LILEE SYSTEMS

Scalable and Reliable Communications Infrastructure For Positive Train Control (PTC)

A Guide to LILEE Systems's PTC/ITCM Solutions and Services

641 River Oaks Parkway, San Jose, CA 95134

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List of Abbreviations and Acronyms

AAR	American Association of Railroads
ACC	Ancillary Card Cage
ACSES	Advanced Civil Speed Enforcement System
AMQP	Advanced Message Queue Protocol
ATC	Automatic Train Control
BCP	Base Communications Package
BNSF	Burlington Northern Santa Fe
BOS	Back Office Servers
CCTV	Closed Circuit TV
CDU	Computer Display Unit
CSX	CSX Transportation
DTS	Dark Territory Server
EMP	Edge Message Protocol
ETMS	Electronic Train Management System
EULA	End-User License Agreement
FRA	Federal Railroad Administration
GE ACC	General Electric Ancillary card Cage
GETS	GE Transportation Services
HLCS	HyRail Limits Compliance System
I-ETMS	Interoperable Electronic Train Management System
IoT	Internet of Things
ISMP	InterSwitch Message Protocol
ITC	Interoperable Train Control Committee
ITCM	Interoperable Train Control Messaging
ITCSM	Interoperable Train Control Systems Management
LMC	LILEE Mobility Controller
LMS	LILEE Mobility Server
M2M	Machine to Machine
MCP	Mobile Communications package
MOW	Maintenance of Way
MPLS	Multiprotocol Label Switching
NEC	Northeast Corridor
NS	Norfolk Southern
NTSB	National Transport Safety Board
OBN	On Board Network
PTC	Positive Train Control
PTC3	Positive Train Control Communications Commander
RME	Remote Command Execution
RSIA	Railway Safety Improvement Act
SDR	Software Defined Radio
SNMP	Simple Network Management protocol
SMA	System Management Agent
SMG	Systems Management Gateway
SSH	Secure Shell
TMC	Train Management Computer
UP	Union Pacific
UPRR	Union Pacific Railroad
WIU	Wayside Interface Unit
WMS	Wayside Messaging Server
WSRS	Wayside Status Relay Service
ZCC	Zero Client Configurations

Executive Summary

In 2008, the U.S. Government introduced legislation that requires the implementation of improved safety measures in the rail sector by 2015. Known as the Rail Safety Improvement Act (RSIA), this legislation requires all Class I railroads and passenger rail operators to implement a mandatory Positive Train Control (PTC) collision avoidance system by December 31st, 2015. Considered the single-largest regulatory cost ever imposed on the industry by the Federal Railroad Administration, PTC technology must be installed on all mainline track where intercity passenger railroads and commuter railroads operate, as well as on lines carrying toxic-by-inhalation hazardous materials.

Because of its complex design and implementation, PTC is not an off-the-shelf system or software that can be implemented quickly. Founded in 2009, LILEE Systems has been providing PTC ITCM wayside and back office products, solutions and services to Class I railroads. These solutions include Wayside Messaging Servers, Wayside Status Relay Service (WSRS), PTC Systems Management Gateway, ITCM-related development services, and ITCM network design, testing, and deployment. In addition, we have developed a number of analytic tools that can improve the ability to predict RF propagation in a high mobility network, and monitor network performance in real or near-real time at the physical layer level. To date, the company's equipment and solutions have been deployed by 5 Class I railroads and several passenger transit systems. Managing in excess of $60B in railroad assets these solutions cover all areas of deployment: back-office, Locomotive, Wayside and Hyrail. In addition, LILEE Systems has partnered with several systems integrators proposing PTC communications solutions for other major U.S. projects.

Table 1: *LILEE Systems PTC/ITCM Portfolio*

APPLICATION	LILEE SYSTEMS PTC SOLUTION HIGHLIGHTS
Back Office	• PTC/ITCM Back Office Design: Data center, Network Infrastructure, High Availability • Professional services: System Integration and Customization, 24x7 TAC Support • SMG : Asset Provisioning and Management, Comprehensive GUI • WSRS: Design and Implementation
Locomotive	• Central Communication Hub: GE ACC Alternative • LMS-2450 as Companion for Wabtec on board computer to replace slot 10 ITCM capability • ZCC : Zero Touch Software Upgrade and Maintenance for LMS/DTS and 3rd Party Devices
Wayside	• DTS-2000 • SMA : System Management Agent (End-to-End Seamless Solution between SMG and SMA) • ZCC : Zero Touch Software Upgrade and Maintenance for LILEE DTS and 3rd Party WIUs • Retrieve WIU information, encapsulate data and send to ITCM Infrastructure
Hyrail	• GPS services for HLCS • Wi-Fi connectivity for crew members

Introduction

Positive train control (PTC) is a set of highly advanced technologies designed to monitor and control train movements to provide increased safety.

Beginning in 1990 the National Transportation Safety Board (NTSB) counted PTC among its “Most Wanted List of Transportation Safety Improvements.” At the time, the vast majority of rail lines relied on the human crew for complying with all safety rules, and a significant fraction of accidents were attributable to human error.

In September 2008, Congress considered a new rail safety law with a deadline of December 15, 2015, for implementation of PTC technology across most of the U.S. rail network. The bill, ushered through the legislative process by the Senate Commerce Committee and the House Transportation and Infrastructure Committee, was developed in response to the collision of a Metrolink passenger train and a Union Pacific freight train in California on September 12, 2008, which resulted in the deaths of 25 and injuries to more than 135 passengers. President George W. Bush signed the 315-page Rail Safety Improvement Act of 2008 into law on October 16, 2008.

How PTC Works

PTC is designed to prevent train-to-train collisions, derailments caused by excessive speed, unauthorized incursions by trains onto sections of track where maintenance activities are taking place, and movement of a train through a track switch left in the wrong position. PTC will not prevent accidents caused as a result of track or equipment failure, improper vehicular movement through a grade crossing, trespassing on railroad tracks, and some types of train operator error.

PTC is a sophisticated, predictive system that works to prevent accidents. The technology must account for a number of factors to measure the appropriate train stopping distance, including train information (weight, length), track composition (curvature, terrain), train speed and train authority (authorization to move across a stretch of track).

It is important to understand however, that PTC does not actively control the train under normal conditions. In virtually all settings, engineers still manually control the trains and PTC only works as a backup system that activates emergency brakes if it detects an imminent collision or derailment.

As illustrated in Figure 1, there are 4 main elements in a PTC system, which are integrated by a wireless communications system:

Onboard System:

Hardware and software that enhance safety by interfacing with locomotive control equipment capable of accepting directives to manage speed limit mandates, braking, and improve communication systems. The system monitors the train's position and speed and activates braking as necessary to enforce speed restrictions and unauthorized train movement onto new sections of track.

Wayside System:

Monitors and reports switch position, signal indications, or status of other monitored wayside devices directly to the Locomotive Segment and Office Segment using one or more radio networks.

Back Office Server:

The storehouse for all information related to the rail network and trains operating across it: speed limits, track composition, speed of individual locomotives, train composition, etc. The back Office transmits the authorization for individual trains to move into new segments of track and interfaces with other railroad back office systems or applications, the railroad dispatch system and the Locomotive and Communications segments.

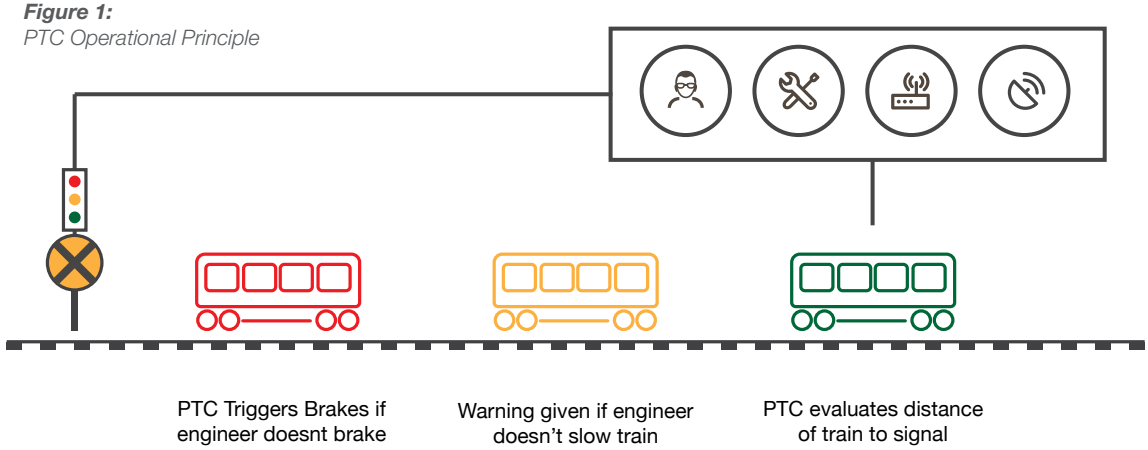
Maintenance of Way:

Maintenance of Way (MOW) vehicles are used for railroad right-of-way maintenance during engineering possessions of the line. They can be driven on roads to near the site and then convert to rail vehicles for the final journey to the worksite. Because these vehicles share the tracks with trains, a key system for maintaining the safety of their operators is the HyRail Limits Compliance System (HLCS), which provides safety overlays by adding a layer of security to the operation of HyRail vehicles on active railroad tracks.

PTC Communication:

Consists of a messaging system and multiple wired and wireless networks through which messages are exchanged between the Locomotive, Wayside and Office Segments

Figure 1:
PTC Operational Principle



Unlike existing reactive train control systems such as Automatic Train Control (ATC), PTC's predictive technology detects upcoming conditions and takes control of the train when needed. The various technologies involved include a central control center or "back office", onboard redundant computers, and a wireless network for communication between the back office and each train, control points, and signals installed along on the wayside.

A lot of the intelligence resides on board the locomotive, giving it the ability to understand its location and what's in front of it. Using the telemetry within the train (GPS, speedometers, odometers, …) and the information stored in the "track database" (elevations, curves, speeds, …) each train not only keeps track of itself, but the master system monitors each train and provides data to a control center where dispatchers and supervisory personnel can monitor the train's location as well. In addition, with PTC, the trains themselves are keeping track of the traffic on the network. In this way, there are multiple layers of monitoring, all aimed at ensuring trains do not collide or derail.

From an architectural point of view, PTC consists of four functional areas interconnected by a communications infrastructure: Back Office, Locomotive, Wayside, and Maintenance of Way (MOW).

The Back Office typically contains a computer-aided dispatch and a datacenter hosting PTC and Back Office servers and other computing and database resources storing information about tracks, train consists, work zones, and speed restrictions. The Back Office issues movement authorities to locomotives based on relevant information received from wayside signals and switches, location information received from trains, and work status from Maintenance of Way vehicles and personnel.

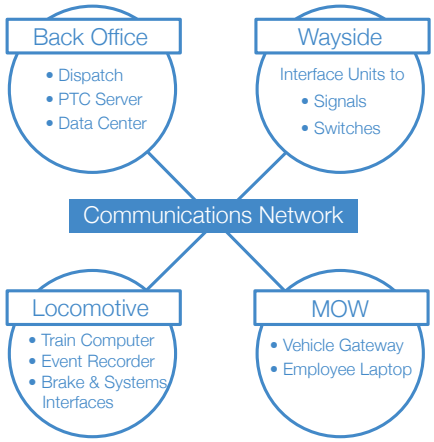
Each train carries a redundant train management computer (TMC), which is a vital component that has the ability to slow down and/or stop the train if it thinks something is unsafe.

The TMC interacts with the Back Office servers (BOS) through the computer display unit (CDU), which presents the latest track section files giving the on-board engineer visual information about the upcoming track:

- What's coming up in from a signal perspective
- Does he need to slow down or even stop the train?
- Is he going over the allowed speed?
- Is he approaching a worker zone with reduced speed?

If the engineer doesn't react properly, the TMC has the ability to slow down and/or stop the train.

Figure 2: *PTC Architectural Domains*



The communications infrastructure is a critical element in the successful and reliable deployment of PTC as it relays critical PTC information between several thousand components that comprise the overall PTC solution. One communications link between the BOS and TMC systems is the proprietary PTC radio system developed by Meteorcomm, which is wholly owned by four Class 1 railroads —BNSF, UP, CSX and NS. It is the predominant supplier of 220MHz SDR technology to the freight industry's PTC initiative. The system utilizes the 220 MHz radio frequencies for onboard, wayside, and base station communication.

Trains also carry cellular modems, and many have two cellular modems as a safety redundancy with each using a different telecom operator for service. Most often communication from the trains is on a private cellular network and delivered to the back office via a dedicated MPLS network. Trains are also equipped with 802.11x Wi-Fi, which is particularly useful in areas like maintenance yards, or within stations as the higher bandwidth provided by the Wi-Fi network allows uploading diagnostics, downloading files, update software and perform a software or computer initialization if necessary.

The Meteorcomm Interoperable Train Control Messaging (ITCM) system is the primary message transport tool in the industry. ITCM is a layer 4, 5, and 6 messaging system that interconnects not only the trains with the back office, but also the back offices of different railroads. This interoperability is critical as railroads not only have to be able to operate on their own tracks but also on other companies' tracks. As an example, a Metrolink train leaving L.A. Union Station, will drive on its own track for about two or three miles. Then it may switch onto the Union Pacific Railroad (UPRR) track or the Burlington Northern Santa Fe (BNSF) track. At that point, the train has to communicate with either the UP or BNSF back office as well as its own back office. When running on other railroad's tracks, a train is effectively being dispatched by that other railroad.

PTC Complexity And Challenges

PTC is an unprecedented technical and operational challenge that requires rail companies to develop, test and implement a new safety system across the vast rail network. In 2008, when Congress passed the RSIA mandate, the technology required had not yet been developed. In the years since, railroads and their technology suppliers have worked tirelessly to meet the deadline and overcome the complexity and challenges involved with the creation and deployment of a reliable failsafe system. The key challenges in developing a homogenous system are:

- Interoperability: Passenger, commuter and freight trains must seamlessly communicate across all railroad systems.
- Integration of thousands of network components, such as GPS, Wi-Fi, radios, antennas, base stations and first-of-its-kind software that predicts when to slow or stop a train.
- Continuously relay critical information such as speed limits, train movement authorization, switch positions, work zone locations and other operational data. Factor in locomotive and rail car mix; train length, weight and speed; terrain and signal aspects to determine safe stopping distances.

LILEE Systems PTC Portfolio

LILEE Systems designs and sells ITCM on-board, wayside and back office products and services. As illustrated in Table 2, these solutions include Wayside Messaging Servers, Wayside Status Relay Service (WSRS), PTC systems management gateway, ITCM-related development services, and ITCM network design, testing, and deployment. In addition, we have developed a number of analytic tools that can improve the ability to predict RF propagation in a high mobility network, and monitor network performance in real or near-real time at the physical layer level.

Table 2: *LILEE Systems PTC/ITCM Portfolio*

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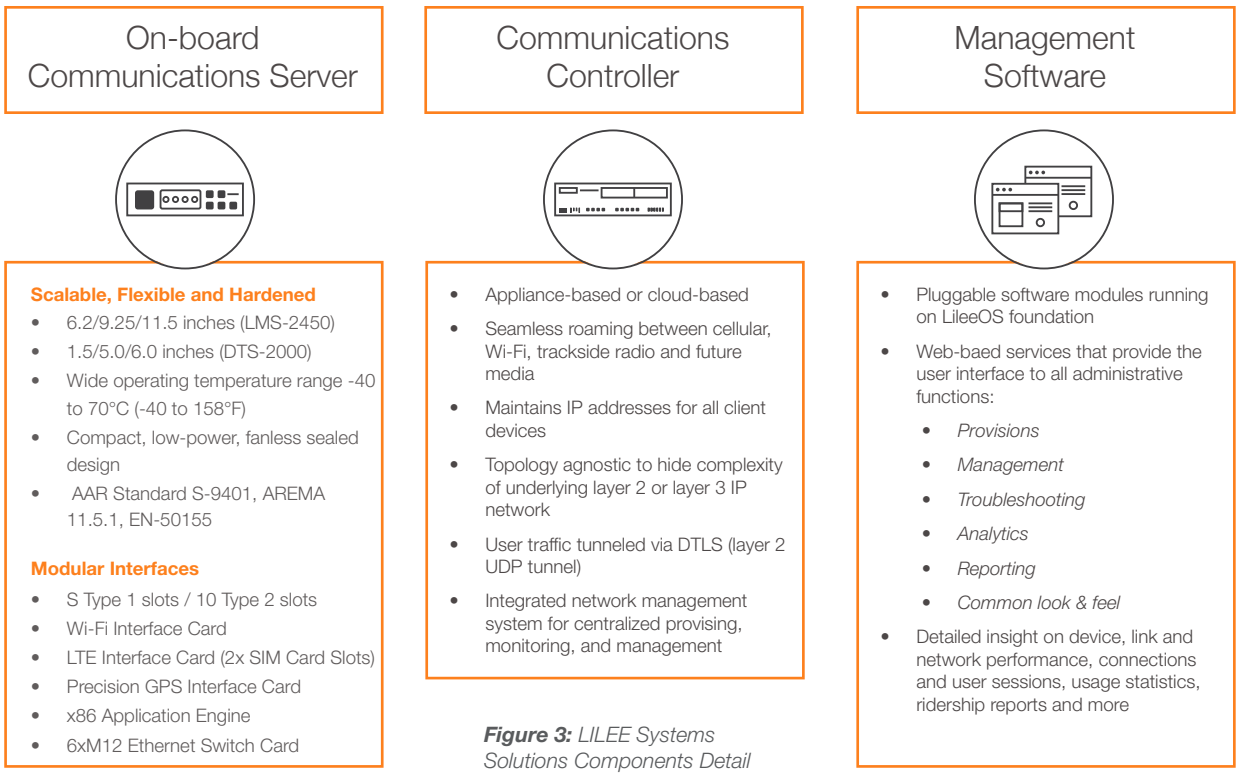

Figure 3: *LILEE Systems Solutions Components Detail*

To date, our solutions for back-office, Locomotive, Wayside and Hyrail have been deployed by 5 Class I railroads and several passenger transit systems to manage in excess of $60B in railroad assets. In addition, LILEE Systems has partnered with a number of larger systems integrators proposing PTC communications solutions for other major U.S. projects.

In March of 2012, LILEE Systems established an end-user license agreement (EULA) with Meteorcomm and began formally working with their products. We leverage this experience to provide our customers with proven paths for interoperability and performance.

LILEE Systems offers solutions for all functional areas of a PTC deployment: Back Office, Locomotive, Wayside, and Maintenance of Way vehicles (MOW). More details are provided in the remainder of this document.

Solutions Components

LILEE Systems' PTC solutions portfolio consists of three components as depicted in Figure 3. The Communications Controller can manage multiple Communications Servers that can be located on locomotives or wayside, and provides integrated network management for centralized provisioning, monitoring, and management. The on-board Communications Servers can house up to 10 wireless network interfaces (3G, LTE, Wi-Fi, GPS) and/or appliances like Ethernet switches and application engines and serves as the network access point and central communications hub for all services that require access to the network.

The Management Software Suite provides the user interface to all administrative functions running to provision, configure manage and monitor all devices in the network. It also supports a suite of troubleshooting and diagnostic tools and provides a comprehensive reporting tool that accumulates all network statistics that are collected by the Communications Controllers and renders them in easy-to-use reports that provide detailed insight on device performance, network performance down to individual networks, connections and user sessions, usage statistics, ridership reports and much more.

Solution Architecture

At the core of the LILEE System's PTC solution architecture are two segments, each offering superior innovation and performance:

- The messaging layer provides the link abstraction and message routing among the applications
- The network layer, consisting of both wired and wireless connectivity, provides physical links that enable the messaging layer components to communicate with each other.

As mentioned earlier LILEE Systems focuses on providing interoperable and high-performance ITCM wayside and back office products and services, including Wayside Messaging Servers, Wayside Status Relay Service (WSRS), PTC systems management gateway (SMG), ITCM-related development services, and ITCM network design, testing, and deployment. In Figure 4, our solutions are highlighted in blue.

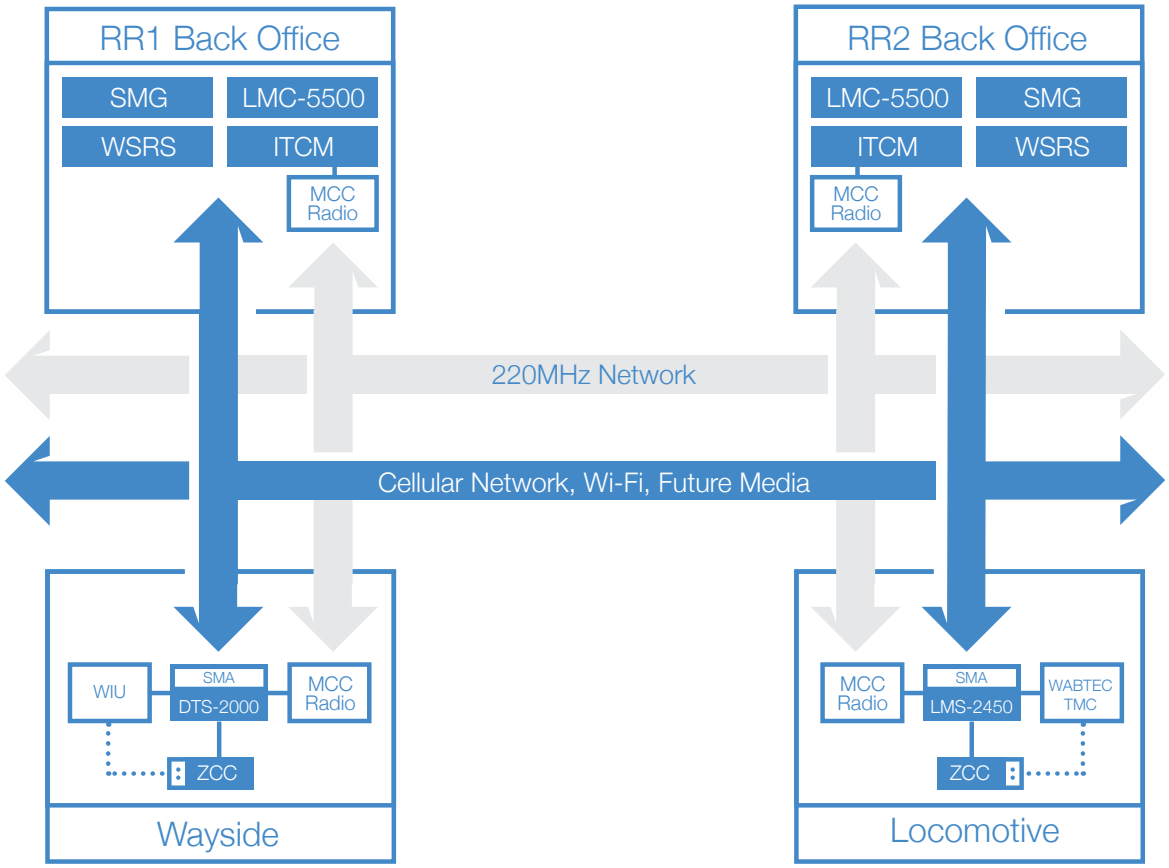

Figure 4: *LILEE Systems PTC Solution Architecture*

Back Office Solutions

LILEE's Back Office solutions include the following products and services:

- PTC/ITCM Back Office Design: Data Center, Network Infrastructure, High Availability
- Professional Services: System Integration and Customization, 24x7 TAC Support
- SMG : Asset Provisioning and Management, Comprehensive GUI
- WSRS: Design and Implementation

PTC/ITCM Back Office Design and Professional Services

Prior to the 2008 Railway Safety Improvement Act there had been multiple train control initiatives based on various technologies and systems from different vendors. By early 2009 there were no less than eleven different PTC projects involving nine different railroads in sixteen states, covering 4,000 track miles . With the consolidation of efforts by the Interoperable Train Control Committee (ITC) two major technical architectures emerged:

Amtrak NEC – Advanced Civil Speed Enforcement System (ACSES)

Amtrak has implemented ACSES on the Northeast Corridor (NEC) between Boston and Washington DC, utilized for the high-speed inter-city Acela Express and regional commuter services. ACSES supplements the existing cab signal and automatic train control system, providing full PTC functionality in support of speed up to 150 mph. Initiated in 1998 and designed by Alstom, by 2010 ACSES was installed on 600 trains and 400 miles of track.

TC – Interoperable Electronic Train Management System (I-ETMS)

ITC standardized on the ETMS platform offered by Wabtec as it met all the RSIA PTC requirements and was already in trials by many of the Class 1s and other rail operators. In addition ETMS provided advanced features such as predictive enforcement timing and monitoring of track integrity, and had integrated components within each of the Locomotive, Back Office and Wayside PTC segments.

Due to multiple architectures, multiple railroads and complex design and requirements, PTC is not an off-the-shelf system or software application that can be implemented quickly, but rather an architectural framework that requires high-levels of customization.

To accomplish this, LILEE Systems focuses on four major activities:

Providing products and solutions direct to the railroads
We are currently providing ITCM wayside and back office products and services to 5 Class I railroads and several passenger transit systems. These solutions include Wayside Messaging Servers, Wayside Status Relay Service (WSRS), PTC systems management gateway, WMS and LMS software imaging, ITCM-related development services, and ITCM network design, testing, and deployment.

Partnerships for PTC projects
LILEE Systems is providing products and services as a subcontractor for PTC projects with suppliers such as Xorail, Herzog, and GE.

Development services to railroad suppliers
LILEE Systems provides software development services to suppliers to implement ITC systems management capabilities into their signal and communications product families.

Collaborative research
Proof of Concept demonstrations with technology such as cellular aggregation, low-power IP-based mesh radio networks, and passenger Wi-Fi with partners such as Cisco.

Within this ecosystem LILEE is recognized industry-wide for the following core competencies:

Technology
Leveraging the talent base from the Silicon Valley, as well as its extensive background in network and wireless communications, LILEE has established a proven channel for bringing next-generation technologies to the industry.

Agility
To accommodate the nature of the technology sector, LILEE is structured in a manner designed to increase responsiveness to customer requirements, reduce bureaucracy in the decision-making process, and enable closer coordination between our customers and our engineering department.

Focus
Unlike other vendors in the industry, LILEE focuses solely on communications technology. We do not dilute our expertise across areas in which we cannot offer our customers a clear, distinct advantage. This is one of the primary reasons that various established systems integrators continue to select LILEE Systems to support their PTC projects.

The Meteorcomm ecosystem
More than 3 years of experience in working with Meteorcomm products allows us to provide our customers with proven paths for interoperability and performance.

Flexibility with Systems Integrators
Each customer's ecosystem of suppliers is different, and given LILEE's focus on communications, we have proven the ability to work with a wide array of suppliers such as GE Transportation, Parsons, Xorail, and Herzog.

Worldwide manufacturing base
Through our exclusive agreement with Wistron, LILEE has established access to an extensive worldwide manufacturing base that can address the various needs of our customers.

LILEE Systems follows an agile and interactive development model to improve responsiveness to customer feature requests and provide the best customer experience. We conduct weekly development review meetings with our customers to review progress and track feature design, implementation, integration and testing. All customer feedback, operational issues, and feature design changes can be addressed in a timely manner within this process. It is a proven model that helped LILEE Systems deliver software and integration solutions across a wide array of projects.

A program manager is assigned to every customer project to ensure continuity of the agile development cycle and coordinate between the various cross-functional teams to timely produce all deliverables.

Program managers are responsible for scoping, planning, and managing projects including management of associated financial and human resources, schedules, communication plans, and deliverables.

As illustrated in Figure 5, our agile development process includes a continuous improvement cycle rather than the traditional waterfall development model

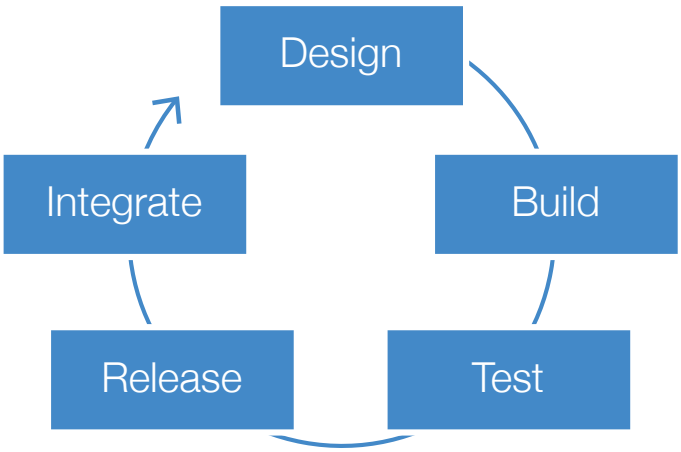

Figure 5: *LILEE Systems PTC/ITCM Solution Design Process*

Design

- Analyze, define, and plan product features, functionality and enhancements
- Collect customer feedback on features to be added for the next release
- Produce mock/prototype to determine feasibility and scope of desired features
- Evaluate technology and feasibility

Build

- Implementation and/or customization of product features
- Heavy cross-functional involvement from engineering, marketing, manufacturing, and customer advocacy to ensure design meets requirement specification, manufacturing, and serviceability goals

Test

- Systems are internally tested and verified, and externally validated when possible
- Requirements are matched and validated

Release

- Verify that customization meets customer specification
- Provide documentation
- Solution compliance validation
- Product knowledge transfer to customer

Integrate

- On-site or remote installation to integrate new releases at customer premises
- Perform user acceptance and qualification
- Collect feedback

System Management Gateway (SMG)

LILEE Systems SMG is a comprehensive solution for monitoring and troubleshooting of wayside, base station, and locomotive networks. Designed to operate on ITC networks utilizing interoperable train control messaging, the SMG provides an intuitive and unified interface for managing complex PTC networks. LILEE Systems SMG provides the following capabilities:

- *Remote site status assessment*
  SMG provides a single portal for locating, identifying, and tracking various fixed and mobile locations via Google Maps.
- *Remote software capability*
  SMG provides the user with the capability to schedule and batch software updates to multiple locations based on railroad-defined criteria, such as time and preferred communications path. The SMG supports remote file transfers over 220 MHz, cell or IP paths.
- *Remote command execution*
  In addition to the aggregation of multiple locations, the SMG allows the user to interface with individual devices on the network with RCE (Remote Command Execution) capability.
- *Remote device configuration and software access*
  SMG supports systems management agents for commercially available Wayside Interface Units (WIUs), Wayside Messaging Servers (WMS), Wayside Status Relay Service (WSRS), ITC radios, and third-party devices.
- *Remote alarm notification and management*
  The SMG provides user-defined alarm notification and processing for handling by field maintenance crews.
- *Locomotive tracking and asset visibility*
  The SMG provides tracking capability for all locomotives on the network. LILEE Systems' Athena software can also be utilized in conjunction with the Wabtec Slot 10 image.

Wayside Status Relay Service (WSRS)

LILEE Systems' interoperable Wayside Status Relay Service (WSRS) is a back office application that sends and receives EMP messages via the ITC messaging system over Class D and AMQP transport protocol. The WSRS is part of the Interoperable Train Control Messaging (ITCM) System. The main function of the WSRS is to ensure timely delivery of Wayside Status Messages (WSM) from Wayside Interface Units (WIU) to interested locomotives.

The LILEE Systems LMC-5500 can be utilized as a hardware platform for running the WSRS application. The Messaging function provided by the LMC-5500 complies with the ITC WSRS version 1.0 requirement.

One of the applications of WSRS is to allow the PTC system to utilize the fiber optic network installed at each signal location to send messages from the base radio locations eliminating the need to have a radio and antenna tower at each signal location.

PTC Solutions for Locomotive

LILEE Systems PTC solutions and applications for locomotives can be summarized as follows:

- LMS-2450 as Central Communication Hub (GE ACC Alternative)
- LMS-2450 as Companion for Wabtec on board computer to replace Wabtec slot 10 ITCM capability
- SMA : System Management Agent (End-to-End Seamless Solution between SMG and SMA)
- ZCC : Zero Touch Software Upgrade and Maintenance for LMS/DTS and 3rd Party Devices
- LMS-2450 as Central Communications Hub and/or Companion for Wabtec TMC

Wabtec's Train Management Computer (TMC) forms the heart of a locomotive's onboard system, with peripherals including computer display units, signal monitor, and interfaces to braking systems and event recorder. All U.S. Class 1 railroads, and many commuter railroads operating on Class 1 tracks are implementing the Wabtec "Interoperable Electronic Train Management System" (I-ETMS) on-board systems as the basis for meeting FRA PTC requirements.

GE Transportation Services (GETS) PTC3 (Positive Train Control Communications Commander) is a modular and scalable AAR S-9101 (Auxiliary Card Cage) compliant platform which integrates networking and communications, plus provides flexible integration options for other systems and applications requirements.

PTC3 can easily be substituted by the LMS-2450, the latest evolution of LILEE's advanced communications systems for the transportation industry. Based on the LileeOS platform, LMS-2450 supports mobile and fixed applications in HyRail and locomotive environments and provides a complete, end-to-end solution that delivers both robust connectivity, Ethernet switching and an x86 application engine that allows users to load any business or PTC applications their business requires.

Figure 6: *LILEE Systems LMS-2450 Mobility Server*

Dynamic on-the-fly roaming, multi-link aggregation, plus static and dynamic load balancing, and link monitoring ensure seamless connectivity and best user experience between back office and mobile environments with integrated GPS, multiple mobile broadband modems, Ethernet, Wi-Fi and software-defined radio (SDR). With the increasing reliance on Wi-Fi for universal connectivity, the LMS-2450 offers an attractive solution for on-board operations networks. And the flexible, modular design delivers scalability that enables users to expand over time.

With these capabilities LMS-2450 also becomes a perfect communications and applications companion for the Wabtec TMC as it offers complimentary features and functionality. A typical example is security; most transportation systems use some form of closed-circuit video (CCTV) for fleet, passenger and personnel safety and security. Cameras mounted on the inside and outside of the locomotive can be monitored during transit, or recorded and available for offline analysis. These systems can be connected directly to LILEE's LMS system. Key features of the LMS-2450 include:

- Modular design allowing for flexible integration of safety and business data management functionality, and addresses all interoperable train control (ITC) IP transport requirements
- Multiple cellular uplinks, channel bonding, link aggregation, and prioritization for multiple high throughput mobile industrial/transportation environments
- Remote management enabled by machine-to-machine (M2M) telematics, enabling users to remotely monitor, control, and perform diagnostics without involving the physical presence of a maintenance or repair crew, which can be expensive
- A fanless, ruggedized system with wide-range power supply support that is well-suited for use on rolling stock including locomotives and maintenance vehicles
- Hardened, extensible system featuring a robust x86 application engine module that can leverage Linux or Windows business specific applications to meet IoT / M2M solution requirements

System Management Agent (SMA)

LILEE ITC systems management agents (SMA) are designed to be interoperable with 3rd party assets. They can be configured as a proxy for translating ITCSM operations into typical NMS operations, such as SNMP, commands over SSH, and operations through 3rd party proprietary utilities. For example, LILEE SMA running on Slot-10 is able to receive instructions over ISMP to update or read and return the current IOC configuration set on the host TMC. Upon request, LILEE can provide professional services to work with our customers on defining the scope and delivering the feature sets to fulfill the systems management requirement for the TMC.
LILEE has demonstrated the ability to integrate our software agents and utilities on third party locomotive electronics to provide functionality such as asset tracking, fuel monitoring, and track other performance metrics. This software was designed to be portable from the TMC slot 10 to other x86-based systems, which includes LILEE's LMS-2450 Series of locomotive messaging and application servers, OBN (Onboard Networks), and the Ancillary Card Cage (ACC). Depending on a customer's population of the ACC, LILEE Systems can provide software integration services in support of PTC and business applications.

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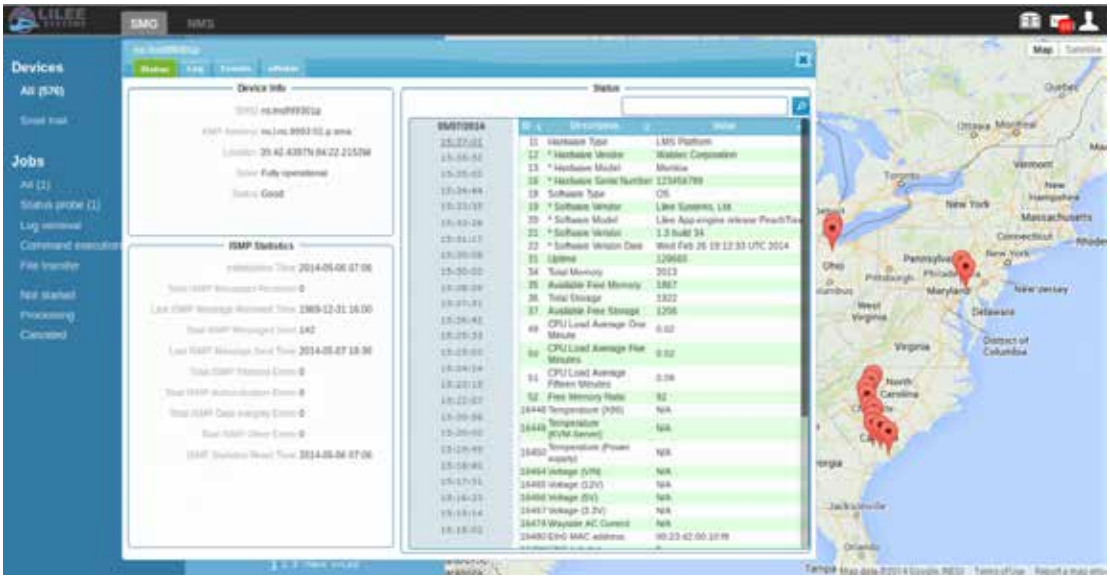

Figure 7: *LILEE Systems Locomotive Messaging Server Software with Asset Tracking within SMG*

Figure 8: *LILEE Systems Locomotive Messaging Server Software with Asset Tracking within SMG*

Zero Client Configuration (ZCC)

LILEE Systems Zero Client Configuration (ZCC) is a zero touch deployment, configuration, upgrade and maintenance tool to automate the process of the deploying ITCM devices in field locations such as wayside and locomotive. ZCC consists of embedded software that allows quick and easy configuration of multiple devices before deployment. ZCC can be installed using a USB drive (supplied by LILEE Systems) or through an IP network.

LILEE Systems works with customers to create customized ZCC system software packages that include:

- LILEE ZCC system software
- ITC messaging topology
- Firmware and configuration template files for devices

LILEE ZCC is a very powerful tool that is very similar to laptop/desktop images used by any company's IT department to manage a standard OS image and configuration of the computing assets. Just like the IT department may re-image the device if the OS or any application stops working on a laptop/desktop, ZCC can do the initial installation and configuration or re-image the asset without worrying about its configuration. Just like the IT department can image multiple devices at one time, LILEE ZCC can be used to deploy multiple assets in one shot. ZCC provides tremendous value when it comes to easy and error free deployment of messaging and radio devices.

PTC Solutions for Wayside

LILEE Systems offers the following hardware and software solutions for the Wayside component of the PTC infrastructure:

- DTS-2000 as Wayside Messaging Server
- SMA : System Management Agent (End-to-End Seamless Solution between SMG and SMA)
- ZCC : Zero Touch Software Upgrade and Maintenance for LILEE DTS and 3rd Party WIUs
- Retrieve WIU information, encapsulate data and send to ITCM Infrastructure

DTS-2000 as Wayside Messaging Server

The DTS-2000 Series from LILEE Systems provides interoperable wayside message server gateway functionality along with modular expansion ports to provide additional communications flexibility. The DTS-2000 features an integrated communications management application that provides a consistent IP address and network connectivity to remote assets. This application dynamically selects the preferred communications path to a centralized facility using user-selectable performance metrics. This unique functionality enables the DTS-2000 to aggregate bandwidth simultaneously across 4G LTE cellular, Wi-Fi, and Ethernet interfaces as these services are available, allowing the greatest amount of throughput at the lowest possible cost.

The DTS-2000 features a powerful application processor certified by Red Hat that allows users to develop their own value-added applications without worrying about network availability. The applications can always be reached from the control center through any of the configured communication links. For applications that demand high reliability, the DTS-2000 offers intelligent link selection according to the internal policy engine configuration. Intelligent link management significantly improves train safety for Positive Train Control applications by delivering the train control commands over the most cost-effective and reliable link available.

For Positive Train Control applications, the DTS-2000 is ideal for use in all wayside location types. The DTS-2000 is suited for harsh environments and locations where utility power is not available. Wake On/Sleep functionality provides on-demand performance that allows the DTS-2000 to rely on a solar powered system to reduce deployment costs and maximize return on investment.

The DTS-2000 is fully compliant with the requirements and specifications set forth both in AAR Standard S-9401 for railroad applications and in EN-50155 for transit and other embedded or Intelligent Systems applications.

System Management Agent (SMA)

As described earlier, the LILEE systems management agent (SMA) was designed to support communications with any asset and provide proxy control operations and status/events forwarding for devices, such as WMS, LMS, and the ITC radios. However, there is recognition that many legacy devices —such as MCPs and BCPs, are managed remotely through dedicated utilities with no relationship to the management system being deployed for PTC. Depending on our customer's approach to consolidation of code line traffic with the ITC messaging system, LILEE Systems can augment the SMG and SMA to include support for legacy devices by creating new asset proxies to communicate with the existing equipment.

Figure 9: *LILEE Systems DTS-2000 On-board Communications Server*

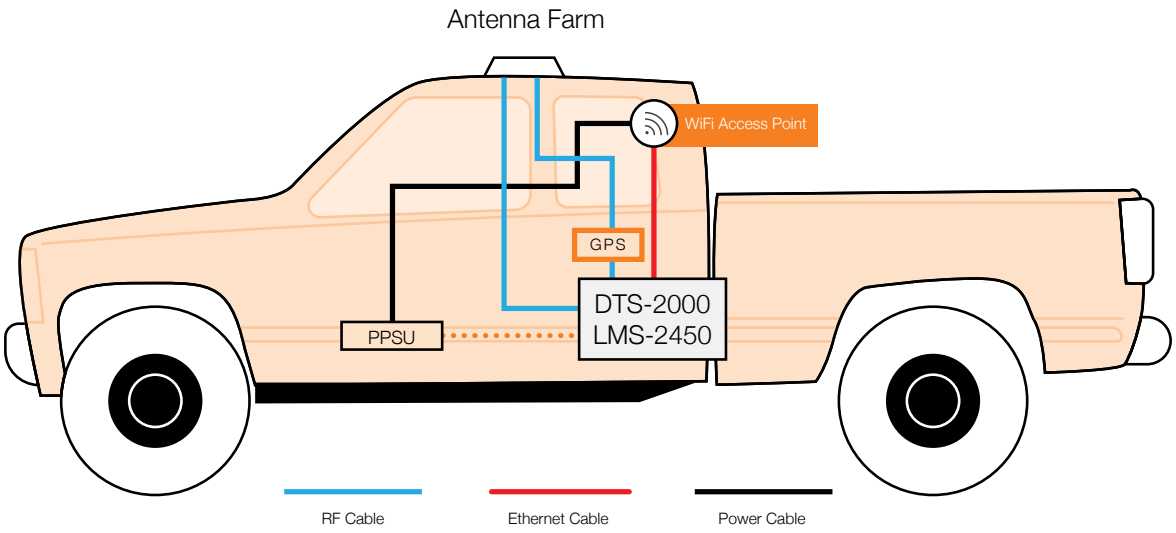

Figure 10: *Wiring Diagram for a Typical Installation on a HyRail Vehicle or Truck*

Maintenance of Way vehicles (HyRail)

Because HyRail vehicles share the rails with freight and passenger trains, a key system for maintaining the safety of their operators is the HyRail Limits Compliance System (HLCS). This systems provides an added layer of security for the operation of HyRail vehicles on active railroad tracks.

HLCS uses global positioning satellites (GPS) to determine the location of HyRail vehicles and transmits that position to the railway operator's back office where it is compared to the authority given to the vehicle operator. As the HyRail vehicle approaches or exceeds its authority limits, the back office will send alerts/alarms to a visual display on the on-board system, as well as to the train dispatcher via the train dispatch computer system. The system also works in a peer-to-peer mode to provide proximity alerts at HyRail vehicles approach other HyRail vehicles that are on or near the railroad tracks.

The HLCS takes a reading from the built in GPS receiver and forms a position report that is sent to the back office. This report includes the truck number, the track selections, the rail status, and additional information. It is cross-referenced to the train dispatch system to ensure the operator had a valid authority to be on the track, and was within the limits of its authority. This allows the back office to activate any necessary alarms or alerts.

Figure 10 shows a wiring diagram for a typical installation on a HyRail vehicle or truck. This application can typically be supported by the 2-slot DTS-2000. Since it requires high-precision GPS, which occupies one slot, the second slot can be used to provide Internet access to the HyRail crew and potentially other crewmembers if a Wi-Fi access point is configured.

If less accurate GPS is acceptable, a combined LTE+GPS module can be used, doubling the LTE capacity., Migrating to the LMS-2450 will provide additional network capacity and the ability to connect additional equipment is desired.

LILEE Systems Integrated Services Portfolio

Regardless of your applications, LILEE Systems Services can make your project successful by integrating engineering services with our portfolio of data and network communications products. Spanning project inception to project implementation and certification, LILEE Systems integrated services portfolio provides value added engineering and technology services that complement our product line and give your company a competitive advantage in meeting your customer's needs, while helping you meet your company's business objectives and gain peace of mind and confidence in achieving your goals in design, development, system deployment, performance, and operational start-up. Our suite of professional services includes:

System Prediction Modeling	Accomplished with analytical engineering services and LILEE Systems "Artemis" Software Suite. Artemis creates a virtual geo-based model of anticipated RF propagation throughout a PTC system. The virtual predictive model is a useful tool for principal contractors in verifying design phase RF propagation that allows verification of proposed base station location and system layout against actual implementation.
Systems Validation and Proof of Concept	This service validates PTC system design parameters and assembles and tests key network components in a test lab environment. During the Proof of Concept phase we test all network communications protocols and determine the viability of third party software integration.
Product and System Testing	Working with your contractor, LILEE Systems provides in-field technical support to ensure schedule milestone compliance. Services include product receipt verification, manufacturing testing compliance documentation, design configuration validation, and related PTC system equipment interfaces, connectivity verifications, and system start-up. Other services include specification driven start-up and systems integration testing required to support the FRA Safety Plan Certification required by the federal PTC mandate.
Post Deployment System Performance Modeling	Accomplished through analytical engineering services and LILEE Systems "Apollo" Software Suite. Apollo creates a performance and measurement model of deployed PTC systems based on waveform recording and data packet authentication. This unique performance model is also applicable to the environmental and energy application markets. Key benefits derived from this software and service suite are collection of RF transmission data to confirm network coverage against design standards, and collection and analysis of data packet information to confirm and ensure data transmission consistency related to radio, terrain, power, and network configuration.
Project Management	LILEE Systems offers a full line of project management services in conjunction with the above technically oriented services. Our project management services are carefully designed and structured based on overall project requirements and needs of prime contractors. Our general services include Project Planning, Project Execution, and Project Close-Out, and are performed by PMP certified project managers.

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LILEE Company Overview

LILEE SYSTEMS was founded in 2009 by industry leaders with extensive backgrounds in wireless communications, network routing and switching, and software defined radio (SDR). Headquartered in San Jose, we opened a subsidiary office in Taipei, Taiwan in 2010 to establish an engineering center and work more efficiently with our manufacturer in production, testing, and rollouts of various PTC projects.

Founded with the main purpose of providing communication networks to the railroad industry, we shipped our first products in 4Q 2011 into the freight railroad market, seizing the opportunity that emerged with the Congress-mandated deployment of Positive Train Control (PTC) which required wired and wireless networking solutions that were previously nonexistent in the railroad industry.

We recently expanded into the broader transportation market with a solutions portfolio that includes passenger connectivity and other broadband solutions such as safety, security, maintenance and management. Additional markets include First Responders, Homeland Security, Military, and Machine-to-Machine (M2M) communications in the broader Internet of Things (IoT) market.

Our mission is to create ”Connectivity in Motion” by merging multiple wireless connections into a predictable, stable and manageable network. All our hardware and software is manufactured in-house, and our hardware is ruggedized, future-proof and modular. LILEE is the market leader in the connected transportation space, with well-established partner and alliance programs. Our hardware, software and services enable customers to provide applications and services in the growing software defined transportation market.

Since our founding in 2009, LILEE Systems has grown from a staff of less than 10 core engineers and administrative staff to over 110 people. Our team is recognized as leaders in the wireless industry, with core strengths and cross-disciplined backgrounds obtained from careers at Cisco, Juniper, Extreme Networks, AMD, Apple Inc., Aruba Networks, Motorola, Citrix, Fujitsu Network Communications, Safetran Systems Inc., Invensys Rail, and GE Transportation. We are actively participating in the standard bodies in defining next generation wireless architectures and have been Voting Members of both 802.11 WLAN and 802.16 WiMAX for several years. Our executives have many years of engineering, project management and go-to-market experience in the networking industry and in wireless design and development, holding several patents for Software Defined Radio.

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