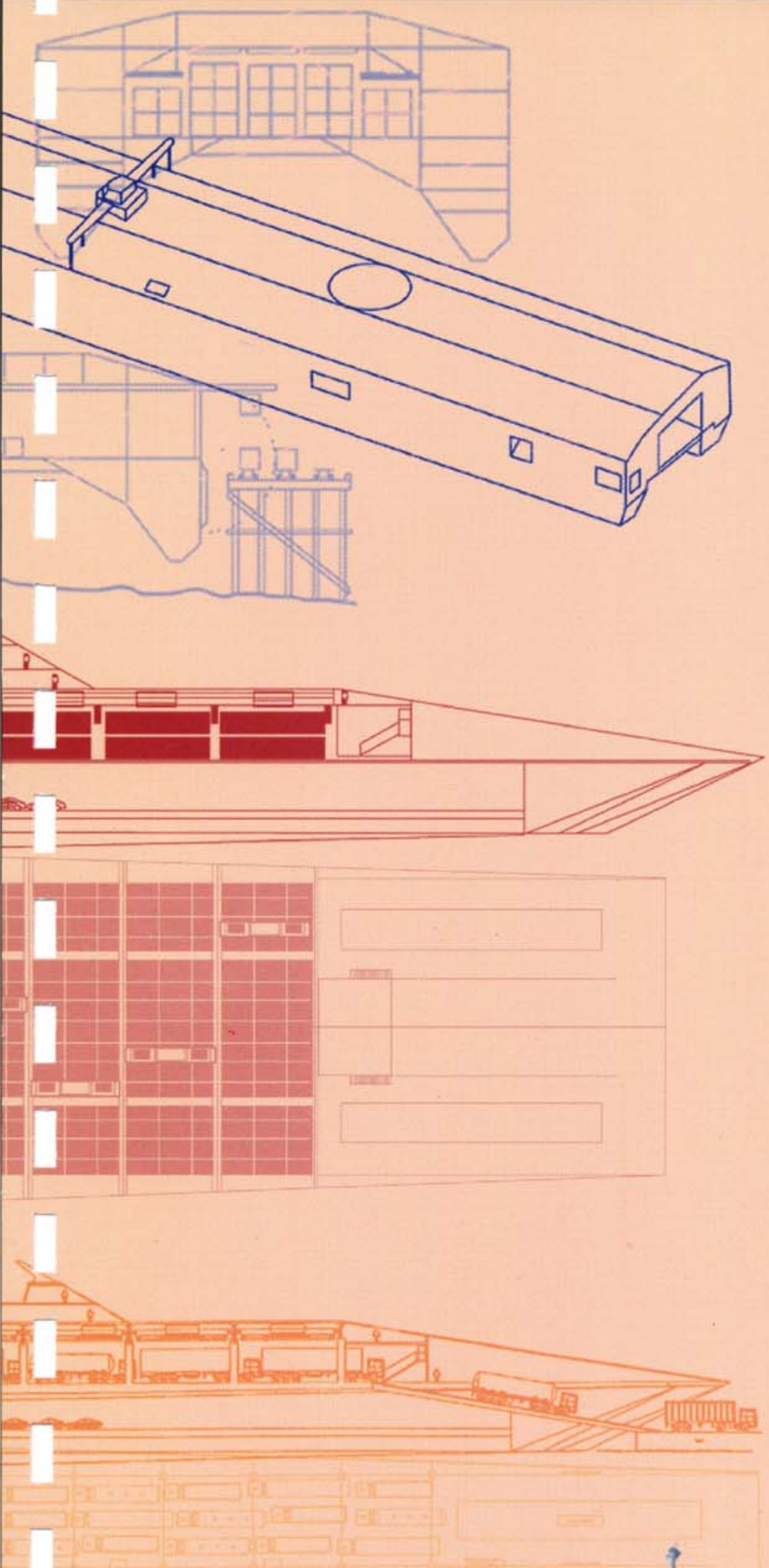

INITIAL DEMONSTRATION OF THE GONETS LOW EARTH ORBIT (LEO) SATELLITE MONITORING, TRACKING, and COMMUNICATIONS SYSTEM

November 1997

prepared for

United States Transportation Command

prepared by

Center for the Commercial Deployment of Transportation Technologies

Integrated Sat/Com Corporation

LOW EARTH ORBIT SATELLITE COMMUNICATIONS SYSTEM

INITIAL DEMONSTRATION OF THE GONETS LOW EARTH ORBIT (LEO) SATELLITE MONITORING, TRACKING, and COMMUNICATIONS SYSTEM

Addressing
"Critical" Communication Applications
for the
Center for the Commercial Deployment of Transportation Technologies

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ES. EXECUTIVE SUMMARY

1. Purpose of the Demonstration

The Center for the Commercial Deployment of Transportation Technologies (CCDoTT) is under contract to the Maritime Administration (MARAD) in partnership with the United States Transportation Command (USTRANSCOM) to develop concepts for Agile Port facilities operating in combination with high speed sealift and related rapid deployment technologies and the enhancement of capabilities for cargo and personnel movement tracking and total asset visibility.

CCDoTT's Agile Port concept envisions the use of advanced material and cargo-handling technologies, tagging, tracking and information management systems to

- Expand the ability of commercial terminals to quickly accommodate military cargo
- Minimize the impact on commercial transportation from military surge deployments
- Improve the ability of terminals to accommodate a variety of ships

CCDoTT's approach to the development of the Agile Port concept is to demonstrate scaled models of key enabling technologies for advanced systems for terminal automation and information management. The desired goal is the capability of demonstrating productivity improvements and ancillary benefits, such as providing real time feedback at entry/exit location and continuous real-time, accurate spotting within the site.

This demonstration was performed by Integrated Sat/Com Corporation (ISC). The principal elements addressed were:

- Accurate tracking of the critical movement of cargo or equipment
- The ability to maintain In Transit Visibility (ITV) and Total Asset Visibility (TAV)
- An additional benefit sought was the ability to handle messaging in a mobile environment

2. Date & Time of Demonstration

The program was set-up and operated over a four day period from Monday, September 21, 1997 to Thursday, September 24, 1997. Monday and Tuesday were used to set-up and test the equipment and to install the mobile equipment in the van that was used for the testbed. The actual demonstration phase of the program was conducted on Wednesday and Thursday, September 23rd and 24th. Data was collected on each of the two demonstration dates. The test was observed and briefing conducted for Colonel Clark Hall of USTRANSCOM on the last day of the program, September 24th.

3. Agenda for Demonstration

The international agenda included establishing communications links between a fixed location at the School of Engineering at California State University, Long Beach where a Network Service Center (NSC), shown in Figures 1 through 3, was maintained, a Mobile site (University van), shown in Figures 4 through 7, and the Network Control Center (NCC) at NPO Precision Instruments, Moscow, Russia.

On Monday and Tuesday of September 21 and 22, 1997 the fixed site NSC was established along with the installation of ISC Gonets mobile satellite equipment in a University provided Ford Van. The equipment installed on the van is shown in Figures 8 and 9. The roof-top mounted antenna is shown in Figure 10. Complete testing of the installed equipment was conducted using a fixed site NCC located in Moscow as the communications control point for each element and then testing the three points, NSC - NCC and Mobile site, randomly to insure proper operation of the various elements in relationship to each other.

Once the system was fully installed and tested, the formal demonstration period was commenced on Wednesday, September 23, 1997. This first day of the demonstration consisted of a series of tests that were randomly conducted using GPS and selected sensors all interfaced with the ISC Gonets tagging technology and ultimately linking with the satellites. The ISC system was functioning according to a satellite session schedule attached hereto and referenced as Exhibit “A1”. Satellite tracking was displayed as shown in Figures 11 and 12. Present for this day of Demonstration testing were business leaders from Mexico interested in the commercial applications of the system, as well as a representative of President Zedillo’s Office, as shown in Figure 13.

On Thursday, September 24, 1997, the final day of demonstration testing was conducted in accordance with the attached session schedule marked Exhibit “A2”. Present for this demonstration was a representative of Congressman Stephen Horn’s Office, Colonel Clark Hall of USTRANSCOM and university and business representatives operating pursuant to government funding of the CCDoTT initiative. The same facilities were used as in the tests conducted on the day previous, with a particular emphasis on the transmission of GPS data for the purpose of meeting In Transit Visibility (ITV) and Total Asset Visibility (TAV) requirements specified by the CCDoTT Program.

The agenda on both days centered around testing during periods of maximum coverage by the Low Earth Orbit Satellite System ISC Gonets D-1. These periods of testing are reflected in Exhibits “A1” and “A2” as the bolded sections in the Exhibits. The agenda was established to acquire a “statistically significant number of events” to establish the reliability of the system in a variety of randomly executed tests using GPS and selected sensors and tag technology interfaced with the mobile installation in the Ford van. Text messaging was also undertaken in both fixed and mobile environments.

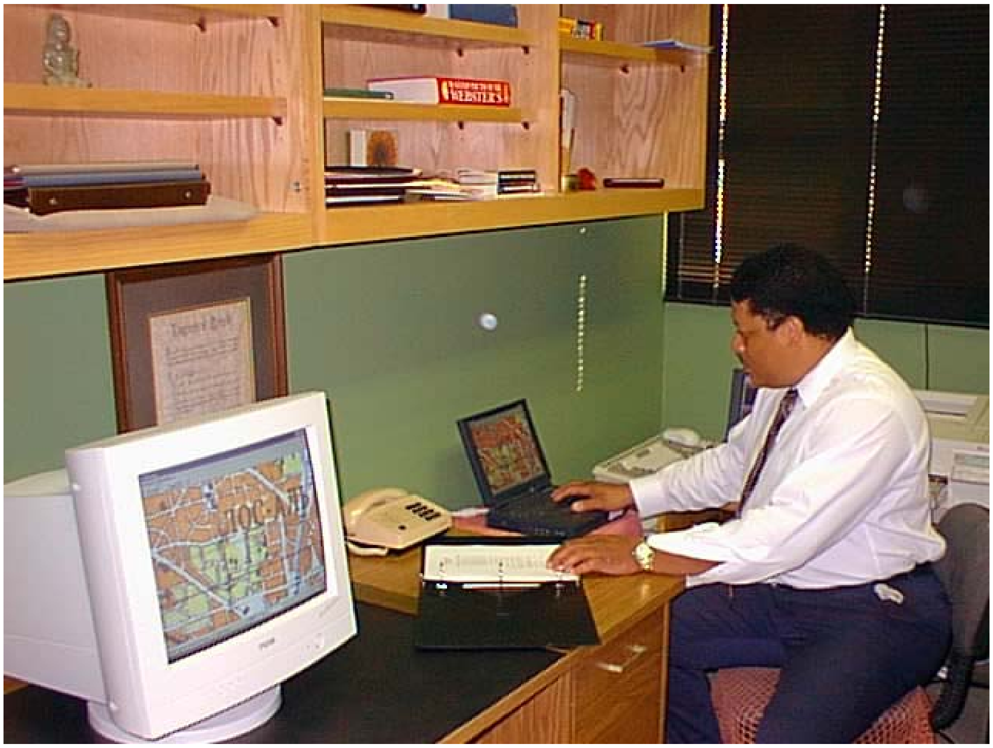

Figure 1. **Network Service Center at California State University, Long Beach, being operated by CCDoTT-CSULB staff.**

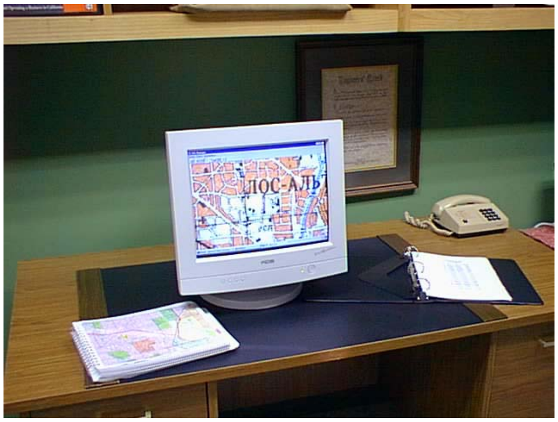

Figure 2. **Display showing scanned map of Long Beach, CA.**

Figure 3. **Network Service Center control computer**

Figure 4. University Van Provided for Demonstration

Figure 5. ISC Communications Equipment Installed in Van

Figure 6. Equipment being Operated by Russian Space Agency Staff

Figure 7. Equipment being Operated by CCDoTT-CSULB Staff

Figure 8. ISC Sensors and Tagging Technology.

Figure 9. GPS and Satellite Communication Equipment

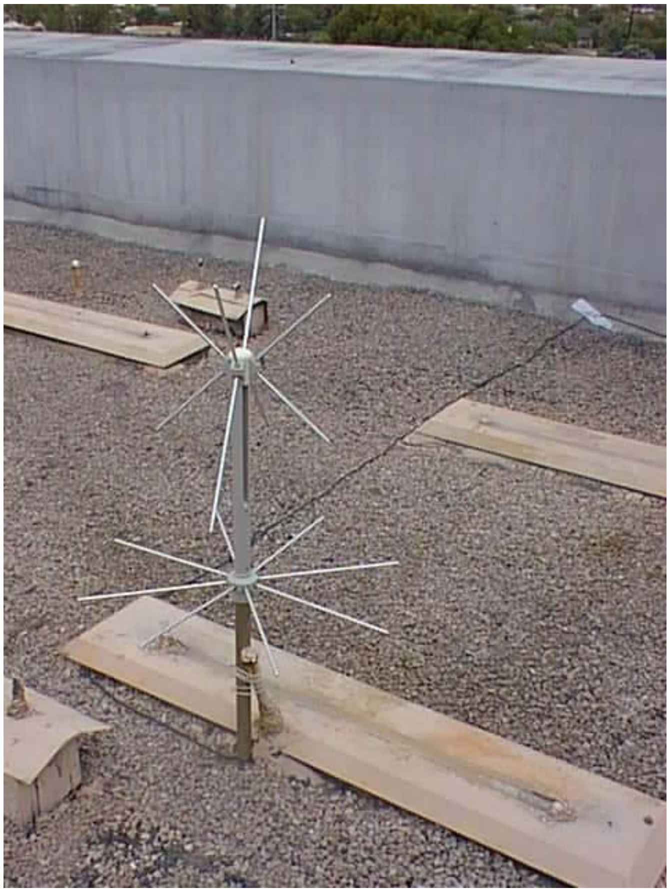

Figure 10. Roof-top Mounted Antenna

Figure 11. Satellite Tracking Simulation Display.

Figure 12. Close-up of Long Beach Satellite Coverage Area

Figure 13. Presentations to Business Leaders from Mexico

4. Participants

The Staff of ISC:

T. Craig Eschrich, Chairman & Chief Executive Officer
Dr. Elliot Axelband, Advisor to the Chairman - Associate Dean of R&D, USC, and Staff Consultant, Rand Corporation
Frank S. Shen, Managing Director of Business Development - Asia
Paul Weatherly, Managing Director of International Facilities
Carl Bennett, Prototype Installations
Anthony Nava, Computer Operator
Vadim Vasillev, Translator
Carmen Romero, Translator
Judy Sealey, Travel Coordinator
Galena Hausman, Translator
Bill Gurzi, Public Relations

California State University, Long Beach - CCDoTT:

Dr. J. Richard Williams, Dean - College of Engineering
Dr. Isaac Maya, Executive Program Manager - CCDoTT
Terridawn Martinez, Administrative Assistant
Dr. Andy Bazzar, Professor of Engineering
Dr. Slawamir Lobodzinski, Professor of Electrical Engineering
Dewitt Cooper, Computer Science Research Associate

Guests of ISC:

James Jancso, President - Communications Corporation
John Sealy, Computer Programmer
Colonel Clark Hall, Chief, Strategic Mobility Division - U.S. Transportation Command
John Shainline, Field Representative - Congressman Stephen Horn of California
James Law, BTG Corporation
Stanley Wheatley - Consultant, Maritime Contract Services

The Staff of Integrated Sat/Com - Latin America, S.A. de C.V.:

Jose Luis Romero, Director of Business Development - Latin America
Redolfo Becerra, Accountant

Guests of Integrated Sat/Com - Latin America, S.A. de C.V.:

Carlos Mora, Attorney & Mexican Presidential Advisor
Carlos Mora, Jr., Translator
Alberto Martinez, Engineering Advisor to Napoleon Avinia

The Russian Space Agency Delegation:

V.M.Khromov, Head of Delegation, Deputy General Director/Chief Designer of NII PI.
V.M.Tamarkin, Leading Expert
A.N.Zaitsev, Technical Expert
I.B.Porokhin, Legal Counsel for RSA
A.Y.Makotinski, Translator

5. ISC Gonets System Description

The inventory of on-site equipment used for this demonstration consisted of the following:

- (1) Tag (transmitter/receiver) designated for fixed site applications - UT-M 22
- (1) Antenna with 75-100 feet of cable (installed on the roof of the Engineering building)
- (2) Tag (transmitter/receiver) designated for mobile and fixed site applications - UT-M
- (2) Consumer available IBM 486 laptop computers
- Conventionally available computer cabling to interface the tag and the fixed site laptop computers
- (2) Portable batteries for the IBM laptop computers (used as an alternate power source)
- (2) Conventionally available power cables for 110 volt power source
- (1) 17" Color computer monitor (used for demonstration purposes only - displayed the map of Long Beach for GPS demonstration for the audience)
- (1) Laptop computer used for displaying the global satellite tracking for the audience
- (1) GPS antenna w/ cabling to the tag
- (1) Electro-magnetic field sensor w/cabling to the tag
- (1) Pressure sensor w/cabling to the tag
- (2) DOS/Windows 95 operating systems for the computers
- (1) Cigarette lighter adapter w/splitter female adapters
- (1) AC/DC power converter

The fixed site NSC was equipped with a tag designated UT-M 22 and two commercially available IBM laptop computers one of which controlled the tag and it's link with the ISC Gonets satellites, the other displayed a map of the Long Beach Area and was used to visually report the location of the mobile terminal which used basic GPS and was installed in a University provided Ford van. The mobile site was equipped with two tags designated UT-M, one of which transmitted pressure and electromagnetic sensor signals in automatic mode and the other, geolocation information of the vehicle and text messages in an operator supported mode.

Not all of the equipment used in the test was an integral part of the operational set-up. Additional elements were used that were not necessary except for the purpose of supporting the audiences view of the demonstration. The total amount of equipment necessary to support this field test was contained in a box just half the size of a traditional footlocker. Total weight of the equipment was not in excess of 50 pounds. Actual installation time from unpacking to operational interface with the satellites is only 15 minutes. The time in setting up this demonstration was in excess of the minimum time because of the distance between the fixed site and the mobile set-up as well as the time it took to make the installation "audience friendly".

All the equipment used in this demonstration, including the underlying software to support the communications with the satellites, is commercially available and the cost of the components would reflect the ability to leverage the commercial applications to reduce DoD cost. In the case of some "critical government communications", the core technology used in this demonstration can be further supported by encryption technology and advanced sensor technology based on the actual needs and operating environment of the user.

Available core tagging technology for a variety of operating situations and environments is available as shown in Exhibit "B". Many of the variations in the technology listed are in the form of power supplies for various operating temperatures and humidities, packaging to address vibration and seismic impact directly on the tag and materials choices to lower the weight of the overall package. For the purpose of this demonstration, the only tag designs used were as indicated in the inventory appearing above. The additional designs may be considered for the focus of future application specific testing and demonstration.

Technical specifications for the ISC Gonets D-1 Program are attached hereto as Exhibit "C".

Technical specifications for an application-specific program that may be applicable to inter-modal container tracking and monitoring is also attached as Exhibit "D".

6. Test Results

General Statistical Details for the Combined Demonstration Period

Total number of possible communication minutes on both days: **542**

Total number of interactive communication minutes with the satellites on both days: **169**

Total number of satellite passes on both days: **46**

Total number of satellite sessions with successful communications on both days: **13**

Total number of GPS signals transmitted on both days: **50**

Total number of sensor readings transmitted on both days: **200**

Total number of pressure sensor readings transmitted on both days: **134**

Total number of electromagnetic sensor readings transmitted on both days: **66**

Total number successfully transmitted text messages on both days: **20**

General Statistical Details for the September 24, 1997 Demonstration

Total number of possible communication minutes on September 24th: **266**

Total number of interactive communication minutes with the satellites on September 24th: **107**

Total number of satellite passes on September 24th: **23**

Total number of satellite sessions with successful communications on September 24th: **8/8**

Total number of GPS signals successfully transmitted on September 24th: **29**

Total number of sensor readings transmitted on September 24th: **91**

Total number of pressure sensor readings transmitted on September 24th: **60**

Total number of electromagnetic sensor readings transmitted on September 24th: **31**

Total number successfully transmitted text messages on September 24th: **17**

General Statistical Details for the September 25, 1997 Demonstration

Total number of possible communication minutes on September 25th: **276**

Total number of interactive communication minutes with the satellites on September 25th: **62**

Total number of satellite passes on September 25th: **23**

Total number of satellite sessions with successful communications on September 25th: **5**

Total number of GPS signals successfully transmitted on September 25th: **21**

Total number of sensor readings transmitted on September 25th: **109**

Total number of pressure sensor readings transmitted on September 25th: **74**

Total number of electromagnetic sensor readings transmitted on September 25th: **35**

Total number successfully transmitted text messages on September 25th: **3**

7. Conclusions and Recommendations of Demonstration Participants

The tests all resulted in 100% performance of the ISC Gonets technology. All signals were delivered without any losses or distortions. Program participants were satisfied that the demonstration was an unqualified success. This was particularly evident in confidential briefings following the second day of demonstrations. The demonstration showed that the system functions reliably

The only difficulties evidenced during the course of the two-day demonstration appeared on the first day when portable power issues were raised in the context of the duration of the demonstrations. Initially, the use of portable batteries used to power the laptop computer in the mobile environment were deemed to be inadequate for the purpose because so much equipment was running off one power supply. This was solved by using a portable power converter running off the van power (cigarette lighter adapter). All the power issues were collateral to the technology of the ISC Gonets program.

ISC technical personnel also pointed out that the use of the power supplies for this demonstration would not be the same as what would be used in an application specific environment or in any long term global test of the system. Instead, self-contained units with a battery supply capable of lasting upwards of 3-5 years would be employed. The present power supply arrangement was based on initial demonstration cost control by ISC.

An important consideration is that the system incorporates commercial off-the-shelf (COTS) technology, funded and maintained by the commercial sector. The transmission frequencies are military frequencies in the United States, an advantage in that this frequency band segment is without a lot of congestion. The bandwidth is thus fairly quiet. The combined benefit of these factors (COTS and a quiet bandwidth of a dedicated system) is higher reliability underwritten globally by the commercial sector.

The U.S., Russian and Mexican participants all expressed interest in continuing joint efforts to promote and utilize the Gonets system to track mobile platforms and handle related Messaging. The U.S. Transportation Command, through it's representative, Col. Clark Hall extended an invitation to Mr. Eschrich to provide a future briefing to U.S. TRANSCOM personnel interested in using this technology. The Mexican interests reaffirmed their commitment to secure licensing in Mexico for Gonets D-1 and all subsequent mature versions of the technology.

Exhibit "A1"

September 24, 1997
Los Angeles

Sat	Date	Time	Duration
15	23.09.97	23:54:58	14:36
13	24.09.97	00:38:57	13:33
14	24.09.97	01:04:03	12:03
15	24.09.97	01:54:20	03:40
01	24.09.97	06:09:49	14:10
16	24.09.97	06:17:18	14:23
12	24.09.97	06:32:03	14:36
01	24.09.97	08:07:46	08:58
16	24.09.97	08:16:17	07:37
12	24.09.97	08:33:44	03:07
13	**24.09.97**	**11:27:59**	**11:19**
14	**24.09.97**	**11:51:49**	**13:13**
15	**24.09.97**	**12:37:57**	**14:37**
13	**24.09.97**	**13:21:25**	**13:25**
14	**24.09.97**	**13:47:34**	**11:44**
01	24.09.97	16:17:52	07:20
16	24.09.97	16:25:16	08:56
12	24.09.97	16:39:37	10:54
01	**24.09.97**	**18:09:52**	**14:23**
16	**24.09.97**	**18:18:05**	**14:13**
12	**24.09.97**	**18:33:27**	**13:41**
15	24.09.97	22:45:17	11:18
13	24.09.97	23:26:11	14:13

Exhibit "A2"

September 25, 1997
Los Angeles

Sat	Date	Time	Duration
14	24.09.97	23:51:33	14:37
15	25.09.97	00:39:20	13:29
13	25.09.97	01:23:05	08:40
01	25.09.97	05:01:13	08:08
16	25.09.97	05:09:00	09:35
12	25.09.97	05:23:22	11:22
01	25.09.97	06:52:13	14:18
16	25.09.97	07:01:05	14:06
12	25.09.97	07:16:57	13:28
15	**25.09.97**	**11:28:52**	**11:42**
13	**25.09.97**	**12:08:20**	**14:18**
14	**25.09.97**	**12:34:12**	**14:36**
15	**25.09.97**	**13:22:46**	**13:16**
13	**25.09.97**	**14:06:55**	**08:02**
01	25.09.97	16:58:01	13:15
16	25.09.97	17:07:00	13:45
12	25.09.97	17:22:31	14:18
01	25.09.97	18:53:24	11:37
16	25.09.97	19:03:01	10:41
12	25.09.97	19:19:38	08:36
13	25.09.97	22:15:55	08:24
14	25.09.97	22:41:04	11:45
15	25.09.97	23:28:05	14:23

Exhibit "B"

TESTED TAG DESIGNS

Abbreviated Name of Terminal	**Purpose of Terminal**
AT-M Portable User Terminal	Low data capacity, 4.8 Kbits
AT-C	High data capacity, 9.6 Kbits transmission/reception
PC Regional Station	Central station for local network, 64 Kbits transmission
AT-TA Automobile Terminal	Automobile installable, 4.8 Kbits
AT-TAH Automobile Terminal	Automobile terminal w/ positioning capability
AT-TX	Rail transport installable
AT-TXH	Rail transport installable w/ positioning capability
AT-TC Ship Terminal	Sea and River transport installable, 4.8 Kbits
AT-TCH	Ship installable w/ positioning capability
AT-II	Portable terminal for field operations
AT-3 Ecological Terminal	Installable at point of data acquisition from ecological, weather and other sensors

Some tag designs are calculated for use only on the Mature ISC Gonets system and are not ISC Gonets D-1 operating system approved

Exhibit "C"

TECHNICAL PRESENTATION OF THE LOW EARTH ORBIT SATELLITE COMMUNICATION SYSTEM GONETS & BASIC SUPPORTED TAG TECHNOLOGY

The Gonets Low Earth Orbit Satellite Systems are designed to transmit digital information in packet mode and to provide dispatch radiotelephone communications. Main applications for the systems are as follows:

- Development of allotted government, corporate, banking, medical and administrative networks;
- Mobile objects condition and position monitoring;
- Ecological and industrial monitoring, scientific information collection (geodetic, hydrological, seismological etc.;
- Communications in remote regions with undeveloped infrastructure;
- Emergency communications (earthquakes, floods, ecological and disaster relief operations); and
- Critical Government Communications (Law Enforcement and Military applications).

GONETS SYSTEM DEVELOPMENT STAGES AND MAIN CHARACTERISTICS

The first 3 Gonets D-1 satellites were launched into orbit on February, 1996 with the second launch of 3 satellites in February, 1997. The Gonets D-1 system is capable of providing communications at 237-265 MHz between a group of users and dispatch point, circular and individual information delivery to the user from Network Service Center. Additionally, direct user to user communications can be provided.

The full scale Gonets system is based on a constellation of 45 spacecraft (5 planes with 9 satellites in each one) in circular LEOs (orbit altitude - 1380 km, inclination - 82.5 degrees). Such structure ensures highly efficient communications due to continuous coverage of the entire Earth surface. Information can be transmitted in two ways: intra-regionlly and inter-regionally. Under intra-regional communications (within an area of about 4000 km diameter) information is transmitted directly via a satellite nearly in real time. If the users are more than 4000 km away from each other, information from the sender is stored in satellite memory and dropped down to the recipient when the satellite is passing over the recipient's region. In this case message delivery still does not exceed a few hours. Urgent messages to the remote regions of the globe can be relayed to the system Network Service Center immediately after reception on board a satellite. Then the message can be transmitted to the recipient via other satellites, Gonets System Network Service Center or via other terrestrial communication channels.

Since the Gonets satellites orbit relatively close to the Earth's surface there is no need for a bulky or heavy antenna. Gonets System terminals are equipped with compact omni-directional antennas that allow them to be mounted on commercial and non-commercial vehicles to support mobile communications. The system includes space segment, Network Control Center, Network Service Center for corporate and governmental networks and user terminals for various applications.

The Mature Gonets (MG) space segment consists of satellites weighing 270 kg operating at 312-315 MHz (downlink) and 387-390 MHz (uplink) bands. Spacecraft life expectancy is between 5-7 years. Satellites are launched into orbit in groups of 6.

Network Service Centers are used to organize communications within government and corporate networks, interfacing with public telephone networks, allotted networks for data exchange, ISDN networks, fixed satellite communication stations. X.25 and X.400 protocols are also supported.

The Gonets System is designed to operate with user terminals of several types. Stationary user terminals are in fact compact radiomodems providing data transmission rates up to 9600 Kbps and semiduplex voice communications. The terminals can be connected to a PC or laptop computer and interfaced with a wide range of peripherals (facsimile, telex, data exchange networks etc). These terminals are designed to operate inside and their antennas can be mounted either on the roof or adjacent to a window.

Mobile service terminals are designed to be mounted onto vehicles to operate in motion. They also provide data transmission rates up to 9600 Kbps, semiduplex voice communications as well as geo-positioning data derived by means of GPS (Global Positioning System) signals. Such terminals can also operate autonomously within the network for mobile positioning data collection.

Unattended terminals provide a data transmission rate of 2400 Kbps. They are designed to function within remote monitoring and control networks and provide interfacing with telemetry information concentrators.

Portable user terminals are compact, light weight devices for semiduplex voice communications. Both group and personal calls can be handled.

GONETS D-1 SYSTEM COMPOSITION AND MAIN CHARACTERISTICS

An on orbit group of 6 satellites (2 planes by 3 satellites in each plane) is in place under the Gonets D-1 program. The planes intersect at 90 degrees to each other along the ascending angle longitude. The satellites are placed into orbit using the Tsyklon launch vehicle. 3 Gonets D-1 satellites were launched simultaneously with 3 other satellites from another unrelated program. The orbital grouping is of an uncorrectable type.

Each satellite carries on-board radiotechnical equipment, including communication information transponder and a Telemetry, Tracking and Control (TT&C) System, magnetogravitational orientation (attitude control) system and electric power supply system.

Global communications is realized on the principle of “electronic mail”. Messages are processed completely at the transponder and can be stored on board over the time period required to deliver them to the recipients. Higher message delivery efficiency in global scale service is achieved through the use of ground network channels and geostationary (GEO) satellite systems. The Gonets D-1 System provides both regional communications and communications between a group of users and a Network Service Center, and communications of “user-to-user” type communications (point to point).

Waiting time for a communication session and session duration depend on a user’s geographic latitude. With 2 planes of 3 satellites, waiting time for the same user would be between 2.7 and 1 hour with a 0.9% probability for error. Session schedules for Mexico are presented in Exhibit E. The average duration of a communication session lasts on average about 10.8 minutes. The closer the communication session is to the poles, the session duration increases. In case sender and recipient are in the same service zone/footprint, communications take place in real time. System throughput (capacity) on a global scale is about 100 Mb per day.

The maximum message volume to be relayed via on-board transponder at one time is 100 Kbps. Messages can contain data on object location and status, or any other alpha-numeric information. On-board memory capacity of a satellite is 1.5 Mb. Mobile object positioning by means of GPS is carried out to 100 meter accuracy. Use of differential GPS can improve that accuracy substantially.

The Gonets D-1 system is designed to provide three main services: data transmission, personal calling (paging) and position determination.

Data transmission service provides:

1. Transparent data transmission/reception at 2.4 Kbps rate (with or without reception acknowledgement) with automatic routing via a Network Service Center;
2. Electronic mail mode (with X.400 protocol support);
3. Personal calling (paging) service provides global scale personal user calling; and
4. Position determination service provides:

- Users coordinate determination at their request; and
- Remote objects condition and position information collection. This information can be automatically registered at the Service Center, another allotted station or satellite communication network.

PRINCIPLES OF COMMUNICATIONS ORGANIZATION

User's terminal detects a satellite within radiovisibility zone by marker signal (MS). MS repetition period is 1 minute Marker signals of different satellites are radiated at the same frequency, but are separated in time. The MS contains all the information necessary to arrange communications with the satellite and to synchronize on-board and ground equipment operations.

Access channels to satellite communications are time divided. On-board each satellite within a minute interval there are 91 channels of priority access. A portion of all access channels are stringently fixed for definite users and the remaining unfixed channels are randomly accessible for the rest of the users.

During a communication session the ground terminal is listening to the down-link channel. Switch-on command to the satellite is transmitted only in cases when the terminal waiting for its communication channel does not detect the signal, confirming the fact that the satellite is engaged in a communication session with another ground station of higher priority.

On-board each satellite there is a single channel for information transmission and reception. Information transmission channels of different satellites are frequency divided.

The Satellite performs all the necessary information processing making possible its storage during the intervening delivery time. Each satellite has over 128 memories with autonomous access to each one for information recording or reading. Each memory is assigned to a certain user or a group of users. Such a group can be arranged in accordance with government, corporate or regional signs.

Information within the system is transmitted in packets not exceeding 10 Kbit in volume. System protocols provide incoming messages (via various routes, i.e. various satellites, Service Centers or other system channels) and restoration from packets occurs at the recipient's terminal.

Communications are organized on "electronic mail" principles and functions in the following manner. User-sender transmits message onto a satellite when it is in his radiovisibility zone. The satellite receives the message and registers it into the memory appointed by the sender. Message presence in the memory is indicated by the satellite in the address word which follows the marker signal. The recipient gets the message as soon as the satellite enters his radiovisibility zone.

Message delivery time within a zone is 1-2 minutes. Special modes provide intra-regional message delivery with the delay nominal as required to relay the message from the satellite.

If "electronic mail" mode efficiency does not meet the customer's requirements, the message can be relayed via Gonets D-1 Network Control and Service Centers and communication channels of other systems. In this case a message sent by a remote user to Gonets D-1 satellite is received by the Network Control and Service Center situated within the user's service zone. Further on, the Network Control or Service Center can transmit the message to the recipient via terrestrial networks, allotted data exchange networks (Sprint, AT&T, Telemex etc) or via fixed communication stations.

ON-BOARD EQUIPMENT OF GONETS D-1 SYSTEM

Gonets D-1 satellite on-board communication and control equipment includes the following main units:

- Receiver providing signal amplification, information signal extraction and their transmission into information and computation device;
- Transmitter providing carrier modulation by the information and marker signal symbols, information signal amplification to the required level as well as frequency plan synthesis for receive/transmit channels;
- Information and control unit providing time sweeps formation necessary for communication sessions, storage of the information received via up-link channel, necessary control commands output into the satellite life-support systems;
- Telemetry, Tracking & Control (TT&C) device receiving singular control commands and forming a bi-frequency signal to measure spacecraft motion parameters and telesignaling information transmission;
- Antenna feeder unit to serve information transmission channel and TT&C subsystem.

Main parameters of the radiotechnical complex:

- Receiver sensitivity at BER=10^{-6} is 145 dB/W;
- Transmitter power supplied to the system - not less than 10 W;
- On-board memory capacity - 1.5 Megabyte;
- Electric power consumption from on-board source (27V) at transmission mode
- Not more than 40 W.

GONETS D-1 SYSTEM GROUND SEGMENT COMPOSITION AND STRUCTURE

Ground segment includes ground control complex, Network Control and Service Centers as well as user network, including stationary, mobile and portable user terminals. The ground control complex consists of the main and back-up Network Control Centers (NCC). The communication system can be controlled either by a single NCC (the other one is a back-up) or by both of them, while the back-up NCC plays the second role supporting the leading and coordinating role of the main NCC.

NETWORK CONTROL CENTER

The Network Control Center performs the following functions:

1. Planning and coordination of works on space group deployment and supply. Command up-link transmission on-board spacecraft, telesignaling information from spacecraft reception and processing. Spacecraft on-board systems status analysis by the results of MS check and telemetry signal processing. Trajectory measurements and satellites orbit parameters determination.
2. Functionality check of all communication system main elements and control over communication resources.
3. Information exchange with the back-up NCC and its function coordination.
4. Data base (DB) development on spacecraft, Network Service Centers (NSC) and user terminals (UT). DBs on NSCs and UTs take into account their regional belonging and terminals geographic coordinates.
5. Radiovisibility zones calculations and determination of spacecraft illumination conditions. Preparation of spacecraft operation schedules for NSCs and certain UTs.
6. Frequency resources distribution between spacecraft and electromagnetic situation analysis.

The Gonets D-1 NCC is located in Moscow. The ISC Gonets Program envisions development of two NCCs: in Moscow (main) and a back-up facility yet to be geographically identified and situated (Mexico is currently being considered). The NCC includes three main hardware complexes: space segment control center, communications control center and central station. Such NCC structure allows ISC flexibly in the number of operator's work places (OWP) connected to ETHERNET via network adapters.

NETWORK SERVICE CENTERS

Network Service Center of the Gonets System are to arrange communications for government and corporate networks. The NSCs ensure the choice of optimum routing for message delivery and relay, interfacing with public telephone networks, allotted data exchange networks and fixed communications stations. Satellite radiovisibility zone covers nearly 4000 km.

Network Service Centers for the Gonets D-1 System can be of two types:

- Network Service Centers, which provide data collection and operation control over allotted user networks within certain regions, such as dispatch services controlling cargo transportation, etc.; and
- Stations providing user traffic switching and routing.

A Network Service Center consists of two identical semicomplexes, each one including antenna, transmit/receive block (TRB) and personal computer (PC). PCs of both semicomplexes are connected with a local area network of the Ethernet type. TRB includes antenna switch, transmitter (Tr), receiver (Re), common frequency synthesizer (FS) and control unit (CU). Peripherals and data exchange channels from the ground communication links are connected via RS-232 interface.

Gonets D-1 system architecture provides for simultaneous operation with a large number of Network Service Centers. However, at the initial stage it is planned to have 5 to 8 NSCs, ultimately with a minimum of one in each country where operations are licensed.

One of the main NSC operation modes is group communication session organization. In this mode the NSC interrogates sequentially several terminals located within its service zone. Group communication sessions allow for the use of Gonets D-1 system resources in an optimum way servicing the terminals, which in accordance to their function, requires regular access to satellite channels to transmit relatively short messages.

A Group session is arranged by a Network Service Center, which places satellite on-board equipment into the session and controls operation of all terminals engaged in the session and terminates the session. The terminals in the session operate under a stringent program defined at the terminal commissioning. For each group session type the number of NSC engaged terminals are rigidly fixed, as well as their operation time intervals, information volumes to be transmitted and operations to be carried out. All group service modes are calculated so that the session is over before the next marker signal (i.e. session duration is under 1 min.).

Group sessions can be arranged to transmit messages on mobile positioning and condition, short telegrams and the like. Geographically NSCs organizing group sessions should be located so that any mobile or stationary terminal and at least one such NSC would be within the same satellite radiovisibility zone/footprint.

USER SEGMENT

The Gonets D-1 System deployment provides for a wide range of user terminals ("Tags"). The design of these Tags will allow for stationary as well as mobile use with mobile terminals being light weight and portable. Each tag on the Gonets System is given a unique identification number, which allows it to communicate from any point on the Earth's surface without registration at the Network Service Center.

Tags are in fact radiomodems, which can operate both with personal computers or laptop computers as well as autonomously. The radiomodem includes the following elements and characteristics:

- Receiver
- Transmitter
- Antenna-feeder device
- Control device based on a single chip computer
- Positioning device (using GPS signals)
- Positioning device antenna.
- Radiomodem has mass under 2 kg.

User terminal main technical parameters are as follows:

- Receiver sensitivity 0.3 mV;
- Signal dynamic range 40 dB;
- Transmitter power 10 W
- Modulation type:

In marker signal channel frequency telegraphy/amplitude manipulation (FM/AM);
In down-link channel DPSK; and
In up-link channel DPSK - with trapeziform phase changing;

- Technical rate in radiochannel 2.7 Kbps;
- Transmitted/received message volume up to 100 Kbps;
- Positioning accuracy 100 m
- Antenna of Gonets D-1 system user terminal:

  Amplification within 120 degree angle sector not less than 0 dB;
  VSWR not more than 2.0; and
  Polarization circular, right-hand;
- Positioning device antenna:

  Gain 3 dB;
  VSWR not more than 1.5; and
  Polarization circular, right-hand;
- Electric power supply - from (220 +/- 10%) VAC, 50 Hz mains or 12 VDC power sources;

USE OF GONETS D-1 FOR TRACKING CARGO

Based on the All-European System for extremely hazardous cargo (EHC) tracking a space subsystem should provide the following:

- Capability to determine transportation vehicles and cargo container positions down to 0.1 - 1.0 Km (RMS) accuracy;
- Centralized data collection from vehicles on their positions and transportable cargo status (data on cargo parameter check);
- On-line communications with any vehicle in case of emergency (accident, unauthorized container opening etc.) and notification of services responsible for cargo delivery;
- Completely automated route information processing with operator interface only in emergency situations;
- Efficient alarm transmission in case of an emergency with the vehicle.

The Gonets D-1 integrated space segment system includes the following subsystems:

- Space segment including an orbit group of 6 spacecraft;
- Ground control segment.
- Network Service Center;
- Cargo transportation control services equipped with stationary terminals;

- User segment.

BRIEF DESCRIPTION OF THE EQUIPMENT USED

Network Service Centers (NSCs) are to collect, process and store data on an objects position and status. Proforma and text message exchanges between vehicles and dispatch points of transportation control services are also typically carried out via the NSC.

Network Service Center 12 System (NSC-12) - This was developed for the Gonets D-1 System can be used without any revision. NSC-12 is powered by 220 VAC, 50 Hz mains. The station includes UPS which ensures station operation during short term failure of the mains. NSC-12 can be installed right at the Transportation Control Center (TCC) and connected to the TCC information network through the local area network of Ethernet type (NSC-12 includes network adapters).

Stationary Terminal (ÀÒ-Ñ) - At the stationary points of the cargo tracking system serial terminal AT-C12-1 by Izhevsk radio plant can be used. This terminal is fed from the 220 VAC, 50 Hz mains. It includes antenna, transmit/receive block (P-AT) without navigation device, main power supply E-AT and a personal computer.

Automobile Terminal - The automobile version of the terminal is based on the design of the AT-B12-1 mobile terminal. The terminal is powered from 12 VDC power supply. The automobile terminal can be delivered in 2 versions:

- Unattended, designed for data transmission on vehicle position and status in automatic mode without driver interface.
- Attended, designed for both data transmission on vehicle position and status and formalized text message exchanges with various services responsible for transportation related issues (police, fire, roadside assistance companies).

The terminal includes an antenna, P-AT block with navigation device and driver's control panel with keyboard and display (in attended version of the terminal).

MESSAGE STRUCTURE ON OBJECT POSITION AND STATUS

Information exchange between Gonets D-1 and the System user is carried out by means of messages having the following structure:

synchro-packet	start pulse	service word	information part	end sign	control sum
140 msec	13(24) bit	24 bit	24N (Nmax=400)	24 bit	24 bit

The message information portion of the communication is divided into packets. Each of them consists of an envelope (header) and information segment. The envelope is used for intranetwork information traffic addressing and routing. Envelope length is the same in all packets and equals 144 bits.

The envelope contains the following:

- Message type;
- Sender's and recipient's network identifiers;
- Message formation date;
- Current number within a day;
- Message urgency sign;
- Flags;
- Meaning volume length within information segment;
- Number of packets in a message;
- Current packet number.

The information segment of a packet contains a message or part of a message. Information segment length can exceed 10 Kbps and must be a multiple of 24. If not, then meaningless binary units are added to the message to get the required volume (meaning volume length in the information segment is indicated in one of the envelope margins). If a longer message (up to 100 Kbps) must be transmitted it is divided into shorter segments and transmitted in sequence.

Object position and status data are transmitted from vehicles as separate packets. The structure of the position data packet is presented below.

Envelope	Information segment		
	Latitude	Longitude	Time
144 bit	96 bit	96 bit	32 bit

Three types of packets on position are formed in by the Gonets D-1 System:

- Empty telegram (if navigation device is perfect, but position is not determined);
- Normal telegram; and
- Emergency telegram (if navigation device is faulty).

The normal telegram contains 224 bit of information received from navigation device:

- Position data (latitude-longitude format, 0-23 bytes of packet 84 according to TSIP protocol); and
- Time of position determination (UTC format, 32-35 bytes of packet 84 according to TSIP protocol);

Structure of status data packet is presented below:

Envelope	Message on object status (192 bit)
144 bit	24 24 24 ..... 24 24

TEXT MESSAGE STRUCTURE

Two-way text message exchanges take place between Transportation Control Services and vehicles. The text message is in fact a data array, symbols of which are coded according to ASCII table. Text message structure is the same as the one of object position and status message. Maximum length of text message information segment must not exceed 9768 bits.

Envelope	Information array
144 bit	up to 9768 bit

Exhibit "D"

INTERMODAL CONTAINER TRACKING & MONITORING

PROBLEM OVERVIEW

Today there is a significant requirement for a real time cargo container monitoring system that can track movement, as well as identify the exact moment and location during transport that cargo containers are illegally opened or their contents violated. This requirement exists because these containers are currently employed worldwide with little or no current ability to monitor their location or condition without using "manual techniques". The reliability factor is marginal at best. For this discussion, the term transport includes truck, rail, sea and air, with extended periods of warehouse storage.

PROPOSED SOLUTION

The solution result is a real time container status monitoring system. It is constructed through the integration of three major subsystems. These subsystems include: a low earth orbiting satellite (LEOSat), a collection of small stand alone RF transmitters referred to as "tags", and a mission control ground station. ISC's 45 LEOSat system, in a polar orbit with a high angle of inclination, will maintain coverage of every location on the earth throughout_every day. The LEOSat is of the store-and-forward type, storing tag data in an on board memory as it is received and then downloading the data as it passes over the ground station. The LEOSat will be capable of performing accurate range measurements on tags with which it communicates, as well as determine its own position by employing a NAVSTAR GPS receiver.

The tags, which may be affixed to any object for which tracking is a requirement, communicate timing/position information and data to the LEOSat. The tags will also be capable of communicating among themselves in such a fashion that they establish a dynamic distributed network. In this way disadvantaged tags, those with an inadequate link margin and unable to communicate with the LEOSat, may forward data to the LEOSat by means of other nearby tags with adequate link margins. Additionally, tags may employ external sensors to gather specific data (intrusion, shock, temperature, leaking tanks, humidity, speed, motion) concerning the device to which it is affixed.

The ground station, which may be located anywhere on the earth, will consist of a tracking antenna, transceiver, analysis station and modem pool. The LEOSat will forward any tag data to the ground station as it passes overhead. This information is received and converted into digital data then stored in a relational database. From the database, the data may be forwarded to the analysis station where, when combined with any historical information, it can be applied against a variety of knowledge based and/or heuristic tools to yield additional insight into tag related activities. The modem pool and standardized report generation packages provide a means by which automated reporting to field sights may be accomplished.

ISC's unique approach is predicated on the ability to produce a set of electronic tags that have the following properties:

1. In a developed state they can be covertly placed on or in the container or asset of concern,
2. They can provide the location of the container or asset,
3. They can monitor the status of the container or asset,
4. They are autonomous and intelligent,
5. They have an intelligent power management system, extended battery life and, with recharging, can operate for many years,
6. They can be interfaced with a full range of sensors, including those required to determine when a container is opened, when it changes internal temperature, when it is moved, and
7. They can communicate with a mission control ground station from anywhere in the world.

Other unique features include:

8. An automated mission control and ground station,
9. An analysis station providing knowledge based analysis tools, automated alarm filters, and automated report generation and dial out,
10. An inexpensive commercially available satellite capable of being launched as a secondary payload, and
11. A satellite that can be reprogrammed while in orbit to allow early implementation of a basic system, provide an on orbit test bed, and be upgraded as modifications and system capabilities expand.

TECHNICAL APPROACH

PROPOSED SOLUTION - GENERAL CONCEPT OF OPERATIONS

The solution presented here results from a system developed through the integration of three major subsystems. These subsystems include: a satellite constellation, a collection of small stand alone RF transmitters, and a mission control ground station. The satellites forming the constellation will be in a polar low earth orbit and thus fall into the general category referred to as LEOSats. At an operational altitude of 1200-1500 Km, a polar orbit will allow for a footprint (view) of 5,000 Km in diameter . By virtue of a LEOSats relatively short slant range, very little power is required to maintain communications with the satellite from the ground. The LEOSat will be capable of accurately determining its position in space by employing a NAVSTAR GPS receiver.

The RF transmitters, referred to as tags, will be small, durable, battery operated devices requiring no man/machine interface and will be capable of communicating with the LEOSat in their primary operational mode. In their secondary mode, these tags will be capable of establishing a distributed network with other nearby tags and acting as a gateway to the LEOSat for any disadvantaged tags. In a tertiary mode, each tag may be interfaced to any of a variety of sensors to assess or indicate a change in state of any monitored condition. In the primary mode, a tag will be capable of responding to a polling transmission from the LEOSat. The tag will receive the polling message and respond in such a fashion that the LEOSat will be able to determine the geo-position of the tag.

Between satellite visits, each tag in its secondary mode will be responsible for verifying the presence of any nearby tag and determining its responsibilities to that family of tags. In a stack of shipping containers, for example, a tag buried near the bottom of the stack may be unable to communicate with the LEOSat. It may, however, be able to communicate with another tag nearby in the stack. The second tag may also not be able to communicate with the satellite, but may be able to communicate with a tag on the top of the stack that can establish the required communication link with the satellite. This tag, functioning as a gateway to the satellite, is referred to as the sequencer tag and will act as the network master. The second tag in the stack, able to directly access the sequencer will establish itself as a network sub-sequencer.

By monitoring the presence of each nearby tag, a distributed network of tags is established. The tag on the bottom of the stack broadcasts its presence to any nearby tag. These tags, in turn, broadcast their own presence and that of any tag for which they are responsible to any other nearby tag(s). In this fashion "disadvantaged" tags are capable of communicating with the satellite by means of the distributed network to a sub-sequencer and eventually to a sequencer tag that may function as a gateway to the LEOSat.

In a more controlled environment, where it can be anticipated that all tags will be disadvantaged, additional tags can be located on adjoining bulkheads or between decks. They can be located in such a manner that they will act as sub-sequencers and pass data from the disadvantaged tags through the RF barrier to other, more optimally placed, sequencer tags whose primary responsibility it is to gateway the appropriate information to the LEOSat.

For illustration purposes, a specific scenario is the stacking of containers on the dock and the subsequent loading of containers onto a ship for transport. Containers are initially stacked in the storage yard. In this situation, tags near the bottom of the stack communicate their presence to each nearby tag and a hierarchy of slave, subsequencer and sequencer tags will be established. As the satellite passes overhead it polls the ground based tags. Those tags able to communicate with the satellite identify themselves. In addition, those acting as sequencers identify themselves and all of the tags for which they are acting as master. In this fashion, tags not normally able to communicate with the satellite are able, in a second hand manner, to make their location known to the satellite. As the tags are moved and separated for loading, the configuration of the distributed network changes dynamically. Each of the tags takes up its new relationship based on its ability to communicate and the process continues so that there are never any blank spots or gaps in the reporting.

During the stacking of containers, the first container moved to the dock will first attempt to contact a local sequencer or sub-sequencer. As described above, a (sub) sequencer may be a semi-permanently emplaced tag possibly employing external power, or it may be another mobile tag (all tags may be fitted to accept external and/or battery power). If the tag fails to find a local sub-sequencer or sequencer, it will then attempt to detect the LEOSat. If the tag is unsuccessful in communicating with the LEOSat, the tag will power down (sleep mode) for a given length of time, after which it will repeat the process. Renewed failure, either in locating a (sub)sequencer or detecting a LEOSat will cause ever increasing periods of quiescence between attempts at communication.

If the tag is successful in detecting the LEOSat, the tag will identify itself as a local sequencer and satellite gateway. Having so identified itself and its location, if the tag is receiving external power (including solar sources) it will begin regular communication with the LEOSat . In the case that no external power is available, the tag will communicate its status and assume a low duty cycle until it is otherwise disturbed. If the tag is disturbed, it will initiate emergency broadcasts, a duty cycle high enough to assure an acceptable probability of detection over a pre-defined period.

When a second tag is deposited near the first, the second tag will attempt to broadcast its new location. It will first seek a sequencer. If the first tag is acting as a sequencer, then the second tag will become a slaved system to the first. The newly arriving tag will also attempt to become a quiescent tag, leaving its tag identifier with the sequencer and relying upon the sequencer tag (in this case the first tag) for regular reporting of its location status. Thus, in any group or family of tags, the majority will be quiescent, operating on a low frequency duty cycle and depending upon the sequencer and gateway to report their status and location. If the sequencer tag falls below a pre-defined power threshold or fails to detect a LEOSat, it will broadcast an alert to any neighboring tags and become quiescent. A new sequencer/gateway will then be selected from the family of tags.

In the case where a container is loaded onto a ship, tags that have been affixed to the vessel as sub-sequencers to pass data between decks will detect the presence of any new container tag and forward this data to a tag intentionally placed to act as a sequencer and gateway to the LEOSat. Such a sequencer tag may be mast mounted or located at some unblocked location on the vessel. In addition, and by virtue of the natural RF barrier presented by a ship's metal structure and control of the transmission power, it can be determined when a tag has been loaded or unloaded from a ship.

It can be seen from the above example that a hierarchy of reporting responsibility is established within each family of tags. Those tags that can "hear" the LEOSat establish themselves as sequencers under the assumption that if they can receive the down link with an acceptable bit error rate, they can successfully communicate with the satellite. Those tags that can directly communicate with the sequencer establish themselves as first order sub-sequencers. Those that can directly communicate with sub-sequencers, but not sequencers, establish themselves as secondary sequencers, and so on. Within any given family of tags, multiple tags may be able to successfully communicate with the satellite. As a result, these tags will arbitrate and time share the responsibility of acting as the sequencer in order to conserve power. This philosophy also applies to each subsequent level of sub-sequencer.

In order to implement both the primary and secondary modes of operation in a power efficient manner, each tag will be capable of implementing two sets of communications protocols. During primary operations, the X.25A protocol is employed. This is an HDLC packet protocol that allows variable length messages to be transmitted to the LEOSat. In the secondary mode a modified broadcast Carrier Sense Multiple Access (CSMA) reliable protocol, as described above, will be employed.

Each tag and the satellite will employ a direct sequence spread spectrum modulation technique. This will serve several functions. First, the wide band nature of direct sequence modulation allows accurate ranging measurements to be derived from the stable carrier. Second, the wide band nature of the signal greatly reduces the impact of the Doppler effect that will result from the relative velocities of the LEOSat and the tags. Third, because the interference contributions of in-band narrow band transmissions will not be correlated upon reception, considerably less transmission power is required to assure a satisfactory link margin. (At 910 MHz, a 1 watt transmitted will have a 3 dB link margin at 600 bps with a LEOSat altitude at 800 Km and elevation angle of 3 degrees.) Finally, the strict synchronization requirements for the reception of direct sequence spread spectrum signals eliminates the occurrence of data loss/collision as a result of multipath. This is most significant in that the confined spaces in and between metal containers, in warehouses, aboard ships and aircraft, multipath is an anathema to traditional narrow band transmissions.

As introduced in the previous paragraph, the LEOSat will be capable of determining the range of the tag. The satellite will include a spread spectrum transmitter and receiver similar to that employed in the tag. In addition, the satellite will know its position precisely by including on board a NAVSTAR GPS receiver. The satellite will note its position in space and the time of occurrence of each of its polling messages. Upon receipt of the appropriate polling message, the tag will transmit its response and append to that response the duration of the period between receipt of the polling signal and transmission of the response. The LEOSat will log its position in space and the time of receipt of the response transmission.

In that the LEOSat "visits" each location on the earth, the mission control ground station may be located anywhere on Earth. The LEOSat will be instructed to forward the stored tag data as it passes over the ground station. The ground station will receive this data and transmit any new instructions to the LEOSat. Upon receipt of the data it will be converted into binary form and stored in a relational database such that the tag may be retrieved based upon identifier or any of a variety of user defined search keys. The information provided by the tag may include geolocation information as well as any data concerning the status of the tag and associated sensors. This data may be stored such that a historical base of information regarding a specific tag or family of tags may be archived.

This archived information may be ported to the analysis work station. The work station will provide a variety of knowledge based and heuristic tools to provide deeper insight into the activity of specific tags or families of tags. The analysis may be employed to develop scenarios, determine or anticipate the occurrence of a rule violation or detect patterns of activities that may reveal the potential for the compromise of the tagged article. The work station may also provide automated report generation and transmission capabilities by virtue of the user pre-established rule/parameter violation detection and modem pool.

HANGING AND GEOLOCATION DETERMINATION

The geolocation approach presented here is based upon the determination of the range to the tag from the LEOSat. This will be accomplished by determining the total duration of the round trip time required for a signal to travel from the LEOSat to the tag of concern and back. More specifically, the LEOSat will mark its location in space and the time at which a specific tag is polled. The tag will receive the signal, append to its transmission the total duration of the period from the time the signal was detected by the tag to the time the tag data leaves the tag. The satellite again marks its position in space and the time the tag transmission was received. This process does not require that the tag and satellite clocks be synchronized, only that they be stable over the total duration of the process. This process is repeated to reduce the range probability ellipsoid to ellipses of probability.

Many of the inherent errors in this ranging process are known and can be estimated. For example, processing delays at the tag and satellite are, in general, known in advance and can be compensated for. However, two LEOSats simultaneously in the same footprint, but at different orbital planes, are required to completely resolve the obvious range ambiguity for surface based tags. Four LEOSats are required to resolve altitude. For a tag located on the surface of the Earth, a single satellite will, in general, provide two estimated solutions: the intersection of the two ranging ellipsoids and the geoid representing the surface of the Earth. A second satellite in a different orbital plane will resolve this to a single location on the geoid representing the Earth.

The requirement for a four satellite solution is reduced if the tags are restricted to the surface of the Earth. The requirement for a two satellite solution reduces as the movement of the tags over the surface of the Earth is reduced. This results from the ability to conduct ranging measurements over multiple passes for the same satellite in different planes with respect to the tag and the increasing accuracy of the compiled historic data as the tags become increasingly static. A single LEOSat can resolve the position of a tag on the face of the earth over two consecutive passes of 100 minute intervals if: that tag is restricted to the surface of the Earth; the tag is further restricted to the relatively slow velocities associated with travel over the Earth's surface; and the 100 minute interval between consecutive passes provides adequate reporting resolution.

Other ranging errors will have limited effect on the ranging accuracy. The instability of the spacecraft and tag clocks will induce errors that cannot be estimated with a single satellite. These instabilities, both independent and relative, will result in errors on the order of 10 to 20 meters. Atmospheric conditions will also affect the accuracy of the ranging process. Relatively accurate estimates of tropospheric activity are available and the resulting errors can be approximated to within a few meters. Ionospheric activity can yield errors of a meter or less and as a result are of little concern.

REAL TIME AND "BY CHOICE" OPTIONS FOR THE USER

Areas where tags are in concentration, as in ports and on ships in port, the authority with control of the area could operate an antenna based system providing real time regional coverage. If there were concerns about the antenna array being adequate enough to reach all tags, an airborne platform could be used, such as a helicopter or airplane to act as a pseudo-satellite. This airborne platform could result in real time coverage or "at choice" coverage on a regional basis. Airborne platforms could be launched over an area as wide as required by the situation. This would yield reports only to the extent and at the time the user required such information. Satellites would be employed only as they came into view and would provide supplemental coverage on a global basis. Satellites would be asked to track the tags as they left areas of concentration, such as at sea or at a pick-up locations where a container may have been dropped for the user's customer.

In the case of railroads, there are RF communication systems in place that will allow for communication while enroute, to be handled through that RF system in a data over voice format. This format does not interfere with the voice traffic in any way. It thus represents an efficient use of existing resources and places the satellite capability in a value added support role.

Ideal installation of this system would result in these tags being standard equipment on ships hauling containers and freight, on each container and on other equipment or materials being shipped. At the ports there would be an antenna array strategically located throughout the complex. As ships entered or left port, the system would get manifest reporting for each ship. While in port the status of each tag would be tracked by the ground based antenna system and supplemented by the satellite or airborne platforms. Each container and every shipment would be easily located and accounted for with no user interface required; it would be automatic. If all ports and shipping were so equipped, the global tracking and control of one's assets would be done from a console in a mission control room, saving many man-hours, preventing theft and delay and all the resulting costs associated therewith. It could be expected that insurance carriers would lower premiums and the resulting savings would be additional net profit to the users.

CONCLUSION

The system discussed is presented in the environment of intermodal containers, because of the complexity that must be addressed to make the system work efficiently and effectively. Having discussed the ability of the LEOSat/tag combination in this complex environment, it can also address the common capabilities of the technology to address general asset management, general GPS assisted tracking, diagnostic capabilities employable in monitoring track conditions, bridge safety (Alabama Amtrak crash) as well as basic fax and e-mail type communications without the benefit of anything more than the stand alone computer or fax machine. No phone lines, no software or internet connections are required to accomplish such communications. ANYTHING that can be sensed, measured or input can be communicated via this satellite based technology. Additionally, the technology supports a value added relationship using other existing wireline, wireless, cellular or RF capabilities built into its architecture.

Cargo tracking device shown at L.B. State

By Jennifer Vigil
Staff writer

LONG BEACH – A new form of satellite technology was demonstrated at Cal State Long Beach on Wednesday, using a signal that may soon be applied by governments and commercial outlets to track shipments around the globe.

The exhibition was put on in the offices of the Center for the Commercial Deployment of Transportation Technologies, a body charged with studying what methods would best aid the government in moving large cargoes, particularly in times of war.

Visitors from Russia and Mexico sat in cramped instructor offices huddled around computers that marked a van's progress around the campus perimeter. A tag – a tracking device about the size of a small package – placed inside the vehicle sent a signal to a satellite, which transmitted the information back to the university.

T. Craig Eschrich, whose Orange County company, Integrated Sat/Com, developed the technology in concert with a multinational crew of experts in satellite communications, believes his intricate systems could be used to record meteorologic changes, provide wireless communications, and track movements of sensitive cargo, such as nuclear materials.

The campus center will launch a yearlong study in October to determine whether the satellite links provided by Eschrich's company are suitable for the government's needs. Isaac Maya, the center's program manager, said at least two other companies will be examined.

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