ORBCOMM
Low Earth Orbit Mobile Satellite Communication System
US Armed Forces Applications

Todd Hara, Senior Communications Engineer, ORBCOMM, Dulles, Virginia
Voice: (703) 406 - 5392 FAX: (703) 406 - 5308

ABSTRACT The ORBCOMM digital data communication and position determination system can provide the United States Armed Forces with two-way on-the-move data messaging anywhere in the world. The ORBCOMM System uses a constellation of small spacecraft in low-Earth orbit (LEO) instead of terrestrial fixed site relays or repeaters to provide worldwide geographic coverage. The user terminals are inexpensive ($450 retail) light-weight and pocket-sized. They transmit and receive short digital burst packets, with inherent LPI/LPD. The ORBCOMM Capabilities Demonstration Satellite is currently in orbit and is available now to the US Armed Forces for test purposes. The first two operational satellites will be launched late this year and will be ready for US Armed Forces Beta tests in early 1994.

Low-Earth orbit communication satellites will be an important part of the world’s communication infrastructure in the coming years. ORBCOMM as the leader in this technology can provide the US Armed Forces with this valuable communication and position/navigation capability.

The ORBCOMM System provides the user with data messaging capabilities beyond anything that is available today. The user will be able to compose, transmit and receive messages on very small hand-held devices or devices integrated with palmtop computers anywhere on the world. The user need only point the antenna (or use an existing vehicle antenna) on the Subscriber Terminal (ST) up toward the sky and push the transmit button. With a constellation of 26 LEO satellites and terrestrial facilities, the user will have a satellite in view continuously over 95% of the time, and will have to wait less than two minutes the rest of the time. A fourth plane of eight satellites (34 total satellites) may be launched for increased capacity and global coverage depending upon demand.

The ORBCOMM System uses 137-138 MHz for transmissions down to the ST and 148-150.5 MHz for transmissions to the satellites. These frequencies have been approved for use by LEO satellite systems at the World Administrative Radio Conference in February 1992. The FCC allocated these frequencies to LEO mobile satellites services in January 1993. The FCC also granted ORBCOMM an experimental license in March 1992 to launch and operate the first two satellites and up to 1,000 ORBCOMM STs. Subsequently, ORBCOMM received authority from the FCC to begin construction of the full constellation of satellites and ground facilities. Receipt of full FCC approval is expected in late 1993.

US Armed Forces Applications The US Armed Forces can establish long haul and beyond line-of-sight (LOS) communications without terrestrial repeaters, relays, or high-powered equipment. The ORBCOMM System uses the LEO satellites to provide connectivity for users. The US Armed Forces can employ the ORBCOMM System to augment the communication capabilities and improve the performance of currently deployed systems.

US Armed Forces Beta Tests The first two satellites along with the ground segment is scheduled to be in-place by the fourth quarter of 1993 or early 1994. Functions and capabilities specific to US Armed Forces can be evaluated in late 1993 and early 1994. Intermittent service with the ORBCOMM system will be available in the first quarter of 1994.

U.S. Government work not protected by U.S. copyright
1.0 Introduction

The ORBCOMM digital data communication and position determination system can provide the United States Armed Forces with two-way on-the-move data messaging anywhere in the world. The ORBCOMM System uses a constellation of small spacecraft in low-Earth orbit (LEO) instead of terrestrial fixed site relays or repeaters to provide worldwide geographic coverage. The user terminals are light-weight and pocket-sized. They transmit and receive short digital burst packets, with inherent LPVLPD. The ORBCOMM System is the world’s first low-Earth orbit satellite system to provide high availability, ubiquitous, low-cost, two-way, on-the-move communications over the entire globe.

ORBCOMM, a subsidiary of Orbital Sciences Corporation (OSC), is developing the ORBCOMM System with the small satellite technology expertise and the low-cost launch systems (the air launched booster Pegasus) developed by OSC. OSC is a pioneer in "microspace" technology and a leader in the commercial space industry and is one of the United States fastest growing high technology enterprises with over 1,200 employees, 1993 sales of over $175 Million, and a $1 Billion order backlog primarily with the US Air Force, NASA, ARPA, and BMDO.

ORBCOMM is developing the ORBCOMM System on private funds (bonds, funds from OSC) primarily for commercial markets in the US and worldwide. ORBCOMM also recently signed a strategic alliance and financing agreement with Teleglobe (Canada). Teleglobe is the world’s fifth largest telecommunications company. Use of the ORBCOMM System by the US Armed Forces would be in-accord with the "dual-use" policy (use of commercial assets by the military) supported by the DOD. US Armed Forces can utilize the unique communication capabilities of the ORBCOMM System without the high costs associated with developing a system solely for use by the military.

ORBCOMM has made substantial technical and financial commitments towards developing and implementing the ORBCOMM System and is confident that the US Armed Forces can use the ORBCOMM System in it’s varied missions. ORBCOMM recently deployed the Capabilities Demonstration Satellite (CDS). The CDS spacecraft is being used as an in-orbit platform to complete the hardware and software engineering required for the first two operational ORBCOMM satellites. The first two operational satellites will be launched late this year or early next year and the full 26 satellite constellation will be completed in 1994.

2.0 Mission Applications of ORBCOMM System for US Armed Forces.

The ORBCOMM System will provide two-way on-the-move digital data messaging between users anywhere on the Earth. US Armed Forces users of the ORBCOMM System will be able to:

- Establish long haul and beyond line-of-sight (LOS) communications without terrestrial repeaters, relays, or high-powered equipment.
  - Transmit Theater High Altitude Area Defense (THAAD) air track information from remotely deployed sensors to dispersed fire units.
  - Communicate to beach heads from ships beyond the horizon
- Communicate on-the-move from with pocket-sized light-weight (less than one pound) ORBCOMM subscriber terminals (STs) without having to locate a satellite, deploy, or aim an antenna.
  - Share existing omni-directional VHF antennas on HMMVWS, APCs, tracked vehicles, tanks.
- Transmit and receive Battle Management information - automatically track positions of units at command posts
- Avoid detection during transmission. STs transmit at less than 5 watts for LPD.
- Communicate covertly. ORBCOMM System transmission bursts are less typically than 100 milliseconds for a 450 byte message for LPI. Difficult to direction find on a short burst. Transmissions from the satellite would be impractical to jam; optional machine-receipt eliminates need for re-transmissions. Satellite transmission footprint is 3,000 miles across, with tens of thousands of messages in each satellite transmission broadcast, making it difficult to detect any one transmission.
- Retrieve messages at any time. Messages are stored and transmitted to ST only when ST is powered. Message store capability is in accordance with 1988 X.400 standards.
- Communicate with US Armed Forces rotary aircraft conducting nape of the earth operations without high powered HF equipment
- Determine own position within 100 meters with ORBCOMM ST Doppler positioning capability or more accurately with a GPS receiver mated with the ORBCOMM ST. Maintain and track the position of US Armed Forces at command headquarters.
- Search and Rescue (SAR) operations, remote ordnance control, transmission of data from remote sensors (intrusion/motion and heat) - monitor perimeter of air fields, naval shore facilities.

Existing and planned military satellite and troposcatter communication systems require the user to stop, deploy, and point an antenna in order to establish a link. Other digital communication systems such as JTIDS and SINGCARS are limited by LOS and require relays. EPLRS is limited by LOS and requires a dense net of users in order to establish connectivity. HF systems provide beyond LOS connectivity, but require power high transmissions that are easy to detect.

Current wide-area commercial mobile message systems provide only one-way messaging (pagers) limited geographically to the major metropolitan areas. They use fixed-site terrestrial towers or require high-powered equipment with large antennas (operating in C or Ku band) such as the geosynchronous satellite based Qualcomm system used by the trucking industry.

3.0 ORBCOMM System Operational Concept

The ORBCOMM System provides the user with data messaging capabilities beyond anything that is available today. The user will be able to compose, transmit and receive messages on very small hand-held devices or devices integrated with palmtop computers anywhere on the world. The user need only point the whip antenna on the ST up toward the sky and push the transmit button. With a constellation of 26 LEO satellites and terrestrial facilities, the US user will have a satellite in view continuously over 95% of the time, and will have to wait less than two minutes the rest of the time (Figure 3-1).
The ORBCOMM System uses 137-138 MHz for transmissions down to the ST and 148-
150.5 MHz for transmissions to the satellites. These frequencies have been
approved for use by LEO satellite systems at the World Administrative Radio Conference
in February 1992. The FCC allocated these frequencies to LEO mobile satellites services
in January 1993. The FCC granted ORBCOMM an experimental license in
March 1992 to launch and operate the first two satellites and up to 1,000 ORBCOMM
STs. Subsequently, ORBCOMM received authority from the FCC to begin
construction of the full constellation of satellites and ground facilities. Receipt of
full FCC approval is expected in 1993.

A message transmitted from an ST
and received at the satellite is then relayed
down to a regional Gateway Earth Station
(GES). The GES then relays the message
via satellite link or dedicated terrestrial line
to the Network Control Center (NCC)
(Figure 3-2). The NCC then determines the

Figure 3-1. ORBCOMM Satellite System Coverage - Availability
location of the recipient of the messages and routes the message to the appropriate GES, which transmits the message up to the satellite, then down to the addressee of the message. The end-to-end time for transmitting and receipt of a message is 3 seconds.

![Diagram of ORBCOMM System Components](image)

**Figure 3-2. ORBCOMM System Components**

### 3.1 ORBCOMM System Components

The three main components of the ORBCOMM System are the space segment, ground segment, and STs (user terminals). For coverage of the US, there will be four unmanned GES in the four corners of the US, one Network Control Center (NCC), and a constellation of 26 small satellites. The satellite constellation is key to providing the following system performance objectives:

- 99% of outages (satellite not in view) < 5 minutes
- 95% of outages (satellite not in view) < 2 minutes

Other countries around the world will have their own NCC and GES (the number of GES being dependent on the size of the country). The satellites are "re-used" by each country as they pass overhead (Figure 3-3).
3.1.1 Low-Earth Orbit Mobile Satellites - Space Segment

The ORBCOMM System's most unique characteristic is the use of low-Earth orbit satellites. The space segment is comprised of 26 small communication satellites in orbit 425 miles (785 km) above the earth. LEO satellite systems provide the following advantages:

- Lower launch costs to place a small satellite in a 425 mile orbit than a big satellite into a 26,000 mile geosynchronous orbit (Figure 3-4).
- Minimal satellite transmission time delays with a LEO satellite versus GEO satellite.
- Availability of Doppler shift in signal for integrated position determination
- Use of proven inexpensive VHF electronics, shared omnidirectional VHF antennas
- Excellent overall link availability independent of local terrain features

Figure 3-3. ORBCOMM Satellite World-Wide Coverage
The first two satellites deployed will be in near-polar orbit. They will be launched in late 1993/early 1994. The next 24 satellites will be deployed in three planes of eight equidistantly spaced satellites in circular orbit inclined 45 degrees at the equator, spaced 135 degrees apart. The full constellation will be deployed by 1994. An additional 8 satellite plane may be deployed in 1995 depending on demand to provide increased coverage. The satellites will be deployed eight at a time using OSC's Pegasus launcher.

The ORBCOMM satellites are very simple spacecraft whose main function is to complete the link between the STs and the NCC. The ORBCOMM satellites have the following characteristics:

- **Mass** 85 pounds
- **Solar Array Power** 160 watts (orbit average)
- **Transmitters**
  - VHF (users links) 2
  - VHF (feeder links) 1
  - UHF 1
- **Receivers**
  - VHF (users links) 7

- Propulsion N₂
- Guidance Autonomous/GPS
- Design Lifetime Four years

### 3.1.2 ORBCOMM Capabilities

**Demonstration Satellite** The ORBCOMM Capabilities Demonstration Satellite (CDS) was deployed as a secondary payload on the February 1993 Pegasus launch of a satellite for Brazil. The CDS spacecraft is being used as an in-orbit platform to complete the hardware and software engineering required for the first two operational ORBCOMM satellites and analyze the capabilities and performance of the fully operational system. The CDS is also being used to test prototype hand-held ORBCOMM STs built by various manufacturers.

The CDS is automatically scanning the frequencies world-wide to measure the existing use of the ORBCOMM System operating radio frequencies and to establish operating requirements for the ORBCOMM satellite Dynamic Channel Activity Assignment System to facilitate optimum
spectrum sharing with existing users of the radio frequencies. The data shows that the noise sources are spaced apart in frequency and duration confirming engineering analysis that frequency sharing of the band is practical (Figure 3-5).

Figure 3-5. Frequency Spectrum Analysis of CDS Data
The CDS is in a near-circular orbit approximately 405 nautical miles above the Earth in an orbit inclined 25 degrees to the Equator. The CDS is about the size of a large briefcase and weighs 32 pounds. Solar cells cover two sides of the spacecraft and supply 35 watts of power. The CDS solar arrays, transmitters, receivers, battery charge regulators, scanning receiver, and other hardware are engineered to provide functional data useful in constructing the operational satellites.

3.1.3 Ground Segment

The ground segment is comprised of the NCC and unmanned GES. The ground segment has most of the "intelligence" of the ORBCOMM System - with very simple satellites in orbit. This approach avoids having expensive spacecraft in orbit that cannot be repaired.

Each country around the world that uses the ORBCOMM System will have their own NCC and GES. Initially, there will be four GES located in the four corners of the US with unobstructed views of the horizon. Each GES has two steerable VHF antennas that track the satellites as they cross the sky.

The GES and the satellites provide transparent access from the ST to the NCC.

US Armed Forces can use the ORBCOMM US ground segment assets during evaluation, training and exercises in the US. For overseas operations, the US Armed Forces could use near-by national ground segment assets through arrangements made by ORBCOMM similar to the arrangements in place for US Armed Forces use of national telecommunication services abroad. The US Armed Forces may prefer to deploy its own compact air transportable or ship-borne NCC/GES. There are a number of ship borne stabilized satellite communication system in use today. Companies in nineteen countries have signed candidate licensee agreements with ORBCOMM to procure ground segments and provide service. One US Armed Forces combination NCC/GES deployed in theater rear can service a 3,000 mile wide area. For Operation Desert Storm, one NCC/GES in Turkey and another in Riyadh, Saudi Arabia could have provided service for the entire Middle East as shown in Figure 3-6.
3.1.3.1 Network Control Station  The NCC provides message routing, satellite control, and customer services. The NCC routes messages to the addressee of the message. The NCC is owned and operated by ORBCOMM in the US and by each licensee abroad. The Satellite Control Center (SCC) is owned and operated by ORBCOMM. It is co-located with the US NCC in Dulles, Virginia (Figure 3-7).
The NCC is comprised of highly available dual processor computers, automatic switch over, and mirrored disks. The NCC is connected to each GES by leased lines, the public data network, or VSATS. The NCC also has connections to customers over leased lines and the public data network (Figure 3-8). The NCC provides the following functions:

- **Message handling** - Management of the delivery of data messages within and in/out of the ORBCOMM System
- **Network management** - Statistics, diagnostics, and configuration control
- **Message transfer** - Delivery of data messages
- **Message gateway** - Conversion to and from other message delivery/receipt formats
- **Customer Service Positions**
- **Satellite Control Center** - Telemetry collection and analysis, commanding of satellites
- **GES Control and Monitoring** - Commanding of GES - track a specific satellite, GES telemetry collection and analysis

Figure 3-7 Network Control Center Facility
3.1.3.2 Gateway Earth Station The GES provides the link between the ground segment and the space segment. The GES are unattended and highly redundant (Figure 3-9). The GES provides the following functions:

- Acquire and track satellites based on orbital elements received from the NCC
- Transmit to and receive from the satellites
- Transmit to and receive from the NCC
- Monitor status of local GES hardware/software
- Monitor the system level performance of the satellite "connected" to the NCC
The GES has two steerable high-gain VHF antennas that track the satellites as they cross the sky. The GES transmits to the satellite in the 148.0 - 150.05 MHz range at 56.7 kbps at 500 watts. The GES receives 3 watt transmissions from the satellite in the 137.0 - 138.0 MHz range.

3.1.4 Subscriber Terminal (User Terminal) The STs are full function compact, light-weight devices with long-life batteries, 5-watt transmitters, antenna, keypad and LCD screens (Figure 3-11).

Many will have RS-232 data ports and some will be integrated (black box version) with GPS receivers, lap-tops and palm-top computers, and other systems. The data transmissions can be encrypted by the application software using standard Digital Encryption Standard (DES) computer chips using the same methodology that is used by STU-IIIIs to encrypt classified conversations over the public telephone network.
Figure 3.11. Full Capability ORBCOMM Subscriber Terminal
The STs have the following RF characteristics:
- **Transmit**
  - Data rate: 2400 baud
  - Frequency: 148 - 150.05 MHz
  - Modulation: DPSK
  - Power: 5-8 watts
- **Receive**
  - Data rate: 4800 baud
  - Frequency: 137 - 138 MHz
  - Modulation: DPSK
  - G/T: 28 dB/K

Panasonic Corporation has built prototype STs that were used to successfully communicate with the ORBCOMM CDS. Samsung, Hull (marine equipment), and Tadiran (provider of the Simplified Hand Held Terminal Unit (SHTU) to the US Army) have also signed agreements to produce STs. Commercial STs are expected to initially cost approximately $450.

Trimble Navigation is evaluating the integration of their GPS receivers with ORBCOMM STs. US Armed Forces could use this in the field to transmit their position accurately to command headquarters, either by the user in the field or remotely on command from HQ. The ORBCOMM System will provide a less accurate geo-location capability that combines the Doppler frequency shift available from a LEO satellite with the satellite on-board GPS receiver to calculate position within 100 meters. This may be sufficient for many US Armed Forces requirements.

4.0 ORBCOMM System Integration & Test
ORBCOMM is currently in the development and testing phase of the system. Functions and capabilities specific to US Armed Forces missions are being evaluated during this development and test phase. The ground segment is scheduled to be in-place with the first two satellites in orbit by the fourth quarter of 1993/first quarter 1994. Functional and performance tests that can be performed:
- Evaluation of LPI/LPD performance and data security aspects
- Analysis of ORBCOMM satellite Dynamic Channel Assignment Algorithm designed to select (frequency hop) a frequency without energy for transmission in jamming environment
- Compatibility of ORBCOMM System with current US Armed Forces data communication equipment, remote sensors (i.e., motion and heat sensors) and command and control (C2) systems
- Demonstration of combined Trimble GPS receiver with ORBCOMM ST for C2 and SAR

Intermittent service (8 passes a day, 10 minutes each) with the ORBCOMM System will be available in the first quarter of 1994. Beta tests will be conducted during this period to fully exercise the capabilities and functions of the ORBCOMM System.