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INTRODUCTION

In this project I am going to explain about weather satellite systems and particularly about HRPT system, I will try to establish communication with the NOAA satellites.

The phrase Weather Satellite is commonly used to refer to a whole family of satellites that can tell us something about the air, water and land in which we live. As such, they are more correctly called environmental satellites. These satellites are operated by the United States, the government agencies of other countries, and commercial businesses.

National Oceanic and Atmospheric Administration's NOAA operational weather satellite system is composed of two types of satellites: geostationary operational environmental satellites (GOES) for short-range warning and "now-casting" and polar-orbiting satellites for longer-term forecasting. Both types of satellite are necessary for providing a complete global weather monitoring system.

There are two polar-orbiting satellites known as Advanced Television Infrared Observation Satellite (TIROS-N or ATN), constantly circling the Earth in an almost north-south orbit, passing close to both poles. The orbits are circular, with an altitude between 830 (morning orbit) and 870 (afternoon orbit) km, and are sun synchronous.

Data from all the satellite sensors is transmitted to the ground via a broadcast called the High Resolution Picture Transmission (HRPT). A second data transmission consists of only image data from two of the AVHRR channels, called Automatic Picture Transmission (APT). For users who want to establish their own direct readout receiving the station, low-resolution imagery data in the APT service can be received with inexpensive equipment, while the highest resolution data transmitted in the HRPT service utilizes a more complex receiver.

Data from the satellite is available when elevation is more than 10 degrees. The system depends on accurate orbital information, which is determined from the keplerian elements. By using the correct elements we can predict accurately the time of arrival azimuth/elevation of the satellite.

The operational satellites this period are NOAA-15 and NOAA-16. NOAA-16 give us early morning good passes and NOAA-15 give us evening passes.

NOTICE

WEATHER SATELLITE SYSTEM

TIME-STEP HRPT

This project is about satellite communication systems and more precisely about polar weather satellite systems. Our aim is to set-up a ground station for reception of weather satellite images. In order to establish proper communication between the satellite and the ground station, a wide range of information is necessary.

The first thing I had to do was to get good general background about satellites and their orbits. In addition, I had to get familiar with the ground system. This consists of an antenna, the rotator that moves the antenna, the controller of the rotator, an ISA card that gets the data from the receiver and puts them into the computer, the satellite receiver with auto-track controller, and a special software that controls the whole system.

At the beginning we had some problems with the PC and especially with the graphic card but after two weeks the problem was fixed by reformatting the hard disk and set-up the windows. Then I started to read information about the system that I have. The first step that I did after studying the theoretical part of the project was to install the software, the time-step ISA card to the PC and make all the connections. This was the easy part of the project.

The second step that I had to do was to calibrate the whole system to work properly. I started to do this but it was really hard at the beginning. Firstly, I realigned the antenna to the right point, which is azimuth south and elevation 0 degrees. The problem that I had after this calibration was a standard error of the alignment of the antenna with respect of the azimuth point because when I tried to auto track the sun the system moved the antenna to a different point.

I did some measurements with different limits for the calibration but the offset error continued to exist. Finally this error was found caused by the rotator. So I should, first calibrate the rotator and the antenna to show the correct point. I pressed the azimuth switch until the rotator meter got its minimum value, this point is North, and afterwards I pressed again the other switch for the azimuth in order to move the antenna for 360 degrees to the opposite direction (North). In this point the meter should show north. If the azimuth of the antenna is 360 degrees and the meter do not show the correct degrees (North), we should correct the displayed value adjusting a screw that is placed at the backside of the rotator. After this calibration the antenna and the rotator meter showed the true azimuth. The elevation was correct so we did not have to adjust it further.

After this, the bracket of antennas was broken. We ordered pieces of steel and we were expecting them two weeks. I had to design and manufacture two new brackets. The new brackets were from steel and not from aluminum like the previous. I repaired the antenna and following the previous process I re-calibrated the system again. After that the alignment of the antenna was very precise and had very good position in the sky.

The next step was to test the system that was done by tracking the sun. The system this time moved the antenna to the right point of azimuth and elevation. Everything was working correctly. The antenna was at the right point of the horizon and the rotator showed also the right point of the antenna. The results were accurate both in normal and inverted (flip over) mode.

After calibrating and testing the system, the next step was to track the operational satellites. Firstly I updated the keplerian elements of the satellites because as we know the orbit of the satellite changes as the time passes. The system communicated first with NOAA-12 but the signal was very weak and the data not enough. I left the system to track NOAA-12, 14, 15 for one week I had downloaded some images only from NOAA-12. The size of the files was 10Mb, 22Mb, 32Mb, 8Mb, 480kb and the best image were 32Mb. Afterwards we found out that the satellites NOAA-12 and NOAA 14 were not operational. Probably the image that I downloaded did not come from NOAA 12 but from another satellite, which follow NOAA-12 very closely. We realized this because we did not have the expected amount of data from high elevation passes. After this I tried to find the right frequencies for the active satellites, which in our case were NOAA-15, NOAA-16. Then I started to track only NOAA-15 and NOAA-16.

The first communication with the satellites comes immediately but with no very good results when the passes were of high elevation. Furthermore I could not establish communication with NOAA-15, because the frequency was changed and I had to find the new one. In addition the level of the signal was very low for the receiver.

The next step was to check my preamplifier and receiver to ensure that everything went well with them. The result which I took was that the preamplifier was working properly, it had gain G=35db,and the receiver could not recognize signals lower than -110dbm which is a very good level of sensitivity for the receiver. Measuring the output frequency of the IF port we found out that it was 10-20KHz higher than the expected, but this offset was not so important .So we concluded that the receiver was working properly. Furthermore I connected a new preamplifier (G=25db) and one attenuator (5-100dbm) just to amplify the signal to10dbm because NOAA-15 did not give me any data and NOAA-16 did not give the data I expected. The reason for this was that the received signals were not strong enough. But also I did not attain very good result because this connection added noise (preamplifier-attenuator-receiver).

The only thing that I had to do then was to check the receiver again after some measurements the conclusion was that the sensitivity of it was not good enough for weak signals under -100dbm. So I tried to improve the receiver's sensitivity and gain in the main frequencies for each channel. I succeeded to improving sensitivity of the receiver, by adjusting the circuit. I tweaked some capacitors from the VHF part of circuit until to achieve the highest output, finally I improved it 12dbm, which was good enough for my system.

After that the system worked for two weeks and the result was as I had was expected. For example, from NOAA-16 I had every day information four to eight times per day the best download period was at night with the amount of data being between 45-60Mb and for NOAA-15 two to four times per day and amount of data 25-35Mb (as we can see in the appendix) . NOAA 15 gave a little bit weaker communication but this is due to the satellite and not from our system.

After that, the next step was to connect a GPS system to achieve the best accuracy for the time. As we now GPS units have very precise timing, which are updated from the satellite continuously.

That was quite easy but sometimes the system was crashed because the GPS system was having poor coverage. So I connected to the GPS system one cable in order to use an antenna outside of the building. After that I did not have any more problems.

Now I have very good timing, very good communication with the satellites and quite good reception. So it is time to compare the quality of the downloaded data with other similar systems. In addition we compared the data in relation with elevation and time of day.

The system was working properly in respect of the quality of data and is the best result that I could achieve. Because in some high elevation passes I did not have the result that I expected, found from the www information about one station that it uses the same system with me so the result that I got from it was that the system was working satisfactorily but not perfect, as it should. That was due to some obstructions (two towers behind my antenna, one big tower and two smaller north of our antenna) so I lost some part of passes. So when our antenna is looking at this direction I loose the communication for angles below 15 degrees. That happens usually because the half passes finish at north point and the other half passes start from the north point again. If the satellite is coming from the south I obtain communication after 5-9 degrees elevation from NOAA 16 , and that give to us the reason that I can not obtain more information from the satellite. I also have compared all the passes for each day for two weeks and I make one table with the results.

So we have obtained good enough communication and that means good images from the satellite. Next we should correct the colors for better results because the satellite send the information in 5 channels, 3 visible and 2 infrared, so channel three and four give infrared images.

I could process the images with one HRPT reader to obtain better color because the Time-step software was not capable of this. The system that I used was David Taylor HRPT and after I used the Paint Pro 7 to handle in the image and remove the noise. The image had changed and looked much better. The colors were very accurate for daytime images and the noise had almost disappeared.

TABLE WITH THE PASSES OF THE SATELLITE AND THE RECEIVING DATA

Comparison between receiving data from satellite and time of pass:

	21/11	22/11	23/11	24/11	25/11	26/11	27/11	28/11	29/11	30/11	1/12	2/12	03/12	5/12	sum
1h			26	24				1.6		17	34.5	28	26.8		157.9
2h							41.2	36							77.19
3h		33	44	51.5				48	41	46	39.2	42	37		381.72
4h				23.3			34	5			6.4				68.69
5h		8	3.8				2		4	10		7.6	11.2	23.3	69.9
6h				1.4											1.4
7h															0
8h															0
9h															0
10h							0.46				6.6			0.72	7.783
11h		2		0.65						23.3	23	19.7	2.5		71.153
12h				42		39	36.8		29					30	176.81
13h	2.57	18	17.7						27	38	33	29	13.4		178.63
14h	13.7		11	28.6		28	14.3				5.8	9.2	12	3.2	125.8
15h		4								2.4					6.4
16h															0
17h	5														5

Comparison between receiving data from satellite and Max Elevation:

	21/11	22/11	23/11	24/11	25/11	26/11	27/11	28/11	29/11	30/11	1/12	2/12/2001	03/12/2001	sum
5deg				1.4				1.6						3
10deg				0.65		2	0.46	5	4				2.5	14.616
15deg	8	2	26	24					10	2.4	6.4	19.7	26.8	125.3
20deg	5.21	4M	3.8							23.3	15	28	11.2	86.51
25deg			11	23.3					29.1		34.5	9.2	23.3	130.39
30deg				28.6			36.8		17				12	94.4
35deg						34								34
40deg								48						48
45deg						28			41					69
50deg				42		41.2								83.19
55deg							14.3		46			29	13.4	102.66
60deg			17.7											17.7
65deg														0
70deg	33	18									39.2			90.2
75deg											33		54.6	87.6
80deg	13.7			51.5					27			42		134.22
85deg			44											44
90deg										38			37	75

CONCLUSION

Finally, the whole system works properly, it gives very good results from the satellite so we receive about 4-6 good images every day. If we didn't have the obstructions that we mentioned above we would be able to achieve the perfect result.

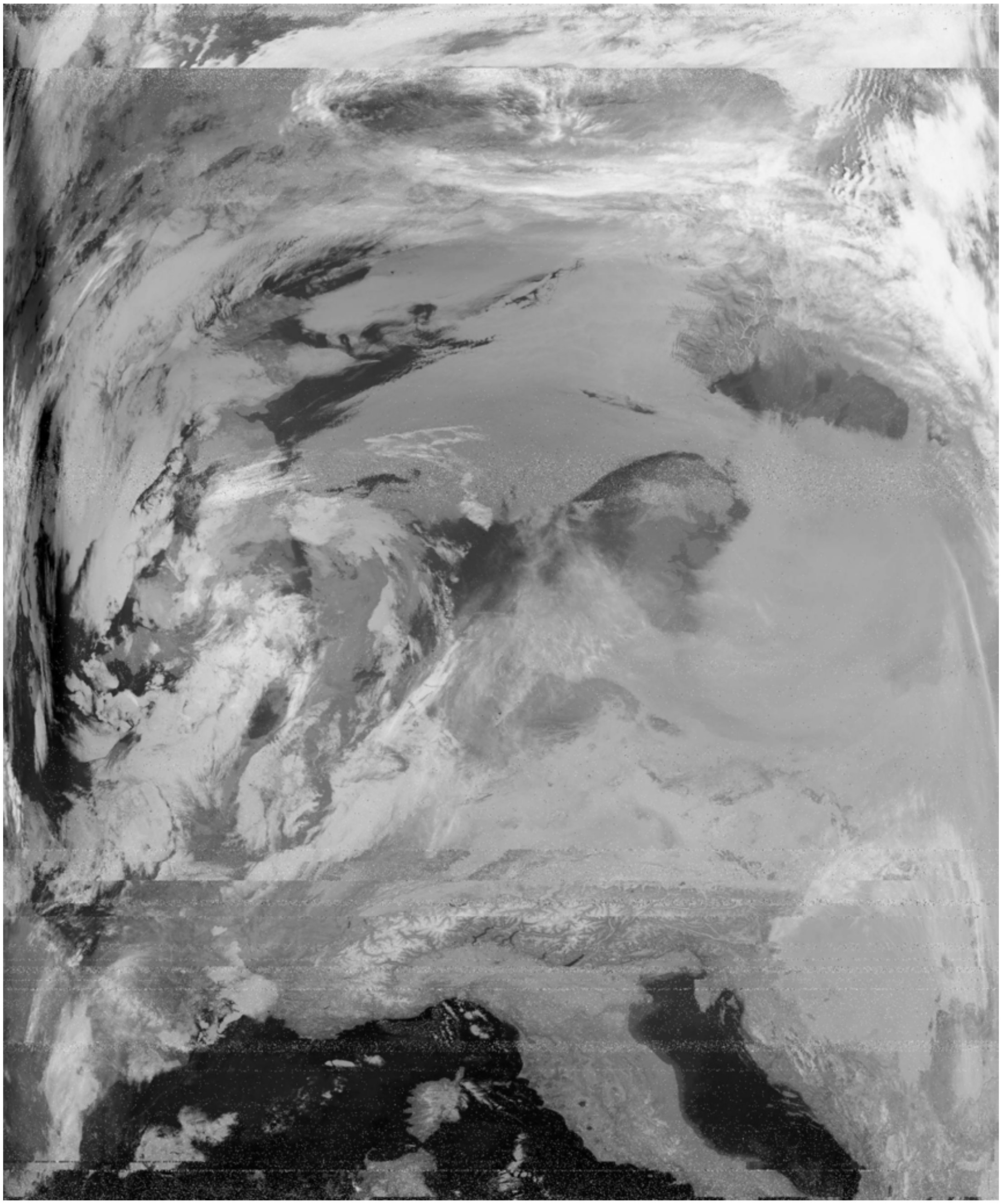
But even now, we have very good results if we think all the problems we had and if we consider the fact that we found the solution for each problem separately, until to the final result was obtained.

If we want to keep the system in proper operation we should do the below instruction:

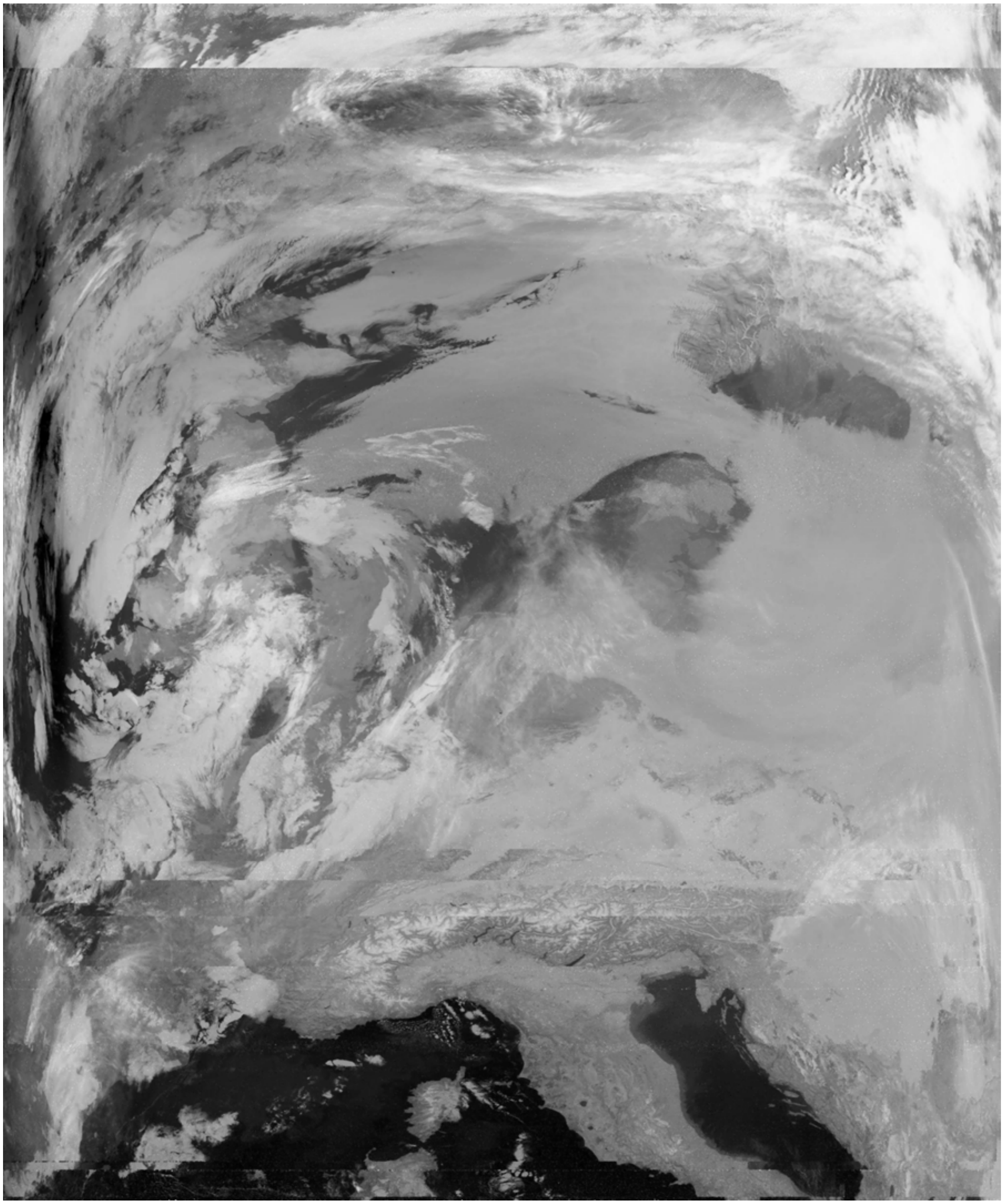
1) The system requires update in time four times daily and update in the keplerian elements at least two times weekly if you want to continue receiving well images

2) Another thing is that we should check the antenna approximately every second week because the weather phenomena move it.

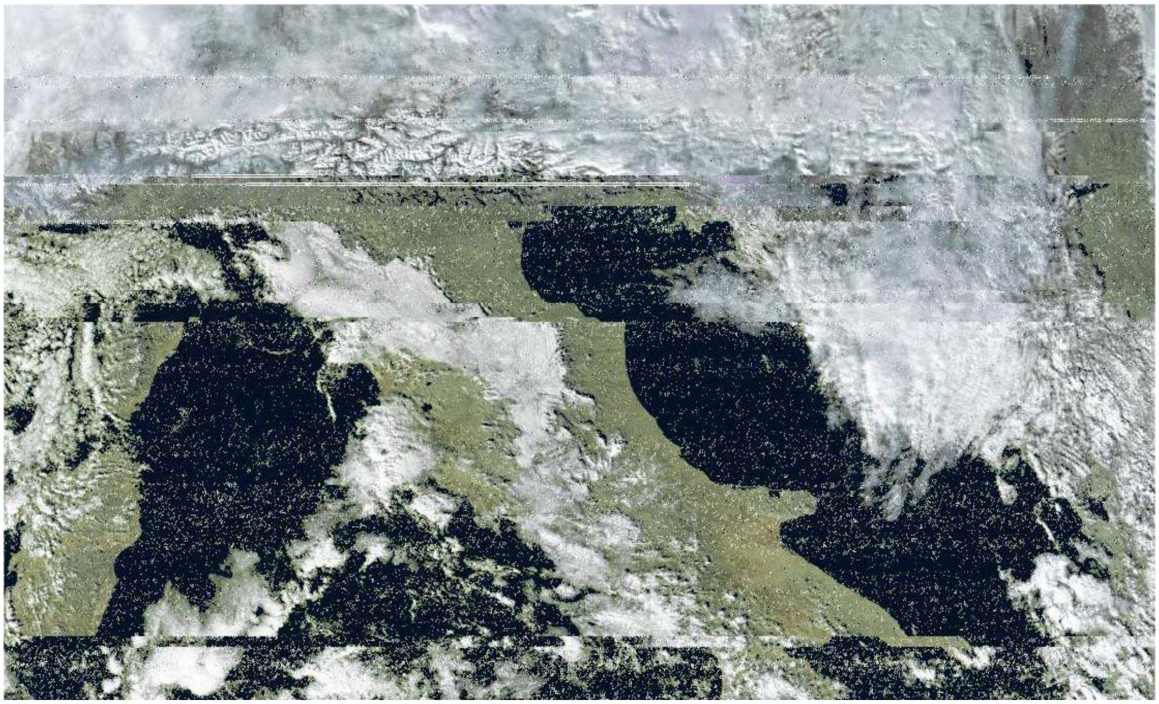
IMAGE PROSSESING



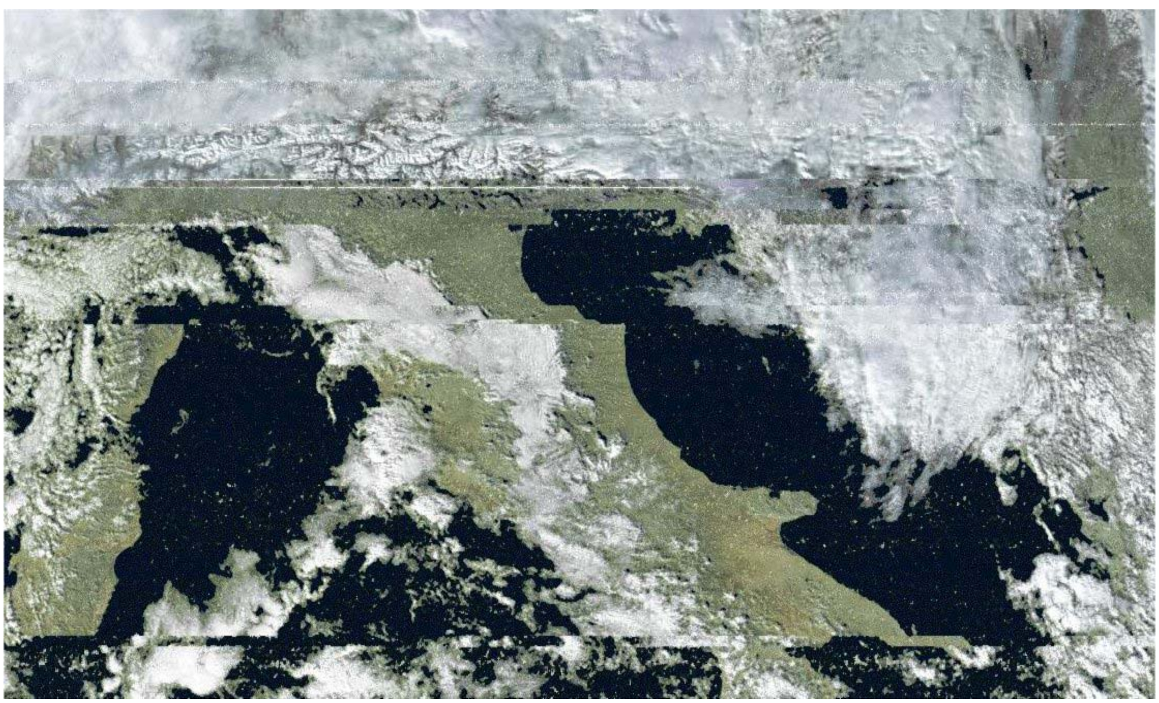
- SOUTH FRANCE AND ITALY BEFORE DESPECTLE THE NOISE



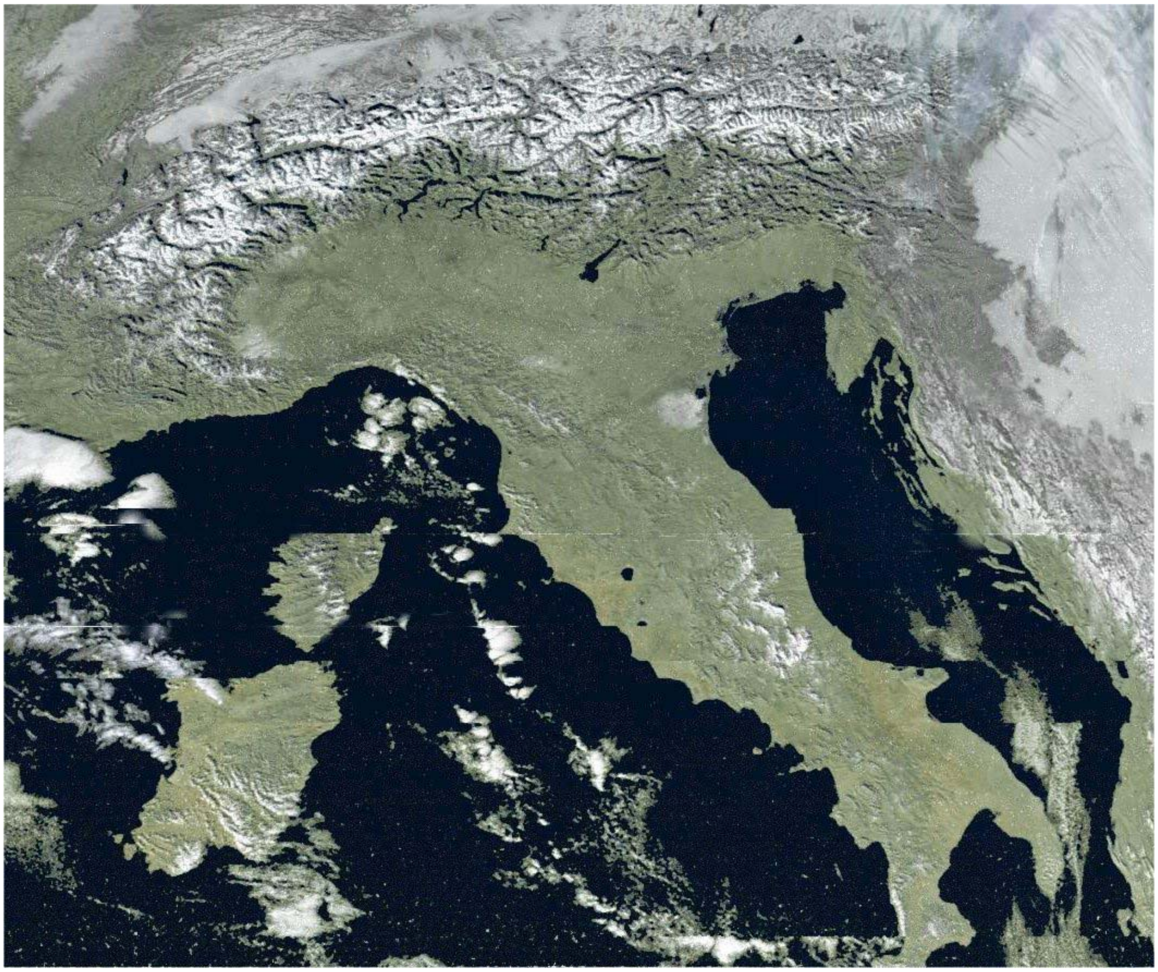
- SOUTH FRANCE AND ITALY AFTER DESPECTLE THE NOISE



- ITALY AT LUNCH TIME WITH NOISE



- ITALY AT LUNCH TIME WITH OUT NOISE

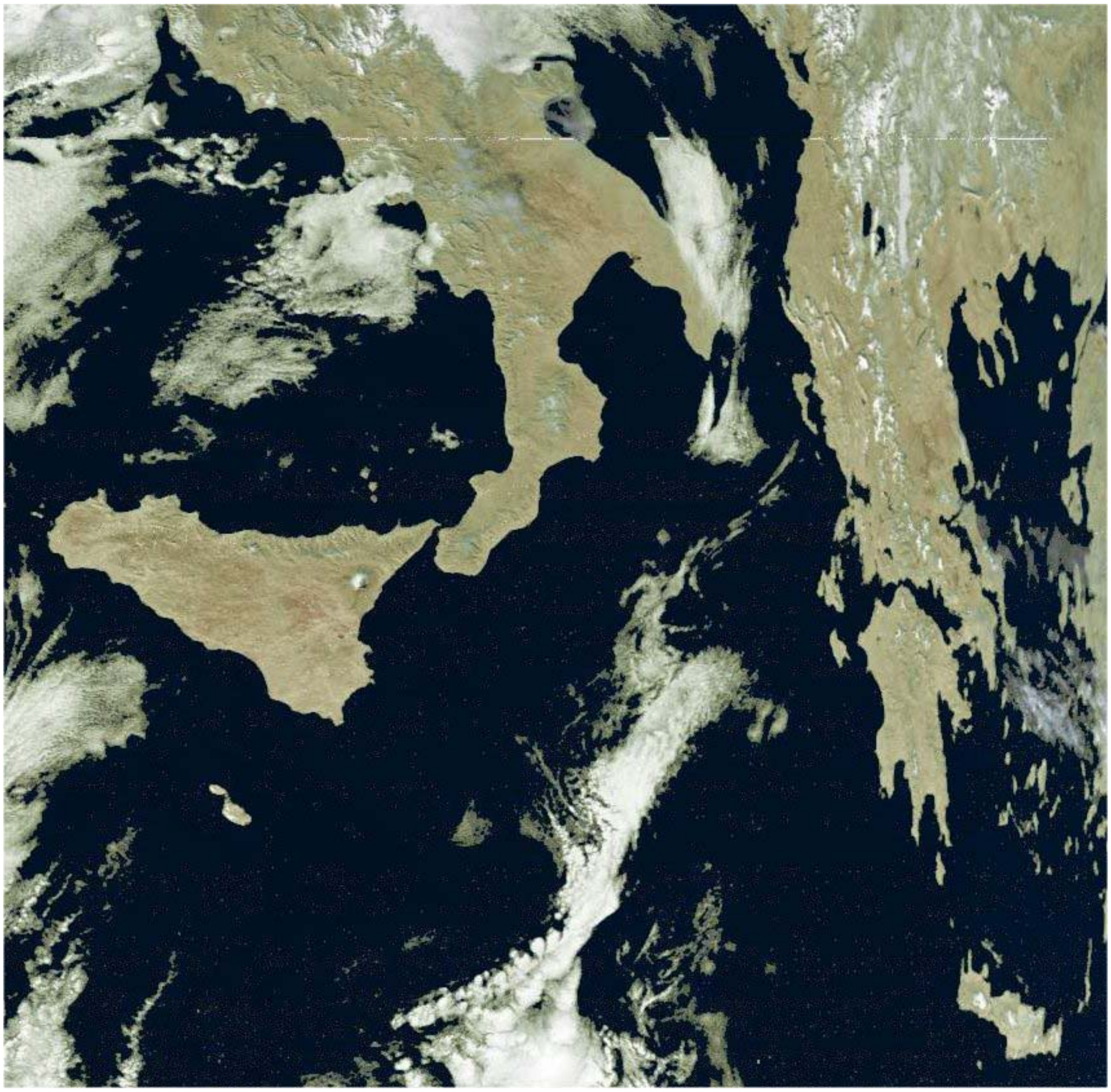


- ITALY LUNCH TIME

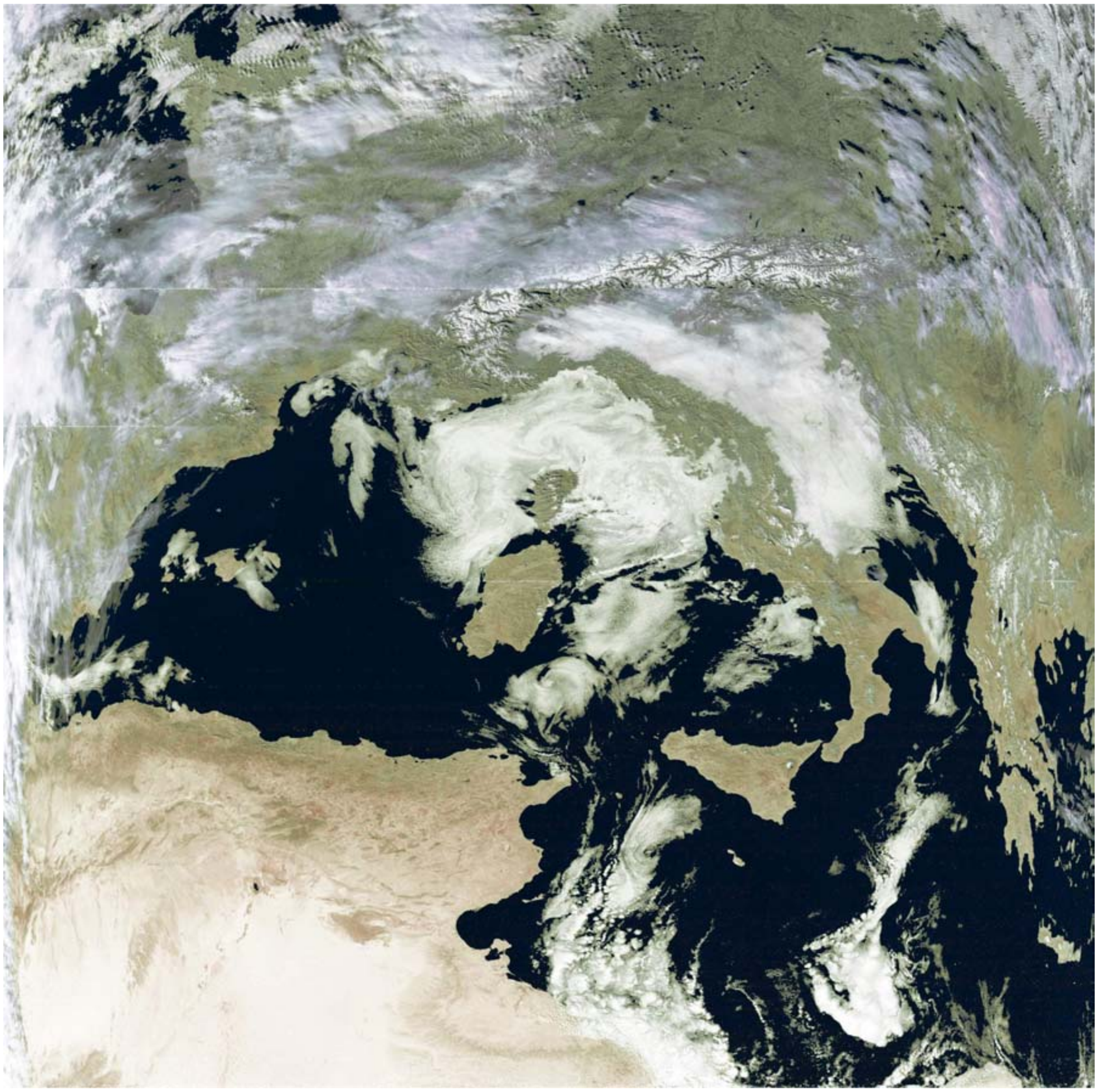
- IRELAND LUNCH TIME

- IRELAND ENGLAND LUNCH TIME

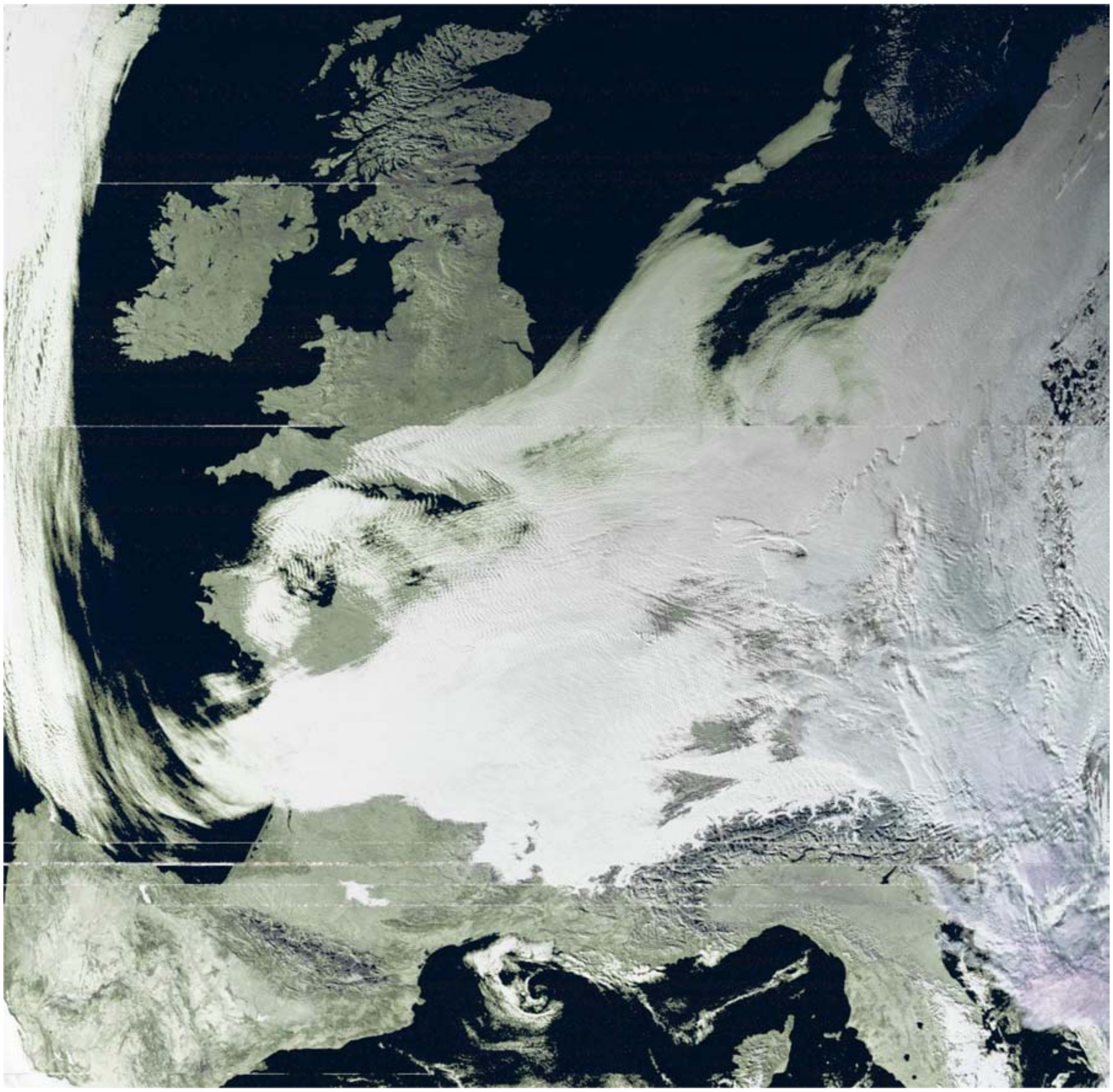
- IRELAND ENGLAND 03:00 AFTER MIDNIGHT



- GREECE AND ITALY LUNCH TIME



- EAST MIDLE AND SOUTH EUROPE



- WEST EUROPE AFTER LUNCH TIME

Appendix 1

Weather satellite and historical events

WEATHER SATELLITE AND HISTORICAL EVENTS

Weather satellites were first launched in 1960 by America to look at weather in real time. The National Geographic Magazine in August 1960 reported on the first image of the earth taken from space. Since then there has been steady progress, and more satellites have been launched on a regular basis. Remarkably, since the early 60's the format has not changed and the rest of the world has adopted the same standards.

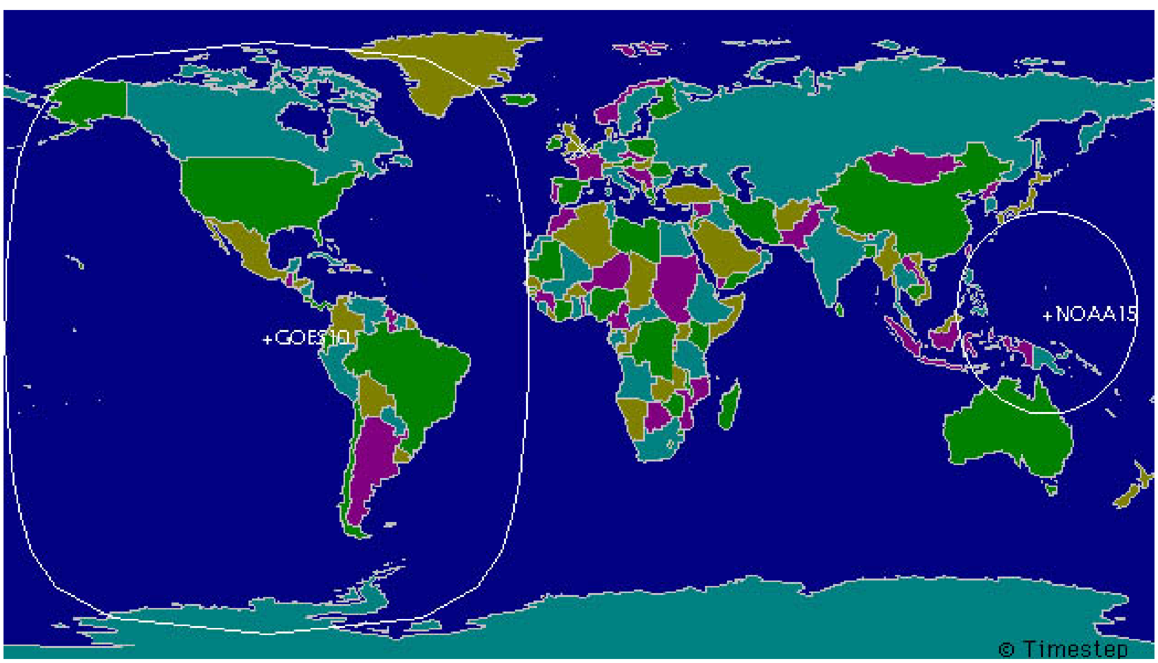
Polar Orbiting:

The first satellite was a polar orbiting type. Usually known as NOAA (National Oceanographic and Atmospheric Administration), these satellites orbit at about 850km above the earth. This means that they have a circular orbit that takes them almost directly over the North pole and South pole, and as the Earth rotates a different strip is imaged. The width of the image is 3000km and as the satellite travels above the earth's surface it scans a line twice a second. It scans continuously and therefore never sends a complete image, rather a continuous, never-ending strip. The satellites use VHF radio to transmit their information directly into your home or office. Using frequencies just above 137MHz means that the satellite is receivable when it comes above your horizon, which can be as far away as 3,000km. In England for example this is from the middle of Africa to way over Iceland. The whole pass from horizon to horizon will take about 15 minutes and the area where you are situated will probably take the middle 5 minutes. Each satellite overlaps each pass and you can expect 2 good passes from each satellite twice a day, so 4 passes per satellite per day. There are two series of satellites, the afternoon NOAA like NOAA 14 that pass over at about 2 o'clock after midnight and after midday. The morning NOAA such as NOAA 12 and 15 pass over at about 7:30 in the morning and early evening. So with 3 operational satellites there are 12 good images per day. The Soviet Union also has a series of satellites and these can be received on any of our multi-channel receivers (not 2 channel). Soviet activity is usually fairly constant but can be unreliable and difficult to predict.

The NOAA satellites have two separate transmissions; APT (automatic picture transmission) is on 137MHz and is very easy to receive. APT is so strong that a fixed antenna will receive nearly all of the pass and certainly much more than you would ever want. So APT is easy and you do not need to move or track the small antenna at all. The other transmission is HRPT (high resolution picture transmission) on 1707MHz and is not so easy to receive. HRPT requires a small dish and you need to track it across the sky following the satellite.

Geostationary:

In the late 70's it became obvious that a satellite transmitting 24 hours a day would be desirable. A satellite 40,000km away will orbit the earth once every 24 hours, exactly the same rate as the earth rotates, so from a fixed point on the earth the satellite appears stationary. A geostationary satellite is much further away from the earth than a polar orbiting type and often the resolution is not as good. However because geostationary satellites appear fixed, they can send images of exactly the same area as frequently as every 30 minutes in some cases. These frequent images can be processed by software to loop or animate that is so that you see moving clouds from, say, the last 8 hours. This gives valuable information on the type, direction, and magnitude of the cloud and hence leads to very easy forecasting. There are several geostationary satellites such as Meteosat 7 over Europe, GOES 8 over Eastern America, GOES 10 over Western America, GMS over Australia/Japanand INSAT/Meteosat 5 over Russia/India. Meteosat and GOES re-transmit images from other geostationary satellites so you can see the weather from Australia in London or Chicago for example. Geostationary satellites transmit on 1691MHz and need a small fixed dish to receive them. The transmission is called WEFAX and is pretty much standard, although there can be small variations between the actual satellites.Our PROsat for Windows software will take most geostationary satellite images and render them in full colour and, if required, automatically and seamlessly animate them.
There are two separate transmissions on most geostationary satellites. WEFAX is on 1691MHz and requires a suitable reception system with a small 90cm (3 foot) dish. PDUS is the high-resolution system from Meteosat and requires a big 1.8m dish.



If you look at the image above you can see 2 satellites. This is a snapshot in time. GOES 10 (Geostationary) has a big circle round it, and this is the area that it covers, like the whole of north and South America. Meteosat covers the whole of Europe and Africa

and GMS the whole of Australia, Japan etc. To put these extra satellites on the map would confuse the issue and so we have tried to make it simple NOAA 15 (Polar Orbiting) is over New Guinea and is receivable in the smaller circle as shown. Remember that this is a snap shot in time and over the next 100 minutes it would travel right around the world. The circles of coverage that are shown do not appear as true circles; this is because of the map projection. If they were displayed onto a true 3D spherical globe, then they would be circular.
And remember, there are a lot of satellites out there, more like a dozen instead of the 2 shown for simplicity!

Everyone needs to know what the weather is doing. Receiving live weather satellites gives you a unique real time view of the earth. If you plan to cut your grass, or sail round the world, you need to know what is happening. The level of detail can be quite dramatic, moving fronts can tell you not to go to sea, or a long clear period can change your plans easily. Astronomers can check for cloud cover in other continents before calling a friend to confirm a new sighting for example. Cloud temperature can be measured giving an indication of height, and sea surface temperature can be monitored for fishing or pollution control.

There are at least two types of image you can receive. Visible light is one, and this shows what you may expect to see if you looked out of the satellite. Visible sensors are good for low cloud and land detail but do not work in the nighttime though. Infrared detects heat and as high cloud is very cold it appears white; space is even colder and appears even whiter. You can see cities as darker spots on the land as they generate more heat than the surrounding land. In fact the overall resolution in general is less than the visible sensor, but because it is a heat sensor it does not matter if it is day or night.
Satellite technology is fun too. The interaction of satellite, receiver and computer is one, which is challenging and can stretch the mind. Teachers will value the ability to monitor the weather almost anywhere in the world from their classroom.

Weather satellites started in 1960 and to this day the standard is exactly the same. As with everything electronic, nothing stays still, so some time the standards may change. However we have been assured that current systems will work well for at least the next 10 years Even then, in this far distant future, antennas and other parts will still be useable. Just like over the last 10 years we have progressed from using 8088 PCs to Pentium II's, in the next 10 years we will all slowly upgrade our weather satellite systems, and who knows where computers will be in 10 years time?

Time-step

Time-step is a limited company made up of 7 dedicated people. Our main business is weather satellites and radio communication with satellites, and of course the software that is inevitable and makes our system so special. We started trading in 1975 and moved into weather satellites in 1984. We have the prestigious ISO9000 award and all our products are FCC and CE approved.

The different systems:

There are 4 separate systems. Most people start with either WEFAX or APT and then add the other one later. After a long time and hard saving, HRPT or PDUS is usually added.

APT Polar

APT satellites give about 12 good images a day, wherever you are in the world. The resolution is 4km per pixel and there are visible and infrared sensors. This is a simple system where the satellite is in low earth orbit and very easily received at 137MHz. The two frequencies in main use are 136.50 for NOAA 12 and 15 and 137.62MHz for NOAA 14. A simple crossed dipole antenna can be used, or for marine use a stainless steel Quadrifilar helix antenna. These simple omni-directional antennas do not need moving or tracking to receive the satellite. The satellite is so strong that when is about 20 degrees above the horizon perfect results will be obtained. As this is the lowest cost entry into weather satellites, a lot of people have asked if they could use their "scanner" that they use for monitoring other transmissions.

There are two problems with using receivers not specifically designed for weather satellites. The first and most important is bandwidth, an APT signal needs about 40kHz of bandwidth, between 30 and 50 is OK. Most scanners have 15kHz, which is far too narrow, and 180kHz or more, which is far too wide. Only a few scanners have the correct bandwidth and these are currently the AOR5000 and Icon IC-PCR1000. The second problem with all scanners, including the ones mentioned, is that a weather satellite system needs a very good performance receiver, one that provides high sensitivity, good signal to noise and high immunity to other adjacent transmissions. So, you may get your scanner to work, but it will not provide the results you see in our color brochures. Our PROscan receiver has been specially designed to provide optimum performance.

WEFAX Geostationary

WEFAX satellites give anything up to 400 images a day and can provide relayed images of the other side of the world. The resolution varies between 2.5 and 10km. There are 3 sensors, visible, infrared and upper atmosphere water vapour. The main frequency is 1691MHz and we provide a special receiver for this purpose. This signal from a 90cm (3 foot) dish and is amplified by a low noise preamplifier mounted directly on the dish, the 1691MHz signal is run down special high quality cable into our WEFAX receiver. The input to the receiver is 1691MHz and the output is an audio signal that you can hear. There are people who convert the 1691MHz signal down to 137MHz to use their existing APT receiver, the philosophy is fraught with problems and customers who have tried this and then upgraded to ourWEFAX receiver have reported a huge increase in image quality and resolution. Our WEFAX receiver has been designed to provide optimum performance.

HRPT

HRPT satellites give 1.1km resolution in 5 spectral bands. Two are visible, and 3 infrared. There are about 12 good images a day and this system will provide the very highest resolution possible from weather satellites. Because there are 5 +sensors they can be mixed together to provide stunning colour images showing an incredible amount of detail. Remember that APT gives a pixel size of 4km and therefore an area of 16 square km per pixel. HRPT gives a pixel size of 1.1km and therefore an area of 1.21 square km per pixel, an amazing increase of 13 times resolution. But there is more, remember that there are 5 bands and that this is also a digital system that gives 10 bit data, 1024 Grey or color levels per band, giving a total of 50 bit data. The system is, though, both complex and expensive and is very definitely not for the beginner. A 90cm (3 foot) dish has to be tracked across the sky as the satellite orbits. This is all taken care of automatically and works really well in practice. There are only a few HRPT system manufacturers in the world, no commercially available receiver is capable of receiving HRPT and so, unless you are good at receiver design and home construction, you need to purchase a complete system from us.

PDUS

PDUS is available from Meteosat and gives images of Europe in 2.5km resolution every 30 minutes. A 1.8m (6 foot) dish is required and it is fixed in one direction. The rest of the world is transmitted frequently in varying resolutions. The 2.5km resolution gives considerable detail to clouds and the image is not cut up at all like WEFAX. You will never find that you are on a join, like Greece is! We find the main use of PDUS is to provide a continuous animating sequence of all of the Atlantic Ocean right through to the Middle East, real time, dynamic pan and zoom together with good colour provides a huge increase in forecasting accuracy. The data is a digital stream on 1694.5 MHz and there are less than a handful of manufacturers, so you need to buy a complete system from us.

Appendix 2

NOAA Geostationary and polar

Orbiting weather satellites

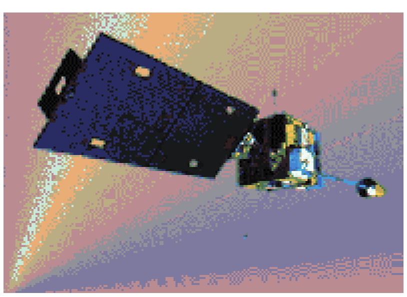
NOAA's Geostationary and Polar-Orbiting Weather Satellites

Operating the country's system of environmental (weather) satellites is one of the major responsibilities of the National Oceanic and Atmospheric Administration's (NOAA's) National Environmental Satellite, Data, and Information Service (NESDIS). NESDIS operates the satellites and manages the processing and distribution of the millions of bits of data and images theses satellites produce daily. The primary customer is NOAA's National Weather Service, which uses satellite data to create forecasts for the public, television, radio, and weather advisory services. Satellite information is also shared with various Federal agencies, such as the Departments of Agriculture, Interior, Defence, and Transportation; with other countries, such as Japan, India, and Russia, and members of the European Space Agency (ESA) and the United Kingdom Meteorological Office; and with the private sector.

NOAA's operational weather satellite system is composed of two types of satellites: geostationary operational environmental satellites (GOES) for short-range warning and "now-casting" and polar-orbiting satellites for longer-term forecasting. Both types of satellite are necessary for providing a complete global weather monitoring system.

The National Aeronautics and Space Administration (NASA) have developed a new series of GOES and polar-orbiting satellites for NOAA. The new GOES-I through M series provides higher spatial and temporal resolution images and full-time operational soundings (vertical temperature and moisture profiles of the atmosphere). The newest polar-orbiting meteorological satellites (that began with NOAA-K in 1998) provide improved atmospheric temperature and moisture data in all weather situations. This new technology will help provide the National Weather Service the most advanced weather forecast system in the world.

Geostationary Operational Environmental Satellites (GOES)



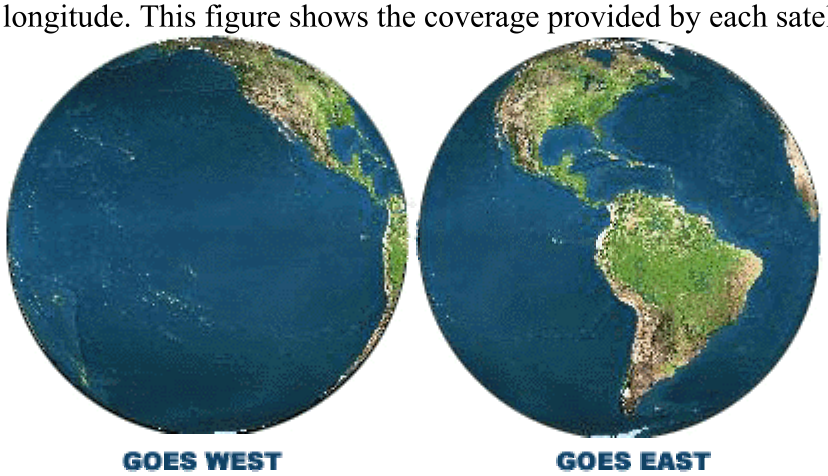
GOES satellites provide the kind of continuous monitoring necessary for intensive data analysis. They circle the Earth in a geosynchronous orbit, which means they orbit the equatorial plane of the Earth at a speed matching the Earth's rotation. This allows them to hover continuously over one position on the surface. The geosynchronous plane is about 35,800 km (22,300 miles) above the Earth, high enough to allow the satellites a full-disc view of the Earth. Because they stay above a fixed spot on the surface, they provide a constant vigil for the atmospheric "triggers" for severe weather conditions such as tornadoes, flash floods, hailstorms, and hurricanes. When these conditions develop the GOES satellites are able to monitor storm development and track their movements.

GOES satellite imagery is also used to estimate rainfall during the thunderstorms and hurricanes for flash flood warnings, as well as estimates snowfall accumulations and overall extent of snow cover. Such data help meteorologists issue winter storm warnings and spring snowmelt advisories. Satellite sensors also detect ice fields and map the movements of sea and lake ice.

NASA launched the first GOES for NOAA in 1975 and followed it with another in 1977. Currently, the United States is operating GOES-8 and GOES-10. (GOES-9, which malfunctioned in 1998, is being stored in orbit as an emergency backup should either GOES-8 or GOES-10 fail.) GOES-11 was launched on May 3, 2000 and is being stored in orbit as a fully functioning replacement for GOES-8 or GOES-10 on failure.

GOES-8 and GOES-10

The United States normally operates two meteorological satellites in geostationary orbit over the equator. Each satellite views almost a third of the Earth's surface: one monitors North and South America and most of the Atlantic Ocean, the other North America and the Pacific Ocean basin. GOES-8 (or GOES-East) is positioned at 75 W longitudes and the equator, while GOES-10 (or GOES-West) is positioned at 135 W longitudes and the equator. The two operate together to produce a full-face picture of the Earth, day and night. Coverage extends approximately from 20 W longitudes to 165 E longitude. This figure shows the coverage provided by each satellite.



The primary instruments, the imager and the.sounder carry out the main mission. The imager is a multi channel instrument that senses radiant energy and reflected solar energy from the Earth's surface and atmosphere. The Sounder provides data to determine the vertical temperature and moisture profile of the atmosphere, surface and cloud top temperatures, and ozone distribution.

Other instruments on board the spacecraft are a Search and Rescue transponder, a data collection and relay system for ground-based data platforms, and a space environment monitor. The latter consists of a magnetometer, an X-ray sensor, a high energy proton and alpha detector, and an energetic particles sensor. All are used for monitoring the near-Earth space environment or solar "weather."

GOES-10 Characteristics	
Main body:	2.0m (6.6 ft) by 2.1m (6.9 ft) by 2.3m (7.5 ft)
Solar array:	4.8m (15.8 ft) by 2.7m (8.9 feet)
Weight at liftoff:	2105 kg (4641 pounds)
Launch vehicle:	Atlas I
Launch date:	April 25, 1997 Cape Canaveral Air Station, FL
Orbital information:	Type: Geosynchronous Altitude: 35, 786 km (22, 236 statute miles) Period: 1,436 minutes Inclination: 0.41 degrees
Sensors:	Imager Sounder Space Environment Monitor (SEM) Data Collection System (DCS) Search and Rescue (SAR) Transponder

The United States reaps many benefits from the new series of GOES satellites as they aid forecasters in providing better-advanced warnings of thunderstorms, flash floods, hurricanes, and other severe weather. The GOES-I series provide meteorologists and hydrologists with detailed weather measurements, more frequent imagery, and new types of atmospheric soundings. The data gathered by the GOES satellites, combined with that from new Doppler radars and sophisticated communications systems make for improved forecasts and weather warnings that save lives, protect property, and benefit agricultural and a variety of commercial interests.

For users who establish their own direct readout receiving station, the GOES satellites transmit low-resolution imagery in the WEFAX service. WEFAX can be received with an inexpensive receiver. Highest resolution Imager and Sounder data is found in the GVAR primary data user service, which requires more complex receiving equipment. More information about establishing receiving stations can be obtained from the Email contact at the bottom of the page.

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Polar-Orbiting Satellites

Complementing the geostationary satellites are two polar-orbiting satellites known as Advanced Television Infrared Observation Satellite (TIROS-N or ATN), constantly circling the Earth in an almost north-south orbit, passing close to both poles. The orbits are circular, with an altitude between 830 (morning orbit) and 870 (afternoon orbit) km, and are sun synchronous. One satellite crosses the equator at 7:30 a.m. local time, the other at 1:40 p.m. local time. The circular orbit permits uniform data acquisition by the satellite and efficient control of the satellite by the NOAA Command and Data Acquisition (CDA) stations located near Fairbanks, Alaska and Wallops Island, Virginia. Operating as pair, these satellites ensure that data for any region of the Earth are no more than six hours old.

A suite of instruments is able to measure many parameters of the Earth's atmosphere, its surface, cloud cover, incoming solar protons, positive ions, electron-flux density, and the energy spectrum at the satellite altitude. As a part of the mission, the satellites can receive, process and retransmit data from Search and Rescue beacon transmitters, and automatic data collection platforms on land, ocean buoys, or aboard free-floating balloons. The primary instrument aboard the satellite is the Advanced Very High Resolution Radiometer or AVHRR.

Data from all the satellite sensors is transmitted to the ground via a broadcast called the High Resolution Picture Transmission (HRPT). A second data transmission consists of only image data from two of the AVHRR channels, called Automatic Picture Transmission (APT). For users who want to establish their own direct readout receiving station, low-resolution imagery data in the APT service can be received with inexpensive equipment, while the highest resolution data transmitted in the HRPT service utilizes a more complex receiver.

Additional information about establishing receiving station can be obtained from the Email contact below.

NOAA-15 Characteristics	
Main body:	4.2m (13.75 ft) long, 1.88m (6.2 ft) diameter
Solar array:	2.73m (8.96 ft) by 6.14m (20.16 ft)
Weight at liftoff:	2231.7 kg (4920 pounds) including 756.7 kg of expendable fuel
Launch vehicle:	Lockheed Martin Titan II
Launch date:	May 13, 1998 Vandenburg Air Force Base, CA
Orbital information:	Type: sun synchronous Altitude: 833 km Period: 101.2 minutes Inclination: 98.70 degrees
Sensors:	Advanced Very High Resolution Radiometer (AVHRR/3) Advanced Microwave Sounding Unit-A (AMSU-A) Advanced Microwave Sounding Unit-B (AMSU-B) High Resolution Infrared Radiation Sounder (HIRS/3) Space Environment Monitor (SEM/2) Search and Rescue (SAR) Repeater and Processor Data Collection System (DCS/2)

The polar orbiters are able to monitor the entire Earth, tracking atmospheric variables and providing atmospheric data and cloud images. They track weather conditions that eventually affect the weather and climate of the United States. The satellites provide visible and infrared radiometer data that are used for imaging purposes, radiation measurements, and temperature profiles. The polar orbiters' ultraviolet sensors also provide ozone levels in the atmosphere and are able to detect the "ozone hole" over Antarctica during mid-September to mid-November. These satellites send more than 16,000 global measurements daily via NOAA's CDA station to NOAA computers, adding valuable information for forecasting models, especially for remote ocean areas, where conventional data are lacking.

Currently, NOAA is operating three polar orbiters: NOAA-14 launched in December 1994 and a new series of polar orbiters, with improved sensors, which began with the launch of NOAA-15 in May 1998 and NOAA-16 on September 21, 2000. NOAA-12 continues transmitting HRPT data as a stand-by satellite.

How Satellites Are Named

NOAA assigns a letter to the satellite before it is launched, and a number once it has achieved orbit. For example, GOES-H, once in orbit, was designated GOES-7, GOES-G, which was lost at launch, was never assigned a number. The same system is used for polar orbiters; for example, NOAA-11, still in orbit, was designated NOAA-H before launch. NOAA-J became NOAA-14.

Advanced Very High Resolution Radiometer – AVHRR

The AVHRR is a radiation-detection imager that can be used for remotely determining cloud cover and the surface temperature. Note that the term *surface* can mean the surface of the Earth, the upper surfaces of clouds, or the surface of a body of water. This scanning radiometer uses 6 detectors that collect different bands of radiation wavelengths as shown below.
The first AVHRR was a 4-channel radiometer, first carried on TIROS-N (launched October 1978). This was subsequently improved to a 5-channel instrument (AVHRR/2) that was initially carried on NOAA-7 (launched June 1981). The latest instrument version is AVHRR/3, with 6 channels, first carried on NOAA-15 launched in May 1998.

AVHRR/3 Channel Characteristics			
Channel Number	Resolution at Nadir	Wavelength (um)	Typical Use
1	1.09 km	0.58 - 0.68	Daytime cloud and surface mapping
2	1.09 km	0.725 - 1.00	Land-water boundaries
3A	1.09 km	1.58 - 1.64	Snow and ice detection
3B	1.09 km	3.55 - 3.93	Night cloud mapping, sea surface temperature
4	1.09 km	10.30 - 11.30	Night cloud mapping, sea surface temperature
5	1.09 km	11.50 - 12.50	Sea surface temperature

Measuring the same view, this array of diverse wavelengths, after processing, permits multi spectral analysis for more precisely defining hydrologic, oceanographic, and meteorological parameters. Comparison of data from two channels is often used to observe features or measure various environmental parameters. The three channels operating entirely within the infrared band are used to detect the heat radiation from and hence, the temperature of land, water, sea surfaces, and the clouds above them.

Satellite Status Information

NOAA Operational Satellites

Satellite	Transmission Frequencies	
NOAA-16	APT – Off	HRPT - 1698.0 MHz
NOAA-15	APT – 137.50 MHz	HRPT - 1702.5 MHz
NOAA-14	APT – 137.62 MHz	HRPT - 1707.0 MHz
NOAA-12	APT – 137.50 MHz	HRPT - 1698.0 MHz
NOAA-11	APT - not operating	HRPT - 1707.0 MHz (TIP)
NOAA-10	APT - not operating	HRPT - not operating
GOES-8	WEFAX - 1691.0 MHz	GVAR PDUS - 1685.7 MHz
GOES-10	WEFAX - 1691.0 MHz	GVAR PDUS - 1685.7 MHz

NOTES:

(1) Effective 9 October 2001, the HRPT frequency was changed to 1707.0 MHz to prevent interference with the NOAA-16 HRPT operating on 1698 MHz. On 18 October 2001, at approximately 1955 UTC, the **NOAA-14 AVHRR** experienced a serious problem with the AVHRR scanning motor. All AVHRR data in the HRPT and APT transmissions are severely degraded and unusable most of the time. Further information will be posted to the Bulletins page on this web site.

(2) **NOAA-16** was declared the operational afternoon satellite 20 March 2001, replacing NOAA-14. Since becoming operational, there was a clock error of +1 second leading to pointing errors of AVHRR data of up to 12 km. (This was corrected in the NOAA 1b data by inserting a corresponding offset time of plus 1 second in addition to the clock correction appearing in the TBUS bulletin.) Due to a configuration error in ground equipment the TIP clock errors reported for NOAA-16, since becoming operational, were determined to be inaccurate by –900 milliseconds, i.e. actual clock errors were 900 milliseconds greater than the values being reported. The NOAA-16 TIP clock was reading +100 milliseconds. The actual errors for NOAA-16 were +1000 milliseconds. To correct this error, on 7 August 2001, 1.0 seconds were subtracted from the NOAA-16 spacecraft clock at 23:59:00 UTC. This change is reflected in the TBUS bulletins after 7 August.

HIRS pixels/FOVs are offset by one FOV in the transmitted data. FOV 1 is in position 2, FOV 2 is in position 3, etc.

The APT transmission system has failed. The HRPT 1707 MHz transmitter had a significant loss of power on 28 September 2001. Effective on 9 October 2001, the HRPT transmitter was changed to the 1698 MHz frequency at full power.

(3) On 10 July 2000, there was an apparent failure of the **NOAA-15 AVHRR** scan motor. HRPT and APT image data was missing through July 12, orbit 11250. On this orbit, AVHRR synchronization was restarted and HRPT and APT image data temporarily resumed. AVHRR synchronization was again lost 22 July on orbit 11395. Tests during December and January 2001 indicated that lowering the temperature of the instrument restored a degree of stability. Beginning 20 March 2001.

NOAA began to resynchronise the AVHRR once daily at 0730 UTC. The AVHRR has shown the ability to retain synchronization for longer periods with this daily reset. During the time of the resynchronization, there is a very brief disruption on all data in the HRPT transmission. When the AVHRR is in synchronization, usable images may be obtained. When the AVHRR synchronization is out of limits, images are unusable. HRPT transmitter will remain ON; the APT transmitter turned ON at 1611 UTC, 15 March 2001. At 1820 UTC, on 30 October 2000, the **NOAA-15 AMSU-A** Channel 14 failed and is no longer usable.
(4) Since the launch of **NOAA-15**, the three high-gain antennas connected to three of the four NOAA-15 transmitters (STX), specifically STX-1, STX-2 and STX-3, experienced increasing performance degradation, including radio frequency interference is being received by the AMSUB instrument. The STX-1 high-gain HRPT antenna (1698.0 MHz) degraded to a level where small dish (1 m) users experienced a significant number of HRPT dropouts, in many cases rendering the data unusable.

At 0100 UTC on 28 September 1999, NESDIS permanently moved the HRPT service from STX-1 to the STX-2 OMNI antenna (1702.5 MHz). This transmitter/antenna combination was tested with small dish receiving stations, and found to provide satisfactory reception under most conditions. (The EIRP for the STX-2 OMNI is equal to or greater than 24 dBm over 90% of a sphere). The STX-2 transmissions are Right Hand Circularly polarized and compatible with existing HRPT antenna systems. APT transmissions are not affected.
Due to a configuration error in ground equipment, the TIP clock errors reported for NOAA-15 since becoming operational, were determined to be inaccurate by –900 milliseconds, i.e. actual clock errors were 900 milliseconds greater than the values being reported. The NOAA-15 TIP clock was reading –100 milliseconds. The actual error for NOAA-15 was +800 milliseconds. To correct this error, on 7 August 2001, 1.0 seconds were subtracted from the NOAA-15 spacecraft clock at 23:59:00 UTC. This change is reflected in the TBUS bulletins after 7 August.
(5) **NOAA-14** SBUV instrument data is unreliable and not being retrieved because of orbital drift.
(6) The **NOAA-12 MSU** scan motor was turned off 5 April at approximately 0222 UTC and remains off. This action was taken due to numerous limit violations, including scan motor temperature, space counts and blackbody counts. It is believed that the scanner was stuck prior to turn-off.

(7) The **NOAA-11** HRPT transmission consists of TIP data only, in the Beacon transmission TIP format. The data rate is 8.32 kbps and not compatible with HRPT format. On 26 February 1999, the **MSU** instrument failed. No further useful data from MSU can be expected. Stored TIP is being retrieved for SBUV instrument data. The NOAA-11 **HIRS** instrument was turned off permanently at 1534 UTC on 26 April 2000 due to a failure of the filter wheel; no further data will be available. The AVHRR has failed.

(8) **NOAA-10** Satellite was permanently deactivated at 0952 UTC, 30 August 2001. The HRPT frequency had been transmitting low rate instrument data (TIP) only and the SARR was being used for for global search and rescue. NOAA-10 was launched in September 1986.

The Seven (or Eight) Keplerian Elements

Seven numbers are required to define a satellite orbit. This set of seven numbers is called the satellite orbital elements, or sometimes "Keplerian" elements (after Johann Kepler [1571-1630]), or just elements. These numbers define an ellipse, orient it about the earth, and place the satellite on the ellipse at a particular time. In the Keplerian model, satellites orbit in an ellipse of constant shape and orientation. The Earth is at one focus of the ellipse, not the center (unless the orbit ellipse is actually a perfect circle).
The real world is slightly more complex than the Keplerian model, and tracking programs compensate for this by introducing minor corrections to the Keplerian model. These corrections are known as perturbations. The perturbations that amateur tracking programs know about are due to the lumpiness of the earth's gravitational field (which luckily you don't have to specify), and the "drag" on the satellite due to atmosphere. Drag becomes an optional eighth orbital element.
Orbital elements remain a mystery to most people. This is due I think first to the aversion many people (including me) have to thinking in three dimensions, and second to the horrible names the ancient astronomers gave these seven simple numbers and a few related concepts. To make matters worse, sometimes several different names are used to specify the same number. Vocabulary is the hardest part of celestial mechanics!
The basic orbital elements are...

1. Epoch
2. Orbital Inclination
3. Right Ascension of Ascending Node (R.A.A.N.)
4. Argument of Perigee
5. Eccentricity
6. Mean Motion
7. Mean Anomaly
8. Drag (optional)

The following definitions are intended to be easy to understand. More rigorous definitions can be found in almost any book on the subject. I've used aka as an abbreviation for "also known as" in the following text.

Epoch

[aka "Epoch Time" or "T0"]
A set of orbital elements is a snapshot, at a particular time, of the orbit of a satellite. Epoch is simply a number, which specifies the time at which the snapshot was taken.

Orbital Inclination

[aka "Inclination" or "I0"]
The orbit ellipse lies in a plane known as the orbital plane. The orbital plane always goes through the center of the earth, but may be tilted any angle relative to the equator. Inclination is the angle between the orbital plane and the equatorial plane. By convention, inclination is a number between 0 and 180 degrees.
Some vocabulary: Orbits with inclination near 0 degrees are called equatorial orbits (because the satellite stays nearly over the equator). Orbits with inclination near 90 degrees are called polar (because the satellite crosses over the north and south poles). The intersection of the equatorial plane and the orbital plane is a line, which is called the line of nodes.

Right Ascension of Ascending Node

[aka "RAAN" or "RA of Node" or "O0", and occasionally called "Longitude of Ascending Node"]
RAAN wins the prize for most horribly named orbital element. Two numbers orient the orbital plane in space. The first number was Inclination. This is the second. After we've specified inclination, there are still an infinite number of orbital planes possible. The line of nodes can poke out the anywhere along the equator. If we specify where along the equator the line of nodes pokes out, we will have the orbital plane fully specified. The line of nodes pokes out two places, of course. We only need to specify one of them. One is called the ascending node (where the satellite crosses the equator going from south to north). The other is called the descending node (where the satellite crosses the equator going from north to south). By convention, we specify the location of the ascending node. Now, the earth is spinning. This means that we can't use the common latitude/longitude coordinate system to specify where the line of nodes points. Instead, we use an astronomical coordinate system, known as the right ascension / declination coordinate system, which does not spin with the earth. Right ascension is another fancy word for an angle, in this case, an angle measured in the equatorial plane from a reference point in the sky where right ascension is defined to be zero. Astronomers call this point the vernal equinox.

Finally, "right ascension of ascending node" is an angle, measured at the center of the earth, from the vernal equinox to the ascending node.
I know this is getting complicated. Here's an example. Draw a line from the center of the earth to the point where our satellite crosses the equator (going from south to north). If this line points directly at the vernal equinox, then RAAN = 0 degrees.
By convention, RAAN is a number in the range 0 to 360 degrees.
I used the term "vernal equinox" above without really defining it. If you can tolerate a minor digression, I'll do that now. Teachers have told children for years that the vernal equinox is "the place in the sky where the sun rises on the first day of spring". This is a horrible definition. Most teachers, and students, have no idea what the first day of spring is (except a date on a calendar), and no idea why the sun should be in the same place in the sky on that date every year.
You now have enough astronomy vocabulary to get a better definition. Consider the orbit of the sun around the earth. I know in school they told you the earth orbits around the sun, but the math is equally valid either way, and it suits our needs at this instant to think of the sun orbiting the earth. The orbit of the sun has an inclination of about 23.5 degrees. (Astronomers don't usually call this 23.5 degree angle an 'inclination', by the way. They use an infinitely more obscure name: The Obliquity of The Ecliptic.) The orbit of the sun is divided (by humans) into four equally sized portions called seasons. The one called Spring begins when the sun pops up past the equator. In other words, the first day of Spring is the day that the sun crosses through the equatorial plane going from South to North. We have a name for that! It's the ascending node of the Sun's orbit. So finally, the vernal equinox is nothing more than the ascending node of the Sun's orbit. The Sun's orbit has RAAN = 0 simply because we've defined the Sun's ascending node as the place from which all ascending nodes are measured. The RAAN of your satellite's orbit is just the angle (measured at the center of the earth) between the place the Sun's orbit pops up past the equator, and the place your satellite's orbit pops up past the equator.

Argument of Perigee

[aka "ARGP" or "W0"]
Argument is yet another fancy word for angle. Now that we've oriented the orbital plane in space, we need to orient the orbit ellipse in the orbital plane. We do this by specifying a single angle known as argument of perigee.
A few words about elliptical orbits... The point where the satellite is closest to the earth is called perigee, although it's sometimes called periapsis or perifocus. We'll call it perigee. The point where the satellite is farthest from earth is called apogee (aka apoapsis, or apifocus). If we draw a line from perigee to apogee, this line is called the line-of-apsides. (Apsides is, of course, the plural of apsis.) I know, this is getting complicated again. Sometimes the line-of-apsides is called the major axis of the ellipse. It's just a line drawn through the ellipse the "long way".
The line-of-apsides passes through the center of the earth. We've already identified another line passing through the center of the earth: the line of nodes. The angle between these two lines is called the argument of perigee. Where any two lines intersect, they form two supplementary angles, so to be specific, we say that argument of perigee is the angle (measured at the center of the earth) from the ascending node to perigee.

Example: When ARGP = 0, the perigee occurs at the same place as the ascending node. That means that the satellite would be closest to earth just as it rises up over the equator. When ARGP = 180 degrees, apogee would occur at the same place as the ascending node. That means that the satellite would be farthest from earth just as it rises up over the equator.
By convention, ARGP is an angle between 0 and 360 degrees.

Eccentricity

[aka "ecce" or "E0" or "e"]
This one is simple. In the Keplerian orbit model, the satellite orbit is an ellipse. Eccentricity tells us the "shape" of the ellipse. When e=0, the ellipse is a circle. When e is very near 1, the ellipse is very long and skinny.
(To be precise, the Keplerian orbit is a conic section, which can be either an ellipse, which includes circles, a parabola, a hyperbola, or a straight line! But here, we are only interested in elliptical orbits. The other kinds of orbits are not used for satellites, at least not on purpose, and tracking programs typically aren't programmed to handle them.) For our purposes, eccentricity must be in the range $0 <= e < 1$.

Mean Motion

[aka "N0"] (related to "orbit period" and "semimajor-axis")
So far we've nailed down the orientation of the orbital plane, the orientation of the orbit ellipse in the orbital plane, and the shape of the orbit ellipse. Now we need to know the "size" of the orbit ellipse. In other words, how far away is the satellite?
Kepler's third law of orbital motion gives us a precise relationship between the speed of the satellite and its distance from the earth. Satellites that are close to the earth orbit very quickly. Satellites far away orbit slowly. This means that we could accomplish the same thing by specifying either the speed at which the satellite is moving, or its distance from the earth!
Satellites in circular orbits travel at a constant speed. Simple. We just specify that speed, and we're done. Satellites in non-circular (i.e., eccentricity > 0) orbits move faster when they are closer to the earth, and slower when they are farther away. The common practice is to average the speed. You could call this number "average speed", but astronomers call it the "Mean Motion". Mean Motion is usually given in units of revolutions per day.
In this context, a revolution or period is defined as the time from one perigee to the next.
Sometimes "orbit period" is specified as an orbital element instead of Mean Motion. Period is simply the reciprocal of Mean Motion. A satellite with a Mean Motion of 2 revs per day, for example, has a period of 12 hours.
Sometimes semi-major-axis (SMA) is specified instead of Mean Motion. SMA is one-half the length (measured the long way) of the orbit ellipse, and is directly related to mean motion by a simple equation.
Typically, satellites have Mean Motions in the range of 1 rev/day to about 16 rev/day.

Mean Anomaly

[aka "M0" or "MA" or "Phase"]
Now that we have the size, shape, and orientation of the orbit firmly established, the only thing left to do is specify where exactly the satellite is on this orbit ellipse at some particular time. Our very first orbital element (Epoch) specified a particular time, so all we need to do now is specify where, on the ellipse, our satellite was exactly at the Epoch time.
Anomaly is yet another astronomer-word for angle. Mean anomaly is simply an angle that marches uniformly in time from 0 to 360 degrees during one revolution. It is defined to be 0 degrees at perigee, and therefore is 180 degrees at apogee.
If you had a satellite in a circular orbit (therefore moving at constant speed) and you stood in the center of the earth and measured this angle from perigee, you would point directly at the satellite. Satellites in non-circular orbits move at a non-constant speed, so this simple relation doesn't hold. This relation does hold for two important points on the orbit, however, no matter what the eccentricity. Perigee always occurs at MA = 0, and apogee always occurs at MA = 180 degrees.
It has become common practice with radio amateur satellites to use Mean Anomaly to schedule satellite operations. Satellites commonly change modes or turn on or off at specific places in their orbits, specified by Mean Anomaly. Unfortunately, when used this way, it is common to specify MA in units of 256ths of a circle instead of degrees! Some tracking programs use the term "phase" when they display MA in these units. It is still specified in degrees, between 0 and 360, when entered as an orbital element.
Example: Suppose Oscar-99 has a period of 12 hours, and is turned off from Phase 240 to 16. That means it's off for 32 ticks of phase. There are 256 of these ticks in the entire 12 hour orbit, so it's off for (32/256)x12hrs = 1.5 hours. Note that the off time is centered on perigee. Satellites in highly eccentric orbits are often turned off near perigee when they're moving the fastest, and therefore difficult to use.

Drag

[aka "N1"]
Drag caused by the earth's atmosphere causes satellites to spiral downward. As they spiral downward, they speed up. The Drag orbital element simply tells us the rate at which Mean Motion is changing due to drag or other related effects. Precisely, Drag is one half the first time derivative of Mean Motion.
Its units are revolutions per day per day. It is typically a very small number. Common values for low-earth-orbiting satellites are on the order of 10^-4. Common values for high-orbiting satellites are on the order of 10^-7 or smaller.
Occasionally, published orbital elements for a high-orbiting satellite will show a negative Drag! At first, this may seem absurd. Drag due to friction with the earth's atmosphere can only make a satellite spiral downward, never upward.
There are several potential reasons for negative drag. First, the measurement, which produced the orbital elements, may have been in error.

It is common to estimate orbital elements from a small number of observations made over a short period of time. With such measurements, it is extremely difficult to estimate Drag. Very ordinary small errors in measurement can produce a small negative drag.
The second potential cause for a negative drag in published elements is a little more complex. A satellite is subject to many forces besides the two we have discussed so far (earth's gravity, and atmospheric drag). Some of these forces (for example gravity of the sun and moon) may act together to cause a satellite to be pulled upward by a very slight amount. This can happen if the Sun and Moon are aligned with the satellite's orbit in a particular way. If the orbit is measured when this is happening, a small negative Drag term may actually provide the best possible 'fit' to the actual satellite motion over a *short* period of time.
You typically want a set of orbital elements to estimate the position of a satellite reasonably well for as long as possible, often several months. Negative Drag never accurately reflects what's happening over a long period of time. Some programs will accept negative values for Drag, but I don't approve of them. Feel free to substitute zero in place of any published negative Drag value.

Other Satellite Parameters

All the satellite parameters described below are optional. They allow tracking programs to provide more information that may be useful or fun.

Epoch Rev

[aka "Revolution Number at Epoch"]
This tells the tracking program how many times the satellite has orbited from the time it was launched until the time specified by "Epoch". Epoch Rev is used to calculate the revolution number displayed by the tracking program. Don't be surprised if you find that orbital element sets which come from NASA have incorrect values for Epoch Rev. The folks who compute satellite orbits don't tend to pay a great deal of attention to this number! At the time of this writing [1989], elements from NASA have an incorrect Epoch Rev for Oscar-10 and Oscar-13. Unless you use the revolution number for your own bookeeping purposes, you needn't worry about the accuracy of Epoch Rev.

Attitude

[aka "Bahn Coordinates"]
The spacecraft attitude is a measure of how the satellite is oriented in space. Hopefully, it is oriented so that its antennas point toward you! There are several orientation schemes used in satellites. The Bahn coordinates apply only to spacecraft which are spin-stablized. Spin-stabilized satellites maintain a constant inertial orientation, i.e., its antennas point a fixed direction in space (examples: Oscar-10, Oscar-13).
The Bahn coordinates consist of two angles, often called Bahn Latitude and Bahn Longitude. These are published from time to time for the elliptical-orbit amateur radio satellites in various amateur satellite publications. Ideally, these numbers remain constant

except when the spacecraft controllers are re-orienting the spacecraft. In practice, they drift slowly. For highly elliptical orbits (Oscar-10, Oscar-13, etc.) these numbers are usually in the vicinity of: 0,180. This means that the antennas point directly toward earth when the satellite is at apogee. These two numbers describe a direction in a spherical coordinate system, just as geographic latitude and longitude describe a direction from the centre of the earth. In this case, however, the primary axis is along the vector from the satellite to the centre of the earth when the satellite is at perigee.
An excellent description of Bahn coordinates can be found in Phil Karn's "Bahn Coordinates Guide".

NASA 2-Line Format

This is the format used by NASA to distribute satellite elements in their *NASA Prediction Bulletin*. The origin of the format is unknown. Some old NORAD reports refer to this as T-card format.
As used in the amateur community, the format consists of groups of 3 lines: One line containing the satellite's name, followed by the standard Two-Line Orbital Element Set Format identical to that used by NASA and NORAD. Tracking programs are generally unforgiving of anything that doesn't fit this format.
NASA format files look like this...

```
OSCAR 10
1 14129U         88230.56274695 0.00000042          10000-3 0  3478
2 14129  27.2218 308.9614 6028281 329.3891   6.4794  2.05877164 10960
GPS-0008
1 14189U         88230.24001475 0.00000013                 0  5423
2 14189  63.0801 108.8864 0128028 212.9347 146.3600  2.00555575 37348
```

Each number is in a specified fixed column. Spaces are significant. The last digit on each line is a mod-10 check digit, which is checked by the program. The program also checks the sequence numbers (first column), and checks each orbital element for reasonable range. This is a very good set of checks, so this format is very safe, and robust.
There seems to be some disagreement about how the "+" character is figured into the check digit. If you have trouble with checksum failures on element sets with "+" signs in them, try replacing all the "+" signs with spaces.
Data for each satellite consists of three lines in the following format:

```
AAAAAAAAAAA
1 NNNNNU NNNNNAAA NNNNN.NNNNNNNN +.NNNNNNNN +NNNNN-N +NNNNN-N N
NNNNN
2 NNNNN NNN.NNNN NNN.NNNN NNNNNNN NNN.NNNN NNN.NNNN
NN.NNNNNNNNNNNNNN
```

Line 1

Line 1 is a eleven-character name.
Actually, there is some disagreement about how wide the name may be. Some programs allow 12 characters. Others allow 24 characters, which is consistent with some NORAD documents.
Some sources encode additional information on this line, but this is not part of the standard format. One scheme for encoding visual magnitude information is described in Ted Molczan's .

There is no checksum on this line.

Line 2

Column	Description
01-01	Line Number of Element Data
03-07	Satellite Number
10-11	International Designator (Last two digits of launch year)
12-14	International Designator (Launch number of the year)
15-17	International Designator (Piece of launch)
19-20	Epoch Year (Last two digits of year)
21-32	Epoch (Day number and fractional portion of the day)
34-43	First Time Derivative of the Mean Motion divided by 2. or Ballistic Coefficient (Depending of ephemeris type)
45-52	Second Time Derivative of Mean Motion divided by 6. (Blank if N/A)
54-61	BSTAR drag term if GP4 general perturbation theory was used. Otherwise, radiation pressure coefficient.
63-63	Ephemeris type
65-68	Element number
69-69	Check Sum (Modulo 10)

The checksum is computed as follows:

1. Start with zero.
2. For each digit in the line, add the value of the digit.
3. For each minus sign, add 1.
4. For each plus sign, add 2 (or maybe 0, depending on who created the element set and when)
5. For each letter, blank, or period, don't add anything.
6. Take the last decimal digit of the result (that is, take the result modulo 10) as the check digit.

All other columns are blank or fixed.
Note that the International Designator fields are usually blank, as issued in the NASA Prediction Bulletins.

Line 3

Column	Description
01-01	Line Number of Element Data
03-07	Satellite Number
09-16	Inclination [Degrees]
18-25	Right Ascension of the Ascending Node [Degrees]
27-33	Eccentricity (decimal point assumed)
35-42	Argument of Perigee [Degrees]
44-51	Mean Anomaly [Degrees]
53-63	Mean Motion [Revs per day]
64-68	Revolution number at epoch [Revs]
69-69	Check Sum (Modulo 10)

The same checksum algorithm is used.
All other columns are blank or fixed.

AMSAT Format

There are several very similar formats generated by several different people that seem to be called "AMSAT" format. Tracking programs generally try to read all of them. This format is very user-friendly, and can be easily read and/or edited by humans. Spaces are not significant. Each orbital element must appear on a separate line. The order in which orbital elements appear is not significant, except that each element set should begin with a line containing the word "satellite". A blank line is usually interpreted as ending the element set.

This file format does not contain any check digits, but an overall checksum is sometimes used.

AMSAT format elements as distributed by AMSAT look like this:

```
Satellite: AO-13
Catalog number: 19216
Epoch time:      94311.77313192
Element set:     994
Inclination:       57.6728 deg
RA of node:       221.5174 deg
Eccentricity:    0.7242728
Arg of perigee:   354.2960 deg
Mean anomaly:       0.7033 deg
Mean motion:    2.09727084 rev/day
Decay rate:     -5.78e-06 rev/day^2
Epoch rev:           4902
Checksum:             312
```

The checksum is the same computation as for the NASA 2-line format, except that the whole sum is used instead of just the last digit. Every character on the line is included, so the "2" in "rev/day^2" does count.

One-Line "Charlie" Elements Format

The One Line Element (OLE) format is a somewhat abbreviated set of data used by the Navy at the Naval Research Laboratory (and perhaps others). Some useful information, which is included in the 2-Line Element format, is omitted, such as the Revolution Number at Epoch. Other information, such as the International Designator, can often be obtained from other sources using the satellite number (NORAD catalogue number). The only virtue to this format is its brevity.

```
         1         2         3         4         5         6
123456789012345678901234567890123456789012345678901234567890
nnnnnyydddffffffdddddddiiiiiinnnnnneeeeeeaaaaaammmmmmxxxxxxxx
206399019071772000014705251829684400765901146334880715202450
```

Column Definitions

Columns	Description	Format	Units
1 - 5	NORAD catalog number	NNNNN	
6 - 7	Year	NN	Years
8 - 10	Day number	NNN	Days
11 - 16	Fraction of a day	0.NNNNNN	Days
17 - 22	Drag	0.NNNNNN	rev/day^2
23 - 28	Inclination	NNN.NNN	Degrees
29 - 34	R.A.A.N.	NNN.NNN	Degrees
35 - 40	Eccentricity	0.NNNNNN	Dimensionless
41 - 46	Argument of Perigee	NNN.NNN	Degrees
47 - 52	Mean Anomaly	NNN.NNN	Degrees
53 - 60	Mean Motion	NN.NNNNNN	rev/day

Example

206399019071772000014705251829684400765901146334880715202450
The following values are obtained:
20639 catalog number
90 year
190 day number
0.717720 fraction of a day
0.000147 drag term
52.518 inclination
296.844 ascending node
0.007659 eccentricity
011.463 argument of perigee
348.807 mean anomaly
15.202450 mean motion
The input of elements in this form may be terminated by a line which contains a zero for the catalog number.

Appendix 3

Time-Step system

HRPT Systems

HRPT satellites give 1.1km resolution in 5 spectral bands. Two are visible, and 3 infrared. There are about 12 good images a day and this system will provide the very highest resolution possible from weather satellites. Because there are 5 sensors they can be mixed together to provide stunning colour images showing an incredible amount of detail. Remember that APT gives a pixel size of 4km and therefore an area of 16 square km per pixel. HRPT gives a pixel size of 1.1km and therefore an area of 1.21 square km per pixel, an amazing increase of 13 times resolution. But there is more, remember that there are 5 bands and that this is also a digital system that gives 10 bit data, 1024 grey or colour levels per band, giving a total of 50 bit data. The system is, though, both complex and expensive and is very Definitely not for the beginner. A 90cm (3 foot) dish has to be tracked across the sky as the satellite orbits. This is all taken care of automatically and works really well in practice. There are only a few HRPT system manufacturers in the world, no commercially available receiver is capable of receiving HRPT and so, unless you are good at receiver design and home construction, you need to purchase a complete system from us.

The HRPT dish is 90cm (3 foot) and is fitted to a Yaesu Azimuth-Elevation positioner unit. The helical feed is connected directly to the preamplifier.

Antenna and rotator

Preamplifier

Our 1700MHz preamplifier is regarded by many as the best available and has a noise figure of just 0.45dB or less. It covers 1690-1710MHz with 35dB of gain. This high gain allows the use of 20m of cable thereby placing the sensitive electronics indoors away from the effects of temperature and the weather. The unit is IP67 water resistant class. The voltage range is 8-14 at a current of 80mA and is power fed by the cable automatically from our receiver. N connector input, F type output.

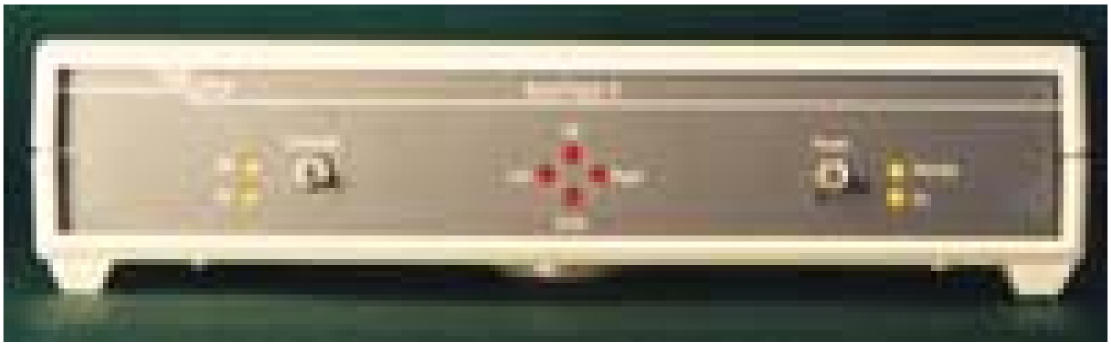
Receiver

The receiver has all known channels fitted and has surprised many by its ability to receive temporary satellites. It has a moving coil signal strength meter to allow easy adjustment. Computer control of the channel selection is available.

HRPT Receiver front panel

Auto Track II

This will automatically point the dish at the satellite as it orbits the earth. Tracking is completely automatic and any errors can be "nudged" out and the error information saved permanently. It is this unit that also changes the receiver channel to automate HRPT reception.



HRPT for Windows software features

HRPT, High Resolution Picture Transmission, the ultimate 5 bands, 1.1km resolution and 10 bit data, nothing even comes close.

1. Windows 95 98 NT multi-tasking, not a DOS application running in Windows
2. Pentium II 450MHz 32-bit software support
3. Automatic scheduling eliminates the need to predict start times
4. Automatic channel switching allows continuous unattended reception of NOAA 12 14 & 15
5. Real time reception and real time contrast stretch and channel selection
6. 6-channel HRPT receiver for "unexpected" satellites
7. All 5 band 10 bit data saved 1.1Km resolution
8. User selectable and predefined contrast curves
9. 30-bit real time Multi Spectral color reception and manipulation
10. Pre-set Multi Spectral band allocations for faster color
11. NOAA 15 band 3a multi-spectral images give greater land detail
12. 256 or 1024 gray scale image manipulation and display
13. Any Windows display resolution supported
14. Color or grayscale printers on any Windows compatible printer
15. Multiple image channels viewable simultaneously
16. Import and Export of industry standard image files
17. SeaWiFS compatible

18. Auto Tracking in real time and minimum elevation set available
19. Both motors driven simultaneously in Auto Track
20. 12-bit Auto Track resolution
21. Nudge operation allows precise dish alignment indoors
22. Element updates available by automatic Internet connection
23. Yaesu, Emotator and "other" Az-El unit compatible
24. Software update service via Internet or post
25. Hardware update service
26. Modular design for flexible operation
27. Only one card to fit in PC
28. Real moving coil S meter independent from computer software
29. Proven design
30. Made to Quality Standard ISO9002 and certified
31. FCC and CE approved
32. NOAA and SeaStar (SeaWiFS) listed

<u>Appendix 4</u>

Assistance I,II,III

ASSISTANCE I

Could be a number of different problems you have.

If you think your receiver and interface are working ok.

First make sure your dish alignment is correct. That is the mounting is true vertical and dish is aligned correctly with respect to south. Also Check the intial rotor/control box setup, is woking as per manual? Make sure your autotrack is correctly calibrated and your satellite keps are up to date. Also make sure your pc clock is exact to with in 2 Seconds of utc. If all this is correct? have you tried the software nudge to try and align manually?

If you have problems with the receiver? I cannot really help, the internal workings of this are beyond my experience. If it's a Time step one? Better Contact them for info.

NOAA frequencies at the moment are.
NOAA16......1698.0 MHz was 1707.0 but tx failure
NOAA15......1702.5 MHz to me not as strong as N16 weak below 20degs
NOAA14......1707.0 MHz synch problems
NOAA12......1698.0 MHz

Recently here at home I have experienced some passes where I have a very strong satellite signal but loose data lock, can last several minutes. Think I have local rf interference but cannot trace it. Happens most at weekends.

Hope some of this helps and you can get some image
Have you also checked all cables and connectors?
In my system Timestep supplied a line amp as well, is there one in your system....if so is it working ok?

When you tracked the Sun, did you try it normal and inverted as well? If you have not, give it a try and see if the shadow is in the centre for both. If it is not then alignment may be your problem.

With everything aligned properly here NOAA 16 normally gives a signal near or into the red zone on the receiver meter, above 30degrees, below this signal varies quite a bit. I have many obstructions such as, houses trees and hills in the way.

If everything is ok for the above I would think there may be a problem with the receiver. Pointing the dish vertically do you get much sky noise? the receiver should show some.

ASSISTANCE II

Some of your data passes seem good.
The following seem to me to be near the amount of data to expect.
NOAA-16 01:53 20/11 40Mb
NOAA-16 03:34 20/11 55Mb
NOAA-16 03:23 21/11 53Mb
For me if a pass is over 30degrees I would expect about 45>66Mb
of data.
What is your exact latitude and longtitude or nearest city?
I can then workout the length of pass and compare with mine.
Have you also, a clear horizon, are there any obstuctions?
If you can get 55Mb of data once then you should on every good pass.
Don't forget NOAA15 is weaker than NOAA16 and data for me is
much shorter.
For colour, have you tried Davd Taylor's HRPTReader?
If not download a copy, it's better than tTimesteps for colour
and I use it all the time. Its a RAM hungry program, make sure
you have a minimum 128Mb, 256Mb works faster.
Can you send me a jpg of your best pass? keep it as small as possible,
say no more than 100kb, keeps isp happy.
Cheers ...Mike

ASSISTANCE III

Hi Manolis.
Thanks for sending your NOAA 16 image.
Looks pretty good to me, compared it to mine and
looks like you got most of that pass.
Yes! any obstuctions will cause data loss, trees are a
real problem. Now the leaves have fallen things are a bit better.
I have lots of trees here and in the summer pass lengths are
quite a lot shorter than the winter.

Re color images.
If you take the night time passes these will be just infrared, color
is not really an option as there is no visible channel to give you the
brightness needed to get color. If you look at the HRPTReader it uses
channel 2 and 4 to give color. Try a NOAA 16 daytime pass, some
color is still possible even though it's relatively dark in the north now.
At night try NOAA 16 channel 3, it gives very good detail and showsup
any hotspots on land.

Sorry I don't know how you can remove cloud layers, I would think
it's not possible but not 100% sure.

With this mail I have included two NOAA 16 images from today the 4th.
First one is a NOAA 16 channel 4 apt style image from 0246utc and the
second is a NOAA 16 apt style false color from 1239utc. Also included
a high resolution image of Southern Italy, from 1239utc.
All my images are processed with the HRPTReader and Paintshop Pro 7.

Keep up the good work.
Cheers...Mike

Appendix 5

Installation and Software Instruction

Manual Time-step

Appendix 6

Instruction Manual YAESU G-5500

Antenna

Azimuth-Elevation Rotators &

Controller

REFERENCES

SOURSE

All information that I found about the satellite and the orbit further for my equipment is from the follow source:

- Weather satellite Handbook, by Dr Ralph E. TAGGART, WB8DQT
- Time-step Weather system manual
- RIG (Remote Imaging Group)
- Web-site:

1. www.amsat.org
2. www.noaa.gov
3. www.time-step.com
4. www.rig.org.uk
5. www.nasa.gov
6. Www.amsat.org/amsat/keps/menu.html
7. http://www.david-taylor.pwp.blueyonder.co.uk/software/hrpt.htm
8. http://www.mindspring.com/~n2wwd/
9. http://noaasis.noaa.gov/NOAASIS/