Going the Distance

Power Supply Management in an Asset Tracking Device

Gary Naden Axonn LLC

Constant vibration, harsh environments, and the requirement to operate unattended for years present radically different challenges for industrial tracking devices, as opposed to personal or in-car units. This becomes quickly apparent in the matter of power supply, which must come from batteries and not a vehicle-borne system, and must support positioning, microprocessor, and communications components, and often temperature and alarm sensors as. A product designer discusses how to optimize location and transmit functions for performance and low power.

The advent of affordable GPS positioning and ubiquitous wireless communications is spurring interest and adoption of tracking capabilities in diverse fields: fleet management, personal location services, pets, electronic surveillance of parolees, cargo and other mobile assets. But the technical and operational requirements for the various tracking applications are not necessarily the same. Power supply represents a key differentiator among tracking systems, which must support positioning, microprocessor, and communications components and often other sensors.

A crucial question for system developers and end users revolves around this issue: can power be obtained from a generation source, such as is available in vehicle-borne systems, or must the tracking equipment rely on battery power?

Although the number of asset tracking devices has increased dramatically in recent years, few models have effectively solved the problem of delivering an integrated and reliable power-management solution. Industrial asset tracking exposes devices to harsh vibration and environments and may require them to operate unattended for years. The need for tracking systems to effectively determine and report location and local status, such as external temperature or alarm sensors, while operating without an outside power source has limited the scope and scale of applications to date.

The power requirements for positioning and communications functionality are challenging in a battery-powered device. Both the location and transmit function must be optimized for performance and low power to enable asset management applications. This was the situation faced by Axonn LLC, a provider of wireless packet data solutions founded in 1985 and based in New Orleans, Louisiana, as it sought to develop a global-

footprint asset management device capable of multiyear operation. The result is the AX-Tracker introduced in June this year, which integrates a low-power GPS module, a satellite communications modem, and host processor powered by innovative hybrid lithium thionyl chloride primary batteries.

Background

Asset management is a critical part of any business entity engaged in the transfer of raw or finished goods. Such companies must carefully manage the resupply of raw materials to ensure uninterrupted operations of the manufacturing or service element of the industries in which they are involved. This, in turn, requires them to carefully manage the transport of finished goods so as to minimize inventory held for sale. Businesses that fail to optimize manufacturing and materials handling are at a significant competitive disadvantage.

The uncertainty associated with raw materials and finished goods in transit presents a substantial problem in asset management. Companies generally operate with an element of uncertainty as to the exact time of delivery or the location of products and raw materials en route to their facilities. Unforeseen conditions affecting the arrival of truck, rail, or other vessel deliveries are impossible to predict and difficult to model. However, companies can use real-time information about material in transit to forecast deliveries, schedule manpower and other materials, and predict finished goods inventory supply.

Losses. The transportation industry estimates losses in excess of $40 billion a year due to the theft of cargo in transit alone. Organized loss of cargo takes place in a wide variety of ways, from employee/driver theft to hijacking of entire fleets of trailers and rail cars. Other losses resulting from accidents, traffic congestion, road closures, and other delays add to this mammoth expense.

The transportation industry has struggled to limit such losses by means of radio communications for more than a decade. Cellular telephone service providers and handset manufacturers have enabled a host of communications products that are making an impact. More than $3 billion to date have been invested in products and services

intending to mitigate asset management problems. These products provide many functions from standard voice communication data services such as Internet or E-mail, and real-time position reporting and status of vehicle operations such as speed, temperature, or brake conditions.

Tracking the Opportunity

Market demand for an untethered asset management device is unsatisfied. The raw number of unpowered cargo containers and other platforms that represent prospective targets for mobile asset tracking is staggering: an estimated 250 million unpowered "platforms" traverse the United States carrying raw and finished goods (see **Table 1**).

Axonn estimates that during the next 10 years only about 15 percent of these will ever be configured to track assets based on business efficiencies as justification. Nonetheless, this yields a capture market of approximately 37.5 million units in the United States alone for devices similar to the AX-Tracker. Homeland Security objectives have the potential to alter these figures dramatically, especially in the container market where interest is mounting to validate cargo security carried in containers from overseas.

Communications Options

Conventional tracking solutions typically rely on cellular communication systems or satellite communication systems. Existing approaches that rely on cellular solutions generally do not provide ubiquitous coverage, which may be adequate for urban and major interstate routes but becomes unreliable in rural or sparsely populated regions. Additionally, a cellular network implemented primarily for voice commerce is a poor solution for rail or vessel transportation data communication. Moreover, as cellular technology advances, the

TABLE 1 U.S. market opportunity — Estimated total platforms	
Trailers in service, U.S.	2,025,000
Containers, U.S.	13,200,000
Containers, U.S. from abroad	230,000,000
Rail cars in service, U.S.	4,500,000
Total domestic "untethered" opportunity	249,725,000

protocols implemented around the world have transitioned from analog to digital and now to tri-band Global System for Mobile Communication (GSM). Thus, some communications systems developed only a few years ago have already become obsolete.

An additional factor in cellular communication–based asset management systems stems from their inherent two-way nature, which requires continuous line power for operation. This type of system does not operate effectively on battery-only power without periodic reconnection to line power sources such as an automotive system.

Coverage. Satellite-based communication systems mitigate some of the coverage problems associated with cellular asset management devices. Instead, the area of service corresponds to the "footprint" of the satellites in the system selected for use, which solves much of the availability problem of rural and maritime coverage.
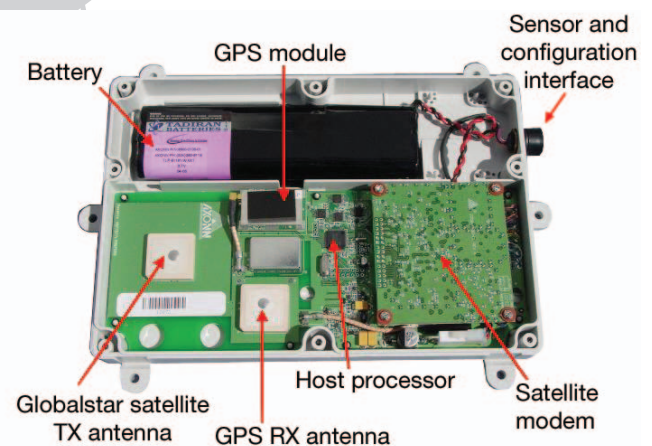
▲ **FIGURE 1** AXTracker integrates a low-power GPS engine, a Globalstar-compatible simplex satellite transmitter, GPS and Globalstar antennas, and hybrid lithium thionyl chloride batteries. It has programmable transmission modes, up to four independently configurable alarm inputs, a serial interface port, and smart sensor or user data input.

MORE THAN $40 BILLION a year is lost to the theft of cargo in transit that can include hijacking of entire fleets of rail cars and road trailers. Railcars on local spurs and sidelines used for staging or storage generally receive no real-time tracking.

Communications Power Play

Customers prefer satellite asset management systems that match the communication bandwidth with the requirements of the application. The data requirements for asset management are generally low-bandwidth in nature. However, many satellite asset management systems are the successors of cellular voice communications systems and offer broadband feature sets such as Internet and voice-over-Internet Protocol. As a result, broadband satellite services are typically expensive and prone to com-

regrowth. Spectral regrowth occurs in non-linear (class C) amplifiers when sine-waves are clipped producing digital signals that have Fourier coefficients outside the allowable spectral band of use.

Linear amplifiers are much less efficient but pass complex transmission signals with minimum distortion, thus preserving spectral utilization. As the band of use is set by the FCC and satellite channelization, the endpoint device is forced to use more spectrally efficient but less power-efficient amplification. As a result, the transmit device must produce up to 10 Watts with amplifier architectures typically only 40 percent efficient. This creates difficult design limitations, usually requiring sufficient line power or bulky high-density battery systems.

Simplex Transmitter. The simplex transmitter operating to a low earth orbit (LEO)

tures, providing simultaneous two-way communications. To send data over a satellite, the remote device must generally negotiate a data channel. Even if the data only goes one way, the communication modem must contain both receive and transmit capability to implement this negotiation. Remote asset management devices must both listen and transmit in order to facilitate data transfer to and from a remote device.

Both cellular and two-way satellite asset management systems require available line power or extensive battery systems to operate. Even existing systems equipped with low-power operational states must consume excessive power to manage two-way communications as well as transmit with sufficient energy to operate within the communications infrastructure.

Other Operational Challenges

Existing asset management devices are generally installed on the tractor-cab of the truck, train locomotive, or vessel. This serves to locate the cargo while the load is attached. Unfortunately, when an accompanying load — such as the trailer, railcar, or barge — is disconnected, the important location information that provides value for asset management is lost. These "untethered assets" may become lost for hours or days or more, resulting in the total loss of perishable cargo or missed deadlines for loads that are nonperishable but time-critical. Inventory management becomes difficult and highly labor-intensive to minimize misplaced loads.

Railcar tracking systems generally lag in capability behind trucking. While railcars remain on class 1 lines, the owners typically know when the railcars have passed checkpoints using barcode or visual identification systems. Once the railcars reach class 2 or class 3 lines, no real-time tracking generally takes place. Class 1 lines are the main, long-haul rail systems that are generally operated by the rail company. Class 2 and 3 lines are local spurs and company-owned sidelines used to stage cars for shipment, or store raw materials or finished goods. Often the end customer loses the cargo once it leaves rail-carrier control, even though it is on his own sideline in the company yard.

Furthermore, customers often use railcars as temporary storage, delaying the

Asset management systems using BROADBAND SATELLITE COMMUNICATIONS package other services to recover the data bandwidth cost, driving up tracking services costs.

munication failures due to weather and obstruction. Asset management systems that employ broadband satellite communications thus end up packaging other broadband services in order to recover the cost of the data bandwidth. This drives up the cost of the associated tracking services.

Another consideration for satellite communications-based tracking is the transmit power required to communicate to geostationary satellites and the constraints that places on a remote asset management device. Existing satellite asset management systems generally must incorporate transmit-power amplifiers of up to 10 Watts to operate adequately. As most satellite communication systems impose tightly controlled spectral masks, digital communication systems must incorporate linear or nearly linear (Class A or Class AB) power amplifier architectures to prevent spectral

system saves power in two ways. First, because it is simplex, the communications link doesn't need to spend power listening or negotiating with the satellite system. Second, because the satellites are in LEO, the distance of transmission is shorter than a geostationary communication link requiring less power. The AXTracker transmits 250 mW versus up to 10 W of transmit power needed for geostationary links. An additional benefit for LEO systems is that the satellites are moving, mitigating the most common problem with geostationary links: shading by stationary objects. Finally, as this satellite system is designed for packet data, it is very well suited for millions of endpoint devices operating with low duty cycles. Users don't needlessly pay for broadband satellite use to pass packet type data.

Currently, satellite-based asset management systems use duplex satellite architec-

off-loading of goods and essentially maintaining inventory at the cost of the rail-fleet owner. The latter have a difficult time assessing demurrage charges because they may not know if the railcar has been offloaded on schedule or even its current location. As a result, rail fleet operators may resort to the expensive solution of adding new cars to the fleet to satisfy logistic problems.

Barge and vessel owners generally are dependent on river pilots and deep-sea vessel operators for the location of goods using voice communication only. As such, commodity traders usually maintain a staff of logistics personnel to voice-track products as they are moved. A radio-telemetry product that works without a cellular infrastructure and without the requirement of available power could dramatically reduce the reliance of pilots and logistics staff.

Building a Solution

The AXTracker mobile asset tracking device is a ready-to-go, self-contained telemetry unit capable of delivering long-term service life through the use of an advanced low-power GPS engine coupled to a Globalstar-compatible simplex satellite transmitter. The units transmit real-time GPS location and other data via one-way simplex communications through the Globalstar satellite system, a constellation of 48 low earth orbiting (LEO) satellites that relay messages to ground-based gateways, which then pass the call on to the terrestrial telephone network and the Internet. The tracking device has a low-profile design, measuring just 9.2×6.45×1 inches. The tracking units attach to the outside of cargo containers, railcars, or trailers.

In designing the product, Axonn took into consideration factors such as product size, service life between battery replacements, and the ability to transmit data reliably under extreme environmental conditions. AXTracker technology integrates an inexpensive simplex modem, GPS and Globalstar antennas, and primary batteries employing a hybrid lithium thionyl chloride technology. It features programmable transmission modes, up to four independently configurable alarm inputs, a serial interface port, smart sensor or user data input, and up to 63 user-definable "geofencing" detection

regions. Geofencing creates virtual fences based on location coordinate boundaries, which an asset may not cross without triggering an alarm or violation notice. This prevents an asset being taken out of a specified zone or entering a prohibited area without alerting system monitors.

GPS On Board

Axonn's mobile asset tracking system uses a 12-channel L1 C/A-code receiver mounted on a motherboard with the GPS antenna, host processor, satellite modem, and Globalstar transmitter. The GPS was selected for three primary reasons: a cold-start time to first fix averaging 45 seconds, a low-power state using only a few micro-amps of current while maintaining battery-backup RAM, and a moderately low run current averaging about 70 mA.

To achieve long service life, the AXTracker device enters an extremely low power state, drawing less than 10 uA which is lower than the self-discharge current of the battery. The device wakes on a preprogrammed schedule or by external alarm/sensor trigger and powers on the GPS module to ascertain location. Next, the GPS module is disabled and the simplex modem is turned on to transmit the location and local status information. The unit then resumes the low-power state until the next wake interval.

Only the required sections of the unit are powered on as needed. Low duty cycles and low transmit current enable the use of primary batteries embedded in the device. During active transmission mode, AXTracker requires high current pulses of up to 1.2 A for intervals of up to 1.3 seconds. This creates a difficult requirement for a battery technology to provide high pulse current, low leakage current, wide environmental operation and years of service life.

Communications Link

The mobile tracking device incorporates new simplex satellite communications technology that enables transmission of packet-switched data. The unit leverages Axonn's core RF spread spectrum data communications technology created by Axonn for the automated meter reading (AMR) market and other applications. The simplex modem utilizes the same custom ASIC developed by Axonn to digitally spread the satellite signal. This is the same basic technology installed over the past 10 years in more than

THE AXTRACKER (white square) on a container in a transit yard. 250 million unpowered cargo containers and other platforms travel the United States carrying raw and finished goods.

12 million AMR simplex devices, many of them using primary cells for power.

Simplex communications offer the most efficient power management method possible because it does not require the device to continually operate a receive capability. The modem, also manufactured by Axonn, operates as a one-way conduit to the satellite system drawing most of the 1.2 A of peak current during transmit. When not in use, it is shut off by the AXTracker host board processor. This enables low-power endpoint hardware and low-cost network interface, suiting the unit to provide location information for assets lacking available power.

Power Supply Alternatives

A primary consideration was the need for AXTracker to work with any form of asset, including automotive trailer, ocean cargo

container, as well as freestanding assets. Use of solar panels with photo-voltaic cells to recharge batteries was ruled out because it adds cost to the cell and requires additional recharging circuitry. Also, due to the harsh, rugged environment of many trailer and rail applications, solar panels were not considered reliable for this application because they are prone to failure as a result of shock, impact, and dirt accumulations.

Rechargeable batteries were also problematic because they are designed to work with only certain types of assets, notably those in the automotive sector. When used in automotive applications, rechargeable batteries typically draw power from the lighting or brake systems, which requires external wiring and installation expense. Design engineers generally prefer not to extract power from these vital safety systems. Also, if an asset is untethered for extended time and the rechargeable batteries cannot be recharged, system failure could result.

Reliability. Rechargeable battery technology also has significant reliability issues for industrial applications requiring more than three years of service life. Rechargeable batteries such as nickel-cadmium (NiCd) or Lithium-Ion (Li-Ion) often suf-

THE TRACKING UNITS (white square) attach to the outside of cargo containers, railcars, or trailers.

the available lithium battery chemistries, bobbin-type Li/SOCL2 cells were selected because they offer advantages such as high energy density, high capacity (19.2 amp hours), low self-discharge rates, excellent safety characteristics, and extended temperature range of −40°C to +85°C. The last feature is critical, as roofs of containers and tractor trailers are often subject to extreme temperature variations. This technology also extends service life due to its low self-discharge rate of 1 to 2 percent per year.

Battery Pack. To accommodate the com-

where batteries lose energy density due to uneven deposition of mineral plating in use, caused by high pulse current. The HLC device provides the peak current and essentially gets recharged from the lithium thionyl chloride batteries during the low-power state.

Conclusion

The Axonn AXTracker has put together the right combination of integral components to enable the global management of unpowered assets. By combining the latest GPS technology with the latest Globalstar satellite simplex technology and advanced battery design, the mobile asset tracking device delivers a place-and-play solution, without the need for harnesses or external power and antennas. It attaches using screws, adhesive tape or industrial glue in seconds. The device is less than three months old and already being used by more than 50 product integrators and data service providers.

Gary Naden is vice-president of engineering and business development of Axonn, L.L.C. His expertise is in design engineering of low-cost, high volume digital radio. He is the author of more than 16 U.S. and international patents issued and pending in the field of digital communications systems. His team designed the satellite modem used by all Globalstar simplex data radio transmission unit (RTU) devices and has integrated that modem into the AXTracker. Prior to joining Axonn he served in design and systems engineering capacity at E-Systems deploying airborne communications intercept equipment. ⊕

RECHARGEABLE BATTERY TECHNOLOGY has significant reliability issues for industrial applications requiring more than three years of service life.

fer from limited "memory," longevity, and temperature range of operation. NiCd will lose full capacity over time based on the point of recharge. For this reason, manufacturers of NiCd devices suggest the unit be fully discharged before recharging. It's a long-known technology problem with NiCd. Li-Ion has similar problems with longevity. Consider how long a cell-phone battery lasts in a benign environment. Primary battery power, by contrast, offers higher energy densities with greater temperature range of operation. Energy density refers to the amount of energy stored in a given cell volume.

To make the tracking unit a true standalone and self-contained device, Axonn selected a hybrid lithium thionyl chloride battery for integration into the unit. Of all of

pact, low-profile design, The manufacturer developed a custom battery pack of eight AA-cells plus a hermetically sealed hybrid layer capacitor (HLC). Use of the battery pack enables the unit to deliver two location reports a day for seven years of uninterrupted service between battery replacements. More frequent updates will reduce service life depending on device configuration.

The batteries are ideally suited for the unit's high current pulse requirements (up to 1.2 A for up to 1.3 seconds). This unique combination enables hybrid lithium cells to deliver their full capacity under higher loads for short-duration events. The hybrid battery configuration affords ready access to high pulse current without passivation from a battery chemistry not known for pulse capability. Passivation is the phenomenon

Manufacturers

The *AXTracker* mobile asset tracking device produced by **Axonn LLC** (New Orleans, Louisiana) uses a *9543LP* GPS module from **LeadTek** (Chung-Ho, Taipei Hsien, Taiwan) incorporating a *SiRFstarII/LP* GPS chipset from **SiRF Technology** (San Jose, California). The GPS ceramic patch antenna *PA25-1575-008SA* is from **Spectrum Control Inc.** (Fairview, Pennsylvania). The hybrid lithium thionyl chloride batteries are *PulsesPlus* from **Tadiran Lithium Batteries** (Port Washington, New York). Axonn manufactures the simplex transmitter compatible with **Globalstar LP**'s (San Jose, California) satellite system.