Purpose: This memorandum is an attachment to the Northrop Grumman Systems Corporation (NGSC) FCC experimental radio license application for the Cygnus NG-17 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	1936-EX-ST-2021

Data Summary: The attached charts summarize the NG-17 spacecraft power flux density (PFD) 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 an NRZ waveform. This equation is listed as Equation D-6. The main parameters used in these PFD calculations are the Cygnus spacecraft's expected nominal mission trajectory (Azimuth, Elevation, Range, and Altitude) to the ISS from the Wallops Island, Virginia launch pad. PFD calculations use NG-17 transmitter data with recent NG-16 as-flown trajectory for the Approach and Berthed phases, and NG-15 for the Departure phase. Each NG-17 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 assume 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-17 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 ISS 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 Cygnus NG-17 mission. Additionally, the PFD requirement exceedances are depicted as ground track plots in Appendix A and tabulated in Attachment 2 of this application. Each exceedance in Attachment 2 also includes the associated latitude, longitude, and duration.

1. Approach Phase

This phase of the 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 14 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 (2287.5 MHz) 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^2/4 kHz required limit are summarized in more detail in the bullet items below.

- Emission designator 6M16G1D PFD exceedances are depicted as follows:
  i. Figure 16 (SSA) and Figure 17 (MA), Appendix A, shows the ground track plots.
  ii. In Attachment 2, Table 1 (SSA) and Table 2 (MA) show additional details on each exceedance.

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

- Figure 18, Appendix A, shows the associated PFD exceedance as ground track plots.
- The PFD limit exceedances are also detailed in Attachment 2, Table 3.

c) Figure 4 shows the PFD results when using emission designator 3M00G1D (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 4.

d) Figure 5 shows the PFD results when using emission designator 5M93G1D (2203.2 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 5.

2. Berthed Phase

This phase of the mission starts after the Cygnus vehicle is grappled by the ISS robotic arm and berthed to the ISS. During this phase, the Cygnus-to-ISS RF communications link (5M93G1D) will not be active (i.e., powered down) after the Cygnus spacecraft is berthed. Cygnus spacecraft telemetry transmission will be via CTC telemetry link to TDRS (emission designator 6M16G1D) or via CTC telemetry link directly to a ground station (emission designator 3M00G1D or 4M98G1D). The detailed PFD summary for the different telemetry links are below. This shows typical berthed performance as taken from the NG-16 as-flown mission.

a) The calculated Cygnus emitter's PFD while berthed at the ISS and using emission designator 6M16G1D (2287.5 MHz) is summarized in Figure 6 below with exceedances.

b) Figure 7 shows the PFD results with exceedances when using emission designator 3M00G1D (2287.5 MHz).

c) Figure 8 shows the PFD results with exceedances when using emission designator 4M98G1D (2287.5 MHz).

3. Departure Phase

The 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 re-entry path into the Earth's atmosphere. All four emitters, 6M16G1D, 4M98G1D, 3M00G1D, and 5M93G1D, will be active during spacecraft departure. Emitters 6M16G1D (TDRS), 4M98G1D (ground station), and 3M00G1D (ground station) will be active throughout the departure phase and spacecraft re-entry. 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 re-entry. The detailed PFD summaries for all four emitters are below.

a) The calculated PFD using emission designator 6M16G1D (2287.5 MHz – TDRS SSA) is summarized in Figure 9. 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 21, Appendix A, show the ground track plots.
    ii. Attachment 2, Table 9 shows additional details on each exceedance.

b) Figure 10 shows the PFD results when using emission designator 6M16G1D (2287.5 MHz – TDRS MA).
    - Figure 22, Appendix A, shows the associated PFD exceedance as ground track plots.
    - The PFD limit exceedances are detailed in Attachment 2, Table 10.

c) Figure 11 shows the PFD results when using emission designator 4M98G1D.
    - Figure 23, Appendix A, shows the associated PFD exceedance as ground track plots.
    - The PFD limit exceedances are detailed in Attachment 2, Table 11.

d) Figure 12 shows the PFD results when using emission designator 3M00G1D.
    - Figure 24, Appendix A, shows the associated PFD exceedance as ground track plots.
    - The PFD limit exceedances are detailed in Attachment 2, Table 12.

e) Figure 13 shows the PFD results when using emission designator 5M93G1D 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 13.

f) Figure 15 shows altitude vs. mission time for the departure phase. There is a long period of loitering at approximately 500 km. During this time experiments with secondary payloads are conducted.

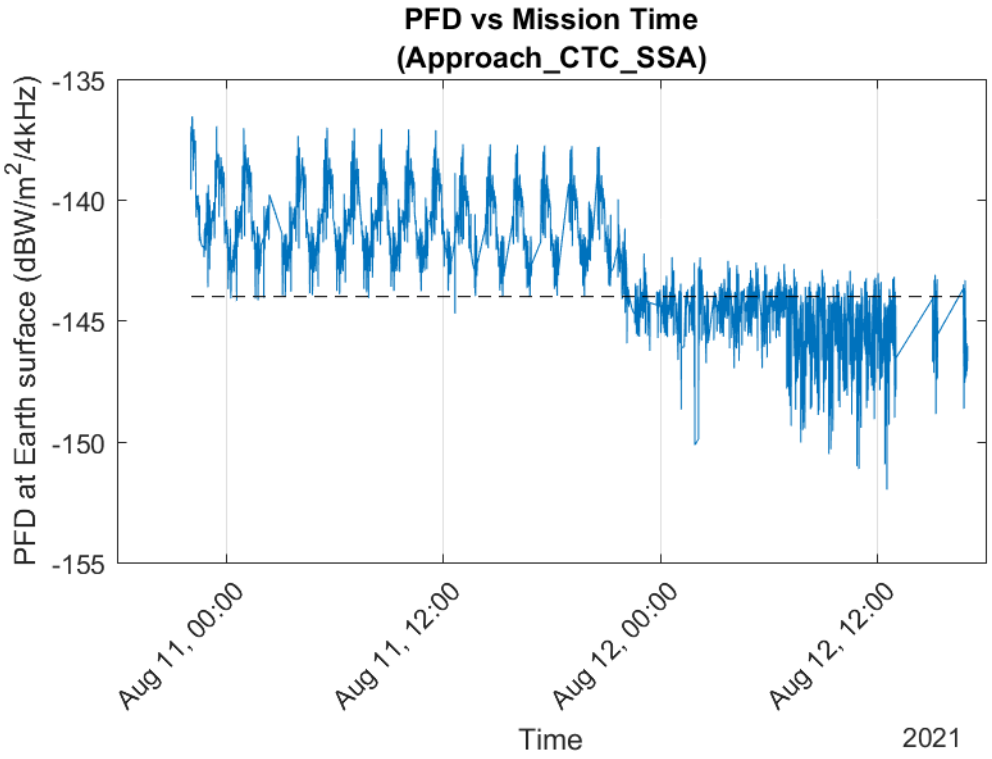

Figure 1. NG-17 PFD during Approach, TDRS SSA (6M16G1D Emitter)

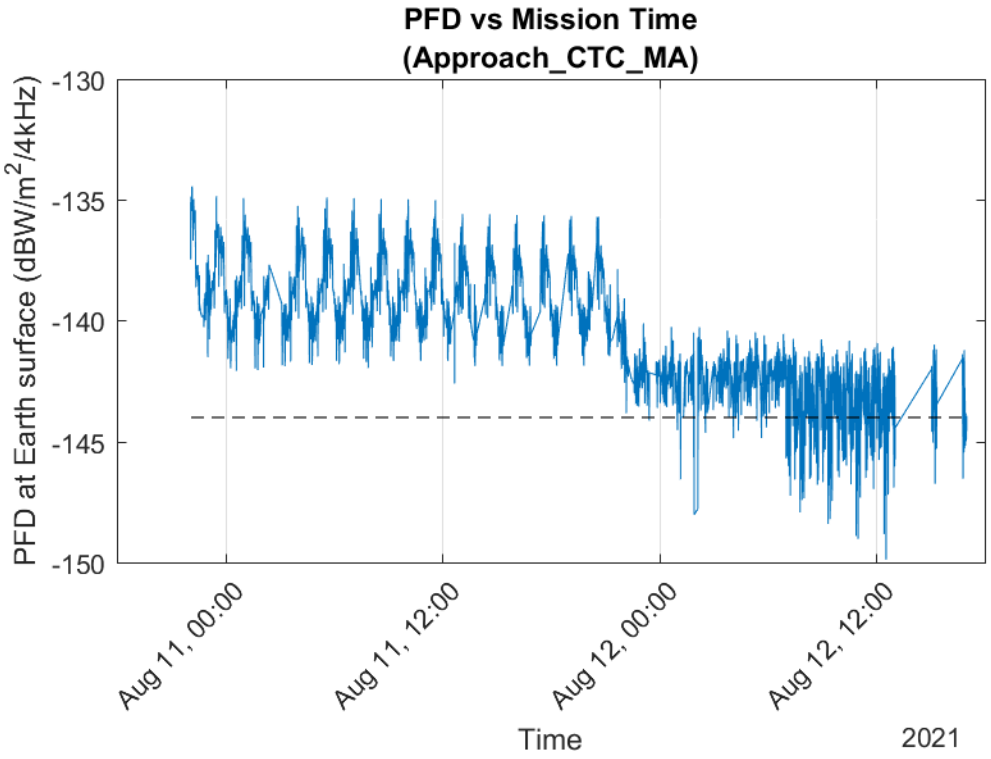

Figure 2. NG-17 PFD during Approach, TDRS MA (6M16G1D Emitter)

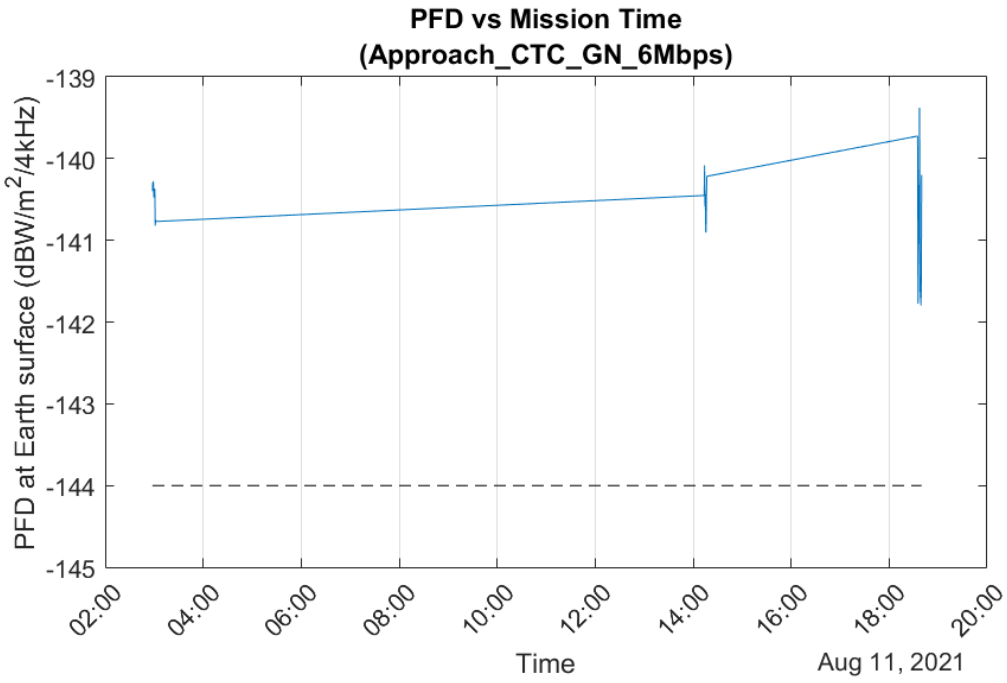

Figure 3. NG-17 PFD during Approach, GN 6 Mbps (4M98G1D Emitter)

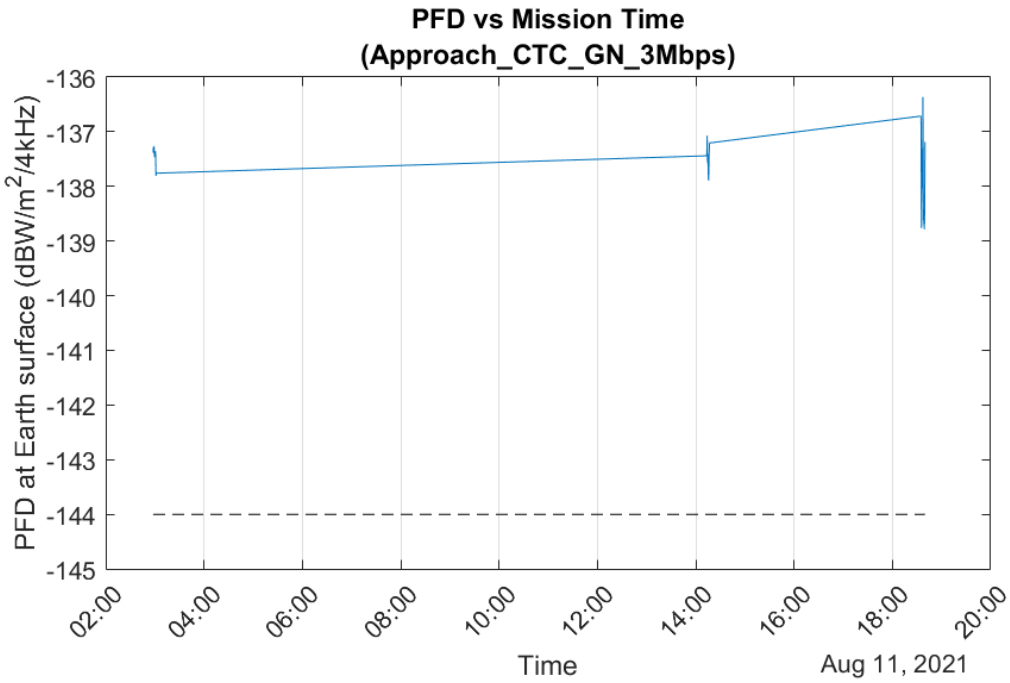

Figure 4. NG-17 PFD during Approach, GN 3Mbps (3M00G1D Emitter)

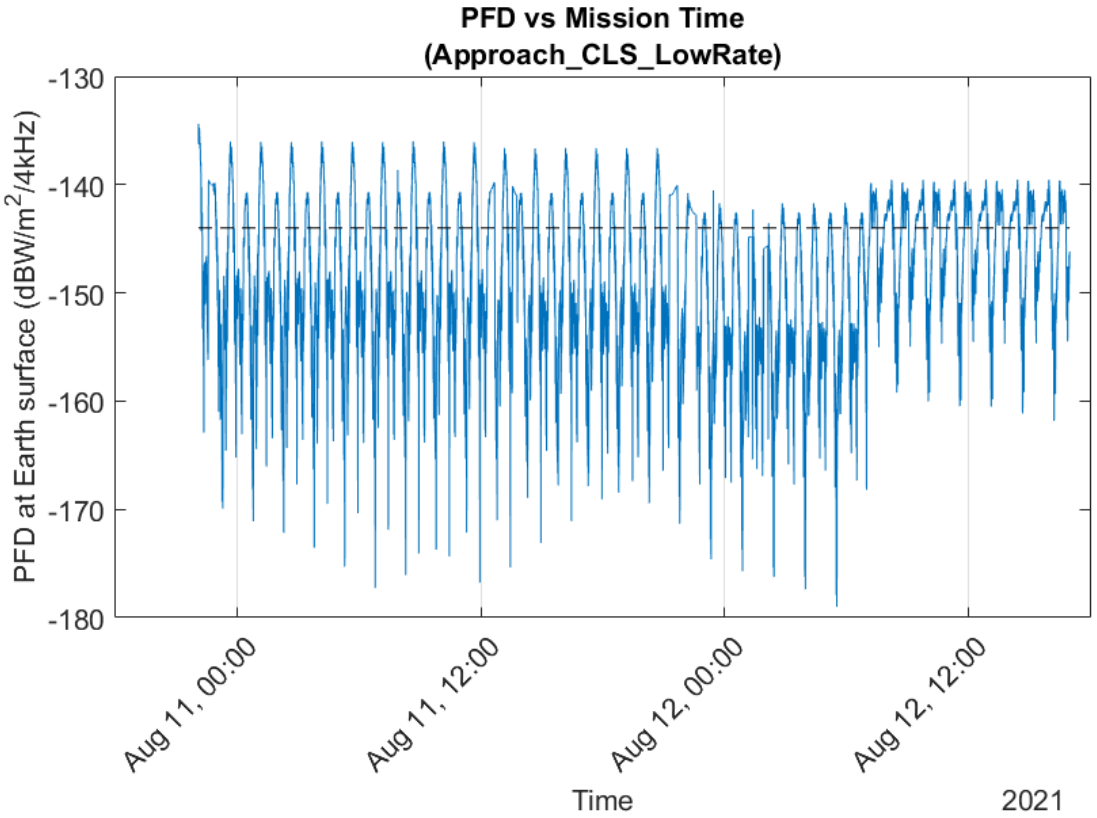

Figure 5. NG-17 PFD during Approach, CLS Low Rate (5M93G1D Emitter)

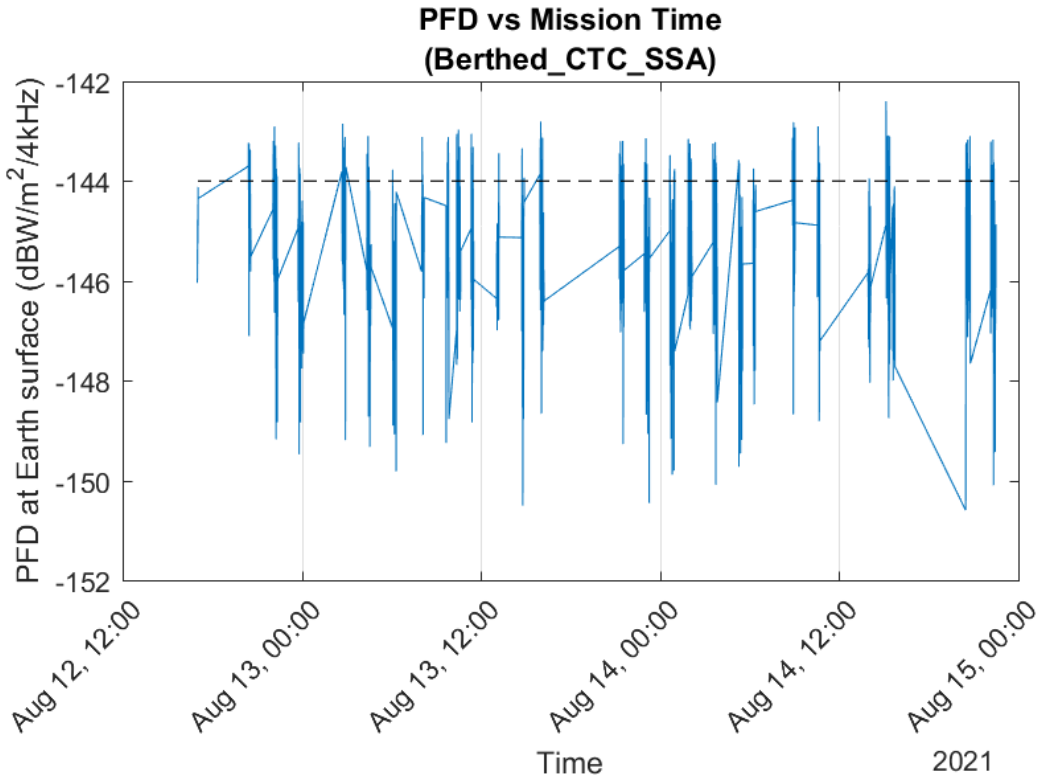

Figure 6. NG-17 PFD during Berthed Phase, TDRS SSA (6M16G1D Emitter)

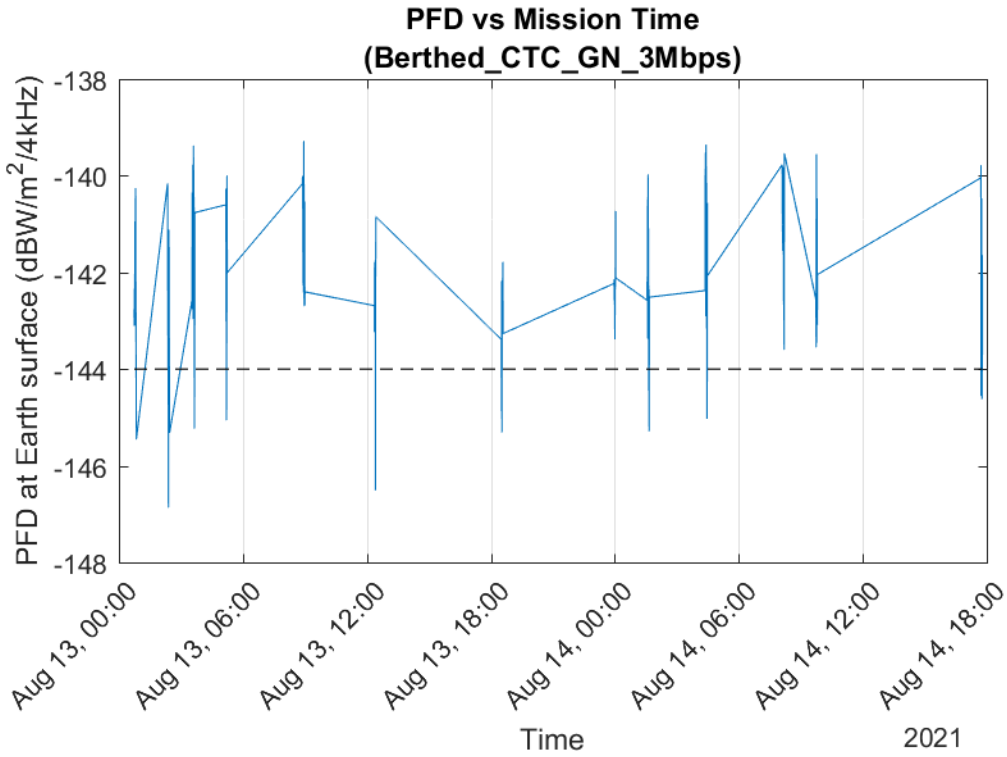

Figure 7. NG-17 PFD during Berthed Phase, GN 3Mbps (3M00G1D Emitter)

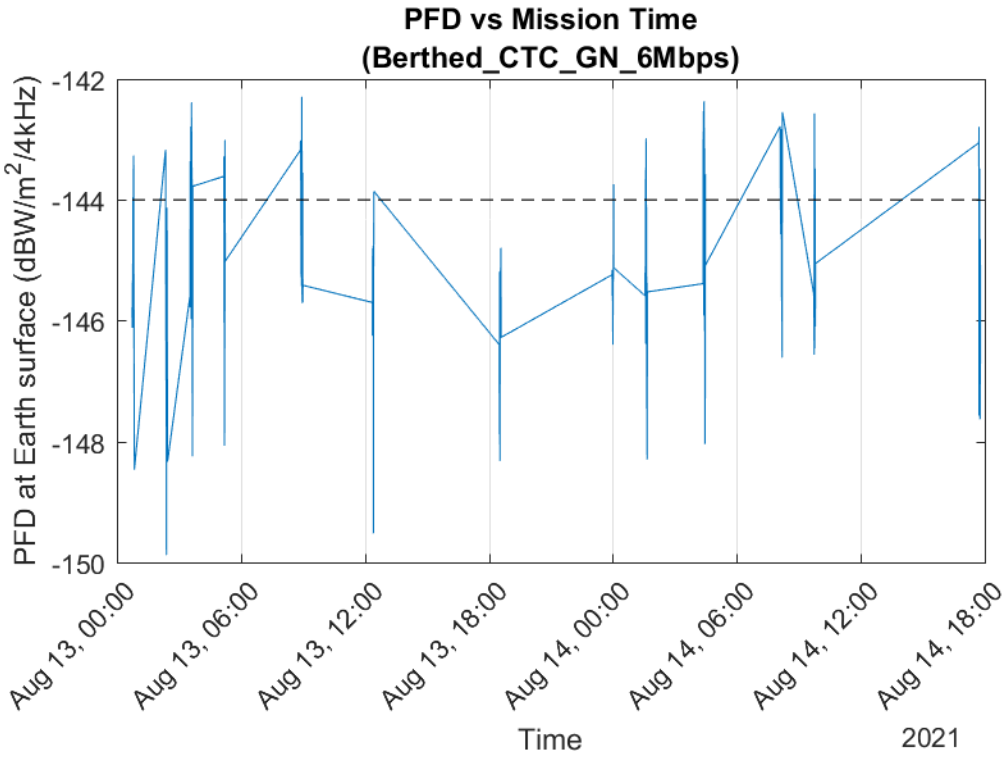

Figure 8. NG-17 PFD during Berthed Phase, GN 6 Mbps (4M98G1D Emitter)

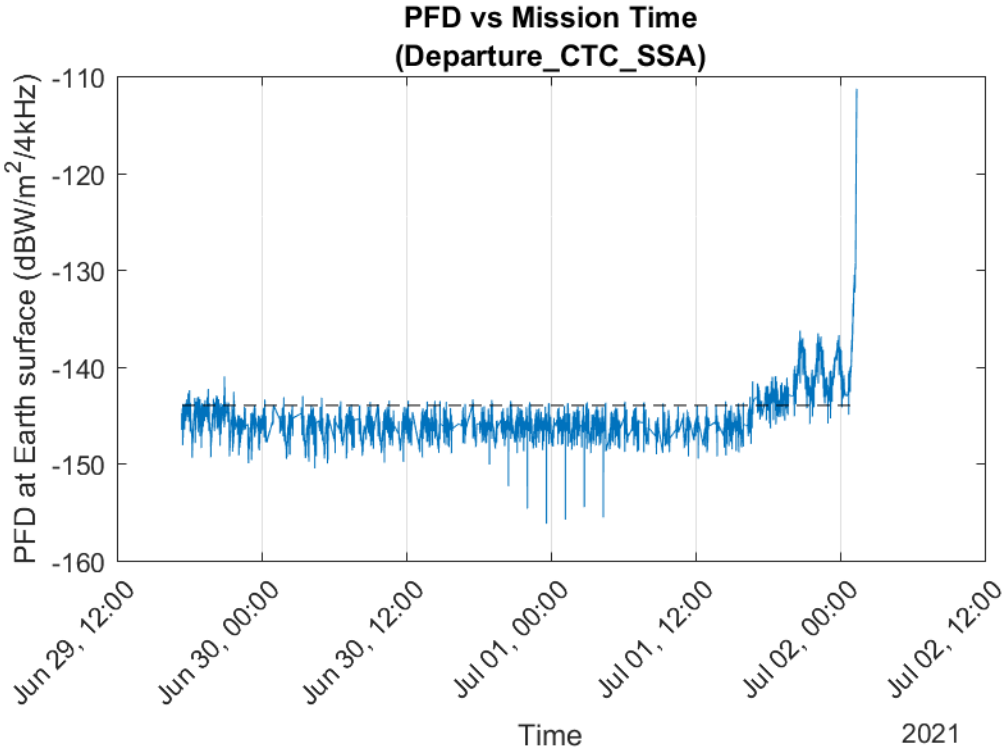

Figure 9. NG-17 PFD during Departure Phase, TDRS SSA (6M16G1D Emitter)

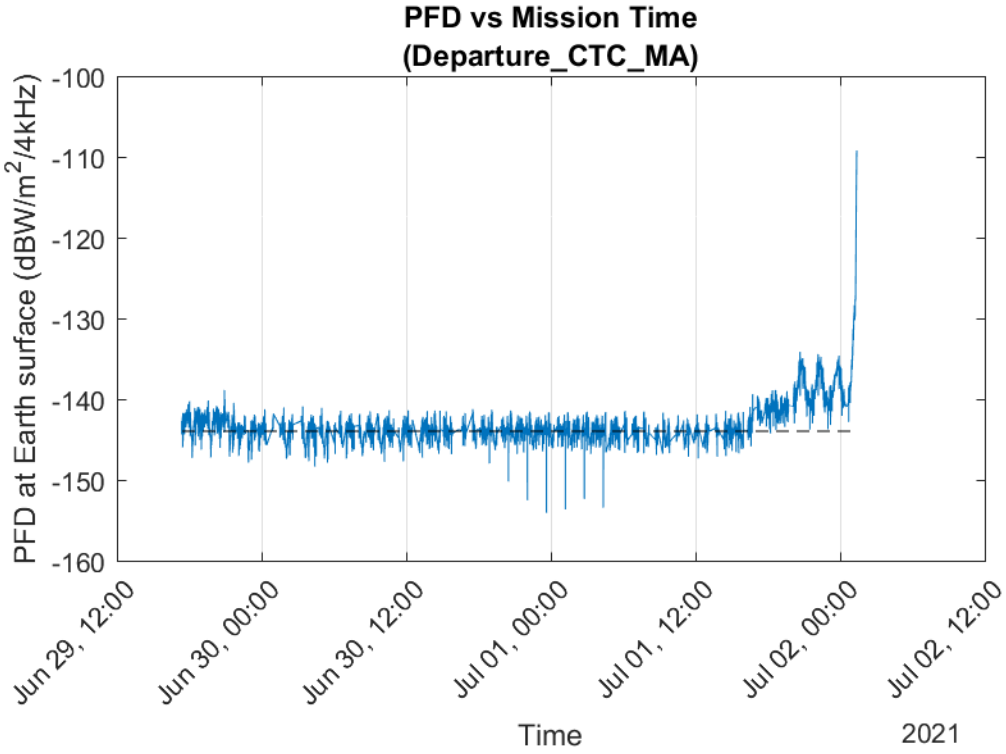

Figure 10. NG-17 PFD during Departure Phase, TDRS MA (6M16G1D Emitter)

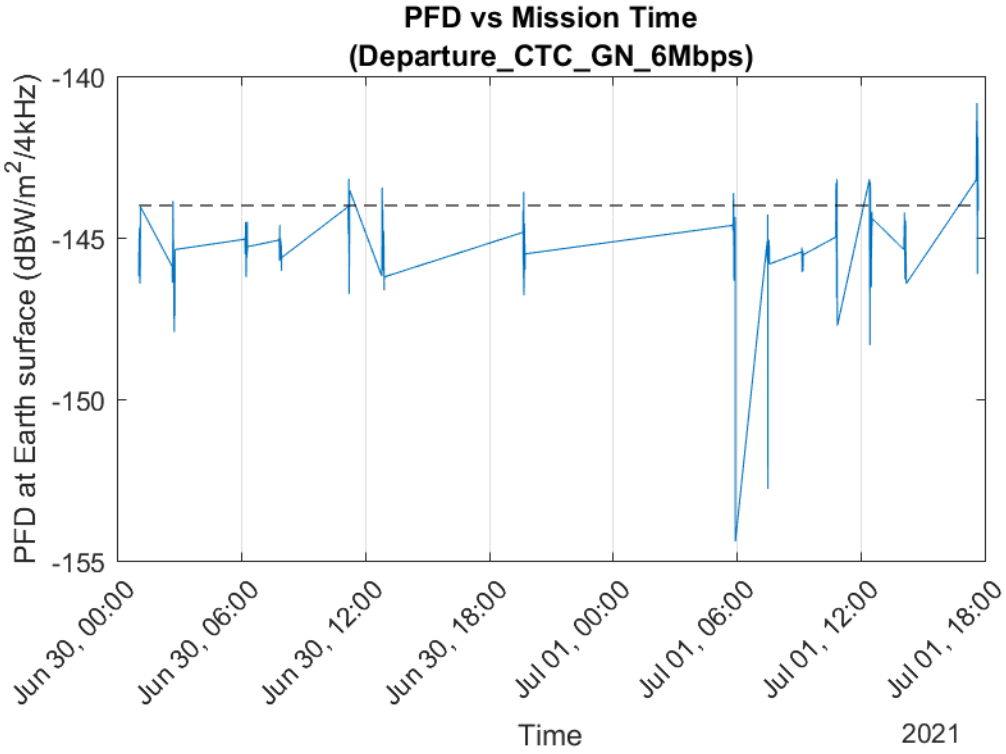

Figure 11. NG-17 PFD during Departure Phase, GN 6 Mbps (4M98G1D)

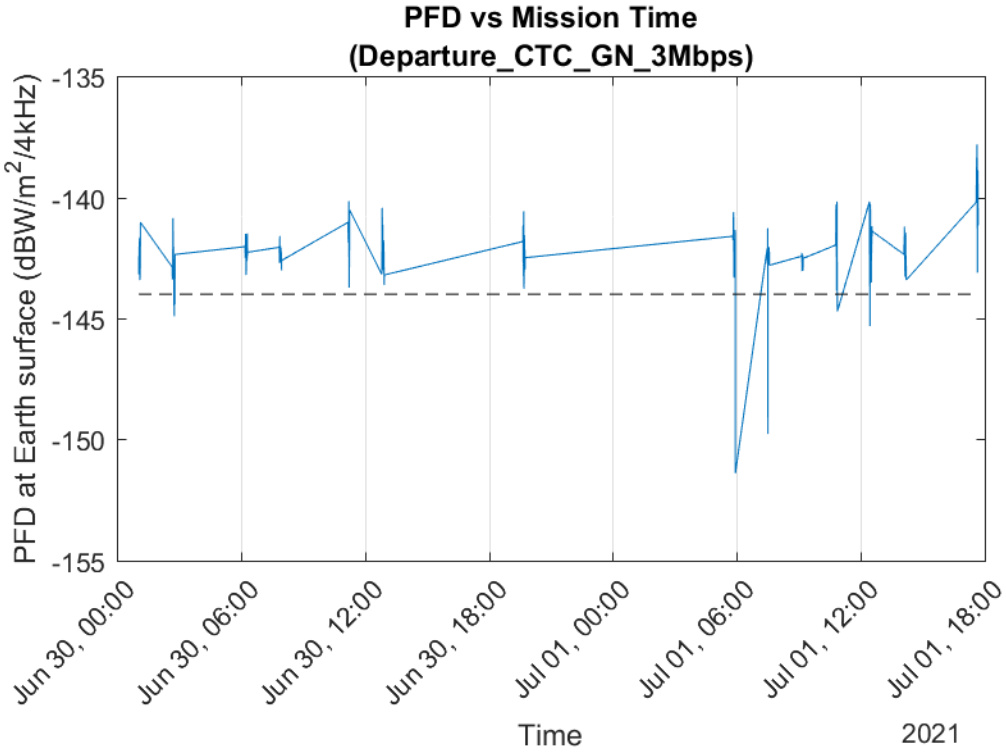

Figure 12. NG-17 PFD during Departure Phase, GN 3 Mbps (3M00G1D Emitter)

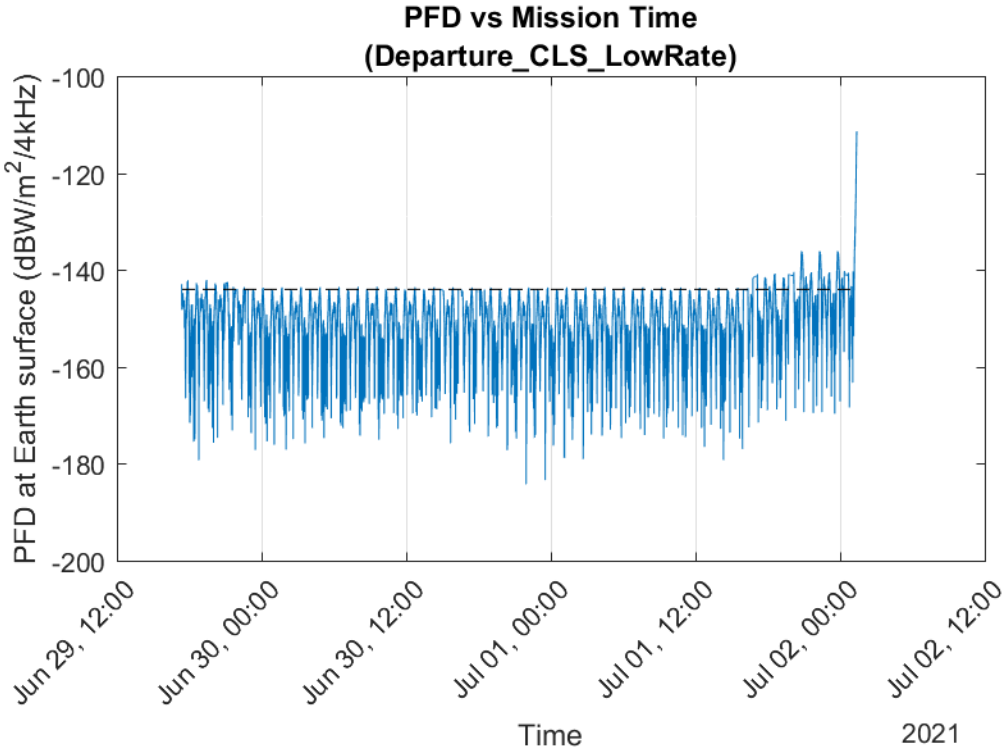

Figure 13. NG-17 PFD during Departure Phase, CLS Low Rate (5M93G1D Emitter)

Appendix A

(Altitude and Ground Track Plots of PFD Exceedances during Mission Phases)

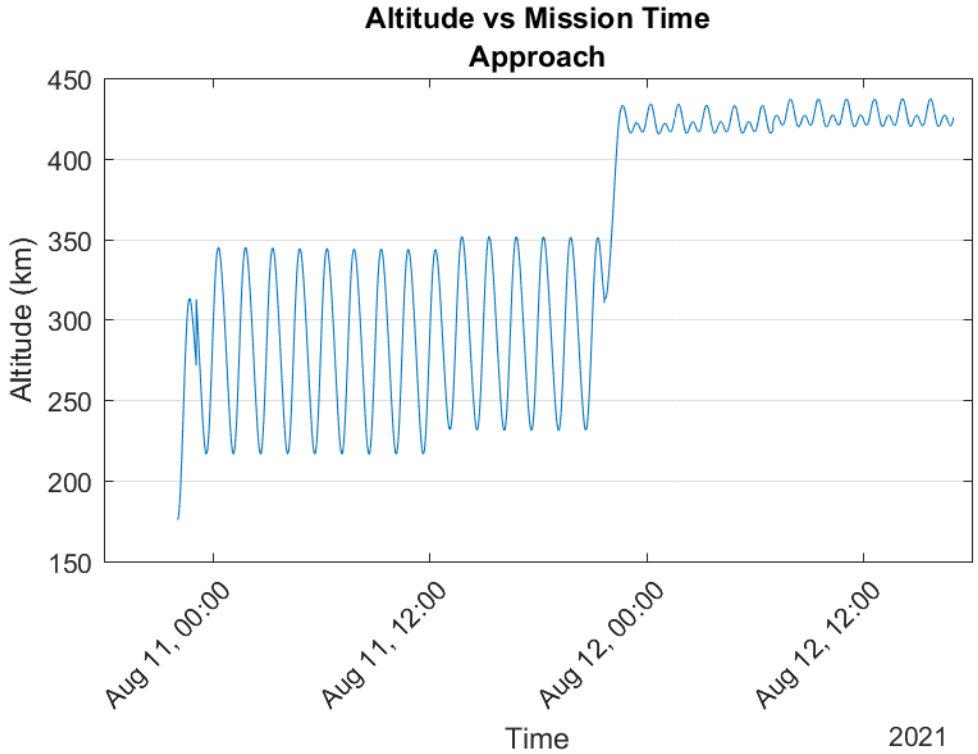

Figure 14. NG-17 Altitude vs. Mission Time (Approach)

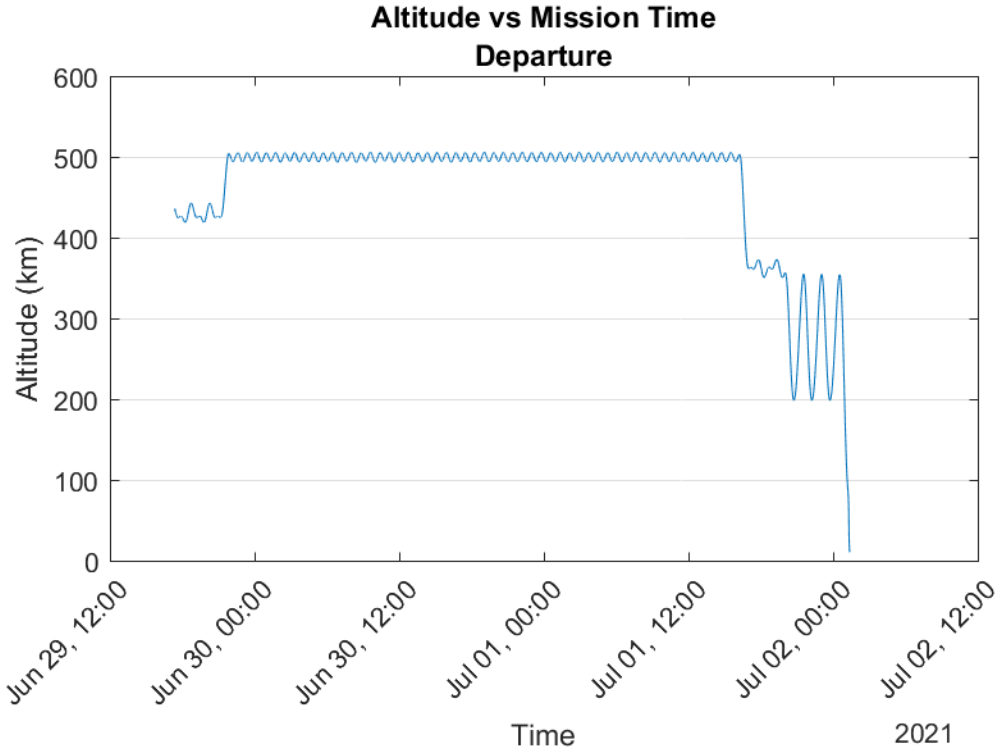

Figure 15. NG-17 Altitude vs. Mission Time (Departure)

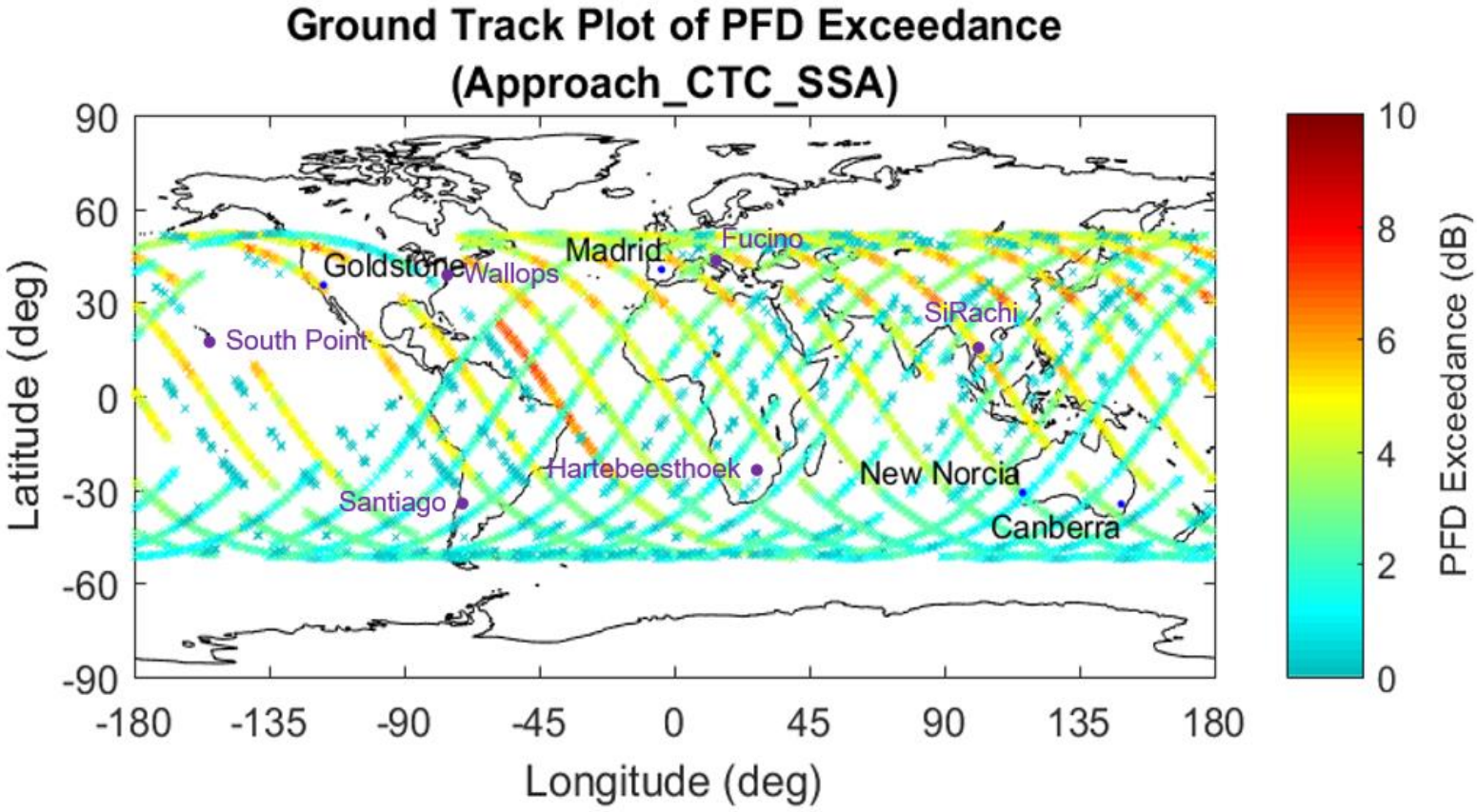

Figure 16. NG-17 PFD Limit Exceedance during Mission Approach, TDRS SSA (6M16G1D Emitter)

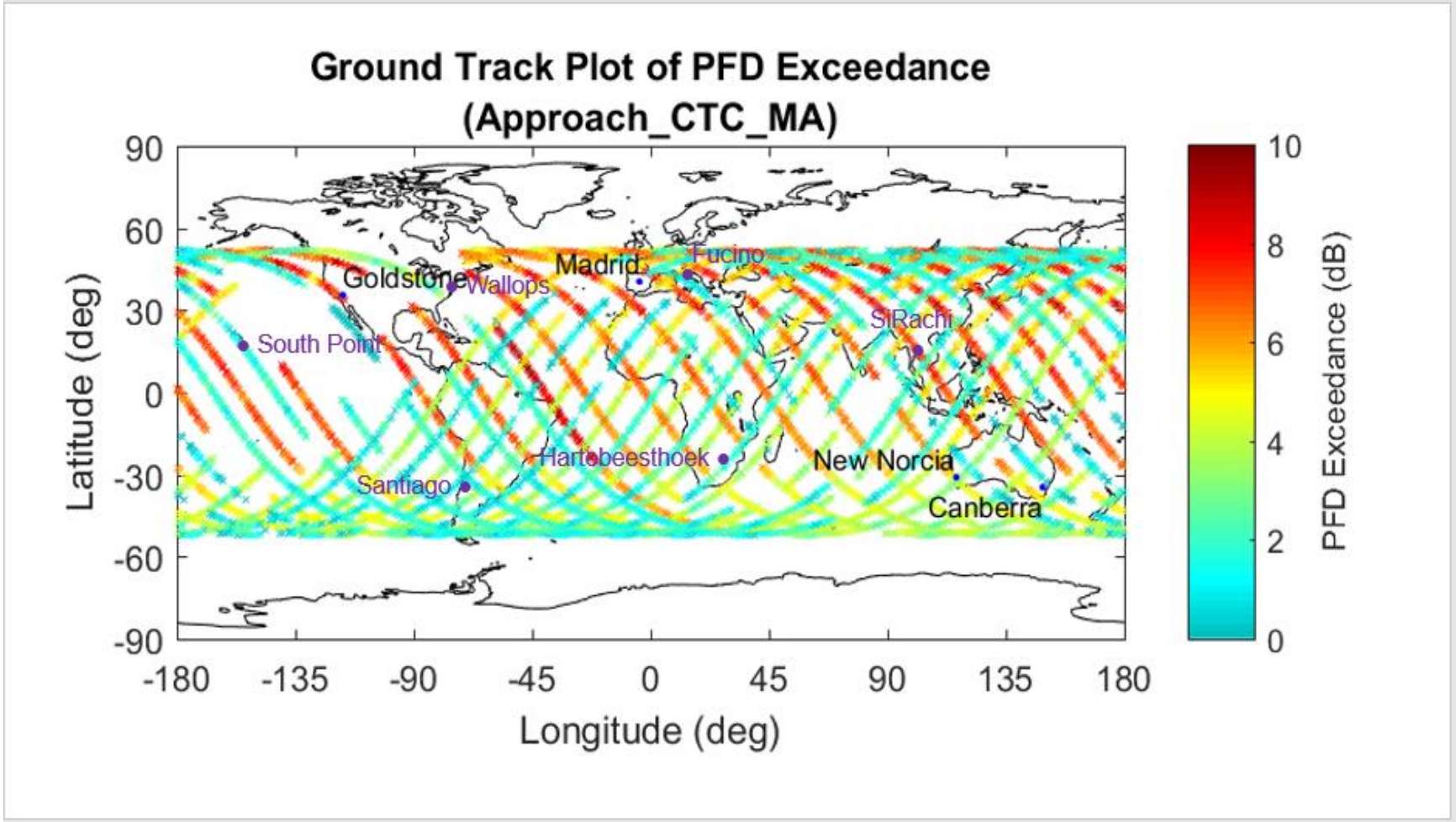

Figure 17. NG-17 PFD Limit Exceedance during Mission Approach, TDRS MA (6M16G1D Emitter)

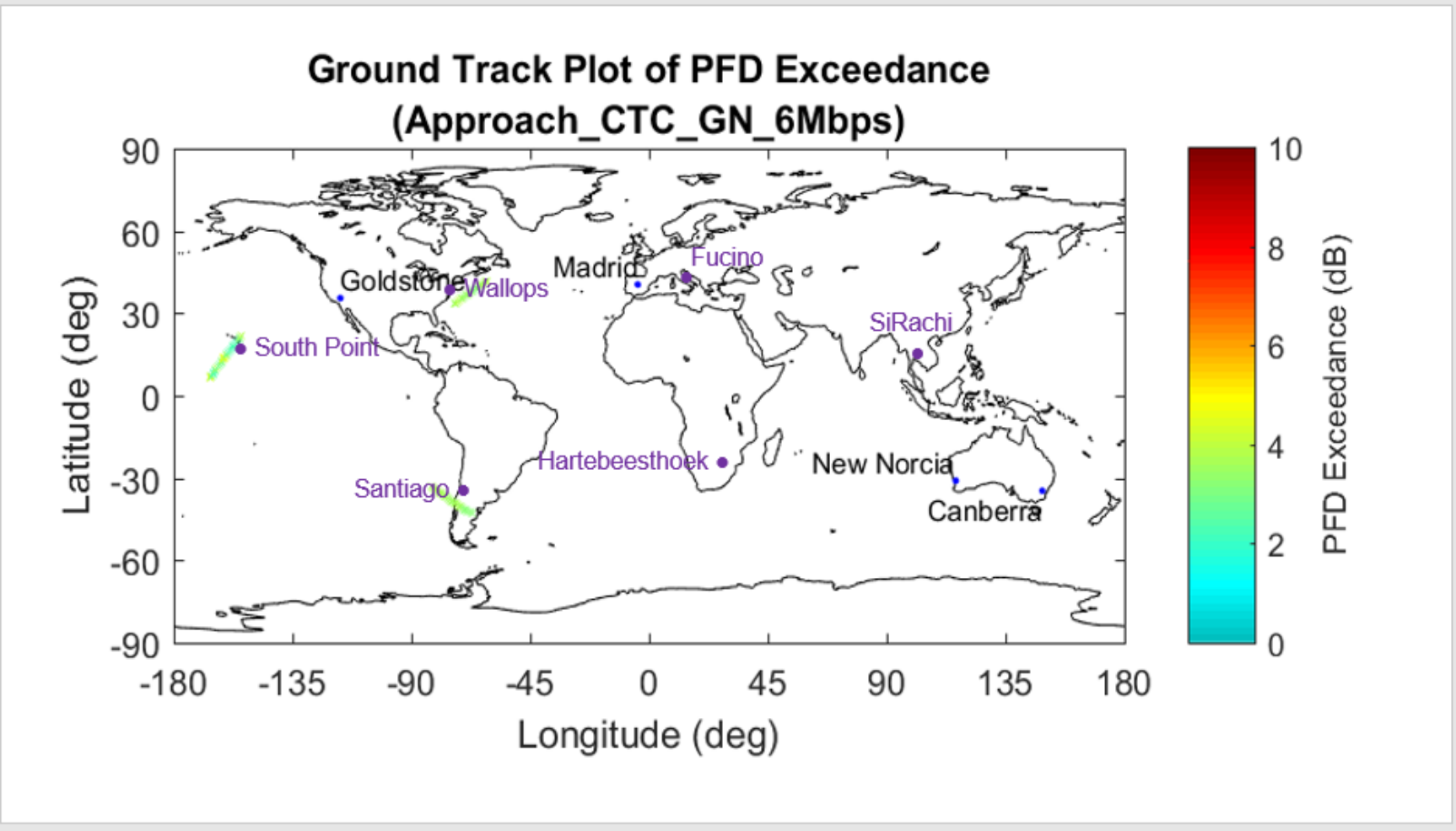

Figure 18. NG-17 PFD Limit Exceedance during Mission Approach, GN 6 Mbps (4M98G1D Emitter)

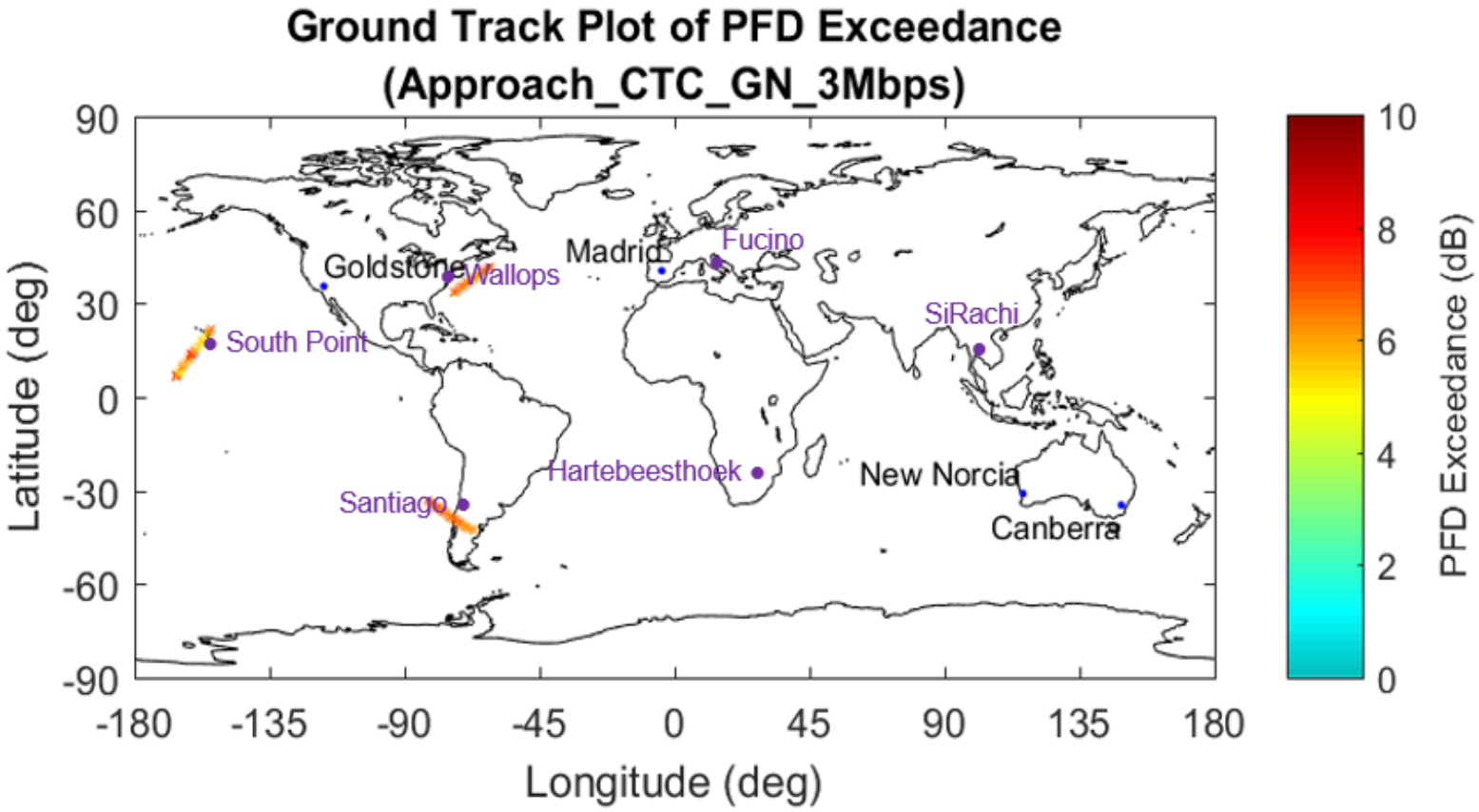

Figure 19. NG-17 PFD Limit Exceedance during Mission Approach, GN 3 Mbps (3M00G1D Emitter)

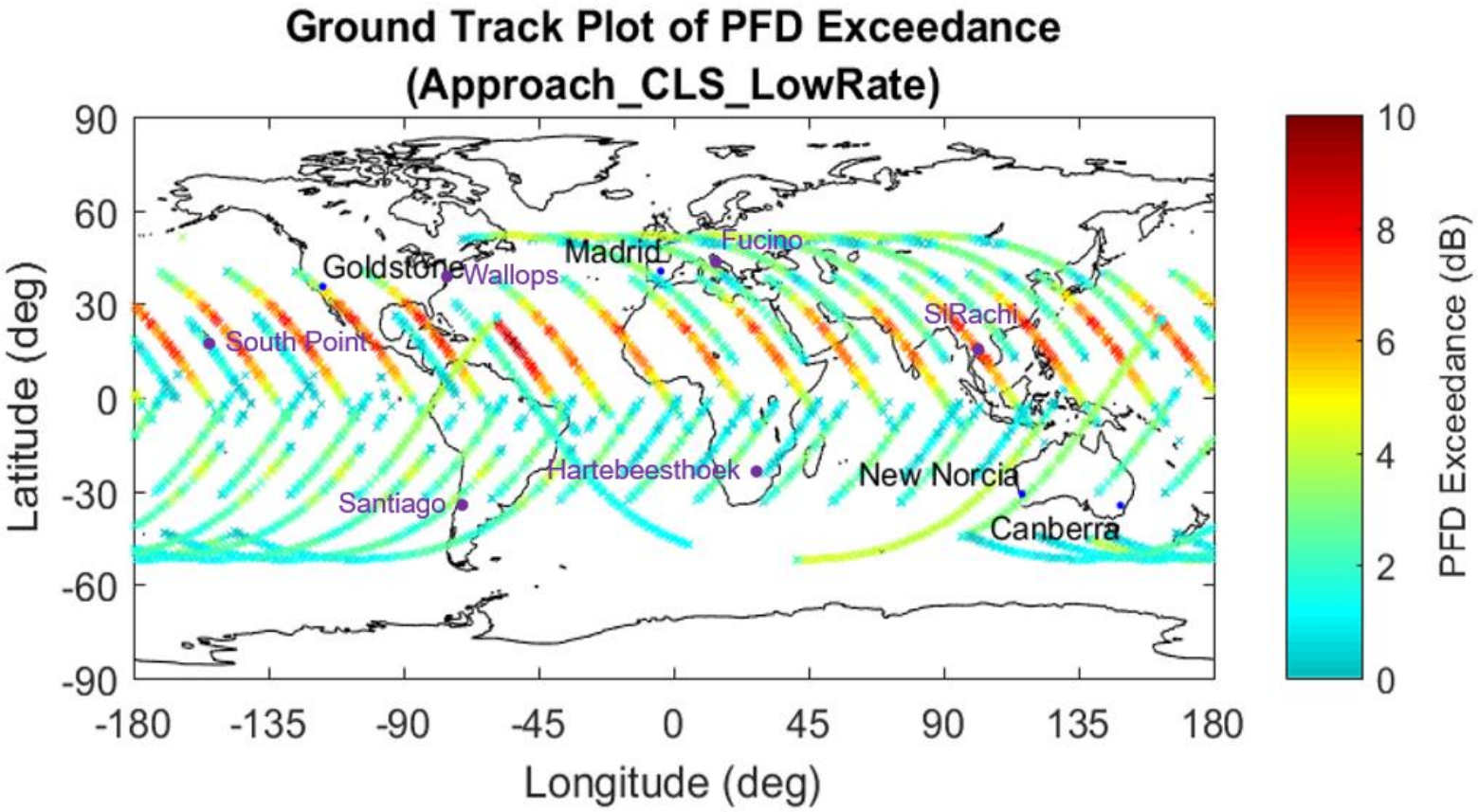

Figure 20. NG-17 PFD Limit Exceedance during Mission Approach, CLS Low Rate (5M93G1D Emitter)

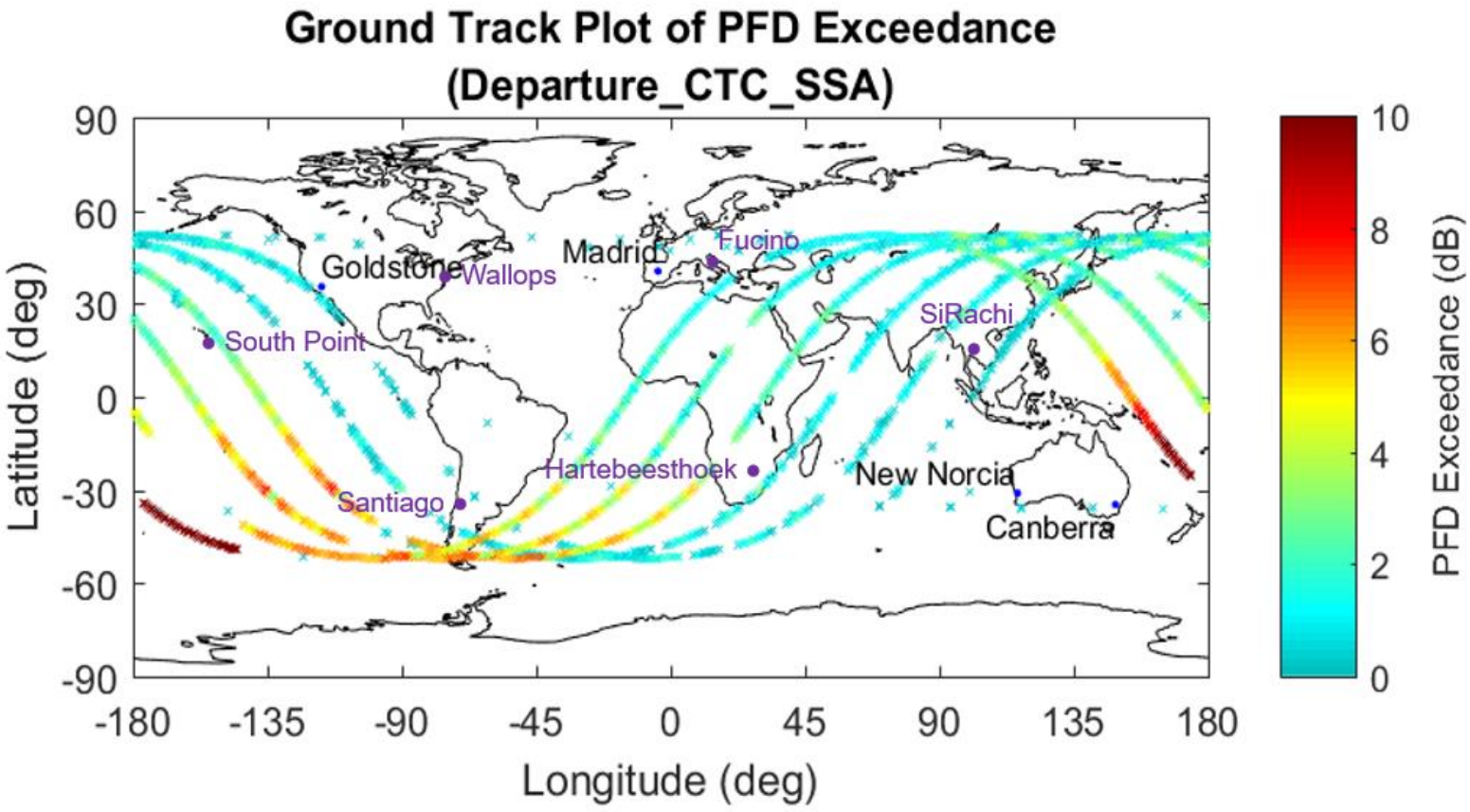

Figure 21. NG-17 PFD Limit Exceedance during Mission Departure, TDRS SSA (6M16G1D Emitter)

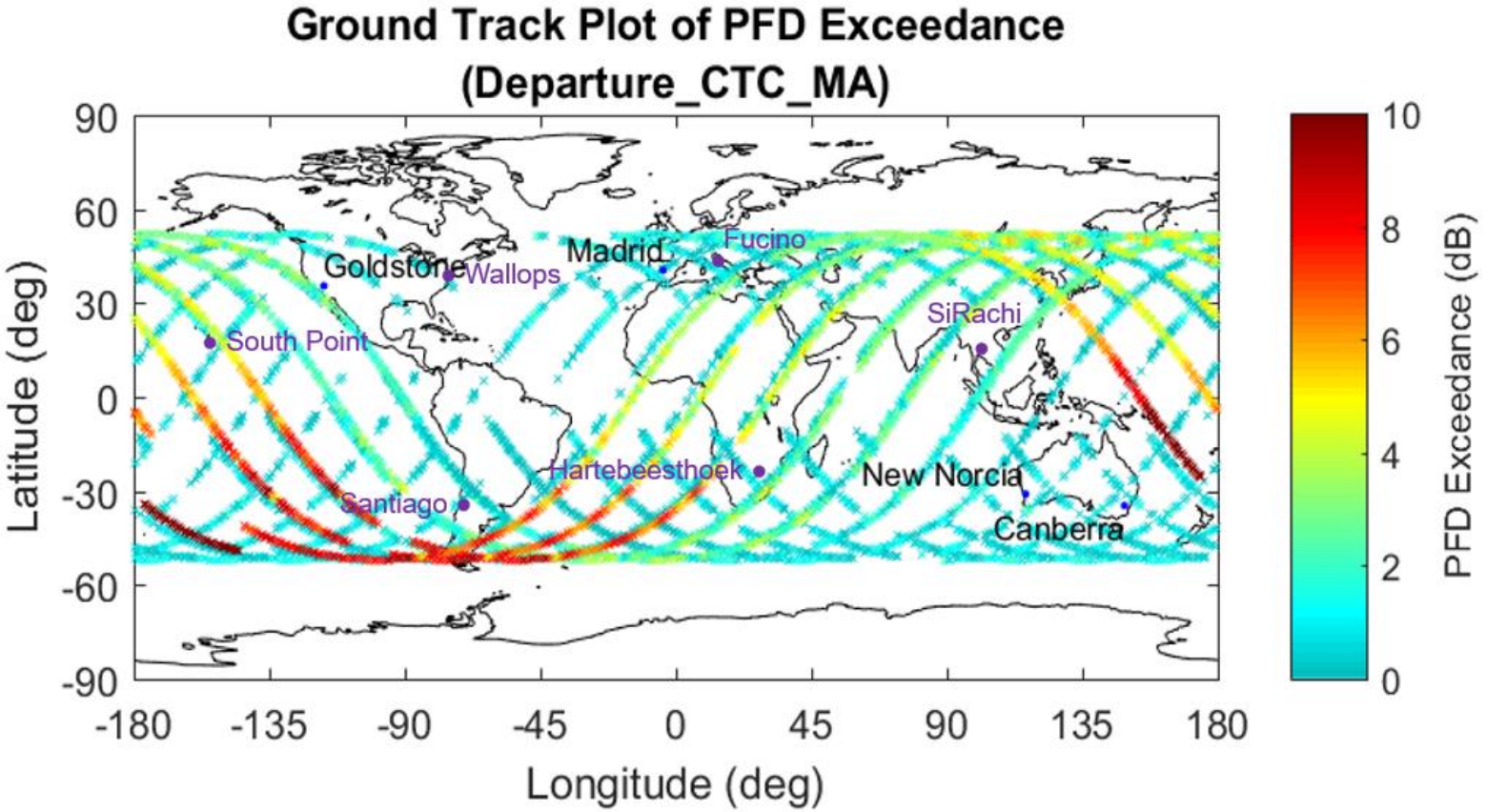

Figure 22. NG-17 PFD Limit Exceedance during Mission Departure, TDRS MA (6M16G1D Emitter)

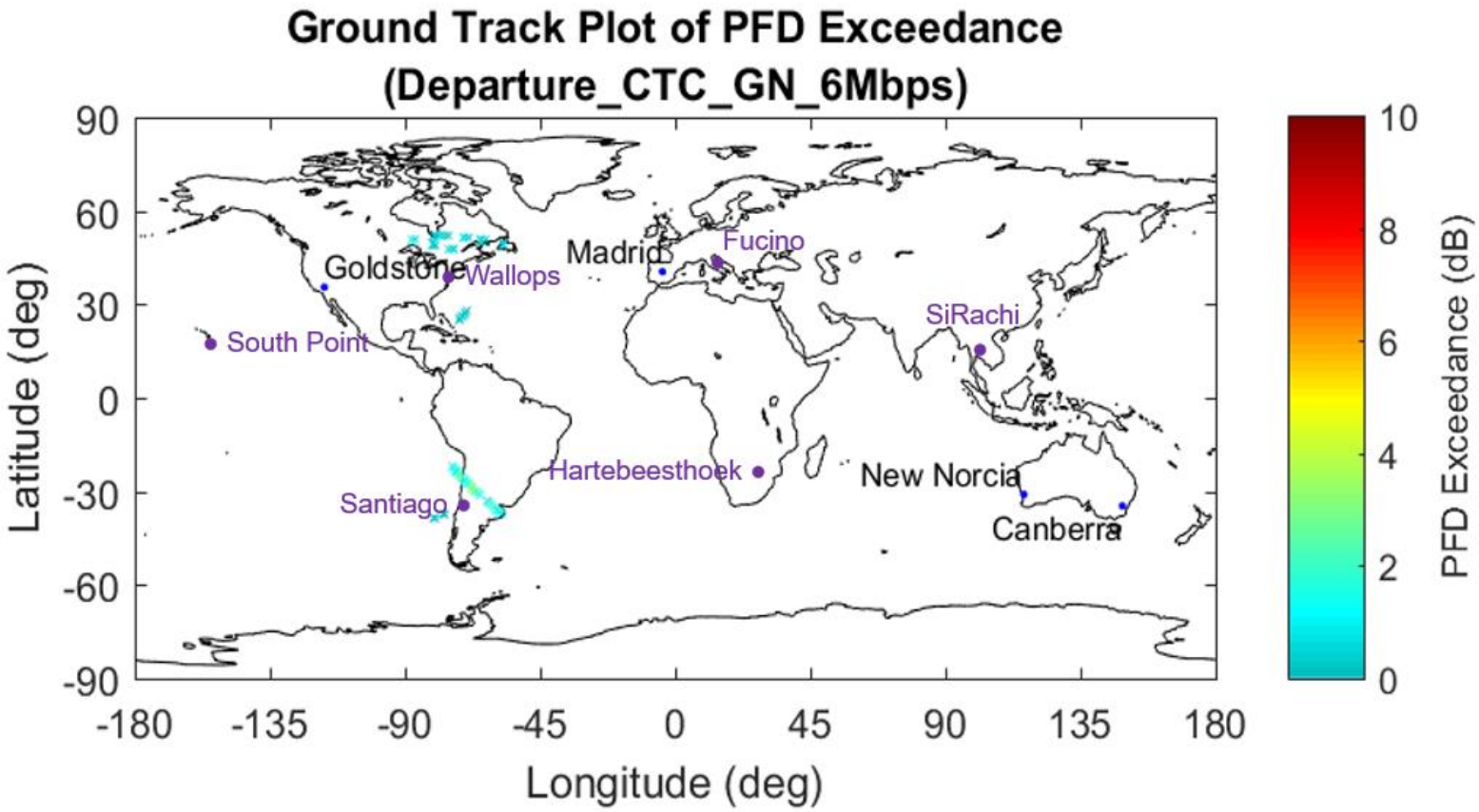

Figure 23. NG-17 PFD Limit Exceedance during Mission Departure, GN 6 Mbps (4M98G1D Emitter)

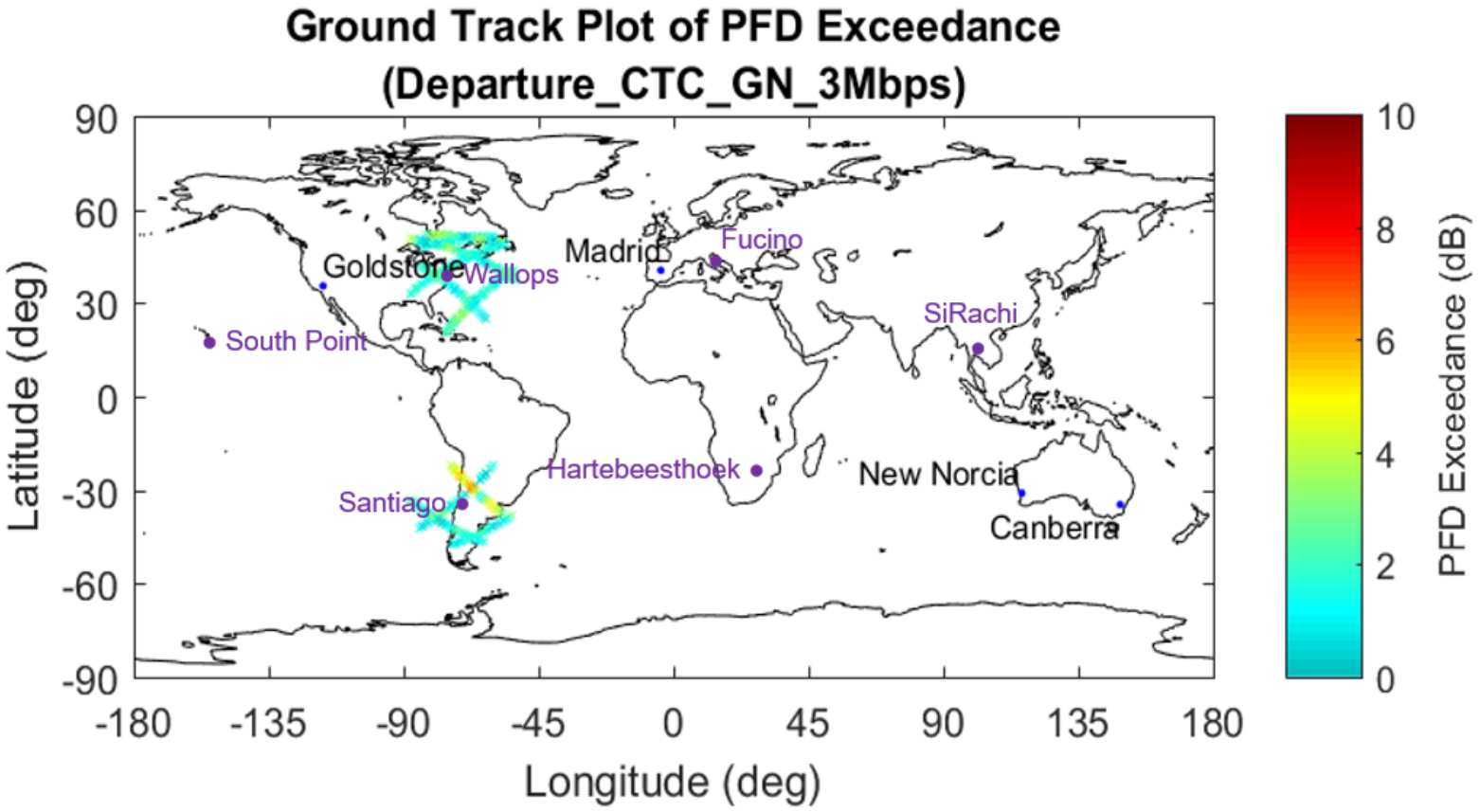

Figure 24. NG-17 PFD Limit Exceedance during Mission Departure, GN 3 Mbps (3M00G1D Emitter)

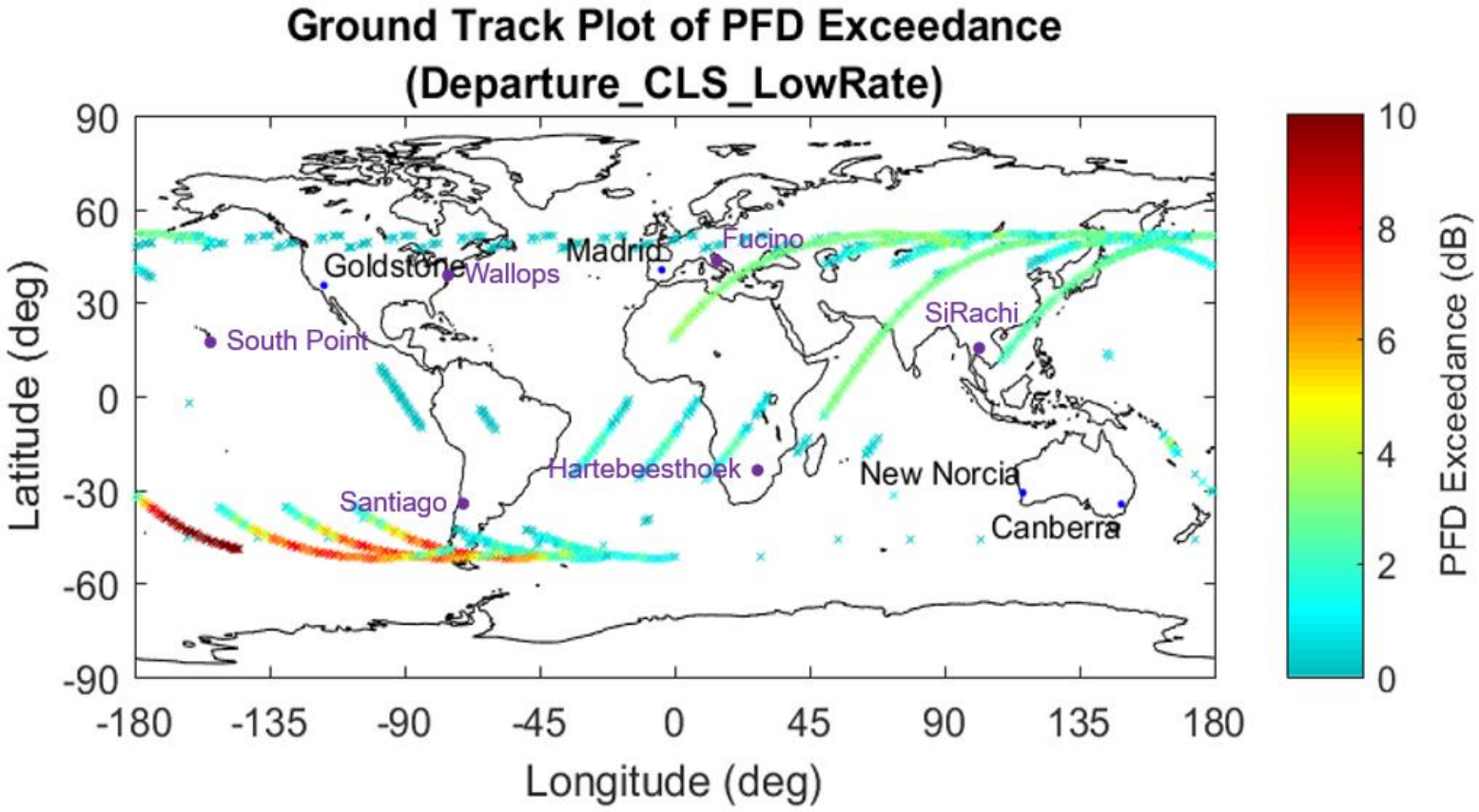

Figure 25. NG-17 PFD Limit Exceedance during Mission Departure, CLS Low Rate (5M93G1D Emitter)