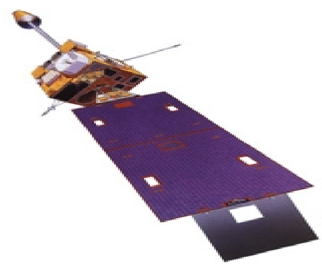

DRAFT

NOAA Satellite and Information Service
National Environmental Satellite, Data, and Information Service (NESDIS)

GEOSTATIONARY OPERATIONAL ENVIRONMENTAL SATELLITE
DATA COLLECTION SYSTEM
(GOES DCS)

SYSTEM DESCRIPTION

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Section 1 Introduction

The Geostationary Operational Environmental Satellite Data Collection System (GOES DCS) provides environmental data from remote data collection sites to Federal, state, and local agencies that are responsible for monitoring the environment and Earth's resources. It developed out of experiments done in the late 1960's by the National Aeronautics and Space Administration (NASA) in the use of satellites for remote data collection. The first satellites used were Earth orbiting satellites that provided two-way communication links between a central receiving station and globally distributed measurement sites. Large-scale operational demonstrations of the communication links began in the late 1960s. In 1974, the National Oceanic and Atmospheric Administration (NOAA) included a communications transponder in its National Geostationary Operational Environmental Satellite to allow radio transmissions from remote sites to be relayed to central collection sites. This was the beginning of the GOES DCS. Although the GOES DCS was initially intended to be for the exclusive use of NOAA, other Federal agencies obtained permission to use the system.

Experimental programs by several NOAA agencies, the United States Geological Survey(USGS), the U.S. Army Corps of Engineers, and other federal agencies began in the late 1970s. The advantages of the GOES DCS in collecting environmental data from remote sites in real-time and sharing these data among disparate users was quickly recognized. As a consequence, these experimental programs continued to expand until they became a part of the critical infrastructure of many agencies' real-time data collection systems. They were established to collect environmental data for meteorological analysis and forecasting, water management, flood control, wildland fire management, and scientific studies. These real-time systems supply current environmental data not only to traditional users of such data but also, by means of the Internet, to all users who need to know environmental conditions to plan various outdoor activities. The GOES DCS has become so critical for these real-time systems that the loss of data from it during extreme meteorological or hydrologic events would severely hamper flood-forecasting, lock and dam operations, disaster planning and operations by emergency managers and civil defense groups as well as other activities that need to have current environmental data from remote sites.

The responsibility for maintaining the GOES DCS in full operation at all times rests with NOAA's National Environmental Satellite, Data, and Information Service (NESDIS). The users of the system are represented by the Satellite Telemetry Interagency Working Group (STIWG) which participates in developing user requirements and future planning. This document provides a description of the current GOES DCS and some planned improvements.

Section 2 GOES Data Collection System Overview

The GOES DCS is a system for automatically collecting environmental data from remote sites by means of government-owned and government-operated geostationary satellites. The satellites used are the Geostationary Operational Environmental Satellites (GOES) operated by the National Environmental Satellite Data Information Systems (NESDIS) of the National Oceanic and Atmospheric Administration(NOAA).

The mission of the GOES system is to observe changing environmental phenomena using satellite-based sensors that include visible and infrared imagers, sounders, and transponders. The GOES DCS is a subsystem of GOES that uses a GOES transponder to relay environmental data from remotely located radios to ground-based receive sites. The radios integrated with sensor-recording devices are referred to within the GOES DCS system as Data Collection Platforms(DCPs) and can be located at or near the Earth's surface within the radio transmission view of a GOES satellite.

The GOES DCS can collect real-time environmental data from DCPs on aircraft, ships, balloons, and fixed sites in a region from Antarctica to Greenland, and from the west coast of Africa to just east of the Hawaiian Islands. The system can be used to collect any environmental data that a DCP can record from one or more sensors and is used to monitor seismic events, volcanoes, tsunami, snow conditions, rivers, lakes, reservoirs, ice cover, ocean data, forest fire control, meteorological and upper air parameters. It is widely used by federal, state, and local agencies to collect environmental data critical to a wide variety of missions.

The system has some important advantages. The two GOES satellites can be viewed from a large area and this allows DCPs to be installed in remote places where terrestrial communications links (telephone, cell phones, etc) are not available. The communication link is reliable and robust and usually not disturbed by terrestrial events, i. e. there are no relay towers, phone lines, or other such structures that could possible be damaged during an extreme event. Data can be retrieved by several methods, including 1) directly from the GOES satellites, 2) from a special communications satellite named DOMSAT, and 3) from an Internet connection. This makes data sharing among various interested users extremely convenient and makes the use of the GOES DCS cost-effective. There is no recurring cost for satellite communications as this is borne by the United States Federal Government. All interested users have access, in one form or another, to the data collected by the GOES DCS. Users collecting data must only get permission to use the GOES DCS and supply their own data collection equipment (sensors and GOES DCPs.)

Figure 1. Example of a Remote DCP

Figure 1 shows an example of a remote DCP buried under 24 ft of snow with only the GOES antenna showing. This picture is a testament to the ruggedness of the equipment, and the forgiveness of the technology. This makes an ideal solution for remote applications.

Figure 2 shows an example of a DCP used at a gaging station to monitor conditions downstream of a reservoir. DCPs such as this can provide valuable information related to dam safety and water conditions, both water flow and quality.

Figure 2. DCP Located Below Reservoir

The GOES DCS is being relied upon to serve a wide variety of monitoring needs. It is a major system in well established environmental monitoring programs and has an ever-increasing role in emergency management because of the ability to quickly install sites anywhere in view of one of the GOES satellites. For example, emergency GOES DCS sites were established in New Orleans to monitor flood conditions before and after Hurricane Katrina, and sites have been set up quickly to monitor flooding conditions in areas that have become vulnerable to flash flooding after a major forest fire. There are over 200 agencies, both domestic and foreign, that employ the GOES DCS to collect mission critical environmental information.

The GOES DCS has these major components:

- An allocated UHF frequency band of 400 kHz (401.7– 402.1 MHz.) and the two frequencies 468.8125 MHz and 468.825 MHz for exclusive use by the GOES DCS,
- Data Collection Platforms(DCPs) which are small radio transmitters integrated with remote data recording devices that transmit data from remote sites to the GOES satellites over assigned frequencies,
- Two operational GOES Satellites, one located at 135° west longitude called GOES-West and one located at 75° west longitude called GOES-East, for relaying the data from DCPs to ground-based receive sites,
- GOES DCS Pilot Transmitters, which assist the GOES DCS data reception systems,
- GOES DCS Data Reception and Distribution systems which receive transmissions relayed by the GOES Satellite and distribute data to users,
- GOES DCS Management System which manages user access and system resources.

Figure 3 illustrates the flow of data from DCPs at remote sites to user systems. It shows data being transmitted from

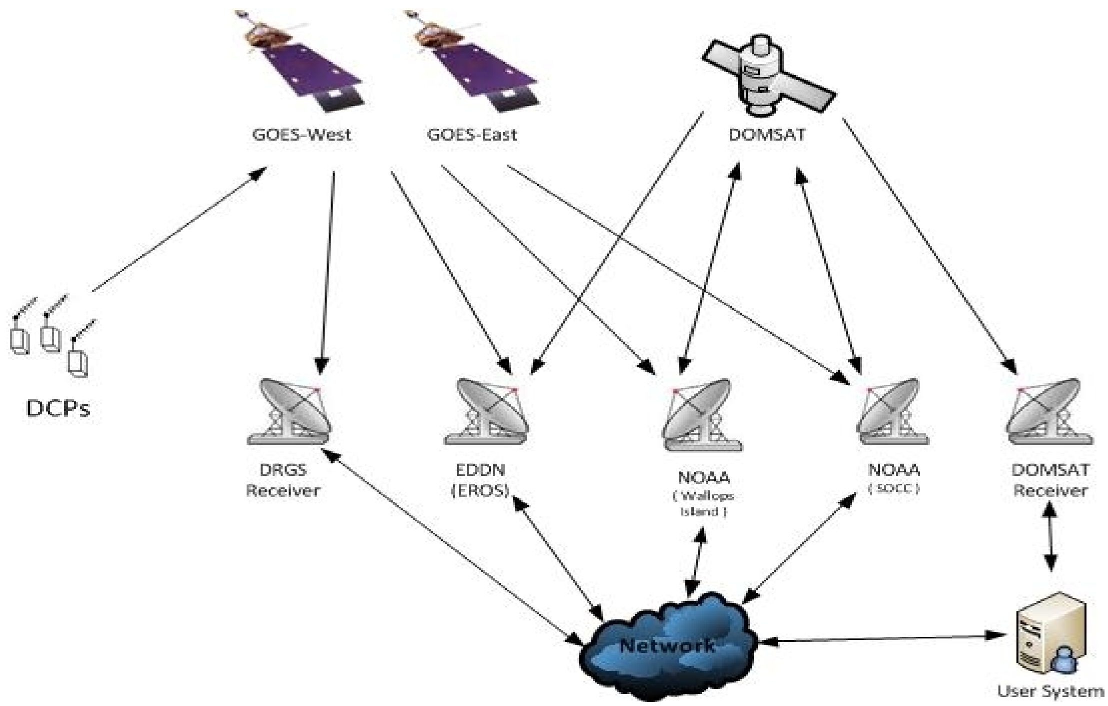

Figure 3: Basic Data Flow within GOES DCS

DCPs to the GOES satellites and relayed to three reception systems (the ones labeled NOAA Wallops and EDDN EROS are special receive sites that will be explained later.) The NOAA Wallops Island site is using two data distribution systems to deliver its data: 1) a commercial communications satellite named DOMSAT and 2) the Internet. The Direct Readout Ground Station (DRGS) Receiver and EDDN at EROS sites are using the Internet to distribute data. Users of the GOES DCS data can obtain data from DOMSAT, over the Internet, or from a locally-operated GOES Direct Readout Ground Station (DRGS.)

The following sections will describe the data transmission model and each of the major components in the system.

Section 3 Data Relay Model

3.1 General Data Collection Requirements

The system used by the GOES DCS to collect data from remote sites is based upon three general requirements: 1) the need to collect and monitor data recorded at fixed time intervals, 2) the need to be notified when some significant, detectable environmental event is occurring and to collect data as quickly as possible during this event, and 3) the need to maximize the total number of Data Collection

Platforms that can operate within the system given the constraints imposed by 2) and 3). The system for transmitting data was set up to try to meet these requirements as best as could be done within the limitations imposed by the radio frequencies available.

3.2 GOES DCS Radio Frequencies

The GOES DCS has been assigned for its exclusive use the 400kHz frequency band from 401.7 to 402.1 MHz for transmitting data from remote sites to receiving stations via the GOES satellites and the frequencies 468.8125 MHz and 468.825 MHz for interrogating remote sites from a ground station.

3.3 Transmitting data from remote sites

In order to meet the general data collection requirements of the system, the assigned frequency band for transmitting data from remote sites has been subdivided, via frequency division multiplexing, into logical channels based on the needed bandwidth of individual DCP transmissions. The original DCPs used in the system transmitted at 100 baud and required a 1.5kHz bandwidth and so the 400kHz band was divided into 266 channels, numbered 1-266, each 1.5kHz wide. By an international agreement to facilitate global data collection, channels 201-266 were originally reserved for international use, but the agreement has now been modified to restrict international use to channels 223 or greater. Because the channel widths for international GOES-like systems, e.g METEOSAT(Euorpe), GMS(Japan), are 3.0 kHz, only even-numbered channels are assigned for international use so that ½ the width of the odd-numbered adjacent channels can be used to supply the required 3.0 kHz width. DCPs assigned to the international channels are usually mobile devices such as buoys, balloons, etc. that can make use of any of the GOES-like satellites that circle the earth for relaying collected data.

With the development of 300 and 1200 baud DCPs some changes to this configuration were needed. The 300 baud DCPs could easily transmit in the 1.5kHz bands that were used by the 100 baud DCPS, but not the 1200 baud DCPS. They required 3.0 kHz bands and so the 20 1.5 mHz channels numbered 180-200 where collapsed into 10 3.0 mHz channels to accommodate 10 channels for use by 1200 baud DCPS. A transition from 100-baud DCPs to 300 and 1200 baud DCPS began in 2005 and will be completed in 2013 and so at that time most of the channels will be either 300 or 1200 baud.

All the transmission channels are divided into three types 1) self-timed channels, 2) random channels, and 3) dedicated channels. The self-timed channels are used to satisfy the requirement to collect data at periodic intervals, and the random channels are used to collect data when some significant environmental event that can be detected by a DCP occurs. Dedicated channels are channels reserved for special applications that determine how the channel is used. For domestic channels, all even-numbered channels are assigned to handle transmissions made to the western satellite, GOES-West, and all odd-numbered channels are assigned to handle transmissions made to the eastern satellite, GOES-East. This provides some protection for adjacent channel interference since transmissions on adjacent channels are directed at different satellites. International channels are all even-numbered and are assigned to dual DCPs and are used to transmit to either satellite, GOES East or GOES West. Table 1 shows the current channel types on each satellite.

Current GOES DCS Channels

GOES East (Odd-numbered)			GOES West (Even numbered)		
Channel(s)	**Type**	**Baud**	**Channel(s)**	**Type**	**Baud**
1	Dedicated		2--98	Self-Timed	100/300
3 – 97	Self-Timed	100/300	100	Pilot	
99-101	Unused		104	Random	100/300
103-113	Self-Timed	100/300	106-108	Self-Timed	100/300
115	Random	100/300	110	Dedicated	100/300
117	Self-Timed	100/300	112	Self-Timed	100/300
119-135	Random	100/300	114	Random	100/300
137-177	Self-Timed	100/200	116	Self-Timed	100/200
151	Test Channel		118-120	Random	100/300
153-177	Self-Timed	100/300	122	Self-Timed	100/300
179	Unused		124-136	Random	100/300
181-189	Self-Timed	1200	138-178	Self-Timed	100/300
191	Unused		180-188	Self-Timed	1200
193	Self-Timed	1200	190	Random	100/300
195	Random		192-194	Self-timed	1200
197	Test Channel		196	Test Channel	100/300
199	Unused		198	Blocked	
201-217	Self-Timed	100/300	200	Random (Test)	1200
215-221	Self-Timed	300	202-222	Self-timed	300

Table 1: Current Channel Types for each satellite

3.3.1 Self-timed Channels

DCPs transmit data on self-timed channels at assigned times. The assigned times are defined by a starting time in each day, a transmission time interval, and a transmission window that defines the maximum duration of a transmission. For example, if a DCP were assigned the starting time of 01:03:00 (HH:MM:SS), a transmission interval of 1 hour, and a transmission window of 10 seconds, the DCP would transmit for no more than 10 seconds starting at these times: 01:03:00, 02:03:00, 03:03:00 … 21:03:00, 22:03:00, 23:03:00 as shown in Figure 4.

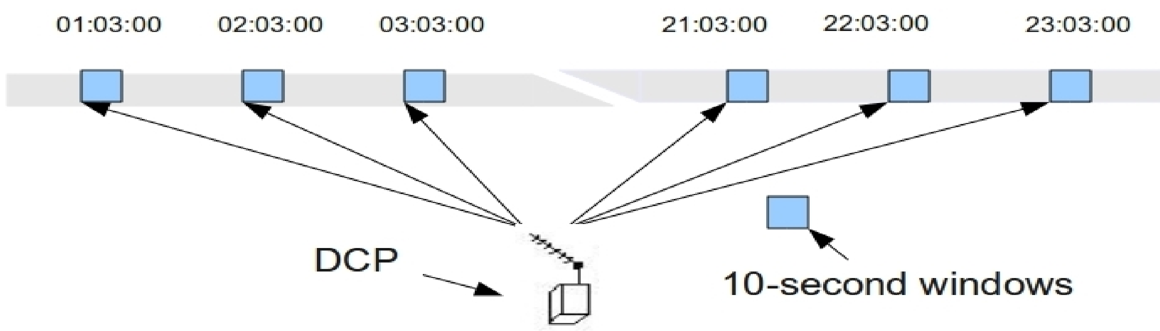

Figure 4: DCP transmitting on self-timed channel

The transmission window is chosen so that it evenly divides the transmission interval, and the transmission interval so that it evenly divides the time in each day. If the same windows and transmission intervals are used for each DCP on a channel, the capacity of the channel, i. e. the maximum number of DCPs that can transmit on a self-timed channel can be determined by the equation

Number of DCPS = transmission interval (in seconds) / transmission window (in seconds)

Table 2 shows the resulting channel capacity for various transmission intervals and windows. The most common ones used are highlighted.

Transmission Interval	Transmission Window	Channel Capacity	Transmission Interval	Transmission Window	Channel Capacity
15 min	1 sec	900	3 hrs	10 secs	1080
	2 secs	450		**60 secs**	**180**
	3 secs	300	4 hrs	10 secs	1440
	4 secs	150		**60 secs**	**240**
	5 secs	180	6 hrs	60 secs	360
30 min	1 secs	1800	12 hrs	1 sec	43200
	2 secs	900		2 sec	21600
	3 secs	600		10 sec	4320
	4 secs	450		60 secs	720
	5 secs	360			
1 hr	**5 secs**	**720**			
	10 secs	**360**			
	15 secs	240			

Table 2: Examples of possible self-timed channel configurations

For 100 baud DCPs, the transmit intervals have historically been four, three, or one hour along with 1 minute transmission windows. With the desire to more efficiently use the bandwidth, DCPS have been developed to transmit at 300 and 1200 baud and use GPS receivers to maintain a highly accurate clock. This allows these DCPs to use smaller transmission windows on a self-timed channel resulting in either more frequent transmissions or an increase in the number of DCPs that can use the channel.

3.3.2 Random Channels

Random channels allow DCPs to transmit data when some significant environmental condition has been detected. However, to minimize interference and increase the probability of a successful random transmission, random channels have constraints that must be followed. These constraints were derived from a probabilistic model developed to determine the probabilities that data randomly transmitted in response to an event would be successfully received given various channel loadings. A summary of the model that was developed and a discussion of the operational constraints imposed by the model is provided in Appendix D. From the model developed, three operational modes were discussed: 1) single random transmissions after an event, 2) multiple random transmissions after the event, and 3) single random transmissions that contained multiple data vales. (Note that all random transmissions had to be < 2 seconds.) The only acceptable mode for event-driven random transmissions was mode 2 and the optimal number of transmissions after an event was determined to be 3. Figure 3 illustrates this mode showing a DCP making 3 transmissions at random intervals t1, t2, and t3 after an event has been detected.

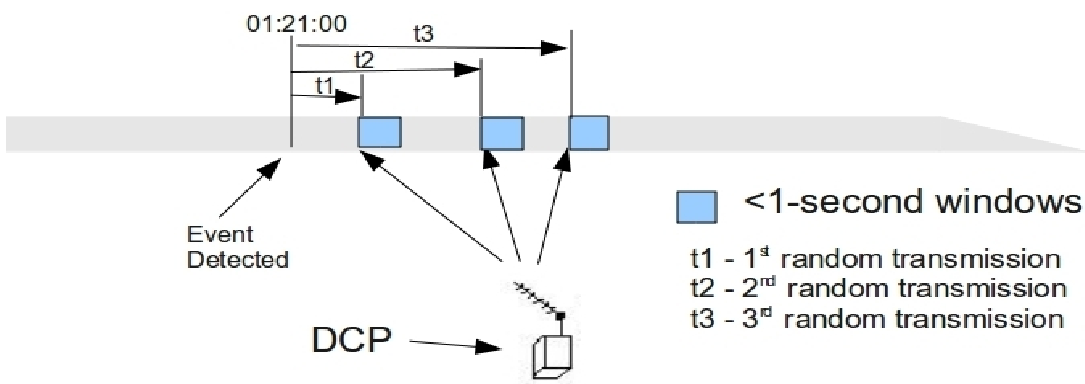

Figure 5: DCP transmitting on random channel

Table 3 shows the maximum channel loading to achieve a probability of 95% that data transmitted in response to an event will be received.

Transmission length	Number of transmissions per day
1 sec	7200
2 secs	3600

Table 3 Maximum loading for a random channel with 1-second and 2-second transmissions

The table shows values for two lengths, 1 second and 2 seconds. The model developed assumed 2 -second transmissions, but 1-second transmissions are currently a more desirable length and so the results have been adjusted for 1-second transmissions. Note that the number of transmission per day must come from all DCPs operating on the channel and so the allocations of DCPs to a channel must take this into account. A channel can be overloaded with DCPs as long as the probability is low that the set of DCPs allocated will not exceed the maximum loading.

3.3.3 Self-timed and Random Transmission Formats

The format of all messages for both self-timed and random transmissions has this format:

Preamble			Identifier	Transmitted Data		Postamble	
Carrier 0.5sec(300 bps) 0.25sec(1200bps)	Clock States 3 ‘0 -1’	FSS 15 bits	GOES ID 32 bits	Flag Word 8 bits	DCP Sensor Data Max: 32,000 bits @ 300 bps, 128,000 bits @ 1200 bps	EOT	Encoder Flush 32 bit

Transmitted messages are divided into four parts: **Preamble**, **DCP identifier**, **Transmitted Data**, and **Postamble**. The **Preamble** and **Postamble** are a part of the communications protocol for data delivery. The **DCP Identifier** is the 32-bits that uniquely identify the DCP from which the data were transmitted.
The **DCP Identifier** is assigned to the operator of the DCP by NESDIS as an 8-character identifier consisting of the 8 hex numbers that represent the 32-bit identifier. The **Transmitted Data** consists of a 8-bit flag word followed by the sensor data. The DCP sensor data can be represented by three different codes: 1) American Standard Code for Information Interchange (ASCII) format, 2) Pseudo ASCII, and 3) pure binary.

3.3.3.1 ASCII Data

Each 7-bit ASCII character is transmitted as an 8-bit byte with an odd parity bit. Many receiving systems will perform a parity check and replace any characters with parity errors with a designated error character, usually the character '?' (question mark). Most reception systems will also convert the 8-bit code to the ASCII 7-bit code by replacing the parity bit with a '0'.

3.3.3.2 Pseudo binary data

Pseudo binary, is an encoding scheme that allows binary data to be transmitted as a sequence of ASCII characters. (The name *pseudo binary* was given to the encoding scheme to indicate that the binary data are being embedded in ASCII characters and not transmitted as *true* binary .) The use of pseudo binary avoids all problems associated with transmitting binary data, for example, the detection of the end of the transmission, the handling of special characters, etc. The encoding method is to store binary data in the low-order six bits of 7-bit ASCII character and a '1' in the high-order bit. The '1' in the high-order bit guarantees that the character will not be an ASCII control character and will be printable. The number of ASCII characters used ranges from 1-3 and provides the ability to encode 6-bit binary numbers (1 character), 12-bit binary numbers (2 characters), or 18-bit binary numbers (3 characters.). The binary numbers can be unsigned or signed using the 2's complement representation of signed integers. Though true ASCII data can be readily examined, pseudo binary is popular as a means of compressing large amounts of data within a specified time slot. Note that just as in ASCII data, each 7-bit ASCII character that is a part of a pseudo binary number is transmitted as an 8-bit byte with an odd parity bit.

3.3.3.3 Binary Data

True binary can be transmitted but is currently not being used. There is a working group that has been charged to develop a binary format suitable for the GOES DCS.

3.4 Interrogating remote sites

The GOES DCS supports the ability to interrogate remote DCPs equipped with special reception hardware from a ground station. This capability was included to allow DCPs to be polled for data or to be remotely configured. However, the inclusion of reception hardware on a DCP was initially very expensive. Because of the ability of DCPs to function independently, and at lower cost without the interrogation function, the interrogation function was largely replaced by self-timed and random operation. However, technology has now advanced to the state where devices with much lower cost and power consumption are available for the interrogation function and a new interrogation system is being developed.

Section 4 Data Collection Platforms

Data Collection Platforms(DCPs) are data recording devices equipped with a GOES radio. DCPs are commercially available and can be classified as standard, interrogable, and dual. Note that these types are not mutually exclusive, i. e. an individual DCP can be all three. GOES radios used in DCPs are manufactured by multiple vendors and each radio must be certified by NESDIS before it can be deployed in the GOES DCS system. The certification requirements are specified in the document *GOES Data Collection Platform Radio Set (DCPRS) Certification Standards at 300 BPS and 1200 BPS*, Version 2.0, June 2009.

4.1 Standard Data Collection Platforms

The standard DCP (Data Collection Platform) operating in the GOES DCS includes both a data acquisition system and a radio transmitter capable of transmitting information to a GOES satellite in a self-timed or random mode. DCPs are powered by batteries which are charged by solar panels in areas where AC power is not available. To support self-timed transmissions, DCPs must maintain an accurate internal clock using some suitable external source of time such as a GPS receiver. Each standard DCP authorized to operate within the GOES DCS is given a GOES assignment by NESDIS. The assignment consists of

- a 32-bit address usually expressed as 8 hex characters,
- the satellite to be used (GOES-East or GOES-West),
- the self-timed channel number to be used for self-timed transmissions,
- an assigned starting time,
- a transmission interval,
- a transmission window,
- and, if necessary, a random channel number to be used when a critical environmental condition has been detected.

4.2 Interrogable Data Collection Platform

At present, there are no interrogable DCPs in use, but they will be used when a new interrogation system has been designed and implemented. See section 14.2 Redesign of the GOES interrogation System.

4.3 Dual Data Collection Platforms

Dual DCPS are special DCPs that can transmit to both GOES-East and GOES-West, either separately or simultaneously. These systems are generally deployed on mobile platforms, which are usually reserved for international applications. These DCPs transmit on frequencies reserved for international use. A dual DCP is also referred to as an international DCP.

Section 5 GOES Spacecraft

5.1 GOES support for the GOES DCS

The GOES DCS uses a transponder on the GOES satellites to relay UHF transmissions from DCPs to ground stations. The transponder acts as a “bent pipe” that shifts the frequency used by DCPs from UHF (401.9 MHz) to L-band (1694.5 MHz) and shifts the frequency used to interrogate the DCPS from from S-band (2034.9 MHz) to UHF (468.8 MHz). The spacecraft transponder used by the GOES DCS is fully redundant on each GOES satellite to prevent DCS outages due to premature equipment failure.

5.2 GOES Command and Control

In order for the GOES DCS to function properly, the GOES satellites upon which it depends must be kept in an operational state. This requires continuous monitoring, occasional adjustments, and both routine and life-cycle maintenance. These functions are carried out by NOAA's Wallops Command and Data Acquisition Station (WCDAS), at Wallops Island, Virginia (37.95° N, 75.46° W) with some backup support from other ground stations, one located Fairbanks, Alaska (64.97° N, 147.51° W) and the other at the Goddard Space Flight Center at Greenbelt, Maryland (39.00° N, 76.84° W). The WCDAS has the primary responsibility for ensuring the scheduled data flow from NOAA satellites to designated user subsystems. Some of the critical functions performed by the WCDAS are

- sends spacecraft commands and schedules to the GOES satellites for spacecraft control
- develops and maintains records of station performance, analyzes system failures, establishes failure trends and implements corrective action
- prepares and issues reports on system anomalies, maintains station configuration control, and ensures operator and maintenance crew proficiency
- plans, designs, and implements system modifications
- tests and evaluates new systems and techniques
- assists in developing emergency procedures to safeguard spacecraft health and safety
- executes emergency plans independently in the event of a communications outage with the NESDIS SOCC (Satellite Operations Control Center)

It might be noted that the GOES DCS could not function without an active command-and-control link to the GOES satellites.

5.3 GOES Spacecraft Positioning

There are many GOES spacecraft currently in the collective satellite constellation, though only two spacecraft are in operation in support of the GOES DCS. The operational positions are referred to as GOES-E (GOES East) and GOES-W (GOES West). GOES-E and GOES-W are positioned approximately 23,000 miles above the equator. GOES-E is positioned at 75° West Longitude while GOES-W is positioned 135° West Longitude. The two satellite operational constellation offers a very large area of DCP coverage, from western Africa to eastern Australia.

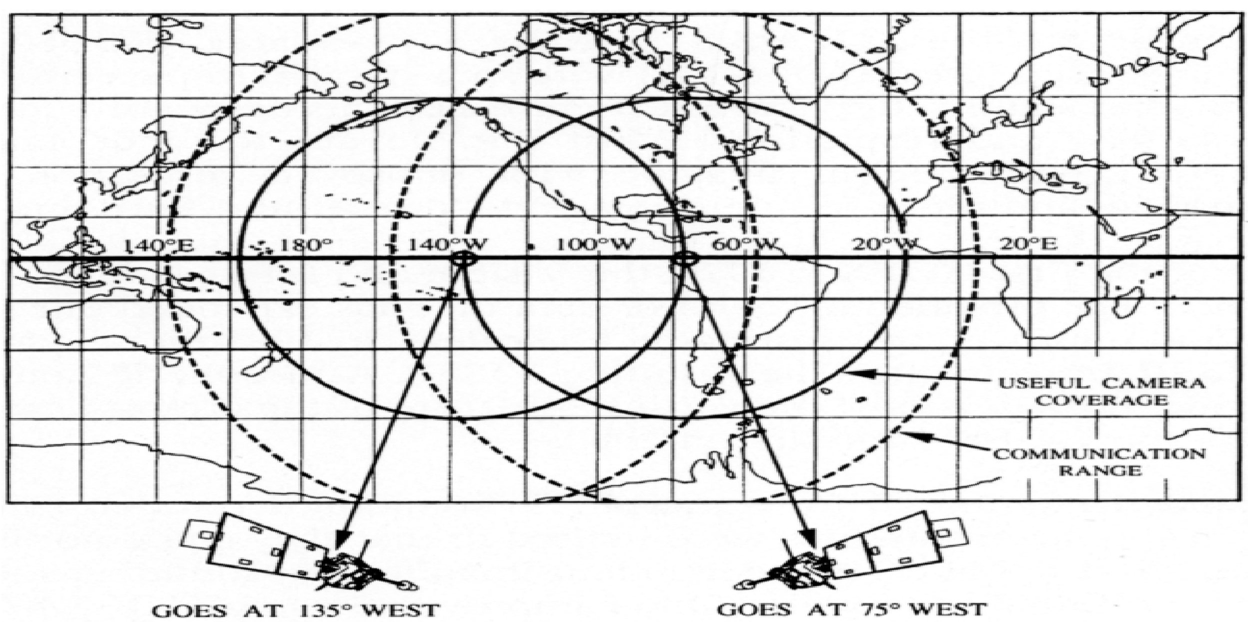

Figure 6: Normal Positions of Operational Satellites

In an optimum situation there is a GOES spacecraft in standby. The standby is usually positioned between GOES-E and GOES-W, to minimize distance and deployment time to either the GOES-E or GOES-W position should either fail. Figure 6 shows the GOES two-satellite constellation with the respective areas of coverage. The dashed ellipses indicate the approximate area from which the GOES DCS can receive information.

In the event that only a single GOES spacecraft is operational (which means the failure of one satellite) with no satellite in constellation storage, NESDIS is prepared to go to a single operational GOES satellite constellation. The position of this satellite is a compromise between the GOES-E and GOES-W position, as shown in Figure 7.

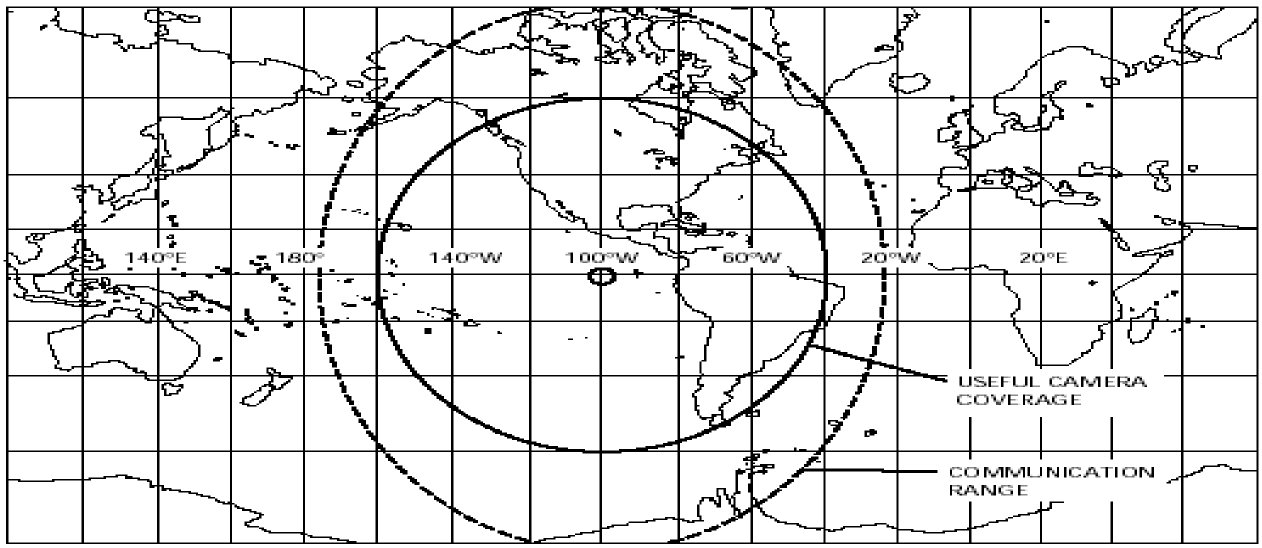

Figure 7: Operational Configuration with only one Satellite

5.4 GOES Spacecraft History and Past and Future Deployments

GOES satellites have an extensive history in weather and ocean climate monitoring in the United States, starting with the launch of SMS (Synchronous Meteorological Satellite) on May 17, 1974.

The GOES spacecraft grew out of the successful use of geostationary weather satellites SMS-1 and SMS-2. SMS-C (GOES-1), which was launched on October 16, 1975, provided an early form of the GOES DCS. GOES-1 was positioned over the Indian Ocean, west of SMS-2. The satellite was later moved to replace SMS-2 (Pacific), to assume a location it still occupies with the current GOES satellite series. There have been two generations of GOES, with a third generation planned with the launch of GOES-R, scheduled for launch in 2012. There have been considerable functional improvements over the same time period. The following 3 figures show how the GOES satellite has changed in appearance.

Figure 8: GOES 1-3

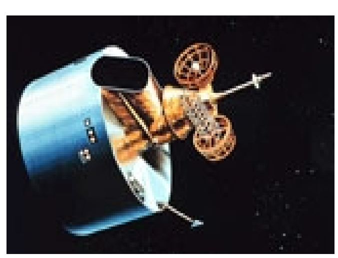

Figure 9: GOES 4-7

Figure 10: GOES 8-13

Table 4 is a summary of GOES spacecraft operations and current status. Though the SMS satellites were essentially identical to GOES-1, GOES-2, and GOES-3, they have been excluded from the table. Satellites are identified by alphabetic characters which are converted to their corresponding ordinal number when the satellite becomes operational, e.g. the first satellite was named GOES-A while it was being launched and tested and changed to GOES-1 when it became operational; likewise, GOES-B became GOES-2, GOES-C became GOES-3, etc. v

	Satellite	Launch	Status
SMS-derived satellites	GOES-1	October 16, 1975	Deactivated
	GOES-2	June 16, 1977	Deactivated
	GOES-3	June 16, 1978	Limited Operations
First Generation	GOES-4	September 9, 1980	Deactivated
	GOES-5	May 22, 1981	Deactivated
	GOES-6	April 28, 1983	Deactivated
	GOES-G	April 28, 1986	Launch Failure
	GOES-7	February 26, 1987	Limited Operations
Second Generation	GOES-8	April 13, 1994	Out of Service
	GOES-9	May 23, 1995	Storage
	GOES-10	April 25, 1997	Deactivated
	GOES-11	May 3, 2000	GOES West
	GOES-12	July 23, 2001	GOES East
Third Generation	GOES-13	May 24, 2006	Standby
	GOES-14	July 27, 2009	Standby
	GOES-P	March 4, 2010	
Fourth Generation	GOES-R	December 2014*	
	GOES-S	April 2016*	
	GOES-T		
	GOES-U		
* Projected Launch Date			

Table 4: GOES Launch History and Projections

GOES satellites are developed and launched by NASA (National Aeronautics and Space Administration), but once operational, are turned over to the NOAA (National Oceanographic and Atmospheric Administration) for day-to-day administration and operations.

5.5 Operations during Eclipse/Sun Outages

The GOES spacecraft undergo eclipse where the spacecraft is not in view of the sun due to the Earth being between the sun and the spacecraft. This occurs during 45-day intervals around the vernal and autumnal equinoxes. The spacecraft eclipse times vary from 10 minutes at the beginning and end of the eclipse periods to a maximum of 72 minutes at the equinox. The eclipse periods begin 23 days prior to the equinox, end 23 days after the equinox, and are centered on spacecraft local midnight.

During these periods, the DCS system remains powered allowing the continued collection of data through these periods. Although the eclipse period does not normally impact DCS users, the spring and fall eclipse schedules are disseminated to all DCS users for informational purposes.

Section 6 GOES DCS Pilot Transmitter

The GOES DCS Pilot transmitter transmits a pilot signal via omni-directional antennas to both the GOES East and West satellites. The primary purpose of a pilot signal is to provide receivers at ground systems with a calibrated reference signal. Currently, there are two pilot transmitters, one at the WCDAS transmitting at 401.085 MHZ and a backup at the Godard Space Center transmitting at xxxxx MHZ. The spacecraft processes these signals like a regular platform signal and the resulting S-band signal is detected and processed at each of the GOES receive sites. Pilot Control systems can detect either of these IF signals and use their phase lock loops to adjust the downlink signal to 5 MHz. Most receive stations support automatic fail-over from one pilot signal to the other when the active signal fails.

It might be noted that the GOES DCS could not function without a GOES pilot signal.

Section 7 GOES DCS Data Reception and Distribution

7.1 Overview

Transmissions from remote Data Collection Platforms are acquired from the GOES satellite by GOES DCS Direct Readout Ground Stations(DRGS) and distributed to users through various distribution systems. DRGSs are commercially available and normally consist of

- an antenna for each GOES satellite (East or West) from which data are to be obtained,
- an RF system to receive, process, and demodulate incoming transmissions, and
- computer systems to store, process, and distribute the incoming data.

The primary receive station in the GOES DCS is the Wallops Command and Data Acquisition System (WCDAS) located at Wallops Island, Virginia. This was the original receive site for GOES DCS data and, until June of 2008, was the only operational system that received data from all Data Collection Platforms in the system. In addition to its reception and distribution functions, it also supports the GOES DCS System Management functions. In order to provide a robust backup system for the Wallops facility, two other receive sites are now operational: 1) the Emergency Data and Distribution Network (EDDN) at the EROS Data Center in Sioux Falls, South Dakota, and 2) a backup receive system at the

NOAA Satellite Operations Facility (NSOF) in Suitland. The EDDN is a system that was developed by the USGS, one of the major users of the GOES DCS, in cooperation with NESDIS and other GOES DCS users to provide a backup for data reception and distribution. It became operational in June of 2007. The backup system at the NOAA Satellite Operations Facility (NSOF) in Suitland, MD was developed by NESDIS to provide a backup for both 1) data reception and distribution and 2) system management functions. It became operational in May of 2010.

In addition to these receive sites, some users operate their own DRGSs. These DRGSs normally do not collect data from all DCPS, but only from DCPs of interest to the user operating the DRGS.

7.2 DCP Performance Measurements

Besides receiving data from DCPs, many reception systems also record and distribute, along with the data, several measurements of a DCPs transmission that relate to its performance. There are four such measurements made by the primary and backup systems shown in Table 5.

Performance Measurement	Description
EIRP	This measurement consists of two ASCII digits ranging between 32 and 57 (decimal) or "//" for an invalid measurement. The nominal operating range is 44 to 49 dBm. (The EIRP is computed assuming that the pilot is a +47 dBm reference.)
Frequency Offset	This measurement consists of signed hex number ranging from -A to +A and represents the frequency offset from the channel center frequency in 50 Hz increments, e,g. -A = -500 Hz, +2=100Hz. The nominal operating range for frequency offset is ±250 Hz (±5).
Modulation Index	The modulation index measurement consists of one of the three characters: • N (Normal, 60^o 9^o) • L (Low, <50^o) • H (High, >70^o)

Performance Measurement	Description
Data Quality	The data quality measurement consists of one of the three characters: • N (Normal, error rate better than 1 X 10^{-6}) • F (Fair, error rate between 1 X 10^{-4} and 1 X 10^{-6}) • P (Poor, error rate worse than 1 X 10^{-4}) The nominal operating character for data quality is N.

Table 5: DCP Performance Measurements

7.3 Data Interface Standards

Two interface standards have been developed to facilitate the reception and distribution of GOES DCS Data: 1) Data Acquisition and Monitoring System – New Technology Network Interface Specification (DAMS-NT NIS) for reception of data from GOES DCS receive sites and 2) the Dcp Data Service (DDS) for distributing data to user systems.

The interfaces define the computer-to-computer protocols for acquiring and distributing data. The DAMS-NT NIS interface is define in the document *DAMS-NT Network Interface Specification, Version 8.0.* The DDS interface is defined in the document *DCP Data Service (DDS) Protocol, Version 8*.

7.4 NESDIS Reception and Distribution Systems

The primary GOES DCS reception and distribution system is located at the Wallops Command and Data Acquisition Station (WCDAS) at Wallops Island, Virginia. This system is backed up by a tightly integrated system located at the National Satellite Operations Facility (NSOF) at Suitland, MD.

The primary processing system used at the NESDIS sites is the Data Administration and Data Distribution System (DADDS.) The Data Administration and Data Distribution System (DADDS) has four functions:

1. acquire GOES DCS data from the receive system,
2. distribute data to the DOMSAT data distribution system,
3. distribute data to all dedicated lines,
4. maintain system management information in distributed and synchronized databases,
5. provide a user interface to acquire user information and to allow users to monitor the system.

DADDS analyzes each message received from a DCP and inserts error messages into the data stream whenever there is some abnormal response from a DCP. These messages are referred to as Abnormal Platform Response Messages (APRMS). A list of the APRMS produced by DADDS in shown in Error: Reference source not found. APRMs are disseminated over DOMSAT but are NOT included with the DCP message data transmitted over dedicated lines.

The primary instance of DADDS is on the WCDAS system, but there is also an instance running on the backup system at NSOF. These two systems are automatically synchronized.

The NESDIS reception sites use four data distribution systems to distribute data in real-time to users:

1) All GOES DCS data are transmitted to a commercial communications satellite called DOMSAT (**DOM**estic **SAT**ellite),

2) All GOES DCS data are distributed over the Internet using store-forward systems called LRGSs (see description of LRGSs in Section 8.6 Local Readout Ground Station (LRGS) . LRGSs supply data to registered users using the Dcp Data Service (DDS) protocol. (Note that all users who register with the LRGSs operated by NESDIS are automatically registered with the LRGSs at the EDDN backup system.)

3) Data of interest to the National Weather Service are transmitted to the NWS Gateway in Silver Spring, Maryland over a dedicated communications line. Note that these data are also forwarded to the National Weather Services' data distribution satellite named NOAAPORT.

4) All GOES DCS data are distributed the LRIT system via a LRGS for transmission over the GOES satellite using the Low Rate Information Transfer(LRIT) service.

Figure 11 shows a diagram of the primary and backup systems. The diagram shows

- the reception of data from both GOES satellites by GOES receivers,
- the transfer of the data from the receivers to both DADDS servers and LRGSs,
- the transmission of data from DADDS to the DOMSAT distribution system,
- the synchronization of the DADDS databases at the backup system at NSOF,
- a network link to the EDDN for the synchronization of LRGS systems,
- the user interface via the public web servers to both the DADDS system and LRGSs.

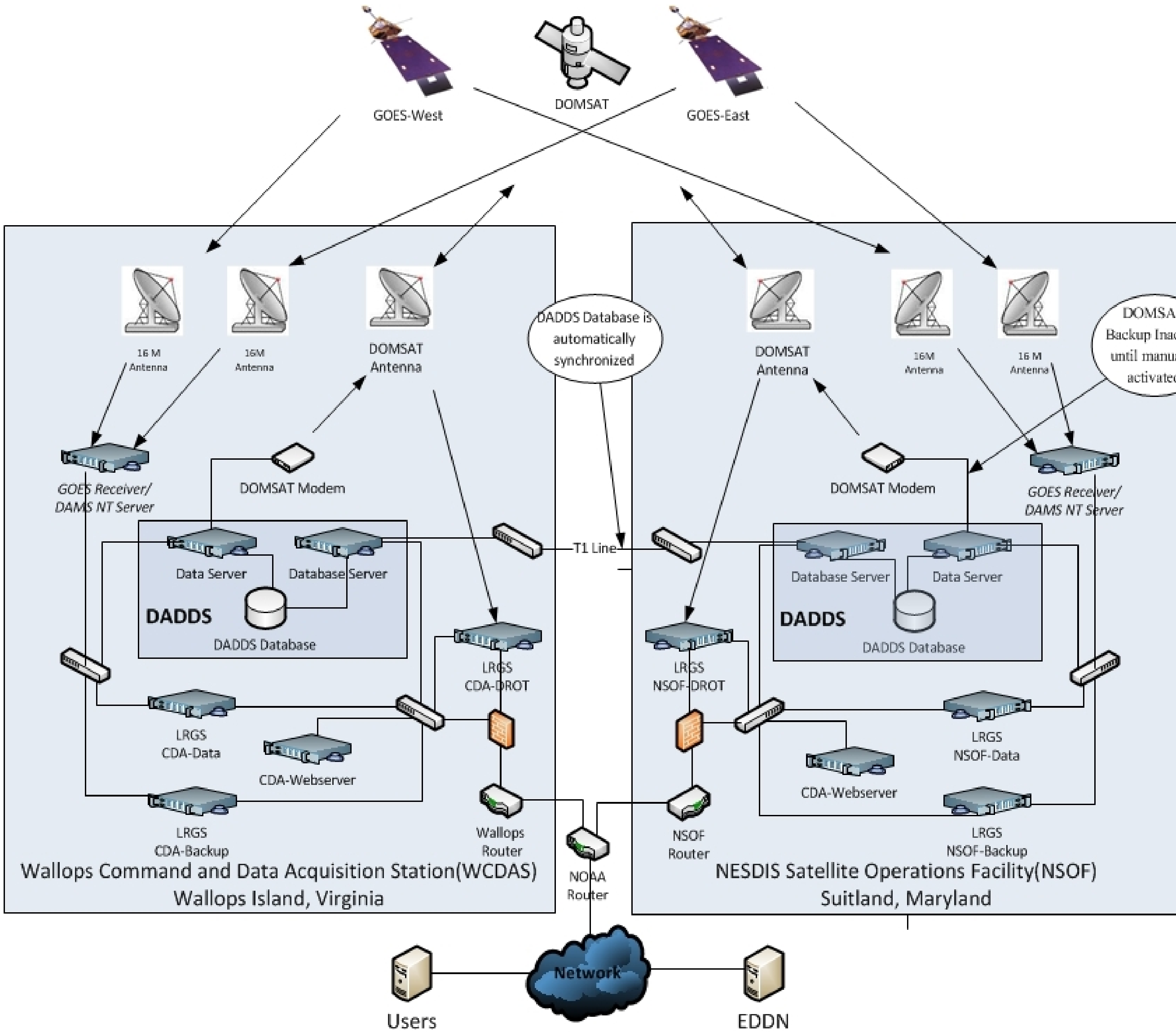

Figure 11 Diagram of NESDIS Reception Systems

It should be noted that all functions are in continuous operation on both systems except 1) the transmission of data to DOMSAT and 2) the distribution of data to external systems, i. e. the users and EDDN. The inactive functions must be activated on the backup system when there is a failure of the primary system.

7.4.1 Wallops Command and Data Acquisition Station (WCDAS)

The WCDAS (Figure 12)maintains the primary GOES DCS reception and distribution system. This consists of GOES antennas, GOES reception equipment, and the Data

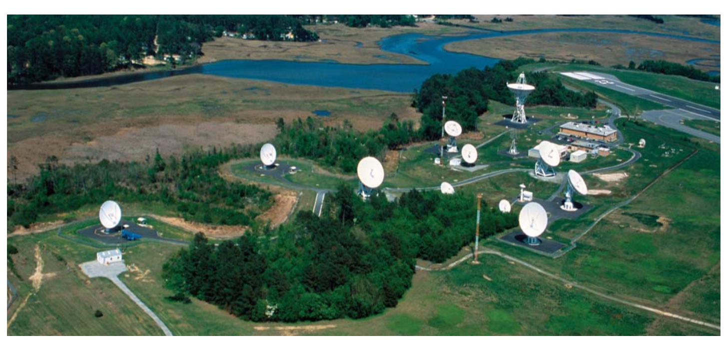

Figure 12:Wallops Command and Data Acquisition Station

Administration and Data Distribution System (DADDS).

7.4.1.1 Antennas

For the GOES DCS, the WCDAS uses two 16-meter tracking antennas that can accurately track the GOES satellites in winds up to 125 mph. These dishes functionally replaced the two original 18-meter tracking antennas in order to provide antennas that could operate hurricane-force winds. The 18-meter dishes now serve as backups to the 16-meter tracking dishes.

7.4.1.2 Receive System

The WCDAS supports a RF system to receive the data from both 16-meter antennas and demodulate the data from all GOES DCS channels. In addition to demodulating the data, the system also generates the data performance measurements that are included in each message that is supplied to the data processing systems (the DAMS-NT protocol defines the format and locations of these performance measurements in the supplied data stream.)

This equipment supports the DAMS-NT protocol and interfaces with two processing systems systems: DADDS and the LRGS systems.

7.4.1.3 Test Transmitters

To insure that all active GOES DCS channels are functioning properly, the WCDAS also operates test transmitters that can provide a test of the full system. The GOES DCS test transmitters are designed such that they can transmit on any GOES DCS channel manually via operator command or automatically. These transmitters are surrogate DCPs that transmit test messages through the system. These messages are received at the WCDAS and analyzed for quality assurance. In the automatic mode, tests can be performed on each active channel every two hours. The scheduling has been designed to minimize interference with DCPs operating on self-timed channels. Test transmitters can also be used to block unauthorized transmissions. If an unauthorized transmission is detected by NESDIS operations management, they are able to issue an automatic blocking command to inhibit the DCP owner and any secondary users from receiving any useful data from this DCP.

7.4.2 National Satellite Operations Facility (NSOF) at Suitland, MD

The National Satellite Operations Facility (NSOF) implemented a backup system for the GOES DCS at the NOAA's Satellite Operations Control Center (Figure 13) in Suitland, Maryland which became operational in May of 2010. This backup system provides a full backup for all GOES DCS reception and distribution functions. The system operates continuously and automatically synchronizes all system databases. Thus, in the event of a major system failure at the WCDAS, the backup system could be immediately used to take over the reception and distribution functions of the GOES DCS.

Figure 13: NSOF Satellite Operations Control Center

The backup system essentially duplicates all the hardware and software systems of the primary system at WCDAS.

7.5 Emergency Data Distribution Network

The Emergency Data Distribution Network (EDDN) (Figure 14) is a system that provides a backup for data reception and distribution of data from the GOES DCS. It was developed by the USGS, one of the major users of the GOES DCS, in cooperation with NESDIS and other GOES DCS users, and is located at the USGS's EROS Data Center in Sioux Falls, South Dakota. It was developed primarily to provide a complete backup of the data reception and distribution functions in a geographic location sufficiently far away from the primary system at Wallops Island so as not to be influenced by any extreme event that might affect the reception and distribution operations of the primary system. It became operational in June of 2008 . The EDDN receives data from all GOES DCS channels directly from the GOES satellites as well as from the primary system at Wallops Island by means of the DOMSAT communications satellite. It transfers the merged stream to LRGSs that are accesible to any registered user of the GOES DCS system.

Figure 14: Emergency Data Distribution Network, EROS Data Center

The EDDN was designed with these principles:

- provide a backup of the reception and distribution functions,
- easily integrate into the current data distribution environment,
- provide 24/7/365 availability, and
- provide a secondary source of data for the recovery of bad transmissions.

The EDDN does not transmit data to DOMSAT and does not support any administrative functions of the GOES DCS. It only provides a backup of the reception of all DCPs transmitting in the GOES DCS and the distribution of these data over the Internet via LRGSs.

7.5.1 Antennas

For the GOES DCS, the EDDN uses a 8.1-meter tracking antenna for GOES East and a 7.5-meter tracking antenna for GOES West. In addition, it has a 3.8-meter antenna for testing and backup. For the DOMSAT link, it has a 2.4-meter antenna.

7.5.2 Receive System

The EDDN supports a RF system to receive data from both GOES antennas and demodulate the data from all GOES DCS channels. In addition to demodulating the data, the system also generates the DCP performance measurements that are included in each message that is supplied to the data processing systems (the DAMS-NT protocol defines the format and locations of these performance measurements in the supplied data stream.)

This equipment supports the DAMS-NT protocol and interfaces with one distribution systems: LRGS systems (discussed later) . The public LRGS systems are available to all registered users of the GOES DCS. User accounts for these systems are automatically synchronized with the LRGSs operated by NESDIS. Figure 15 shows a diagram of the EDDN system. The diagram shows

- the reception of data from both GOES satellites by GOES receivers,
- the transfer of the data from the receivers to LRGSs,
- the reception of data from the DOMSAT link,
- the transfer of data from the DOMSAT receiver to internal LRGS servers(lrgseros1, lrgseros2),
- the transfer of data from the internal LRGS servers to public LRGS servers (lrgseddn2, lrgseddn2,lrgsedd3),
- a network link to the WCDAS at Wallops Island for the synchronization of user access information from the LRGSs at the WCDAS with the the public EDDN LRGS servers,
- the user interface via the Internet to the public LRGS servers.

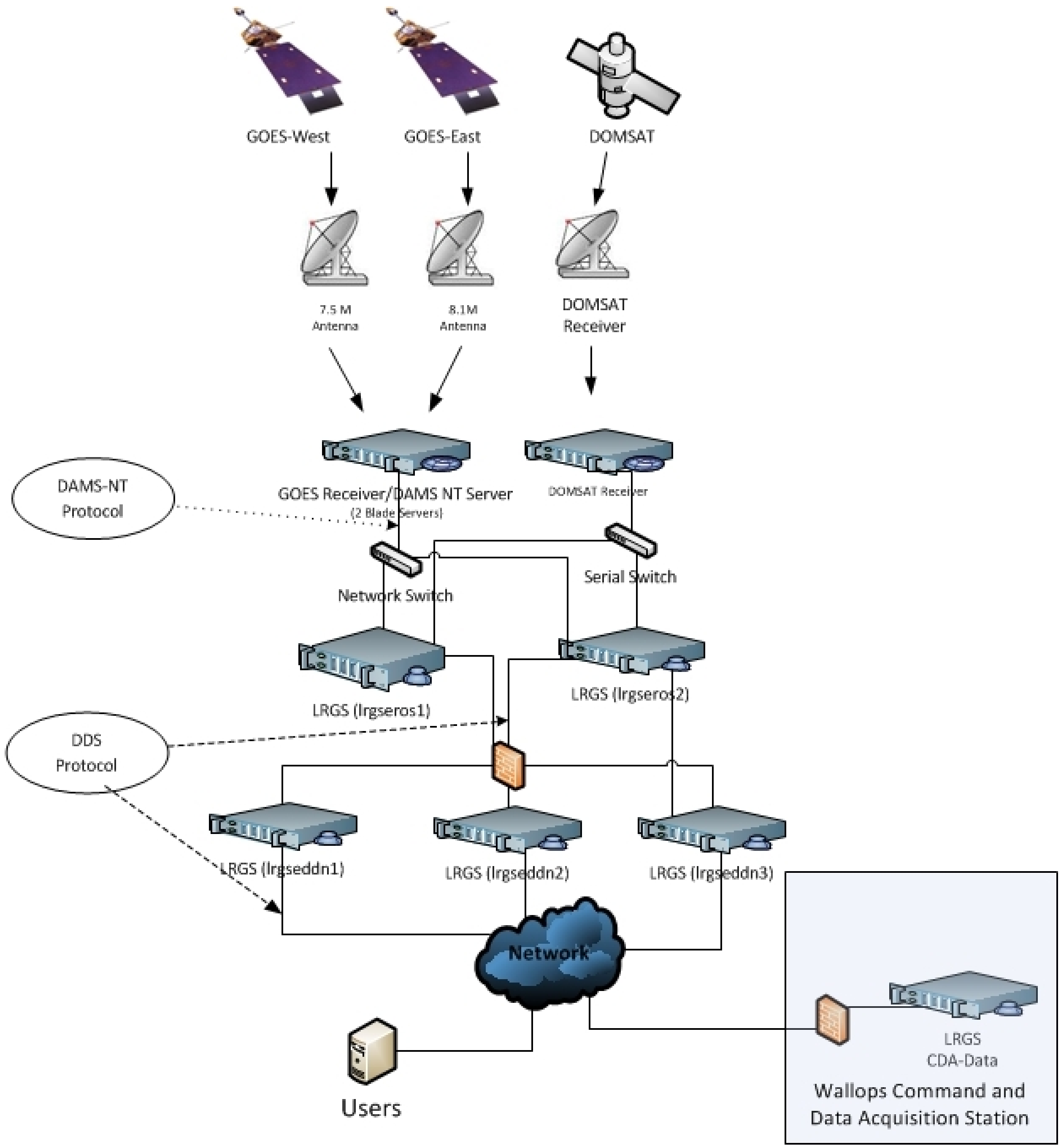

Figure 15 Diagram of EDDN Reception System

Section 8 Data Distribution Systems

Users who operate their own GOES reception systems can receive DCP messages directly from the GOES satellites. The National Weather Service receives selected DCP messages over a dedicated communications line the links their facility with the NESDIS reception systems. For other users there are several data distribution systems from which they may obtain data from the GOES DCS:

- a commercial communications satellite named DOMSAT,
- dedicated network servers supported by the NESDIS reception system and the EDDN that support the Dcp Data Service (DDS),
- the GOES Low Rate Information Transfer (LRIT) system, and
- the NOAAPORT data distribution system.

8.1 DOMSAT DCP Data Distribution System

NESDIS supports the distribution of DCP messages to user-organizations via a domestic communications satellite called DOMSAT (**DOM**estic **SAT**ellite.) NESDIS agreed in 1988 to support the DOMSAT link as a way of distributing all GOES DCS data to users operating their own DOMSAT receive sites named Local Readout Ground Stations (LRGSs). The DOMSAT service is a contracted service and is funded by the major users of the service by a contract managed by NESDIS. Any user may use the DOMSAT service as long as the user acquire and operate their own LRGS systems. The DOMSAT dissemination footprint is limited to essentially the continental United States and is unsuitable for users in other areas.

The NESDIS receive sites can continuously broadcast all incoming DCP messages over DOMSAT using a single high-speed channel. The WCDAS is the primary system that transmits to DOMSAT and is backed up by the system at the NSOF. The user can obtain this stream of data from DOMSAT by deploying a Local Readout Ground Station (LRGS) which consists of a small antenna (1.9-2.4 meters), a suitable DOMSAT satellite modem, and a computer system running the public domain LRGS software. The LRGS system is discussed in section 8.6 Local Readout Ground Station (LRGS) .

8.2 DCP Data Service(DDS) Network Servers

The GOES DCS also supports the direct transmission of DCP data to users via Internet. This uses a TCP socket protocol called DDS (DCP Data Service). The DDS allows users to specify data of interest by DCP address, channel, or time range. Users can retrieve historical data or a real-time stream. The DDS service is supported at NESDIS and the EDDN by LRGS servers. In order to use this service on the NESDIS and EDDN systems, a user must register with NESDIS which automatically registers the user on the EDDN systems. There are at least 3 software packages that can use the DDS service to acquire data: 1) the LRGS software supports the DDS protocol and can be configured to receive (as well as supply) the Internet data stream in real-time, 2) a public domain message browser supports retrieving data interactively using the DDS, and 3) a public domain data decoder named DECODES that supports receiving and decoding data using the DDS protocol.

8.3 Low Rate Information Transfer(LRIT) System

In 2004, NOAA started a new service called LRIT (Low Rate Information Transfer). This service distributes low resolution WEFAX images and all GOES DCS data over the GOES satellites on it own assigned frequencies that are separate from those used by the GOES DCS. The digital Low Rate Information Transmission (LRIT) is an international standard for data transmission that was developed by the Coordination Group for Meteorological Satellites (CGMS) in response to a recommendation on digital meteorological satellite broadcasts. NOAA designed its LRIT system based on the CGMS standard. The LRIT/HRIT Global Specification can be located at

http://www.wmo.ch/pages/prog/sat/documents/CGMS-03_HRIT-LRIT_v2-6.pdf.

The NOAA LRIT system provides digital data, via a broadcast service, through its geostationary satellites. NOAA operates an LRIT broadcast on its GOES East and GOES West satellites (I-M) and will continue an LRIT broadcast on the GOES N-P Series. On the GOES-R series of satellites, the broadcast will be merged with the Emergency Managers Weather Information Network1 (EMWIN) service and will be a combined data rate of 400 Kilobits per Second. Figure 16 shows the flow of GOES DCS data through the LRIT distribution system.

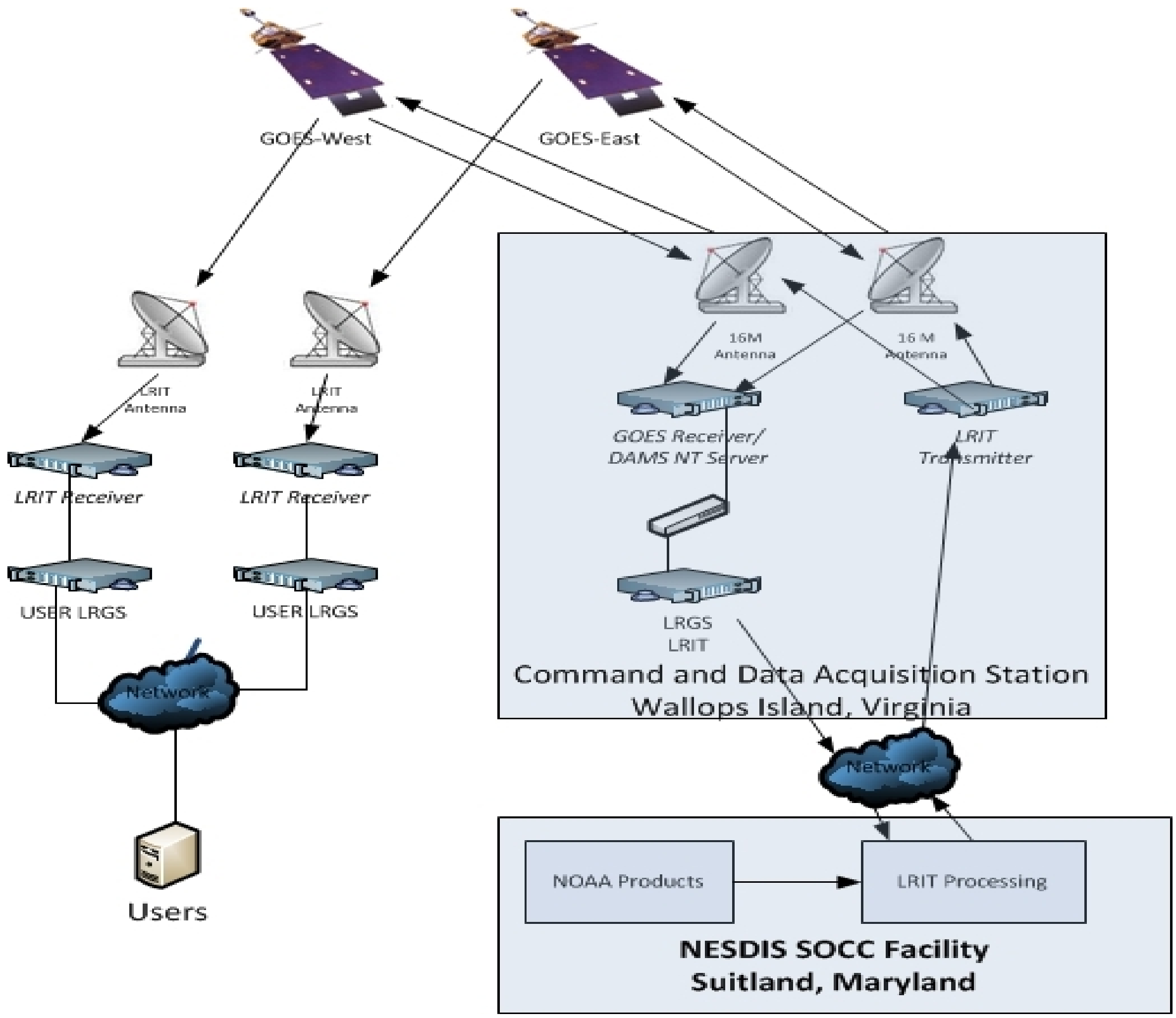

Figure 16 Diagram of LRIT Distribution System

The NOAA LRIT service became operational October 1, 2005. The LRIT broadcasts provide the users with additional imagery data, products and broadcast services. Service included in the LRIT broadcast includes the GOES Data Collection Service in-situ observations, the NWS' Emergency Manager's Weather Information Network (EMWIN), GOES visible and infrared imagery, and other hydrometeorological products. Users may purchase the necessary equipment (computer, software, antenna) from commercial companies for unlimited access to LRIT signals. There is no fee or license requirement required by NOAA to receive this data.

8.4 NOAAPORT Data Distribution System

The NOAAPORT broadcast system provides a one-way broadcast communication of NOAA environmental data and information in near-real time to NOAA and external users. This broadcast service is implemented by a commercial provider of satellite communications utilizing a C-band frequency.

The NOAAPORT data stream is similar to DOMSAT in that it operates on a separate domestic satellite. It differs from DOMSAT in the following ways:

- NOAAPORT contains imagery data, weather bulletins and other products, in addition to DCP messages.
- Only DCP messages processed by the National Weather Service are transmitted over NOAAPORT.
- There can be a several minute delay in retrieving DCP data via NOAAPORT; DOMSAT is almost instantaneous.

The overall flow of the major operational components that feed data to NOAAPORT is shown in the figure below.

Figure 17 Diagram of NOAAPort Distribution System

Weather data is collected by GOES satellite environmental sensors and NWS observing systems, and processed to create products. The products are fed to the AWIPS Network Control Facility (NCF) which routes the products to the appropriate NOAAPORT channel for uplink and broadcast.

8.5 Dedicated real-time communication lines

The NESDIS reception systems support a dedicated communications line for supplying selected data from the GOES DCS to the National Weather Service headquarters in Silver Spring, MD. The DCP data are transmitted to the NWS in the WMO bulletin format. This allows all users capable of processing WMO bulletins from the NWS to receive the data sent over this dedicated line.

8.6 Local Readout Ground Station (LRGS)

LRGS stands for Local Readout Ground Station. It it originally was simple a DOMSAT reception system that included a DOMSAT antenna, a DOMSAT receiver , and a computer processing system that could distribute data over a network. It has evolved through a series of government contracts with the United States Geological Survey Water Resources Discipline(USGS WRD), the United States Army Corps of Engineers, and the National Oceanic and Atmospheric Administration (NOAA) into a universal store-and-forward device for the reception and distribution of GOES DCS data. It can receive data via several satellite links and the Internet. It stores the raw DCP data efficiently for a month or more, automatically deleting the oldest data when preset storage limits are reached. It provides the DDS network service to distribute data efficiently to client processes connected as DDS clients..

The LRGS can retrieve data via any of the input interfaces as shown in Figure 18. The LRGS can be configured with multiple interfaces. It can merge data simultaneously from any or all of the interfaces shown at the left. The LRGS acts as a store-and-forward device. It archives any amount of historical data (limited only by available disk space) and provides network interfaces to a variety of programs shown at the right.

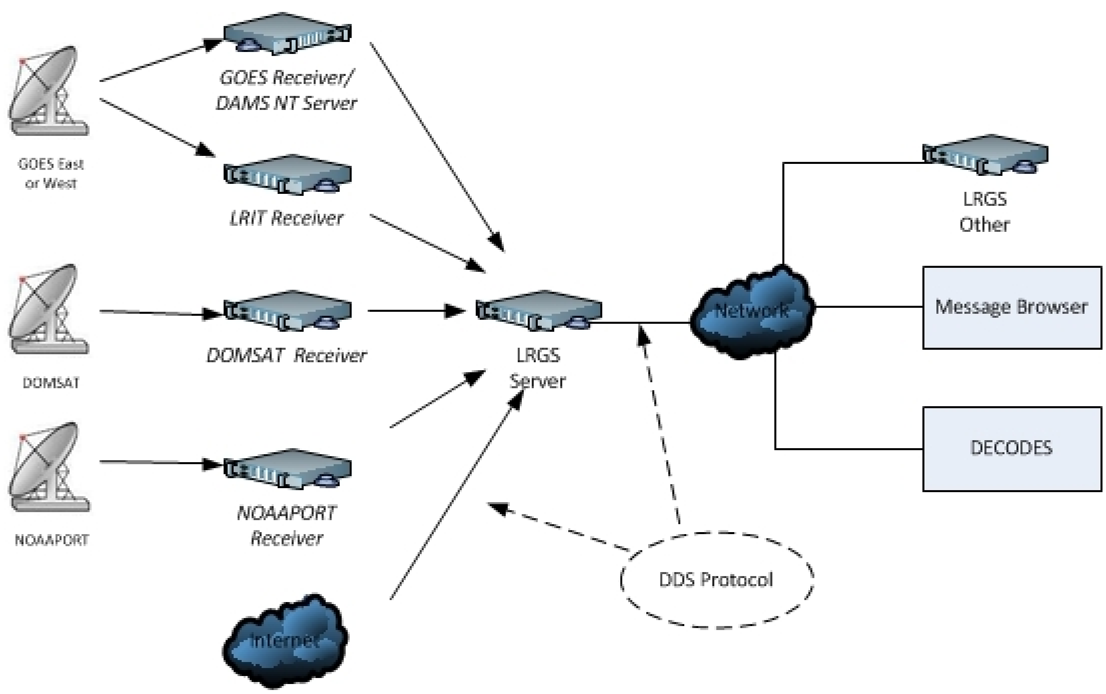

Figure 18 LRGS Store and Forward System

There are at least 3 software packages that can use the DDS service to acquire data: 1) the LRGS software supports the DDS protocol and can be configured to receive (as well as supply) the Internet data stream in real-time, 2) a public domain message browser supports retrieving data interactively using the DDS, and 3) a public domain data decoder named DECODES that supports receiving and decoding data using the DDS protocol.

8.7 Data Formats Used for Distribution

There are two data formats used for data distribution. One is used for distributing data to the NWS and consequently to the NOAAPORT system and the other used for all other distribution systems.

8.7.1 Format used for NWS dedicated line and NOAAPORT

The general format used for distributing data to the NWS and NOAAPORT is by means of a WMO Bulletin. WMO Bulletins are a standard established by the WMO for the transfer of meteorological data world wide. (See http://www.nws.noaa.gov/tg/head.html .)

The general format of the bulletin used for GOES DCS data is

Start of WMO Bulletin	WMO Product Identifier	Record Separator	DCP Header	Dcp Data	DCP Performance Measurments	GOES Channel and Satellite	End of WMO Bulletin

A detailed description of this format is provided in section F.1 of Appendix F. Data Distribution Formats,.

8.7.2 Format for distribution over DOMSAT, Network, LRIT

GOES DCS data are distributed to DOMSAT, LRIT, and the Internet in this general format:

DCP Header	DCP Performance Measurements	GOES Channel and Satellite	DCP Reception Source	Dcp Data

A detailed description of this format is provided in section F.2 of Appendix F. Data Distribution Formats.

Section 9 GOES DCS Interrogation System

A description of the GOES DCS Interrogation System will be included when the new interrogation system has been implemented.

Section 10 GOES DCS System Management

The Data Administration and Data Distribution System (DADDS) in addition to serving as an integral part of the GOES DCS reception and dissemination system for the NESDIS systems, it also manages the database that stores information about DCPs operating within the GOES DCS. DADDS provides the following capabilities to all registered users:

1. Retreive DCP data by platform id or group id,
2. View information stored about platforms, radios, channels, and radios.
3. View the status of GOES channels.
4. View the status of DADDS processing tasks that includes the status of the data reception from the DRGSs,, dissemination of data to DOMSAT and to the NWS dedicated communication line, and the status of the message processor.

In addition, DADDS provides the capability of updating the DCP information that is required by NESDIS to privileged users.

The generation of the unique 8-character DCP IDS that are assigned to DCPs for identification and that include a correction code that allows the id to be corrected if a single bit is corrupted during transmission are maintained in an off-line database separate from DADDS. The DCP IDs are assigned from this database upon request, and the assigned ids are entered into DADDS after assignment.

Section 11 System Redundancy

As the GOES DCS matured from an experimental system into a critical operational one, the need for system redundancy became more important to support continuity of operations. The deployment of the EDDN in June of 2008 at the USGS's EROS Data Center in Sioux Falls, South Dakota provided an alternate system for receiving and distributing data from all GOES channels which until that time had been done exclusively by the Wallops Command and Data Acquistion Station at Wallops Island and, for this function, was a single point of failure. The system redundancy was further enhanced by the deployment in 2008 of the backup system at the NSOF's Satellite Operations Control Center (SOCC) in Suitland, Maryland. This system provides a backup of the data reception and distribution system and the system management functions. Table lists the components of the GOES DCS and the existing backups for each component.

Component		Primary	Backups
GOES Satellites	Satellite	GOES East at 75^{o} West GOES West at 175^{o} West	Most recently launched GOES satellites that are position in a standby mode between the two operational satellites.
	Command and Control	Wallops Command and Data Acquisition station(WCDAS) at Wallops Island, Virginia	For GOES West, the Command and Data Acqusition Station (CDAS) at Fairbanks Alaska. For GOES East, there is no current operational backup, but there are emergency procedures to enlist a NASA facility in case of a failure. A backup for both GOES East and West will be provided by the new Remote Backup (RBU) facility that will be located at Fairmont, West Virginia.
GOES Pilot Transmitters		Wallops Command and Data Acquisition station(WCDAS) at Wallops Island, Virginia	Godard Space Center in Greenbelt Maryland.
Reception and Distribution Systems		Wallops Command and Data Acquisition station(WCDAS) at Wallops Island, Virginia	NSOF Satellite Operations Control Center at Suitland, Maryland Emergency Data Distribution Network at Sioux Falls, Sough Dakota
GOES DCS System Management		Wallops Command and Data Acquisition station(WCDAS) at Wallops Island, Virginia	NSOF Satellite Operations Control Center at Suitland, Maryland

Section 12 Major Uses of the GOES DCS

The GOES DCS is used by federal, state and international agencies, academic institutions and private industry to collect various types of environmental data. The data collected are used to support critical operational systems that need real-time data to make operations decisions as well as support long-term environmental research programs. A number of the activities that are highly dependent on data from the GOES DCS are described in this section.

Flood Forecasting – One of the most critical activities for which the GOES DCS supplies real-time data is flood forecasting. Flood forecasting allows for timely warnings that save lives and decrease property damage. Flood forecasts are based upon river models that provide estimates of how a river will respond to rainfall. These models depend on current data collected from stream gages and precipitation gages in the relevant area. The National Weather Service (NWS), which is part of the National Oceanic and Atmospheric Administration, is the federal agency charged by law with the responsibility for issuing river forecasts and flood warnings and develops, and maintains the forecast models. The data supplied to these models originates from a network of stream and precipitation gages operated by several federal, state, and local agencies using the GOES DCS. The GOES DCS supplies the real-time data from this network of gages to 13 NWS river-forecast centers in real-time for inclusion into their forecast models. These data are deemed essential by the forecast centers for accurate forecasts.

Water Supply Applications – Streamflow transmitted over the GOES DCS are used by water managers to make daily operational decisions concerning the allocation of water for use by municipalities, industry, and agriculture as well as for use in hydroelectric power generation and managing the water levels in reservoirs for flood control. There are over 2,900 gages operated by the United States Geological Survey, Army Corps of Engineers, the Bureau of Reclamation and other agencies that transmit data over the GOES DCS to assist in operating more than 2,000 flood control, navigation, and water-supply reservoirs.

Recreational Activities – The same streamflow data that are transmitted over the GOES DCS and used for flood forecasting and managing water supplies are also available to anyone planning outdoor recreational activities through public web sites operated by the USGS, the Corps of Engineers, the NWS, and others. Such information as how high or low the water in a stream is or how fast the water is flowing at the current time benefits countless outdoor enthusiasts, from canoeists and whitewater rafters, to fisherman and swimmers and the safety of such activities.

Tsunami Warning – The GOES DCS is one of the data collection systems used to acquire data from sea-level gauges that is used in developing tsunami warnings. Sea-level gauges are usually located on piers in harbors along coastlines throughout the world. The data from these gauges are primarily used for monitoring the tides for navigation purposes, but are also used by the tsunami warning centers to monitor the sea level and determine whether tsunamis were generated for a given earthquake. Sea level data are used to confirm the generation of a tsunami and to predict the tsunami hazard for locations where the waves have yet to strike. They are critical to the warning centers' ability to provide timely and accurate tsunami watches, warnings and cancellations.

U.S. Port Management – The GOES DCS supplies real-time water-level data for use in the PORTS® system operated by the National Ocean Service(NOS). PORTS® is a system that integrates real-time environmental observations (e. g. wind speed and direction, atmospheric pressure, air and water temperature), forecasts, and other geospatial information to promote navigation safety, improve the efficiency of U.S. ports and harbors, and ensure the protection of coastal marine resources.

Wildfire Warning and Management – Wildfire warning and management is supported by data transmitted by nearly 2,200 DCPs in the GOES DCS. The GOES DCPs bundled with a specified set of sensors to measure data related to soil and weather conditions are deployed as Remote Automated Weather Stations (RAWS.) RAWS stations are deployed in strategic locations throughout the United States where they can monitor fire danger. They are also packaged for rapid deployment in areas where data need to be collected to monitor changing conditions. Fire managers use these data to predict fire behavior and monitor fuels; resource managers use the data to monitor environmental conditions. The data from these stations also assist land management agencies with a variety of projects such as monitoring air quality, rating fire danger, and providing information for research applications.

Climate Monitoring – The GOES DCS is used to collect data to support the U.S. Climate Reference Network (USCRN) which consists of stations deployed in the continental United States for the express purpose of detecting long-term climate change. These stations are managed to provide a high-quality climate observation network to monitor climate change over the next 50 years. Three independent measurements of temperature and precipitation are made at each station, insuring continuity of record and maintenance of well-calibrated and highly accurate observations. The stations are placed in pristine environments expected to be free of development for many decades. Stations are monitored and maintained to high standards, and are calibrated on an annual basis. In addition to temperature and precipitation, these stations also measure solar radiation, surface skin temperature, and surface winds, and are being expanded to include triplicate measurements of soil moisture and soil temperature at five depths, as well as atmospheric relative humidity. Experimental stations have been located in Alaska since 2002 and Hawaii since 2005, providing network experience in polar and tropical regions. Deployment of a complete 29 station USCRN network into Alaska began in 2009. This project is managed by NOAA's National Climatic Data Center and operated in partnership with NOAA's Atmospheric Turbulence and Diffusion Division.

Management of Remote Data Collection – The GOES DCS provides the ability to collect data in almost any location within North and South America and as far west as Eastern Australia. Having data from real-time sensor and performance data through the from such remote sites through the GOES DCS improves the quality and quantity of the data collected. Problems with remote DCPs, such as sensor failures, low battery power, etc., can be detected immediately which allows for the efficient scheduling of field trips to correct any specific problem and to perform routine maintenance as needed. This greatly improves the quality of the data collected and prevents long periods of missing data.

Section 13 GOES DCS Users

There are over xx DCP assignments in the GOES DCS made to federal, state and international agencies, academic institutions and private industry. Figure xxx provides a summary of the DCP assignments for domestic and international users. The major users are described in this section.

13.1 National Oceanic Atmospheric Administration (NOAA)

Several NOAA agencies have critical programs that require real-time data from the GOES DCS. This includes the National Weather Service (NWS), the Nation Oceanic Survey (NOS), the National Environmental Satellite Data Information System (NESDIS.)

13.1.1 National Weather Service

The National Weather Service (NWS) uses real-time data from the GOES DCS to support

1. the flood, flash flood, and other warning programs at its forecast centers throughout the United States,
2. monitoring gulfs and oceans from fixed buoys,
3. monitoring changes in the climate.

Data collected by the GOES DCS are supplied to the NWS's Weather Forecast Offices (WFOs) and River Forecast Centers (RFCs) who use the data in their hydrologic models and create informational displays that may be viewed on the NWS's Advanced Hydrologic Prediction Service (AHPS) web page which is an essential component of the NWS's Climate, Water, and Weather Services. AHPS is a web-based suite of accurate and information-rich forecast products that display the magnitude and uncertainty of occurrence of floods or droughts, from hours to days and months, in advance. These graphical products are useful information and planning tools for many economic and emergency managers. AHPS enables government agencies, private institutions, and individuals to make more informed decisions about risk based policies and actions to mitigate the dangers posed by floods and droughts. Figure 19 shows a AHPS flood forecast display at the Big Sioux River at Akron, South Dakota. The actual observations from a GOES DCP operated by the United States Geological Survey is shown in blue; the NWS forecast is shown in green.

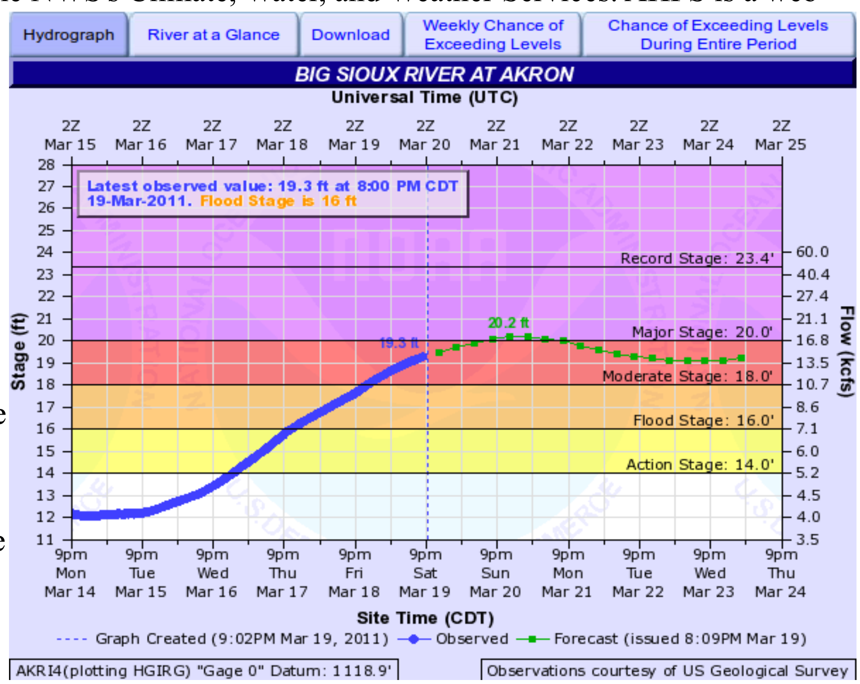

Figure 19: Example of AHPS Forecast for the Big Sioux River at Akron, S.D.

The data from the GOES DCS is supplied to the WFOs and RFCs by the Hydrometeorological Automated Data System (HADS) operated by the Office of Hydrologic Development of the National Weather Service. The HADS system is a data acquisition, data processing, and data distribution system. It acquires GOES DCS data from three dissemination sources to insure an adequate backup for data acquisition:

1. a dedicated communications line from a NESDIS receive site,
2. a local DOMSAT receiver,
3. a dedicated real-time connection to the EDDN.

HADS translates the data received from DCPs using meta data stored about each DCP into the NWS's Standard Hydrometeorological Exchange Format (SHEF) and disseminates the SHEF-encoded data along with other SHEF-encoded products derived from these data to each of the 13 River Forecast Centers (RFCs) and 122 Weather Forecast Offices(WFOs) in the county. The WFOs and RFCs subsequently use the data in their hydrologic models and create the informational displays that may be viewed on the AHPS web pages. In addition to supplying the GOES DCS data to the WFOs and RFCs, HADS also provides the data to several specialized users within the NWS. The data are distributed via the internal NWS communication system AWIPS - Satellite Broadcast Network (SBN) and to external users via NOAAPORT. Some of the data products are also distributed to the river forecast centers via the Internet. HADS also provides meta-data for each DCP along with tabular and graphical displays of the data on the Internet. The NWS uses data from over 14,200 DCPs operating in the GOES DCS while directly operating only a relatively small network of DCPs themselves. The vast majority of these DCPs are owned and operated by other federal, state and local agencies who share the data with the NWS. The NWS reciprocates by sharing derived hydrologic and meteorological products and information with these agencies. The primary agencies who supply data to the NWS from their GOES DCPS are the Water Resources Division of the U.S. Geologic Survey, the U.S. Army Corp of Engineers, the Tennessee Valley Authority, the Bureau of Land Management, the U.S. Forest Service, the Bureau of Reclamation, and departments of natural resources from numerous state and local agencies throughout the country.

13.1.1.1 National Data Buoy Center

The Natioanl Data Buoy Center of the NWS uses the GOES DCS to supply frequent, high-quality marine observations from data buoys to NWS forecasters to assist in preparing and validating forecasts of maritime conditions. The observations and derived forecasts are used for commercial and recreational activities. NDBC provides hourly observations from a network of about 90 buoys and 60 Coastal Marine Automated Network (C-MAN) stations. All stations measure wind speed, direction, and gust; barometric pressure; and air temperature. In addition, all buoy stations, and some C-MAN stations, measure sea surface temperature and wave height and period. Conductivity and water current are measured at selected stations. The observations from moored buoys and C-MAN stations are transmitted hourly through NOAA Geostationary Operational Environmental Satellites (GOES) to a ground receiving facility at Wallops Island, VA, operated by the NOAA National Environmental Satellite, Data, and Information Service (NESDIS). The satellite reports are immediately relayed to the NWS Telecommunications Gateway (NWSTG) in Silver Spring, MD. At the NWSTG, NDBC systems perform automated quality control on the reports. Data analysts at NDBC monitor the data and adjust the controls to release only good quality data. From the NWSTG, the data are transmitted via various communications networks to NDBC and NWS offices. Private meteorologists receive the reports via the NWS Family of Services. The general public may receives the data via the Internet.

After additional quality analysis, NDBC data are transmitted to NOAA's archive centers, the National Oceanographic Data Center, NODC, and the National Climatic Data Center, NCDC.

Surveys of meteorologists have shown about 40 percent of NWS marine warnings and advisories are based, at least in part, on NDBC's meteorological data. In addition to this critical purpose, the observations are used by meteorologists who need to adjust flight level wind speeds reported by hurricane reconnaissance aircraft to surface winds; by geophysicists who use our sea surface temperature, wind, and wave reports to help calibrate remotely sensed measurements from spacecraft; and by engineers who obtain directional wave measurements to study beach erosion and shore protection.

Surfers, fishermen, and boaters acquire the reports via the Internet to help them determine if they want to venture offshore.

13.1.1.2 Historical Climate Network

The GOES DCS will be used to support the Historical Climate Network (HCN) which provides a network of sites to provide the most accurate, unbiased, modern historical climate record available for detecting climate change in the US over the past 100 years or more, The HCN is a sub-network of Cooperative Observer Network (COOP) consisting of 1221 stations. The HCN stations are maintained by the NOAA’s NWS and the HCN data set is maintained by NOAA’s National Climatic Data Center (NCDC). The HCN-M will sustain the Nation’s regional climate record through modernization of the HCN. Specially, this project will:

- Modernize 1,000 of the existing 1221 HCN stations to collect temperature and precipitation data through automation;
- Provide for expansion capacity to collect other data sets (e.g., National Integrated Drought Information System (NIDIS), dataset); and
- Address gaps in the HCN including: data quality, data availability, and aging technology.

13.1.2 National Ocean Service (NOS)

The National Ocean Service (NOS) is responsible for providing real-time oceanographic data and other navigation products to promote safe and efficient navigation within U.S. waters. The need for these products is great and rapidly increasing; maritime commerce has tripled in the last 50 years and continues to grow. Ships are getting larger, drawing more water and pushing channel depth limits to derive benefits from every last inch of draft. By volume, more than 95 percent of U.S. international trade moves through the nation's ports and harbors, with about 50 percent of these goods being hazardous materials. A major challenge facing the nation is to improve the economic efficiency and competitiveness of U.S. maritime commerce, while reducing risks to life, property, and the coastal environment. With increased marine commerce comes increased risks to the coastal environment, making marine navigation safety a serious national concern. From 1996 through 2000, for example, commercial vessels in the United States were involved in nearly 12,000 collisions, allisions, and groundings.

13.1.3 National Environmental Satellite Data Distribution System (NESDIS)

Figure 20: U.S. Climate Reference Site with GOES DCP in the North Cascades National Park, State of Washington

NOAA/NESDIS uses the GOES DCS to collect data from sites in its **U.S. Climate Reference Network (USCRN)** which currently consists of 114 stations and is managed by NOAA's National Climatic Data Center of NESDIS and operated in partnership with NOAA's Atmospheric Turbulence and Diffusion Division. Each site provides three independent measurements of temperature and precipitation insuring continuity of record and maintenance of well-calibrated and highly accurate observations. The stations are placed in pristine environments expected to be free of development for many decades. Figure 20 shows one of the stations in the North Cascades National Park. The stations are monitored and maintained to high standards, and are calibrated on an annual basis. In addition to temperature and precipitation, these stations also measure solar radiation, surface skin temperature, and surface winds, and are being expanded to include triplicate measurements of soil moisture and soil temperature at five depths, as well as atmospheric relative humidity. Experimental stations have been located in Alaska since 2002 and Hawaii since 2005, providing network experience in polar and tropical regions. Deployment of a complete 29 station USCRN network into Alaska began in 2009. It is anticipated that this network will grow to over 500 sites.

13.2 United States Geological Survey – Water Resources Discipline

The Water Resources Discipline (WRD) of the U.S. Geological Survey (USGS) conducts the critical mission of monitoring the Nation’s surface and ground water resources through a Nation-wide network of surface water streamgages and ground water wells. The overwhelming majority of the streamgages and wells in the WRD's data collection network that use telemetry systems use the Geostationary Operational and Environmental Satellite Data Collection System (GOES-DCS) for transmitting data. In year 2010, the USGS operated over 8,700 GOES Data Collection Platforms (DCPs) at streamgages and over 1000 at ground water wells making the GOES DCS a critical component of WRD's real-time data collection system.

13.2.1 Surface Water Streamgages

Most of WRD's surface water streamgages are equipped with telemetry equipment that allows data to be transmitted from them in near real-time, usually hourly. Figure 21 provides a visual summary of the location of these streamgages throughout the nation. The green dots show streamgages that transmit data in near real-time. The red dots show streamgages that only record data locally.

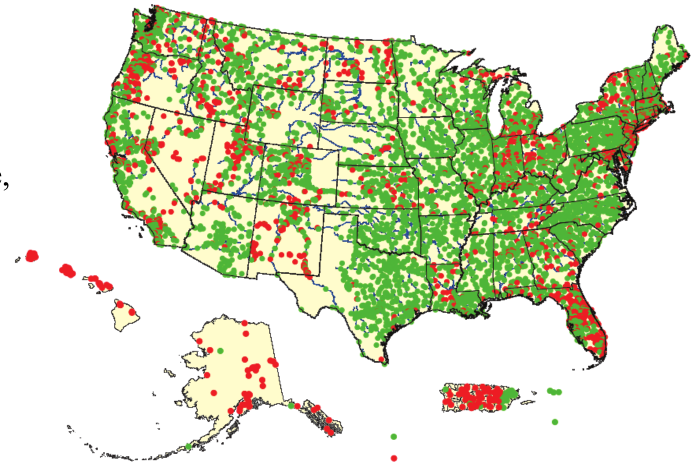

Figure 21: USGS Streamgages

These streamgages provide up-to-date streamflow information for a wide variety of uses including flood prediction, water management and allocation, engineering design, research, operation of locks and dams, and recreational safety and enjoyment. They are operated by the USGS in partnerships with more than 800 Federal, State, Tribal, and local cooperating agencies. Figure 22 shows an USGS streamgage with a GOES DCP.

Figure 22: Example of USGS Streamgage with GOES DCP

13.2.2 Ground Water Wells

The WRD ground water network consists of thousands of wells in the United States where groundwater level data are collected and stored as either discrete water level measurements or as continuous time-series data from automated recorders. Over 1200 of these sites have GOES DCPs for collecting real-time ground water data. These data are used for ground water management, especially in monitoring drought conditions, monitoring groundwater quality, and managing well fields. Figure 23 shows an USGS groundwater well with a GOES DCP.

Figure 23: Example of USGS Ground Water Well with GOES DCP

13.2.3 Acquisition and Processing of Data From GOES DCS

The USGS acquires its data from two sources. The primary source is the GOES receive site operated by NESDIS at Wallops Island. A backup to the primary source is the GOES Emergency Data Dissemination Network (EDDN) system operated by the USGS at Sioux Falls, South Dakota. The data are entered into the WRD's National Water Information System (NWIS) where they are processed and stored. Other agencies acquire the processed data from the NWIS's website and the unprocessed data directly from the GOES receive sites at Wallops Island or Sioux Falls or their own.

The data from streamgages and ground water wells with DCPs transmitting over the GOES DCS are made available to the public in near real-time by means of the NWIS Web site: (http://waterdata.usgs.gov/nwis).

Figure 24 provides a hydrograph generated by NWIS using the data transmitted by the same DCP that provided data for the NWS forecast in Figure 19.

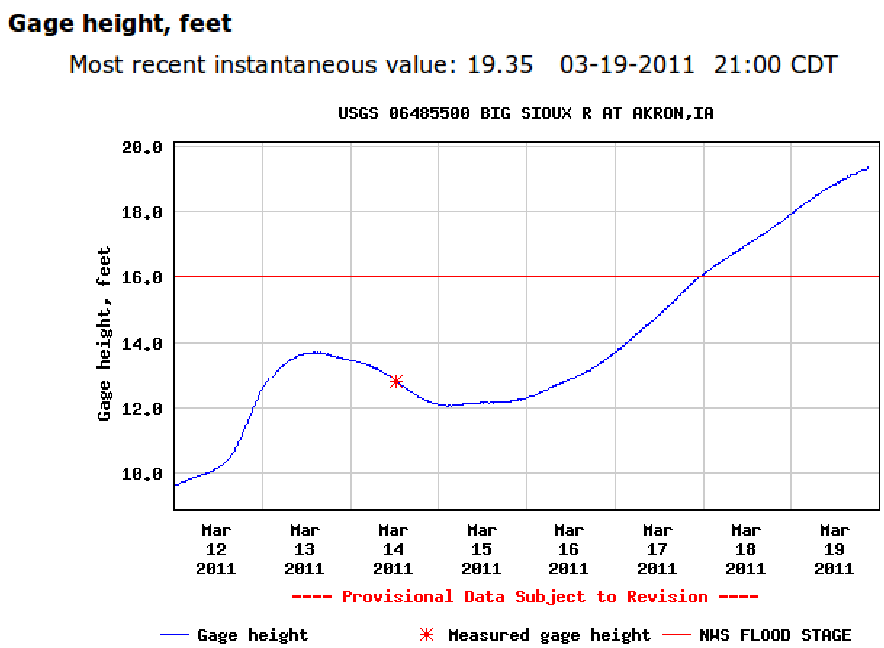

Figure 24: USGS Hydrograph of the Big Sioux River at Akron, Iowa

13.3 United Stages Geological Survey – Geologic Discipline

The GOES Data Collection System is used to collect real-time deformation data from active earthquake fault zones and volcanic regions in the United States. The system plays a critical part in our monitoring effort for real-time fault failure, earthquake size, surface rupture, magma injection under volcanoes, and explosive eruption detection from volcanoes. The GOES DCS provides invulnerability during large earthquakes and volcanic eruptions when power and phones cease to operate. It also provides independence of the transmitting sites such that failure of any particular site does not affect the capability of other sites to continue transmitting. The GOES system provides reliability during and after a large event to enable transmission of data that may provide information useful in reducing future risks to public health and safety involving seismic and volcanic hazards.

13.4 Bureau of Reclamation

Established in 1902, the Bureau of Reclamation is best known for the dams, powerplants, and canals it constructed in the 17 western states. These water projects led to homesteading and promoted the economic development of the West. Reclamation has constructed more than 600 dams and reservoirs including Hoover Dam on the Colorado River and Grand Coulee on the Columbia River.

Today, we are the largest wholesaler of water in the country. We bring water to more than 31 million people, and provide one out of five Western farmers (140,000) with irrigation water for 10 million acres of farmland that produce 60% of the nation's vegetables and 25% of its fruits and nuts.

Reclamation is also the second largest producer of hydroelectric power in the western United States. Our 58 powerplants annually provide more than 40 billion kilowatt hours generating nearly a billion dollars in power revenues and produce enough electricity to serve 3.5 million homes.

Today, Reclamation is a contemporary water management agency with a Strategic Plan outlining numerous programs, initiatives and activities that will help the Western States, Native American Tribes and others meet new water needs and balance the multitude of competing uses of water in the West. Our mission is to assist in meeting the increasing water demands of the West while protecting the environment and the public's investment in these structures. We place great emphasis on fulfilling our water delivery obligations, water conservation, water recycling and reuse, and developing partnerships with our customers, states, and Native American Tribes, and in finding ways to bring together the variety of interests to address the competing needs for our limited water resources.

13.5 National Interagency Fire Center (NIFC)

The National Interagency Fire Center (NIFC), located in Boise, Idaho, is the nation's support center for wildland firefighting. Eight different agencies and organizations are part of NIFC. Decisions are made using the interagency cooperation concept because NIFC has no single director or manager. The NIFC uses the GOES DCS to transmit weather data from their network of Remote Automated Weather Stations (RAWS.) The network consists of nearly 2,200 interagency RAWS units strategically located throughout the United States. These stations monitor the weather and provide weather data that assists land management agencies with a variety of projects such as monitoring air quality, rating fire danger, and providing information for research applications. Figure 25 shows a standard RAWS unit.

Figure 25: RAWS Unit with GOES DCP on the Bull Elk Park Fire

Most of the RAWS units owned by the wildland fire agencies are placed in locations where they can monitor fire danger. RAWS units collect, store, and forward data to a computer system at the National Interagency Fire Center (NIFC) in Boise, Idaho. This computer receives GOES data from a DRGS receiver which is backed up by a LRGS receiver and the EDDN receive site. The GOES data are automatically forwarded to several other computer systems including the Weather Information Management System (WIMS) and the Western Regional Climate Center (WRCC) in Reno, Nevada.

Fire managers use these data to predict fire behavior and monitor fuels; resource managers use the data to monitor environmental conditions.

13.6 United States Corps of Engineers

The civil works mission of the Army Corps of Engineers (Corps) is to construct and manage water projects for flood control, navigation, and other purposes authorized by Congress. The Corps' charter as a principal water resources development agency for the nation places broad responsibilities on the Corps to manage limited water resources for best overall public interest. As such, the Corps is responsible for the judicious operation of these projects.

Real-time data such as river stage, precipitation, and temperature are needed to judiciously operate projects for their authorized purposes. The Corp uses the GOES DCS to provide a reliable, real-time, and cost-effective means of collecting these data from remote sites. The data collected are subsequently used for analysis, forecasting, and reservoir control decision-making, and managing Corps water projects. Each Corps division manages its own network of DCPs.

13.6.1 Rock Island Division

The Rock Island Division of the U.S. Army Corps of Engineers maintains 180 GOES DCPs in Iowa and Illinois that are used to monitor water levels of rivers and lakes in order to operate flood control and navigation dams. The GOES DCS data are received from DOMSAT and DRGS receivers. The GOES data are critical to the Rock Island Division's ability to regulate its projects .

13.6.2 Great Lakes and Ohio River Division

The Great Lakes and Ohio River Division receives data from over 100 GOES DCPs. It has been using the GOES Data Collection System since 1989 to provide real-time hydrologic data for regulating its reservoirs, locks, and dams to reduce flooding, support the navigation and ensure dam safety. The GOES DCS data are received from DOMSAT, a DRGS receiver and is backed up by the EDDN and NESDIS receive sites. They also act as a backup to other GOES users throughout the Great Lakes and Ohio River Division and other Divisions within the US Army Corps of Engineers.

13.6.3 Portland Division

The Corps Portland Division receives data from DCPs over GOES DCS to monitor the operation of 22 dams. The authorized purposes of the dams include flood control, power generation, navigation, water supply, water quality, fish and wildlife, and recreation. The DCPs are placed in crititical areas to monitor inflow, reservoir pool elevation, outflow, and key locations along the rivers. Data are collected to monitor both water quantity and quality at the DCP sites.

13.6.4 Fort Worth Division

The Fort Worth Division Reservoir control office uses the GOES DCS to collect rainfall and weather data from approximately 20 sites in Texas. The division uses these data in its mission of real time flood control operations for the 25 Corps of Engineers reservoirs that it manages. The data are used to make reservoir releases and to compile data for ongoing historical records. The data are also shared with local, state, and federal cooperators as well as to the public.

13.6.5 Tulsa Division

The Tulsa Division receives data from over 560 DCPs that transmit over the GOES DCS to support its the Water Control Projects. These DCPS transmit data from 1 to 15 types of sensors to provide the necessary information to manage controlled releases from the division's dams for stage reduction, hydro-power generation, navigation, and other environmental reasons. Real-time data are necessary to make releases in response to rapidly changing weather conditions to mitigate flooding that could cause the loss of life and property and structural damage to the reservoirs. Data transmitted over the GOES DCS is by far the division's most important source of such data. The division receives data transmitted by its DCPs from the NESDIS receive sites and uses various LRGS systems as backups.

13.6.6 Memphis Division

The Memphis Division Corps of Engineers receives data from over 68 data collection platforms (DCP) that operate on the GOES DCS. These DCP's transmit data from a variety of sensors including but not limited to river stage, precipitation, and battery voltage. Figure 26 provides an example of a Corps' gage in the Memphis Division from which a GOES DCP transmits data.

Figure 26: Example of Corps of Engineer's Gage with GOES DCP

13.7 State of Colorado

The State of Colorado uses real-time data transmitted by DCPs over the GOES DCS for four activites:

- water rights administration,
- hydrologic records development,
- water resources accounting, and
- dam safety.

13.7.1 Water Rights Administration

The primary utility of the Colorado satellite-linked monitoring system is for water rights administration. The availability of real-time data from a network of key gaging stations in each major river basin in Colorado provides an overview of the hydrologic conditions of the basin that was previously not available. By evaluating real-time data for upstream stations, downstream flow conditions can typically be predicted 24 to 48 hours in advance. This becomes an essential planning tool in the hands of the Division Engineers and Water Commissioners. The "river call" can be adjusted more precisely to satisfy as many water rights as possible, even if just for short duration flow peaks caused by precipitation events. Access to real-time data makes it possible to adjust the "river call" to match dynamic hydrologic conditions. If additional water supplies are available, more junior rights can be satisfied. On the other hand, if water supplies decrease, then water use can be curtailed to protect senior rights.

The administration of water rights in Colorado is becoming increasingly more complex due to increased demands, implementation of augmentation plans, water exchanges, transmountain diversions, and minimum stream flow requirements. For example, the number of water rights has increased from 102,028 in 1982 to over 173,000 in 2007. Increasing numbers of water rights has continued to the present. Water rights transfers approved by the water courts are becoming increasingly complex. This is especially evident where agricultural water rights are transferred to municipal use.

There is considerable interest in monitoring transmountain diversions, both by western slope water users and the eastern slope entities diverting the water. Trans-mountain diversion water is administered under different laws than water originating in the basin. In general, this water may be claimed for reuse by the diverter until it is totally consumed. Forty transmountain diversions are monitored by the SMS.

Water exchanges between water users are becoming increasingly frequent. These exchanges can provide for more effective utilization of available water resources in high demand river basins, but can be difficult to administer. The satellite-linked monitoring system has proven to be an integral component in monitoring and accounting of these exchanges.

Many municipalities and major irrigation companies have reservoir storage rights. Generally, these entities can call for release of stored water on demand. The Division Engineer must be able to delineate the natural flow from the storage release while in the stream. He/she then must track the release and ensure that the proper delivery is made. The SMS has demonstrated to be effective in this area.

The utility of the SMS in the administration of interstate compacts is an especially important application. The State Engineer has the responsibility to deliver defined amounts of water under the terms of the various interstate compacts, but not to over-deliver and deprive Colorado of its entitlement. Data collected from over twenty gage stations operated by both the CO DWR and the USGS are incorporated in the Statewide monitoring network and utilized for the effective administration of these interstate compacts.

The majority of the large, senior water rights in Colorado belong to irrigation companies. These rights are often the calling right in the administration of a water district. The direct diversion rights exercised can affect significantly the hydrology of the river. Dozens of major irrigation diversions are monitored by the system.

Water rights have been acquired by federal and state agencies to guarantee minimum stream flow for both recreational and fisheries benefits. As well, instream flow water rights have been developed by the Colorado Water Conservation Board to ensure minimum instream flows are maintained in critical stream reaches around the State. The availability of real-time data is essential in ensuring that these minimum stream flows are maintained.

13.7.2 Hydrologic Records Development

Specialized software programs provide for the processing of raw hydrologic data on a real-time basis. Conversions such as stage-discharge relationships and shift applications are performed on a real-time basis as the data transmissions are received. Mean daily values are computed automatically each day for the previous day. Data values that fall outside of user defined normal or expected ranges are flagged appropriately. Flagged data values are not utilized in computing mean daily values. Missing values can be added and invalid data values corrected by the respective hydrographer for that station using data editing functions.

Data can be retrieved and displayed in various formats including the standardized US Geological Survey-Water Resources Division annual report format adopted by the Colorado Division of Water Resources for publication purposes. An advantage of real-time hydrologic data collection is in being able to monitor the station for on-going valid data collection. If a sensor or recorder fails, the hydrographer is immediately aware of the problem and can take corrective action before losing a significant amount of data.

It is essential to understand that real-time records can be different from the final record for a given station. This can be the result of editing raw data values because of sensor calibration errors, sensor malfunctions, analog-to-digital conversion errors, or parity errors. The entering of more current rating tables and shifts can modify discharge conversions. Corrections to the data are sometimes necessary to compensate for hydrologic effects such as icing. Human error can also result in invalid data. The final record for those gauging stations operated by non-state entities, such as the US Geological Survey-Water Resources Division, is the responsibility of that entity. Modifications to the real-time records for these stations are accepted by the State of Colorado.

The Hydrographic Branch develops historic streamflow records in coordination with other State and Federal entities and the water user community. At the conclusion of each water year, the State Engineer’s Office compiles streamflow information and measurements conducted throughout the year for publication. Published streamflow records describe the mean daily discharge, the instantaneous maximum, lowest mean discharge, and monthly/ annual volumetric totals for a specific location on a river or stream. These annual streamflow records are computed using two critical sources of information: streamflow measurements made throughout the water year to calibrate the stage-discharge relationship at a specific site, and, the electronic record of stream stage collected by the satellite monitoring system. Using these data a continuous record of streamflow for the water year is computed. Streamflow records undergo a rigorous data quality control/quality assurance program to ensure the product is accurate. The Division of Water Resources Hydrographic program computes and publishes over 240 streamflow records annually. Published historical streamflow data are extremely valuable in support of water resources planning and management decision-making, assessment of current conditions and comparisons with historical flow data, and hydrologic modeling.

13.7.3 Water Resources Accounting

Currently, the satellite-linked monitoring system is being utilized for accounting for the Colorado River Decision Support System (CRDSS), the Colorado-Big Thompson Project, the Dolores Project, and the

Fryingpan-Arkansas Project Winter Water Storage Program among others around the State. The ability to input real-time data into these accounting programs allows for current and on-going tabulations.

13.7.4 Dam Safety

Dam safety monitoring has developed in recent years into a major issue. Numerous on-site parameters are of interest to the State Engineer in assessing stability of a dam. At this time, the system monitors reservoir inflow, water surface elevation and reservoir release or outflow at more than fifty reservoirs in Colorado. These data provide a basis for evaluating current operating conditions as compared to specific operating instructions. The installation and operation of additional sensor types could provide essential data on internal hydraulic pressure, vertical and horizontal movement, and seepage rates.

13.8 Other U. S. States

- The State of California uses data transmitted over the GOES DCS data for reservoir management, water quality management, river forecasting activities, forest fire management, and other things.
- The State of Nebraska uses data transmitted over the GOES DCS in managing its streams in "real time" and helping to keep hydrologic records up to date in a timely manner. Data from its GOES DCPs also help other environmental and emergency management agencies within the state to collect reservoir, stream, river and precipitation data to help protect life and property in the state.
- The State of Nevada uses data transmitted over the GOES DCS to forecast runoff, provide early warnings of dam failures, and real-time operational decision-making.

13.9 Water Survey of Canada – Alberta Province

The Water Survey of Canada , Alberta Province operates the hydrometric network in Alberta in partnership with Alberta Environment. Water level information is collected to determine the flow past the gaging stations in this network in real-time to monitor flood events and to manage the flow of data for irrigation and the apportionment of water flow, especially in low flow periods. The GOES DCS is used to acquire real-time data from sites in this network. The real-time data is extremely important because many Alberta streams originate on the eastern slopes of the Rocky Mountains and flood conditions can occur quickly. The data from the GOES DCS are used to monitor the sites and the operational state of the DCP to determine when site visits are necessary.

Figure 27 illustrates the importance of the telemetry data received over the GOES DCS. The Little Red Deer River flows into Gleniffer Reservoir. The GOES DCP in the gaging station on the far side of the bridge transmitted water-level data that was used to determine the amount of water to spill out of the reservoir in order to limit the damage to cities and property downstream of the reservoir. A result of having this information, a town downstream added a foot to their dike and prevented flooding within the town.

Figure 27: GOES DCP on Little Red Deer River

13.10 Caribbean Nations

The GOES DCS is used in many Caribbean nations for flood monitoring, tsunami warnings, etc. The GOES DCS will be forming the backbone for an international tsunami warning network, and has dedicated channels for observations that can be received in transmission ranging from every 5 minutes to every 15 minutes.

13.11 Central and South America

The GOES DCS supports data collection systems in many Central and South American countries to support flood, fire, and weather monitoring.

Section 14 Future Enhancements

14.1 Narrowing the bandwidth of GOES DCS channels

The original DCPs used in the system transmitted at 100 baud and required a 1.5kHz bandwidth. The new 300 baud DCPs can transmit in a .75kHz bandwidth and the 1200 baud DCPs can transmit it 1.5kHz, which allows the bandwidth of all channels to be reduced by ½ with the result that the capacity of the GOES DCS will be doubled when all DCPs have been converted to either 300/1200 baud DCPs. To facilitate the transition to narrow-band channels, the bandwidth of each channel will be reduced by ¼ on each side which will maintain the center frequency of existing channels and require no modifications to already deployed DCPs. The new channels will be inserted between the existing channels and will be assigned new channel numbers starting at channel 301 and ending with 566. This method of allocating frequencies to channels will allow existing DCPs to be received by the new narrow-band demodulators as well as the old current demodulators and thus facilitating the transition to the new narrow bands.

Table 6 and Table 7 illustrate how channels 1-4 will be reduced from 1.5kHz to .75 kHz and how channels 301-304 will be inserted to maintain the center frequency of channels 1-4 so that existing DCPS transmitting on channels 1-4 will not be affected by the reduction of the channel bandwidths.

Channel	Frequency (MHz)			Bandwidth (kHz)
	Begin	Center	End	
1	410.700250	410.701000	410.701000	1.5kHz
2	410.701000	410.702500	410.703250	1.5kHz
3	410.703250	401.704000	410.704750	1.5kHz
4	410.704750	401.705500	410.706250	1.5kHz

Table 6: Current 1.5kHz frequency band for channels 1-4 (center frequency in blue)

Channel	Frequency (MHz)			Bandwidth (kHz)
	Begin	Center	End	
1	410.700625	410.701000	410.701375	0.75
301	410.701375	410.701750	410.702125	0.75
2	410.702125	410.702500	410.702875	0.75
302	410.702875	410.702875	410.703250	0.75
3	410.703250	401.704000	410.704375	0.75
303	410.704375	401.704750	410.705125	0.75
4	410.705125	401.705500	410.705975	0.75
. . . . .				

Table 7: New .75 kHz frequency bands for channels 1-4, 301-303 (center frequency in blue)

14.2 Redesign of the GOES interrogation System

The GOES system for interrogating remote DCPs is being redesigned to facilitate the management of DCPs including setup and maintenance. The old system provided a mechanism for communicating with DCPs, but left it up to individual users to define the functions to be communicated. It also did not provide a user interface suitable for an operational system.

The new design will

- establish a centralized user gateway that will perform user authentication and security and will control the types of commands send and responses received,
- define the protocol that will allow DCPs to connect and receive commands from a field receiver, and
- define a set of common commands that will be supported by all DCPs, and
- a mechanism to allow vendor-specific commands to be used.

Some of the common functions for which commands will be developed include

- adjusting transmission settings, e.g. assignment time, channel, transmission interval, etc.
- requesting additional data, and
- performing remote diagnostics.

14.3 Additional GOES Backup Facility

For the fourth generation of GOES satellites starting at GOES-R, a new Remote Backup (RBU) facility is scheduled to be established in Fairmont, West Virginia that will include the new Ground Segment for these new satellites. The new Ground Segment will be a distributed system with three operational sites. Currently, the operational facilities include the NOAA Satellite Operations Facility (NSOF) in Suitland, MD and the Wallops Control and Data Acquisition Station (WCDAS) at Wallops, VA. With the addition of the new RBU facility at Fairmont, West Virginia, the ground segment functions will be distributed across these three prime sites. The NSOF will house primary Mission Management and Enterprise Management functions, Product Generation, and prime Product Distribution functions. The WCDAS will provide primary space communications services and primary product generation. The RBU will function as an independent backup to maintain satellite health and safety and to provide the production and delivery of, at a minimum, key performance and legacy products including the GOES DCS. The RBU will provide a complete backup of the other two sites in a geographic location sufficiently far away from both of them so as not to be influenced by any extreme event that might affect the operations of those systems.

Appendix A. Abbreviations

-A-

AWIPS	Advanced Weather Interactive Processing System

-B-

BIA	Bureau of Indian Affairs
BLM	Bureau of Land Management
bps	bits per second
BuMines	Bureau of Mines

-C-

CDA	Command and Data Acquisition
COE	U.S. Army Corps of Engineers

-D-

D	Dual (domestic and international) channel DCP
DAMS	Data Acquisition and Monitoring System
DAPS	DCS Automatic Processing System
DBMS	Data Base Management System
DCP	Data Collection Platform
DCS	Data Collection System
DOC	Department of Commerce
DOD	Department of Defense
DOE	U.S. Department of Energy
DOI	Department of the Interior
Domsat	Domestic Satellite
DOS	U.S. Department of State
DOT	U.S. Department of Transportation
DRGS	Direct Readout Ground Station
DROT	Domsat Receive-Only Terminal

-E-

EPA	Environmental Protection Agency

-F-

FS	Forest Service
FWS	Fish and Wildlife Service
FY	Fiscal Year

-G-

GMS	Geosynchronous Meteorological Satellite
GOES	Geostationary Operational Environmental Satellite

-H-

HAZMAT	hazardous material
HS	Hydrology Subcommittee
Hz	Hertz or cycles per second

-I-

ICMSSR	Interdepartmental Committee for Meteorological Services and Supporting Research

-K-

kHz	kilohertz

-L-

Landsat	Land Satellite

-M-

METEOSAT	Meteorological Satellite
MHz	megahertz
MOA	Memorandum of Agreement

-N-

NASA	National Aeronautics and Space Administration
NCAR	National Center for Atmospheric Research
NCEP	National Centers for Environmental Prediction
NDBC	National Data Buoy Center
NESDIS	National Environmental Satellite, Data, and Information Service
NICC	National Interagency Coordinating Center
NIFC	National Interagency Fire Center
NOAA	National Oceanic and Atmospheric Administration
NOS	National Ocean Service
NPS	National Park Service
NSC	NOAA Science Center
NSF	National Science Foundation
NWLON	National Water Level Observation Network
NWS	National Weather Service

-O-

OAR	Office of Oceanic and Atmospheric Research
OFCM	Office of the Federal Coordinator for Meteorological Services and Supporting Research
OMB	Office of Management and Budget
OSDPD	Office of Satellite Data Processing and Distribution

OWDC	Office of Water Data Coordination

-P-

PD	Presidential Directive
PDT	Platform Description Tables

-R-

RAWS	Remote Automatic Weather Station
REMS	Remote Environmental Monitoring System
RF	Radio Frequency
RFP	Request for Proposal
R/I	Random reporting and Interrogatable DCP
Reclamation	Bureau of Reclamation

-S-

SDCSIWG	Satellite Data Collection System Interagency Working Group
SHEF	Standard Hydrometeorological Exchange Format
STIWG	Satellite Telemetry Interagency Working Group

-T-

TCP/IP	Transmission Control Protocol/Internet Protocol
TVA	Tennessee Valley Authority
TWG	Technical Working Group

TCP/IP Transmission Control Protocol/Internet Protocol
TVA Tennessee Valley Authority
TWG Technical Working Group

-U-

UCAR	University Corporation for Atmospheric Research
UDT	User Description Table
UHF	Ultra High Frequency
USA	United States Army
USAF	United States Air Force
USDA	U.S. Department of Agriculture
USGS	U.S. Geological Survey
USN	United States Navy

-W-

WWB	World Weather Building
WRCC	Western Regional Climate Center
WRD	Water Resources Division

Appendix B. Glossary

-B-

Bandwidth. A range of consecutive wavelengths or frequencies.

Baud. A unit of speed in data transmission (one bit per second for binary signals).

Byte. Adjacent binary bits that are operated on as a unit.

-C-

Channel. A specific frequency band for transmitting and receiving electromagnetic signals.

Conductance. The ability of a material to conduct an electric charge.

-D-

Demodulator. An electronic device that removes a signal from its carrier wave.

Downlink. Communication downward on a link between a satellite and ground station.

-F-

Footprint. The region beneath a satellite imaged by a satellite sensor or illuminated by a satellite antenna.

-G-

Geostationary. An Earth-orbiting satellite in equatorial plane and traveling at Earth's speed of rotation. Earth appears motionless beneath the satellite.

-I-

Imager

-M-

Multiplex. To simultaneously send more than one signal on a single channel or frequency.

-N-

NOAAPORT. Point-to-multipoint broadcast service available with the initial deployment of AWIPS.

-P-

pH. Negative logarithm of the hydrogen ion concentration. Measure of acidity or alkalinity of a solution.

Protocols. Procedure for interaction through a communications facility.

-S-

Sounder

-T-

Transponder. A radio receiver-transmitter activated for transmission by reception of a specific signal.

-U-

Uplink. Communication upward on a link between a ground site and satellite.

Appendix C. Brief History of GOES DCS

The technical successes of NASA and NOAA in the late 1960's in developing and orbiting satellite telemetry systems for collection of global environmental data enabled a number of Federal agencies to make use of such systems. A working group of major agencies, the Satellite Data Collection System Interagency Working Group (SDCSIWG), was formed in 1976 to formulate a plan for a National GOES DCS. The SDCSIWG was composed of the Army Corps of Engineers (COE), the U.S. Geological Survey (USGS), NOAA, the U.S. Environmental Protection Agency (EPA), the U.S. Department of Energy (DOE), the U.S. Department of Agriculture (USDA), and NASA.

The SDCSIWG served as a focal point for the various GOES DCS user agencies to NESDIS. In addition to its coordination function, the SDCSIWG also arranged for cooperative funding for specific surveys and research projects, and identified issues related to the GOES DCS. The issues identified by the SDCSIWG reflected the need for a continuous, operational data collection system. The work of the SDCSIWG lead to the issuance of a Presidential Directive (PD), in November 1979, giving NOAA a mandate to operate the GOES DCS to satisfy national requirements.

The SDCSIWG completed a draft plan for satellite data relay in May 1980, but the plan was never formalized by the member agencies or forwarded to the Office of Management and Budget (OMB). In 1983, NESDIS published a document (Ref NOAA/NESDIS, 1983) describing the GOES DCS and identifying requirements of the GOES DCS user agencies.

From 1980 to 1984, the SDCSIWG held regular meetings with NESDIS to formulate a national plan, and to reach agreement on interagency funding for expansion of the DCS to the full capabilities of the GOES spacecraft. Neither of these objectives was attained. Nevertheless, demand for use of the GOES DCS by the various Federal agencies increased by about 20 percent annually.

To anticipate the impact of increasing demand for use of the GOES DCS, the SDCSIWG commissioned the preparation of two important studies. The first study (Ref U.S. Army, January 1984) defined further user requirements and associated costs for optional upgrades of the DCS ground system. The second study (Ref U.S. Army, October 1984) identified critical elements in the GOES DCS relative to projected system saturation. It proved useful for NESDIS to extend existing ground system capabilities at that time to accommodate over 7,000 Data Collection Platforms (DCPs).

In March 1985 and July 1986, NESDIS asked user agencies for proposed enhancements to the upgraded DCS and advised the user agencies that they might be required to fund the enhancements. At this time, NESDIS assigned the name “DCS Automatic Processing System (DAPS)” to the upgraded ground system.

In June 1985, the ICMSSR and the IACWD chartered the STIWG to continue in a capacity similar to that of the SDCSIWG. The ICMSSR and IACWD derived their authority from OMB Circulars A-62 and A-67, respectively. Circular A-67 has since been supplanted by M-92-01 (10 December 1991).

During 1986 and 1987, the STIWG worked to obtain agreements from the Federal user agencies concerning DAPS enhancements and how to pay for them. This effort resulted in the decision to purchase additional demodulators to operate additional GOES DCS channels. Funding for the additional demodulators was to be in proportion to the number of DCPs assigned to each of the user agencies, with only agencies having 4 percent or more of the DCP assignments taking part. STIWG also agreed to fund an interim Domestic Satellite (Domsat) broadcast communications link until a NOAA satellite broadcast called NOAAPORT became operational.

In 1989, the Office of the Federal Coordinator for Meteorological Services and Supporting Research (OFCM) and Office of Water Data Coordination (OWDC) determined the need for a Federal Plan to ensure the effective use of the GOES DCS, and accordingly sanctioned the STIWG to prepare a draft of such a plan and this resulted in the National Geostationary Operational Environmental Satellite Data Collection System Operations Plan. This document provided among other things a system description, a statement of mission requirements, general polices and procedures for the use of the system, procedures for interagency coordination and funding, and a list of proposed enhancements. Two major system enhancements were described in this document: 1) the use of NOAA's NOAAPORT satellite to replace the DOMSAT system for data dissemination, and 2) the use of a higher transmission rates for data communications.

Because of a delay in the implementation of the NOAAPORT system and certain changes that made what originally seemed an easy transition from the DOMSAT system to NOAAPORT a more difficult one, the use of the DOMSAT system continued to expand and became a major component of many users' systems.

In the early 1990’s the Satellite Telemetry Interagency Working Group (STIWG) and the associated user community commissioned Cyberlink to study the feasibility of transmitting data through the GOES satellite at baud rates higher than 100 bps. The results of the study led STIWG to initiate a contract, managed by NOAA/NESDIS, to develop high data rate (HDR) demodulators and transmitters for the GOES DCS. The first incremental upgrade was supposed to occur in 1998 but was delayed because of technical problems until the early 2000's when new demodulators and transmitters were developed to allow the GOES DCS to support 300 and 1200 baud transmissions. In 2004 the STIWG developed a transition plan to convert all transmitters to the new baud rates by the year 2013.

In the mid 2000s, users with critical systems that depended on the GOES DCS for real-time data became concerned about single points of failure in the system. One particular concern was the GOES DCS receive facility at Wallops Island, Va. This was the only ground station that received all data from the GOES DCS, and many users were dependent on it for the reception of data from the GOES DCS. (Note that some users operated their own GOES receive site to obtain their data – but not all data from the GOES DCS.) The STIWG proposed that an alternate reception and distribution system called the Emergency Data Distribution Network (EDDN) be developed to provide a backup for the reception and distribution of data from the GOES DCS. As noted , there existed many GOES receive sites operated by various users of the GOES DCS. However, each receive site was configured to collect the subset of the GOES data of interest to the operator. The original plan for the EDDN was to link these existing

GOES receive sites into a network of receive sites and then expand their reception capability so that all GOES data could be obtained within this network. The EDDN would then be made available to all users that were completely dependent on the receive site at Wallops Island. In 2007, the USGS proposed instead of this network of receive sites that a single receive site be developed that would provide a complete backup of the data reception and distribution functions in a geographic location sufficiently far away from the primary system at Wallops Island so as not to be influenced by any extreme event that might affect the reception and distribution operations of the Wallops system. They further proposed that it be placed at the USGS's EROS Data Center in Sioux Falls, South Dakota. The EDDN became operational in June of 2008 . The EDDN receives data from all GOES DCS channels directly from the GOES satellites as well as from the primary system at Wallops Island by means of the DOMSAT communications satellite. It transfers the merged stream to LRGSs that are accesible to any registered user of the GOES DCS system.

Appendix D. Random Reporting

This appendix summarizes the work done in the publication "Users Guide For Random Reporting" published in December 1980 to provide guidelines for using random reporting in the GOES DCS system. This document considered both the use of random reporting for routine data collection and also to provide transmissions triggered by an environmental event. In the current GOES DCS, the only use of random reporting is in reporting environmental events and so that will be the focus of this appendix.

In the referenced publication, two primary reasons were given for random reporting:

1. the complexity of a DCP would be reduced because of the lack of a need for rigid scheduling as is required in self-timed transmissions, and
2. DCPs could transmit when conditions warrant rather than on a fixed schedule, i. e. they could be driven by environmental events.

It might be noted that reason 1 does not apply to the current GOES DCS because the self-timed mode has been chosen as the most effective mode for routine data collection. So the primary reason for using random reporting is reason 2. However, the advantage of using random reporting is not achieved without some cost. It was stated that random reporting had these disadvantages:

1. the probability of receiving a given message successfully is limited by the activity on the channel,
2. to achieve a desirable success, it may be necessary to transmit the same messages multiple times.

In order to characterize the performance on a channel using random reporting, a model was developed based on the following assumptions:

1. *Fixed length transmissions* - all transmissions are of the same duration, designated by T and measured in seconds.
2. *Many platforms; short, infrequent transmissions* - the channel is shared by a large number of platforms N where N is at least 50, and each of the platforms issues short transmissions at a time average rate sufficiently small that no single platform uses more than 1/10 of the total time available on the channel, i.e if the number of transmissions/second is designated by λ_n, then $\lambda_n * N < .1$ of total time on channel,
3. *Satellite sees constant transmission rate* - the overall rate at which transmissions arrive at the satellite, i.e the sum of the individual platform transmission rates is a constant over the interval of time during which the channel's performance is to be characterized.
4. *Independent, random transmissions* – the starting time of each transmission's arrival at the satellite is statistically independent of the starting time of the arrival of any other transmission.

From these assumptions, a simple analytic model of channel performance was developed assuming an underlying Bernoulli distribution approximated by a Poisson distribution for sufficiently large loading - N (the number of platforms) > 50. From this model these equations were derived:

1. The probability of a single transmission arriving successfully without interference (time overlap) from another transmission is given by

   $$p = e^{-2G}$$

   where G is the average number of transmissions attempted in T seconds (called the overall channel loading) and is given by

   $$G = \lambda T$$

   where λ is the average rate of transmissions for the time period T.

2. The average number of successful transmissions in T seconds (called the channel throughput and designated by the letter S) is

   $$S = G e^{-2G}$$

Using this model, three scenarios were considered that would yield a 95% probability that a message could be successfully transmitted.

1. *One short transmission per message.* No messages would be repeated; instead the channel would be loaded so that the probability of success for a single transmission would be 95%.
2. *K short transmissions per message.* Each message would be repeated in K randomly spaced short transmissions containing one message each. The channel would be loaded so that the probability of one successful transmissions in K attempts would be 95%.
3. *K messages sent in one transmission.* Each time a new message is sent, the last K-1 messages are appended to it. Thus, K messages are sent in each transmission, and each message is eventually transmitted K times. Again, the channel would be loaded so that the probability of a least one success in transmitting the message K times would be 95%.

The analysis of the three scenarios concluded that

- If a high probability of success is required for each message, very few platforms can share a channel if no messages are repeated. However, if all messages are repeated, many platforms can share a channel and still achieve a high probability of success for each message, especially if the messages are short.
- Scenario 3 permits more platforms to share a channel than scenario 2 and both these allow more than scenario 1.
- Scenario 3 permits more platforms to share a channel but with longer delays in message reception. Scenario 2 permits fewer platforms to share, but delays are shorter. Scenario 1 achieves near instantaneous communications but requires the channel loading to be light.

- The better performance of scenario3 over scenario 2 is more pronounced for shorter messages than for longer messages.
- The optimal number of times a transmission should be randomly repeated in scenario 2 is 3.

In the paper, the results were summarized by showing how many DCPs could be accommodated on a channel with various random reporting rates. A more useful summary is the number of transmissions allowed from any group of DCPS. This better illustrates the “loading” concept required if a channel is “overloaded” with DCPs. Note that the original analysis was done assuming a transmission duration of 2 seconds that included 1.52 seconds of overhead followed by .48 seconds of data (48 bits at 100 bits/seconds .) An additional computation has been done using a duration of 1 second that includes either .6 seconds of overhead followed by .4 seconds of data (120 bits of data) for 300 baud or .3 seconds of overhead followed by .7 seconds of data (840 bits of data) for 1200 baud.

Scenario	**Channel Loading Required To Achieve 95% probability of success.**	**Amount of usable time per day in seconds.**	**Transmission Duration**	**Transmission Repetitions**	**Maximum Number of Transmissions per day**
1	0.026	2246.4 seconds (.026*86400)	2 secs	0	1123
			1 sec	0	2246
2	0.25	21600 seconds (.25*86400)	2 secs	3	3600
			1 sec	3	7200
3*	0.25	21600 seconds (.25*86400)	2.96 secs	0	7297
			1.8 secs(300B)	0	12000
			1.6 secs(1200B)	0	13500
	* Scenario 3 assumes 3 messages in a single transmission, hence for 100 baud the total time is overhead + 3* data length. E.g. for 100 baud the time is .6 + 3 *.4 = 1.8.				

Some observations about the results:

1. As recommended in the paper, scenario 1 should not be used. The channel loading has to be too low to achieve the desired probability of success.
2. As a consequence of 1, the desired probability of success cannot be achieved without multiple random transmissions of the same message.
3. With a channel loading factor of approximately .25, three random transmissions are required to achieve the desired probability.
4. Scenario 3 is more efficient than scenario 2 because the transmission overhead is reduced by packing 3 messages into 1 transmission rather than having 3 separate transmissions, i. e. the one transmission with 3 messages is shorter that 3 transmissions with 1 message.

5. The paper recommended using either scenario 2 or 3 with incentives to use 3. Note, however that, although scenario 3 provided slightly better loading for the desired performance, it is not suitable for event-driven transmissions. So for event-driven transmissions, scenario 2 is the preferred mode of operation.

Appendix E. Abnormal Platform Response Messages

The following table contains all the Abnormal Platform Response Messages (APRMS) produced by DADDS.

Abnormal Platform Response Messages		
Category	**Type**	**Message Text/Description**
Timing Errors	T	**Text:** MESSAGE OVERLAPPING ASSIGNED TIME WINDOW **Desc:** Message received late/early, partially within its window, but straddling the prior or next time slot.
Wrong Channel Errors	W	**Text:** MESSAGE RECEIVED ON WRONG CHANNEL **Desc:** Message received on the wrong channel - usually DCP setup error.
	D	**Text:** MESSAGS RECEIVED ON MORE THAN ON CHANNEL **Desc:** Messages received on more than one channel – usually indicates a problem with the DCP.
Address Errors	A	**Text:** DCP ADDRESS ERROR CORRECTED; ORIGINALLY CE5EB17C **Desc:** The address received differed by 1 bit from the address with this time assignment – usually caused by transmission interference rsulting in a bit error but could be caused by a user user programming the DCP with the wrong address.
	B	**Text:** BAD DCP ADDRESS – NON-CORRECTABLE **Desc:** The address received differed by more than 1 bit from the address with this time assignment and could not be corrected.
	I	**Text:** INVALID DCP ADDRESS - NOT IN PDT **Desc:** The address of this DCP is not in the Platform Description Table .
Unexpected Message	U	**Text:** UNEXPECTED MESSAGE **Desc:** This transmission from this DCP that is not the DCP assigned to the time window in which is was received – usually caused by the DCP transmitting at the wrong time. Issued only for S or I type DCPs.
Missing Message	M	**Text:** MISSING SCHEDULED DCP MESSAGE **Desc**: DADDS expected a transmission from the indicated DCP and none was received . Issued only for S or I type DCPs.
Incomplete PDT	I	**Text: PDT INCOMPLETE.** **Desc:** One or more of the following required information is not in the Platform Description Table for this DCP:

Table 8: Abnormal Platform Response Messages produced by DADDS

Appendix F. Data Distribution Formats

F.1 GOES DCS Distribution format for NWS/NOAAPORT

DCP Message Format
(WMO Bulletin)

Divisions	Field Name	Length (in bytes)	Description
Begin WMO Bulletin	SOH	1	ASCII Start-of-header character. Begins WMO Bulletin
	End Of Line	3	2 ASCII Carriage-return characters (hex 1f) followed by an ASCII End-of-line character (hex 0f).
WMO Product Header	Sequence Number	3	WMO Bulletin sequence number
	End Of Line	3	2 ASCII Carriage-return characters (hex 1f) followed by an ASCII End-of-line character (hex 0f).
	Bulletin Data Type	6	WMO Data Type (NWS -)
	Space	1	ASCII Space character
	Bulletin Origin	4	WMO International location identifier (NWS -)
	Space	1	ASCII Space character
	DayTime	6	WMO International date-time group. Day of month followed by UTC (format – DDHHMM)
	End Of Line	3	2 ASCII Carriage-return characters (hex 1f) followed by an ASCII End-of-line character (hex 0f).
Record Separator	Record Separator	1	End of header; beginning of Bulletin data - ASCII Record Separator character
DCP Message Header	DCP Identifier	8	8 hex characters that identify the DCP that produced the transmission.
	Failure Code		Code — Meaning ' ' — Space indicates good message. ? — Question mark indicates message with a parity error.
	Day	2	Day of the month
	Hour	2	Hour (UTC)
	Minute	2	Minute
	Second	2	Second

<table>
<tr><th colspan="4">DCP Message Format
(WMO Bulletin)</th></tr>
<tr><th>Divisions</th><th>Field Name</th><th>Length
(in bytes)</th><th>Description</th></tr>
<tr><td>DCP Data</td><td>Data</td><td>1-15750</td><td>Data bytes transmitted</td></tr>
<tr><td rowspan="3">DCP Performance Measurements</td><td>Signal Strength</td><td>2</td><td>This measurement consists of two ASCII digits ranging between 32 and 57 (decimal) or “//” for an invalid measurement. The nominal operating range is 44 to 49 dBm. (The EIRP is computed assuming that the pilot is a +47 dBm reference.)</td></tr>
<tr><td>Frequency Offset</td><td>2</td><td>This measurement consists of signed hex number ranging from -A to +A and represents the frequency offset from the channel center frequency in 50 Hz increments, e,g. -A = -500 Hz, +2=100Hz. The nominal operating range for frequency offset is ±250 Hz (±5).</td></tr>
<tr><td>Modulation Index</td><td>1</td><td>The modulation index measurement consists of one of the three characters:
• N (Normal, 60^{o} 9^{o})
• L (Low, <50^{o})
• H (High, >70^{o})</td></tr>
</table>

DCP Message Format (WMO Bulletin)			
Divisions	**Field Name**	**Length** (in bytes)	**Description**
	Data Quality	1	The data quality measurement consists of one of the three characters: • N (Normal, error rate better than 1 X 10^{-6}) • F (Fair, error rate between 1 X 10^{-4} and 1 X 10^{-6}) • P (Poor, error rate worse than 1 X 10^{-4}) The nominal operating character for data quality is N.
DCP Channel and Spacecraft	Channel	3	GOES DCS Channel Number
	Spacecraft	1	'E' – GOES East, 'W' – Goes West
End WMO Bulletin	End Of Line	3	2 ASCII Carriage-return characters (hex 1f) followed by an ASCII End-of-line character (hex 0f).
	ETX	1	ASCII End-header character. Ends WMO Bulletin

F.2 DCS Distribution Format for DOMSAT/LRIT/Network

DCP Message Format (DOMSAT/LRIT/Network)			
Divisions	**Field Name**	**Length** (in bytes)	**Description**
DCP Message Header	Address	8	32-bit DCP address expressed as 8 hex digits.
	Year	2	Last 2-digits of current year.
	Julian Day	3	Julian day
	Hour	2	Hour (UTC)
	Minute	2	Minute
	Second	2	Second
DCP Performance Measurements	Failure Code	1	**Code Meaning** G Good message ? Message received with parity errors W Message received on wrong channel D Message received on multiple channels (duplicate) A Message received with address error(s) (correctable) T Message received late/early (time error) U Unexpected message received (over two minutes early/lateof assigned time N PDT incomplete (user required data is missing) M Scheduled message is missing
	Signal Strength	2	This measurement consists of two ASCII digits ranging between 32 and 57 (decimal) or "//" for an invalid measurement. The nominal operating range is 44 to 49 dBm. (The EIRP is computed assuming that the pilot is a +47 dBm reference.)
	Frequency Offset	2	This measurement consists of signed hex number ranging from -A to +A and represents the frequency offset from the channel center frequency in 50 Hz increments, e,g. -A = -500 Hz, +2=100Hz. The nominal operating range for frequency offset is $\pm$250 Hz ($\pm$5).

DCP Message Format (DOMSAT/LRIT/Network)			
Divisions	**Field Name**	**Length** (in bytes)	**Description**
	Modulation Index	1	The modulation index measurement consists of one of the three characters: • N (Normal, 60^{o} 9^{o}) • L (Low, <50^{o}) • H (High, >70^{o})
	Data Quality	1	The data quality measurement consists of one of the three characters: • N (Normal, error rate better than 1×10^{-6}) • F (Fair, error rate between 1×10^{-4} and 1×10^{-6}) • P (Poor, error rate worse than 1×10^{-4}) The nominal operating character for data quality is N.
DCP Channel and Spacecraft	Channel	3	GOES DCS Channel Number
	Spacecraft	1	'E' – GOES East, 'W' – Goes West

<table>
<tr><th colspan="4">DCP Message Format
(DOMSAT/LRIT/Network)</th></tr>
<tr><th>Divisions</th><th>Field Name</th><th>Length (in bytes)</th><th>Description</th></tr>
<tr><td>Reception Source</td><td>Source</td><td>2</td><td>2-character code that indicates where the message was received. These following codes have been defined:
<table>
<tr><th>Code</th><th>Source</th></tr>
<tr><td>LE</td><td>GOES East-USACE, Cincinnati</td></tr>
<tr><td>d1</td><td>GOES West-NIFC, Boise ID - Unit 1</td></tr>
<tr><td>d2</td><td>GOES West-NIFC, Boise ID - Unit 2</td></tr>
<tr><td>OW</td><td>GOES West-USACE, Omaha</td></tr>
<tr><td>RE</td><td>GOES East-USACE, Rock Island</td></tr>
<tr><td>RW</td><td>GOES West-USACE, Rock Island</td></tr>
<tr><td>SF</td><td>GOES East-SFWMD,West Palm Beach</td></tr>
<tr><td>UB</td><td>GOES East & West-WCDAS Backup, Wallops Island</td></tr>
<tr><td>UP</td><td>GOES East & West-WCDAS Primary, Wallops Island</td></tr>
<tr><td>XE</td><td>GOES East,EDDN, Sioux Falls</td></tr>
<tr><td>XW</td><td>GOES West,EDDN, Sioux Falls</td></tr>
</table>
Any other code indicates the message was received at one of the NESDIS receptions sites.</td></tr>
<tr><td rowspan="2">DCP Data</td><td>Data Length</td><td>5</td><td>Length of data in bytes</td></tr>
<tr><td>Data</td><td>1-15750</td><td>Data bytes transmitted</td></tr>
</table>