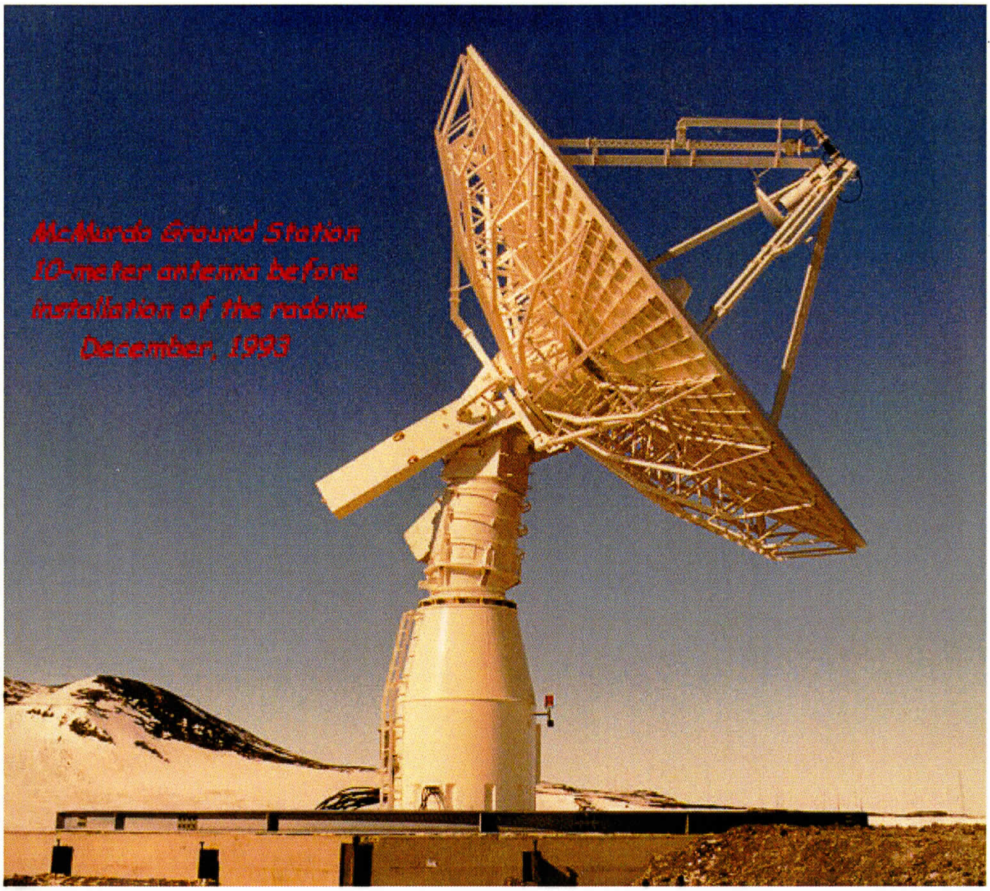
MGS Workshop Annual Project Report: NSF-OPP Grant #0412586, March 1, 2004 to March 1, 2005

McMurdo Ground Station Science Workshop

An Annual 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 20, 2005

Annual Report for Period:03/2004 - 03/2005 **Submitted on:** 04/20/2005

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'

Post-doc

Graduate Student

Undergraduate Student

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:

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 annual 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.

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

Web/Internet Site

URL(s):

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

Description:

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

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:

Special Requirements

Special reporting requirements: None

Change in Objectives or Scope: None

Unobligated funds: less than 20 percent of current funds

Animal, Human Subjects, Biohazards: None

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.

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

Matthew A. Lazzara and Charles R. Stearns
Antarctic Meteorological Research Center
Space Science and Engineering Center
University of Wisconsin-Madison

July 30, 2004

Funded by NSF-OPP Grant #OPP-0412586

UW SSEC Publication No.04.07.L1.

Photo by Pat Smith, NSF-OPP

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Space Science and Engineering Center
University of Wisconsin-Madison

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(http://library.ssec.wisc.edu/).

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.

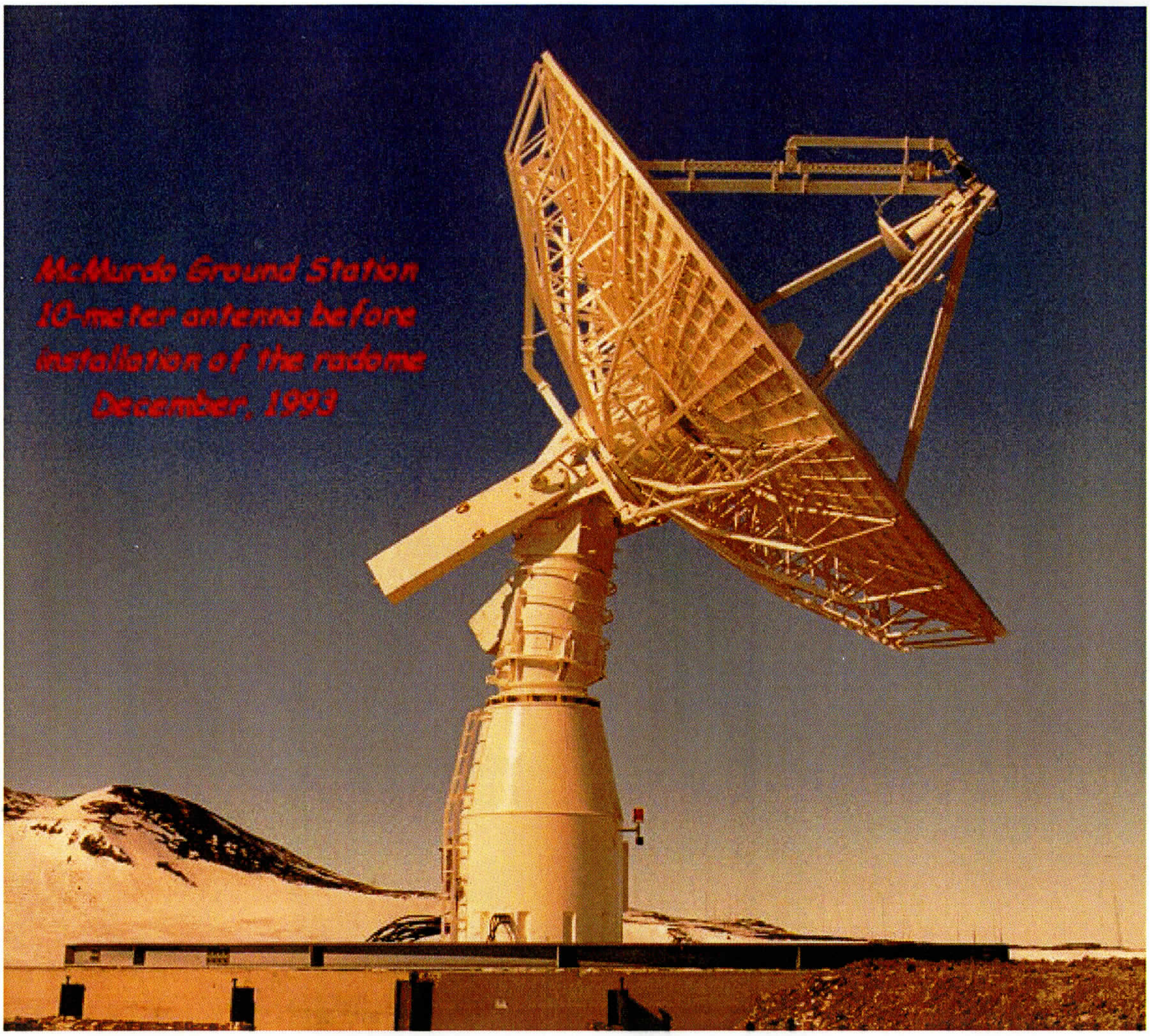


Figure 1 A photograph of the McMurdo Ground Station 10-meter antenna (without the radome) taken in December of 1993 (*Courtesy of M. Comberiate*).

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.

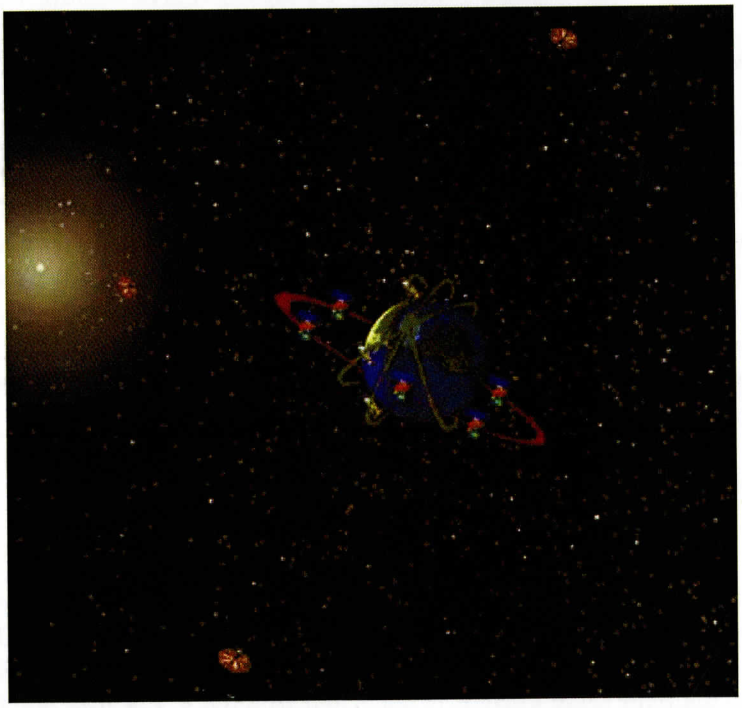


Figure 4 One vision for the future satellite series, including two polar sitting satellites - one for the Arctic and one for the Antarctic. (Courtesy Pat Mulligan/NOAA)

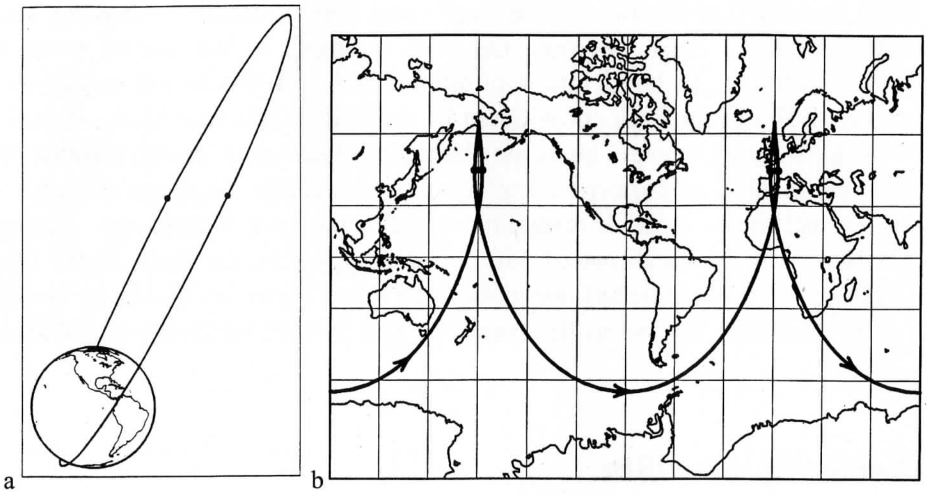


Figure 5 a) the orbit of a Molniya satellite, with the best view over the Arctic/Northern Hemisphere region: Similar orbit could be setup for the Antarctic. b) the ground track for the Molniya satellite. Note on both figures, there is a dot placed 4 hours before and 4 hours after apogee. [From Kidder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

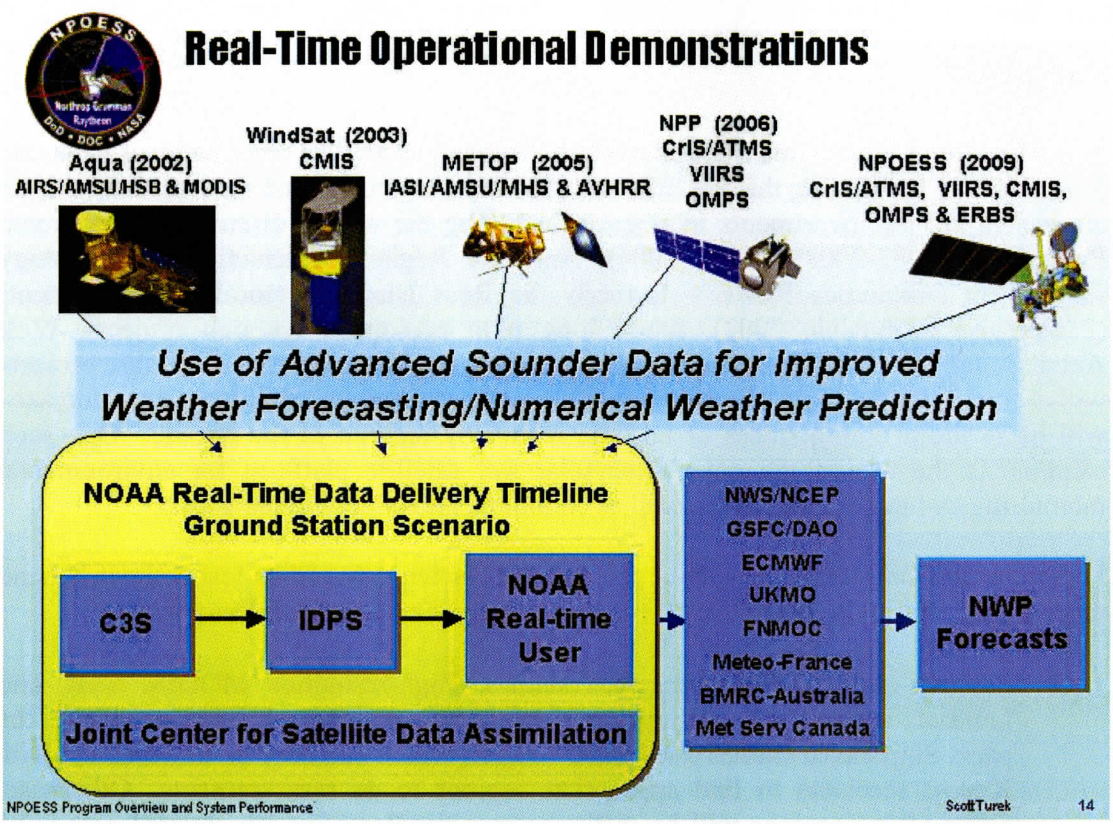
Perhaps in the long term, one should consider what science would be lost without X-band reception capability in Antarctica. Some key examples include the following:

- 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.



Real-Time Operational Demonstrations

Aqua (2002)
AIRS/AMSU/HSB & MODIS

WindSat (2003)
CMIS

METOP (2005)
IASI/AMSU/MHS & AVHRR

NPP (2006)
CrIS/ATMS
VIIRS
OMPS

NPOESS (2009)
CrIS/ATMS, VIIRS, CMIS, OMPS & ERBS

Use of Advanced Sounder Data for Improved Weather Forecasting/Numerical Weather Prediction

NOAA Real-Time Data Delivery Timeline
Ground Station Scenario

C3S → IDPS → NOAA Real-time User

Joint Center for Satellite Data Assimilation

NWS/NCEP
GSFC/DAO
ECMWF
UKMO
FNMOC
Meteo-France
BMRC-Australia
Met Serv Canada

NWP Forecasts

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

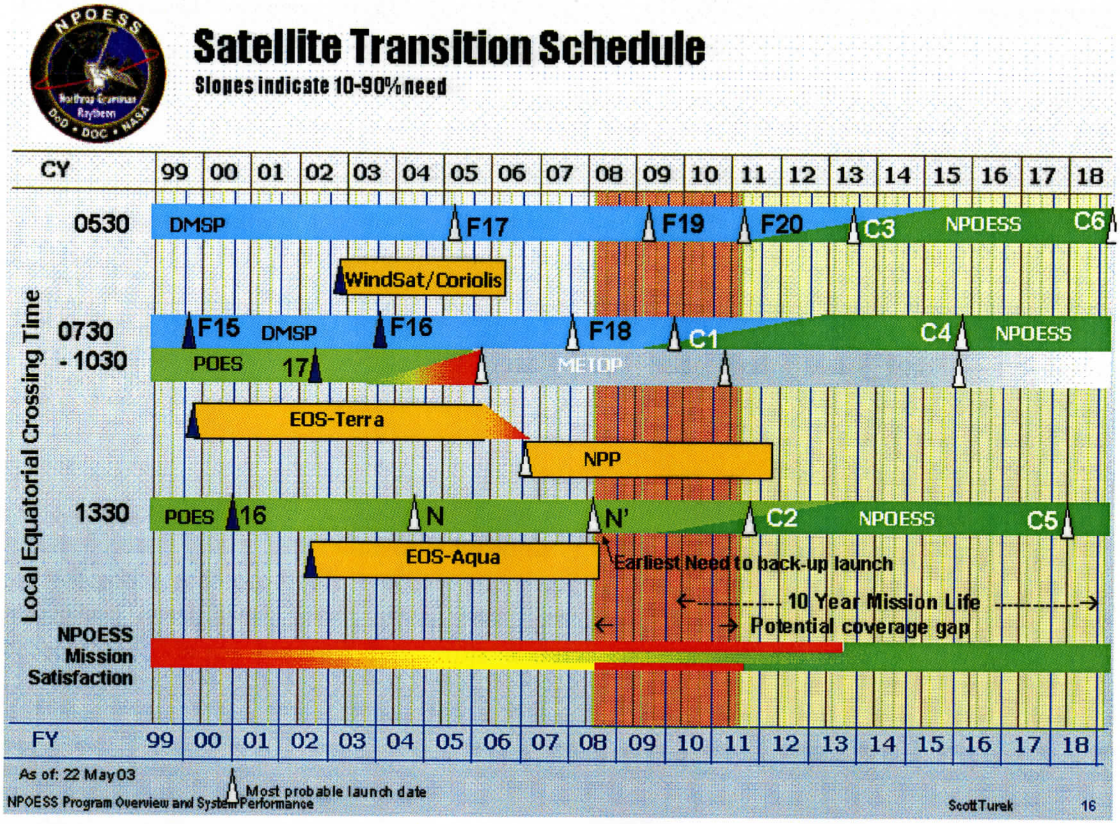

Figure 7 The transition from the current satellite system to the new generation satellite system depicts the timelines and "bridge" missions into the future.

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

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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
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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

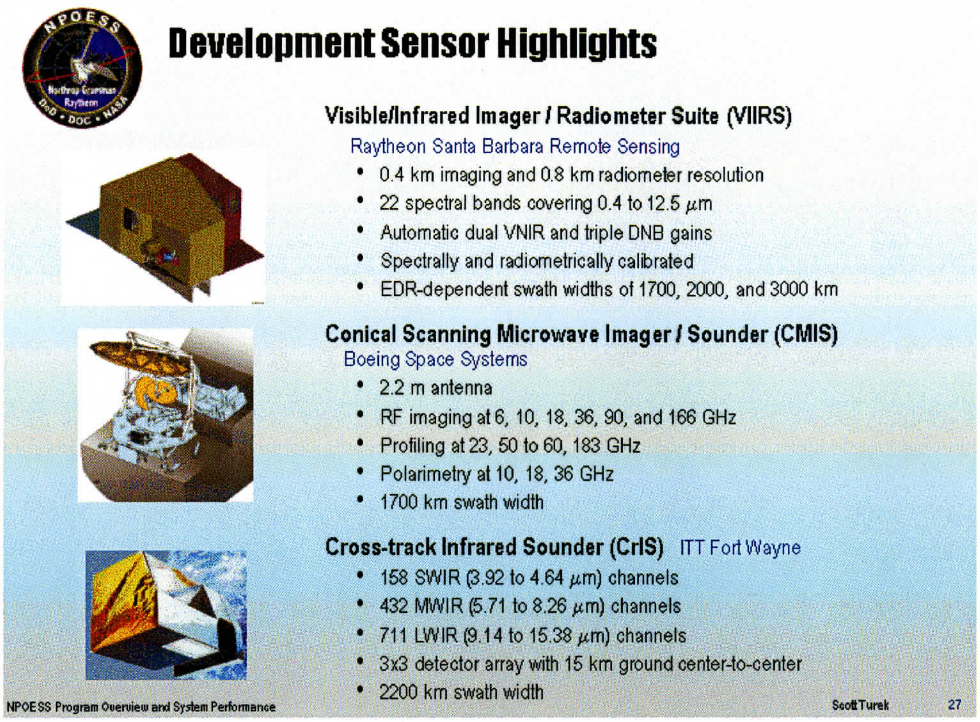
Acronyms

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 Apertũre 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

Visible/Infrared Imager / Radiometer Suite (VIIRS)

Raytheon Santa Barbara Remote Sensing

- 0.4 km imaging and 0.8 km radiometer resolution
- 22 spectral bands covering 0.4 to 12.5 μm
- Automatic dual VNIR and triple DNB gains
- Spectrally and radiometrically calibrated
- EDR-dependent swath widths of 1700, 2000, and 3000 km

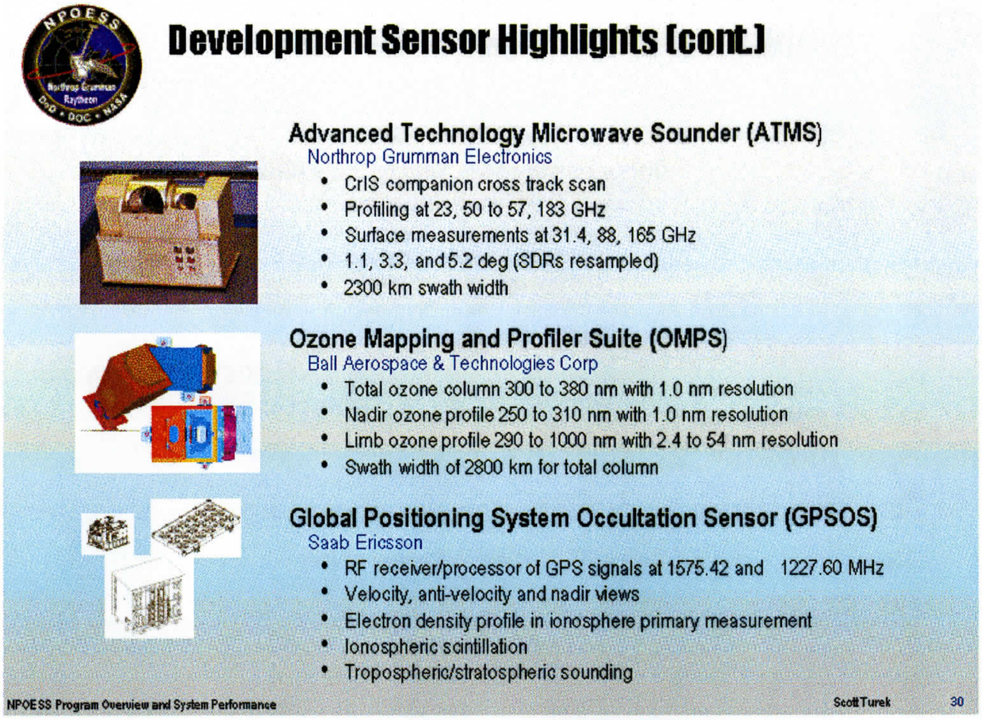
Conical Scanning Microwave Imager / Sounder (CMIS)

Boeing Space Systems

- 2.2 m antenna
- RF imaging at 6, 10, 18, 36, 90, and 166 GHz
- Profiling at 23, 50 to 60, 183 GHz
- Polarimetry at 10, 18, 36 GHz
- 1700 km swath width

Cross-track Infrared Sounder (CrIS) ITT Fort Wayne

- 158 SWIR (3.92 to 4.64 μm) channels
- 432 MWIR (5.71 to 8.26 μm) channels
- 711 LWIR (9.14 to 15.38 μm) channels
- 3x3 detector array with 15 km ground center-to-center
- 2200 km swath width



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

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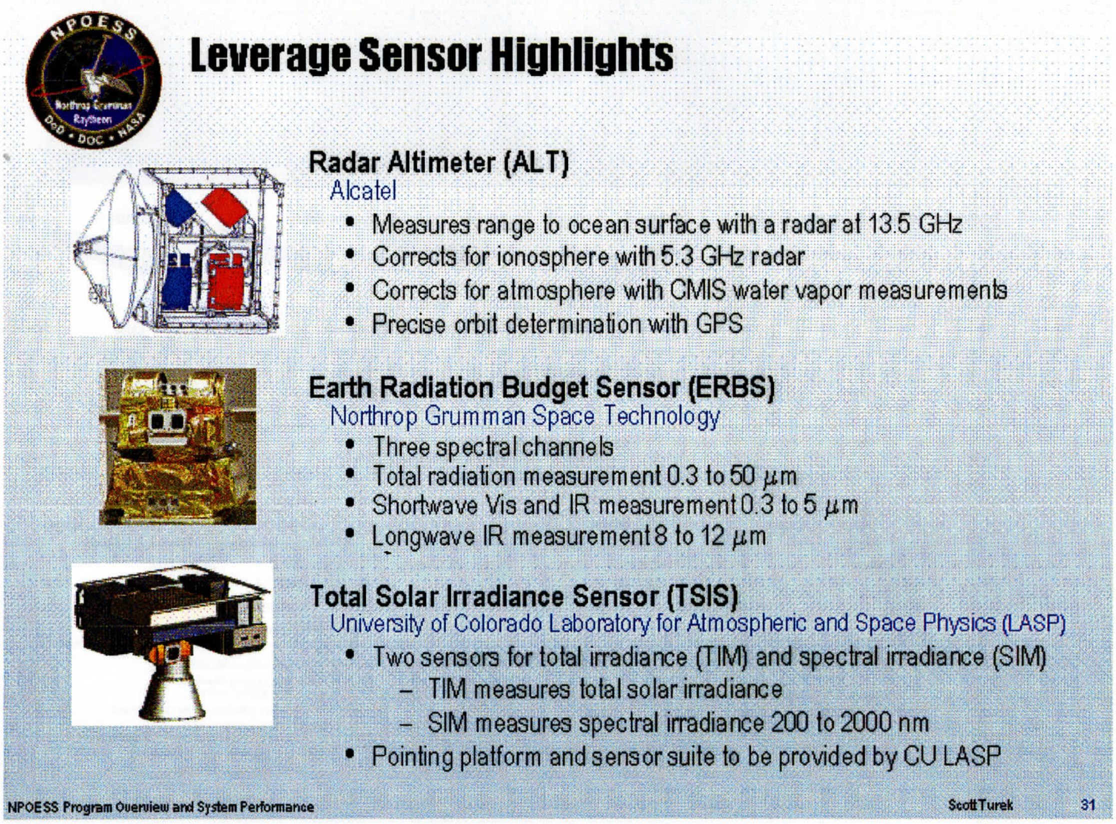

Leverage Sensor Highlights

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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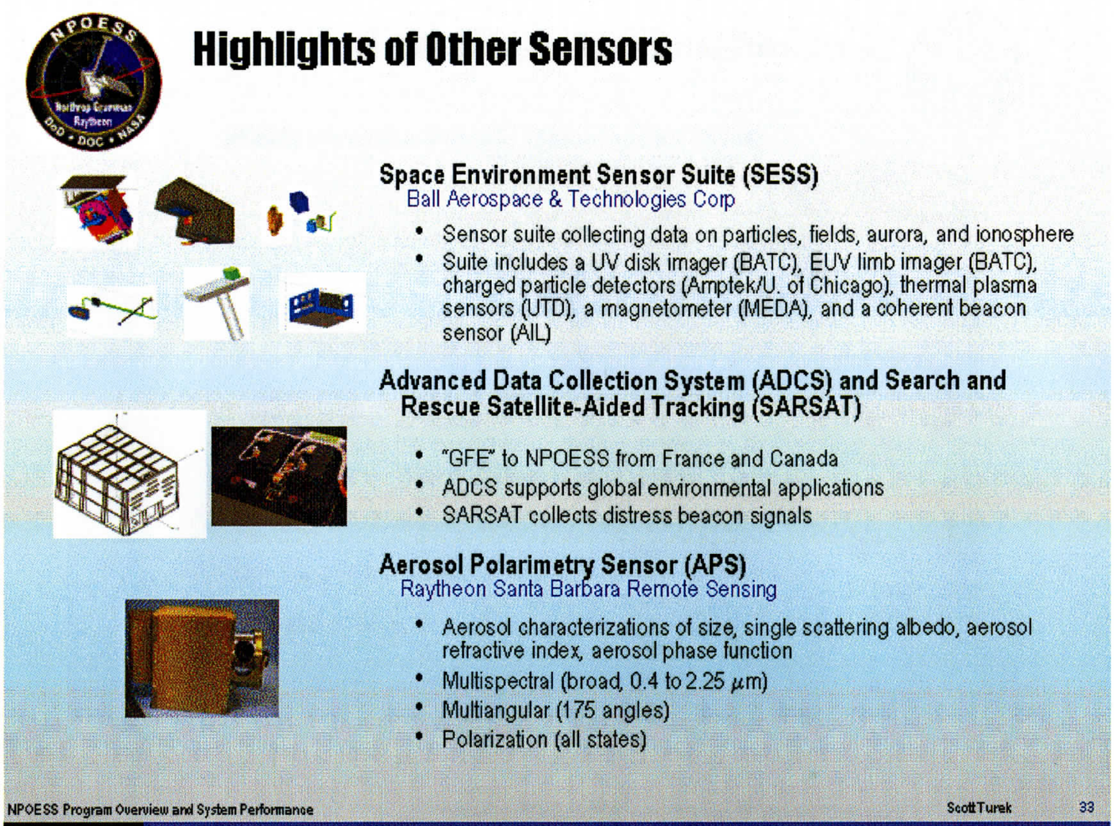


Highlights of Other Sensors

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)

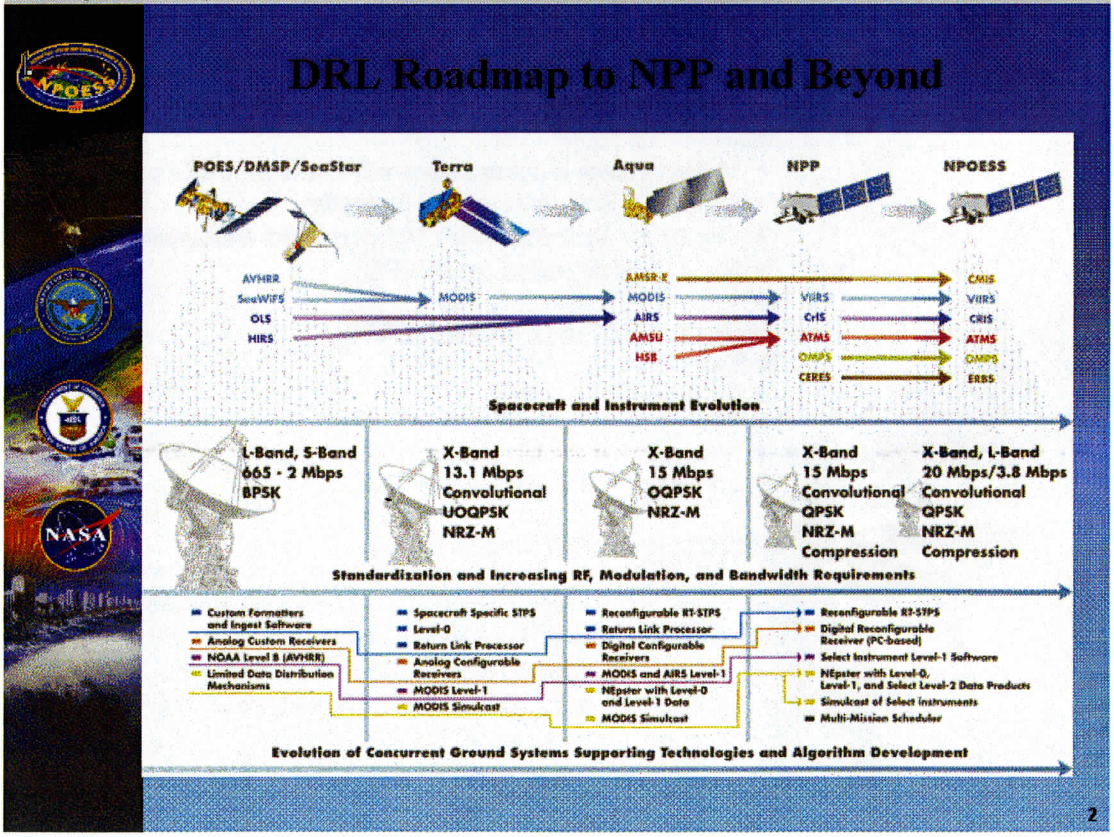
Advanced Data Collection System (ADCS) and Search and Rescue Satellite-Aided Tracking (SARSAT)

- "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)

NPOESS Program Overview and System Performance Scott Turek 33



DRL Roadmap to NPP and Beyond

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

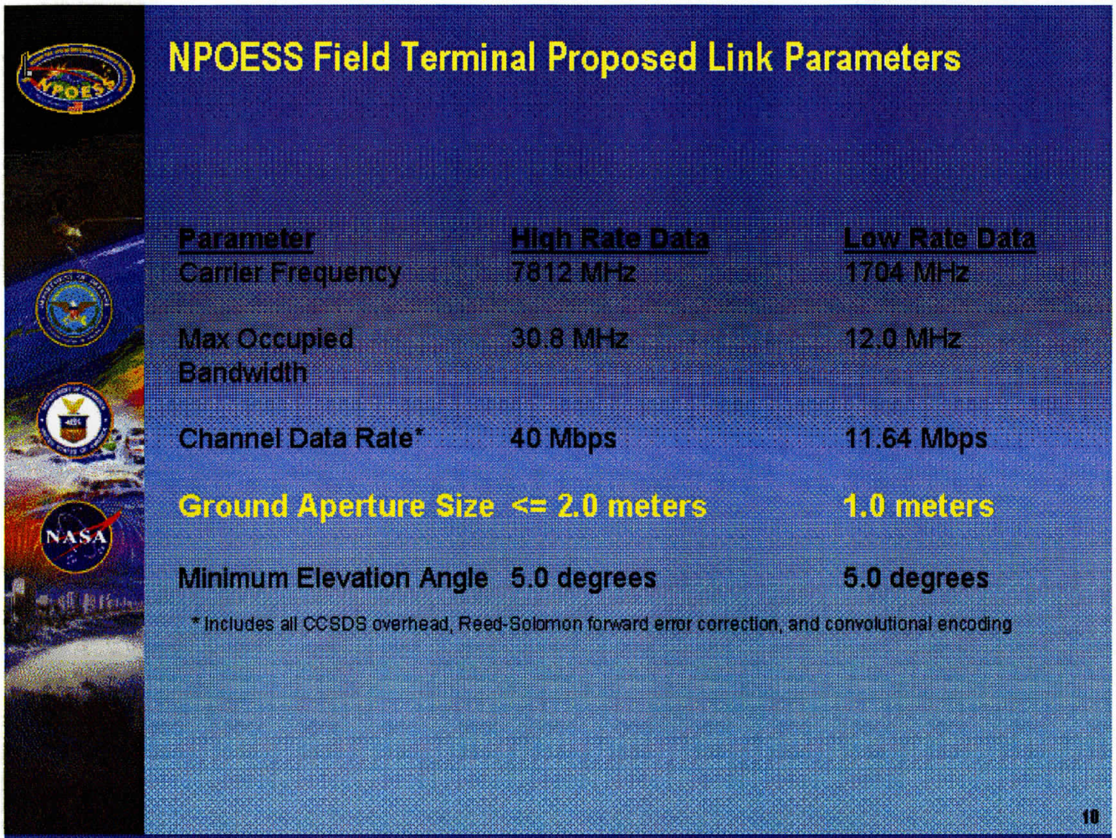
- Spacecraft Specific STPS
- Level-0
- Return Link Processor
- Analog Configurable Receivers
- MODIS Level-1
- MODIS Simulcast

- 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

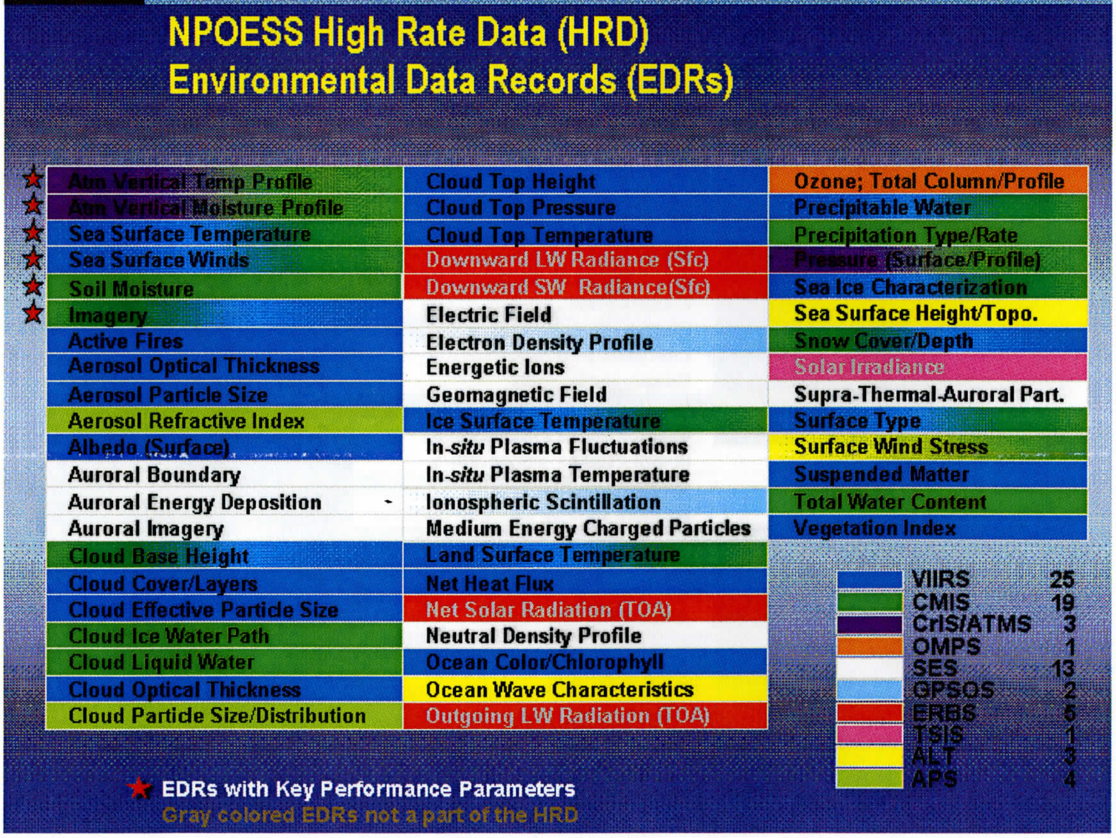
2



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



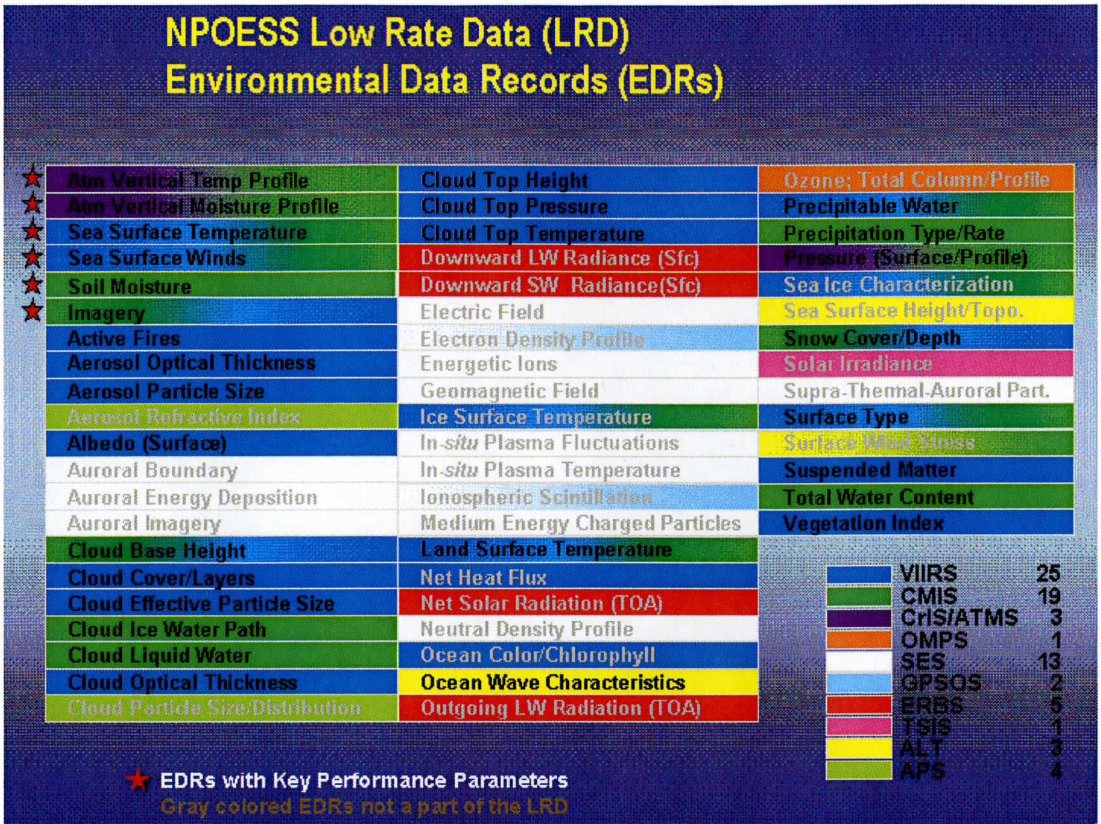
NPOESS High Rate Data (HRD) Environmental Data Records (EDRs)

★ 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
- ★ Atm Vertical Moisture Profile
- ★ Sea Surface Temperature
- ★ Sea Surface Winds
- ★ Soil Moisture
- ★ Imagery
- Active Fires
- Aerosol Optical Thickness
- Aerosol Particle Size
- Aerosol Refractive Index
- Albedo (Surface)
- Auroral Boundary
- Auroral Energy Deposition
- Auroral Imagery
- Cloud Base Height
- Cloud Cover/Layers
- Cloud Effective Particle Size
- Cloud Ice Water Path
- Cloud Liquid Water
- Cloud Optical Thickness
- Cloud Particle Size/Distribution

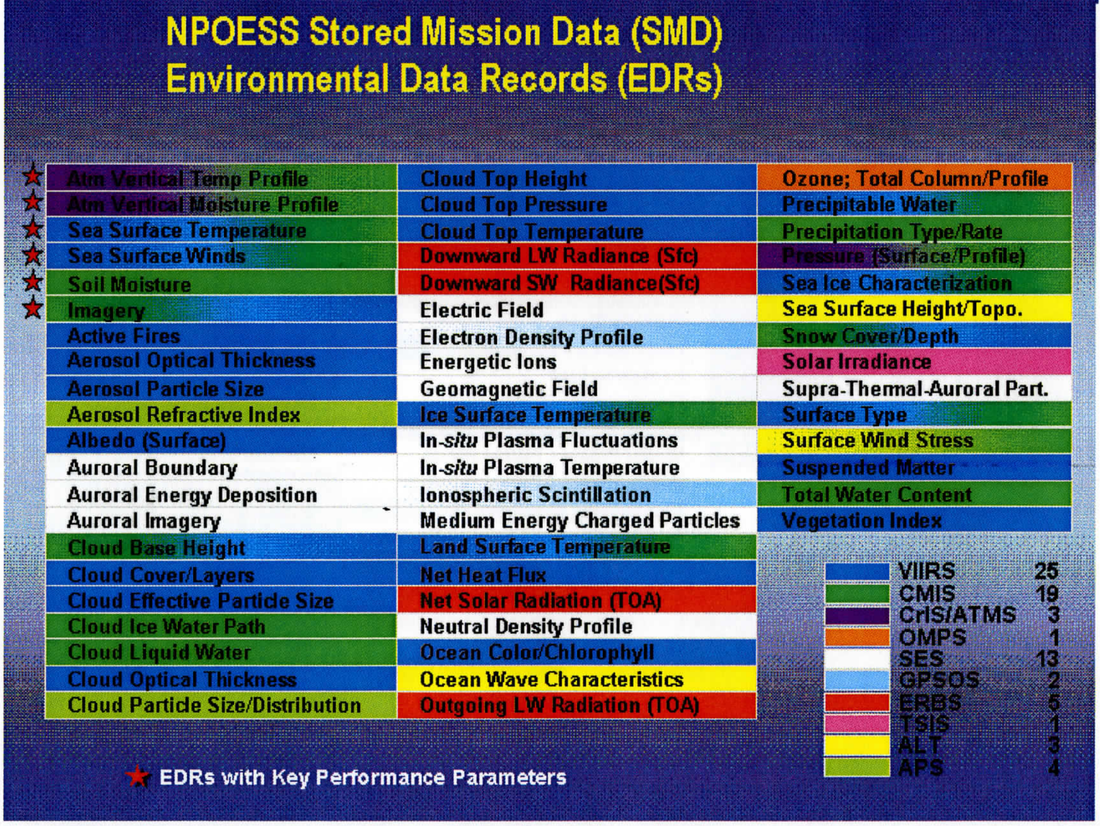
- Cloud Top Height
- Cloud Top Pressure
- Cloud Top Temperature
- Downward LW Radiance (Sfc)
- Downward SW Radiance(Sfc)
- Electric Field
- Electron Density Profile
- Energetic Ions
- Geomagnetic Field
- Ice Surface Temperature
- In-*situ* Plasma Fluctuations
- In-*situ* Plasma Temperature
- Ionospheric Scintillation
- Medium Energy Charged Particles
- Land Surface Temperature
- Net Heat Flux
- Net Solar Radiation (TOA)
- Neutral Density Profile
- Ocean Color/Chlorophyll
- Ocean Wave Characteristics
- Outgoing LW Radiation (TOA)

- Ozone; Total Column/Profile
- Precipitable Water
- Precipitation Type/Rate
- Pressure (Surface/Profile)
- Sea Ice Characterization
- Sea Surface Height/Topo.
- Snow Cover/Depth
- Solar Irradiance
- Supra-Thermal-Auroral Part.
- Surface Type
- Surface Wind Stress
- Suspended Matter
- Total Water Content
- Vegetation Index

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
- ★ Atm Vertical Moisture Profile
- ★ Sea Surface Temperature
- ★ Sea Surface Winds
- ★ Soil Moisture
- ★ Imagery
- Active Fires
- Aerosol Optical Thickness
- Aerosol Particle Size
- Aerosol Refractive Index
- Albedo (Surface)
- Auroral Boundary
- Auroral Energy Deposition
- Auroral Imagery
- Cloud Base Height
- Cloud Cover/Layers
- Cloud Effective Particle Size
- Cloud Ice Water Path
- Cloud Liquid Water
- Cloud Optical Thickness
- Cloud Particle Size/Distribution

- Cloud Top Height
- Cloud Top Pressure
- Cloud Top Temperature
- Downward LW Radiance (Sfc)
- Downward SW Radiance(Sfc)
- Electric Field
- Electron Density Profile
- Energetic Ions
- Geomagnetic Field
- Ice Surface Temperature
- In-*situ* Plasma Fluctuations
- In-*situ* Plasma Temperature
- Ionospheric Scintillation
- Medium Energy Charged Particles
- Land Surface Temperature
- Net Heat Flux
- Net Solar Radiation (TOA)
- Neutral Density Profile
- Ocean Color/Chlorophyll
- Ocean Wave Characteristics
- Outgoing LW Radiation (TOA)

- Ozone; Total Column/Profile
- Precipitable Water
- Precipitation Type/Rate
- Pressure (Surface/Profile)
- Sea Ice Characterization
- Sea Surface Height/Topo.
- Snow Cover/Depth
- Solar Irradiance
- Supra-Thermal-Auroral Part.
- Surface Type
- Surface Wind Stress
- Suspended Matter
- Total Water Content
- Vegetation Index

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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