Purpose and Scope:

This document is Attachment 3 of Northrop Grumman Systems Corporation's application for an FCC Special Temporary Authorization (STA) for operation of the Cygnus NG-17 spacecraft. The FCC file number for this application is 1936-EX-ST-2021.

This document provides an assessment of NG-17 compliance with the requirements for protection of the NASA Deep Space Network (DSN) frequency band (2290-2300 MHz). In addition, this document contains a proposed Special Condition for inclusion in the NG-17 STA.

Background:

The Cygnus-to-ISS links with emission designator 4M98G1D and 5M93G1D, operating at 2203.2 MHz, are fully compliant to the DSN protection requirements in ITU-R SA1157-1 and SFCG 14-R1 and therefore are not addressed in this document.

The Cygnus-to-TDRS return links with emission designator 6M16G1D, operating at 2287.5 MHz, do not meet the DSN protection requirements in ITU-R SA1157-1 and SFCG 14-R1. These links are addressed in this document.

Requirements:

ITU-R SA1157-1 and SFCG 14-R1 contain requirements for transmissions in the 2290-2300 MHz band from spacecraft in view of a DSN site (New Norcia, Goldstone, Madrid, and Canberra).

Cygnus-to-TDRS return link transmissions (emissions designator 6M16G1D) do not meet the ITU and SFCG requirements. The inability to use Cygnus-to-TDRS return links when Cygnus is in view of a DSN would have a significant impact on mission operations. For this reason, Northrop Grumman Systems Corporation and the NASA JSC Spectrum Management Office (SMO) worked together to develop an alternate, less restrictive DSN protection requirement for Cygnus-to-TDRS return link transmissions, which is documented in Preliminary Interface Revision Notice (PIRN) 50885-NA-0068B and is as follows:

> ***E.3.3.7.1.2.7 RADIO INTERFERENCE***
>
> *B. The Cygnus vehicle radio links shall produce an Out-of-Band power flux density not to exceed levels specified in SSP 50808, 3.3.7.1.2.7, except the Cygnus Vehicle's TDRS 6MHz spread spectrum return link on 2287.5 MHz shall produce a power spectral density (PSD) of less than -222 dBW/Hz from 2293 – 2300 MHz, referenced at the input of the DSN ground station receiver and using a DSN antenna gain of +32 dBi.*
>
> *Note: The ISS Program approved Cygnus out-of-band emissions requirement for Cygnus TDRS 6 MHz spread spectrum return link on 2287.5 MHz do not comply with the US regulations. The Cygnus vehicle will accept and comply with constraints imposed in the Special Temporary Authorization (STA) license not relieved through the coordination process.*

Acceptance Rationale:

Recognizing that the existing Space Network return link service at 2287.5 MHz, spread 3 Mcps, from LEO spacecraft to the TDRS is unable to satisfy the 2290 – 2300 MHz deep space protection criteria, a modified protection level for TDRS 2287.5 MHz spread return link was agreed by NASA DSN as stated in the exception above.

The Cygnus plans to meet this requirement for the 2287.5 MHz TDRS link by implementing a mask shown in Figure E.3.3.7.1.2.7-1, Referenced At The Input Of The DSN Ground Station Receiver And Using A DSN Antenna Gain Of +32 dBi for 2287.5 MHz TDRS 6 MHz spread spectrum return link. Provided that the measured transmit output spectrum from the Cygnus spread spectrum TDRS return link at 2287.5 MHz shows compliance to the modified protection level agreed by NASA DSN, no operational restriction will be required for this TDRS operation. ISS Program agreements are in place to accept the COTS Vehicle implementation, pending formal RF system verification testing.

The Cygnus 2203.2 MHz proximity link and 2287.5 MHz direct downlink are subject to meet the Out-of-Band power flux density not to exceed levels specified in SSP 50808, 3.3.7.1.2.7. Cygnus mask shown in Figure E.3.3.7.1.2.7-1 does not apply to the 2203.2 MHz proximity and 2287.5 MHz direct downlink.

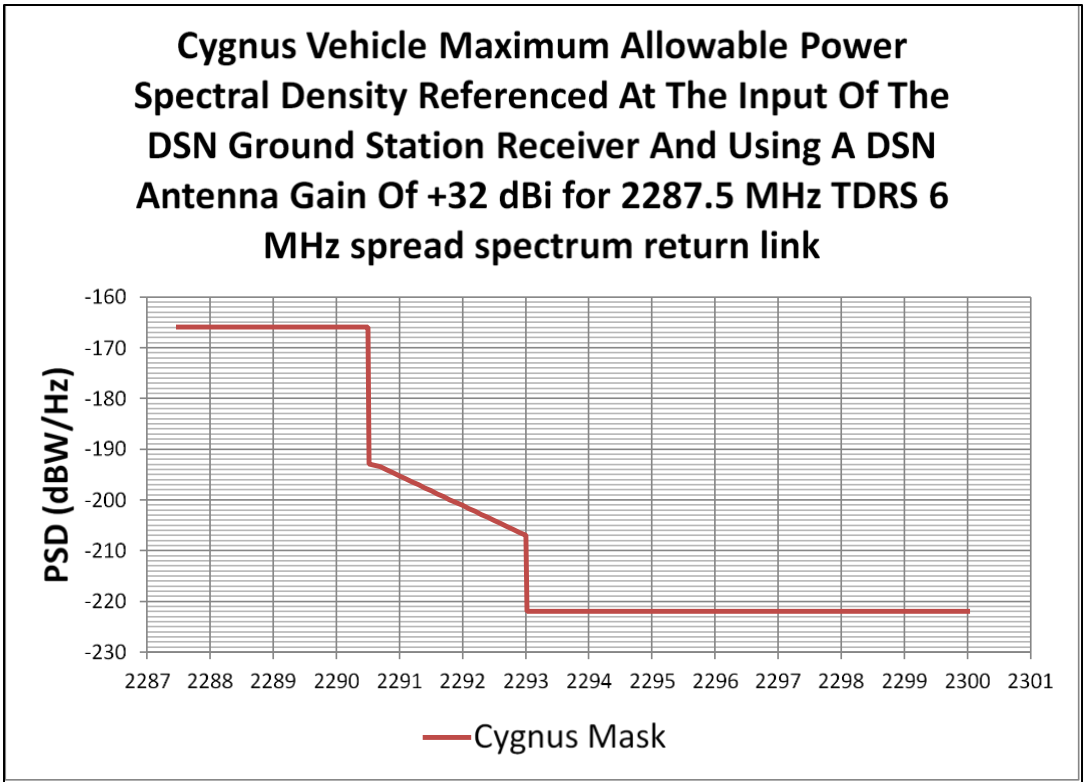

FIGURE E.3.3.7.1.2.7-1 REFERENCED AT THE INPUT OF THE DSN GROUND STATION RECEIVER AND USING A DSN ANTENNA GAIN OF +32 DBI FOR 2287.5 MHZ TDRS 6 MHZ SPREAD SPECTRUM RETURN LINK

This exception does not guarantee FCC license approval, does not exempt the Cygnus from any FCC regulatory requirements, and the Cygnus will obtain an FCC STA license on a mission-by-mission basis, provide system impacts to any constraints imposed by those licenses, and will comply with any licensing restrictions.

Flight Effectivity: OA-9 through OA-17

Additionally, Northrop Grumman Systems Corporation has implemented the filtering recommended in the Space Network Users' Guide (450-SNUG), Appendix D, Figure D-6. That recommended filtering profile is reproduced in Figure 1 for reference.

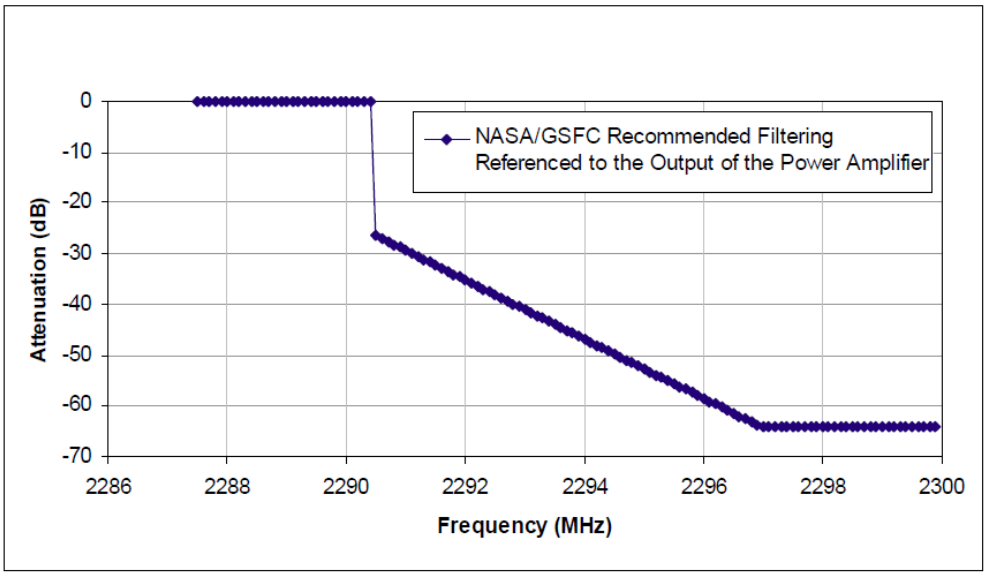

Figure 1. NASA/GSFC Recommended Filtering Referenced to Output of Power Amplifier

Performance:

The following plots show the measured performance of the NG-17 primary and redundant transmitters (CTC-A and CTC-B, respectively) relative to the requirement in PIRN 50885-NA-0068B and the filtering recommended by 450-SNUG.

The peak Cygnus antenna gain is used to present a true worst-case Power Spectral Density (PSD) at the DSN receiver input. A DSN antenna gain of +32 dBi is used per PIRN 50885-NA-0068B.

Figure 2 shows the performance of the NG-17 primary transmitter (CTC-A) when operating at an ERP of 4.0 W, with a slant range of 250 km between the DSN site and Cygnus spacecraft. A slant range of 250 km corresponds to the minimum slant range at which the DSN protection requirements in PIRN 50885-NA-0068B can be met.

Figure 3 shows the performance of the NG-17 redundant transmitter (CTC-B) when operating at an ERP of 4.0 W, with a slant range of 200 km between the DSN site and Cygnus spacecraft. A slant range of 200 km corresponds to the minimum possible slant range based on Cygnus' trajectory following launch and the time of initial transmitter emission. (In other words, a Cygnus transmitter will never be transmitting when the slant range between a DSN site and the spacecraft is less than 200 km.)

Figure 4 shows the performance of the NG-17 primary transmitter (CTC-A) when operating at an ERP of 6.3 W, with a slant range of 400 km between the DSN site and Cygnus spacecraft. A slant range of 400 km corresponds to the minimum expected slant range during use of the higher-power return link. (The higher power level is used in combination with MA mode during secondary payload operations after departure from the ISS. The minimum expected slant range during this time period is 400 km. MA mode is typically used during secondary payload operations because TDRS MA resources are more abundant than TDRS SSA resources. MA

mode requires a higher transmit power level because the TDRS G/T for MA mode is lower than that for SSA mode.)

Figure 5 shows the performance of the NG-17 redundant transmitter (CTC-B) when operating at an ERP of 6.3 W, with a slant range of 400 km between the DSN site and Cygnus spacecraft. A slant range of 400 km corresponds to the minimum expected slant range during use of the higher-power return link.

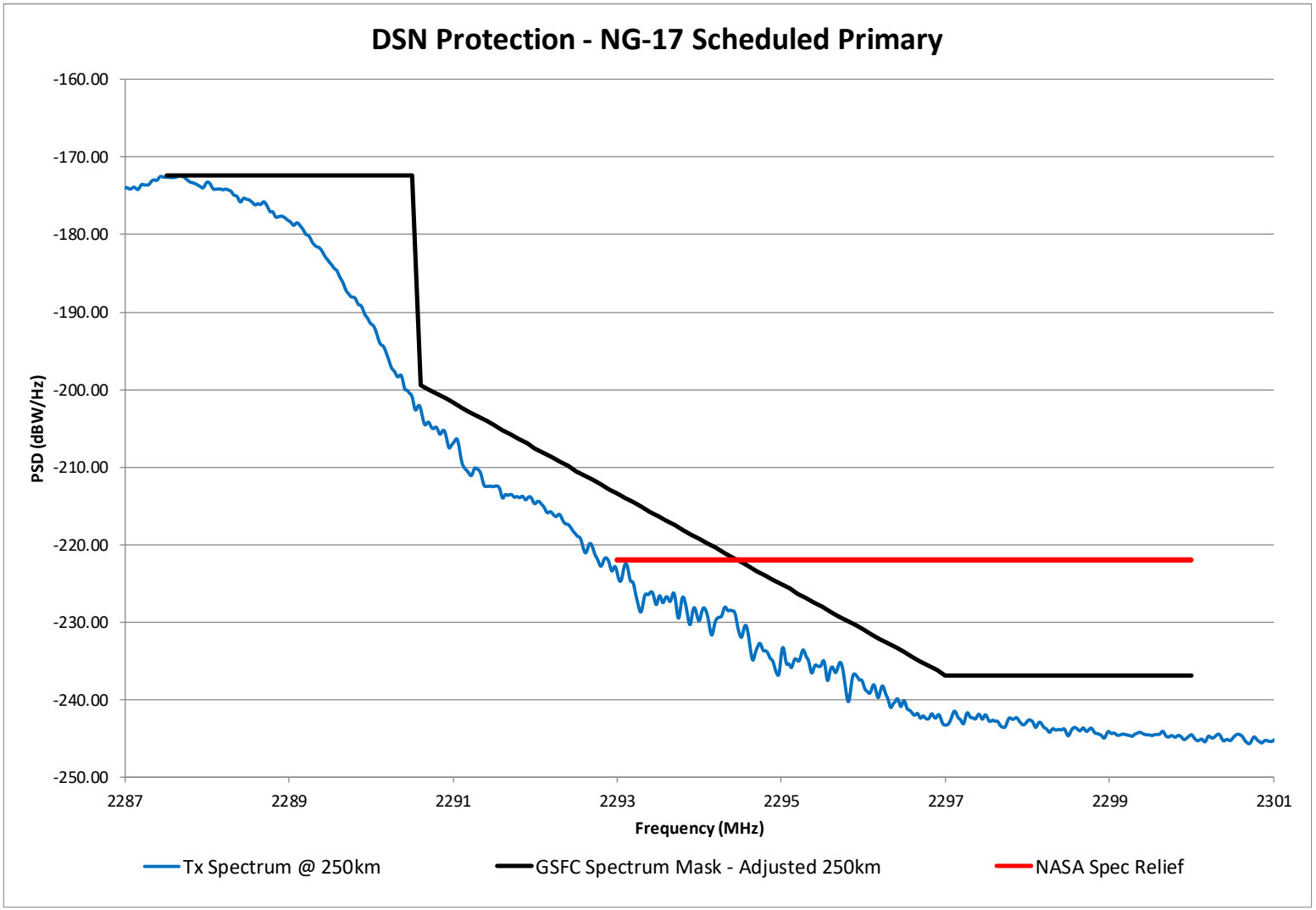

Figure 2. DSN Performance for TDRS Return Link 6M16G1D, ERP = 4.0 W, Range = 250 km, Primary Transmitter (CTC-A)

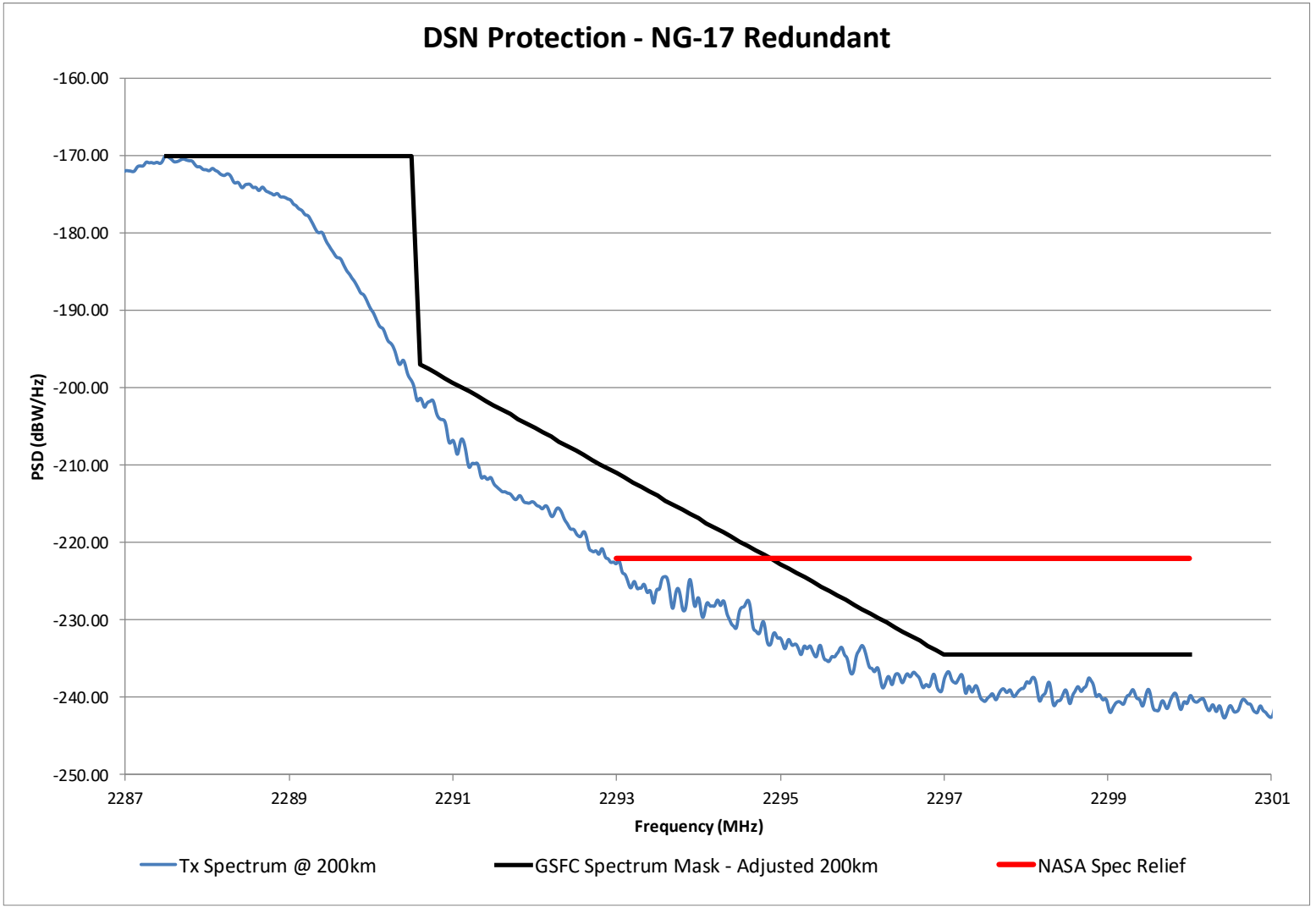

Figure 3. DSN Performance for TDRS Return Link 6M16G1D, ERP = 4.0 W, Range = 200 km, Redundant Transmitter (CTC-B)

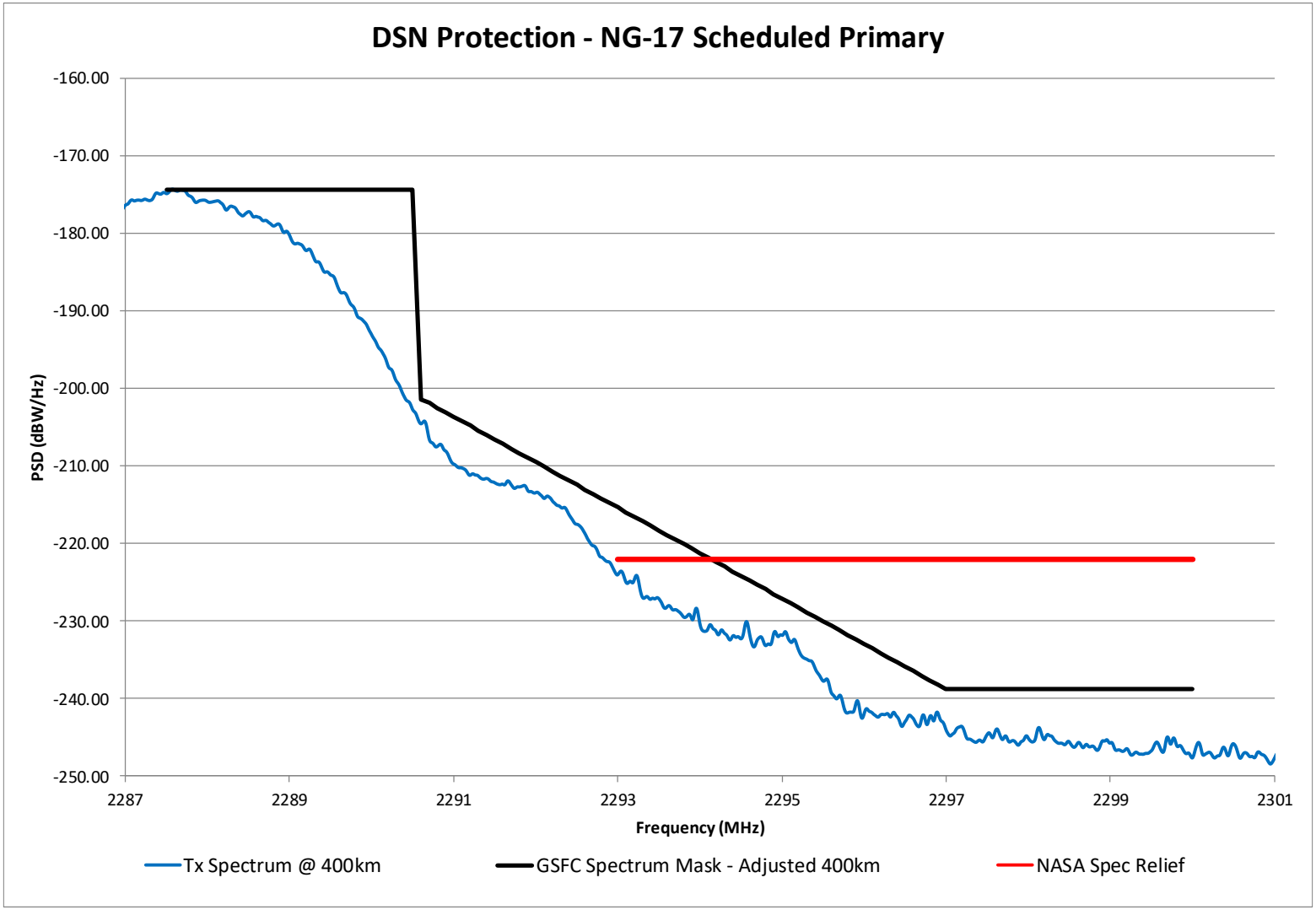

Figure 4. DSN Performance for TDRS Return Link 6M16G1D, ERP = 6.3 W, Range = 400 km, Primary Transmitter (CTC-A)

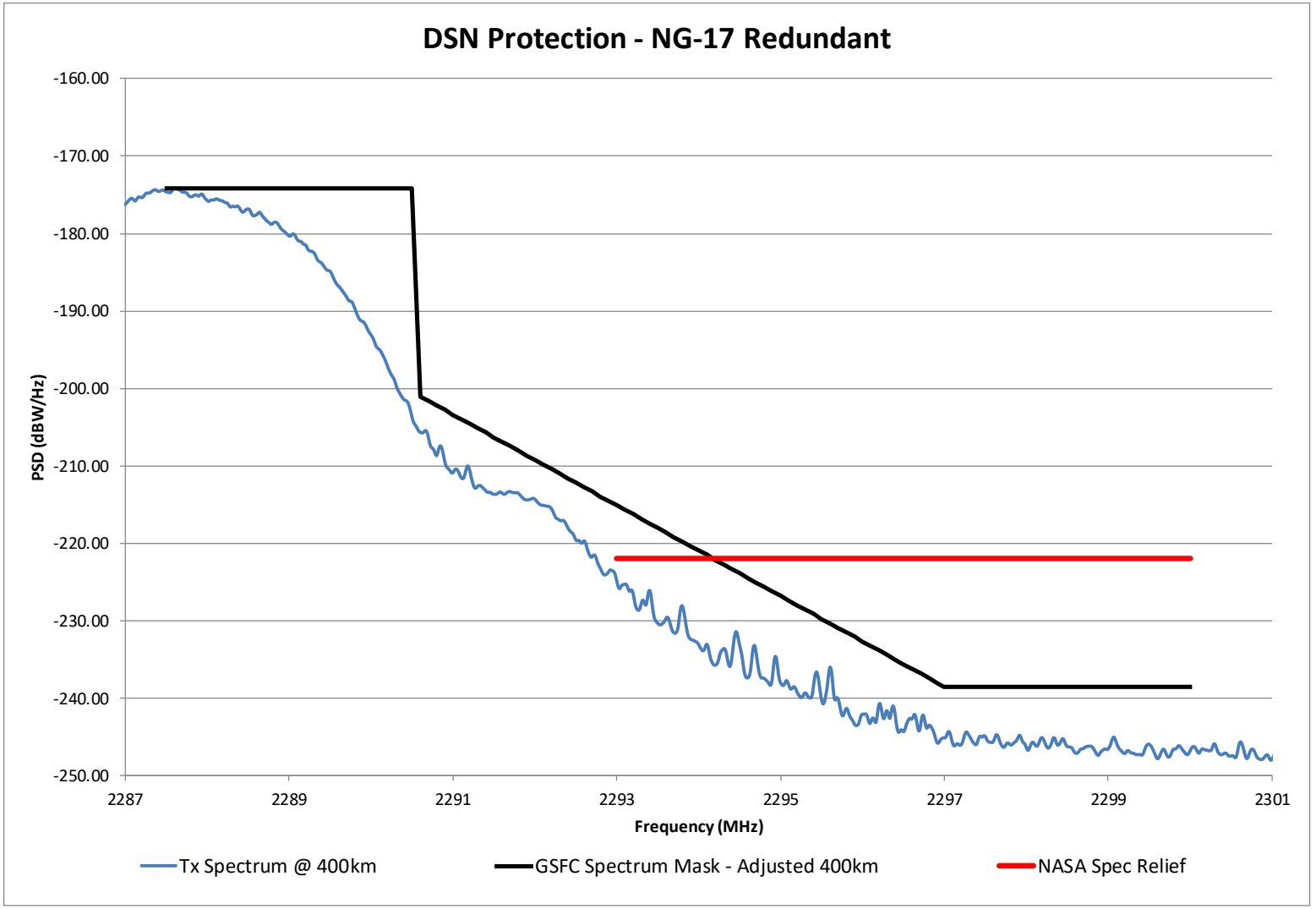

Figure 5. DSN Performance for TDRS Return Link 6M16G1D, ERP = 6.3 W, Range = 400 km, Redundant Transmitter (CTC-B)

Proposed Special Condition for NG-17 STA:

Below is the Northrop Grumman Systems Corporation proposed Special Condition for the NG-17 Special Temporary Authorization (STA). Adherence to the restrictions in this proposed Special Condition will guarantee NG-17 compliance with the DSN protection requirements contained in PIRN 50885-NA-0068B.

Cygnus-to-TDRS return link transmission using CTC Transmitter A, frequency of 2287.5 MHz, emission designator of 6M16G1D, and ERP of 4.03 Watts, is prohibited when Cygnus is in view of the deep space earth stations listed below, with a slant range of less than 250 km.

Cygnus-to-TDRS return link transmission using CTC Transmitter B, frequency of 2287.5 MHz, emission designator of 6M16G1D, and ERP of 4.03 Watts, is prohibited when Cygnus is in view of the deep space earth stations listed below, with a slant range of less than 200 km.

Cygnus-to-TDRS return link transmission using CTC Transmitter A or CTC Transmitter B, using frequency of 2287.5 MHz, emission designator of 6M16G1D, and ERP of 6.34 Watts, is prohibited when Cygnus is in view of the deep space earth stations listed below, a slant range of less than 400 km.

Coordination requests for clearance to transmit at slant ranges below the aforementioned limits shall be provided to Cathy Sham (catherine.c.sham@nasa.gov, NASA JSC SMO) at least 7 days in advance. The deep space earth stations subject to this prohibition are as follows: Goldstone Deep Space Communications Complex (GDSCC), Madrid Deep Space Communications Complex (MDSCC), Canberra Deep Space Communications Complex (CDSCC), and New Norcia Station.

Conclusion:

Cygnus-to-TDRS return link transmissions (emissions designator 6M16G1D) do not meet the ITU and SFCG requirements for protection of the DSN frequency band (2290-2300 MHz). Northrop Grumman Systems Corporation and the NASA JSC SMO worked together to develop an alternate DSN protection requirement for Cygnus-to-TDRS return link transmissions, which is documented in PIRN 50885-NA-0068B. The Cygnus NG-17 spacecraft will meet the alternate DSN protection requirement in PIRN 50885-NA-0068B if the proposed Special Condition above is implemented. Northrop Grumman recommends that this proposed Special Condition be included in the NG-17 STA. Northrop Grumman would then integrate the restrictions of the Special Condition into the standard mission operations planning process.