ORBITAL TEST BED-3, ADVANCED DATA COLLECTION SYSTEM (A-DCS) HOSTED PAYLOAD SERVICES

EXHIBIT A -
TECHNICAL NARRATIVE FOR FCC FORM 442

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REVISION HISTORY

Revision	Date	Description of Change
1	2020/10/10	Draft release

POINT OF CONTACT

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ACRONYMS

Acronym	Definition
A-DCS	Advanced Data Collection System
ARGOS-4	Argos Hosted Payload
BPSK	Binary Phase Shift Keying
CFE	Customer Furnished Equipment
CFR	Code of Federal Regulations
CNES	Center National d'Études Spatiales (National Center for Space Studies)
dB	DeciBel
dBi	deciBel relative to isotropic radiator
dBm	deciBel relative to 1 milli-Watt
dBW	deciBel relative to 1 Watt
EIRP	Effective Isotropic Radiated Power
EoL	End of Life
EESS	Earth Exploration Satellite Services
FCC	Federal Communications Commission
GA	General Atomics
HoPS	Hosted Payload Services
ITU	International Telecommunication Union
LEO	Low Earth Orbit
METSAT	Meteorological Satellite Service
MOC	Mission Operations Center
MSS	Mobile Satellite Services
N/A	Not Applicable
NOAA	National Oceanic and Atmospheric Administration
NTIA	National Telecommunications and Information Administration
ODAR	Orbital Debris Assessment Report
OTB-3	Orbital Test Bed 3 (satellite)
PoC	Point of Contact
QPSK	Quadrature Phase Shift Keying
RADMON	Radiation Monitor (Primary Payload)
RF	Radio Frequency
TBD	To Be Determined
T&C	Telemetry and Commanding
UHF	Ultra High Frequency
W	Watt
WAN	Wide Area Network (Internet)

1 INTRODUCTION

This document contains the supplemental technical narrative information required within the Code of Federal Regulations (CFR) Part 5 rules for a Conventional Experimental License application for the Orbital Test Bed 3 (OTB-3) spacecraft. This document provides a technical overview, equipment technical descriptions, spacecraft operations, and additional required data in connection with the associated Form 442 Experimental License application.

2 REFERENCE DOCUMENTS

(deleted)

3 OVERVIEW

3.1 Mission Overview

The GA "Orbital Test Bed #3" (OTB-3) satellite is a small LEO experimental satellite that will provide an in-orbit test bed for the experimentation and demonstration of scientific, research and prototype payloads, subsystems and equipment. GA is the spacecraft owner-operator of the OTB-3 spacecraft, and the owner of the OTB-3 Primary Payload mission. The OTB-3 satellite will accommodate a primary experimental payload called the Radiation Monitor (RADMON), sponsored by GA, which provides near real-time measured data on the long-term radiation environment experienced in the LEO environment, and correlates the radiation activity with on-board electronics performance. The RADMON is considered a 'passive' payload in that it does not generate RF.

The OTB-3 will also host the Customer-Furnished Argos Advanced Data Collection Service (A-DCS) ARGOS-4 payload, under the Hosted Payload Services (HoPS) contract with the U.S. Air Force Space and Missile Systems Center. Argos is an international collaboration that supports geolocation and tracking services of thousands of ground transmitters used for wildlife monitoring, tracking of ocean buoys, atmospheric and ocean monitoring/research, fishery management, oil spill tracking, and vessel tracking, among other commercial and non-commercial uses. Additional information on the Argos program is provided below in Section 3.7.

3.2 Program Critical Dates and Launch Schedule

The OTB-3 satellite is currently in development against the following program schedule and planned launch date.

Table 1. Program Critical Dates and Launch Schedule

Milestone	Date
Kickoff	08 January 2019 (completed)
Preliminary Design Review (PDR)	05 May 2019 (completed)
Critical Design Review (CDR)	10 December 2019 (completed)
Test Readiness Review (TRR)	01 April 2021
Pre-Launch Review (PLR)	02 September 2021
Proposed Launch	**02 December 2021**

3.3 Launch Program

The OTB-3 satellite is planned for launch from Mahia, New Zealand, using the Rocket Lab Electron launch vehicle. The Rocket Lab Launch Complex 1 is located at 39.26S, 177.26E.

3.4 Mission Duration

The OTB-3 satellite will operate in-orbit for 5 years to allow the primary RADMON payload sufficient time to gather measurement data on the effects of long-term exposure to radiation on the experiments. The contractual obligation of the ARGOS-4 HoPS mission is also 5 years. Therefore, this application is requesting the maximum 5 year duration of the experimental license.

3.5 Orbital Summary

The OTB-3 orbital characteristics are summarized in Table 2.

Table 2. Orbital Characteristics Summary

Orbital Characteristic	
Elevation	750 kilometers maximum
Inclination	98.3±0.05 degrees
Local Time of Ascending Node (LTAN)	17:30 (±1 hour)
Pointing and Maneuvers	
Spacecraft Pointing	Three-axis spin stabilized spacecraft. Nadir pointing during operations

Propulsion	None. OTB-3 has no means to alter the orbit into which it is delivered. There are no orbit maneuvers or transfers planned over the mission duration.
Mass	120kg
End of Life	
End of Life	Deployable drag augmentation device to accelerate orbit decay. See ODAR for details.

3.6 General Atomics Licensing Point of Contact

The GA point of contact for licensing matters is the following:

Victor Gomez
3550 General Atomics Court
San Diego, CA 92121
+1 858-676-7255
victor.gomez@ga.com

3.7 Argos Hosted Payload Government Contract Information

The Argos Hosted Payload contract was awarded to GA by the U.S Air Force Space and Missile Systems Center under contract number FA8814-14-D-0005. The National Oceanic and Atmospheric Administration (NOAA) is the Government Program Office responsible for technical oversight and management of the Argos HoPS mission, and is one of the international signatories for the Argos program, in collaboration with the A-DCS payload provider – the French Center National d'Études Spatiales (CNES).

The Government contracting officer point of contact is the following:

Ms. Kaylyn Padawang, Contracting Program Manager, USAF AFSCP SMC
Kaylyn.Padawang.1@us.af.mil
310-653-9062
Space & Missile Center
El Segundo, CA 90245

The NOAA Program Manager point of contact is the following:

Mr. Charles DeLee, ARGOS-4 HoPS Deputy Program Manager
NOAA/NESDIS Office of Projects, Planning, and Analysis (OPPA)
Charles.Delee@noaa.gov
301-713-7199
Silver Spring, MD

4 FREQUENCY PLAN

The OTB-3 spacecraft will make use of multiple frequencies to support the overall satellite operations, in addition to hosting the Argos-4 mission as described below, and illustrated in Figure 1.

- **S-Band:** S-Band supports the overall satellite Telemetry and Command links (T&C), the Argos payload Telemetry & Commanding, and RADMON experimental Payload data downloads. The S-Band two-way links will be active only during ground station contacts between 1-2 times a day for nominal operations.
- **UHF Band:** UHF Band supports the uplink from and downlink to thousands of Argos ground-based mobile tracking radios. Most of the uplinks contain data used to locate the mobile radios. Some of the mobile devices also have the ability to receive a UHF downlink to the tracking radio. This band usage is required by the ARGOS-4 Hosted Payload. The UHF transceiver will be continuously on during normal operations over the 5-year mission. NOAA will submit the NTIA frequency filing for the UHF spectrum.
- **L-Band:** L-Band supports downlink of Argos payload mission data to various Kineis ground stations, formerly known as CLS America, and Kineis stations in France. This band usage is also required for the Argos mission. The L-Band transmitter downlink will be continuously on during normal operations over the 5-year mission. NOAA will submit the NTIA frequency filing for the L-Band downlink.

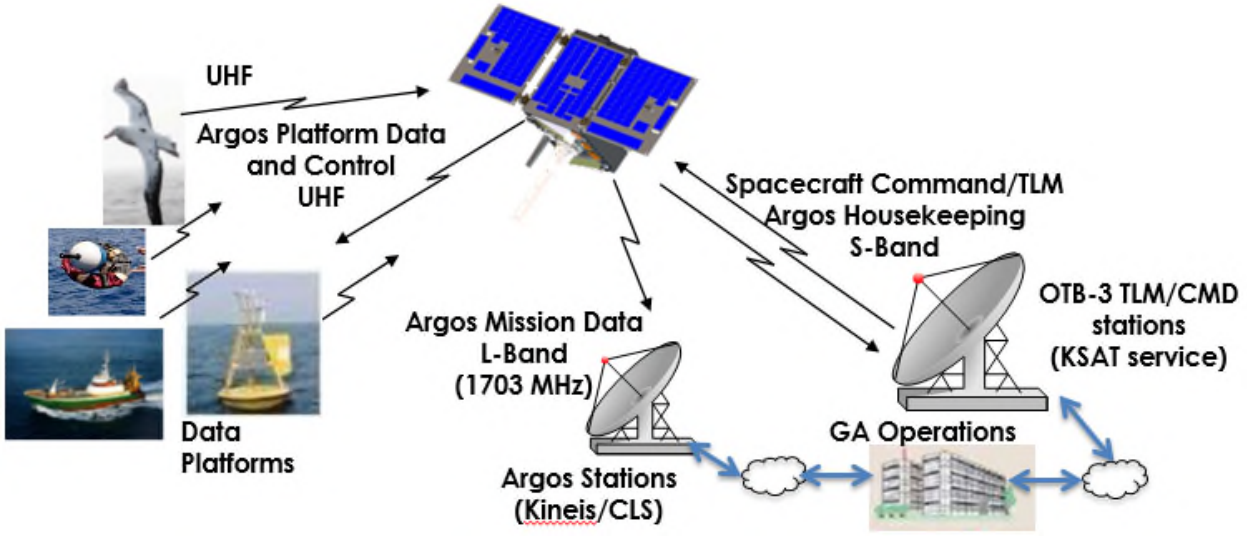

Figure 1. OTB-1 RF Command and Telemetry Links and Argos Hosted Payload Links

Table 3 shows the OTB-3 S-Band Frequency Plan. (Unshaded rows represent frequencies GA seeks authority to use in this license application. Shaded rows represent frequencies that NOAA/CNES or KSAT will obtain authority to use and are provided here only for completeness.)

Table 3. OTB-3 Frequency Plan

Comment	Frequency (MHz)	Station Class	Output Power (watts)	ERP ([milliwatts or watts])	Mean or Peak	Frequency Tolerance (+/- %)	Emission Designator	Modulating Signal	Width of beam (degrees at the half-power point)	Orientation in horizontal plane (degrees from True North)	Orientation in vertical plane (degrees from horizontal)
To be licensed by NOAA/CNES for HoPS (Note 1)	399.9-400.05	MSS (Earth-to-Space)	(Note 1)	(Note 1)		Unknown					
To be licensed by NOAA/CNES for HoPS (Note 2)	401 - 403	EESS (Earth-to-Space)	(Note 2)	(Note 2)		Unknown					
To be licensed by NOAA/CNES for HoPS (Note 3)	465.9875	EESS (Space-to-Earth)	10	10 Watts	P	+/- 0.001%	2M00G1D	OQPSK with 1 Mcps SS	180	N/A	N/A
To be licensed by NOAA/CNES for HoPS (Note 4)	1703.0	METSAT (Space-to-Earth)	5	3.16 Watts	M	+/- 0.001%	2M00G1D	QPSK with ½ FEC	150	N/A	N/A
To be licensed by GA (Note 5)	2270.2	Space Ops (Space-to-Earth)	0.25	70 mW	M	+/- 0.002%	80K0G1D	BPSK	Omni-directional	N/A	N/A

To be licensed by GA (Note 5)	2270.2	Space Ops (Space-to-Earth)	1.6	2.09 Watts	M	+/- 0.002%	2M07G1D	QPSK	70	N/A	N/A
Uplink from KSAT Svalbard station (Note 6)	2080.25	Space Ops (Earth-to-Space)	50	42 dBW nominal (53 dBW max.	M	Unknown	38K4G1D	CPFSK	1.6	0-360 degrees	5-90 degrees
Uplink from KSAT Svalbard station (Note 6)	2079.75	Space Ops (Earth-to-Space)	50	42 dBW nominal (53 dBW max.	M	Unknown	38K4G1D	CPFSK	1.6	0-360 degrees	5-90 degrees
Uplink from KSAT Svalbard station (Note 6)	2080.25	Space Ops (Earth-to-Space)	50	45 dBW nominal (53 dBW max.	M	Unknown	80K0G1D	BPSK	1.6	0-360 degrees	5-90 degrees
Uplink from KSAT Svalbard station (Note 6)	2079.75	Space Ops (Earth-to-Space)	50	45 dBW nominal (53 dBW max.	M	Unknown	80K0G1D	BPSK	1.6	0-360 degrees	5-90 degrees

Notes:

1. UHF uplink spectrum licensing request in the 399.9-400.05 MHz MSS band for the Argos Hosted Payload will be submitted by NOAA to the NTIA, and linked to the OTB-3 spacecraft.

2. UHF uplink spectrum licensing request in the 401-403 MHz EESS band for the Argos Hosted Payload will be submitted by NOAA to the NTIA, and linked to the OTB-3 spacecraft.

3. UHF downlink spectrum licensing request in the 466 MHz EESS band for the Argos Hosted Payload will be submitted by NOAA to the NTIA, and linked to the OTB-3 spacecraft.

4. L-Band downlink spectrum licensing request in the 1703 METSAT band for the Argos Hosted Payload will be submitted by NOAA to the NTIA, and linked to the OTB-3 spacecraft.

5. Request for S-Band spectrum is consistent with federal Space Operations usage for the OTB-3 satellite telemetry, Hosted Payload telemetry, and RADMON experimental data download.

6. GA seeks authority to receive on these S-band frequencies. KSAT will obtain all necessary S-band spectrum authorizations for communications between the Svalbard station and OTB-3.

4.1 Space/Ground Communications

The spacecraft space/ground communications consists of RF links in multiple frequency bands. These RF links are described in the following sections.

4.1.1 UHF Argos Downlink

The Argos UHF RF downlink supports the Argos broadcast downlink to the beacon field units that have receivers. The RF characteristics of the UHF downlink are provided here for information only. Filing will be submitted to NTIA by NOAA for the Argos UHF Payload.

Table 4. UHF-Band Downlink

Parameter	ARGOS-4 UHF TX Downlink
Function	EESS: ARGOS-4 Beacon Broadcast Downlink
Operating Frequency	465.9875 MHz
Maximum Transmit Power	10 Watts
EIRP	10 Watts
Antenna Type	Isoflux
Antenna Gain (peak, main lobe)	2 dBi
Beamwidth	180 degrees
Polarization	RHCP
Modulation	OQPSK, with spreading
Data Rate	-
Necessary Bandwidth	2.000 MHz
Emission Designator	2M00G1D

4.1.2 L-Band Argos Data Downlink

The L-Band RF downlink supports the Argos mission data that is received by the Kineis/CLS ground stations. The RF characteristics of the L-Band downlink are provided here for information only. Filing will be submitted to NTIA by NOAA for the Argos L-Band downlink.

Table 5. L-Band Downlink

Parameter	L-Band TX Downlink
Function	METSAT: ARGOS-4 Mission Data Downlink
Operating Frequency	1703.0 MHz

Maximum Transmit Power	5 Watts
EIRP	3.16 Watts
Antenna Type	Isoflux
Antenna Gain (peak, main lobe)	3 dBi
Beamwidth	150 degrees
Polarization	RHCP
Modulation	QPSK, ½ FEC
Data Rate	2.0 Mbps
Necessary Bandwidth	2.000 MHz
Emission Designator	2M00G1D

4.1.3 S-Band Telemetry Downlink

Data generated from the various payloads are multiplexed together along with the spacecraft T&C data, and downlinked via the S-Band link. The S-band spacecraft equipment supports two data rates, with only one data rate active at a time.

The OT-3 spacecraft houses two S-Band transceivers. Both receivers power up after separation from the launch vehicle and function as a primary and emergency back-up receiver. During ground contacts, a single transmitter is active, with the second unit functioning as a cold-redundant spare. The transceiver transmit function can select either a low or high data rate link, but only one data rate will be active at any time. The low data rate signal routes to a monopole antenna. The high data rate signal routes to a patch antenna with slightly higher gain earth coverage.

The RF characteristics of the S-Band low and high date rate downlinks are as follows:

Table 6. S-Band Telemetry Downlinks

Parameter	S-Band Low Data Rate Downlink	S-Band High Data Rate Downlink
Function	Space Operations: Spacecraft Telemetry Downlink, RADMON Payload Data	Space Operations: Spacecraft Telemetry Downlink, Argos Telemetry Downlink, RADMON Payload Data
Operating Frequency	2270.2 MHz	2270.2 MHz
Maximum Transmit Power	0.25 Watt	1.6 Watts
EIRP	0.070 Watt	2.09 Watts
Antenna Type	Monopole, Omni-directional	Patch
Antenna Gain (peak, main lobe)	0 dBi	3 dBi
Beamwidth	360 degrees	70 degrees

Polarization	Linear	RHCP
Modulation	BPSK	QPSK, ½ FEC
Data Rate	38.4 kbps	2.0736 Mbps
Necessary Bandwidth	80 kHz	2.07 MHz
Emission Designator	80K0G1D	2M07G1D

GA is pre-coordinating operations in the S-band with NOAA, NASA, and the USAF.

The S-Band telemetry downlink is fully compliant with the Commission's Experimental license Rules, except for Section 5.115 of the Commission's Rules which requires the provision of a Station Identification. The OTB-3 satellite downlink does not transmit the call sign at the end of the downlink transmission in either clear voice or Morse code, as the OTB-3 heritage satellite does not contain the ability to do so. Also, the satellite maximizes the full duration of the downlink communication time during each satellite pass for mission critical space operations telemetry for the satellite bus and payloads. GA acknowledges the intent of the Rule for station identification as a means of allowing others to trace unwanted interference, and assumes that the frequency coordination process will fulfill the public interest in this regard. As such, GA respectfully requests a waiver for Section 5.115 of the Commission's Rules.

5 SATELLITE DESCRIPTION

5.1 Satellite Bus

The OTB-3 satellite is an evolution of the ESPA compatible SSTL-150 spacecraft, first flown in 2007. The spacecraft will be operated in a nadir fixed orientation for the mission duration, and will require only seasonal attitude maneuvers to adjust for the position of the sun relative to the orbit.

Additional information on the OTB-3 spacecraft equipment description and physical configuration can be found in Exhibit E - ODAR, Section 2.

5.2 Satellite RF Equipment

The OTB-3 satellite RF transmission equipment is listed in Table 7.

Table 7. Spacecraft Transmitters

Manufacturer	Model Number	Number of Units	Experimental
Surrey Satellite Technologies, Ltd.	SSTL S-Band LRTX/HRTX	2	No. Although the S-Band transmitter is necessary to downlink RADMON experimental data, and to downlink telemetry for the OTB-3

			spacecraft, the transmitter is not the object of the primary payload experiment. The second transmitter unit is identical, and is in a cold-redundant configuration. The second unit will remain off unless a failure is detected in the first transmitter.
Microwave Innovations	L-TX	2	No. The L-Band transmitter is listed here for reference. Spectrum licensing will be submitted separately as part of the Argos-4 Hosted Payload licensing. The second transmitter unit is identical, and is in a cold-redundant configuration. The second unit will remain off unless a failure is detected in the first transmitter.
Thales Alenia	ARGOS-4 Payload	2	No. The UHF Band transmitter is listed here for reference. Spectrum licensing will be submitted separately as part of the Argos-4 Hosted Payload licensing. The second transmitter unit is identical, and is in a cold-redundant configuration. The second unit will remain off unless a failure is detected in the first transmitter.

5.3 Mission Operations

GA will provide positive control of the satellite at all times to operate and monitor the satellite and payload T&C functions via its Mission Operations Center (MOC) located in Englewood, CO. The GA MOC is connected via terrestrial WAN to the earth station at Svalbard that will communicate with the satellite via S-Band T&C links.

5.3.1 Spacecraft S-Band Link Sessions

The satellite remains powered off until after separation from the launch vehicle. During Early Operations and spacecraft commissioning, GA will require approximately four 7-10 minute link sessions daily. The commissioning phase will last for approximately 45 days. After satellite commissioning, GA will enter into nominal operations for the primary and hosted payloads. The satellite will require one to three 10 minute link sessions daily for normal operations. This is the minimum practical to ensure spacecraft health, and retrieve payload data. The S-Band downlink will not radiate at any other time.

All data generated from the various payloads are multiplexed prior to downlink on the single high rate S-Band 2.07 Mbps data link to the ground station.

5.3.2 OTB-3 Satellite Control Point of Contact (PoC)

Each satellite transmit chain can be individually turned on and off via ground operations commanding. The satellite will be under the control of ground operations, and if the satellite experiences any on-board failures, all transmissions will cease until control can be re-gained from the ground team.

The GA point of contact for emergency cessation of emissions ("STOP buzzer PoC") is the following:

Mr. Brian Douglass, Operations Engineer
Brian.Douglass@ga.com
SM-OTB-Mission-Operations@ga.com
(+1) 720-275-3440
7304 South Joliet Street, Suite 200
Englewood, CO 80112

5.4 Orbital Debris Assessment

A complete Orbital Debris Assessment is provided as part of this application. Exhibit E contains the full orbital debris analysis and demonstrates compliance with the orbital debris mitigation requirements outlined in 47 CFR 5.64 (at pp. 20-22).

6 GROUND STATION SUPPORT

Primary Ground Station support is provided Kongsberg Satellite Services (KSAT), under contract to GA. The KSAT earth station at Svalbard will support S-Band Telemetry and Command links with the OTB-3 satellite, with data transfer delivered via WAN to the OTB-3 MOC.

The Ground Station provider will obtain all relevant ground station licenses as required to support the OTB-3 spacecraft uplink.

6.1 S-Band Ground Stations

The primary Ground Station support for the OTB-3 S-Band T&C is at the KSAT SVALSAT site on the Platafjellet plateau outside of Svalbard, Norway. KSAT has multiple redundant antennas at the Svalbard site, and thus back-up stations, if necessary, are the same as the below information.

Location: 78° 14' N, 15° 24' E
Site Elevation: 450 m
Antenna Height above Terrain: 7.3 m
Antenna Type: Parabolic Tracking Antenna, 7.3-meter reflector

Azimuth Range: 000 – 360 degrees
Minimum Elevation Angle: 5 degrees downlink, 10 degrees uplink
Antenna Polarization: Right or Left Hand Circular
Peak Gain: 41 dBi TX; 42 dBi RX mid-band
Antenna Beamwidth: 1.6 degrees TX; 1.5 degrees RX
Maximum Transmit Power: 50 Watts
Maximum S-Band EIRP: 53 dBW
S-Band G/T: 19 dBi/K

6.1.1 S-Band Ground Station Uplinks for OTB-3 Spacecraft Commands

The OTB-3 spacecraft houses two S-Band transceivers, with a single transceiver active, as selected via frequency diversity. The transceiver receive function can select either a low or high data rate link, but only one data rate will be active at any time. The spacecraft receive antenna is a patch antenna with earth coverage. The 2080.25 MHz link will be the primary uplink used for operations. The secondary uplink frequency of 2079.75 MHz is requested as an emergency back-up frequency only.

The RF characteristics of the S-Band low and high date rate uplinks are provided for information only. The Ground Station provider will submit a modification to their existing licensing to support the two spacecraft command uplink rates as follows:

Table 8. S-Band Command Uplinks

Parameter	S-Band Low Data Rate Uplink	S-Band High Data Rate Uplink
Function	Space Operations: Spacecraft Command Uplink	Space Operations: Spacecraft Command Uplink, Argos Command Uplink,
Operating Frequency	2080.25 MHz (primary), 2079.75 MHz (emergency operations only)	2080.25 MHz (primary), 2079.75 MHz (emergency operations only)
Maximum Ground Station Transmit EIRP	53 dBW	53 dBW
Nominal Ground Station EIRP for a pass	42 dBW	45 dBW
Polarization	RHCP	RHCP
Modulation	CPFSK	BPSK
Data Rate	19.2 kbps	38.4 kbps
Necessary Bandwidth	38.4 kHz	80 kHz
Spacecraft G/T	-39.9 dBi/K (Edge of Coverage)	-39.9 dBi/K (Edge of Coverage)
Emission Designator	38K4G1D	80K0G1D

6.2 L-Band Ground Stations

The Argos mission data L-Band downlink will continuously broadcast at 1703 MHz directly to Kineis/CLS ground stations around the world. NOAA has a partnership with the Kineis CONUS stations, formerly known as CLS America, and will be coordinating and submitting license modifications for existing ground stations to the NTIA to support receipt of the L-Band downlink. Ground station support will be receive-only for the spacecraft downlink.

6.3 UHF Ground Mobile Stations

NOAA will be coordinating and submitting new license applications (or modifications to existing licenses) to the NTIA to support the UHF uplinks and downlinks. Please see Table 3, Notes 1 and 2 for further detail on the UHF uplinks.