Purpose: This memorandum is an attachment to the Northrop Grumman Systems Corporation FCC experimental radio license application for the NG-14 Cygnus spacecraft flight operations.

Scope: This memorandum provides a data summary in support of the FCC Office of Engineering and Technology (OET) e-File system application. The data is submitted in support of the following application:

Description	Number
FCC File Number:	0927-EX-ST-2020

Data Summary: The attached charts summarize the NG-14 Cygnus spacecraft power flux density during each phase of the mission on a nominal trajectory to the International Space Station (ISS). The mission phases covered in this summary are the Approach (to the ISS), Berthed (at the ISS), and Departure (from the ISS). The PFD algorithm has been updated to match the equations presented in the NASA Space Network User's Guide, Revision 10, Appendix D. The specific equation is the one used for Total Power in the Reference Bandwidth (PtB) of a NRZ waveform. This equation is listed as Equation D-6. The main parameters used in this PFD calculations are calculated using the NG-14 Cygnus spacecraft's nominal mission trajectory (Azimuth, Elevation, Range and Altitude) to the ISS from the Wallops Island, Virginia launch pad. Additionally each NG-14 Cygnus transmitter EIRP was used in the PFD calculation. The PFD limit line shown on each plot is specified in ITU-R Radio Regulations S21.16 Table S21-4 Power Flux Density Limits.

Attachment 2 to this application gives more details on the PFD limit exceedances identified in the data summary but in each case the exceedance is below the 16 dB relaxation granted in Section 2 of the NTIA Report 84-152. The PFD results presented herein assumes on orbit Cygnus operation where the primary emitter is radiating for the duration of a scheduled communication pass which is controlled by the mission timeline and the mission phase (approach, berthed and departure).

The NG-14 Cygnus spacecraft will transmit in the Spacecraft Operations Service S-Band. This band is allocated to the US Federal Government and covers 2200 to 2290 MHz. The band allocation is consistent with operations for the International Space Station cargo delivery service. The Cygnus spacecraft RF communication subsystem operates with multiple data rates and different modulation schemes. Table 1 below lists the primary RF communication links along with the phase of the mission in which they are active.

Table 1 Mission Primary RF Communication Links

					Mission Phase (Active)			
Link Operation	Carrier Frequency (MHz)	NTIA Emission Designator	NGIS Designation	Modulation Scheme	In-Orbit-Test	ISS Approach	ISS Berth	ISS Departure
Space-to-Space (Cygnus-to-TDRS SMA)	2287.5	6M16G1D	TDRS SMA	SQPN		√		√
Space-to-Space (Cygnus-to-TDRS SSA)	2287.5	6M16G1D	TDRS SSA	SQPN	√	√	√	√
Space-to-Ground (Cygnus-to-GN)	2287.5	4M98G1D	GN At 6 Mbps	SQPSK		√	√	√
Space-to-Ground (Cygnus-to-GN)	2287.5	3M00G1D	GN At 3 Mbps	SQPSK		√	√	√
Space-to-Space (Cygnus-to-ISS)	2203.2	5M93G1D	CLS At 36 kbps (LowRate)	SQPN	√	√	√	√

The detailed PFD results are shown below for each phase of the NG-14 Cygnus mission. Additionally the PFD requirement exceedances are depicted as ground track plots in Appendix A and tabulated in Attachment 2 to this application. Each exceedance in Attachment 2 also includes the associated latitude, longitude and duration.

1. **Approach to the ISS Phase**
   This phase of the Cygnus mission to the ISS starts after the Cygnus spacecraft separates from the Antares launch vehicle. The Cygnus spacecraft initial telemetry transmission will be via the telemetry link to TDRS with the emission designator of 6M16G1D. Figure 15 shows the Cygnus spacecraft altitude during the approach phase of the mission. The detailed PFD summaries for each of the different telemetry links are below.

a) The calculated PFD using emission designator, 6M16G1D, is summarized in Figure 1 and Figure 2. This assumes nominal performance from the Antares launch vehicle (i.e. nominal Cygnus orbit insertion). The PFD values which exceed the -144 dBW/m_2/4kHz required limit are summarized in more detail in the bullet items below.
   - Emission designator, 6M16G1D, PFD exceedances are depicted as follows:
     i. Figure 17 (SSA) and Figure 18 (MA), Appendix A, shows the ground track plots.
     ii. In Attachment 2, Table 1 and Table 2: Approach – TDRS SSA (6M16G1D) shows additional details on each exceedance.

b) Figure 3 shows the PFD results when using emission designator, 4M98G1D (2287.5 MHz).

- Figure 19, Appendix A, shows the associated PFD exceedance as ground track plots.
- The PFD limit exceedances are also detailed in Attachment 2, Table 3: Approach – 4M98G1D (2287.5 MHz).

c) Figure 4 shows the PFD results when using emission designator, 3M00G1D (2287.5 MHz).
   - Figure 20, Appendix A, shows the associated PFD exceedance as ground track plots.
   - The PFD limit exceedances are also detailed in Attachment 2, Table 4: Approach – 3M00G1D (2287.5 MHz).

d) Figure 5 shows the PFD results, when using emission designator, 5M93G1D.
   - Figure 21, Appendix A, shows the associated PFD exceedance as ground track plots.
   - The PFD limit exceedances are also detailed in Attachment 2, Table 5: Approach (CLS – 5M93G1D).

2. Berthed at the ISS Phase

This phase of the mission starts after the Cygnus vehicle is grappled by the ISS robotic arm and berthed at the ISS. During this phase of the mission, the Cygnus to ISS RF communications link (5M93G1D) will not be active (i.e. powered down) after the Cygnus spacecraft is berthed. The Cygnus spacecraft telemetry transmission will be via the CTC telemetry link to TDRS with the emission designator 6M16G1D. The Cygnus to ground station links will use the emission designator 4M98G1D. The detailed PFD summary for the different telemetry links are below.

a) The calculated Cygnus emitter's PFD while berthed at the ISS and using emission designator, 6M16G1D, is summarized in Figure 6 below. All calculated PFD values meet the PFD requirements with margin.

b) Figure 7 shows the PFD results, when using emission designator, 3M00G1D (2287.5 MHz). All calculated PFD values met the PFD limits.

c) Figure 8 shows the PFD results, when using emission designator, 4M98G1D (2287.5 MHz). All calculated PFD values met the PFD limits.

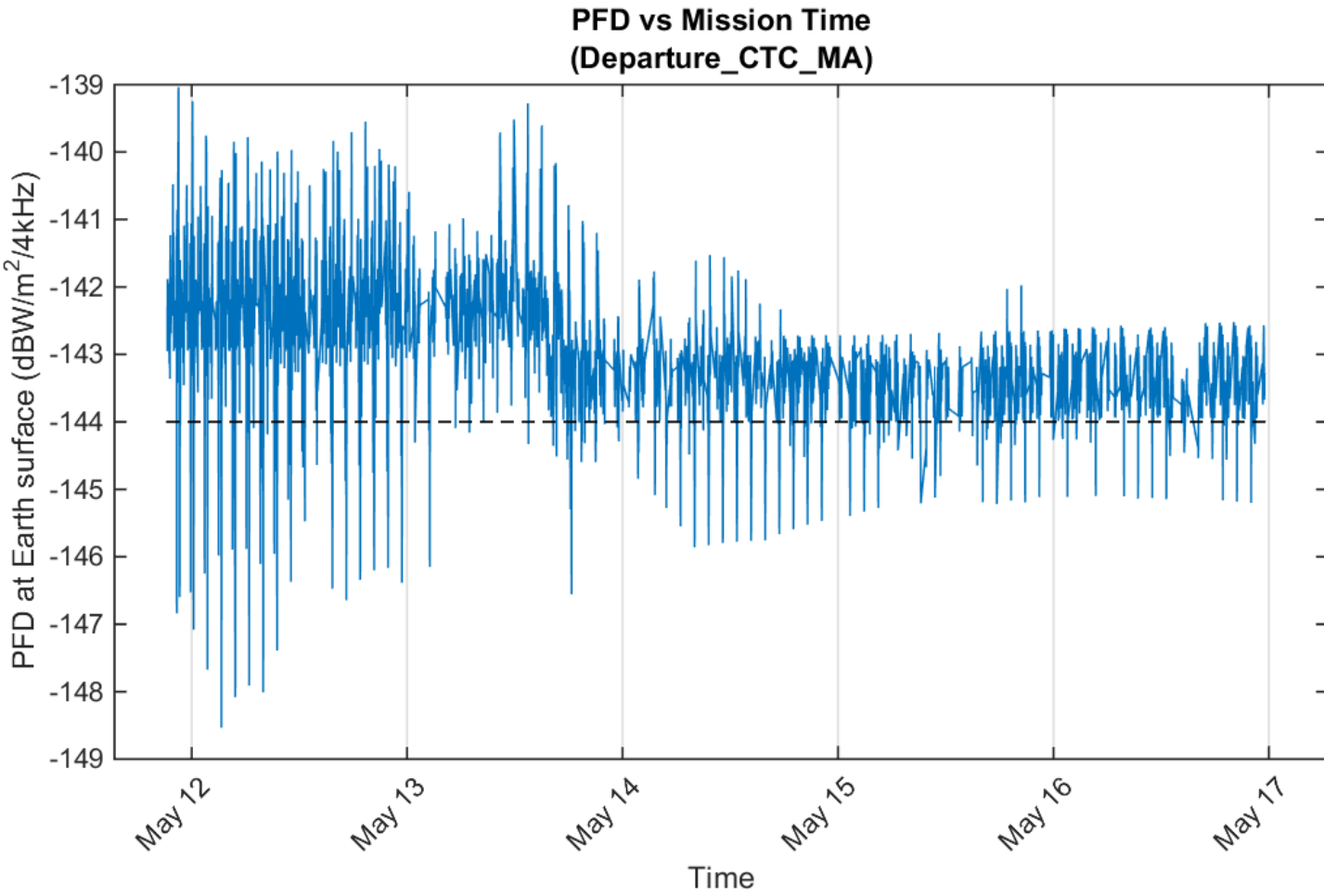
d) Figure 9 shows the PFD results, when using emission designator, 5M93G1D (2203.2 MHz).
   - Figure 22, Appendix A, shows the associated PFD exceedance as ground track plots.
   - The PFD limit exceedances are also detailed in Attachment 2, Table 1: Berthed – 5M93G1D (2203.2 MHz).

3. Departure from the ISS Phase

The Departure Phase of the mission starts after the Cygnus spacecraft is already unberthed from the ISS and released by the ISS robotic arm. The Cygnus spacecraft

then performs a series of departure burns to lower its perigee. A final reentry burn will put the Cygnus spacecraft on a controlled reentry path into the Earth's atmosphere. All four emitters, 6M16G1D, 4M98G1D and 5M93G1D will be active during the Cygnus spacecraft departure from the ISS. Emitters 6M16G1D (TDRS), 4M98G1D (ground station) will be active throughout the ISS departure phase and the spacecraft reentry. The CLS link, 5M93G1D, will be active during the Cygnus spacecraft departure from the ISS but will be powered off prior to the vehicle's destructive reentry. The detailed PFD summaries for all four emitters are below.

a) The calculated PFD using emission designator, 6M16G1D, is summarized in Figure 10. The PFD values which exceed the -144 dBW/m_2/4kHz required limit are summarized in more detail in the bullet items below.
   - Emission designator, 6M16G1D, PFD exceedances are depicted as follows:
     i. Figure 23, Appendix A, show the ground track plots.
     ii. Attachment 2, Table 1: Departure – TDRS SSA (6M16G1D) shows additional details on each exceedance.



b) Figure 11 shows the PFD results, when using emission designator, 6M16G1D (2287.5 MHz – TDRS MA), during the departure phase.
   - Figure 24, Appendix A, shows the associated PFD exceedance as ground track plots.
   - The PFD limit exceedances are detailed in Attachment 2, Table 2: Departure (TRDS SMA – 6M16G1D).

c) Figure 12 shows the PFD results, when using emission designator, 4M98G1D, during the departure phase.
   - Figure 25, Appendix A, shows the associated PFD exceedance as ground track plots.
   - The PFD limit exceedances are detailed in Attachment 2, Table 3: Departure – GN (4M98G1D).

d) Figure 13 shows the PFD results, when using emission designator, 3M00G1D, during the departure phase.
   - Figure 26, Appendix A, shows the associated PFD exceedance as ground track plots.
   - The PFD limit exceedances are detailed in Attachment 2, Table 4: Departure – GN (3M00G1D).

e) Figure 14 shows the PFD results, when using emission designator, 5M93G1D, during the departure phase.
   - Figure 27, Appendix A, shows the associated PFD exceedance as ground track plots.
   - The PFD limit exceedances are detailed in Attachment 2, Table 5: Departure – GN (5M93G1D).

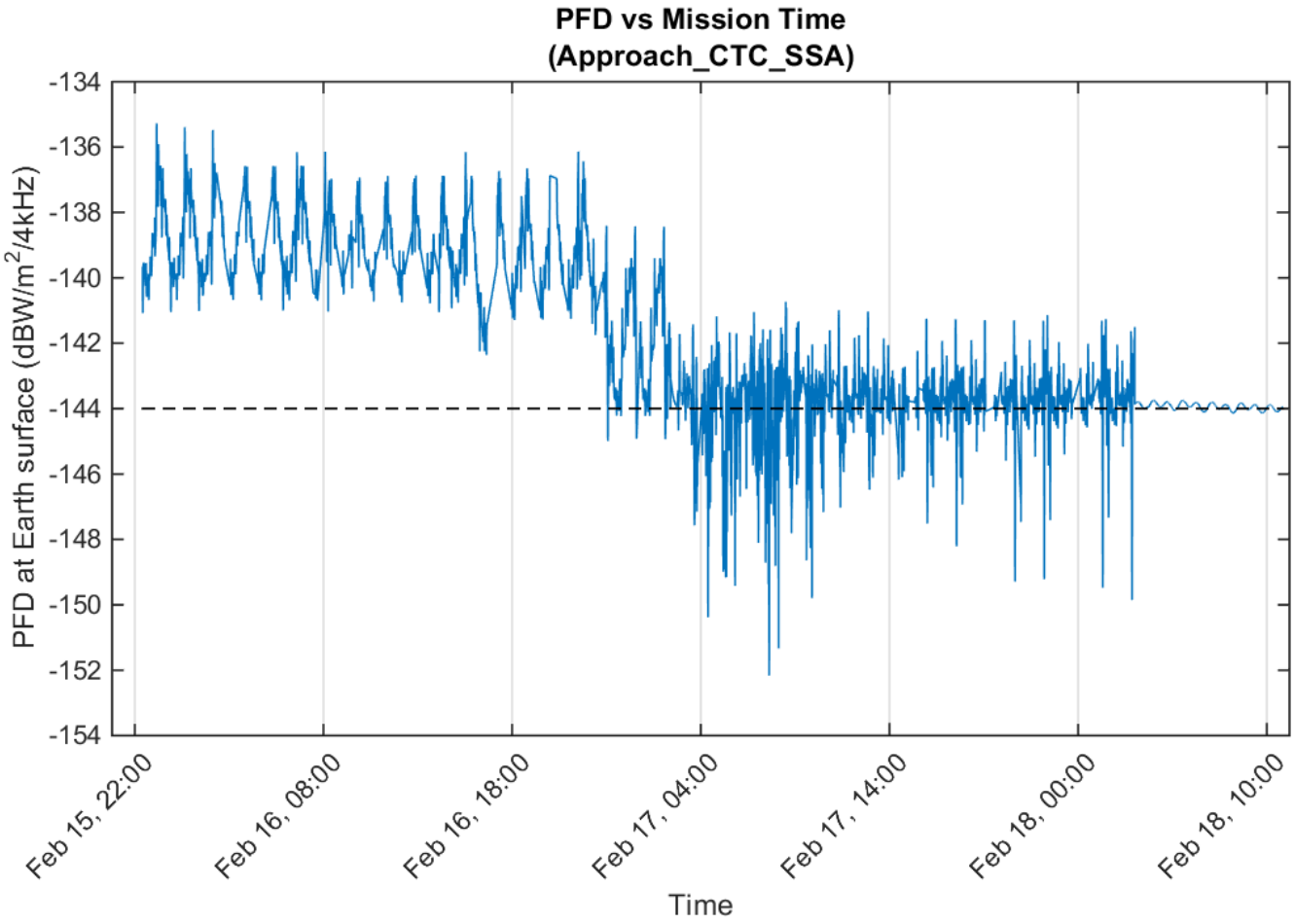


Figure 1 NG-14 Cygnus PFD During Mission Nominal Approach TDRS SSA (6M16G1D Emitter)

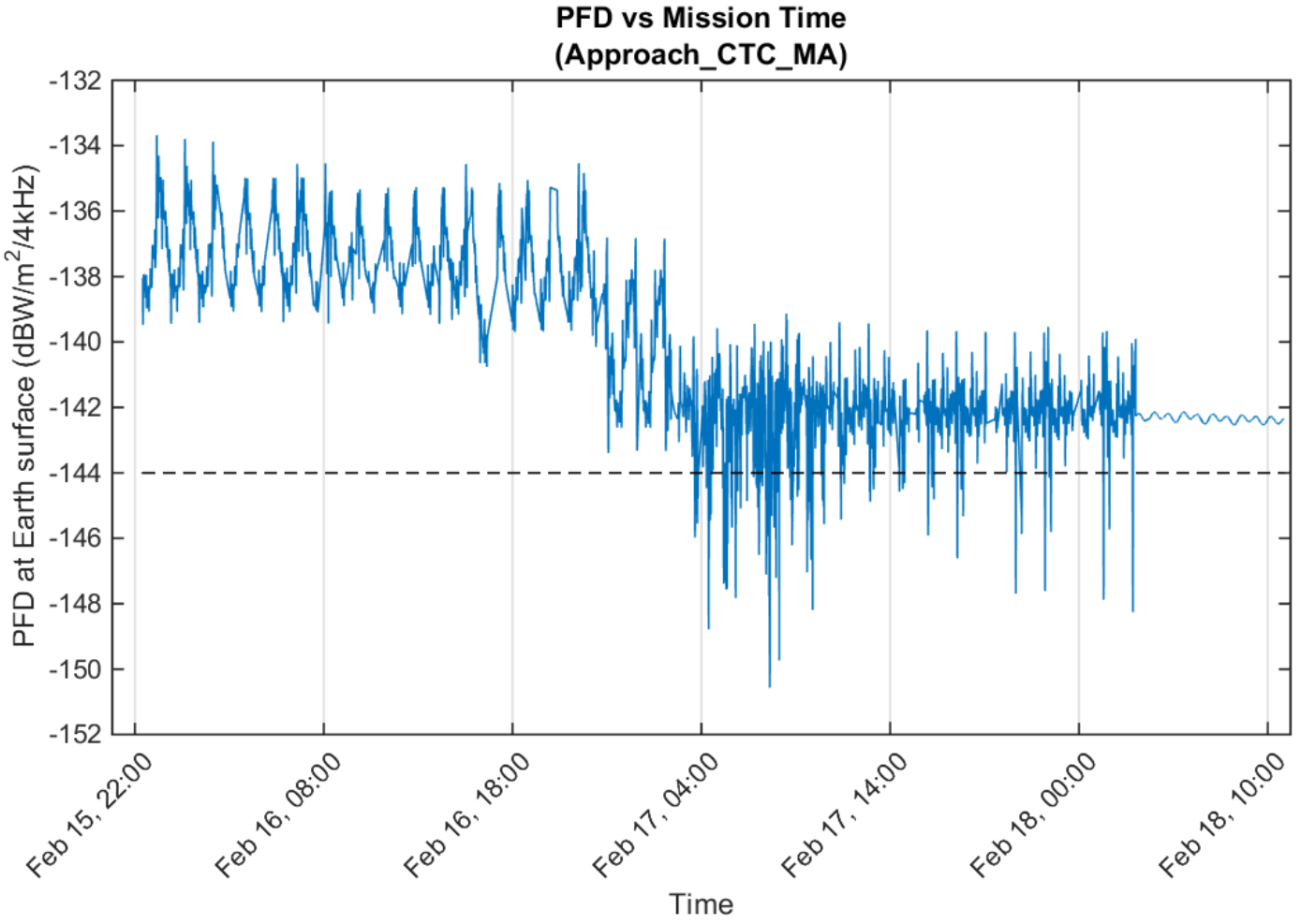


Figure 2 NG-14 Cygnus PFD During Mission Nominal Approach TDRS MA (6M16G1D Emitter)

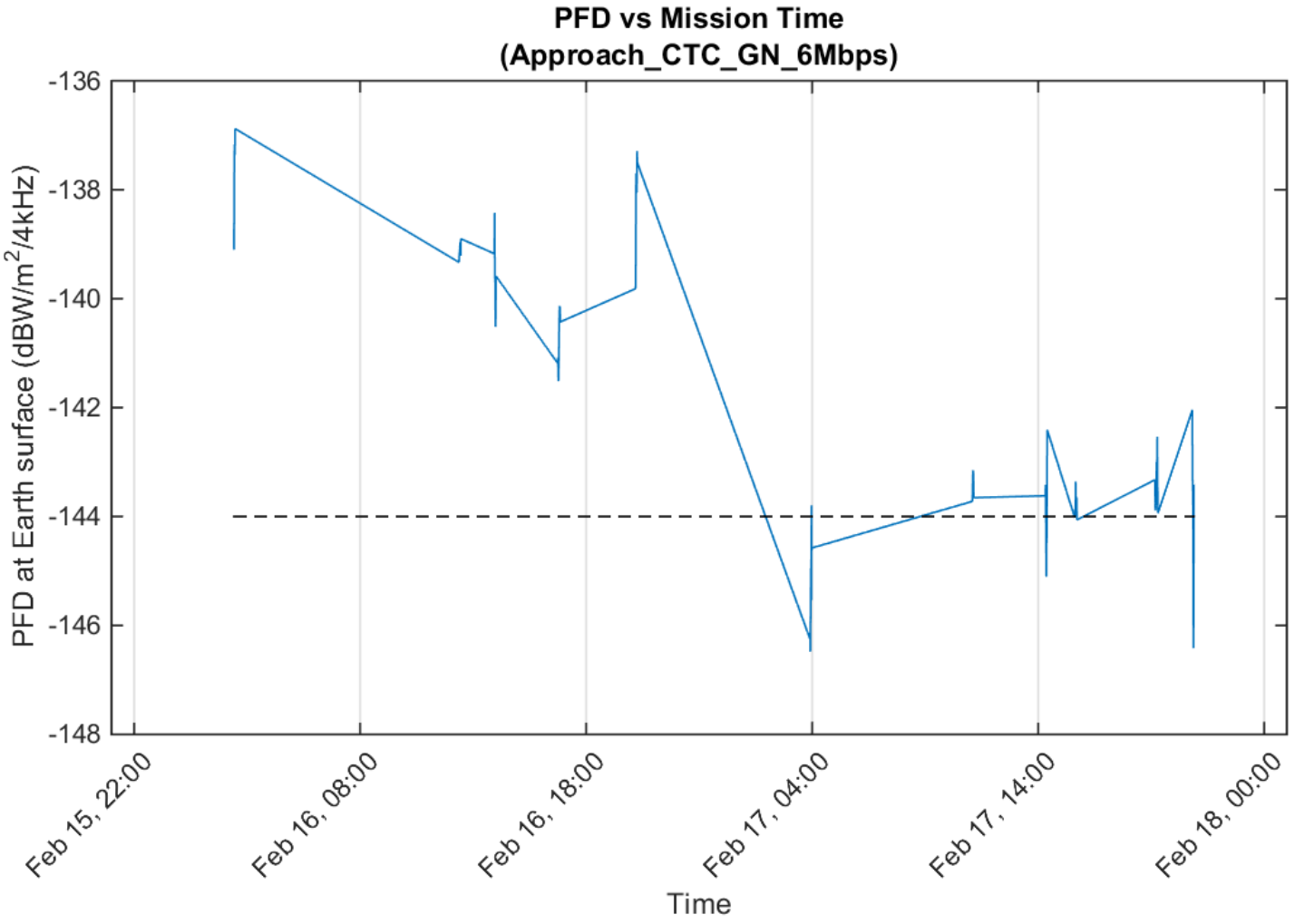


Figure 3 NG-14 Cygnus PFD During Mission Nominal Approach (4M98G1D Emitter)

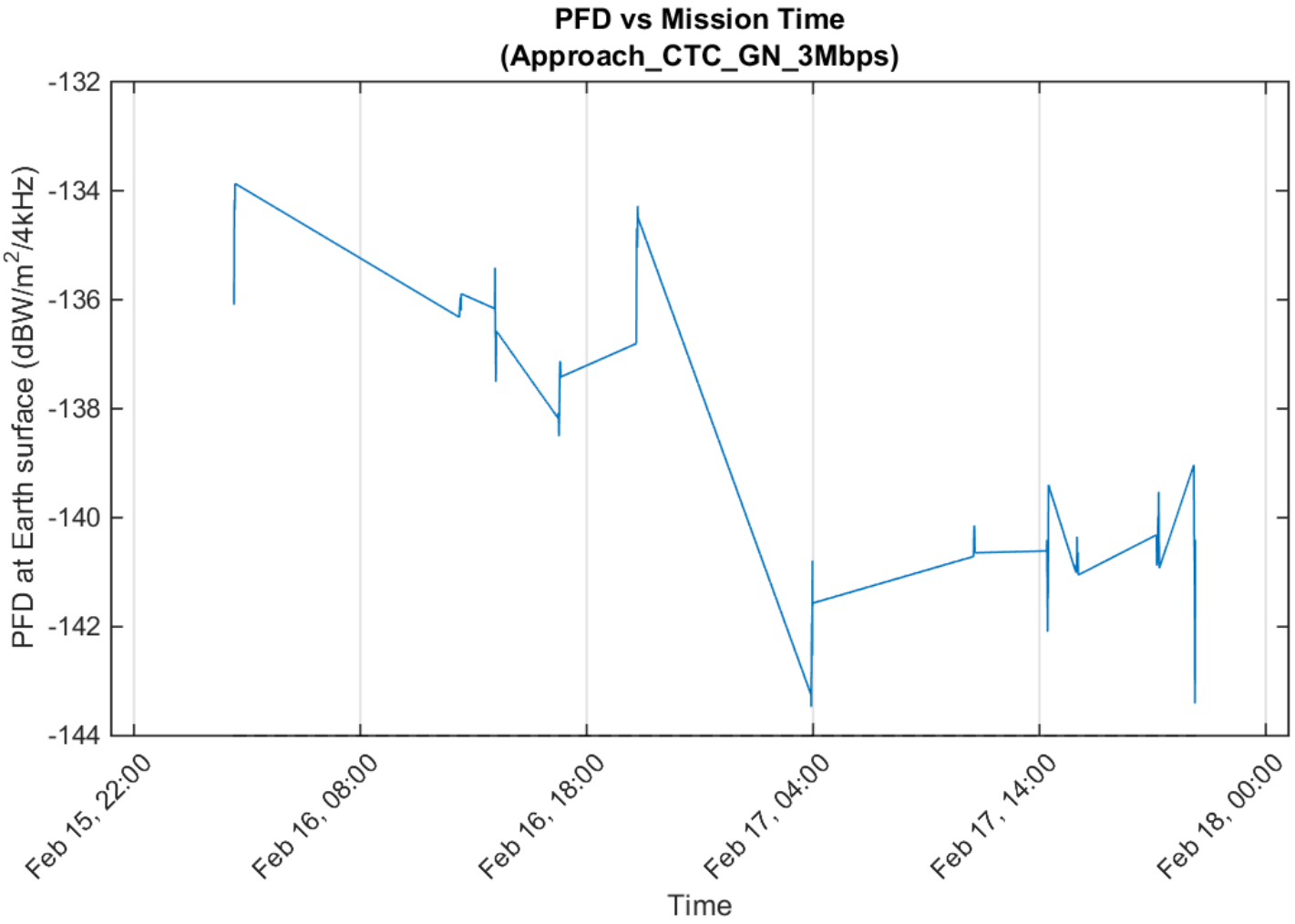


Figure 4 NG-14 Cygnus PFD During Mission Nominal Approach (3M00G1D Emitter)

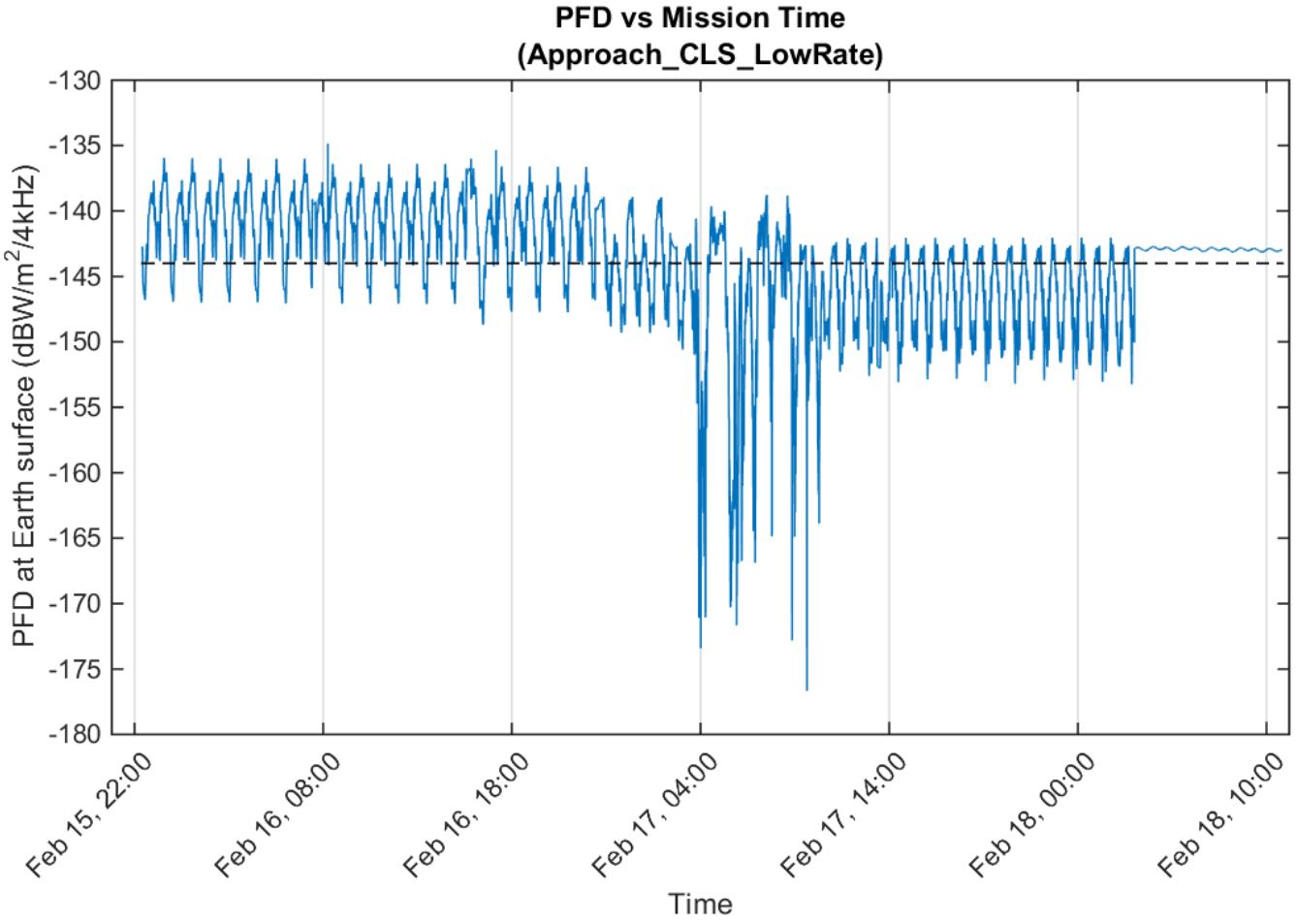


Figure 5 NG-14 Cygnus PFD During Mission Nominal Approach (5M93G1D Emitter)

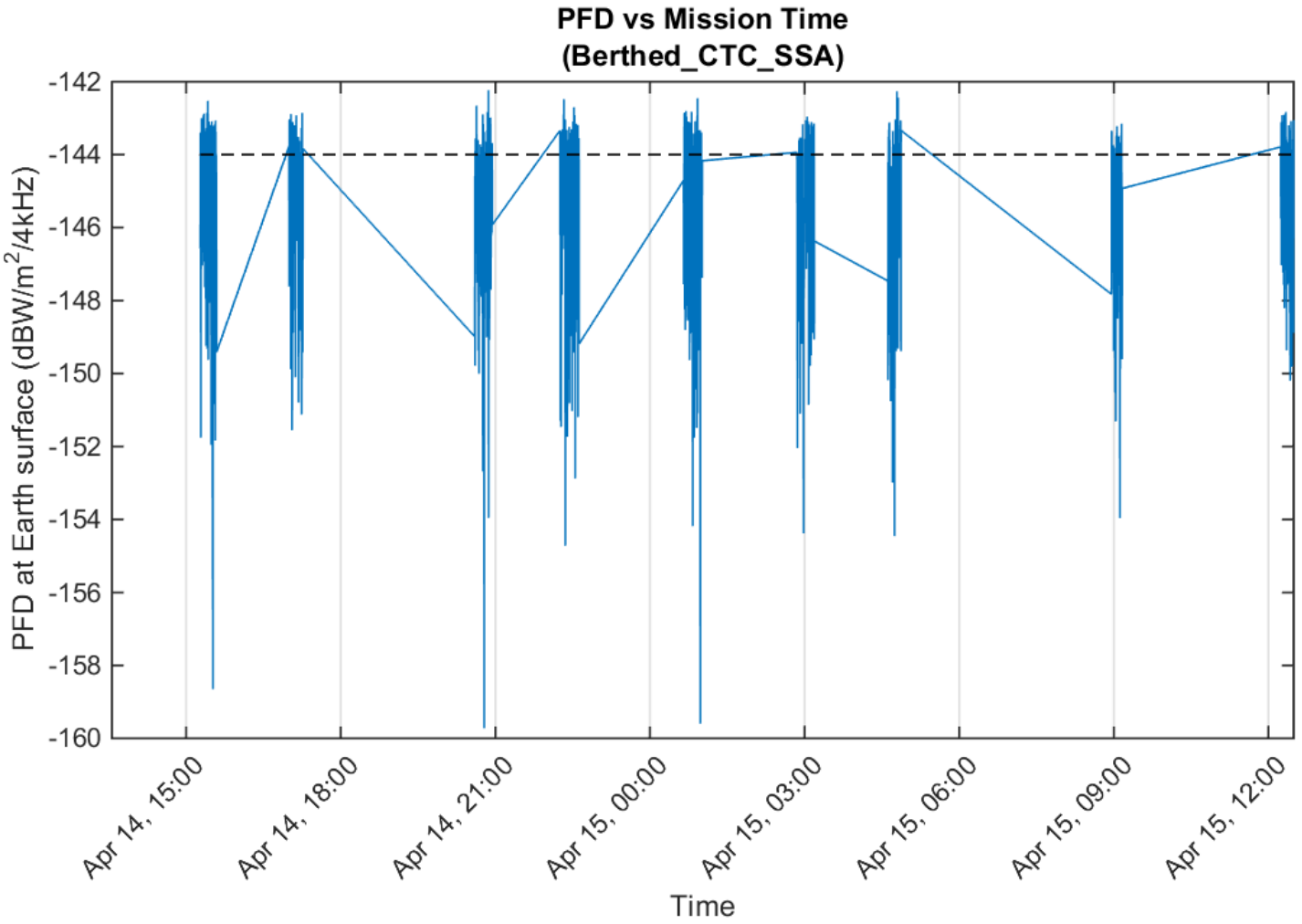


Figure 6 NG-14 Cygnus PFD During Berthed Phase (6M16G1D Emitter – TDRS SSA)

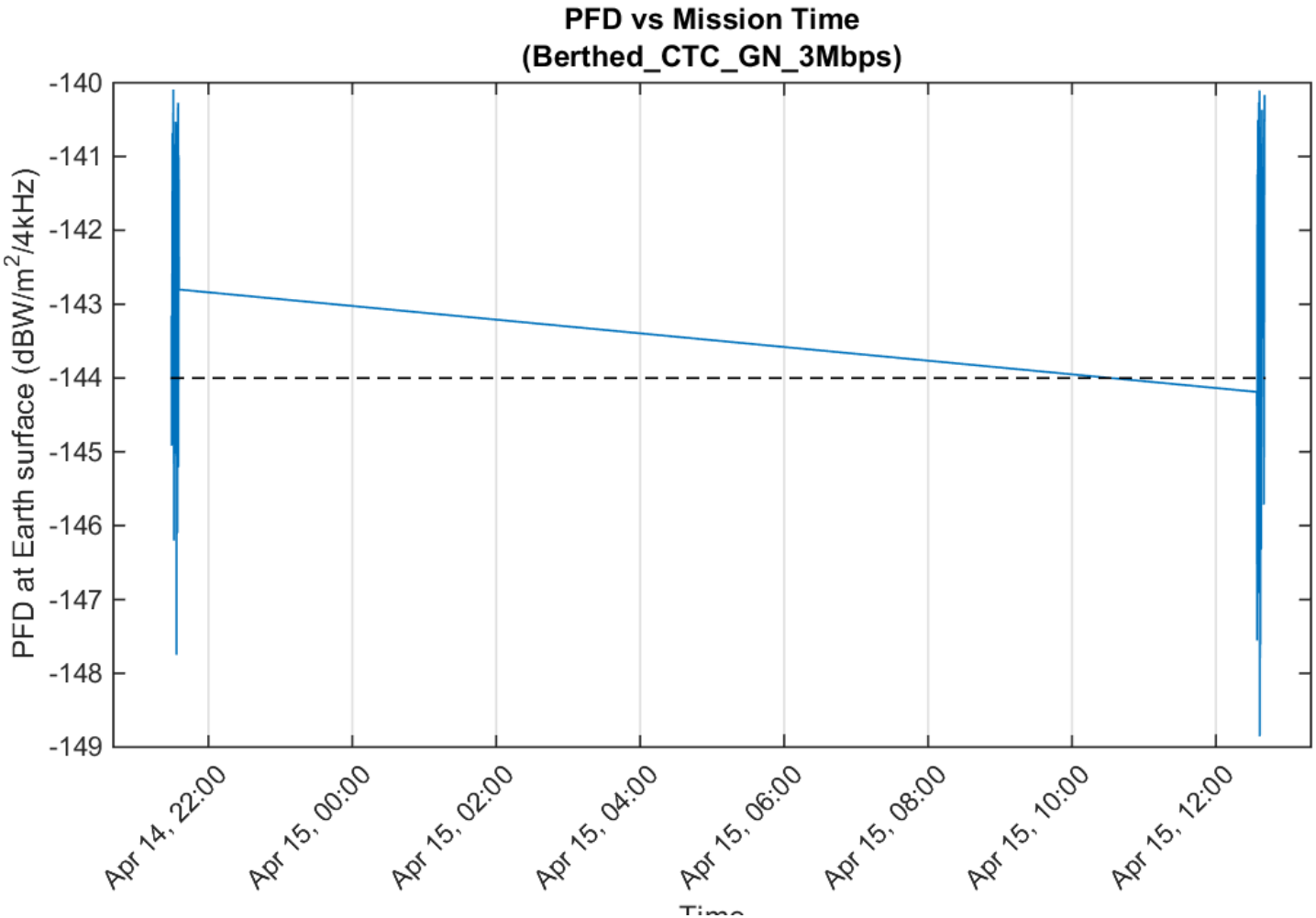


Figure 7 NG-14 Cygnus PFD During Berthed Phase (3M00G1D Emitter – GN 3 Mbps)

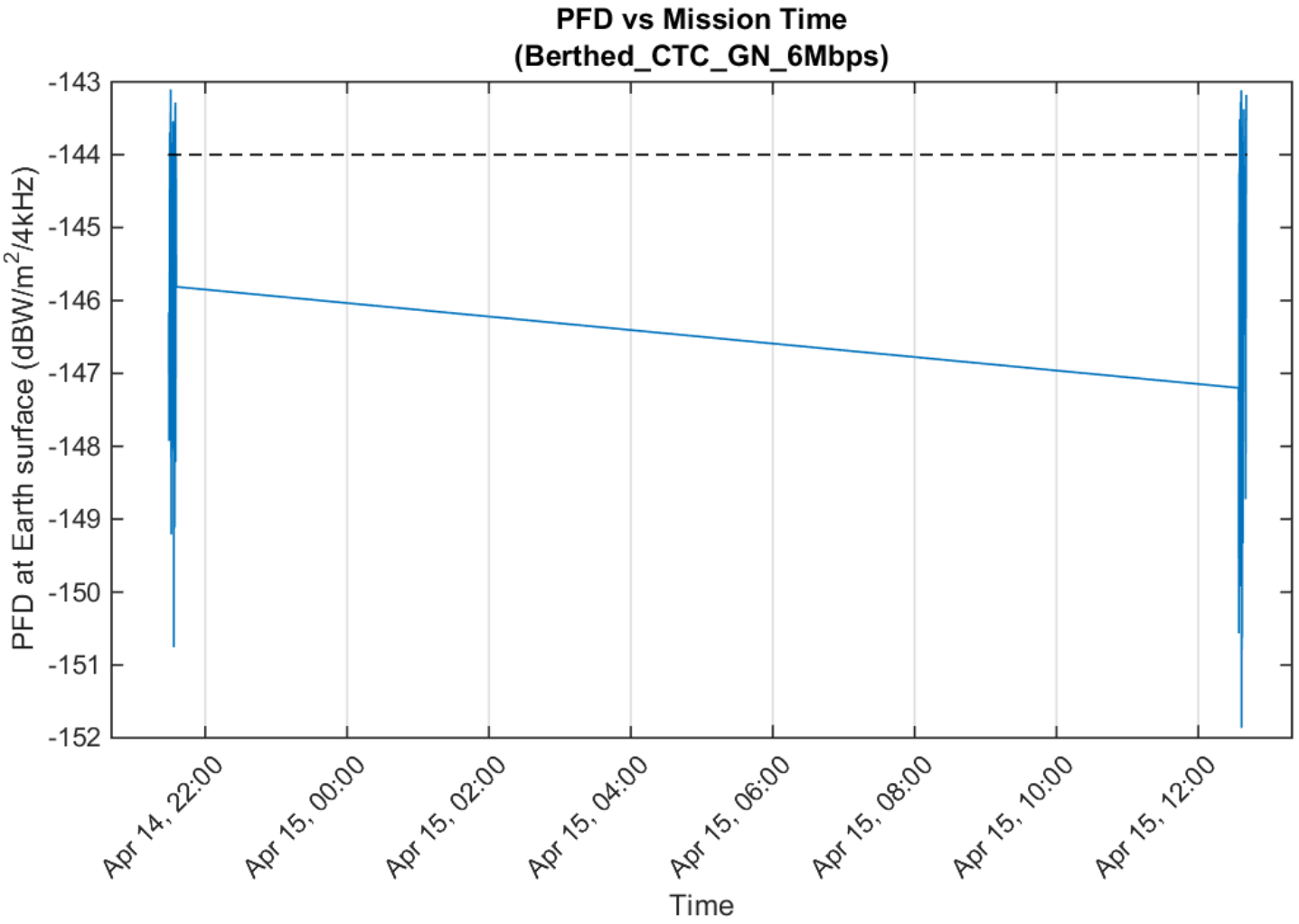


Figure 8 NG-14 Cygnus PFD During Berthed Phase (4M98G1D Emitter – GN 6 Mbps)

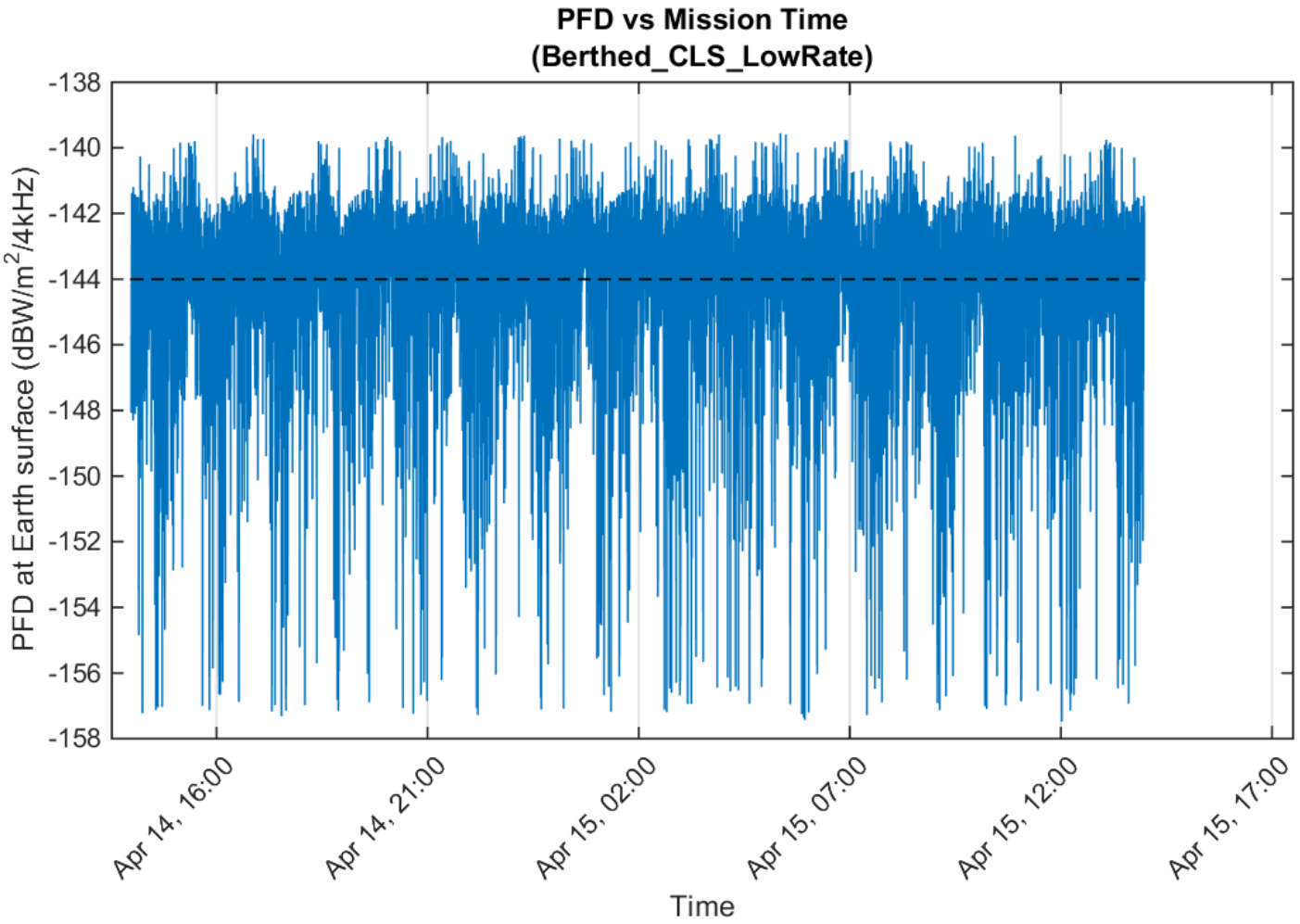


Figure 9 NG-14 Cygnus PFD During Berthed Phase (5M93G1D Emitter)

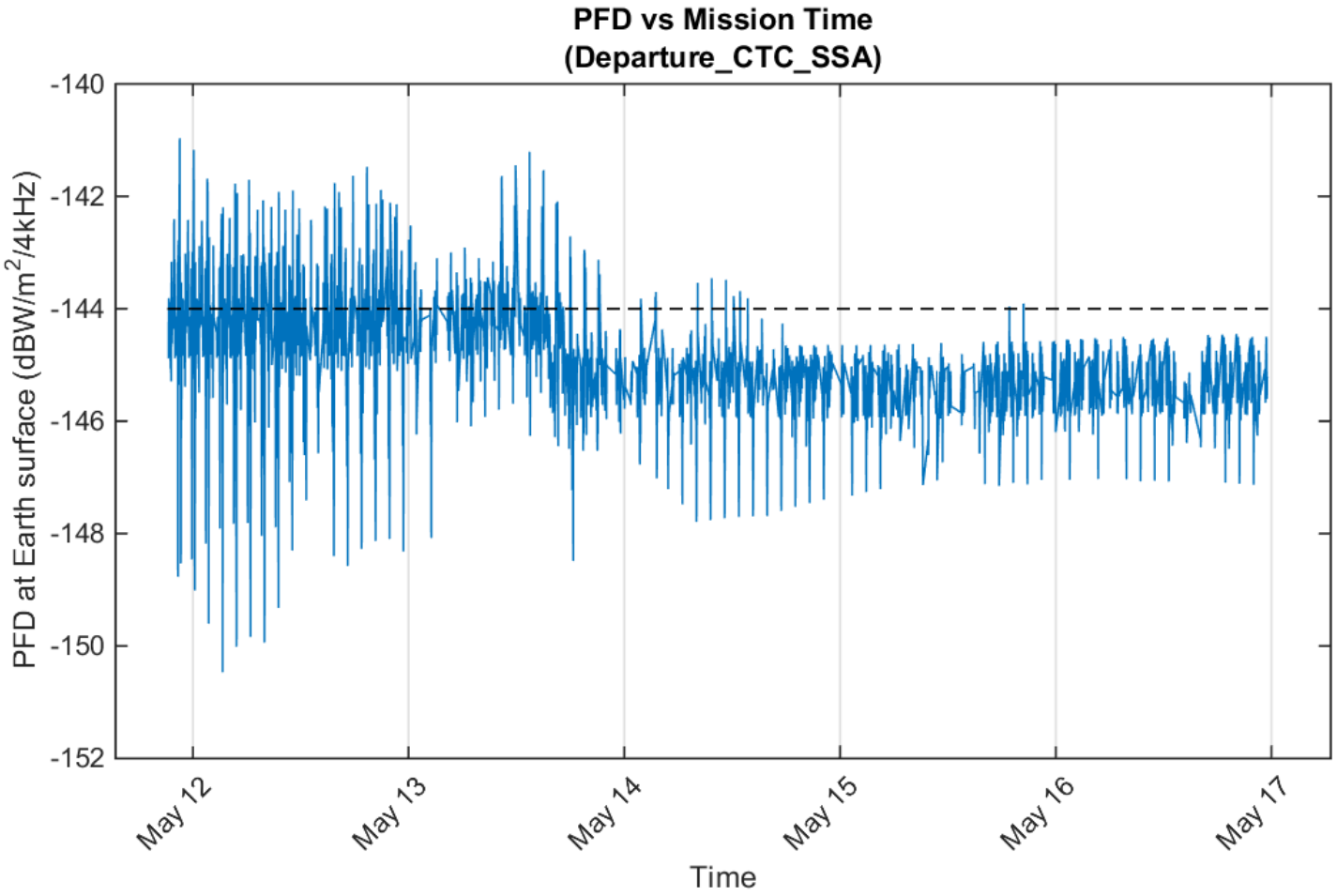


Figure 10 NG-14 Cygnus PFD During Departure Phase (6M16G1D Emitter – TDRS SSA)

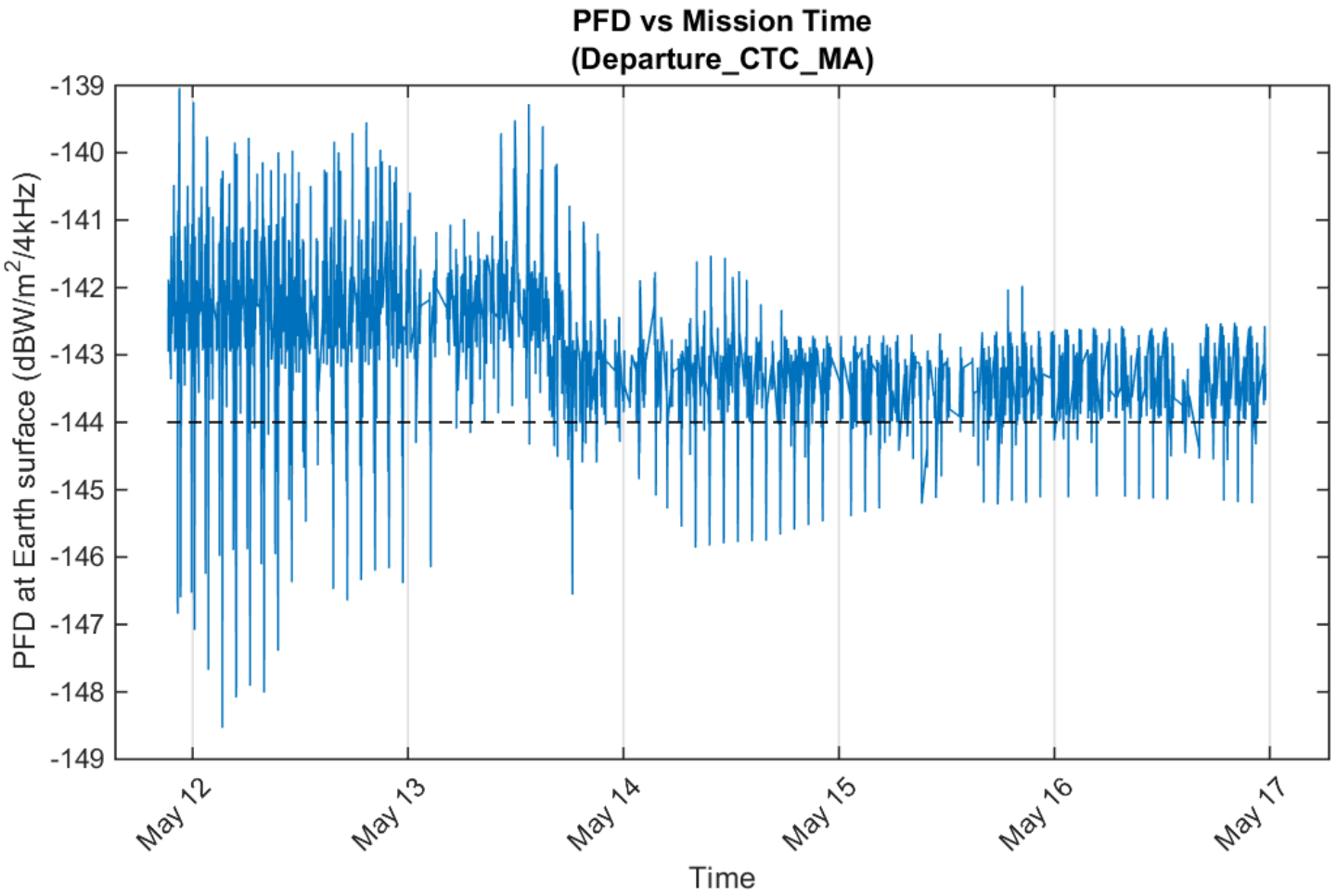


Figure 11 NG-14 Cygnus PFD During Departure Phase (6M16G1D Emitter – TDRS MA)

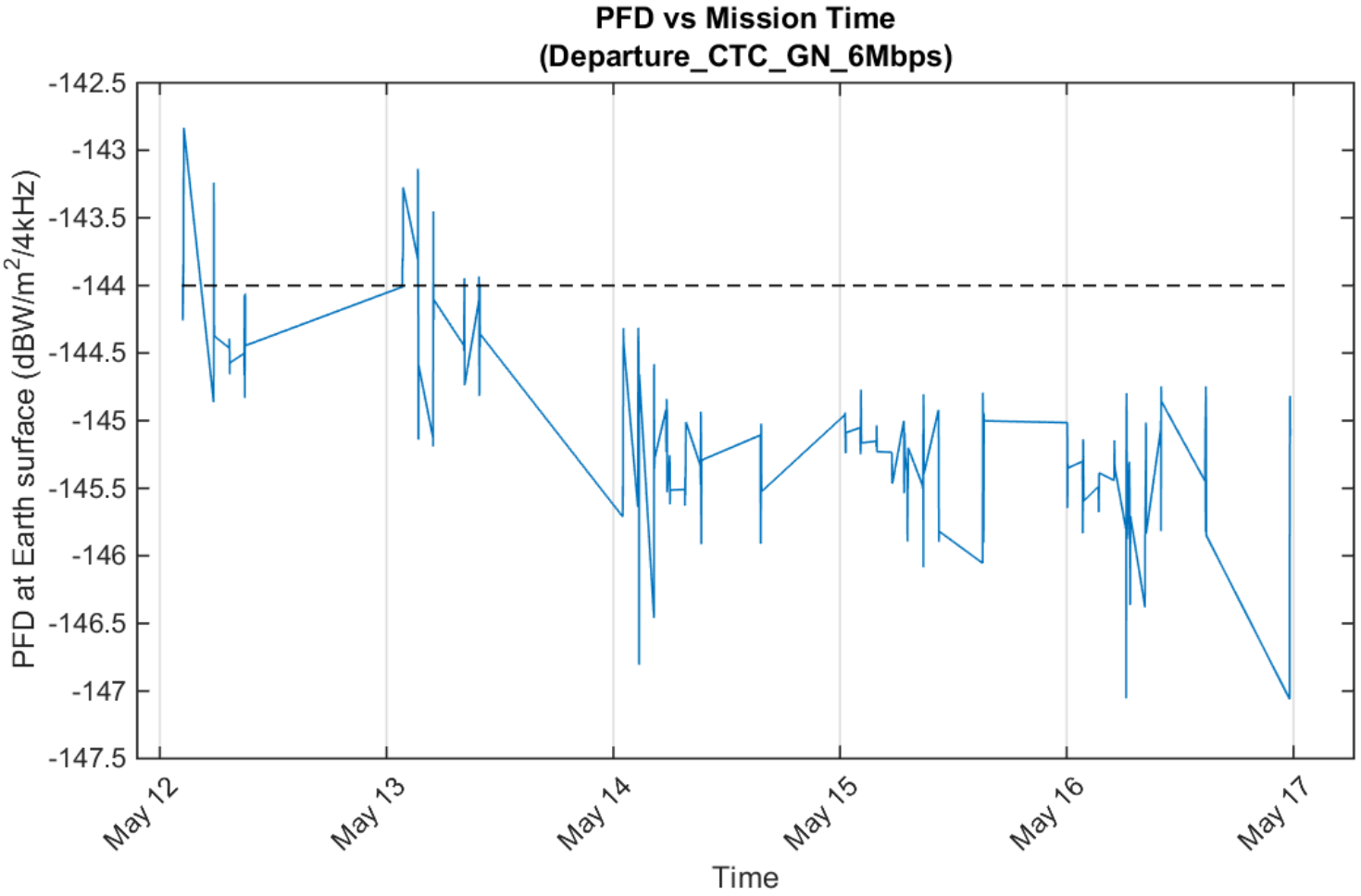


Figure 12 NG-14 Cygnus PFD During Departure Phase (4M98G1D Emitter – GN 6 Mbps)

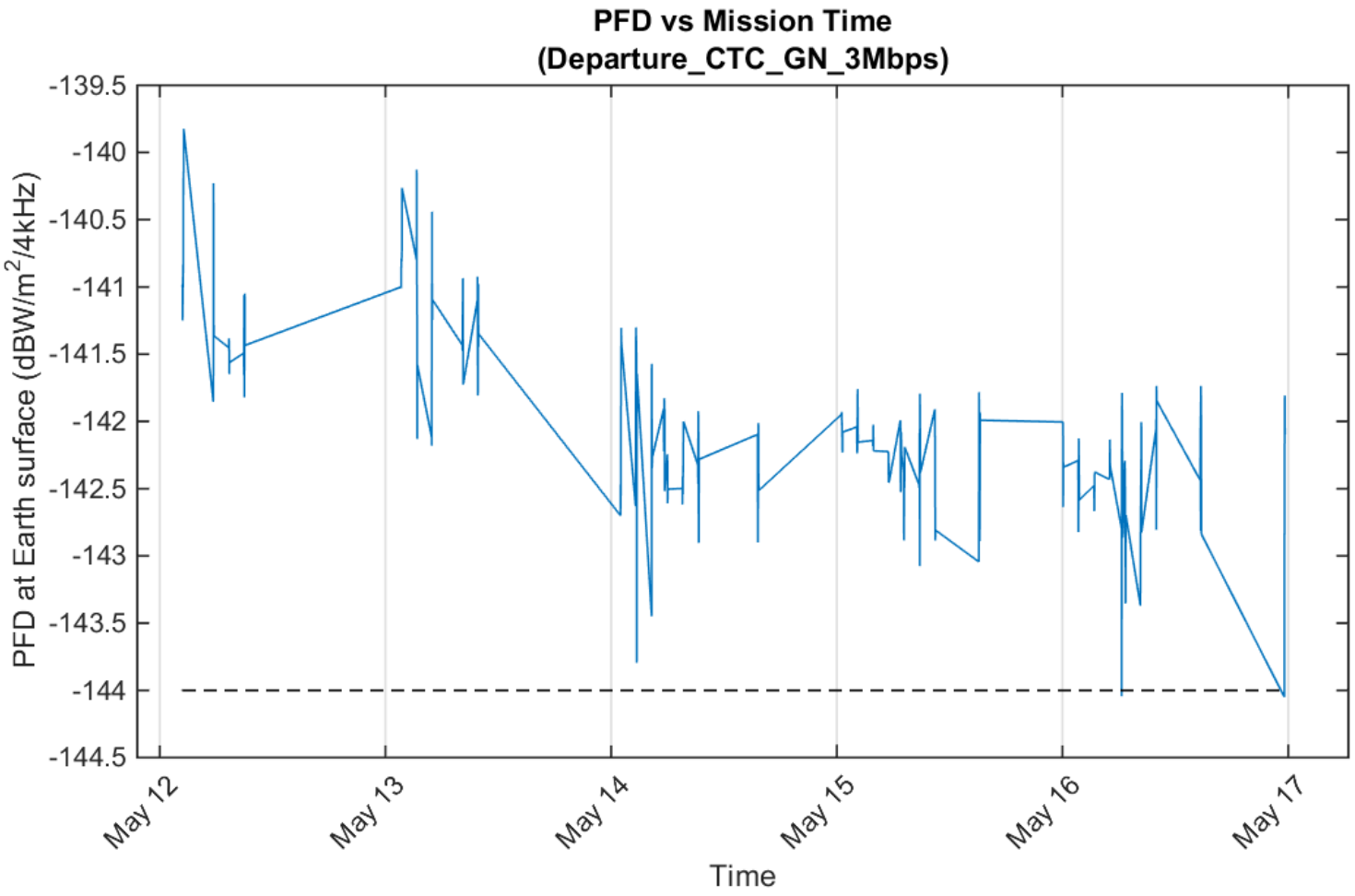


Figure 13 NG-14 Cygnus PFD During Departure Phase (3M00G1D Emitter – GN 3 Mbps)

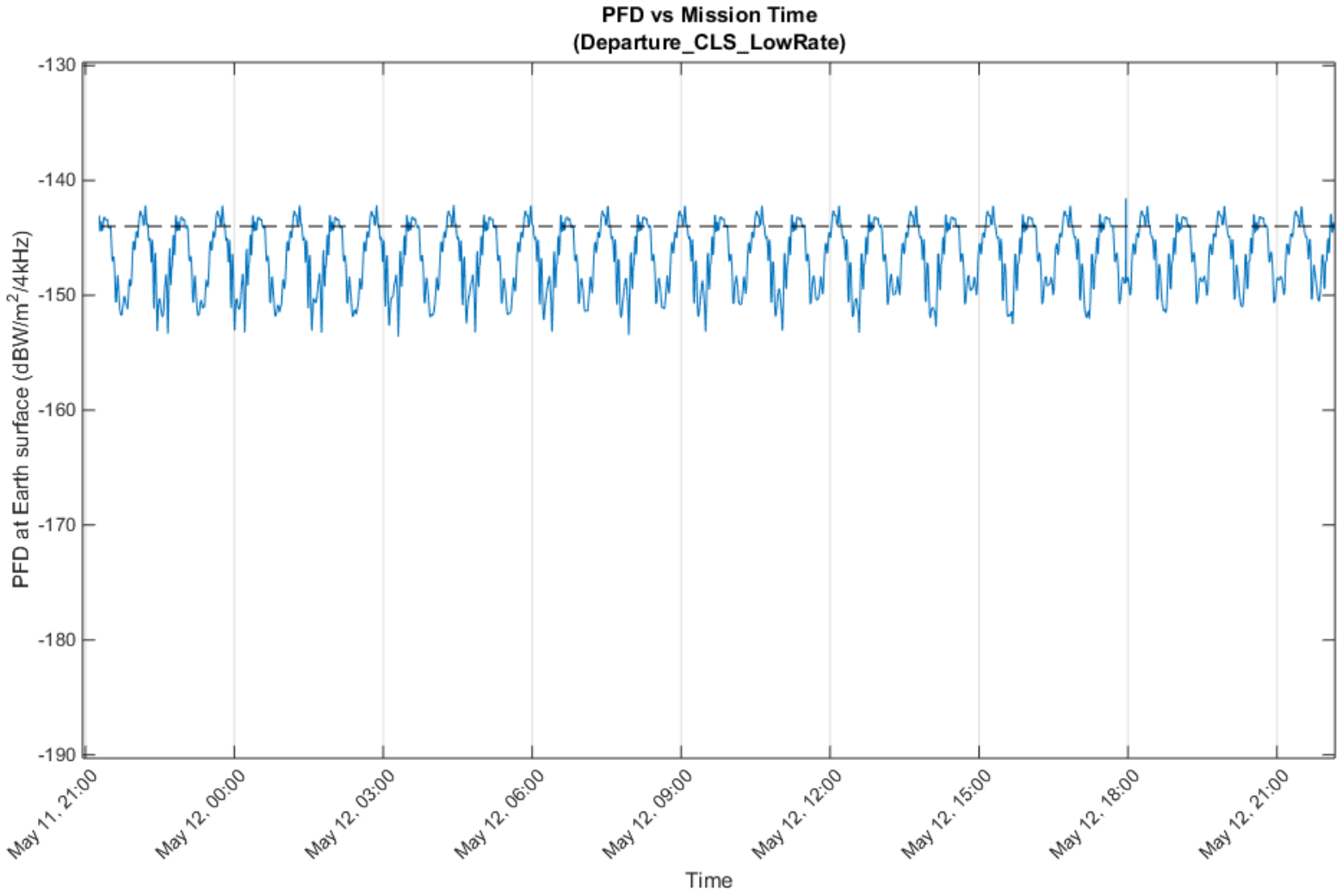


Figure 14 NG-14 Cygnus PFD During Departure Phase (5M93G1D Emitter)

Appendix A

(Ground Track Plots of PFD Exceedances during Mission Phases)

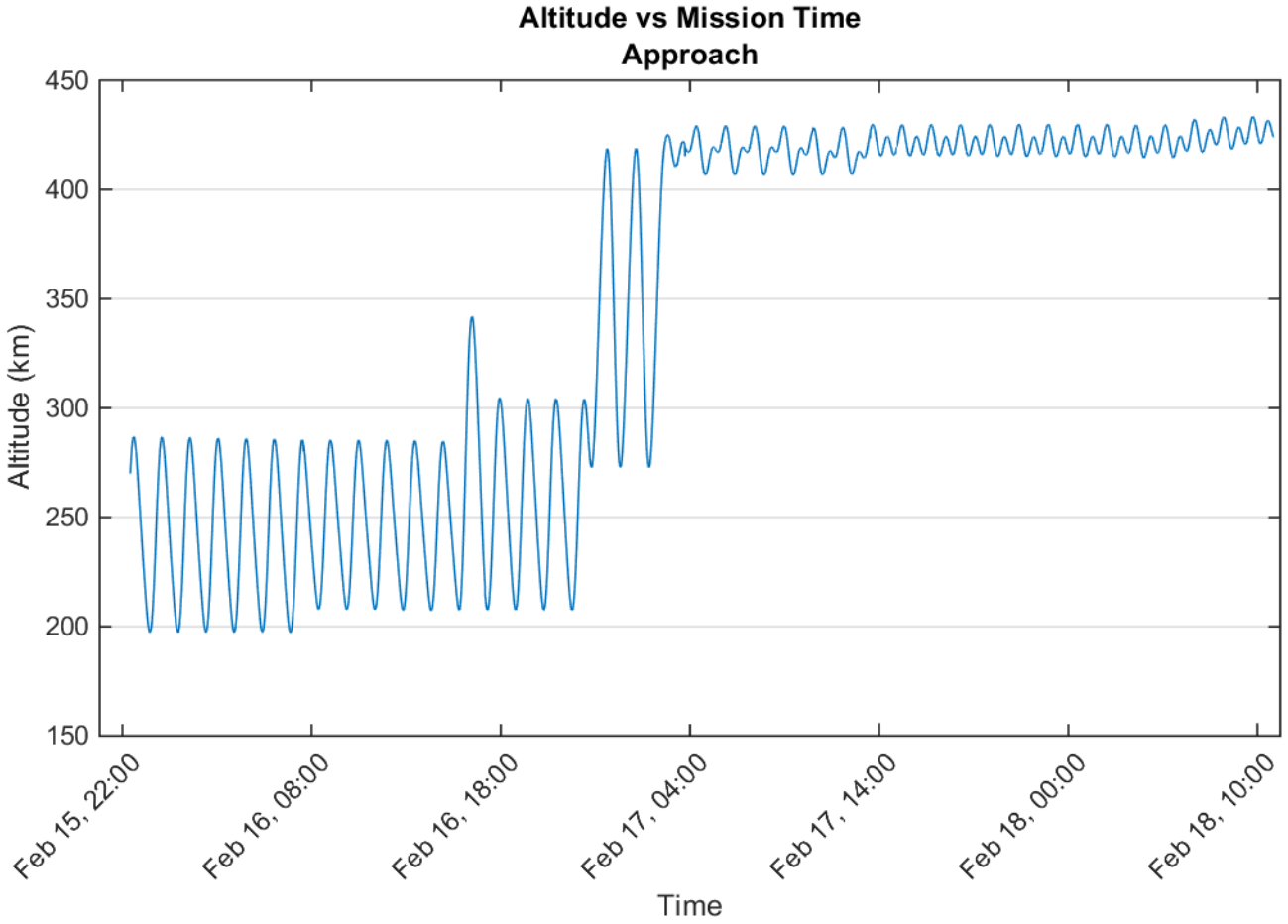


Figure 15 NG-14 Cygnus Altitude vs. Mission Time (Approach)

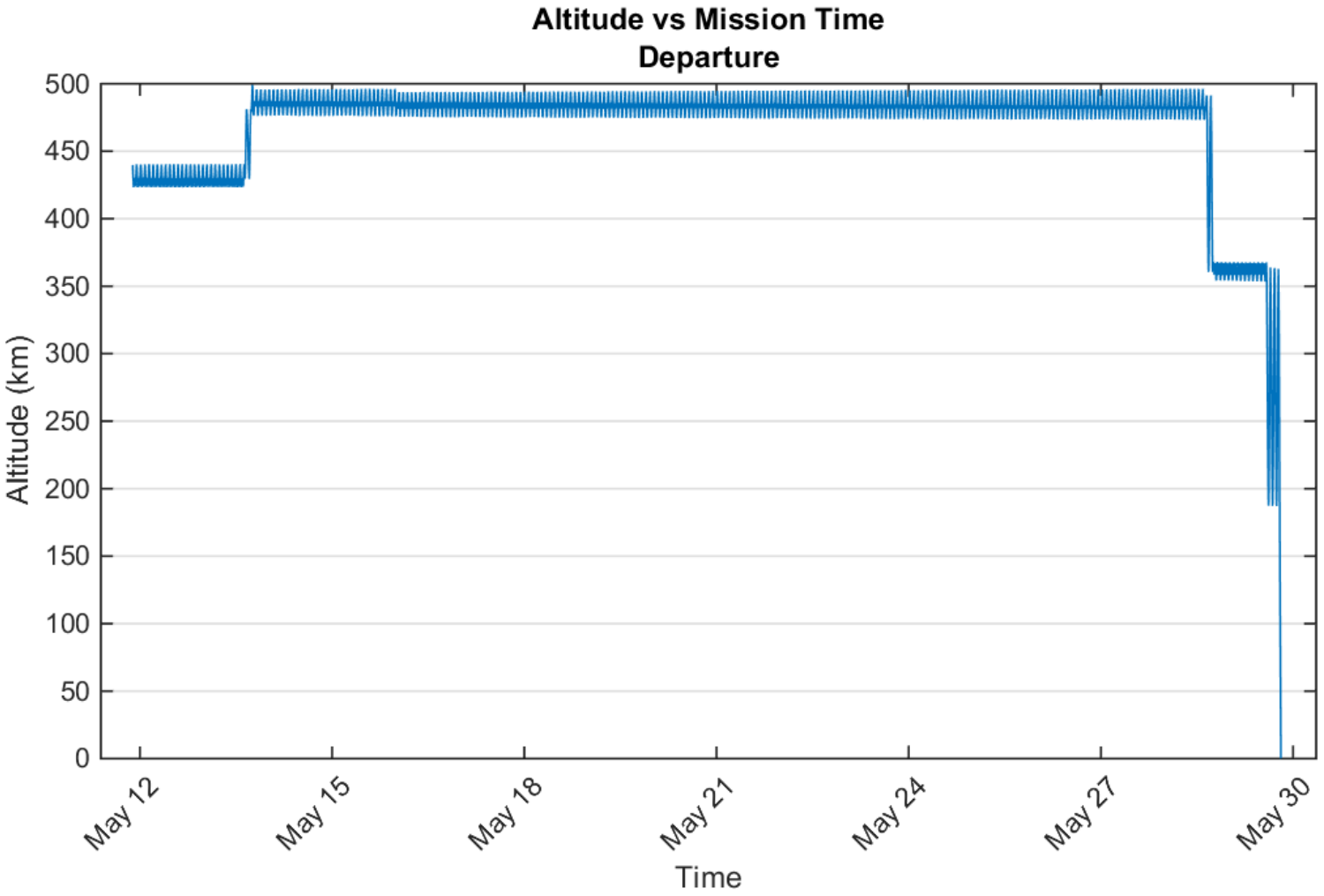


Figure 16 NG-14 Cygnus Altitude vs. Mission Time (Departure)

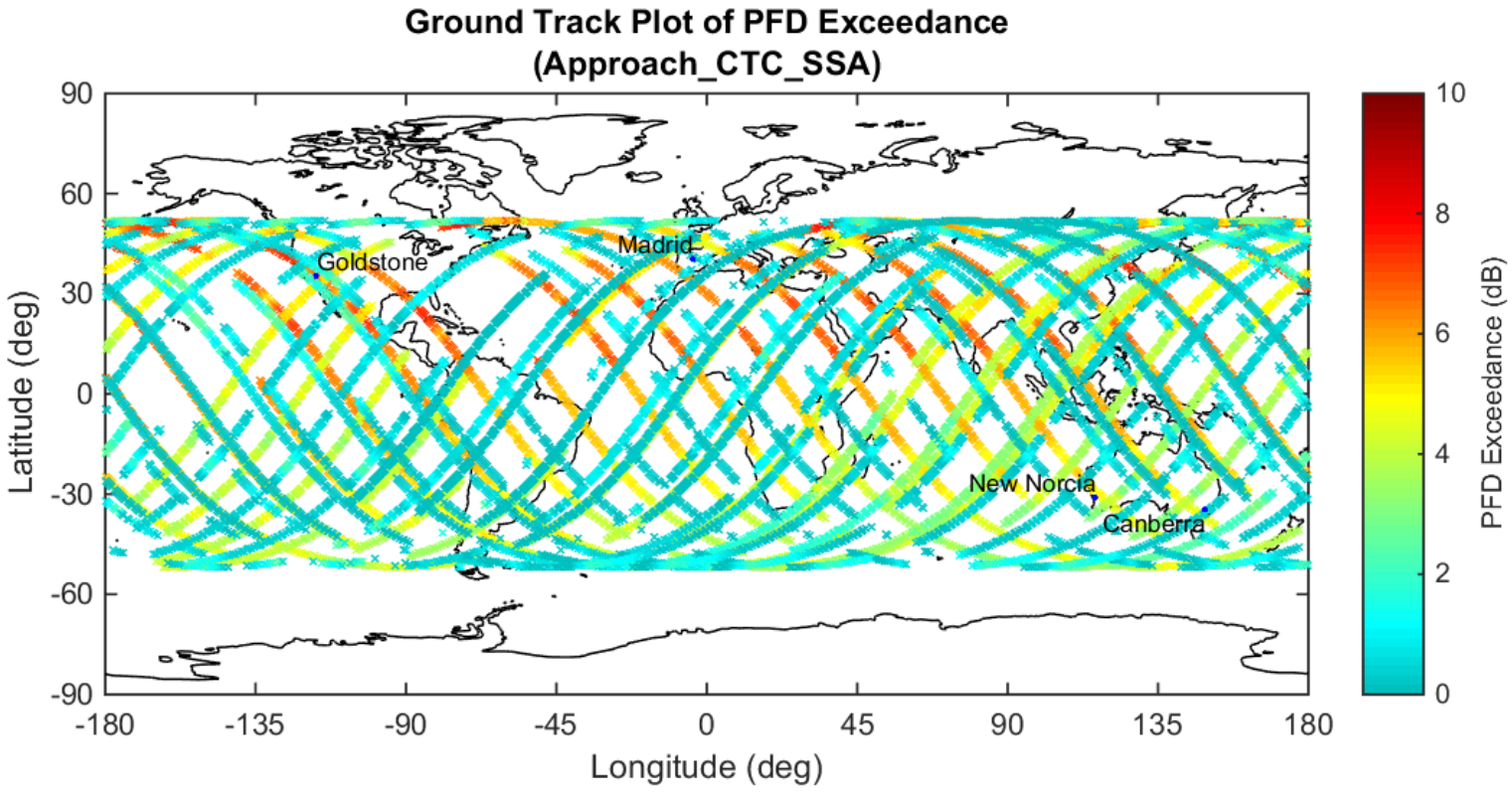


Figure 17 NG-14 Cygnus PFD Limit Exceedance During Mission Approach TDRS SSA (6M16G1D Emitter)

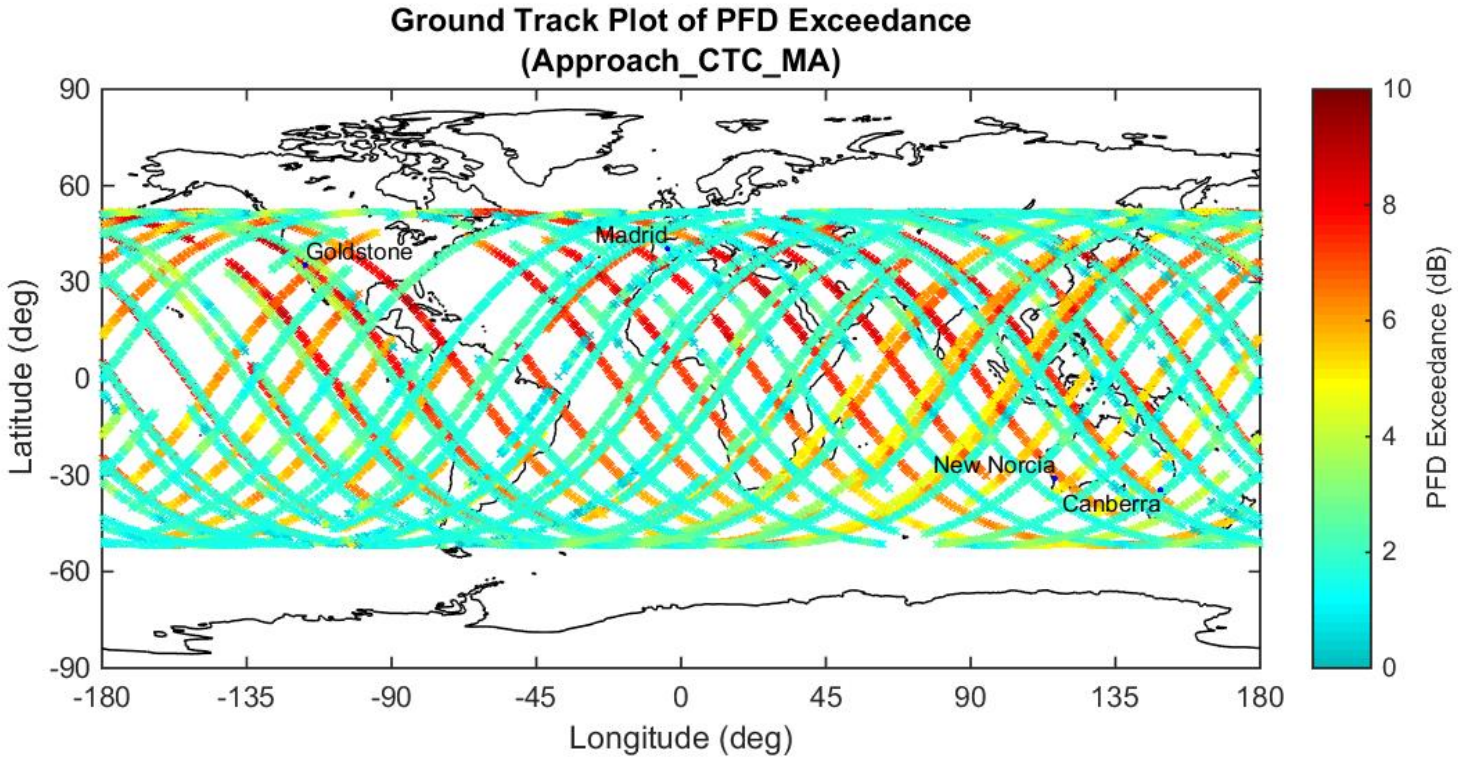


Figure 18 NG-14 Cygnus PFD Limit Exceedance During Mission Approach TDRS MA (6M16G1D Emitter)

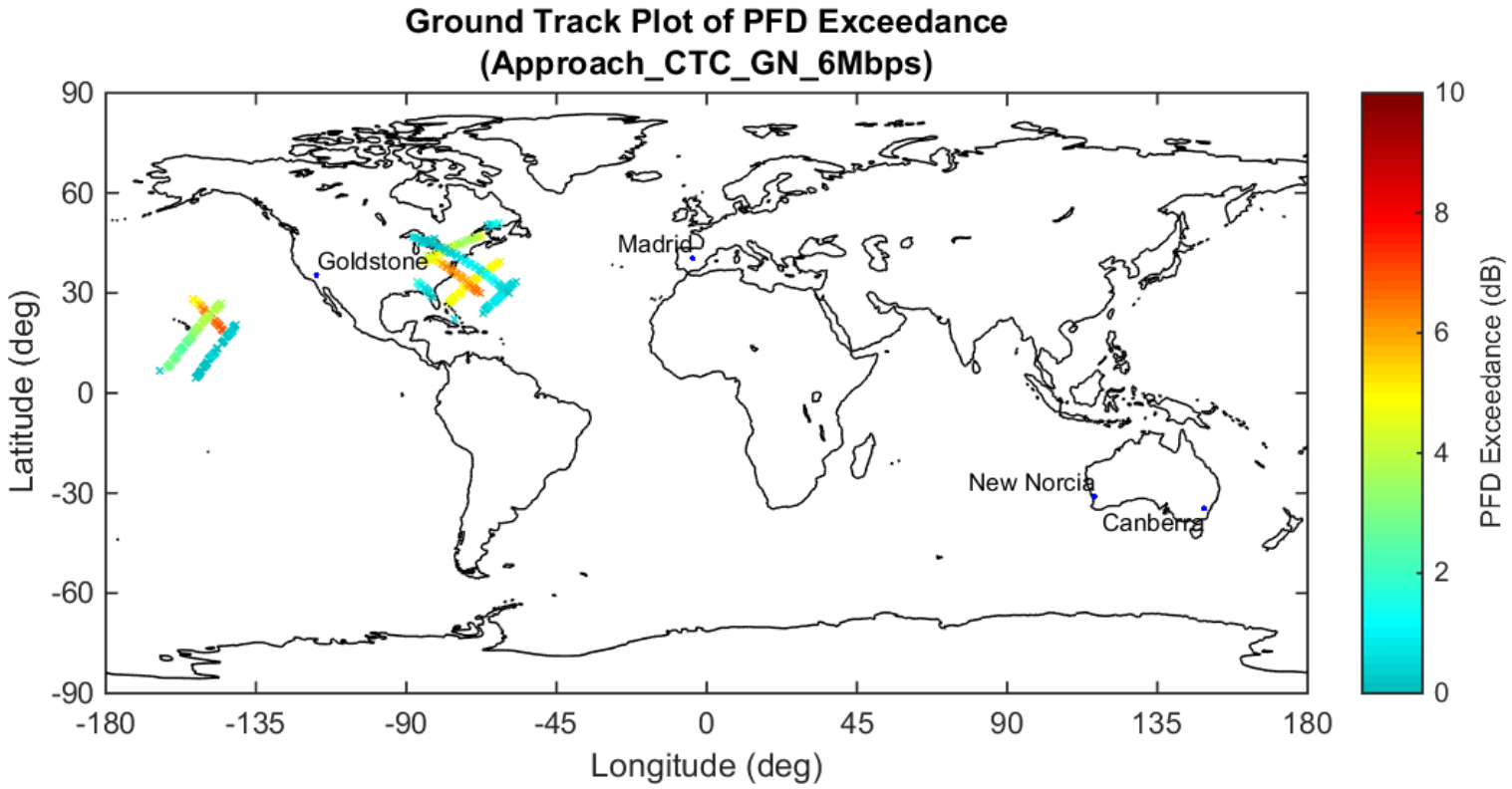


Figure 19 NG-14 Cygnus PFD Limit Exceedance During Mission Approach (4M98G1D Emitter GN 6 Mbps)

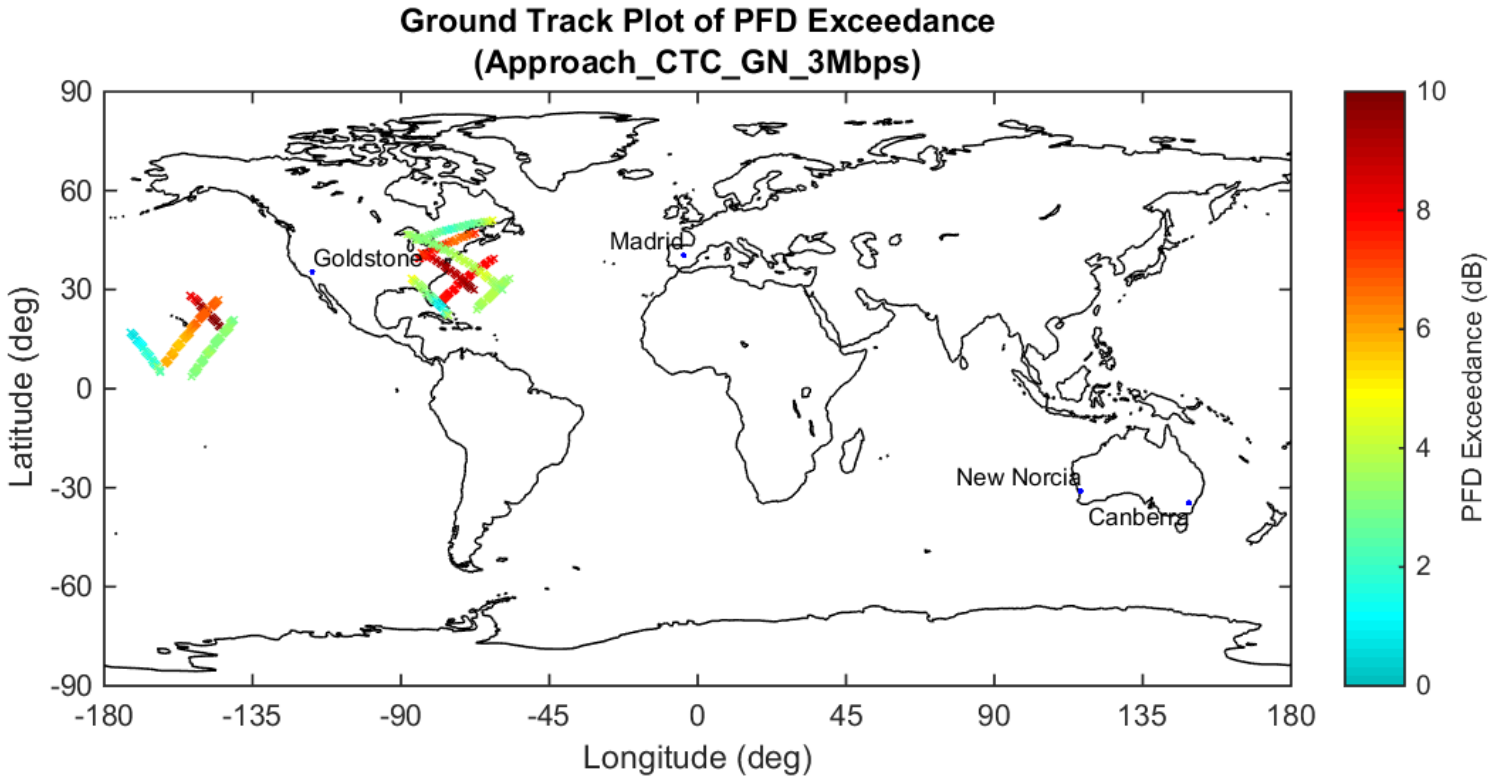


Figure 20 NG-14 Cygnus PFD Limit Exceedance During Mission Approach (3M00G1D Emitter GN 3 Mbps)

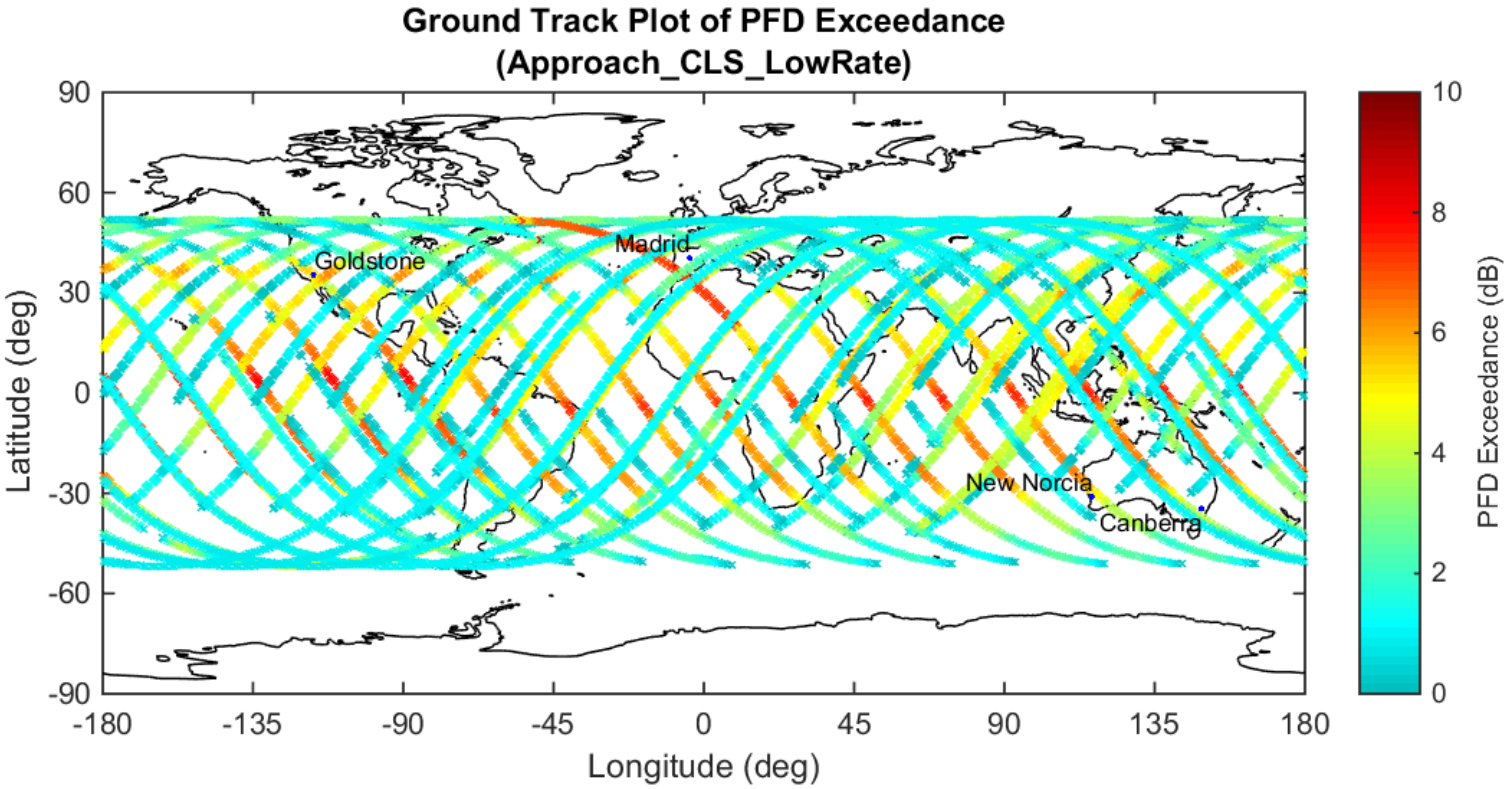


Figure 21 NG-14 Cygnus PFD Limit Exceedance During Mission Approach (5M93G1D Emitter)

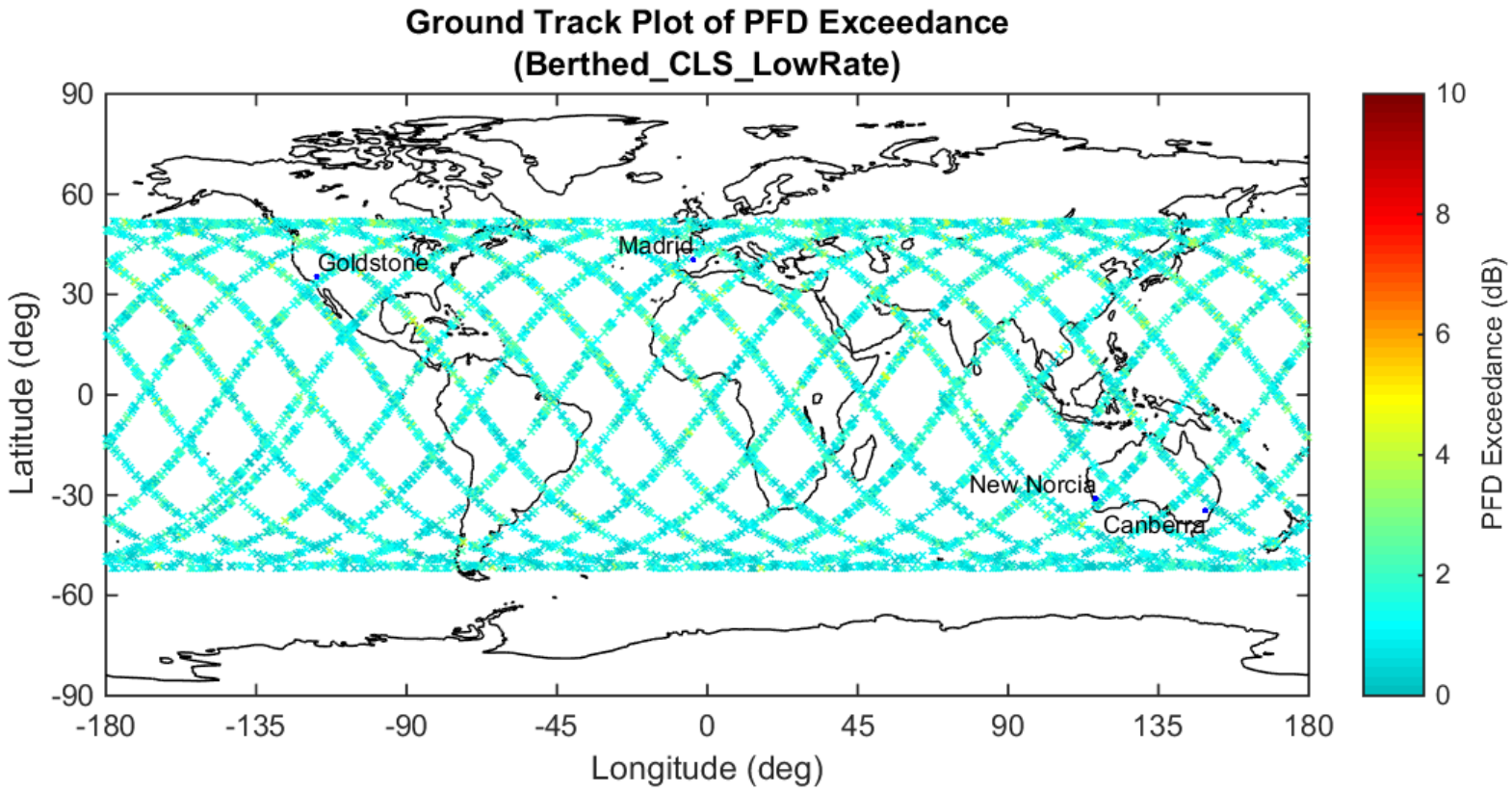


Figure 22 NG-14 Cygnus PFD Limit Exceedance During Mission Berthed (5M93G1D Emitter)

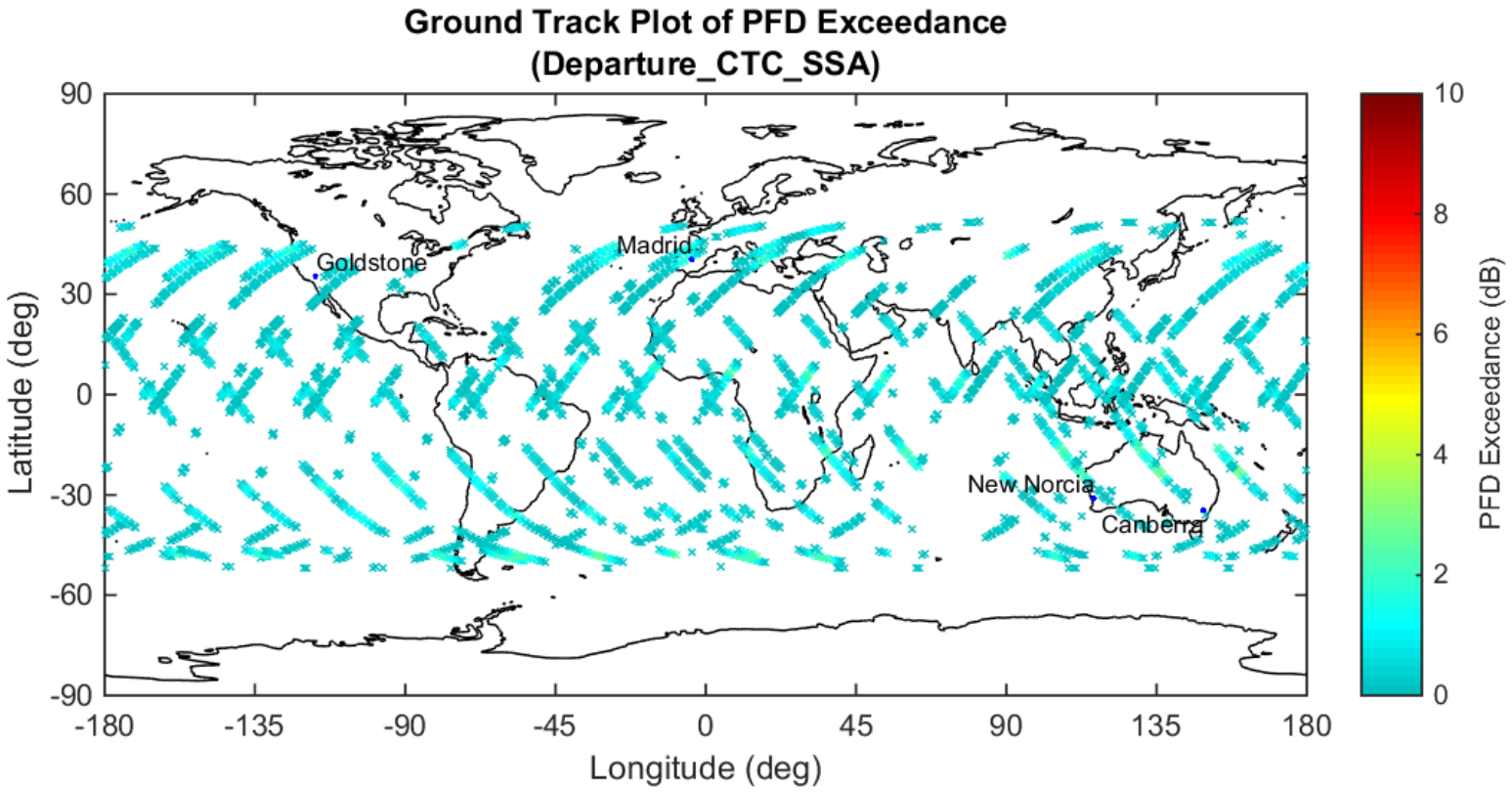


Figure 23 NG-14 Cygnus PFD Limit Exceedance During Mission Departure (6M16G1D Emitter – TDRS SSA)

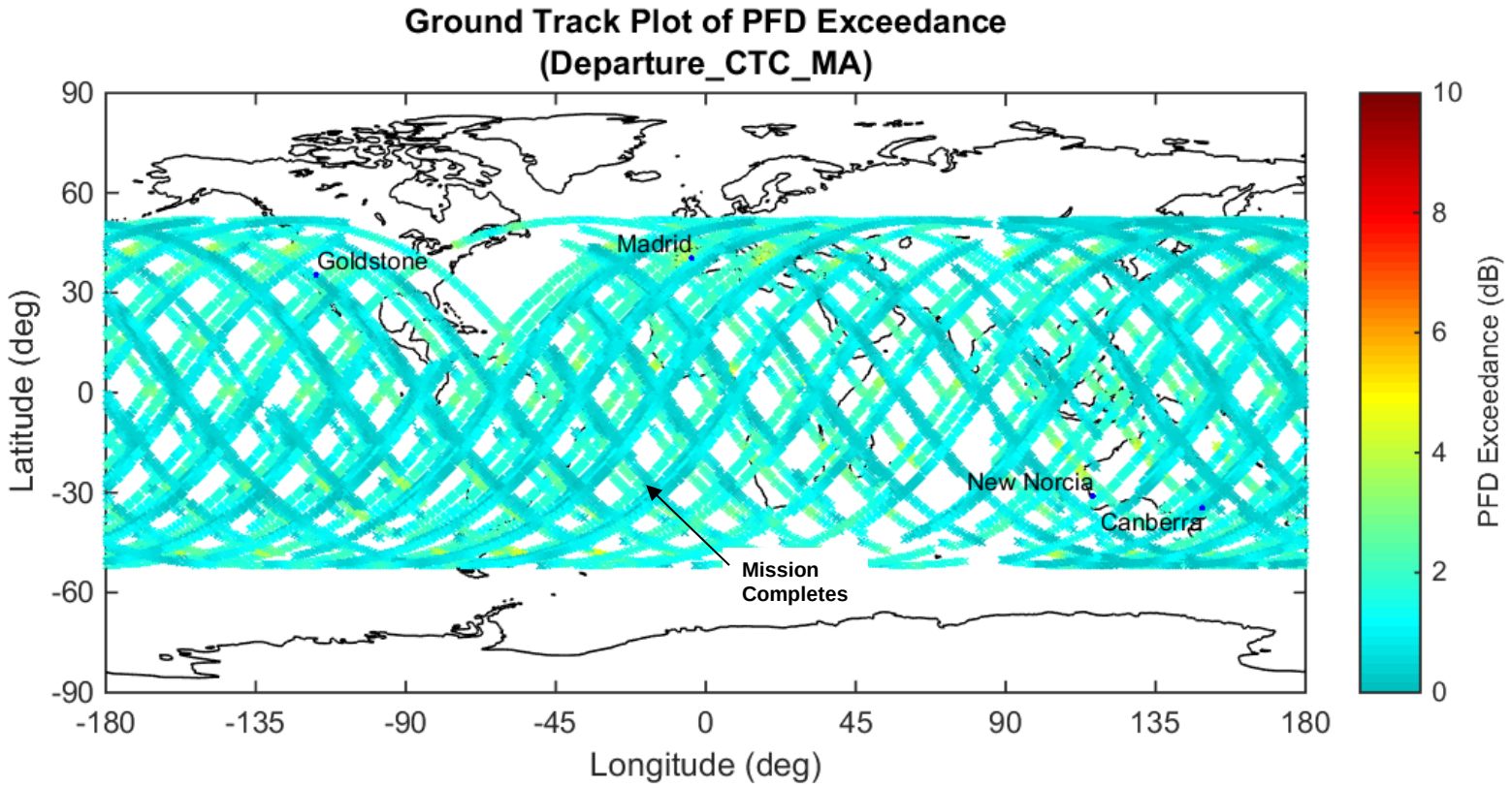


Figure 24 NG-14 Cygnus PFD Limit Exceedance During Mission Departure (6M16G1D Emitter – TDRS SMA)

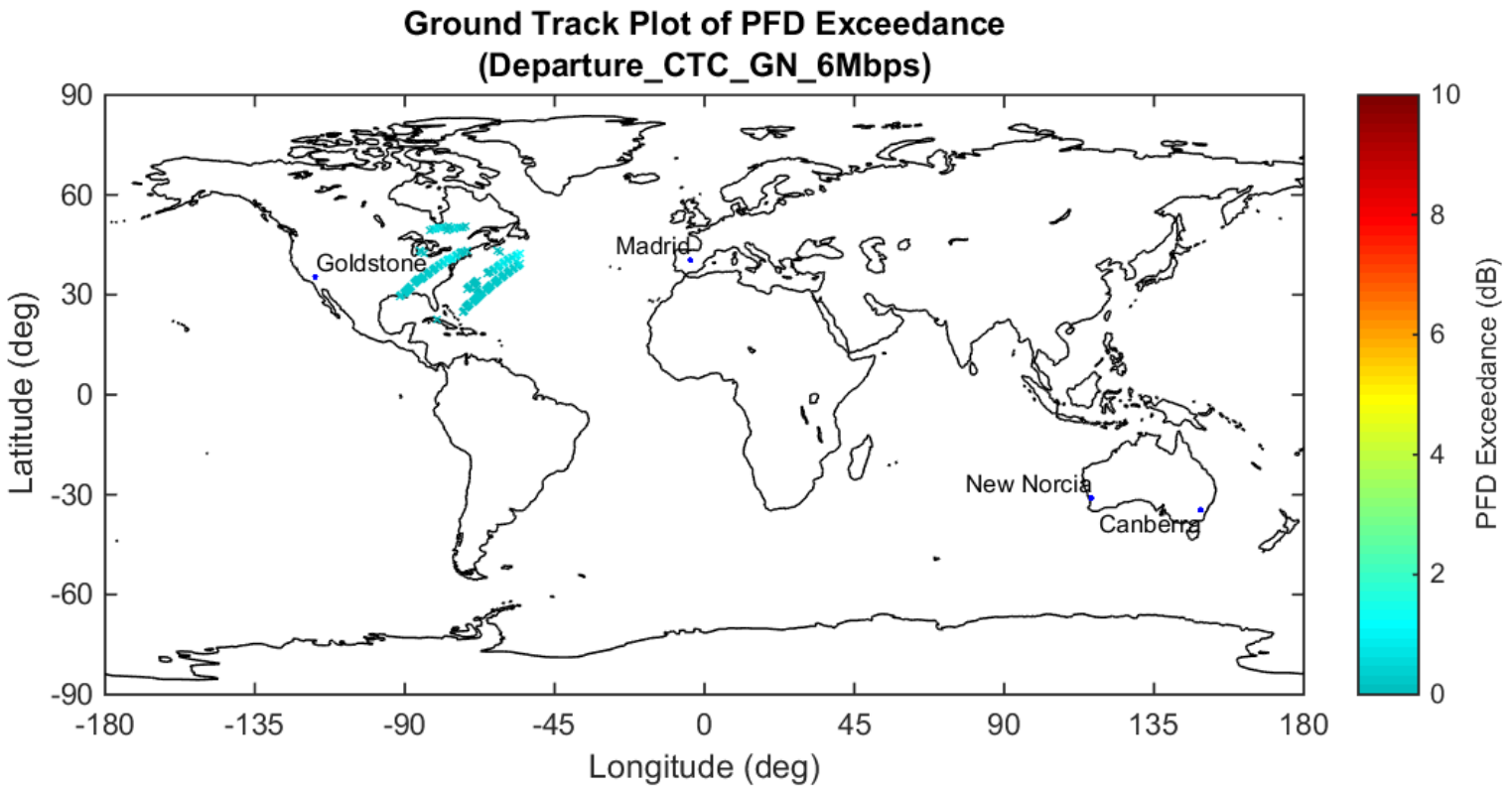


Figure 25 NG-14 Cygnus PFD Limit Exceedance During Mission Departure (4M98G1D Emitter – GN 6 Mbps)

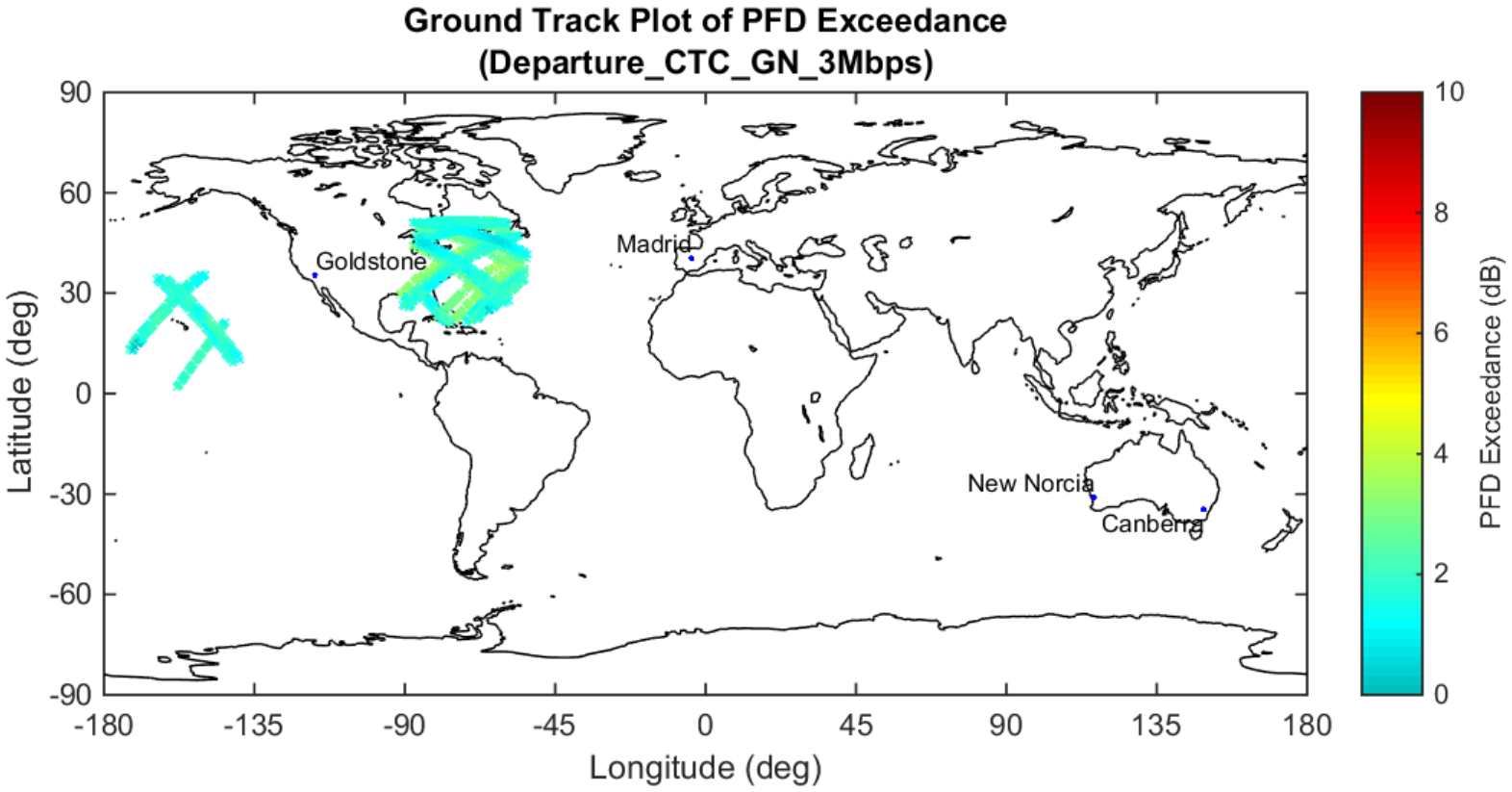


Figure 26 NG-14 Cygnus PFD Limit Exceedance During Mission Departure (3M00G1D Emitter – GN 3 Mbps)

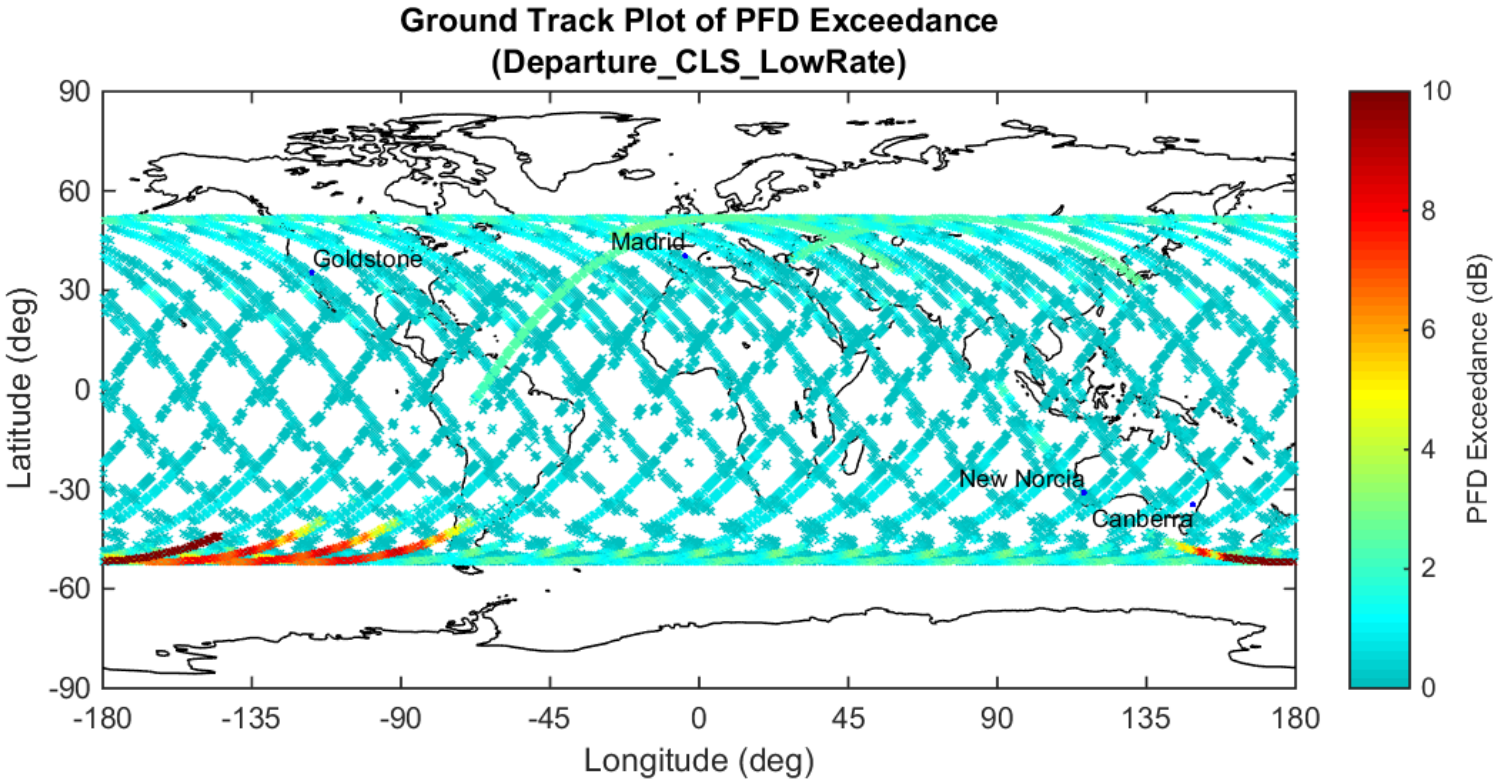


Figure 27 NG-14 Cygnus PFD Limit Exceedance During Mission Departure (5M93G1D Emitter)