ARKYD 3 SPACECRAFT

Support Documentation

Document: 11-WP-003

Date: 4/10/2014

INITIAL RELEASE

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1.0 INTRODUCTION AND EXPERIMENT SUMMARY DESCRIPTION

The Arkyd 3 (A3) spacecraft is an experimental nanosatellite being developed for launch in October 2014. A3 is a product of Planetary Resources Development Corporation (PRDC), of Redmond, Washington. The vehicle is a technology demonstrator for PRDC's Arkyd Spacecraft Series, which includes the Arkyd 100, 200 and 300 vehicles currently in development. The A3 spacecraft is envisioned as an orbiting testbed for PRDC-developed spacecraft hardware and software components that also provides a relevant platform for spaceflight operations development. Shown in Figure 4.1, A3 is a CubeSat that complies with a NTE mass of 5.0 kg and meets the volumetric constraints of the 3U form factor, as defined by the NanoRacks CubeSat Deployer Specification (NanoRacks, 2013). The primary mission life for A3 is planned for 30 days, although secondary mission operations will likely extend until vehicle deorbit, which is anticipated to occur at or around 1 year of elapsed time.

The following paragraphs contain additional supporting information for PRDC's application for an FCC experimental license with Special Temporary Authority (STA) for A3's flight operations.

2.0 EXPERIMENT OBJECTIVES

The primary objectives of the A3 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 and independent 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

3.0 LAUNCH PROVIDER

PRDC has signed a Launch Services Agreement (LSA) with Spaceflight Services, Inc. and NanoRacks, LLC, to facilitate transport and deployment of the A3 spacecraft from the International Space Station (ISS). The spacecraft will nominally be transported to the ISS aboard Orbital Sciences' Antares ORB-3 launch, currently scheduled for October 3rd, 2014. A3 will be transported, enclosed in its satellite deployer, as cargo within the Cygnus cargo module. Upon arrival, the spacecraft / deployer will be unloaded by ISS astronauts, prepared for launch, and then integrated and deployed via the airlock of JAXA's Kibo module. NanoRacks, LLC serves as the technical interface between PRDC and NASA, which provides access to the ISS as a platform for research and development activities.

3.1 SPACECRAFT ORBIT AND LIFETIME

The A3 spacecraft is deployed from the ISS, and therefore initially shares its orbital characteristics. At the start of its mission, A3 will be at or around the ISS's nominal 400 km altitude, at an orbital inclination of 51.6 degrees. Based on its estimated ballistic coefficient and the expected state of the space environment at the time of the October 2014 launch, the spacecraft's on-orbit lifetime is anticipated to be around 1 year or less, depending on orbital conditions. For further information, PRDC's completed Orbital Debris Assessment Report (ODAR) is included in Section 6.0 of this document.

4.0 SPACECRAFT SUMMARY

The A3 spacecraft is shown in Figure 4.1 in 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
- Microhard Systems 2.4 GHz 1W serial FHSS modem
- Ubiquiti Networks XR2 600 mW WiFi radio module
- GPS receiver and antenna
- Two (2) PRDC star tracker assemblies; one single-stage baffle, one two-stage baffle
- Three (3) PRDC reaction wheel modules
- Two (2) external sun sensors
- Three (3) magnetorquer assemblies
- Six-cell 40 W-hr Lithium-Polymer packaged battery assembly
- Context imaging payload that includes a deployable boom, TFT LCD display screen, and a small context imager to verify solar array deployment and display screen function

- RF antenna module that includes one low gain patch antenna (~3 dBi peak) and one (1) medium gain patch antenna (~8.5 dBi peak)

The spacecraft has five-panel solar array consisting of a single panel fixed to the top structural element and two deployable double-hinged assemblies measuring 220 x 300 mm each. The array is deployed from its stowed configuration no earlier than 30 minutes after ISS deployment. The context 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.

A3 is a CubeSat that complies with a NTE mass of 5.0 kg and meets the stowed volumetric constraints of the 3U form factor (~100 mm x 100 mm x 300 mm long), as defined by the NanoRacks CubeSat Deployer (NRCSD) Specification (NanoRacks, 2013). The NRCSD allows for a small additional volume at one end of the stowed vehicle, which the A3 configuration uses to accommodate one of the two star tracker experiments.

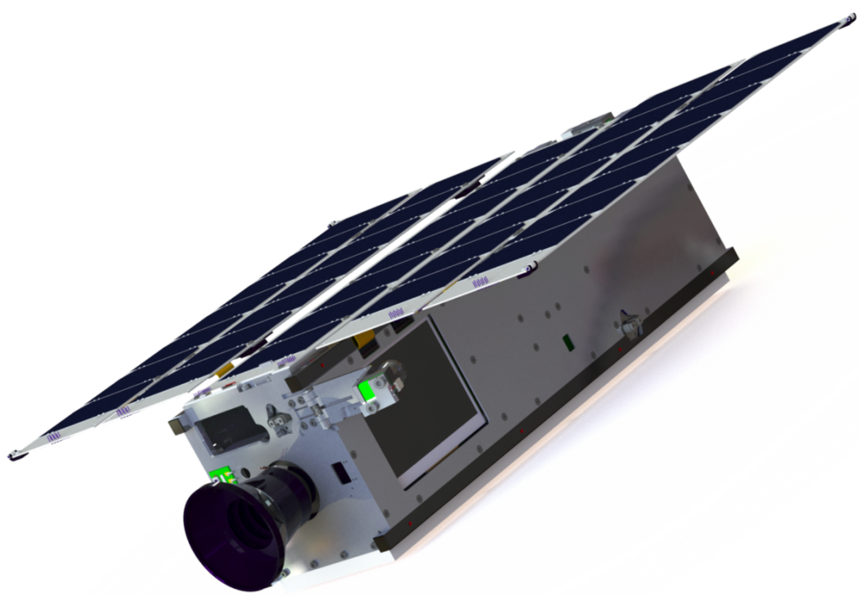


Figure 4.1: A3 Configuration, Solar Array Deployed

5.0 RF COMMUNICATIONS

The A3 spacecraft employs a dual path RF communications system onboard the spacecraft, consisting of a primary and secondary S-band transceiver. The system uses the Microhard Systems MHX 2420-SL transceiver as its primary conduit for telemetry, mission data, and command / control signals. The second radio is the Ubiquiti Networks XR2 802.11 b/g OEM radio, being flown in tandem with the MHX 2420-SL as an experimental element of the spacecraft's RF system. The paragraphs below provide additional detail on the A3's RF implementation, including both planned space-based and ground assets.

5.1 MICROHARD MHX 2420-SL (Space and Ground Elements)

The Microhard Systems MHX 2420-SL is a frequency-hopping spread-spectrum radio operating under part 15.247 of CFR 47. It utilizes a minimum of 77 hopping channels with bandwidths between 50 kHz and 400 kHz depending on data rate. The radio supports half-duplex operation. This radio is used both on the spacecraft and in the ground station. It is used to pass telemetry and engineering data from the spacecraft to the ground and spacecraft commands from the ground to the spacecraft. The nominal in-flight communications data rate for the 2420-SL will be 19.2 kbps.

5.2 UBIQUITI SYSTEMS XR2 (Space and Ground Elements)

The Ubiquiti Networks XR2 is a half-duplex transceiver using a digital modulation in accordance with part 15.247 of CFR 47. It implements addendums -b and -g of the IEEE 802.11 Wi-Fi standard, using one of the eleven WLAN channels allocated for use within the 2.4 GHz - 2.485 GHz frequency band. This radio will be used both on the spacecraft and in the ground station as part of a high-bandwidth downlink experiment. It is not critical to the proper functioning of the spacecraft. The nominal in-flight communications data rate for the XR2 will be 1 Mbps.

5.3 A3 SPACECRAFT ANTENNA ARRAY (Space Element Only)

The antenna for use on the spacecraft is a dual-element, circularly-polarized planar antenna array. It consists of two microstrip antenna elements. The first element is right-hand circularly polarized with a peak gain of 3dB and possesses a half-power beamwidth of more than 160 degrees. This element will interface with the Microhard Systems MHX 2420-SL. The second element is left-hand circularly polarized with a peak gain of ~8.5 dB and possesses a half-power beamwidth of less than 90 degrees. This element will interface with the Ubiquiti Networks XR2. Both antenna elements have a resonant frequency range of 2.4 GHz - 2.85 GHz and can tolerate up to 1W of radiated output power. The elements will be fed through independent 50-ohm SMA connectors. The antenna manufacturer is Star-H Corporation.

5.4 A3 GROUND ANTENNA SYSTEM (Ground Element Only)

The antenna for use on the ground is a parabolic dish antenna with a diameter of 2.4 meters. Within its resonant frequency range of 2.4 GHz - 2.85 GHz, it possesses a beamwidth of approximately 3.6 degrees, giving an isotropic gain of approximately 33 dBi. The ground system is capable of simultaneously receiving right- and left-hand circular polarizations and interfacing with both the Microhard Systems MHX 2420-SL and the Ubiquiti Networks XR2 such that they can be operated concurrently. The ground antenna system will be located in Redmond, WA and is produced by Orbit Communication Systems.

6.0 ARKYD 3 ORBITAL DEBRIS ASSESSMENT REPORT (ODAR)

Section 6 of this document outlines PRDC's orbital debris assessment report (ODAR) for the Arkyd 3 (A3) spacecraft. The format for this report complies with that which is recommended in NASA-STD-8719.14, Appendix A.1 and includes Sections 2 – 8 as applicable to the A3 vehicle.

6.1 ODAR SECTION 1: PROGRAM MANAGEMENT AND MISSION OVERVIEW

Project Manager: Chris Voorhees

Foreign Government / Space Agency Participation: None

Schedule of Upcoming Mission Milestones:

- Flight Readiness Review: August, 2014
- Launch: No Earlier Than October 3rd, 2014

Mission Overview:

The A3 spacecraft will be released from a NanoRacks Containerized Satellite Deployer (NRCSD) at the International Space Station (ISS) into an anticipated circular orbit of approximately 400 km, at an inclination of 51.6 degrees. The A3 mission will demonstrate several new PRDC-developed hardware and software technologies in a relevant space environment over its nominal 30-day primary mission life.

ODAR Summary:

1. No orbital debris is released as a result of normal operations
2. There are no credible scenarios for spacecraft breakup
3. Collision probability is compliant with NASA ODAR Requirement 4.5-1 and 4.5-2 (as calculated by DAS v2.0.2)
4. Estimated nominal decay lifetime due to atmospheric drag is significantly less than 25 years (less than 1 year as calculated by DAS v2.0.2 and ~1.2 years by PRDC internal analysis) and is therefore compliant with NASA ODAR Requirement 4.6
5. Reentry debris casualty risk is compliant with NASA ODAR 4.7-1 (as calculated by DAS 2.0.2)

Launch Vehicle and Launch Site: Antares / Cygnus ORB 3 Mission; Wallops Island, Virginia, USA

Proposed Launch Date: No earlier than October 3rd, 2014

Mission Duration:

1. Primary nominal operations: 30 days from ISS release
2. Secondary mission operations up to 90 days from ISS release
3. Post-operations orbital lifetime: ~1 year

Launch and Deployment Profile:

The spacecraft will nominally be transported to the ISS aboard Orbital Sciences' Antares ORB-3 launch, currently scheduled for October 3rd, 2014. A3 will be transported, enclosed in its satellite deployer, as cargo within the Cygnus cargo module. Upon arrival, the spacecraft / deployer will be unloaded by ISS astronauts, prepared for launch, and then integrated and deployed via the airlock of JAXA's Kibo module. NanoRacks, LLC serves as the technical interface between PRDC and NASA, which provides access to the ISS as a platform for research and development activities.

A3 will deploy into a nominal 400 km circular orbit at an inclination of 51.6 degrees. The spacecraft will naturally decay from these initial conditions through its on-orbit lifetime.

A3 has no propulsive elements onboard and can therefore not actively maintain or change its orbit.

6.2 ODAR SECTION 2: SPACECRAFT DESCRIPTION

Section 4.0 of this document provides a general summary of the spacecraft description, including hardware complement, mass, and volume. Section 5.0 provides a summary of A3's RF hardware complement and implementation plan.

Total satellite mass at launch, including all propellants and fluids: ~ 5.0 kg

Dry mass of satellite at launch, excluding solid rocket motor propellants: ~ 5.0 kg

Description of all propulsion systems: None

Identification, including mass and pressure, of all fluids (liquids and gases) planned to be on board and a description of the fluid loading plan or strategies, excluding fluids in sealed heat pipes: None

Fluids in pressurized batteries: None. A3 uses unpressurized COTS lithium-polymer battery cells

Description of attitude control system and indication of normal attitude of spacecraft with respect to the velocity vector:

A3 has utilizes a system of three (3) coil magnetorquers and three (3) reaction wheel assemblies to provide redundant means of spacecraft attitude control. Nominally, the spacecraft will fly in an “edge-on” condition with respect to the velocity vector, with its solar arrays in a sun-point configuration.

Description of any range safety or other pyrotechnic devices: None

Description of the electrical generation and storage system:

A battery assembly of six (6) COTS Lithium-Polymer battery cells is charged at the time of vehicle delivery for launch integration. This 40 W-hr battery provides electrical energy to spacecraft subsystems during the completion of the primary mission. Solar cells located on the primary structure and the two (2) deployable array elements recharge the battery assembly while on-orbit. Onboard power management and distribution electronics controls the state of charge of the battery and distribution of power to other spacecraft elements, while a protection circuit at the battery cells prevents inappropriate cell charge and discharge events.

Identification of any other sources of stored energy not noted above: None

Identification of any radioactive materials on board: None

6.3 ODAR SECTION 3: ASSESSMENT OF SPACECRAFT DEBRIS - NOMINAL OPERATIONS

Identification of any object > 1 mm expected to be released from spacecraft after launch: None

Rationale / necessity for release of each object: N/A

Time of release of each object, relative to launch time: N/A

Release velocity of each object with respect to spacecraft: N/A

Expected orbital parameters of each object after release: N/A

Calculated orbital lifetime of each object, including time spent in Low Earth Orbit: N/A

Assessment of spacecraft compliance with ODAR Requirements 4.3-1 and 4.3-1 (per DAS v2.0.2)

- 4.3-1, Mission Related Debris Passing Through LEO: **COMPLIANT**
- 4.3-2, Mission Related Debris Passing Near GEO: **COMPLIANT**

6.4 ODAR SECTION 4: ASSESSMENT OF SPACECRAFT INTENTIONAL BREAKUPS AND POTENTIAL FOR EXPLOSION

Potential causes of spacecraft breakup during deployment and mission operations:

There are no credible causes of spacecraft breakup during nominal deployment and mission operations

Summary of failure modes and effects analyses of all credible failure modes that may lead to an accidental explosion:

The spacecraft's energy management system uses COTS Lithium-Polymer battery cells. In the unlikely event of a failure of the cell's protection circuit, a short circuit could occur, resulting in potential overheating and a remote possibility of cell material venting. PRDC's internal FMEA indicates (including below) indicates the multiple failures required for a battery system failure to initiate an unexpected, accidental vehicle explosion.

The vehicle's configuration also includes two (2) simple spring-deployed solar array deployments and a single spring-deployed context camera deployment boom, all of which are restrained by a burn-wire device with redundant launch load restraint elements. The probability of an unexpected detachment before, during, and after deployment is therefore considered negligible.

Detailed plan for any designed spacecraft breakup: None planned

List of components that shall be passivated at End of Mission (EOM):

No component passivation is planned. The spacecraft's six Lithium-Polymer cells will not be passivated at the end of primary mission due to the low risk and negligible impact of accidental explosion. The maximum total energy stored in each cell is ~ 25 kJ.

Rationale for all items that are required to be passivated but cannot due to their design:

The design of A3 includes onboard battery management and overcharge protection for each battery cell, making the risk of a cell failure while on orbit very low. However, in the event that a cell failure does result in material venting, the cell's small size and low overall storage energy ensures that debris from the event will remained contained by the spacecraft's aluminum primary structure.

Assessment of spacecraft compliance with ODAR Requirements 4.4-1 through 4.4-4:

- 4.4-1: Limited the risk to other space systems from accidental explosions during deployment and mission operations while in orbit about Earth or the Moon
    - Required Probability: 0.001 – **COMPLIANT**
    - Supporting Rationale and FMEA
        - The following failure could theoretically result in a battery explosion with a remote possibility of orbital debris generation. However, in the event that a cell failure does result in material venting, the cell's small size and low overall storage energy ensures that debris from the event will

remained contained by the spacecraft's aluminum primary structure. The probability of multiple independent failures leading to orbital debris generation in the event of a cell failure is considered to be much less than 0.1%

- Failure Mode 1: Internal cell short circuit
  - Mitigations: Qualification and acceptance dynamic, thermal, and vacuum testing, followed by qualification charge / discharge cycling.
- Failure Mode 2: Increase in cell temperature resulting in venting
  - Mitigation: Cell screening included an overtest of expected in-flight charge / discharge characteristics to evaluate the possibility of unexpected intra-cell heating and subsequent failures. No failures were seen during these overtests. This test was also completed at the battery assembly level to ensure no integration issues were present.
- Failure Mode 3: Excessive discharge rate or short circuit due to external device failure
  - Mitigations: 1) qualification testing of short-circuit protection of each battery cell; 2) design of battery assembly to ensure that there is no possibility of contact with other conductive paths in proximity to the battery; and 3) confirmation of no other credible mechanical failure near the battery through a full, successful environmental test program, including launch dynamics.
- Failure Mode 4: Battery cell vent path failure
  - Mitigation: Failure mode is mitigated by the design of the battery assembly, which includes a vent path for each cell
- Failure Mode 5: Crushing
  - Mitigation: Failure mode is mitigated by the design of the battery assembly housing. Multiple, catastrophic internal mechanical failures must occur for an individual battery cell to be crushed.
- Failure Mode 6: Excess battery cell temperature due to orbital environment
  - Mitigation: Failure mode is mitigated by spacecraft thermal design and subsequent ground thermal vacuum testing of non-operational and operational thermal environments to ensure spacecraft design compatibility. Specifically, the battery assembly is subjected to maximum charge and discharge events while under "hot-case" thermal environment conditions to ensure that no deleterious effects are indicated.

- Requirement 4.4-2: Design for passivation after completion of mission operations while in orbit about Earth or the Moon:
  - Compliance Statement: The design of A3 includes onboard battery management and overcharge protection for each battery cell, making the risk of a cell failure

while on orbit very low. However, in the event that a cell failure does result in material venting, the cell's small size and low overall storage energy ensures that debris from the event will remained contained by the spacecraft's aluminum primary structure.

- Requirement 4.4-3: Limiting the long-term risk to other space systems from planned breakups:
    - Compliance Statement: **Not applicable**; there are no planned spacecraft breakups.
- Requirement 4.4-4: Limiting the short-term risk to other space systems from planned breakups:
    - Compliance Statement: **Not applicable**; there are no planned spacecraft breakups.

6.5 ODAR SECTION 5: ASSESSMENT OF SPACECRAFT POTENTIAL FOR ON-ORBIT COLLISIONS

Assessment of spacecraft compliance with ODAR Requirements 4.5-1 and 4.5-2:

- 4.5-1: Limiting debris generated by collisions with large objects when operating in Earth orbit (per DAS v2.0.2):
    - **COMPLIANT** per DAS v2.0.2; Collision Probability = 0.000000
- 4.5-2: Limiting debris generated by collisions with small objects when operating in Earth or lunar orbit:
    - Compliance Statement: **Not applicable**; The spacecraft is planned orbital disposal by atmospheric entry, and does not require a specific spacecraft orientation and drag state to meet the disposal requirements outlined in ODAR Section 6. Therefore, no element or component of the spacecraft system is required to complete post-mission operations.

6.6 ODAR SECTION 6: ASSESSMENT OF SPACECRAFT POST-MISSION DISPOSAL PLANS AND PROCEDURES

Description of spacecraft disposal option selected:

Per NASA-STD 8719.14, the A3 spacecraft will be disposed naturally through atmospheric entry. Due to the vehicle's low initial orbit, it is expected to naturally de-orbit on its own well within the time limit specified in ODAR Requirement 4.6-1(a).

Plan for any spacecraft maneuvers required to accomplish post-mission disposal

No special maneuvers or operations are required to accomplish post-mission disposal. The spacecraft will naturally de-orbit well within the requirements of NASA-STD 8719.14 without any special action.

Calculation of area-to-mass ratio after post-mission disposal

- Spacecraft mass: ~ 5.0 kg
- Cross-sectional area: 0.075 m^2 (average)
- Area-to-mass ratio: 0.015 m^2 / kg (average)

Assessment of spacecraft compliance with ODAR Requirements 4.6-1 through 4.6-4

- 4.6-1(a): Disposal for space structures in or passing through LEO:
    - **COMPLIANT** per DAS v2.0.2; Passed with expected de-orbit in 2015, less than a 1-year on-orbit lifetime
    - Additional analysis was completed at PRDC using the Satellite Tool Kit (STK) orbital simulation software. Figure 6.6.1 shows the results of orbit lifetime, assuming a quiescent solar weather environment. This analysis produced results similar to DAS v2.0.2, indicating an estimated de-orbit of 416 days, just over a 1-year on-orbit lifetime.

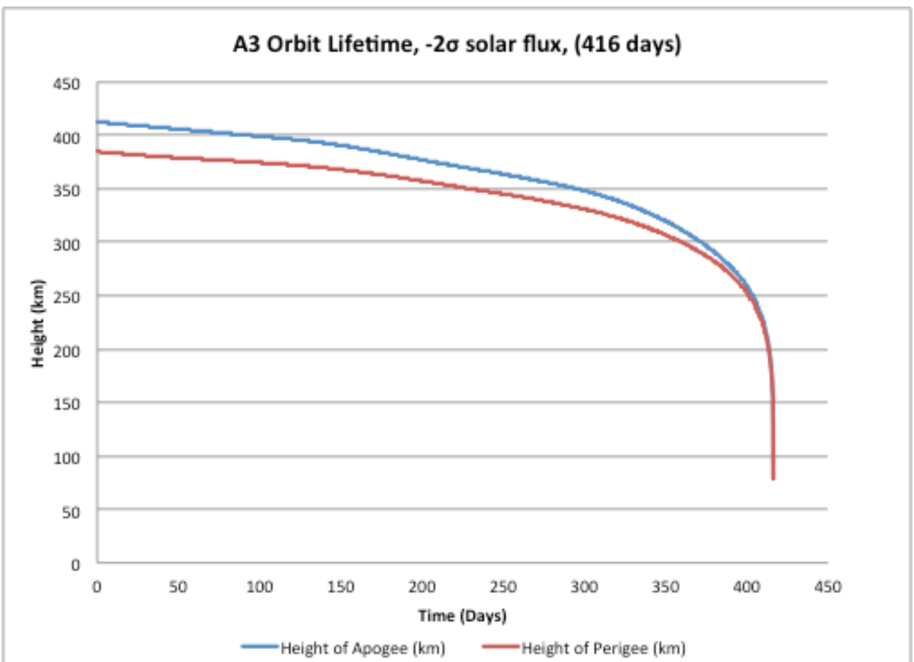


Figure 6.6.1: STK De-Orbit Analysis for Arkyd 3 Spacecraft

- 4.6-2: Disposal for space structure near GEO
    - Not applicable
- 4.6-3: Disposal for space structures between LEO and GEO
    - Not applicable
- 4.6-4 Reliability of post-mission disposal operations
    - The spacecraft's maximum drag orientation is also its aerodynamically stable state. Therefore, even given a fault scenario in which spacecraft orientation

control is lost, the spacecraft will de-orbit at or before the timeframe outlined in 4.6-1(a), which assumes a lower, average area-to-mass mass ratio instead of the maximum drag orientation.

6.7 ODAR SECTION 7: ASSESSMENT OF SPACECRAFT REENTRY HAZARDS

Assessment of spacecraft compliance with ODAR Requirement 4.7-1:

- 4.7-1(a): Limit the risk of human casualty from surviving debris for an uncontrolled reentry to no greater than 0.0001 (1:10,000)
    - **COMPLIANT** per DAS v2.0.2; No risk of human casualty for surviving debris
- 4.7-1(b): **Not applicable**; relevant only to controlled reentry
- 4.7-1(c): **Not applicable**; relevant only to controlled reentry

6.8 ASSESSMENT FOR TETHER MISSIONS

This ODAR section is not applicable. There are no tethers utilized onboard the A3 spacecraft

6.9 ARKYD 3 DAS v2.0.2 OUTPUT FILE

The following is the raw output file from utilization of NASA's DAS v2.0.2 software in support of ODAR assessment of the Arkyd 3 (A3) spacecraft.

```
03 12 2014; 20:49:55PM    DAS Application Started
03 12 2014; 20:49:58PM    Opened Project C:\Program Files (x86)\NASA\DAS 2.0\ARKYD3\
03 12 2014; 20:50:02PM    Opened Project C:\Program Files (x86)\NASA\DAS 2.0\ARKYD3\
03 12 2014; 20:50:22PM    Processing Requirement 4.3-1:    Return Status :  Not Run

=====================
No Project Data Available
=====================

=============== End of Requirement 4.3-1 ===============
03 12 2014; 20:50:31PM    Mission Editor Changes Applied
03 12 2014; 20:50:39PM    Processing Requirement 4.3-1:    Return Status :  Not Run

=====================
No Project Data Available
=====================

=============== End of Requirement 4.3-1 ===============
03 12 2014; 20:50:48PM    Processing Requirement 4.3-2: Return Status : Passed
```

====================
No Project Data Available
====================

=============== End of Requirement 4.3-2 ===============
03 12 2014; 20:51:05PM Requirement 4.4-3: Compliant

=============== End of Requirement 4.4-3 ===============
03 12 2014; 20:51:14PM Processing Requirement 4.5-1: Return Status : Passed

==============
Run Data
==============

INPUT

Space Structure Name = Arkyd 3
Space Structure Type = Payload
Perigee Altitude = 400.000000 (km)
Apogee Altitude = 400.000000 (km)
Inclination = 51.600000 (deg)
RAAN = 0.000000 (deg)
Argument of Perigee = 0.000000 (deg)
Mean Anomaly = 0.000000 (deg)
Final Area-To-Mass Ratio = 0.015000 (m^2/kg)
Start Year = 2014.900000 (yr)
Initial Mass = 5.000000 (kg)
Final Mass = 5.000000 (kg)
Duration = 0.500000 (yr)
Station-Kept = False
Abandoned = True
PMD Perigee Altitude = -1.000000 (km)
PMD Apogee Altitude = -1.000000 (km)
PMD Inclination = 0.000000 (deg)
PMD RAAN = 0.000000 (deg)
PMD Argument of Perigee = 0.000000 (deg)
PMD Mean Anomaly = 0.000000 (deg)

OUTPUT

Collision Probability = 0.000000
Returned Error Message: Normal Processing
Date Range Error Message: Normal Date Range
Status = Pass

==============

=============== End of Requirement 4.5-1 ===============
03 12 2014; 20:51:27PM Requirement 4.5-2: Compliant
03 12 2014; 20:51:35PM Processing Requirement 4.6 Return Status : Passed

==============
Project Data
==============

INPUT

Space Structure Name = Arkyd 3
Space Structure Type = Payload

Perigee Altitude = 400.000000 (km)
Apogee Altitude = 400.000000 (km)
Inclination = 51.600000 (deg)
RAAN = 0.000000 (deg)
Argument of Perigee = 0.000000 (deg)
Mean Anomaly = 0.000000 (deg)
Area-To-Mass Ratio = 0.00000 (m^2/kg)
Start Year = 2014.900000 (yr)
Initial Mass = 5.000000 (kg)
Final Mass = 5.000000 (kg)
Duration = 0.500000 (yr)
Station Kept = False
Abandoned = True
PMD Perigee Altitude = -1.000000 (km)
PMD Apogee Altitude = -1.000000 (km)
PMD Inclination = 0.000000 (deg)
PMD RAAN = 0.000000 (deg)
PMD Argument of Perigee = 0.000000 (deg)
PMD Mean Anomaly = 0.000000 (deg)

OUTPUT

Suggested Perigee Altitude = 400.000000 (km)
Suggested Apogee Altitude = 400.000000 (km)
Returned Error Message = Reentry during mission (no PMD req.).

Released Year = 2015 (yr)
Requirement = 61

Compliance Status = Pass

==============

=============== End of Requirement 4.6 ===============
03 12 2014; 20:53:31PM *********Processing Requirement 4.7-1
Return Status : Passed

***********INPUT****
Item Number = 1

name = Arkyd 3
quantity = 1
parent = 0
materialID = 5
type = Box
Aero Mass = 5.000000
Thermal Mass = 5.000000
Diameter/Width = 0.100000
Length = 0.300000
Height = 0.100000

name = Arkyd 3
quantity = 1
parent = 1
materialID = 5
type = Box
Aero Mass = 5.000000
Thermal Mass = 5.000000
Diameter/Width = 0.100000
Length = 0.300000
Height = 0.100000

**************OUTPUT****
Item Number = 1

name = Arkyd 3
Demise Altitude = 77.996644
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = Arkyd 3
Demise Altitude = 62.232663

Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****

=============== End of Requirement 4.7-1 ===============

7.0 APPENDIX – RF DATA SHEETS

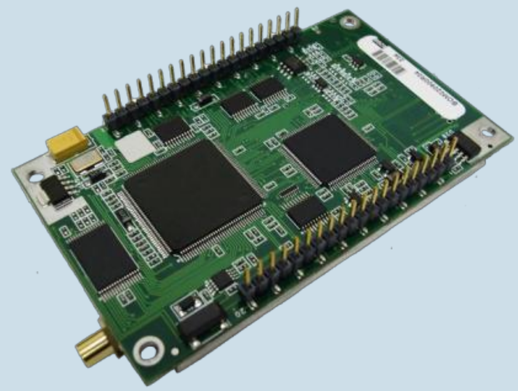
MHX2420

2.4 GHz OEM Industrial Wireless Modem

The MHX2420 is a 2.4 GHz Frequency Hopping Spread Spectrum Modem, which can be optimized for long distance communication over 30 miles (50km). MHX2420 radios offer the fastest communication over the longest distances

Applications

- *SCADA (PLCs, MODBUS), Telemetry*
- *Commercial Communications*
- *GPS Vehicle Data/Tracking, DGPS*
- *Electric, Oil & Gas Sensors/Detection*
- *Display Signs*
- *Transparent Low Latency Communication*



Microhard Systems Inc.'s proprietary radio technology excels in the most demanding RF and physical environments.

The MHX2420 features robust, low latency, secure data communications. It has full serial port and separate diagnostics port for real-time diagnostics without interrupting data communications. Excellent noise figure, superior interference rejection, very agile frequency synthesis, digital modulation, and matched filter detection, are among the many advantages to using the MHX2420.

Features of the MHX2420

- Transparent, low latency link, providing 230 kbps continuous throughput to support protocols such as MODBUS
- Communicates with virtually all PLCs, RTUs, and serial devices
- Industrial Grade - extended temperature specification
- Supports Point-to-Point, Point-to-Multipoint, Peer-to-Peer, Store and Forward Repeater, TDMA, Multimaster
- Maximum allowable transmit power (1W)
- Low power consumption in Sleep Mode and High Voltage Option
- 32 bits of CRC, selectable Forward Error Correction with retrans-mission
- Separate diagnostics port - transparent remote diagnostics and online network control
- Footprint backwards compatible with MHX2400

MHX2420 HV Option

MHX2420 Specifications

Frequency	2.4000 - 2.4835 GHz
Spreading Method	Frequency Hopping
Band Segments	Selectable via Freq. Restriction
Error Detection	32 bits of CRC, ARQ
Encryption	Optional (Canada & USA only. NOT AVAILABLE for export, see –AES option)
Range	30+ miles (50+ km) (dependant on link rate and line of sight)
Output Power	100mW to 1W (30dBm)
Sensitivity	-108dBm @ 115.2kbps link rate (Also see option –SL)
System Gain	142dB (w/rubber duck antennas)
Serial Interface	RS232/RS485/RS422 TTL Driver Level (see –HV option)
Serial Baud Rate	300bps to 230.4kbps
Link Rate	19.2 kbps - 230.4kbps (See Order Options)
Operating Modes	Point-to-Point, Point-to-Multipoint, Store & Forward Repeater, Peer-to-Peer, TDMA, Multimaster
Signals Interface	RxD1, TxD1, RTS, CTS, DCD, DSR, DTR, RxD2, TxD2, RSSI LEDs, Tx/Rx LEDs, Reset, Config, Wake-up, RSmode
Diagnostics	Battery Voltage, Temperature, RSSI, and remote diagnostics
Rejection	Excellent strong signal interference & rejection characteristics
Core Voltage	4.0VDC to 5.5VDC, 7VDC to 30VDC (see –HV option)
I/O Voltage (user selectable)	3.3VDC to 5.5VDC; RS232/485/422 levels (See –HV option)
Antenna Connector	MCX
Environmental	-40°F - +185°F (-40°C - +85°C) 5-95% humidity, noncondensing
Weight	Approx. 2oz. (55 grams)
Dimensions	Approx. 3.5" x 2.1" x .7" (89mm x 53.4mm x 17.8mm)
Approvals	FCC Part 15.247 IC RSS210

Order Options

-HV	HV Option - High input voltage (12V to 30V) with RS232/485/422 Drivers
-FT	Standard FAST Mode 115kbps - 230.4kbps
-FT1	Extended FAST mode 115kbps - 345.6kbps
-SL	Extended sensitivity / SLOW Mode 19.2kbps - 230.4kbps
-C1D2	Class 1 Div 2 (for use in hazardous environments)
-AES	128-AES Encryption (Canada & USA only. NOT AVAILABLE for export)

Contact Information

Microhard Systems Inc.
#17, 2135 - 32nd Avenue N.E.
Calgary, AB, Canada T2E 6Z3

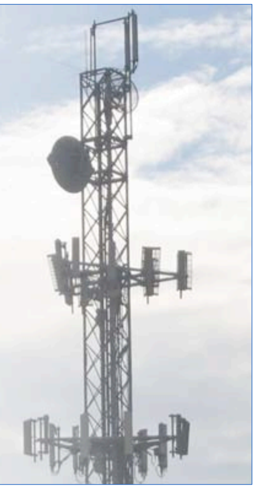
Email: info@microhardcorp.com
Tel: (403) 248-0028
Fax: (403) 248-2762

microhard SYSTEMS INC.

www.microhardcorp.com

XTREMERange2

Carrier-Class 2.4GHz 802.11b/g Radio Module

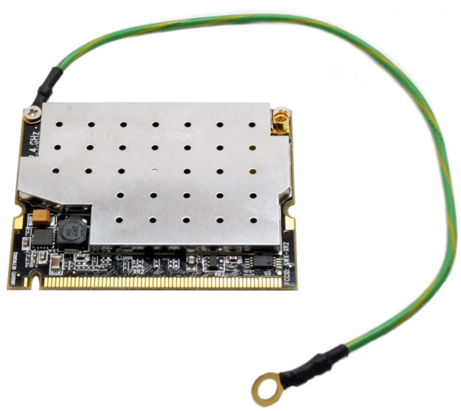


The XtremeRange series of radio modules by Ubiquiti leverages our strong knowledge and experience gained from customer interactions, field performance evaluations, and lab research; and improves upon the original and highly successful SuperRange series of high-performance 802.11 radio cards. The XtremeRange2 is a carrier-class 802.11b/g based 2.4GHz radio module specifically designed for mesh, bridging, and infrastructure applications requiring the high levels of performance and reliability.

Designed to Link Farther and Faster

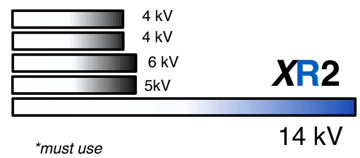
Built to Last Outdoors in Harshest Environments

FEATURES
600mW Output Power
ESD/EMP Protection
Industry-Best Sensitivity
Extended Temperature
Enhanced Filtering
5/10/20/40 MHz Channels
MMCX Ant. Connector



RF ESD/EMP Earth Ground Cable

RF ESD/EMP Immunity Threshold vs. Standard Cards

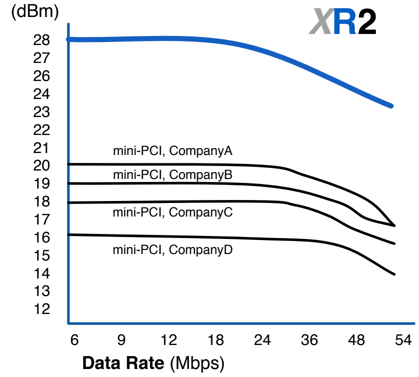


**must use included grounding cable*

Built for Industrial / Rugged Applications

Built-in HeatSink for Temperature Performance

Power, 2.4GHz (dBm)



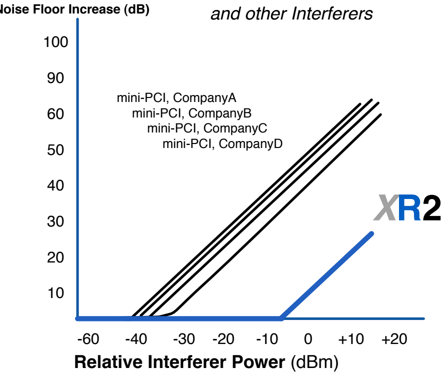
Tested with and Optimized for

MikroTik MADWiFi

Mikrotik is a trademark of Mikrotikls SIA, Latvia

1.9GHz Rejection
Noise Floor Increase (dB)

Overcome Cellular Towers and other Interferers



XTREMERange2

TECHNICAL SPECIFICATIONS

CARD INFORMATION	
Chipset	Atheros, 6th Generation, AR5414
Radio Operation	IEEE 802.11b/g, 2.4GHz
Interface	32-bit mini-PCI Type IIIA
Operation Voltage	3.3VDC
Antenna Ports	Single MMCX
Temperature Range	-45C to +90C (extended temp version up to +95C)
Security	WPA, WPA2, AES-CCM & TKIP Encryption, 802.1x, 64/128/152bit WEP
Data Rates	6Mbps, 9Mbps, 12Mbps, 24Mbps, 36Mbps, 48Mbps. 54Mbps
TX Channel Width Support	5MHz / 10MHz / 20MHz / 40MHz
RoHS Compliance	YES

REGULATORY INFORMATION	
Wireless Modular Approvals	FCC Part 15.247, IC RS210

RADIO OPERATING FREQUENCY 2412-2462 MHz

TX SPECIFICATIONS				RX SPECIFICATIONS			
	DataRate	TX Power	Tolerance		DataRate	Sensitivity	Tolerance
802.11b	1Mbps	28 dBm	+/-1dB	802.11b	1Mbps	-97 dBm	+/-1dB
	2Mbps	28 dBm	+/-1dB		2Mbps	-96 dBm	+/-1dB
	5.5Mbps	28 dBm	+/-1dB		5.5Mbps	-95 dBm	+/-1dB
	11Mbps	28 dBm	+/-1dB		11Mbps	-92 dBm	+/-1dB
802.11g OFDM	6Mbps	28 dBm	+/-1dB	802.11g OFDM	6Mbps	-94 dBm	+/-1dB
	9Mbps	28 dBm	+/-1dB		9Mbps	-93 dBm	+/-1dB
	12Mbps	28 dBm	+/-1dB		12Mbps	-91 dBm	+/-1dB
	18Mbps	28 dBm	+/-1dB		18Mbps	-90 dBm	+/-1dB
	24Mbps	28 dBm	+/-1dB		24Mbps	-86 dBm	+/-1dB
	36Mbps	26 dBm	+/-1dB		36Mbps	-83 dBm	+/-1dB
	48Mbps	25 dBm	+/-1dB		48Mbps	-77 dBm	+/-1dB
	54Mbps	24 dBm	+/-1dB		54Mbps	-74 dBm	+/-1dB

ADJUSTABLE CHANNEL SIZE SUPPORT (Increase Channel Capacity or Increase Throughput)

5MHz	10MHz	20MHz	40MHz (Turbo)

CURRENT CONSUMPTION INFORMATION

TX CURRENT CONSUMPTION				RX CURRENT CONSUMPTION			
	DataRate	Current	Tolerance		DataRate	Sensitivity	Tolerance
802.11b	1Mbps	1.30 A	+/-100mA	802.11b	1Mbps	300 mA	+/-100mA
	2Mbps	1.30 A	+/-100mA		2Mbps	300 mA	+/-100mA
	5.5Mbps	1.30 A	+/-100mA		5.5Mbps	300 mA	+/-100mA
	11Mbps	1.30 A	+/-100mA		11Mbps	300 mA	+/-100mA
802.11g OFDM	6Mbps	1.30 A	+/-100mA	802.11g OFDM	6Mbps	300 mA	+/-100mA
	9Mbps	1.30 A	+/-100mA		9Mbps	300 mA	+/-100mA
	12Mbps	1.30 A	+/-100mA		12Mbps	300 mA	+/-100mA
	18Mbps	1.30 A	+/-100mA		18Mbps	300 mA	+/-100mA
	24Mbps	1.30 A	+/-100mA		24Mbps	300 mA	+/-100mA
	36Mbps	1.10 A	+/-100mA		36Mbps	300 mA	+/-100mA
	48Mbps	1.00 A	+/-100mA		48Mbps	300 mA	+/-100mA
	54Mbps	0.90 A	+/-100mA		54Mbps	300 mA	+/-100mA

ESD/EMP CABLE SPECIFICATIONS	
Cable Dimensions	8 in length, 0.55mm diameter (26AWG)
Terminal Material / Dimensions	Copper / 4.3mm diameter
Attachment Procedure	Ground end to enclosure point tied to Earth Ground

RANGE PERFORMANCE	
Indoor (Antenna Dependent):	Up to 200meters
Outdoor (Antenna Dependent):	Over 50km

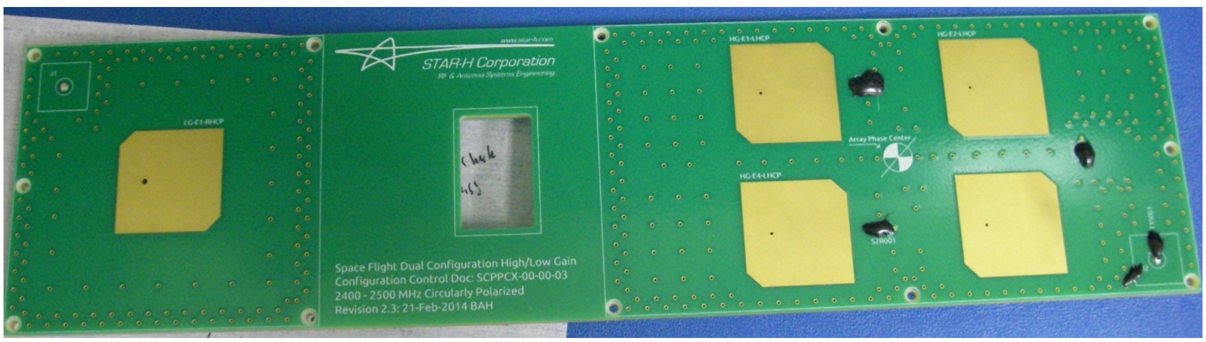
DRIVER INFORMATION	
Operating System Support	Linux MADWIFI, WindowsXP, Windows2000
Advanced Mobility / QuickHandoff	WindowsXP/2000 Utility with Enhanced Mobility Driver from Ubiquiti
Cisco Support	CCX 4.0 Supported Driver/Utility also available from Ubiquiti

For help with MADWIFI or other Special Driver Support, Please e-mail support@ubnt.com

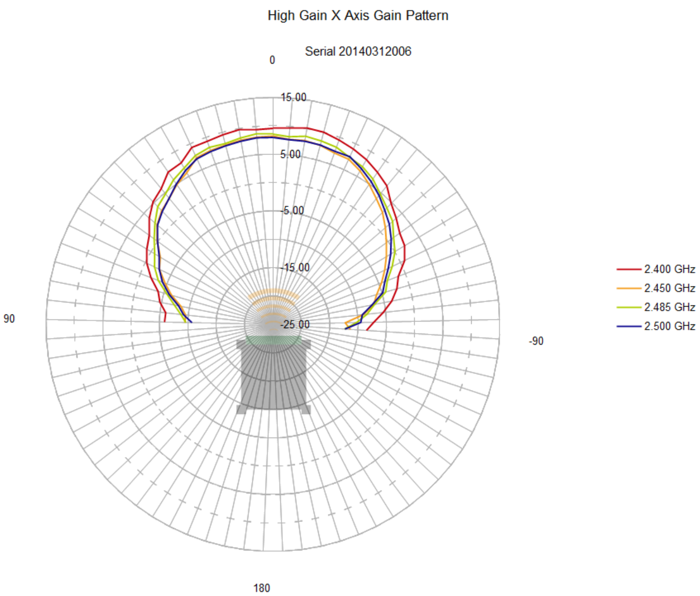
Planetary Resources Development Corporation

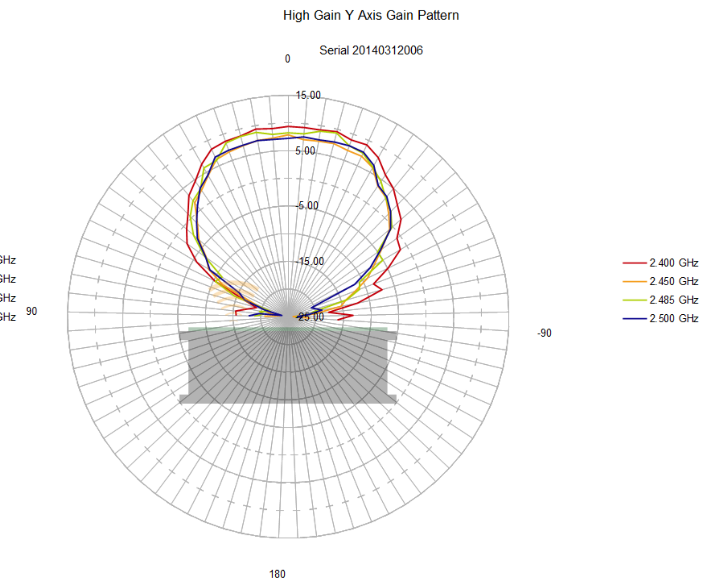
<u>Arkyd 3 RF Antenna 1001195-1</u>

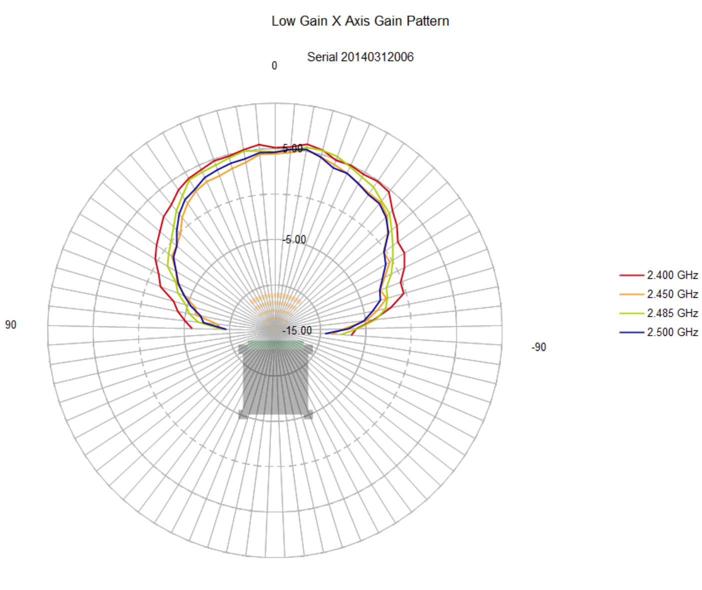
- FR-4 substrate with copper feedlines and radiating elements, with ENIG finish
- Two independent radiating elements
    - RHCP element with approx. 3 dBi gain
    - LCHP array element with approx. 8.5 dBi gain
- Both antennas provide VSWR of less than 2.0 over the 2.4-2.485 GHz frequency band
- Exterior dimensions less than 8mm x 100mm x 300mm
- Designed, manufactured, and tested by Star-H Corporation of Pennsylvania

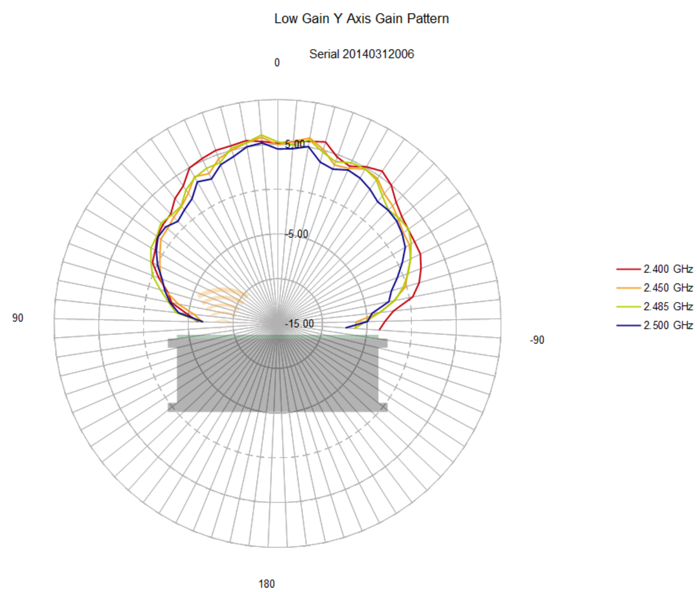


Arkyd 3 RF Antenna 1001195-1 Gain Patterns



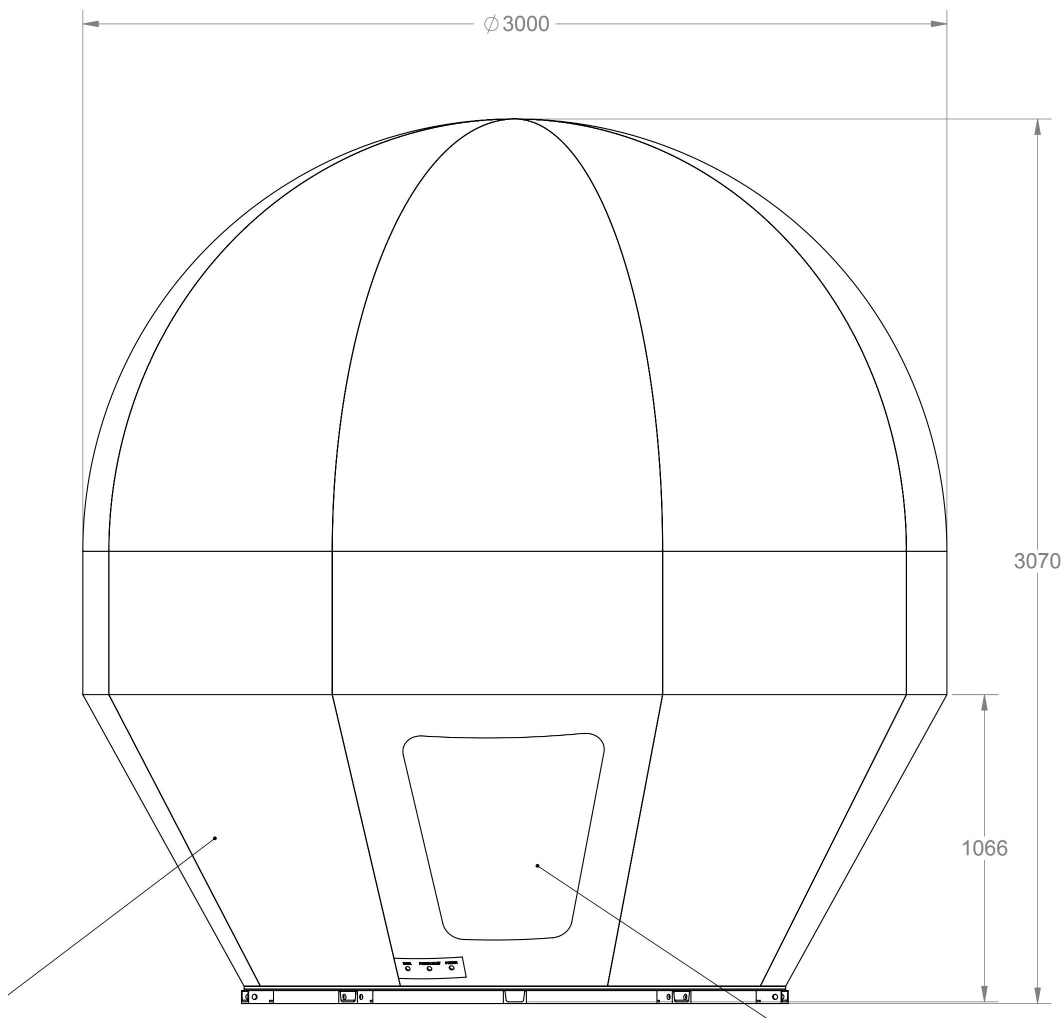






ORBIT COMMUNICATIONS SYSTEMS AL-6202 GROUND STATION

Manufacturer	Orbit Communications Systems
Frequency	S-Band; 2.4 – 2.4850 GHz
Antenna Diameter	2.4 meter parabolic
Peak Gain	33 dBi
Half-power beamwidth	3.6°
Gimbal Type	3-DOF: Az / El / Tilt
Site Location	Redmond, Washington N 47° 40.019483’ W 122° 5.575876’ 40.2 m AMSL site elevation



AL-6202 Outer Dimensions, including Radome (in mm)

ORBIT CS AL-6202 REPRESENTATIVE GAIN PATTERN (2.45 GHz)