The Space Congress® Proceedings

1974 (11th) Vol.1 Technology Today for Tomorrow

Apr 1st, 8:00 AM

Expansion Of Meteorological Satellite Potential

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ABSTRACT

Meteorological satellites in polar and geostationary orbit are presented in this paper along with examples and limitations. NOAA and NASA satellite programs, present and future in the meteorological field, are discussed along with spectral interval, ground resolution and operational applications. The USAF/AWS Defense Meteorological Satellite Program (DMSP) is scheduled for operation at the Air Force Eastern Test Range (AFETR) in the Spring of 1974. The DMSP acquisition system is described with respect to sensor type and satellite orbital parameters. Two satellites are in orbit at any given time providing real time, visual and infrared, imagery every six hours. Imagery examples depicting meteorological, geophysical, oceanographic, and earth resources applications are presented. Some added benefits with regard to the energy crisis are a possibility with the DMSP system or similar sensor use.

DISCUSSION

Today, we are going to talk about the meteorological satellites with specific emphasis on the Defense Meteorological Satellite Program. The first meteorological satellite was launched on 1 April 1960, April Fool's Day and, in light of the outstanding success of the program, the venture has proven to be anything but a foolish under taking.

The National Satellite System consists of NASA and NOAA vehicles. Most meteorological satellites launched have either been polar orbiting or geosynchronous orbiting systems. Polar orbits have periods from 100 to 120 minutes with altitudes from 400 to 1,000 nautical miles. Geosynchronous satellites, of course, are at 19,300 nautical miles altitude and remain in one position over the earth's surface at zero degrees latitude.

Figure 1 - Figure 1 shows some of the national system satellites that have been launched. In discussing geostationary satellites (ATS) or polar orbiters (ITOS), the advantages and disadvantages should be mentioned.

Geostationary satellites, of course, can view the same spot on the earth continuously in video-infrared scanning and enables near instantaneous tracking of probable storms and, of course, excellent monitoring of severe weather. At great distances from the equator, however, the resolution of the satellite product decreases considerably. If the Indian Ocean areas or Africa must be viewed continuously, other geostationary satellites have to be launched. The newest geostationary satellite system is called GOES. Two launches are planned in 1974. Some of the capabilities are shown on the next figure. Figure 2 indicates that resolutions to a 1/2 mile are expected.

For higher latitudes, polar orbiting meteorological satellites like ITOS are used. ITOS satellites are classified as NOAA when operational. An example of NOAA-2 video and infrared imagery of the scanning radiometry is shown (Figure 3).

NOAA-3, the newest satellite, as well as NOAA-2, has a Vertical Temperature Profile Radiometer able to acquire vertical temperature profiles worldwide.

Part of the U.S. national system is the NASA Nimbus program. There have been five Nimbus vehicles launched to date, primarily on an R&D basis. However, there have been numerous operational uses of the data. Some of the early Nimbus had automatic picture transmission (APT) which was used in many places at the same time that ESSA-2, 4 and 6 APT capabilities existed--NIMBUS was local noon whereas ESSA was early morning. Nimbus 4 capabilities are shown on Figure 4.

The enhancement or the use of a temperature/humidity infrared radiometer as well as the Image Dissector Camera System (IDCS) over India is contrasted on Figure 5.

Figure 6 is an infrared photograph of the Gulf Stream from the Nimbus 2, which has been converted into color using the color densitometer. This was done by a group of NASA scientists.

We will now discuss the Weather Service satellite system developed by the Department of Defense. The system is called the Defense Meteorological Satellite Program (DMSP), formerly known as the Data Acquisition and Processing Program (DAPP).

Imagery characteristics are as follows: Spectral interval of the visual band ranges from .4 to 1.1 microns, and the spectral interval of infrared is from 8 to 13 microns. Resolution options are available at .33 and 2.0 NM. The coverage of these polar orbiting satellites is a 1600 to 1700 swath every six hours from an altitude of about

450 nautical miles. IR characteristic temperatures 210-310°K (-63°C to +37°C).

This Figure (7) shows a nighttime photograph taken over the US. There are two revolutions of data shown here in the spectral interval from .4 to 1.1 microns, producing a visible low light imagery taken at midnight. You can see all of the major cities of the US and, of course, you can see the Aurora Borealis up to the north. The US military bases that are involved in the DMSP, either tracking or processing, are labelled on the picture. There are other stations all over the world because we have military requirements all over the world.

The worldwide applications of DMSP are nearly limitless as illustrated by the next several slides. Some will be meteorological, others will stress oceanography, geophysics, earth resources and, finally, miscellaneous applications of the system products. We have already seen the Auroral display. The daily mapping of this phenomena is a first by DMSP. Geophysicists are using the data for study of affects on communications, space environmental anomolies, solar relations and weather.

Figures 8, 9 & 10 show the DMSP versatility in the visual and IR modes. The first one is a visible image taken over Florida on a clear day. Lake Okeechobee, Cuba, and parts of the Bahamas are clearly visible. The smudging gray along the east coast is caused by the chemicals from the roll in processing. This might be mistaken for clouds except that the next picture would clearly show that it is not a cloud formation. The next picture is an infrared picture with sixteen gray shades that is time synchronized with the previous one. It clearly shows the Gulf Stream off the east coast of Florida. The temperature range is from 300 degrees Kelvin to 275 degrees Kelvin, a 25 degree temperature spread, divided into sixteen gray shades. Oceanographers, fishermen, hydrologists and meteorologists all would have great interest in these data. If a densitometer or other device to separate numerous gray shades is not available, you have the option of displaying only four or even two gray shades at one degree temperature intervals. For example, we have enhanced the image of the Gulf Stream east of Jacksonville. Each one of the shades shown from white to black represents a one degree temperature change. From 294 to 296 degrees Kelvin, the two gray shades between the black and white are specific emission temperatures.

Figure 11 shows very high resolution data (1/3 nautical mile) off the west coast of Florida--you can see what we believe to be river run-off in April 1973. There was heavy rainfall at this time of the year, and the swollen rivers are clearly shown in the Gulf states. A cold front is located to the south of Florida. Wind direction and speed intelligence can be determined by the lee waves in the cloud forms and cumulus cloud streets.

Many weather experiments have been conducted around the Line Islands in the Pacific which were discovered by Captain Cook in the late 1700s.

Figure 12 - The next very high resolution imagery of the DMSP shows a multitude of meteorological intelligence--cloud location, easterly wave, low level wind flow, wave height and direction, and anomolous gray. This anomolous gray area on the photo is believed to be invisible clouds (water droplet concentrations) because of the expanded viewing spectral interval of the DMSP.

Figure 13 - The corresponding infrared imagery of the Line Island area shows four gray shades with white indicative of clouds above 12,000 feet. The islands and cumulus streets are in black, which was set for temperatures which existed below the 4,000 foot level.

Figure 14 - We have already seen low light imagery of the DMSP delineating the Aurora Borealis and city lights. This photo was taken over the Hawaiian Islands at local midnight with no moonlight. The lights of Oahu are seen. A ringed pattern around the lava flow of Keleaua volcano is clearly apparent, much like a sun dog in day time. This ringed pattern is believed to be caused by large sized smoke particle refraction from the volcano; although it could be produced by noctilucent cloud refraction or sensor aberation. The black line through the center of the source is probably radiometer overdrive.

The US Forest Service spends a great deal of money fighting forest fires and the fires themselves are also collosal wastes. The DMSP or similar system could help in the location of fires in remote regions such as the Tundra fires in Alaska, and perhaps reduce some of these wasted resources.

Figure 15 - Lights that have not shown up on previous pictures are most likely electrical storms. Bright specks of light in the clouds east of the Bahamas are shown on the moonlight imagery, for example.

Figure 16 - Wind flow can be determined by several features shown on satellite imagery. Cumulus cloud streets have already been mentioned. Cloud movement, plumes, cirrus streaks, transverse bands and lee waves are other markers of wind flow. Billow clouds indicate speed and direction. IR data fixes the cloud altitude by relating it to vertical temperature profiles. Turbulent strong winds were occurring over Egypt and Isreal as indicated by the billow clouds.

Figure 17 - Anomolous cloud lines cannot be ignored when discussing satellite photos. The next series of photos show these cloud lines. Ship contrails? The lines merge into the stratocumulus deck.

Figure 18 - A cone shock wave around Hainan Islands? Subsonic flow around islands create this pattern of cumulus as well as blunt appearing shock waves.

Figure 19 - CB dissipation created circular cloud lines around various stages of connective decay.

Figure 20 - And, finally, two lines of converging clouds over the area east of San Francisco Bay. This point is the rendezvous position for high flying aircraft in the Bay area. These aircraft-induced phenomena are probably contrail formations.

Figure 21 - DMSP has been very instrumental in the recent success of the Joint Typhoon Warning Center in Guam. Cape Kennedy AFS should enjoy similar successes when DMSP becomes operational on the Air Force Eastern Test Range. The eye of typhoon Betty is nearly 35 NM across in this picture.

Figure 22 - The spectral interval of the DMSP VHR (.4 to 1.1 microns) enables typhoon Pamela's eye to be easily seen wherein poorer resolution and narrower spectral intervals would have necessitated other means of investigation.

Figure 23 - Earth resources research is being conducted by NASA's ERTS and SKYLAB. DMSP is a meteorological satellite system. However, the use of DMSP to determine when to turn on cameras of these systems is valuable. This DMSP picture shows the location of the lumber industry on the island of Cyprus.

Figure 24 - The eclipse of the sun showing the moon's shadow over Africa was captured by the DMSP noon vehicle. The umbra and penumbra are shown over the Sahara Desert northwest of Lake Chad.

In conclusion, the satellite systems unquestionably have opened and lent themselves to a multitude of applications heretofore thought to be beyond the scope of sensors in space.

ILLUSTRATIONS

Figure 1. National Meteorological Satellites.
Figure 2. GOES Capabilities.
Figure 3. Real Time NOAA-2 Scanning Radiometer Data, 20 October 1972.
Figure 4. Nimbus 4 Capabilities.
Figure 5. Nimbus Temperature/Humidity Infrared Radiometer vs the Image Disector Camera System.
Figure 6. Nimbus 2 Infrared Imagery over Gulf Stream.
Figure 7. DMSP Nighttime Visual Imagery over North America.
Figure 8. DMSP Very High Resolution Data over Florida, 24 March 1972 (.3 NM Resolution) (.4 to 1.1 Microns Spectral Interval).
Figure 9. DMSP Infrared Imagery Taken Simultaneously with Figure 8. Sixteen Gray Shades are Depicted Corresponding to Emission Temperatures of 300°K to 275°K (Black to White). The Resolution of the Sensor is 1.5 NM with a Spectral Interval of 8 to 13 Microns.
Figure 10. DMSP Infrared Imagery Taken Simultaneously with Figure 8. Four Gray Shades are Depicted Corresponding to Emission Temperatures of 296°K (Black), 295°K and 294°K (White). The Resolution of the IR Sensor is 1.5 NM.
Figure 11. DMSP Very High Resolution Data (.3 NM Resolution) (.4 to 1.1 Microns Spectral Interval), 11 April 1973.
Figure 12. Very High Resolution (.3 NM) Photo of Line Island Area Taken on 9 March 1970 at Local Noon. This Geographically Gridded Photo Shows the Exact Location of Each and Every Cloud. In Addition, Low Level Wind Flow can be Determined, Especially in the ENE Flow at Christmas Island(A). Disturbed Weather (B) is Shown on a Small Scale North of Christmas Island. Water Droplet Anomalies and Other Sea Surface Data can be Determined from this Visible and Near Infrared Photo (C) (.4 to 1.1 Microns). This is only a Portion of the 1,800 NM Swath Taken Every Revolution by this Sun Synchronous Satellite.
Figure 13. This Infrared (IR) Photo was Taken Simultaneously with Figure 12. Four Gray Shades are Depicted for the Following Thermal Emissions. Black is 290°K (17°C) or Warmer--That is, Sea Surface or Clouds Less Than 4,000 Feet are in the Black Region. The Dark Gray is Temperatures from 290°K to 280°K, That is, Clouds with Tops From 4,000 Feet to 8,000 Feet. The Light Gray is Emission Temperature Range from 280°K to 270°K, That is, Clouds from 8,000 Feet to 12,000 Feet. White is Temperatures Less Than 270°K or Cloud Tops Greater than 12,000 Feet. This Remarkable 3-D Analysis is Vital to Many Operations in the Pacific Area. AWS Personnel have Performed the Calibration to Correct Emission Temperatures to Cloud Tops.
Figure 14. No Moonlight Local Midnight DAPP HR Photo over Pacific Ocean. Photo Taken on 28 Dec 1970 Shows Erupting Kilauea on Island of Hawaii, as well as Lights of Oahu, Honolulu and Waikiki Beach are Elongated Horizontal Bright Line on this Geographically Gridded Imagery. Halo Effect Could be Radiometer out of Focussing or Atmospheric Refraction. Oil Refineries and Gas Fields Exhibit this Same Imagery Signature.
Figure 15. Nighttime Visual (Full Moon) Showing Lightning in Bahamas, 29 October 1972.
Figure 16. DMSP Very High Resolution Imagery Over Middle East (.3 NM Resolution).
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Resolution) (.4 to 1.1 Microns Spectral Interval), 7 November 1972.

Figure 23. Air Weather Service DMSP Photo Very High Resolution (.3 NM Resolution) (.4 to 1.1 Microns Spectral Interval), 30 June 1973, Local Noon.

Figure 24. Air Weather Service DMSP Photo, 8 Jan 72, Local Noon (.3 NM Resolution) (.4 to 1.1 Microns).

Figure 1

Figure 2

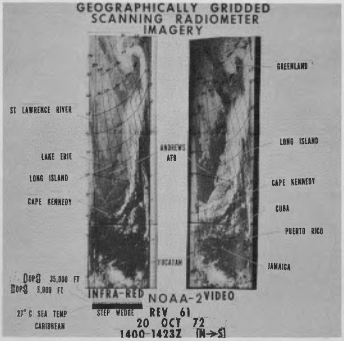


Figure 3

Spacecraft	Launch Date	Meteorological Sensor Compliment	Nodal Time
Nimbus IV	8 Apr 70	1 IDCS (Image Dissector Camera System) 1 THIR (Temperature Humidity Infrared Radiometer) 1 IRIS (Infrared Interferometer Spectrometer) 1 SIRS (Satellite Infrared Spectrometer) 1 MUSE (Monitor of ultraviolet solar energy) 1 BUV (Backscatter ultra-violet Spectrometer) 1 FWS (Filter Wedge Spectrometer) 1 SCR (Selective Chopper Radiometer) 1 IRLS (Interrogation, Recording and Location System)	1155A 2355D

Figure 4

Figure 5

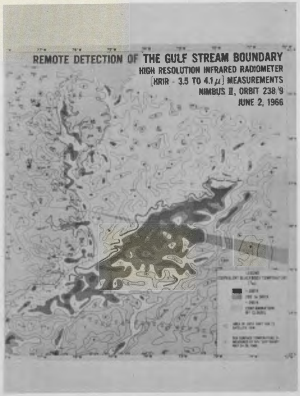


Figure 6

Figure 7

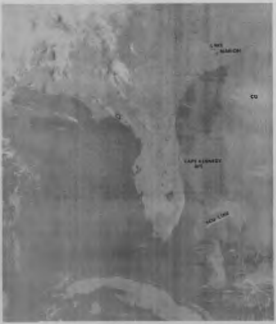


Figure 8

Figure 9

Figure 10

Figure 11

Figure 12

Figure 13

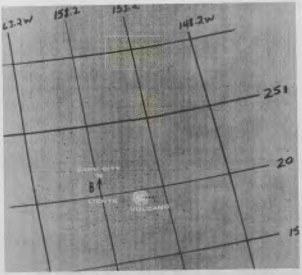


Figure 14

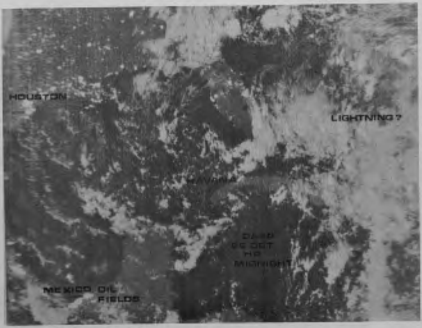


Figure 15

Figure 16

Figure 17

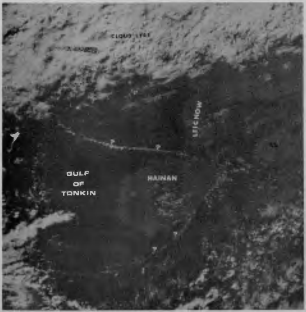
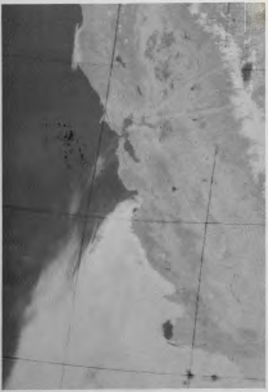


Figure 18

Figure 19



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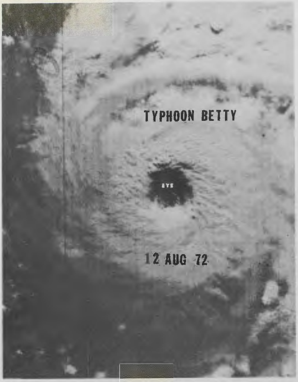

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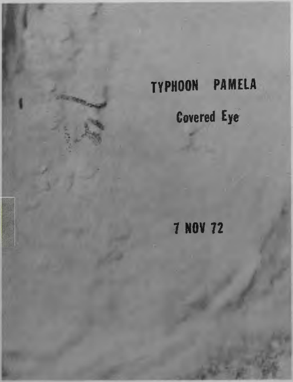

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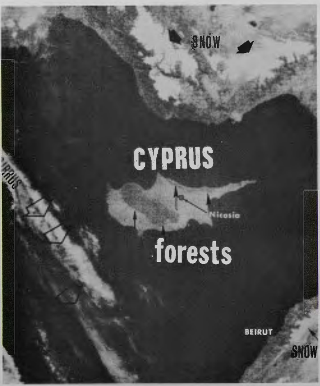

Figure 23

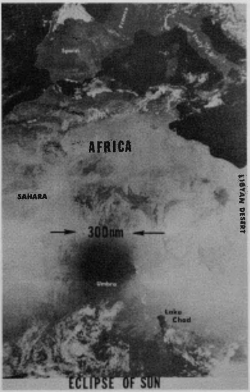

Figure 24