DARPA Advanced Logistics Transceiver Study

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Logisticians today must be able to locate combat-trackable items (major end items) on the battlefield "in theater," but a Joint systems-level capability to do so is not available within DoD. The Information Systems Office of the Defense Advanced Research Projects Agency commissioned the study described in this article to determine the concept of operations and perform a communications analysis for a system of small, expendable tags to operate in several logistical settings using a variety of communications relay payloads. This article defines the logistics problem (number of units, message length, frequency, bandwidth, power, communications relay, etc.) from which a development effort could be initiated to field a system within roughly the next 25 years.
(Keywords: Concept of operations, Logistics, Tags, Transceivers.)

INTRODUCTION

A variety of logistics transceivers (commonly called "tags") exist in the commercial and defense sectors to track the movement of everything from a small microchip to a 5-ton truck. The ability to know an item's location and status has profit implications for those in business and readiness implications for warfighters. Two of the most common types of such transceivers are radio frequency (RF) tags and bar codes. They carry information such as an item's name, identification number, transportation carrier, location, etc. The most common RF tag can carry up to 128,000 bytes of data.

Today, tagging technology is geared toward commercial applications and is usually unique to a product or particular industry. DoD has leveraged this technology from the commercial sector and applied it for its own uses. There have been many challenges in integrating these tags into the operation of the Services. In most cases, each Service has selected different tags, protocols, and information systems, making a global defense picture of asset visibility difficult.

The Defense Advanced Research Projects Agency (DARPA) has chosen to make a system-of-systems examination of the problem to determine if advanced technology can remedy the situation. APL was tasked to determine a viable concept of operations and perform a communications analysis for a potential system of small, expendable tags. These tags would operate in various logistics settings from now through the 2025 time frame using communications relay payloads to monitor and transmit the necessary information to warfighters and logisticians. The APL study focused on the in-theater logistics problem to assess the significant parameters involved, and just as importantly, to emphasize the impact of those parameters on warfighting operations. In addition, combat-trackable items (major end items such as weapon systems, trucks, command

and control [C^2] equipment, etc.) required for combat readiness were selected for in-depth study to determine minimum tracking capability.

THE PROBLEM

All of the Services have their own unique Automated Information Systems (AIS) that collect logistics data (e.g., receipt, location, owner, destination) about their assets. Procedures and formats differ in every case. The individual systems feed the DoD databases for a more global picture. The aim of the Joint Total Asset Visibility (JTAV) Program is to facilitate and encourage the development of a common logistics picture on asset visibility, both within and outside the theater, based on information from all Service AIS and DoD databases.

Automated Information Technology Systems (AIT), also called Tagging Systems, are specific to the Services and feed each Service's AIS. Again, these systems are all different; there are no common standards among them. The JTAV Program can only recommend policy. Currently, no integrated asset visibility system, either AIS or AIT, exists. The goal, therefore, is to achieve an integrated system of systems in which the logistics picture can be drawn from the AIS. Reliability of and access to AIS are vital. An AIT is just one mechanism for passing information to an AIS from which the user can access intelligence.

Further complicating the issue is the way in which this problem is being addressed by the different warfare communities (C^2, logistics, and combat identification [ID]). Each is attempting a similar end (theater-wide surveillance of friendly forces and assets), but with different systems and with no coordination of effort. The vision should be one integrated visibility system. Just as the Services are using different systems, the various warfighting communities are seeking different solutions. Cooperation and pooling of scarce funding could go far in fielding a capable Joint system.

TAGGING SYSTEM CONCEPT OF OPERATIONS

The concept of operations developed for this future generation of tagging systems (Fig. 1) gives DoD the capability of tracking all transportation assets, containers, and combat-critical items wherever they are in the theater or logistics pipeline. The basic approach is to adopt a tiered tracking system for containers, prime movers, and combat-trackable items via satellite and/or unmanned aerial vehicles (UAVs). "Tags" will report with a short "license plate" message of ≈25 bytes, giving an item's ID number, unit ID code, and location, or with a slightly longer status message of ≈100 bytes, giving information such as vehicle faults or breakdowns. The message will be downlinked to an AIS.

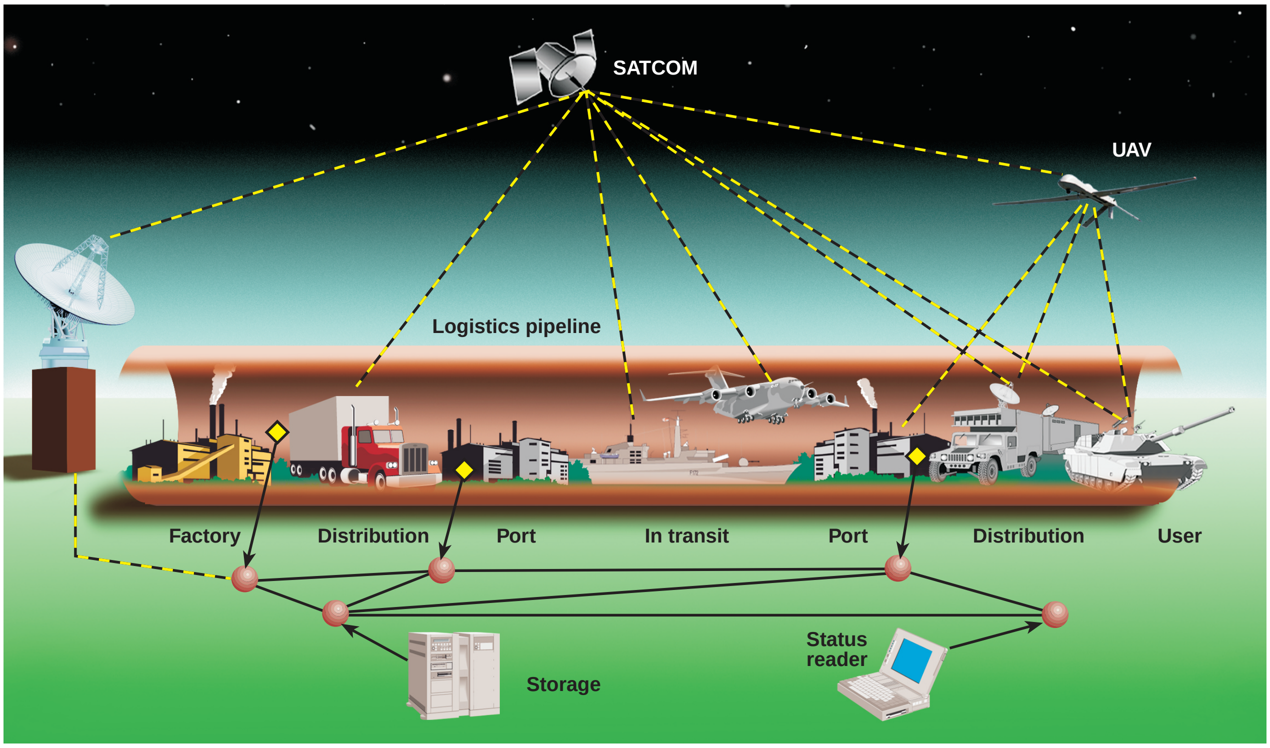

Figure 1. Concept of operations (diamonds represent input to the Automated Information System [AIS] computers, network, and databases via readers; UAV = unmanned aerial vehicle).

This AIS will contain much more information, such as the entire contents of the containers (≈100 KB), and will be updated via readers at various points in the logistics system. The entire system relies on access to the AIS infrastructure, and this is consistent with current DoD policy and efforts.

REQUIREMENTS

The development of any future advanced tagging system must be based on operational requirements. Therefore, the first phase of the APL study concentrated on collecting requirements for asset visibility from the Services and agencies. No authoritative requirements documents were found, other than those for the JTAV Program. However, all the Services are participating in the program and are pursuing their own asset visibility objectives.

Requirements were also derived from operational scenarios. Two operational extremes—the Southwest Asia Major Regional Contingency (MRC) and Operational Maneuver from the Sea (OMFTS)—were selected to determine coverage and data flow needed within a theater. The MRC, which is patterned after Desert Storm, examined the introduction and support of large numbers of Joint forces operating within an extended geographic area. The second scenario, based on the Marine Corps' OMFTS concept, helped to highlight the need for a responsive and secure system capable of supporting small, highly mobile units.

The MRC scenario amplifies the need for any asset visibility system to be able to cover a vast area containing tens of thousands of combat-trackable items. In this MRC, large numbers of U.S. forces are deployed to Saudi Arabia. Both the size of the area of operations (≈160,000 km^2, Fig. 2) and the significant number of U.S. troops make this operation logistically strenuous. In such a scenario, rapid movement of materiel through the relatively few Saudi ports is critical to achieving U.S. objectives.

The OMFTS scenario (Fig. 3) places small groups of Marine forces ashore over a widely dispersed area. All logistics requirements will initially be provided from amphibious ships at sea (sea-based logistics), as far as 100 nmi from the shore. In time, a small Combat Service Support Operating Center (CSSOC) will be deployed ashore to provide logistical support to the forces. However, the CSSOC will still rely on the sea base for sustainability. Given the limited logistics footprint available ashore, this scenario highlights the need for rapid and robust communications and resupply. Also, because these Marine forces will be (relatively) lightly armed and reliant on rapid maneuver and surprise, the need for protection against RF exploitation is critical. Although the OMFTS scenario covers a smaller area than the MRC scenario, it still indicates the need for a tracking system to monitor many items over a wide area. In addition, since there is no infrastructure on shore, a satellite or UAV would be required to relay status to the sea base or CSSOC.

Figure 2. Major regional contingency area of operations.

Every Service wants to know what it has, where its assets are, and what the status of its materiel is. In the theater (i.e., a secure environment), this knowledge is essential; however, as activities shift back to the continental United States, the need for secure transmissions is less critical. Finally, this knowledge must be acquired at a low cost to enable the Services to put their systems into operation, replace functions currently performed by personnel, and allow more of the force structure to be placed in the combat units as the overall size of the force is reduced. Thus, the operational requirements for a tagging system must consist of situational awareness, security, and cost.

Because of the diversity of DoD's operating environments, one requirement documented by the DoD AIT Working Group was the need for a suite of AIT devices. This suite will consist of linear bar codes, two-dimensional bar codes, optical memory cards, RF ID tags, and satellite tracking systems. In addition, AIS must capture and provide departure and arrival information to logistics decision makers and customers throughout DoD within

- 1 h for all shipments of unit and nonunit equipment from original source of supply
- 1 h for all air shipments
- 4 h for all ocean surface shipments
- 2 h for all intratheater shipments
- 0.5 h for in-theater container and power unit tracking

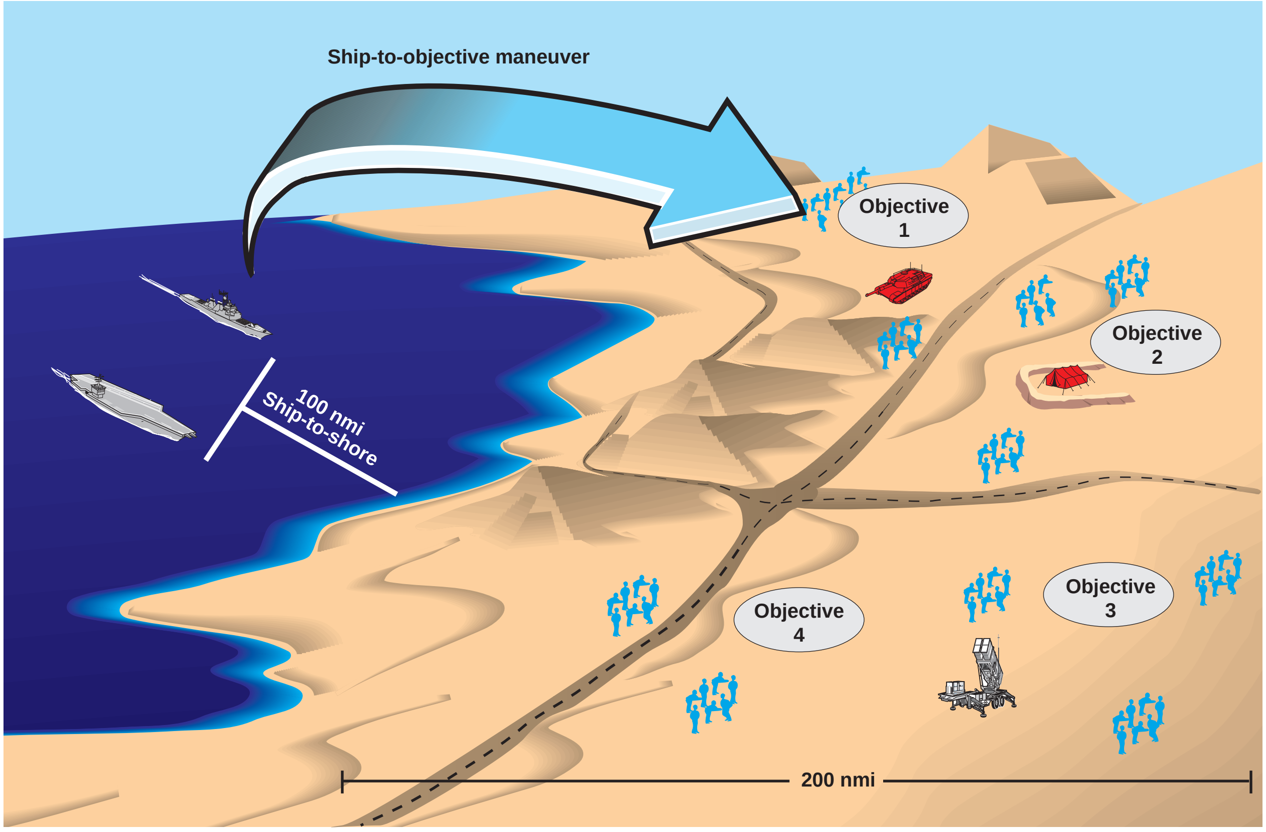

Figure 3. Operational Maneuver from the Sea scenario.

DoD will ensure the full operability of all AIT and AIS devices.

Based on operational requirements, APL studied and selected system options. Although this task focused on advanced transceiver technologies, commercial off-the-shelf (COTS) products were examined. The philosophy of the effort was to use commercial technology and services as much as possible and focus development on any technology deficiencies; the vision was to integrate any logistics data flow with C^2 and combat ID systems. (The Selected Bibliography at the end of this article lists various resource materials on the topics covered here.)

FINDINGS

Tag Types and Architecture

Given the operational requirements defined by the scenarios and those gathered from the Services, we identified four tag types to meet the stated goals: (1) item, (2) strategic lift asset, (3) container/power unit, and (4) combat-trackable. Each type corresponds directly to an item or specific type of vehicle. The item tag, which could be attached to an item or to the box in which it is placed, would track the item in the factory or warehouse and could be used to generate a vehicle manifest automatically (when the item is loaded onto a vehicle for transport). The tag used on a strategic lift asset must be a communications system that specifically addresses transoceanic communications requirements. The container/power unit tag would permit tracking of a container or power unit over a wide area. In addition, it would have a high data rate download capability to support manifest download (containers) or real-time engine monitoring (power units). Similarly, the combat-trackable item tag would permit tracking over a wide area as well as high data rate download.

To define the specific capabilities of the tag, one must consider the overall architecture of the tagging system. For this study, we examined three such architecture options.

1. ID-only. Tag provides ID data only (name, serial number, unit ID code, and perhaps limited status information about the item). All detailed information about the item (manufacturer, manifest list, condition code, billing information, etc.) is maintained in the infrastructure. This approach is likely to minimize tag capability (and thus cost), but places demands on the logistics information infrastructure to provide reliable and timely information on the items.

2. Full details. Tag provides all information about the item. No information is stored in the infrastructure. This approach minimizes the need for infrastructure. However, infrastructure is still necessary to move tracking information from sensors to users. Furthermore, it must be possible to increase tag capability to accommodate more data storage, etc.
3. Combined. Tag provides all information, and infrastructure maintains detailed information as well. Although this architecture requires both a more capable tag and more investment in the infrastructure, redundancy reduces the need for a highly capable tag and highly reliable infrastructure.

By overlaying the tagging requirements onto the systems architecture options, one can examine the implications of each option. With item tags, the critical trade-off is cost versus capability. It is expected that the item tag will be used primarily in a controlled setting (e.g., factory or warehouse), where much of the detailed logistics information can be maintained within the infrastructure. When the item must be tracked over a wide area, it will be aggregated with other items and placed into a container that can be tracked. Since minimizing cost is a major factor, especially for a device that may be deployed in significant numbers, the item tag should be limited to the ID-only option.

Tags for container/power units will require significantly more capability than the item tag since such units must be tracked over a wide area and will potentially transfer more data. The requirements for these tags fall into three categories: (1) data transferred per unit, (2) number of units tracked, and (3) tracking update rate. If the container tag is required to send an ID and limited status only, it will be possible to limit transmissions to a short 25- to 100-byte message. However, a full manifest would require transmitting up to 100 KB. At 2400 bits/s, which is a typical digital voice data link rate, a manifest download would take 5.5 min. This data rate could be increased substantially (to rates on the order of 500 KB/s) if COTS tagging technology were used, but the communications range would decrease dramatically.

Like the container tag, the power unit ID and status message could be limited to less than 100 bytes. It could contain the status of critical parameters (e.g., fuel consumption) as well as any fault conditions identified by the vehicle. However, if real-time diagnostic data on power-train operation were required, a continuous 1200-bits/s data link would be necessary (this estimate is based on the data flow between the Advanced Amphibious Assault Vehicle Engine Control System and Vehicle Master Processing Unit).

Combat-trackable items have requirements similar to those of power units. There are expected to be 350 combat-trackable items per brigade, including tanks, artillery, C^2 systems, etc. Therefore, in the MRC scenario, 8400 units would need to be tracked across the theater. Near–real-time updates would be required on all these units during combat.

From an architectural perspective, the ID-only option is appealing because it is likely to have the lowest cost. It also makes many wide-area tracking options viable. However, this option relies on the logistics information infrastructure to continuously provide accurate and timely data. Since the design of this system must anticipate crisis situations, selection of an architecture that can operate with a degraded infrastructure is desirable. Therefore, the architecture assessment leads to the option where both the ID and the full details are provided by the tag. In this case, however, the full details are not transmitted over wide-area RF communications, but rather are used only when local interrogation is necessary and can be accomplished using a high data rate mode. The wide-area tracking requirements are met using a low data rate ID-only mode. Table 1 summarizes the system architecture assessment for combat-trackable items.

Tracking Technology

The technology options to meet the selected tag architectures can be divided into two groups, the first addressing the local interrogation options (e.g., while a vehicle is in a maintenance bay), and the second addressing the wide-area tracking options. The local interrogation capability can be focused on a high data rate download to obtain manifests and support the transfer of real-time engine diagnostics. This capability is currently available through COTS products and standards. Wide-area tracking options have been limited to military systems and commercial satellite systems, even though there are security concerns associated with the latter.

Given the need for theater-level coverage, terrestrial military or commercial wireless operations are severely hampered by the line-of-sight requirement for radio communications. Terrestrial wireless systems typically cover less than 20 km (radius) per base station. In addition, the base stations cannot be redeployed rapidly enough to cover highly dynamic situations. Conversely, UAV- and satellite-based options (Table 2) can cover significantly more area with less infrastructure. The satellite altitude alone suggests that a single low-Earth orbit (LEO) satellite could cover thousands of kilometers, although a constellation of satellites would be needed to provide continuous area coverage.

Given the lack of existing military satellite systems to support mobile users and the potentially significant expense in deploying such a system, the military satellite option was not considered viable. However, commercial satellite systems *are* viable, assuming certain

Table 1. Combat-trackable item tag system architecture assessment.

	Option		
Requirement	ID-only	Full details	Combined
Situational awareness	Depends on reliable infrastructure	Requires high data rate communications link	Requires ID and limited status information only or wide-area tracking plus a high data rate download for local interrogation
Security	Provides security owing to limited amount of information transmitted	Requires access and privacy protection; in-theater use may also have to address RF exploitation	Requires access protection or local interrogation only
Cost	Offers low (<$100) tag cost	Requires development of a wide-band over-the-horizon communications system	Combines low-cost over-the-horizon communications system and high data rate (short-range) download

Note: The "combined" architectural option is recommended.

Table 2. Combat-trackable item tags for wide-area tracking.

	Requirements		
Option	Situational awareness	Security	Cost
Terrestrial military wireless system	Geographic coverage is limited by base station deployment	Physical control of base station, encryption, and specialized waveforms would enhance security	Assuming base stations are supporting C^2, data terminal cost is a driver
UAV	Coverage is a function of altitude	Transmit power is low (compared with satellite solutions); UAV and ground segment are physically secured	Includes development of UAV systems to support logistics
Military satellite	Continuous coverage is provided by GEOs; otherwise a large LEO constellation is required	Physical control of satellite and ground segment, encryption, and specialized waveforms would enhance security	Includes development of a satellite system
Commercial satellite	GEO or LEO MSS can provide continuous coverage; capacity limitations exist	Use of commercial (foreign) gateways; RF exploitation is an issue	Data terminals must be modified to address security

Note: LEO = low-Earth orbit; GEO = geosynchronous Earth orbit; MSS = mobile satellite system. UAVs and commercial satellites are the recommended options.

security issues can be addressed, because of lower costs. Although the UAV option would require funding for development, it would permit the government to own the complete signal path, thereby mitigating several potential information security issues raised when using a commercially operated communications system.

Based on the detailed requirements and a comparison of UAV versus commercial satellites, a functional description of the container/power unit tag for in-theater tracking is possible. There are at least two operating mode options: high data rate, short-range; and low data rate, low-power/commercial LEO. The former will permit the rapid download of full manifests or engine diagnostic information to be transmitted in real time. The latter would be used with a UAV, *if* one is available and security risks require the user to resort to it. However, if costs and security issues are addressed, this mode could be based on the commercial LEO instead.

The high data rate mode can be supported by existing tagging products. This mode should be exactly the same as the high data rate mode in the container tag. The low data rate, low-power mode (and the accompanying UAV system) would have to be developed. Commercial LEO constellations will soon be available, but all the modifications needed to support the required security features may not be.

In addition to the operating modes, the tag should be microprocessor controlled (with a standardized interface to off-tag sensors or processors) so that it can adapt more readily to different applications. For example, the tag may simply act as a pass-through for real-time engine diagnostics; however, it may also need to buffer specific information in the diagnostic flow, identify fault conditions from sensors, etc.

RECOMMENDATIONS

For an item tag, we found that an RF (ID-only) tag could be used in the manufacturing and warehousing environments and could support automanifesting as well. The container/power unit tags and combat-trackable item tags will require significantly more capability than the item tag because of the need to track units over a wide area and transfer more data. In depot, an RF (high data mode) tag on containers or power units will permit high data rate download of manifest or sensor information. For wide-area (theater-wide) tracking, a UAV or commercial satellite will allow continuous coverage of containers/power units and combat-trackable items. Terrestrial wireless systems are limited by short line-of-sight communications (<20-km radius per base station), whereas one LEO satellite can cover an area 1000 km in diameter. Given the need to track over 30,000 items in theater, it is possible for a satellite to provide this coverage. Where satellite coverage is lost, UAVs could fulfill the requirement of any localized area (battalion- to division-sized units).

Figure 4 illustrates a typical commercial voice-capable ("Big") LEO mobile satellite system scenario. These satellites operate at altitudes of several hundred to over 1000 km, providing coverage over a region several thousand kilometers in diameter. Each satellite is visible for only a few minutes, so a large constellation of satellites is necessary to provide continuous area coverage (e.g., Motorola's Iridium satellite system consists of 66 satellites that provide continuous global coverage). Each satellite's coverage area is further subdivided into antenna beams that are functionally similar to terrestrial cellular system cells. Beams vary in size up to 1000 km in diameter, thus a single beam would be able to cover an entire theater.

In addition to satellite antenna coverage, a critical mobile satellite system component is the gateway, which receives information from the space segment and routes it to the public switched telephone network. If the satellite system uses processing satellites with cross-links, like Iridium, a gateway could provide service to a handset located anywhere. The satellites receive handset transmissions and route the calls over the cross-links from satellite to satellite, until they reach a satellite that can downlink the calls to the gateway. However, if the satellite system uses transponding satellites, like Loral/Qualcomm's Globalstar, then a gateway and handset must simultaneously view the same satellite to communicate. Thus, gateway location limits connectivity.

Table 3 presents data for two commercial satellite systems, Globalstar and Iridium. In this case, 32,800 transceivers (14,400 trucks, 8,400 combat units, 10,000 containers) might be interrogated for their 25-byte license-plate message or their 100-byte status message. Additionally, the 10,000 containers carry a full-manifest database that has a size on the order of 100 KB for each container.

Table 3 shows the minimum required reporting times to send full-manifest data from each container through the data channels. Although these times are based on the maximum number of channels that might be available, it is extremely unlikely that anything close to such numbers would actually be allocated. Consequently, the total reporting time will probably be much greater

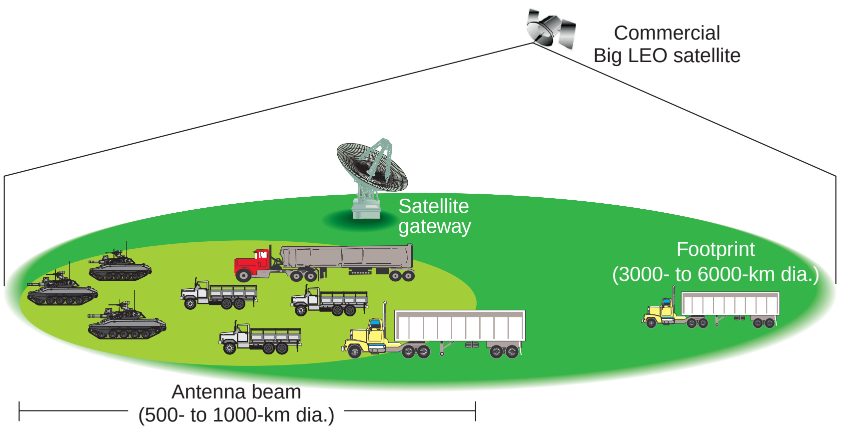

Figure 4. Typical mobile satellite system scenario.

Table 3. Commercial satellite capabilities.

Commercial satellite	No. of access channels	No. of data channels	Time required to: Report manifest (h)	Time required to: Call each transceiver (min)
Globalstar	1 (200-ms cycle)	<400 (4800 bytes/s)*	>1.20*	10.9
Iridium	3 (90-ms cycle)	<880 (2400 bytes/s)*	>1.05*	16.4

*Number represents upper limits for available channels and lower limits for report times; actual report times are expected to be much longer.

than the 1 h indicated. However, 1 h still exceeds the in-theater allowable time of 0.5 h mentioned earlier. Based on these times, the use of commercial satellites for full-manifest reporting would seem infeasible. The AIS infrastructure appears to be better for carrying the full-manifest data, with periodic updates as containers pass choke points.

There is more flexibility in reporting the 25- or 100-byte status messages. If each transceiver were individually called, the total time to cycle through all 32,800 transceivers without receiving acknowledgments is 10 to 15 min, depending on the satellite system. Although this is within the minimum required reporting time, the individual "dialing" approach saturates the access channel for significant blocks of time, preventing access by other users. The 100% duty cycle for calling may also raise power concerns.

Two alternative approaches are shown in Fig. 5, based on paging the entire field of transceivers and then letting them randomly report back on the paging channel during some time period. This paging approach frees the access channel for other users. Of course, some combination of the two approaches could also be employed.

Figure 5a shows the basic concept for tracking tags with Globalstar using code division multiple access (CDMA). The theater contains 24 brigades with 14,400 trucks, 8,400 combat vehicles, and approximately 10,000 containers. The satellite has 1 paging channel, 1 access channel to set up calls, and 128 voice channels in each beam; 1 beam will cover the theater. The concept is to use the access channel to report the 25- or 100-byte messages along with the regular voice users. This approach has two limitations: 2 messages originating within 0.1 ms of each other "collide" and are lost, and no more than 40 messages can be carried at one time over all 130 channels. DoD would also have to purchase a gateway to operate in this mode.

The simplest way to conduct an inventory is to "strobe" the field of tags via the paging channel and request that they randomly report back over some time window T. One then accepts some reasonable number of lost messages, with a good chance that those units would be received at the next inventory. If the messages were perfectly synchronized, minimum reporting times would be 0.5 min for 25 bytes and 2 min for 100 bytes, indicated by the colored bands in Fig. 5a. The figure also shows the loss rate and the probability that more than 10 messages will be under way at one time on the access channel. Loss rates appear low, in the few percentage range for even short inventory intervals, and

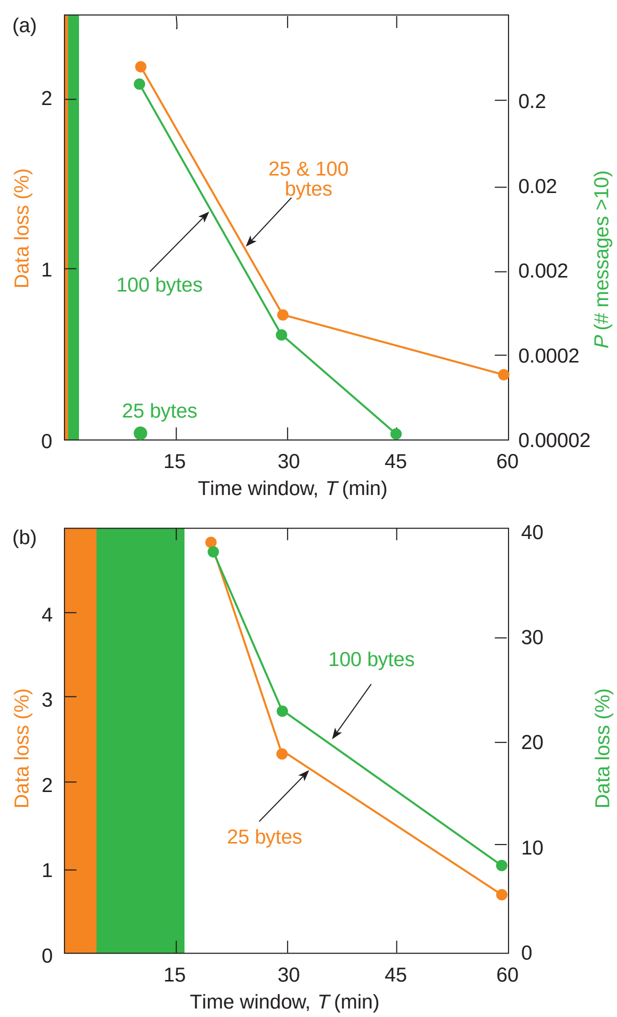

Figure 5. Two alternative tagging concepts: (a) Globalstar using CMDA (code division multiple access; P = probability) and (b) Iridium using TDMA (timed division multiple access).

the number of messages is usually well under 10, leaving some capacity to handle voice traffic as well. The time window numbers scale directly with numbers of objects tracked; if the number of objects doubles, so does the time to get the same loss rates. If the satellite were lost, several UAVs would be needed to provide coverage. Subsets of tags could be paged, and a limited number of tags could be called individually.

The same concept using Iridium, a system based on timed division multiple access (TDMA), is shown in Fig. 5b. With Iridium, there are three paging/ringing channels for each beam, and every 90 ms each channel carries four uplink time bins, each lasting 8.3 ms with a 30-kHz burst transmit rate. Each time bin is sufficient to carry the 25-byte short message, so four short messages can be carried by each channel every 90 ms. Four uplink time bins are required for the 100-byte status message, so only one status message can be sent in 90 ms on each channel. The same concept of strobing the field and asking for random responses during a time window *T* is used here. For perfectly timed signals, the minimum reporting times required are much larger, 4 and 16 min for 25 and 100 bytes, respectively, because there are only three channels and they are not devoted 100% to uplink traffic. Again, one beam will cover the theater.

As with Globalstar, different signals that try to use the same uplink time window on the same channel collide and are lost, with a good chance that they will be picked up during the next inventory period. In Fig. 5b, the loss rates are shown for 25- and 100-byte messages. Again, the time window scales with number of units tracked. The proposed system concept will support the 25-byte messages, but at a slightly higher loss rate than for CDMA. However, performance significantly deteriorates for the longer status messages, with unacceptable data loss rates. The rapid deterioration for the 100-byte case comes about because the average number of messages in every 90-ms window is around two to three, making for a high probability that messages will collide. Additional constraints may also come from satellite power limitations and other design limitations in the communications system. Therefore, the Iridium TDMA is most likely unacceptable for meeting the full range of inventory update requirements.

ROADMAP

Since this study was intended to cover the present through 2025, a roadmap is helpful to show how today's systems will transition into future systems. As indicated in Fig. 6, a two-tiered system is proposed with the detailed data carried in an AIS infrastructure and tags communicating with this infrastructure either directly through readers at various sites or indirectly through UAV or satellite communications.

This study was not intended to address the AIS

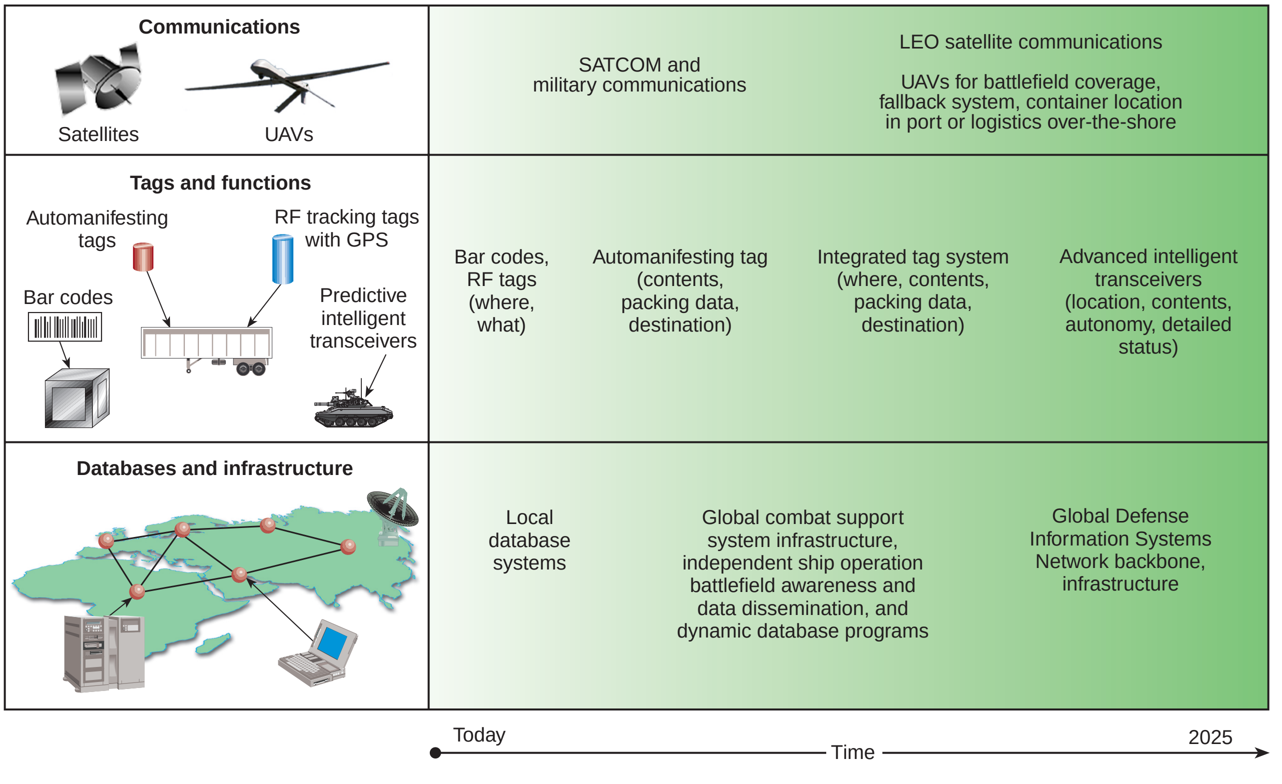

Figure 6. Advanced logistics transceiver roadmap.

infrastructure directly. Programs are currently under way to build the future AIS, transforming the infrastructure from localized, stand-alone databases into a globally connected set of databases and services. This transition is shown on the bottom right in Fig. 6, moving from local databases to a global DISN (Defense Information Systems Network) backbone.

The transition expected for the tags is presented in the middle of Fig. 6. A family of tags serving various functions is envisioned, as shown by the continual growth in added capability. Today's bar codes and RF tags will continue to have a role, but will be supplemented by tags with added capabilities. For example, tags and readers that read items loaded into or removed from containers are anticipated soon, providing an automanifesting capability. These automanifesting tags can be integrated with RF interrogation capability to provide location as well. Ultimately, advanced intelligent transceivers are expected that can monitor the status of trucks and self-propelled combat equipment, reporting not only location, but anticipated needs such as refueling requirements, or potential equipment failures. Finally, the communications will move from the current military satellites to commercial satellite systems, with UAVs providing fallback capability or increased security when needed.

CONCLUSIONS

Most logistics tagging requirements can be met with commercial technology, and development can be divided into UAV and commercial satellite thrusts. Since a number of UAV programs are under way, it would be desirable if a single UAV system could be identified for this application. The commercial satellite thrust would focus on development of waveforms and protocols that could operate over a transponding satellite system, but hide under the commercial users' transmissions. This would decrease the likelihood of detection through RF exploitation. Resolution of other security issues would have to rely on government procurement of a satellite gateway.

There are many ongoing efforts (including DARPA's Advanced Logistics Program) devoted to the issues of integrating the appropriate databases and information systems. Continuing efforts must be made to implement the necessary technology for a theater-wide tracking system that can eventually fill the needs of logisticians and operators.

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