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Establishment of a NOAA and Fengyun Receiving Station in a Singapore High School

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Abstract: A project to establish a low cost NOAA and Fengyun 1C receiving station in a Singapore high school for education purposes was initiated in late 2000. CRISP was engaged to assist in the purchasing of the hardware, and integration and installation of the system. CRISP also provided its in-house developed processing software. The system has been installed and is able to receive and process NOAA 12,14, 16 and Fengyun 1C data automatically without the necessity of human intervention.

Keywords : NOAA, AVHRR, Fengyun 1C

1. INTRODUCTION

In late 2000, the Centre for Remote Imaging, Sensing and Processing (CRISP) received an inquiry from a High School in Singapore, Pioneer Junior College, about the feasibility of setting up a low cost satellite receiving station for education purposes in the school's Science Club. The school had received a donation from a private enterprise for this project. After evaluation, CRISP recommended to build a NOAA and Fengyun 1C receiving and processing system based on PCs with Windows 98/2000 and equipped with a 1.5m L-band tracking antenna. The budget available were mainly use to procure the hardware and site renovation. The processing software, system integration and installation were provided by CRISP without cost.

2. NOAA AND FENGYUN 1C

The NOAA satellites are a series of polar orbiting satellites operated by the National Oceanic and Atmospheric Administration (NOAA) of the United States. The nominal attitude of these satellites are 833 – 870 km, the orbital inclination is about 98.8°, and the orbital period is about 102 minutes. Near the equator, like Singapore, a receiving station will be able to receive 2 day-passes and 2 night-passes for each satellite.

The current operational NOAA satellites are NOAA 12, 14 and 16. The satellites carry several instruments for various meteorological applications, but for this project, we will only be focussing on the AVHRR instrument. The AVHRR instrument has five spectral bands/channels, at 1.1km resolution, as follows:

Band/Channel	Spectral Range (μm)	Objectives
1	0.55 – 0.68	Daytime cloud, surface image, vegetation
2	0.725 - 1.1	Daytime cloud, surface image, vegetation and water
3	3.55 – 3.93	Heat source, night time cloud image
4	10.3 - 11.3	SST, diurnal cloud image
5	11.5 - 12.5	SST, diurnal cloud image

Besides meteorological applications, this AVHRR data has been widely used in many non-meteorological applications such as forest fire monitoring, sea surface temperature determination, global vegetation monitoring etc.

Fengyun 1C (FY1C) is a polar orbiting meteorological satellites operated by the National Satellite Meteorology Centre (NSMC) of China. Its orbital characteristics is similar to that for NOAA. Its instrument (VIRR) is also similar in characteristics to the NOAA AVHRR except that it has 10 spectral bands. The first 5 bands are similar to that of NOAA AVHRR. The downlink telemetry of FY1C is also very similar to that for NOAA, except that the transmission rate is doubled to 1.3303 Mbps. The 10 spectral bands of FY 1C are as follows:

Band/Channel	Spectral Range (μm)	Objectives
1	0.58 - 0.68	Daytime cloud, surface image, vegetation
2	0.84 - 0.89	Daytime cloud, surface image, vegetation and water
3	3.55 - 3.93	Heat source, night time cloud image
4	10.3 - 11.3	SST, diurnal cloud image
5	11.5 - 12.5	SST, diurnal cloud image
6	1.58 - 1.64	Soil moisture, ice/snow
7	0.43 – 0.48	Ocean colour
8	0.48 – 0.53	Ocean colour
9	0.53 – 0.58	Ocean colour
10	0.90 – 0.985	Total water vapour amount

3. SYSTEM OVERVIEW

The system can be divided into two subsystems. The first is the data reception sub-system and consist of a 1.5m L band tracking antenna system hosted by a Windows based PC. This subsystem is responsible for the automatic tracking and recording of the data in a simple raw format from each satellite at it passes. After each pass, the PC in this subsystem will automatically ftp the raw data to another PC for subsequent processing. The PC will also delete old raw data files so that there is enough diskspace to record new data.

The second sub-system is the data processing subsystem. It consisting of another Windows based PC with all the CRISP processing software, such as those for generating the level 1B format files and other image files. It is connected to the data acquisition subsystem by standard Ethernet cable. A freeware ftp server (WarFtp) is also installed to allow the reception subsystem to ftp the raw file into its disk drives for subsequent processing.

4. RECEPTION SUBSYSTEM

The main component of the reception subsystem is the tracking antenna. For this project, we have selected a 1.5m diameter antenna system from Quorum Communications Inc, USA. The selection is mainly because of its low cost.

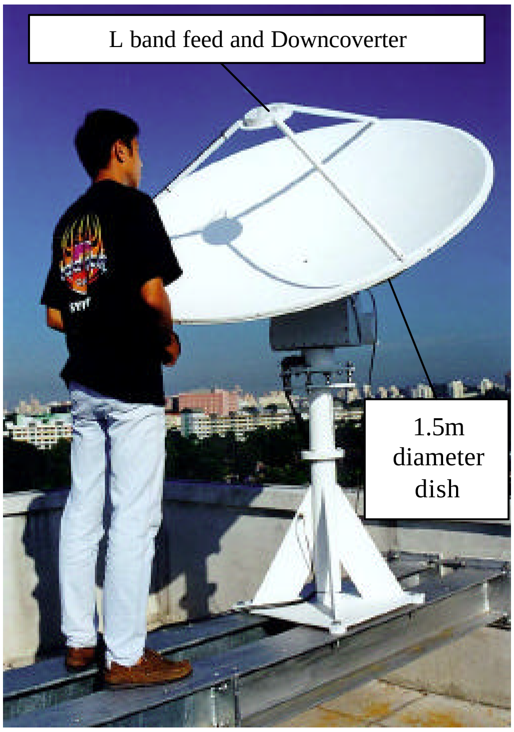

Fig 1 – 1.5m L band Tracking Antenna (outdoor equipment)

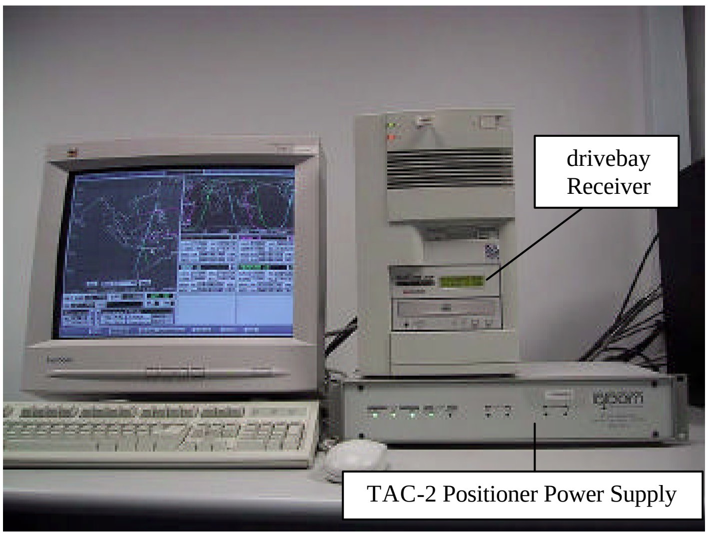

Fig 2 – Reception Subsystem (indoor equipment) – TAC-2 Positioner Power Supply, PC running QTRACK S/W

The antenna, pedestal, positioner mechanism and the feed and downconverter electronics were installed outdoor on the roof. Power to the antenna is supplied by the 'TAC-2' positioner power supply box located indoor beside the tracking PC. Inside the tracking PC are two PCBs and a DSP based drivebay receiver (size of a CD-ROM drive). The first PCB is responsible for controlling the 'TAC-2' positioner power supply unit that controls the pointing of the antenna. The other PCB works with the drivebay receiver to do the frame synchronisation and reformatting of the received signal. The outdoor and indoor equipment are connected by two cables – one for transmission of the received data at the IF of 137 Mhz and another for providing the power supply to power the feed and the motor of the positioner.

Quorum also provides the Windows-based QTRACK software that drives the antenna and records the received signal into the disk drives. The data is recorded in the same order as the bitstreams signal sent down by the satellites, except for a conversion from 10 bits to 16 bits by padding 6 zero bits to every 10 bits of data received. The QTRACK software also inserts the NORAD TLE in the beginning of the file as well as the start time of the data. These information were found to be particularly helpful in the subsequent data processing.

In order for automatic unmanned operation of the system, some scripts were written to do the following functions:

i. to download new NORAD two line elements ephemeris, once a day via internet
ii. to ftp the received data to another PC for subsequent processing

To be able to point the antenna, we need to have good knowledge of the time. The PC clock time is known to drift many seconds in a day. The solution implemented is to installed a freeware network time protocol (NTP) software called Automachron which will synchronised the PC time periodically with CRISP NTP server (other NTP server could also be used).

To increase the reliability, the tracking PC was made to reboot itself once a day.

5. PROCESSING SOFTWARE

In order to keep the system simple and reliable, we choose to ftp the received raw data to another computer for processing. The first step involved the generation of the NOAA level 1B format file from the raw data. The NOAA level 1B format is documented in NOAA's Polar Orbiter Data (POD) user's guide available from http://www2.ncdc.noaa.gov/docs/podug. The NOAA level 1B format is selected because it is widely supported by many remote sensing packages such as ENVI and ERDAS Imagine. Besides data formatting, the generation of level 1B format file also involves:

i. replacing of lines lost during reception
ii. computing the calibration coefficients for the infrared channels of the AVHRR
iii. calculating the earth location information and solar azimuth and elevation angles of 51 pixels for each scan line

Detection of lost lines is done by carefully checking the time information of each line. Since the timing information may also have bit errors, a robust filtering algorithm that extract the reliable time information by examining at a 4 scan lines simultaneously is implemented.

The calibration coefficients (slopes and intercepts) for the infrared bands (3,4 and 5) were computed from the received data. The gray level values measured by the sensor when it is observing the satellite's internal black body and deep space, the temperature of the calibration black body and the published detector spectral sensitivity in the various spectral bands (NOAA Technical Memorandum 107 or NOA-KLM user's guide section 7) were used to compute the slopes and intercepts of each spectral bands.

The slope and intercept for bands 1 and 2 (visible and near-infrared) were not computed from the data. Instead, the nominal pre-launch values were used. For more precise work, one may obtain updated slopes and intercepts values of these two bands, particularly for NOAA 14, from various sites in the internet. For NOAA 16, we have left the slope and intercept values zero for bands 1and 2 because the currently level 1B format cannot support the dual gain characteristics of NOAA 16 bands 1 and 2. NOAA has a new level 1B format for NOAA 16 (see http://www2.ncdc.noaa.gov/docs/klm), but we are not implementing it yet.

For each record / scan line, the level 1B format requires 51 earth location and solar azimuth and elevation angles data. The first value corresponds to pixel 25 and subsequent values at interval of 40 pixels. Computation of the earth location data requires firstly the knowledge of the satellite's state vectors (position and velocity) at each scan time. We used the NORAD TLE ephemeris and the SGP4 algorithm to compute these state vectors. Next, the look direction of the pixel is determined by assuming the scanner sweeps with linear angular velocity over the span of +/- 55.4 degrees from first to last pixel. Assuming the scan is normal to the direction of satellite travel and assuming that there were no tilts, the look vector of the pixel is computed. The earth location of the pixel is determined by intersecting this look vector with the ellipsoidal earth. After computing the earth location, the solar azimuth and elevation angles can then be computed.

6. FENGYUN 1C PROCESSING

Fengyun 1C (FY1C) has 10 spectral bands. The first five is similar to that in NOAA AVHRR's. At this moment, we do not have documentation of the downlink format of FY1C. But with some trial and error, we were able to extract the time information and image pixels from the downlink data files. We then choose to extract the first 5 bands of the FY1C data, which is similar to NOAA AVHRR and create a dataset similar to NOAA level 1B format, except that the calibration coefficients are not filled. An option is also provide to select any 5 out of the 10 bands in case the user wants to experiment with the other spectral bands of FY1C.

7. POST LEVEL 1B PROCESSING

As mentioned earlier, the level 1B can be ingested to many off-the-shelf remote sensing packages for further processing. To facilitate easy browsing and viewing of the received data, we have written a two additional programs to do the following:

i. generate a colour composite images in TIFF format, with bands 1,2 and 4 for data acquired in the day and bands 3,4 and 5 for data acquired in the night, with geographical grid and coastlines superimposed, and
ii. re-project the colour composite image to a north-up map projection image in TIFF format.

These two programs are made to run immediately after the level 1B files are generated. TIFF file format is selected because it is a standard format supported by almost all the PC software that handle images.

8. CONCLUSIONS

The system is completed in September 2001 and installed in the Singapore high school, Pioneer Junior College. In the next few months, we plan to work with the students and teachers to add more post processing modules to the system. Of immediate interest will be a module to generate forest fire hotspots and a module to generate NDVI.

REFERENCES

NOAA Polar Orbiter Data User's Guide, November 1998 Revision, http://www2.ncdc.noaa.gov/docs/podug

NOAA KLM User's Guide, September 2000 Revision, http://www2.ncdc.noaa.gov/docs/klm

NESDIS Satellite Sensor Calibration, http://psbsgi1.nesdis.noaa.gov:8080/EBB/ml/niccal.html

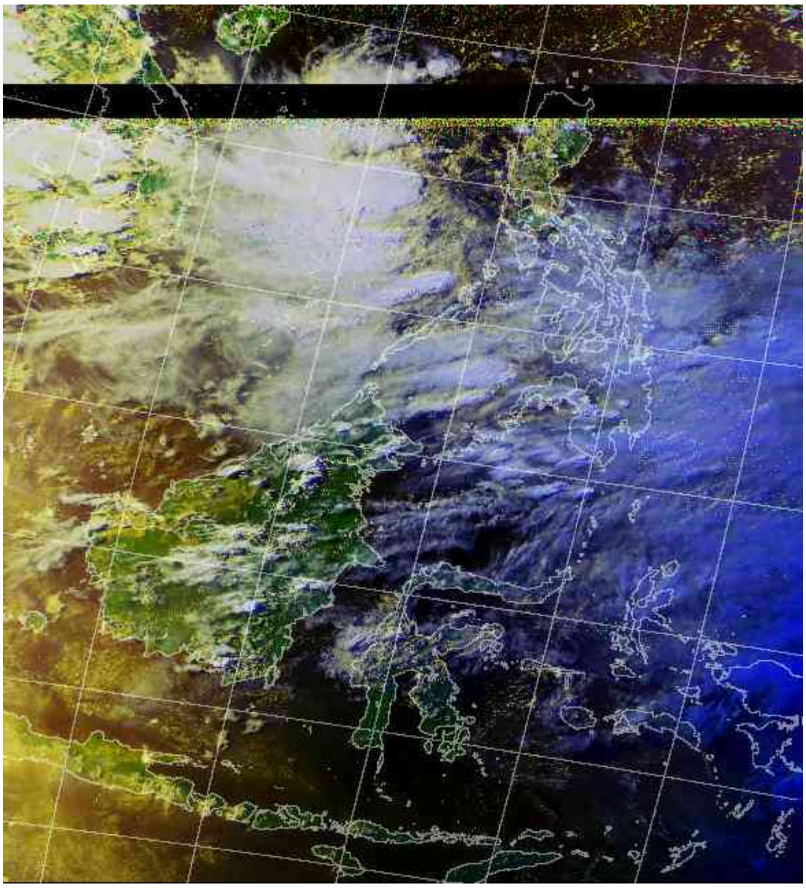

Fig 3 – Band 1,2 4 composite image of NOAA 14
note the droplines filled by the software

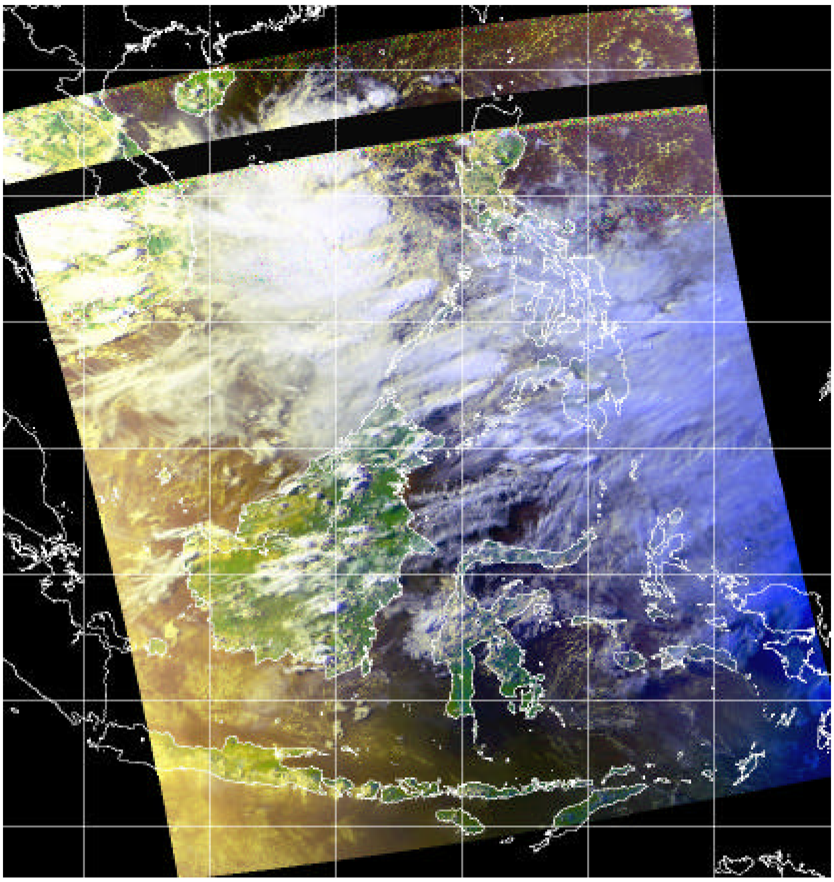

Fig 4 – Image re-projected to a North-Up map projection