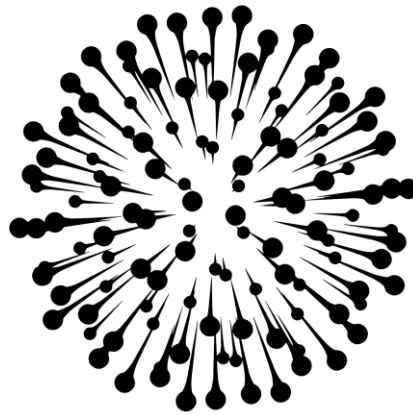


PIXXEL SPACE TECHNOLOGIES, INC.

Application for experimental spectrum utilization (FCC Part 5)
(Question 7 response, FCC Form 442)



PIXXEL

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7.a DESCRIPTION OF EXPERIMENT

7.a.1 INTRODUCTION

7.a.1.i APPLICANT

Pixxel Space Technologies, Inc. (hereinafter referred to as 'Pixxel') is a Delaware C-Corporation with its office at 3260 Hillview Avenue, Palo Alto, CA - 94304. Pixxel plans to design, construct, and operate hyperspectral Earth-imaging small satellites. Pixxel is aware of the requirement to obtain a NOAA license for the aforementioned purpose and has already initiated this process.

7.a.1.ii MISSION SUMMARY

Anand is a hyperspectral imaging technology demonstration mission, intended to demonstrate Pixxel's capabilities of operating a miniaturized hyperspectral imager on a low-Earth orbit (LEO), smallsat mission. The imager is built by Space Advisory Company from South Africa, and the mission is scheduled for a June 2020 launch. The mission goal is to demonstrate the imager on-orbit and verify its performance and applicability to small spacecraft in the 10-15 kg range. The mission will demonstrate the reliability, performance, and utility of this hyperspectral imager.

The satellite mission *Anand* will be launched in a 530 km – 600 km sun-synchronous lower earth orbit with an inclination of 97.8 degrees. The mission life is less than three years from launch.

7.a.2 SATELLITE PHYSICAL AND ORBITAL CHARACTERISTICS

7.a.2.i MASS AND DIMENSIONS

Anand is a custom-built nano-satellite weighing 14.5 kg. In the stowed configuration the bounding cuboid measures 335 mm x 335 mm x 387.5 mm. The satellite does not contain any propulsion system. The below images show the major dimensions of the satellite in the stowed and deployed configuration.

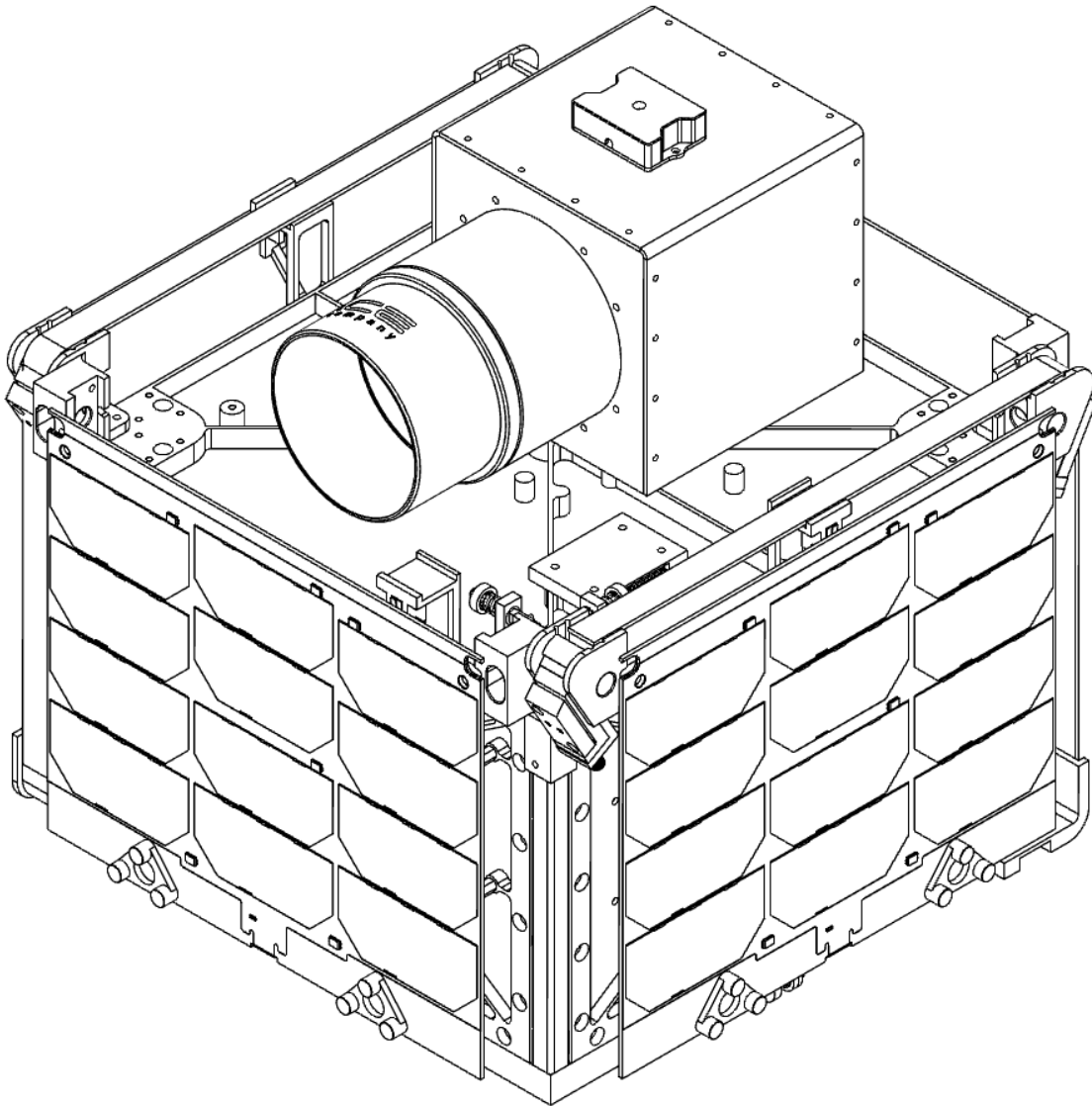


Figure 1: Spacecraft Stowed Configuration

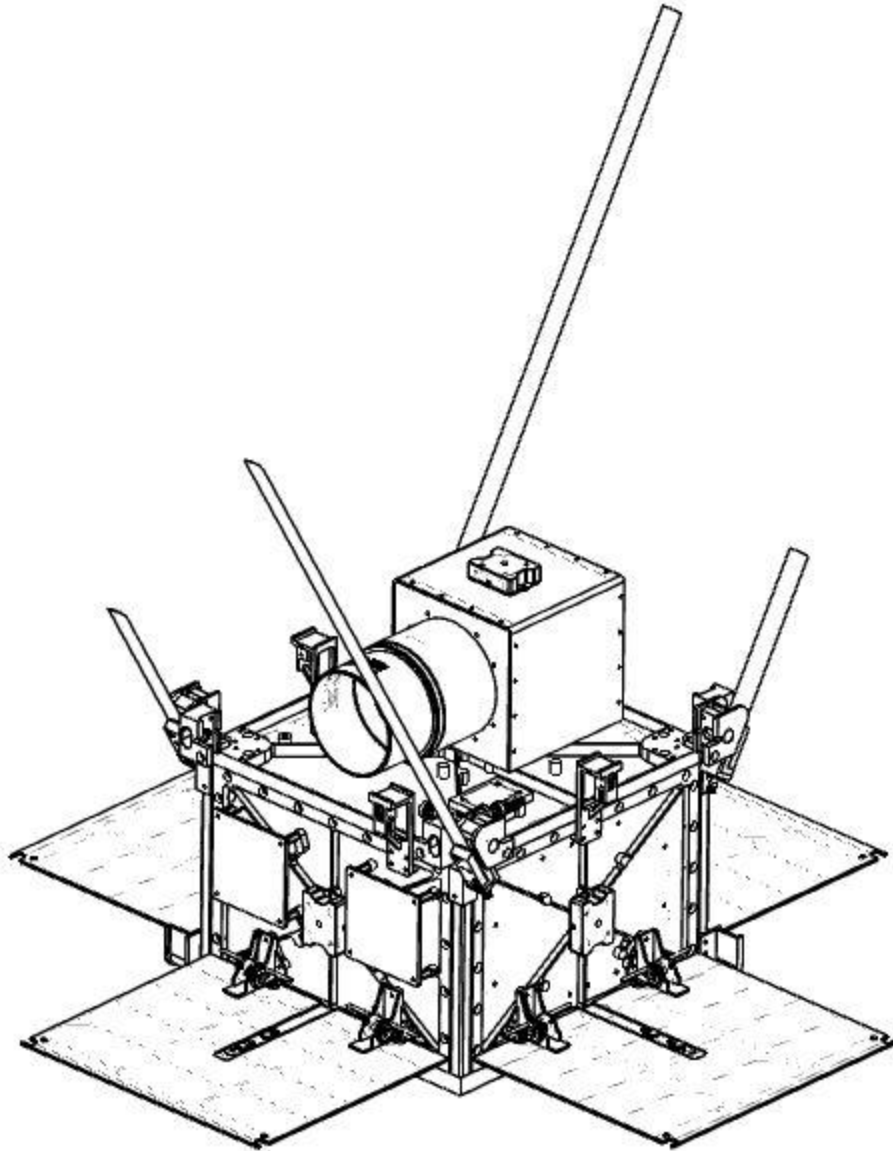
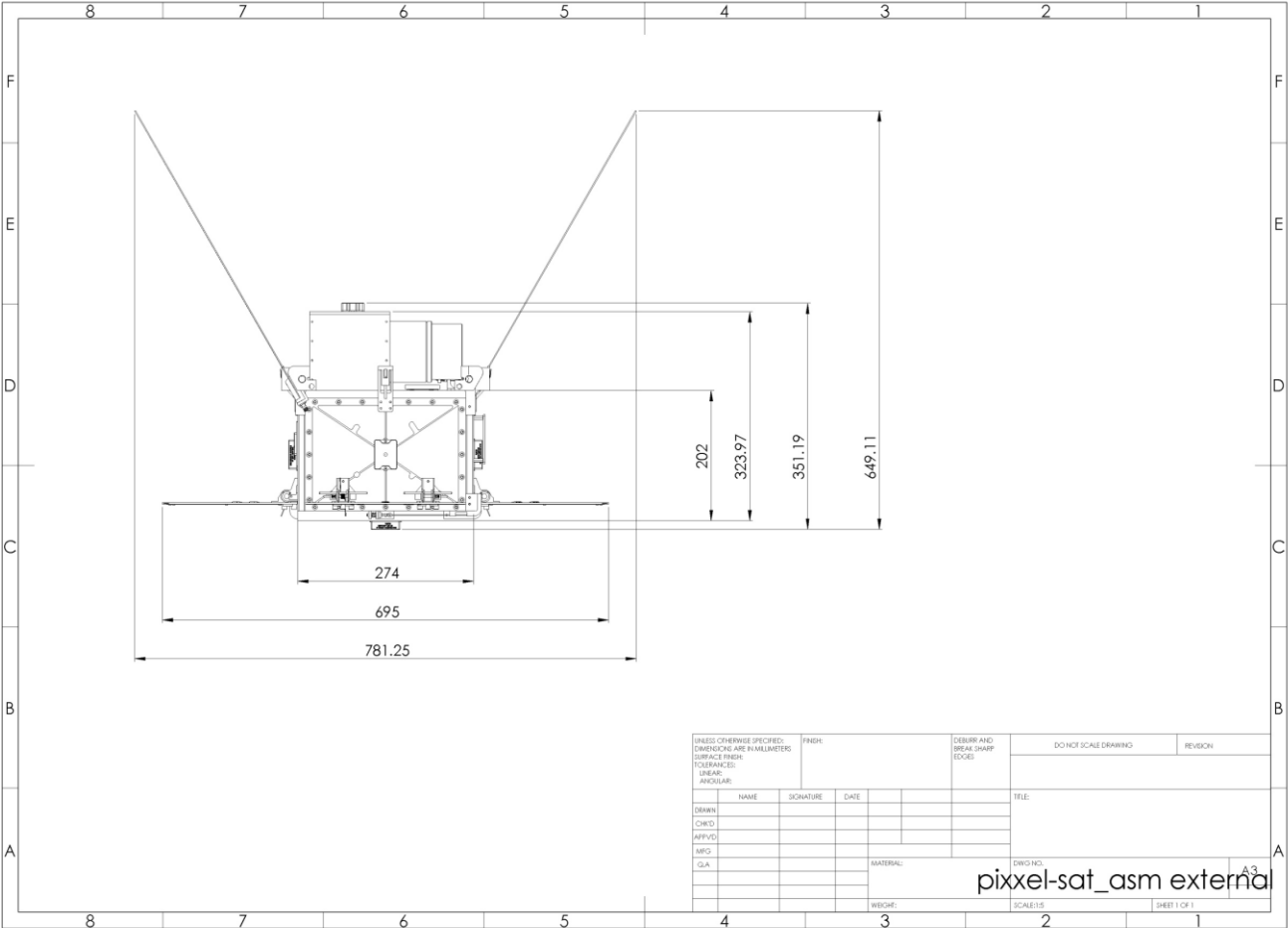


Figure 2: Spacecraft Deployed Configuration

a)



b)

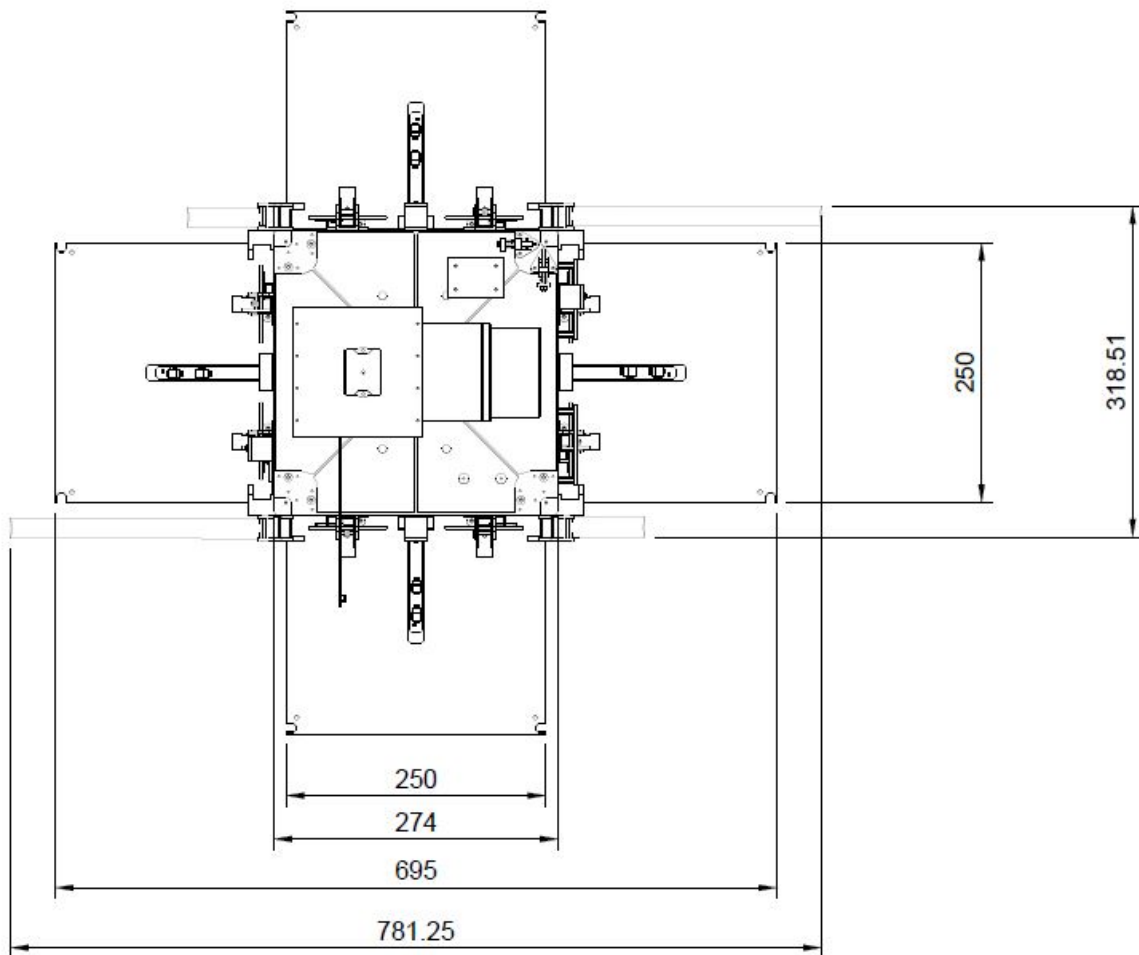


Figure 3: Satellite Major Dimensions - (a) Right view; (b) Top view. [All units are in mm]

7.a.2.ii OVERVIEW OF PAYLOAD

Anand is a hyperspectral earth imaging small-satellite. The hyperspectral imager on Anand is developed by Space Advisory Company which is based in South Africa.

The physical size of the imager assembly is 215 mm x 100 mm x 100 mm, and the mass is 1.35 kg.

7.a.2.iii INITIAL (DEPLOYMENT) ORBIT

The injection orbit of the Pixxel Mission is anticipated to be as follows:

Orbit Altitude: 530 km – 600 km (550 km desired)

Inclination: $97.8^{\circ} \pm 0.30^{\circ}$ (Nearly circular, SSO)

Local Time of Ascending Node (LTAN): 11:00 AM $\pm$ 8 minutes

Anand will use a secondary payload launch opportunity. Thus, it is possible that the injection orbit parameters could be different, as we could be re-assigned to fly on the launch of a different primary satellite system. Pixxel will advise the Commission should such an event occur.

7.a.2.iv RADIO FREQUENCY CHARACTERISTICS OF THE CHAMELEON IMAGER:

The imaging system contains no RF generating sources. No component of the imaging system is designed to radiate in the radio spectrum.

7.a.2.v MISSION OPERATIONS

Pixxel plans to use the Anand spacecraft imaging system to demonstrate the capability of low-power, low-weight miniaturized hyperspectral camera on-orbit. The spacecraft will also be used to assess the longevity and durability of the low-power hyperspectral camera on-orbit by operating it for 3 years.

Planned Orbital Maneuvers:

Pixxel does not plan to perform any orbital manoeuvres for the Anand mission.

Orbital Debris:

Pixxel has provided an Orbital Debris Assessment Report (ODAR) which is attached with our Form 442 submission. We hereby summarize the findings of our ODAR document.

7.a.3 ODAR SUBMISSION

7.a.3.i Human Casualty Risk:

Our debris analysis shows that as our reentry is uncontrolled, we are compliant with ODAR Requirement 4.7-1 regarding human casualty risk using the “Atmospheric Reentry Option (a) as

the probability of human casualty is less than 0.0001. DAS v2.1.1 has been used and reports that the Anand spacecraft is COMPLIANT with the requirement.

7.a.3.ii Panel Deployment Failure vs Orbit Altitude:

The baseline orbital lifetime of our spacecraft, in accordance with our ODAR submission, is less than 25 years. Pixxel has determined that if the satellite is dead on arrival at an injection orbit altitude of 600 km, it will have a worst-case orbital lifetime of less than 15 years.

7.a.4 RADIO FREQUENCY CHARACTERISTICS

7.a.4.i Introduction and Ground Segment

Pixxel has engaged with a third-party provider based out of Italy (Leaf Space S.r.l or “Leaf Space”) for their ground segment needs. Leaf Space has had a series of success stories demonstrating their capabilities in the market, including providing LEOP (Launch and Early Operations Phase) support to the INS I-C mission of the Indian Space Research Organisation (ISRO).

Pixxel will be purchasing service time for 6 ground station locations from Leaf Space. The ground station’s time will be shared between different customers and missions using a scheduling algorithm, handled by Leaf Space.

<i>Ground Station</i>	<i>Location</i>	<i>Latitude [N]</i>	<i>Longitude [E]</i>	<i>Service</i>
<i>IT - 01</i>	<i>Milan - Italy</i>	<i>45.59</i>	<i>9.36</i>	<i>TT&C</i>
<i>IE - 01</i>	<i>Cork - Ireland</i>	<i>51.95</i>	<i>-8.17</i>	<i>Payload Downlink</i>
<i>LT-01</i>	<i>Kaunas - Lithuania</i>	<i>54.91</i>	<i>23.99</i>	<i>Payload Downlink</i>
<i>ES-01</i>	<i>Puertollano - Spain</i>	<i>38.67</i>	<i>-4.16</i>	<i>Payload Downlink</i>
<i>NA-05</i>	<i>Southbury, Connecticut - USA</i>	<i>41.45</i>	<i>-73.29</i>	<i>Payload Downlink</i>
<i>NA-34</i>	<i>Las Cruces,</i>	<i>32.27</i>	<i>-106.91</i>	<i>Payload</i>

	New Mexico - USA			Downlink
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Pixxel will be using the Italian ground station (IT-01) solely for TT&C operations, and the remaining ground stations solely for payload downlink operations. Leaf Space will provide the dynamic schedule 72 hours prior to the ground station service is to be used, and Pixxel will command the spacecraft to accordingly downlink at the select location, in accordance with the schedule.

Nominally, the spacecraft will have 14 physical passes over the network, with 17 required transmissions:

Service	Number of [transmissions] per day
Payload Downlink	14
TT&C	3

Since the number of physical passes is less than the number of transmissions, multiple contacts will be required on some passes.

7.a.4.ii TT&C FREQUENCIES

The frequencies proposed for data transmission (downlink) from the satellite for telemetry and uplink for telecommand are in the UHF band and the VHF band respectively, and the associated details are provided in the table below:

Link Type	Frequency range(MHz)	Required bandwidth (kHz)	Data Rate
Downlink (Telemetry)	401.8974-401.9026	5.2	1200 bps
Uplink (Telecommand)	148.9974-149.0026	5.2	1200 bps

The telemetry downlink will employ a narrow bandwidth signal at a low data-rate of 1200 bps. The link utilises the Space Operation (Space-to-Earth) allocation in the spectrum (401-402 MHz band, consistent with the U.S. and ITU Table of Frequency Allocations 47 C.F.R. § 2.106.

The telecommand uplink utilises the Space Operation (Earth-to-Space) allocation spectrum in the 148-149.9 MHz band, consistent with the U.S. and ITU Table of Frequency Allocations. See 47 C.F.R. § 2.106 n. 5.218. We anticipate little to no coordination issues in this spectrum, considering

that the IT-01 ground station will be the only station operating at this frequency for telecommand and is based in Italy.

7.a.4.ii.1 COORDINATION STATUS OF UHF FREQUENCIES

The Anand mission would be using only the IT-01 ground station in **Milan, Italy** for the UHF telemetry downlink. Accordingly, Pixxel anticipates minimal coordination issues with current operators in this band.

7.a.4.ii.2 GROUND STATION LOCATION AND CHARACTERISTICS

There is only one ground station associated with the TT&C for Anand, as described below:

Ground Station	Location	Latitude [N]	Longitude [E]	Service
IT - 01	Milan - Italy	45.59	9.36	TT&C

7.a.4.iii PAYLOAD FREQUENCIES

The frequency proposed for data transmission (downlink) from the satellite for the payload data lies in the S-band, and the associated details are provided in the table below:

Link Type	Frequency range(MHz)	Bandwidth(MHz)	Data Rate
Downlink (Payload)	2242.35-2243.65	1.3	2 Mbps

The payload downlink utilizes the (Federal) Earth-Exploration Satellite Services (space-to-Earth) allocation in the 2200-2290 MHz band consistent with the U.S. and ITU Table of Frequency Allocations. 47 C.F.R. 2.106. Pixxel seeks a waiver of the U.S. Table of Frequency Allocations for its use of this band and will coordinate with incumbent users of this band (refer to 7.a.4.iii.1) to avoid causing potential interference, as discussed below.

7.a.4.iii.1 COORDINATION STATUS OF S-BAND FREQUENCIES

The 2200-2290 MHz band is heavily used in the United States and all over the world, and Pixxel is aware of the importance of avoiding interference to existing operations. Leaf Space will conduct interference analysis for the ground stations in the United States to tackle any issues that might arise with incumbent users. Pixxel will be utilising five ground stations for downlink in this band, owned and operated by Leaf Space but remotely operated by Pixxel for receiving mission data.

Two of these ground stations are located in the United States, and three in Europe.

Pixxel anticipates the bulk of the traffic to be handled by the European ground stations, with an average of seven passes at the American ground stations per day, reducing the probability of interference with incumbent users in the United States. Moreover, the dynamic nature of the schedule can account for and correct any anticipated interference by reassigning the downlink to another ground station.

7.a.4.iii.2 GROUND STATION LOCATION AND CHARACTERISTICS

The Anand mission will utilise 5 ground stations for receiving the payload downlink. Two ground stations are in the United States, and 3 are in Europe.

Ground Station	Location	Latitude [N]	Longitude [E]	Service
IE - 01	Cork - Ireland	51.95	-8.17	Payload Downlink
LT-01	Kaunas - Lithuania	54.91	23.99	Payload Downlink
ES-01	Puertollano - Spain	38.67	-4.16	Payload Downlink
NA-05	Southbury, CT - USA	41.45	-73.29	Payload Downlink
NA-34	Las Cruces, New Mexico - USA	32.27	-106.91	Payload Downlink

7.b SPECIFIC OBJECTIVES OF EXPERIMENT

The research objectives of this project are:

1. Demonstrate the capability of low-power, low-weight miniaturized hyperspectral camera on-orbit.
2. Assess the longevity and durability of the low-power hyperspectral camera on-orbit by operating it for 3 years.
3. Use the image data obtained to design species detection algorithms for crops in small-farmer holdings that follow mixed cropping patterns in Asia and Africa using distinctive spectral signatures and track the life-cycle of these crops.

4. Use change detection algorithms over three years (for three cycles of every cropping season) to predict crop yield more accurately.

7.c How will the program of experimentation demonstrate a reasonable promise of contributing to the development, expansion or utilization of the radio art, or is along a research line not already investigated?

Pixxel's objective is to use hyperspectral image data obtained from 'Anand' to design species detection algorithms for crops in small-farmer holdings that follow mixed cropping patterns in Asia and Africa. Currently, available satellite imagery does not have enough spectral and temporal resolution for species detection in small farmer holdings.

Pixxel's satellite imagery will be used to monitor crop health and predict crop yield in these small farmer holdings. The data collected in 100+ spectral bands will allow Pixxel to detect spectral signatures for different chemical constituents of plants and soil and follow the life-cycle of multiple crops.

Pixxel's satellite imagery will also be used to create a unique dataset of crop species information and soil information as we measure the effects of seasonal changes on crop health throughout the mission life.