GPS Intermediate Frequency (IF) Receiver Recorder

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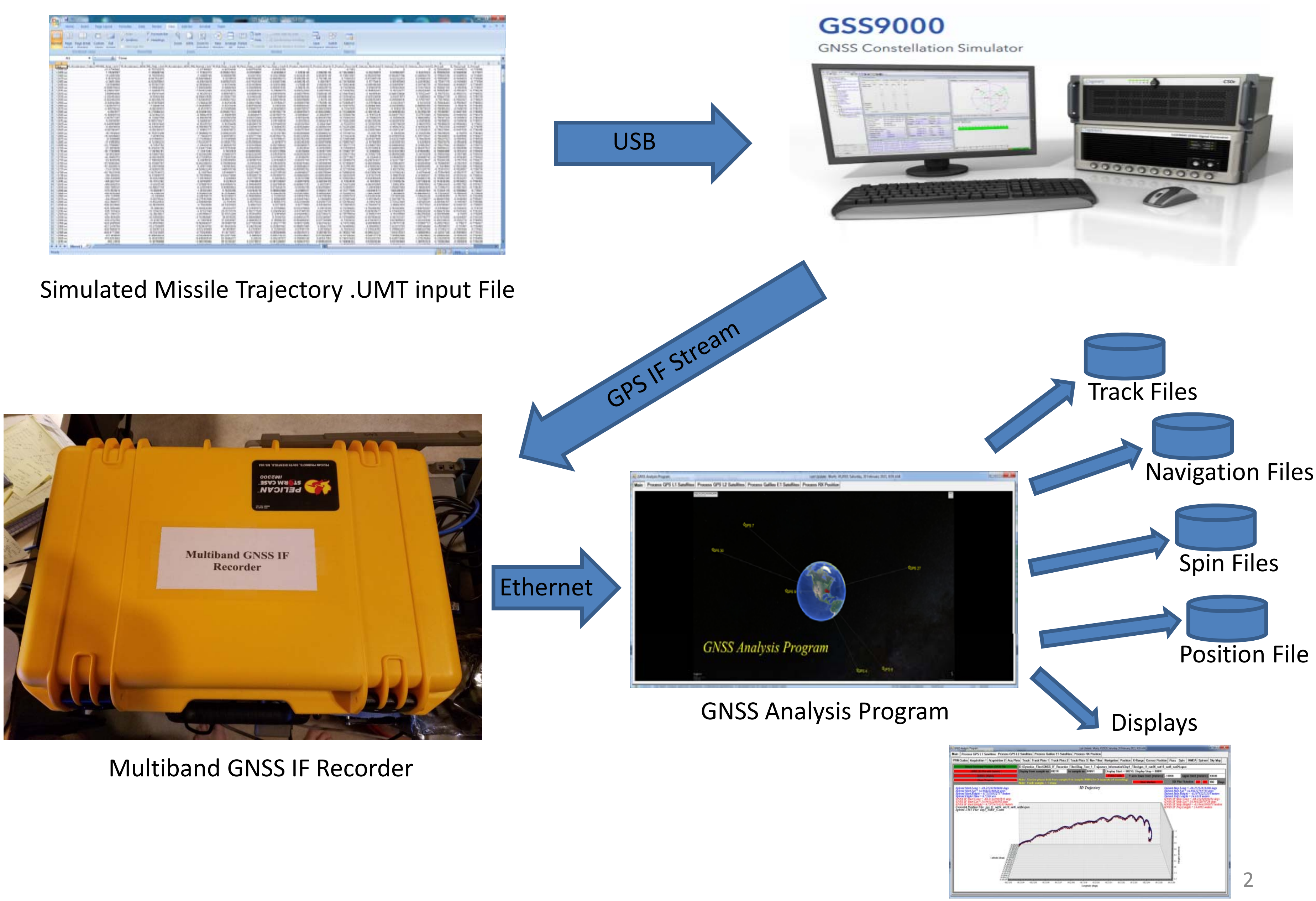
3 June 2021

With the testing of rocket projectiles, is desirable to determine the flight trajectory immediately after the projectile has left the launch tube. This is difficult to achieve in that telemetry GPS receivers require time to acquire satellites, phase lock on satellite tracks, and generate timing and position data. Many msecs of time can pass before PNT data is generated after the projectile has been launched. Once the PNT data stream is received by a ground receiver, typically PNT data is good until the projectile crashes or reaches it's target unless telemetry drop outs are experienced.

With this study, it is assumed that an on-board projectile telemetry device records the GPS IF data stream directly from the antenna (i.e. Haigh-Farr wrap antenna on the projectile body) to internal non-volatile memory during the projectile flight and is retrieved after the projectile flight and post-processed for PNT information. By this method, a typical GPS software receiver would provide PNT information immediately after the wrap antenna leaves the launch tube only to be delayed by the time it takes for software phase tracking loops to lock. Phase tracking loops require several msecs to lock which would delay the generation of PNT information after the projectile has launched.

To solve this time delay issue, the GPS software algorithm within the GNSS Analysis Tool was reversed so that the recorded GPS IF stream is processed in reverse order from trajectory end to beginning. In this way, the software phase tracking loop lock delays are experienced at the end of the flight trajectory resulting in good PNT information immediately after projectile launch. The following slides show this method of "reverse" processing the GPS IF data stream to not only be doable; but, provides excellent PNT information immediately after projectile launch.

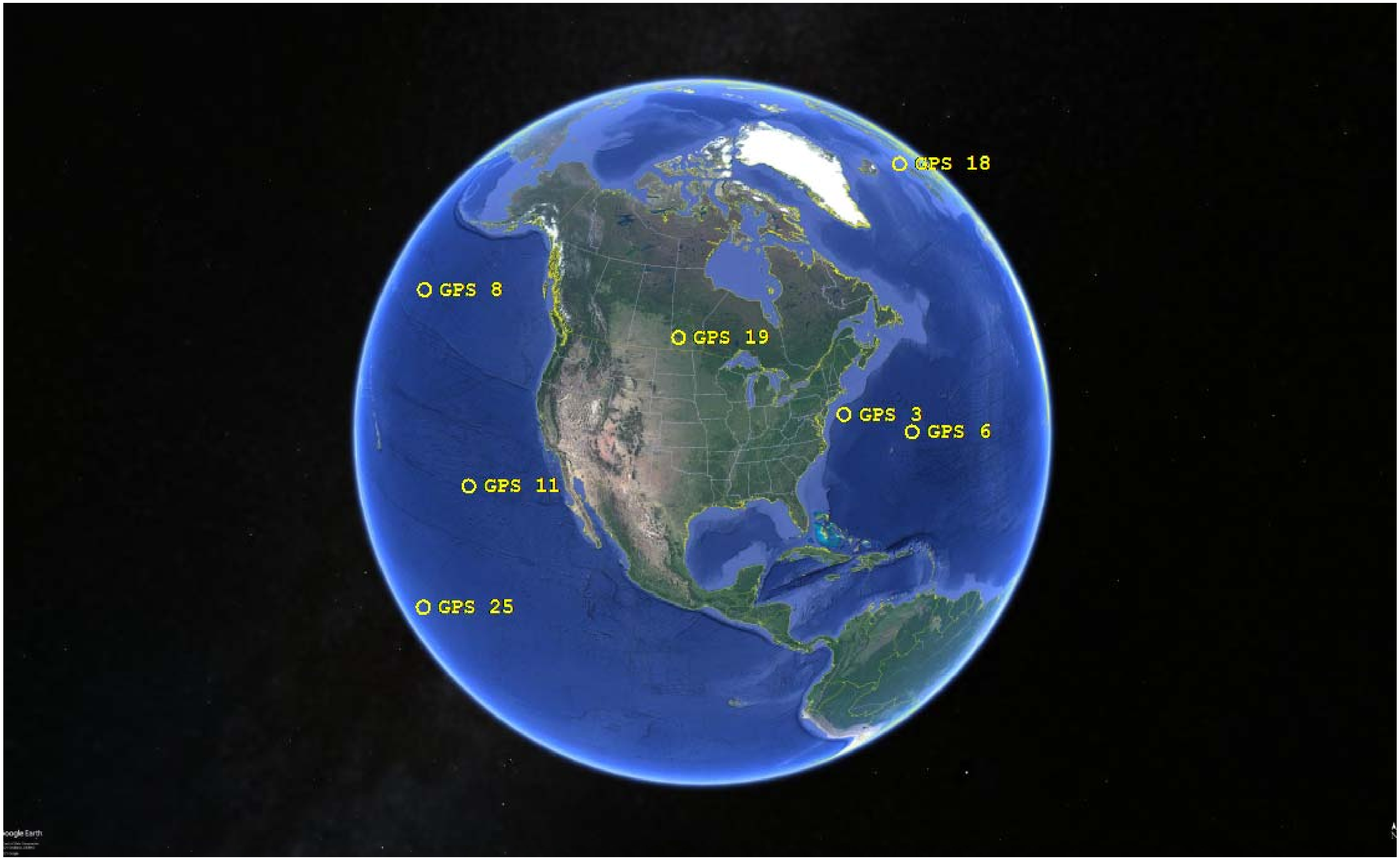
GPS IF Stream Software Processing Flow



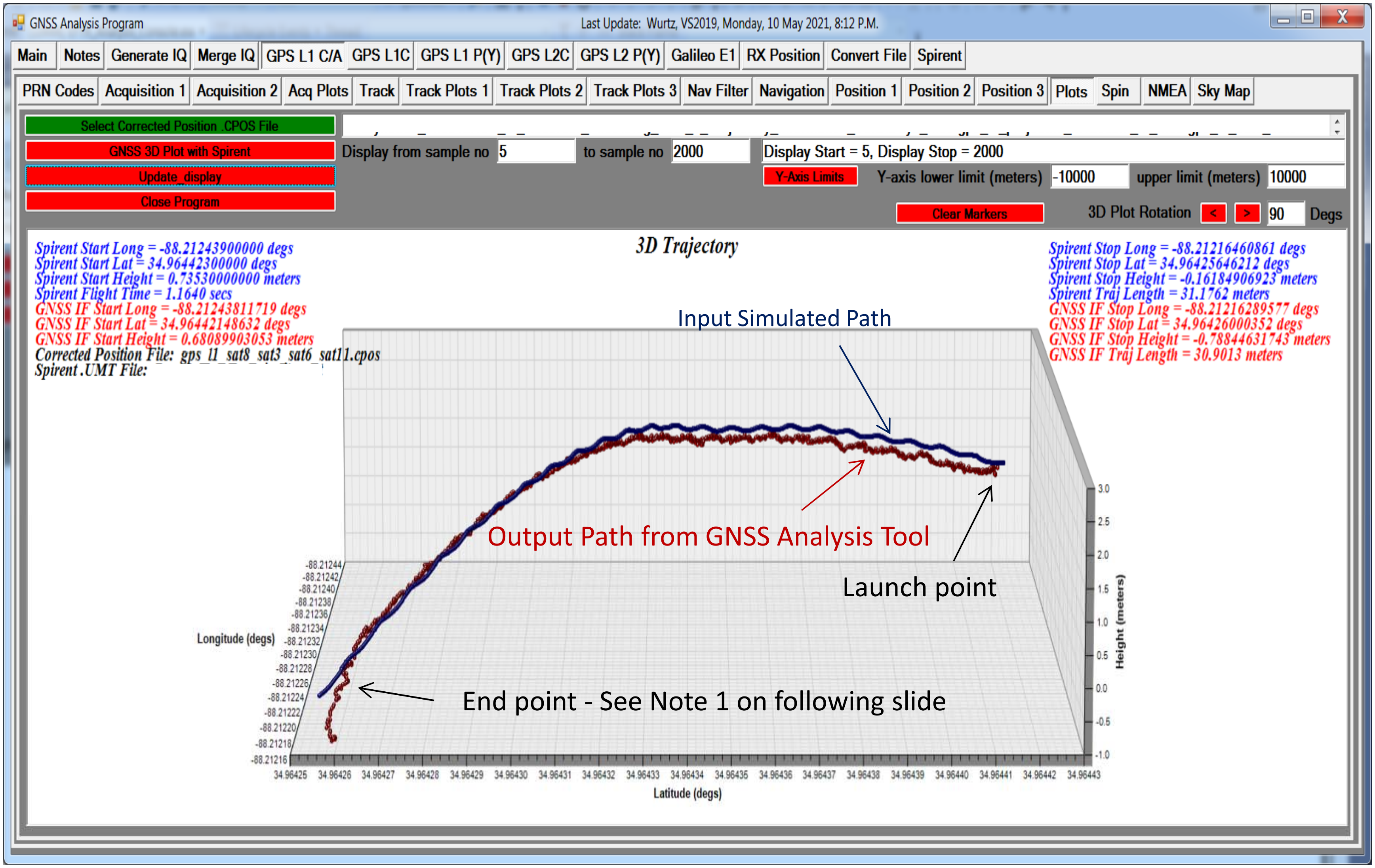
Spirent GSS9000 Simulation Notes

- Transmitter antenna simulated as a Haigh-Farr wrap antenna (Model 8310-3MD).
- Power level set to -125 dBm with Haigh-Farr antenna 8310_3MD modeled in file Haigh_Farr_8310_3MD_Profile.csv for projectile IF recording.
- IF output of Spirent collected by the GNSS_IF_Recorder_Pelican_Case and stored in file gps_l1_projectile_m125dBm_hf.dat for projectile recording.
- Spirent input files included ECEF XYZ positions, ECEF XYZ velocities, ECEF XYZ accelerations, heading, elevation, and band data. Jerk and body roll, yaw, and pitch were set to all zeroes.
- Spirent projectile IF simulation starts at a 15 March 2021, 1:02 PM. Projectile IF recording has 8 to 10 seconds of dead IF at start to represent a blocked Haigh-Farr antenna in the launch tube. Projectile flight time is less than 2 seconds. On impact, the attitude is maintained for an additional 60 seconds of IF recording.
- The sudden impact and hold of attitude causes extreme dynamics which really do not exist in that the projectile will actually roll and tumble on the ground after impact.

Satellites acquired from simulated projectile IF stream by the GNSS Analysis Tool



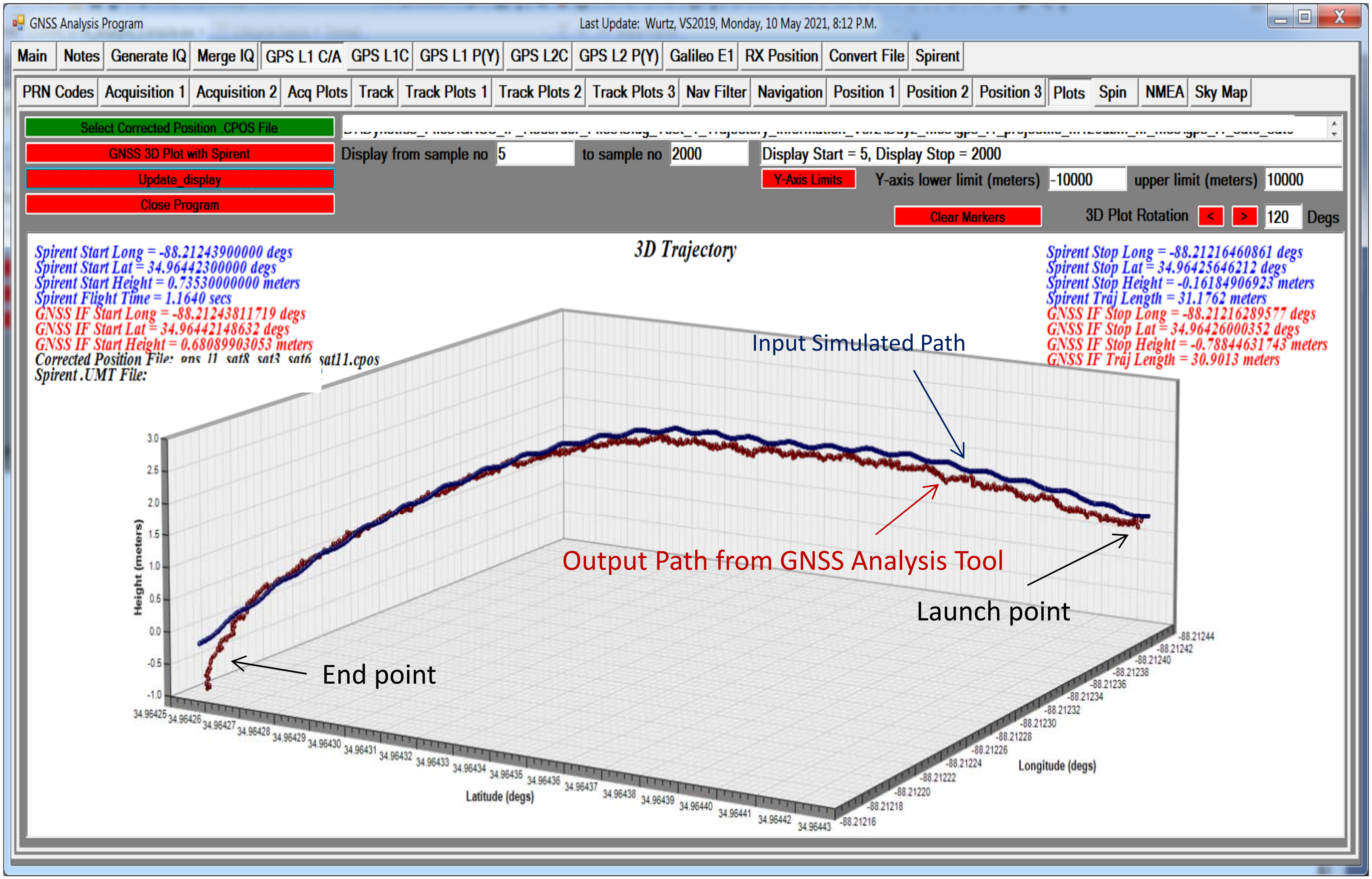
Satellites 8, 3, 6, and 11 (90 deg view)



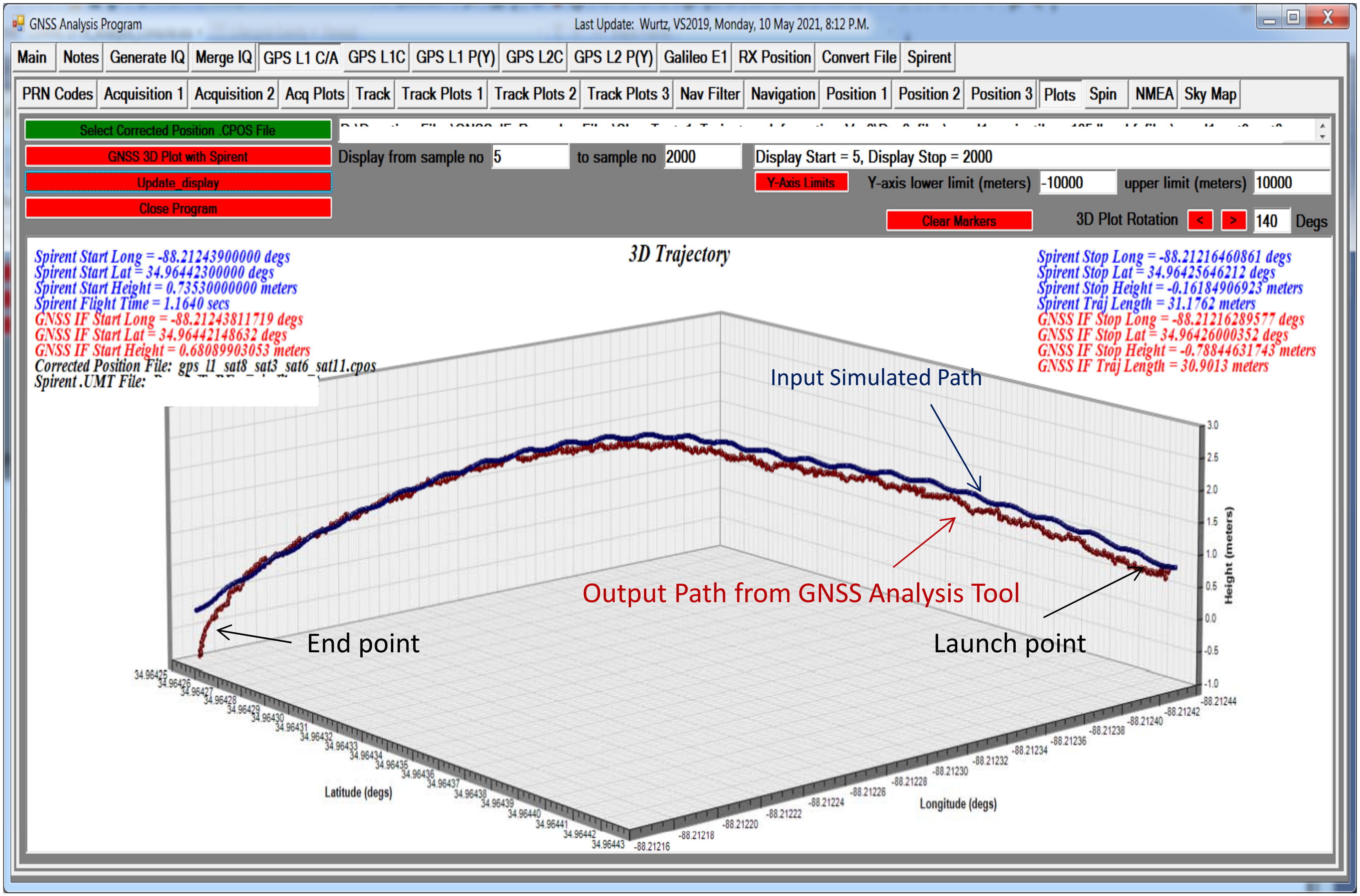
Note 1

The carrier-phase tracking loop operates in reverse from end of recording to start. In this way, the carrier-phase tracking loop locks using IF data while the projectile is laying on the ground after a flight. The carrier-phase tracking loop is completely locked during the projectile flight to the point of the projectile leaving the launch tube. With the Spirent simulation, the projectile attitude was maintained when the projectile struck the ground at flight end. Accordingly, the dynamics are extreme and the carrier-phase tracking loop tends to weaken at the point of impact. In reality, the projectile will not stick in the earth and hold attitude at flight end; rather, the projectile tumble along the ground coming to rest. The actual movement at flight end will not stress the lock of the carrier-phase tracking loop.

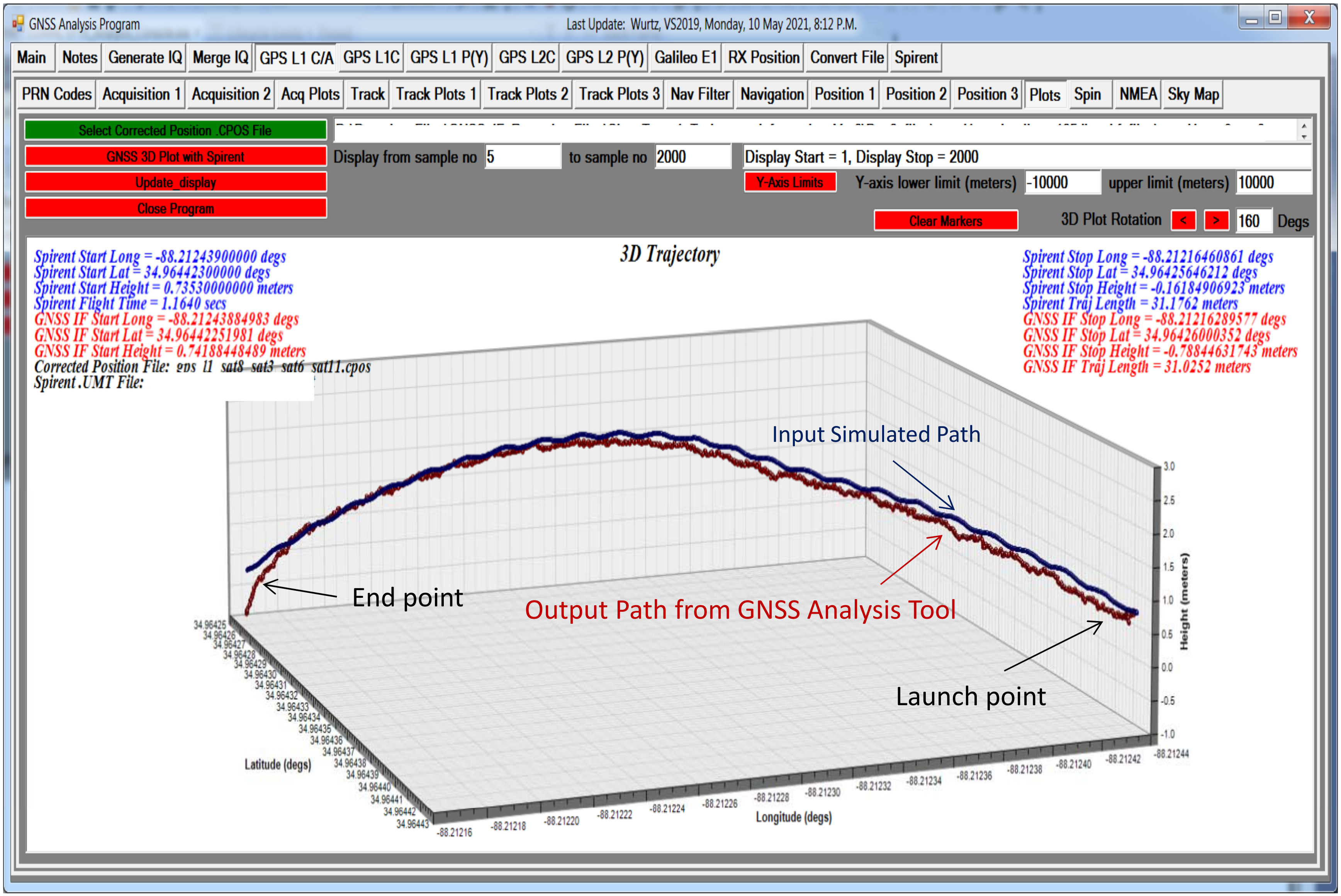
Satellites 8, 3, 6, and 11 (120 deg view)



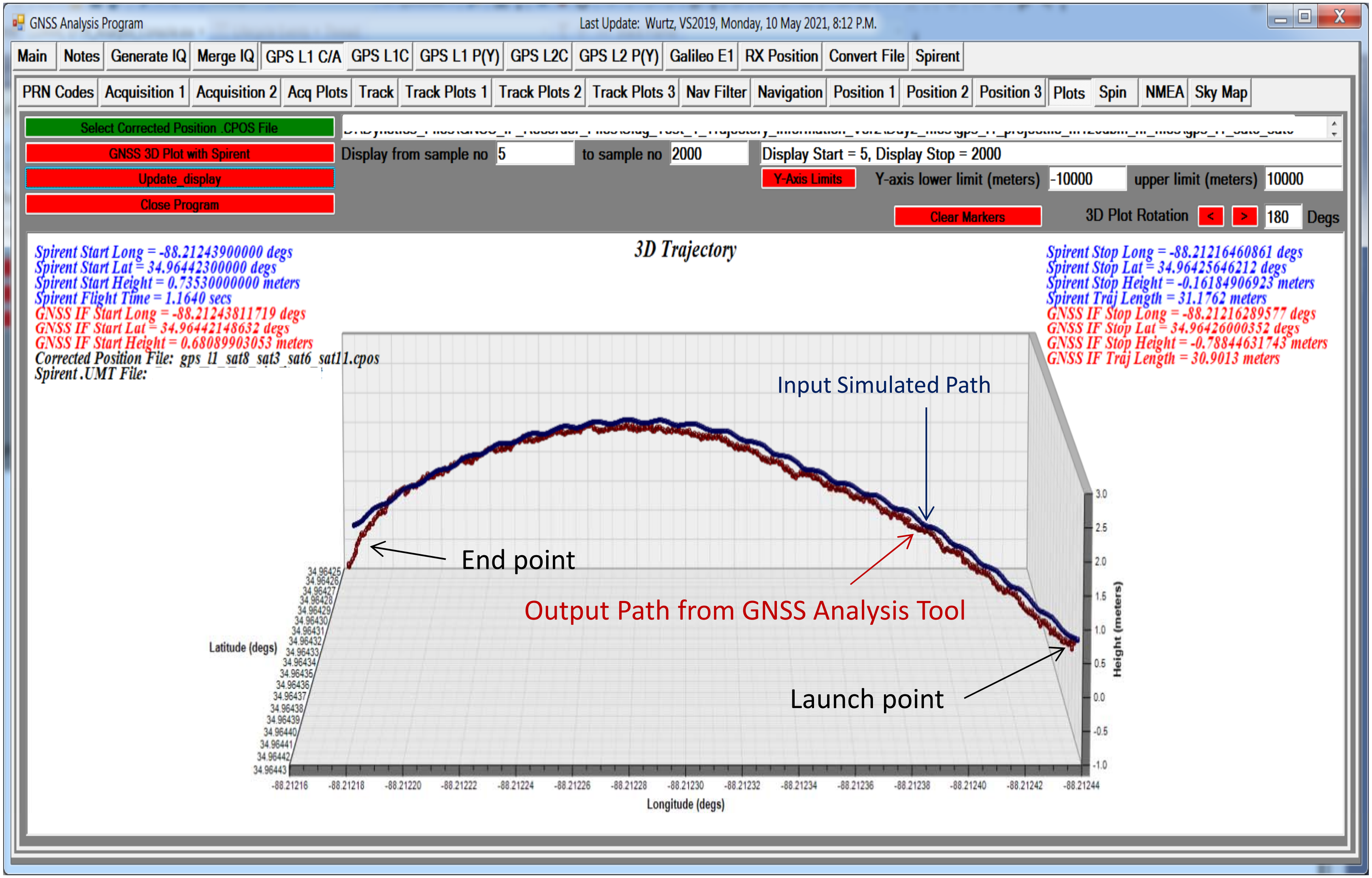
Satellites 8, 3, 6, and 11 (140 deg view)



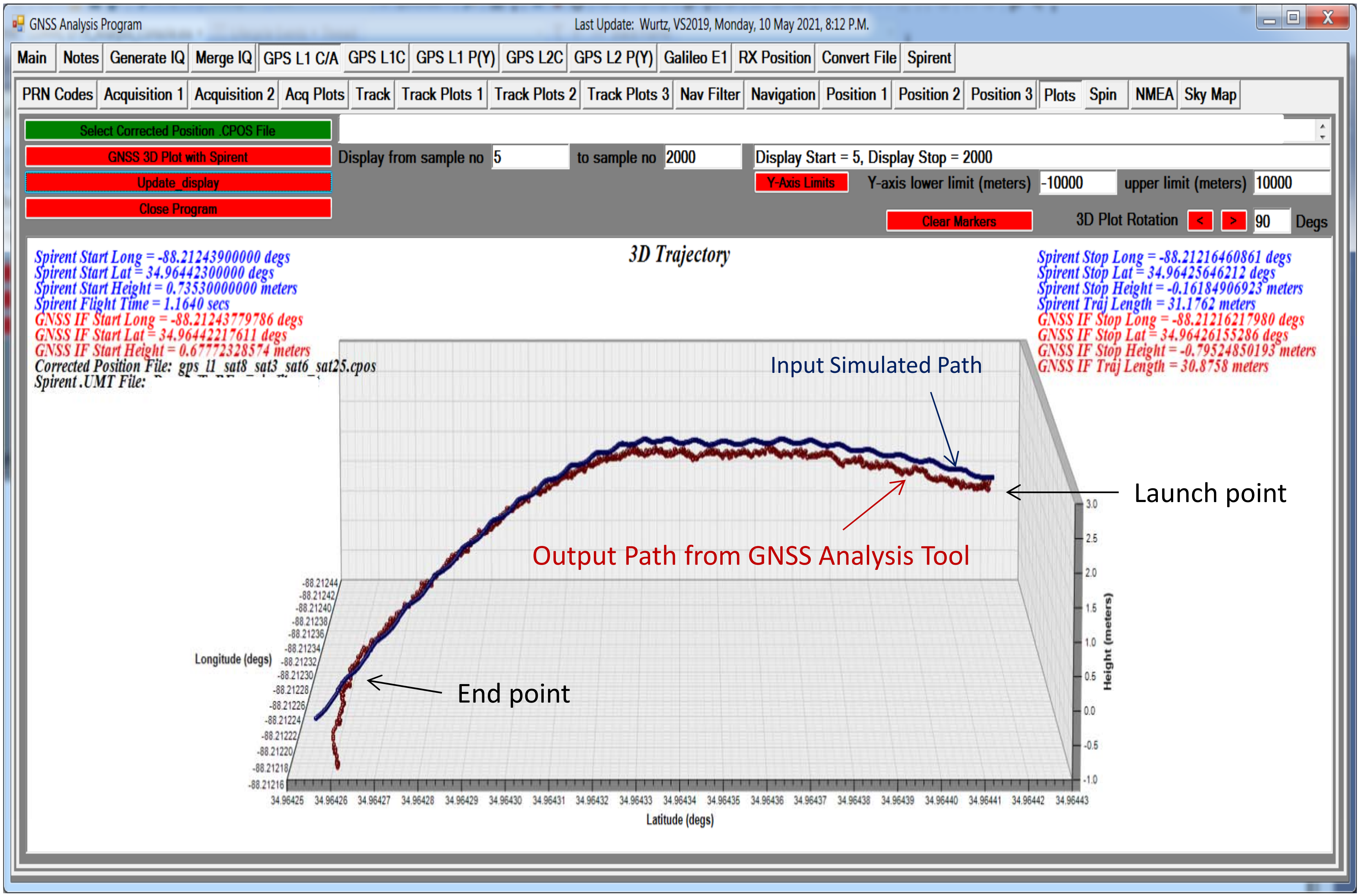
Satellites 8, 3, 6, and 11 (160 deg view)



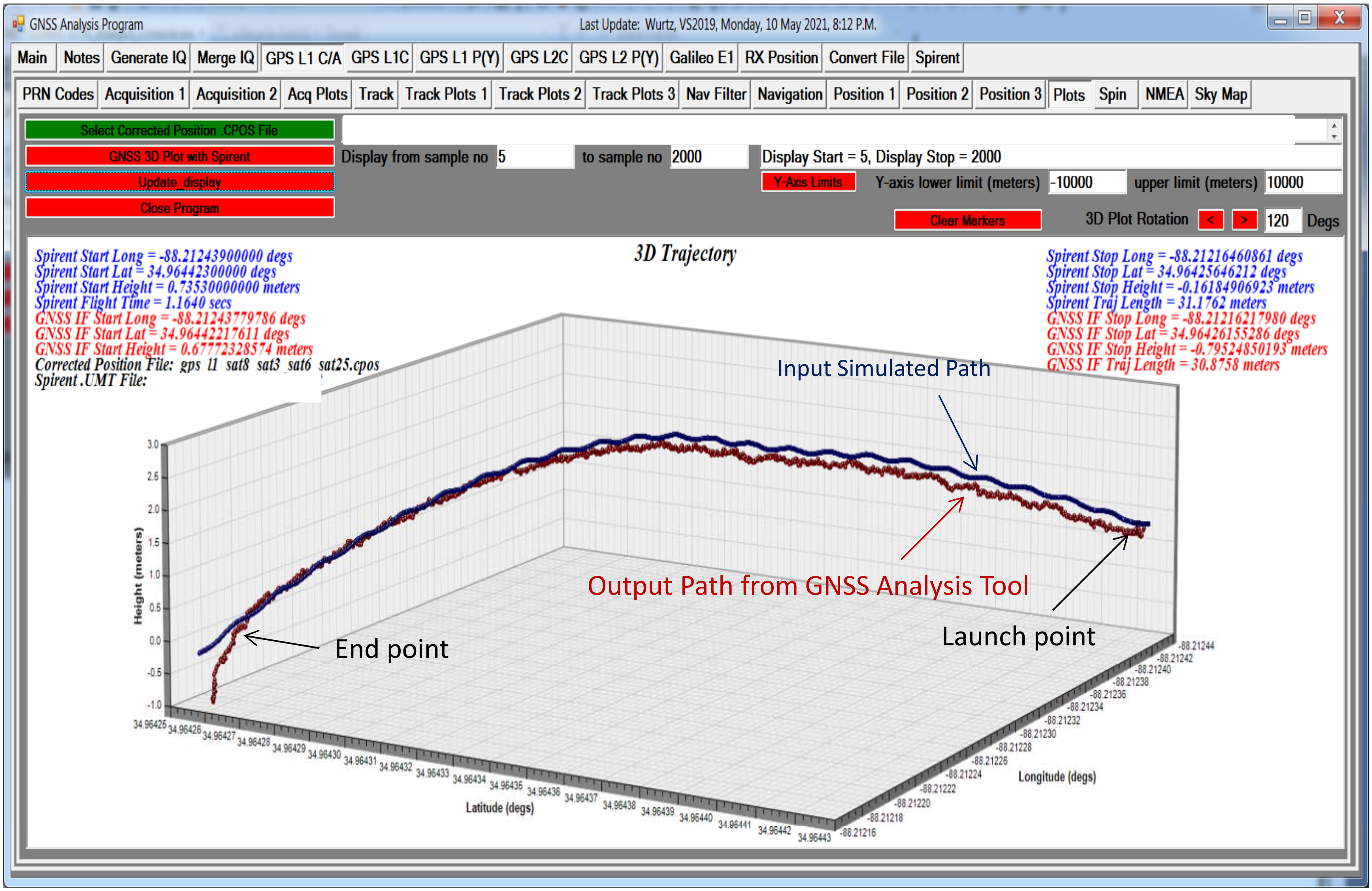
Satellites 8, 3, 6, and 11 (180 deg view)



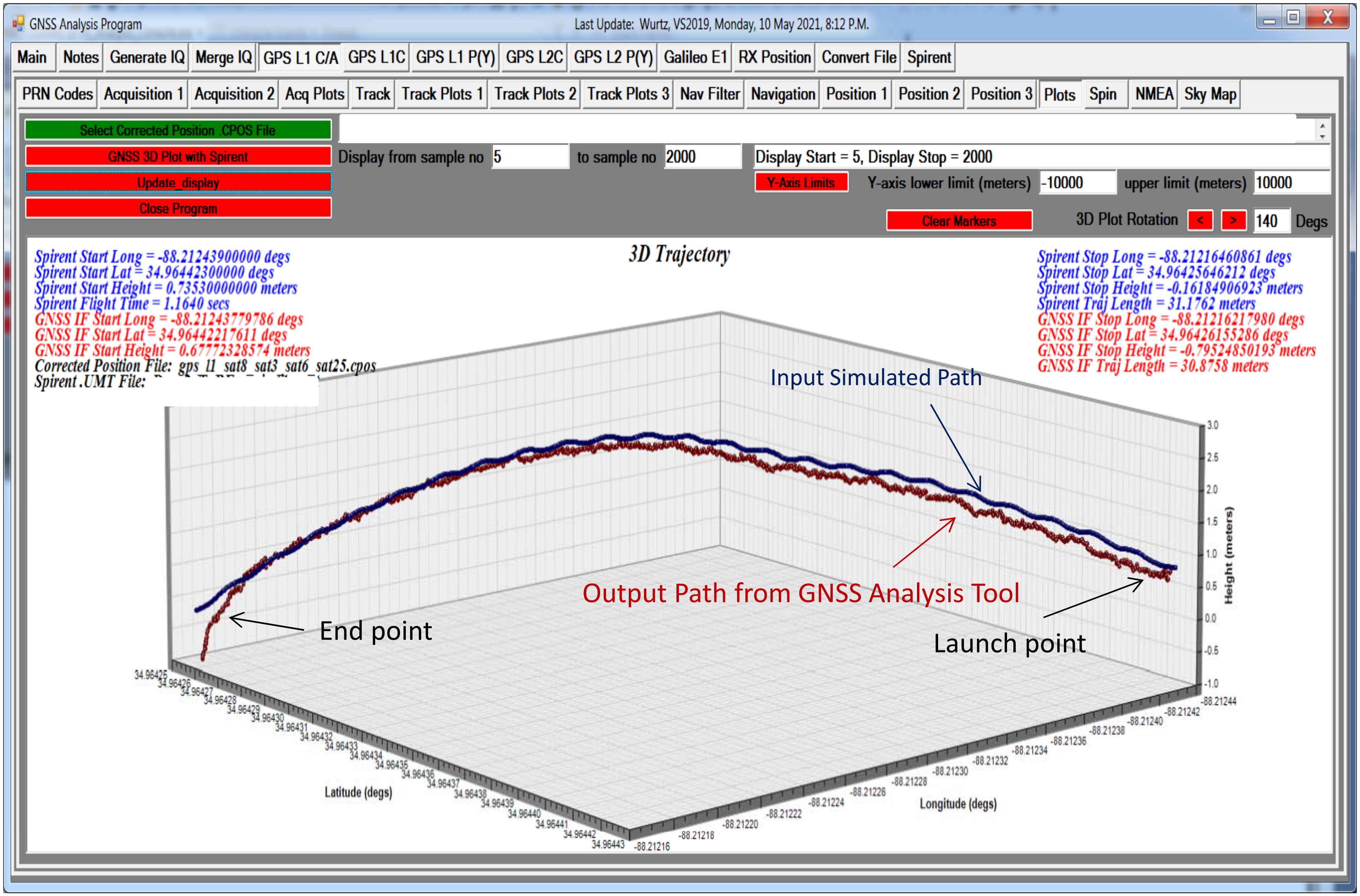
Satellites 8, 3, 6, and 25 (90 deg view)



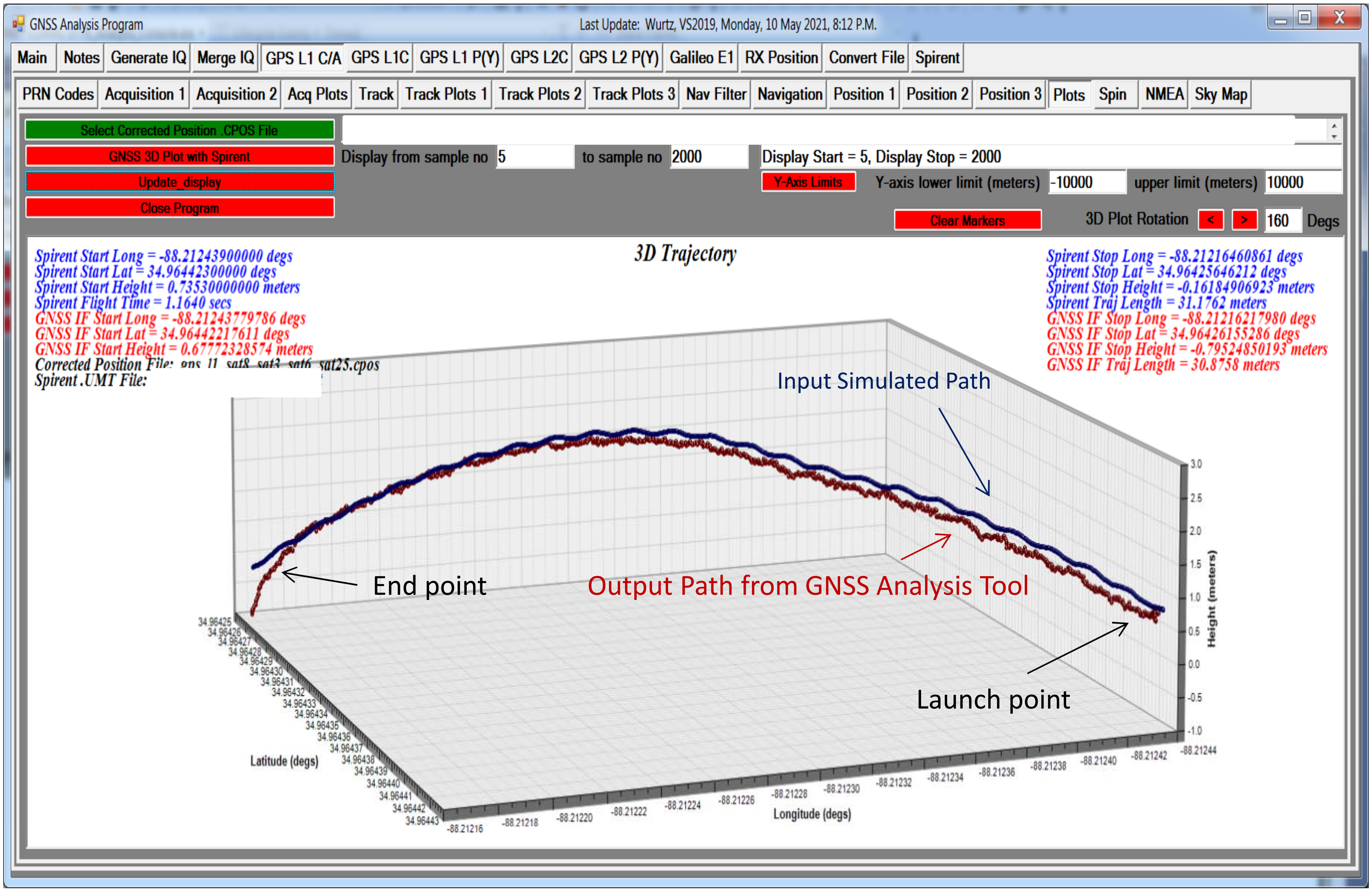
Satellites 8, 3, 6, and 25 (120 deg view)



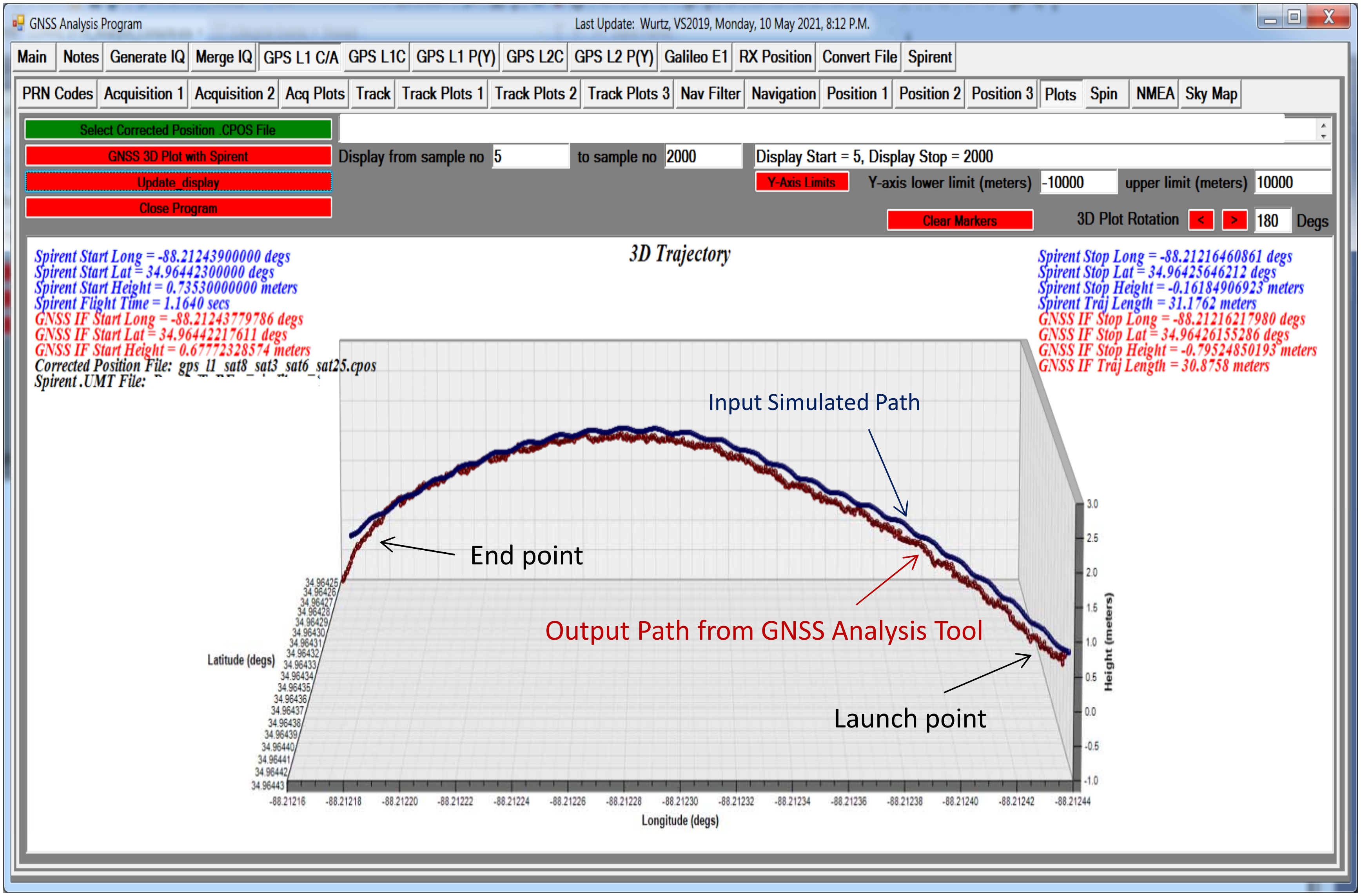
Satellites 8, 3, 6, and 25 (140 deg view)



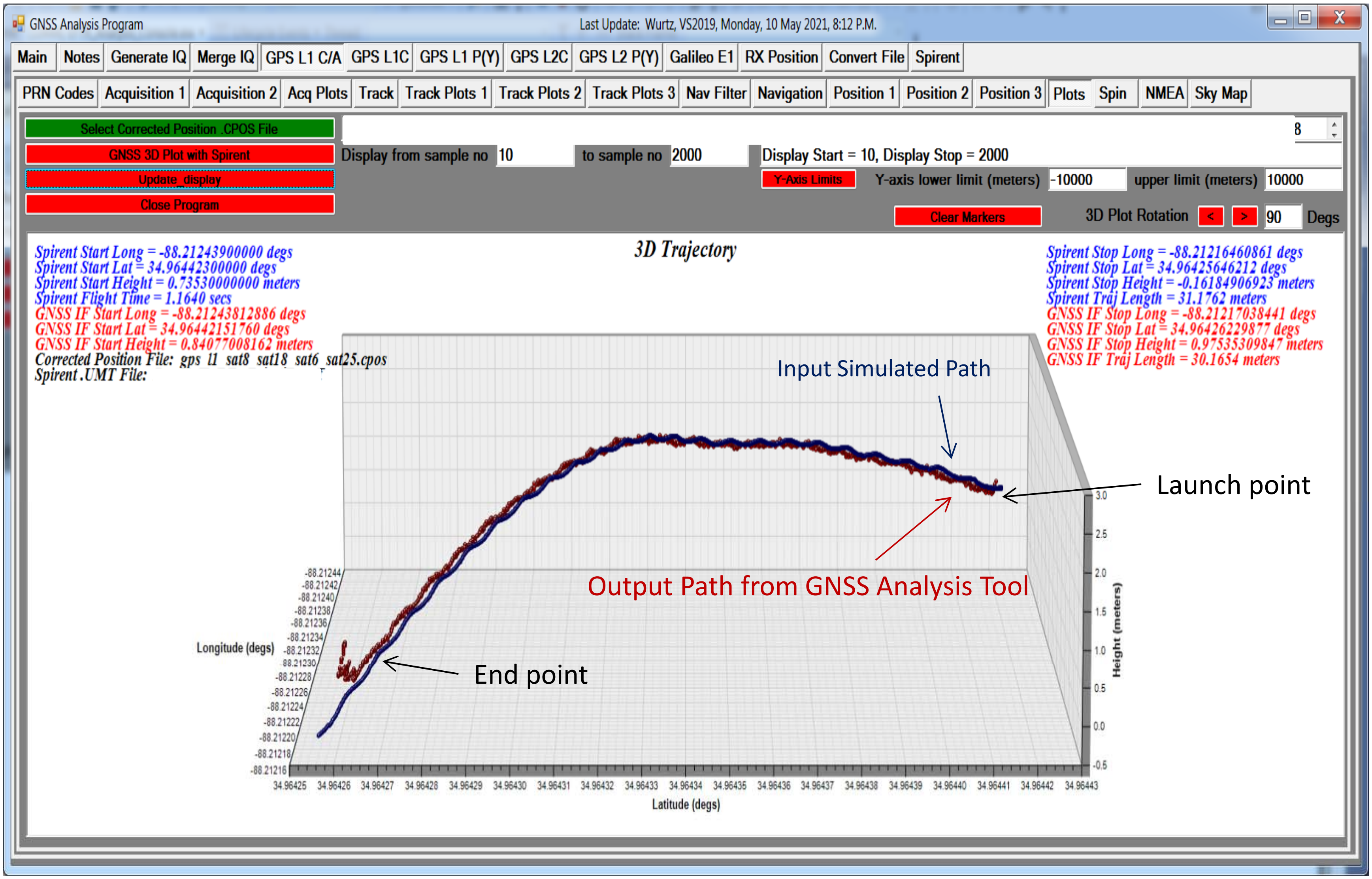
Satellites 8, 3, 6, and 25 (160 deg view)



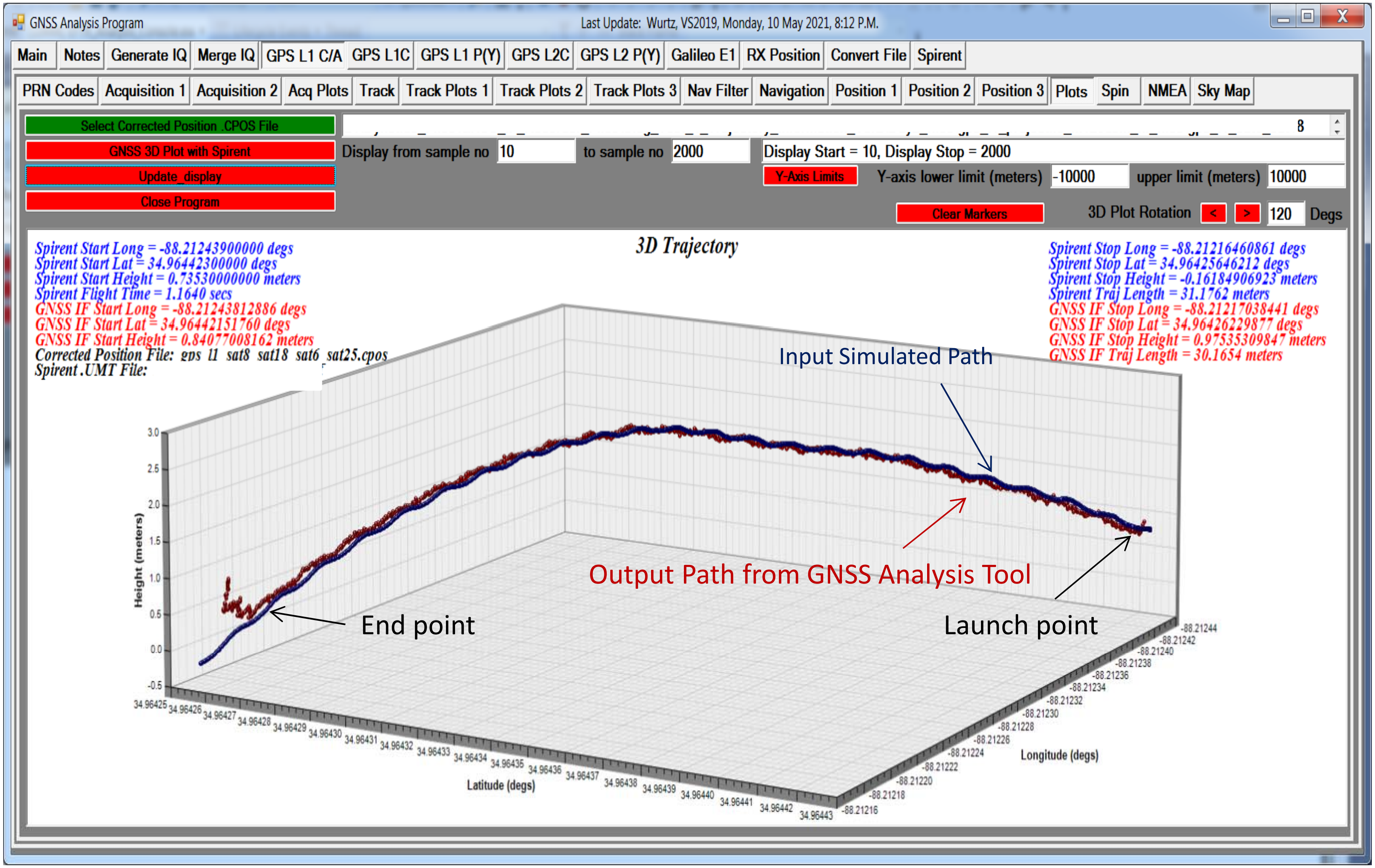
Satellites 8, 3, 6, and 25 (180 deg view)



Satellites 8, 18, 6, and 25 (90 deg view)



Satellites 8, 18, 6, and 25 (120 deg view)



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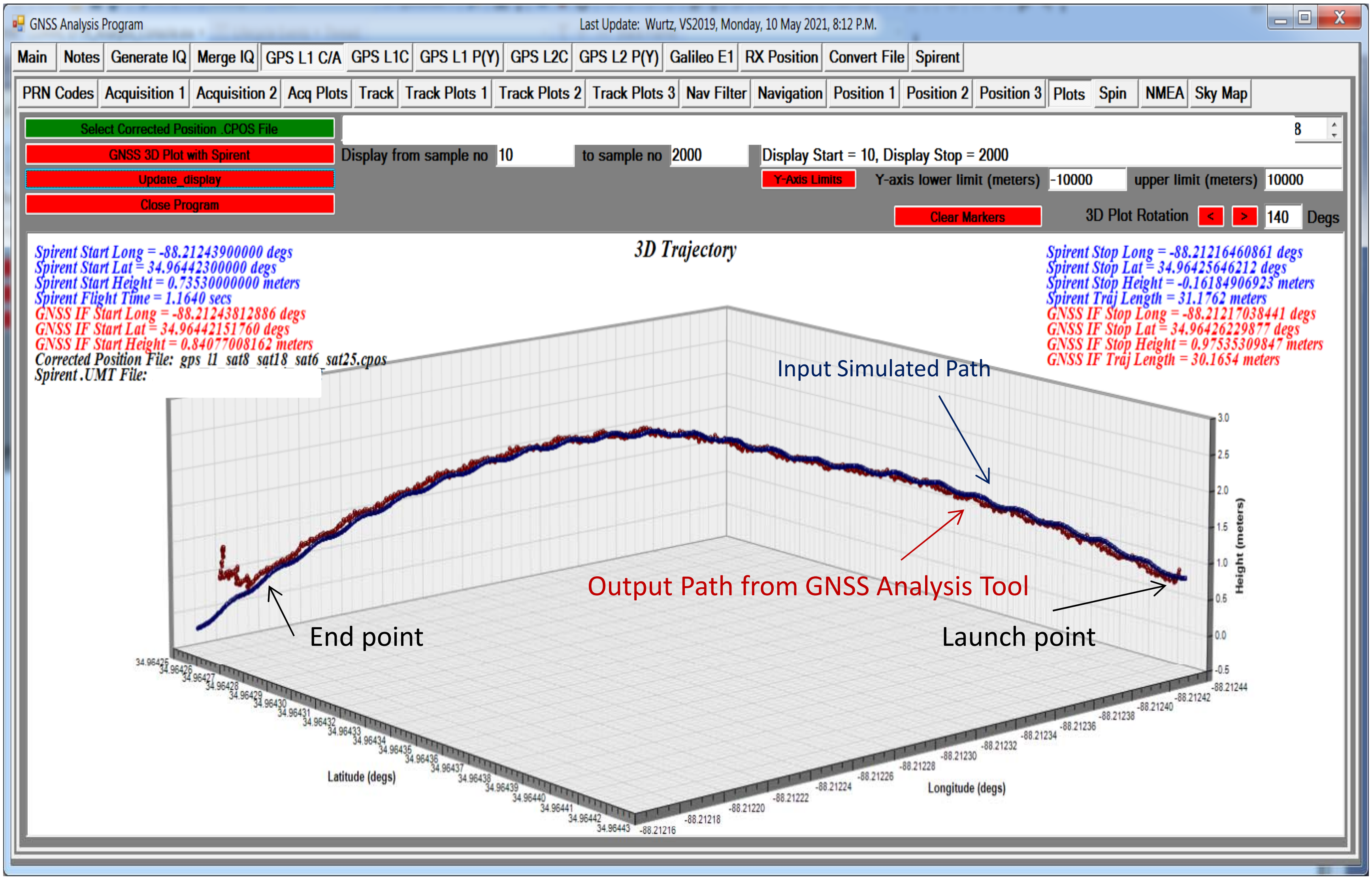
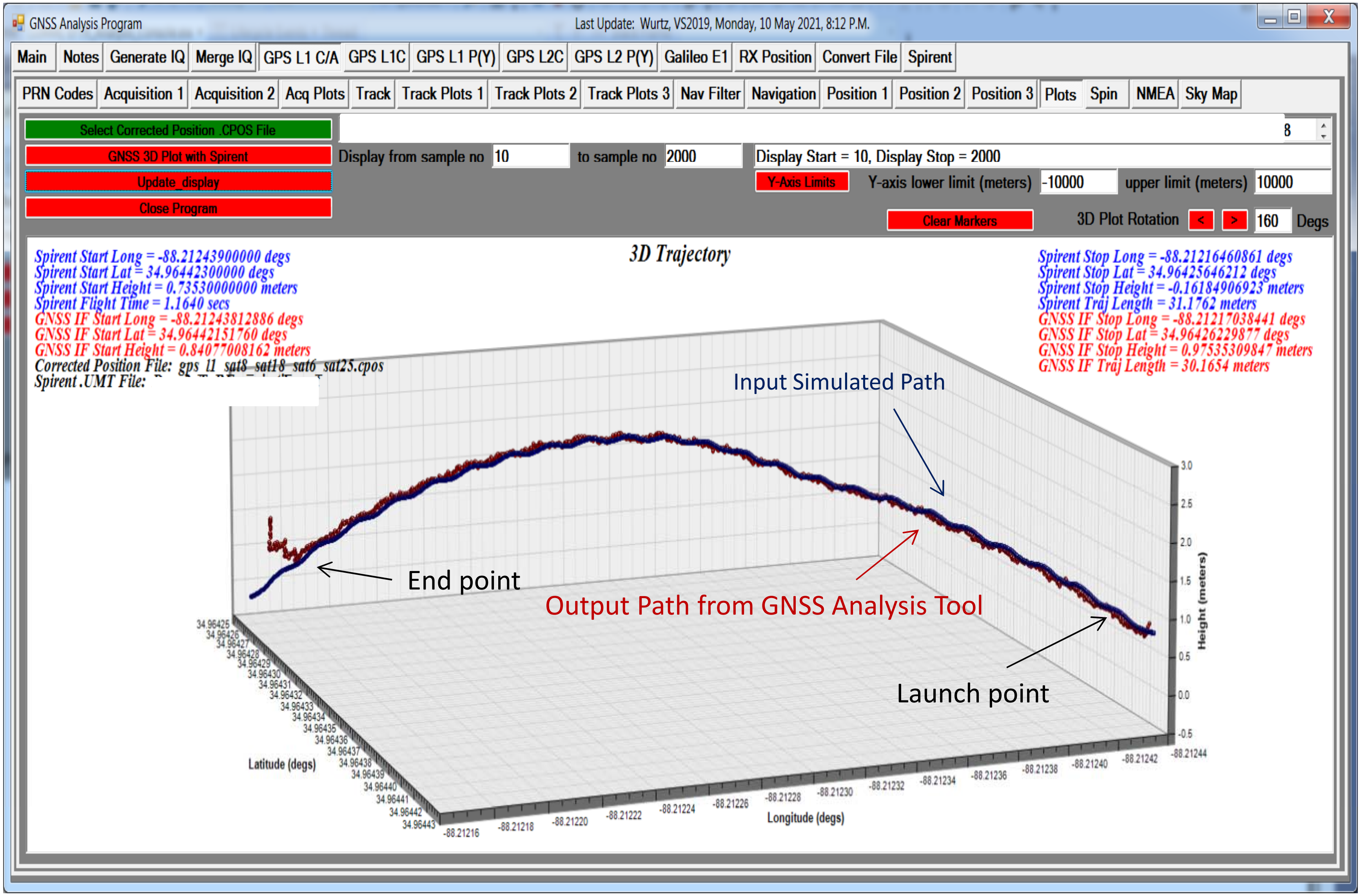
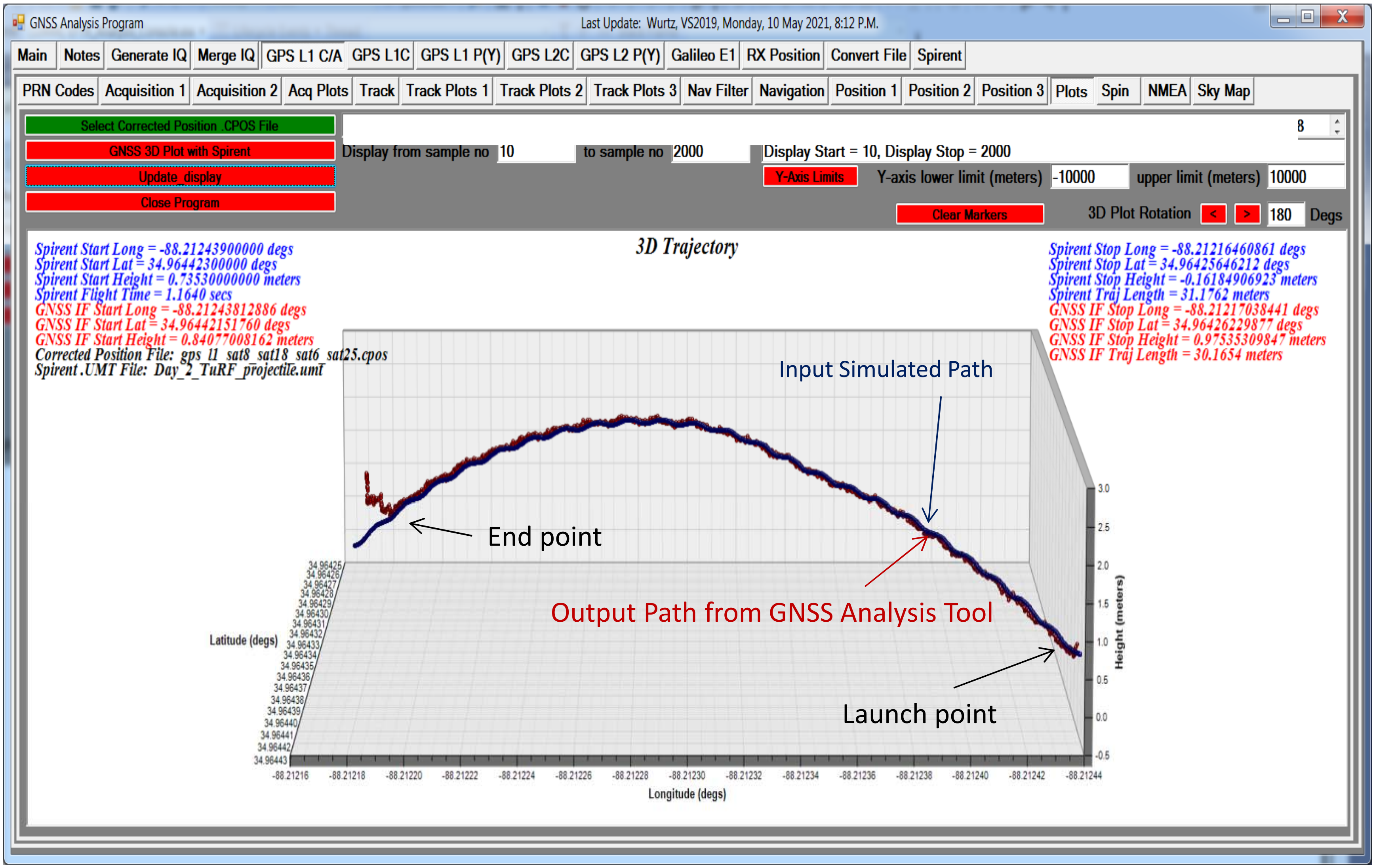


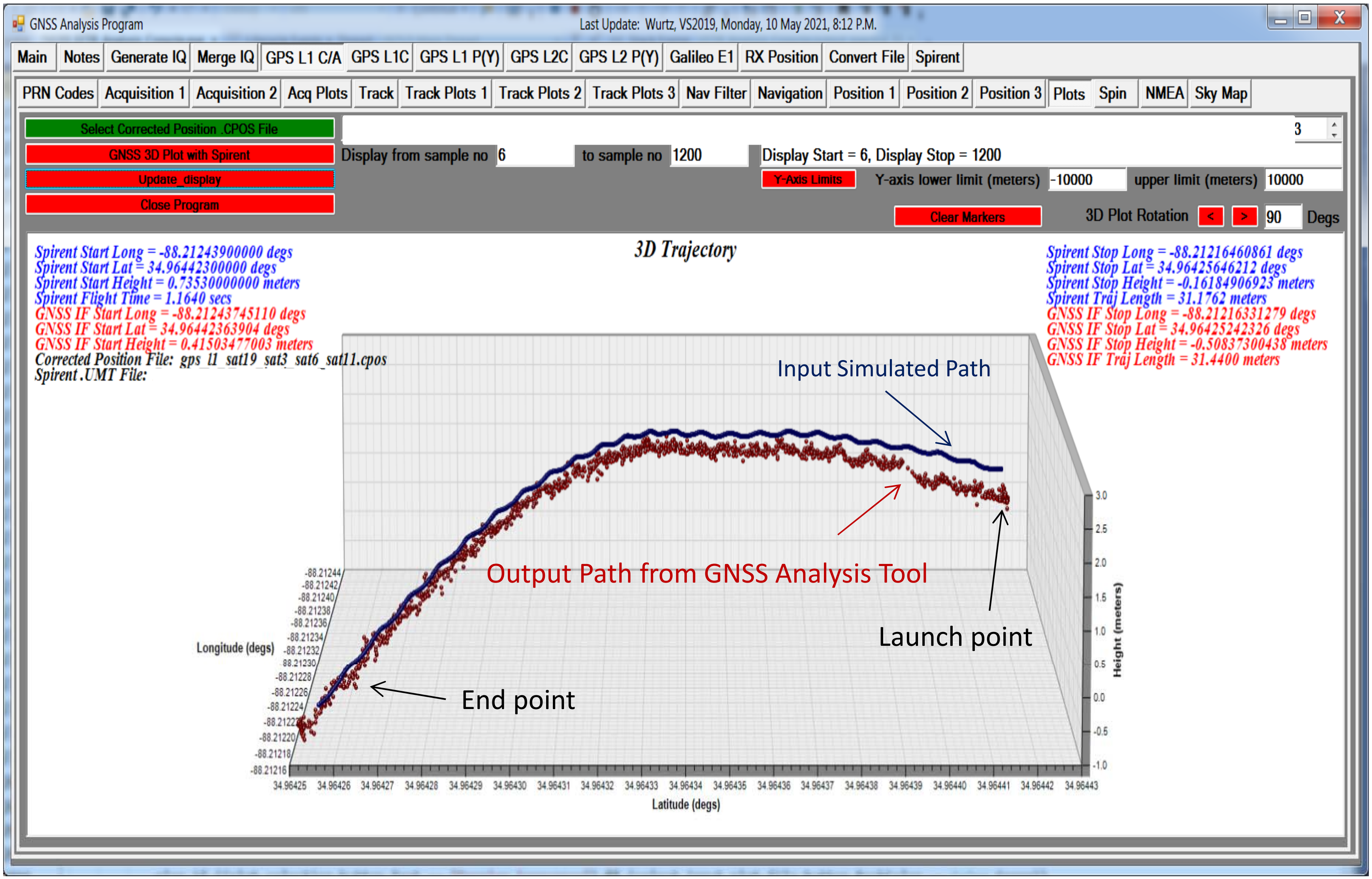
Satellites 8, 18, 6, and 25 (160 deg view)



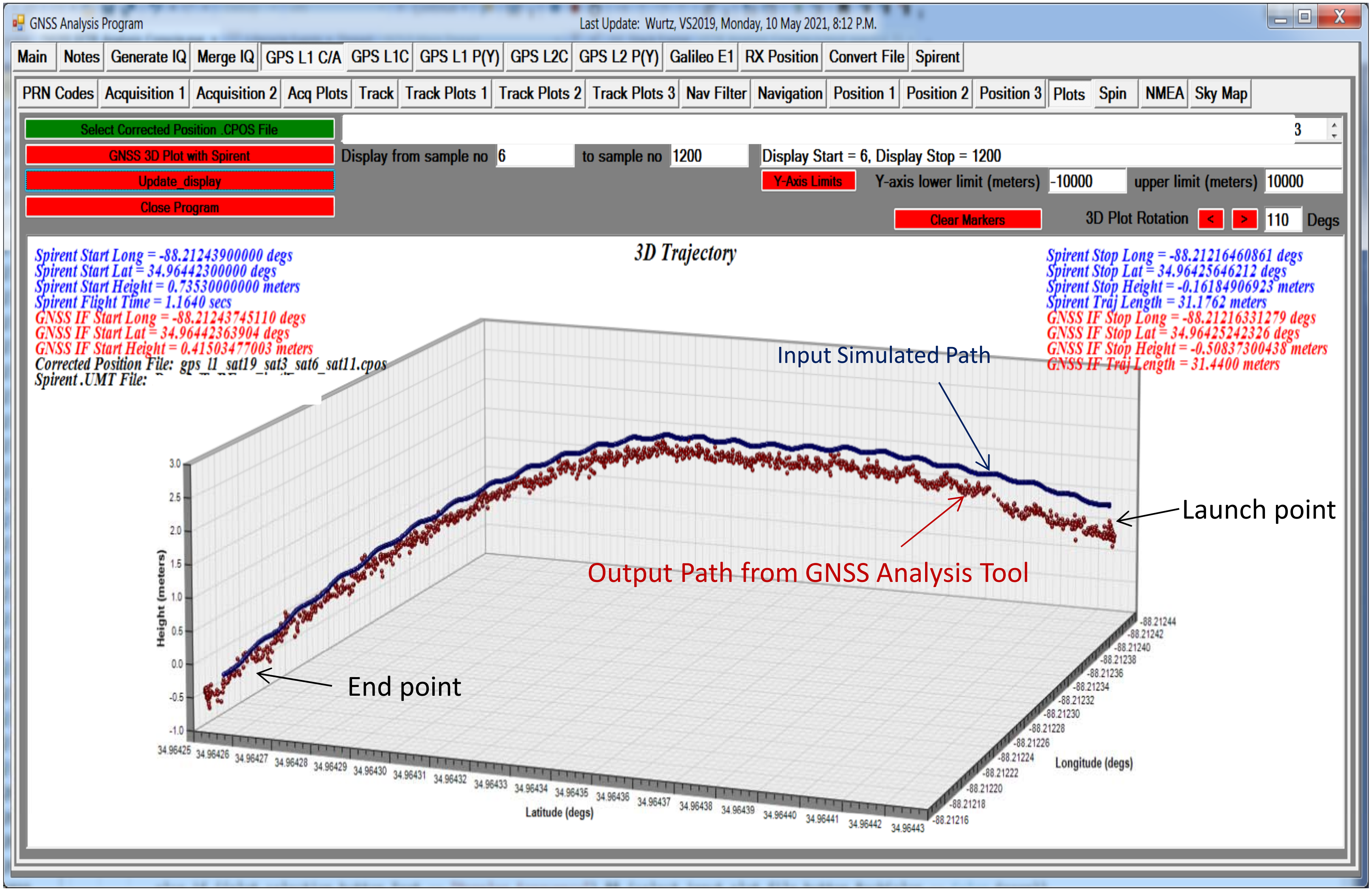
Satellites 8, 18, 6, and 25 (180 deg view)



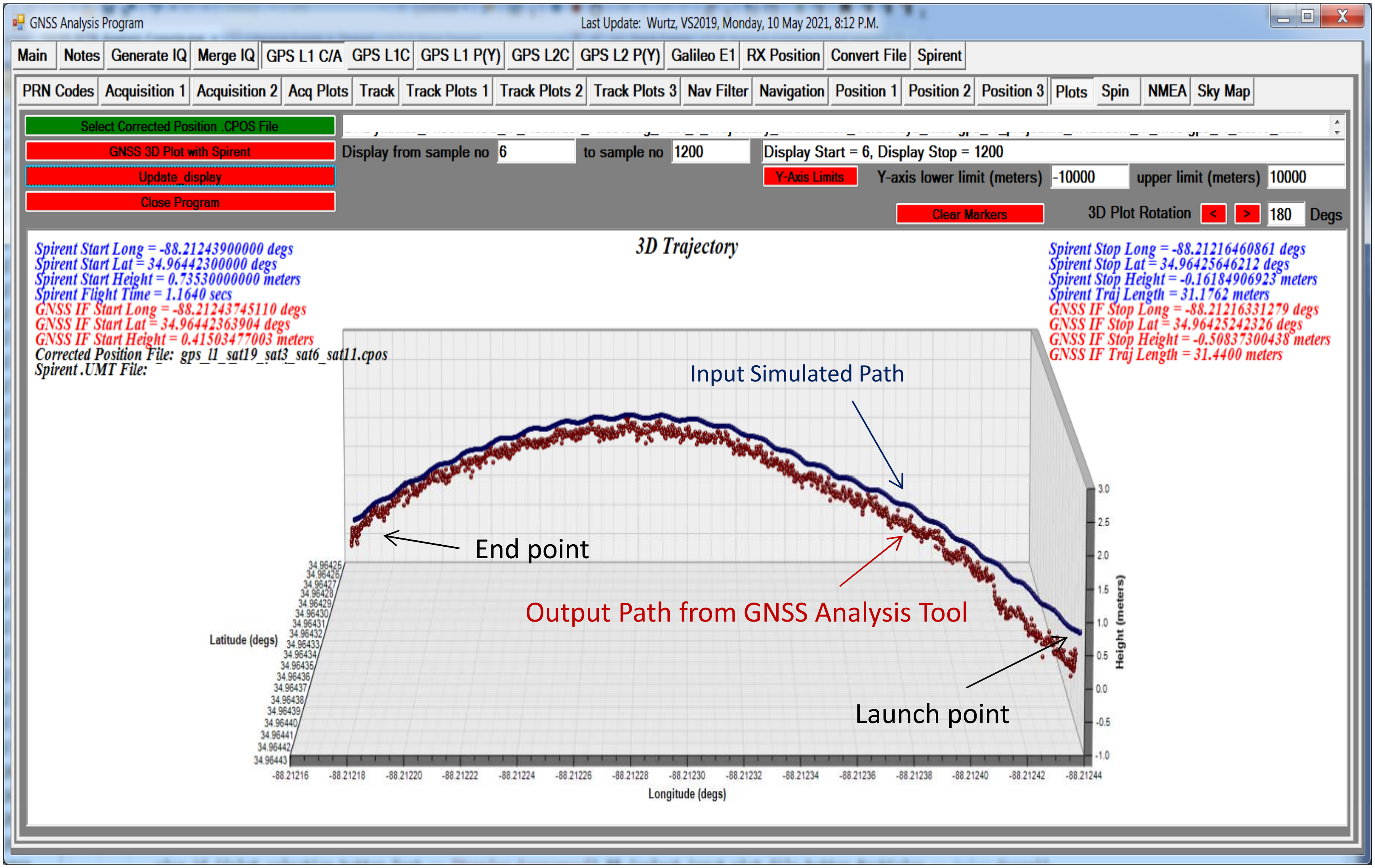
Satellites 19, 3, 6, and 11 – Weak Track (90 deg view)



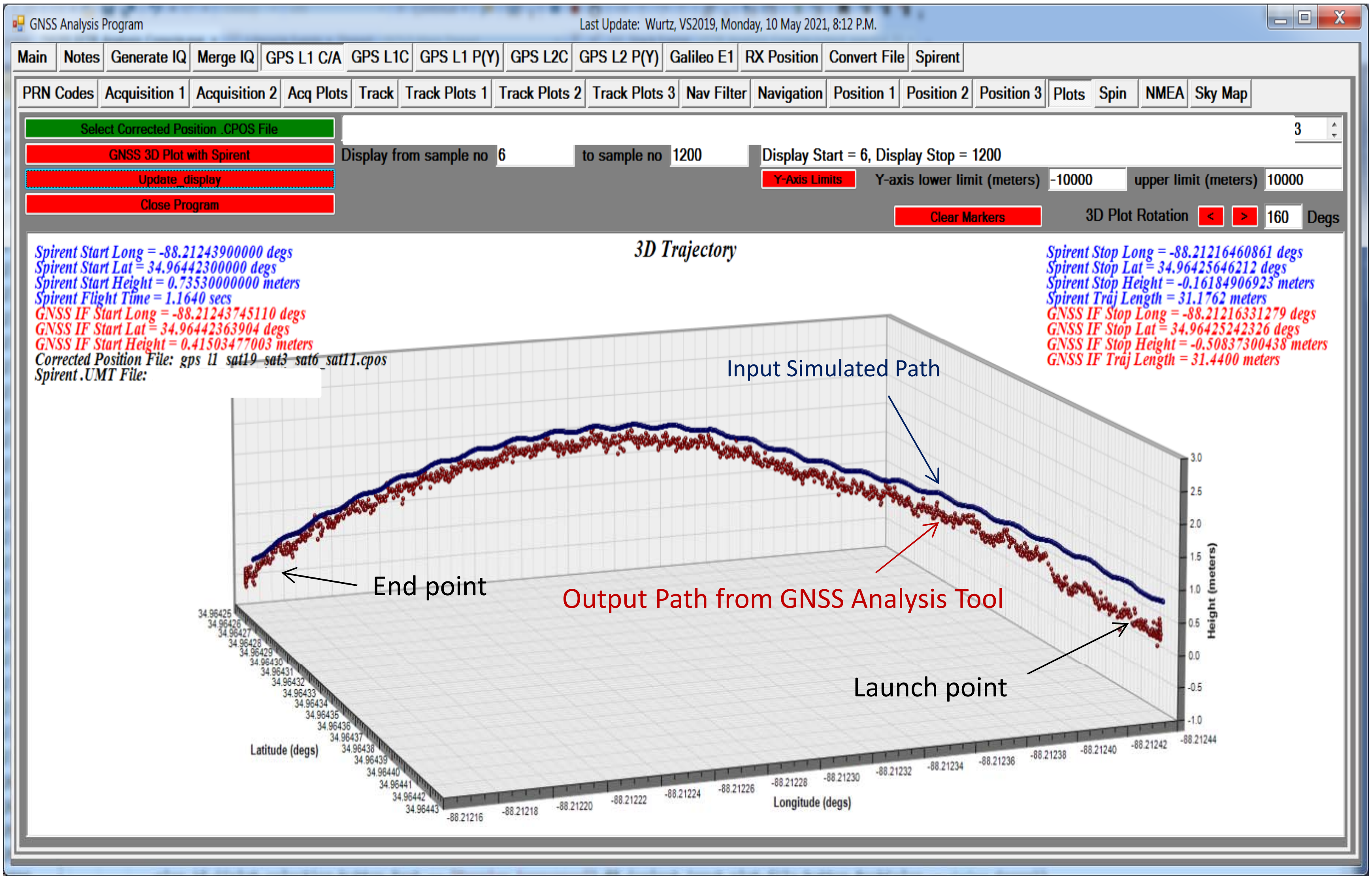
Satellites 19, 3, 6, and 11 – Weak Track (120 deg view)



Satellites 19, 3, 6, and 11 Weak Track (140 deg view)



Satellites 19, 3, 6, and 11 – Weak Track (160 deg view)



Satellites 19, 3, 6, and 11 – Weak Track (180 deg view)