NASA Phase III REPORT

NASA Revised Phase III Response to NTIA

1755-1850 MHz Relocation

Revision 2

October 5, 2011

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NASA Phase III Response to NTIA Regarding 1755-1850 MHz Relocation

October 5, 2011

I. Introduction and Executive Summary

This report describes NASA's current operations and relocation strategy related to the 1755-1850 MHz band which is being considered by NTIA for reallocation to the commercial wireless broadband service. NASA has a total of 18 Radio Frequency Assignments (RFAs) in the band supporting aeronautical telemetry/telecommand operations for a variety of aircraft research and flight test programs involving manned aircraft, unmanned aerial vehicle/remote piloted vehicle (UAV/RPVs), and high altitude scientific balloons. There is also a single RFA supporting Shuttle space-to-space communications. These operations are under the control of four NASA Centers: (1) Wallops Flight Facility (WFF); (2) Langley Research Center (LaRC); (3) Dryden Flight Research Center (DFRC); and (4) Johnson Space Center (JSC). For this Phase III effort, the NASA Headquarters Spectrum Office requested that each of these Centers provide an update of their relocation plans that identifies comparable/preferable bands for relocating their 1755-1850 MHz operations and estimates of the time and cost to transition to these bands. The NASA Phase II report of June 1, 2011 contained initial estimates and Section II of this report contains the updated estimates. Note in this Report, the term "telemetry" refers to air-to-ground/downlink transmissions while "telecommand" refers to ground-to-air/uplink transmissions. Of the (18) NASA RFAs: nine support aero-telemetry, eight support aero-telecommand and one supports Shuttle short range space-to-space communications. Bands that have been identified for relocation of aero telemetry/telecommand operations are: 1435-1525 MHz; 2360-2395 MHz; and 4400-4940 MHz. These are all existing aero-telemetry/telecommand bands currently being used by NASA for similar operations. For WFF, time for relocation is estimated to be 12-24 months with estimated costs of $0.6M, if migrating to 1435-1525/2360-2395 MHz or $6M, if migrating to 4400-4940/5091-5150 MHz. For LaRC, time for relocation is estimated to be 12-18 months with an estimated cost of $4.189M, based on a migration to 4400-4940 MHz. For DFRC, time for relocation is estimated to be 36-60 months with an estimated base cost of $27.3M based on migration to the 2025-2110 MHz and 4400-4940/5091-5150MHz bands. If the installation requires the full 60 months, the estimated cost would be $30.7M. For JSC, NASA does not intend to relocate the Shuttle RFA since the Space Shuttle program ended July 31, 2011. NASA HQ coordination and technical support for the NASA Centers is estimated to be 12-36 months with a cost of $0.4M. Thus, total NASA base cost to relocate from the 1755-1850 MHz band is approximately $35.5M with an upper estimated limit of $41.3M .

As described in Section III, NASA also has conducted compatibility analysis for potential relocation of some types of federal operations from the 1755-1850 MHz band to two of its most critical space operation bands: 2025-2110 MHz and 2200-2290 MHz.

With regard to the 2025-2110 MHz band, NASA currently has 209 RFAs in the band. As shown in Figure 1, this band is used to support (direct-from-ground) satellite uplinks and Tracking Data and Relay Satellite (TDRS) forward links (GEO TDRS-to-LEO satellite). The victim receivers in this case are therefore onboard LEO satellites. The analysis focused on the TDRS forward links (interference path #2 in Figure 1), since these are more vulnerable to interference than the direct uplinks due to the relatively weak TDRS forward link signal to the LEO satellites. Only DoD has identified the 2025-2110 MHz band for relocation of some of its systems.

Section III.A.1 of the Report considers the 2025-2110 MHz band and interference from DoD SGLS (Space Ground Link System) uplink operations to the NASA TDRS forward links. In this analysis, interference from 13 different SGLS earth stations were considered along with 21 different NASA TDRS user satellites and 3 different TDRS satellites. Based on DoD provided SGLS data, the analysis shows that for the LEO case, where DoD SGLS earth stations are transmitting to LEO satellites, interference levels from the DoD earth stations exceed the ITU-R recommended TDRS forward link interference threshold (i.e. I/N = -10 dB not to be exceeded more than 0.1% of the time) for about 9% of the TDRS user cases analyzed. For the GEO case, where DoD earth stations are transmitting to GEO satellites, interference levels exceed the ITU-R threshold in about 17% of the TDRS user cases analyzed. Accommodation of DoD SGLS in the band therefore appears workable. NASA recommends that DoD avoid using frequencies in the TDRS MAF portion of the band (the 6.2 MHz between 2103.3 – 2109.5 MHz) due to the large number of user spacecraft that NASA supports over this channel. DoD has indicated that they will attempt to avoid assignments in the MAF band. However, they also stated that they will use it if required, and if so, this use will be coordinated with NASA via the DoD/NASA/NOAA frequency pre-coordination process and the FAS.

Section III.A.2 of the Report considers the 2025-2110 MHz band and interference from other DoD systems (i.e. ACTS, TRR, UAS) to the NASA TDRS forward links. Based on the specific parameters and assumptions used in the analysis, it appears that accommodation of these DoD systems – with the exception of ACTS in its present form - is possible. It must be emphasized, however, that this conclusion is based on the assumption that the transmit/deployment characteristics of the DoD TRR and UAS systems moving into the band are consistent with those used in the analysis. This conclusion does not hold if there is significant deviation from these characteristics. With regard to ACTS, based on the characteristics we have on these systems from DoD (which represent current 1755-1850 MHz operation), the interference from ACTS alone exceeds the ITU criteria by about 5-9 dB and therefore remains a concern. The analysis assumed only (4) co-frequency interfering emitters (located in NV,AZ,FL,VA), but the ACTS transmit power is very high (100W) and uses non-directional/omni antennas along with large duty cycles (50%). These types of transmit characteristics make it difficult to share with DRS systems on a co-frequency basis. There has been some discussion with DoD of using frequency avoidance for ACTS so that they do not operate co-frequency with TDRSS forward links, but DoD has stated that at this point it is not a primary option. NASA will continue to work with DoD to investigate improvements to the current ACTS (e.g. different modulations, spread spectrum, power, antenna characteristics, etc.) to ensure compatibility with NASA systems as these systems move into the band.

Section III.B of the Report considers the 2200-2290 MHz band. This band is also a critical space operation band for NASA. NASA currently has 207 RFAs in the band. As shown in Figure 2, this band is used to support (direct space-to-ground) satellite downlinks (i.e. victim receivers at NASA earth stations); TDRS return links (i.e. links from LEO satellites to GEO TDRS satellites with victim receivers onboard the GEO TDRS satellites); air-to-ground telemetry (i.e. victim receivers are at ground stations receiving telemetry from aircraft and launch vehicles); and ISS (International Space Station) proximity operations with nearby resupply spacecraft. A number of agencies (DoD, Treasury, USPS, DHS, DOJ, DOI) have proposed moving some of their 1755-1850 MHz operations, primarily video surveillance and military TRR, into the band. Therefore NASA has performed analysis of interference from these systems to its satellite receiving earth stations; aero-telemetry receiving ground stations; and to the TDRS return links. NASA satellite receiving earth stations and aircraft telemetry receiving ground stations will require protection from incoming transmitters using appropriate coordination contours around the earth station and telemetry sites. The Report provides some sample coordination contours based on the expected EIRP levels of video surveillance systems. Additional coordination contours may be required for protection from DoD TRR systems if they move into the band. Note DoD has identified the 2025-2110 MHz band as the primary band for TRR, but also selected 2200-2290 MHz as an alternate band. Analysis was also performed to assess the impact to NASA TDRSS return links. Based on the system characteristics of DoD, DHS, DOJ, DOI, and Treasury systems described in the Report, it appears that interference from these systems into the NASA TDRSS return links is acceptable. Again, however, this conclusion is only valid as long as there is no significant deviation of these agency system characteristics from those used in the analysis.

Figure 1.Interference Scenarios for NASA 2025-2110 MHz Operations

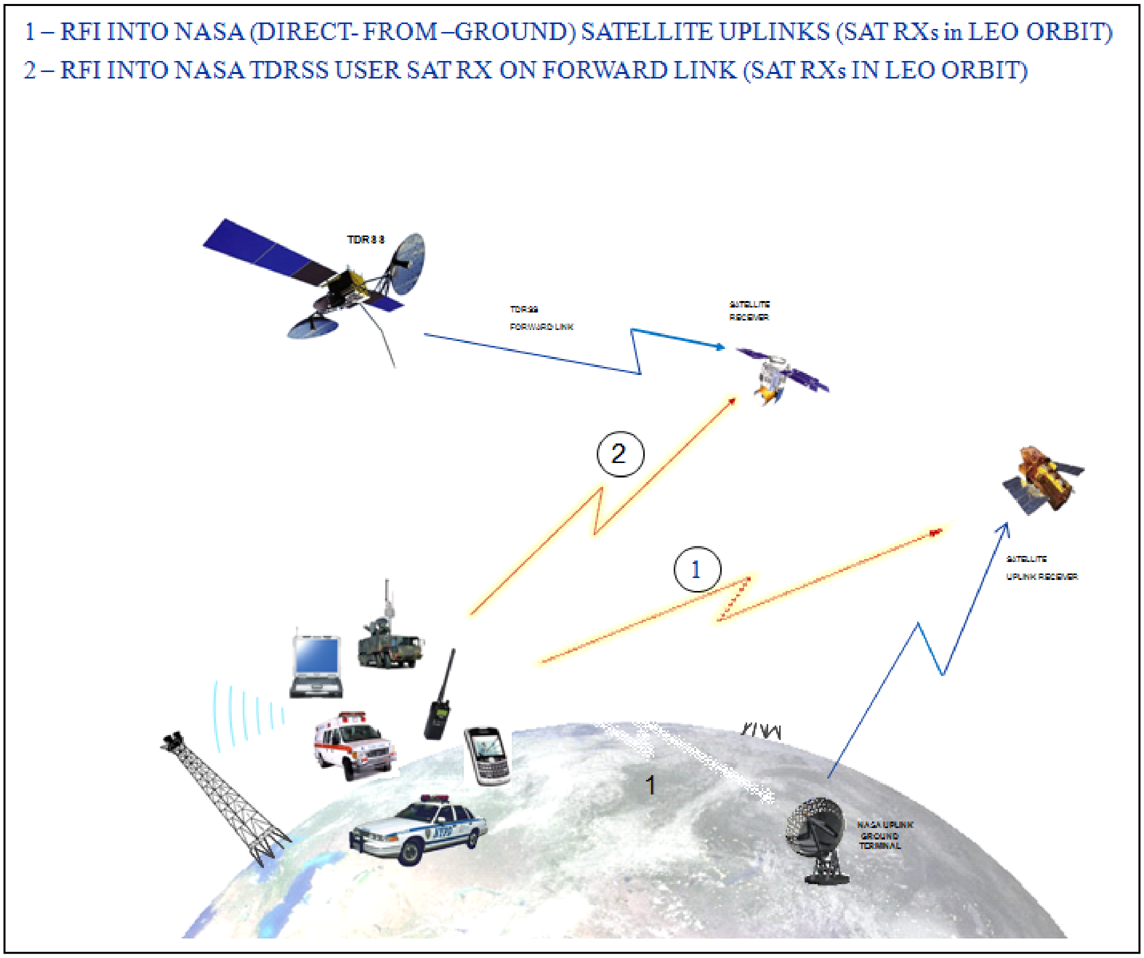
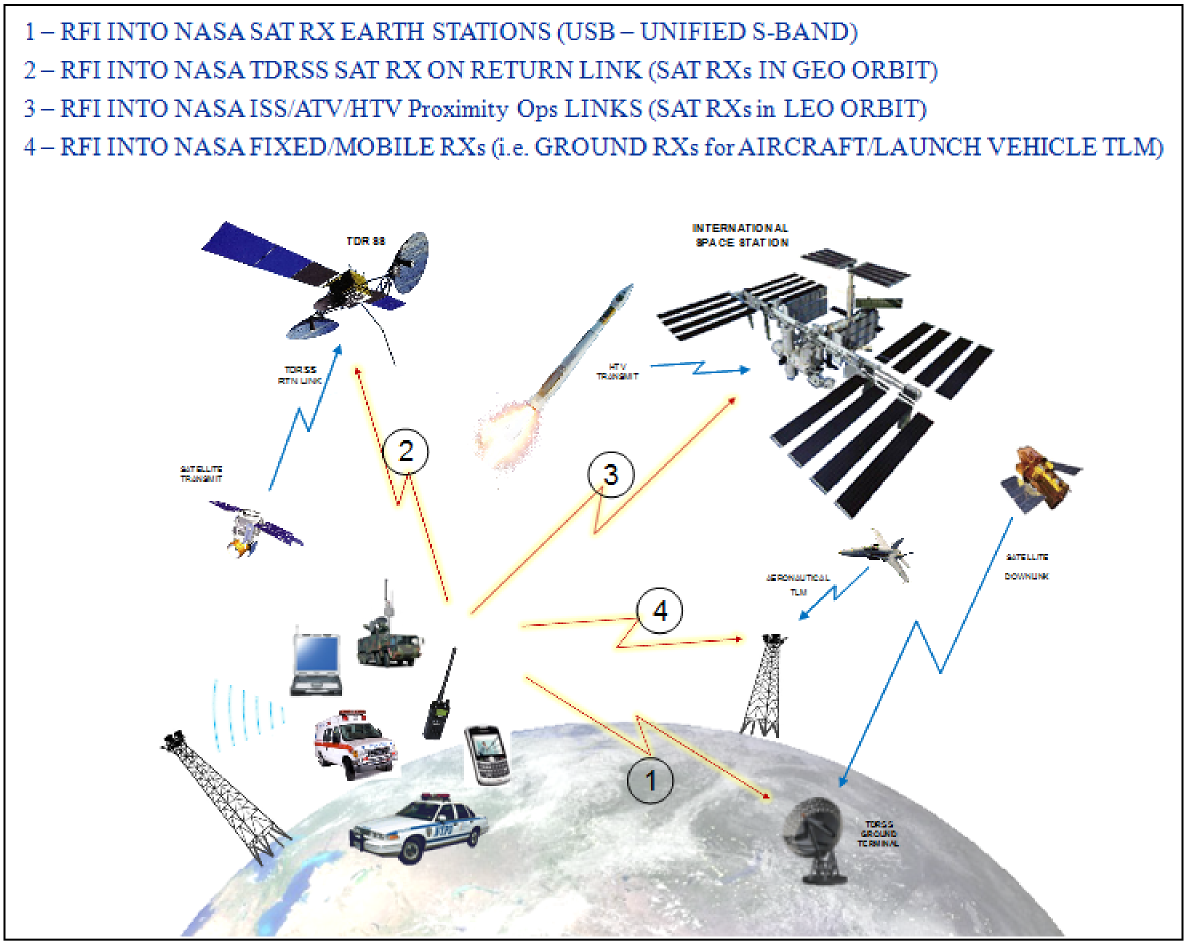


Figure 2. Interference Scenarios for NASA 2200-2290 MHz Operations



II. Relocation of NASA Assignments

The NASA Phase II Report of June 1, 2011 contains detailed descriptions of NASA's current operations and assignments in the 1755-1850 MHz band. It also contains initial cost estimates and timelines for relocation. We therefore did not include all that data here. The information below contains updated relocation cost and timeline data from the various NASA Centers.

II.A. NASA Wallops Flight Facility (WFF) 1755-1850 MHz Operations and Relocation Plan

NASA WFF, located on Virginia's Eastern Shore, currently has (7) RFAs in the 1755-1850 MHz band supporting UAV video telemetry and high altitude scientific balloon video/data telemetry. WFF plans to transition these RFAs to other aero-telemetry bands (i.e. 1435-1525/2360-2395 MHz) where similar NASA operations are being conducted. The specific transition frequencies in these bands are:

A. Primary Band Selection:

   1. 1440 MHz, 10 MHz BW
   2. 1470 MHz, 10 MHz BW
   3. 1490 MHz, 10 MHz BW
   4. 2365 MHz, 10 MHz BW
   5. 2380 MHz, 10 MHz BW
   6. 2390 MHz, 10 MHz BW

B. Secondary Band Selection in order:

   1. 4400-4940 MHz or
   2. 5091-5250 MHz (Telemetry - Regulatory Action Required).

In the 1435-1525/2360-2395 MHz bands, NASA has contacted existing assignment holders (Air Force, Army, and Navy) and there is no additional coordination required. NASA has existing assignments and operations in these bands as well. If we are able to relocate to these two bands the estimated cost would be $ 600K with a relocation time frame of 12 to 18 months. See Exhibits 1 and 2 below.

If we are unable to relocate to the above primary bands and instead choose either of the secondary bands, the cost will increase significantly due to the need to purchase all new equipment. The estimated cost then would be in the neighborhood of $ 6M with a relocation time frame of up to 24 months. See Exhibits 1 and 2 below.

II.B. NASA Langley Research Center (LaRC) 1755-1850 MHz Operations and Relocation Plan

NASA LaRC, located in Hampton, VA, has (7) RFAs in the 1755-1850 MHz band. Six of these support telecommand links and one supports telemetry for various UAV and research aircraft projects. NASA already has similar aero-telemetry/telecommand operations in the 4400-4940 MHz band and therefore LaRC plans to transition all these RFAs to that band. NASA has contacted existing assignment holders (Air Force, Army, Coast Guard, DHS, DOE, Marine Corps, Treasury and USPS) and there is no additional coordination required. NASA has existing assignments and operations in these bands as well. Estimated relocation time is 18 months and cost is $4.189M. Please see Exhibits 3 (cost estimate) and 4 (relocation timelines for the various RFAs) below.

II.C. NASA Dryden Flight Research Center (DFRC) 1755-1850 MHz Operations and Relocation Plan

NASA DFRC, located at Edwards, CA, in the western Mojave Desert and adjacent to Edwards Air Force Base, is NASA's primary center for atmospheric flight test research and operations. DFRC has 3 RFAs in 1755-1850 MHz, all at 1804.5 MHz, to provide flight test telemetry (1 RFA) and telecommand links (2 RFAs) for developmental aircraft and RPVs in the R-2508 test airspace. DFRC provides both telemetry and telecommand services for internal and external customers and since the demand for these services is ongoing and growing, they will pursue several relocation avenues to ensure that they maintain the capability required by their customers. NASA has contacted existing assignment holders and there is no additional coordination required. NASA has existing assignments and operations in these bands as well.

A. Planned Relocation Bands:

   1. 2025-2110 MHz Band (for telecommand ops) (Federal Aeronautical Mobile - Regulatory Action Required)

   2. 4400-4940 MHz Band (for both telecommand and telemetry)

   3. 5091-5150 MHz Band (for telemetry)

Relocation of telecommand to the 2025-2110 MHz band would require regulatory action for a (Federal) aeronautical mobile service allocation (currently there is a non-fed only MOBILE service allocation). NASA has contacted existing assignment holders (Air Force, Army, DOE) in the 2025-2110/4400-4940 MHz bands and there is no additional coordination required. NASA has assignments in these bands. With regard to the 4400-4940 MHz band, NASA has 10 RFAs in the band to support similar video/data telemetry operations for high performance aircraft and UAVs. NASA has contacted existing assignment holders (Air Force, Army, Coast Guard, DHS, DOE, Marine Corps, Treasury and USPS) and no further coordination is required. Aero-telemetry use of 5091-5150 MHz will require regulatory action for a new aeronautical mobile service allocation that allows aero telemetry. NASA has contacted government assignment holders in the band (Air Force and FAA) and there has been no objection to potential relocation. Estimated relocation time is 3 to 5 years. Please see Exhibits 5 and 6.

II.D. NASA Johnson Space Center (JSC) 1755-1850 MHz Operations and Relocation Plan

The one assignment in this band that the Johnson Space Center has in the band is being cancelled due to the end of the Space Shuttle Program and will not be replaced.

EXHIBIT 1 - Wallops Flight Facility (WFF)

COSTS

Option 1: Total approximately $.5M to $.6M

Requested Frequencies:
Three L-Band allocations: 1440.0 MHz, 1470.0 MHz, 1490.0 MHz all 10MHz wide.
Three S-Band allocations: 2365.5 MHz, 2380.5 MHz, 2390.5 MHz all 10 MHz wide.

If frequencies are acquired, then:

New Equipment cost
1 - Telemetry Receivers to cover wide IF, video capability, SOQPSK 8 dual receiver units @ $54K each (16 Total receivers for PSN, FTS, Winslow) = $432,000
2 - Telemetry Transmitters
8 units @ $8.5K each = $68,000

Option #2: Total Approximately $5M to $6M

If we cannot get authorization for the noted channels above then we will have to move to C-Band at much increased cost:

Engineering/design costs
NRE and link budget analysis for new frequency band: $250,000 Flight Hardware testing, changes to PCM Encoders, NTSC Encoders:
$250,000

New Equipment Cost
Test equipment to cover C band (Spectrum analyzer, Signal Generator, Wattmeters, PCM Encoders, etc): $500,000
C Band Telemetry transmitters: 8 units @ $16K each = $68,000
Telemetry Receivers 8 dual receiver units @ $54K each = $432,000
Tri-band Telemetry Antenna system, 7 units @ $450K each = $3,150,000
Tri-band Multicoupler, 7 units @ $13K each = $91,000
Flight Antenna for C-band 50 @ 10K each = $50,000

Acceptance/Testing cost
Flight Testing, qualification (Batteries, expendables, flight piggyback costs): $250,000

Total Approximately $5M to $6M.

EXHIBIT 2 - Wallops Flight Facility (WFF)

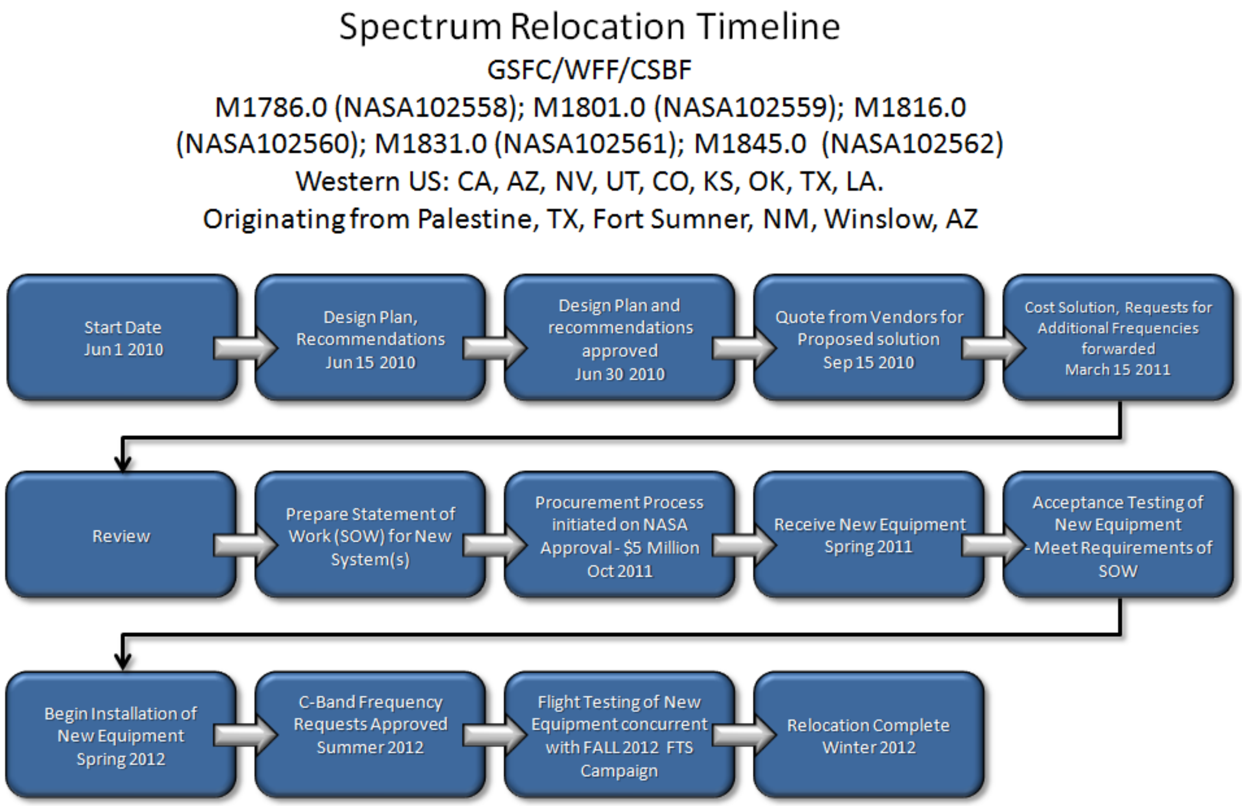


EXHIBIT 3 - Langley Research Center (LaRC)

ESTIMATED COSTS

Planning Cost	$ 250K	
Engineering/Design Cost	$ 800K	
New Equipment Cost	$ 2,289K	
Installation Cost	$ 350K	
Acceptance/Testing Cost	$ 500K	
Estimated Total Cost		$4,189K

EXHIBIT 4 - Langley Research Center (LaRC)

CURRENT AIRCRAFT RF ASSIGNMENTS

TIMELINE (1 of 4)

Spectrum Relocation Timeline
Langley Research Center
NASA760222, NASA940174
Langley Research Center (Aircraft RF)

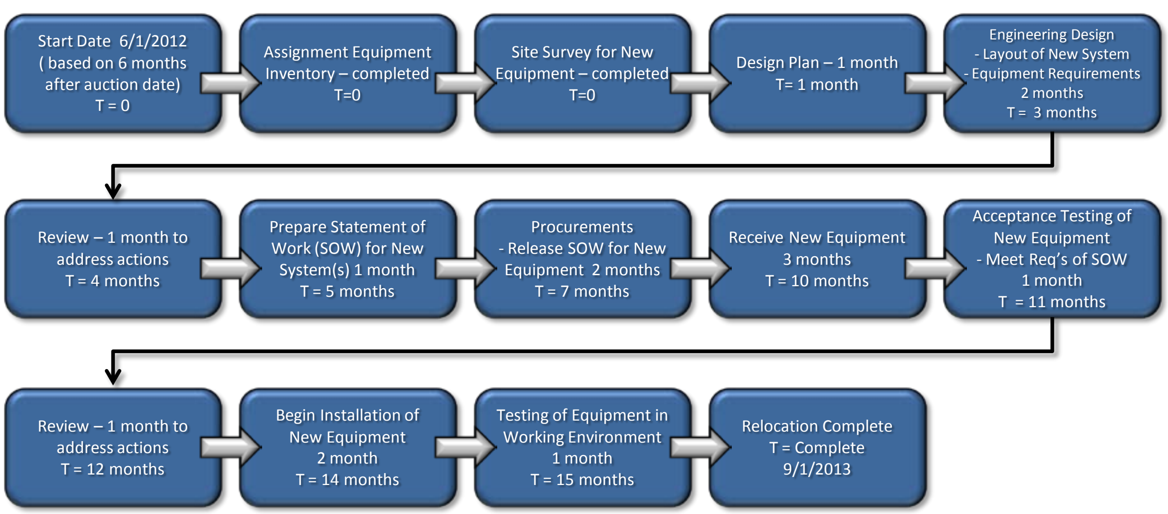


EXHIBIT 4 (cont.) - Langley Research Center (LaRC)

CURRENT AIRCRAFT RF ASSIGNMENTSTIMELINE (2 of 4)

Spectrum Relocation Timeline

Langley Research Center
NASA940130
Langley Research Center

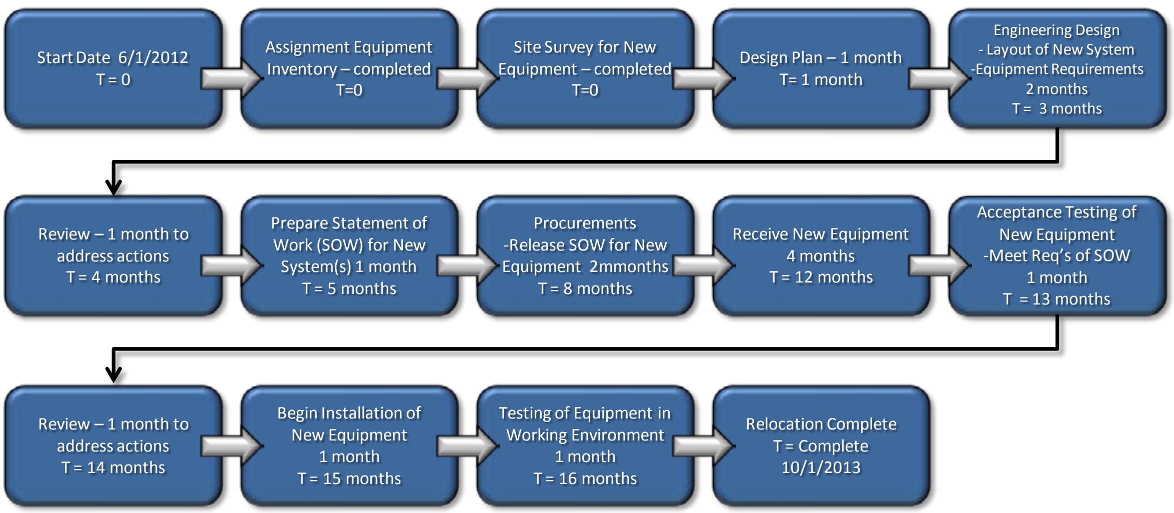


EXHIBIT 4 (cont.) - Langley Research Center (LaRC)

CURRENT AIRCRAFT RF ASSIGNMENTS

TIMELINE (3 of 4)

Spectrum Relocation Timeline

Langley Research Center
NASA900122
Langley Research Center (Aircraft RF)

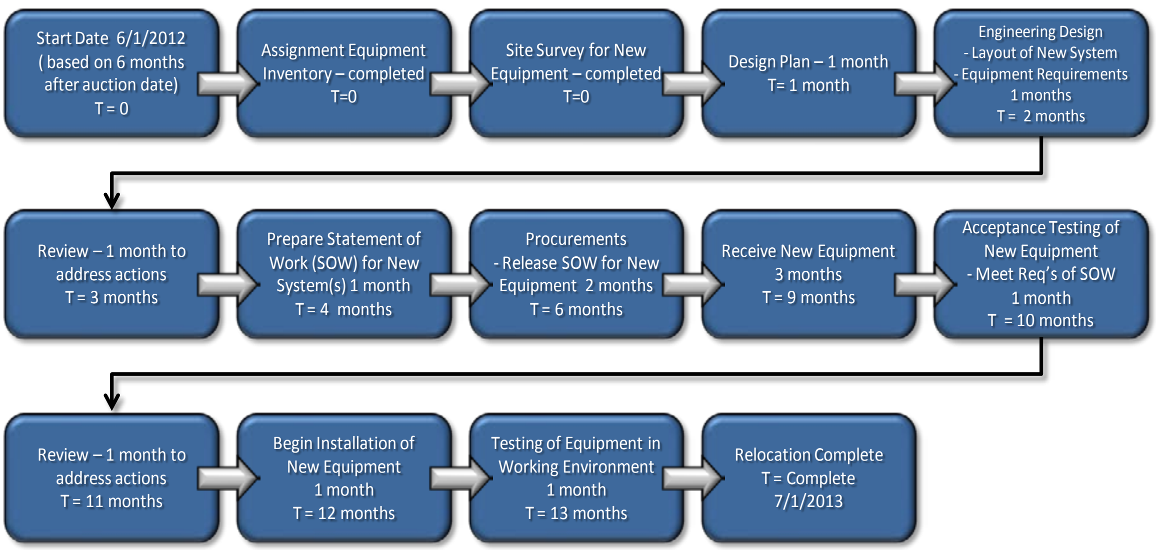


EXHIBIT 4 (cont.) - Langley Research Center (LaRC)

CURRENT AIRCRAFT RF ASSIGNMENTS

TIMELINE (4 of 4)

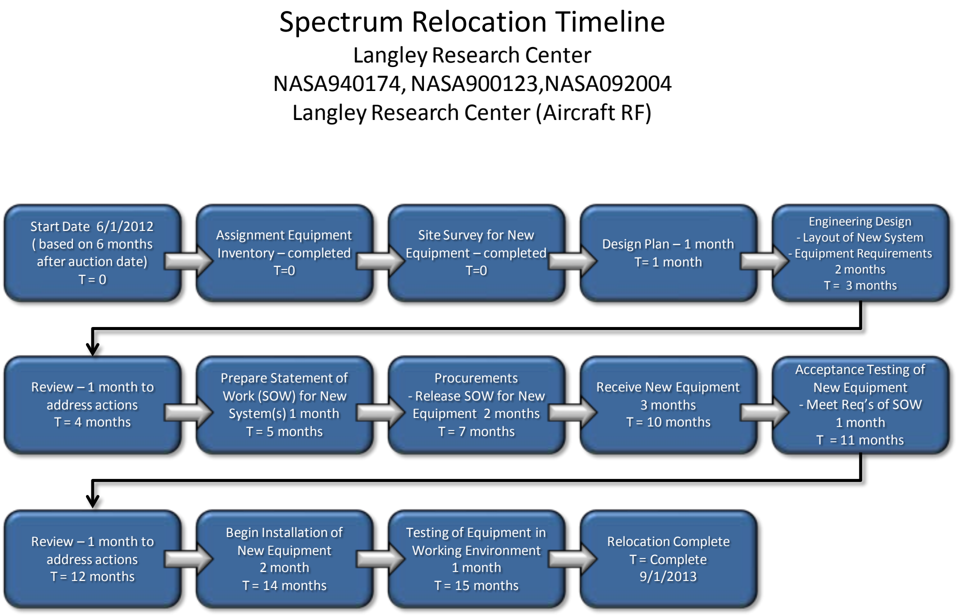


EXHIBIT 5 - Dryden Flight Research Center (DFRC)

ESTIMATED COSTS

Functional Area	Item	Units	Each	Line Cost	Subtotals
Uplink move to M2025-2110:					
Ground side	In-use S band uplink xmtr/PA/antenna/pedestal systems	5	$0.00	$0.00	
Ground side	Modulators (additional modes to match L band rcvr demod schemes)	5	$12,000.00	$60,000.00	
Ground side	Cabling, connectors, filters	5	$7,000.00	$35,000.00	
Airborne side	Airborne rcvrs	10	$21,000.00	$210,000.00	
Airborne side	Airborne rcvr development	1	$100,000.00	$100,000.00	
Airborne side	Filters, cabling, connectors, splitters, diplexers, antennae	10	$24,000.00	$240,000.00	
Ground side	Update/additional spectrum monitoring/direction finding system	1	$1,224,000.00	$1,224,000.00	
Ground side	Monitoring/direction finding system site development and installation	1	$510,000.00	$510,000.00	
Ground side	Spectrum monitoring; ops & maintenance (20 year sustainment)	1	$3,800,000.00	$3,800,000.00	
Ground and air	Uplink ops & maintenance (20 year sustainment)	1	$520,000.00	$520,000.00	
Ground and air	Planning, engineering, installation, training, and system certification	1	$315,000.00	$315,000.00	$7,014,000.00
Uplink move to M4400-4940 and M5091-5150:					
Ground side	In-use C band antenna/pedestal systems	5	$0.00	$0.00	
Ground side	Uplink xmtr/PA	5	$110,000.00	$550,000.00	
Ground side	Exciter/modulator	5	$28,000.00	$140,000.00	
Ground side	Filters, cabling, waveguides, connectors, combiners, feeds, diplexers	5	$41,000.00	$205,000.00	
Airborne side	Airborne rcvrs	10	$27,000.00	$270,000.00	
Airborne side	Airborne rcvr development	1	$100,000.00	$100,000.00	
Airborne side	Filters, cabling, connectors, splitters, diplexers, antennae	10	$28,000.00	$280,000.00	
Ground side	Update/additional spectrum monitoring/direction finding system	1	$1,124,000.00	$1,124,000.00	
Ground side	Monitoring/direction finding system site development and installation	1	$910,000.00	$910,000.00	
Ground side	Spectrum monitoring; ops & maintenance (20 year sustainment)	1	$3,800,000.00	$3,800,000.00	
Ground and air	Uplink ops & maintenance (20 year sustainment)	1	$620,000.00	$620,000.00	
Ground and air	Planning, engineering, installation, training, and system certification	1	$645,000.00	$645,000.00	$8,644,000.00
Aero TM receive move to M4400-4940 and M5091-5150:					
Ground side	In-use C band antenna/pedestal systems	5	$0.00	$0.00	
Ground side	Feeds, subreflectors, waveguides, cabling, connectors, diplexers	5	$45,000.00	$225,000.00	
Ground side	TM rcvr/demod upgrades	28	$54,000.00	$1,512,000.00	
Ground side	TM rcvr development	1	$100,000.00	$100,000.00	
Ground side	TM signal simulator/modulator	6	$85,000.00	$510,000.00	
Airborne side	Airborne xmtrs	40	$21,000.00	$840,000.00	
Airborne side	Filters, cabling, connectors, splitters, diplexers, antennae	40	$22,000.00	$880,000.00	
Ground side	Update/additional spectrum monitoring/direction finding system	1	$1,124,000.00	$1,124,000.00	
Ground side	Monitoring/direction finding system site development and installation	1	$910,000.00	$910,000.00	
Ground side	Spectrum monitoring; ops & maintenance (20 year sustainment)	1	$3,800,000.00	$3,800,000.00	
Ground and air	Uplink ops & maintenance (20 year sustainment)	1	$890,000.00	$890,000.00	
Ground and air	Planning, engineering, installation, training, and system certification	1	$866,000.00	$866,000.00	$11,657,000.00
Grand Total					**$27,315,000.00**
Grand Total with Inflation for +1 Year (3%)					**$28,134,450.00**
Grand Total with Inflation for +2 Year (3%)					**$28,978,483.50**
Grand Total with Inflation for +3 Year (3%)					**$29,847,838.01**
Grand Total with Inflation for +4 Year (3%)					**$30,743,273.15**

Dryden's initial estimate had zero spectrum mgt cost as they had considered solely the costs to alter the RF gear performing the function of the RFA. The first three items were added due to the extremely heavy spectrum use at EAFB and the need to be able to more completely monitor usage and respond in timely fashion to RFI/EMI events. The first item is obvious: more/better hardware. The second item addresses improving the site for the monitoring gear (rack mounting, power, A/C, internet connectivity, RF cabling, antennae installation, etc.) and completing and certifying the installation. The third item covers operating and maintaining the spectrum monitoring gear for the 20 years following the transition (the period suggested by the DoD brief).

The fourth item includes the operations and maintenance costs associated with the RF gear itself (in this case, the uplink section) for the 20 year period following the transition.

EXHIBIT 6 - Dryden Flight Research Center (DFRC)

CURRENT RF ASSIGNMENTS

TIME LINE (1 of 3)

Spectrum Relocation Timeline

DFRC (uplink relo to S band)

NASA900149, NASA990018

DFRC

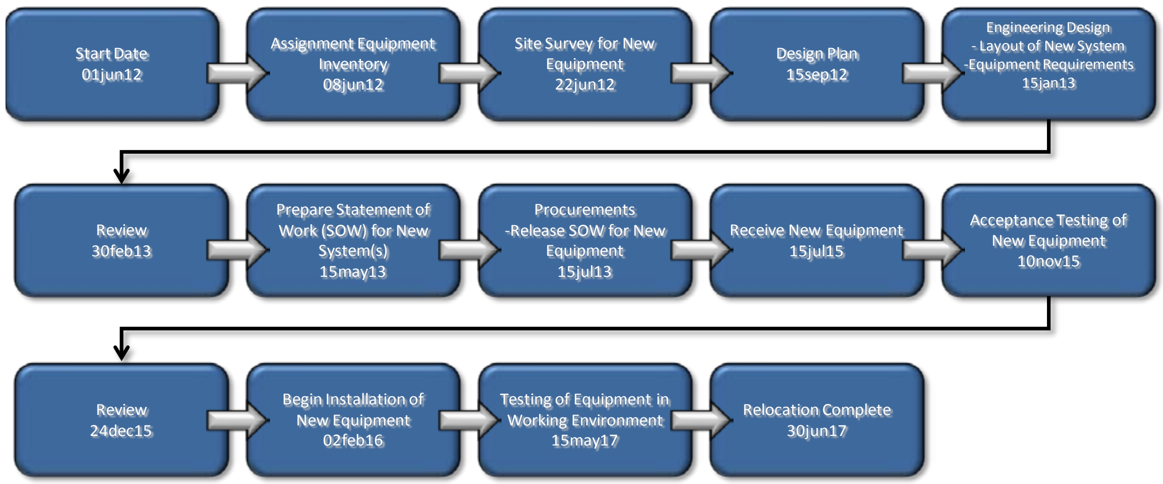


EXHIBIT 6 (cont.) - Dryden Flight Research Center (DFRC)

CURRENT RF ASSIGNMENTS

TIME LINE (2 of 3)

Spectrum Relocation Timeline
DFRC (uplink relo to C band)
NASA900149, NASA990018
DFRC

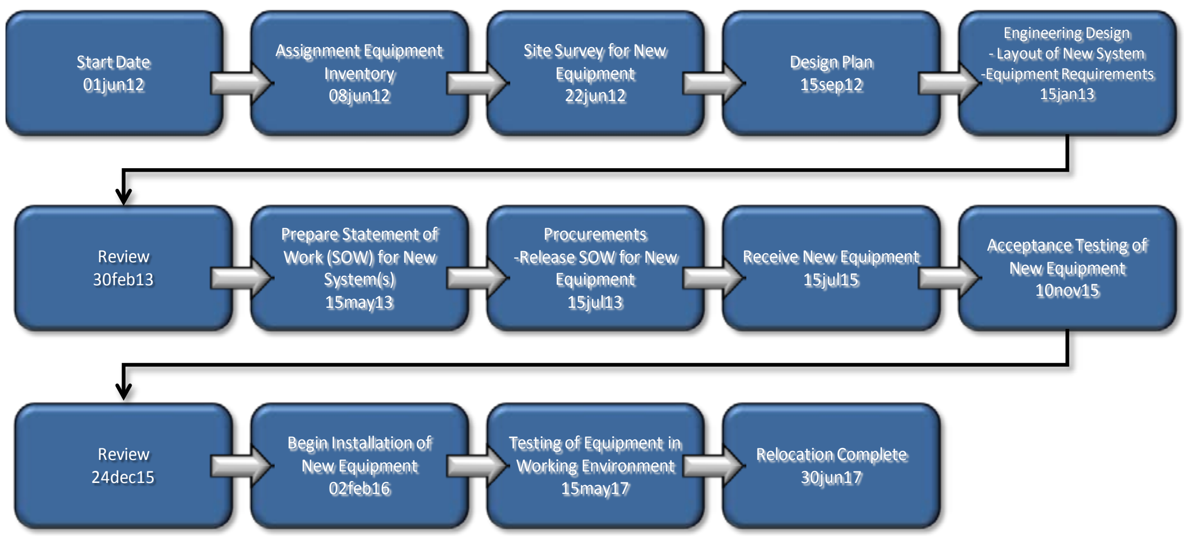
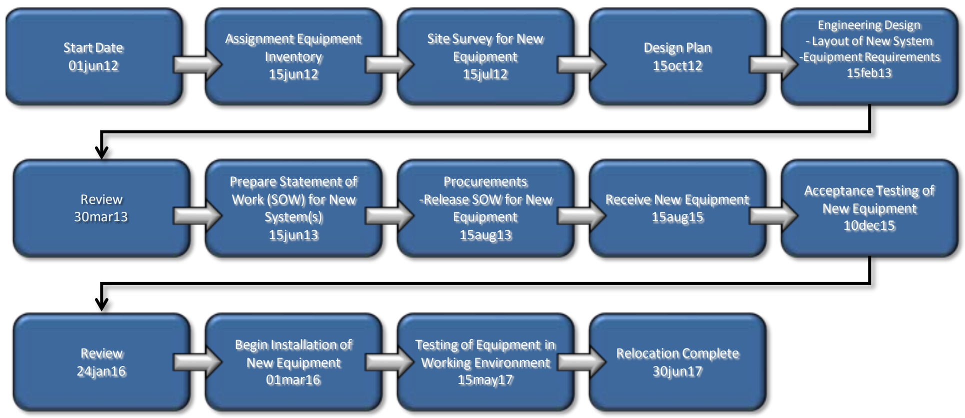


EXHIBIT 6 (cont.) - Dryden Flight Research Center (DFRC)

CURRENT RF ASSIGNMENTS

TIME LINE (3 of 3)

Spectrum Relocation Timeline
DFRC (aero TM relo to C band)
NASA940205
DFRC



III. Relocation of Other Agencies and Departments to NASA Bands

III.A. 2025-2110 MHz Band

III.A.1. Relocation of DoD SGLS/Satellite TT&C Operations into 2025-2110 MHz Band

III.A.1.a. Background

As a result of the Broadband relocation efforts, the DoD has indicated that it intends to use Unified S-band (USB, 2025-2110 MHz band) for uplinks to future DoD spacecraft. NASA has a large number of Tracking and Data Relay Satellite (TDRS) forward link users that receive commands from TDRS in the 2025-2110 MHz band. This analysis summarizes the interference results from DoD uplinks into NASA TDRS forward links based on the latest information provided by DoD.

III.A.1.b. DoD Uplink Parameters

USB uplink characteristics used in this analysis are based on the latest information provided by DoD in response to Action Item 2011Mar/01 from the most recent NASA/DoD/DoC pre-coordination meeting in March 2011. These characteristics are summarized as follows:

- DoD earth station transmitted nominal power is 1325W for all stations;
- DoD uplink antenna gain is 46.43 dBi for all stations and are assumed to use a pattern provided by DoD shown in Figure 3a below. The simulations use an envelope of this pattern which is shown in Figure 3b below;
- Potential interference is modeled from 7 AFSCN (Air Force Satellite Control Network) ARTS (Automated Remote Tracking Station) earth stations for the LEO case and 6 AFSCN ARTS earth stations for the GEO case;
- It is assumed that each DoD earth station uplink may transmit to either a low Earth orbit (LEO) or geostationary (GEO) DoD satellite, with parameters shown in Table 1;
- Each DoD earth station transmits to only a single DoD satellite at any given time;
- DoD uplinks to LEOs operate with 70% duty cycle during an orbital pass;
- DoD uplinks to GEOs will generally operate with a 5.6% duty cycle (80 minutes/day).

Figure 3a. DoD Provided SGLS Antenna pattern

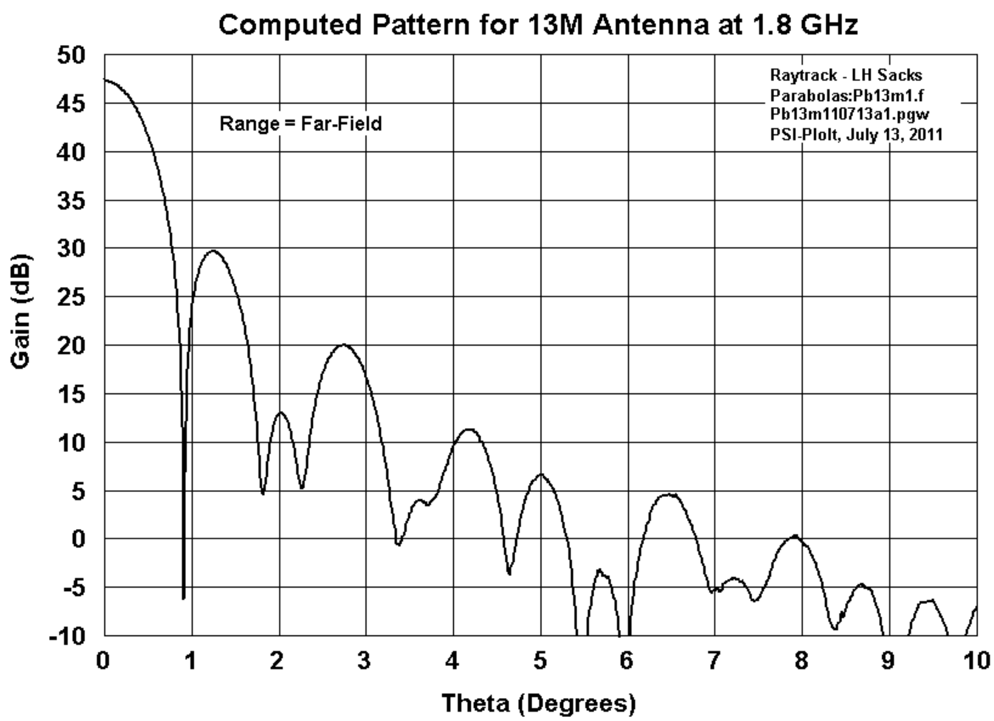


Figure 3b. Envelope of DoD SGLS Antenna pattern

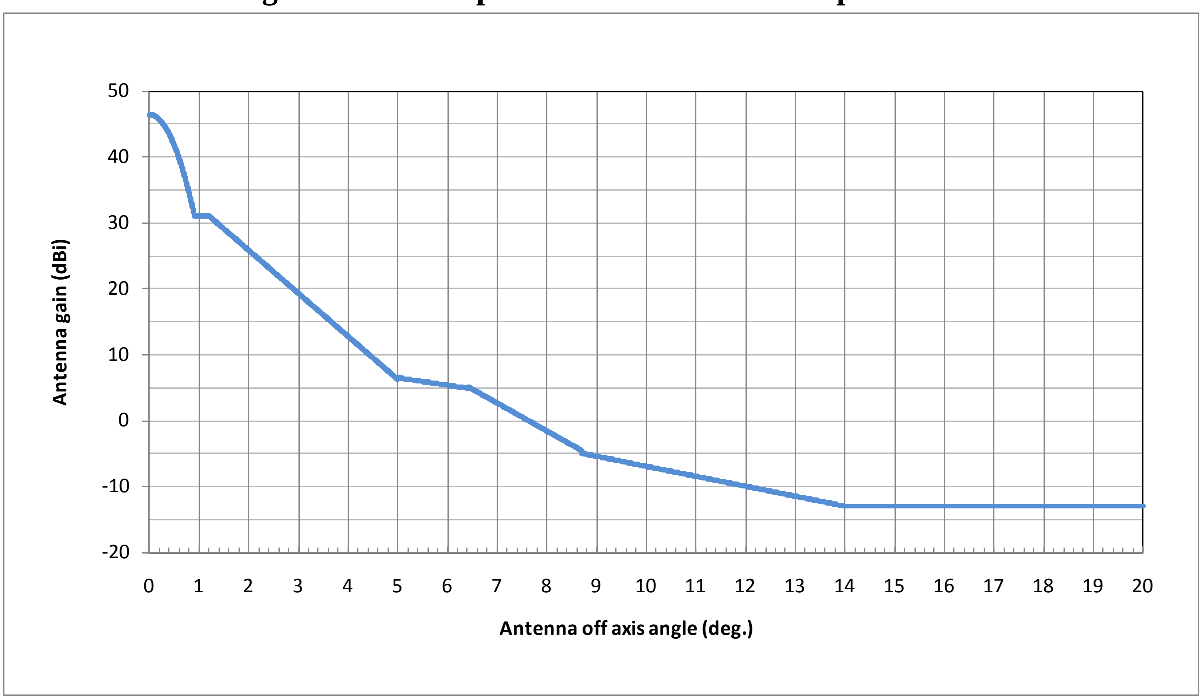


Table 1. Key Uplink Parameters

Transmit Earth Station					Receive Spacecraft			
Name	Lat. (deg.)	Long. (deg.)	Power (W)	Ant. Gain (dBi)	Orbit Type	Long. (deg.)	Alt. (km)	Inc. (deg.)
Vandenburg, CA	34.82	-120.5	1325	46.43	LEO	n/a	800	98.7
Diego Garcia	-7.27	72.37	1325	46.43	LEO	n/a	800	98.7
Oakhangar, England	51.12	0.91	1325	46.43	LEO	n/a	800	98.7
Guam	13.62	144.86	1325	46.43	LEO	n/a	800	98.7
New Boston, NH	42.94	-72.37	1325	46.43	LEO	n/a	800	98.7
Thule, Greenland	76.52	-69.4	1325	46.43	LEO	n/a	800	98.7
Hawaii	21.56	-159.8	1325	46.43	LEO	n/a	800	98.7
Vandenburg, CA	34.82	-120.5	1325	46.43	GEO	-105	35786	0
Diego Garcia	-7.27	72.37	1325	46.43	GEO	50	35786	0
Oakhangar, England	51.12	0.91	1325	46.43	GEO	-23	35786	0
Guam	13.62	144.86	1325	46.43	GEO	180	35786	0
New Boston, NH	42.94	-72.37	1325	46.43	GEO	-105	35786	0
Hawaii	21.56	-159.8	1325	46.43	GEO	180	35786	0

II.A.1.c. NASA TDRS Forward Link Parameters

NASA has a number of S-band Single Access Forward (SSAF) and Multiple Access Forward (MAF) users as illustrated in Figure 4 and Table 2.

Figure 4. SSAF (Yellow) and MAF (blue) users

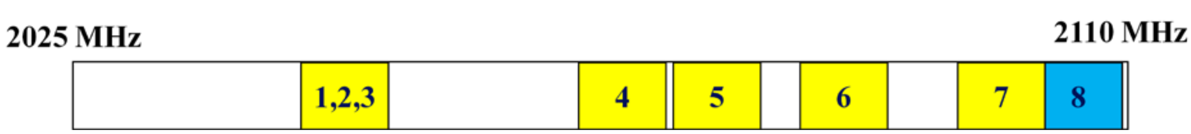


Table 2. SSAF and MAF TDRS users

	System	Center Frequency (MHz)	Bandwidth (MHz)	Date of Bring to Use	Service Type
1	SpaceX - Dragon	2040.5675	6.16	2011/05	SSA
2	Cygnus	2040.5675	6.16	2011/10	SSA
3	CONNECT	2041.0271	6.16	2011/07	SSA
4	WISE	2070.4938	6.16	IN ORBIT	SSA
5	TRMM	2076.9396	6.16	IN ORBIT	SSA

6	ISS	2085.6875	6.16	IN ORBIT	SSA
7	MMS	2101.2496	6.16	2014/10	SSA
8	AQUA	2106.4063	6.16	IN ORBIT	MA
8	ATV (ESA)	2106.4063	6.16	2007/05	MA
8	AURA	2106.4063	6.16	IN ORBIT	MA
8	C/NOFS	2106.4063	6.16	TBD	MA
8	CONNECT	2106.4063	6.16	2011/07	MA
8	GLAST	2106.4063	6.16	IN ORBIT	MA
8	GP-B	2106.4063	6.16	IN ORBIT	MA
8	GPM	2106.4063	6.16	2013/07	MA
8	HST	2106.4063	6.16	IN ORBIT	MA
8	HTV (JAXA)	2106.4063	6.16	2009/07	MA
8	LANDSAT-7 (NOAA)	2106.4063	6.16	IN ORBIT	MA
8	SWIFT	2106.4063	6.16	IN ORBIT	MA
8	TERRA	2106.4063	6.16	IN ORBIT	MA
8	RXTE	2106.4063	6.16	IN ORBIT	MA

Three TDRS transmitting locations were modeled (41W, 174W, 85E) with several SSAF and MAF user satellites as receivers. Table 3 summarizes the NASA forward link victim parameters used in this analysis.

Table 3. NASA SSAF and MAF System Parameters

Transmit TDRS Long. (deg.)	Receive Spacecraft						
	Name	BW (MHz)	Center Frequency (MHz)	Alt. (km)	Inc. (deg.)	Ant. Gain (dBi)	Ant. Temp (K)
174 W	AURA Forward Link	6.16	2106.406	705	98.2	7.0	240
174 W	CONNECT -HGA	6.16	2041.027	400	51.6	12.0	600
174 W	Cygnus	6.16	2040.568	460	51.6	1.6	1849
174 W	GPM Forward Link	6.16	2106.406	407	65.0	23.0	226
174 W	ISS -HGA	6.16	2085.688	400	51.6	12.9	589
174 W	MMS Forward Link	6.16	2101.250	35700	28.0	4.0	1023
174 W	Swift Forward Link	6.16	2106.406	600	22.0	3.5	139
174 W	Terra Forward Link	6.16	2106.406	705	98.2	25.8	410
174 W	TRMM -HGA	6.16	2076.940	403	35.0	23.0	513
174 W	WISE	6.16	2070.490	500	97.3	6.0	437
41 W	AURA Forward Link	6.16	2106.406	705	98.2	7.0	240
41 W	CONNECT -HGA	6.16	2041.027	400	51.6	12.0	600
41 W	Cygnus	6.16	2040.568	460	51.6	1.6	1849

41 W	GPM Forward Link	6.16	2106.406	407	65.0	23.0	226
41 W	ISS -HGA	6.16	2085.688	400	51.6	12.9	589
41 W	MMS Forward Link	6.16	2101.250	35700	28.0	4.0	1023
41 W	Swift Forward Link	6.16	2106.406	600	22.0	3.5	139
41 W	Terra Forward Link	6.16	2106.406	705	98.2	25.8	410
41 W	TRMM -HGA	6.16	2076.940	403	35.0	23.0	513
41 W	WISE	6.16	2070.490	500	97.3	6.0	437
85 E	AURA Forward Link	6.16	2106.406	705	98.2	7.0	240
85 E	CONNECT -HGA	6.16	2041.027	400	51.6	12.0	600
85 E	Cygnus	6.16	2040.568	460	51.6	1.6	1849
85 E	GPM Forward Link	6.16	2106.406	407	65.0	23.0	226
85 E	ISS -HGA	6.16	2085.688	400	51.6	12.9	589
85 E	MMS Forward Link	6.16	2101.250	35700	28.0	4.0	1023
85 E	Swift Forward Link	6.16	2106.406	600	22.0	3.5	139
85 E	Terra Forward Link	6.16	2106.406	705	98.2	25.8	410
85 E	TRMM -HGA	6.16	2076.940	403	35.0	23.0	513
85 E	WISE	6.16	2070.490	500	97.3	6.0	437

III.A.1.d. Interference Criteria

Note that ITU-R SA.1155 which applies to protection of Data Relay Satellite (DRS) forward links states that the received interference level from all sources should not exceed a threshold of Io/No = -10 dB for more than 0.1% of the time which corresponds to a link margin degradation of 0.4 dB.

III.A.1.e. Simulation Approach

Simulations were used to calculate long-term interference statistics to the NASA forward links. Each simulation was run for 30,000 samples points. The simulation included:

- Interferer: orbit simulation of a typical DoD polar LEO orbit at 800 km altitude and 98.7 degree inclination or example GEO orbits;
- Victim: orbit simulation of the TDRS (GEO) and TDRS user spacecraft (LEO).
- In order to account for DoD LEO (70%) and GEO (5.6%) duty cycles, at each time step each DoD interfering uplink earth station has a 70% or 5.6% probability (as appropriate) of transmitting. These probabilities are generated independently at each time step and for each uplink.

Results were obtained for single earth station interference cases.

III.A.1.f. Assumptions

All DoD uplink interferers transmit only when the receiving DoD satellite is in view of the transmitting DoD earth station and above 3 degrees elevation. One uplink signal from each of the corresponding DoD USB earth stations is communicating with either a LEO or a GEO satellite. Also, a NASA TDRS satellite transmits only when its respective user satellite is in view.

- Single earth station case:
    - Calculate interference separately from each of the corresponding USB earth stations and provide the results;
    - Assumes DoD and NASA systems operate co-frequency;
    - Assumes all DoD emission power falls within the NASA victim receiver bandwidth.

III.A.1.g. Results

A. Interference from LEO with 70% duty cycle

The results of the interference simulations for the case of DoD uplinks to LEO spacecraft are summarized in Table 4. The cases where the interference criterion is exceeded are highlighted.

Table 4. Interference Results from LEO with 70% duty cycle

		LEO Interferers (Io/No @ probability = 0.1%), 70% duty cycle						
User Satellite	**Tx GEO Location**	**Vandenburg, CA**	**Diego Garcia**	**Oakhangar, UK**	**Guam**	**New Boston, NH**	**Thule, Greenland**	**Hawaii**
AURA Forward Link	174 W	<-100	<-100	<-100	<-100	-27.0	-2.0	<-100
CONNECT -HGA	174 W	-17.0	<-100	<-100	-34.0	-43.5	<-100	-26.3
Cygnus	174 W	-17.7	<-100	<-100	<-100	-29.7	<-100	-23.0
GPM Forward Link	174 W	-10.0	<-100	<-100	<-100	-9.0	-8.0	<-100
ISS HGA	174 W	-16.0	<-100	<-100	-34.0	-43.5	<-100	-26.3
MMS Forward Link	174 W	-33.0	-30.6	-31.1	-33.0	-30.6	-30.1	-35.6
Swift Forward Link	174 W	-13.3	<-100	<-100	-7.2	<-100	<-100	-14.6
Terra Forward Link	174 W	<-100	<-100	<-100	<-100	-14.4	-4.4	<-100
TRMM -HGA	174 W	-10.3	<-100	<-100	-11.5	-13.9	<-100	-11.0
WISE	174 W	<-100	<-100	<-100	<-100	-28.0	-4.2	<-100
AURA Forward Link	41 W	-22.0	<-100	-12.2	<-100	-17.0	-2.9	<-100
CONNECT -HGA	41 W	-15.0	<-100	-23.0	<-100	-14.3	<-100	<-100
Cygnus	41 W	-18.7	<-100	-24.5	<-100	-16.2	<-100	<-100
GPM Forward Link	41 W	-9.5	<-100	-7.2	<-100	-9.3	-7.6	<-100
ISS HGA	41 W	-14.9	<-100	-23.0	<-100	-14.3	<-100	<-100
MMS Forward Link	41 W	-30.5	-31.8	-34.1	-32.9	-34.6	-33.3	-29.8
Swift Forward Link	41 W	-12.0	-24.0	<-100	<-100	<-100	<-100	<-100
Terra Forward Link	41 W	-14.4	<-100	-11.6	<-100	-14.0	-4.0	<-100

TRMM -HGA	41 W	-7.8	<-100	<-100	<-100	-10.8	<-100	<-100
WISE	41 W	<-100	<-100	-18.4	<-100	-13.5	-3.1	<-100
AURA Forward Link	85 E	<-100	<-100	-12.5	<-100	<-100	-6.5	<-100
CONNECT -HGA	85 E	<-100	<-100	-14.0	-22.0	<-100	<-100	<-100
Cygnus	85 E	<-100	-23.0	-19.4	-40.0	<-100	<-100	<-100
GPM Forward Link	85 E	<-100	<-100	-6.4	<-100	<-100	<-100	<-100
ISS HGA	85 E	<-100	<-100	-14.0	-22.0	<-100	<-100	<-100
MMS Forward Link	85 E	-32.2	-33.4	-30.8	-30.4	-31.8	-29.9	-32.0
Swift Forward Link	85 E	<-100	-9.6	<-100	-5.6	<-100	<-100	<-100
Terra Forward Link	85 E	<-100	<-100	-12.5	<-100	<-100	-5.0	<-100
TRMM -HGA	85 E	<-100	-12.7	<-100	-12.5	<-100	<-100	<-100
WISE	85 E	<-100	<-100	-14.5	<-100	<-100	-11.7	<-100

B. Interference from GEO with 5.6% duty cycle

The results for DoD uplinks to GEO spacecraft operating at the assumed 5.6% duty cycle are summarized in Table 5. The cases where the interference criterion is exceeded are highlighted.

Table 5. Interference results from GEO with 5.6% duty Cycle

		GEO Interferers (Io/No @ probability = 0.1%), 5.6% duty cycle					
User Satellite	**Tx GEO Location**	**Vandenburg, CA**	**Diego Garcia**	**Oakhangar, UK**	**Guam**	**New Boston, NH**	**Hawaii**
AURA Forward Link	174 W	-12.5	<-100	<-100	-12.4	-16.0	-14.4
CONNECT -HGA	174 W	-11.7	<-100	<-100	-14.9	-22.0	-15.2
Cygnus	174 W	-15.5	<-100	<-100	-17.7	-24.0	-18.7
GPM Forward Link	174 W	-5.7	<-100	<-100	-6.8	-7.1	-7.3
ISS HGA	174 W	-11.7	<-100	<-100	-14.8	-22.0	-15.0
MMS Forward Link	174 W	-29.5	-25.0	-31.3	-30.0	-27.2	-31.8
Swift Forward Link	174 W	-9.7	-19.6	<-100	-4.3	<-100	-8.0
Terra Forward Link	174 W	-11.4	<-100	<-100	-11.8	-12.6	-11.9
TRMM -HGA	174 W	-6.8	<-100	<-100	-8.5	-12.2	-8.0
WISE	174 W	-13.5	<-100	<-100	-19.3	-23.0	-16.6
AURA Forward Link	41 W	-8.7	-25.7	-7.8	<-100	-10.6	-32.0
CONNECT -HGA	41 W	-9.7	<-100	-13.0	<-100	-10.3	<-100
Cygnus	41 W	-14.9	<-100	-16.0	<-100	-13.9	<-100
GPM Forward Link	41 W	-6.0	<-100	-6.1	<-100	-4.8	<-100
ISS HGA	41 W	-9.5	<-100	-12.7	<-100	-10.3	<-100
MMS Forward Link	41 W	-29.0	-27.1	-32.7	-30.6	-30.6	-25.4
Swift Forward Link	41 W	-7.9	-18.4	<-100	<-100	-29.0	-23.0
Terra Forward Link	41 W	-10.3	-14.8	-9.0	<-100	-11.3	-15.2
TRMM -HGA	41 W	-6.3	<-100	-13.9	<-100	-10.8	<-100
WISE	41 W	-11.5	<-100	-9.7	<-100	-13.2	<-100
AURA Forward Link	85 E	<-100	-15.5	-9.5	-13.0	<-100	<-100

CONNECT -HGA	85 E	<-100	-20.0	-11.7	-18.3	<-100	<-100
Cygnus	85 E	<-100	-18.8	-12.7	-17.1	<-100	<-100
GPM Forward Link	85 E	<-100	-6.9	-4.9	-7.7	<-100	<-100
ISS HGA	85 E	<-100	-19.0	-11.0	-18.3	<-100	<-100
MMS Forward Link	85 E	-31.8	-28.0	-28.0	-26.5	-31.1	-26.4
Swift Forward Link	85 E	<-100	-7.6	<-100	-2.7	<-100	-21.0
Terra Forward Link	85 E	<-100	-12.8	-9.5	-12.9	<-100	<-100
TRMM -HGA	85 E	<-100	-10.4	<-100	-7.8	<-100	<-100
WISE	85 E	<-100	-17.7	-9.8	-16.0	<-100	<-100

C. Results Summary

For the LEO case, in about 9% of the cases, aggregate interference levels exceed the recommended Io/No = -10 dB threshold value. For the GEO case, in about 17% of the cases, aggregate interference levels exceed the recommended Io/No = -10 dB threshold value.

The exceedance is no more than 8 dB. For the LEO case, the maximum level of interference of -2 dB occurs at Thule, Greenland for the Aura forward link from TDRS 174W. For the GEO case, the maximum level of interference of -2.7 dB occurs at Guam for the Swift forward link from TDRS 85E.

III.A.1.h. Recommendations

NASA recommends that DoD not select frequencies in the TDRS MAF Band (2103.3 – 2109.5 MHz) because of the large number of spacecraft that NASA supports over this channel (i.e., over a 6.2 MHz portion of the entire 2025-2110 MHz band). DoD has indicated that they will attempt to avoid assignments in the MAF band. However, they also stated that they will use it if required, and if so, this use will be coordinated with NASA via the DoD/NASA/NOAA frequency pre-coordination process and the FAS.

III.A.2. Relocation of DoD Terrestrial Operations into 2025-2110 MHz Band

III.A.2.a. Background

As a result of the Broadband relocation efforts, the DoD is considering relocating some or all of its current terrestrial operations in the 1755-1850 MHz band to the 2025-2110 MHz band. As stated previously, NASA supports a large number of TDRS forward link users in this band. Analysis results of interference from DoD terrestrial systems into NASA TDRS forward links based on the latest information provided by DoD (in August/September 2011) is given below.

III.A.2.b. DoD Terrestrial Parameters

The DoD characteristics used in this analysis are based on information provided by DoD to NASA in August/September 2011:

- DoD intends to move the following systems into the USB band:

- Air Combat Training Systems (ACTS) – see Table 6.
- Tactical Radio Relay (TRR) for the Army– see Table 7.
- Tactical Radio Relay (TRR) for the Navy– see Table 8.
- Tactical Radio Relay (TRR) for the U.S. Marine Corps only – see Table 9.
- Unmanned Airborne Systems (UAS) – see Table 10.

- For systems with antenna gain equal to 0 dBi, 0 dBi was used in all directions. For systems with antenna gain more than 0 dBi but less than or equal to 20.0 dBi, the antenna pattern used is based on Recommendation ITU-R F.1336. For systems with antenna gain greater than 20.0 dBi, the antenna pattern used is based on Recommendation ITU-R F.1245
- all simulated links operate with 50% duty cycle except UAS systems which operate with 25% duty cycle
- TX QTY "1+" indicates that 1 full emission and 1 partial emission should be simulated, based on the 4.68 MHz channel spacing per 6.16 MHz TDRS. Therefore the total power level is increased by 10*LOG(6.16/4.68)=1.19 dB, relative to the single entry power level.
- TX QTY "2+" indicates that 2 full emissions and 2 partial emissions should be simulated, based on the 4.68 MHz channel spacing per 6.16 MHz TDRS. Therefore the total power level is increased by 10*LOG(2*6.16/4.68)=4.19 dB, relative to the single entry power level.
- The interfering antennas' azimuth angle is randomly distributed between 0º and 360º and its elevation angle is 0º, except for TRR Army and TRR USMC systems where the elevation angle is randomly distributed between -5º and +5º.

Table 6. ACTS Transmitter Parameters

Location	State	Latitude (N)	Longitude (E)	Bandwidth (MHz)	Single Tx. Power (dBW)	Tx. Quantity	Total Tx. Power (dBW)	Ant. Gain (dBi)
Fallon NAS	NV	39.29	-116.45	1.5	20.0	1	20.0	0.0
Luke AFB	AZ	32.23	-113.02	1.5	20.0	1	20.0	0.0
Key West NAS	FL	24.55	-81.81	1.5	20.0	1	20.0	0.0
Langley AFB	VA	37.08	-76.35	1.5	20.0	1	20.0	0.0

Table 7. TRR ARMY Transmitter Parameters

Location	State	Latitude (N)	Longitude (E)	Bandwidth (MHz)	Single Tx. Power (dBW)	Tx. Quantity	Total Tx. Power (dBW)	Ant. Gain (dBi)
Aberdeen Proving Ground	MD	39.42	-76.17	2.0	-2.0	2	-5.0	24.8

Camp Atterbury	IN	39.30	-86.05	2.0	-2.0	2	-5.0	24.8
Camp Roberts	CA	35.78	-120.79	2.0	-2.0	2	-5.0	24.8
Camp Shleby	MS	31.14	-89.07	2.0	-2.0	2	-5.0	24.8
CP MABRY	TX	30.32	-97.77	2.0	-2.0	2	-5.0	24.8
Dugway Proving Grounds	UT	40.24	-113.05	2.0	-2.0	2	-5.0	24.8
England Industrial Park	LA	31.32	-92.54	2.0	-2.0	2	-5.0	24.8
Faribault	MN	44.30	-93.28	2.0	-2.0	2	-5.0	24.8
Ft AP Hill	VA	38.11	-77.29	2.0	-2.0	2	-5.0	24.8
Ft Benning	GA	32.34	-84.88	2.0	-2.0	2	-5.0	24.8
Ft Bliss	TX	31.94	106.25	2.0	-2.0	2	-5.0	24.8
Ft Bragg	NC	35.13	-78.82	2.0	-2.0	2	-5.0	24.8
Ft Campbell	KY	36.64	-87.49	2.0	-2.0	2	-5.0	24.8
Ft Carson	CO	38.63	-104.87	2.0	-2.0	2	-5.0	24.8
Ft Drum	NY	44.05	-75.73	2.0	-2.0	2	-5.0	24.8
Ft Eustis	VA	37.14	-76.60	2.0	-2.0	2	-5.0	24.8
Ft Gordon	GA	33.42	-82.15	2.0	-2.0	2	-5.0	24.8
Ft Greely	AK	63.98	-145.72	2.0	-2.0	2	-5.0	24.8
Ft Hood	TX	31.24	-97.75	2.0	-2.0	2	-5.0	24.8
Ft Huachuca	AZ	31.54	110.38	2.0	-2.0	2	-5.0	24.8
Ft Hunter Liggett	CA	35.95	-121.23	2.0	-2.0	2	-5.0	24.8
Ft Irwin	CA	35.37	-116.62	2.0	-2.0	2	-5.0	24.8
Ft Jackson	SC	33.93	-81.12	2.0	-2.0	2	-5.0	24.8
Ft Knox	KY	37.93	-85.84	2.0	-2.0	2	-5.0	24.8
Ft Leavenworth	KS	39.36	-94.95	2.0	-2.0	2	-5.0	24.8
Ft Lee	VA	40.85	-73.97	2.0	-2.0	2	-5.0	24.8
Ft Leonard Wood	MO	37.75	-92.13	2.0	-2.0	2	-5.0	24.8
Ft Lewis	WA	47.09	-122.59	2.0	-2.0	2	-5.0	24.8
Ft McCoy	WI	43.95	-90.73	2.0	-2.0	2	-5.0	24.8
Ft Meade	MD	39.11	-76.75	2.0	-2.0	2	-5.0	24.8
Ft Polk	LA	31.06	-93.21	2.0	-2.0	2	-5.0	24.8
Ft Richardson	AK	61.25	-149.70	2.0	-2.0	2	-5.0	24.8
Ft Riley	KS	38.97	-96.86	2.0	-2.0	2	-5.0	24.8
Ft Rucker	LA	31.39	-85.76	2.0	-2.0	2	-5.0	24.8
Ft Stewart	GA	31.88	-81.55	2.0	-2.0	2	-5.0	24.8
Huntington Beach	CA	33.75	-118.04	2.0	-2.0	2	-5.0	24.8
JRTC (Ft Polk North)	LA	31.36	-93.25	2.0	-2.0	2	-5.0	24.8
Kauai	HI	22.06	-159.61	2.0	-2.0	2	-5.0	24.8
Letterkenny	PA	40.00	-77.64	2.0	-2.0	2	-5.0	24.8
McGregor	NM	32.25	-106.20	2.0	-2.0	2	-5.0	24.8

Oahu	HI	21.50	-158.06	2.0	-2.0	2	-5.0	24.8
Pinon Canyon	CO	37.42	-103.90	2.0	-2.0	2	-5.0	24.8
Pohakuloa	HI	19.76	-155.54	2.0	-2.0	2	-5.0	24.8
PT Loma	CA	32.69	-117.27	2.0	-2.0	2	-5.0	24.8
Redstone Arsenal	AL	34.66	-86.66	2.0	-2.0	2	-5.0	24.8
Rosemount	MN	44.74	-93.13	2.0	-2.0	2	-5.0	24.8
St Joseph	MO	39.77	-94.79	2.0	-2.0	2	-5.0	24.8
Two Rivers	WI	44.15	-87.55	2.0	-2.0	2	-5.0	24.8
Vichy Airfield	MO	38.12	-91.77	2.0	-2.0	2	-5.0	24.8
Whitesands Missile Range	NM	33.00	-106.50	2.0	-2.0	2	-5.0	24.8
Yukon Range	AK	64.58	-146.72	2.0	-2.0	2	-5.0	24.8
Yuma Proving Grounds	AZ	32.87	-114.12	2.0	-2.0	2	-5.0	24.8

Table 8. TRR Navy Transmitter Parameters

Location	State	Latitude (N)	Longitude (E)	Bandwidth (MHz)	Single Tx. Power (dBW)	Tx. Quantity	Total Tx. Power (dBW)	Ant. Gain (dBi)
Apra Harbor	GUM	13.44	144.66	1.0	11.0	1	11.0	6.0
Charleston	SC	32.92	-79.97	1.0	11.0	1	11.0	6.0
Elizabeth City	NC	36.23	-76.13	1.0	11.0	1	11.0	6.0
Pearl Harbor	HI	21.37	-157.97	1.0	11.0	1	11.0	6.0
ST Juliens Creek	VA	36.85	-76.30	1.0	11.0	1	11.0	6.0

Table 9. TRR U.S. Marine Corp Transmitter Parameters

Location	State	Latitude (N)	Longitude (E)	Bandwidth (MHz)	Single Tx. Power (dBW)	Tx. Quantity	Total Tx. Power (dBW)	Ant. Gain (dBi)
Bogue Field	NC	34.69	-77.03	2.0	-2.0	2	-5.0	24.8
Bridgeport	CA	38.26	-119.09	2.0	-2.0	2	-5.0	24.8
Brooklyn	NY	40.58	-74.00	2.0	-2.0	2	-5.0	24.8
Cincinnati	OH	39.14	-84.48	2.0	-2.0	2	-5.0	24.8
CP Lejeune	NC	34.64	-77.39	2.0	-2.0	2	-5.0	24.8
CP Pendleton	CA	33.38	-117.43	2.0	-2.0	2	-5.0	24.8
Fox Lake	IL	42.40	-88.19	2.0	-2.0	2	-5.0	24.8
Great Lakes	IL	42.35	-87.86	2.0	-2.0	2	-5.0	24.8
Greensboro	NC	36.09	-79.97	2.0	-2.0	2	-5.0	24.8

Grissom	IN	40.66	-86.16	2.0	-2.0	2	-5.0	24.8
Hawthorne	NV	38.54	-118.63	2.0	-2.0	2	-5.0	24.8
Kaneohe	HI	21.45	-157.75	2.0	-2.0	2	-5.0	24.8
Mcas Yuma	AZ	32.48	-114.48	2.0	-2.0	2	-5.0	24.8
Miramar	CA	32.88	-117.13	2.0	-2.0	2	-5.0	24.8
Quantico	VA	38.52	-77.32	2.0	-2.0	2	-5.0	24.8
Sand Ridge	IL	39.75	-89.30	2.0	-2.0	2	-5.0	24.8
Twentynine Palms	CA	34.31	-116.18	2.0	-2.0	2	-5.0	24.8

Table 10. UAS Transmitter Parameters

Location	State	Latitude (N)	Longitude (E)	Bandwidth (MHz)	Single Tx. Power (dBW)	Tx. Quantity	Total Tx. Power (dBW)	Ant. Gain (dBi)
Aberdeen Proving Ground	MD	39.42	-76.17	4.7	1.8	1+	3.0	2.0
Bend	OR	44.05	-121.32	4.7	1.8	1+	3.0	2.0
Boardman Range	OR	45.73	-119.68	4.7	1.8	1+	3.0	2.0
Brookville	KS	38.69	-97.82	4.7	1.8	1+	3.0	2.0
Camp Claiborne	LA	31.15	-92.60	4.7	1.8	1+	3.0	2.0
Camp Ripley	MI	46.20	-94.42	4.7	1.8	1+	3.0	2.0
Camp Roberts	CA	35.78	-120.79	4.7	1.8	1+	3.0	2.0
CP Atterbury	IN	39.36	-86.02	4.7	1.8	1+	3.0	2.0
CP Blanding	FL	29.93	-81.98	4.7	1.8	1+	3.0	2.0
CP Grayling	MI	44.77	-84.57	4.7	1.8	1+	3.0	2.0
CP Gruber	OK	35.65	-95.21	4.7	1.8	1+	3.0	2.0
CP Guernsey	WY	42.26	-104.73	4.7	1.8	1+	3.0	2.0
CP Rilea	OR	46.12	-123.93	4.7	1.8	1+	3.0	2.0
CP Shelby	MS	31.16	-89.17	4.7	1.8	1+	3.0	2.0
Dugway PG	UT	40.18	-112.93	4.7	1.8	1+	3.0	2.0
Fort McClellan	AL	33.66	-85.97	4.7	1.8	1+	3.0	2.0
Ft AP Hill	VA	38.11	-77.29	4.7	1.8	1+	3.0	2.0
FT Benning	GA	32.33	-84.99	4.7	1.8	1+	3.0	2.0
FT Bliss	TX	31.86	-106.36	4.7	1.8	1+	3.0	2.0
FT Bragg	NC	35.13	-79.01	4.7	1.8	1+	3.0	2.0
Ft Campbell	KY	36.67	-87.50	4.7	1.8	1+	3.0	2.0
FT Carson	CO	38.68	-104.79	4.7	1.8	1+	3.0	2.0
Ft Chaffee	AR	35.27	-94.19	4.7	1.8	1+	3.0	2.0
FT Drum	NY	44.03	-75.73	4.7	1.8	1+	3.0	2.0
Ft Eustis	VA	37.14	-76.60	4.7	1.8	1+	3.0	2.0

Ft Gillem	GA	33.61	-84.37	4.7	1.8	1+	3.0	2.0
Ft Gordon	GA	33.35	-82.25	4.7	1.8	1+	3.0	2.0
Ft Greely	AK	63.85	-145.77	4.7	1.8	1+	3.0	2.0
FT Hood	TX	31.13	-97.70	4.7	1.8	1+	3.0	2.0
Ft Huachuca	AZ	31.54	-110.38	4.7	1.8	1+	3.0	2.0
FT Indiantown Gap	PA	40.41	-76.68	4.7	1.8	1+	3.0	2.0
Ft Irwin (NTC)	CA	35.37	-116.62	4.7	1.8	2+	6.0	2.0
Ft Knox	KY	37.93	-85.84	4.7	1.8	1+	3.0	2.0
FT Knox	KY	37.88	-85.93	4.7	1.8	1+	3.0	2.0
Ft Leavenworth	KS	39.36	-94.95	4.7	1.8	1+	3.0	2.0
Ft Lee	VA	40.85	-73.97	4.7	1.8	1+	3.0	2.0
FT Leonard Wood	MO	37.74	-92.15	4.7	1.8	1+	3.0	2.0
FT Lewis	WA	46.84	-122.76	4.7	1.8	1+	3.0	2.0
FT Mccoy	WI	44.02	-90.98	4.7	1.8	1+	3.0	2.0
Ft Meade	MD	39.11	-76.75	4.7	1.8	1+	3.0	2.0
FT Pickett	VA	37.10	-77.88	4.7	1.8	1+	3.0	2.0
FT Polk - JRTC	LA	31.35	-93.17	4.7	1.8	2+	6.0	2.0
FT Riley	KS	39.05	-96.77	4.7	1.8	1+	3.0	2.0
FT Rucker	AL	31.32	-85.70	4.7	1.8	1+	3.0	2.0
FT Sill	OK	34.66	-98.42	4.7	1.8	1+	3.0	2.0
FT Stewart	GA	31.85	-81.60	4.7	1.8	1+	3.0	2.0
MCGregor	NM	32.09	-106.08	4.7	1.8	1+	3.0	2.0
Muldrow Field	OK	35.03	-97.23	4.7	1.8	1+	3.0	2.0
Patuxent River (Webster Field)	MD	38.15	-76.43	4.7	1.8	2+	6.0	2.0
Pinon Canyon	CO	37.54	-103.91	4.7	1.8	1+	3.0	2.0
Pohakuloa	HI	19.73	-155.60	4.7	1.8	1+	3.0	2.0
Ravenna	OH	41.20	-81.09	4.7	1.8	1+	3.0	2.0
Redstone Arsenal	AL	34.65	-86.71	4.7	1.8	1+	3.0	2.0
Schofield Barracks	HI	21.53	-158.15	4.7	1.8	1+	3.0	2.0
Simi Valley	CA	34.28	-118.72	4.7	1.8	1+	3.0	2.0
Smokey Hill	KS	38.75	-97.76	4.7	1.8	1+	3.0	2.0
Taft	CA	35.13	-119.40	4.7	1.8	1+	3.0	2.0
Warren Grove Range	NJ	39.75	-74.38	4.7	1.8	1+	3.0	2.0
Whitesands Missile Range	NM	32.43	-106.18	4.7	1.8	2+	6.0	2.0
Yakima	WA	46.66	-120.46	4.7	1.8	1+	3.0	2.0
Yuma Proving Grounds	AZ	32.87	-114.12	4.7	1.8	1+	3.0	2.0
Atlantic Field	NC	34.89	-76.35	4.7	1.8	1+	3.0	2.0
Dam Neck	VA	36.73	-75.95	4.7	1.8	1+	3.0	2.0

Fallon	NV	39.23	-118.15	4.7	1.8	1+	3.0	2.0
Mayport	FL	30.39	-81.42	4.7	1.8	1+	3.0	2.0
SAN Clemente IS	CA	32.92	-118.49	4.7	1.8	1+	3.0	2.0
SAN Nicolas IS	CA	33.24	-119.50	4.7	1.8	1+	3.0	2.0
Stennis	MS	30.37	-89.60	4.7	1.8	1+	3.0	2.0
Albert Whitted	FL	27.77	-82.63	4.7	1.8	1+	3.0	2.0
Avon Park	FL	27.60	-81.51	4.7	1.8	1+	3.0	2.0
Camp Edwards	MA	41.69	-70.53	4.7	1.8	1+	3.0	2.0
CP Rilea	OR	46.12	-123.93	4.7	1.8	1+	3.0	2.0
Edwards	CA	34.92	-117.92	4.7	1.8	1+	3.0	2.0
Eglin	FL	30.49	-86.51	4.7	1.8	1+	3.0	2.0
Fort Carson	CO	38.44	-104.89	4.7	1.8	1+	3.0	2.0
FT Pickett	VA	37.07	-77.96	4.7	1.8	1+	3.0	2.0
Hancock Field	NY	43.12	-76.12	4.7	1.8	1+	3.0	2.0
Hanscom	MA	42.46	-71.27	4.7	1.8	1+	3.0	2.0
Point Bravo	NV	36.54	-115.57	4.7	1.8	1+	3.0	2.0
Smokey Hill	KS	38.70	-97.85	4.7	1.8	1+	3.0	2.0
South Ranges	NV	36.56	-115.43	4.7	1.8	1+	3.0	2.0
USAF Academy	CO	39.03	-104.84	4.7	1.8	1+	3.0	2.0
UT Test Training Range	UT	40.00	-113.50	4.7	1.8	1+	3.0	2.0
Vandenberg	CA	34.73	-120.58	4.7	1.8	1+	3.0	2.0
Whitesands Missile Range	NM	32.97	-106.40	4.7	1.8	1+	3.0	2.0
Bellows	HI	21.36	-157.75	4.7	1.8	1+	3.0	2.0
Bridgeport	CA	38.40	-119.52	4.7	1.8	1+	3.0	2.0
CP Lejeune	NC	34.59	-77.33	4.7	1.8	1+	3.0	2.0
CP Pendleton	CA	33.39	-117.35	4.7	1.8	1+	3.0	2.0
Quantico	VA	38.56	-77.49	4.7	1.8	1+	3.0	2.0
Stoval	AZ	32.73	-113.63	4.7	1.8	1+	3.0	2.0
Twentynine Palms	CA	34.44	-116.12	4.7	1.8	1+	3.0	2.0

III.A.2.c. NASA TDRS Forward Link Parameters

For this analysis the sample TDRS Forward links listed in Table 11 were used.

Table 11. NASA Forward Link Parameters

Transmit TDRS Long. (deg.)	Receive Spacecraft						
	Name	Bandwidth (MHz)	Alt. (km)	Inc. (deg.)	Ecc.	Ant. Gain. (dBi)	Ant. Temp. (K)
174 W	GPM	6.16	407	65.0	0.000	23.0	226.0

41 W	GPM	6.16	407	65.0	0.000	23.0	226.0
174 W	ISS	6.16	400	51.6	0.000	12.9	589.0
41 W	ISS	6.16	400	51.6	0.000	12.9	589.0

III.A.2.d. Interference Criteria

Note that ITU-R SA.1155 which applies to protection of Data Relay Satellite (DRS) forward links states that the received interference level from all sources should not exceed a threshold of Io/No = -10 dB for more than 0.1% of the time which corresponds to a link margin degradation of 0.4 dB.

III.A.2.e. Simulation Approach

Simulations were used to calculate long-term interference statistics to the NASA forward links. Each simulation was run for 30,000 sample points (time step = 86.4 seconds) for a period of 1 month.

Results were obtained for aggregate ACTS, TRR Army, TRR Navy, TRR U.S. Marine Corps, UAS interference cases separately and finally the aggregate of all these systems combined.

III.A.2.f. Assumptions

1. DoD and NASA systems operate co-frequency.
2. All DoD emission power falls within the NASA victim receiver bandwidth.
3. Transmitter (linear) to Receiver (elliptical) polarization mismatch is 2 dBi.
4. DoD transmit system passive loss (line loss between transmitter and antenna) is 2 dBi.
5. NASA receive system passive loss (line loss between antenna and LNA) is 2 dBi.
6. NASA TDRS victim user receive antenna pattern is based on ITU-R F.672 Annex 1 with Ls = -25 dB side-lobe level and beamwidth = 12° (for GPM) and 38° (for ISS)
7. NASA TDRS victim user receive interference and corresponding statistics are calculated at all times during the period of simulation for which the user satellite is visible to TDRS. Interference exceedance percentages are based on all 30,000 time samples in this simulation.

III.A.2.g. Results

A. Interference Results

The results of the interference simulations from the aggregate of all DoD systems, ACTS, TRR Navy, TRR USMC, and UAS are summarized in Table 12. It is assumed that all DoD systems except UAS operate at 50% duty cycle while UAS operates at 25% duty cycle. Cases where the interference criterion is exceeded are highlighted in Table 12.

Table 12. Interference Results from DoD Terrestrial Systems

User Satellite	Transmitter Name	Io/No (dB) @ probability = 0.1%					
		Aggregate	ACTS	TRR ARMY	TRR NAVY	TRR USMC	UAS
GPM	174 W	-0.80	-1.20	-11.30	-10.0	-13.70	-9.30
GPM	41 W	-0.90	-1.20	-12.50	-10.1	-14.10	-12.80
ISS	174 W	-4.40	-4.80	-15.80	-14.1	-17.40	-16.70
ISS	41 W	-3.90	-3.90	-11.30	-14.3	-16.20	-15.00

B. Results Summary

Aggregate interference levels (from all DoD systems combined) exceed the ITU criteria by as much as 9.2 dB [i.e.-0.8 – (-10)].

Aggregate interference from DoD ACTS systems exceeds the threshold criteria by as much as 8.8 dB [-1.2 – (-10)]. Note that ACTS is the dominant contributor to the overall interference.

Aggregate interference from DoD TRR Army systems satisfies the criteria.

Aggregate interference from DoD TRR Navy systems satisfies the criteria.

Aggregate interference from DoD TRR USMC systems satisfies the criteria.

Aggregate interference from DoD UAS systems essentially satisfies the criteria.

III.A.2.h. Recommendations

Based on the specific parameters and assumptions stated in Sections III.A.2.b-III.A.2.f above, the analysis indicates that relocation of DoD TRR (Army,Navy,USMC) and UAS systems (but not ACTS in its current form) into the 2025-2110 MHz band is feasible. It must be emphasized, however, that this conclusion is based on the assumption that the transmit characteristics (transmit power, antenna gain, bandwidth) and deployment characteristics (number of co-channel emitters, locations, duty cycles) of the DoD TRR/UAS systems moving into the band are consistent with those indicated in Tables 7-10. This conclusion does not hold if there is significant deviation from these characteristics that causes an increase in interference.

With regard to ACTS, based on the characteristics we have on these systems from DoD (which represent current 1755-1850 MHz operation), the interference from ACTS alone exceeds the ITU criteria by about 5-9 dB and therefore remains a concern. Note that the analysis assumes only (4) co-frequency interfering emitters (located in NV,AZ,FL,VA), but the ACTS transmit power is very high (100W) and they use non-directional/omni antennas along with large duty cycles (50%). These types of transmit characteristics make it difficult to share with DRS systems on a co-frequency basis. The four major characteristics of mobile systems that facilitate sharing with the space science services (see Annex 2 of ITU-R SA.1154) are: (1) low power spectral density; (2) intermittent transmissions (low duty cycle); (3) directional antennas; and (4) number of mobile stations is self limiting (low population density). ACTS has only one of these characteristics (low number of terminals). There has been some discussion with DoD of using frequency avoidance for ACTS so that they do not operate co-frequency with TDRSS forward links, but DoD has stated that at this point it is not a primary option. NASA will continue to work with DoD as it investigates modifications/improvements to the current ACTS (e.g. different modulations, spread spectrum, power, antenna characteristics, etc.) to ensure compatibility with NASA systems as these systems move into the band.

III.B. 2200-2290 MHz Band

NASA has coordinated with a number of agencies that are considering moving operations from the 1755-1850 MHz band to the 2200-2290 MHz band and, based on information from these agencies, performed interference analysis to assess impact to NASA operations in the 2200-2290 MHz band. The following federal agencies were considered:

a. Department of Defense (DoD)
b. Department of Treasury (T)
c. Department of Justice (DOJ)
d. Department of Homeland Security (DHS)
e. Department of Interior (DOI)
f. United States Postal Service (USPS)

NASA is concerned about (3) interference scenarios in this band:

(1) Interference into NASA earth stations receiving satellite telemetry/mission data since the band is used for satellite downlinks;
(2) Interference into NASA ground stations receiving aeronautical telemetry data from test aircraft, unmanned aircraft, and launch vehicles since the band is used for aeronautical flight test telemetry;
(3) Aggregate interference into receivers onboard TDRS satellites in GEO since the band is used for TDRS space-to-space return links (user satellite-to-TDRS satellite).

The first and second of these scenarios will require one-on-one coordination as systems come into operation in areas near NASA receive sites. To facilitate this, NASA has developed coordination contours based on anticipated interfering transmit power levels and NASA station sensitivity. The third scenario will need to consider the long term growth and development of the band by incoming services. NASA is working with the various agencies and departments to obtain this information. In many cases, current usage in 1755-1850 MHz is indicative of the growth. However, not all relocated equipment from a given agency will be moved to the 2200-2290 MHz band. Interference scenarios were developed for each agency based on the information provided in their Phase III Reports and also data they sent directly to NASA. Details of the analysis and resulting conclusions are given in the following sections.

III.B.1 Interference Scenario 1: Coordination Contours around NASA Earth Stations

NASA uses the 2200-2290 MHz band for satellite-to-Earth downlink communications. This spectrum provides data, telemetry, and tracking information necessary for successful mission communications. In some cases, mission data is relayed to the ground via the geostationary Tracking and Data Relay Satellite System (TDRSS). The TDRSS return links (LEO-to- GEO TDRS) also use the 2200-2290 MHz band.

In the case of satellite-to-Earth transmissions, NASA earth stations must work with very weak signals transmitted from satellites that often use low gain omni-directional antennas and limited transmit power. Earth stations track the LEO satellites using relatively high gain antennas down to elevation angles of about 5°. The earth station antennas are capable of pointing 0°-360° in azimuth. Consequently, RFI sources in the vicinity of these earth station sites can disrupt signal reception, particularly when the earth station antenna is oriented towards the interfering source as it tracks the LEO. Section 8.3.15 in the NTIA manual contains the list of coordinated 2200-2290 MHz earth stations.

For the protection of earth stations against incoming systems, NASA has generated coordination contours based on the following considerations:

- A worst case interference geometry is assumed in which the NASA earth station receive antenna is pointed at a minimum elevation angle of 5° and is oriented in azimuth towards the interferer. In this case, the earth station antenna gain towards the interferer is assumed to be 14.3 dBi based on the ITU-RR Appendix 8 antenna pattern and 5° off-boresight angle (i.e. 32-25log(5°) = 14.3 dBi);
- For purposes of developing contours, based on data provided by DHS and DOJ, it is assumed that EIRP in the direction of the earth station will range from -10 dBW to +15 dBW. Multiple coordination contours can be drawn. Transmitters with higher EIRP toward the earth stations will need to coordinate when within 125 km of the station;
- The noise temperature of the earth station is dependent on application and location;
- ITM Propagation Model is used to determine propagation loss with the confidence setting set at 5% for the interference path;
- Contour distance is found when I/N calculation into the NASA earth station from the interferer is less than a threshold of I/N = - 10 dB;
- Contour distance is calculated along every 1 degree azimuth, 360 degrees around the NASA earth Station and smoothed with a moving average over every 5 degrees of azimuth.

Example contours are shown in Figures 5 to 8 for Goldstone, CA; White Sands, NM; Greenbelt, Md; and Wallops Island, Va. Once the analysis procedure is finalized and full data is received from all agencies moving into this band, these contours will be updated. These contours represent the locus of points within which coordination of a transmitter with an EIRP of 2.15 dBW toward the earth station is required. The value of 2.15 dBW EIRP is based on data received from DOJ and DHS for typical video surveillance transmitters with 1 W transmit power and 2.15 dBi omni (dipole) antenna. The contours are irregular in shape due to the nature of the terrain. Although not shown here, NASA has generated additional contours for each of its earth stations assuming interfering EIRP values of -10, 0, 2.15, and 15 dBW. A tentative set of coordination values is given in Table 13.

Figure 5. 2.15 dBW Coordination contour around Goldston, CA

Figure 6. 2.15 dBW Coordination contour arounds white Sands, NM

Figure 7. 2.15 dBW Contour around Greenbelt, Md

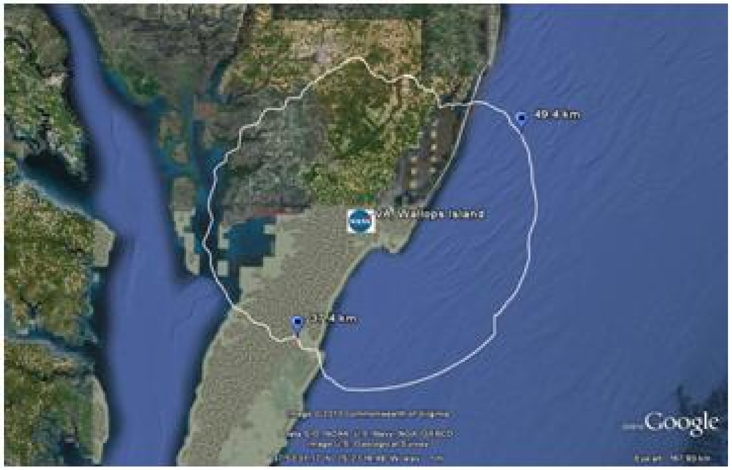


Figure 8. 2.15 dBW Contour around Wallops Island Earth Station

Table 13. Max/Min Coordination Distance of NASA Earth Stations For Various Interferer EIRP

NASA Rx Earth Station			Interferer EIRP Max Coordination Distance				Interferer EIRP Min Coordination Distance			
Name	Latitude	Longitude	-10 dBW	0 dBW	2.15 dBW	15 dBW	-10 dBW	0 dBW	2.15 dBW	15 dBW
AK, Fairbanks	64.98	-147.52	7	8	8	19.4	2	2	2	2
AK, Fairbanks	64.86	-147.86	93.4	93.4	93.4	93.6	3	4	5	7.8
AK, North Pole	64.81	-147.50	79.6	83.6	83.6	84.4	9	10.4	11	11
AK, Poker Flat	65.10	-147.05	7	7	8	9	1	1	1	2
AK, Poker Flat	65.14	-147.51	11.4	13.2	13.2	21.6	1	1	1	2
AL, UAH Huntsville	34.72	-86.64	26.2	29	31	41	5	5	5	5.6
AZ, Kitt Peak	31.95	-111.62	37.8	77.2	77.2	113.4	1	1	1	1
CA, Berkeley	37.88	-122.24	52	60	62	132	1	2	2	3
CA, Edwards AFB	34.96	-117.91	59.8	59.8	59.8	60.4	4	10	10	12.4
CA, Goldstone	35.34	-116.87	10.2	12	12.2	33.2	2	3	3	5
CA, Goldstone (DSS-16)	35.34	-116.87	10.2	12	12.2	33.2	2	3	3	5
CA, Goldstone (SWAS)	35.30	-116.87	27	34	34.4	46	27	34	36	46
CA, Goldstone	35.43	-116.89	17.6	18.2	24.4	34.4	1	2	2	3
CA, Goldstone	35.34	-116.87	11	16.6	18.2	32.4	2	3	3	5
CA, Goldstone	35.24	-116.78	22.6	23.2	23.2	41	2	3	3	3
CA, Table Mountain	34.38	-117.68	59.2	64.4	67.8	94.6	1	1	1	1
FL, Merritt Island	28.51	-80.69	33.8	44.6	47.4	66.8	22.8	34	36.2	50.6
FL, New Smyrna Beach	29.05	-80.88	31	44.2	45.6	63.8	24	32.6	34.4	40.2
Guam, GRGT	13.62	-144.86	27	34	36	46	27	34	36	46
Guam, Marianas	13.31	-144.73	27	34	36	46	27	34	36	46
HI, Kamaoa-Puueo	19.01	-155.66	96	112	116	137	2	2.2	3	5
HI, Kauai	22.13	-159.67	6.2	7	37.8	183	2	2	2	2
HI, Nelha	19.02	-155.76	72	86	89	109	6	7	8	10
HI, South Point	19.10	-155.66	146	156	160	183	2	3.2	4	7
HI, South Point	19.00	-155.10	27	48.8	72	72.2	27	34	36	43
MA, Boston	42.35	-71.11	28.2	43.2	46.2	63	3	4	6.2	14.4
MA, Westford	42.62	-71.49	29.6	40.6	43.4	50.2	2	2	3.6	13

MD, Blossom Point	38.43	-77.09	31	42.4	43.4	60.6	6	9.6	10.2	22.6
MD, Blossom Point (12W)	38.43	-77.08	31.6	42.6	44.6	61.2	7.2	9.4	12.8	23.6
MD, Greenbelt	39.00	-76.84	27	34.4	34.4	66.2	9	11.8	15.6	20.2
MD, Laurel	39.18	-76.90	24.2	44.4	47.2	75.8	5	6	6.2	14.6
NM, Las Cruces	32.27	-106.75	46.6	54.2	56.2	66.2	6	6	6	6
NM, White Sands (STGT)	32.54	-106.61	68	73	73	83.4	3	4	4	6
NM, White Sands (WSGT)	32.50	-106.61	61.8	74.2	75.8	87.6	4	4	4	4
NM, White Sands (WSGT-TDRS East)	32.35	-106.61	79.6	94.2	95	116	4	4	4	4
PA, Horsham	40.20	-75.17	21	35	35	44	6	9	9	9
PTR, Mayaguez	18.21	-67.14	42	52	55	68	2	2	2	7
VA, Chantilly	38.89	-77.84	26.2	31.8	35.4	37	2	2.4	3.2	8
VA, Dulles	39.01	-77.43	29.6	32.2	32.2	33	6	9	9	10
VA, Wallops Island	37.93	-75.48	37.2	47.2	53.6	61.8	25.6	34.8	11	51.2
VA, Wallops Island (SWAS)	37.93	-75.30	31.8	44.8	49.4	57.6	24	33	37.6	45
VA, Wallops Island	37.93	-75.48	37.4	47.2	49.2	61.8	25.6	35	37.8	48.8
WV, Fairmont	39.26	-80.11	7	9	10.4	10.8	2	2	2	2

III.B.2 Interference Scenario 2: Coordination Contours around NASA Aero-Telemetry Sites

NASA also uses the 2200-2290 MHz band for aeronautical telemetry from test aircraft at selected test ranges. Telemetry spectrum is required for the transmission of real-time data from a test vehicle to ground. It allows the testers to conduct safe, effective, and efficient tests by displaying and analyzing data in real time. The band supports aerospace flight research and technology integration, space exploration concepts, airborne remote sensing, and a wide variety of science missions. Coordination contours can be generated with similar considerations as in III.B.1. In this case, however, since the telemetry receiving ground station may point down to the horizon while tracking an aircraft, the antenna main beam gain rather than sidelobe gain is used to determine the maximum coordination contours.

To protect telemetry receiving stations, NASA generated coordination contours based on the receive parameters given in Table 14 for various power levels. Sample sites are shown in Figures 9 and 10 for Edwards, CA and White Sands, NM. Table 15 shows representative maximum and minimum coordination values for various interfering EIRP levels directed at the telemetry sites.

Table 14. Parameters for Aero-Telemetry Ground Station Coordination Contours

Name	Rx Latitude (deg N)	Rx Longitude (deg E)	Noise temperature (deg K)	Antenna Gain (dBi)
Merritt Island, FL	28.3578	-80.7033	150	44
White Sands	32.4178	-106.3194	150	38
EDWARDS, CA	34.9608	-117.9114	150	42
Wallops Island, VA	37.8508	-75.4706	150	43
Fairbanks, Alaska	65.1172	-147.4592	150	43

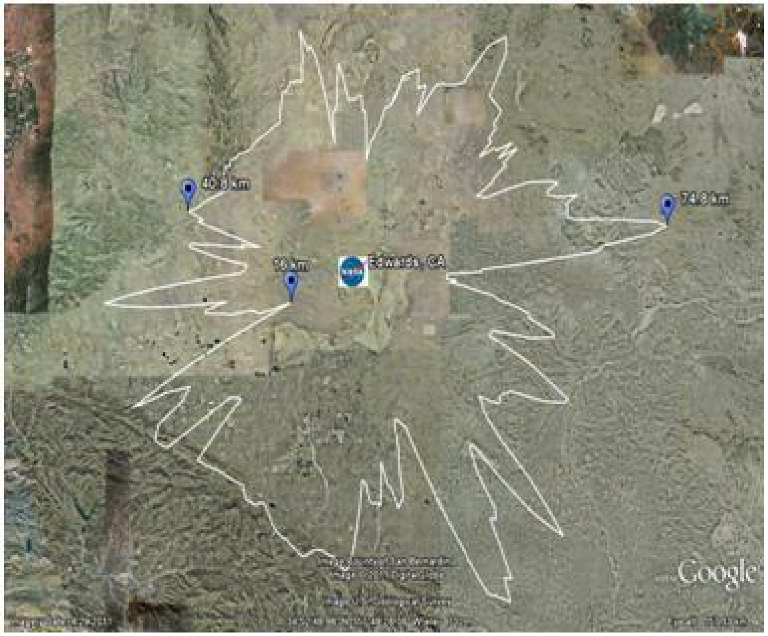


Figure 9. 2.15 dBW Coordination contour around Edwards, CA Telemetry Station

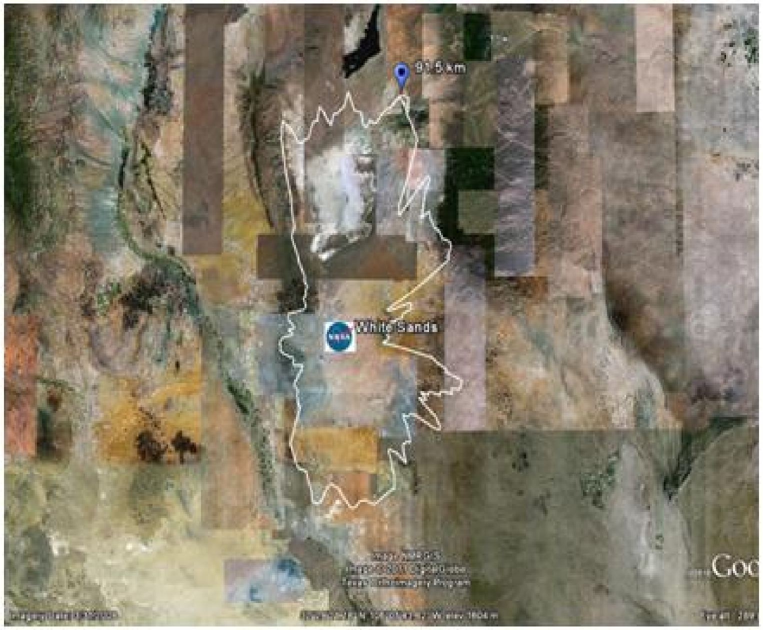


Figure 10. 2.15 Coordination contour around White Sands, NM Telemetry Station

Table 15. Max/Min Coordination Distances of NASA Telemetry Stations versus Interferer EIRP

	Interferer EIRP		
	Max Coordination Distance		
NASA Rx Aero-Telemetry Station	-10 dBW	0 dBW	2.5 dBW
Merrit Island, FL	64.8	92.4	111.2
White Sands, NM	91	91.3	91.5
Edwards, CA	59.2	74.8	74.8
Wallops Island, VA	32.4	41.8	43.7
Fairbanks, AK	39.2	40.6	40.8

III.B.3 Interference Scenario 3: Aggregate Interference into TDRS System

III.B.3a Impact from DoD Systems

DoD has indicated that this band is an alternate band for relocation of TRR (Tactical Radio Relay) systems used by the Army, Navy, and Marine Corps (the primary band selected by DoD for these systems is 2025-2110 MHz as discussed in Section III.A).

The technical parameters and deployment were provided by DoD and are the same as used in the 2025-2110 MHz analysis (see Tables 7-9 in Section III.A). However, instead of interference into the TDRS user satellite on the TDRS forward link, here we are concerned with interference into the TDRS satellite itself on the TDRS return link. Note that for TRR/Army systems, 52 sites are listed with two (2) co-channel interfering emitters per site; for TRR/USMC, 17 sites are listed with two (2) co-channel interfering emitters per site; and for TRR/NAVY, 5 sites are listed with (1) co-channel interfering emitter per site. TRR/Army and TRR/USMC transmitters are assumed to have identical characteristics. Note also that the -8 dBW (22 dBm) transmit power for TRR Army/MC and 13 dBW (43 dBm) transmit power for TRR NAVY are nominal power levels for these devices assuming they have automatic transmit power control (ATPC). The peak power is 2 dBW (32 dBm) and 20 dBW (50 dBm), respectively. Further, it is assumed that the DoD/TRR systems operate with a 50% duty cycle. As in the 2025-2110 MHz analysis, the ITU-R SA.1155 interference criterion (i.e. I/N = -10 dB not to be exceeded more than 0.1% of the time) is applied.

The TDRS SSA (S-band Single Access) tracking antenna (4.8 meter diameter) has a relatively high gain of 36.8 dBi (2.4° beamwidth) at S-band and so is very sensitive to interference. In addition, TDRSS space-to-space links (both forward and return) generally operate on tight link margins (typically 2-4 dB or less) due to limited power on both ends of the link. As such the raising of the noise floor by even 1 dB (i.e. I/N=-10 dB) is critical. The TDRS satellite system noise temperature is assumed to be 410K in this analysis.

Figures 11a-11d give the results of the analysis for four cases: (1) TDRS 41W tracking ISS (International Space Station) in a 400 km altitude orbit inclined 51.6°; (2) TDRS 41W tracking the Aura satellite in a 705 km altitude orbit inclined 98.2°; (3) TDRS 174W tracking ISS; and (4) TDRS 174W tracking Aura. Note that in each case, the combined 143 TRR emitters (i.e. 104 Army + 34 USMC + 5 NAVY) satisfies the ITU-R criterion. The assumptions and results are summarized in Table 16.

Table 16. Interference from DoD Systems into TDRS Satellite Receiver

	ISS/TDRS 41W		ISS/TDRS 174W		Aura/TDRS 41W		Aura/TDRS 174W	
	Army/MC	Navy	Army/MC	Navy	Army/MC	Navy	Army/MC	Navy
Duty Cycle %	50%	50%	50%	50%	50%	50%	50%	50%
Power (dBW)	-8	13	-8	13	-8	13	8	13
Elevation angle random	+-5 deg	0 deg	+-5 deg	0 deg	+-5 deg	0 deg	+-5 deg	0 deg
Azimuth -random	360		360		360		360	
Ant Gain (dBi)	24.5	6 dBi	24.5	6 dBi	24.5	6 dBi	24.5	6 dBi
Ant Pattern ITU-R	1245-1	1336-2	1245-1	1336-2	1245-1	1336-2	1245-1	1336-2
I/N @ 0.1% (dB)	-10.8	-17.3	-13	-14.1	-12	-18.0	-14.1	-15

Figure 11a.

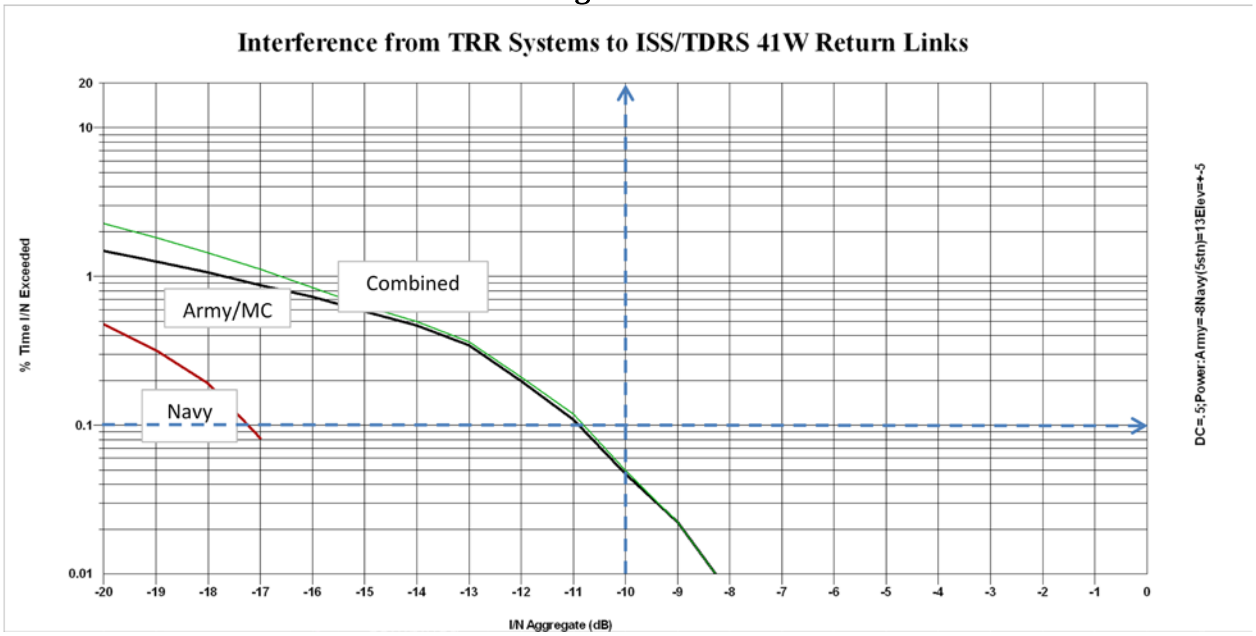


Figure 11b.

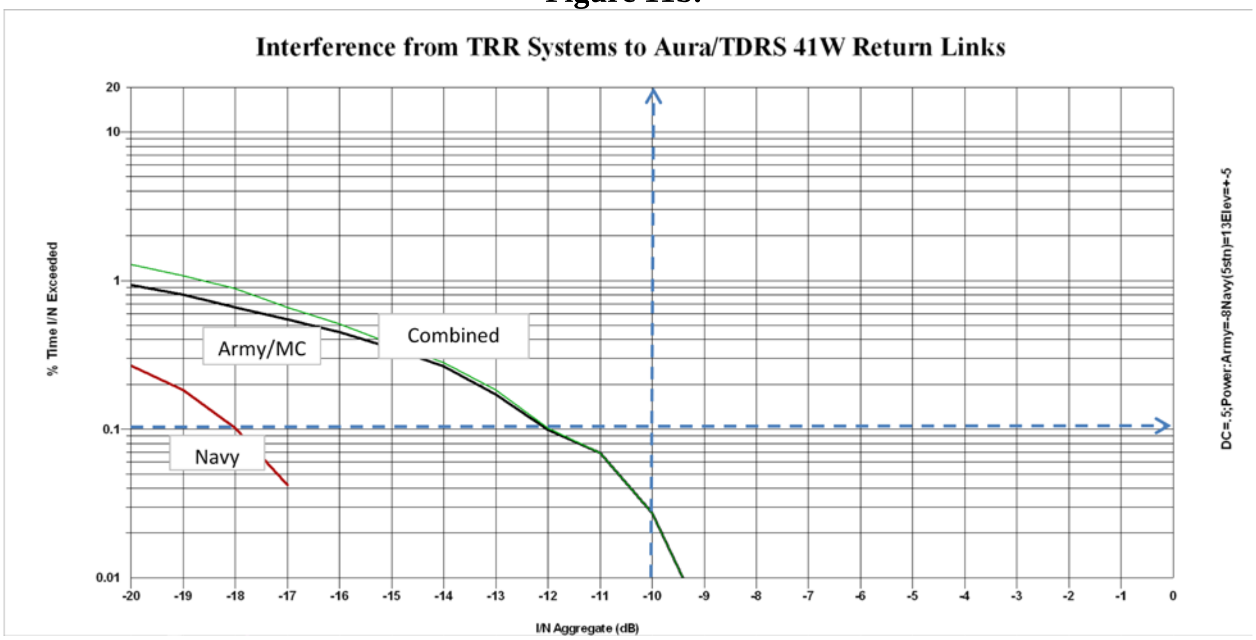


Figure 11c.

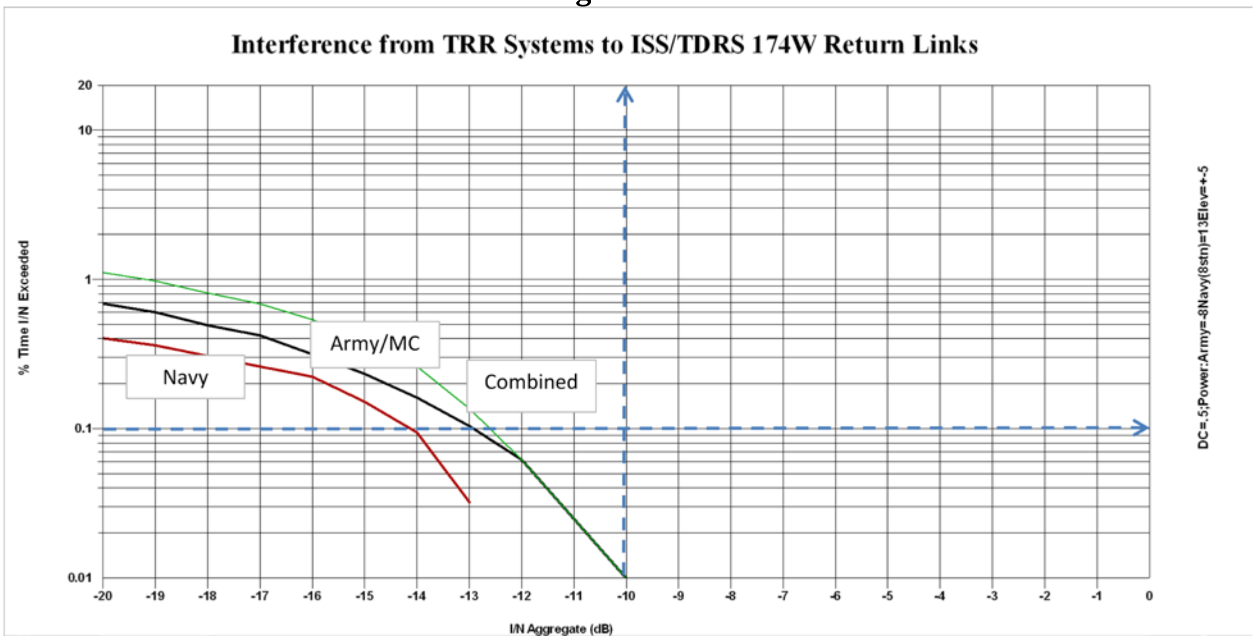
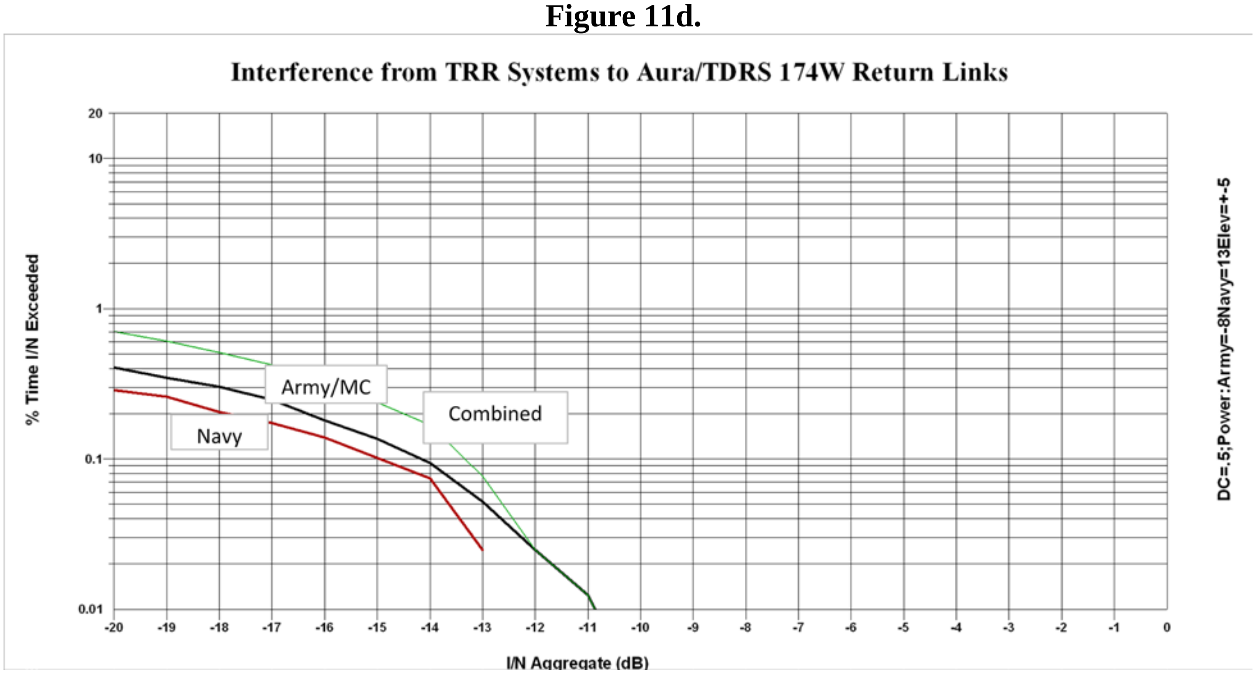


Figure 11d.



III.B.3b Impact from Department of Justice Systems

The following is an assessment of the aggregate interference from DOJ emitters into TDRS satellites located at 41W and 174W when tracking the non-GSO satellites AURA and ISS space station.

Interference Parameters

The Department of Justice has provided its plans for the use of the 2200 MHz band in its Phase II Report. DOJ already operates video surveillance systems in the 2200-2290 MHz band and they plan to relocate additional video surveillance into the band. This is indicated in Table 17. These video surveillance systems are comprised of the following:

a. Miniature concealment devices, analog: 200 mW, 25 MHz transmitters;
b. Miniature concealment devices, digital: TBD;
c. Small concealment devices: analog: 50 mW, 5-10 MHz;
d. Remote control analog or SD or HD Camera: 200 mW , 5-10 MHz;
e. Antenna gain = 2.15dBi.

Table 17. Proposed Destination Bands for DOJ Operations

PROPOSED DESTINATION BANDS FOR DOJ OPERATIONS

(Law Enforcement Sensitive - please handle appropriately) *(Law Enforcement Sensitive - please handle appropriately)*

Operation	Types of Systems	Current Technical Parameters (1)	Anticipated Technical Parameters (2)	# of Ops / Duration (3)	Proposed Destination Band (MHz
Transportable Surveillance	Miniature Concealment	Analog, FM, 200 mW, 17 Mhz BW, omni radiator	Digital, COFDM, 50 mW, 10 Mhz BW, omni Ant	10 / 6 hrs	2200 - 2290; 1675 - 1695
	Airborne	Downlink, Digital, COFDM, 5 W, 10 MHz BW, Blade Ant	Downlink, Digital, COFDM, 2 W, 5 MHz BW, Blade Ant	8 / 6 hrs	4800 - 4940
	Audio Surveillance Covert	Digital, CQPSK, 100 mW, 12.5 khz BW, Omni Ant	Digital, CQPSK, 100 mW, 6.25 khz BW, Omni Ant	20 / 2 hrs	1435 - 1525
	UAS	Downlink, Digital, COFDM, 200 mW, 10 MHz BW, Blade Ant	Downlink, Digital, COFDM, 200 mW, 5 MHz BW, Blade Ant	1 / 6 hrs	1435 - 1525
	Robotics	Analog, FM, 3 W, 22 Mhz BW, omni radiator	Digital, COFDM, <3 W, 10 Mhz BW, omni Ant **(4)**	3 / 6 hrs	1435 - 1525
Fixed Surveillance	Small Concealment	Analog, FM, 2 W, 17 Mhz BW, omni radiator	Digital, COFDM, 200 mW, 5 Mhz BW, omni Ant	34 /24-7 **(5)**	2200 - 2290; 1675 - 1695
	Large Concealment	Analog, FM, 1-3 W, 17 Mhz BW, directional patch Ant	Digital, COFDM, 200mW, 5 Mhz BW, directional patch Ant	34 /24-7 **(5)**	2200 - 2290; 1675 - 1695
	MESH Networks	Digital, COFDM, 200mW, 10Mhz BW, Omni Ant, 6-8 Tx nodes/network	Digital. COFDM, 200mW, 5 Mhz BW, Omni Ant, 6-12 Tx nodes/network	3 / 24-7	1675 - 1695; 4400 - 4800
	Video Repeaters (in-band and X-band)	Analog, FM, 1-3 W, 17 Mhz BW, parabolic or directional patch Ant	Digital, COFDM, 200mW, 5 Mhz BW, directional patch Ant (+ potential broadband compliment)	12 / 24-7	1435 - 1525
	Fixed Point-to-Point	Analog, FM, 3 W, 17 Mhz BW, parabolic Ant	Digital, COFDM, 2 W, 10 Mhz BW, parabolic Ant (+ potential broadband compliment)	5 / 24-7	4400 - 4800; 8100 - 8500
	Central Receiver	**(6)**	Digital, COFDM, 5 W, 5 Mhz BW, Omni Ant (+ potential broadband compliment) **(6)**	3 / 24-7 **(7)**	1435 - 1525

NOTES

(1) Characteristics represent mazimum device operating parameters
(2) Assumes successful deployment of narrower bandwidth technology, with appropriate funding, and equitable access status to the destination bands
(3) Estimates based on typical operational tempo experienced in Top Metroplitan areas, per month, throughout US (rural/remote ares are dramatically less)
(4) Surveillance activities will typically be in the 200 mW range, while Bomb Squad activities exploit heavier devices capable of higher power levels
(5) Cumulative figure for all fixed concealment devices
(6) Current operation "Recieves" signals within 1700 Band; Future state will incorporate return "control" path capability
(7) # of Devices/Ops may reduce with consolidation initiatives between DOJ Components

Based on Table 17, the DOJ interference across the United States is modeled to include (10) 10 MHz channels working 6 hours per day with 50 mW of power and (68) 5 MHz channels working 24 hours per day across the entire band. Assuming operations occur in the ten top cities (Table 18), this is modeled as 8.8 channels per city. As there is about 90 MHz available, it is estimated that at any given instant there will be one co-channel video surveillance transmitter per city in each of the top 10 cities. So interference into a single TDRS channel (6.16 MHz bandwidth) is assumed to consist of a total of 10 simultaneous DOJ emitters operating at 100% duty cycle (i.e. 24/7).

Table 18. Top Ten Urban Areas Census 2009

City	Longitude (W)	Latitude (N))
New York city	73.9179	40.70423
Los Angeles city	118.376	34.08616
Chicago city	87.6794	41.84068
Houston city	95.3832	29.7629
Philadelphia city	75.1448	39.99801
Phoenix city	112.076	33.52837
San Diego city	117.146	32.77954
Dallas city	96.7872	32.79953
San Antonio city	98.5127	29.45153
Detroit city	83.1026	42.38714

Like the DoD analysis, two GEO TDRS satellites are considered (41W and 174W) and two user satellites are considered (ISS and Aura). The relevant parameters are given in Table 19.

Table 19. LEO and TDRS Parameters

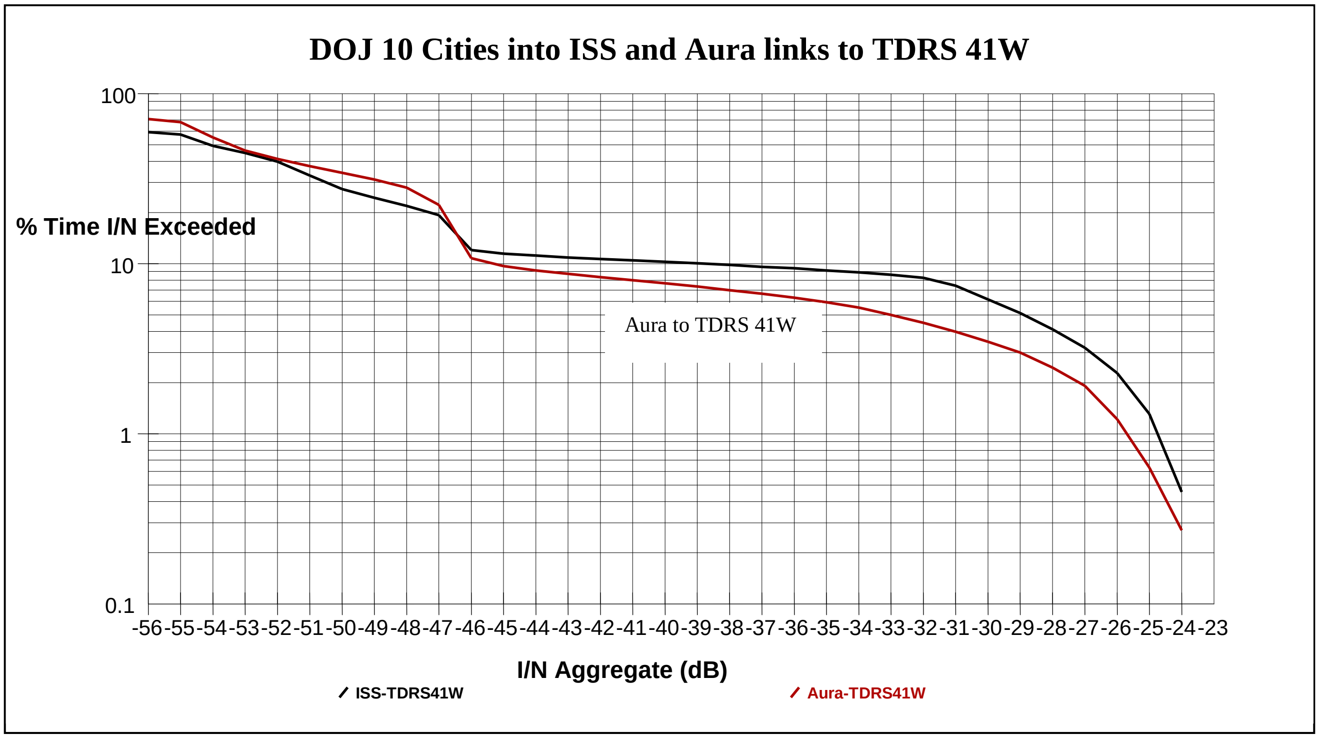
Parameter	Units	Value
TDRS		
TDRS satellite Longitude	deg	-41 or -174
Antenna Gain	dBi	36.8
Antenna Pattern	ITU-R Rec 672-4 Rec 1 circular beam pattern	

Carrier Frequency Range	MHz	2200-2290
Signal Bandwidth	MHz	6.16
Noise temperature	K	410
Thermal Noise	dBW/Hz	-202.47
<u>Interference Criteria</u>		
ITU-R Criteria Rec. ITU-R SA.1155 (s-s links)	I/N exceeded less than 0.1% of the time (dB)	-10
<u>Aura satellite</u>		
Apogee	km	705
Perigee	km	705
Inclination	deg	98.2
<u>ISS</u>		
Apogee	km	400
Perigee	km	400
Inclination	deg	51.6

<u>Results of Simulation Exercises</u>

Visualyse software was used to calculate the interference statistics. Since the majority of video surveillance operations are carried out in urban/suburban areas, interference from these units to the satellite will often be mitigated by clutter losses (buildings, walls, floors, signs, bodies, etc). Due to the difficulty in accurately modeling these losses, this analysis assumes a worst case assumption of no clutter loss (i.e. unobstructed LOS between DOJ emitters and TDRS satellite). Figure 12 shows that even under this worst case assumption, the ITU protection threshold is satisfied since the I/N does not exceed -24 dB and this is 14 dB below the -10 dB ITU threshold.

Figure 12.

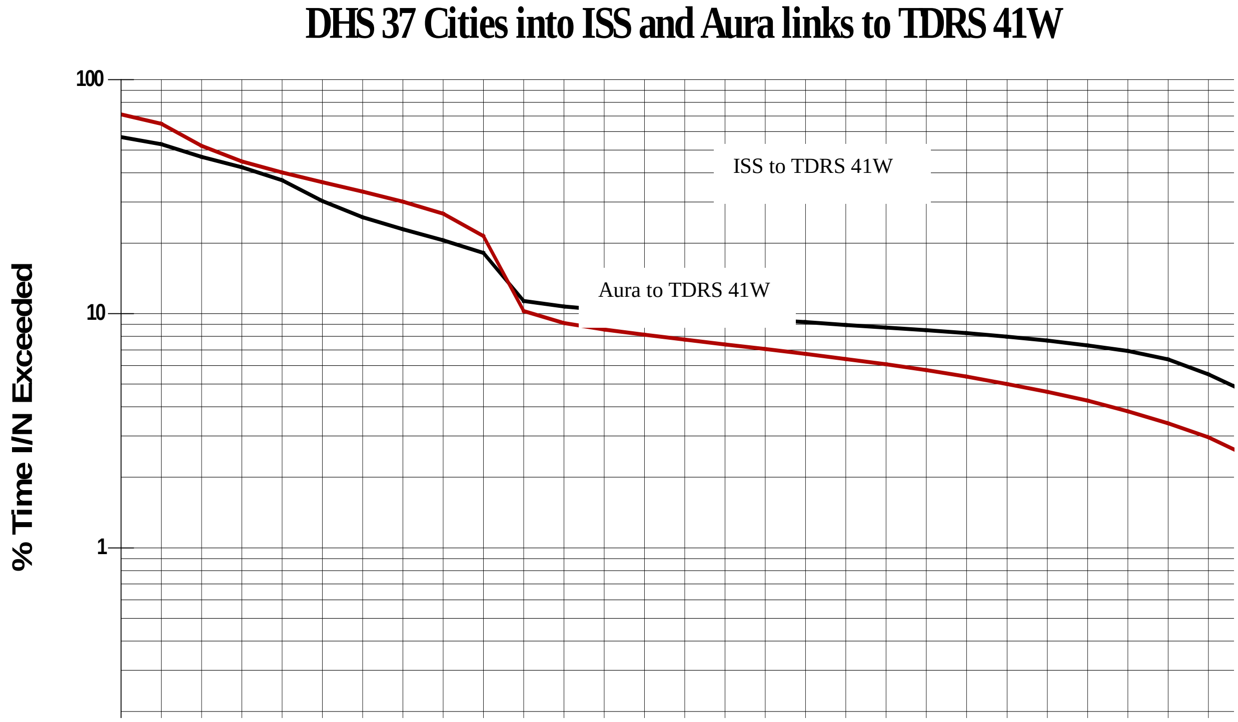


III.B.3c. Impact from Department of Homeland Security Systems

Like DOJ, DHS intends to move additional video surveillance into the 2200-2290 MHz band. Therefore similar analysis was performed. Deployment and technical information was based on material included in the DHS Reports and direct correspondence with DHS. It is estimated that there would be 100-500 simultaneously transmitting DHS emitters nationwide at any given time across the entire band (11 partially overlapping channels each 8 MHz wide). Thus for a given 8 MHz channel, 9 emitters (100/11) to 46 emitters (500/11) are anticipated. Of these, 80% are expected to be located outdoors while the rest are body-worn indoor devices that will not be a significant threat due to low power and clutter loss. Therefore, in the TDRS channel bandwidth of 6.16 MHz, a maximum of 37 (0.8 x 46) simultaneous DHS emitters operating at 100% duty cycle is assumed. These 37 emitters are assumed to be located in the 37 most populated cities. From DHS information, each emitter is assumed to operate at 1 Watt transmit power; 7.5 MHz emission bandwidth; and omni/dipole antenna (2.15 dBi gain and pattern modeled using the omni pattern in ITU-R Rec F.1336-2/Recommends 2.2).

The impact of this deployment on the TDRS satellite receiver is shown in Figure 13. The results show that the maximum I/N = -15 dB which satisfies the ITU threshold.

Figure 13.



III.B.3.d. Impact from Department of Treasury Systems

Treasury has similar video surveillance equipment as DOJ and DHS. It currently has 120 units at 1755-1850 MHz for indoor and outdoor use. According to their Phase II Report, the outdoor webcam units will be transferred to IP related transmissions, so most of the outdoor units may not require use of 2200-2290 MHz radio. Notwithstanding this possibility, interference was modeled similar to that used for DOJ (i.e. 10 simultaneous co-frequency emitters nationwide in top 10 cities operating 24/7). Therefore, like DOJ, interference impact is expected to be negligible (i.e. I/N = -24 dB).

III.B.3.e. Impact from Department of Interior Systems

Based on their Reports, DOI's planned usage of the 2200-2290 MHz band is to support downlink video transmissions from helicopters in the Washington DC area during major events. The transmitters would typically be 10 watts; omni (3 dBi) antennas; and 18 MHz bandwidth. The helicopter altitude is typically 1000 feet in the Washington, D.C. area (centered around 38.52N, 76.59W). For the interference analysis, a single interfering co-channel DOI emitter operating in DC at 100% duty cycle was assumed. This results in a maximum I/N = -22.2 dB which satisfies the ITU threshold.

III.B.3.f Impact from USPS

The USPS has advised that they have similar but considerably less extensive video surveillance operations as DOJ. Since DOJ is expected to have negligible impact (I/N = -24 dB), USPS is also expected to be negligible.

III.B.3.g Impact from Combined Systems

Additional analysis was performed to estimate the combined aggregate interference impact to TDRS from the systems described above. A total of 201 interfering emitters was assumed (i.e. 5 Navy/TRR + 104 Army/TRR + 34 USMC/TRR + 37 DHS + 10 DOJ + 10 Treasury + 1 DOI) using their respective transmit characteristics as described in the previous sections. The analysis showed a net I/N = -8.6 dB (exceeded for no more than 0.1% of the time) and that the threshold level of I/N = -10 dB is exceeded only 0.24% of the time. Although, strictly speaking, this exceeds the ITU limit by 1.4 dB, this interference is considered acceptable given that it is based on several conservative assumptions (e.g. DHS/DOJ/DOI/DOT transmitters operate continuously 24/7 with no building or clutter losses included and maximum expected number of co-channel emitters). The DoD and DHS systems are the main contributors to the overall interference.

III.B.4 Conclusion

With regard to systems being relocated to the 2200-2290 MHz band, NASA satellite receiving earth stations and aircraft telemetry receiving ground stations will require protection from incoming transmitters using appropriate coordination contours around its earth stations and telemetry sites. This Report provided sample coordination contours based on the expected EIRP levels of some incoming video surveillance systems. Additional coordination contours may be required for protection from DoD TRR systems if they move into the band. Based on the system characteristics of DoD, DHS, DOJ, DOI, and Treasury systems described in the previous sections, it appears that interference from these systems into the NASA TDRSS return links is acceptable. Like the 2025-2110 MHz band, however, this conclusion is only valid as long as there is no significant deviation of these agency system characteristics from those used in the above analyses.

III.C. 2360-2395 MHz Band

In accordance with US276[1], mobile service use of this band is limited to aeronautical telemetry and associated telecommand operations. Table 20 shows the 13 NASA RFAs in the band – most of them supporting WFF high altitude scientific balloon air-to-ground telemetry and WFF sounding rocket/launch vehicle telemetry. As indicated in Section II, NASA WFF plans to relocate (3) additional balloon telemetry channels from the 1755-1850 MHz band into this band. The band also has a primary allocation for the radiolocation service and NASA has one RFA (NASA105581) for the Lunar Reconnaissance Orbiter (LRO) radar.

Table 20. NASA RFAs in the 2360-2395 MHz Band

Serial #	Frequency (MHz)	Power (W)	Bandwidth (MHz)	NASA Center	Location of Transmitter
NASA062502	2365.5	10	1	WFF	BALLOON
NASA062503	2366.5	10	1	WFF	BALLOON
NASA062504	2367.5	10	1	WFF	BALLOON
NASA020034	2370.5	10	20	WFF	SOUNDING ROCKET
NASA930180	2378.5	5	1	WFF	BALLOON
NASA105581	2380	12	19.2	GSFC	MOON ORBIT
NASA930181	2380.5	5	1	WFF	BALLOON
NASA102557	2382.5	10	3	WFF	LAUNCH VEHICLE
NASA930182	2382.5	5	1	WFF	BALLOON
NASA930183	2384.5	5	1	WFF	BALLOON
NASA010030	2386.5	10	1	WFF	BALLOON
NASA010031	2387.5	10	1	WFF	BALLOON
NASA062505	2388.5	10	1	WFF	BALLOON

III.D. 4400-4940 MHz Band

This band has a (G-only) FIXED allocation and (G-only) MOBILE allocation and it is heavily used for Federal fixed and mobile systems including aero-telemetry (and associated telecommand); point-to-point microwave; ACTS; tactical data links; and UAV command and control systems. As shown in Table 21, NASA has 11 RFAs in the band, most of them supporting video/data air-to-ground (A/G) telemetry for high performance aircraft and UAVs at DFRC (7 RFAs) and WFF (3 RFAs). KSC also has an RFA for UWB (Ultra WideBand) experimental testing. As indicated in Section II, NASA LaRC intends to relocate all (7) of its RFAs in 1755-1850 MHz supporting aero telemetry/telecommand to this band. Also, NASA DFRC plans to relocate its (3) aero telemetry/telecommand RFAs in 1755-1850 MHz to this band.

[1] US276 Except as otherwise provided for herein, use of the band 2360-2395 MHz by the mobile service is limited to aeronautical telemetering and associated telecommand operations for flight testing of aircraft, missiles or major components thereof. The following three frequencies are shared on a co-equal basis by Federal and non-Federal stations for telemetering and associated telecommand operations of expendable and reusable launch vehicles, whether or not such operations involve flight testing: 2364.5 MHz, 2370.5 MHz, and 2382.5 MHz. All other mobile telemetering uses shall not cause harmful interference to, or claim protection from interference from, the above uses.

According to the most recent NTIA comparable band chart, this band is a DoJ preferred band for relocating their fixed PTP microwave systems and UAS systems from the 1755-1850 MHz band. The DoD has also indicated that this is a preferred band for A/G telemetry and possibly also UAS systems. With regard to relocation of 1755-1850 MHz aero telemetry/telecommand operations and UAS operations to this band, it should be noted again that US implementation of ITU FN 5.440A (and the associated ITU Resolution 416) without modification would actually exclude telecommand (ground-to-air) transmissions in the 4400-4940 MHz band and the disposition of existing telecommand ops in the band would also need to be considered.

Table 21. NASA RFAs in the 4400-4940 MHz Band

Serial #	Frequency (MHz)	Power (W)	Bandwidth (MHz)	NASA Center	Location of Transmitter	Latitude of Transmitter	Longitude of Transmitter	Transmitter Gain	Location of Receiver	Reciever Latitude	Receiver Longitude	Receiver Gain
NASA092506	4420	5	16	WFF	AIRCRAFT			2	WALLOPS ISLAND	37.941	-75.462	3
NASA092507	4430	5	16	WFF	AIRCRAFT			2	WALLOPS ISLAND	37.941	-75.462	3
NASA092508	4440	5	16	WFF	AIRCRAFT			2	WALLOPS ISLAND	37.941	-75.462	3
NASA078527	4565	5	18	DFRC	EDWARDS	34.961	-117.911	0	EDWARDS	34.961	-117.911	30
NASA820231	4583	5	12	DFRC	EDWARDS	34.961	-117.911	0	EDWARDS	34.961	-117.911	30
NASA078528	4612	5	18	DFRC	EDWARDS	34.961	-117.911	0	EDWARDS	34.961	-117.911	30
NASA078529	4665	5	18	DFRC	EDWARDS	34.961	-117.911	0	EDWARDS	34.961	-117.911	30
NASA104015	4700	0.0001	3200	KSC	KSC	28.523	-80.642	2	KSC	28.523	-80.642	2
NASA078530	4710	5	18	DFRC	EDWARDS	34.961	-117.911	0	EDWARDS	34.961	-117.911	30
NASA940148	4760	5	12	DFRC	EDWARDS	34.95	-117.887	0	EDWARDS	34.95	-117.887	30
NASA820230	4790	5	12	DFRC	EDWARDS	34.961	-117.911	0	EDWARDS	34.961	-117.911	30

III.E. 5091-5250 MHz Band

According to the most recent NTIA comparable band chart, this band is a DoD preferred band for relocating their A/G telemetry operations and possibly also some UAS systems. NASA and DoD are in detailed discussions about all of the DoD Systems that will be moving into 5091-5250 MHz from 1755-1850 MHz.

As explained in Section II, NASA has also selected this band as a potential relocation band for telemetry/UAS systems, but there are complicating factors as described previously and noted again below. As shown in Table 22, NASA GRC currently has 7 RFAs in the 5091-5150 MHz band supporting experimental wireless airport surface networks at Cleveland Hopkins Airport.

Relocation of telemetry/UAS operations into the 5091-5150 MHz portion would require adoption of ITU FN 5.444B. Again, note that like 5.440A for the 4400-4940 MHz band, 5.444B (and the associated WRC-07 Resolution 418) limits aeronautical use to only the telemetry (air-to-ground) direction and prohibits telecommand (ground-to-air) transmissions. A large influx of aero-telemetry systems into this band would also likely raise concern from Globalstar, which operates feederlink uplinks to its NGSO constellation of satellites over the 5091-5250 MHz band. The impact to Globalstar feeder links will depend on the aggregate interference across CONUS from all transmitters operating simultaneously in the band. Even though the small number of NASA operations would likely not pose a problem, the contribution from all users of the band must be considered. It should also be noted that there is an AMS(R)S (i.e. safety-of-life) allocation in 5091-5150 MHz (FN 5.367) and although there is currently no AMS(R)S system using the band, it is being considered for UAS satellite command and control links under WRC-12 Agenda Item 1.3. Furthermore, besides aero-telemetry use, FN 5.444B also allows AM(R)S applications such as airport surface broadband comm/surveillance networks (ASDE-X) and aeronautical security communications in the 5091-5150 MHz band. This will require that aero-telemetry users operating near major airports coordinate with these (safety-of-life) aviation systems. The AM(R)S use may also be extended to also allow terrestrial UAS command and control as part of WRC-12 AI 1.3.

Relocation of aero-telemetry/UAS ops into the 5150-5250 MHz portion will also require regulatory action since there is currently no aero telemetry service allocation. FN 5.444B only covers the 5091-5150 MHz portion – not 5150-5250 MHz. There is an ITU FN (5.446C) that permits aero-telemetry in the band, but only in Region 1 (Europe). Aero-telemetry users would again be constrained by the need to protect Globalstar feederlinks which span the entire 5091-5250 MHz. The 5150-5350 MHz band is also a UNII (Unlicensed National Information Infrastructure) band used in wireless LANs (i.e. 802.11a/h/j/n).

Table 22. NASA RFAs in the 5091-5250 MHz Band

Serial #	Frequency (MHz)	Power (W)	Bandwidth (MHz)	NASA Center	Location of Transmitter	Location of Receiver
NASA077505	5095	3	4.5	GRC	CLEVELAND	CLEVELAND
NASA077506	5100	3	4.5	GRC	CLEVELAND	CLEVELAND
NASA077507	5105	3	4.5	GRC	CLEVELAND	CLEVELAND
NASA077508	5110	3	4.5	GRC	CLEVELAND	CLEVELAND
NASA077509	5115	3	4.5	GRC	CLEVELAND	CLEVELAND
NASA067519	5120	9.7	18.5	GRC	CLEVELAND	CLEVELAND
NASA067518	5125	9.7	18.5	GRC	CLEVELAND	CLEVELAND

III.F. 7125-8500 MHz Band

According to the NTIA comparable band chart, a number of agencies have proposed to relocate their fixed PTP microwave systems from the 1755-1850 MHz band to this band. These agencies are DHS, DOJ, DOE, USCG, DOI, DOD, and FAA. In the US Table of Allocations, this band consists of a number of sub-bands as shown in Table 23. Most of these sub-bands have a primary FIXED service allocation. NASA currently has a total of 115 RFAs throughout the 7125-8500 MHz band and the distribution of these RFAs is also shown in Table 23. A detailed listing of these 115 RFAs is shown in Table 24. The two most important NASA sub-bands are 7145-7190 MHz where high-power uplinks (up to 20 kW) are operated from the Deep Space Network (DSN) in Goldstone, CA; and 8400-8500 MHz which is used for Goldstone DSN downlinks. Agencies relocating systems to 7125-8500 MHz should therefore avoid operating in these two sub-bands near the Goldstone, California DSN complex. NASA reviewed the Phase II/III Reports from the above agencies and although they identified the 7125-8500 MHz band as a potential relocation band for fixed point-to-point microwave systems, specific sub-bands were not identified.

Table 23. Breakdown of 7125-8500 MHz Band and NASA Usage in the Band

SUBBAND	US TABLE ALLOCATIONS (blue text indicates non-fed only allocation)	ASSOCIATED ALLOCATION FOOTNOTES	# NASA RFAs	NASA USAGE OF BAND
7125-7145	FIXED	5.458 In the band 6425-7075 MHz, passive microwave sensor measurements are carried out over the oceans. In the band 7075-7250 MHz, passive microwave sensor measurements are carried out. Administrations should bear in mind the needs of the Earth exploration-satellite (passive) and space research (passive) services in their future planning of the bands 6425-7025 MHz and 7075-7250 MHz.	1	Lunar recon orbiter radar in lunar orbit
		G116 The band 7125-7155 MHz is also allocated for Earth-to-space transmissions in the Space Operations Service at a limited number of sites (not to exceed two), subject to established coordination procedures.		
7145-7190	FIXED SPACE RESEARCH (deep space) (Earth-to-space) US262 5.458 G116 (shown above)	US262 The band 7145-7190 MHz is also allocated to the space research service (deep space) (Earth-tospace) on a secondary basis for non-Federal use. Federal and non-Federal use of the bands 7145-7190 MHz and 34.2-34.7 GHz by the space research service (deep space) (Earth-to-space) and of the band 31.8-32.3 GHz by the space research service (deep space) (space-to-Earth) is limited to Goldstone, CA (35° 20' N, 116° 53' W).	59	Goldstone CA Deep Space Network (DSN) Uplinks (20 kW power)
7190-7235	FIXED SPACE RESEARCH (Earth-to-space) G133 5.458 (shown above)	G133 In the band 7190-7235 MHz, emissions to deep space are prohibited. Geostationary satellites in the space research service operating in the band 7190-7235 MHz shall not claim protection from existing and future stations in the fixed service and ITU Radio Regulation No. 5.43A does not apply.	2	Goldstone telecommand/tracking for ESA Planck/Herschel spacecraft at L2 Langrangian during critical/emerg events
7235-7250	FIXED 5.458 (shown above)		1	Color TV broadcast from Edwards shuttle landing area to DFRC
7250-7300	FIXED-SATELLITE (space-to-Earth) MOBILE-SATELLITE (space-to-Earth) Fixed G117	G117 In the bands 7.25-7.75 GHz, 7.9-8.4 GHz, 17.3-17.7 GHz, 17.8-21.2 GHz, 30-31 GHz, 33-36 GHz, 39.5-41 GHz, 43.5-45.5 GHz and 50.4-51.4 GHz, the Federal fixed-satellite and mobile-satellite services are limited to military systems.	0	
7300-7450	FIXED FIXED-SATELLITE (space-to-Earth) Mobile-satellite (space-to-Earth) G117		2	WFF data link for lightning detection and ranging (LDAR) system
7450-7550	FIXED FIXED-SATELLITE (space-to-Earth) METEOROLOGICAL-SATELLITE (space-to-Earth) Mobile-satellite (space-to-Earth) G117		0	
7550-7750	FIXED FIXED-SATELLITE (space-to-Earth) Mobile-satellite (space-to-Earth) G117		3	Range ops data link at DFRC supports landing video for shuttle and other aero flight tests; data links at Goldstone; KSC video link for public affairs
7750-7850	FIXED METEOROLOGICAL-SATELLITE (space-to-Earth) 5.461B	5.461B The use of the band 7750-7850 MHz by the meteorological-satellite service (space-to-Earth) is limited to non-geostationary satellite systems.	4	LDAR data link at WFF; video link for public affairs TV at KSC
7850-7900	FIXED		1	video link for public affairs TV at KSC
7900-8025	FIXED-SATELLITE (Earth-to-space) MOBILE-SATELLITE (Earth-to-space) Fixed G117		2	Goldstone data links
8025-8175	EARTH EXPLORATION-SATELLITE (space-to-Earth) FIXED FIXED-SATELLITE (Earth-to-space) Mobile-satellite (Earth-to-space) (no airborne transmissions) US258 G117	US258 In the bands 8025-8400 MHz and 25.5-27 GHz, the Earth exploration-satellite service (space-to-Earth) is also allocated on a primary basis for non-Federal use. Authorizations are subject to a case-by-case electromagnetic compatibility analysis.	4	GSFC LEO sat downlinks to various sites (McMurdo Antarctica, Fairbanks AK, Poker Flat AK)
8175-8215	EARTH EXPLORATION-SATELLITE (space-to-Earth) FIXED FIXED-SATELLITE (Earth-to-space) METEOROLOGICAL-SATELLITE (Earth-to-space) Mobile-satellite (Earth-to-space) (no airborne transmissions) US258 G104 G117		3	GSFC LEO sat downlinks to various sites (South Point HI, North Pole, USA)
8215-8400	EARTH EXPLORATION-SATELLITE (space-to-Earth) FIXED FIXED-SATELLITE (Earth-to-space) Mobile-satellite (Earth-to-space) (no airborne transmissions) US258 G117		4	GSFC LEO sat downlinks to Wallops Island VA and Fairbanks AK; DFRC data link; WFF rainfall attenuation measurements
8400-8450	FIXED SPACE RESEARCH (deep space) (space-to-Earth)		25	Goldstone CA Deep Space Network (DSN) downlinks; couple microwave data links at Goldstone and WFF/Wallops Is
8450-8500	FIXED SPACE RESEARCH (space-to-Earth)		4	Goldstone DSN downlink from ESA spacecraft

Table 24. NASA RFAs in 7125-8500 MHz Band

Serial #	Frequency (MHz)	Power (W)	Bandwidth (MHz)	NASA Center	Location of Transmitter	Location of Receiver	Supplemental Notes
NASA105582	7140	12	19.2	GSFC	MOON ORBIT	MOON ORBIT	SUPPORTS LUNAR RECONNAISSANCE ORBITER (LRO) ACTIVE SENSOR. LRO WILL ORBIT AROUND MOON WITH A 50 KM ALTITUDE FOR FIRST YEAR. 30X216 KM ALTITUDE AFTER FIRST YEAR. RADAR WILL OPERATE TOWARD THE MOON ONLY. RADAR WILL OPERATE ON AN UNPROTECTED, NON-INTERFERENCE BASIS. RADAR OPERATES ONLY IN LUNAR ORBIT.
NASA000309	7155.3773	20000	0.034	JPL	GOLDSTONE	DEEP SPACE MARS ORBIT	GOLDSTONE 34-METER STATION DSS-15 SUPPORT FOR MARS SURVEYOR 2001 ORBITER (MARS ODYSSEY) FOR TELEMETRY, RANGING AND PLANET OPERATIONS.
NASA000310	7155.3773	20000	0.034	JPL	GOLDSTONE	MARS ORBIT	GOLDSTONE 34-METER STATION DSS-25 SUPPORT FOR MARS SURVEYOR 2001 ORBITER (MARS ODYSSEY) FOR TELEMETRY, RANGING AND PLANET OPERATIONS.
NASA023074	7156.5331	20000	0.036	JPL	GOLDSTONE DSS 14	DEEP SPACE	SUPPORTS TELECOMMAND, TRACKING AND RANGING FOR MUSES-C SPACECRAFT.
NASA023075	7156.5331	20000	0.036	JPL	GOLDSTONE DSS 15	DEEP SPACE	SUPPORTS TELECOMMAND, TRACKING AND RANGING FOR MUSES-C SPACECRAFT.
NASA023076	7156.5331	20000	0.036	JPL	GOLDSTONE DSS 24	DEEP SPACE	SUPPORTS TELECOMMAND, TRACKING AND RANGING FOR MUSES-C SPACECRAFT.
NASA023077	7156.5331	20000	0.036	JPL	GOLDSTONE DSS 25	DEEP SPACE	SUPPORTS TELECOMMAND, TRACKING AND RANGING FOR MUSES-C SPACECRAFT.
NASA023078	7156.5331	20000	0.036	JPL	GOLDSTONE DSS 26	DEEP SPACE	SUPPORTS TELECOMMAND, TRACKING AND RANGING FOR MUSES-C SPACECRAFT.
NASA990149	7161.1566	20000	0.036	JPL	GOLDSTONE DSS 14	DEEP SPACE	SUPPORTS NASA SPACE INFRARED TELESCOPE FACILITY (SIRTF) SATELLITE SYSTEM
NASA990147	7161.1566	20000	0.036	JPL	GOLDSTONE DSS 15	DEEP SPACE	SUPPORTS NASA SPACE INFRARED TELESCOPE FACILITY (SIRTF) SATELLITE SYSTEM
NASA043027	7165.78	20000	0.036	JPL	GOLDSTONE DSS 14	DEEP SPACE	SUPPORTS TELECOMMAND, TRACKING AND RANGING FOR EUROPEAN SPACE AGENCY VENUS EXPRESS SPACECRAFT.
NASA043028	7165.78	20000	0.036	JPL	GOLDSTONE DSS 15	DEEP SPACE	SUPPORTS TELECOMMAND, TRACKING AND RANGING FOR EUROPEAN SPACE AGENCY VENUS EXPRESS SPACECRAFT.
NASA043030	7165.78	20000	0.036	JPL	GOLDSTONE DSS 24	DEEP SPACE	SUPPORTS TELECOMMAND, TRACKING AND RANGING FOR EUROPEAN SPACE AGENCY VENUS EXPRESS SPACECRAFT.
NASA043031	7165.78	20000	0.036	JPL	GOLDSTONE DSS 25	DEEP SPACE	SUPPORTS TELECOMMAND, TRACKING AND RANGING FOR EUROPEAN SPACE AGENCY VENUS EXPRESS SPACECRAFT.
NASA043032	7165.78	20000	0.036	JPL	GOLDSTONE DSS 26	DEEP SPACE	SUPPORTS TELECOMMAND, TRACKING AND RANGING FOR EUROPEAN SPACE AGENCY VENUS EXPRESS SPACECRAFT.
NASA023066	7166.9359	20000	0.036	JPL	GOLDSTONE DSS 14	DEEP SPACE MARS	SUPPORTS TELECOMMAND, TRACKING AND RANGING FOR EUROPEAN SPACE AGENCY MARS EXPRESS SPACECRAFT.
NASA023067	7166.9359	20000	0.036	JPL	GOLDSTONE DSS 15	DEEP SPACE MARS	SUPPORTS TELECOMMAND, TRACKING AND RANGING FOR EUROPEAN SPACE AGENCY MARS EXPRESS SPACECRAFT.
NASA023069	7166.9359	20000	0.036	JPL	GOLDSTONE DSS 24	DEEP SPACE MARS	SUPPORTS TELECOMMAND, TRACKING AND RANGING FOR EUROPEAN SPACE AGENCY MARS EXPRESS SPACECRAFT.
NASA023070	7166.9359	20000	0.036	JPL	GOLDSTONE DSS 25	DEEP SPACE MARS	SUPPORTS TELECOMMAND, TRACKING AND RANGING FOR EUROPEAN SPACE AGENCY MARS EXPRESS SPACECRAFT.
NASA023071	7166.9359	20000	0.036	JPL	GOLDSTONE DSS 26	DEEP SPACE MARS	SUPPORTS TELECOMMAND, TRACKING AND RANGING FOR EUROPEAN SPACE AGENCY MARS EXPRESS SPACECRAFT.
NASA023061	7168.0918	20000	0.036	JPL	GOLDSTONE DSS 15	DEEP SPACE	SUPPORTS TELECOMMAND, TRACKING AND RANGING FOR ESA ROSETTA SPACECRAFT.
NASA033054	7168.0918	20000	0.036	JPL	GOLDSTONE DSS 25	DEEP SPACE	SUPPORTS TELECOMMAND, TRACKING AND RANGING FOR ESA ROSETTA SPACECRAFT.
NASA093008	7170.4035	20000	0.036	JPL	GOLDSTONE DSS 14	DEEP SPACE	EARTH-TO-SPACE COMMAND LINK REQUIRED FOR SUPPORT OF KEPLER DEEP SPACE SPACECRAFT. KEPLER IS IN AN EARTH TRAILING HELIOCENTRIC ORBIT WITH A PERIOD OF 372.5 DAYS.
NASA093007	7170.4035	20000	0.036	JPL	GOLDSTONE DSS 25	DEEP SPACE	EARTH-TO-SPACE COMMAND LINK REQUIRED FOR SUPPORT OF KEPLER DEEP SPACE SPACECRAFT. KEPLER IS IN AN EARTH TRAILING HELIOCENTRIC ORBIT WITH A PERIOD OF 372.5 DAYS.
NASA960381	7173	1	25	WFF	ASSATEAGUE ISLAND	WALLOPS ISLAND	FOR LIGHTNING DETECTION AND RANGING (LDAR) MICROWAVE SYSTEM.
NASA003017	7175.027	20000	0.034	JPL	GOLDSTONE DSS 14	DEEP SPACE	FOR TELECOMMAND AND RANGING SUPPORT OF THE STARDUST SPACECRAFT
NASA950174	7175.027	20000	0.034	JPL	GOLDSTONE DSS 14	DEEP SPACE CASSINI CRAFT	EARTH-TO-SPACE LINK FOR COMMANDING AND RANGING OF CASSINI SPACECRAFT.
NASA950173	7175.027	20000	0.034	JPL	GOLDSTONE DSS 15	DEEP SPACE CASSINI CRAFT	EARTH-TO-SPACE LINK FOR COMMANDING AND RANGING OF CASSINI SPACECRAFT.
NASA990010	7175.027	20000	0.034	JPL	GOLDSTONE DSS 15	DEEP SPACE PROBE	SUPPORTS STARDUST DEEP SPACE PROBE FOR TELEMETRY AND RANGING.
NASA003018	7175.027	4000	0.034	JPL	GOLDSTONE DSS 25	DEEP SPACE	FOR TELECOMMAND AND RANGING SUPPORT OF THE STARDUST SPACECRAFT
NASA003019	7175.027	4000	0.034	JPL	GOLDSTONE DSS 25	DEEP SPACE PROBE	FOR TELECOMMAND AND RANGING SUPPORT OF THE CASSINI SPACECRAFT
NASA020010	7177.3387	20000	0.034	JPL	GOLDSTONE DSS 14	DEEP SPACE	SUPPORTS MESSENGER EARTH-TO-SPACE FOR EMERGENCY COMMUNICATIONS AND SPECIAL EVENTS SUCH AS BURNS AND PLANETARY FLYBYS.
NASA020011	7177.3387	20000	0.034	JPL	GOLDSTONE DSS 15	DEEP SPACE	SUPPORTS MESSENGER FOR EARTH-TO-SPACE PRIMARY COMMANDING/RANGING AND TELEMETRY DURING ORBITAL PHASE OF MISSION APRIL 2009-2010.
NASA020012	7177.3387	20000	0.034	JPL	GOLDSTONE DSS 25	DEEP SPACE	SUPPORTS MESSENGER FOR EARTH-TO-SPACE PRIMARY COMMANDING/RANGING
NASA020046	7179.6504	4000	0.034	JPL	GOLDSTONE	DEEP SPACE MARS ORBIT	SUPPORTS COMMANDING AND RANGING OF THE MARS MER-1 SPACECRAFT.
NASA020048	7179.6504	20000	0.034	JPL	GOLDSTONE	DEEP SPACE MARS	SUPPORTS COMMANDING AND RANGING OF THE MARS ROVER MER-1.
NASA020050	7179.6504	20000	0.034	JPL	GOLDSTONE	DEEP SPACE MARS	SUPPORTS COMMANDING AND RANGING OF THE MARS ROVER MER-1.
NASA030009	7179.6504	20000	0.036	JPL	GOLDSTONE DSS 14	DEEP SPACE	SUPPORTS TELECOMMAND AND RANGING OPERATIONS OF THE DEEP IMPACT IN JULY 07, DEEP IMPACT HAD NEW ASSIGNMENT AFTER SUCCESSFULLY COMPLETED ITS PRIMARY MISSION. NOW KNOWN AS EPOXI, IT IS ON THE WAY FOR COMET HARTLEY 2 FLYBY IN FALL 2010.
NASA040012	7179.6504	20000	0.036	JPL	GOLDSTONE DSS 14	DEEP SPACE PROBE	EARTH-TO-SPACE COMMAND AND RANGING UPLINK REQUIRED FOR SUPPORT OF DAWN SPACECRAFT. DAWN WILL EXPLORE THE STRUTURE AND COMPOSITION OF CERES AND VESTA, TWO OF THE LARGEST ASTEROIDS IN THE SOLAR SYSTEM. DAWN WILL RENDEZVOUS WITH CERES IN 2011 AND VESTA IN 2015.
NASA030008	7179.6504	20000	0.036	JPL	GOLDSTONE DSS 25	DEEP SPACE	SUPPORTS TELECOMMAND AND RANGING OPERATIONS OF EPOXI (PREVIOUSLY KNOWN AS DEEP IMPACT). IN JULY 07, DEEP IMPACT HAD NEW ASSIGNMENT AFTER SUCCESSFULLY COMPLETING ITS PRIMARY MISSION. NOW KNOWN AS EPOXI, IT IS ON THE WAY FOR COMET HARTLEY 2 FLYBY IN FALL 2010.
NASA040011	7179.6504	20000	0.036	JPL	GOLDSTONE DSS 25	DEEP SPACE PROBE	EARTH-TO-SPACE COMMAND AND RANGING UPLINK REQUIRED FOR SUPPORT OF DAWN SPACECRAFT. DAWN WILL EXPLORE THE STRUTURE AND COMPOSITION OF CERES AND VESTA, TWO OF THE LARGEST ASTEROIDS IN THE SOLAR SYSTEM. DAWN WILL RENDEZVOUS WITH CERES IN 2011 AND VESTA IN 2015.
NASA063003	7182.043388	20000	3	JPL	GOLDSTONE DSS 14	DEEP SPACE	SUPPORTS NEW HORIZONS MISSION TO PLUTO COMMANDING AND RANGING UPLINK OPERATIONS.
NASA063004	7182.043388	20000	3	JPL	GOLDSTONE DSS 15	DEEP SPACE	SUPPORTS NEW HORIZONS MISSION TO PLUTO COMMANDING AND RANGING UPLINK OPERATIONS.
NASA063005	7182.043388	20000	3	JPL	GOLDSTONE DSS 24	DEEP SPACE	SUPPORTS NEW HORIZONS MISSION TO PLUTO COMMANDING AND RANGING UPLINK OPERATIONS.
NASA063006	7182.043388	20000	3	JPL	GOLDSTONE DSS 25	DEEP SPACE	SUPPORTS NEW HORIZONS MISSION TO PLUTO COMMANDING AND RANGING UPLINK OPERATIONS.
NASA063007	7182.043388	20000	3	JPL	GOLDSTONE DSS 26	DEEP SPACE	SUPPORTS NEW HORIZONS MISSION TO PLUTO COMMANDING AND RANGING UPLINK OPERATIONS.
NASA020045	7183.118	4000	0.034	JPL	GOLDSTONE	DEEP SPACE MARS	SUPPORTS COMMANDING AND RANGING OF THE MARS ROVER MER-2.
NASA020047	7183.118	20000	0.034	JPL	GOLDSTONE	DEEP SPACE MARS	SUPPORTS COMMANDING AND RANGING OF THE MARS ROVER MER-2.
NASA020049	7183.118	20000	0.034	JPL	GOLDSTONE	MARS	SUPPORTS COMMANDING AND RANGING OF THE MARS ROVER MER-2.

Table 24. NASA RFAs in 7125-8500 MHz Band (cont.)

NASA030042	7183.118	20000	0.036	JPL	GOLDSTONE DSS 14	DEEP SPACE MARS ORBIT	SUPPORTS COMMANDING AND RANGING OF THE MARS RECONNAISSANCE ORBITER SPACECRAFT.
NASA030043	7183.118	20000	0.036	JPL	GOLDSTONE DSS 15	DEEP SPACE MARS ORBIT	SUPPORTS COMMANDING AND RANGING OF THE MARS RECONNAISSANCE ORBITER SPACECRAFT.
NASA030044	7183.118	20000	0.036	JPL	GOLDSTONE DSS 25	DEEP SPACE MARS ORBIT	SUPPORTS COMMANDING AND RANGING OF THE MARS RECONNAISSANCE ORBITER SPACECRAFT.
NASA040001	7186.5856	20000	0.036	JPL	GOLDSTONE DSS 14	DEEP SPACE	SUPPORTS COMMANDING AND RANGING OF THE STEREO SPACECRAFT (A).
NASA040002	7186.5856	20000	0.036	JPL	GOLDSTONE DSS 15	DEEP SPACE	SUPPORTS COMMANDING AND RANGING OF THE STEREO SPACECRAFT (A).
NASA040004	7186.5856	20000	0.036	JPL	GOLDSTONE DSS 24	DEEP SPACE	SUPPORTS COMMANDING AND RANGING OF THE STEREO SPACECRAFT (A).
NASA040003	7186.5856	20000	0.036	JPL	GOLDSTONE DSS 25	DEEP SPACE	SUPPORTS COMMANDING AND RANGING OF THE STEREO SPACECRAFT (A).
NASA040006	7188.8973	20000	0.036	JPL	GOLDSTONE DSS 14	DEEP SPACE	SUPPORTS COMMANDING AND RANGING OF THE STEREO SPACECRAFT (B).
NASA040007	7188.8973	20000	0.036	JPL	GOLDSTONE DSS 15	DEEP SPACE	SUPPORTS COMMANDING AND RANGING OF THE STEREO SPACECRAFT (B).
NASA040009	7188.8973	20000	0.036	JPL	GOLDSTONE DSS 24	DEEP SPACE	SUPPORTS COMMANDING AND RANGING OF THE STEREO SPACECRAFT (B).
NASA040008	7188.8973	20000	0.036	JPL	GOLDSTONE DSS 26	DEEP SPACE	SUPPORTS COMMANDING AND RANGING OF THE STEREO SPACECRAFT (B).
NASA093017	7196.358	2000	2	JPL	GOLDSTONE DSS 26	NONGEOSTATIONARY	SUPPORTS TELECOMMAND AND TRACKING FOR EUROPEAN SPACE AGENCY PLANCK SPACECRAFT DURING CIRTICAL AND EMERGENCY EVENTS. SPACECRAFT ORBIT CAN NOT BE DESCRIBED USING THE CLASSICAL ORBITAL ELEMENTS. PLANCK IS IN L2 ORBIT ABOUT 1.5 MILLION KM AWAY FROM EARTH. IT IS A GRAVATIONAL SADDLE POINT WHERE SPACECRAFT WILL REMAIN AT ROUGHLY CONSTANT DISTANCE FROM THE EARTH THROUGHOUT THE YEAR BY SMALL STATION-KEEPING MANEUVERS.
NASA093015	7207.8483	2000	2	JPL	GOLDSTONE DSS 26	NONGEOSTATIONARY	SUPPORTS TELECOMMAND AND TRACKING FOR EUROPEAN SPACE AGENCY HERSCHEL SPACECRAFT DURING CIRTICAL AND EMERGENCY EVENTS. SPACECRAFT ORBIT CAN NOT BE DESCRIBED USING THE CLASSICAL ORBITAL ELEMENTS. HERSCHEL IS IN L2 ORBIT ABOUT 1.5 MILLION KM AWAY FROM EARTH. IT IS A GRAVATIONAL SADDLE POINT WHERE SPACECRAFT WILL REMAIN AT ROUGHLY CONSTANT DISTANCE FROM THE EARTH THROUGHOUT THE YEAR BY SMALL STATION-KEEPING MANEUVERS.
NASA760170	7245	1	25	DFRC	EDWARDS	EDWARDS	SUPPORTS COLOR TELEVISION BROADCAST FROM SHUTTLE LANDING AREA TO DRYDEN FLIGHT RESEARCH CENTER BUILDING 4800.
NASA092523	7325	1	25	WFF	NEW CHURCH	WALLOPS ISLAND	FOR LIGHTNING DETECTION AND RANGING (LDAR) MICROWAVE SYSTEM.
NASA960382	7325	1	25	WFF	WALLOPS ISLAND	WALLOPS ISLAND	FOR LIGHTNING DETECTION AND RANGING (LDAR) MICROWAVE SYSTEM.
NASA870201	7605	1	25	DFRC	EDWARDS	EDWARDS	SUPPORTS LANDING VIDEO FOR SHUTTLE AND OTHER AERONAUTICAL FLIGHT TEST PROGRAMS.
NASA800505	7710	2	30	JPL	GOLDSTONE	GOLDSTONE	MARS-ECHO SITE MICROWAVE LINK AT GOLDSTONE DEEPSPACE COMMUNICATION COMPLEX. R01, R02 AND R03 ARE PASSIVE REFLECTORS. R01 AND R02 ARE ADJACENT TO EACH OTHER.
NASA960100	7710	2	25	KSC	KENNEDY SPACE CENTER	KENNEDY SPACE CENTER	REMOTE VIDEO LINK FOR PUBLIC AFFAIRS TV. VIDEO LINK FOR PUBLIC AFFAIRS ENG VANS.
NASA960101	7765	2	25	KSC	KENNEDY SPACE CENTER	KENNEDY SPACE CENTER	REMOTE VIDEO LINK FOR PUBLIC AFFAIRS TV. VIDEO LINK FOR PUBLIC AFFAIRS ENG VANS.
NASA092524	7765	1	25	WFF	MODEST TOWN	WALLOPS ISLAND	FOR LIGHTNING DETECTION AND RANGING (LDAR) MICROWAVE SYSTEM.
NASA960380	7765	1	25	WFF	WALLOPS ISLAND	WALLOPS ISLAND	FOR LIGHTNING DETECTION AND RANGING (LDAR) MICROWAVE SYSTEM.
NASA960102	7825	2	25	KSC	KENNEDY SPACE CENTER	KENNEDY SPACE CENTER	REMOTE VIDEO LINK FOR PUBLIC AFFAIRS TV. VIDEO LINK FOR PUBLIC AFFAIRS ENG VANS.
NASA960103	7885	2	25	KSC	KENNEDY SPACE CENTER	KENNEDY SPACE CENTER	REMOTE VIDEO LINK FOR PUBLIC AFFAIRS TV. VIDEO LINK FOR PUBLIC AFFAIRS ENG VANS.
NASA853070	8010	2	30	JPL	GOLDSTONE	GOLDSTONE	ECHO-MARS SITE MICEOWAVE LINK AT GOLDSTONE DEEPSPACE COMMUNICATION COMPLEX. R01, R02, AND R03 ARE PASSIVE REFLECTORS. R02 AND R03 ARE ADJACENT TO EACH OTHER.
NASA013063	8025	0.01	0.0001	JPL	GOLDSTONE	GOLDSTONE	TEST TRANSMITTER INSTALLED AT GOLDSTONE COLLIMATION TOWER LOCATED NEAR STATION DSS-17. USED TO CALIBRATE THE AUTOTRACK CAPABILITY OF THE X-BAND ACQUISITION AID LOCATED AT DSS-16. TRANSMITTED FREQ. IS BASED ON FREQ. OF SPACECRAFT PLANNED TO BE TRACKED. BAND ASSIGNMENT IS NECESSARY TO CALIBRATE SYSTEM TO PROPOSED SPACECRAFT FREQUENCY. TRANSMITTER IS TUNED IN 1 KHZ INCREMENTS.
NASA040020	8040	14.1	24	GSFC	NONGEOSTATIONARY	MCMURDO 10M	SUPPORTS RECEIVING OF EARTH RESOURCES DATA AT 10M SITE AT MCMURDO FROM MCMURDO FROM ESA ERS-2.
NASA960316	8140	20	120	GSFC	NONGEOSTATIONARY	FAIRBANKS ASF 10 MTR	REQUIRED TO PASSIVELY RECEIVE EARTH RESOURCES DATA AT UNIV OF ALASKA ASF ON 10M AND 11M, AND 10M AT MCMURDO FROM ERS -1
NASA010059	8160	18	15	GSFC	NONGEOSTATIONARY	POKER FLAT	SUPPORTS EARTH OBSERVATION SYSTEM - AURA SATELLITE SYSTEM DATA DOWNLINK OPERATIONS. PER SPS RECOMMENDS 3(A) NASA REAL TIME BROADCAST MODE MUST BE LIMITED TO THOSE PERIODS WHEN THE SATELLITE IS WITHIN LINE-OF-SIGHT OF ALASKA.
NASA990084	8160	25	15	GSFC	NONGEOSTATIONARY	POKER FLAT	SUPPORTS AQUA (EOS-PM) SATELLITE SYSTEM DATA DOWNLINK BROADCAST OPERATIONS WORLDWIDE USING 15 MBPS. 150 MBPS AT POKER FLAT AK ONLY.
NASA020023	8190	6	50	GSFC	NONGEOSTATIONARY	SOUTH POINT	SUPPORTS NASA GALAXY EVOLUTION EXPLORER (GALEX) SATELLITE SYSTEM - DATA DOWNLINK
NASA050007	8190	3.31	40	GSFC	NONGEOSTATIONARY	NORTH POLE	SUPPORTS NASA GLORY SATELLITE SYSTEM DATA DOWNLINK
NASA095501	8212.5	9	60	GSFC	NONGEOSTATIONARY	USA	R01 SUPPORTS TERRA FORMERLY EARTH OBSERVING SYSTEM (EOS-AM) SPACE-TO-GROUND LINKS. ALL EARTH TERMINALS MUST OPERATE ON A NON-INTERFERENCE BASIS TO OTHER GOVERNMENT OPERATIONS. R02 SUPPORTS EOS-DAS DIRECT ACCESS SYSTEM.
NASA990076	8225	3	105	GSFC	NONGEOSTATIONARY	WALLOPS ISLAND	SUPPORTS EARTH ORBITER-1 SATELLITE SYSTEM DATA DOWNLINK OPERATIONS. PER SPS RECOMMENDS 2 IN IRAC 30978 NASA COORDINATE THIS SYSTEMS OPERATIONS WITH DSCS EARTH STATIONS (INCLUDING TRANSPORTABLE), AND BE AWARE THAT THE DOD CANNOT GUARANTEE PROTECTION FROM EXISTING DSCS OPERATIONS IN THE POKER FLAT AK AREA.
NASA870202	8330	1	25	DFRC	EDWARDS	EDWARDS	SUPPORTS LANDING VIDEO FOR SHUTTLE AND OTHER AERONAUTICAL FLIGHT TEST PROGRAMS.
NASA010039	8330	9	80	GSFC	NONGEOSTATIONARY	FAIRBANKS	SUPPORTS PICASSO DATA DOWNLINK OPERATIONS.
NASA082509	8350	0.1	0	WFF	WALLOPS ISLAND	WALLOPS ISLAND	FOR IMPROVING TECHNIQUES FOR MEASURING RAINFALL BY MEASURING THE ATTENUATION OF RF TRANSMISSIONS
NASA000311	8406.8518	15	2	JPL	DEEP SPACE MARS ORBIT	GOLDSTONE DSS 15	SUPPORTS MARS SURVEYOR 2001 ORBITER (MARS ODYSSEY) TELEMETRY AND RANGING
NASA023079	8408.2098	12	3.1	JPL	DEEP SPACE	GOLDSTONE DSS 24	SUPPORTS TELEMETRY AND RANGING OF THE JAPANESE HAYABUSA SPACECRAFT PREVIOUSLY DESIGNATED MUSES-C.
NASA880301	8408.2098	17.8	0.8	JPL	DEEP SPACE	GOLDSTONE	SUPPORTS ULYSSES PROGRAM (FORMERLY ISPM).
NASA990148	8413.6419	15	8.8	JPL	DEEP SPACE	GOLDSTONE DSS 15	SUPPORTS NASA SPACE INFRARED TELESCOPE FACILITY (SIRTF) SATELLITE SYSTEM
NASA043034	8419.074	5	4	JPL	DEEP SPACE	GOLDSTONE DSS 24	SUPPORTS TELEMETRY AND RANGING OF THE EUROPEAN SPACE AGENCY VENUS EXPRESS SPACECRAFT.
NASA023073	8420.432	13	3.5	JPL	DEEP SPACE MARS	GOLDSTONE DSS 24	SUPPORTS TELEMETRY AND RANGING FOR EUROPEAN SPACE AGENCY MARS EXPRESS SPACECRAFT.
NASA800427	8420.4321	20	3.3	JPL	DEEP SPACE	GOLDSTONE	TRACKING AND COMMAND OF VOYAGER 1
NASA023049	8421.7901	28	2.5	JPL	DEEP SPACE	GOLDSTONE DSS 24	SUPPORTS TELEMETRY AND RANGING OF THE ROSETTA SPACECRAFT
NASA093005	8424.5061	25	0.156	JPL	DEEP SPACE	GOLDSTONE DSS 25	SPACE-TO-EARTH DATA AND TELEMETRY DOWNLINK REQUIRED FOR SUPPORT OF KEPLER DEEP SPACE SPACECRAFT. KEPLER IS IN AN EARTH TRAILING HELIOCENTRIC ORBIT WITH A PERIOD OF 372.5 DAYS.
NASA950176	8427.222	20	3.8	JPL	DEEP SPACE CASSINI CRAF	GOLDSTONE DSS 14	CASSINI SPACECRAFT TELEMETRY AND RANGING (DIRECT SPACE-TO-EARTH) VIA DEEP SPACE NETWORK. SPS STAGE IV APPROVED 12 JUNE 97
NASA990012	8427.2222	15	1.5	JPL	DEEP SPACE PROBE	GOLDSTONE DSS 15	SUPPORTS STARDUST DEEP SPACE PROBE SPACECRAFT TELEMETRY AND RANGING.
NASA950177	8429.938	20	1	JPL	DEEP SPACE CASSINI CRAF	GOLDSTONE DSS 14	CASSINI SPACECRAFT TELEMETRY AND RANGING (DIRECT SPACE-TO-EARTH) VIA DEEP SPACE NETWORK. SPS STAGE IV APPROVED 12 JUNE 97
NASA990013	8429.9382	15	1.5	JPL	DEEP SPACE PROBE	GOLDSTONE DSS 15	SUPPORTS STARDUST DEEP SPACE PROBE SPACECRAFT TELEMETRY AND RANGING.
NASA963054	8430	1	0.0001	JPL	GOLDSTONE	GOLDSTONE	TRANSMITTER INSTALLED AT COLLIMATION TOWER-16 FOR OCCASIONAL CALIBRATION OF THE X-BAND ACQUISITION AID LOCATED AT GOLDSTONE 11-METER VLBI STN. DSS-23.TERRESTRIAL STATION EMPLOYING SPACE STATION TECHNIQUES - SPD REQUIRED.

Table 24. NASA RFAs in 7125-8500 MHz Band (cont.)

NASA020013	8432.6543	22.7	2	JPL	DEEP SPACE	GOLDSTONE DSS 15	SUPPORTS MESSENGER SPACE-TO-EARTH TELEMETRY AND RANGING THROUGHOUT THE MISSION.
NASA030010	8435.3703	20	2.5	JPL	DEEP SPACE	GOLDSTONE DSS 14	IN JULY 07, DEEP IMPACT HAD NEW ASSIGNMENT AFTER SUCCESSFULLY COMPLETED ITS PRIMARY MISSION. NOW KNOWN AS EPOXI, IT IS ON THE WAY FOR COMET HARTLEY 2 FLYBY IN FALL 2010. SUPPORTS DEEP IMPACT SPACECRAFT TELEMETRY AND RANGING.
NASA040013	8435.3703	100	1.48	JPL	DEEP SPACE	GOLDSTONE DSS 25	SPACE-TO-EARTH DATA DOWNLINK (TELEMETRY AND RANGING) REQUIRED FOR SUPPORT OF DAWN PROBE. DAWN WILL EXPLORE THE STRUCTURE AND COMPOSITION OF CERES AND VESTA, TWO OF THE LARGEST ASTEROIDS IN THE SOLAR SYSTEM. DAWN WILL RENDEZVOUS WITH CERES IN 2011 AND VESTA IN 2015.
NASA020052	8435.3703	15	2.05	JPL	DEEP SPACE MARS	GOLDSTONE DSS 25	SUPPORTS TELEMETRY AND RANGING OF THE MARS ROVERS MER-1 AND MER-2. ALSO SUPPORTS TELEMETRY ON SURFACE OF MARS DIRECT-TO-EARTH FROM TWO ROVERS. UHF UPLINK FM MARS SURFACE TO X-BD XPNDR IN ORBITER TO EARTH.
NASA060002	8437.894737	12	3.31	JPL	DEEP SPACE	GOLDSTONE DSS 14	SUPPORTS NEW HORIZONS MISSION TO PLUTO DATA DOWNLINK OPERATIONS.
NASA060001	8438.181818	12	3.31	JPL	DEEP SPACE	GOLDSTONE DSS 14	SUPPORTS NEW HORIZONS MISSION TO PLUTO DATA DOWNLINK OPERATIONS.
NASA020051	8439.4444	15	2.05	JPL	DEEP SPACE MARS	GOLDSTONE DSS 25	SUPPORTS TELEMETRY AND RANGING OF THE MARS ROVERS MER-1 AND MER-2. ALSO SUPPORTS TELEMETRY ON SURFACE OF MARS DIRECT-TO-EARTH FROM TWO ROVERS. UHF UPLINK FM MARS SURFACE TO X-BD XPNDR IN ORBITER TO EARTH.
NASA030045	8439.4444	100	6	JPL	DEEP SPACE MARS ORBIT	GOLDSTONE DSS 25	SUPPORTS TELEMETRY AND RANGING OF THE MARS RECONNAISSANCE ORBITER SPACECRAFT. PFD WAIVER GRANTED BY NTIA.
NASA093009	8443.5185	50.2	3.84	JPL	DEEP SPACE	GOLDSTONE DSS 25	SUPPORTS DATA AND TELEMETRY DOWNLINK FOR THE STEREO-A SPACECRAFT. REPLACEMENT FOR NASA040005 THAT EXPIRES WHILE WAITING FOR AGENDA REVIEW.
NASA040010	8446.2345	50.2	3.84	JPL	DEEP SPACE	GOLDSTONE DSS 26	SUPPORTS DATA DOWNLINK FROM THE STEREO SPACECRAFT (B).
NASA082510	8450	0.1	0	WFF	WALLOPS ISLAND	WALLOPS ISLAND	FOR IMPROVING TECHNIQUES FOR MEASURING RAINFALL BY MEASURING THE ATTENUATION OF RF TRANSMISSIONS
NASA093012	8455	25	6.2	JPL	NONGEOSTATIONARY	GOLDSTONE DSS 26	SUPPORTS TELEMETRY FOR EUROPEAN SPACE AGENCY PLANCK SPACECRAFT DURING CIRTICAL AND EMERGENCY EVENTS. SPACECRAFT ORBIT CAN NOT BE DESCRIBED USING THE CLASSICAL ORBITAL ELEMENTS. PLANCK IS IN L2 ORBIT ABOUT 1.5 MILLION KM AWAY FROM EARTH. IT IS A GRAVATIONAL SADDLE POINT WHERE SPACECRAFT WILL REMAIN AT ROUGHLY CONSTANT DISTANCE FROM THE EARTH THROUGHOUT THE YEAR BY SMALL STATION-KEEPING MANEUVERS.
NASA093016	8468.5	14	6.2	JPL	NONGEOSTATIONARY	GOLDSTONE DSS 26	SUPPORTS TELEMETRY FOR EUROPEAN SPACE AGENCY HERSCHEL SPACECRAFT DURING CIRTICAL AND EMERGENCY EVENTS. SPACECRAFT ORBIT CAN NOT BE DESCRIBED USING THE CLASSICAL ORBITAL ELEMENTS. HERSCHEL IS IN L2 ORBIT ABOUT 1.5 MILLION KM AWAY FROM EARTH. IT IS A GRAVATIONAL SADDLE POINT WHERE SPACECRAFT WILL REMAIN AT ROUGHLY CONSTANT DISTANCE FROM THE EARTH THROUGHOUT THE YEAR BY SMALL STATION-KEEPING MANEUVERS.
NASA963055	8480	1	0.0001	JPL	GOLDSTONE	GOLDSTONE	TRANSMITTER INSTALLED AT COLLIMATION TOWER-16 FOR OCCASIONAL CALIBRATION OF THE X-BAND ACQUISITION AID LOCATED AT GOLDSTONE 11-METER VLBI STN. DSS-23.TERRESTRIAL STATION EMPLOYING SPACE STATION TECHNIQUES - SPD REQUIRED.
NASA963065	8494	0.003	10	JPL	GOLDSTONE	GOLDSTONE	TRANSMITTER INSTALLED AT COLLIMATION TOWER-16 FOR CALIBRATION OF THE X-BAND ACQUISITION AID LOCATED AT GOLDSTONE 11-METER VLBI STN. DSS-23. SYSTEM SIMULATES A SPACE STATION. TOM WOODS AGREE THAT PARA 5.3.3 DOE NOT APPLY FOR THIS SIMULATED SPACE STATION OPERATION.