ARKYD 6 SPACECRAFT

Experiment Description Document for FCC Application

REVISION A

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DOCUMENT CHANGE LOG

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1.0 INTRODUCTION

The Arkyd 6 (A6) spacecraft is an experimental nano-satellite being developed for launch in Q3 2015. A6 is a product of Planetary Resources Development Corporation (PRDC) of Redmond, Washington. The A6 vehicle is a technology demonstrator for PRDC's Arkyd Spacecraft Series, which culminates in the deployment of the Arkyd 300 spacecraft, a commercial interplanetary space research vehicle for the exploration of near Earth asteroids (NEA). The A6 spacecraft is envisioned as an orbiting research testbed for PRDC-developed spacecraft hardware and software components and also provides a relevant platform for spaceflight operations development. Shown in Figure 4.1, A6 is a CubeSat that complies with a Not To Exceed (NTE) mass of 10.0 kg and meets the volumetric constraints of the 6U form factor, as defined by the ISIPOD CubeSat Deployer Specification (ISISLaunch, 2011). The primary mission life for A6 is planned for two (2) years.

PRDC is requesting a 24-month experimental license from the Federal Communications Commission's Office of Experimental Technology in order to complete the objectives of the A6 flight experiment.

2.0 FLIGHT EXPERIMENT DESCRIPTION

As stated in Section 1.0, A6 is a space research platform used to evaluate the performance of spacecraft subsystems and instruments developed internally at PRDC. The specific objectives of the A6 mission are as follows:

1. Successful launch and on-orbit demonstration of core Arkyd spacecraft elements developed internally at Planetary Resources, including avionics, attitude determination and control, and power and energy management
2. Demonstration of spacecraft communication to PRDC Earth stations, including command uplink, telemetry and payload data downlink, and software updates
3. Demonstration of PRDC mission operations, including strategic and tactical planning, command execution, and anomaly resolution
4. On-orbit operation of A6 Mid-Wave IR (MWIR) Instrument Experiment
5. On-orbit operation of Arkyd context imaging payload
6. Space environment lifetime testing and degradation evaluation of PRDC-developed avionics, ADCS, and instrument subsystems over the course of the 24-month mission lifetime.

Usage of RF spectrum for this flight experiment is critical to the success of the flight experiment. The requested RF communications implementation provides both the ability to successful command the spacecraft and the ability to receive critical engineering telemetry and experiment data from it.

3.0 LAUNCH PROVIDER

PRDC has signed a Launch Services Agreement (LSA) with Spaceflight Services, Inc. to facilitate launch and deployment of the A6 spacecraft. A6 will be launched, enclosed in its satellite deployer, as a secondary payload on a SpaceX launch in Q3 2015. Planned vehicle integration, and corresponding need for granting of license, is in June 2015. A6 will launch from SpaceX's SLC-4E facilities at Vandenberg Air Force Base, California, USA.

Upon orbital insertion and primary payload separation, A6 will be released from its deployer, power-on, and begin initial vehicle checkout operations. Spaceflight Services provides launch vehicle interface, launch integration, and on-orbit deployment services for the mission. Table 3.1 is a summary of specific launch details, for reference.

Table 3.1: A6 Launch Information

Target Launch Date	Q3 2015
Launch Vehicle	SpaceX Falcon 9
Secondary Payload Config.	ESPA
Secondary Payload Aggregator	Spaceflight Services, Inc.
A6 Launch Configuration	ISIPOD 6U CubeSat, Innovative Solutions in Space (ISIS)
Perigee Altitude	450 +/- 50 km
Apogee Altitude	720 +/- 20 km
Local Time of Descending Node	10:30 +15m / -30m
Inclination	98.0 +/- 1 degrees

3.1 SPACECRAFT ORBIT AND LIFETIME

As the launch vehicle's primary payload dictates its deployment altitude, A6 will initially share its nominal 450 km x 720 mm elliptical sun-synchronous orbit as described in Table 3.1. Based on its estimated ballistic coefficient and the expected state of the space environment at the time of the Q3 2015 launch, the spacecraft is anticipated to last 9 years in orbit, based on results from NASA's DAS 2.0.2 software.

4.0 EXPERIMENTAL SPACECRAFT SUMMARY

The A3 spacecraft is shown in Figures 4.1 and 4.2 in its deployed configuration. The spacecraft's internal configuration is organized into three distinct areas. The main avionics stack is centralized within the volume, with power, attitude determination / control, and context imaging components straddling the central core. The spacecraft's internal hardware complement includes the following:

- PRDC avionics stack, including power distribution unit
- PRDC Low Data Rate Radio (UHF uplink / UHF downlink)
- BitBeam High Data Rate Radio (S-band uplink / X-band downlink)
- Novatel GPS receiver and antenna
- Two (2) PRDC star tracker assemblies, with baffles
- Four (4) PRDC reaction wheel modules
- Two (2) external sun sensors
- Three (3) magnetorquer assemblies
- Ten-cell 96 W-hr packaged battery assembly
- Context imaging payload that includes a deployable visible imager and TFT LCD display screen
- Compact Mid-wave IR (MWIR) telescope with 50 mm aperture
- RF antenna configuration that includes deployable omnidirectional UHF antennas and one (1) dual-band S/X-band patch antenna (~16.5 dBi peak X; 4 dBi S)

The spacecraft has five-panel solar array consisting of a single panel fixed to the top structural element and two deployable double-hinged assemblies. The array, antenna, and instrument experiment cover are deployed from its stowed configuration 30 minutes after spacecraft deployment from the secondary payload adapter. The visible imaging payload is also deployed at that time from within the stowed vehicle to a position that allows visibility of the exterior spacecraft structure and deployed solar array.

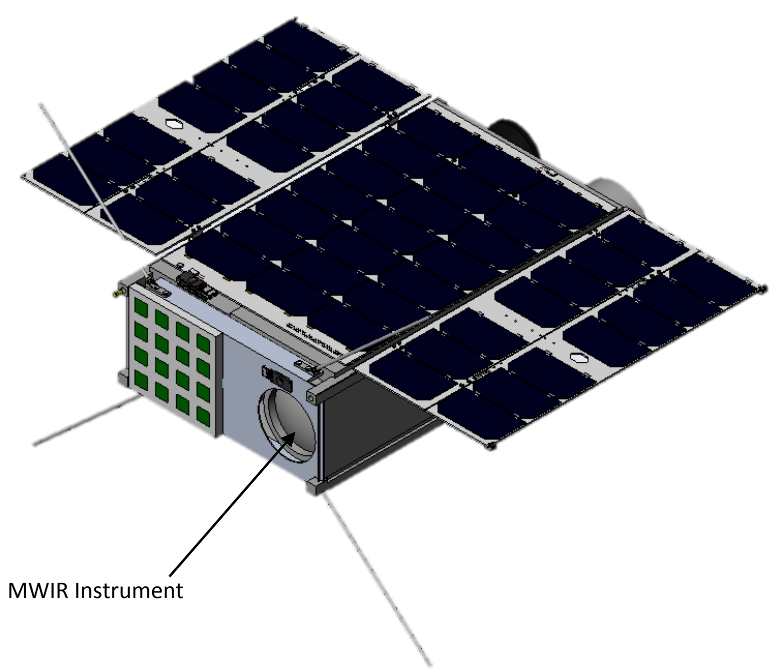

Figure 3.1.1: Arkyd 6 Spacecraft, Front Side View

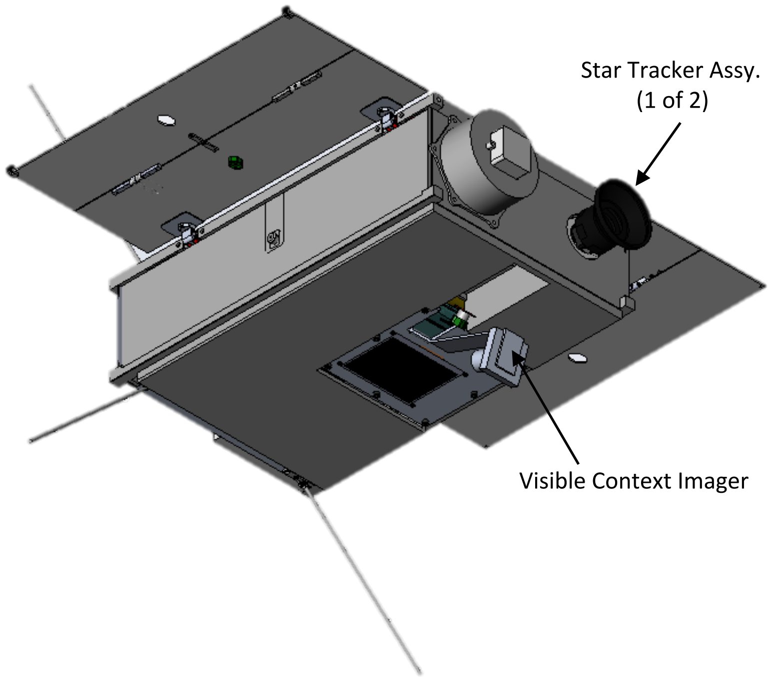

Figure 3.1.2: Arkyd 6 Spacecraft, Aft Side View

5.0 RF CONFIGURATION

5.1 RF FREQUENCY UTILIZATION

While the primary objective of the A6 research spacecraft is demonstration of PRDC-developed technologies, the vehicle is also a pathfinder for the usage of RF spectrum by future Arkyd commercial space research spacecraft, and is therefore proposing to utilize RF spectrum consistent with the needs and constraints of this future implementation. Specifically, the A6 experimental license request includes utilization of the following allocations:

1. Low-rate telecommand (Earth-to-Space): 449.75 – 450.25 MHz (FCC Footnote US87)
2. Low-rate telemetry (Space-to-Earth): 401 – 402 MHz (Space Research Service)
3. High-rate uplink (Earth-to-Space): 2025 – 2110 MHz (FCC Footnote US347)
4. High-rate mission data (Space-to-Earth): 8.450 – 8.500 GHz (Space Research Service)

While PRDC's experimental application requests specific center frequencies for each of the four utilizations above, it has flexibility to modify its requests within the above allocations in the event of coordination issues with other users.

5.2 PRDC LOW DATA RATE RADIO

The low data rate radio (PRDC part number 1005315) is a half-duplex FSK transceiver based on the popular CC1101 from Texas Instruments paired with a custom RF front end. It is intended for A6 spacecraft operations, specifically engineering telemetry and commanding. Both the spacecraft and the ground system will use this radio. It operates within the 401-402 MHz Space Operations Service allocation for downlink and the 449.75-450.25 MHz Space Telecommand (Footnote US87) allocation for uplink. The radio is capable of a data rate up to 512 kilobits per second; however, for this mission, it makes use of up to 50 kHz of bandwidth, providing a net data rate of up to 40 kilobits per second using MSK modulation. This radio will be used on both the spacecraft and the ground system and is capable of a maximum of 2.5 W transmitted RF power.

5.3 PRDC HIGH DATA RATE RADIO

The high data rate radio (BitBeam Incorporated model number BBSDR) is a full-duplex SDR-based transceiver developed by BitBeam Incorporated. It is intended for payload operations including downlink of instrument observations and uplink of spacecraft software updates. Both the spacecraft and the ground system will use this radio. It makes use of a daughter card architecture to support selecting from among multiple bands at build time. For this mission, the spacecraft will be loaded with a BB84PA transmit daughter card and a BB24LN receive daughter card, while the ground system will be configured with a BB24PA transmit daughter card and a BB84LN receive daughter card. This will allow the use of 10 MHz in the X-band 8.45 to 8.5 GHz Space Research Service allocation for downlink and 1 MHz in the 2025-2110 MHz Space Research Service (Footnote US347) allocation for uplink. Both the spacecraft and the ground system will transmit at a maximum of 2.5 W.

5.4 SPACECRAFT UHF ANTENNA

The spacecraft low data rate radio is attached to a UHF turnstile antenna. The antenna provides a near-isotropic radiation pattern at UHF frequencies (both 401-402 MHz and 449.75-450.25 MHz). Polarization is right-hand circularly polarized. The antenna's radiating pattern is shown in Figure 5.4.1.

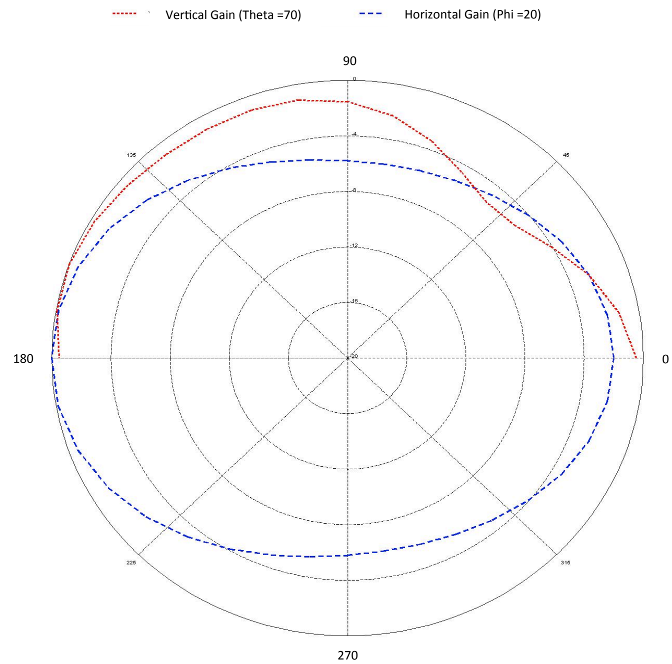

Figure 5.4.1: A6 Spacecraft UHF Gain Pattern

5.5 SPACECRAFT X/S ANTENNA

The spacecraft high data rate radio is attached to a dually resonant X/S band patch antenna. The antenna provides 16 dBi of gain at X-band transmit frequencies (between 8.45 and 8.5 GHz) and 4 dBi of gain at S-band receive frequencies (between 2025-2110 MHz). Polarization is left-hand circularly polarized. The antenna's X-band radiating pattern is shown in Figure 5.5.1.

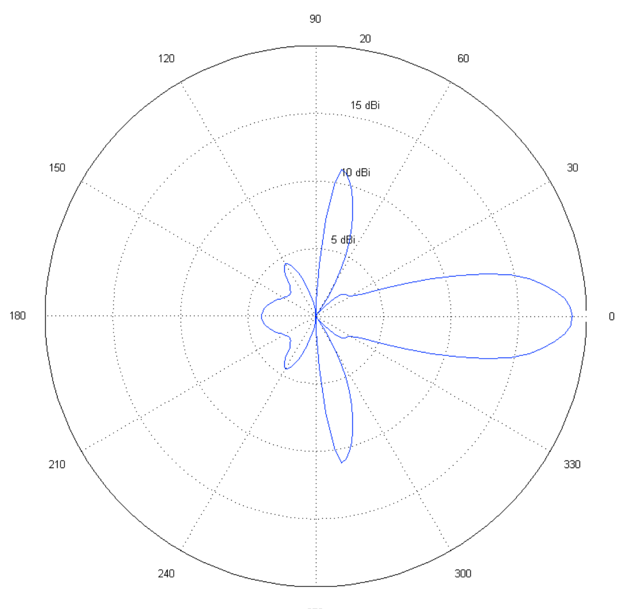

Figure 5.5.1: A6 Spacecraft X-Band Gain Pattern

5.6 GROUND STATION UHF ANTENNA

The ground system low data rate radio is attached to a two-bay gimbaled Yagi antenna array. One of the Yagi antennas is resonant at the uplink frequency (449.75-450.25 MHz) while the other is resonant at the downlink frequency (401-402 MHz). Both antennas are 2.8 meters long and provide 16 dBi of gain. Polarization is right-hand circularly polarized. The antenna's radiating pattern is shown in Figure 5.7.1.

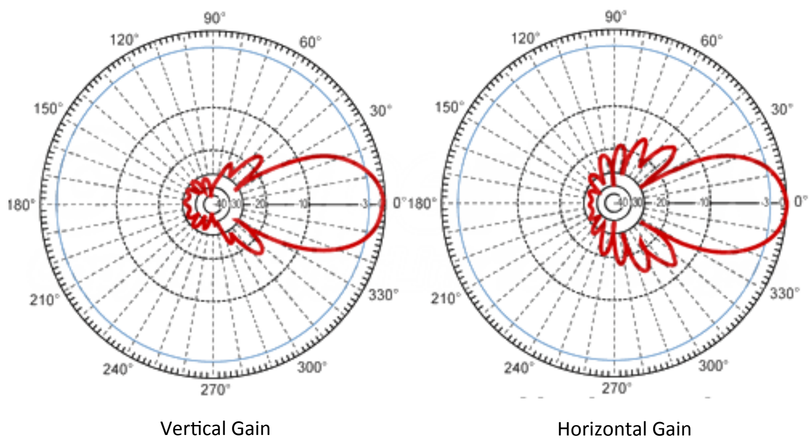

Figure 5.6.1: A6 Ground Station UHF Gain Pattern

5.7 GROUND STATION X/S ANTENNA

The ground system high data rate radio is attached to a 2.4-meter gimbaled parabolic dish antenna with a dually resonant X/S band feed. The antenna provides 31 dBi of gain at S-band transmit frequencies and 41 dBi of gain at X-band receive frequencies. The antenna is capable of dual circular polarization, however for this mission only the left-hand circular polarization is used. The antenna's S-band radiating pattern is shown in Figure 5.7.1.

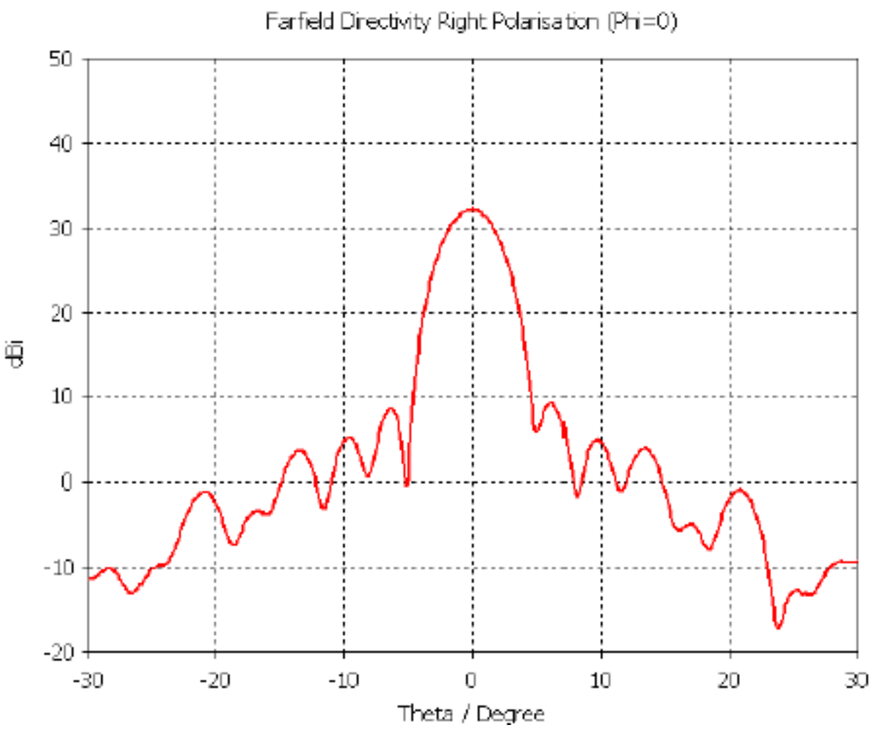

Figure 5.7.1: A6 Ground Station S-Band Gain Pattern