Basic Description of the Argos System

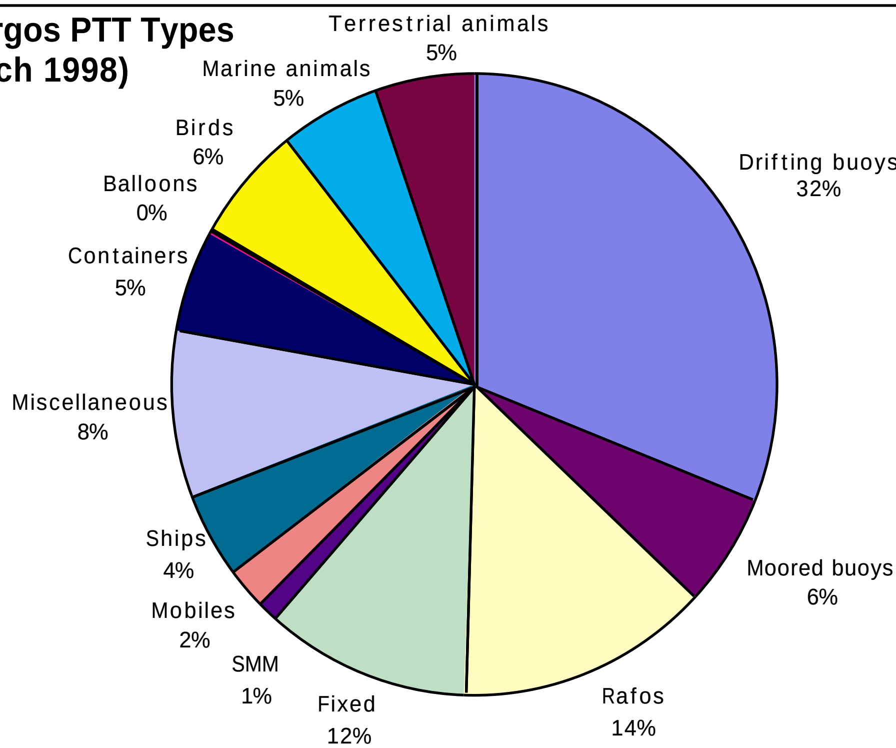
INTRODUCTION

Argos is a satellite-based system which collects environmental data from autonomous platforms and delivers it to users worldwide. Argos has *truly* global service and is fully integrated - providing data from the source to the User's desktop. Telemetry from User platforms is also used to calculate geographic position. Since it began in the late-1970's, Argos use continues to expand. The system has proven to be simple to use and highly reliable. Currently, approximately 6,000 transmitters are operating in a variety of applications involving either study of the earth or protection of the environment (Figure 1).

The Argos system involves three interactive subsystems:

1) Platform Transmitter Terminals (PTTs)
2) The Space Segment
3) The Ground Segment

Figure 1. Argos PTT Types (March 1998)



Platform Transmitter Terminals (PTTs)

Argos operation begins with transmissions from PTTs attached to sensor equipment and the platform from which data is collected. PTTs have been adapted for applications as diverse as tracking migratory birds (ie.,miniaturized, Figure 2) to

Courtesy: Patuxent Wildlife Research Center

Figure 2. Miniaturized PTT

monitoring ice floes in harsh environments. Typically, they are built rugged to withstand punishment, both expected and unexpected (Figure 3).

Courtesy: Smithsonian Institution

Figure 3. Rugged Construction

Transmitters are interfaced with sensors on moored or drifting buoys (Figure 4), animals, ships, containers, balloons, and many other platforms. They are configured by size, weight, power consumption, and housing according to application. The smallest PTTs, used to track birds, weigh as little as 17 grams. Power consumption on all PTTs is low due to the satellite's low-earth orbit and highly sensitive receiver equipment. This enables extended operation —a year or more— on battery power alone.

Characteristics - Platform Tansmitter Terminals (PTT)

Uplink Frequency: 401.65

Message Length: up to 32 bytes

Repetition Period: 45 to 200 seconds

Messages/pass: varies depending on latitude and type of service (see figure 8)

Transmission time: 360 - 920 ms

Duty Cycle: Varies

Power: battery, solar, external

Table 1

PTTs uplink (transmit) their message at prese intervals without interrogation by the satellite. Eacl message may contain up to 256 bits of sensor data A full message uplink takes as long as 96 milliseconds. The uplink "time-out" or repetitior period, is normally set between 45 and 200 seconds depending on the application. Although all PTTs transmit nominally at 401.65 MHz, differen frequencies are received by the satellite receivers due to Doppler shift.

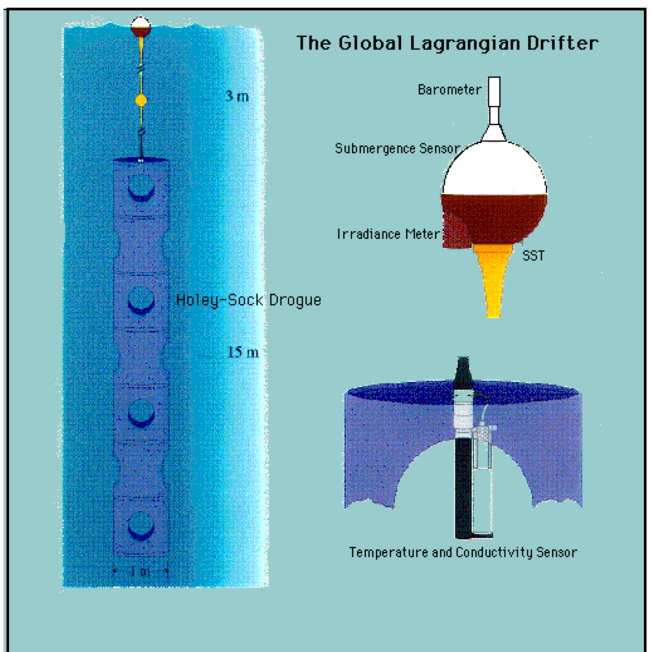


Figure 4. Buoy w/Sensors

The Space Segment

Argos instruments are flown on board the National Oceanic and Atmospheric Administration (NOAA) Polar Orbiting Environmental Satellites (POES). The

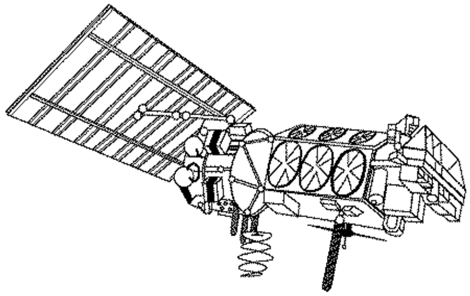


Figure 5. TIROS - Polar Orbiting Environmental Satellite

satellites receive Argos messages from PTTs and relay them to the ground in realtime. They also store them on tape recorders and read out ("dump") the messages to one of three main system ground stations:

- Wallops Island, Virginia, USA
- Fairbanks, Alaska, USA,
- Lannion, France.

At least two satellites are operational at any time and launches are scheduled well into the 21st century. Data from additional satellites is processed on an "as available" basis. From around the turn of the century, Argos instruments will also be flown on satellites operated by the Japanese space agency NASDA and the European Meteorological Satellite organization, Eumetsat.

Figure 6. Visibility Circles for NOAA Satellites

Near-polar, sun-synchronous orbits

The POES satellites see the North and South Poles on each orbital revolution. Their orbital planes rotate about the polar axis at the same rate as the Earth about the Sun, or one complete revolution per year. Each orbital revolution transects the equatorial plane at fixed local solar times. Therefore, each satellite passes within visibility of any given transmitter at almost the same local solar time each day. The time required to complete one revolution around the Earth is approximately 102 minutes.

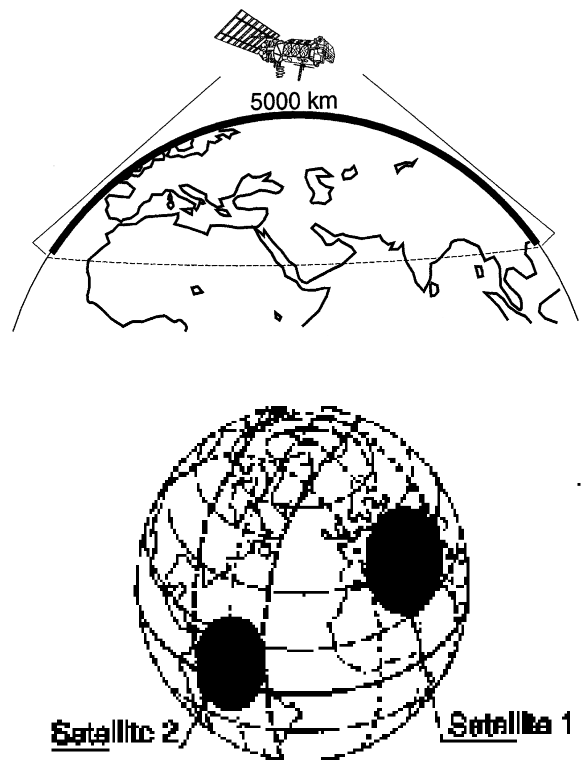


Figure 7. Satellite Visibility and Movement (not to scale)

Visibility area

At any given time, each satellite simultaneously "sees" all transmitters within an approximate 5000-kilometer-diameter "footprint", or visibility circle (Figures 6 & 7). As the satellite proceeds in orbit, the visibility circle sweeps a 5000 kilometer swath around the Earth, covering both poles. Due to the Earth's rotation, the swath shifts about the polar axis on each revolution.

Because of the near-polar orbit, the number of daily passes over a transmitter increases with latitude. At the poles, each satellite passes approximately 14 times a day for a total of 28 (two satellites). At the equator there are 6 to 7 passes total (Figure 8).

The duration of transmitter visibility by the satellite (pass duration over the transmitter) is the “window” during which the satellite can receive messages from the transmitter. It lasts between 8 and 15 minutes (10 minutes on average).

<u>**The Ground Segment**</u>

Figure 9 shows the Argos System Configuration for receiving and processing facilities. Upgrades to computer equipment and communications links are made throughout the segment. Argos Global Processing Centers (GPC) are fully redundant.

Receiving Stations

The three main ground stations (Wallops Island, Fairbanks, and Lannion) receive all messages recorded by the satellite during an orbital revolution, providing complete global coverage. Regional receiving stations receive transmitter data from the satellites in realtime whenever a satellite is within station visibility. The main ground stations also act as regional receiving stations.

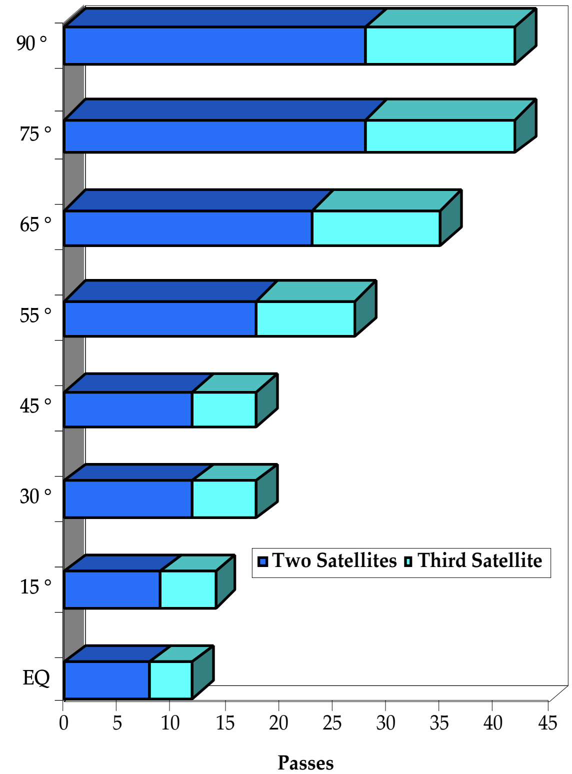


Figure 8. Passes/Day (by Latitude)

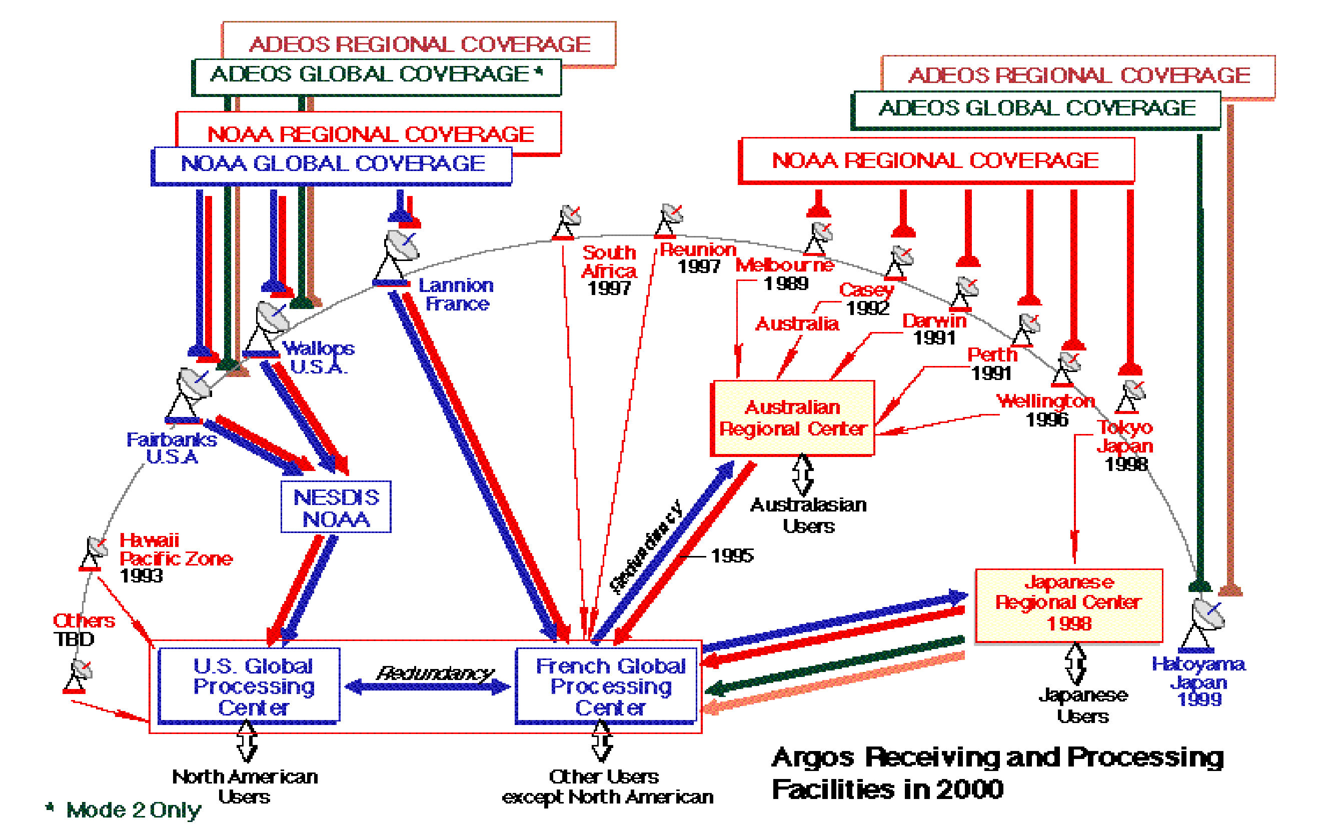


Figure 9

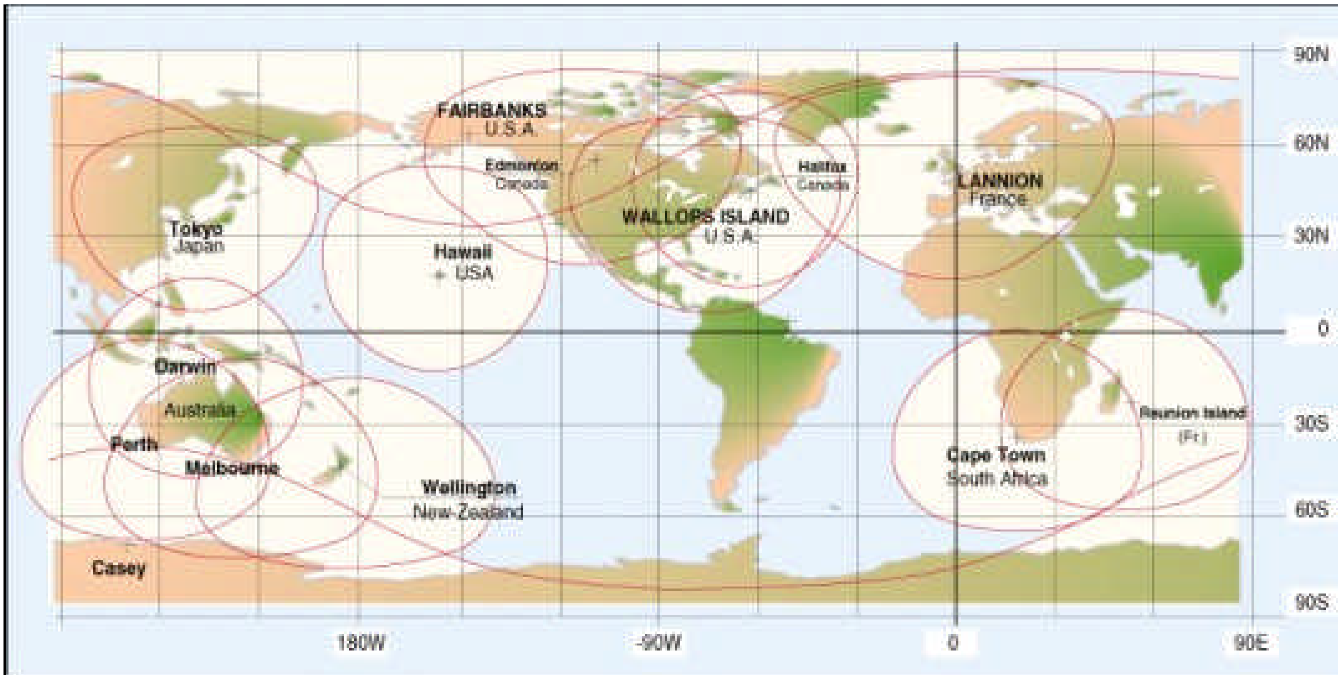


Figure 10. Regional (near-realtime) Coverage

Regional receiving stations operate in Largo, Hawaii and Monterey in the USA; Halifax and Edmonton in Canada; Toulouse, France; Casey, Antarctica; Cape Town, South Africa; Toyko, Japan; Darwin, Melbourne and Perth in Australia; Wellington, New Zealand; Reunion Island (FR) (Figure 10). More regional stations are planned.

The Global Processing Centers (GPCs) in Largo, MD, USA and Toulouse, France process all data received from the receiving stations. They archive the results and make them available to users on line.

Regional Processing Centers (RPCs) provide users in a region with local access to results. For example, Japanese users can connect to the Argos RPC in Tokyo to access locations and sensor data from transmitters around the world.

Some RPCs, such as Melbourne, are connected to one or more regional receiving stations. This means they can process data received in real time from transmitters in visibility of the receiving stations.

Each RPC is also connected to a GPC so that it can provide its users with global coverage, i.e. data received in other parts of the world.

Processing

The work of a GPC includes:

- quality control, including checking of message time-tagging, signal level, transmitter ID number, length of sensor data message, and the receive frequency for use in the Doppler location calculation.
- message classification in chronological order.
- location calculation
- sensor data processing
- data distribution via network or physical media
- archival of processed data

The data from each sensor on a given transmitter is processed separately. Users can therefore choose different processing options:

- A - which outputs the raw sensor data as numerical values,
- B - which converts raw sensor data into physical values using a different calibration curve for each sensor.

ARGOS LOCATION PROCESSING

Argos locations are calculated by measuring the "Doppler shift" on the platform transmissions. This enables the use of robust, and simple to operate field equipment (PTTs). Relative to the transmit frequency (nominal frequency), the frequency measured by the satellite instrument is shifted upward as a satellite "approaches" a PTT, and downward as the satellite moves away. Each time a message is received, the satellite instrument measures the receive frequency and time-tags the message arrival.

The nominal platform transmit frequency is estimated using the set of reception frequencies. The Doppler shift in frequency, along with other information, is used to calculate location of the transmitter.

To assign a class of location accuracy, the Argos processing centers need four messages from a transmitter during a pass. Optimally, the four messages should be spread approximately equally over the pass. There must be messages on each side of the point of inflection, i.e. where the satellite is closest to the transmitter in the middle of the pass. Knowing the position and movement of the satellite, the transmit frequency, the receive frequencies (and times), and the altitude of the platform, two geometrically determined positions can be calculated. The “theoretical” Doppler curve for these two locations is compared with the measured Doppler curve to refine the position and provide quality control. Other plausibility checks employed to further enhance quality control include the stability of the transmitter, change in position since the last location, and anticipated velocity.

Location accuracy (Class designation) is determined using all the parameters in the calculation: spread of messages during the pass, pass duration, angular separation from ground track, least-squares residual of the Doppler measurement, and platform velocity. Standard locations (a minimum of 4 messages) comprise Classes 3, 2, 1, and 0 (Table 2). Class 0 locations have failed certain quality control checks; thus, there is no upper limit on their accuracy.

Table 2
Location Class

Class	Estimated accuracy in latitude and longitude
3	≤ 150 m
2	150 m < accuracy < 350 m
1	350 m < accuracy < 1000 m
0*	> 1000 m
A	no estimate of location accuracy
B	no estimate of location accuracy
Z	(invalid locations)

However, these locations are available upon request and are usually used in the event of a transmitter problem. Classes A, B and Z have less than messages and are available under a separate service, Auxiliary Location Processing.

Orbitography

Orbitography Processing is necessary to compute the orbit of the spacecraft. Knowing the location, direction of travel, and velocity of the spacecraft at any given time is a prerequisite to successful location of the PTTs. This is accomplished through a network of special transmitters. These are very stable and transmit a high-power signal. They are placed at geodedically surveyed locations around the world. When the system computes a location for one of these transmitters, the position of the spacecraft is adjusted to bring it into accordance with the known location of the transmitter. These adjustments are translated into a new set of parameters describing the size, shape, and orientation of the spacecraft’s’ orbit, known as the orbital elements.

This information is then used to create a table which describes the location, direction, and velocity of the spacecraft for the next twelve hours. The location processing system references this table and interpolates to obtain the precise values required.

Argos plus GPS

Global Positioning System (GPS) positions are processed along with Argos locations through the Argos system. Since GPS receivers continuously recalculate position fixes, higher temporal resolution is possible. For example, samples taken every 3 minutes can be associated with a location. Results are integrated with Argos data, and GPS and Argos locations appear in the same format (a flag indicates whether Argos or GPS). Of course, use of a GPS receiver impacts on the platform's power requirements and costs.

DATA DISTRIBUTION

Argos data is distributed by a variety of methods (Figure 11). The most commonly used involve automatic delivery of the data to users via networks such as the Internet. Archived data is available on floppy diskette or CDRom.

GTS Subsystem

One of the fundamental reasons for developing the Argos system was to provide buoy data—drift tracks and sensor data such as atmospheric pressure and temperature—for meteorologists and oceanographers. These data are usually relayed onto the Global Telecommunications System (GTS), a world-wide operational system for the sharing of meteorological and climate data. Argos established a powerful Argos/GTS processing subsystem to simplify the transmission of data directly onto the GTS. The system provides maximum flexibility in processing sensor data. This has resulted in increased quantity and quality of Argos data on the GTS.

Automatic Distribution Service (ADS)

ADS supplies results automatically, either at fixed times, which are User-defined, or whenever new data become available. The User specifies the most appropriate distribution network. For example, in the US, many users are taking advantage of the Internet to receive their data via FTP or email. There is no need to interrogate Argos on-line since data is delivered automatically to the User's system.

Table 3. Advanced Argos Instrument Characteristics

Satellite Name	Est. Launch	Band-width	Receiver	Proc. Units	Link Speed (bits/sec.
NOAA F, G, D	orbiting	24 KHz	-128, -108 dBm	4	720
H	orbiting	24 KHz	-128, -108 dBm	4	960
I J	failed orbiting	24 KHz	-128, -108 dBm	4	1200
K	orbiting	80 KHz	-131, -108 dBm	8	2560
L M	1999 2001	80 KHz	-131, -108 dBm	8	2560
ADEOS2	2000	100 KHz	+Com. Link	8	TBD
N, N′ METOP	2000+	80 KHz	+ ??	8 ??	2560 ??

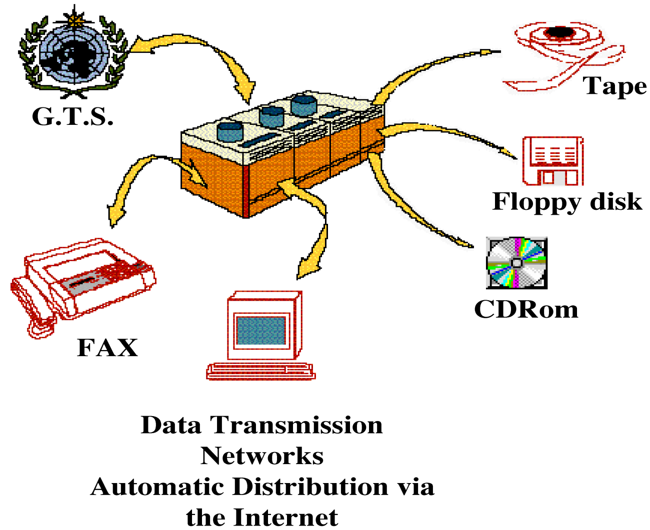


Figure 11. Argos Data Distribution

ARGOS - 2 INSTRUMENT

NOAA-K was successfully launced in May 1998. It will be the first satellite to carry the next generatior of Argos instruments (Argos II). This instrument comprises 8 data recovery units (as opposed to 4) operates at a wider bandwidth and carries a more sensitive receiver (Table 3). These capabilities will enable a near quadrupling of capacity for the Argos system.

Additional NOAA satellites are planned well into th next century and agreements are being establishec to carry Argos on other satellites as well.

Future considerations are to use the added bandwidth to establish "channels" to meet particular User requirements. For example, a "sensitive" channel for low power transmitters, and a "high data rate" channel for large data volume applications.

NASDA, the Japanese Space Agency will fly the Argos instrument on ADEOS II (launch in 2000). Plans include a downlink to the platforms to enable remote control of PTTs in the field. This "two-way" capability will enable transmitters and sensors to be switched on and off, recalibrated, etc. I markedly increases system functionality and provides Users added flexibility to manage their pro grams. Indeed, "Downlink Messaging" represents yet another era in the evolution of the Argos system