Chapter 2
Doppler Satellite Positioning, Telemetry and Data Systems

Before we consider the GPS system and its international equivalents, there are still two operational satellite systems that rely on the Doppler technique originally developed for Transit. These are the Argos environmental data system and the Cospas-Sarsat satellite search and rescue system. These systems, although not generally well known, provide excellent capabilities, and operate in a spirit of international cooperation and collaboration for the benefit of all humankind.

Argos Technology

The Argos positioning and data telemetry system is a satellite-based timing, positioning and data collection system that is dedicated to environmental research and uses. Unlike modern GNSS systems, it is a two-way telemetry system that is designed so that Argos terminals on the ground, in the air, or at sea can collect and store data and then broadcast the data up to a satellite, which passes it along to a ground station and then on to the end user. This is sometimes referred to as a 'store-dump' satellite data system. It can use both fixed and mobile platforms, and was first established in 1978 as a joint project between the United States and France. On the U. S. side was NASA and the National Oceanic and Atmospheric Administration (NOAA) and for France there was the French Space Agency (CNES). Argos was originally developed by the United States and France to use French hardware on existing U. S. NOAA polar-orbiting satellites. Although Argos operates with quite low data rates, it provides very cost-effective access to remote data collection devices around the world and is an important part of many global research programs. The system has been operated since 1986 under contract to CLS/Argos, based in Toulouse, France, with a U. S. subsidiary, CLS America, operating in Maryland. The European Meteorological Satellite Organization (EUMETSAT) has recently joined the partnership, as has the Indian Space

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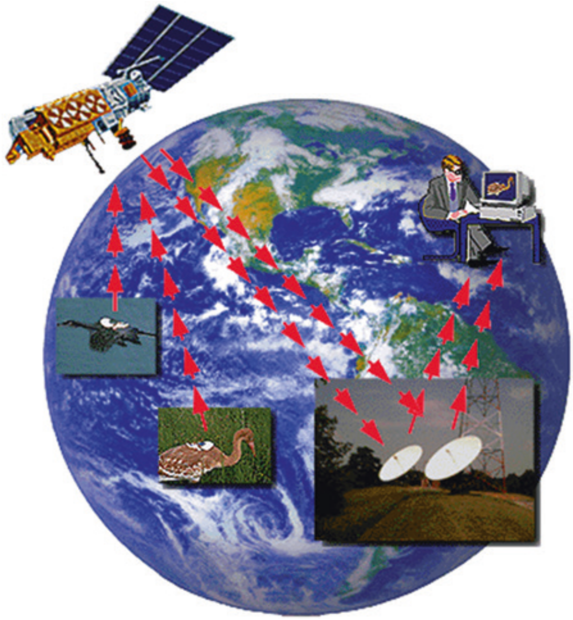


Fig. 2.1 The Argos data system, showing two wildlife systems transmitting data to a U. S. NOAA polar-orbiting satellite, where the data are sent to a ground station and on to the end user. (Image courtesy of Argos.)

Research Organization (ISRO). These new partners have expanded the capability of the overall system (Fig. 2.1).

The system includes the space segment (NOAA and now other polar satellites), the control segment (ground receiving stations and command and control centers), and the user segment (individual Argos devices). Argos devices are programmed to collect the data, store the data, and then transmit signals to the satellites at periodic intervals, set by the user.

There are many kinds of Argos transmitters available on the commercial market. The space segment now includes six polar-orbiting satellites flying in an 850 km altitude orbit (three NOAA polar orbiting satellites and three METOP European satellites operated by EUMETSAT). These make up the EUMETSAT/NOAA Initial Joint Polar System (IJPS). The satellites receive the data and store them onboard until they can download the data to a receiving station.

Argos has a total of over 40 automated ground receiving stations located around the world, with three main receiving stations that also collect all data on each pass, located at Fairbanks, Alaska; Wallops Island, Virginia; and Svalbard, Norway. The receiving stations automatically pass the data to the French and U. S. global processing centers, which then process the data from the various receiving stations and distribute the data on to the end users, often as an automated email message. Secure access is provided by the ArgosWeb website (http://www.Argos-system.org). This specially designed website can display data on world maps, or as tables and charts as defined by the user. Data can also be sent by the ArgosDirect automatic distribution system via email, ftp, or on CD-ROM. Data are archived for 12 months.

Users purchase Argos platforms, as the transmitters are called, both mobile or fixed, from one of several commercial vendors. These are fitted with various sensors to measure a wide variety of parameters, including sea surface temperature, salinity, wildlife parameters such as heartbeat, river or tide gage data, earthquakes and more. Each platform has a unique identifier and transmits the platform identification number and all collected data on 401.650 MHz. Each platform has a fixed repetition period, variable between 90 and 200 s, depending on the user requirements. Each platform transmission lasts less than 1 s, so the system can accommodate multiple platforms in the same area. The first generation of the system had platforms blindly transmitting the data using a transmission process akin to the so-called Aloha system. Users of this process simply hoped that the satellite would receive its signals, and if not it would do so on the next transmission. The new generation devices are smarter, as described below (Figs. 2.2 and 2.3).

The Argos systems fly as small 'parasite payloads' on the six NOAA Polar Orbiting Environmental Satellites (POES) and Eumetsat MetOp satellites. These satellites are in 100 min, near polar, Sun-synchronous orbits that are each offset from the other satellite orbits, so that they cover as much ground as possible in each day. Areas at the poles see the transmitter on each pass, acquiring 14 data takes per day, while areas at the equator get around 8–10 per day, day or night, rain or shine. Each orbit overlaps 25 % at the equator with the last pass, as shown in Fig. 2.4, as Earth rotates under the satellites in a polar orbit.

Each satellite covers an area 5,000 km across as it orbits Earth and can receive data from all Argos transmitters within this area. The satellite will be in view of a platform for approximately 10 min, but it only takes a second to transmit and receive the data.

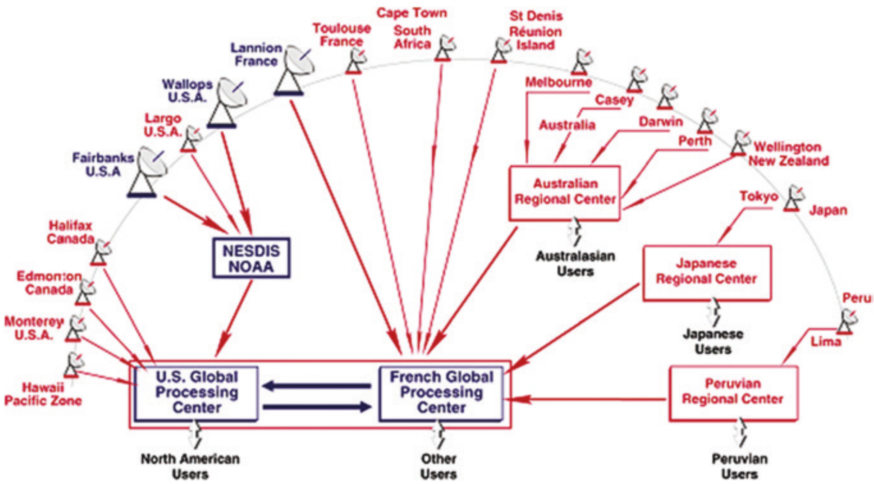


Fig. 2.2 This shows the overall Argos system design. (Image courtesy of Argos.)

Fig. 2.3 The location of Argos ground receiving stations. Satellites receiving data while in view of a ground station can download the data in near real time. If over remote areas, the satellites store the data until in view of a ground station, rarely over 2 h. (Image courtesy of Argos.)

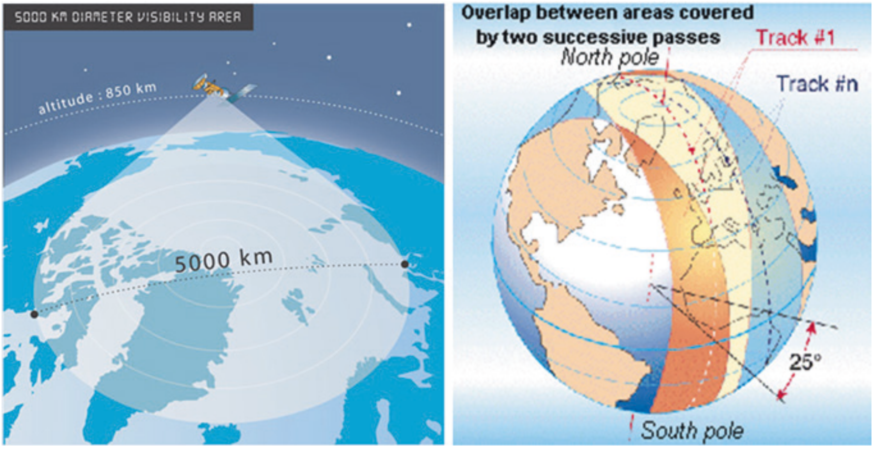
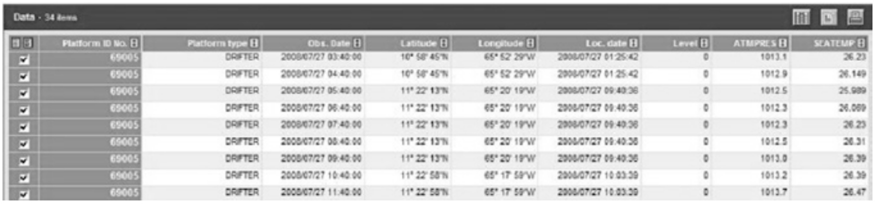


Fig. 2.4 Argos visibility area and orbit overlap. (Image courtesy Argos.)

The two processing centers offer redundant capabilities, with one near Washington, D. C., and one in Toulouse, France. These centers process and check the data, and then make it available to the end users, usually within minutes of receiving the data from the satellite. Transmissions within sight of one of forty ground receiving stations are downloaded in near real time, while remote ocean data, for example, have the data stored on the satellite until it is in view of a ground receiving station.

The data are processed using the Doppler shift technique described above, but modern platforms can also be fitted with GPS receivers, and the more precise GPS



Data - 34 items

Platform ID No.	Platform type	Obs. Date	Latitude	Longitude	Loc. date	Level	ATMPRES	SEATEMP
69005	DRIFTER	2008/07/27 03:40:00	10° 58' 45"N	65° 52' 29"W	2008/07/27 01:25:42	0	1013.1	26.23
69005	DRIFTER	2008/07/27 04:40:00	10° 58' 45"N	65° 52' 29"W	2008/07/27 01:25:42	0	1012.9	26.149
69005	DRIFTER	2008/07/27 05:40:00	11° 22' 13"N	65° 20' 19"W	2008/07/27 09:40:36	0	1012.5	25.989
69005	DRIFTER	2008/07/27 06:40:00	11° 22' 13"N	65° 20' 19"W	2008/07/27 09:40:36	0	1012.3	26.069
69005	DRIFTER	2008/07/27 07:40:00	11° 22' 13"N	65° 20' 19"W	2008/07/27 09:40:36	0	1012.3	26.23
69005	DRIFTER	2008/07/27 08:40:00	11° 22' 13"N	65° 20' 19"W	2008/07/27 09:40:36	0	1012.5	26.31
69005	DRIFTER	2008/07/27 09:40:00	11° 22' 13"N	65° 20' 19"W	2008/07/27 09:40:36	0	1013.0	26.39
69005	DRIFTER	2008/07/27 10:40:00	11° 22' 58"N	65° 17' 59"W	2008/07/27 10:03:39	0	1013.2	26.39
69005	DRIFTER	2008/07/27 11:40:00	11° 22' 58"N	65° 17' 59"W	2008/07/27 10:03:39	0	1013.7	26.47

Fig. 2.5 An Argos message. (Image courtesy of Argos.)

position and time can be automatically extracted from the data. All data are distributed in latitude/longitude using the WGS84 (World Geodetic System 1984) reference system. Estimated positioning error is processed for each reception. With GPS, the true position is within 20 m, and with the Doppler technique it can range from 1,500 to 250 m in accuracy, depending on several parameters. Due to technical issues, some passes cannot compute the Doppler position, and so may sometimes transmit the data parameters without coordinates. For terrestrial readings, a global digital elevation model (DEM) is automatically used in all ground mobile data to improve the precision of the location by including the altitude above sea level (Fig. 2.5).

Each platform has an ID, a type, the date, latitude and longitude coordinates, the precision level, and then the various data parameters. In the figure above, the platform was measuring seawater salinity and water temperature, each measured at 11 different sea depths. Argos readings are dedicated to studying and protecting our natural environment, and must be non-commercial in nature. New users simply fill out an online request, which is reviewed by the Argos Operations Committee. This committee consists of representatives from NASA, NOAA, Eumetsat, CNES, and ISRO. Once approved, the user fills out a Program Overview, describing their data parameters, ID numbers of transmitters, and other information. Before deployment the devices are tested under conditions similar to their anticipated in situ conditions, to ensure proper operations. Once deployed, the data are accessed via the ArgosWeb, ArgosServer, or ArgosDirect, ArgosShare, ArgosMonitor or WebServices methods as described in the Argos website (www.Argos-system.org).

Argos transmitters (originally called Platform Transmitter Terminals, or PTTs) can be purchased from several vendors, and the prices range between US$2,500 and US$4,500, depending on size, battery life, data storage, and other factors. Some are tiny, for attaching to small birds or other animals, while some are quite large and designed for use on permanent marine buoys or other fixed locations. Yet others are designed for deep-diving whales and can pop off and transmit their data after a fixed time (Fig. 2.6).

This example is a tiny 17 g (or just over a half ounce) solar powered system for bird tracking. It has been used to track gulls and kites, and has a 16-channel GPS, providing location accuracy of about 20 m, a solar panel for battery charging, and a three-year operating lifetime.

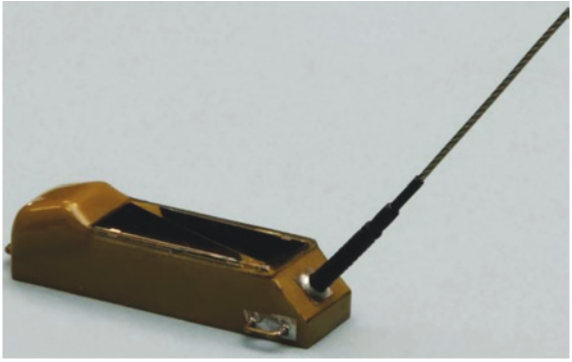


Fig. 2.6 A miniature 17 g Argos bird transmitter. (Image courtesy of Argos.)

Fees are based on PTT transmissions. The standard service costs US$15 per day per PTT, with data only (no position) costing $7.50 per day. To access via email, Internet, ftp or by fax, the cost is US$0.12 per kilobyte. This is a very modest cost for such a valuable service.

Argos Applications

There are over 21,000 Argos transmitters in use today, and the system can accommodate many more (so think up a novel application!). The number of applications is very broad, including monitoring of marine, land, wildlife, hazardous materials tracking, ocean racing, and disaster applications. Self-contained Argos systems are used to transmit housekeeping data from remote dams, pipelines, power stations and other sites, many located in inaccessible regions that do not have permanent staff.

Over 6,000 drifting and moored ocean buoys transmit global ocean data on a continual basis via Argos. Information such as wind speed and direction, air pressure, air temperature, water temperature and salinity are collected throughout the world's oceans. These provide valuable 'ground truth' data to calibrate satellite data, and are important parts of the World Climate Research Program (WCRP). Over 70 % of all Argos data are voluntarily exchanged globally for use in ocean and weather prediction models (Fig. 2.7).

Here is a sample transmission:

- Marine station WMO 12345 on 29 January 1993 at 06:00 UTC, Latitude = 21° 22 min. North, Longitude = 43° 52 min. West, Wind Direction = 70°, Wind Speed = 23 m/s, Air Temperature = 12.5 Celsius, Temperatures at selected depths: Surface: 12.4 C, 10 m: 8.2 C, 150 m: 2.2 C. Salinity at 10 m: 35 ppm."

A global marine drifter array operates around the world, with drogues set at different depths to map ocean currents and collect other data (Fig. 2.8).

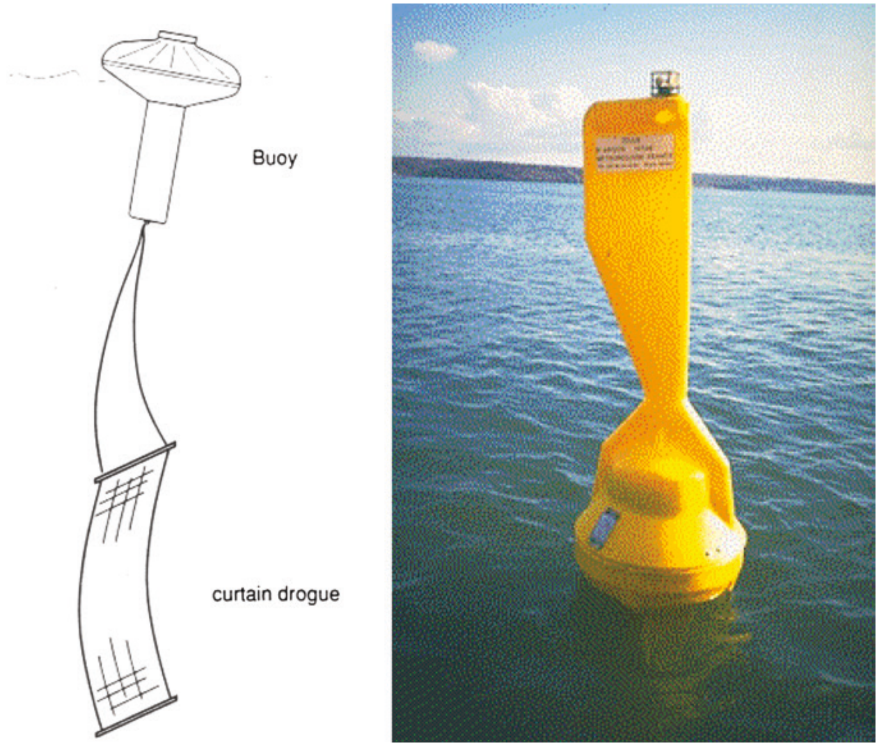


Fig. 2.7 Argos marine buoy. The drogue can be set at different depths to track underwater ocean currents. (Images courtesy of NOAA.)

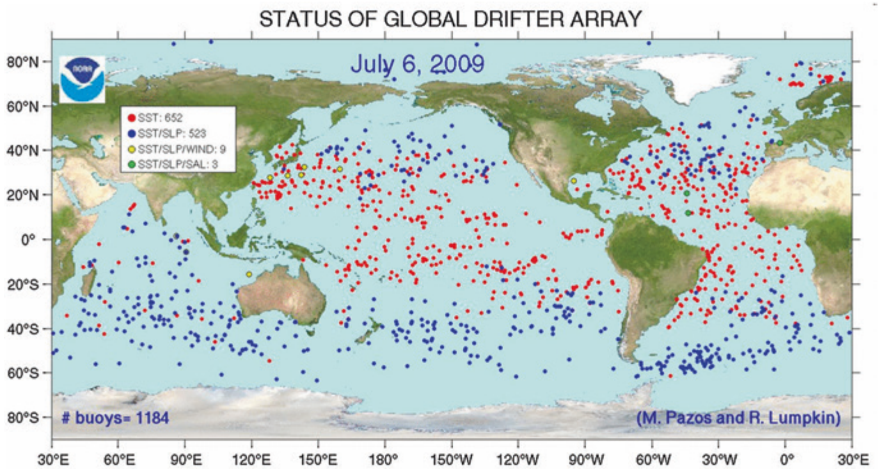


Fig. 2.8 Status of Global Drifter Array. Colors indicate different types of buoys. (Image Courtesy of NOAA.)

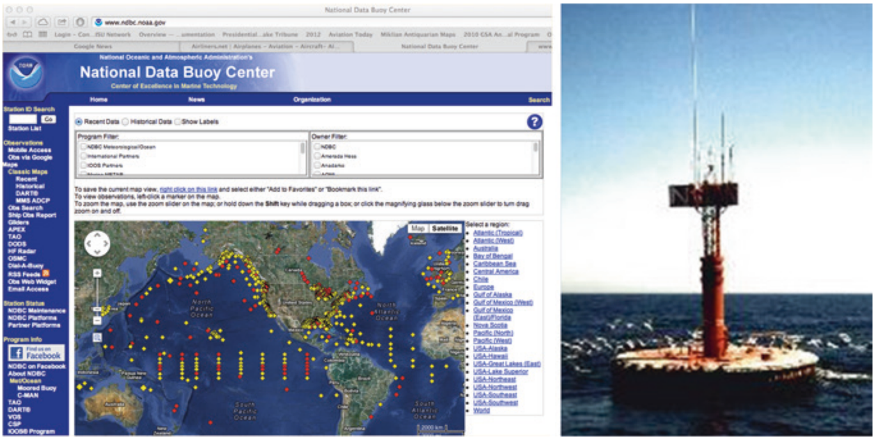


Fig. 2.9 NOAA fixed ocean buoy array locations and marine-anchored buoy. (Images courtesy of NOAA.)

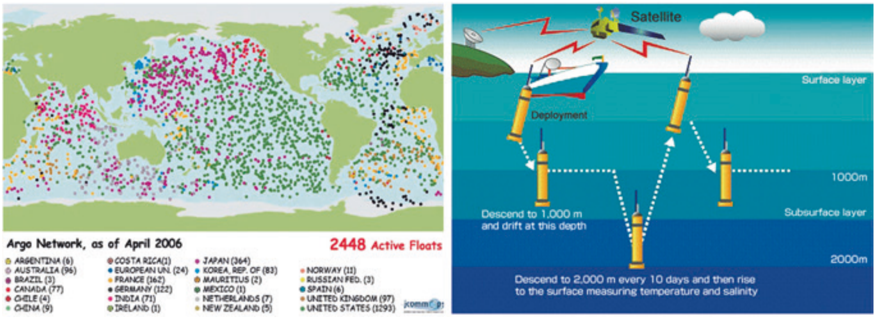


Fig. 2.10 Argo float network showing drifting floats in the world's oceans. (Image courtesy of Argo and the Japanese Agency for Marine-Earth Science and Technology.)

Fixed marine buoy networks are also located around the world's coastlines, the arctic sea, and across the Pacific Ocean, providing vital wind and wave height data. These data are available in real time through the NOAA National Data Buoy Center's website (http://www.ndbc.noaa.gov) (Fig. 2.9).

Over 3,000 Argo program devices (different from Argos) that are called floats are in the world's oceans. These collect water temperature, salinity and current data for the upper 2,000 m of the world's oceans each day. They drift at 1,000 m depth for days, and then dive to 2,000 m every 10 days and rise to the surface, collecting water profile data. On their return to the surface, they broadcast the data collected using the Argos system, and then start the process again. These are operated by many nations around the world, and the data are all freely shared with the international scientific community (Fig. 2.10).

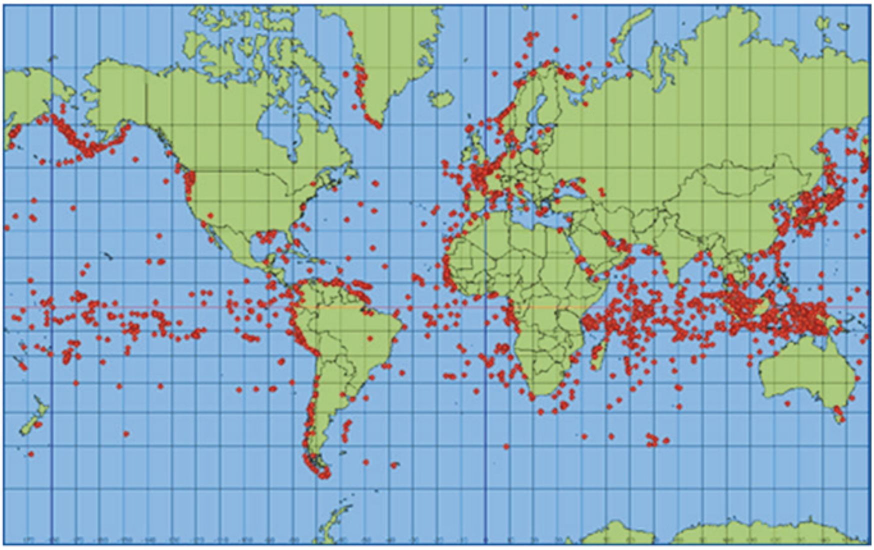


Fig. 2.11 Over 8,000 fishing vessels use the ArgoNet fleet tracking system. (Image courtesy of ArgoNet.)

One of the most interesting applications is the use of Argos transmitters on fishing vessels to monitor exclusive economic zone (EEZ) compliance. These vehicle monitoring systems (VMS) provide data that are admissible in court regarding illegal fishing operations and are used around the world to monitor fish catch data and EEZ fishing compliance in the United States and other countries. The ArgoNet system provides a turnkey package for monitoring fishing fleet operations. Over 8,000 fishing vessels around the world are equipped with these systems (www.argonet-vms.net), and several nations have successfully prosecuted illegal fishing operations within their EEZ limits.

Since 2005, the United Kingdom has required all fishing vessels over 15 m to have installed onboard a satellite tracking system, and using this system they have successfully prosecuted offenders. The use of ArgoNet data has been upheld by the British courts. Vessels can upload their position and catch information (by zone and species) automatically to the appropriate regulatory agency. The International Maritime Organization has mandated that all vessels over 500 gross tons must install an Argos-based Ship Security Alert System (SSAS) that allows crews to send a message in case of acts of piracy, and to allow fleet managers to track their vessels worldwide (Fig. 2.11).

Icebergs in the North Atlantic Ocean are routinely tracked using specially designed Argos buoys that are dropped from U. S. Coast Guard aircraft onto large icebergs. This is part of the International Ice Patrol program created after the sinking of the *Titanic*. The location of these dangerous icebergs can then be broadcast to ships at sea.

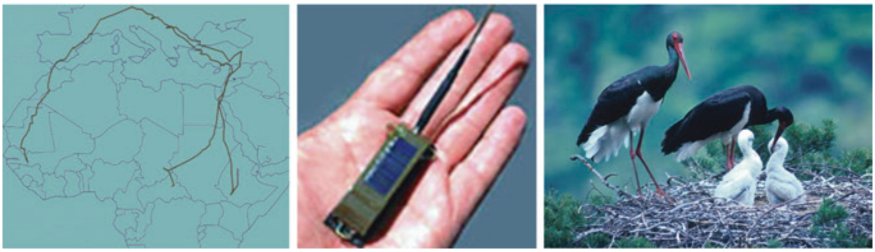


Fig. 2.12 Stork migration tracking using Argos. (Image courtesy of Argos.)

One of the most important uses of Argos is for wildlife tracking. Thousands of animals, ranging from migrating birds to deep-diving whales and land animals, are tracked across the globe using Argos devices. These have revolutionized our understanding of the migration patterns of many species of animals, feeding and breeding patterns, and more. Some of these miniaturized Argos transmitters can fit on the smallest birds and can track movements for over a year. Black storks (*Ciconia nigra*) travel some 4,000 km each year in an annual migration between Africa and northern Europe. Their migration patterns were tracked using tiny Argos receivers weighing only a few grams. One stork moved some 5,320 km from Prague to wintering grounds in central Africa, with daily migration distances between 150 and 350 km per day. One tracked bird flew some 476 km in a single day over the Sahara Desert (Fig. 2.12).

Marine species are also tracked, including deep-diving species of whales, sharks, marine turtles and more. Information on depth of dives, temperature, duration of dives and more can be automatically collected and received as email by the researchers. Land species such as artic caribou are routinely tracked on their annual migration routes.

Important public health applications include transmitting information about hospital and clinic admissions, food status, and even remote school attendance levels. Argos systems can provide vital early warning for human and environmental disasters in the most remote locations of the world by transmitting flood, earthquake and other data.

The Argos network has been in operation since 1978, about the same time that the GPS system was introduced, and Argos technology has changed significantly since then. The new Argos-3 next-generation system is now in the process of being implemented with the launch of Eumetsat's MetOp satellite. This new capability includes many improvements, including two-way communications (down to the Argos device, now called Platform Messaging Transceivers, or PMTs). The updated system has greater data volume transmitted, more efficient data collection and battery savings, and remote control and re-programming of the PMT while in operation. The original system allowed for data ranging from 32 to 256 bits, which is now increased to 4,608 bits per satellite pass, nearly 20 times the previous limit. Although the original system had transmitters constantly broadcasting, waiting for a satellite to come overhead, the new design allows receivers to know when satellites

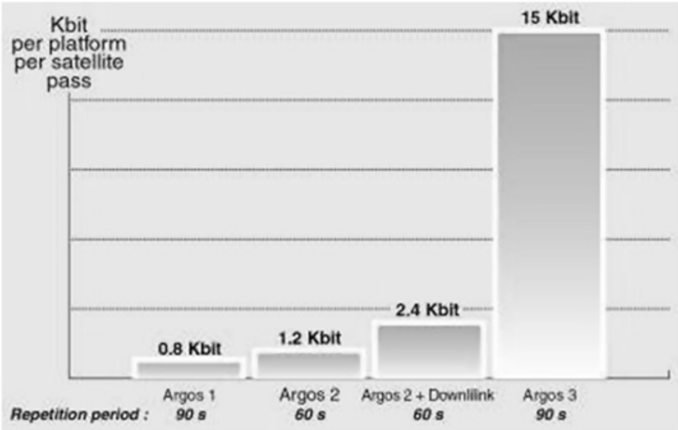


Fig. 2.13 Argos data transmission per pass. (Image courtesy of Argos.)

will be overhead and to only broadcast in these windows, and then the satellite can broadcast down to the PMT that it has successfully received a transmission of data so that it can stop broadcasting, thus saving battery life and extending PMT lifetime. System users can also now send short messages to their transmitters, to alter the transmission schedule, change data collection parameters, or re-program their platforms. The new system is fully compatible with the existing Argos 1 and 2 systems, but significantly increase the utility and efficiency of the overall system (Fig. 2.13).

Cospas-Sarsat

The second Doppler-based satellite system still in use is the Cospas-Sarsat Satellite search and rescue system (http://www.cospas-sarsat.int). This is another excellent example of Cold-War era cooperation in space applications. The system is designed to take the search out of search and rescue operations, and was originally a collaborative project of the United States, Canada, France and the USSR. It was founded in 1979, and there are now 43 other nations and entities who are involved in this vital service. These include the four original parties to the Cospas-Sarsat agreement, 26 ground segment providers, 11 user states, and 2 participating international organizations. Cospas is short for *Cosmitscheskaja Sistema Poiska Awarinitsch Sudow* (Russian for “space system for search of vessels in distress”) and Sarsat is short for “search and rescue satellite-aided tracking.” (Figs. 2.14 and 2.15).

Studies show that aircraft accident survivors have a greater than 50 % survival rate if they are rescued within 8 h, but this drops to less than 10 % after 2 days. Search and rescue is very costly and dangerous and is often conducted in bad weather and inaccessible terrain. Satellites offer an excellent way to improve this

Fig. 2.14 The Cospas-Sarsat mission patch. (Image courtesy of Cospas-Sarsat.)

Fig. 2.15 A map showing the current Cospas-Sarsat participating nations. (Image courtesy of Cospas-Sarsat.)

process. The Cospas-Sarsat system originated after the October 16, 1972, air crash in Alaska that killed two members of the U. S. Congress, House Majority Leader Hale Boggs and Alaska Congressman Nick Begich. A massive search program was initiated, with thousands of soldiers, aircraft and even military reconnaissance satellites used in the search, but no trace of them or their aircraft was ever found. The U. S. Congress requested that NASA investigate the use of satellites for search and rescue, and eventually mandated all U. S. commercial aircraft to use distress beacons.

The Cospas-Sarsat system is very similar in design to the Argos system, which was developed around the same time. Both were designed as small parasite payloads to be mounted on NOAA polar-orbiting environmental satellites. The Cospas-Sarsat program added similar payloads onto two Russian satellites for additional coverage (Fig. 2.16).

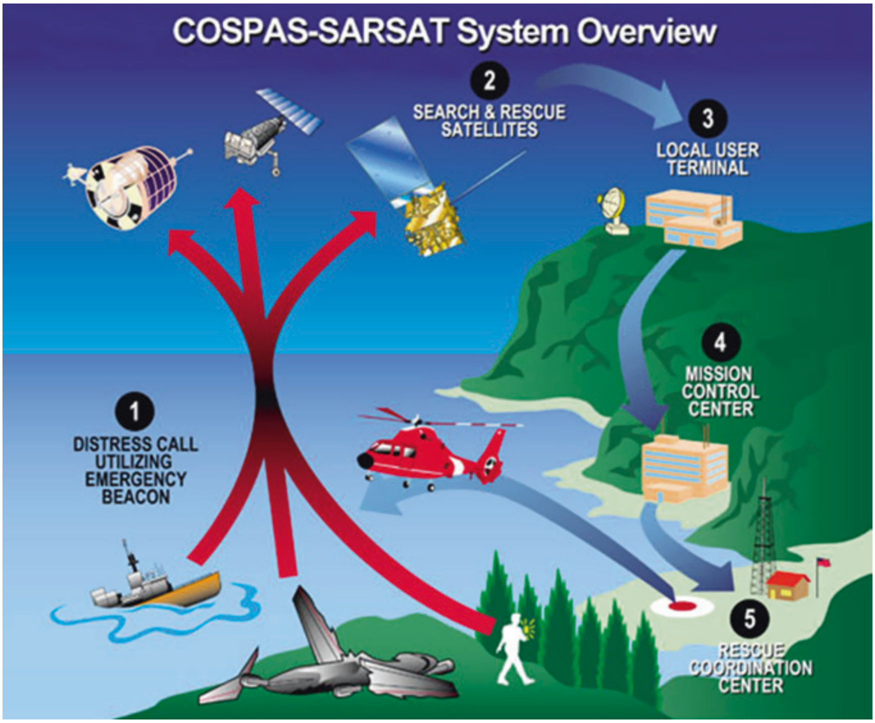


Fig. 2.16 The Cospas-Sarsat system. A signal is sent to a satellite from a crashed plane or sinking ship, and the signal is forwarded to an automated ground station, and from there to a mission control center and rescue coordination center. (Image courtesy of Cospas-Sarsat.)

The space segment originally consisted of satellite payloads on two U. S. NOAA and two Russian Nadejda polar-orbiting environmental satellites that received the distress signal on 243 MHz (military) and 121.5 MHz (civilian) from a distress beacon. The satellite then passed the message along to one of several automated ground receiving stations (local user terminals) around the world on 1,433.3 MHz. The message was then transmitted to the appropriate national search and rescue coordination center, which managed the search and rescue operation. Search aircraft could then home in on the distress beacon broadcast. The current constellation includes five LEO (3 NOAA and 2 EUMETSAT) satellites in Sun-synchronous orbits at 850 km altitude and an orbital period of 100 min and several GEO satellites as well. The original 243 MHz (military) and 121.5 MHz (civilian) frequencies were updated to a single, dedicated 406 MHz frequency in 2009. The LEO satellites can receive alerts in a 6,000 km wide area, and the satellites are in view for approximately 15 min from the ground on each pass. Any point on Earth will be within view of one of the satellites within a maximum of 2 h (Fig. 2.17).

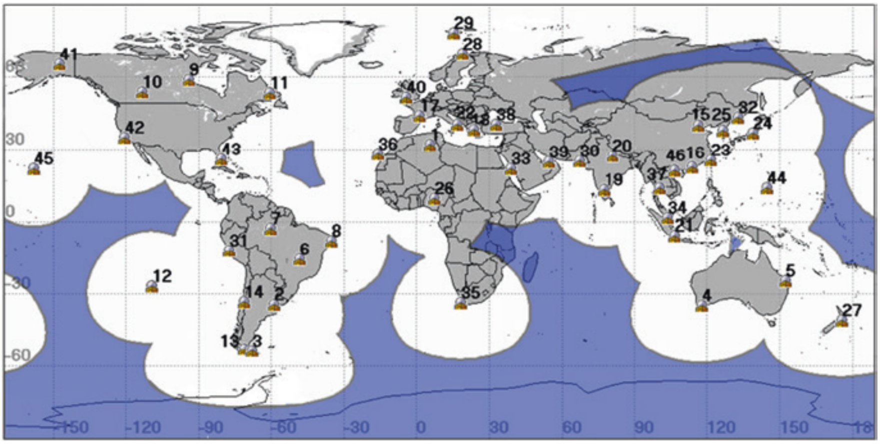
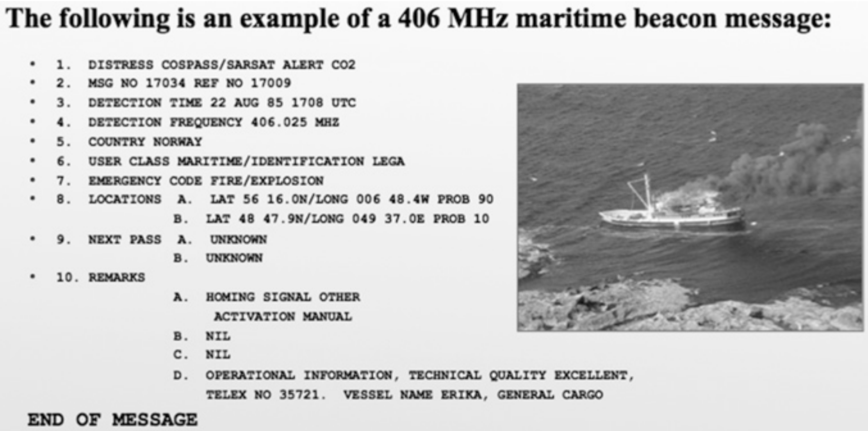


Fig. 2.17 The global network of Cospas-Sarsat ground stations and their coverage. Areas in *white* can receive alert messages immediately, while areas in *blue* have messages stored on the satellite until they come into range of a ground station. (Image courtesy of Cospas-Sarsat.)

The ground segment consists of a network of automated local user terminals (LUTs) around the world, some of which work with the LEO satellites (LEOLUTs) and some with the new geostationary satellites discussed below (GEOLUTs). These take the message from the satellite and pass it along to the appropriate national mission control centers (MCCs) for action and to direct the search effort. There are currently 31 mission control centers around the world, 58 LEO automated ground stations and 22 GEO automated ground stations, and a total of 6 LEO and 9 GEO satellites provided by the United States (GOES), Russia (Electro-L and Louch), Eumetsat (MSG) and India (INSAT).

The user segment consists of low cost distress beacons for aviation, marine and, recently, individual use. There are over 1.2 million distress beacons in use worldwide. EPIRBs (emergency position indicating radio beacons) are marine systems and are widely used on commercial and pleasure vessels. They can be triggered manually or be automatically activated when exposed to water, and can automatically detach, activate and float if a vessel sinks. The message can be pre-programmed with the name and owner of the vessel, number of people on board, cargo, etc. Specialized ship security alert devices (SSAS) are used to report incidents of marine piracy (Fig. 2.18).

Aviation ELTs (emergency locator transmitters) are used in all commercial and most private aircraft, can be manually activated, and are automatically triggered if a sufficient G-force is applied in a crash. These originally broadcast on the international aviation distress frequency of 121.5 MHz, in addition to 406 MHz, but the 121.5 frequency was phased out in 2009. Recently, personal locator beacons (PLBs) have been offered to backpackers and others, originally in a pilot project in Alaska. This brings satellite search and rescue to individuals, such as campers and explorers. One of the many mysteries with regard to the missing Malaysian



The following is an example of a 406 MHz maritime beacon message:

- 1. DISTRESS COSPASS/SARSAT ALERT CO2
- 2. MSG NO 17034 REF NO 17009
- 3. DETECTION TIME 22 AUG 85 1708 UTC
- 4. DETECTION FREQUENCY 406.025 MHZ
- 5. COUNTRY NORWAY
- 6. USER CLASS MARITIME/IDENTIFICATION LEGA
- 7. EMERGENCY CODE FIRE/EXPLOSION
- 8. LOCATIONS A. LAT 56 16.0N/LONG 006 48.4W PROB 90
  B. LAT 48 47.9N/LONG 049 37.0E PROB 10
- 9. NEXT PASS A. UNKNOWN
  B. UNKNOWN
- 10. REMARKS
  A. HOMING SIGNAL OTHER
  ACTIVATION MANUAL
  B. NIL
  C. NIL
  D. OPERATIONAL INFORMATION, TECHNICAL QUALITY EXCELLENT,
  TELEX NO 35721. VESSEL NAME ERIKA, GENERAL CARGO

END OF MESSAGE

Fig. 2.18 An example of a Cospas-Sarsat marine EPIRB message. (Image provided by the author.)

Fig. 2.19 Cospas-Sarsat marine, aviation, personal and safety-at-sea beacons. (Image courtesy of Cospas-Sarsat.)

airline (Flight 370 of March 8, 2014) is why the emergency locator transmitters did not go off and alert the SARSAT global search team as to the exact crash location (Fig. 2.19).

The first satellite launch was in 1982, and the system was operational in 1984 using two U. S. NOAA polar- orbiting satellites and two Soviet Nadejda satellites. Using Doppler techniques, it provided approximately 1 km positioning, which was judged to be sufficient for global search and rescue use. Worldwide, over 35,000 people have been rescued around the world in over 9,000 individual searches over the lifetime of the program (Figs. 2.20, 2.21 and 2.22).

Many current generation systems also include GPS receivers, thus significantly improving the location provided from 1 km to less than 20 m. Recently, the system

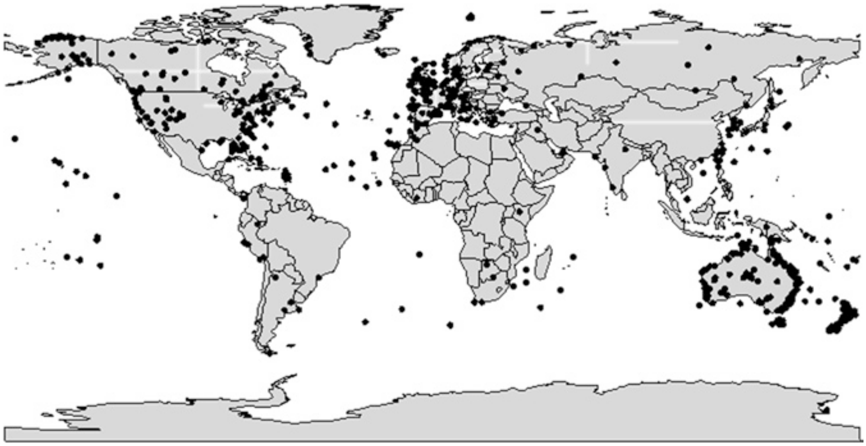


Fig. 2.20 Cospas-Sarsat rescues in 2011, where some 2,313 people were saved in 644 individual operations. (Image courtesy of Cospas-Sarsat.)

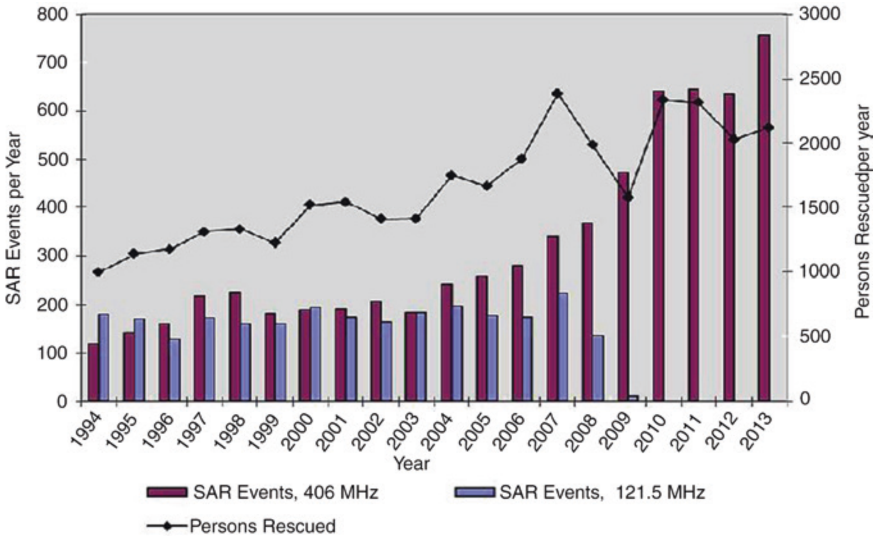
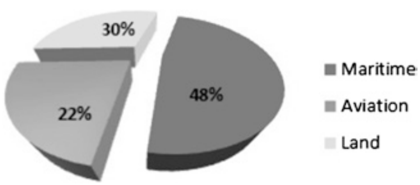


Fig. 2.21 This shows the number and type of Cospas-Sarsat operations from 1994 to 2012

Fig. 2.22 The type of SAR event for 2012. (Image courtesy of Cospas-Sarsat.)



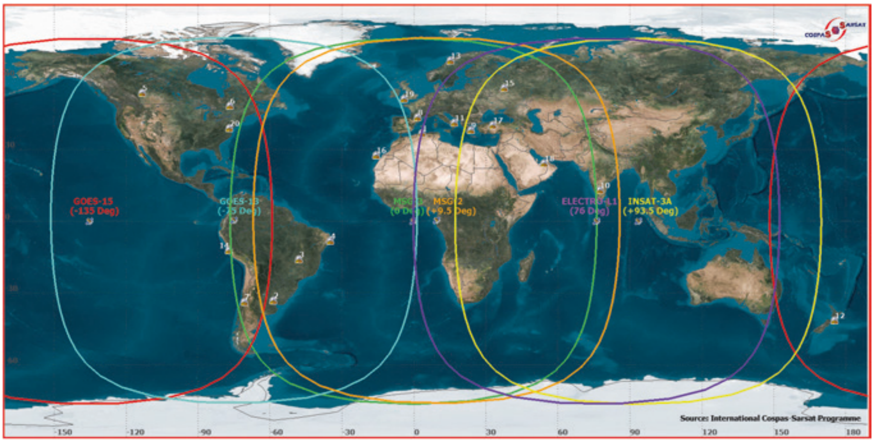


Fig. 2.23 This shows the overlapping GEOSAR coverage provided by U. S., Indian and EUMETSAT geostationary satellites. (Image courtesy of Cospas-Sarsat.)

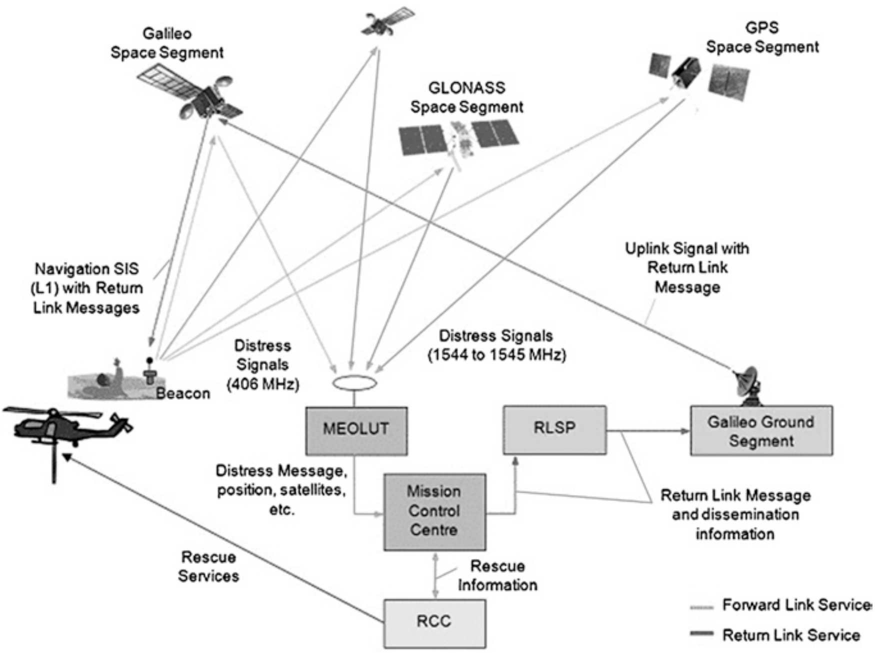


Fig. 2.24 The MEOSAR and GEOSAR Cospas-Sarsat architecture. (Image courtesy of Cospas-Sarsat.)

has been expanded to include receivers in geostationary orbit, as it was determined that existing distress beacon messages could be received at that distance. If the beacon is equipped with a GPS, the GEOSAR constellation provides near-instant alerts, using the U. S. GOES, Indian INSAT and EUMETSAT MSG satellites. Because the GEO satellites are not moving relative to the ground, they cannot use Doppler tracking and only work with GPS-equipped beacons (Fig. 2.23).

The next generation of capability will be provided by the addition of a MEOSAR system, with Cospas-Sarsat receivers to be included on all next-generation U. S. GPS 3, Russian GLONASS, and ESA Galileo satellites. The U. S. component is called DASS, the distress alerting satellite system, designed by NASA (Fig. 2.24).

These three constellations will be fully compatible and interoperable, and will provide GPS accuracy using GPS-enhanced beacons, but will also provide improved location data for traditional Doppler-only systems. These three overlapping systems, LEOSAR, MEOSAR and GEOSAR, are complimentary, and each provides enhanced capabilities. For example, the LEOSAR satellites provide superior detection near the poles, where GEOSAR signals are weak.

Argos and Cospas-Sarsat are excellent examples of the powerful benefits of space technology for practical applications, and are excellent examples of international cooperation in space for the benefit of humankind.

Although Doppler-based systems, all dating back to the 1970's, have excellent capability, there are also significant limitations to the Doppler approach. Receivers need to maintain a track on a satellite for several minutes, and the coverage is not global. Doppler also does not allow for elevation differences; thus, it is not useful for aviation or space consumers. These limitations led to the development of the next generation of space positioning systems, the U. S. NAVSTAR global positioning system, or GPS.

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