



Amateur Optical and Radio Based Satellite Tracking

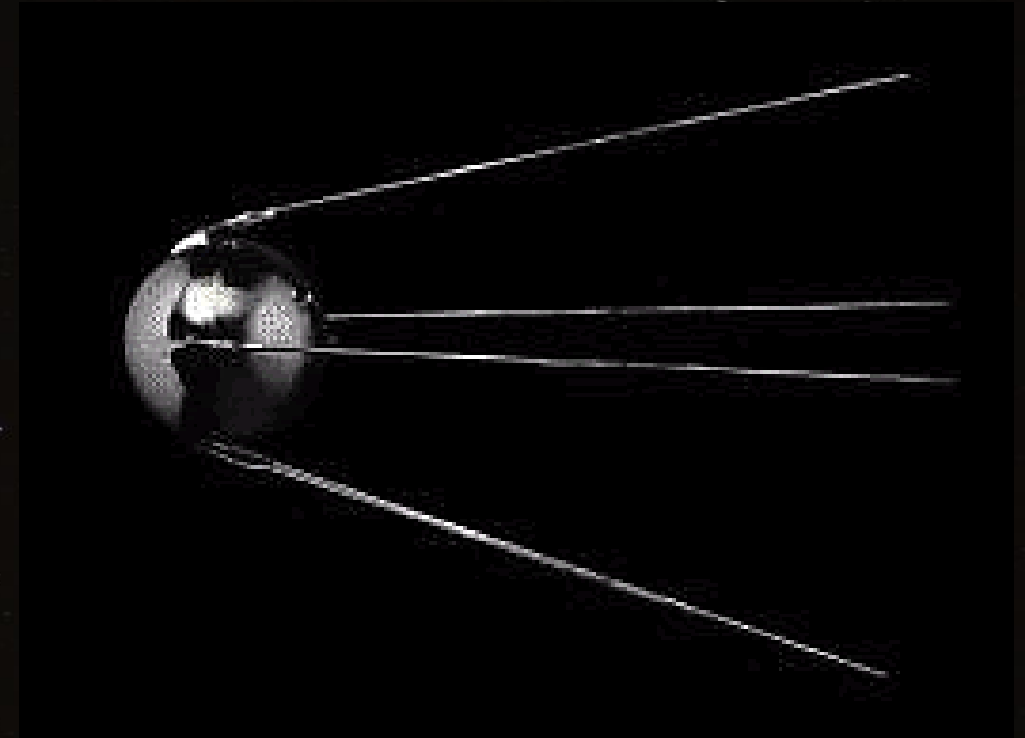
BY SCOTT TILLEY



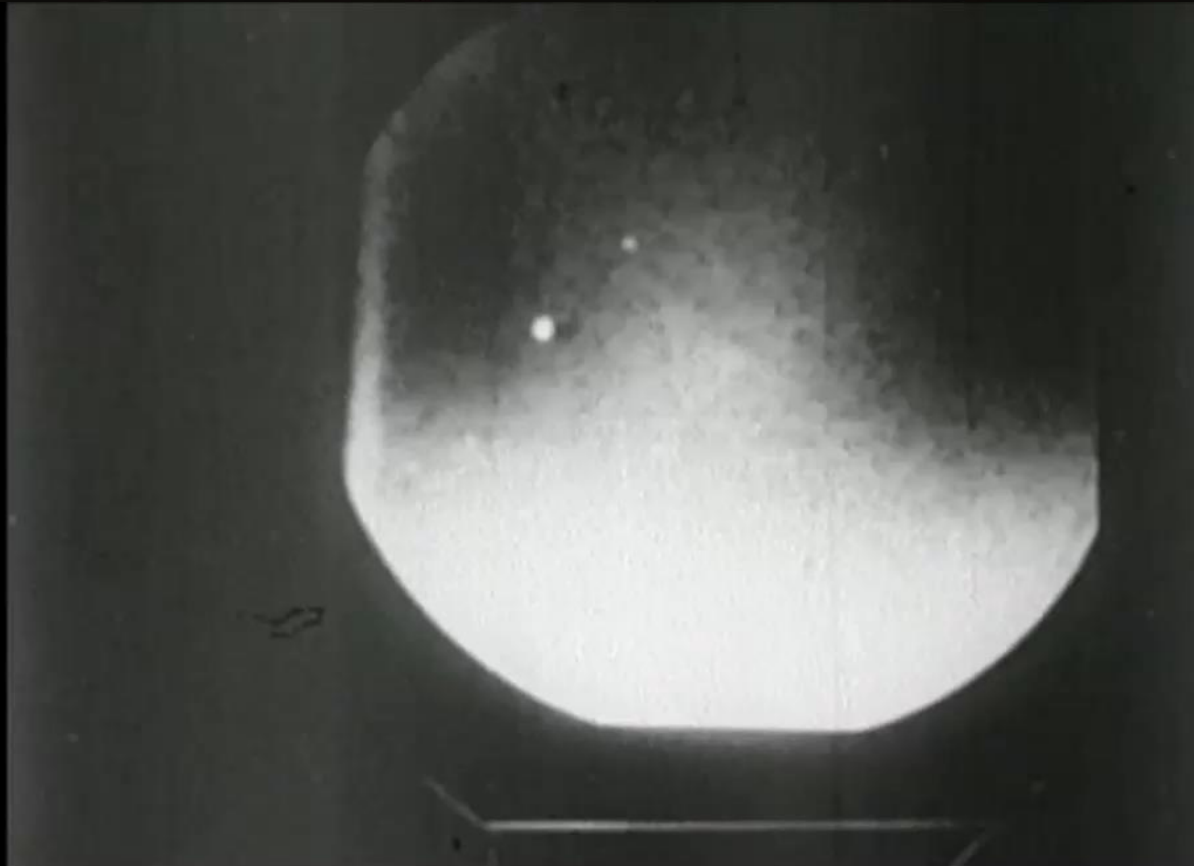
Dawn of the Space Age

Amateurs looking up

Radio based Satellite Tracking begins with Sputnik 1



Sputnik 1's Rocket Booster Tracked with Video



Bright star is Alkaid in handle of Big Dipper, mag 1.8

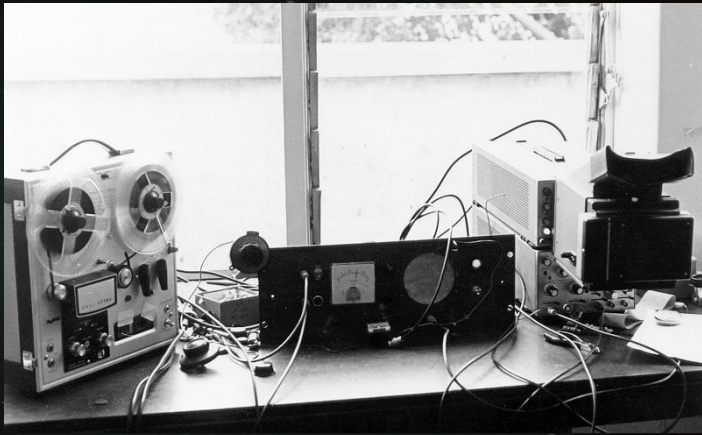
10:17:29 UTC



Tracking Project GEMINI in 1966



Early Amateur APT Station



S-Band Tracking in the 1970s





Leveling the Playing Field

Why amateurs look up

Transparency in the use of Space

1967

Outer Space Treaty

- Peaceful use of Space
- No weapons of mass destruction allowed
- Celestial bodies free from appropriation by claim of sovereignty

1976

Registration Convention

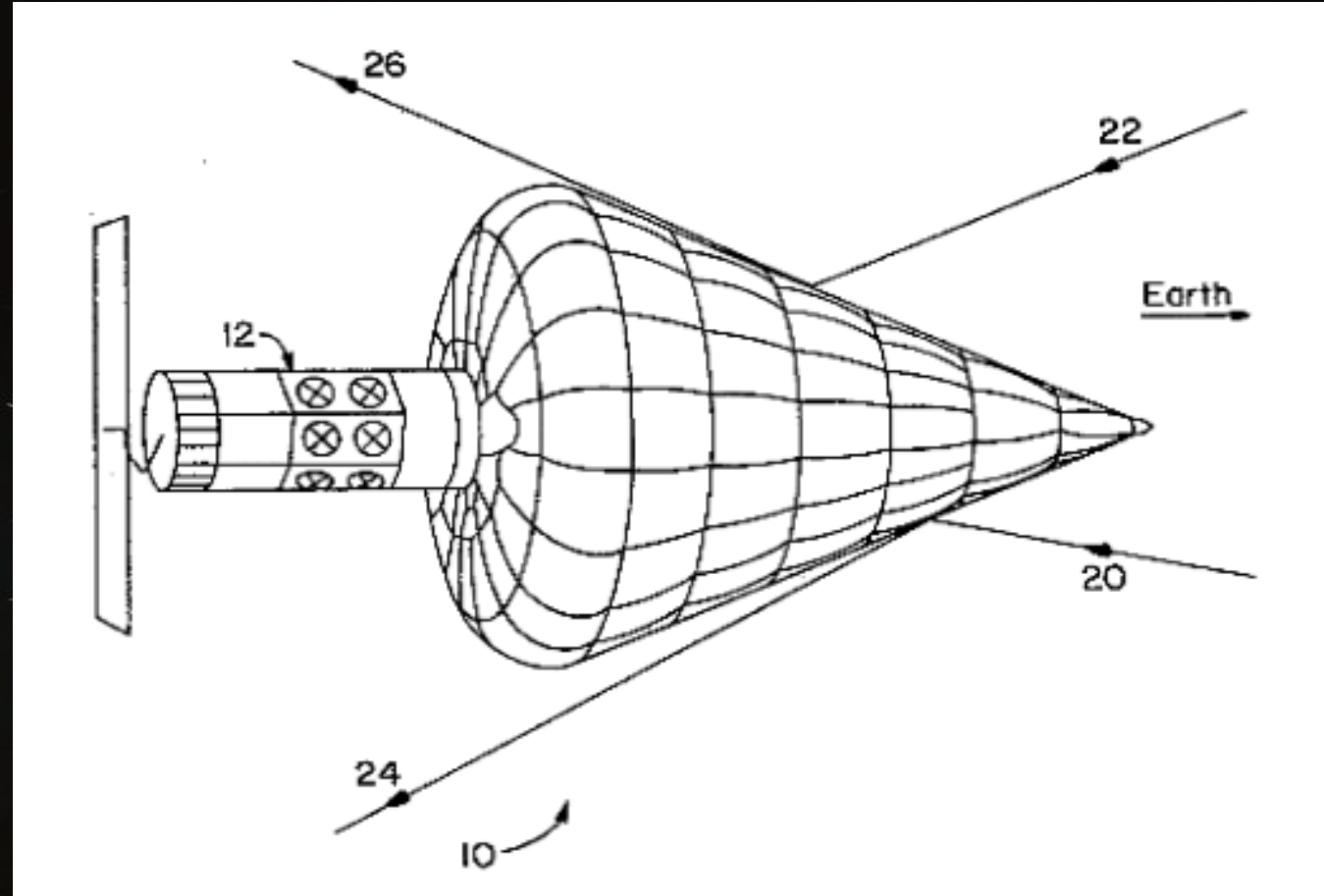
- Signatories shall report what they put into space to ensure transparency
- Basic orbital information required
- Purpose of object required

1984

US Classifies Military Satellite Orbits

- The USA stops reporting orbital information for US and allied military missions
- Registration with UN of missions often incorrect or misleading for military missions
- Amateurs begin monitoring military missions with more interest

The Cases of USA-53 and USA-144 'MISTY'



A PROWLER found in Orbit...





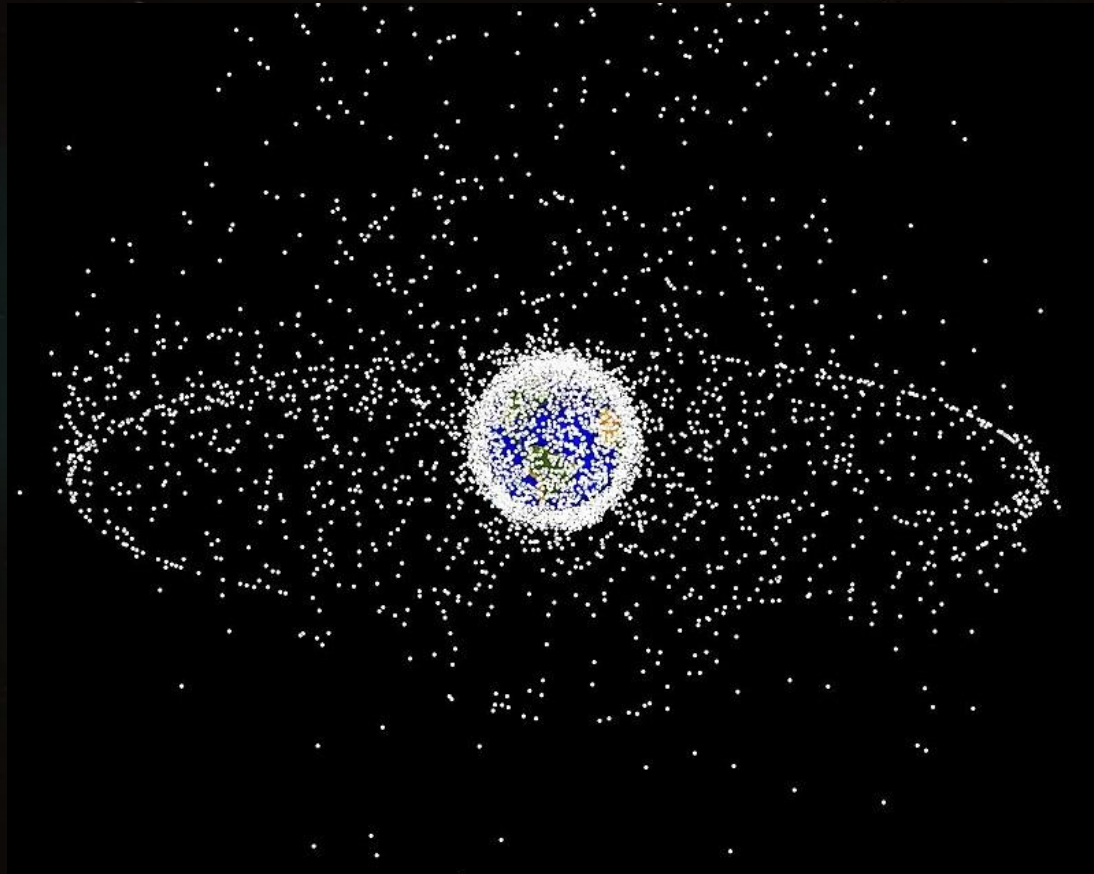
Amateur Tracking Techniques Evolve

From simple techniques to state of the art

Space has become a busy place...

Thousands of Objects in Orbit...

Computers allow us to see the forest for the trees...

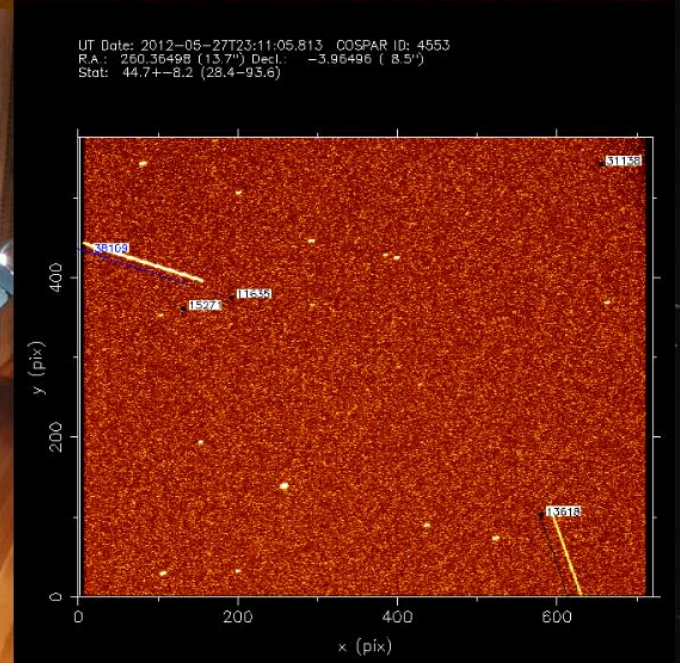
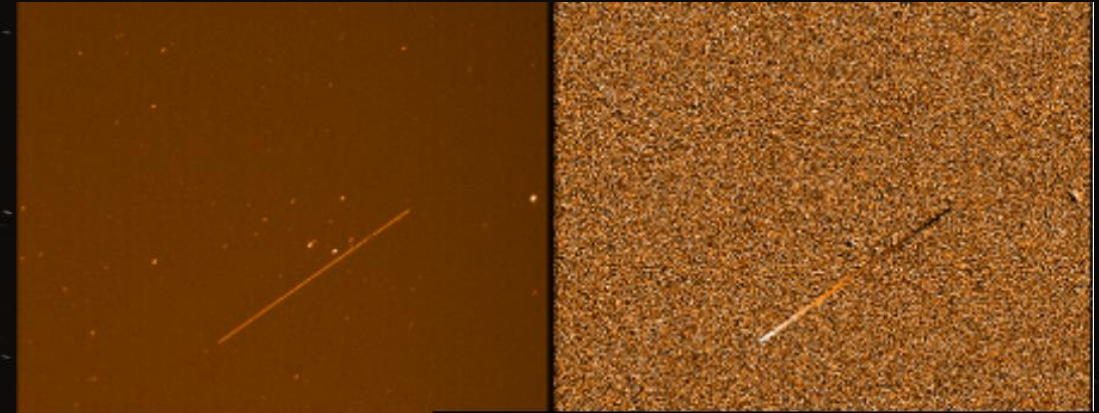


Optical Tracking Techniques

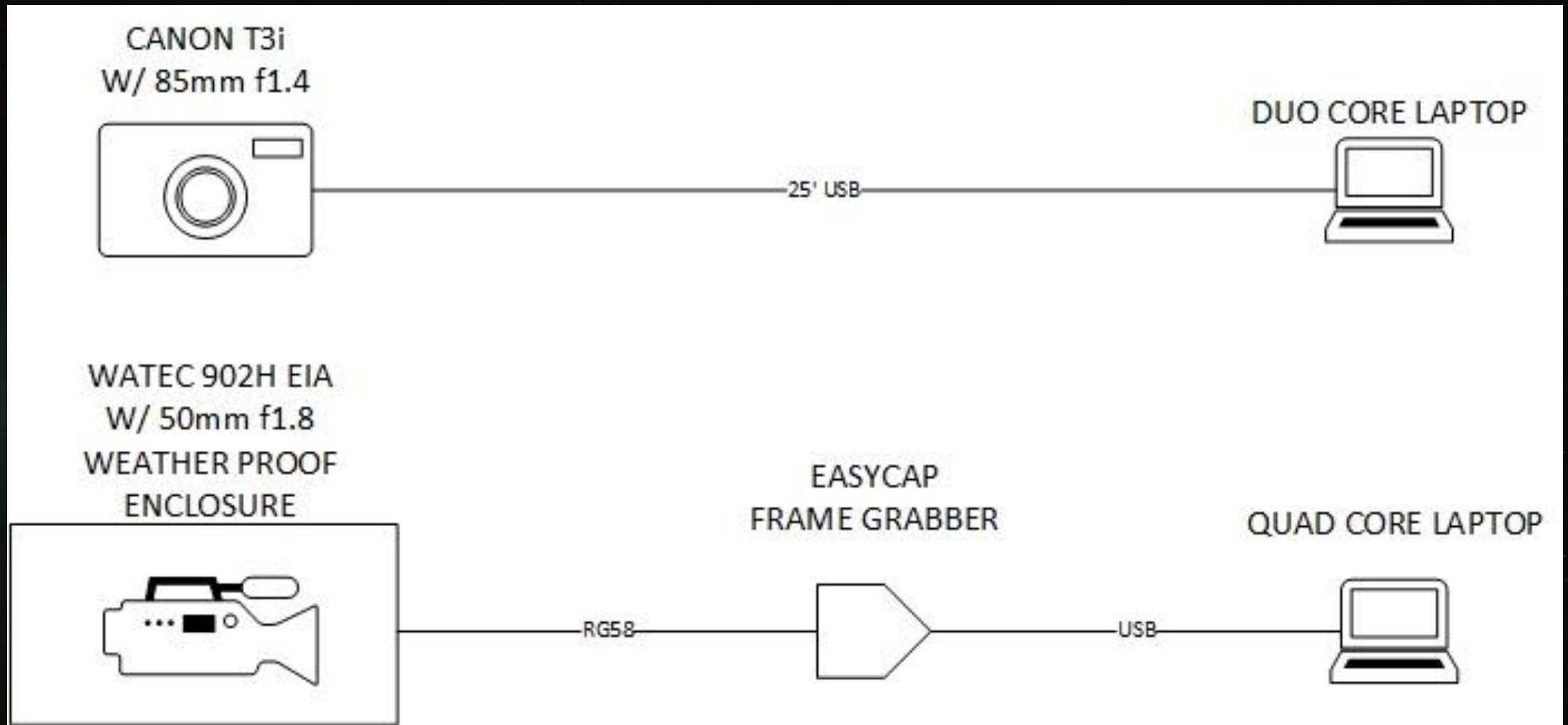
Binoculars and Stopwatch



Video and Computer



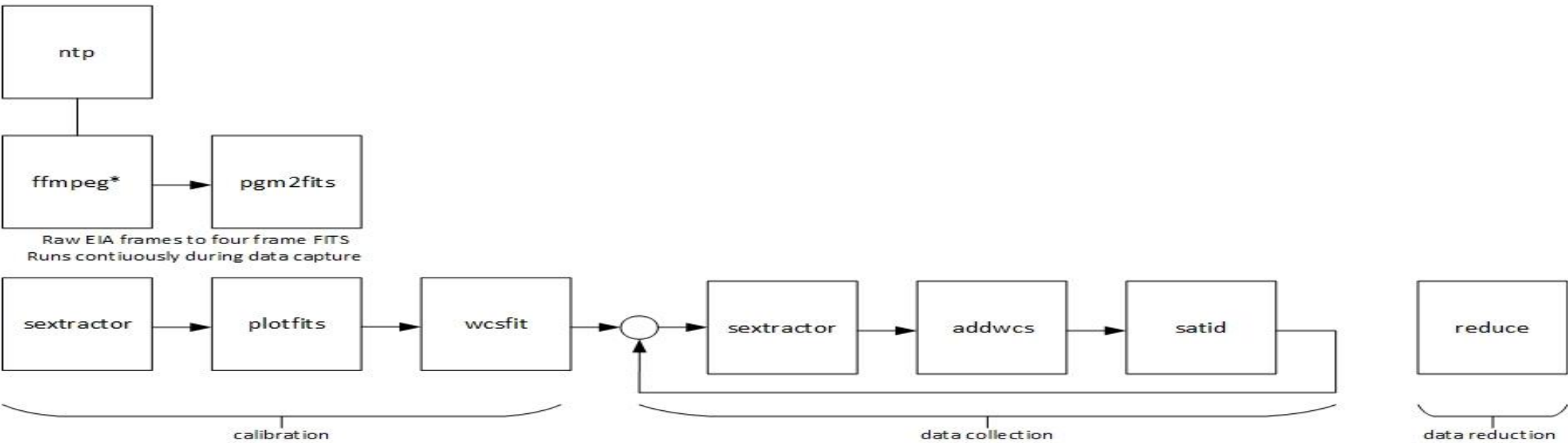
Imaging System Layout



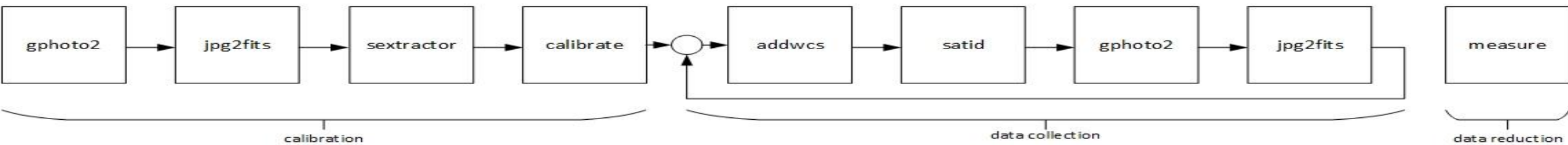
SATTOOLS

SATTOOLS VIDEO AND STILL SOFTWARE TOOLS

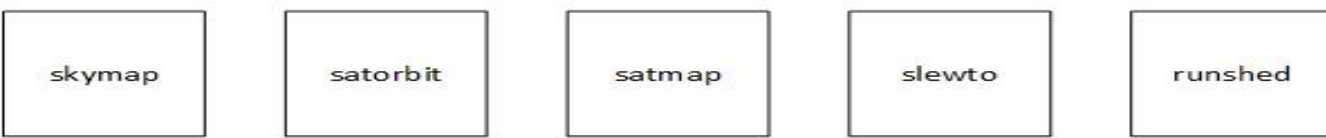
REALTIME VIDEO DATA COLLECTION



REALTIME STILL DATA COLLECTION

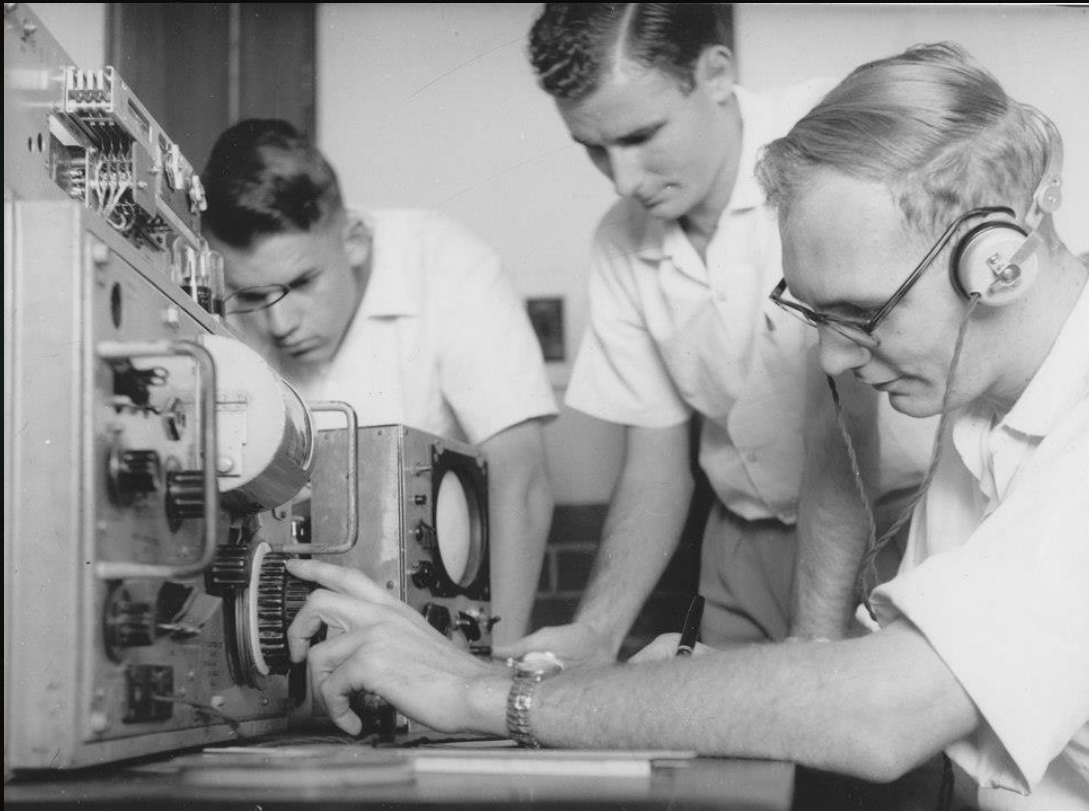


MAJOR ANALYSIS AND MOUNT CONTROL TOOLS

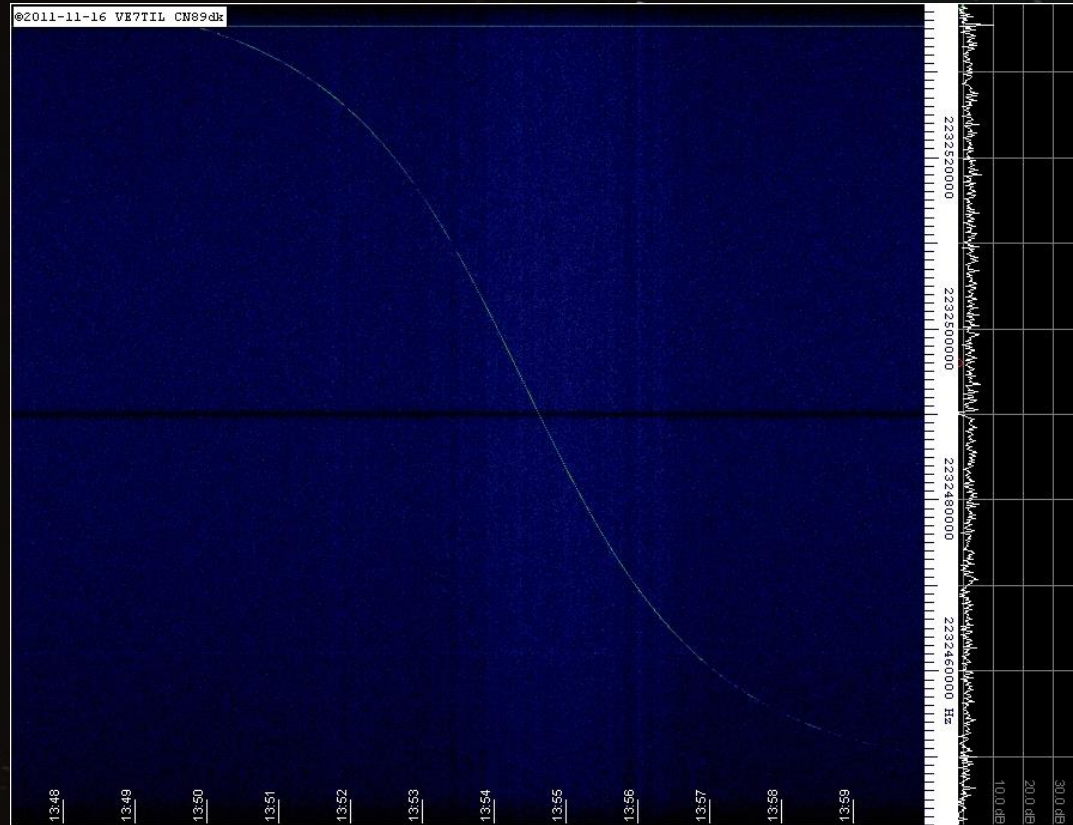


Radio Tracking Techniques

Listening to Audio



Recording of Doppler Data

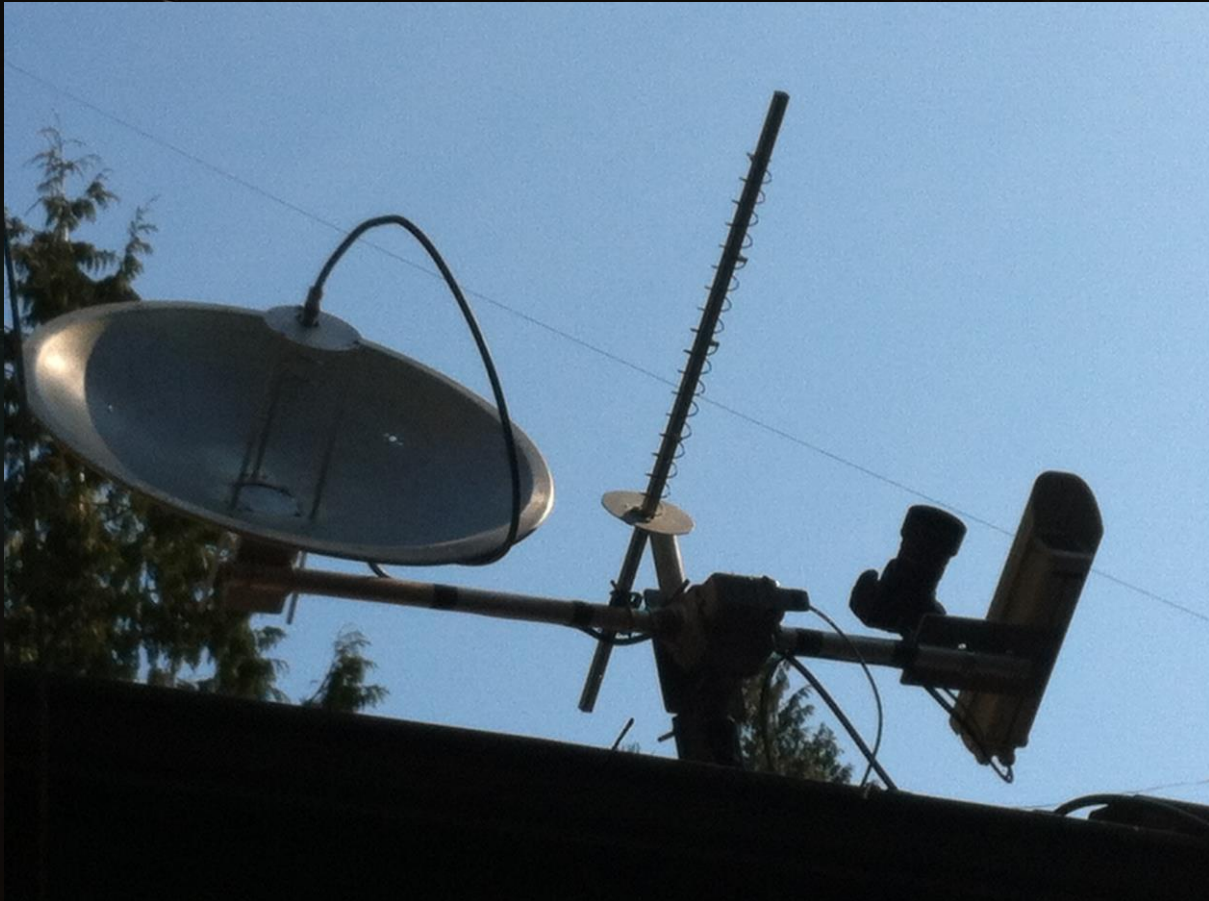


Optical and Radio Tracking Unit

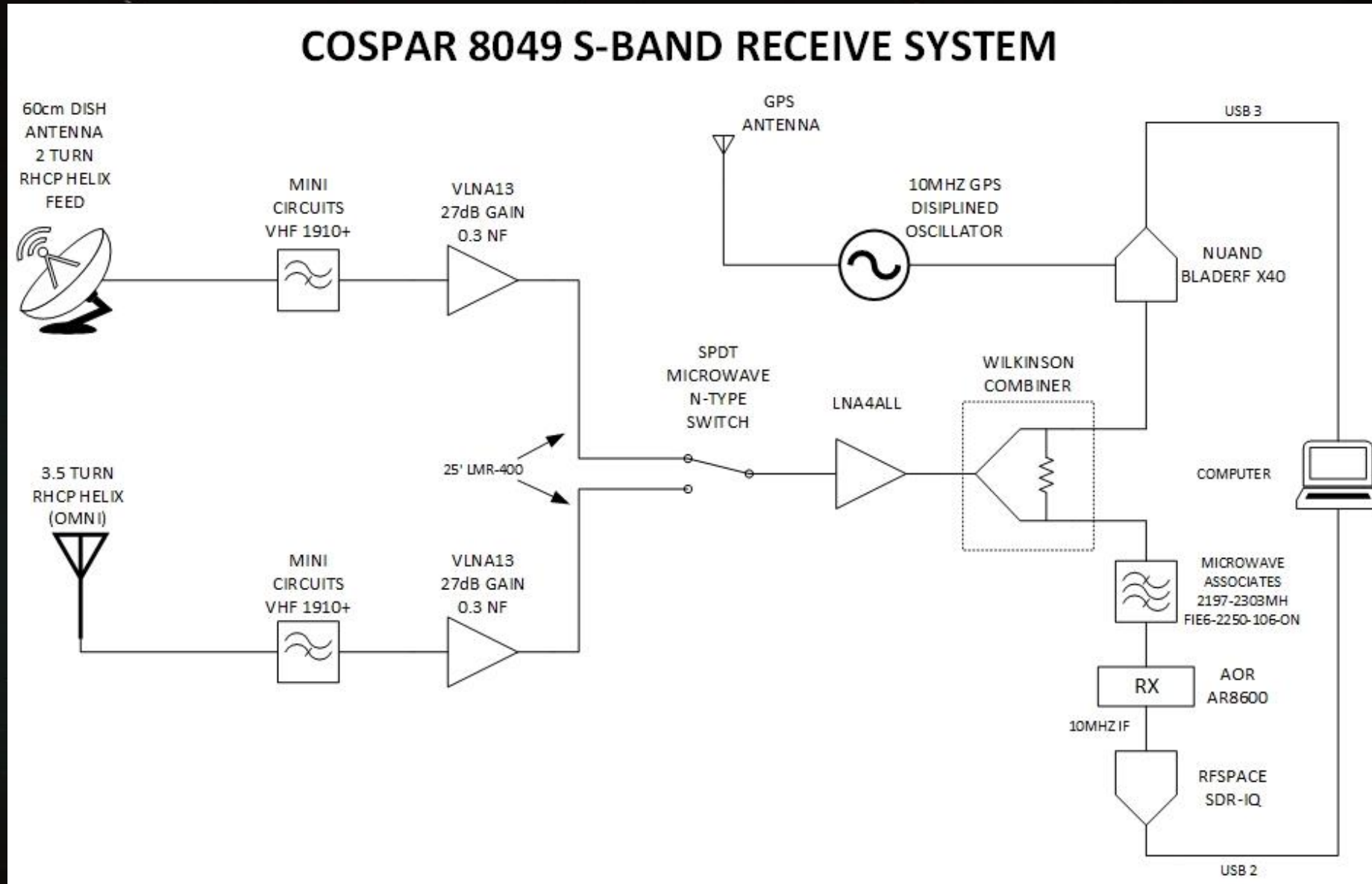


Optical/Radio Tracking Rig

S-Band Search Antenna



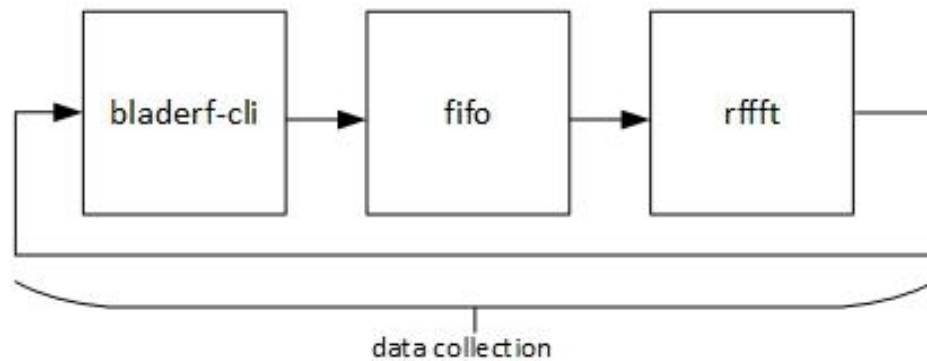
S-Band System Diagram



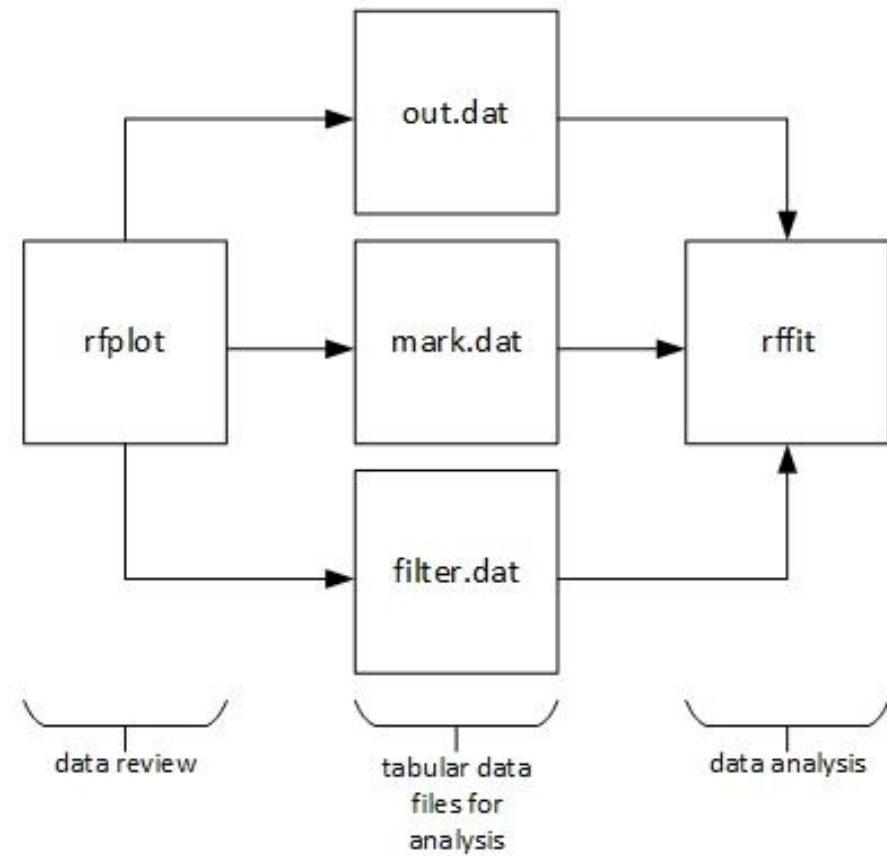
STRF (SATTOOLS RF)

STRF SOFTWARE TOOLS

RF DATA COLLECTION



RF DATA REVIEW AND ANALYSIS





Optical and Radio Tracking Unite...

The story of GSSAP 3 & 4

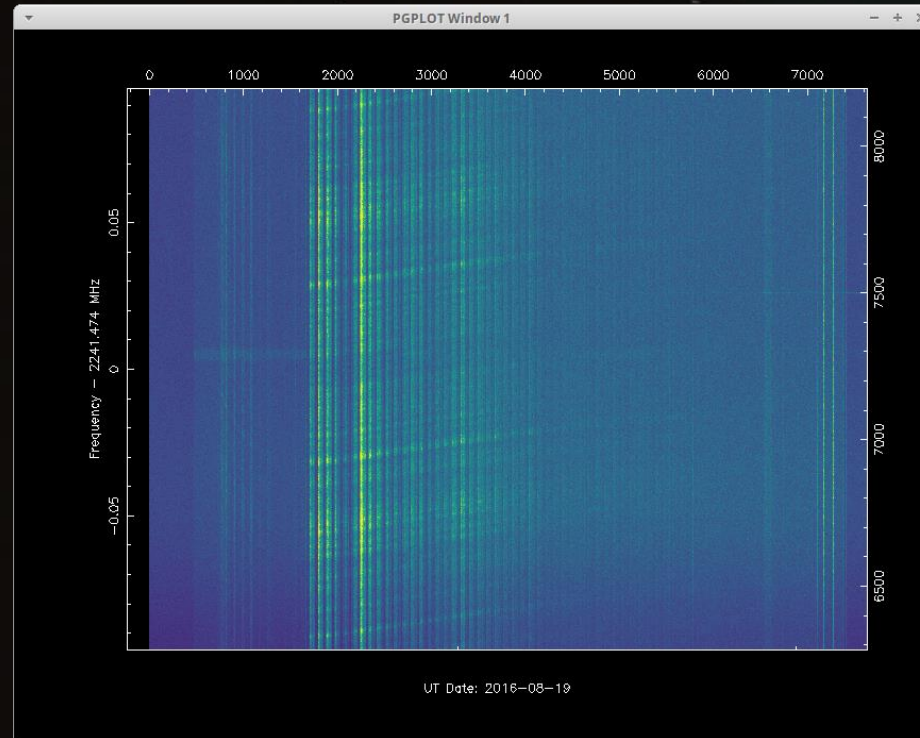
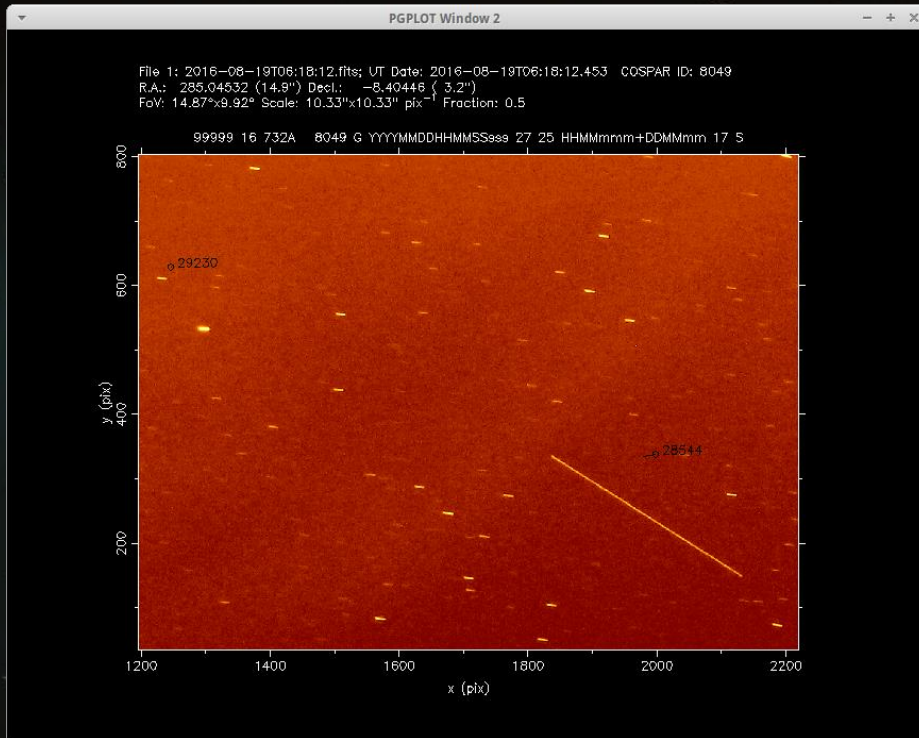
AFSFC-6 Launches...



GSSAP Stack Captured Optically and by Radio

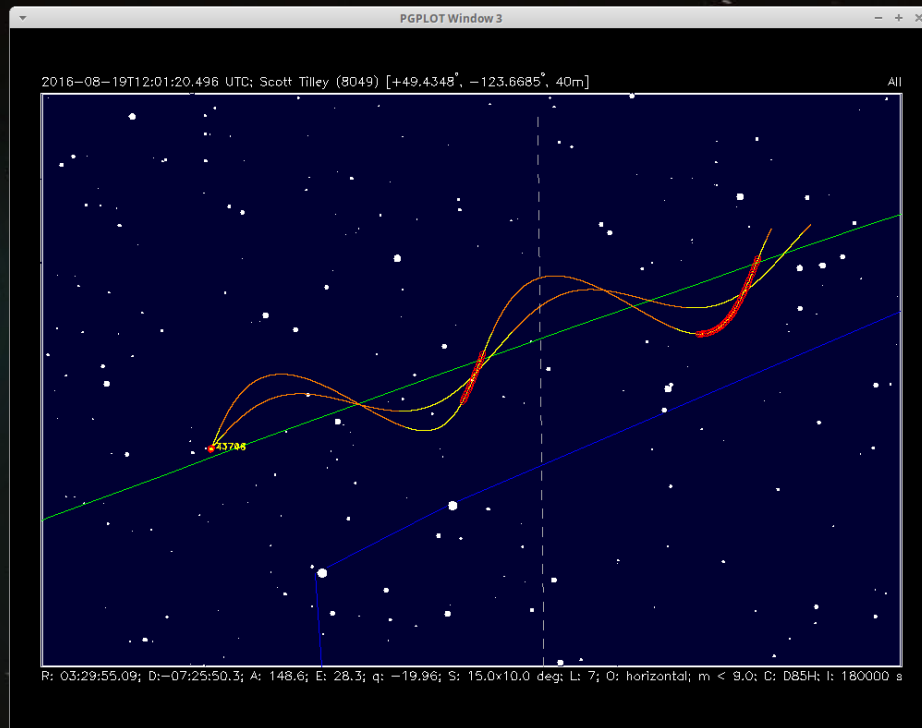
GSSAP 3&4 stack low pass

Delta IV upper Stage
Beacon from same low pass

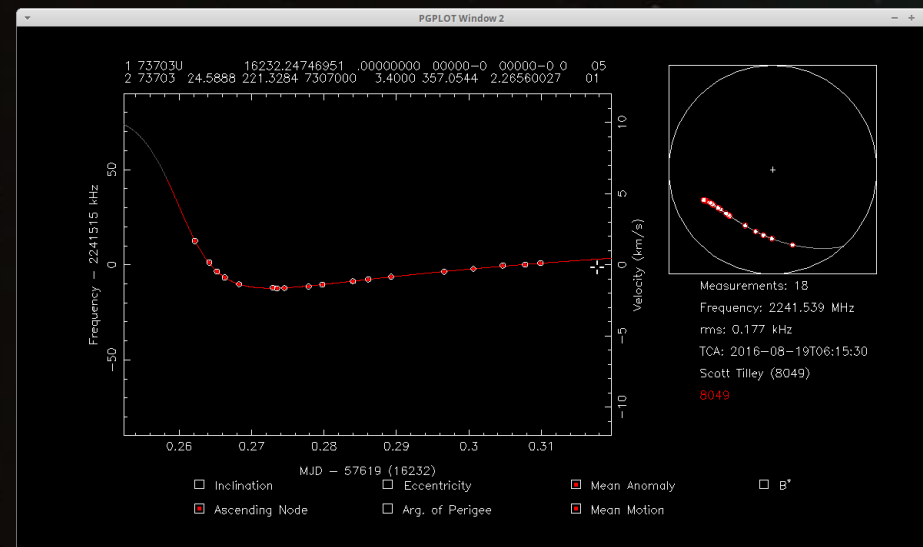


Arrival in GEO Predicted

Optical Fit produces Orbital Element Refinement



Doppler Fit Refines Trajectory

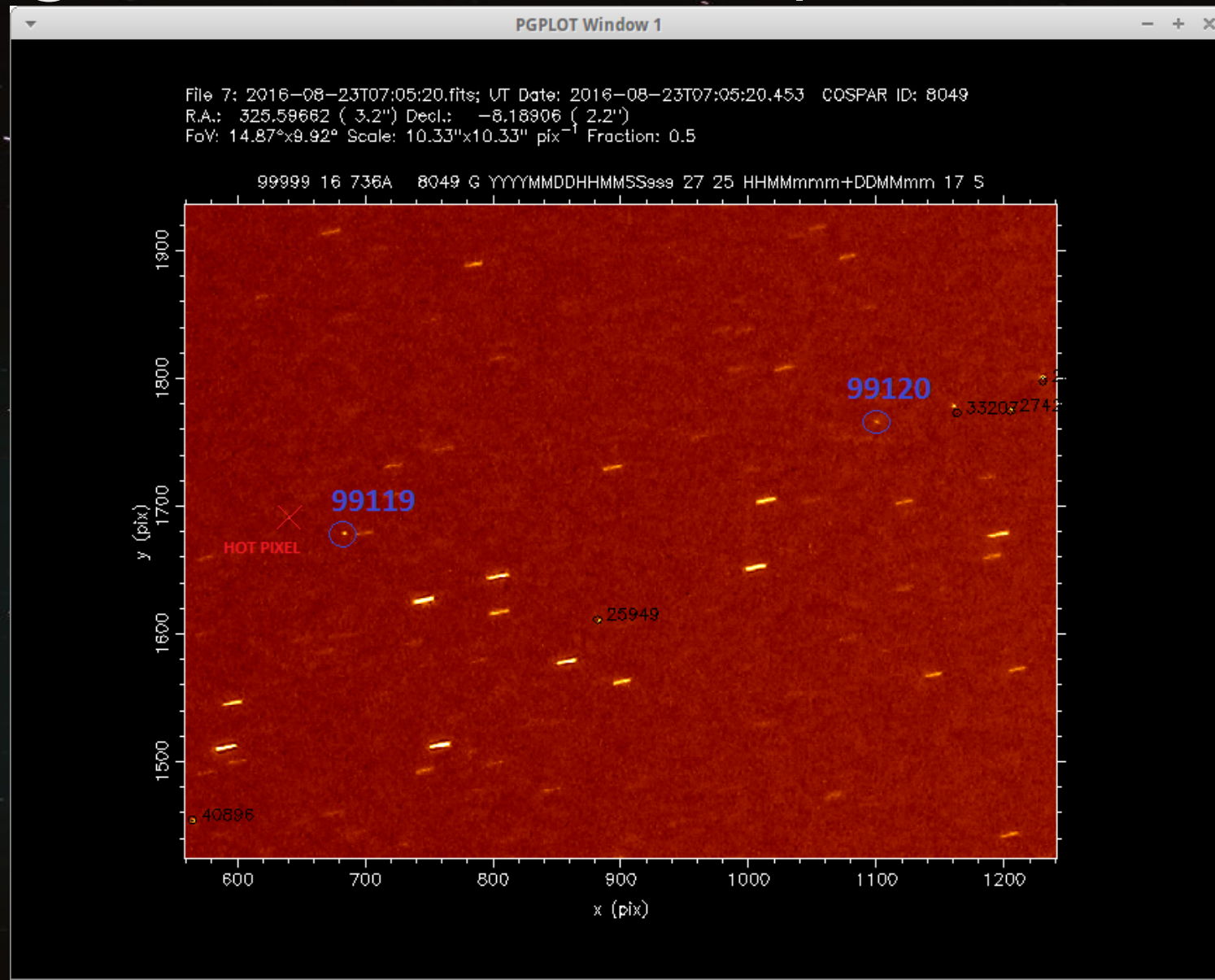


GSSAP 3 & 4 Arrive in GEO Orbit!

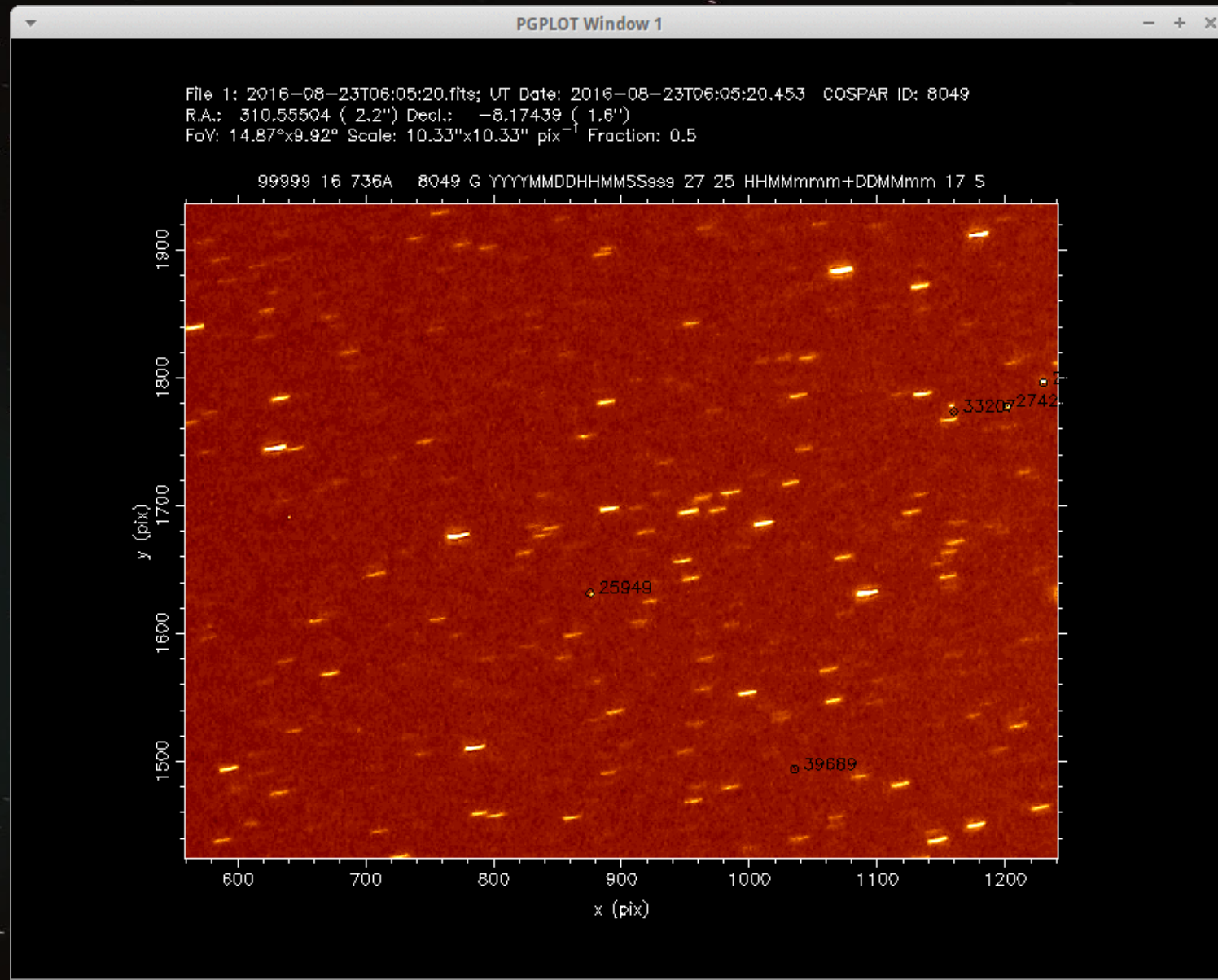


Delta 4/AFSPC 6 Circularization by Scott Tilley 2016-08-19T10:42:31

Locating GSSAP 3 & 4 Payloads



Location of GSSAP 3 & 4



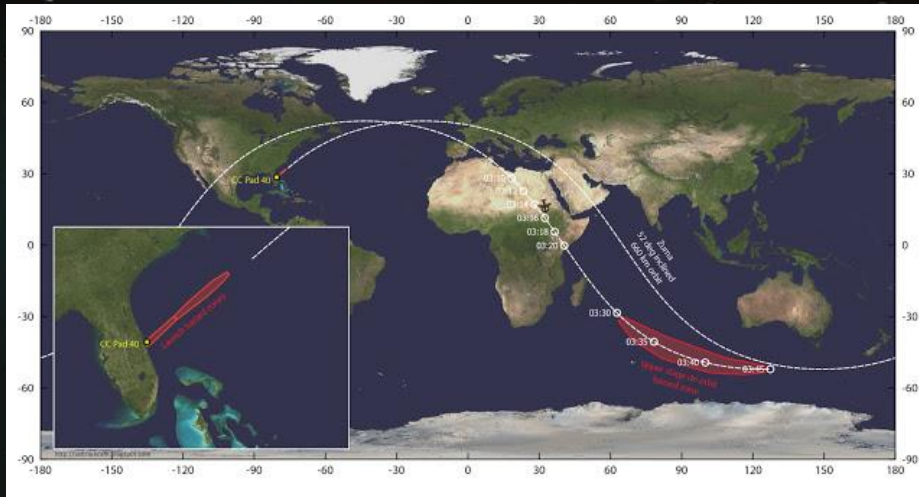


The Search for ZUMA...

The recovery of IMAGE

ZUMA Gone ALMOST without a Trace...

NOTAMs give insight into Possible Orbit



Pilot over Sudan catches fuel vent of second stage...

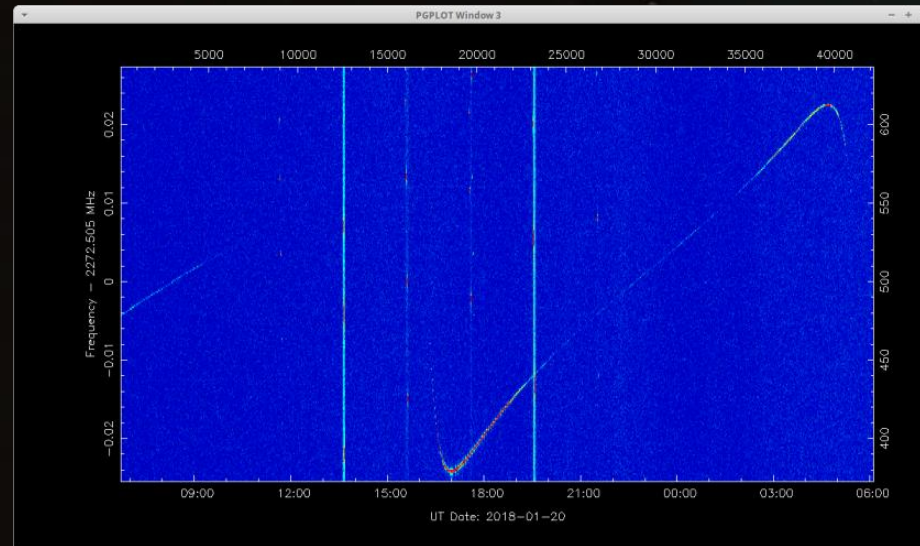


28MHz at a Time...

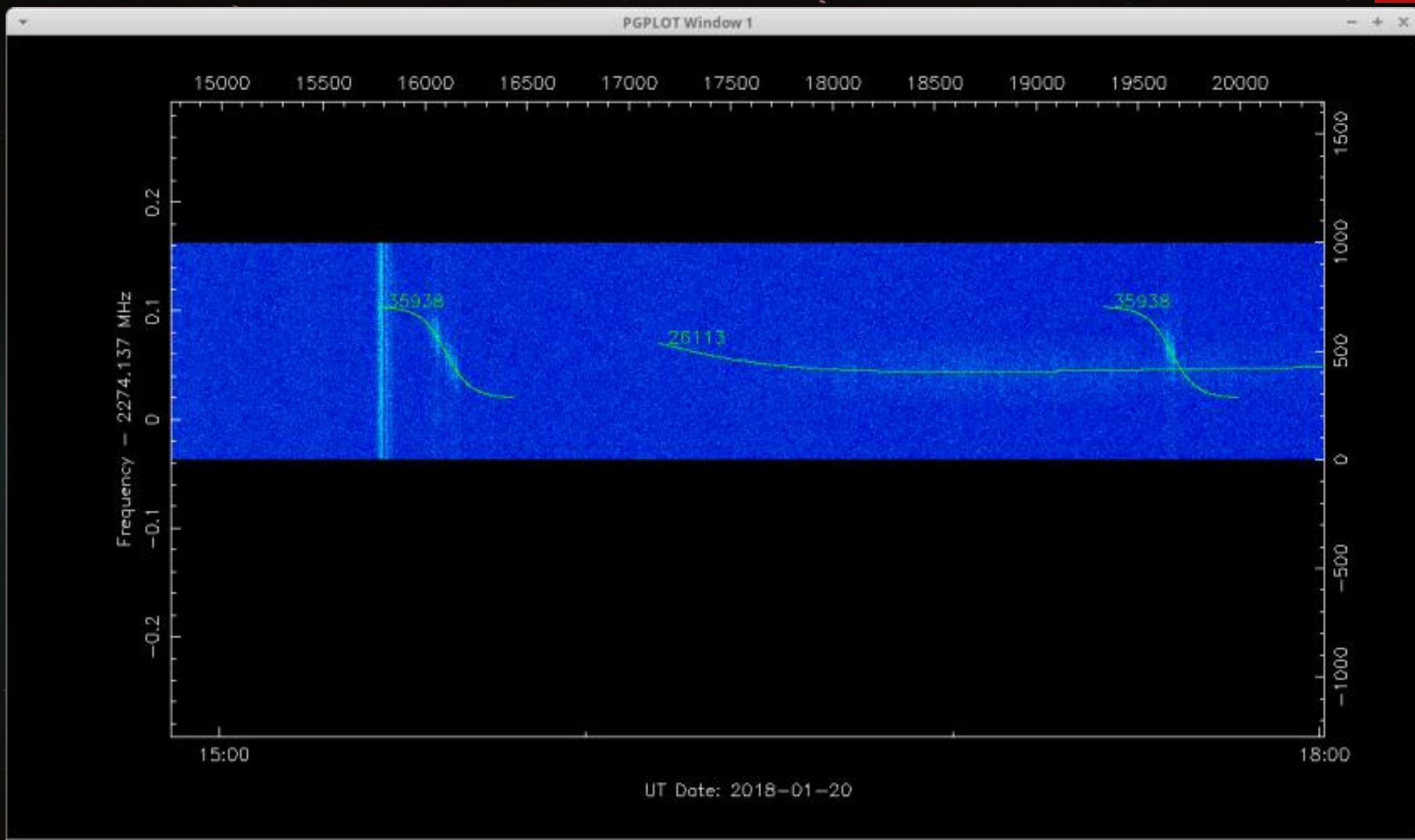
SDR BladeRF



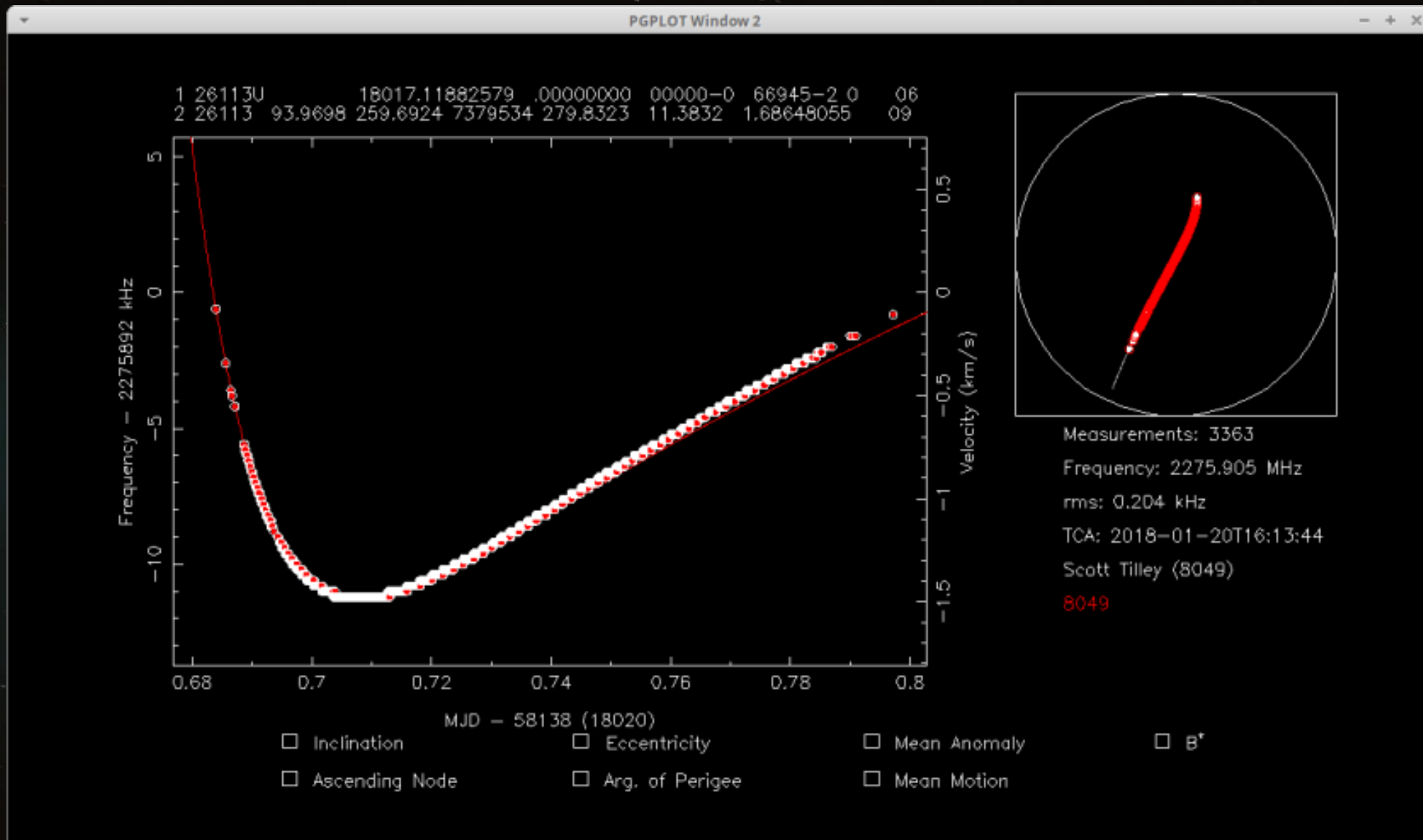
Sattools RF



Hey that's not ZUMA!



That's IMAGE!



Studying IMAGE's Signal

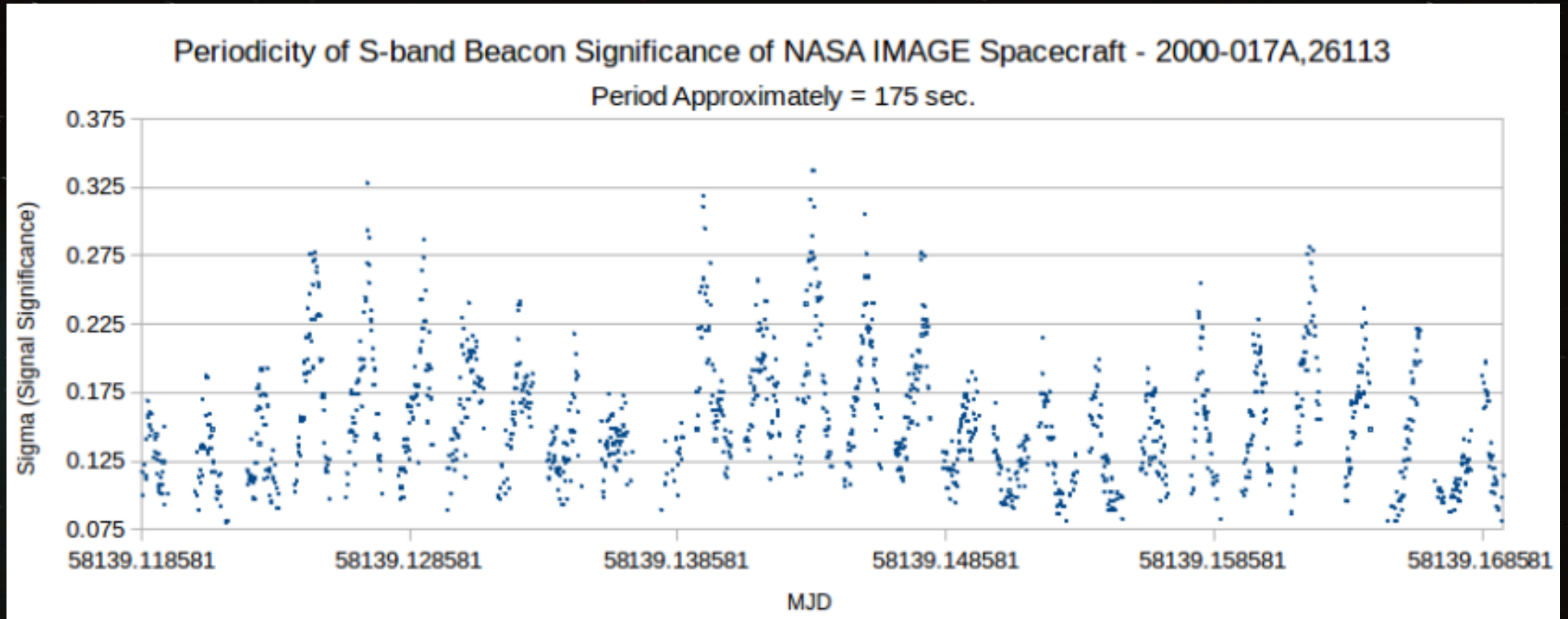
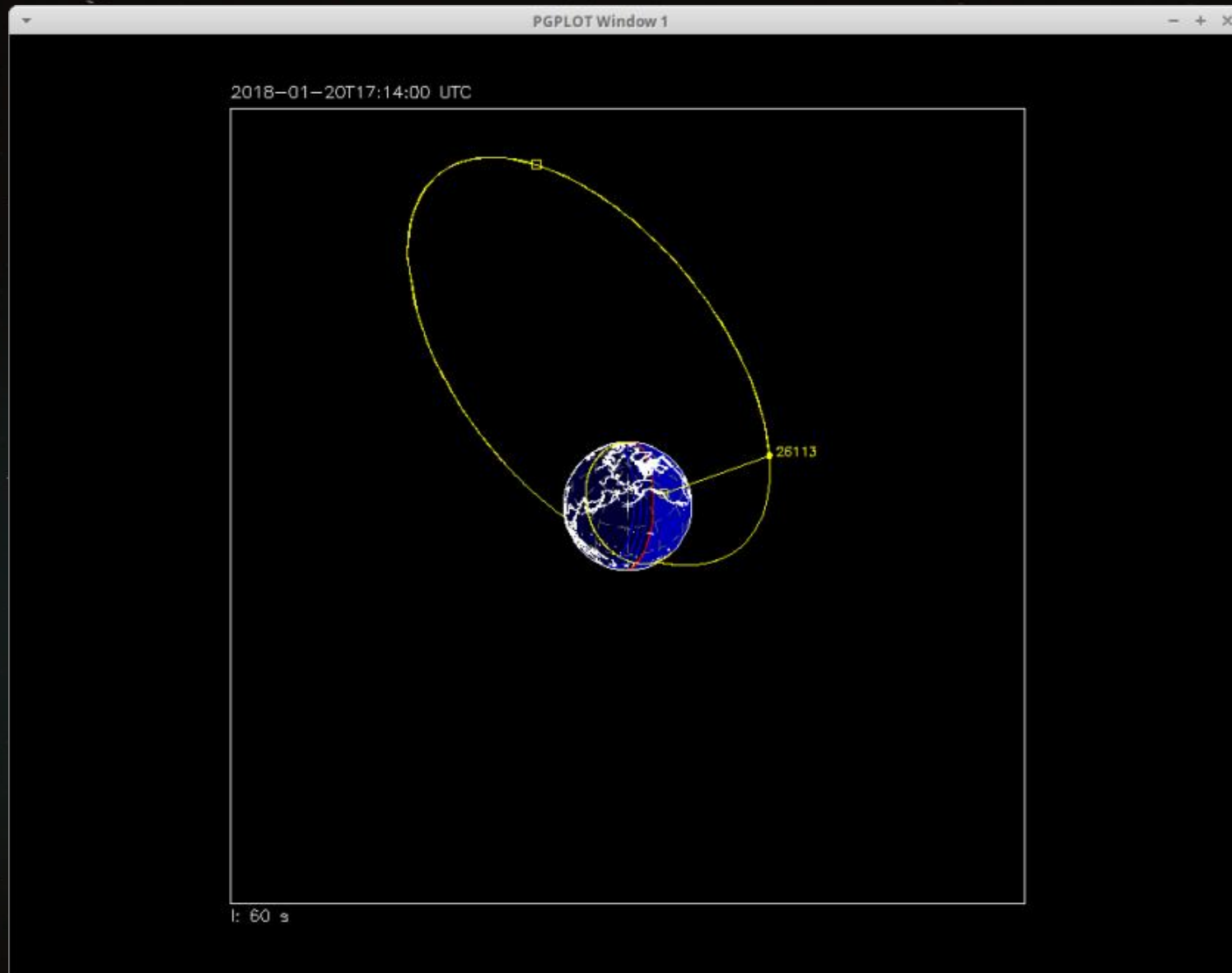


IMAGE not lost just lonely...



A kind gesture...

Scott,

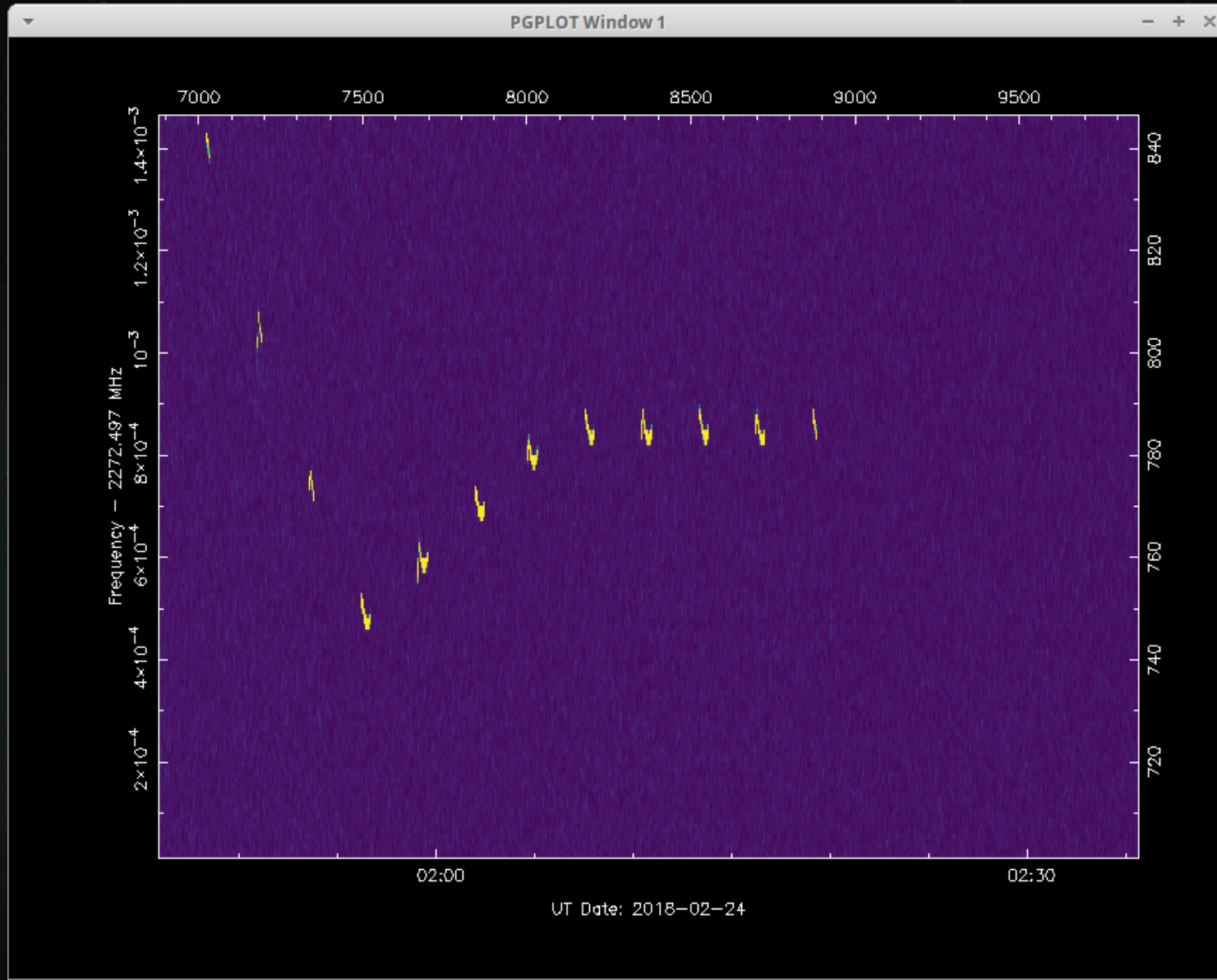
I wanted you to have this small memento.

Best regards,

Jim



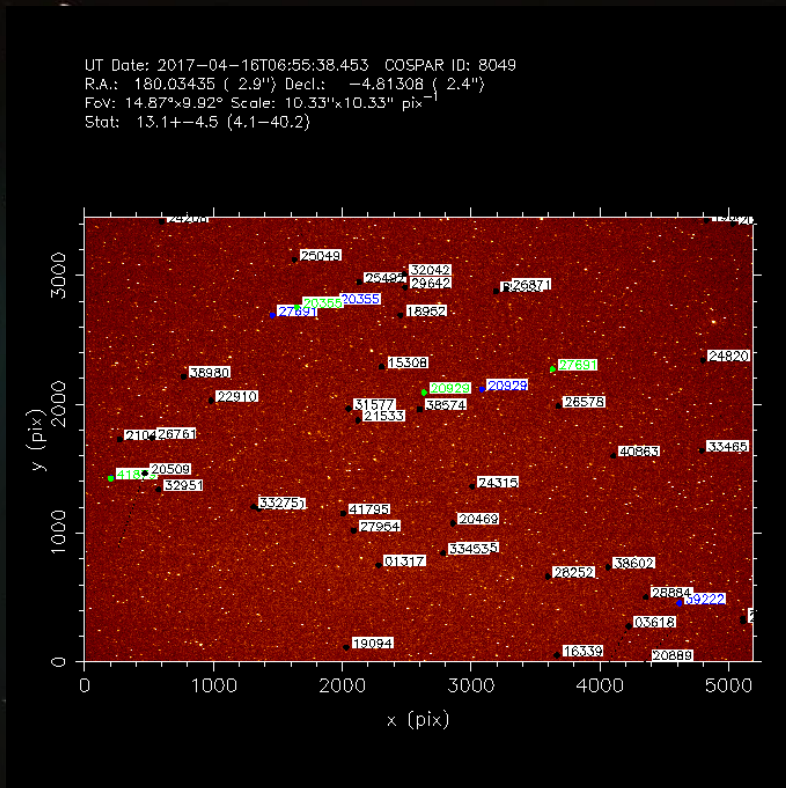
Not a Hollywood Ending?



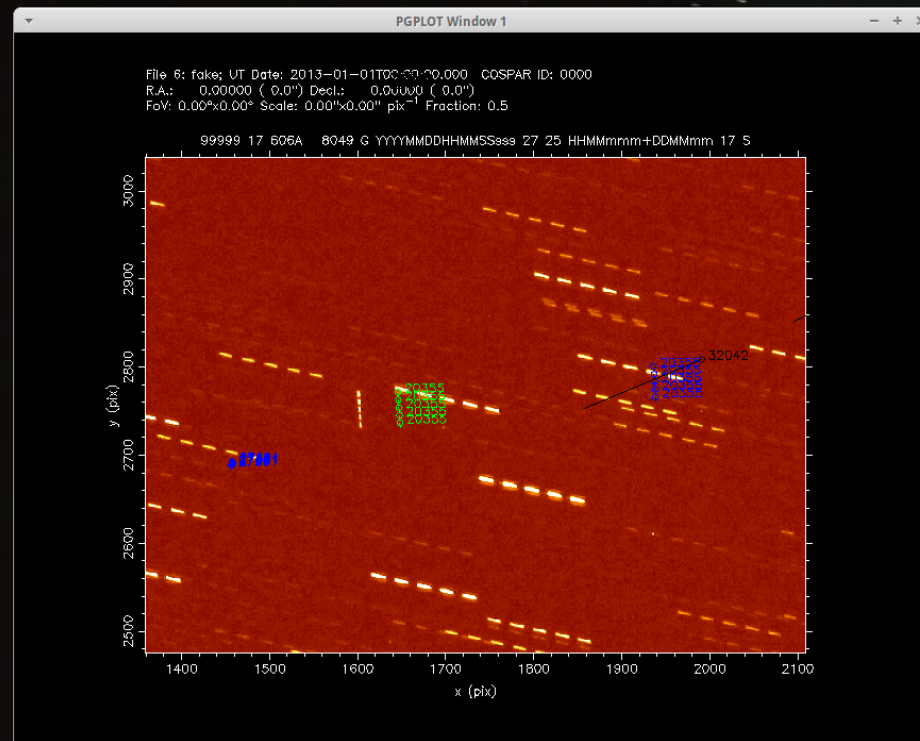
Questions?

The Background Image is Full of Satellites!

Its full of satellites !



Zooming in...



Image, Video and Audio Credits

Background - Scott Tilley

Slide 2 – Sputnik 1 image USSR, Audio WOSL, Slide 3 - Sputnik 1 video, Ted Molzcan

Slide 4 - Project Moonwatch, Greg Roberts

Slide 5, 6 and 7 – Various antennas and rigs, Greg Roberts

Slide 9 – U.S. Patent 5,345,238

Slide 10 – NASA STS-38

Slide 12 – NASA (left), Cees Bassa (right)

Slide 13 – Ted Molzcan (right), Cees Bassa/Scott Tilley (right)

Slide 14 – Greg Roberts (left), Scott Tilley (right)

Slide 15 – Scott Tilley

Slide 17 – USAF

Slide 18-23 – Scott Tilley

Slide 24 – Marco Langbroek (left), Peter Horstink (right)

Slide 25-30 – Scott Tilley

Slide 32 – Scott Tilley