | 1             | Yes/No               | 1                  | 1                  |            | 1                  |
| <i>Intrinsic safety rating</i>   | 1             | Class 1, Div. 2      | 1                  | 1                  |            | 1                  |
| <i>Training Provided</i>         | 0.5           | Yes/No               | 1                  | 1                  |            | 1                  |
| <i>Simplicity of Use</i>         | 0.5           | Qualitative          | 1                  | 1                  |            | 1                  |
| <i>Price</i>                     | 0.75          | Under \$X            | 1                  | 1                  |            | 1                  |
| <i>Past performance</i>          | 0.75          | Two written          | 1                  | 0.5                |            | 0                  |
| <i>Weight Sum (Score)</i>        |               |                      | 13.5               | 12.95              |            | 11.525             |

## Wireless Design Checklist

| <i>Checklist Item</i>   | <i>Status</i> |
|---|---------------|
| <i>Review objectives with stakeholders</i>  |               |
| <i>Review technical requirements</i>  |               |
| <i>Radio frequency characterization</i> <ul style="list-style-type: none"> <li>• <i>Direct measurement through site survey</i></li> <li>• <i>Indirectly through link budget analysis</i></li> </ul>   |               |
| <i>Frequency allocation plan</i>  |               |
| <i>Design network architecture</i>  |               |
| <i>Interoperability interfaces and protocols</i>  |               |
| <i>Perform factory software modifications</i> <ul style="list-style-type: none"> <li>• <i>Database Upgrades</i></li> <li>• <i>Interface Upgrades</i></li> <li>• <i>Logic Upgrades (PLC/Software/Firmware)</i></li> <li>• <i>Analysis Reporting tools and integration</i></li> </ul> |               |
| <i>Develop spectrum monitoring plan</i>   |               |
| <i>Interference mitigation plan</i>   |               |
| <i>Develop security plan</i>  |               |
| <i>Performance measurement plan, preliminary</i>  |               |
| <i>Develop deployment plan for the selected candidates</i>  |               |
| <i>Develop a training plan</i>  |               |
| <i>Develop or update BYOD Policies</i>  |               |
| <i>Develop a roll-out plan for the wireless deployment</i>  |               |

## Wireless Deployment Checklist

| <i>Checklist Item</i>                                  | <i>Status</i> |
|--|---------------|
| <i>Review objectives with stakeholders</i>             |               |
| <i>Review technical requirements</i>                   |               |
| <i>Review design and roll-out plan</i>                 |               |
| <i>Roll-out network (iteratively)</i>                  |               |
| <i>Verification of deployment to design</i>            |               |
| <i>Perform continuous training</i>                     |               |
| <i>Performance wireless awareness training</i>         |               |
| <i>Implement spectrum monitoring plan</i>              |               |
| <i>Implement security management plan</i>              |               |
| <i>Implement wireless performance monitoring</i>       |               |
| <i>Validate that deployment meets design intention</i> |               |
| <i>Schedule and perform regular maintenance</i>        |               |

# Wireless Applicability Matrix

Table 8. Wireless applicability matrix for industrial processes

|             |                 | Process Monitoring | Supervisory Control | Feedback Control | Alarm Conditions | In-situ Inspection | Factory Monitoring | Assembly: Sensing | Assembly: Actuation | Robots: Supervision | Robots: Feedback Control | Quality Inspection | Fall Prevention | Confined Spaces | Critical Event Detection | Human-Machine Colocation | Nearby or Indoor | Distant: LOS | Distant: BLOS | Geographically Remote | Indoor Machine Localization | Materials in Storage | Materials in Production | Tools    | Personnel | Voice and Video Communication | Video Surveillance | Drone-based Surveillance | Grounds Control | Spectrum Monitoring Data | Personnel Authorization | Well-head Monitoring | Pipeline Monitoring | Tank Level Monitoring | Machine Health Monitoring | Building Automation | Augmented Reality |
|-------------|-----------------|--------------------|---------------------|------------------|------------------|--------------------|--------------------|-------------------|---------------------|---------------------|--------------------------|--------------------|-----------------|-----------------|--------------------------|--------------------------|------------------|--------------|---------------|-----------------------|-----------------------------|----------------------|-------------------------|----------|-----------|-------------------------------|--------------------|--------------------------|-----------------|--------------------------|-------------------------|----------------------|---------------------|-----------------------|---------------------------|---------------------|-------------------|
|             |                 | Flow-based         |                     |                  |                  |                    | Job-based          |                   |                     |                     |                          | Safety             |                 |                 |                          | Back-haul                |                  |              |               | Tracking              |                             |                      |                         | Security |           |                               |                    | Remote                   |                 |                          | Maint.                  |                      |                     |                       |                           |                     |                   |
| Home/Office | 802.11          | ●                  | ●                   | ●                | ●                | -                  | ●                  | ●                 | ●                   | ●                   | ●                        | ●                  | ●               | ○               | ○                        | ○                        | ●                | ●            | ●             | -                     | ☆                           | ↗                    | ↗                       | ↗        | ↗         | ●                             | ●                  | ●                        | ●               | ●                        | ●                       | ●                    | ●                   | ●                     | ●                         | ●                   | ●                 |
|             | 802.15.1        | ○                  | ○                   | ○                | ○                | ○                  | ○                  | ●                 | ●                   | ●                   | ○                        | ●                  | ●               | ●               | ●                        | ●                        | ○                | ○            | ○             | ○                     | ○                           | ○                    | ○                       | ○        | ○         | ▼                             | ▼                  | ▼                        | ○               | ○                        | ○                       | ○                    | ○                   | ○                     | ○                         | ○                   | ○                 |
| Industrial  | 802.15.4 TDMA   | ●                  | ●                   | ●                | ●                | -                  | ●                  | ●                 | ●                   | ●                   | ●                        | ●                  | ●               | ●               | ●                        | ○                        | ▼                | ▼            | ▼             | ▼                     | ●                           | ↗                    | ↗                       | ↗        | ○         | ▼                             | ▼                  | ▼                        | ○               | ○                        | ○                       | ●                    | ●                   | ●                     | ○                         | ●                   | ▼                 |
|             | 802.15.4 CSMA   | ●                  | ●                   | ○                | ○                | -                  | ●                  | ●                 | ●                   | ●                   | ●                        | ●                  | ●               | ●               | ●                        | ○                        | ▼                | ▼            | ▼             | ▼                     | ●                           | ↗                    | ↗                       | ↗        | ○         | ▼                             | ▼                  | ▼                        | ○               | ○                        | ○                       | ●                    | ●                   | ●                     | ○                         | ●                   | ▼                 |
|             | 802.11 TDMA     | ☆                  | ☆                   | ☆                | ☆                | -                  | ☆                  | ☆                 | ☆                   | ☆                   | ☆                        | ☆                  | ☆               | ☆               | ☆                        | ☆                        | -                | -            | -             | -                     | ☆                           | -                    | -                       | -        | -         | -                             | -                  | -                        | ☆               | -                        | -                       | ☆                    | ☆                   | ☆                     | ☆                         | ☆                   | -                 |
|             | VLBR WAN        | ●                  | ●                   | ○                | ○                | -                  | ●                  | ●                 | ●                   | ●                   | ●                        | ●                  | ●               | ○               | ○                        | ○                        | ▼                | ▼            | ▼             | ▼                     | ●                           | ●                    | ●                       | ●        | ●         | ▼                             | ▼                  | ▼                        | ○               | ○                        | ○                       | ○                    | ○                   | ○                     | ○                         | ○                   | ○                 |
| Satellite   | Geostationary   | ●                  | ●                   | ○                | ○                | ○                  | ○                  | ○                 | ○                   | ○                   | ○                        | ○                  | ○               | ○               | ○                        | ○                        | ○                | ○            | ○             | ○                     | ○                           | ○                    | ○                       | ○        | ○         | ○                             | ○                  | ○                        | ○               | ○                        | ○                       | ○                    | ○                   | ○                     | ○                         | ○                   | ○                 |
|             | Low-earth Orbit | ●                  | ●                   | ○                | ○                | ○                  | ○                  | ○                 | ○                   | ○                   | ○                        | ○                  | ○               | ○               | ○                        | ○                        | ○                | ○            | ○             | ○                     | ○                           | ○                    | ○                       | ○        | ○         | ○                             | ○                  | ○                        | ○               | ○                        | ○                       | ○                    | ○                   | ○                     | ○                         | ○                   | ○                 |
|             | VLBR WAN        | ●                  | ●                   | ○                | ○                | ○                  | ●                  | ●                 | ●                   | ●                   | ●                        | ●                  | ●               | ○               | ○                        | ○                        | ▼                | ▼            | ▼             | ▼                     | ○                           | ○                    | ○                       | ○        | ○         | ▼                             | ▼                  | ▼                        | -               | ○                        | ○                       | ○                    | ○                   | ○                     | ○                         | ○                   | ▼                 |
| Tracking    | RFID            | -                  | -                   | -                | -                | -                  | -                  | -                 | -                   | -                   | -                        | -                  | -               | -               | -                        | -                        | -                | -            | -             | ○                     | ●                           | ●                    | ●                       | ●        | -         | -                             | -                  | -                        | -               | -                        | -                       | -                    | -                   | -                     | -                         | -                   |                   |
| Optical     | Visible         | ○                  | ○                   | ○                | ○                | ○                  | ☆                  | ☆                 | ☆                   | ☆                   | ☆                        | ☆                  | ☆               | ☆               | ☆                        | ☆                        | ○                | ○            | ○             | ○                     | ☆                           | ○                    | ☆                       | ☆        | ○         | ○                             | ○                  | ○                        | ○               | ○                        | ○                       | ○                    | ○                   | ○                     | ☆                         | ○                   | ○                 |
|             | Infrared        | ○                  | ○                   | ○                | ○                | ○                  | ☆                  | ☆                 | ☆                   | ☆                   | ☆                        | ☆                  | ☆               | ☆               | ☆                        | ☆                        | ○                | ○            | ○             | ○                     | ☆                           | ○                    | ☆                       | ☆        | ○         | ○                             | ○                  | ○                        | ○               | ○                        | ○                       | ○                    | ○                   | ○                     | ☆                         | ○                   | ○                 |
|             | Free-space      | ●                  | ●                   | ●                | ●                | ○                  | ○                  | ○                 | ○                   | ○                   | ○                        | ○                  | ○               | ○               | ○                        | ○                        | ○                | ○            | ○             | ○                     | ●                           | ●                    | ●                       | ●        | ○         | ●                             | ●                  | ●                        | ○               | ○                        | ○                       | ●                    | ●                   | ●                     | ○                         | ○                   | ○                 |
| Cellular    | Legacy          | ●                  | ●                   | ○                | ○                | -                  | ○                  | ○                 | ○                   | ○                   | ○                        | ○                  | ○               | ○               | ○                        | ○                        | ○                | ○            | ○             | ○                     | ○                           | ○                    | ○                       | ○        | ○         | ○                             | ○                  | ○                        | ○               | ○                        | ○                       | ○                    | ○                   | ○                     | ○                         | ○                   | ○                 |
|             | 4G              | ●                  | ●                   | ○                | ○                | -                  | ○                  | ○                 | ○                   | ○                   | ○                        | ○                  | ○               | ○               | ○                        | ○                        | ○                | ○            | ○             | ○                     | ○                           | ○                    | ○                       | ○        | ○         | ○                             | ○                  | ○                        | ○               | ○                        | ○                       | ○                    | ○                   | ○                     | ○                         | ○                   | ○                 |
|             | 5G              | ☆                  | ☆                   | ☆                | ☆                | -                  | ☆                  | ☆                 | ☆                   | ☆                   | ☆                        | ☆                  | ☆               | ☆               | ☆                        | ☆                        | ●                | ●            | ●             | ○                     | ☆                           | ☆                    | ☆                       | ☆        | ☆         | ☆                             | ☆                  | ☆                        | ☆               | ☆                        | ☆                       | ☆                    | ☆                   | ☆                     | ☆                         | ☆                   | ☆                 |
| Land-mobile | All types       | ○                  | ○                   | ○                | ○                | ○                  | ○                  | ○                 | ○                   | ○                   | ○                        | ○                  | ○               | ○               | ○                        | ○                        | ▼                | ○            | ○             | ○                     | ○                           | ○                    | ○                       | ○        | ○         | ○                             | ○                  | ○                        | ○               | ○                        | ○                       | ○                    | ○                   | ○                     | ○                         | ○                   | ○                 |
| Specialty   | Leaky Coax      | ●                  | ●                   | -                | ○                | ○                  | ○                  | -                 | -                   | ○                   | ○                        | -                  | ○               | ○               | ○                        | -                        | ○                | ○            | ○             | ○                     | ○                           | ●                    | ●                       | ○        | ○         | ○                             | ○                  | ○                        | ○               | ○                        | ○                       | ○                    | ○                   | ○                     | ○                         | ○                   | ○                 |

**Legend:** ● Fully supports problem domain, ○ Partially supports problem domain but may have practicality, throughput, latency, reliability, or energy limitations, ↗ Energy requirements limit applicability, ○ Network latency precludes applicability, ▼ Network throughput severely limits applicability, ☆ Future technology may support problem domain, ○ Not recommended, - Not considered