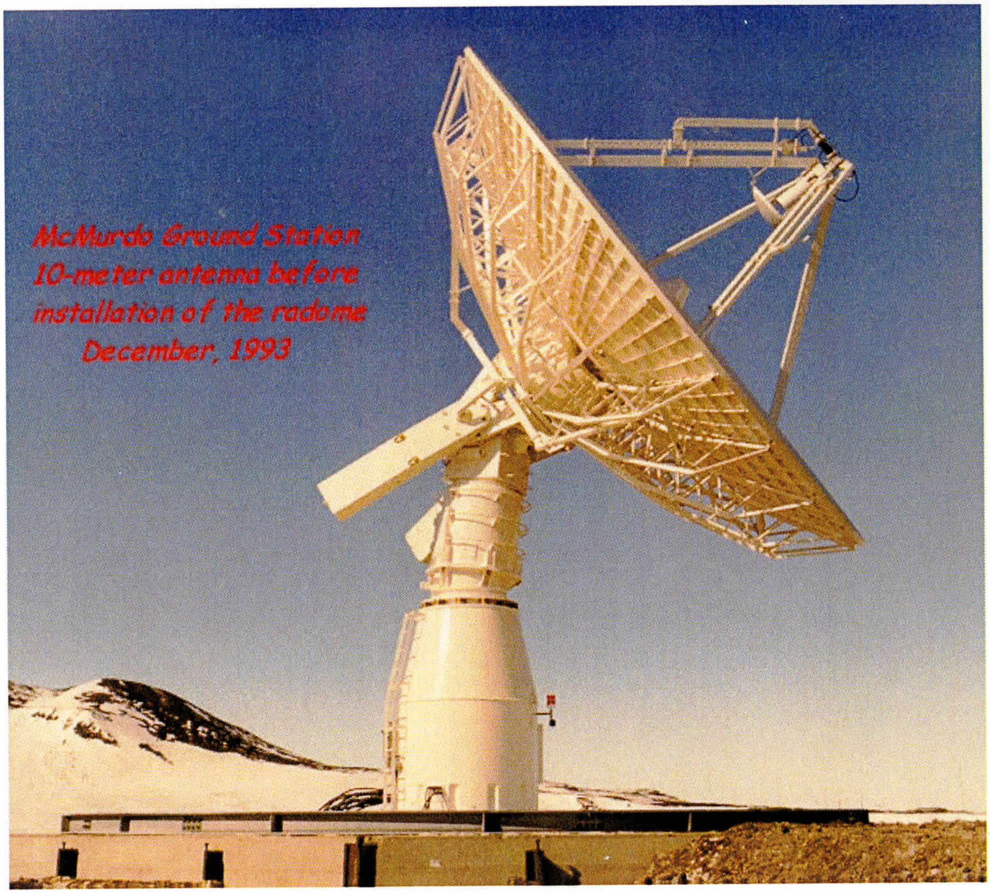
MGS Workshop Final Project Report: NSF-OPP Grant #0412586, March 1, 2004 to February 28, 2006

McMurdo Ground Station Science Workshop

An Final Report to the Office of Polar Programs, National Science Foundation



Professor Charles R. Stearns, Principal Investigator
Matthew A. Lazzara, co-Principal Investigator
Michael A. Comberiate, co-Principal Investigator

Space Science and Engineering Center
University of Wisconsin-Madison

Submitted on April 3, 2006

Final Report for Period: 03/2004 - 02/2006 **Submitted on:** 04/03/2006

Principal Investigator: Stearns, Charles R. **Award ID:** 0412586

Organization: U of Wisconsin Madison

Title:

McMurdo Ground Station Science Workshop; March 9-11, 2004; Columbus, OH

Project Participants

Senior Personnel

Name: Stearns, Charles

Worked for more than 160 Hours: No

Contribution to Project:

During the grant, Dr. Charles R. Stearns, oversaw the McMurdo Ground Station Science Workshop, including co-host of the workshop as well as facilitator of community input during the event.

Name: Comberiate, Michael

Worked for more than 160 Hours: No

Contribution to Project:

During the grant, Michael Comberiate contributed his wealth of experience and technical expertise to the workshop disucssions, background information on the McMurdo Ground Station, and advised on the technical aspects of the workshop report entitled 'The Future of the Next Generation Satellite Fleet and the McMurdo Ground Station'

Name: Lazzara, Matthew

Worked for more than 160 Hours: Yes

Contribution to Project:

During the grant, Matthew Lazzara organized, co-hosted, and chaired the McMurdo Ground Station Science Workshop as well as generated the workshop reported entitled 'The Future of the Next Generation Satellite Fleet and the McMurdo Ground Station' During the final year of this effort, a report entitled 'Antarctic Meteorological Satellite Report 2006' was accomplished by Matthew.

Post-doc

Graduate Student

Undergraduate Student

Name: Berger, Joy

Worked for more than 160 Hours: No

Contribution to Project:

This student hourly assisted with the production of the MGS workshop report.

Name: Kudick, Karen

Worked for more than 160 Hours: No

Contribution to Project:

This student hourly assisted with the production of the MGS workshop report.

Technician, Programmer

Other Participant

Research Experience for Undergraduates

Organizational Partners

Byrd Polar Research Center

The McMurdo Ground Station Science Workshop was held on March 9-11, 2004 at the Byrd Polar Research Center (BPRC), Ohio State University (OSU), Columbus Ohio. The partnership with BPRC involved having the workshop at the Byrd Center (use of facilities), as well as some assistance from support staff at BPRC.

Other Collaborators or Contacts

Activities and Findings

Research and Education Activities: (See PDF version submitted by PI at the end of the report)

The major activity with this project was the McMurdo Ground Station Science Workshop. See the PDF of the workshop report, entitled 'The Future of the Next Generation Satellite Fleet and the McMurdo Ground Station' and is submitted by the PI at the end of this report. In the final year of the effort, a meteorological satellite report was updated, entitled 'Antarctic Meteorological Satellite Report 2006' and is also submitted by the PI at the end of this report.

Findings: (See PDF version submitted by PI at the end of the report)

The findings for this project are fully described in the workshop report entitled 'The Future of the Next Generation Satellite Fleet and the McMurdo Ground Station' and is submitted by the PI at the end of this annual report. Other recommendations are included in the accompanying report entitled 'Antarctic Meteorological Satellite Report 2006' at the end of this annual report.

Training and Development:

Outreach Activities:

Journal Publications

Books or Other One-time Publications

Lazzzara, M.A.
Stearns, C.R., "The future of the next generation satellite fleet and the McMurdo ground station", (2004). , Published
Bibliography: UW SSEC Publication No.04.07.L1. Space Science and Engineering Center, University of Wisconsin-Madison [Available from the Schwerdtfeger Library, University of Wisconsin]

Lazzara, M.A., "Antarctic Meteorological Satellite Report 2006", (2006). , Published
Bibliography: UW SSEC Publication No.06.03.L1.
Space Science and Engineering Center,
Unversity of Wisconsin-Madison
[Available from the Schwerdtfeger
Library, University of Wisconsin]

Web/Internet Site

URL(s):

http://amrc.ssec.wisc.edu/MGS

Description:

This web site is the official web site of the McMurdo Ground Station Science Workshop, and has all of the materials related to the workshop posted, including the final report from the workshop.

Other Specific Products

Contributions

Contributions within Discipline:

This workshop and the resulting report have given a formal community voice regarding the McMurdo Ground Station and the future satellite systems that will be utilized as well as recommendations. These are expanded upon in the workshop report attached to this report. In addition, the Antarctic Meteorological Satellite Report also outlines the applications from a meteorological stand point as well.

Contributions to Other Disciplines:

The workshop was specifically geared to be interdisciplinary. As with the attendees at the workshop, the workshop report represents mulitple communities.

Contributions to Human Resource Development:

Contributions to Resources for Research and Education:

Contributions Beyond Science and Engineering:

Categories for which nothing is reported:

Activities and Findings: Any Training and Development

Activities and Findings: Any Outreach Activities

Any Journal

Any Product

Contributions: To Any Human Resource Development

Contributions: To Any Resources for Research and Education

Contributions: To Any Beyond Science and Engineering

Corrigendum

In the “The Future of the Next Generation Satellite Fleet and the McMurdo Ground Station” report, there is the following statement on page 20:

"Visibility of TDRSS satellite series may pose a problem, as currently there is only one TDRSS available to McMurdo for a limited time."

Currently McMurdo Station can see all the TDRSS satellites at 174, 171 and 150 degrees West. These TRDSS satellites are all in an inclined geostationary orbit. From Black Island there is greater than 20 hours per day visibility to these group of satellites. There is less visibility from Ross Island. There are two independent MTRS systems in McMurdo. The second MTRS or MTRS-2 is not on the closed network. The MGS RAID is on the closed network. This can be readjusted if necessary, so that data generated in McMurdo Station could go to another RAID and onto the MTRS-2 without ever leaving the open network. MTRS-2 status and control is on the mcmurdo.usap.gov local area network or open network, but not the data inputs. There is no Internet Protocol connection for data. Data inputs are on a patch panel and are single ended emitter couple logic or ECL. At present the data is patched into the ECL data output of the MGS RAID. There is a project underway now that is doing this with Tom Hawat at the University of Denver. Onsite MGS operators handle the use of the existing RAID for the data interface, until another RAID can be installed.

Antarctic Meteorological Satellite Report 2006

With Support from the Office of Polar Programs
National Science Foundation (#OPP-0412586) and
SPAWAR Systems Center Charleston (Code 66)

February 2006

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UW SSEC Publication No.06.03.L1

Compiled in 2005-2006 by the
Antarctic Meteorological Research Center
Space Science and Engineering Center
University of Wisconsin-Madison

This report may be cited as:

Lazzara, M.A., 2006: Antarctic Meteorological Satellite Report 2006. UW SSEC Publication No.06.03.L1. Space Science and Engineering Center, University of Wisconsin-Madison, 50 pp. [Available from The Schwerdtfeger Library, University of Wisconsin-Madison, 1225 W. Dayton St., Madison, WI 53706.]

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UW SSEC Publication No.06.03.L1
(http://library.ssec.wisc.edu/).

Or on-line at:

http://amrc.ssec.wisc.edu/Satellite-Report2006.pdf

This report is dedicated to Elena Teresa Susi Fountain for her endless encouragement and bringing clarity to these reports.

Table of Contents

Introduction

Meteorological satellites are perhaps the most critically important observing tools available to operational Antarctic weather forecasters and decision-makers. Having this information affords improved weather forecasts and ultimately increased safety for those working and traveling in and around the Antarctic. This report reviews the current and future launch status of both operational and research meteorological satellites, with a focus on those impacting the Antarctic. It is an update to reports from 2002 entitled *Meteorological Satellite Status Report* (Lazzara, 2002) and from 2004 entitled *Antarctic Meteorological Satellite Status Report* (Lazzara, 2004). The current uses, limitations, and potential applications of meteorological satellites acquired by the United States Antarctic Program (USAP) are outlined. Meteorological satellites that are currently not available to the USAP are reviewed, including their applications, benefits, limiting factors and other miscellaneous considerations. Some important issues facing satellite meteorology are also discussed, especially with regard to data encryption and availability of frequencies for remote sensing.

Geostationary Satellites

Although geostationary satellites may not seem to be of great importance since the Antarctic region is on the limb of the field of view, they are indeed important. Most geostationary satellites do image the Southern Ocean and up to the coast of the Antarctic. Observations from geostationary platforms are a critical basis for satellite composites such as those generated by the Antarctic Meteorological Research Center (Lazzara et al. 2003a, and Lazzara et al. 2003b) because they show systems that will impact Antarctic weather. See Figure 1.

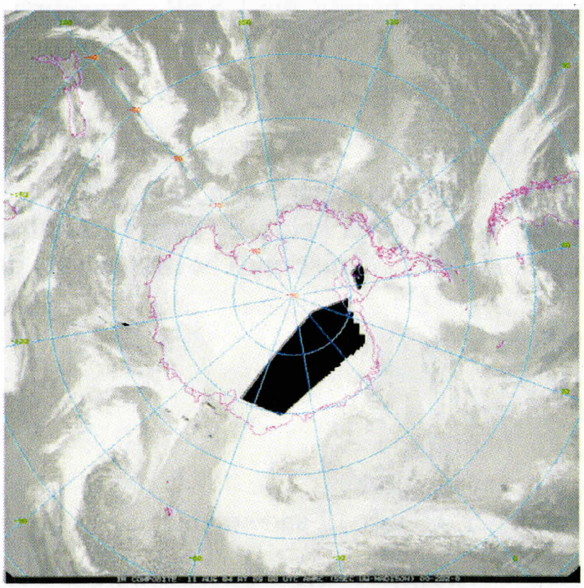
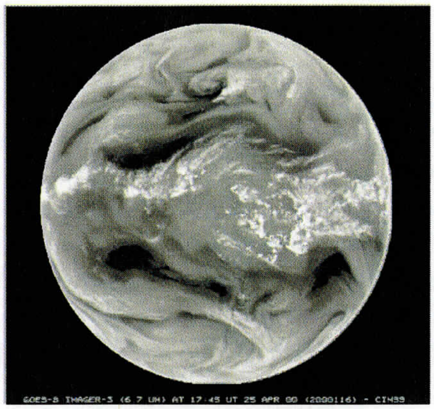


Figure 1. An infrared Antarctic composite satellite image combined from both geostationary and polar orbiting satellite platform observations. (*Courtesy of AMRC*)

Geostationary Operational Environmental Satellite (GOES)

Boeing



UW-Madison/SSEC/CIMSS

The Geostationary Operational Environmental Satellite (GOES) program operated by the National Oceanic and Atmospheric Administration (NOAA), United States, currently has four satellites in orbit. GOES-10 (West – 135 degrees West) and GOES-12 (East – 75.1 degrees West) are the current operational satellites, with GOES-11 (105 degrees West) currently in on-orbit storage. GOES-11 is a fully functional satellite ready for use as a backup within 48 hours. In mid-June, 2006, GOES-11 is due to be reactivated for testing and will replace GOES-10 as the operational GOES West satellite on July 20, 2006. GOES-9 (formerly Pacific – 155 degrees East) satellite was on loan to the Japanese Meteorological Agency (JMA) from NOAA to assist with coverage over the Far East due to the end of the useful life of the GMS satellite and failure of the MTSAT-1 satellite launch (see MTSAT). NOAA terminated GOES-9 operations on November 15, 2005 with the successful launch and operations of MTSAT-1R. In a recent development, there are plans to have GOES-10 be used for the benefit of Central and South America, when it is expect to be replaced with GOES-11 as the GOES West satellite. This special GOES-10 mission may indeed benefit the USAP, depending on the scanning schedule and field of view selected. (See Appendix for letter of support and details). As of this writing, the plans for this mission and scheduling are under review.

All GOES satellites in this generation are 3-axis stabilized satellites offering visible, short & long wave and window infrared, as well as water vapor data. The GOES satellites also offer a 19 channel sounder; however, they do not cover below 60 degrees South or the Antarctic at all. This may be changed with the GOES-10 special mission. The instruments on board include:

Sensors	**Description**
Imager	5 Channel imager
Sounder	19 Channel sounder
DCP	Data Collection Platform
SEM	Space Environment Monitor
SXI	Solar X-Ray Imager (GOES-12 and beyond)

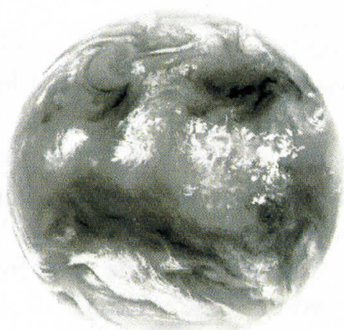
Built by Boeing, the next series of GOES satellites begins with launches in the middle of the first decade of 2000. This next series of satellites will be very much like the current series (similar instruments with a magnetometer added and still a 3-axis stabilized satellite), with some modifications for which channels and resolutions are available (including a 13.3 micron band replacing the pre-GOES-12 era of 12.7 microns). The GOES-N/O/P do have improvements for navigation accuracy as well as have capability to operate through eclipse times. It is expected that GOES-N after on-orbit checkout, will be placed in storage. Otherwise, this is the best-known launch schedule:

Platform	Launch Date
-----------	---------------
GOES-N	Not before May 3, 2006
GOES-O	April 2008
GOES-P	October 2009
GOES-Q	*Cancelled*
GOES-R	September 2012
GOES-S	April 2014

It is important to note that the GOES-R satellite will mark a significant change in this satellite series. GOES-R will be the platform for the Advanced Baseline Imager (ABI) and Hyperspectral Environmental Sounder (HES, formally called the Advanced Baseline Sounder or ABS). These instruments are currently under development by NOAA, with additional instrumentation planned, including a lightning mapper. The launch of GOES-R offers the first operational sounder with Southern Hemisphere support (not the Antarctic continent itself), as well as having routine imaging to cover the Southern Hemisphere on a half-hourly or hourly basis since the pre-GOES-NEXT era (pre-GOES-8). As a minor note, the GOES low rate data transmission and distribution method, to comply with international agreement, has been moving away from the historical analog method (WEFAX) in favor of the new LRIT digital method (at 1691 MHz). GOES high rate data transmission and distribution or GVAR (GOES Variable) continues as before (at 1685.7 MHz)

Meteosat

EUMETSAT



UW-Madison/SSEC

The Meteosat geostationary satellite program is overseen by EUMETSAT (Europe) with assistance from the European Space Agency. Currently, EUMETSAT is operating its older satellite series, Meteosat Operational Program (MOP), and its new Meteosat Second Generation

(MSG). The oldest satellite, Meteosat-5 (INDOEX - 63 degrees East) continues an extended Indian Ocean Data Coverage (IODC). This satellite is beyond its life span and is starting to acquire an almost one-degree inclination or more. EUMETSAT plans to continue to operate this satellite at this location into 2006. Meteosat-6 is the in-orbit stand-by spacecraft and is located around 10 degrees East. It is noteworthy that the stand-by satellite is used for rapid scanning operations over Europe. Meteosat-7 is the operational spacecraft at a position of 0 degrees (since 3 June 1998) and is due to be terminated for primary use as of 14 June 2006. Meteosat-8 (3 degrees West - formally MSG-1) became operational on 29 January 2004. EUMETSAT plans to have a two satellite configuration with a primary operational satellite and a backup spare satellite located near 0 degrees. IODC will likely continue, with the likely movement of the Meteosat-7 satellite to 63 degrees East, to have it take over for the aging Metosat-5 satellite. This satellite might also support a rapid scanning service, although it is unlikely this will impact the Antarctic region. On December 21, 2005 MSG-2 (6.5 degrees West) was launched, and as of the writing of this report, it is undergoing commissioning and will soon be renamed Meteosat-9. Last known future launches, including the estimated start of Meteosat Third Generation (MTG) are:

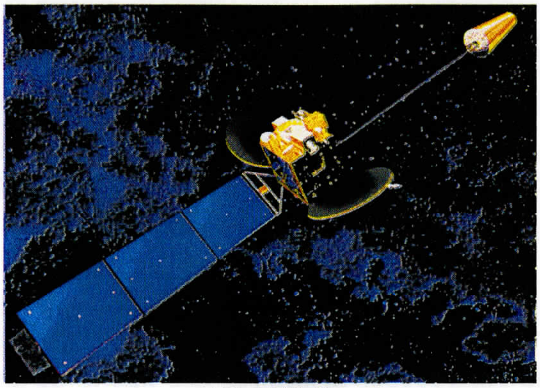
Platform	Launch Date
MSG-3	2009
MSG-4	2012
MTG	2015

All MOP satellites are spinner satellites offering visible, infrared and water vapor data. The MSG satellites are also a spinner satellite system that carries the Spinning Enhanced Visible and Infrared Imager (SEVIRI) 10-channel imager system. EUMETSAT also offers a rebroadcast service to its user community via commercial telecommunications satellites named EUMETCAST. The broadcast contains Meteosat data, products and more, which are retransmitted to the European community for a fee. The Hotbird satellite at 13 degrees East hosts the EUMETCAST service (much like USA's DOMSAT service), among others. IODC data will be provided via direct broadcast as well as via EUMETCAST.

Sensors	**Description**
SEVIRI	Spinning Enhanced Visible and Infrared Imager (MSG satellites only)
MVIRI	Meteosat Visible and InfraRed Imager (MOP satellites only)

As with the GOES satellite series, the Meteosat satellites also offer a WEFAX service, with the older satellites (Meteosat-5, -6, and –7) offering analog transmissions (1691 and 1694.Z Mhz), and the new satellite (Meteosat-8) offering LRIT along with the full data service HRIT – however not directly from the satellite, but from EUMETCAST. The older satellites full data service is HRI (1691 and/or 1694.5 Mhz).

Multifunctional Transport Satellite (MTSAT)



ABoM/JMA

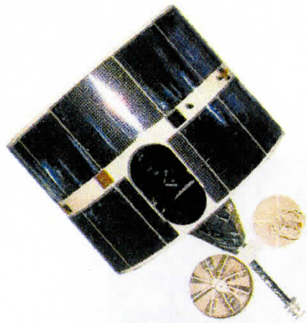
The replacement satellite series for the Japanese GMS series is the Multifunctional Transport Satellite (MTSAT). This satellite system is built for both meteorological and communication applications. The first MTSAT-1 satellite unfortunately failed on launch. The replacement is MTSAT-1R, which was launched on February 26, 2005 and declared operational by JMA on June 28, 2005. MTSAT-1R (140 degrees East) is also known at Himawari-6. The second satellite in the series, MTSAT-2, recently launched on 18 February 2006, will be placed in a standby mode until it is needed to replace MTSAT-1R. These satellites are a 3-axis stabilized system carrying a 5-channel imager. This imager has visible, infrared (short wave, window and long wave), and water vapor bands.

As of this writing, plans for MTSAT-3 and beyond are just getting underway. It is expected at this time that any launches will take place next decade close to the time frame that GOES-R and MTG would be launched.

The MTSAT supports the LRIT transmission service, common to many current and all planned geostationary satellites, and may share the service with a WEFAX analog transmission service as well. It also offers a full resolution service, HiRID (enhanced SVISSR)/HRIT (1691 Mhz).

Sensors	**Description**
S-VISSR	Stretched Visible Infrared Spin Scan Radiometer

Feng Yun (FY)



CMA

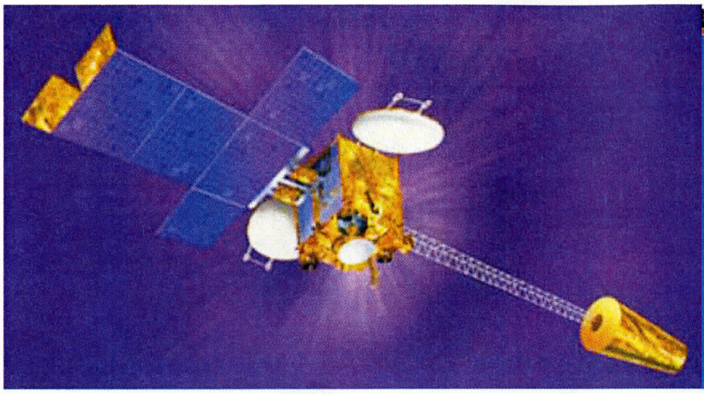
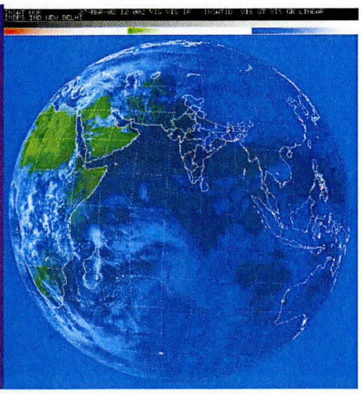
CMA

The Chinese geostationary satellite series, operated by the Chinese Meteorological Agency (CMA), is Feng Yun 2 (FY-2, Feng Yun means Wind and Cloud). The first satellite, FY-2A (FY-2 1R) launched on June 10, 1997, is of limited use due to de-spin subsystem problems and S-Band antenna problems and has been operated as only an experimental satellite. The next operational satellite, FY-2B launched June 25, 2000, had to be turned off for eclipse seasons (mainly in autumn and spring for roughly 90 days). For technical reasons there were no image transmissions covering the Southern Hemisphere. FY-2B has been moved to 123.5 degrees East and, like its experimental sister, is a three-channel (visible, infrared, and water vapor) spinner satellite, and suffers spin stabilization problems. The current active operational satellite, FY-2C, located at 105 degrees East, was launched on 19 October 2004. Full resolution data is transmitted at 1687.5 Mhz (last known frequency) (S-VISSR) with future satellites to offer LRIT data. The Chinese geostationary satellite program expects to launch four more satellites in its current series and begin a new series in the future (FY-4). It is expected that the rest of the FY-2 series will be a five-channel spinner satellite system, taking data in the visible, infrared and perhaps water vapor bands. The FY-4 series will be divided into two series of satellites: A-series for visible and infrared observations and B-series for microwave. The FY-4 series will be a 3-axis stabilized satellite series.

Sensors	**Description**
S-VISSR	Stretched Visible and Infrared Spin Scanning Radiometer

Platform	Launch Date
FY-2D	2007
FY-2E	2009
FY-2F	2011
FY-2G	2013
FY-4	Not before 2012 for A-series Not before 2015 for B-series

INSAT

IRSO IMD

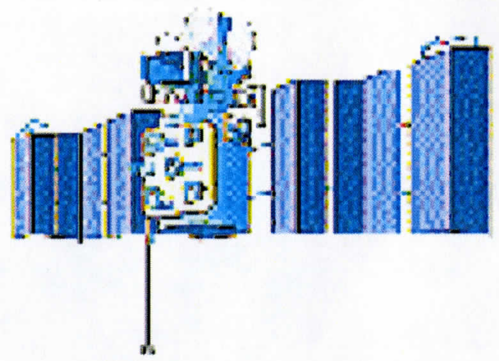
The India Meteorological Department (IMD) operates the INSAT series of geostationary satellites. These satellites are shared for meteorological and communications use. The INSAT constellation includes both spinner (older series) and 3-axis stabilized satellites, most with the 5 channel Very High Resolution Radiometer (VHRR) sensors including visible, infrared, and water vapor channels. The historical satellites include INSAT–1A, -1B, -1C, -1D, -2A, -2B, and -2E located typically at 74, 83, and 93.5 degrees East. There are two currently operational satellites: Kalpana-1 and INSAT-3A. Originally known as METSAT-1, Kalpana-1 was launched 12 September 2002 (74 degrees East). It was re-named in Feb 2003 after Kalpana Chawla, one of the seven-crew members of the Space Shuttle Columbia STS-107, first Indian-born woman in space. INSAT-3A was launched 10 April 2003. Both INSAT-3A and Kalpana-1 host the VHRR instrument, which is transmitted and encrypted at 2599 Mhz. In addition to the VHRR, Kalpana-1 also has a Charge Coupled Device (CCD) camera/payload with three channels in the visible and near infrared. All of the meteorological data from the INSAT satellites is encrypted. However, NOAA and IMD have made arrangements to share data.

Sensors	**Description**
VHRR	Very High Resolution Radiometer
CCD	Charged Coupled Device

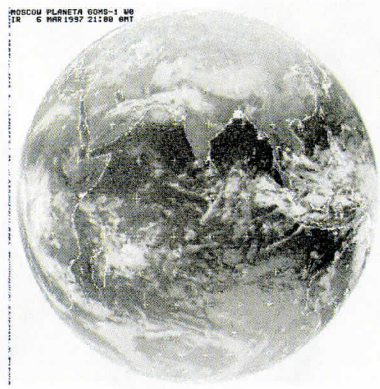
The next Indian INSAT series satellite to be launched is the INSAT-3D. This new satellite will carry a 6-channel imager and a 19-channel sounder very much like the GOES satellite system. At this time, it appears the data will remain encrypted. It is unclear if the US will work to navigate and calibrate the data retransmitted to NOAA, although there are some efforts on-going. It is noteworthy that INSAT-3D may possibly be renamed Kalpana-2 after it is launched and operating. There may be possible plans for a Kalpana-3, but little is known at this time. The launch information is:

Platform	Launch Date
INSAT-3D/Kalpana-2	2007 or 2008

Global Operational Meteorological System (GOMS)



Planeta-C

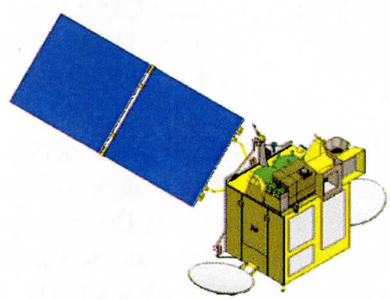


Planeta-C

The Russian Planeta-C Meteorological Space System includes Elektro or the Global Operational Meteorological System (GOMS or GOMS-N1) that was launched 31 October 1994. GOMS went operational 1 June 1996 and broadcasts on 1691 MHz (WEFAX). It has provided very little imagery since it was launched and placed on orbit due to some operational issues. This three-axis stabilized satellite offers two channels - visible and infrared. It appears to have come to the end of its life in September 1998. It was expected that the Russian Federation would launch the GOMS-N2, also known as Elektro 2 satellite sometime in 2005 or 2006, and that this may have been canceled at this time (this information is not confirmed at this time). The three-axis stabilized satellite was due to carry the Scanning Television Radiometer (STR) which will offer three-channels of visible, infrared and water vapor data, and may carry other sensors as well. Updated information notes that GOMS-N2 was to have a new satellite sensor system, the Multi-Channel Scanning Unit (MSU-GS), which would be much like the SEVIRI 10 channel sensor system with one exception, a 0.85-micron water vapor sensitive channel. The new satellite will likely have HRIT and LRIT data formats.

Sensors	**Description**
STR	Scanning Television Radiometer

Platform	Launch Date
GOMS/Elektro-L (N1) 2	2006/2007
GOMS/Elektro-L (N2) 3	2009



KMA

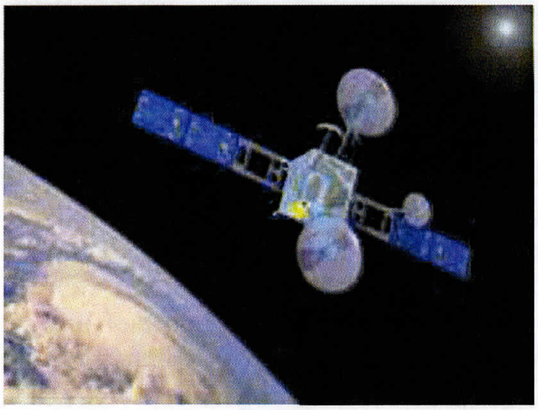
Communications, Ocean and Meteorological Satellite (COMS)

The Korea Meteorological Administration (KMA) in a joint effort with other governmental agencies of the Republic of Korea has started to plan a geostationary satellite of its own, named COMS (communication, ocean and meteorological satellite), with a planned launch date in 2008 and a second satellite in 2014. It is due to carry a 5-channel instrument, very much like the GOES imager. This 3-axis stabilized satellite will also carry a geostationary ocean color imager

(GOCI), as well as a communications payload. This satellite will offer HRIT and LRIT transmission data format, and will likely be placed at either 128.2 degrees East or 116.2 degrees East.

Platform	Launch Date
COMS-1	2008
COMS-2	2014

Geosynchronous Imaging Fourier Transform Spectrometer (GIFTS)



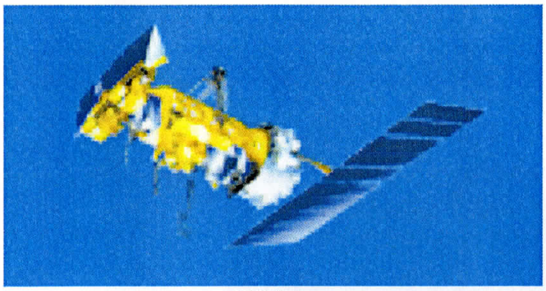
NASA

The Geosynchronous Imaging Fourier Transform Spectrometer (GIFTS) is an instrument set to go on the New Millennium Program (NMP) Earth Observing 3 (EO-3) geostationary satellite. GIFTS has 32,600 sensors to collect data, scanning an area of 512 kilometers square every ten seconds resulting in over 3000 spectral channels. The data rate is roughly 60 Megabytes per second, in the X-band for data transmission. This project is a joint partnership of NASA, NOAA and the US Navy. The instrument development is a joint effort by SSEC/UW-Madison and Space Dynamic Laboratory/Utah State University. The original plans called for the NASA EO-3 platform, after finishing the NMP mission for NASA, to be moved to the Eastern hemisphere for US Navy use. At such time, the satellite/sensor would have been subsequently renamed Indian Ocean Meteorology and Oceanography (METOC) Imager (IOMI).

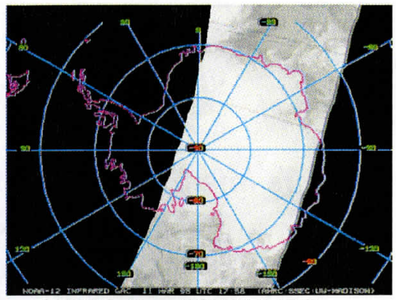
As of the summer of 2004, NASA had in essence canceled the NMP EO-3. The US Navy continues to be a partner in the project despite the lack of spacecraft funding. NOAA is still funding the research and development effort, because it is a risk reduction effort for the GOES-R satellite. It does appear the instrument will still be built and tested regardless of the lack of a spacecraft to place it on in the immediate future. Other satellite systems, especially foreign, are being actively pursued as possible platforms to launch the GIFTS instrument. Overall, GIFTS represents the future of remote sensing from space platform. As of the writing of this report, the US National Research Council (NRC) has started to draft a report on the future of satellite systems and missions for the US entitled a Decadal Survey. The GIFTS instrument is one of the key topics in the initial testimony from the NRC to the U.S. Congress (See: http://www.spaceref.com/news/viewsr.html?pid=16381).

Polar Orbiting Satellites

Polar Operational Environmental Satellite (POES)



NOAA



UW-Madison/SSEC/AMRC

The US Polar Operational Environmental Satellite (POES) system operated by NOAA currently has five satellites in primary, backup, or standby mode. Currently, NOAA-18 and NOAA-17 are operational, with NOAA-16 and NOAA-15 in backup mode, and NOAA-12 and NOAA-14 in stand-by or limited use mode. NOAA-11 has been decommissioned as of 16 June 2004. NOAA-9, which was permanently deactivated some years ago and is tumbling freely, has a sporadic carrier on 137.5 Mhz (varies quickly according to orientation) and can cause interference to NOAA-12 and NOAA-15. This problem has not been reported recently as it has been compared to the past several years. Additionally, there are reports from the amateur community of TIROS-N and NOAA-6 satellites putting out carrier signal on the same 137.5 Mhz frequency, also interfering with NOAA-12 and NOAA-15 when they are within the same footprint.

NOAA-18 was launched on May 20, 2005 into an afternoon approximately 2 pm equatorial cross-time. The satellite is transmitting well with Automatic Picture Transmission (APT - analog) on137.1 Mhz, and with high-resolution picture transmission (HRPT - digital) on 1689 Mhz. NOAA-17 has a mid-morning orbit with an approximate 10:30 am equatorial cross time. There have been some problems with the HRPT, causing the STX-3 to reduce power from 8 watts to 2.4 watts, resulting in reduced signal strength. NOAA-17 is transmitting on APT 137.62 Mhz and HRPT on 1707 Mhz. NOAA-16 has an afternoon orbit with an approximate 2 pm equatorial cross time. This satellite is fully functional, with the exception of the APT system, which failed a few months after launch. It is transmitting HRPT on 1702.5 Mhz. NOAA-15 has a morning orbit with an approximate 7:30 am equatorial cross time. This satellite is also functional. NOAA-15 also is transmitting direct broadcast data from its backup antenna system after a failure occurred with its primary system (APT on 137.5 Mhz and HRPT on 1702.5 Mhz). Recently NOAA-16, like NOAA-15 has had in the past, had problems with its imager, the Advanced Very High Resolution Radiometer (AVHRR), scan motor and the High resolution Infrared Radiation Sounder (HIRS).

NOAA-14, which has an older suite of satellite instrumentation, is in an afternoon orbit with an approximate 2 pm equatorial cross-time. It is functional, but its AVHRR unit scan motor has had problems much like NOAA-16 and NOAA-15, making the data unusable at times. NOAA engineers will no longer be making attempts to restart the scan motor on NOAA-14. Reports from the amateur satellite community note that NOAA-14 has been doing much better in recent months and does have some fairly good imagery. NOAA-14 does not have APT transmitting on however it does have its HRPT transmissions on 1707 Mhz. NOAA-12 is in a morning orbit with a 6:40 am cross-time that is currently functioning well, with the exception of the sounding instruments. It did have a recent problem that forced the satellite into a safe-mode with the instruments turned off. NOAA operators have since turned back on the instrumentation, and the satellite continues to operate at this time. NOAA-12 operates APT on 137.5 Mhz and HRPT on 1698 Mhz.

The POES series plans one more satellite in the series. This satellite will carry the AVHRR imager, and an advanced sounding system (both infrared and microwave). The NOAA-N' satellite will also carry the next generation of Argos-III 2-way messaging capability for remote data collection systems, including Automatic Weather Stations (AWS). After the launch of NOAA-N', the POES series of satellites will combine with the DMSP series to form a new national polar orbiting satellite series (NPOESS).

NOAA-KLM series:

Sensors	**Description**
AVHRR	Advance Very High Resolution Radiometer
HIRS	High Resolution Infrared Radiation Sounder
AMSU-A	Advanced Microwave Scanning Unit-A (1 and 2)
AMSU-B	Advanced Microwave Scanning Unit-B
DCS	Data Collection System (Service Argos)
SEM	Space Environment Monitor
SARP/SARR	Search and Rescue Processor/Repeater

Platform	Launch Date
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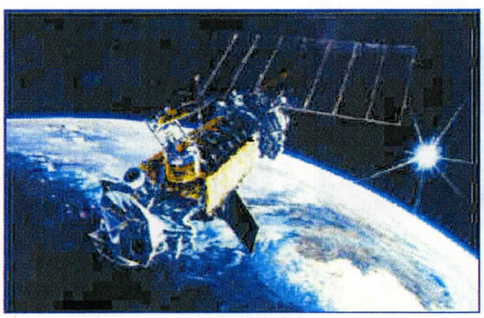
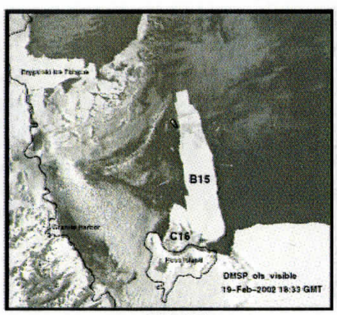
NOAA-N'	2008 (Afternoon equatorial cross-time: Launch date is pending on repairs)

Defense Meteorological Satellite Program (DMSP)



NGDC



RPSC

The Defense Meteorological Satellite Program (DMSP) satellite system is a polar orbiting satellite series, operated by the United States (NOAA) for both military and civilian (in non-real-time) use. Over the Antarctic (south of 60 degrees South), the DMSP send clear transmissions in what would otherwise be an encrypted satellite data signal. Current operational satellites are the DMSP F-16, F-15, F-14, F-13, and F-12. All DMSP satellites have a morning equatorial crossing time orbit. These satellites offer a high-resolution imager of infrared and visible data (OLS instrument) and microwave imager and sounder data (SSM/I, SSM/T, & SSM/T2). Starting with the DMSP F-16 satellite, the new special sensor microwave imager/sounder (SSMIS) replaces the SSM/I, SSM/T, and SSM/T2 sensors, and will also be on future DMSP satellites.

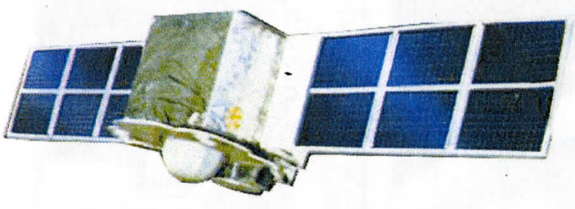
Sensors	**Description**
OLS	Operational Linescan System
SSM/I	Special Sensor Microwave Imager (F-15 and before)
SSM/T	Special Sensor Atmospheric Temperature Profiler (F-15 and before)
SSM/T2	Special Sensor Atmospheric Water Vapor Profiler (F-15 and before)
SSMIS	Special Sensor Microwave Imager/Sounder (F-16 and after)

There are other sensors on the DMSP satellites for space weather applications including: X-ray detectors, Ion spectrometers, precipitating electron detectors, etc.

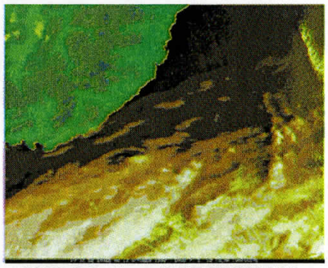
The DMSP program plans four more launches over the next several years. These series of satellites will offer the same or similar instruments and sensors, visible and infrared data as well as microwave data. It may be that the F17, F19, and F20 satellites will break from the current morning satellites, and be launched as afternoon satellites. After the launch of DMSP F-20, the DMSP series of satellites will combine with the POES series to form a new national polar orbiting satellite series (NPOESS).

Platform	Launch Date
DMSP F-17	TBD
DMSP F-18	October 2007
DMSP F-19	April 2009
DMSP F-20	October 2011

Feng Yun (FY)



CMA



UW-Madison/SSEC/CIMSS

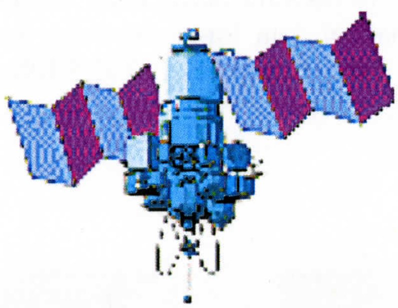
The Feng Yun (FY-1) is the operational polar orbiting satellite series operated by the Chinese Meteorological Agency for China. Currently, FY-1C and FY-1D are the operational satellites. The main instrument on the FY-1 series of satellite, a color HRPT (CHRPT), has 10 channels in the visible and infrared spectrum. Both FY-1 satellites transmit on 1700.4 Mhz, with the FY-1C satellite no longer transmitting data. It is important to note that the FY-1 series of satellites are not encrypted and transmit in the free and clear for users worldwide to use, including the Antarctic.

Sensors	Description
MVISR	Multichannel Visible and Infrared Scan Radiometer

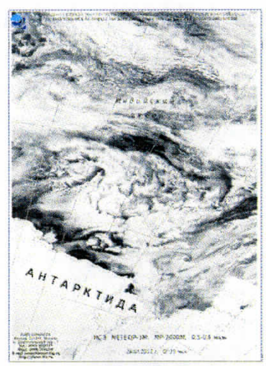
The next generation polar orbiting satellite system from China is the FY-3 series. It is expected that this series of satellites will have improved imaging abilities, and that all of these satellites will be in morning equatorial cross-times. In the meantime, one more of the existing generation of satellites will be launched.

Platform	Launch Date
FY-1E	Unknown
FY-3A	2007
FY-3B	2010

Meteor



Planeta-C



Planeta-C

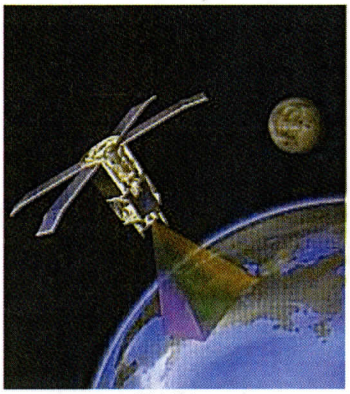
The Russian Federation operates the Meteor polar orbiting satellite system. Currently, there are no Meteor satellites operating. At this time, the Russian Federation has plans to launch an additional Meteor satellite Meteor-3M N2. It is likely that this satellite will be launched in a sun-synchronous orbit with a morning equatorial cross time. Meteor-3M N1 failed by December 2003 after all of its data transmitters failed.

Sensors	Description
SAGE III	Stratospheric Aerosol and Gas Experiment (NASA Instrument)

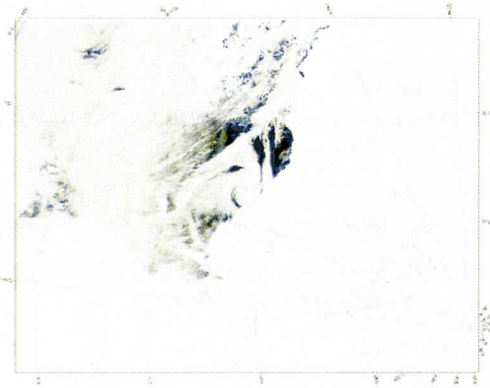
Other instruments for infrared and visible scanning

Platform	Launch Date
Meteor-3M N2	2006

SeaStar



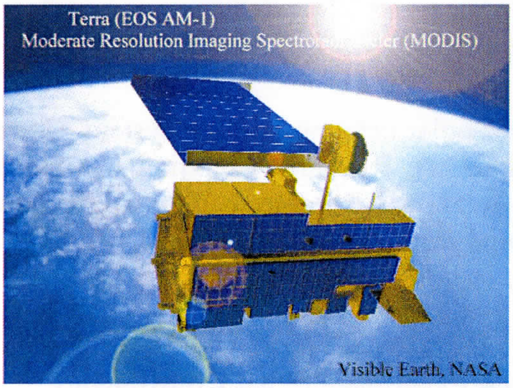
NASA



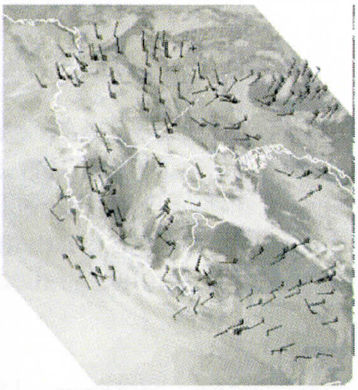
NASA

Orbital Science Corporation in conjunction with NASA operates the Orbview-2/SeaStar polar orbiting satellite, which has the SeaWiFS (Sea-viewing Wide Field-of-view Sensor) instrument (a Coastal Zone Color Scanner or CZCS) onboard. This satellite system is a joint NASA/private corporation effort. These observations have been made available in real-time to the weather forecasters at McMurdo Station, Antarctica and are used for science projects in the Antarctic by the USAP. However, the data is encrypted, thus requiring a decryption unit. They are also available for science use, with permission from NASA. However, within the last year or two, this offer has come to an end with the availability of MODIS ocean color channels. The observations from SeaWiFS offer a variety of visible channel data for ocean color applications as well as infrared data. Data is transmitted in an HRPT styled format at 1702.5 Mhz. No future satellites with the SeaWiFS/CZCS are planned.

Earth Observing System (EOS)



NASA



UW-Madison/SSEC/CIMSS

NASA's Mission to Planet Earth (MTPE) includes an Earth Observing System (EOS). This system offers a series of research polar orbiting satellites with the aim of studying the Earth system. The flag satellites of EOS are Terra, launched in 1999; Aqua, launched on 4 April 2002; and Aura, launched on 15 July 2004. Terra and Aqua offer direct broadcast data, while Aura does not. There are a host of other satellites considered a part of the EOS program, and they are reviewed in the "Other Polar Orbiting Satellites" section.

These flagship satellites offer a suite of instruments and sensor systems. This new generation of polar orbiting observing systems offers dramatic increases in geographic and spectral resolution. The MODIS instrument, which has been derived from AVHRR and is on the Terra and Aqua satellite, offers 36 channels of one-kilometer resolution data, of which seven offer half-kilometer resolution data, and two offer quarter-kilometer resolution data. The AIRS instrument, which has heritage from the HIRS instrument and is on the Aqua satellite, offers thousands of spectral channels of data that allow high-resolution profiles of temperature and moisture to be generated. The AIRS sensor, combined with the AMSU and HSB, gives a complete atmospheric profiling system. The AMSU is much like the AMSU-A on the NOAA satellites while the HSB is much like the AMSU-B on the NOAA satellites. The AMSR-E instrument is also on the Aqua satellite, and is a next generation microwave sensor.

Aqua:

Sensors	Description
MODIS	Moderate-resolution Imaging Spectroradiometer
AMSR-E	Advanced Microwave Scanning Radiometer for EOS
AIRS	Atmospheric Infrared Sounder
AMSU	Advanced Microwave Sounding Unit
HSB	Humidity Sensor for Brazil
CERES	Clouds and the Earth's Radiant Energy System

Aura:

Sensors	Description
HiRDLS	High Resolution Dynamics Limb Sounder
MLS	Microwave Limb Sounder
OMI	Ozone Monitoring Instrument
TES	Tropospheric Emission Spectrometer

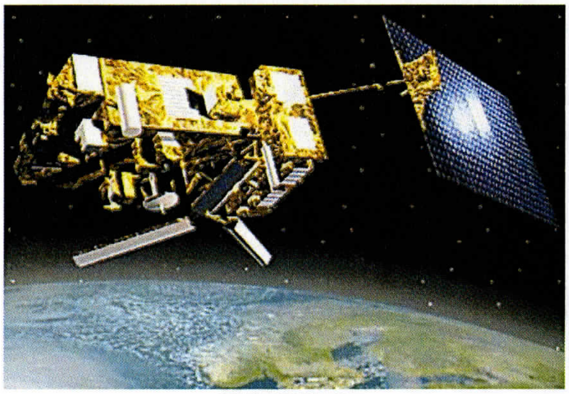
Terra:

Sensors	Description
MODIS	Moderate-resolution Imaging Spectroradiometer
MISR	Multi-angle Imaging SpectroRadiometer
MOPITT	Measurements of Pollution in the Troposphere
ASTER	Advanced Spaceborne Thermal Emission and Reflection Radiometer
CERES	Clouds and the Earth's Radiant Energy System

Terra is operational and has had a few problems over its five years of operation, but is currently operating nominally. It is nearing its end of life expectancy. Aqua is operational as well, and is also operating nominally, with only a few problems with some channels (known before launch). Only the MODIS sensor is offered from the Terra satellite, while all sensors on Aqua are a part of the direct broadcast.

The plans to install a dual X-band and L-band satellite system at McMurdo Station became a reality during the 2004-2005 field-season (Lazzara and Stearns, 2004). This has made Terra and Aqua observations for the first time available to the weather forecasters for real-time use. Products and observations are being produced in a joint effort between the AMRC and the Cooperative Institute for Meteorological Satellite Studies at UW-Madison on site at McMurdo Weather Office (Straka et al 2006).

EUMETSAT Polar System (EPS)



EUMETSAT

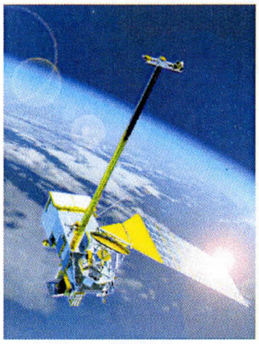
In a joint venture between EUMETSAT and the European Space Agency (ESA) and in collaboration with the new US national polar orbiting satellite program (named the International Joint Polar-orbiting Satellite (IJPS) system) , the European community plans to launch its first series of polar orbiting meteorological satellites, called MetOp. The MetOp satellite series will host many common instruments already on board POES, including AVHRR, HIRS, etc. In addition, a suite of European sensors will be onboard as well:

Sensors	Description
A/DCS	Advanced Data Collection System (also known as ARGOS)
AMSU-A1	Advanced Microwave Sounding Unit (USA)
AMSU-A2	Advanced Microwave Sounding Unit (USA)
ASCAT	Advanced SCATterometer (Europe)
AVHRR/3	Advance Very High Resolution Radiometer (USA)
GOME-2	Global Ozone Monitoring Experiment 2 (Europe)
GRAS	GNSS Receiver for Atmospheric Sounding (Europe)
HIRS/4	High Resolution Infra-Red Sounder (USA)
IASI	Infra-Red Atmospheric Sounder Interferometer (Europe)
MHS	Microwave Humidity Sounder (Europe)
SARP-3	Search And Rescue Processor (SARP-3)
SARR	Search And Rescue Repeater
SEM	Space Environment Monitor (USA)

One concern with regard to accessing this platform over the Antarctic is data transmission encryption and data denial (See section on Data Encryption). MetOp-2 will indeed be launched first in the series, followed by MetOp-1. MetOp-2 will be renamed METOP-A after launch.

Platform	Launch Date
METOP-1	2010
METOP-2	June 2006
METOP-3	2015

National Polar-orbiting Operational Environmental Satellite System (NPOESS)



IPO

The US next generation polar orbiting meteorological observing platform is the National Polar-orbiting Operational Environmental Satellite System (NPOESS). By combining prior US civilian and military programs, NPOESS aims to take polar orbiting observing into the next decade, with lessons learned from the DMSP, POES and EOS satellite systems as well as be a part of the International Joint Polar-orbiting System (IJPS) (See Figure 2). NPOESS will offer an advanced imaging system Visible/Infrared Imager/Radiometer Suite (VIIRS), a sounding system Crosstrack Infrared Sounder—atmospheric moisture (CrIS), and a microwave sounding system Advanced Technology Microwave Sounder (ATMS), among other instruments. One major concern for the Antarctic is that the imaging instrument currently planned for NPOESS does not have any partly absorptive channels, especially the water vapor channel. Water vapor channel data, at high resolution, had not been available on polar orbiting platforms until the launch of the Terra satellite in the EOS satellite program. It is expected that by the third NPOESS satellite a water vapor channel will be available. NPOESS system will offer an L-band (low rate data or LRD) direct broadcast service as well as an X-band (high rate data or HRD) direct broadcast service.

Sensors	Description
VIIRS	Visible/Infrared Imager/Radiometer Suite
CMIS	Conical Microwave Imager/Sounder
CrIS	Crosstrack Infrared Sounder
GPSOS	Global Positioning System Occultation Sensor
OMPS	Ozone Mapping and Profiler Suite

SESS	Space Environment Sensor Suite
APS	Aerosol Polarimeter Sensor
ATMS	Advanced Technology Microwave Sounder (NASA)
ADCS	Data Collection System (Service Argos)
ERBS	Earth Radiation Budget Sensor
SARSAT	Search and Rescue Satellite Aided Tracking
TSIS	Total Solar Irradiance Sensor
RADAR	Radar Altimeter

As an important aspect of this program, there are plans to launch an NPOESS Preparatory Project satellite, allowing all who are involved in polar orbiting meteorological satellites - users to developers - the chance to test out and learn about this new system.

As of this writing, the NPOESS program is suffering from budget overruns, and is currently under review by the Nunn-McCurdy commission. The launch of the satellite series has been delayed for roughly two years or more, pending.

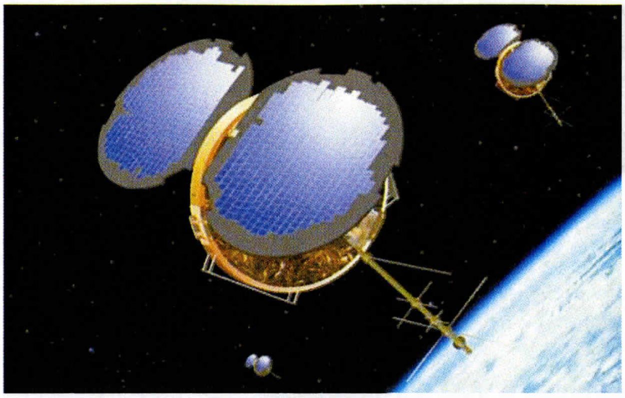
Platform	Launch Date
NPP	2008 or later
NPOESS-1	2012

Other Polar Orbiting Satellites

NASA

Many other satellites are due to be launched over the next several years, others have already been launched as well. Many of these listed below have some impacts on Antarctic meteorology, with regard to forecasting, observing, and research. Here is the list of some of these satellites in the categories of GPS/MET, Environmental and other noteworthy satellite systems.

Global Positioning System/Meteorology Satellites (GPS/MET)



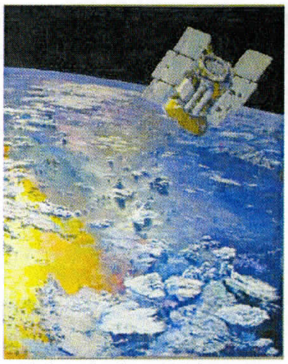
COSMIC

Currently, there are three satellites, SAC-C, CHAMP, and GRACE that are already in orbit that could offer the ability to profile temperature and moisture using the global positioning system instrumentation. A future and much more definitive satellite system to offer this ability is the COSMIC satellite series. These satellites will offer the ability to provide tens, if not hundreds of profiles of temperature and moisture around and over the Antarctic.

- Gravity Recovery and Climate (GRACE)- in orbit (USA/Germany/Russian Federation)
- Satelite de Aplicaciones Cientificas-C (SAC-C) - in orbit (Argentina/USA/Italy/France/Brazil)
- CHAllenging Minisatellite Payload (CHAMP) - in orbit (Germany)
- Constellation Observing System for Meteorology, Ionosphere and Climate (COSMIC) – Planned launch April 2006/TBD (USA/Taiwan)

Platform	Launch Date
FORMOSAT-3/COSMIC	April 2006/TBD

Other Environmental Satellite Systems



Colorado State University

There are a host of other polar orbiting satellites that may offer some information that could be of value to weather forecasting operations in the Antarctic. However, often the data are not available, costly to process, or unable to be received as a direct broadcast. Some of those satellites with the country sponsoring them are:

- Envisat: Launched 1 March 2002 with Advanced Synthetic Aperture Radar (ASAR), Medium Resolution Imaging Spectrometer (MERIS), Advanced Along-Track Scanning Radiometer (AATSR), Microwave Radiometer (MWR), etc. among other instruments (Europe/ESA)
- QuikScat: Launched 19 June 1999 Scatterometer sensor satellite offering ocean surface derived winds (NASA/USA)
- ERS-1 and ERS-2: Launched 17 July 1991 (ERS-1) and 21 April 1995 (ERS-2) Synthetic Aperture Radar (SAR) and Along-Track Scanning Radiometer (ATSR), Wind scatterometer, microwave sounder, GOME, etc. (Europe/ESA)
- Coriolis/WindSat: Polarimetric microwave radiometer Launched 6 January 2003 (IPO/USA)
- ICESAT: Launched 12 January 2003 with Geoscience Laser Altimeter System (GLAS) (NASA/USA)
- ADEOS-II: Launched 16 December 2002; Failed October 24, 2003 (Japan/USA/NASA – Carried new Argos/2 system in addition to a microwave radiometer (AMSR), a scatterometer (SeaWinds), an imager (GLI), a limb sounder (IILAS-II) and a polarimetric visible and infrared radiometer (POLDER))
- OceanSat-1 (IRS P4): Launched 26 May 1999 (India – Carrying Ocean Color Monitor (OCM) and a Multifrequency Scanning Microwave Radiometer (MSMR)).
- Sich 1-M: Unsuccessfully launched 24 December 2004. Satellite may be tumbling (unconfirmed). There may be plans for a Sich 2 & Sich 3 satellite series. (Ukraine)
- PARASOL: Launched successfully December 18, 2004 (France)

This is not an exhaustive list, but offers reference to some other satellites that are in operation, or were attempted. Earth resource satellites such as Radarsat, Landsat, Spot, Cryosat, Resurs, etc. are left off of these lists due to the limited meteorological applications. Below is a selective list of satellites to be launched in the future. It is interesting to note that several of these polar orbiting satellites are planned to fly in formation, specifically Aqua, Aura, Cloudsat, Calipso, OCO, and PARASOL (See Figure 3). This planned formation has been dubbed the "A-Train." Also CLOUDSAT and CALIPSO will be launched on the same rocket.

Platform	Launch Date
OceanSat-2 (India)	2006/2007
Cloudsat (USA)	NET 10 April 2006 (shared launch vehicle w/ CALIPSO)
CALIPSO (USA/France)	NET 10 April 2006 (shared launch vehicle w/ Cloudsat)
OCO (USA)	September 2008
Megha-Tropique (France/India)	December 2009

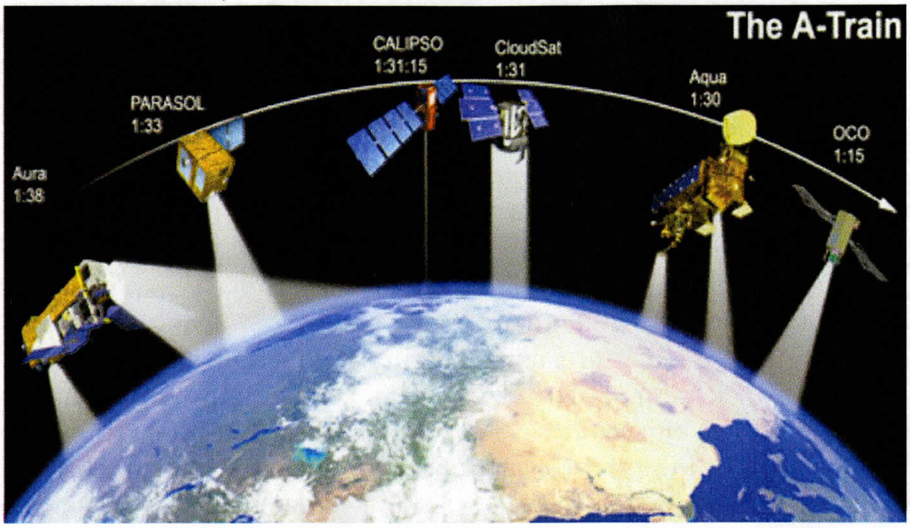
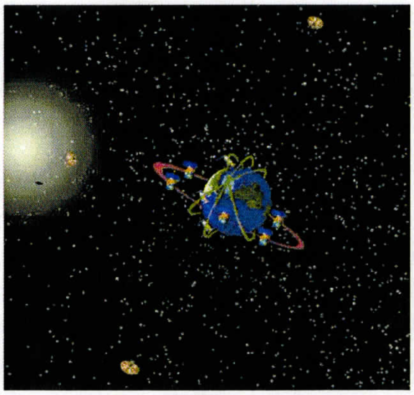


Figure 2. The near future will showcase a series of satellites flying in formation, also known as the A-Train (*Courtesy of NASA*).

Below is a listing of the key sensors that will be a part of the CloudSat, CALIPSO and PARASOL portion of the "A-train":

Sensors	Description
CPR	Cloud Profiling Radar (CloudSat)
CALIOP	Cloud Aerosol Lidar with Orthogonal Polarization (CALIPSO)
IIR	Imaging Infrared Radiometer (CALIPSO)
WFC	Wide-Field Camera (CALIPSO)
POLDER	Polarization and Directionality of the Earth's Reflectance (PARASOL)

Polar Sitter/Solar Sail



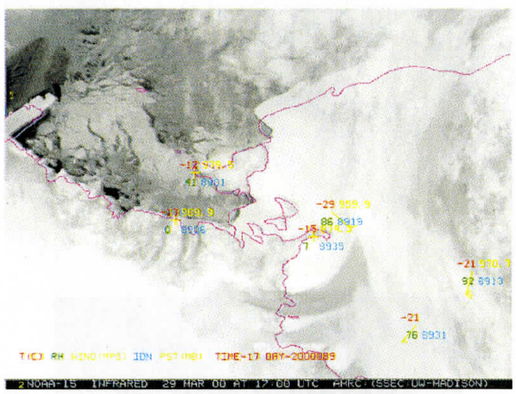
NOAA

Meteorological satellites in other orbits are being considered and planned. One such satellite was to be Triana, which was proposed to orbit between the Sun and Earth at the LaGrange 1 point. Triana and its major sensor, EPIC, currently is in storage pending identification of launch flight/vehicle. Geostorm is another project (joint NOAA and United States Air Force) that had proposed to place a solar sail into an orbit that would have a mission of monitoring space weather.

Recently, NOAA has begun the investigation of placing a solar sail satellite into a polar stationary orbit (artificial LaGrange orbit or ALO), primarily for inter-satellite communications (McInnis and Mulligan, 2003). Of course, this orbit offers the exciting chance to image the Antarctic directly and often as well as give the opportunity to have improved communications (both inter-satellite and with the ground). Currently, the most active solar sail activities are private efforts, although there are efforts underway in the government sector as well. Other solar sail efforts are underway, including efforts in Germany and work in Japan. Unfortunately efforts by the Planetary Society, which would have been the first to launch a demonstration satellite, named COSMOS, launched from a Russian submarine platform, failed after launch in 2005. Another casting of the Triana, the DSCOVR or Deep Space Climate Observing mission, which would have placed the Triana sensors at L1 has been canceled by NASA.

Meteorological Satellite Usage in the USAP

Current Uses and Applications



UW-Madison/SSEC/AMRC

The USAP has used POES and DMSP satellite data for over 25 years. These satellites have been the staples for weather forecasting and research applications during this period. It is worthwhile to emphasize the high importance and value that these two satellite platforms have to weather forecasting activities for the USAP. Beginning in 1992, the Antarctic composites generated at the University of Wisconsin offered a critical supplement. Additionally during the 1990s, the GMS satellite observations had been used for some years as yet another supplement to the mainstay polar orbiting satellites. The major use of the data from each of these sources has been limited to just viewing the imagery for weather forecasting applications (Lazzara et al. 2003a). Some derived products have been utilized (i.e. sea ice depiction). This is beginning to change, however, as the USAP is embarking on the beginning of a new era in Antarctic meteorology. The

Antarctic Mesoscale Prediction System (AMPS) is making significant progress in Antarctic numerical weather prediction and is beginning to utilize satellite-derived observations (Jordan et al. pers. comms. 2004). The Antarctic Regional Interaction Meteorology Experiment (A-RIME – formerly the Ross Island Meteorology Experiment) has plans to begin its program. It will investigate a variety of Antarctic meteorological phenomena leading toward improved applications of satellite observations (Parish and Bromwich, 2002). Finally, the installation of a dual X-and L-band satellite receiving system at McMurdo for joint operational and research use will be the means to acquire and apply advanced satellite observations for the benefit of both forecasters and researchers at the same time (Lazzara and Stearns, 2004).

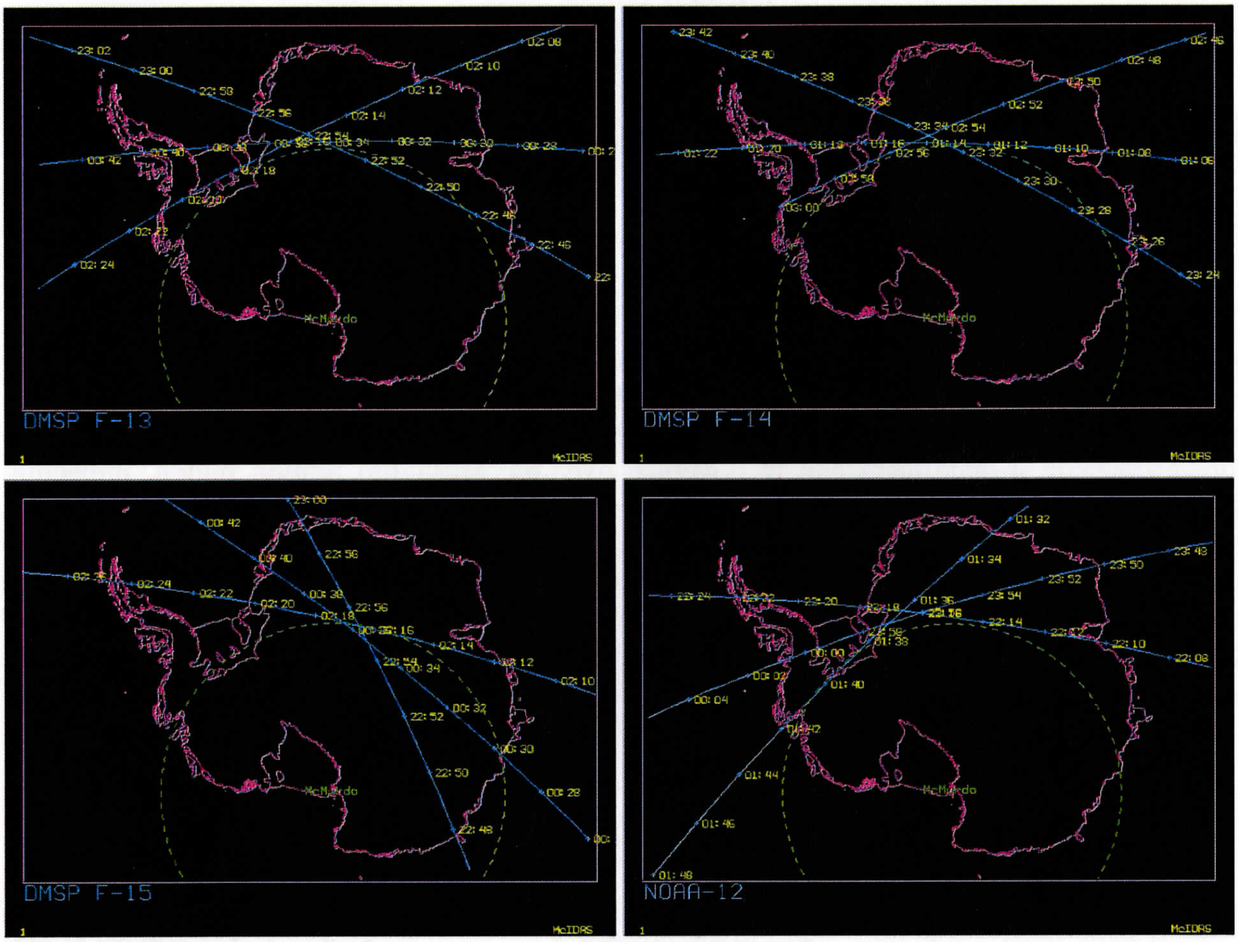
Current Limitations

The "Data Gap"

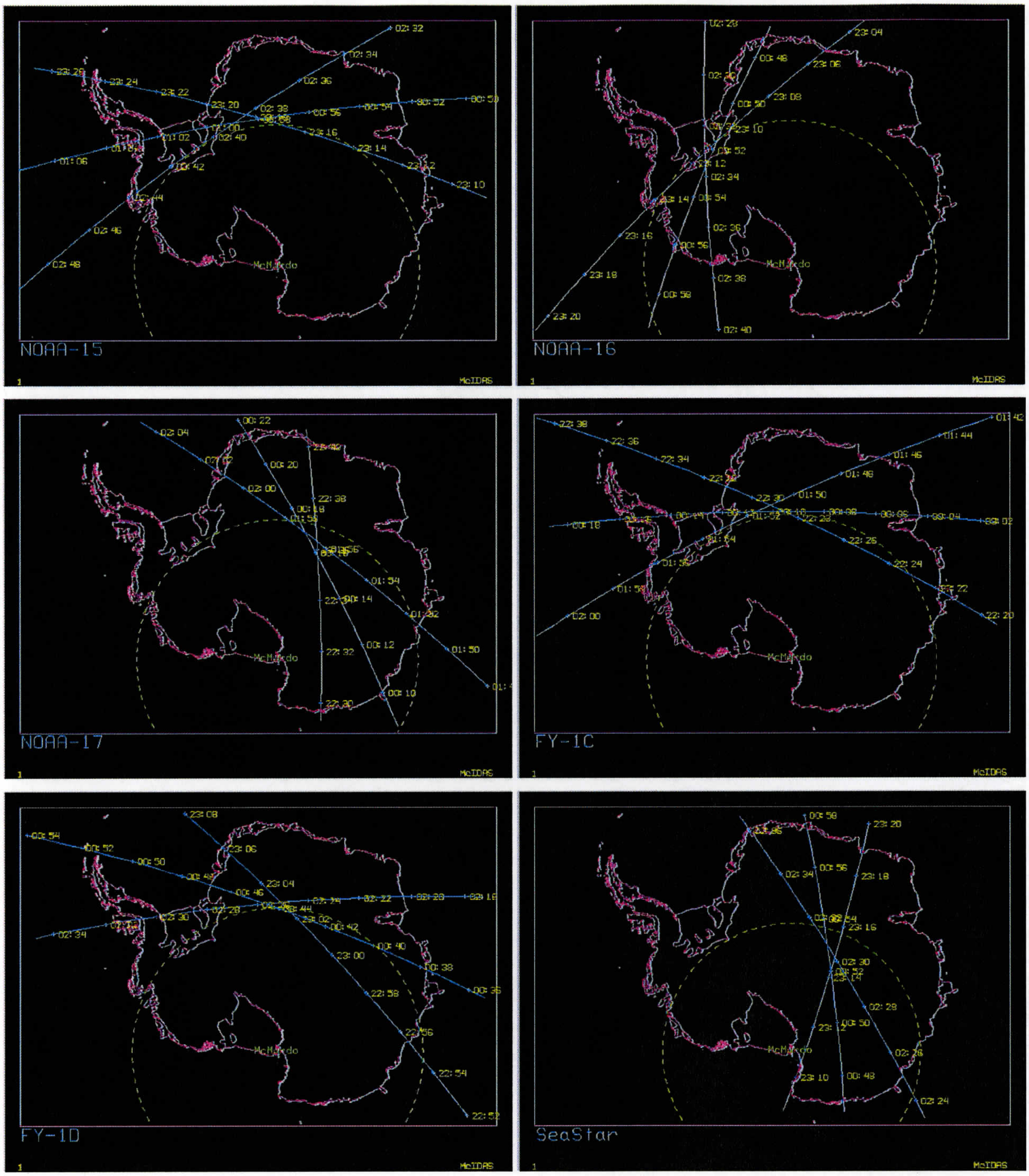
The biggest issue that affects the use of polar orbiting data for forecasting operations is the coverage limitations during the operational day at McMurdo Station, Antarctica, and the headquarters for USAP forecasting activities. Before the launch of NOAA-16 and NOAA-17, the orbital drift of older NOAA satellites and the limits of DMSP satellites to morning orbits only resulted in a significant gap in coverage over the McMurdo Station region, impacting weather forecasting operations at the nearby airfields for aircraft landing forecasts. Since the launch of the NOAA-16 and NOAA-17 satellites this gap has been reduced – as much as can be practically accomplished given the limitations placed on sun-synchronous polar orbiting slots for satellites as imposed by operators' climatological, operational and operating/maintenance requirements. Use of other satellites (e.g. Aqua and Terra) by the USAP with new X-band capabilities will allow the USAP to have more access to other satellites that could keep this gap at a minimum for the forecasting efforts.

Satellite Orbital Analysis: Over-flight Tracks

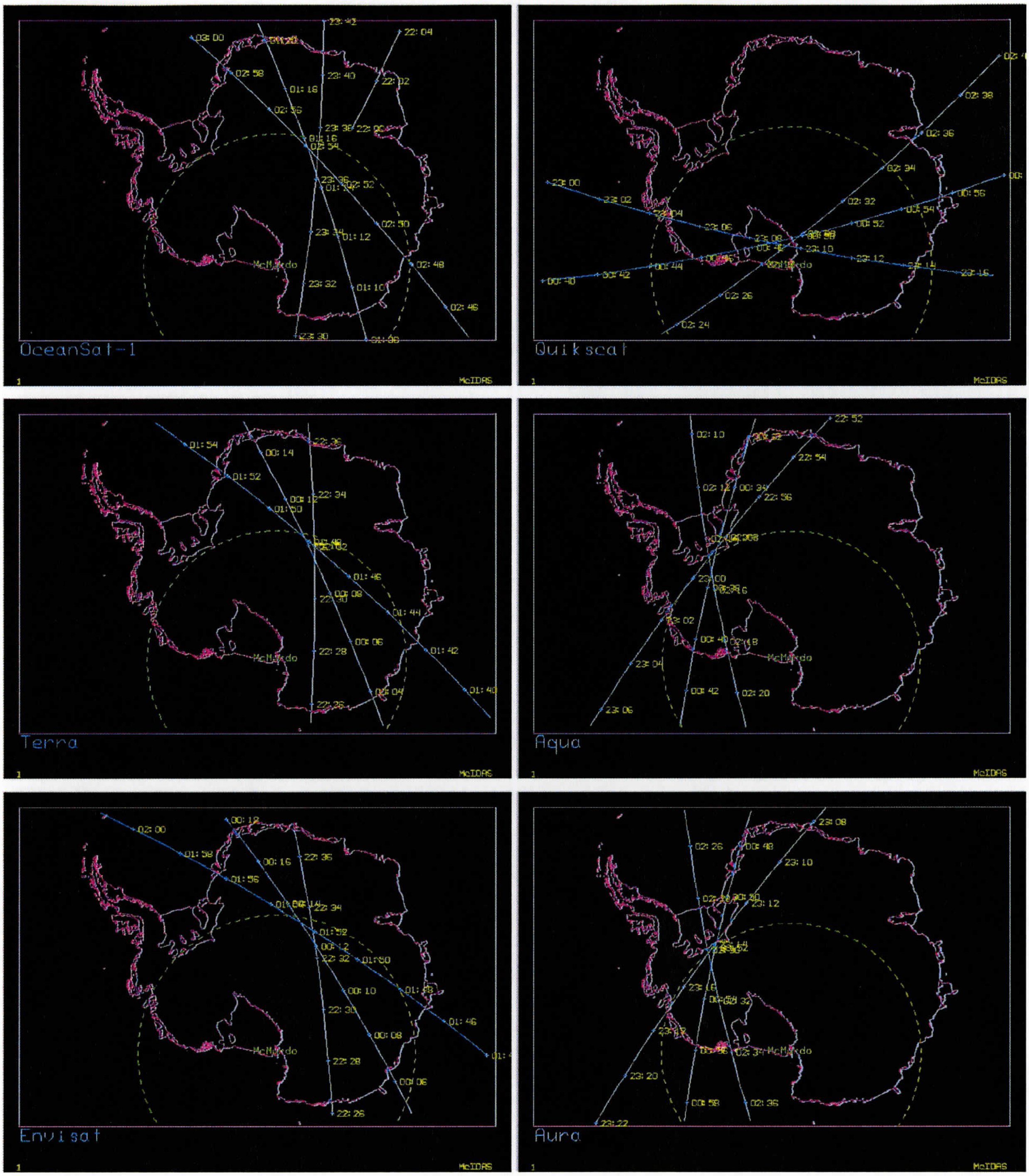
Below are depictions of several meteorological satellites and their over-flight tracks during the peak of the data gap period from 22 UTC to 3 UTC from an example day during WINFLY (25-26 August 2004). As can been seen visually, several satellites offer no coverage for McMurdo Station and the Ross Island/Ross Ice Shelf/Ross Sea region, including but not limited to DMSP F-13, DMSP F-14, NOAA-12, NOAA-15, FY-1C and FY-1D. There are some satellites that offer some help of varying degrees, such as DMSP F-15, NOAA-16, NOAA-17, OceanSat-1, Aqua, Terra, Envisat and Aura. Other satellites such as Quikscat offer the best help, but this platform does not offer the right sensors to benefit weather forecast operations (as well as the inability of McMurdo Station to receive this data and process it for science use in real-time on station). Thus the SeaStar (SeaWiFS) satellite is the only platform that assists with this problem. It would appear that due to the preference for current and future polar orbiting satellites to be in fixed equatorial cross-times, there will be no polar orbiting solution available to close this data gap completely. Given this, it is clear the launch and availability of NOAA-16 and NOAA-17 along with DMSP F-15 and SeaWiFS, all of which are available at McMurdo Station clearly have been of great help to forecasting efforts. The new Dual L-band/X-band satellite reception system adds Terra and Aqua overpasses which will support this effort. It is not clear that this new system will receive OceanSat-1 or Aura data (and Aura's sensor suite, even if it is directly broadcast, may not have the best sensors for forecasting operations). Envisat would offer some sensors of interest, however there maybe some issues with regard to processing, encryption, and permission that would need to be worked out with Envisat's operator (ESA) for this data stream to be used.



Panel 1. This first panel displays the orbital analysis for the DMSP F-13, F-14, F-15 and NOAA-12 (listed top to bottom, right to left) satellites during McMurdo's "data gap" period of 22 UTC to 3 UTC daily.



Panel 2. This panel displays the orbital analysis for the NOAA-15, NOAA-16, NOAA-15, FY-1C, FY-1D, and SeaStar (listed top to bottom, right to left) satellites during McMurdo's "data gap" period of 22 UTC to 3 UTC daily.



Panel 3. This panel displays the orbital analysis for the OceanSat-1, Quikscat, Terra, Aqua, Envisat and Aura (listed top to bottom, right to left) satellites during McMurdo's "data gap" period of 22 UTC to 3 UTC daily.

Potential Additional Forecasting Applications

There are several applications of meteorological satellite data that could be put to use operationally that potentially offer the chance to aid and improve weather forecasting for the USAP. Two classes of applications will be discussed: those for direct use by the forecaster, and those for direct use by numerical modelers, for indirect benefit of the forecaster. In many cases, the same product or application can benefit both classes at the same time. As a note, with the update of this document, some of the activities suggested here have started to take place (Straka et al. 2006).

Cloud Drift and Water Vapor Target Winds

One of the first applications that could be put into use is deriving satellite observed winds (See Figures 4 and 5). Recently placed on the web, the Cooperative Institute for Meteorological Satellite Studies (CIMSS) has a near real-time operational ability to compute winds from a series of consecutive NOAA AVHRR, Aqua, and Terra MODIS imagery. This data maybe of great value to the forecaster for flight forecasting as well as input to the mesoscale numerical models run over the Antarctic in support of USAP operational forecasting activities. With limited radiosonde launches around the Antarctic, these winds offer a significant increase in this class of observations. Plans for the 2004-2005 operational field season included making these datasets from Terra and Aqua MODIS data from the new dual L-band/X-band system to be installed at McMurdo Station. This has taken place and data is now beginning to be utilized and distributed for the benefit of the USAP and others.

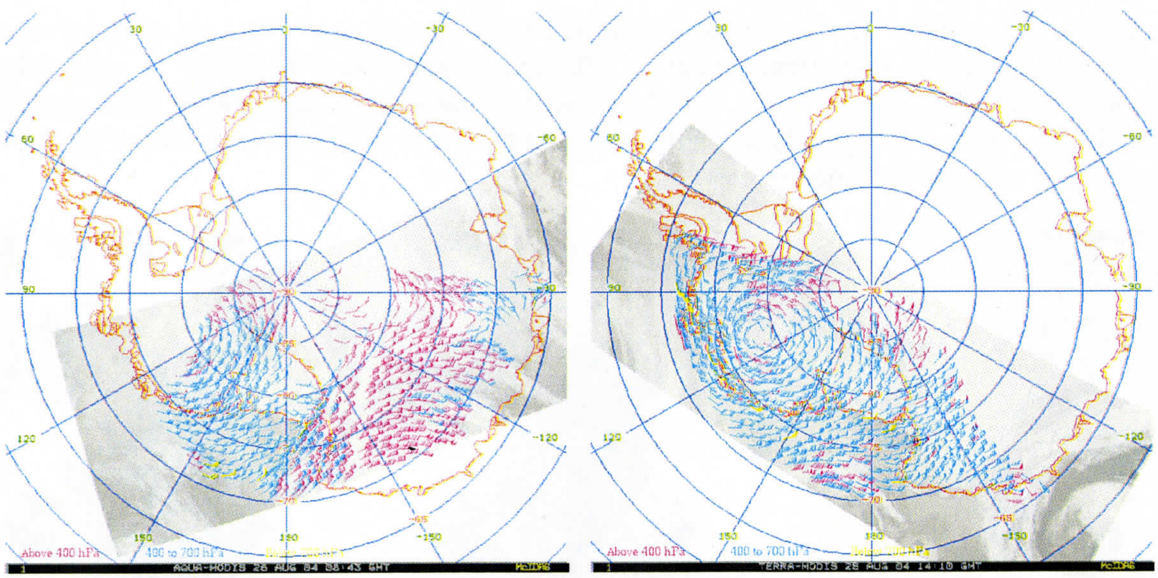


Figure 3. Sample cloud drift winds from Aqua (left) and Terra (right) depicting the wind regime over the Ross Ice Shelf region (*Courtesy of J. Key and CIMSS*).

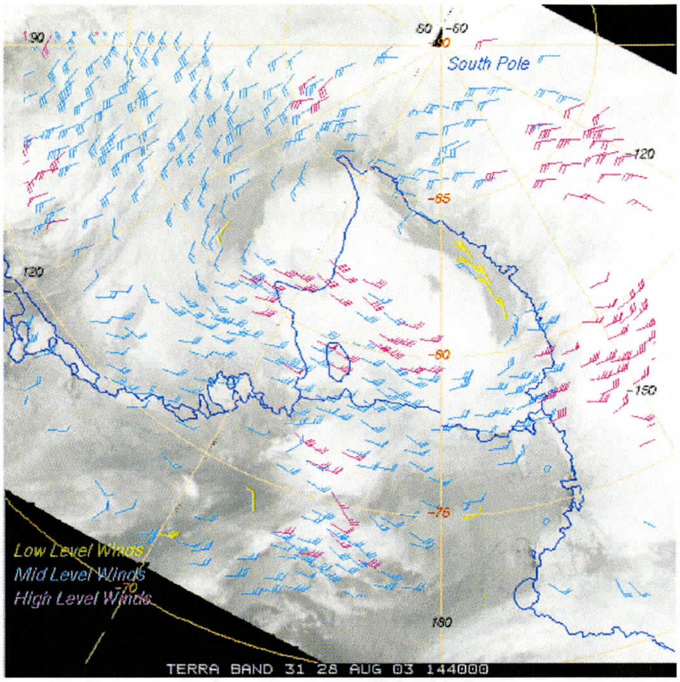


Figure 4. Another sample of satellite-derived winds, showing a closer view over the Ross Ice Shelf sector of the Antarctic (*Courtesy of J. Key and CIMSS*)

Cloud Detection and Cloud Properties

The ability to put cloud detection products from satellite to use may be of equal importance to forecasters, pilots, and numerical modelers alike (See Figure 6). The ability to offer pilots a depiction of where there are or are not clouds with some level of confidence is of significant value. Having mesoscale models correctly represent the cloud field allows for better forecasts of clouds and precipitation in the forecast.

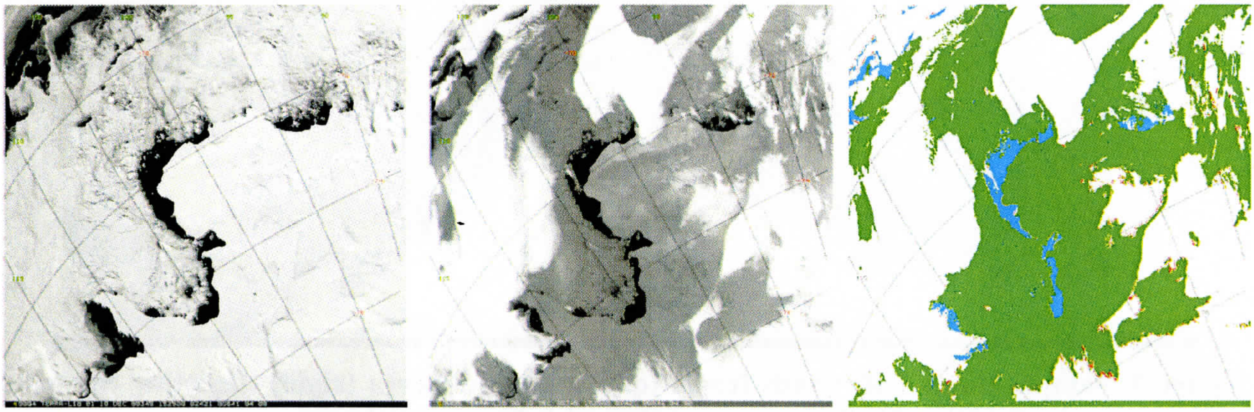


Figure 5. Examples of two channels (visible, left and infrared, center) and the cloud product (right) derived from the Terra MODIS over Pine Island Bay, Antarctica showing clear (green), cloudy (white), and perhaps open water areas (cyan) (*Courtesy of R. Frey and CIMSS*).

Additionally, cloud properties can also be derived from satellite sensing. Possible products include cloud top pressure, cloud phase, and total precipitable water content (See Figure 7). These products will likely have primary interest to numerical modelers, but may also be handy for forecasters, as forecast situations often call for this kind of information.

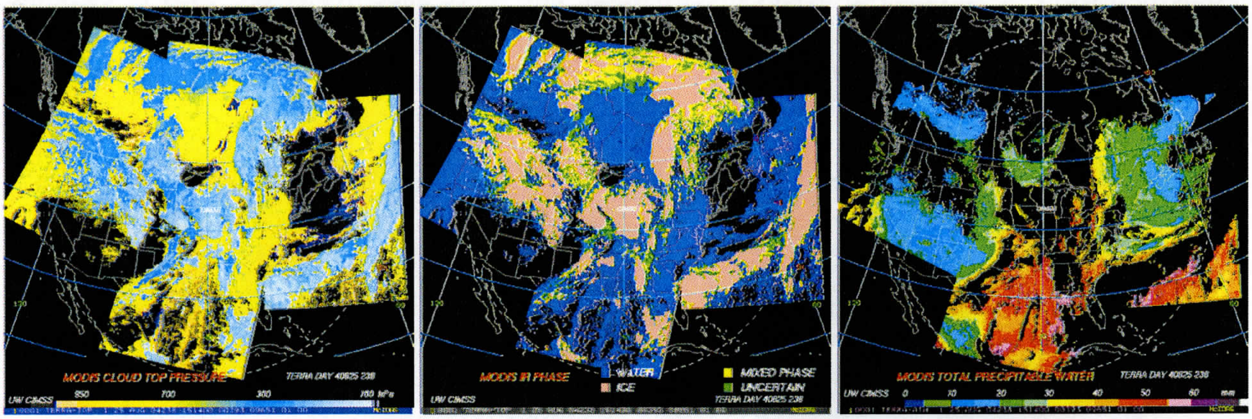


Figure 6. Examples of cloud top pressure (left), cloud phase (center), and total precipitable water (right) from Terra MODIS over the Continental United States taken at the University of Wisconsin Direct Broadcast system (*Courtesy of K. Strabala and CIMSS*). Colors of the display varing in meaning from product to product above.

Fog Detection

Another application is the possibility of being able to depict fog from satellite, giving forecasters aid with this number one aviation forecast problem. Efforts are currently underway to learn more about fog. It is too early to know if a fog detection method will be available from the research, but at the very least the improvement in enhancing and tracking fog may very well be possible from new satellite sensors such as MODIS over older sensors such as AVHRR.

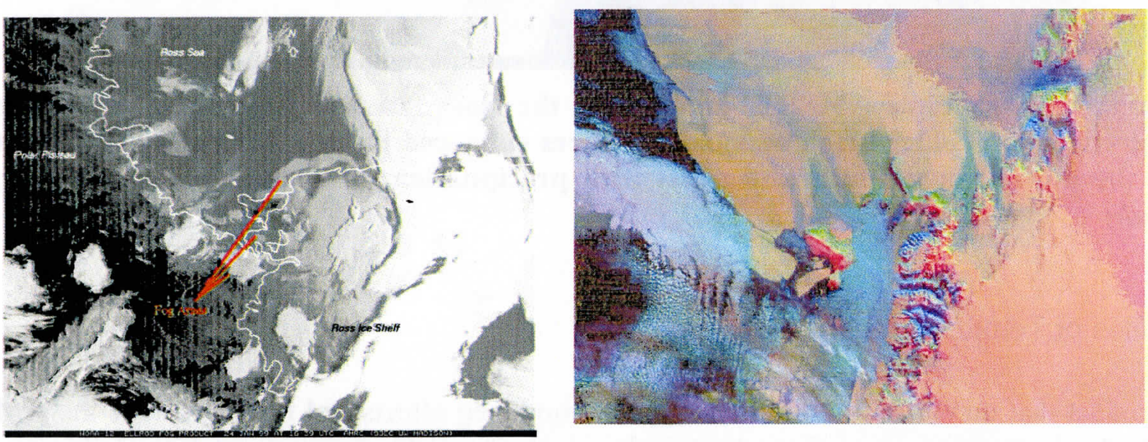


Figure 7. This display shows two separate example fogs over the Ross Island Region of Antarctica as seen on enhanced NOAA AVHRR (red pointers, left) and Terra MODIS (blue middle area, right) imagery. (*Courtesy of AMRC*)

Precipitation

A top problem for weather forecasters is precipitation. Microwave sensors are used in the middle and tropical latitudes to detect precipitation, and more specifically are used to estimate precipitation rates. Research on this topic in the Polar Regions faces some challenges and is in its infancy. Efforts in this area are underway for the Antarctic, and future results may offer improved information on precipitation to forecasters.

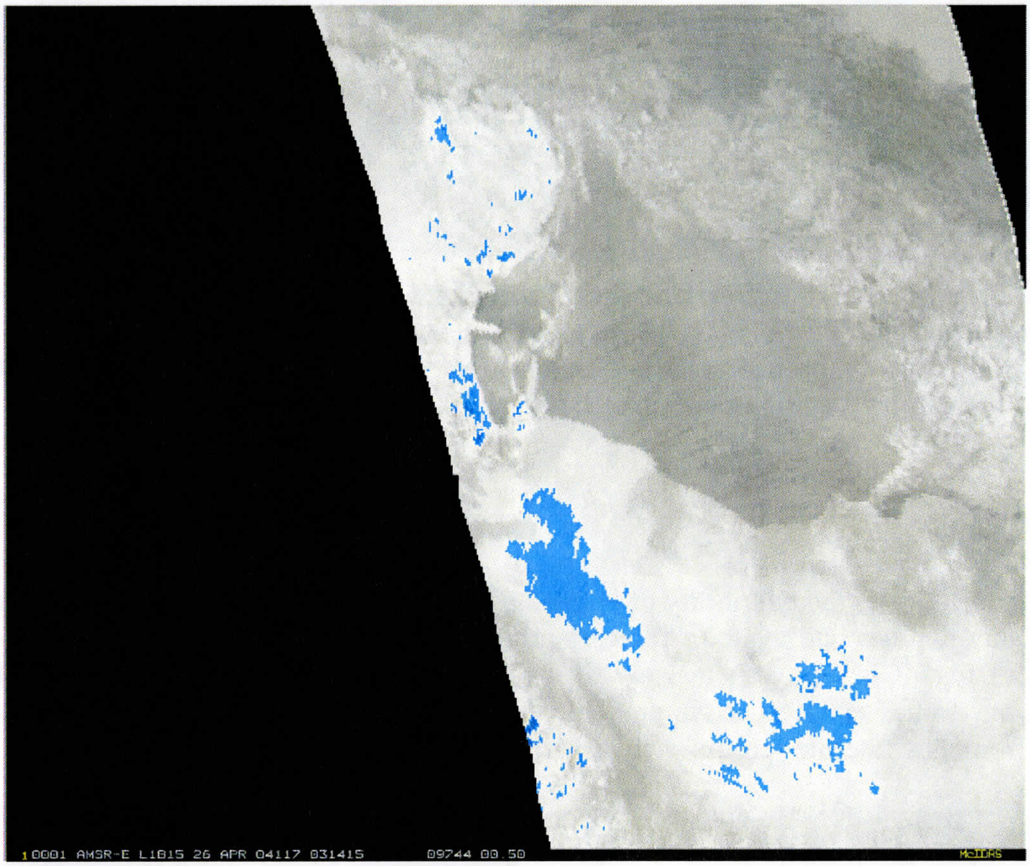


Figure 8. An example AMSR-E image over the Ross Sea and Ross Ice Shelf region of Antarctica with colder brightness temperatures enhanced in blue. Microwave information may be utilized in the future to assist with precipitation determinations (*Courtesy of S. Knuth*)

Profiles of Temperature and Moisture

A product that may benefit both the numerical modeling efforts and forecasters are the profiles of temperature and moisture from the sounder sensors available on some satellite platforms. The NOAA satellites offer the HIRS and AMSU sensors – together making up the ATOVS system. On the Aqua satellite, the combination of the AIRS, AMSU, and HSB sensors allow for the retrieval of vertical profiles of temperature and moisture. With limited radiosonde soundings around the Antarctic, the use of the satellite for this information over much more of the Antarctic may provide key information. With the availability of direct broadcast data from Aqua, additional high-resolution profiles from the several thousand-channel AIRS sensor may provide improved profiles beyond the POES ATOVS system (See Figure 10). In any case, both systems offer information that is currently under utilized in the forecasting arena. In addition, in the near future as a complement to these systems, COSMIC will start to come on-line and offer profiles as well. The combination of the two may prove to be powerful information throughout the Antarctic and adjacent waters region.

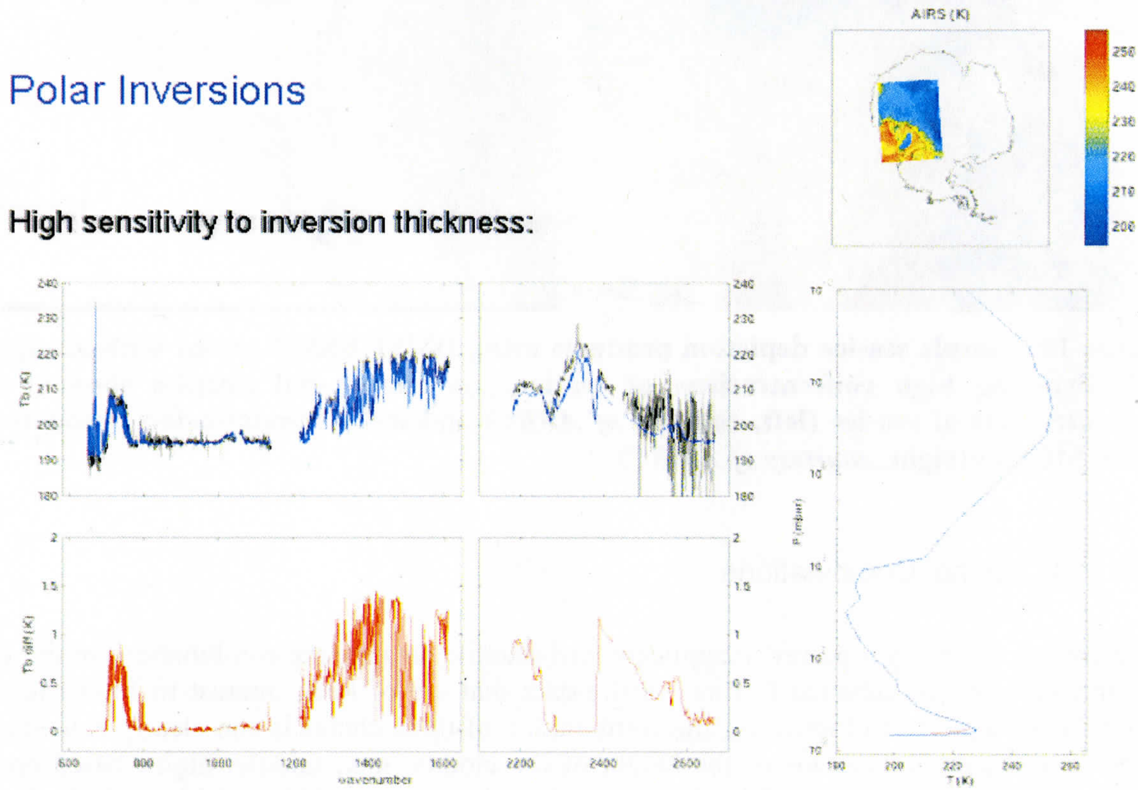


Figure 9. Sample displays of spectra, profile, and image from the AIRS instrument on Aqua (*Courtesy of David Tobin*)

Sea Ice Depiction and Iceberg Monitoring

Sea ice and icebergs can pose problems for USAP shipping interests - both supply and research vessels. Since the 2001-2002 field season, the icebergs outside McMurdo Sound have changed the sea ice dynamics and ocean current flow in the Western Ross Sea. Hence, now more than ever, sea ice and iceberg monitoring has become an important concern for ship routing and forecasting. Existing sensors such as the SSM/I on the DMSP (see Figure 11) satellite system as well as new sensors on the research satellites, such as AMRS-E on Aqua, offer improved monitoring. In addition to microwave sensors, SAR and scatterometer sensor capabilities offer an all weather means to monitor sea ice, although these datasets are not always available in real-time to USAP forecasters.

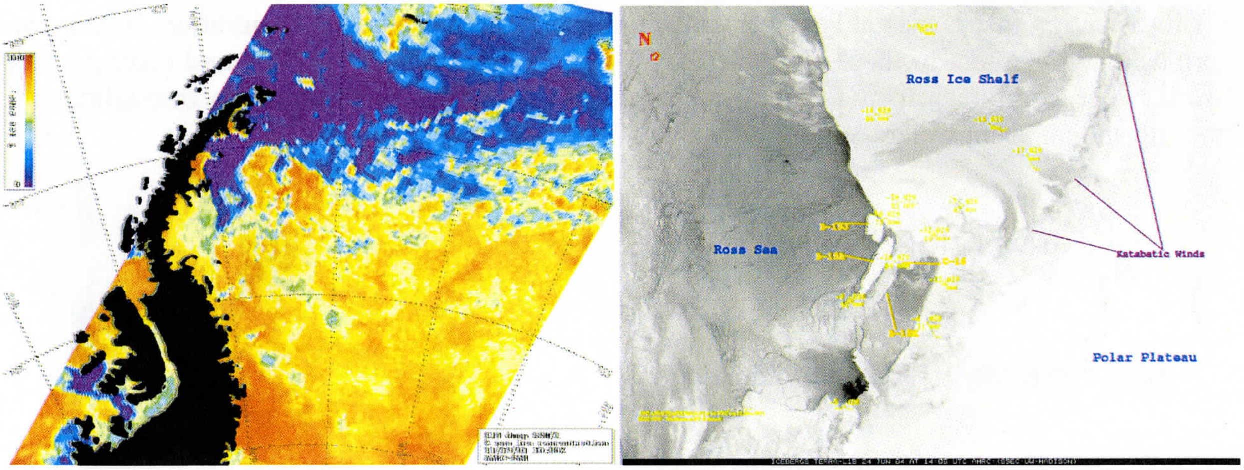


Figure 10. Sample sea-ice depiction products using DMSP SSM/I sensor with oranges and reds denoting high concentrations of sea-ice, and blues and purples showing lower concentrations of sea-ice (left, *courtesy of AARC*) and iceberg monitoring products using Terra MODIS (right, *courtesy of AMRC*).

Spectral Channel Combinations

A seemingly simple, yet powerful application of satellite data are the combinations of the various spectral channels to enhance features in the data that are of keen interest to forecasters. For example, as depicted in Figure 12, the combination of three channels can clearly enhance cloud features, and give indications of the height of the clouds (low, middle, high), based on color, shading and depiction. Some of the depictions are only possible with available sunlight, but other combinations can be done with infrared channels only as the figure denotes. Other multi-channel and "super-channel" combinations are being researched actively as newer sensors such as AIRS offer thousands of channels and require the deluge of data to be converted into a more easily used and understood presentation.

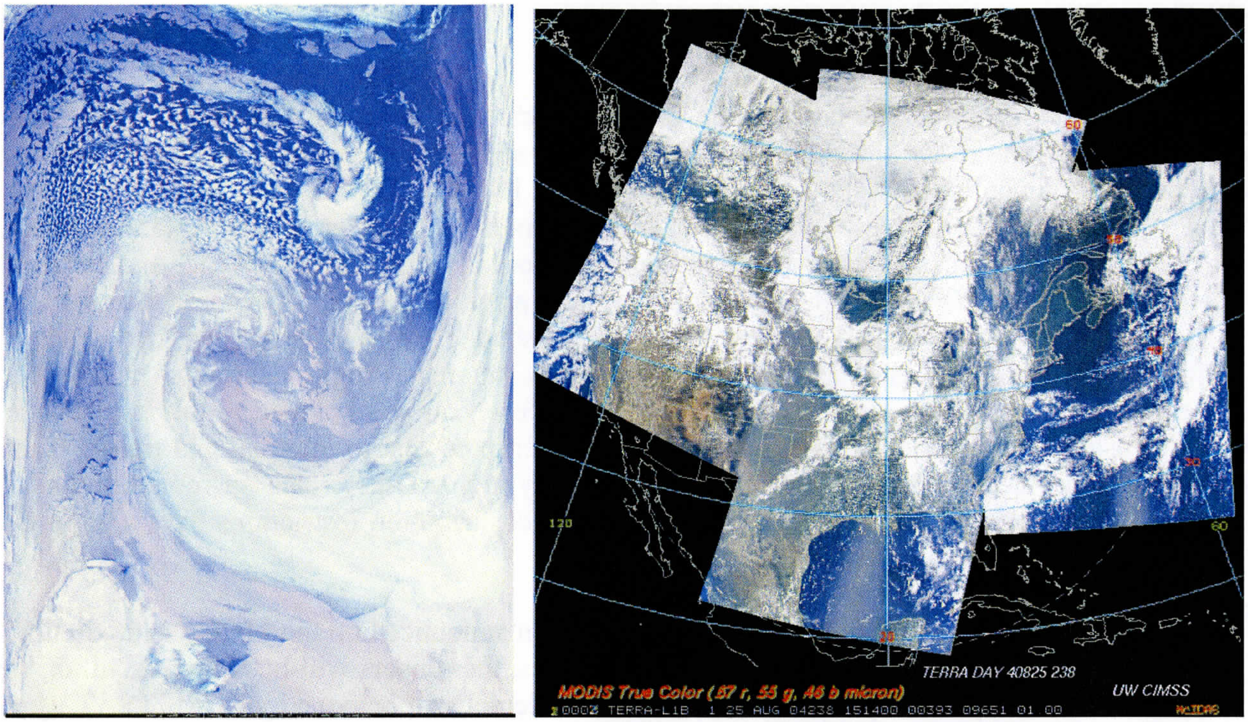


Figure 11 Two examples of three channel combinations from NOAA-16 AVHRR using the shortwave, window and longwave infrared channels (left), and Terra MODIS using the three natural color visible channels (right, *courtesy of K. Strabala and CIMSS*) Both of these combinations enhance features in the imagery.

Potential Satellites to Benefit USAP Operations

In the short run, it is clear that the USAP will continue to need to utilize the traditional polar orbiting satellite platforms (NOAA and DMSP). Meanwhile, in the coming years, the next generation polar orbiting satellites (Terra, Aqua, etc.) will need to be integrated into the forecast office. The learning curve to work with these new satellites is not trivial. Lessons and experience with these next generation satellites will prepare the USAP for the use of future operational polar orbiting platforms (NPOESS, MetOp, etc.).

In the mid-term, the USAP may benefit from the ability to acquire and utilize other satellites such as OceanSat or FY-1 series satellites. In the long run, the polar stationary satellite platform offers the most promise. If the platform becomes available, it gives the Antarctic its first "geostationary" like observing, with routine hourly, half-hourly or even rapid-scan coverage of a large portion of the Antarctic (Lazzara, 2004).

Each of these satellite systems offers huge gains in capability in terms of improved spatial resolution, larger spectral depth and greater temporal coverage. These are the capabilities that will place Antarctic meteorology in the best position possible with the assets available or soon to be available in space.

Data Encryption

The availability of satellite observations over the years has encountered some issues with availability and data encryption. For many years, some satellite systems have been and currently are encrypted, including DMSP, SeaStar/SeaWiFS and INSAT. DMSP observations have been unencrypted from 60 degrees South to 90 degrees South, in respect of the Antarctic treaty, providing an important source of weather satellite information for the Antarctic, and adjacent waters. With SeaStar/SeaWiFS being a public/private satellite system, NASA has arranged for data to be freely available and unencrypted for registered users who have a science research project use for the data stream, as is the case for the US Antarctic Program, although this service has come to an end. Other satellite systems have in recent years been added to this list, such as the Meteosat satellite series. These data are not all encrypted due to international treaty. Data every six hours is available in real-time without encryption. Other rules on redistribution of Meteosat data also apply, depending on availability. Redistribution restrictions have also in the past been imposed on GMS data as well.

Recently, new partial data encryption policies have been announced on the MetOp and NPOESS future satellite platforms. For the MetOp satellite series, the sensors will be encrypted all of the time, however decryption keys will be provided. Data denial will be done by EUMETSAT when asked to do so by the US Government (ESA, 2006). It also appears that DCS (Service ARGOS) and all Search and Rescue (SAR) capabilities will never be encrypted. For NPOESS, the policy will be similar. With the Integrated Program Office (IPO) planning to offer a required software and key registration for anyone to acquire and use NPOESS data streams, the encryption will be tiered. It is expected that during nominal operation, all NPOESS sensors and data streams will be available freely. However, at the request of the US Government, encryption can be imposed over a geographical region, by sensor, and/or by registered user. Like MetOp, it is expected that DCS (Service ARGOS), and all SAR capabilities will never be encrypted.

In general, there have been concerns over the limited availability of some satellite systems observations. This is a part of a larger discussion that the World Meteorological Organization (WMO) has taken up in the past, and specifically what is widely known as WMO Resolution number 40. Although this resolution has much of the middle and tropical latitudes in mind, it is hoped that the Antarctic Treaty, and the free exchange and availability of data will dominate for the Antarctic and adjacent waters.

Frequency Spectrum Threats

In recent years, the portions of the electromagnetic spectrum that are used or may be used in the future for meteorological remote sensing from satellite platform have been under attack. As it turns out, not all of the likely frequencies that have or may be of important value to meteorological satellite observations are completely protected by international agreement, and are reserved for passive remote sensing. Hence, some of these frequencies have been requested by other industries for commercial and consumer use, such as for car radar systems which are under development (Rochard, 2004). Currently this threat impacts some of the microwave portion of the spectrum (near 24 Ghz), as well as some of the frequencies used for satellite data transmission. This threat will likely grow. If current and future research efforts reveal important applications in these threatened regions of the spectrum, they may suffer from debilitating interference from other uses. Hence, it is important for the USAP, and more formally, the NSF to encourage that these unprotected bands become protected by international agreement and reserved for remote sensing applications and Earth discovery.

Summary and Considerations

Several key findings from this report can be summarized as follows:

- Review of the status of current and future meteorological and related satellites.
- The USAP forecast operations currently benefit greatly from meteorological satellites.
- Meteorological satellite observations and products over the Antarctic have to be put to increased use in numerical modeling efforts. This effort should be continued and increased especially for those observations and products that positively impact the numerical forecast output. Derived products from satellite observations not only are input for numerical modeling efforts but also must be available for direct use by weather forecasters.
- The USAP is starting to become active in acquiring new data streams of satellite data (i.e. X-band polar orbiting platforms). This effort is applauded and must continue with backup and additional systems for reliability and increased acquisition.
- The USAP must strongly consider the polar stationary satellite, as a long-term solution to its meteorological satellite and possibly communications needs. If such a platform becomes available, it offers the chance to nearly eliminate the data gap. It also offers a geostationary like set of routine and more frequently available observations to forecasters.
- The USAP and NSF have a duty to inform satellite-operating agencies such as NOAA, the Department of Defense, and NASA of its support requirements for operations and research. The USAP has, from an operational point of view, articulated its meteorological satellite needs to satellite operator agency NOAA in 2002 (Cayette, 2002). It is important for the USAP to continue to communicate its needs, both operational and research, to NOAA and to the other important satellite agencies named above as well as partnership agencies such as the IPO. This needs to be a done in a routine, regular fashion (annually perhaps).

There is no question that there are some issues that must be considered in facing the future of Antarctic operational satellite meteorology. Some of these limiting issues must be kept in mind for any future Antarctic meteorological satellite activities:

- Limited ground receiving abilities
- Processing needs on station
- High data volume connectivity for return to the mid-latitudes for supporting use.
- Satellite coverage and data gap issues
- Training and education along with operational integration

- Funding to solve these problems and meet goals as well as maintain an active research, development and operational program.
- Data encryption issues
- Threats to the frequency spectrum

It is hoped that this report will serve to aid the USAP with these important issues.

Acknowledgements

The author would like to thank the many people who have provided information and support to produce this report including the many unnamed here who have offered information via the Internet. Special thanks goes to Art Cayette at SPAWAR System Center Charleston, Miyamoto Hitomi at the Japanese Meteorological Agency, O-Ung Kwon at the Korean Meteorological Administration, Dr. Bernhard Lettau at the Office of Polar Programs, National Science Foundation and Timothy Schmit at NOAA/NESDIS. This report would not have been possible without prior funding from SPAWAR System Center Charleston (PO-#N65236-02-P-1646 and PO-#N65236-04-P-6624), and the National Science Foundation, Office of Polar Programs Grant #OPP-0412586.

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ESA, 2006: Data Denial Agreement: http://www.eumetsat.int/idcplg?IdcService=SS_GET_PAGE&ssDocName=005264&l=en&ssTargetNodeId=114

Lazzara, Matthew A., 2005: Polar environmental monitoring, communications, and space weather from pole sitter orbit. Madison, WI, University of Wisconsin-Madison, Space Science and Engineering Center, Antarctic Meteorological Research Center (AMRC). 12p. UW SSEC Publication No.05.04.L1. [Available from The Schwerdtfeger Library, University of Wisconsin-Madison, 1225 W. Dayton St., Madison, WI 53706.]

Lazzara, M.A., and C.R. Stearns, 2004: The future of the next generation satellite fleet and the McMurdo ground station. University of Wisconsin-Madison, Space Science and Engineering Center, Antarctic Meteorological Research Center (AMRC), 40p. UW SSEC Publication No.04.07.L1 [Available from The Schwerdtfeger Library, University of Wisconsin-Madison, 1225 W. Dayton St., Madison, WI 53706.]

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[Available from The Schwerdtfeger Library, University of Wisconsin-Madison, 1225 W. Dayton St., Madison, WI 53706.]

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On-line Resources

This document was almost completely created using information available via Internet from official and unofficial sources. In some cases, some of the information available, especially launch dates, conflicts with other information. The author made the best assessment of the information and sources of information in compiling this report. Due to the diversity of information and time limitations, a limited set of explicit references (see above) have been made with the text. However, a list of web sites is given below that were the major sources for much of the information contained within this report. It is important to note that this report, especially the future launch dates and status of operating satellites, is subject to change. Within three to six months the contents of this report is apt to be somewhat outdated.

United States Antarctic Program Meteorological/Satellite Data sites:
- http://amrc.ssec.wisc.edu/
- http://arcane.ucsd.edu/
- http://nsidc.org/usadcc/

Japanese Meteorological Agency (JMA):
- http://www.kishou.go.jp/english/index.html
- http://mscweb.kishou.go.jp/general/future_plan/index.htm
- http://mscweb.kishou.go.jp

Russian Federation:
- http://sputnik.infospace.ru/
- http://sputnik.infospace.ru/goms/engl/goms_e.htm

Chinese Meteorological Agency (CMA):
- http://nsmc.cma.gov.cn/indexe.html
- http://www.cma.gov.cn/ywwz/constitute/nsmc.php
- http://nsmc.cma.gov.cn/fy2e.html

Australian Bureau of Meteorology (ABOM):
- http://www.bom.gov.au/
- http://www.bom.gov.au/sat/MTSAT/MTSAT.shtml
- http://www.bom.gov.au/sat/Othersat/othersats.shtml

United States/NOAA/NASA:
- http://www.noaa.gov
- http://www.nasa.gov
- http://noaasis.noaa.gov/NOAASIS/ml/launch.html
- http://www.oso.noaa.gov/operation/index.htm
- http://www.oso.noaa.gov/goesstatus/
- http://www.oso.noaa.gov/poesstatus/
- http://www.ipo.noaa.gov

http://www.jpl.nasa.gov/calendar/calendar.html
http://rsd.gsfc.nasa.gov/goes
http://poes2.gsfc.nasa.gov/campaign/campaign_home.htm
http://liftoff.msfc.nasa.gov/RealTime/JTrack/3d/JTrack3d.html
http://nssdc.gsfc.nasa.gov/nmc/sc-query.html

India Meteorological Department (IMD)/ Indian Space Research Organization (IRSO):
http://www.isro.org/
http://www.imd.ernet.in/
http://www.isro.org/programmes.htm:
http://www.isro.org/insat3e/pg1.html

EUMETSAT/ESA:
http://www.eumetsat.de/
http://www.esa.int/
http://www.esa.int/export/esaME/ESAPY1094UC_index_0.html
http://www.esa.int/export/esaME/ESAMG1094UC_index_0.htm
http://www.eumetsat.int/idcplg?IdcService=SS_GET_PAGE&ssDocName=005264&l=en&ssTargetNodeId=114

France/CNES:
http://smsc.cnes.fr/PARASOL/index.htm

Canadian Space Agency:
http://www.space.gc.ca/asc/eng/media/press_room/news_releases/2004/040206.asp

Taiwan:
http://www.nspo.gov.tw/e50/home/index.html
http://www.nspo.gov.tw/e50/home/index.html

Miscellaneous:
http://fas.org/spp/guide/china/earth/index.html
http://fas.org/spp/index.html
http://www.teamencounter.com/
http://groups.yahoo.com/group/weather-satellite-reports/
http://www.itc.nl/research/products/sensordb/Launch_Schedule.aspx
http://www.satsignal.net
http://celestrak.com/
http://www.satelliteonthenet.co.uk/launch.html
http://pages.ivillage.com/spacehorizons/id23.html
http://www.spaceflightnow.com/tracking/index.html
http://www.boeing.com/defense-space/space/bss/factsheets/601/goes_nopq/goes_nopq.html
http://www.astronautix.com/craft/insat3.htm
http://www.spaceandtech.com/spacedata/logs/2002/2002-043a_metsat-1_sumpub.shtml
http://www.tbs-satellite.com/tse/online/mis_meteo_geo.html

http://www.tbs-satellite.com/tse/online/mis_meteo_defilement.html
http://www.allmetsat.com/en/weather_satellites.html
http://www.sinodefence.com/space/spacecraft/fy1.asp
http://www.solidgoldman.com/DMSP.Sensor.Ste.html
http://www.designation-systems.net/dusrm/app3/s-1.html

Satellite Sensor Band/Channel Listings

As a compliment to this report, the following on-line resource offers a good listing of several satellite sensor systems' bands or channels offerings.

http://www.ssec.wisc.edu/mcidas/doc/users_guide/2005/app_d-1.html#16239

Appendix A: Memo to NOAA/NESDIS November 15, 2005

Benefits Of A South American/Southern Hemisphere Dedicated GOES Mission For The United States Antarctic Program And Possible Contributions To The International Polar Year

Recommendations to the National Oceanic and Atmospheric Administration's (NOAA) National Environmental Satellite, Data, and Information Service (NESDIS)

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Abstract

Recent consideration of a Geostationary Operational Environmental Satellite (GOES) mission, likely GOES-10, dedicated for the remote sensing needs for South America and the Southern Hemisphere, would also have benefits for the polar regions as well. This essay outlines how such a mission may have benefits for the United States Antarctic Program (USAP), specifically the Antarctic satellite composite project at the University of Wisconsin, as well as being a contribution to the International Polar Year (IPY).

GOES and Antarctic Composites Satellite images

For over 13 years, the Antarctic Meteorological Research Center (AMRC) has been funded by the National Science Foundation's (NSF) Office of Polar Program (OPP) to generate a mosaic of satellite observations centered on the Antarctic continent and adjacent Southern Ocean (Lazzara et al. 2003a, Lazzara et al. 2003b, and Stearns et al. 2003). The resulting infrared (~11 microns) composites (Figure 1) cover a significant portion of the Southern Hemisphere using a combination of both geostationary and polar orbiting satellites and are made at a nominal resolution of five kilometers. The AMRC also makes composites in additional spectral channels such as water vapor (~6.7 microns) and has begun to experiment with visible channel (~0.6 microns) (AMRC, 2005). In the near future, additional channels will be created such as short wave and long wave infrared, with the advent of those channels being common among a sufficient number of the base satellites used in the composites. However, these composites are only generated every three hours, meant to coincide with the availability of the GOES West and GOES East full disk imagery. The prospect of having a GOES mission dedicated to imaging operations in the Southern Hemisphere with a primary objective of improved imaging for the South American continent is very beneficial to the AMRC's activities. This GOES mission would have secondary benefits for these composites, especially if the imaging schedule and coverage of the Southern Hemisphere missions will be more frequent with full disk or at least full Southern Hemisphere imaging on an hourly basis or better. With improved temporal resolution of GOES imagery matching the similar temporal resolution of other geostationary satellites, Antarctic composite imagery on an hourly basis can become a reality. With a more frequent composite, synoptic systems around the Southern Ocean and

Antarctic region will be able to be tracked more closely for operational and research activities, for example, among other possible applications.

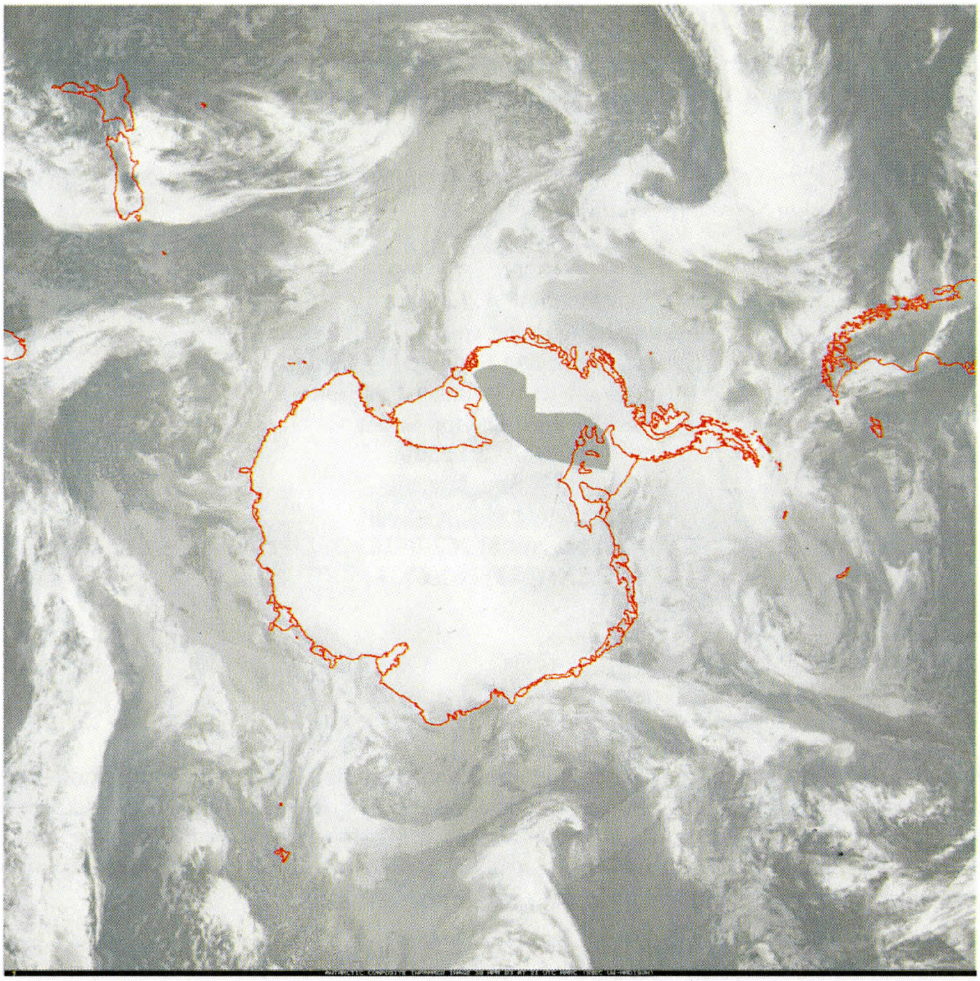

Figure 1. A sample Antarctic Composite infrared image made from a combination of GOES, Meteosat, MTSAT-IR, FY-2C, NOAA, DMSP, Terra and Aqua satellites, with data within 50 minutes of the top of the synoptic hour.

GOES for the International Polar Year

The potential time line for having a Southern Hemisphere GOES mission in place by late 2006, and with operations into 2007 and beyond, coincides with the International Polar Year (IPY) (NAS, 2004). Hence, without additional cost, NOAA is in the unique position of having this GOES mission have a secondary application – special observing that can benefit the activities of the International Polar Year. In addition to the AMRC Antarctic composite, there may be other Southern Ocean activities that may benefit from enhanced and increased satellite observations over this time frame. The IPY proposes to be an exciting time of field study, data collection and analysis. NOAA has the chance to contribute to this effort while achieving the main objective of this particular GOES mission.

Recommendations

NOAA is strongly urged to consider the following recommendations:

1. Implement the South American/Southern Hemisphere GOES mission.

2. If at all possible, have the imaging schedule for the GOES imager on this mission take full disk or at least full Southern Hemisphere imaging (from the South Pole to at least 35 degrees South latitude) on a basis more frequently than current GOES missions. Hourly imaging is ideal.

3. Strongly consider this extraordinary mission to not only meets the needs of the South American region of the Western Hemisphere, but also to potentially contribute to monitoring and observing for the International Polar Year (IPY) in the Southern Ocean region.

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Distribution

This document has been distributed to the following:

Dr. Bernhard Lettau, NSF/OPP
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Dr. Jeffrey Key, NOAA/NESDIS/CASC
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Appendix B: Memo T. Schmit December 2005

Thoughts on Possible Schedules of GOES-10 near 60W

T. Schmit, NOAA/NESDIS/STAR December 2005
Madison, WI

Introduction

To arrive at the best schedule for a GOES operated near 60W one would need to canvas the needs of the various effected countries and user communities. One method is to suggest a possible schedule based on known requests. For example the requests made at the "Direct Read-out Conferences" for more frequent GOES Imager and Sounder coverage. These scans would be independent of GOES-East rapid scan operations. In general, the operational concept of operations needs to be defined before any benefits can be finalized.

First, any operational constraints need to be defined. In this case we are assuming no special scans, etc. Other groups (WMO, AMS Satellite group, VAACs, NWS Aviation Weather Center, NWP community, etc) could be canvassed for inputs.

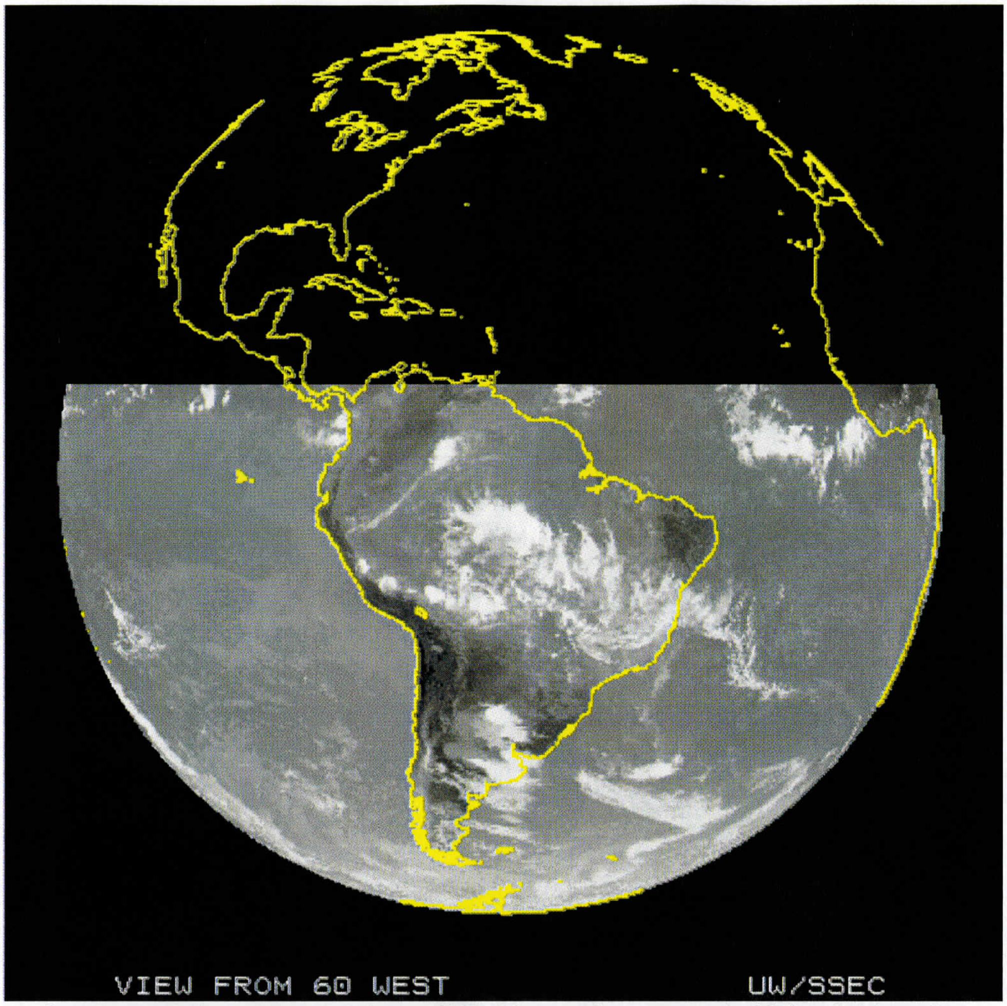
The following proposed scan scenarios are suggested as a starting point and are based on current routine coverage for the northern hemisphere and with an effort to keep the schedules simple.

Imager (15min Extended Southern Hemisphere (ESH))

For access by many countries, the Antarctic community, and other groups, the imager could scan from limb to limb at least each hour down to the South Pole region. The northern extent could be north of the equator (say 10N). [The exact extents may need to be modified if more time is needed for navigation. For example, by reducing the west-east extent.] This scan would help short-term aviation forecasts via improved satellite composites. This scan may take approximately 15 minutes.

During the other (approximately) 45 minutes of each hour, the same scans could be generated. This would provide higher time resolution images for monitoring southern hemisphere clouds, storms, fires, etc. This is similar to the routine 15 coverage over the CONUS.

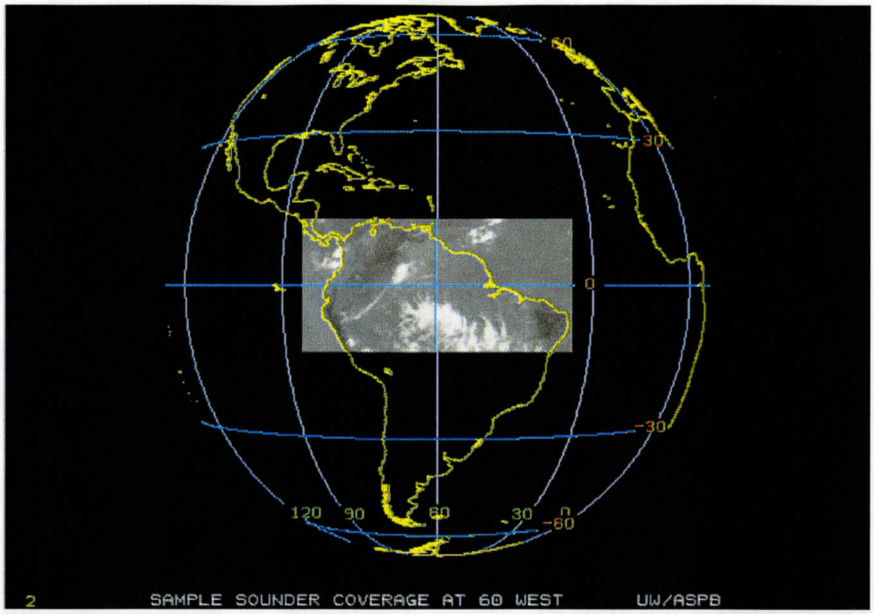
As with the GOES-East and West Imagers, consider a full disk image scan. The start times could be staggered, compared to GOES-East and West. So, these would be nominally 1:30UTC, 4:30UTC, 7:30UTC, etc. Another option would be to just scan a full disk image during the spring/fall outage times of the GOES-East imager. This can help reduce the outage times by approximately one hour (due to the differing outage times which is in turn due to the differing satellite positions).



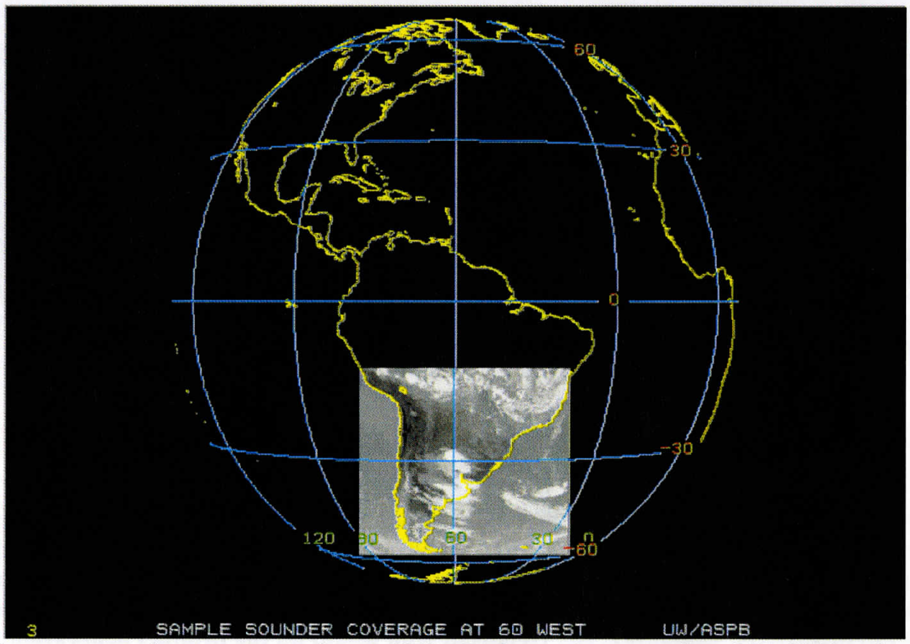
Sample image from a geostationary perspective at 60W. The northern extent is 10N and this region would take approximately 15 minutes to scan by the Imager.

Sounder (Alternating Hourly South America scans)

The GOES Sounder scans much slower than the GOES Imager. Consider alternating hourly scans centered on (0S, 60W) and (30S, 58W). This would be the first ever-routine GOES Sounder coverage of the Southern Hemisphere. This scenario allows most locations an image loop every two hours. A number of products could be produced: retrievals; Derived Product Images (DPI) such as Total Precipitable Water (TPW), Lifted Index (LI), etc.; cloud top properties; radiances; etc. Details of who would do the product generation and distribution would need to be defined. The exact coverage is a function on how much area can be covered in one hour. The figures (below) are only estimates of the coverage area per hour.



Sample image from a geostationary perspective at 60W. The image is centered on 0S, 60W and would take approximately one hour to scan with the sounder.



Sample image from a geostationary perspective at 60W. The image is centered on 30S, 58W and would take approximately one hour to scan with the sounder.

Disclaimer

The many colleagues are thanked who have given insight to these possible schedules. The McIDAS system was used to generate these images. The views, opinions, and findings contained in this document are those of the author and should not be construed as an official National Oceanic and Atmospheric Administration or U.S. Government position, policy, or decision.

The Future of the Next Generation Satellite Fleet and the McMurdo Ground Station

A Report to the

Office of Polar Programs
National Science Foundation
United States Antarctic Program

Edited by

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July 30, 2004

Funded by NSF-OPP Grant #OPP-0412586

UW SSEC Publication No.04.07.L1.

Photo by Pat Smith, NSF-OPP

Compiled in 2004 by the
Antarctic Meteorological Research Center
Space Science and Engineering Center
University of Wisconsin-Madison

This report may be cited as:

Lazzara, M.A., and C.R. Stearns, 2004: The future of the next generation satellite fleet and the McMurdo ground station. UW SSEC Publication No.04.07.L1. Space Science and Engineering Center, University of Wisconsin-Madison, 40 pp. [Available from The Schwerdtfeger Library, University of Wisconsin-Madison, 1225 W. Dayton St., Madison, WI 53706.]

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Or on-line at:

http://amrc.ssec.wisc.edu/MGS/MGS-final-report.pdf

Table of Contents

Executive Summary

The purpose of this report is to provide information, options, and recommendations for deciding how to collect and provide the transmitted data from the next generation of polar orbiting satellites for use by the United States Antarctic Program (USAP) in Antarctica. X-band direct broadcast satellites are replacing the operational L-band direct broadcast satellites currently used by USAP as soon as 2006. Since the 1990s there have been research X-band direct broadcast satellites in polar orbit. The new satellites offer increased capabilities and open the doors to new science and possibilities for observing and learning about the atmosphere, ocean, cryosphere, lithosphere, and biosphere system. However, there is a need for lead-time to prepare to acquire and train for the applications of the new streams of data. The new satellite systems require X-band receiving equipment. One option is to utilize the existing McMurdo Ground Station (MGS) X-band receiving system. The MGS is an Earth reception station at McMurdo Station, Antarctica installed in 1993 with the goal of collecting data from Synthetic Aperture Radar (SAR) sensor equipped satellites. Funded mutually by the National Science Foundation (NSF) and the National Aeronautics and Space Administration (NASA), this reception system has been pivotal in the collection of remotely sensed satellite data that would not be otherwise available as well as being utilized in the support of satellite and spacecraft commanding. The goals and uses of the MGS are at a crossroads, however. Other reception systems should be considered as well. The focus of this document is to report on the Antarctic science and operations community recommendations regarding the capabilities of the next generation satellite fleet along with applications and reception possibilities with a focus on the MGS, especially as it relates to USAP research and operation activities. The recommendations of this report with regards to these issues as well as critically related communications issues are the following:

- Recommend that the United States Antarctic Program actively pursue increased and improved Internet communications both to and from McMurdo Station, Antarctica. This recommendation is critical for both the MGS and other stand alone direct readout reception stations at McMurdo Station, as the fast return of data received at these locations to users is critical.

- Recommend the installation of an additional stand-alone X-band direct readout reception station for science and operational use by the United States Antarctic Program and its partners.

- Recommend the processing and use of X-band direct broadcast data be deployed both on site at McMurdo Station as well as off site.

- Recommend that the MGS is a viable ground station – it has been and continues to be an important resource and provide valuable data. With continued reasonable demand for use, sufficient resources to adequately manage and maintain MGS should be

provided so as to insure a year round reliability consistent with other satellite ground stations.

Given some recent developments, the following additional recommendations have been put forth:

- Recommend that the second L-band direct readout ground system get upgraded to Dual X-/L-Band system during its next maintenance cycle upgrade to match the first system or if at all possible, a pure X-Band system be installed in the L-band system's place.

- Additionally, it is strongly encouraged that the capabilities of the MGS be expanded to be a backup for these systems in the case of catastrophic failure. In addition, it will be of benefit to the MGS to have this capability, as it will likely make the MGS more attractive to other users, and in turn a more valuable asset to the NASA Ground Station Network.

Additional explanation of these recommendations is based on the contents of this report. This report is the result of the McMurdo Ground Station Science Workshop, held at the Byrd Polar Research Center, the Ohio State University on March 9 through 11, 2004 co-host by the Antarctic Meteorological Research Center at the Space Science and Engineering Center, University of Wisconsin-Madison and the Byrd Polar Research Center, the Ohio State University.

Introduction and Background

The McMurdo Ground Station (MGS)

The MGS is a 10-meter S and X Band antenna located at McMurdo Station, Antarctica (See Figures 1 and 2; Table 1). It is the result of the cooperation of two government agencies, the National Science Foundation (NSF) and National Aeronautical and Space Administration (NASA). The original purpose of the antenna was to collect the satellite radar mapping of the entire Antarctic continent, along with two other similar ground stations elsewhere on the continent. (Jezek and Carsey, 1991) This station is designed to collect SAR image data from a number of international satellites. It has been actively engaged in this activity for several years. It became active in January 1995 and was operational one year later. As early as March 1996 it was collecting 105 Mbps telemetry (X-Band) on about 25 passes each day, from ERS-1 & ERS-2 (European Earth Resource Satellites). For several months in the mid to late 1990s, it supported the Canadian SAR mapping of Antarctica with the RADARSAT satellite. It is collecting 85 Mbps and 105 Mbps telemetry routinely. At times a Tracking and Data Relay Satellite System (TDRSS) link to forward that data back to continental United States has been used. MGS has also supported the Southern Hemisphere science campaign of NASA's Fast Auroral Snapshot Explorer (FAST) mission, which is an S-Band mission.

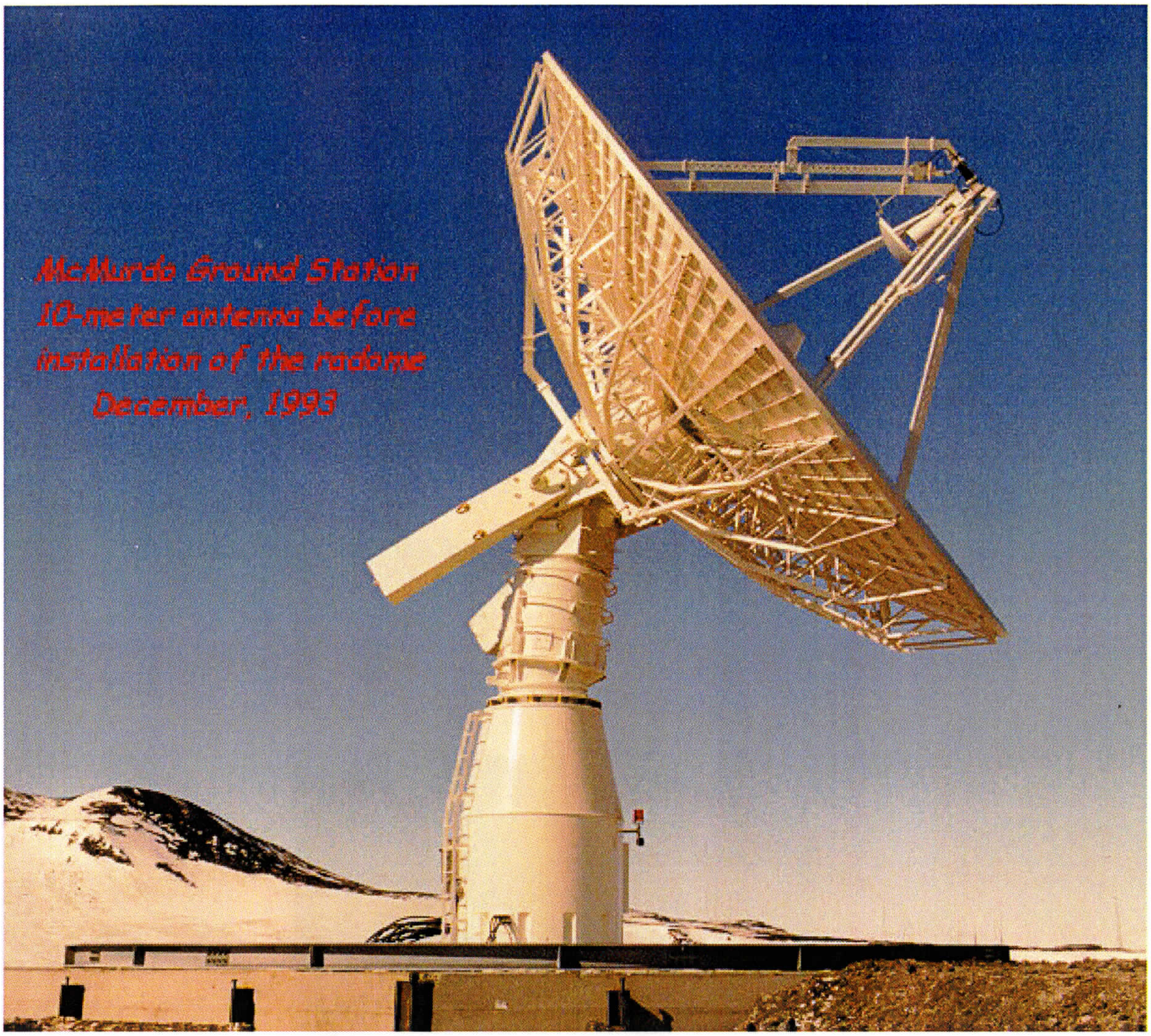

Figure 1 A photograph of the McMurdo Ground Station 10-meter antenna (without the radome) taken in December of 1993 (*Courtesy of M. Comberiate*).

In August 1997, this McMurdo Ground Station (MGS) was configured quickly to command at S-Band as well. The capability had been built in but not used for any flight missions until the Lewis Satellite started tumbling. Because MGS could see virtually every pass, it was a real asset in the rescue attempt. Both store and forward commanding and real-time commanding were used. All commanding was initially tested on the active FAST satellite, using the 128Kbps full duplex channel on NSF's T1 Commercial service (available 24 hours/day). MGS inherently has the capability to support polar-orbiting satellites of all kinds, such as those that are in NASA's Mission to Planet Earth. These satellites generate in excess of 100Mbps telemetry rates due to the high-resolution images of the Earth and geophysical processes that they capture. This antenna can automatically track and collect data from multiple satellites. (With so many satellite passes that are visible from McMurdo, the MGS has to schedule which ones it will acquire).

Only a few other ground stations have the capability of MGS to unload the enormous volume of data that a polar ground station can collect. This is because of NASA's McMurdo TDRSS Relay System (MTRS). Since January 1996, a TDRSS link on Black Island has the capability of returning extremely high rate data to continental United States. It can return 300 Mbps with 10 dB margins. The one limitation has been on available ground equipment in continental United States to handle this high-speed data, since it is not the current norm. There have been some reliability issues with this in the past. MGS has been used often for launch supports, where (like its 2-meter predecessor, NASA Antarctic Interactive Launch Support (NAILS)) the telemetry it collects is returned to the control center in continental United States during or immediately following the pass. In figure 2, the photos show the large radome that is situated on one of the highest hills around McMurdo (Arrival Heights). From this vantage point it has a fantastic view in all directions and looking south it can see satellites on the other side of the South Pole.

Figure 2 A three-panel photograph of the complete McMurdo Ground Station radome that depicts its location atop Arrival Heights at McMurdo Station, Antarctica (*Courtesy of M. Comberiate*).

Table 1. Technical Specifications for the McMurdo Ground Station (*Courtesy of M. Comberiate*)

Coordinates	77 50' 20.87" S x 193 19' 58.50" W
Altitude	150.00 meters
Mount:	Az-El with Tilt, no keyhole limitations
Diameter:	10 meter dish
Antenna Gain	45.0 (S-Band); 56.0 (X-Band)
Beam width:	0.91 deg (S-Band); 0.26 deg (X-Band)
G/T @ Zenith:	21.5 dB/K (S-Band); 31.8 dB/K (X-Band)
Transmit Frequencies:	2000 to 2100 MHZ (S-Band)
Uplink Power Amplifier:	200 Watts
Receive Frequencies	2200 to 2400 MHz (S-Band) & 8025 to 8400 MHz (X-Band)
Freq Resolution	50KHz
Rcvr Dynamic Range	130 dB
LO Ref Freq Stability	+ 1000
Threshold	- 150 dBm @ 10KHz
Loop BWs	30Hz, 100Hz, 300Hz, 1kHz, 3kHz
Sweep Range	+ 250 kHz
Pointing	Autotrack, Program, or Slave
Slew Range	0 to 10 deg/sec in EL; 0 to 17 deg/sec in AZ
Polarization	RHC/LHC
Telemetry Options	BPSK, PM, FM, AM (S-Band); QPSK (X-Band)
Symbol Rate Range	10 to 4Msps (S); 85 & 105 Msps (X)
Subcarrier/Symbol rate limit	> 1.5
Data Format	Source Packet
Modulation Options	NRZ-X, BiO-X, SAR Data (X-Band)
Mod Index range	0.2 to 2.8 radians, peak
Subcarrier Frequency Range	0.5 to 4 MHz (S); 60 & 105 MHz (X)
Subcarrier Waveform	Sine; Stability + 10E-5
Data Transmission:	Transfer Frame, with Reed-Solomon Channel Coding
Frequency Standard & Stability	Crystal Oscillator Datum 9390 10E-11 stability @1sec; 8x10E-9 @ 1 hr; 10E-10 @ 24 hr; 10E-11@mo

McMurdo Station Meteorological Satellite Direct Readout History

Since the early 1980s, McMurdo Station has had the ability to receive satellite imagery directly from the NOAA, and later DMSP satellites. Initial capabilities were analogue hard copy reception, and later moved to a digital/computer display and reception system for HRPT NOAA and RTD DMSP data (Wiesnet et al. 1980, Office of Polar Programs 1988; Van Woert et al. 1992; Lazzara et al. 2003). The primary use of this system was for weather forecasting (Foster, 1982) and secondarily for research activities (Wiesnet et al. 1980). Data from this system was archived and made available to the community at large primarily by the Arctic and Antarctic Research Center (AARC) and as a backup by the Antarctic Meteorological Research Center (AMRC) (Lazzara et al. 2003).

Today, these reception capabilities are installed atop Building 165, with two Sea Space Corporation antenna systems – one devoted to NOAA satellite direct readout and one devoted to DMSP satellite direct readout (See Figure 3). Sea-viewing Wide Field-of-view Sensor (SeaWiFS) direct readout has a partial share of reception time during the operational field season.

Figure 3 Photo of McMurdo Operations/McMurdo Weather building 165 showing the two Sea Space NOAA and DMSP direct readout reception systems on the left hand side of the building. The system on the right is no longer installed. ***(Photo courtesy, NSF-OPP)***

Communications

Present Status

The success of the McMurdo Ground Station and direct readout reception systems at McMurdo Station requires communications, specifically sufficient Internet communications bandwidth on and off station. Currently and for the last 15 years, McMurdo Station Internet communications is a T1 satellite link via geostationary satellite (Office of Polar Programs, Pers. Comms.). Roughly half of the T1 is used for 7 telephone lines. The remaining bandwidth has been increasingly used over the years by science projects, e-mail communications, World Wide Web usage, operational usage, etc. The last several field seasons, the bandwidth has become nearly saturated in both inbound and outbound directions. (Noted at the USAP Antarctic Operations and Engineering Conference in 2003).

At the workshop, the community quickly denoted the critical importance of communications to the success of any ground station operation for both the benefit of operations and science – on and off station. It is felt that the value of any ground station or direct readout system is tremendously increased with reliable and adequate communications.

Future Requirements

With the goal of improving inter-station Internet communications, the community recommends a set of short-term, mid-term and long-term solutions that will give tremendous value to the McMurdo Ground Station and to McMurdo Station hosting the reception of direct broadcast data.

Short Term

In the near term, the community strongly recommends that the National Science Foundation consider two options. The first is to acquire a second T-1 Internet connection for a period of roughly three years. This may be an expensive option, from the point of view of direct costs to NSF, as costs could run $700,000 per year for 3 years. Another near term option is to make arrangements with NASA for having the McMurdo TDRSS Relay System (MTRS) behave just like the South Pole TDRSS Relay (SPTR) and treat McMurdo Station as an "Instrument on a satellite." This could give McMurdo Station dedicated or near dedicated T-3 bandwidth. Costs to set this up could range in the more affordable $100,000 for ground station changes. Regardless of the path taken, the community recommends that NSF set up a study of the feasibility of a dual fiber optic (undersea) cable between New Zealand and McMurdo Station/Scott Base. At a cost of roughly $200,000 dollars or less, such a study could lead toward giving Antarctica significant connectivity on the order of 22 Gigabyte per second. The model for this might be the connectivity that Norway has established between the Norwegian mainland and Svalbard.

Mid Term

In the mid-term, one serious possibility is to have the USAP piggyback onto the Integrated Program Office's (IPO) NPOESS data relay plans set for 2008. This data relay is designed to capture and retransmit back to continental United States NPOESS satellite data. This data relay system is specified to have a T-3 line out from McMurdo Station, but a T-1 in. It in essence requires a joint communication satellite purchase coordinated between NSF and IPO with usage allotted as required by IPO and the remainder used by NSF/USAP. It is hoped during the midterm, the feasibility study of fiber optic lines would be completed and made available to the USAP/NSF community for open discussion.

Long Term

In the long term, two or three options exist including the installation of fiber optic line, specifically 2 lines for redundancy, between McMurdo Station/Scott Base and New Zealand. Other options that exist include satellite communications from either Polar sitter satellites using solar sail technology (See Figure 4) (McInnes and Mulligan, 2003) or Molniya orbiting satellites (See Figure 5 a and b) (Lazzara et al. 2003). Polar sitter satellites offer the first real possibility for the polar regions of the world to have continuous satellite coverage. Molniya satellites offer pseudo-geostationary like coverage for a roughly 8-hour period (4-hours before and after apogee). Although both of these options may be expensive, they offer the possibility of megabytes to gigabytes per second or more bandwidth service to and from McMurdo Station and many other locations in Antarctica, such as South Pole with perhaps fairly high reliability. This report strongly encourages the polar sitting satellite concept as perhaps the best option of the two satellite concepts, given the possibility of such missions being multi-agency, and thus reducing the costs and risks for the USAP. It is clear that if it is at all possible to have fiber optic line installed between McMurdo Station and New Zealand that such a prospect offers perhaps the best bandwidth possibilities today.

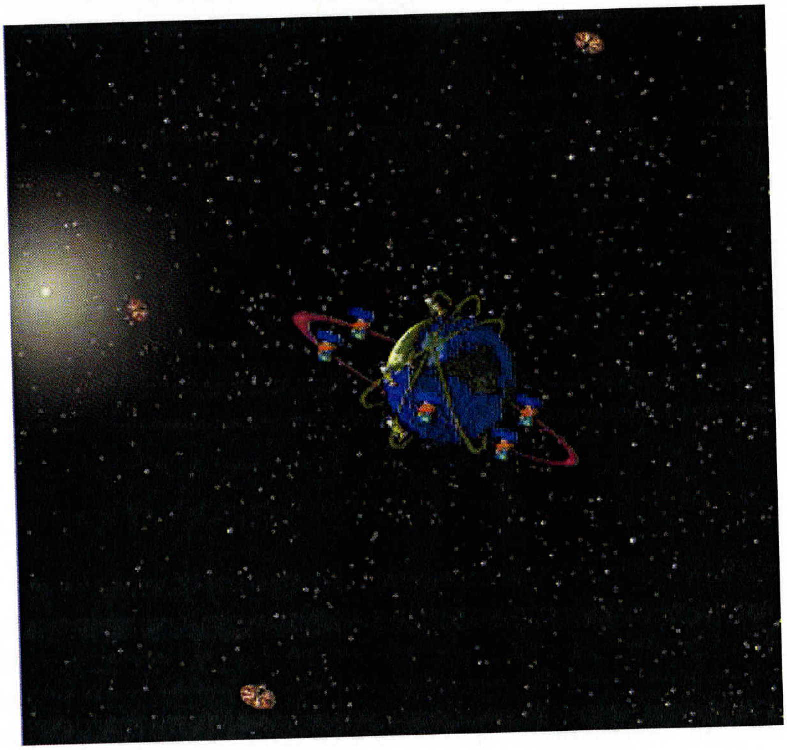

Figure 4 One vision for the future satellite series, including two polar sitting satellites - one for the Arctic and one for the Antarctic. (Courtesy Pat Mulligan/NOAA)

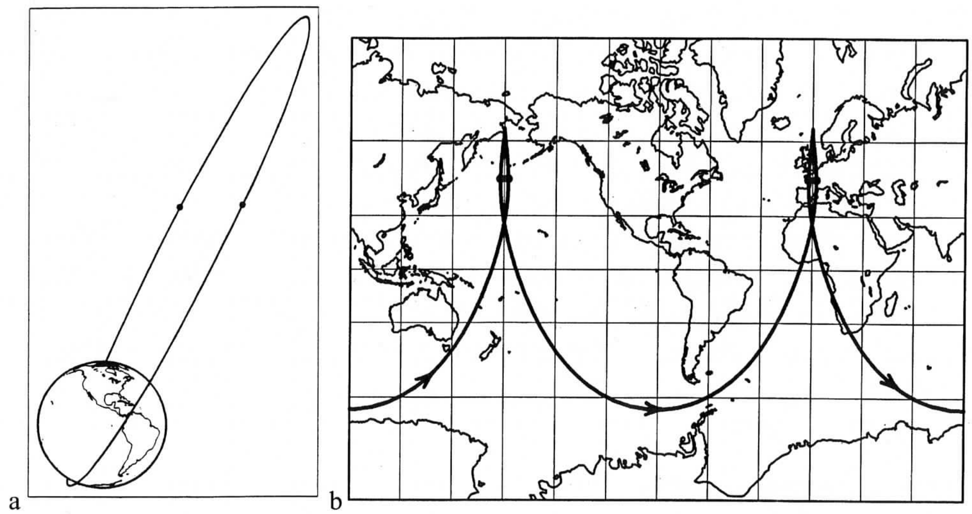

Figure 5 a) the orbit of a Molniya satellite, with the best view over the Arctic/Northern Hemisphere region: Similar orbit could be setup for the Antarctic. b) the ground track for the Molniya satellite. Note on both figures, there is a dot placed 4 hours before and 4 hours after apogee. [From Kidder and Vonder Haar (1991).]

Science and Operational Requirements

Scope and Effects

Currently, the McMurdo Ground Station, and other direct readout systems at McMurdo are capable of retrieving local coverage, especially with satellites that have limited on-board storage, and work well for the reception of direct broadcast data (RADARSAT in the case of MGS and NOAA, DMSP, and SeaWiFS in the case of the meteorology direct readout systems at Mac Weather, etc.) The future use of these systems impacts science and operations. One concern with these systems is the lack of historical reliability of the MGS system. There is a need to prove the MGS can perform at minimal costs or alternatively price out the costs of a second, stand-alone direct readout system that can be used for the reception of data in support of science and operations. In this same vein, there is also a need to assess the cost differences and benefit differences between a stand-alone direct readout system with X-band reception capabilities as compared to the cost of system improvements to the existing operational L-band systems with limited reception abilities and leaving the MGS system aside. Will the next generation satellites broadcast of information via L-band transmission for targeted environmental data records (EDR) be enough for science and operational applications for the USAP? (See Appendix for more on X- vs. L-band EDR as defined by IPO).

It is becoming more and more clear, that the applications of satellite data observations from X-band broadcast platforms such as Aqua and Terra satellite are having impacts in the polar and middle latitude regions. On such example is the use of polar orbiting satellite observations assimilated into a numerical weather prediction model impacting and improving the forecast for a snow event in the middle latitudes (Key, Pers. Comms. 2003). Non-traditional data sets such as direct broadcast data could provide the only means of economical data collection for Antarctica and the Southern Ocean. Further more, there are still more areas of research needed to put such data to use. For example, many algorithms and applications of satellite data applications from Earth Observing System satellites (Terra and Aqua) are global in focus. There are needs to modify these algorithms and methods for use in the Antarctic and South Ocean region (Menzel, Pers. Comms., 2003).

Multi-discipline Benefits

It is clear that the future will bring more demand and growth for the usage of data both on station and off station. Here is a sample list of the cross-discipline range of possibilities:

- Real-time satellite data available for assimilation into the Antarctic Mesoscale Prediction System (AMPS) and Polar MM5 modeling systems at National Center for Atmospheric Research and the Ohio State University.
- Real-time use in science support of future McMurdo area Long Term Ecological Research (LTER) project with sea ice state information
- Real-time use for weather forecasting for USAP flight, station and ship operations.
- Ocean color plankton/marine science studies
- Wave climate detection
- Geology land resource applications
- Glaciological feature studies/iceberg studies and tracking/monitoring
- Sea ice formation, detection, and tracking
- Cloud/fog recognition products – Fog detection
- Cloud droplet products - Aircraft icing, and potential snowfall
- Wind, Temperature, and Humidity profiling – Improved analysis for forecaster and numerical data input
- Daily surface reflectance - Global change
- Cryosphere identification by class – Blowing snow forecasting
- Land and ocean surface temperature – McMurdo Sound potential icing conditions

With readily available data, this list will likely grow.

Impacts

With the combined improvements in communications and reception of direct broadcast from the next generation satellite series, impacts will ripple through both the science and operational communities. A sample of possible improvements include:

- Global model improvements using information from the Antarctic in real-time.
- Timely availability of products to global modeling centers, weather forecasters on and off continent, real-time science data available to researchers, and polar remote sensing data available to the educational community via existing NSF funded projects (e.g. Unidata project).
- Availability of derived products on the World Meteorological Organization's (WMO) Global Telecommunications System (GTS).

Implementation

One of the key topics discussed at the meeting was the utility of the data. With the ability to receive the data, and with good communications, issues with regard to data processing location, real-time use of the data in both the operational and research arenas, and data format and easy interactive processing become critical issues.

The state of communications clearly dictates the possibilities of data processing on station, off station or a combination of the two. Without significantly improved communications, it is impossible to import or export high volume data, even data in a raw, data stripped, and/or compressed format. Next generation satellites, especially those transmitting direct broadcast data in the X-band range, have gigabytes of data available daily. The ability to send this data over smaller communication methods is impossible. With improved bandwidth, it may be possible to have data captured at McMurdo Station and be sent off site for additional data processing, and/or have data received and processed at other locations be imported to McMurdo Station. With applications that require timely, real-time data, such as weather forecasting, numerical weather prediction, etc., some combination of these options will prove best. For example, weather forecast operations on station may require data to be received and processed on station to provide the data as soon as possible to the forecaster. However, for numerical weather prediction, data received on station may not need to be completely processed on site, but partially processed, with the remaining processing done at the numerical weather prediction center or institution. In the NPOESS era, data may not need to be received on location at all, as the NPOESS/IPO SafetyNet design of globally distributed ground stations will provide 95% of the NPOESS data to numerical weather prediction centers within ~28 minutes of reception.

One key need for everyone, and especially the research community, is the format and ease of working with the data via interactive processing systems. There is unfortunately no one size fits all for both of these topics. However, it is strongly recommended that regardless of choice of interactive display and processing system that it is able to convert between various formats of choice of the satellite operators. Likewise it is the advice of this report that any selected formats are well documented, non-propriety, and if at all possible, a self-describing format.

Short Term

The community at the workshop recommends an immediate short-term demonstration of the capabilities of the McMurdo Ground Station. The goal is to generate cloud drift wind datasets, two times a day, from a set (2 triplets or three successive passes of Aqua/Terra data two times a day) of MODIS imagery acquired by the McMurdo Ground Station (MGS). We learned at the meeting that the MGS might have a one-way-out electronic networking capability. Given that critical piece of information, it is possible to have the MGS folks acquire these passes and send them to the Antarctic Meteorological Research Center (AMRC) office [in Crary Lab] for further processing. At the AMRC office [in Crary lab], this raw pass data would be received by a computer system that Jeff Key's group at the University of Wisconsin would set up to process the raw passes into science level data (Level 1b HDF-EOS), and in turn make the cloud drift winds. The cloud drift wind sets, being so much smaller than the raw data (on the order of kilobytes large), could then be sent back to the US for a variety of users, including, the NCAR/MMM AMPS group, the Ohio State/BPRC Polar MM5 group, NASA Global Modeling and Assimilation Office (GMAO) group, and used at Wisconsin as well. Meanwhile, the Operational Weather Forecasters at McMurdo Weather would also benefit by being able to view the raw imagery, the cloud drift wind sets and any other products that can be generated on station (since there is not a bandwidth limit for moving data around the station, for the most part).

Mid Term

In the mid term, the community strongly recommends the installation of a stand-alone direct readout system that is not a part of the McMurdo Ground Station. This system, perhaps as small as 3 or 4 meters in diameter, would have X-band, S-band and L-band capabilities. This system would be an automated system, devoted to receiving data from currently active satellites such as Aqua, Terra, Aura, Envisat, etc. and would be in a position to receive direct broadcasts from the NPP, NPOESS, and other satellites to be launched in the future. The community also discussed having this kind of support and capability at both South Pole and Palmer Stations for science.

In the mid-term, the community notes that the applications and users of datasets from the short-term activities will be broadened. This is natural, especially with the enactment of recommendations made with regards to communications. On the horizon, spin up activities for the International Polar Year (2007-2008) (NRC, 2004) likely will see the need for both a stand-alone system as well as the McMurdo Ground Station as more than one direct readout satellite system will be needed to be acquire the variety of observations and data from multiple satellite platforms. Examples of this include the need to continue to get SAR data or other similar type data such as Envisat, or other SAR or very high-resolution earth resource satellite such as LANDSAT. Meantime, meteorological satellite observations will be needed as well from Aqua, NPP and other available platforms. A single direct readout or ground station cannot accommodate all of the needs this requires. Some of these activities such as a pending proposal for the National Ice Center to acquire Envisat data in real-time from the MGS to test a possible sea ice monitoring and detection method are not directly an NSF sponsored project (in this case, it is a NASA sponsored project, with cooperation from the European Space Agency). However, this example project brings to light two key points. First, this project has a limiting problem with the lack of high-speed communications return back to the NIC in Washington, DC. Second, this project, if the research is successful, will indeed benefit the USAP/NSF with an improved sea ice monitoring and detection means, perhaps critical to USAP ship operations, especially US Coast Guard icebreaker operations in McMurdo Sound.

Long Term

In the long-term, the United States Antarctic Program, as well as other national Antarctic programs will be entering the NPOESS era (See Figures 4 and 5 and the Appendix). This era ushers in new investments in science, including the widely discussed International Polar Year (2007-2008) (NRC, 2004), Antarctic Regional Interactions Meteorology Experiment (Antarctica RIME – formerly the Ross Island Meteorology Experiment) (Parish and Bromwich, 2002), future long term ecological research projects, West Antarctic Ice Sheet Ice Core (WAIS Core) projects, etc. Each of these and future projects will require satellite based observations. Other projects and possibilities not yet foreseen will be in the planning stages or become reality by the end of the decade. One such example is the use of the polar sitter/solar sail satellite platform for environmental monitoring and remote sensing as well as communications as outlined above.

Perhaps in the long term, one should consider what science would be lost without X-band reception capability in Antarctica. Some key examples include the following:

- Polynya and Ice shelf processes studies. High-resolution MODIS, SAR, and Landsat images are essential in identifying regions of interest within the pack. Ship based studies need these images, which can only be downloaded with X-band receivers to find appropriate regions to do measurements. Otherwise, finding these regions will be difficult since the Ross Sea ice covered area is so big. The passes from SAR are really important for time series studies. SAR data provide the only high-resolution data that have day/night and almost all weather coverage. The other data available are in the visible and infrared and do not provide the same information.

- Calving/iceberg studies: Time series studies of high-resolution satellite images are needed to study development of weaknesses in the ice shelves and the distribution and tracks of icebergs.

- Ocean color/water mass transport studies: Near time ocean color data from SeaWiFS, MODIS, etc. are needed during ship-based programs to ensure that the study locations are done where the biology is most interesting. Also, the detection of water mass movements can be done with ocean color data but validation is needed and the availability of real time data when the latter is being done is very important.

- Satellite algorithm validations: Geophysical parameters derived from satellite data are valuable only if the algorithms used to generate the parameters have been validated. Near real time high resolution data are required during validation programs to find suspected areas where the algorithms could be vulnerable.

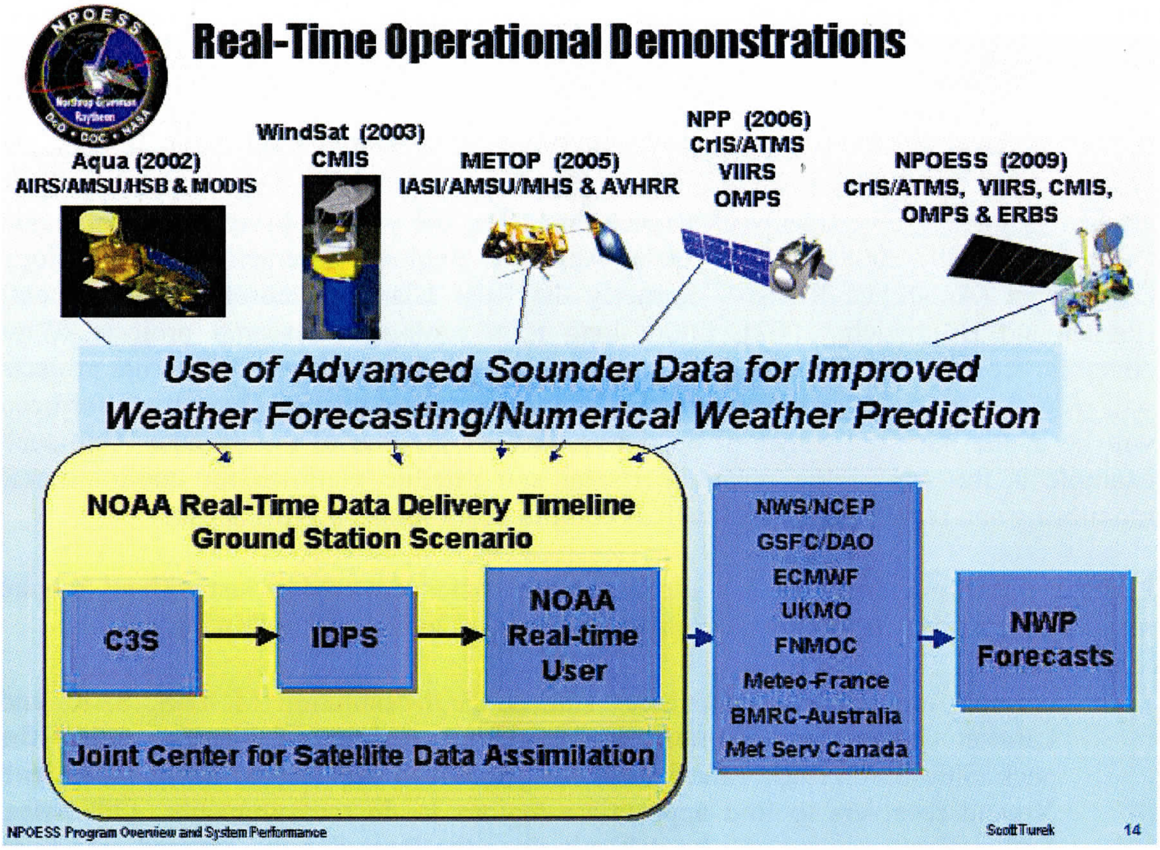

Figure 6 During the next several years, there is an evolution of satellites towards the NPOESS era.

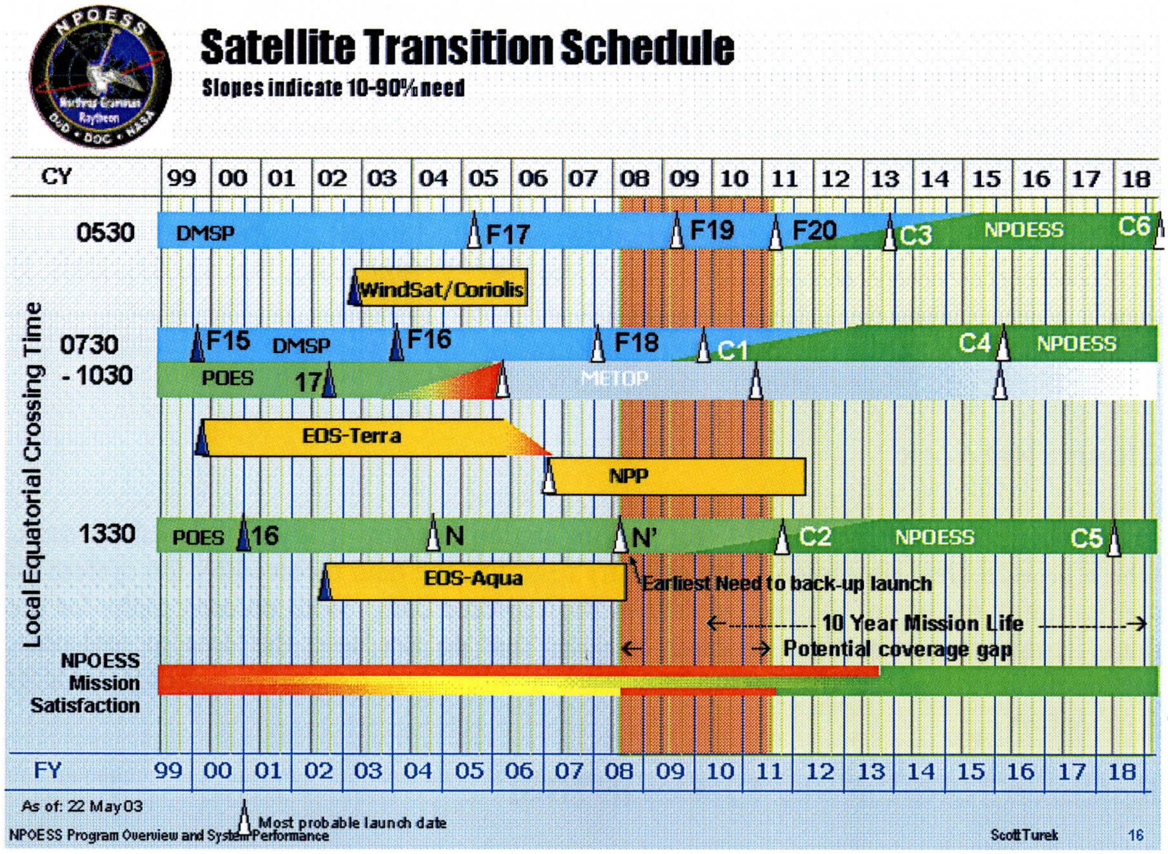

Figure 7 The transition from the current satellite system to the new generation satellite system depicts the timelines and "bridge" missions into the future.

The USAP is currently at a cross roads with regards to its long-term satellite reception future at McMurdo Station: Will it be able to receive and utilize high-resolution data (HRD) or low-resolution data (LRD) rate from NPOESS? Clearly, LRD data will be an improvement over the current HRPT and RTD systems with NOAA and DMSP, and there is no operational requirement for the HRD data (Cayette, 2002; Cayette, 2003). However, as of the publishing of this report, the content of the LRD data stream is not yet completely defined, although the products that can be produced from that yet-to-be-defined data stream are. In addition, it is not clear from the point of view of research activities if LRD data from NPOESS will be sufficient. Advances made using HRD data will not be able to be implemented at McMurdo Station, without a means of getting that data. Will the USAP be able to receive and utilize SAR or LANDSAT quality data in the future? Although the use of this data is at a relative minimum at the time of this report's publication, it is not clear that this will be the case for the future.

Limiting Factors

It is clear from the discussions and issues raised at the workshop and in this report that there are some clear limiting factors that impede the viability of the McMurdo Ground

Station, and the reception and use of direct broadcast satellite data. Discussions on communications and infrastructure are presentedbelow.

Communications

Aside from the obvious limits that no improvements in Internet communications to and from McMurdo Station presents, there are some specific limitations that are important to denote with regards to the communication solutions presented in this report. These include the fact that the MGS is on a closed network, limits on the McMurdo TDRSS Relay system, and infrastructure needs for the MGS.

Closed Network

The MGS is not readily available for use on station because it is on a closed network, which poses a clear limitation. The inability to utilize the data received by the system on station limits the use of the ground station for real-time data. With no easy paths for the data, it only serves best for research projects that do not need the data in real-time, especially with spacecraft that do not have a store and forward capability such as RADARSAT.

McMurdo TDRSS Relay System (MTRS)

With the possible option to have the MTRS used as a means for Internet communications for McMurdo Station, targeted for science and operational use much like the South Pole TDRSS Relay System (SPTR), there will be some issues that may limit the viability of the system. Visibility of TDRSS satellite series may pose a problem, as currently there is only one TDRSS available to McMurdo for a limited time. Two TDRSS satellites would need to be available to give 24 hours, 7 days per week coverage for a constant connection. Scheduling TDRSS time may be a problem as well. Unlike the SPTR system, NASA may not be able to offer a dedicated TDRSS. Sharing TDRSS with Space Shuttle or other NASA missions may not give McMurdo the timely connectivity required. Finally, the MTRS is at present set up on a closed network. This would have to change to be more like the SPTR system to give open access to a variety of sites off station.

Infrastructure

In reviewing the state of the MGS, and direct readout systems on station there are some clear infrastructure issues that need to be addressed for either system to be viable in the future.

Discussions at the workshop clearly indicated that the MGS's reliability has been an issue over the years. The MGS and associated facilities at Wallops Flight Facility (WFF) in Virginia may be in need of infrastructure upgrades. For example, there was an inability to efficiently accommodate rescheduling of the downlinks to MGS during the 2000

Modified Antarctic Mapping Mission (MAMM) mission. This was partly a WFF issue and partly a MGS local issue. The viability of the MGS is at stake; otherwise the MGS is far less useful unless the station is reliable. Apparently a set of upgrades is (or at least were) needed, and perhaps some have been accomplished.

Some of the recent upgrades to the MGS have been primarily with regards to the MTRS function of the MGS. Specific recent enhancements have been to add the disk space (a RAID system) and tape libraries at the White Sands downlink to the TDRSS in the continental United States, and add the capability to transmit over TDRSS non-telemetry data files into the TDRSS telemetry based protocol. This work is critical if MTRS is to be used to transmit very large processed data files back to users in the continental United States. This foundation work includes the availability of a "science" computer on the USAP open network at McMurdo Station with the tape drive or other media (DVD) that will allow data to be moved between the MGS closed network and the USAP open network.

Concerns have been raised regarding local processing power and data storage at McMurdo Station. These problems are becoming more easily solved, as computing and data storage become less expensive. The bottom line is that resources such as these will be needed to utilize observations from next generation satellite system.

Conclusions and Recommendations

This report, based on the discussions with the science and operational community at both the workshop and afterwards, has the following specific recommendations:

- Recommend that the United States Antarctic Program actively pursue increased and improved Internet communications both to and from McMurdo Station, Antarctica. This recommendation is critical for both the MGS and other stand alone direct readout reception stations at McMurdo Station, as the fast return of data received at these locations to users is critical.

- Recommend the installation of an additional stand-alone X-band direct readout reception station for science and operational use by the United States Antarctic Program and its partners.

- Recommend the processing and use of X-band direct broadcast data be deployed both on site at McMurdo Station as well as off site.

- Recommend that the MGS is a viable ground station – it has been and continues to be an important resource and provide valuable data. With continued reasonable demand for use, sufficient resources to adequately manage and maintain MGS should be provided so as to insure a year round reliability consistent with other satellite ground stations.

In essence these recommendations fall out from two important questions: How does the USAP get the critical data it needs and how do others back in the Continental United States get the critical data they need about Antarctica? As noted above in this report, there are several different users of satellite observations such as USAP, NASA and other researchers needing data on ice conditions from SAR data using the current MGS system; the National Ice Center gets data from the existing L-band systems at McMurdo to help support the US Coast Guard operations for NSF in the McMurdo Sound and would like to get more data in near real time from Envisat using MGS to do research; USAP researchers would like MODIS data from Terra and Aqua to be processed and available for application in the continental US in real-time; etc. Having the availability of high bandwidth and a stand alone X-band direct readout system solves many of these problems. However, not all are solved, especially the need to get real-time data to users from the MGS, which is on a closed system. It is clear that the MGS has met a need, and continues to today. Although its current use for NSF sponsored research has diminished, the MGS may be needed again in the future. Meantime, the community needs more, faster, and better data - data which must be made widely available, easily accessible, to the whole scientific community, not just members of a small group. Hence, this report strongly encourages the USAP to aim to satisfy the recommendations via the consideration of the short-, mid- and long-term possible solutions offered. As the process is undertaken, new options may surface that should also be considered.

Postscript: McMurdo Station Dual X-/L-Band Reception System – Impacts and Implications

As this report was being drafted, efforts immediately began to attempt to satisfy the short term goal of having the MGS collect a triple of Terra or Aqua passes in a row twice a day for the generation of cloud drift winds. Our goals with this dataset are multi-fold. We want to get the data in real-time, and process it as fast as possible to then make it available to the research community for ingestion into the Antarctic Mesoscale Prediction System, the numerical modeling efforts at the NASA Global Modeling Assimilation Office, modeling efforts and validation studies at UW-Madison (both the AMRC and the NOAA/NESDIS folks at the Cooperative Institute for Meteorological Satellite Studies), and perhaps others. In addition, the intent is to make any of this data available in real-time to the forecasters as well. It is important that the operational forecasters start to see and slowly, but steadily begin to learn about and understand these datasets. They are going to be the bread and butter datasets the forecaster will have to work with in the future.

First, it is important to clarify the needs and demand for data from such a system. The short-term goal was to make use of the MGS and the existing infrastructure as much as possible to satisfy a multi-institutional group of researchers. It is important to realize that the MGS is devoted to other tasks. As it turns out for the upcoming year, the request to get two sets of "triplets" per day will likely turn into one set of triplets and a few other passes at best, due to the loading on the MGS system (and there will be significant times where there will not even be that much data available to us due to MGS scheduling). It is critical to have consecutive sets of data, from the same spacecraft to do the derivation of cloud drift and water vapor feature track winds, the major goal for this short-term use.

Secondly, the MGS presents some challenges in making the data available to the research community in a timely enough fashion. The premise for using the MGS was the hope that there was a one-way communications connection out of the MGS closed network to move received raw data on station at McMurdo (within Crary Lab or even between new Joint Science Operations Center and Crary Lab). This turns out to not be the case. Thus the options for getting the data will be limited to a stream of clock and data (literally wires of raw signal) or data tapes. The moving of data tapes daily from the closed network of the MGS to the open USAP network at McMurdo Station is not an option from the point of view of timeliness – the data would no longer be real-time and not available for applications soon enough. This is an important aspect of the activity. Hence efforts began by the major partners in this effort (both NASA Ground Station Network and AMRC/UW-Madison) to setup and work with the clock and data raw signal stream, without spending significant additional funds. This situation points to how the existing system setup for the MGS, which is on a closed network, significantly reduces its value.

Finally, it is important to note that the USAP has the opportunity to benefit both the research and operational communities at the same time. Currently both communities utilize the existing L-band systems at Mac Weather. It is hoped that future systems would be utilized in the same manner. Hence, the recommendation is that the USAP should begin to plan for an operational X-band system for the benefit of both the operational and research communities within the USAP. Such a plan should include the recycled use of hardware that is available to the USAP or any opportunities for donated, recycled or "handed-over" hardware to reduce costs. Obviously, using outdated, mis-matched or inappropriate hardware is foolish, and will likely be costly down the road to the USAP.

As of mid June 2004, the NSF has optioned to take advantage of a routine maintenance cycle of one of its existing L-band systems and upgrade it from a larger L-band system to a dual X-band and L-band system. This will be primarily a system used for operational weather forecasting, but will be shared with the research community. This development will likely provide more data from Terra and Aqua and follow-on satellites than the MGS can offer in the next year or so, in a more readily usable format. Plans remain to continue the short-term science objective (cloud drift and water vapor wind derivations from Terra and Aqua) outlined above in this report, but instead of utilizing the MGS, this new system will be employed instead.

This development is applauded. However, the needs for the reception are of as many passes or orbits from the current and future X-band transmitting meteorological satellites as possible. Although this development won't meet that need, it is an excellent development. Additional explanation of these recommendations is based on the contents of this report. In any case, this development leads to additional recommendations:

- Recommend that the second L-band direct readout ground system get upgraded to Dual X-/L-Band system during it next maintenance cycle upgrade to match this first system or if at all possible, a pure X-Band system be installed in the L-band system's place.

- Additionally, it is strongly encouraged that the capabilities of the MGS be expanded to be a backup for these systems in the case of catastrophic failure. In addition, it will be of benefit to the MGS to have this capability, as it will likely make the MGS more attractive to other users, and in turn a more valuable asset to the NASA Ground Station Network.

As an important note, although these developments significantly help to meet some of the recommendations of this report, the communications issue is still the most outstanding issue facing the MGS and operational direct readout systems at McMurdo Station. The suggestions in this report stand, including the possibilities of using the MTRS, the NPOESS ground system communications system, and the future polar sitter or fiber optic solutions in the future to improved high speed and high bandwidth communications and data return.

Additionally, the likely specifications and operational tasks of this dual L-/X-band system will be such that the acquisition of SAR, LANDSAT, or similar satellite system will be extremely unlikely if not impossible. This further accents the value and possible future need for the MGS. It remains the only United States asset in Antarctica with the capability or at the very least the potential capability to work with these types of satellite systems. The future of the MGS should not be considered lightly, as it has been a significant investment by the United States (NASA, NSF, etc.), and replacement may be difficult in the current fiscal climate.

Acknowledgements

The editors wish to thank Lynn Everett, David Bromwich, and Andy Monaghan at the Byrd Polar Research Center at the Ohio State University, and Marlene McCaffery at the Space Science and Engineering Center, University of Wisconsin-Madison. Their help made this workshop come to life. We wish to acknowledge all of the workshop participants who helped to make the workshop, and in turn, the report a success. We wish to thank the Office of Polar Programs, National Science Foundation, grant number OPP-0412586 without whose funding this workshop would have not been possible.

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Appendices

Web sites

The following list of web sites offer related information and in some cases supporting information to this report:

http://www.nsf.gov/
http://www.nsf.gov/od/opp/start.htm
http://amrc.ssec.wisc.edu/
http://amrc.ssec.wisc.edu/MGS
http://arcane.ucsd.edu
http://www.npoess.noaa.gov
http://npoesslib.ipo.noaa.gov
http://www.esa.int/export/esaSA/ESAOC976K3D_earth_0.html
http://www.esa.int/export/esaCP/SEMXVFXLDMD_Protecting_0.html
http://www.isc.nipr.ac.jp/office/SATELLITE/satellite.html
http://www.us-ipy.org/index.html
http://seawifs.gsfc.nasa.gov/SEAWIFS.html
http://seawifs.gsfc.nasa.gov/SEAWIFS/HTML/Mcmurdo.html
http://oceancolor.gsfc.nasa.gov/
http://www.wff.nasa.gov/~code452/mcmurdo.html
http://nmsp.gsfc.nasa.gov/tdrss/murdohome.htm
http://msp.gsfc.nasa.gov/groundnetwork/mcmurdo.htm
http://coolspace.gsfc.nasa.gov/nasamike/antarc/mcmurdo/10m/10m.htm
http://coolspace.gsfc.nasa.gov/nasamike/antarc/mcmurdo/tdrss/tdrss.htm
http://www.polar.org/science/SciPlanSummaries/sps03_04/html/tech_events.htm#nails
http://www.tsi-telsys.com/services/eng.htm
http://scp.gsfc.nasa.gov/communicator/SC_Page25_0604.pdf
http://scp.gsfc.nasa.gov/communicator/SC_Page26_0604.pdf
http://project-tools.com/pages/mcmurdo1.htm
http://tea.rice.edu/stoyles/12.8.2003.html
http://ieeexplore.ieee.org/iel3/3772/11018/00516798.pdf?isNumber=11018
http://www.gmra.org/n0nhj/ice99/p20.htm
http://web.geog.gla.ac.uk/~gpetrie/polar_crossroads.pdf
http://www.viasat.com/_files/_08fe203b613bc02b87de181a370e2bdf/pdf/comtrack10mSX.pdf
http://isc.gsfc.nasa.gov/TechReviews/2004Mar2425/583_McMurdo_Ground_Station_RAID_Demonstration_T_Sardella.ppt
http://www.bu.edu/satellite/mission/missionops.html
http://www.qadas.com/qadas/nasa/nasa-hm/0575.html

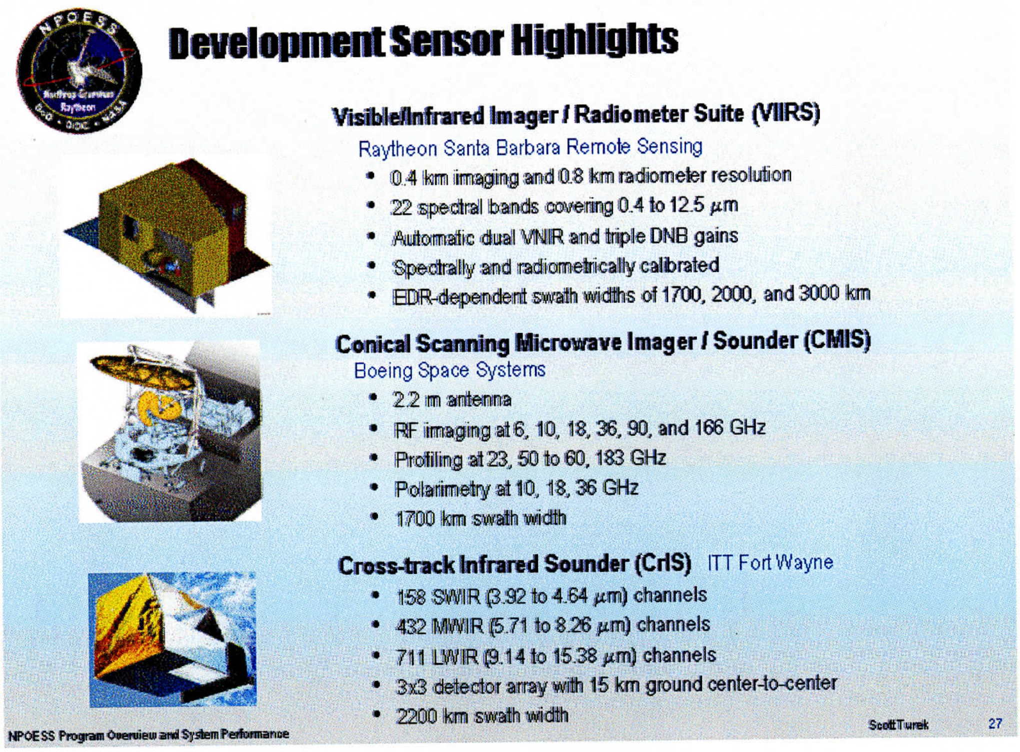
Acronyms

AARC	Arctic and Antarctic Research Center
AMPS	Antarctic Mesoscale Prediction System
AMRC	Antarctic Meteorological Research Center
AVHRR	Advanced Very High Resolution Radiometer
DMSP	Defense Meteorological Satellite Program
EDR	Environmental Data Records
EOS	Earth Observing System
FAST	Fast Auroral Snapshot Explorer
GMAO	Global Modeling and Assimilation Office
GTS	Global Telecommunications System
HRD	High Resolution Data
HDF	Hierarchal Data Format
HRPT	High Resolution Picture Transmission
IPO	Integrated Program Office
LRD	Low Resolution Data
MAMM	Modified Antarctic Mapping Mission
Mbps	Megabits per second
MGS	McMurdo Ground Station
MM5	Mesoscale Model version 5 (Penn. State/NCAR)
MMM	Mesoscale, Microscale Meteorology
MODIS	Moderate resolution Imaging Spectroradiometer
MTRS	McMurdo TDRSS Relay System
NSF	National Science Foundation
NAILS	NASA Antarctic Interactive Launch Support
NASA	National Aeronautics and Space Administration
NCAR	National Center for Atmospheric Research
NOAA	National Oceanographic and Atmospheric Administration
NPOESS	National Polar Orbiting Environmental Satellite System
NPP	NPOES Preparatory Platform
OPP	Office of Polar Programs
RIME	Regional Interactions Meteorology Experiment (formerly Ross Island Meteorology Experiment)
RTD	Real Time Data
SAR	Synthetic Aperture Radar
SATCOM	Satellite Communications
SeaWiFS	Sea-viewing Wide Field-of-view Sensor
SPTR	South Pole TDRSS Relay
T1	A dedicated1.544 Megabits per second Internet connection
T3	A dedicated 43 Megabits per second Internet connection
TDRSS	Tracking Data and Relay Satellite System
USAP	United States Antarctic Program
WAIS	West Antarctic Ice Sheet

WFF	Wallops Flight Facility (NASA)
WMO	World Meteorological Organization

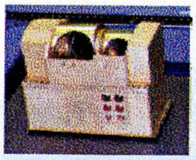
NPOESS Sensors and Capabilities

The following section presents information on NPOESS Sensors and Capabilities.



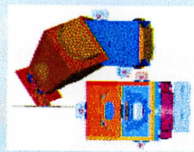
Development Sensor Highlights (cont.)

Advanced Technology Microwave Sounder (ATMS)
Northrop Grumman Electronics



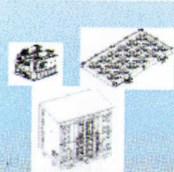
- CrIS companion cross track scan
- Profiling at 23, 50 to 57, 183 GHz
- Surface measurements at 31.4, 88, 165 GHz
- 1.1, 3.3, and 5.2 deg (SDRs resampled)
- 2300 km swath width

Ozone Mapping and Profiler Suite (OMPS)
Ball Aerospace & Technologies Corp



- Total ozone column 300 to 380 nm with 1.0 nm resolution
- Nadir ozone profile 250 to 310 nm with 1.0 nm resolution
- Limb ozone profile 290 to 1000 nm with 2.4 to 54 nm resolution
- Swath width of 2800 km for total column

Global Positioning System Occultation Sensor (GPSOS)
Saab Ericsson

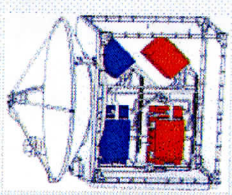


- RF receiver/processor of GPS signals at 1575.42 and 1227.60 MHz
- Velocity, anti-velocity and nadir views
- Electron density profile in ionosphere primary measurement
- Ionospheric scintillation
- Tropospheric/stratospheric sounding

NPOESS Program Overview and System Performance — Scott Turek — 30

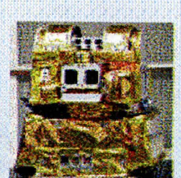
Leverage Sensor Highlights

Radar Altimeter (ALT)
Alcatel



- Measures range to ocean surface with a radar at 13.5 GHz
- Corrects for ionosphere with 5.3 GHz radar
- Corrects for atmosphere with CMIS water vapor measurements
- Precise orbit determination with GPS

Earth Radiation Budget Sensor (ERBS)
Northrop Grumman Space Technology



- Three spectral channels
- Total radiation measurement 0.3 to 50 μm
- Shortwave Vis and IR measurement 0.3 to 5 μm
- Longwave IR measurement 8 to 12 μm

Total Solar Irradiance Sensor (TSIS)
University of Colorado Laboratory for Atmospheric and Space Physics (LASP)

- Two sensors for total irradiance (TIM) and spectral irradiance (SIM)
  - TIM measures total solar irradiance
  - SIM measures spectral irradiance 200 to 2000 nm
- Pointing platform and sensor suite to be provided by CU LASP

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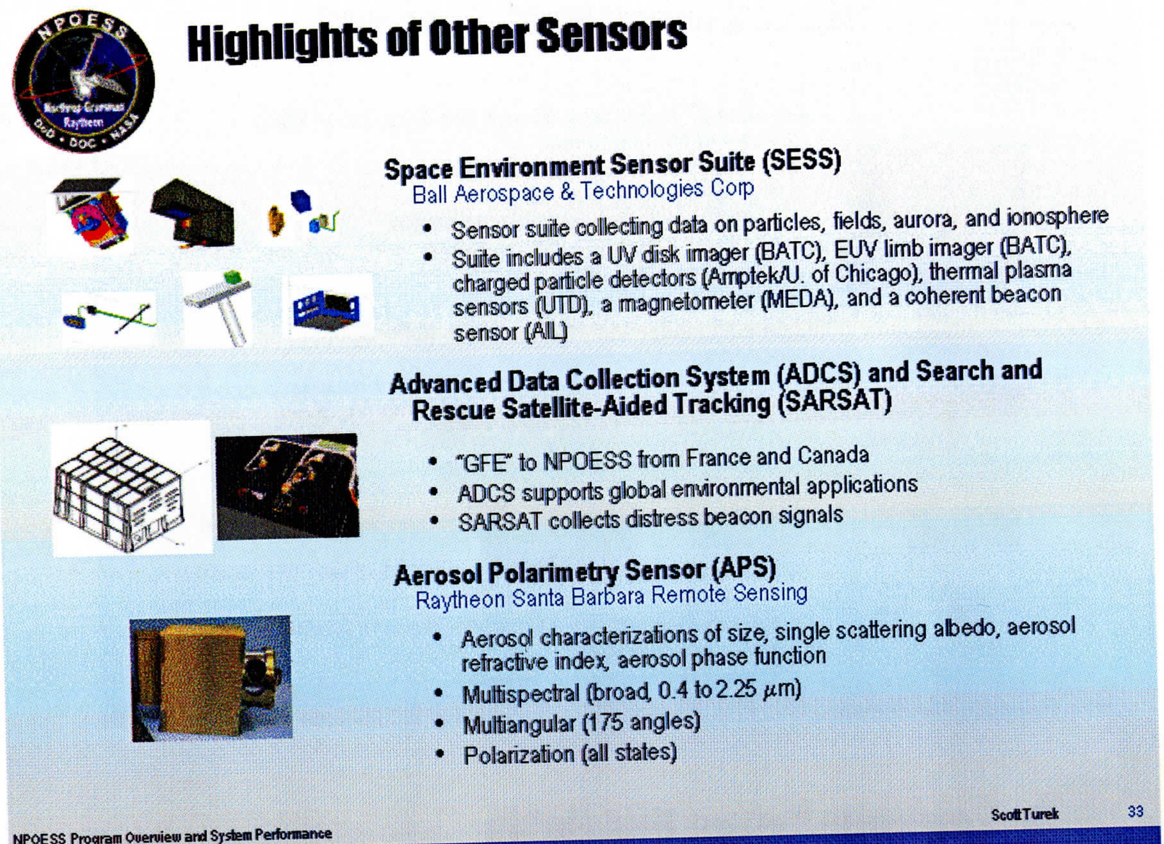
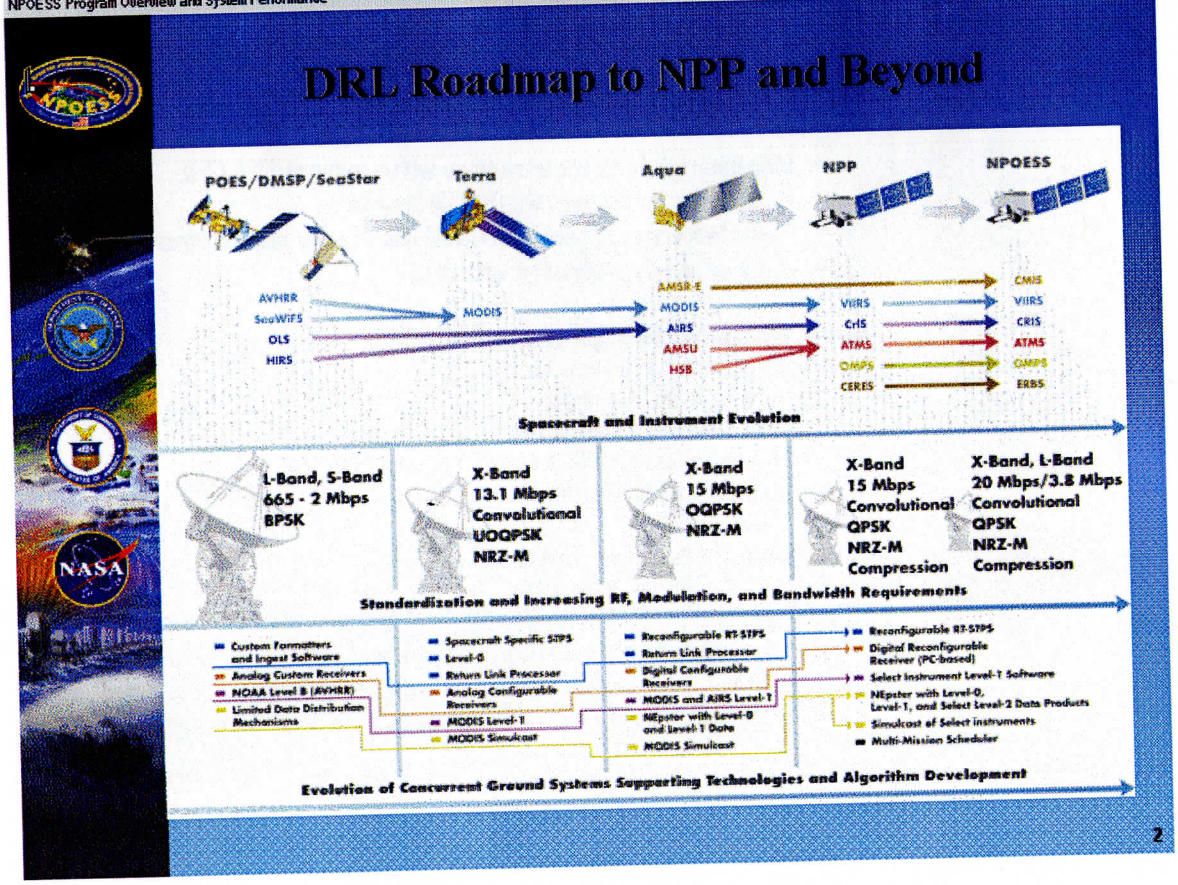

Highlights of Other Sensors
Space Environment Sensor Suite (SESS)
Ball Aerospace & Technologies Corp
• Sensor suite collecting data on particles, fields, aurora, and ionosphere
• Suite includes a UV disk imager (BATC), EUV limb imager (BATC), charged particle detectors (Amptek/U. of Chicago), thermal plasma sensors (UTD), a magnetometer (MEDA), and a coherent beacon sensor (AIL)
Advanced Data Collection System (ADCS) and Search and Rescue Satellite-Aided Tracking (SARSAT)
• "GFE" to NPOESS from France and Canada
• ADCS supports global environmental applications
• SARSAT collects distress beacon signals
Aerosol Polarimetry Sensor (APS)
Raytheon Santa Barbara Remote Sensing
• Aerosol characterizations of size, single scattering albedo, aerosol refractive index, aerosol phase function
• Multispectral (broad, 0.4 to 2.25 μm)
• Multiangular (175 angles)
• Polarization (all states)
Scott Turek
33
NPOESS Program Overview and System Performance


DRL Roadmap to NPP and Beyond
POES/DMSP/SeaStar
Terra
Aqua
NPP
NPOESS
AVHRR
SeaWiFS
OLS
HIRS
MODIS
AMSR-E
MODIS
AIRS
AMSU
HSB
VIIRS
CrIS
ATMS
OMPS
CERES
CMIS
VIIRS
CRIS
ATMS
OMPS
ERBS
Spacecraft and Instrument Evolution
L-Band, S-Band
665 - 2 Mbps
BPSK
X-Band
13.1 Mbps
Convolutional
UOQPSK
NRZ-M
X-Band
15 Mbps
OQPSK
NRZ-M
X-Band
15 Mbps
Convolutional
QPSK
NRZ-M
Compression
X-Band, L-Band
20 Mbps/3.8 Mbps
Convolutional
QPSK
NRZ-M
Compression
Standardization and Increasing RF, Modulation, and Bandwidth Requirements
Custom Formatters and Ingest Software
Analog Custom Receivers
NOAA Level 8 (AVHRR)
Limited Data Distribution Mechanisms
Spacecraft Specific STPS
Level-0
Return Link Processor
Analog Configurable Receivers
MODIS Level-1
MODIS Simulcast
Reconfigurable RT-STPS
Return Link Processor
Digital Configurable Receivers
MODIS and AIRS Level-1
NEpster with Level-0 and Level-1 Data
MODIS Simulcast
Reconfigurable RT-STPS
Digital Reconfigurable Receiver (PC-based)
Select Instrument Level-1 Software
NEpster with Level-0, Level-1, and Select Level-2 Data Products
Simulcast of Select Instruments
Multi-Mission Scheduler
Evolution of Concurrent Ground Systems Supporting Technologies and Algorithm Development
2

NPOESS Field Terminal Proposed Link Parameters

Parameter	High Rate Data	Low Rate Data
Carrier Frequency	7812 MHz	1704 MHz
Max Occupied Bandwidth	30.8 MHz	12.0 MHz
Channel Data Rate*	40 Mbps	11.64 Mbps
Ground Aperture Size	<= 2.0 meters	1.0 meters
Minimum Elevation Angle	5.0 degrees	5.0 degrees

* Includes all CCSDS overhead, Reed-Solomon forward error correction, and convolutional encoding

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NPOESS High Rate Data (HRD) Environmental Data Records (EDRs)

★ Atm Vertical Temp Profile	Cloud Top Height	Ozone; Total Column/Profile
★ Atm Vertical Moisture Profile	Cloud Top Pressure	Precipitable Water
★ Sea Surface Temperature	Cloud Top Temperature	Precipitation Type/Rate
★ Sea Surface Winds	Downward LW Radiance (Sfc)	Pressure (Surface/Profile)
★ Soil Moisture	Downward SW Radiance(Sfc)	Sea Ice Characterization
★ Imagery	Electric Field	Sea Surface Height/Topo.
Active Fires	Electron Density Profile	Snow Cover/Depth
Aerosol Optical Thickness	Energetic Ions	Solar Irradiance
Aerosol Particle Size	Geomagnetic Field	Supra-Thermal-Auroral Part.
Aerosol Refractive Index	Ice Surface Temperature	Surface Type
Albedo (Surface)	In-*situ* Plasma Fluctuations	Surface Wind Stress
Auroral Boundary	In-*situ* Plasma Temperature	Suspended Matter
Auroral Energy Deposition	Ionospheric Scintillation	Total Water Content
Auroral Imagery	Medium Energy Charged Particles	Vegetation Index
Cloud Base Height	Land Surface Temperature	
Cloud Cover/Layers	Net Heat Flux	
Cloud Effective Particle Size	Net Solar Radiation (TOA)	
Cloud Ice Water Path	Neutral Density Profile	
Cloud Liquid Water	Ocean Color/Chlorophyll	
Cloud Optical Thickness	Ocean Wave Characteristics	
Cloud Particle Size/Distribution	Outgoing LW Radiation (TOA)	

VIIRS	25
CMIS	19
CrIS/ATMS	3
OMPS	1
SES	13
GPSOS	2
ERBS	5
TSIS	1
ALT	3
APS	4

★ EDRs with Key Performance Parameters

Gray colored EDRs not a part of the HRD

NPOESS Low Rate Data (LRD) Environmental Data Records (EDRs)

★ Atm Vertical Temp Profile	Cloud Top Height	Ozone; Total Column/Profile
★ Atm Vertical Moisture Profile	Cloud Top Pressure	Precipitable Water
★ Sea Surface Temperature	Cloud Top Temperature	Precipitation Type/Rate
★ Sea Surface Winds	Downward LW Radiance (Sfc)	Pressure (Surface/Profile)
★ Soil Moisture	Downward SW Radiance(Sfc)	Sea Ice Characterization
★ Imagery	Electric Field	Sea Surface Height/Topo.
Active Fires	Electron Density Profile	Snow Cover/Depth
Aerosol Optical Thickness	Energetic Ions	Solar Irradiance
Aerosol Particle Size	Geomagnetic Field	Supra-Thermal-Auroral Part.
Aerosol Refractive Index	Ice Surface Temperature	Surface Type
Albedo (Surface)	In-*situ* Plasma Fluctuations	Surface Wind Stress
Auroral Boundary	In-*situ* Plasma Temperature	Suspended Matter
Auroral Energy Deposition	Ionospheric Scintillation	Total Water Content
Auroral Imagery	Medium Energy Charged Particles	Vegetation Index
Cloud Base Height	Land Surface Temperature	
Cloud Cover/Layers	Net Heat Flux	
Cloud Effective Particle Size	Net Solar Radiation (TOA)	
Cloud Ice Water Path	Neutral Density Profile	
Cloud Liquid Water	Ocean Color/Chlorophyll	
Cloud Optical Thickness	Ocean Wave Characteristics	
Cloud Particle Size/Distribution	Outgoing LW Radiation (TOA)	

VIIRS	25
CMIS	19
CrIS/ATMS	3
OMPS	1
SES	13
GPSOS	2
ERBS	5
TSIS	1
ALT	3
APS	4

★ EDRs with Key Performance Parameters
Gray colored EDRs not a part of the LRD

NPOESS Stored Mission Data (SMD) Environmental Data Records (EDRs)

★ Atm Vertical Temp Profile	Cloud Top Height	Ozone; Total Column/Profile
★ Atm Vertical Moisture Profile	Cloud Top Pressure	Precipitable Water
★ Sea Surface Temperature	Cloud Top Temperature	Precipitation Type/Rate
★ Sea Surface Winds	Downward LW Radiance (Sfc)	Pressure (Surface/Profile)
★ Soil Moisture	Downward SW Radiance(Sfc)	Sea Ice Characterization
★ Imagery	Electric Field	Sea Surface Height/Topo.
Active Fires	Electron Density Profile	Snow Cover/Depth
Aerosol Optical Thickness	Energetic Ions	Solar Irradiance
Aerosol Particle Size	Geomagnetic Field	Supra-Thermal-Auroral Part.
Aerosol Refractive Index	Ice Surface Temperature	Surface Type
Albedo (Surface)	In-*situ* Plasma Fluctuations	Surface Wind Stress
Auroral Boundary	In-*situ* Plasma Temperature	Suspended Matter
Auroral Energy Deposition	Ionospheric Scintillation	Total Water Content
Auroral Imagery	Medium Energy Charged Particles	Vegetation Index
Cloud Base Height	Land Surface Temperature	
Cloud Cover/Layers	Net Heat Flux	
Cloud Effective Particle Size	Net Solar Radiation (TOA)	
Cloud Ice Water Path	Neutral Density Profile	
Cloud Liquid Water	Ocean Color/Chlorophyll	
Cloud Optical Thickness	Ocean Wave Characteristics	
Cloud Particle Size/Distribution	Outgoing LW Radiation (TOA)	

VIIRS	25
CMIS	19
CrIS/ATMS	3
OMPS	1
SES	13
GPSOS	2
ERBS	5
TSIS	1
ALT	3
APS	4

★ EDRs with Key Performance Parameters

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30 July 2004

Dear McMurdo Ground Station Science Workshop Enthusiast,

Enclosed is the *The Future of the Next Generation Satellite Fleet and the McMurdo Ground Station* a report to the Office of Polar Programs at the National Science Foundation. This report is the result of the McMurdo Ground Station Science Workshop held at the Byrd Polar Research Center at The Ohio State University 9-11 March 2004 and co-host by the Antarctic Meteorological Research Center, Space Science and Engineering Center, University of Wisconsin-Madison. Several scientists and engineers from a variety of institutions have contributed to the content.

As you read the report, please keep in mind that satellite usage, reception and distribution issues are dynamic and ever changing. The topics this report takes up and the paths suggested must be followed up, and where needed, investigated further. Given the recommendations of this report, it is hoped that the innovative ideas presented are seriously considered or even new ideas not suggested here are considered to meet the goals this report outlines. Comments, suggestions and questions on this report are welcome any time.

Best Regards,

Matthew A. Lazzara & Charles R. Stearns

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Corrigendum

In the “The Future of the Next Generation Satellite Fleet and the McMurdo Ground Station” report, there is the following statement on page 20:

"Visibility of TDRSS satellite series may pose a problem, as currently there is only one TDRSS available to McMurdo for a limited time."

Currently McMurdo Station can see all the TDRSS satellites at 174, 171 and 150 degrees West. These TRDSS satellites are all in an inclined geostationary orbit. From Black Island there is greater than 20 hours per day visibility to these group of satellites. There is less visibility from Ross Island. There are two independent MTRS systems in McMurdo. The second MTRS or MTRS-2 is not on the closed network. The MGS RAID is on the closed network. This can be readjusted if necessary, so that data generated in McMurdo Station could go to another RAID and onto the MTRS-2 without ever leaving the open network. MTRS-2 status and control is on the mcmurdo.usap.gov local area network or open network, but not the data inputs. There is no Internet Protocol connection for data. Data inputs are on a patch panel and are single ended emitter couple logic or ECL. At present the data is patched into the ECL data output of the MGS RAID. There is a project underway now that is doing this with Tom Hawat at the University of Denver. Onsite MGS operators handle the use of the existing RAID for the data interface, until another RAID can be installed.