Capturing Images From Weather Satellites

A presentation for EPARA – de KD2FTA

Introduction

- Weather satellites have been around since the beginning of the space age, with increasing levels of image and data gathering sophistication
- Although not a typical HAM topic, the technology, hardware and radios necessary to capture these images are already available to you , and you probably own a few of the items necessary to successfully download images
- We'll cover how to capture the analog and digital images of the NOAA , and Meteor series of satellites, and will briefly touch on the more sophisticated satellites like GOES.

Worse Case Scenario- Why do we want to capture these images?

- It's day 5 after the worse day of your life
  - The grid is down – no electrical power
  - News services are not available, no internet
  - The EMP knocked out regular AM and FM band communications, and all you hear is static
  - The forest fire is near and a " weather bird" is flying over soon, so you might get an image that helps you
  - You want to see images from space to determine what's affecting you, and how the weather might look like tomorrow
    - Which way is the radiation / smoke from the fires going?
  - Fortunately your go kit is intact, and your HT is operational!
    - Your computer had the latest Keplers downloaded before the catastrophe happened

Regular Everyday Scenario- Why do we want to capture these images?

- You live in a remote area, camping, or out on the ocean sailing
  - You want to see what tomorrow's weather looks like
  - You're not near any regular AM or FM weather broadcast stations
  - You're into SATComm and enjoy working with satellite transmissions, and what they provide. Image or telemetry.

Let's begin

- The current weather satellites in orbit have been placed there by several countries, (U.S.A., Russia, China, Japan etc..) and but except for a few weather birds, they are mostly polar or equatorial orbiting satellites*.
- The easiest satellites to gather images from are the NOAA (National Oceanic, & Atmospheric Agency) series of satellites
- Today there are three active NOAA satellites that pass over at roughly twelve hour intervals, with predictable passes.
- These satellites operate in the analog mode, and the signal is easily captured just above the frequencies used by aircraft near the 2 meter HAM radio band
- Since the signals are analog, a simple FM radio or scanner capable of tuning in the 137MHz range will permit you to capture or download the signal produced by the NOAA birds

* There are satellites parked at Lagrange points


DSCOVR
COMS
FY-2
SOHO
ACE
HIMAWARI-8
FY-2
INSAT-3D
140.7° E
128.2° E
105° E
90° E
86.5° E
82° E
NOAA-15/18/19
ELECTRO-L
78° E
74° E
GPM
180° W
SENTINEL-1
KALPANA
57° E
JASON -2/3
SENTINEL-2
GCOM
METEOSAT-7
SENTINEL-3
FY-3
METEOR
135° W
METOP
0°
DMSP-F14-18
A-TRAIN CONSTELLATION
COSMIC
105° W
90° W
75° W
SUOMI NPP
METEOSAT-10
GOES - WEST
GOES - 14
GOES - EAST
USA
JAPAN
SOUTH KOREA
INDIA
CHINA
FRANCE
RUSSIA
NOAA
EUMETSAT
EUROPEAN COMMISSION
NATIONAL SPACE ORGANIZATION (NSPO)
EUROPEAN SPACE AGENCY
GEOSTATIONARY ORBIT
NEAR-POLAR ORBIT
LAGRANGE POINT 1


EPS Contributes to the Global Operational Satellite Observation System
FY-1/3 (China)
METEOR 3M (Russian Federation)
Terra
NPP
Jason-1/2
Okean series
GOES
(USA)
75W
GOES
(USA)
135W
Aqua
QuickScat
TRMM
MTSAT-1R/2
(Japan)
140E
Geostationary orbit
R & D orbit
Polar orbit
35,800 km
ALOS
COMS-1
(Rep. of Korea)
120E
ENVISAT/ERS-2
METEOR 3M N1
SPOT-5
GPM
GCOM
FY-2/4
(China)
105E
MSG
(EUMETSAT)
0 Longitude
Meteosat
(EUMETSAT)
63E
INSATs
(India)
83E
GOMS / Electro N2
(Russian Federation)
76E
NOAA
(USA)
NPOESS
(USA)
Metop
(EUMETSAT)
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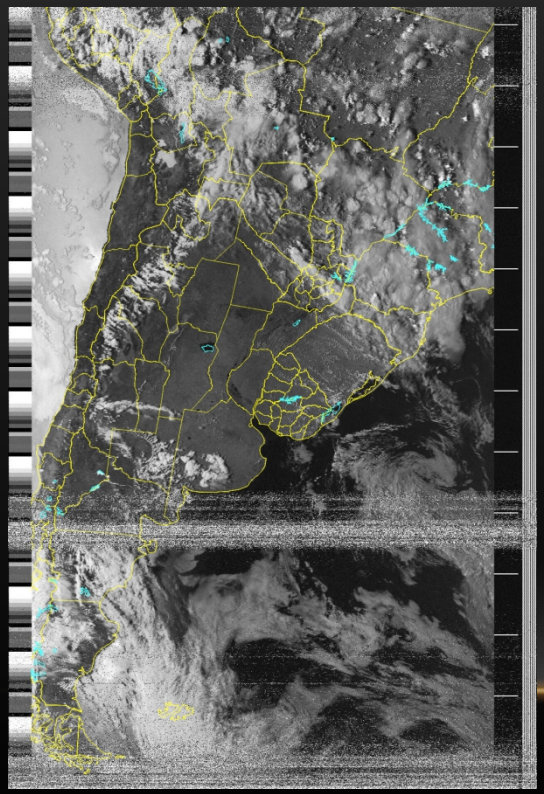
NOAA weather birds

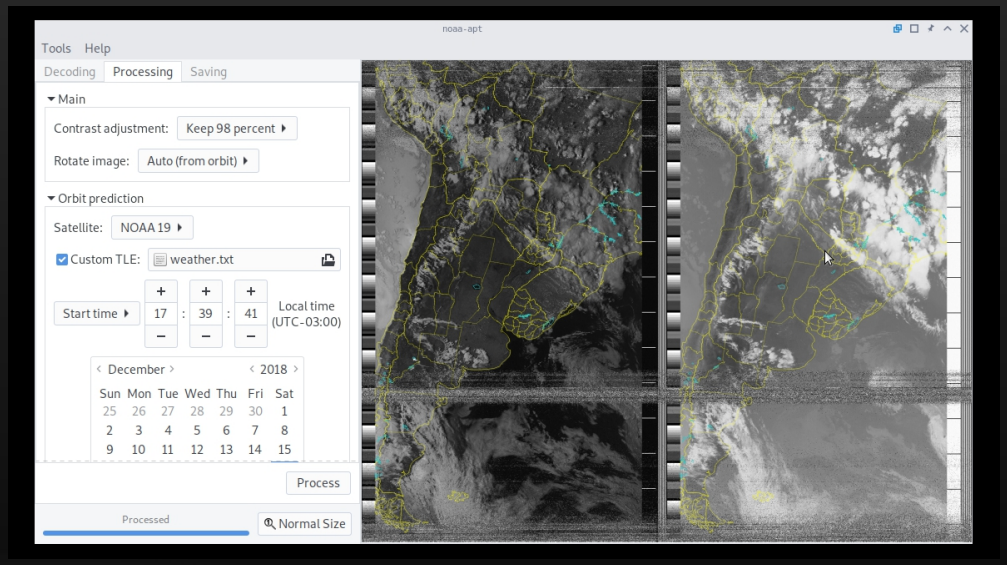
- To get started you'll need an FM radio capable of receiving signals from 137.100 to 140.00 MHZ. Below are the NOAA frequencies.
  - **NOAA 15** on 137.6200 MHz FM
  - **NOAA 18** on 137.9125 MHz FM
  - **NOAA 19** on 137.1000 MHz FM
- You'll need a laptop or desktop with the WXtoImg software installed. Go to https ://WXtoImgrestored.xyz/ to download the software.
- NOAA APT* Satellites transmit on frequencies between 137.1000 and 137.9125 MHz FM using between 30 and 40kHz bandwidth. WXtoImg will function with receivers using a bandwidth as low as 12kHz, but there will be some image degradation. Receiver sensitivity should ideally be about 0.2uV to 0.25uV.

* APT = Automatic Picture Transmission

NOAA weather birds

- There are other software developers that are now creating APT decoding software due the popularity of capturing images from space. These developers are using software defined radio dongles as the radio source instead of a traditional HT or FM radio. Here's an alternative software site.
  - https://noaa-apt.mbernardi.com.ar/





NOAA weather birds

- Probably the most important item to chose will be your reception antenna.
- You can build your own and there are many options available on line
- Most satellite websites will offer you where to purchase or build a Quadrifilar Helical Antenna
- Another option is double crossed Yagi antenna
- These antennas are specifically made for the reception of the polarized signals the weather satellites are sending
- Antenna resources:
  - http://www.askrlc.co.uk/
  - https://www.wraase.de/hardware/antennas/#kx-137
  - https://newt.phys.unsw.edu.au/~map/weather/notes/buildyourown/lindenblad.html
  - https://www.nationalrf.com/satellite-tenna.htm

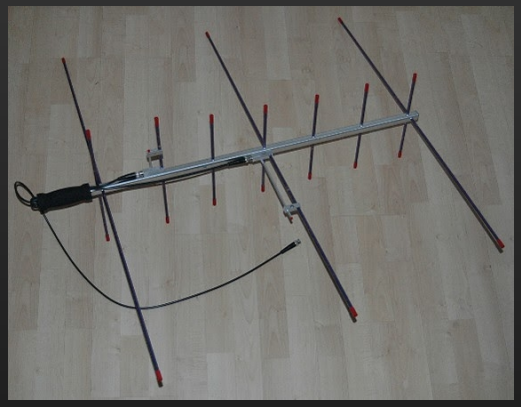
NOAA weather birds

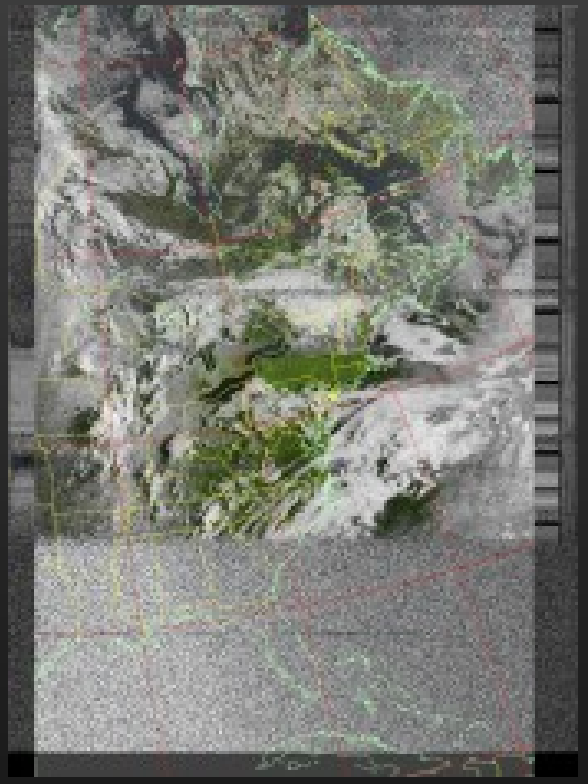
Or you can try your luck with a simple V dipole design :
https://www.rtl-sdr.com/techminds-building-a-v-dipole-for-weather-satellite-reception/

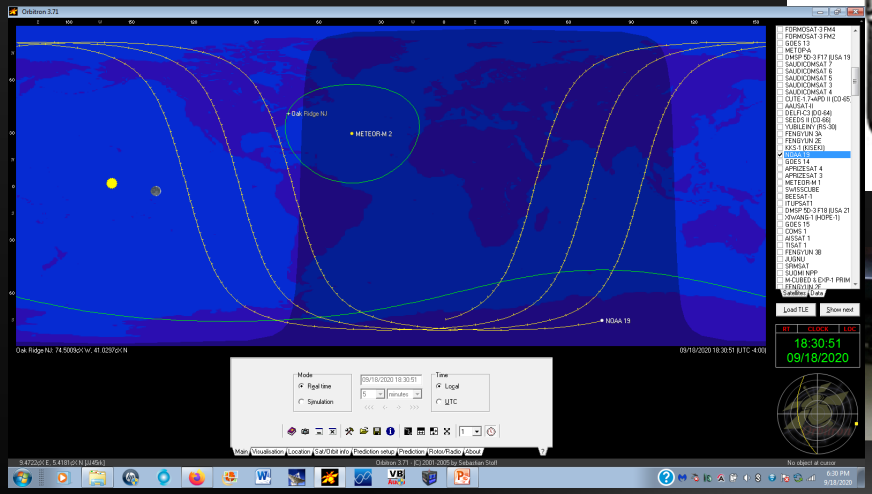
Try to place it as high above the ground as possible to avoid any buildings or obstructions

NOAA weather birds

- My set up







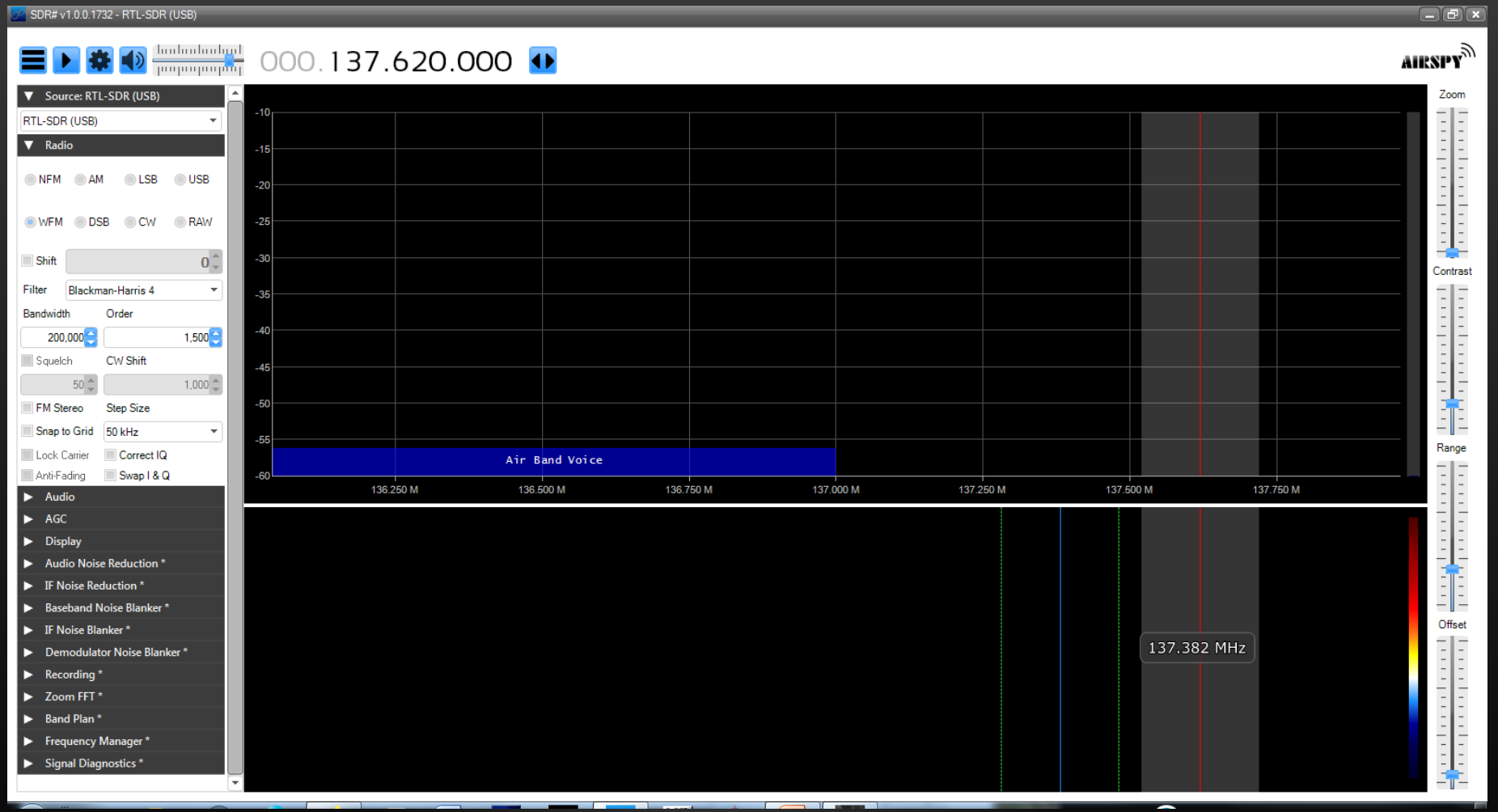
NOAA weather birds

- If you're going to use an SDR the set up is a little more involved
  - Select the SDR you're going to use – there are several companies that offer HF/VHF/UHF dongles, that will work with Windows or Linux operating systems
  - Configure the SDR correctly with your laptop – manufacturers offer on line help with the software configuration
  - Download the SDR software to run your SDR, there are a few but I use **SDR Sharp**
  - Download a **virtual audio cable** that will connect your SDR with the soundcard on your laptop. I used **VB cable** which can be found at :

    https://vb-audio.com/Cable/index.htm

  - Configure your computer in the control panel with the virtual cable software you used
  - Connect your SDR to the antenna
  - If you're using WXtoImg software you'll need set up the audio levels in your soundcard so as to not saturate the card with unnecessary noise
  - Start your SDR software and select the frequency for the bird. Follow the instructions in WXtoImg to adjust the audio levels.
  - Select the auto record option and WXtoImg will select the next NOAA bird that will fly over your location

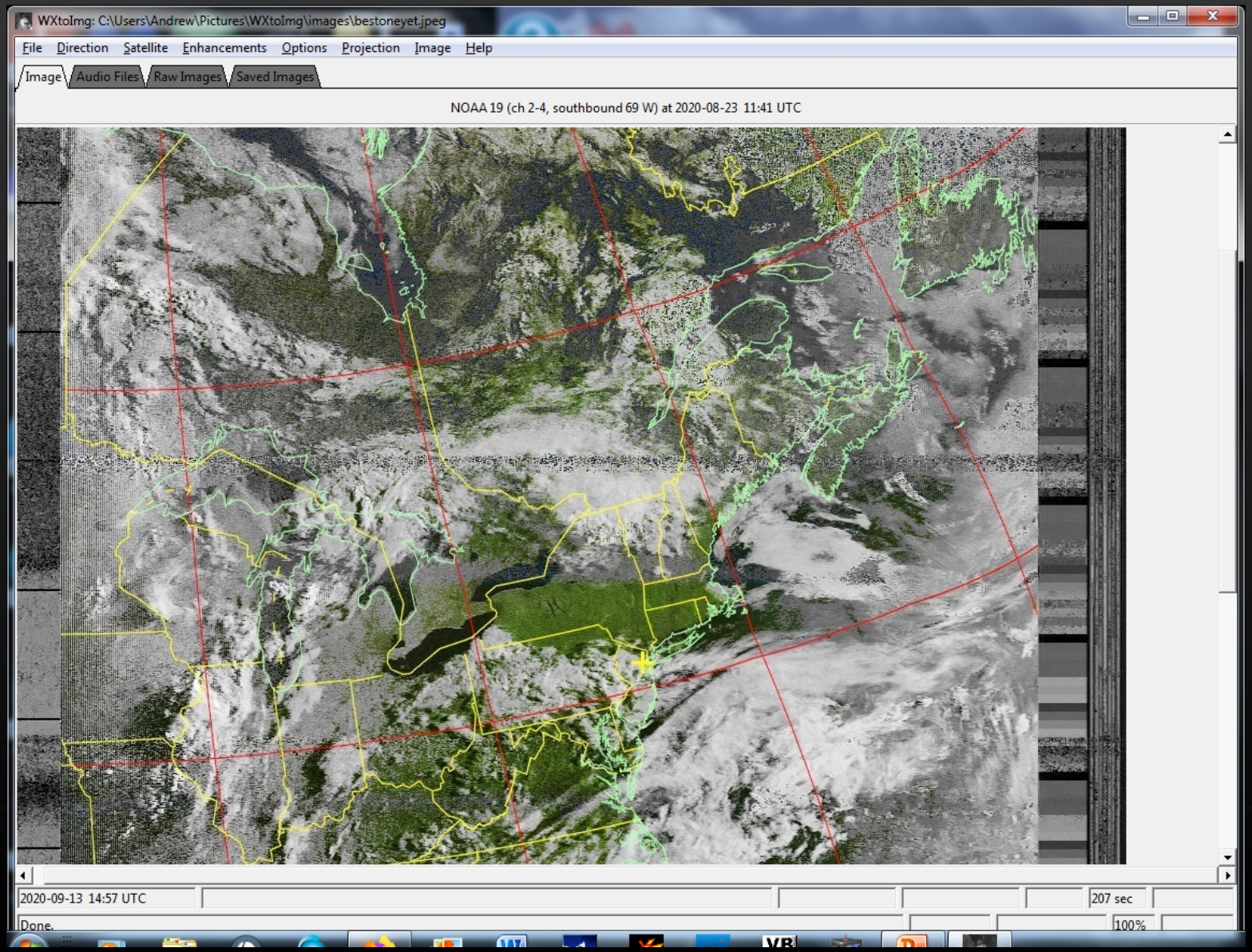
NOAA weather birds



Screen shot of SDR Sharp software by Airspy

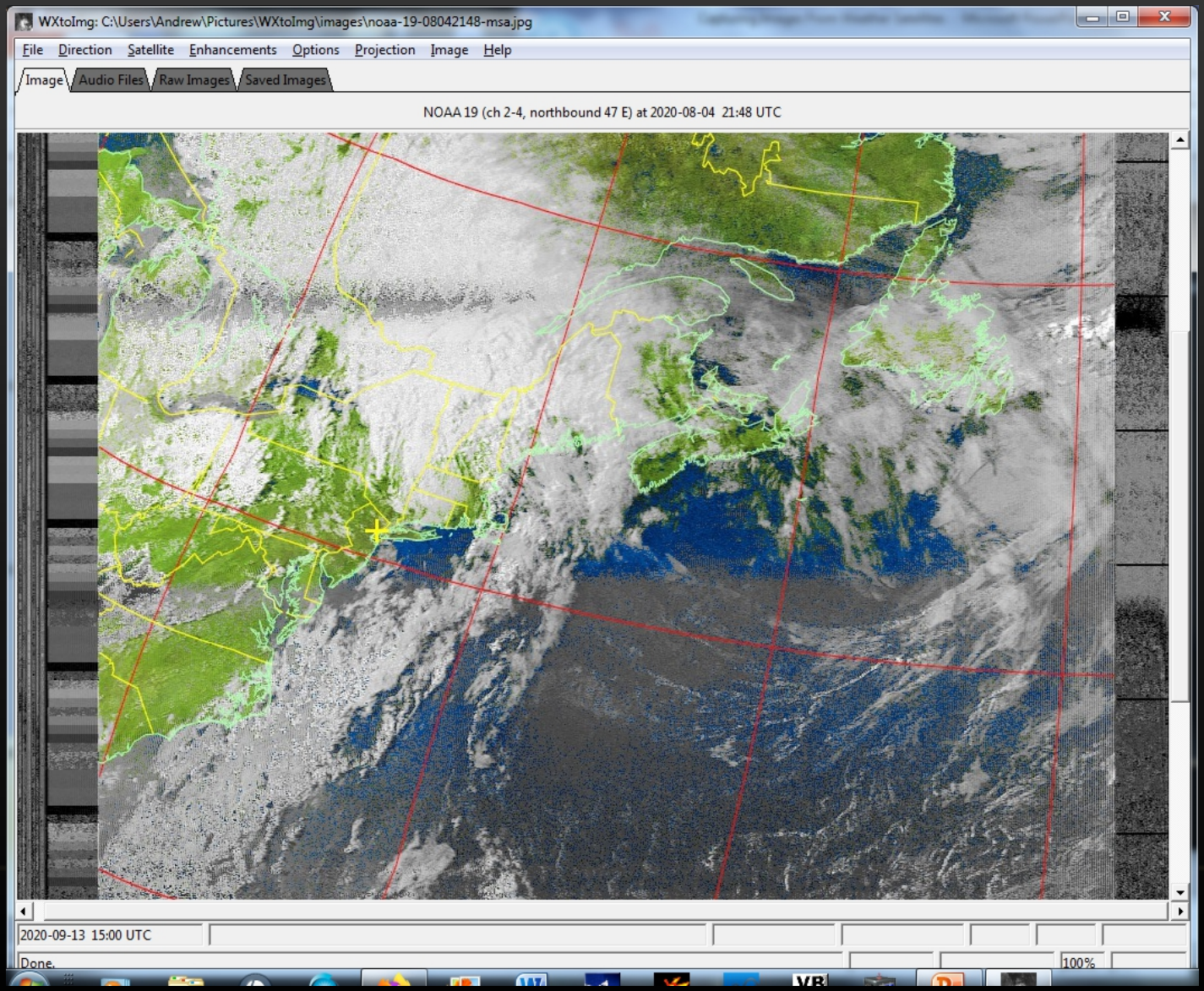
NOAA weather birds

- NOAA 19 Image captured using the Yaesu HT , my arrow antenna and WXtoImg software



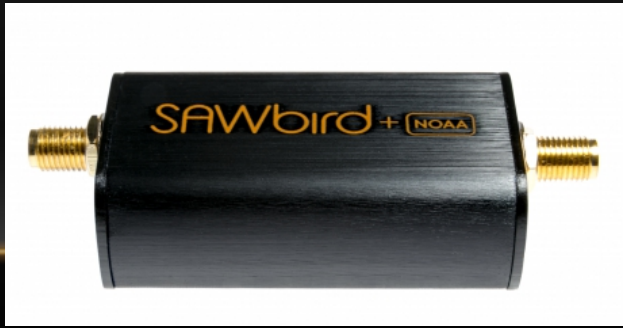
NOAA weather birds

- NOAA 19 Image captured using the Yaesu HT , my arrow antenna and WXtoImg software



NOAA weather birds

- Some additional tricks that can be done using SDR to improve images
  - If you live in an area where there's a large mount of FM RF energy, or electrical noise it pays to invest in two additional items for your SDR radio
  - An FM Filter, and a SAWBird NOAA LNA
  - APT signals are boosted with an LNA (Low Noise Amplifier), and the filter limits any noise outside of the bandwidth selected by your software
  - These can all be placed in line and attached to your laptop via a USB cable



Next level of Image Capturing sophistication - Meteor

- The first Meteor-M satellite, Meteor-M No.1, was launched 17 September 2009 16:55:07 UTC from Baikonur by a Soyuz-2-1b/Fregat rocket. Its mission ended in 2014.
- The second satellite, Meteor-M No.2 (also known as Meteor M2), was launched 8 July 2014 16:58:28 UTC from Baikonur by a Soyuz-2-1b/Fregat rocket. Its mission is scheduled to last 5 years.
- On 27 November 2017, the launch of Meteor-M No.2-1 was lost after a programming error.
- On 5 July 2019, the replacement satellite for the failed Meteor-M No.2-1 satellite, the Meteor-M No.2-2 (also known as Meteor M2-2) was launched from Vostochny Cosmodrome.

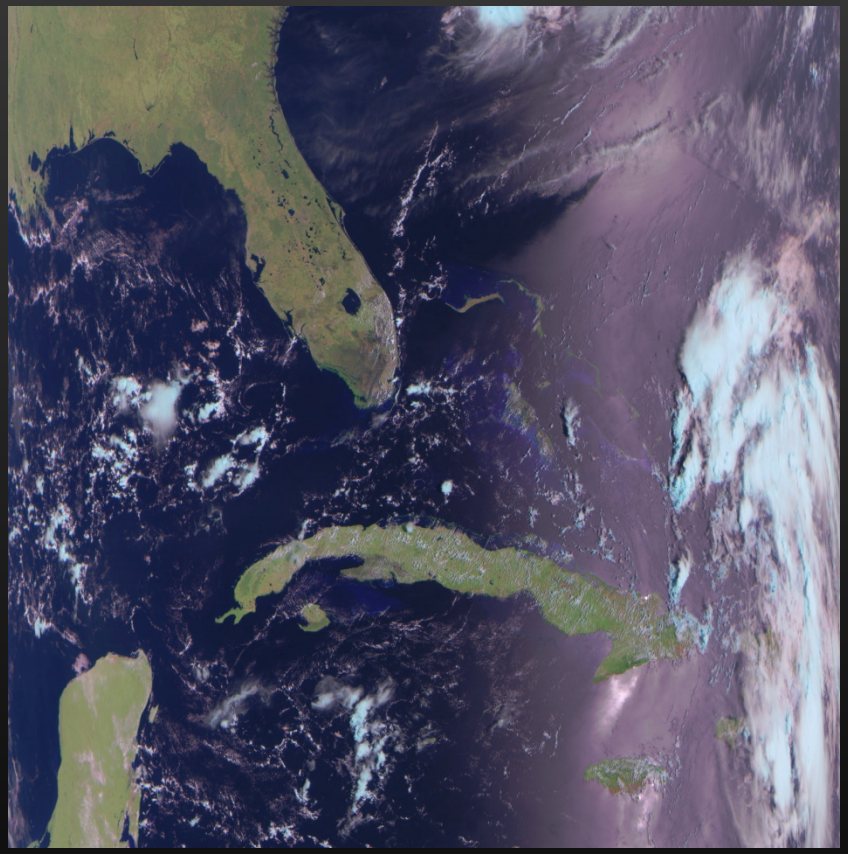
Next level of Image Capturing sophistication - Meteor

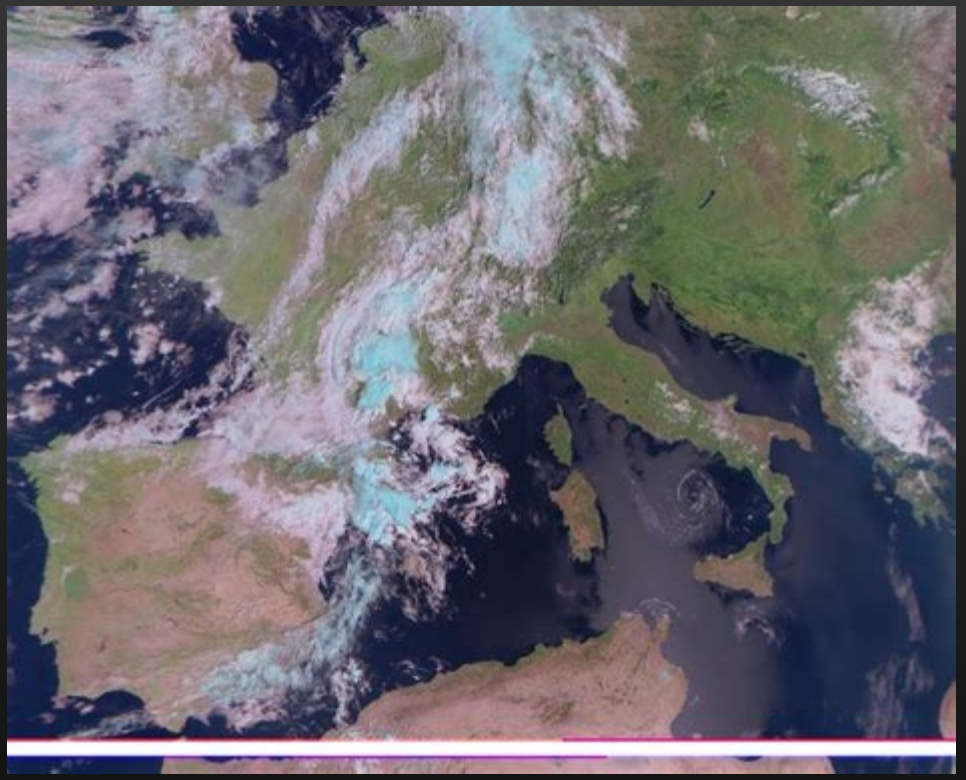
- On 18 December 2019, image downlink from Meteor-M No.2-2 ceased. Tracking revealed the craft had suffered degradation in orbit with a 2 km (1.2 mi) decrease in perigee. NORAD was not able to identify any space object involved in a collision.
- Roscosmos later confirmed that the satellite had suffered a decompression of its thermal control system following what is presumed to be a micrometeoroid impact. Following the incident, the spacecraft was automatically switched into a low-power mode and ground operators worked to restore the satellite's orbit and orientation. By 25 December 2019, the satellite had resumed controlled flight, but the future of its mission remains uncertain.

HRPT and lrpt digital reception

- The meteor satellite series doesn't use APT, it uses HPRT and LPRT (High Resolution and Low Resolution Picture Transmission) to send images back to Earth
- An analog FM HT or radio won't work in this case although you can hear the Meteor M2 signal on 137.100 MHz using an SDR dongle
- For the meteor series you'll need an SDR dongle to capture the images, and *several other pieces of software* to process the image
- This is much more involved than capturing the NOAA satellite images, but the quality of the images is much higher due to the higher resolution digital cameras on board the satellite

HRPT and lrpt digital reception



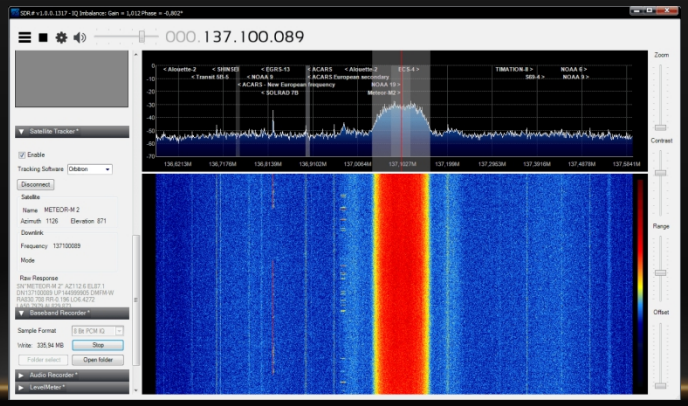


Meteor M2 Image Capture Requirements

- Unlike the APT process HRPT requires a significant amount of image processing and unless you have a digital FM receiver, you'll be using SDR exclusively to receive and process the images
- You'll need to follow the SDR instructions previously described with the ability to tune to the Meteor frequencies and then to record the transmission and process it into an audio file which will require more processing.
- A regular Yagi antenna can be used as long as it can receive polarized signals properly, but a double crossed Yagi, V-dipole Yagi, or QHA antenna is preferable.

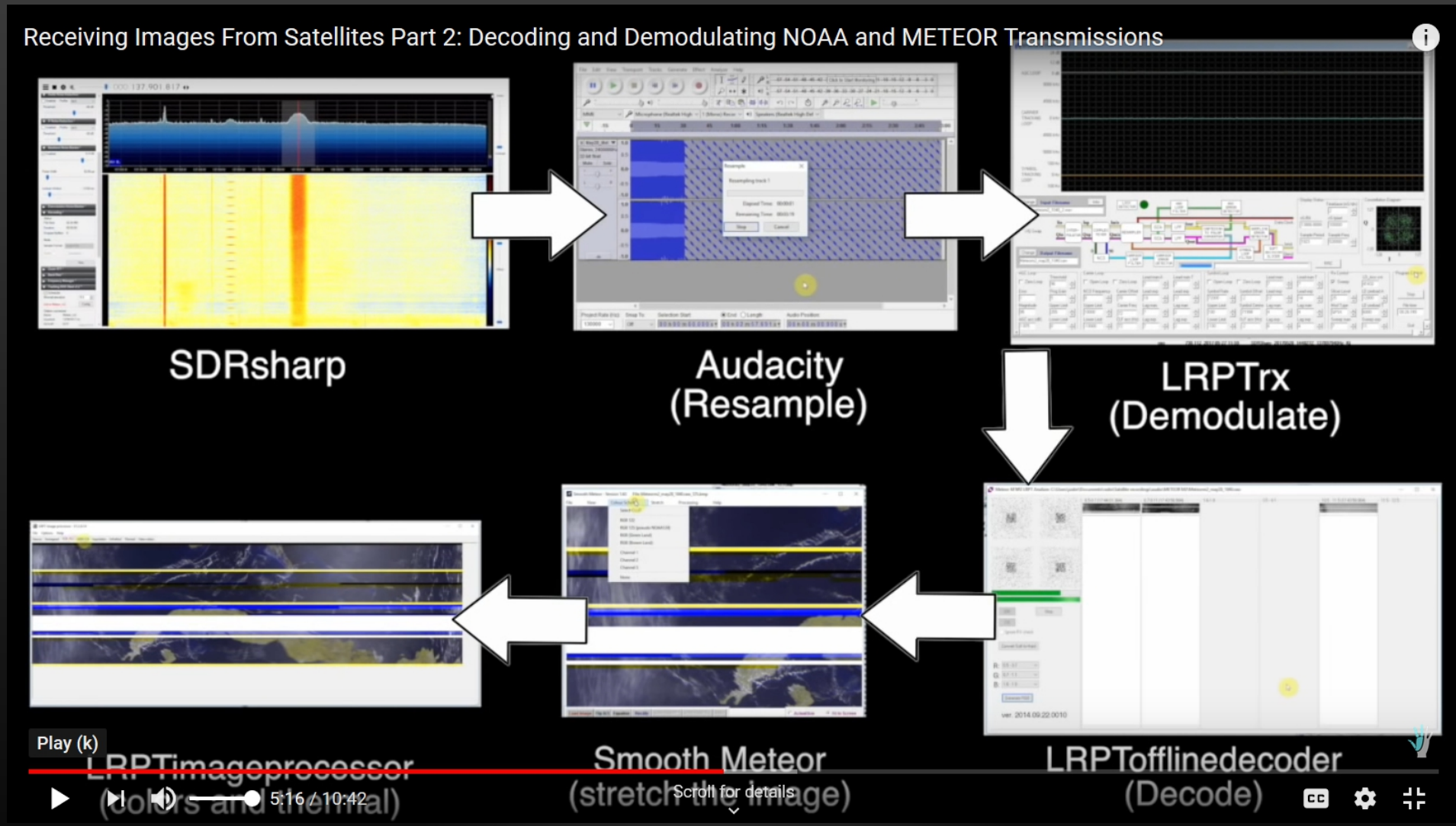
Meteor M2 Image capture Requirements

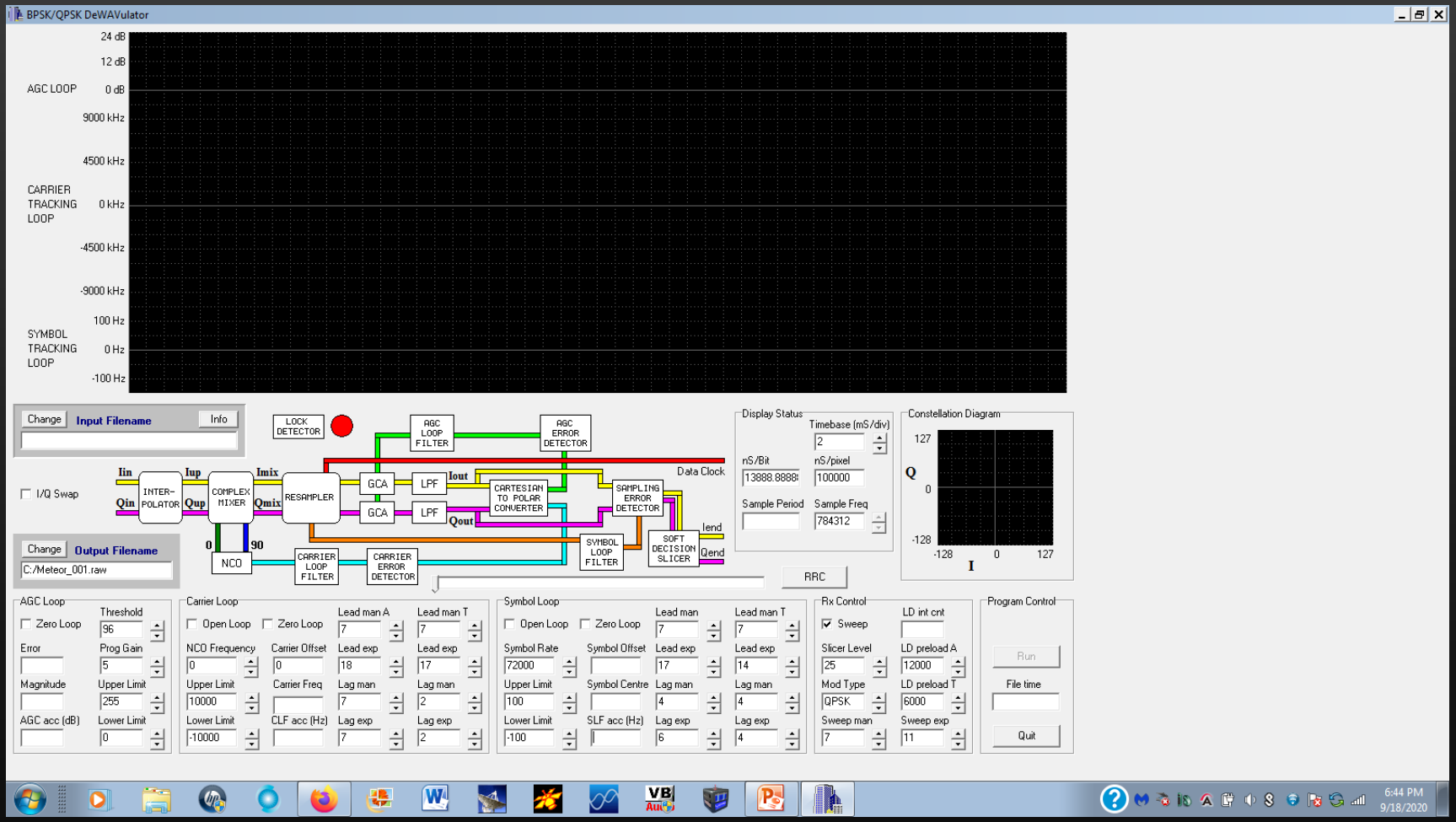
- When recording Meteor data with the SDR software (SDR Sharp) record using only the baseband mode.
- SDR Sharp allows you to record the signals for future play back, and by default the SDR file will save the image to the file folder SDR Sharp resides on your computer (Usually the C drive). Go to the file and find it.
- Rename the file you just recorded, which can be pretty large, a few megabytes worth so don't be surprise. These are digital images and consume a lot of memory - 2 to 6 gigabytes worth of data is not unusual
- After renaming the file , place it where you can find it on your C drive
- Now you'll need a five new pieces of software to complete this process, which is not the most efficient way of doing this but its all freeware!



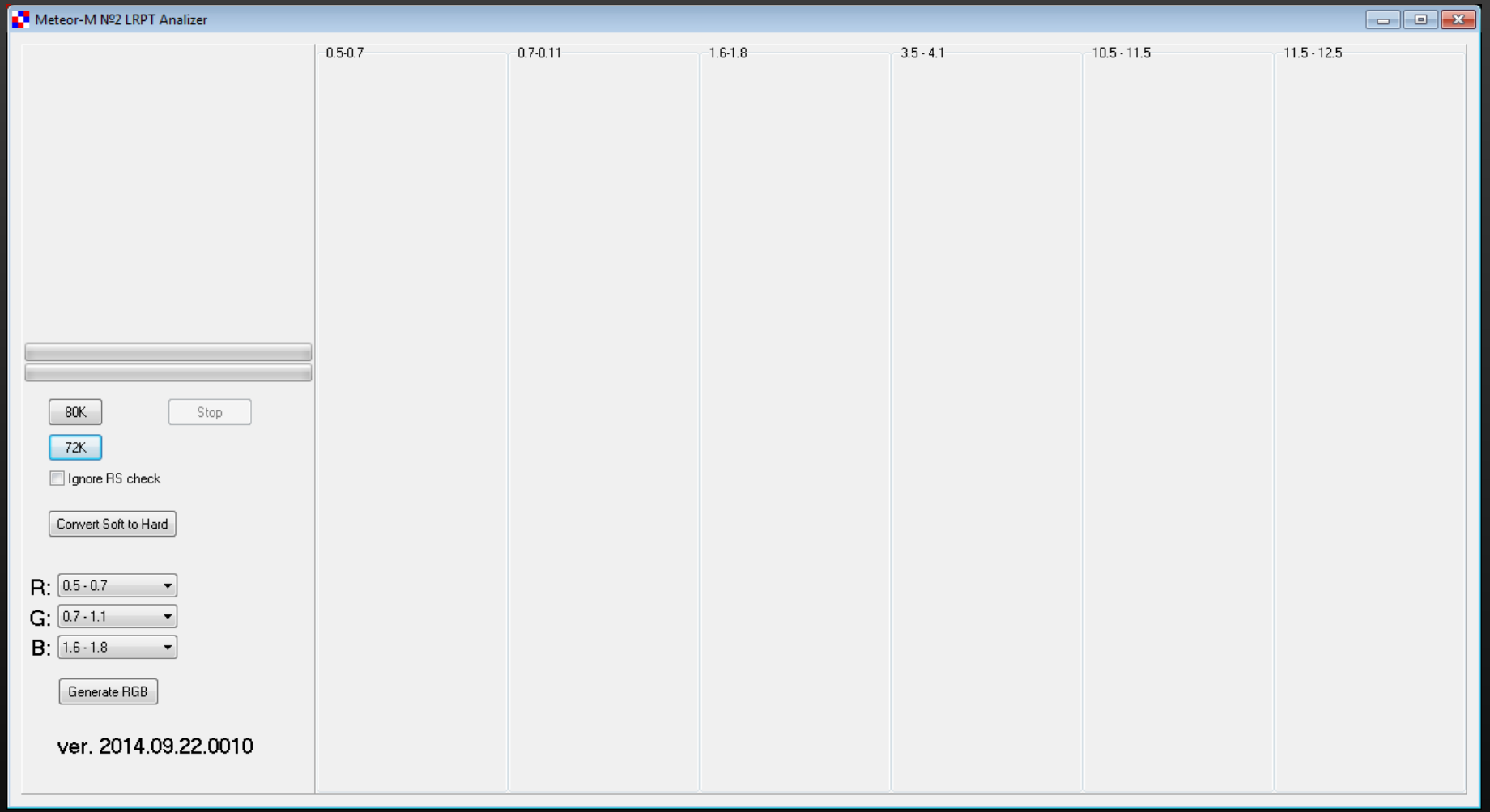
Meteor M2 Image capture Requirements

- Here's a list and the web sites you'll need to go to for the software:
  - Audacity: http://www.audacityteam.org/download/
  - WXtoImg: https://WXtoImgrestored.xyz/
  - LRPTrx: https://www.dropbox.com/s/qq1fjyitpa3...
  - LRPTofflinedecoder: http://www.radioscanner.ru/files/download/file17709/lrptofflinedecoder_2014.09.22.0010.zip
  - Smooth Meteor: http://leshamilton.co.uk/meteor3m.htm
  - LRPTimageprocessor: http://www.satsignal.eu/software/LRPT...


Receiving Images From Satellites Part 2: Decoding and Demodulating NOAA and METEOR Transmissions
SDRsharp
Audacity
(Resample)
LRPTrx
(Demodulate)
LRPTofflinedecoder
(Decode)
Smooth Meteor
(stretch the image)
LRPTimageprocessor
(colors and thermal)
Play (k)
5:16 / 10:42
Scroll for details



LRPTrx Demodulator Software

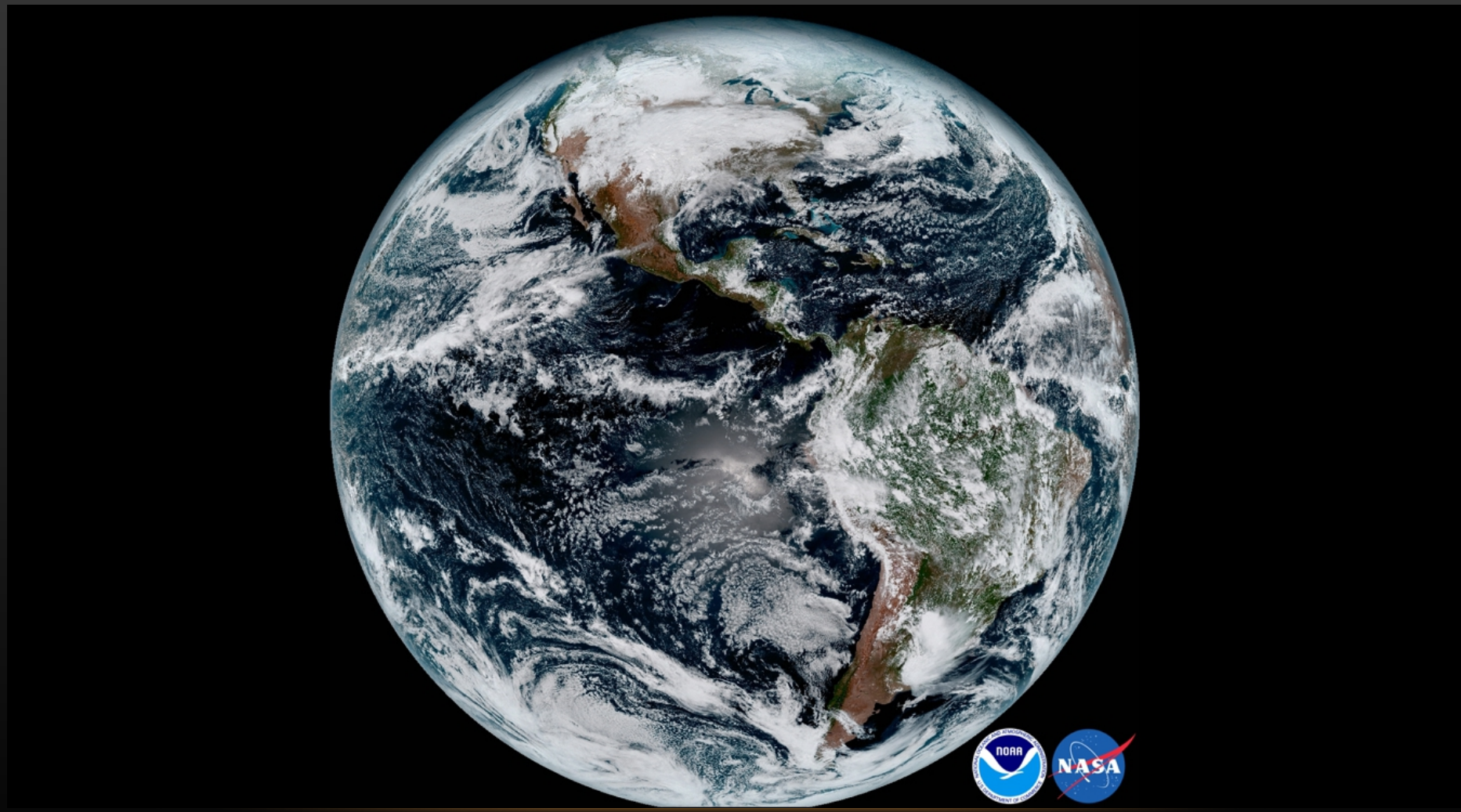


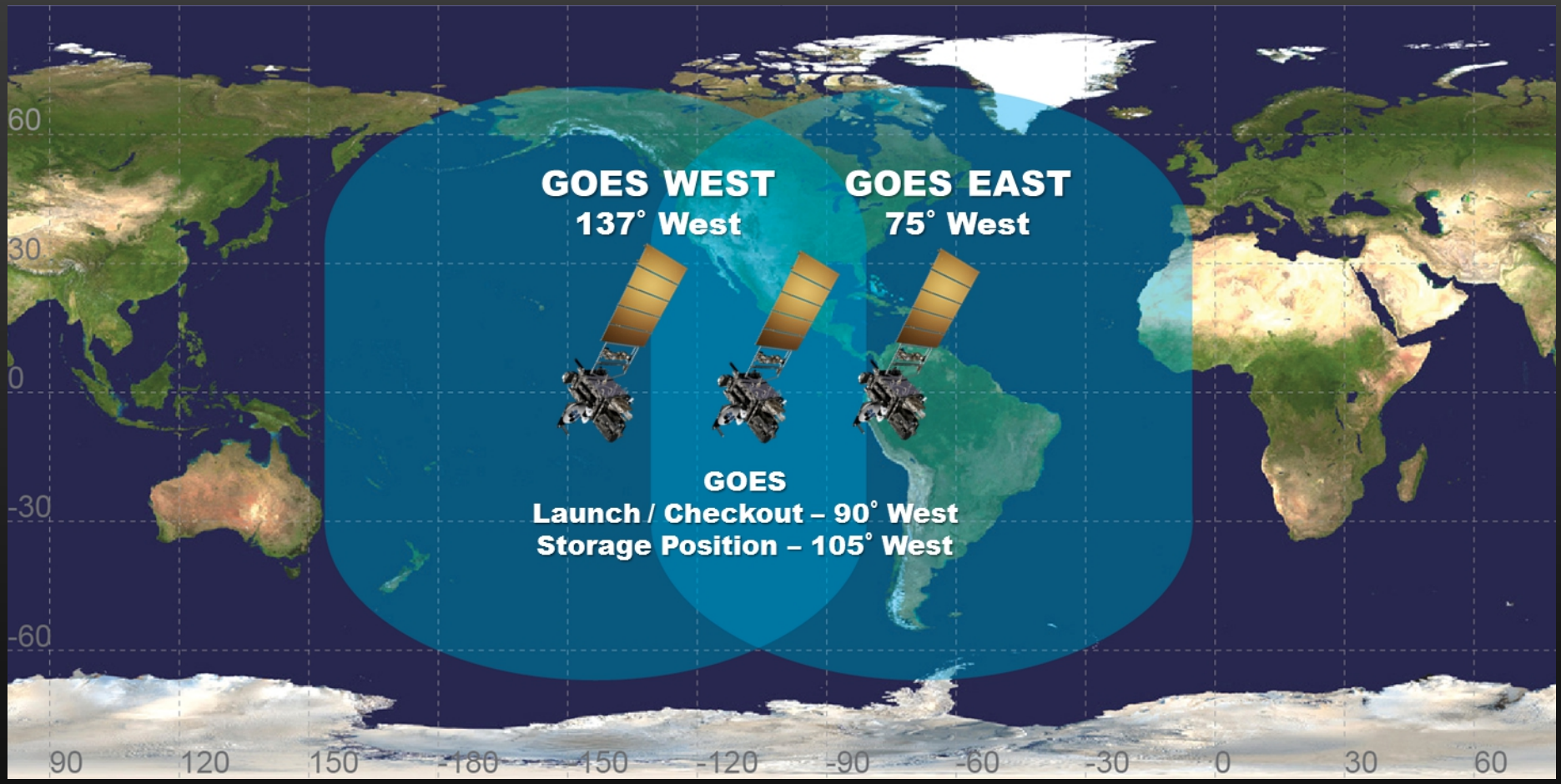
LRPT Offline decoder

Meteor M2 Image capture Requirements

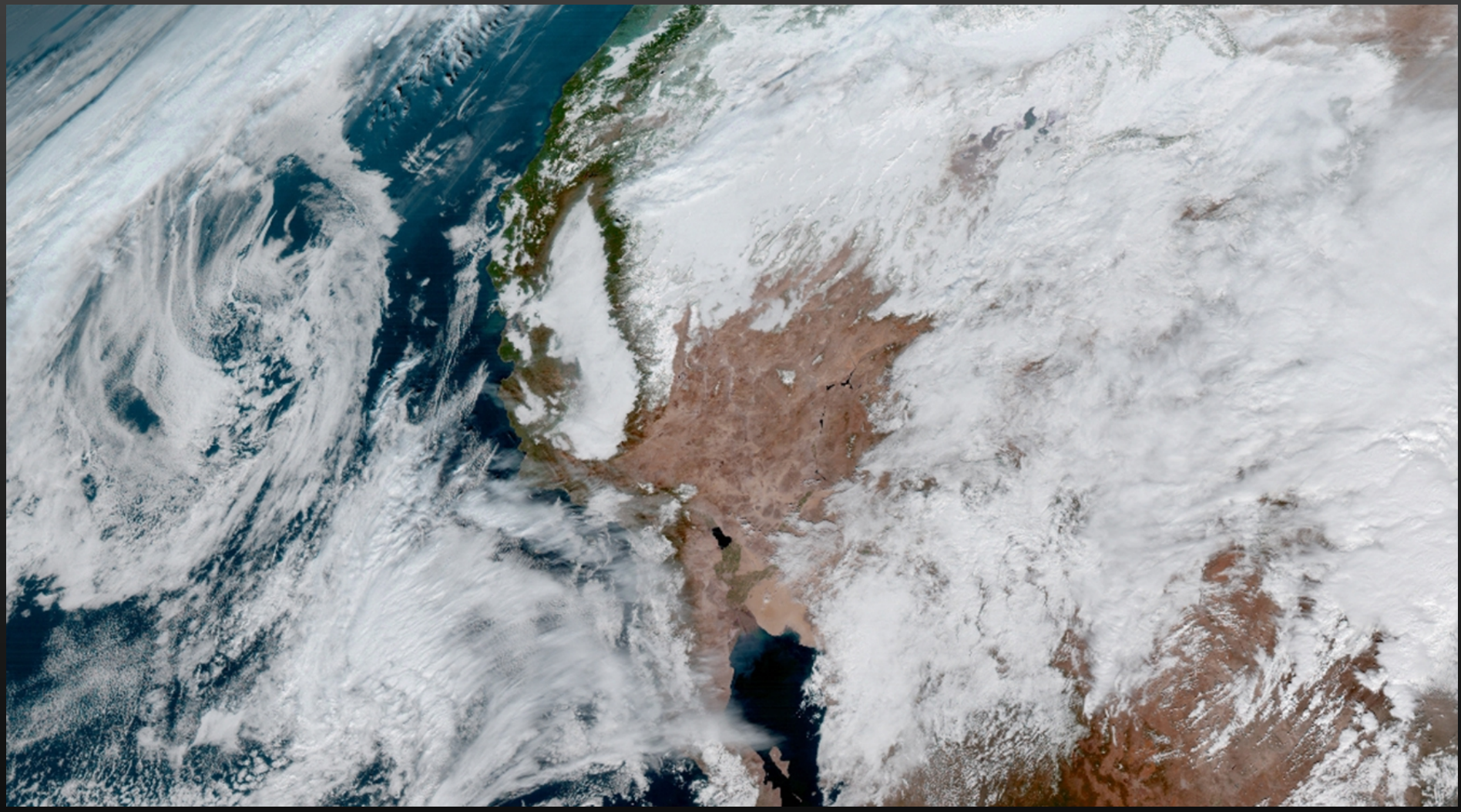
- All of the software interaction must be done in a series of steps after recording the images
- Audacity is used to resample the rate of image processing
- LRPTrx is used to demodulate the signal into a wav file that can be used to process the image
- The LRPT offline decoder is used to create the meteor images
- Smooth Meteor is used to make the image normal as it would look from space

GOES Images




GOES WEST
137˚ West
GOES EAST
75˚ West
GOES
Launch / Checkout – 90˚ West
Storage Position – 105˚ West
60
30
0
-30
-60
90
120
150
-180
-150
-120
-90
-60
-30
0
30
60


GOES-R Instruments
Solar Array
Extreme Ultraviolet and X-Ray
Irradiance Sensor (EXIS)
Solar Ultraviolet
Imager (SUVI)
Magnetometer
Geostationary
Lightning Mapper (GLM)
Advanced Baseline Imager (ABI)
NOAA / NASA



The quality and resolution of a GOES image is unsurpassed by any of the other LEO Weather Satellites

GOES Images

- Perhaps the most challenging images to capture because of the software / hardware combinations that are needed are the GOES images.
- Also digital in nature you will need a physical setup similar to the image below


ETHERNET

Goes Images

- What you're going to need for GOES image collection
  - A Dish antenna capable of recieivng in the 1.7 GHz range
  - SDR
  - LNA
  - Various N to SMA cables
  - Laptop
  - Software

Goes Images -Antenna

- The PremiertekANT-GRID-24DBI is being used at 1.694 GHz with the secondary reflector flipped. •This antenna is specified for operation from 2.4 to 2.483 GHz and the GOES HRITsignal is at 1.6941 GHz. The flipped secondary reflector helps with reception at 1.6941 GHz on this antenna.

XHRPT Ecosystem Primer

USA Satcom™
@usa_satcom

Tracking Options

- UltraTrack [usa-satcom]
- Orbitron [stoff.pl]
- WxTrack [satsignal.eu]
- Hand Tracking (skill and art)

DDE w/Doppler — DDE — DDE

Streamers

- RSP TCP[2] [sdrplay.com] — USB — IQ TCP
- SpyServer[1] [airspy.com] — USB — IQ TCP
- RSP Streamer X[2] [usa-satcom] — USB — IQ UDP
- USRP Streamer[3] [usa-satcom] — UDP USB — IQ UDP

Radio Options

SDRplay · AIRSPY · SDRplay · Ettus Research™ (A National Instruments Brand) UHD

SDR supported by GRC (with >= 6 MSPS)

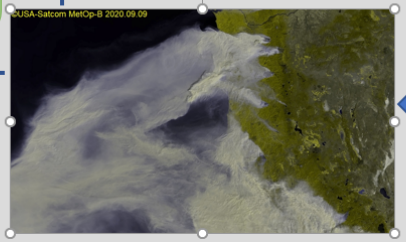
Demodulation / Decoding

- GNURadio (THE FREE & OPEN SOFTWARE RADIO ECOSYSTEM) — UDP USB — .demod
- XHRPT Decoder[4] [usa-satcom] — real-time — .demod — offline
- XHRPT Standalone Decoder (XSD)[5] [usa-satcom]

Image Processing

- MetFy3x.exe [sat.cc.ua] — .hpt, .dat, .c10
- HRPT Reader [satsignal.eu]
- HRPT [github.com[6]]

.bin · .raw16 · .bin · .bin · .raw16 · .bin



[1] *R2 and MINI (10 or 6 MSPS)*
[2] *Any SDRplay SDR (6 or 10 MSPS)*
[3] *USRP2 and later (6 or 10 MSPS)*
[4] *Supports NOAA-15/18/19, MetOp-A/B/C and FengYun-3A/B/C*
[5] *Supports MetOp-A/B/C and FengYun-3A/B/C*
[6] *github.com/rocketscientist-fred/weathersat*

Goes Images

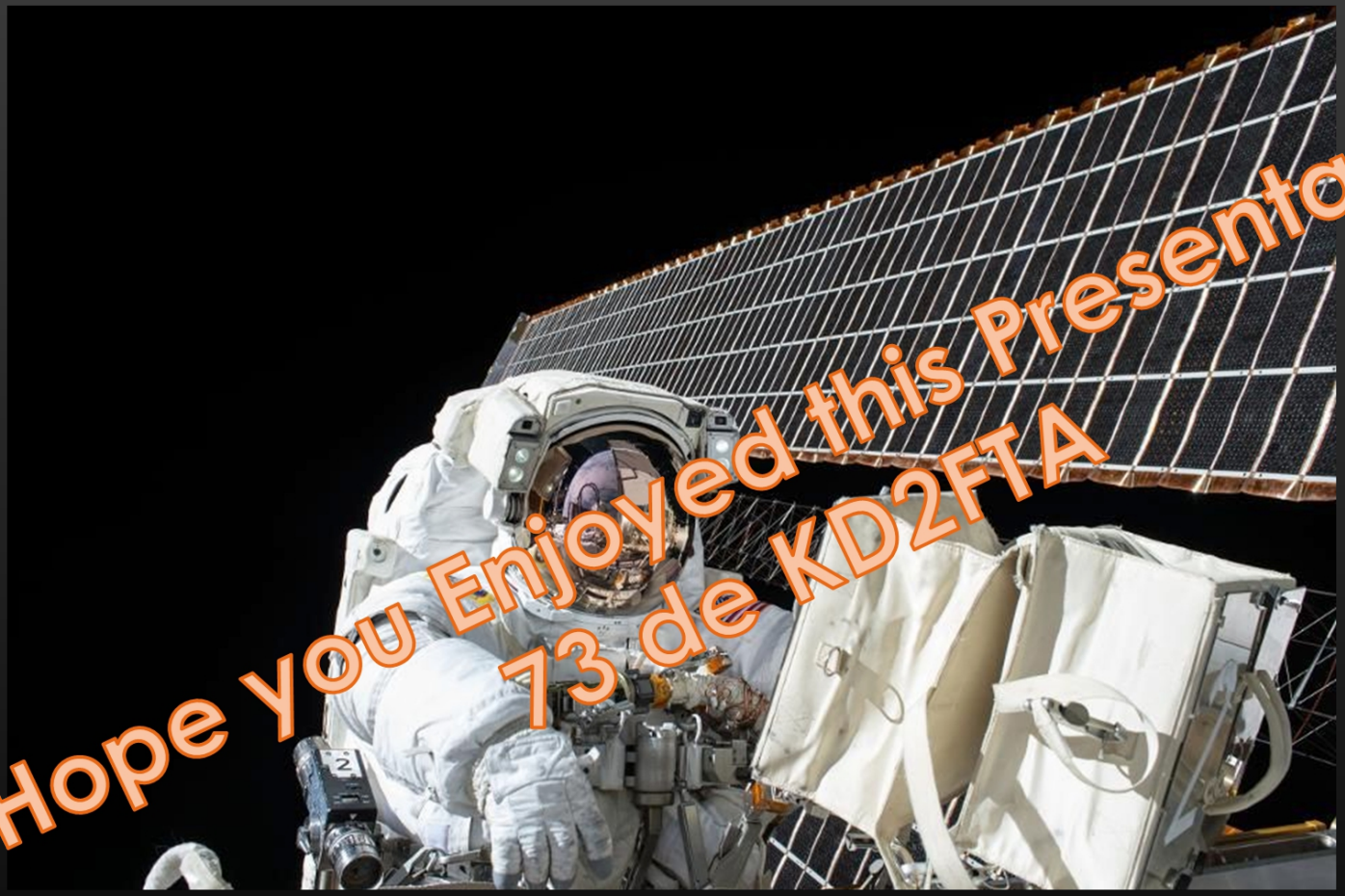
- Software
- Software is required to interface with the SDR, stream the data to a demodulator, the ingestor, finally to a file manager to create the final images. We created a batch file to maintain the folders as the package can fill a drive with high resolution images in less than a week.
- The 3 software packages are:
- •rsp_streamer,
- •xrit_decoder(which include ingestor), and
- •xrit_file_manager.

The Software package is available by contacting Joe at the the following link:

- https://usa-satcom.com/contact_form/

CONCLUSION

- Weather satellite images can be received and downloaded using common VHF HAM geat
- Antennas make the difference in image quality
- APT/LRPT/HPRT images can alos be received using SDR radios
- FM noise filters and LNAs help with the NOAA Satellites
- The Russian Meteor satellite requires a little more software sophistication but generally uses the same radio and antenna gear that is used with the NOAA birds
- The sharpest and highest resolution images can be gathered from the geosynchronous GOES satellites
- These require special antennas, SDR, LNAs, and software which is generally specifically made for the XHRPT environment


Hope YOU Enjoyed this Presentation
73 de KD2FTA