

## **U.S. Railroads' PTC & Wireless** which frequencies, where, & how much

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### **Statements: PTC Value**

PTC would likely cost railroads between \$9.5 billion and \$13.1 billion . . . and . . . Implementing PTC would result in \$440 million to \$674 million in safety benefits over a 20-year period. FRA Analysis noted in GAO 11-133, Dec 2010

~~"PTC systems also enable a railroad to run scheduled operations and provide improved running time, greater running time reliability, higher asset utilization, and greater track capacity."~~ FRA Website

PTC will be a "terrible waste of money," and President Barack Obama should junk the idea.  
Union Pacific's CEO Jim Young

### **Statements: PTC Wireless**

"(FCC) should evaluate its inventory of spectrum in the 217.6 – 222 MHz range (keeping in mind the need for contiguous 25 KHz channels)"  
PTC-220's submission to WT Docket No. 11-79

~~"The spectrum (to be used for PTC) must be in the 217-220 MHz range."~~ APTA's submission to WT Docket No. 11-79

Referrals to past and current advanced train control systems where the associated wireless spectrum was insufficient or is extremely critical, respectively  
PTC-220's submission to WT Docket No. 11-79

"(PTC) will be deployed with multiple wireless networks... including 220 MHz ... WiFi ... cellular and satellite" Mandated PTC Development Plan for UP's PTC platform

### **Objectives**

Provide a threshold understanding of the U.S. freight rail industry and its current & future use of wireless

. . . **Including** an understanding of the wireless issues associated with the deployment of PTC

. . . **By** providing a basic understanding of PTC as to objectives, functionality, structure, and implementation

### **Credentials**

**Class I Railroad Management**

- ❖ Chief Engineer Communications
- ❖ Director Advanced Train Control  
Conceived & managed development of the first PTC system

**Independent Consultant**

- ❖ Strategic wireless planning: FRA / Class I's / Suppliers
- ❖ PTC courses & presentations
- ❖ PTC & technology market studies
- ❖ Publication and PTC / wireless articles published  
*Full Spectrum*, *Railway Age*, *IEEE Vehicular Technologies*, *Journal of Transportation*, *Progressive Railroad*, *Wireless for the Corporate User*, *Mission Critical Communications*
- ❖ Project Leader Egyptian National Railways:  
Safety, PTC, and efficiency study.
- ❖ [www.strategicrailroading.com](http://www.strategicrailroading.com)

### **Agenda**

- **Summary**
- **Railroad Industry**
  - ❖ Statistics
  - ❖ Wireless use
- **PTC**
  - ❖ Why PTC
  - ❖ Mandate & Specifications
  - ❖ Primary Definitions
  - ❖ How PTC Works
  - ❖ PTC Wireless Requirements
  - ❖ PTC System Architecture
  - ❖ PTC Investment & Benefits
  - ❖ Strategic Perspective
  - ❖ Wireless Alternatives
- **Questions & Answers**
- **What We Offer FCC**

### Summary: Frequencies?

- PTC's mandate provides no specifications as to frequencies. PTC-220's band is **NOT** the only choice for freight or passenger operators.
- PTC's on-board platform provides for multiple bands to be used, including other VHF, cellular, and WiFi.
- Software Defined Radio can provide an additional level of cost effective spectrum utilization, but is not being considered.
- The railroads have several bands that are not being used efficiently
  - 160 is being converted to conventional narrowband and not trunked
  - 900 is not being used for the advanced train control purpose for which the spectrum was given by the FCC
  - 44 is owned by PTC-220 (via Meteorcomm) and is only used by BNSF – which initially planned to use it for PTC

### Summary: Where?

- There are several key **PTC wireless corridors** that differ substantially as to coverage and data throughput for freight and passenger operations
- Such differences suggest the possible use of **multiple wireless data services**, the capability of which is currently included in PTC's architecture . . . but that is not being considered by the railroads overall

### Summary: How Much?

- No appropriate wireless data analyses (a.k.a. data models) are known to exist as to the various requirements of PTC
- The wireless requirements for PTC are relatively low compared to advanced train control systems, and such data models are inappropriate
- The freight railroads are developing a complex wireless platform that is expected to far exceed PTC's wireless requirements in the various **wireless corridors**
- Major metropolitan areas have voice radio challenges for yard crews, but not necessarily data radio challenges for PTC. Trunked radio would have been ideal

### U.S. Freight Railroad Industry

|                   | STB<br>Revenue<br>Definition<br>\$ Million | #   | ANNUAL<br>REVENUE,<br>\$ Billion |
|-------------------|--|-----|----------------------------------|
| Class 1*          | > 250                                      | 7*  | 45                               |
| Regional          | 20 ↔ 250                                   | 36  | 2                                |
| Local /<br>Switch | < 20                                       | 510 | 1.5                              |

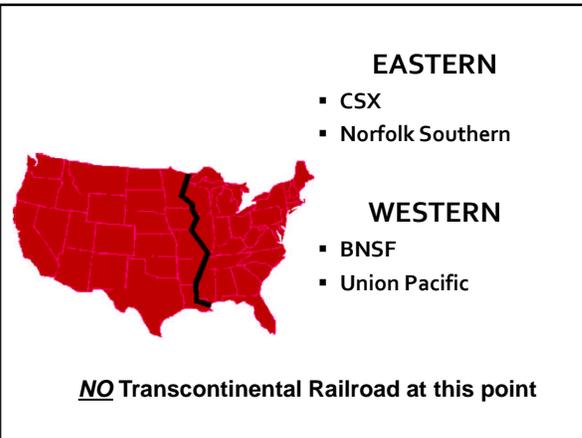
\* BNSF, CSX, Grand Trunk (CN), KCS, NS, Soo (CPR), UP

### AAR's Industry Statistics

| Class I's                       | Route Miles*    | Locomotives   |
|---------------------------------|-----------------|---------------|
| BNSF                            | 32,000          | 6,300         |
| CSX                             | 22,000          | 3,700         |
| NS                              | 21,200          | 3,800         |
| UP                              | 32,400          | 8,100         |
| Grand Trunk (CN)<br>+ Soo (CPR) | ?               | ?             |
| KCS                             | 3,100           | 400           |
| <b>Total</b>                    | <b>~140,000</b> | <b>22,800</b> |

\* Route miles are individual tracks. This is not Miles of Road which does not include multiple track configurations.

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## Railroads' Private Wireless

- Extensive analog 160 Mhz platform (primarily voice)
  - 140,000 portables
  - 17,000 VHF base stations
  - 1,000 UHF base stations
  - 52,000 mobiles
  - 30,000 locomotives

## 2013: What Could Have Been

There is one Federal entity that could have had a tremendous effect on the advancement of railroad operations within the next decade. And, it's not the FRA, NTSB, DHS, or even Congress.

The **FCC's** narrow-banding of the VHF spectrum provided the incentive to make a major change in the railroads' primary wireless infrastructure

. . . **But**, the railroads took a tactical approach instead of a strategic one

## VHF Narrow-banding

- The sleeping giant rulemaking that reconfigures the channel / frequency allocation; a 2-fold increase by 2013, with an additional 2-fold split by a TBD date.
- This will require up to a \$1 Billion investment by the industry to replace the current analog infrastructure with a digital one
- Railroads were only considering the first split as what they believed to be the least expensive as to hardware, and they started with analog
- They switched to digital, but they selected conventional instead of trunked radio which would have been much more useful for their usage ... as well as spectrum efficiency.

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## Railroads' Private Wireless

- Extensive analog 160 Mhz platform (primarily voice)
- 6 pairs nationwide at 900 given to the railroad's for advanced train control systems, but now used for business and low-safety systems - explained later
- 6 pairs nationwide at 450 UHF for End of Train (EOT)
- Purchased 5 pairs at 220 MHz band for Remote Control Locomotive (RCL) + ?
- UP / NS purchased additional 220 prior to the mandate

## Industry Politics

- ✓ UP & NS purchased 220 spectrum prior to mandate.
- ✓ CSX & BNSF were *persuaded* to use 220 for the sake of PTC interoperability, even though they had selected other wireless, e.g., cellular and 44.
- ✓ 220 decision was not based upon data requirements in that no credible data analyses had been performed.
- ✓ The use of VHF refarming and trunked operation was not considered – vendor influence ?

## Why PTC ?

September 2008: Chatsworth, CA  
Metrolink passed red signal & collided with UP  
**25 passenger deaths**

The Rail Safety Improvement Act of 2008 was created and signed by President Bush in less than 2 months

- ✓ All mainlines of Class I freight carriers with at least 5MGT that handle any amount of hazardous materials
- ✓ All mainlines that have regularly-scheduled commuter or intercity passenger trains
- ✓ Any lines designated by the Secretary of Transportation

### PTC Mandate Specifications

Functional  
Operational  
Technical

### Mandate Specifications: Functional

#### Designed to Prevent

- (1) train-to-train collisions;
- (2) over-speed derailments;
- (3) incursions into established work zone limits; *and*
- (4) prevent trains from moving through misaligned switches

### Mandate Specifications: Operational

"... will provide for *interoperability* of the system with movements of train of other railroad carriers over its lines."

defined as " the ability to control locomotives of the host railroad and tenant railroad to communicate with and respond to the positive train control system, including uninterrupted movements over property boundaries"

### Interoperable Train Control (ITC)

- ❖ Agreement signed by BNSF, CSX, NS, & UP to establish PTC interoperability standards
- ❖ CN, CP, & Amtrak also involved
- ❖ Passenger operations have not been involved
- ❖ Suppliers sit on the sidelines and watch

### Interoperability: Wireless

- ✓ The host railroad determines the type of wireless to be used on its property.
- ✓ Passenger operations can make their own decision as to what to use on their property. PTC's onboard platform, with or without Software Defined Radio (SDR), provides for that capability

### Mandate Specifications: Technical

THERE ARE ABSOLUTELY ***NONE***

... including *WIRELESS*

## Why PTC ?

*Actually , the pursuit of PTC began with*

February 1996: Silver Spring, Md  
Marc passed red signal & collided with  
Amtrak

11 passenger deaths

Hired by CSX to  
develop the first  
Overlay  
PTC system

## Primary Definitions

### Traffic Control Systems

provides for the integrity of train movements

### Enforcement Systems

prevents errors by train crews

e.g., PTC

### Advanced Traffic Control / Management

improves the efficiencies of railroad operations

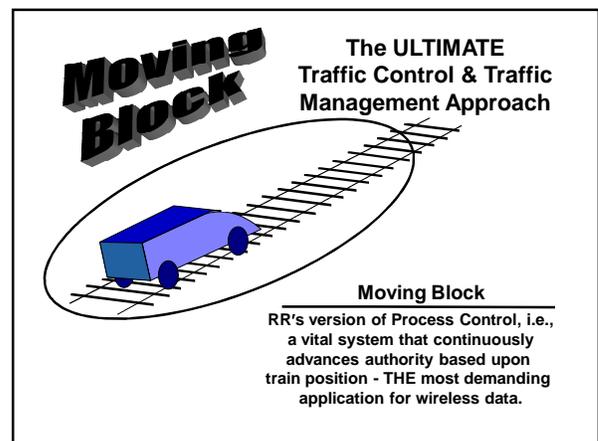
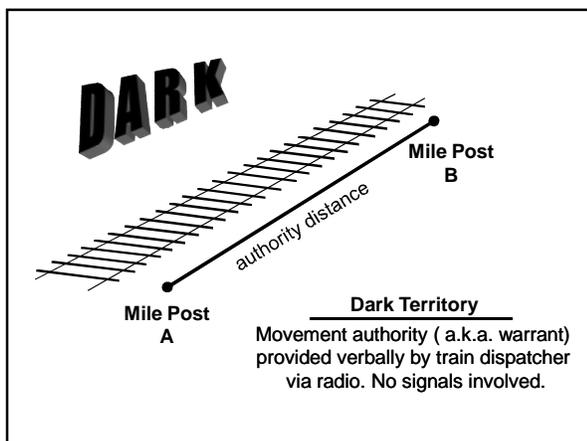
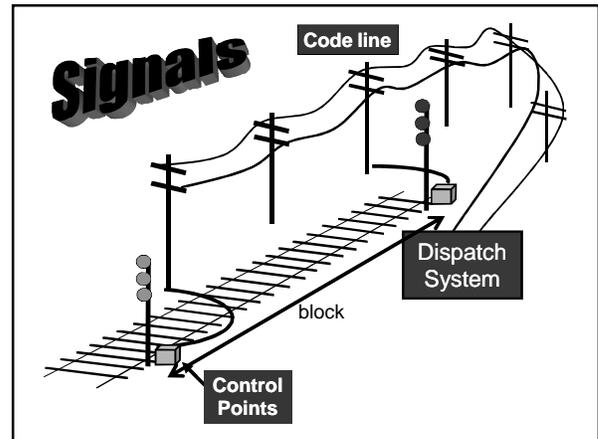
## Traffic Control

### Traditional

- Signaled Territory
- Dark Territory

### Advanced

- Moving Block
- ETCS



## U.S. "PTC" Systems

### Advanced Civil Speed Enforcement System (ACES)

- ❖ As used on NEC corridor by Amtrak and sharing railroads, both passenger and freight

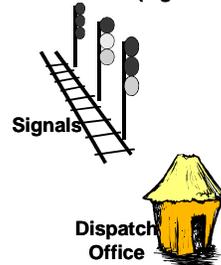
### PTC

- ❖ As used by freight railroads and affected passenger operations

ACES and freight PTC are two totally different concepts with similar functionality, but totally different wireless requirements

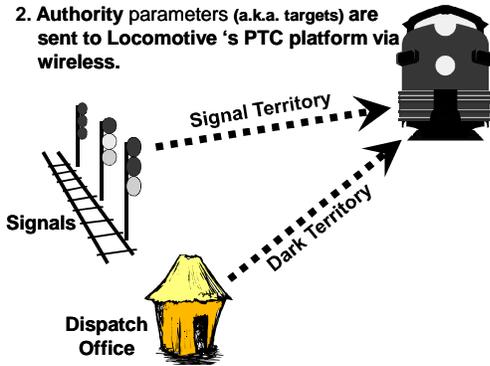
## How PTC Works

1. Movement authorities are generated by traffic control equipment at the wayside (signaled) or via the dispatcher (dark).



## How PTC Works

2. Authority parameters (a.k.a. targets) are sent to Locomotive's PTC platform via wireless.



## How PTC Works

3. On-board PTC monitors train's compliance to targets to detect potential authority violations and alert crew



## How PTC Works

4. If alerts not handled properly, then enforcement is made to avoid likely violation.



## How PTC Works

PTC is *locomotive-centric*  
NO DATA need be sent back to office, including position / speed

If PTC fails in route, the railroad does not stop



### Wireless Requirements

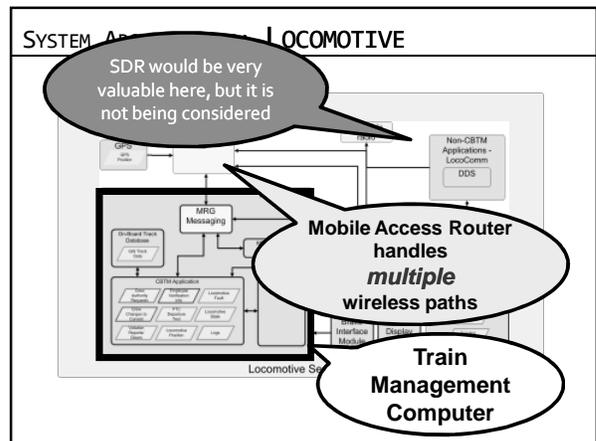
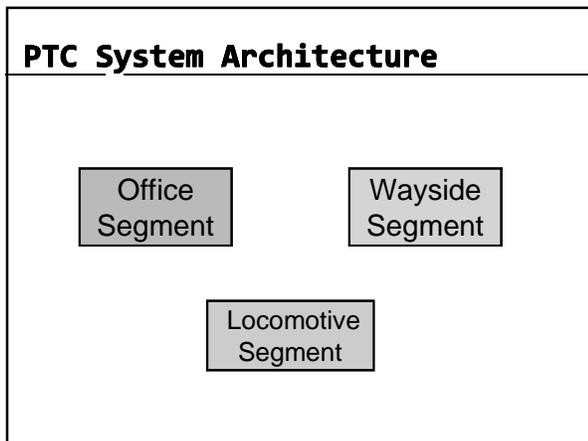
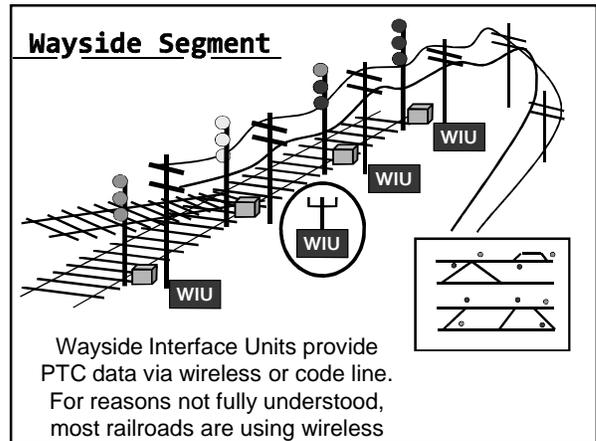
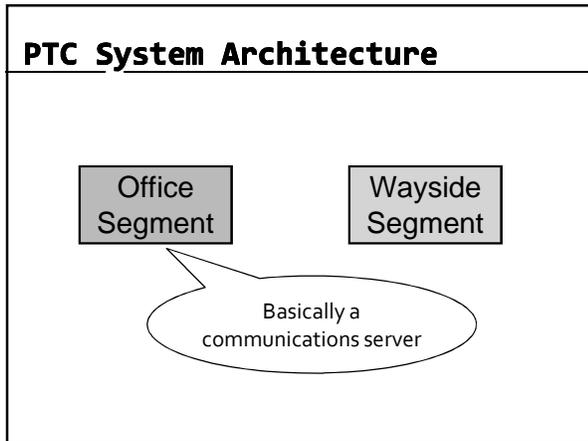
|   | TO TRAIN               | FROM TRAIN              | % US Trackage |
|---|------------------------|-------------------------|---------------|
| <b>PTC</b><br>Dark Territory            | <b>Infrequent Data</b> | <b>Infrequent Pings</b> | <b>30 *</b>   |
| <b>PTC</b><br>Signaled Territory        | <b>Moderate Data</b>   | <b>Frequent Pings</b>   | <b>70</b>     |
| <b>Advanced Traffic Control (Vital)</b> | <b>Intense Data</b>    | <b>Intense Data</b>     | <b>0</b>      |

\* Rough estimate based upon 45 / 55 split of trackage

### Wireless Network Requirements

|                               | Advanced Traffic Management | PTC                  |
|-------------------------------|-----------------------------|----------------------|
| Reliability                   | <b>Best</b>                 | <b>Would be Nice</b> |
| Throughput                    | <b>Tremendous</b>           | <b>Modest *</b>      |
| VITAL<br>(movement integrity) | <b>YES</b>                  | <b>NO!</b>           |

\* excluding track data base downloads which are handled normally by WiFi in the yards

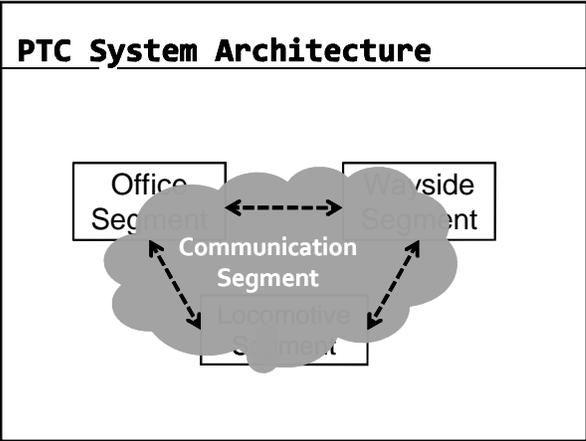


**SYSTEM ARCHITECTURE: LOCOMOTIVE**

**PURPOSE**  
Provides PTC functional logic (PTC is locomotive-centric) as well as wireless options.

**ISSUES**

- Currently, there is only one provider of the TMC due to the exclusivity of the source code (programmed logic).
- ITC promotes 220MHz as the only spectrum that can be used for wireless of PTC parameters (targets). In fact, this is not the case given the availability of the MAR.
- Technologies and spectrum are available that permits other options for passenger operations on their own property.



**SYSTEM ARCHITECTURE: COMMUNICATIONS**

**PURPOSE**  
Provides communication links between the WIUs, locomotive, and office components

**ISSUES**

- Most Class 1s, but not all, are determined to use a RR-designed 220 MHz protocol.
- Passenger operators are being pressured to use 220 MHz, even though MAR provides for flexibility.
- Technologies (e.g. Software Defined Radio) and other spectrum exists that invalidates the 220 –only position that has been perceived by passenger operators and others.
- Amtrak’s communication selection for ACSES / NEC is proprietary suggesting a restriction in competition.

**PTC Investment**

**EQUIPMENT**

**FREIGHT:**

- 70,000 track miles covered
- 17,000 locomotive units
- 50,000 WIU’s +
- 220 MHz wireless network

**COMMUTERS:**

- 4,100 vehicle units
- different wireless possibilities

**PTC: Investment vs. Return \***

**COSTS**  
FRA’s 2009 Estimate: \$9.5 – 13.1 billion

**Cost / Benefit Ratio: 20 to 1**

**BENEFITS**  
FRA’s 2010 Estimate: \$440 - 674 million  
over 20 years

\* As reported in GAO report Rail Safety, December 2010, GAO-11-33

**Strategic Perspective \***

While individual railroads may have their individual technology strategies, several railroads have limited that perspective to addressing PTC for now. And, there is no apparent industry strategy.

**Consider the following**

\* 1. Ron Lindsey, "An analysis of the Opportunities for Wireless Technologies in Passenger and Freight Rail Operations", FRA, December 2007  
2. Ron Lindsey, "Wireless for Railroads, Skybridge Spectrum Foundation, January 2011

## Applications Require Different Data

|                               | Low | Med | High |
|-------------------------------|-----|-----|------|
| Moving Block                  |     |     | X    |
| Proactive Traffic Mgmt        | X   |     |      |
| Flexible Block                |     | X   |      |
| Digital Authorities           | X   |     |      |
| PTC                           |     | X   |      |
| Communication Based Signaling |     | X   |      |
| Remote Switch                 | X   |     |      |
| Yard Loco Tracking            |     | X   |      |
| Train Pacing                  |     | X   |      |

|                        | Low | Med | High |
|------------------------|-----|-----|------|
| Mainline Work Order    |     | X   |      |
| Industrial Work Order  |     | X   |      |
| Loco Diagnostics       | X   |     |      |
| Track Data Base        |     | X   |      |
| Locomotive Fueling     | X   |     |      |
| M of W Monitoring      | X   |     |      |
| Industry Loco Tracking | X   |     |      |
| EIC Authority          | X   |     |      |

## Applications Have Different Values

|                               | Low | Med | High |
|-------------------------------|-----|-----|------|
| Moving Block                  |     |     | \$   |
| Proactive Traffic Mgmt        |     |     | \$   |
| Flexible Block                |     |     | \$   |
| Digital Authorities           |     |     | \$   |
| PTC                           |     |     | \$   |
| Communication Based Signaling |     |     | \$   |
| Remote Switch                 |     |     | \$   |
| Yard Loco Tracking            |     |     | \$   |
| Train Pacing                  |     |     | \$   |

|                        | Low | Med | High |
|------------------------|-----|-----|------|
| Mainline Work Order    |     | \$  |      |
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| Loco Diagnostics       |     | \$  |      |
| Track Data Base        |     | \$  |      |
| Locomotive Fueling     |     | \$  |      |
| M of W Monitoring      | \$  |     |      |
| Industry Loco Tracking | \$  |     |      |
| EIC Authority          | \$  |     |      |

## Communications: Value vs. Data

|      |        | VALUE                           |   |  |
|------|--------|---------------------------------|---|--|
|      |        | LOW                             | MEDIUM  | HIGH                                       |
| DATA | LOW    | EIC Authority<br>Loco - Foreign | Remote Switch<br>Loco Fueling                         | <b>PROACTIVE<br/>MANAGEMENT</b>            |
|      | MEDIUM | PTC<br>MofW Monitor             | Pacing<br>Mainline WO<br>Industrial WO<br>Loco Health | Flexible Block<br>Digital -<br>Authorities |
|      | HIGH   | Moving Block-<br>EAST           |   | Moving Block-<br>WEST                      |

## Communications: Value vs. Data

|      |        | VALUE                                   |        |      |                           |
|------|--------|---|--------|------|---------------------------|
|      |        | LOW                                     | MEDIUM | HIGH |                           |
| DATA | LOW    | What's too often<br>being<br>overlooked |        |      |                           |
|      | MEDIUM |   |        |      | RR's<br>Function<br>Focus |
|      | HIGH   |   |        |      | <b>RR's Data FOCUS</b>    |

## Strategic Wireless Perspective

| COVERAGE                | THROUGHPUT (think function) |
|-------------------------|-----------------------------|
| ➢ Inter-City (mainline) | ➢ Monitor                   |
| ➢ Metropolitan          | ➢ Voice                     |
| ➢ Terminal / Yard       | ➢ Page                      |
| ➢ Group                 | ➢ Transaction               |
|                         | ➢ Data Transfer             |
|                         | ➢ Loose Control             |
|                         | ➢ Tight Control             |

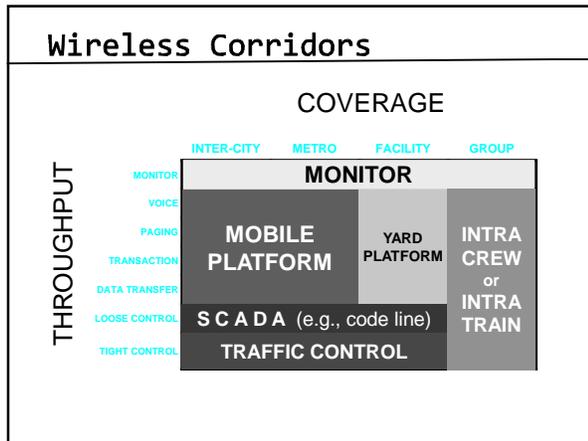
## COVERAGE

|            |               | INTER-CITY | METRO | FACILITY | GROUP |
|------------|---------------|------------|-------|----------|-------|
| THROUGHPUT | MONITOR       | 1          | 2     | 3        | 4     |
|            | VOICE         | 5          | 6     | 7        | 8     |
|            | PAGING        | 9          | 10    | 11       | 12    |
|            | TRANSACTION   | 13         | 14    | 15       | 16    |
|            | DATA TRANSFER | 17         | 18    | 19       | 20    |
|            | LOOSE CONTROL | 21         | 22    | 23       | 24    |
|            | TIGHT CONTROL | 25         | 26    | 27       | 28    |

28 different possible combinations of coverage / function

... 28 different possible wireless solutions

... 28 different possible wireless strategies



- ### PTC's Wireless Corridors
- ✓ Freight Mainline
  - ✓ Freight High Density Mainline
  - ✓ Dark Territory
  - ✓ Metropolitan Freight
  - ✓ Metropolitan Passenger

- ### Data Models?
- Based upon the submissions to FCC's Docket 11-79, there has not been credible data models developed for PTC.
  - Each *wireless corridor* needs its own analysis
  - Only CSX is known to be taking on the challenge of most effectively deploying 220 by the consideration of complementary alternatives.

- ### Industry Perspective
- Arguably, the greatest value of the expenditure being made by the freight railroads for PTC is the availability of an industry-wide wireless network
- However,**
- ✓ they have yet to develop a strategy on how to use the network.
  - ✓ they have yet to provide the various data models that are appropriate for PTC
  - ✓ the railroads have chosen to use conventional refarmed 160 instead of trunked
  - ✓ they have not put the 44 (Meteorcomm) or 900 spectrum bands into the pot for consideration.

- ### Questions & Answers
- ❑ Did the PTC mandate require any specific technology, including 220?  
**No!** The mandate stated functional and operational issues.
  - ❑ Did the PTC mandate drive the search for 220?  
**No!** UP and NS had purchased the spectrum before the mandate. CSX and BNSF were using other wireless, both private and commercial.
  - ❑ Is 220 the one & only spectrum that will support PTC?  
**No!** The MAR on-board provides for multiple wireless routes ... and SDR provides for multiple spectrum / protocols with the same unit. The MAR is already handling 220, WiFi, and cellular.

- ### Questions & Answers
- ❑ Will the current amount of 220 owned by PTC-220 service the freight PTC requirements?  
**Yes!** Although no data analyses had been provided at the time of the FCC submissions, we believe that the current 220 is more than enough for freight operations with or without consideration of other wireless paths that can be provided via the MAR.
  - ❑ Will the current amount of 220 owned by PTC-220 service the passenger PTC requirements?  
**Unknown**
  - ❑ Are there alternatives to the current 220 for the passenger operations?  
**Yes!** The alternatives are numerous especially in the light of the MAR and Software Defined Radio

## Questions & Answers

- ❑ Do the railroads have a strategic position on how they will use the current or expanded 220, e.g., can and will the railroads use current or additional 220 for more than just PTC?  
**No! If there are strategies in individual railroads, then they have not been made public. Clearly, there is no strategy as to how the network will service the industry as a whole.**
- ❑ Are the passenger operators in a position to determine their wireless requirements and deal with the freight railroads as to the 220?  
**Not Really. Several roads have done significant analyses, apparently, but based upon their FCC submissions they are under the impression that they must go with 220 ... and bring their own to the table**
- ❑ Are there alternatives to current 220 for the passenger operations?  
**Yes! The alternatives are numerous especially in the light of the MAR and SDR**

## Primary Points

- Railroads are making significant advances in their use of wireless to advance the safety and efficiency of their operations.
- **However**, data models should be provided by railroads to justify their request for additional spectrum, 220 or other, for railroad operations.
- Many passenger operations are not being properly represented as to their wireless requirements for wireless relative to PTC
- PTC should not be considered in the same light of past and future railroad requirements that deal with advanced traffic control & management systems (as mentioned in PTC-220's submission to FCC's Docket 11-79).
- The industry could benefit from the development of an overall wireless strategy that services the broad range of business and safety applications for railroads, both individually, and collectively as an industry.

## What we offer FCC

- We can provide objective analyses, including data model development and technologies– we represent no PTC suppliers nor accept commissions.
- Skybridge has spectrum alternatives for FCC's consideration.
- We provide answers that others may not provide given their individual agendas.
- We will participate with FCC in open discussions with all parties on the issues that we have presented as to wireless usage, advancing PTC, and advancing railroad operations via the use of wireless.
- We will provide further, and more in depth understanding of railroad operations and PTC from both a tactical and strategic perspective.