SYSTEM PLANNING CORPORATION
1000 Wilson Boulevard•Arlington, Virginia 22209-2454•(703) 351-8200•Fax (703)-351-8663

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21st Century Evolution of Connective Technology in the Global Supply Chain

CSCMP Member/Author: Joseph H. McKinney, Vice President – Business Development

Contact information

Business Address: System Planning Corporation
1000 Wilson Boulevard
Arlington. Virginia 22209-2454

Telephone: 703-351-8284
Blackberry: 703-338-9041

Email: Jmckinney@sysplan.com

Joseph H. McKinney System Planning Corporation

21st Century Evolution of Connective Technology in the Global Supply Chain

Introduction

Military historian John Keegan compared the challenges of leadership of Alexander the Great in the 4th century B.C., and Arthur, Lord Wellington, in his Peninsular campaign against Napoleon in Spain. At the beginning of the 19th century, advances in military technology gave Wellington muskets, canonry, Congreve rockets, and the formidable battle square formation. However, the maneuverability and efficacy of both men's forces still were determined by the same simple logistical calculation of how large a load of food and fodder a team of oxen could drag across the countryside.

We've come a long way since we stationed sharp-eyed boys at the harbor to spot our ships on the horizon. The twentieth century gave us steady improvement in communications, allowing us to know the moment when our goods were made, the moment they were shipped, and the moment they were delivered.

Ships, ports, trucks, and railcars have been physically transformed to accommodate the robust steel container. Though containers make it more likely that an order from a supplier anywhere in the world will arrive "whole," old worries remain about theft, vandalism, delays, and accidents. Long, murky time periods – blank spaces in the information flow – remain between those moments when goods are manufactured, shipped, and delivered.

And now governments are clamoring for ever greater amounts of information about our cargoes: What are they? Where have they been? Who has handled them? Their concerns include the traditional ones about smuggling as well as the twenty-first century fear of terrorists turning a container into a Trojan Horse with a weapon of mass destruction.

It is now possible to take positive action to maintain the safety and quality of high-value shipments in global commerce, to fill in the blank spaces and answer both management and government questions about a supply chain's operation. This paper focuses on the revolution in supply chain connective technologies.

"Dumb" Containers

Improving supply chain management means getting information that allows you to predict, facilitate, and protect the flow of goods. The big, dumb steel cargo boxes in use today are subject to the vagaries of transport, assorted accidents, the predations of thieves and vandals, the effects of temperature, and the schemes of smugglers. Terrorism fears are stimulating government efforts to monitor the contents and travels of the boxes in the name of national security. A box without a voice limits good management like a team of oxen formerly limited Wellington.

A Container Monitoring Device Adds Security *and* Value

As it became clear that container monitoring solutions designed solely to meet security requirements create an external cost to companies and shippers, System Planning Corporation (SPC) configured its new container security device to add value by supplying the information crucial to predicting, facilitating, and protecting the flow of cargo in containers, trucks, and railcars.

SPC's work on its container security system called GlobalTrak® began in late 2001 and has evolved through four stages into a new connective technology: 1) early proto-type development in 2001-2002, 2) demonstration and refinement in two global supply chains as part of the US Federal Government's Operation Safe Commerce program in 2003-2004, 3) major upgrades in information management and flow for commercial applicability in 2005-2006, and 4) on-going commercial adaptation to meet global trade-line needs and provide in-transit and total asset visibility (ITV and ATV) as well as support national security requirements for ever-improving marine domain awareness.

Patented in August, 2006, GlobalTrak® is in early commercial application, and is projected to see extensive global use and extensions over the coming three to five years. Supporting additional patents are under review for enhancements and other implementations.

The system is based upon a wireless device that is attached in or on a container (or virtually any type of vehicle), includes an antenna set, and has a communication center known as the Information Management Bureau (IMB). The device itself is a box containing a central monitoring unit (CMU), a sensor suite, batteries, and a communications capability. Communications are transmitted wirelessly via cell and/or satellite communications, using appropriate antennas, and are two-way.

Figure 1 is the CMU logic for standard communication. Through the communication linkage, information is sent to or from the IMB, providing data from (or to) the device concerning its status and location as programmed, as requested, or in an alert mode. Figure 2, is a schematic of the data flow with the GlobalTrak System. The system provides anywhere, anytime, worldwide connectivity. It provides 24x7 enterprise mobility.

Figure 1. GlobalTrak CMU Logic for Communication

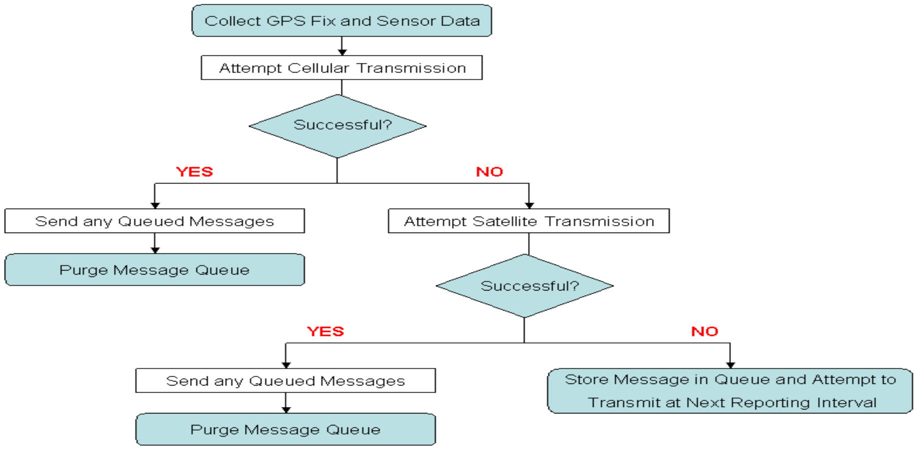
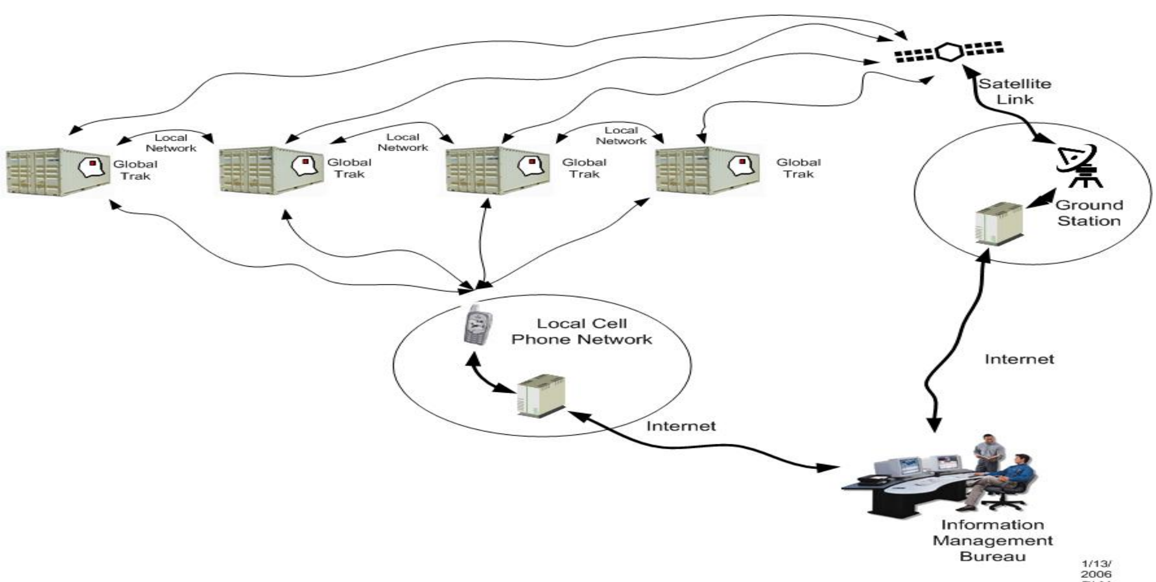


Figure 2. GlobalTrak System Internal Data Communications Flow



Communicating Wirelessly: Enterprise Mobility through GlobalTrak

In a March, 2006, industry survey by Forbes Inc., done in conjunction with Management Insight Technologies, 851 business and IT professionals were interviewed to learn their business priorities, budget expectations, and core objectives concerning enterprise mobility -- how businesses communicate through mobile technologies. Some highlights of the survey:

- 48 percent of the respondents consider enterprise mobility to be a top five initiative of their organization

- 91 percent believe they have realized productivity gains from their mobilization efforts
- Security, data management and synchronization are the biggest challenges facing mobile enterprises.

GlobalTrak® today addresses these elements of enterprise (or business) system mobility. As a key system, it offers in-transit visibility, total asset visibility, and provides security, data management, and virtually instantaneous synchronization.

Employing Real-Time Observation to Monitor and Protect Your Shipments

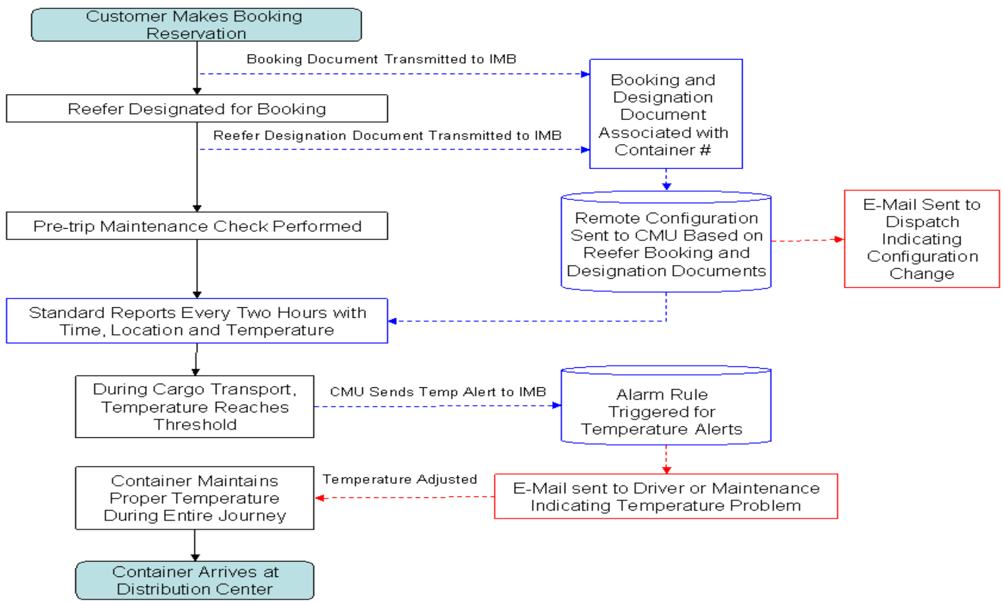
With advanced sensor and communication devices such as GlobalTrak® there is no requirement for additional system components beyond the device itself. This characteristic means that the need to a massive global network of reader devices, representing sizable investments by many if not all participants in the supply chain, is eliminated. After placing the device on or in the container at the point of stuffing and initiating operation, all further actions and operations can be performed remotely until the container is opened at a point of deconsolidation. No need to pass by Point A or B so as to have the RFID or bar code tag read by an expensive reader. Information is transmitted to and from the IMB, where the transmitted data is transformed into actionable reports providing information to the system users.

Sensors contained in these devices should be able to be called up at the operator's request; a standard set of sensors includes heat, light, sound, acceleration (g-loading), and door opening. Other sensors – radiation, chemical, biological— are available. Power consumption is a consideration in sensor use, since some are more power consumptive than others. Batteries are the principal source of power, although external power can be used when available, for example, with refrigerated containers. Battery life can be more than two years: this is dependent upon the reporting frequency chosen, and the communications mode utilized.

The centralized information management service center has the primary function of the collection and transfer of container sensed messages about the cargo and the shipping container condition—sort of like having your family check in, and using the same device. Beyond this capability, the IMB can be used to create more supply chain efficiencies by effectively managing processes involved with container deployment and utilization while securely sharing relevant information with supply chain partners and alerting appropriate stakeholders when predefined conditions are met.

The IMB has the capability of managing document flow related to any part of the supply chain. Documents can be uploaded and associated (or "fused") to messages from containers, viewed through the web, or published to stakeholders. Such documents include Purchase Orders, Manifests, Bills of Lading, and Advance Shipping Notices. To best make use of these capabilities, business processes must be thoroughly mapped and appropriate solutions implemented for efficient process management. Figure 3 is an example of the data flow where the IMB is used within the deployment and monitoring processes of a typical container journey.

Figure 3. IMB Integration with Current Processes



<u>A Truly "Smart" Container</u>

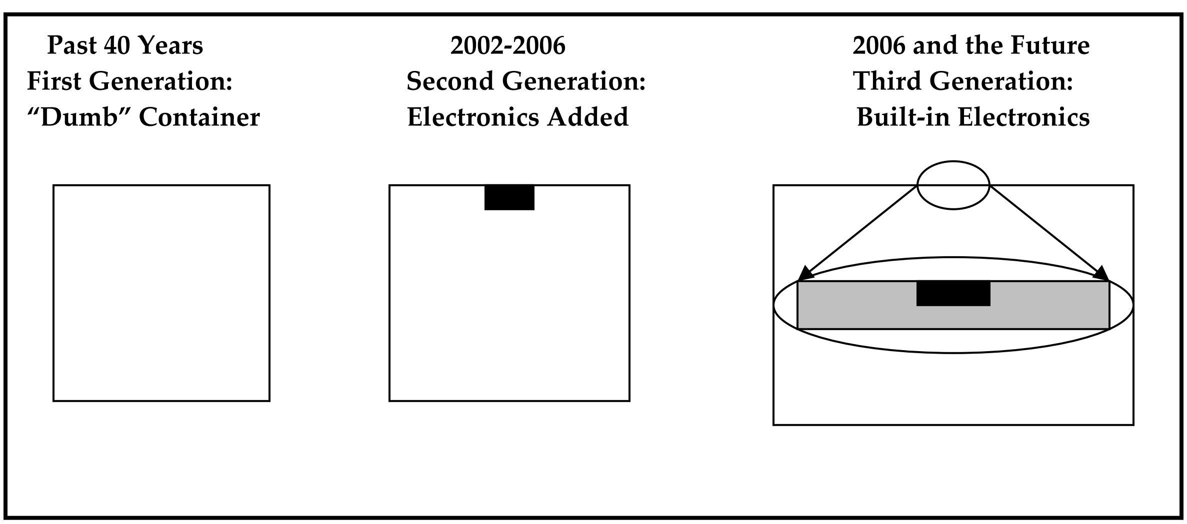
Industry and the government are demanding ever more information to support management of a supply chain and meet security requirements. They need an intermodal shipping container capable of allowing electromagnetic penetration of the steel box. Such a capability would allow 1) reading RFID tags located on pallets in a container, 2) detection of various threats, unauthorized materials, tampering, or exposure to harmful chemical or biological substances, and, obviously, 3) better tracking and reporting on location and contents. This is the description of a "smart" container versus the "dumb box" that has been employed by the industry for more than 40 years.

In the future some are proposing to meet this need for electromagnetic penetration, to "see through" a container with a plastic "window" or wall segment with embedded sensors and supporting electronics. The structure under investigation today is called e-Wall™. The developers are assessing state-of-the-art material usage, especially the status of high-strength polymer development. Figure 4 depicts an early e-Wall™ concept. Integration of the container's steel skeleton and polymer skin (that is, for example, a combination of filament wound plastic and steel structural members) is planned. (Since containers were first manufactured in the 1960's, many materials and processes have been used. Large polymer containers have been investigated, and are currently fabricated and used by the US Dept of Defense to move missile and rocket components. Thus, plastics do not represent a totally new approach to container fabrication.)

Figure 4: A 20-foot container showing the location of the plastic eWall™ panel.

Figure 5, below, schematically shows the development process to move from the current ISO container to a "smart" system. This graphic shows the 40-year first generation ISO container cross-section (left), evolved to a second generation system with added internal electronics (sensors, batteries, communications capability), shown in the center. The right-hand schematic shows the eWall, inserted into a container wall that has had a window cut into the box; the embedded electronics are within the eWall. The eWall "Smart" containers are hybrids of metal and plastic with electronics embedded in the walls, both vertical and horizontal, as shown in Figure 5.

Figure 5: Cross sectional schematic, three generations of ISO containers



The features of an eWall smart container will include the following.

1) A GPS transponder provided for real-time tracking capability.

2) X-ray transparency: X-rays will easily pass though a non-steel container eWall™ for security screening.

3) The "Smart" container incorporating an in-transit visibility and sensing system will allow for a single-source logistical system capable of wireless encrypted data transmission to handheld as well as fixed data download stations; centralized data retrieval will be possible.

4) Commercial applications for this technology are extensive and include commercial merchant shipping, dry and refrigerated cargos -- possibly using a foamed polymer shell.

5) The "Smart" container will meet Department of Homeland Security directives regarding container security.

Coming in the Near Future: Wireless Sensor Networks

SPC is researching a promising new technology for use in asset tracking of any kind is the extended wireless sensor network (WSN). Progress on WSN has been rapid: Micro-computers were developed in the early 1980s. So-called "smart sensors" were created when these were integrated with sensors so that they could deliver information, and not merely data, to users. In the 1990s, single chip radios were developed. These were integrated with smart sensors in this decade to enable wireless sensor networks. Concurrent software developments made it possible for the networks to organize and reorganize themselves, which has led to major deployment advantages and to increased reliability.

WSN are, of course, information generation systems, in which the information comes directly from sensors, not people or computers. They are coupled with a database to serve the users of the information. The payoff of the system is appropriate information delivered to the required users in a timely fashion. In a WSN, a sensor network made up of nodes, links, and gateway sends information to a central point with a database and user interface that serves users either at that center or remotely. All three elements are needed to achieve this general goal.

WSN can have a variety of topologies. They include linear, star, tree and mesh configurations and combinations of these fundamental arrangements. It is now possible to buy commercial hardware/software that automatically handles all of these topologies.

ZigBee technology (an element of the GlobalTrak System) is the primary example of such development. As noted, it is based on a radio standard (IEEE 802.15.4) and a network software protocol that enables interoperability (ZigBee).

Our Latest Research in Progress

The architecture of the WSN under review at SPC will almost certainly be a set of identical sensor nodes, with considerable on-node computing power for on-board processing of signals into information (such as chemical presence) and, later, multi-sensor data fusion at the node level. We expect to need at least six nodes in order to test both linear and mesh configurations of the WSN. A single gateway will accept information from the nodes, either directly or via multiple hops, and pass it to a PC by a wired connection. The gateway will be a sensor node with a different program in its controller. This will evaluate alternatives to insure that this simplest architecture will not suffer from scalability or other problems. Specifically, it will review alternatives to ZigBee to see if they have recently advanced to a point of being candidates for the WSN to be developed and demonstrated. The alternatives primarily consist of proprietary communication protocols, plus a few products based on WiFi.

A flexible wireless sensor network (WSN) will provide smart decision making capabilities for the real-time detection of chemical warfare agents and toxic industrial chemicals, providing the basis for detection of chemical/biological threats. Nodes within the network will pre-process and condense data before transmission to a collection location, an Information Center. The “sensor layer” of the network architecture will be separate from the “network layer”, so that sensors can be easily inter-changed, depending on the needs of the application. Subsequent development will extend to additional relevant sensors, with a larger WSN that has more advanced on-node processing. Both military and civilian scenarios will be developed to demonstrate the WSN developed in this program.

This research effort will exploit leading-edge commercial sensor, computer and communications technologies in a creative fashion to demonstrate the long-sought ability to monitor chemical and biological threats and conditions in real-time over an extended area. There are multiple health, safety, and military applications for this technology, including 1) real-time monitoring of chemical and biological threats to mass transit, 2) pre-monitoring potential battlefields, 3) remote monitoring of personnel in combat zones, and 4) monitoring of patients with chronic medical conditions for maintenance of independent living at home.

The initial phase of this SPC effort will demonstrate the ability to place and operate sensitive chemical sensors in the outdoor environment for an extended period. This is very significant because chemical sensors are the limiting factor in determining the longevity of many monitoring systems needed by the military, for example, at fixed installations such as bases. It must be demonstrated that sensors for a range of chemicals (that will result in alerts) and for specific chemicals (that will give managers and responders needed detailed information) can operate within calibration for usefully long times.

A second phase will provide a similar test for sophisticated bio-sensors in the larger network. This is no less significant or challenging that the initial demonstration for chemical sensors. Long-term deployment of biological sensors is much more challenging than chemical sensors for two reasons. In general, bio-agents like anthrax spores are particles that usually have to be collected out of the air, which involves the use of relatively large samplers. Then, the particles have to be subjected to complex processes to prepare for and conduct the actual analyses. Ancillary chemicals have to be stored in the system for all functions. Fielding of bio-sensors is a larger challenge than the extension of the network to a larger size. The integration of commercial bio-sensors into a WSN and its operation outdoors will be a very significant demonstration.

The overall program when successfully completed will result in multiple technologies that will benefit both civilian and military users. It will be significant to have both the demonstrated design and the field experience with chemical and biological sensors within a cutting-edge WSN. Such integration is only now possible because of recent advances in chemical/biological sensors and in *ad hoc* self-forming and self-healing networks, aided by the availability of very low-power and high-performance micro-controllers. The integration requires a focused research effort because neither existing sensor companies nor the wireless network companies are doing it. They supply the critical components needed for the overall needed WSN, but the actual integration and demonstration by a company is both needed and possible now.

Conclusion

Connective technology is rapidly evolving, driven by commercial as well as security forces. Considering that international trade based on the adoption of containerization has become as dominant as it has today, we can expect the revolution in connectivity –devices, systems, methodology – to continue to penetrate the industry in the next decade, and GlobalTrak and similar systems will become standards for connectivity and international communication throughout the Supply Chain.