PIXXEL PRODUCTS SPECIFICATIONS

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Glossary

Term	Definition
Application Programming Interface (API)	A set of protocols enabling software applications to interact with each other.
Area of Interest (AOI)	A specific Earth surface area defined for targeted satellite data collection.
Atmospheric Correction	The process of compensating for the influence of Earth's atmosphere on captured satellite imagery.
Bottom of Atmosphere (BOA)	Earth's surface as it would appear without atmospheric distortion, obtained through correction algorithms.
Digital Elevation Model (DEM)	A digital representation depicting Earth's terrain elevation.
Digital Number (DN)	A numerical value assigned to each pixel in a digital image, representing the intensity of light or radiation received by a sensor and converted into a discrete digital format for processing and analysis.
GeoJSON	A standard file format for encoding geographical data using JSON to represent geographic features and their properties.
GeoTIFF	A geospatial image file format that includes geographic information that can be accessed in GIS or other geospatial software.
Graphical User Interface (GUI)	A visual interface that allows users to interact, preview, and download Pixxel's imagery.
Ground Sample Distance (GSD)	The physical distance on the ground that each pixel in a satellite image represents, indicating the level of detail captured in the image.
Metadata	Descriptive information about the imagery product that provides further information on the content of the data product which can be used for additional analysis or processing.
Nadir	The point on the Earth's surface directly below a satellite.

Term	Definition
Near-Infrared (NIR)	The portion of the electromagnetic spectrum just beyond the visible red light, often used in satellite imagery to detect vegetation health and moisture content.
Off Nadir Angle (ONA)	The angle between the satellite's positioning direction and point directly below the satellite on the Earth's surface (nadir).
Orthorectification	The process of correcting satellite imagery to remove distortions caused by terrain variations and sensor viewing angles, resulting in accurate maps.
Radiometric Correction	The correction of variations in data that are not caused by the object or image being scanned. These include correction for relative radiometric response between detectors, filling non-responsive detectors, and scanner inconsistencies.
Sensor Correction	The correction of data variations caused by sensor geometry, attitude, and ephemeris.
SpatioTemporal Asset Catalog (STAC)	A standardized catalog specification used to discover and index a wide range of geospatial datasets.
Sun Azimuth	The angle of the Sun as seen by an observer located at the target point, as measured in a clockwise direction from the North.
Sun Elevation	The angle of the Sun above the horizon.
Sun Synchronous Orbit (SSO)	A geocentric orbit that combines altitude and inclination so that the satellite passes over any given point of the planet's surface at the same local solar time.
SWIR	Short Wave Near Infrared Product (900-2500 nm) from the Honeybee satellites.
Top of Atmosphere (TOA)	The outermost boundary of the Earth's atmosphere in satellite imagery, representing measurements captured by a sensor before any atmospheric effects or interactions are considered.
VNIR	Visible Near Infrared Product (470-900 nm) from the Firefly satellites.
Quaternion	Quaternions are mathematical operators that are used to rotate and stretch vectors. Quaternions are an alternate way to describe orientation or rotations in 3D space using an ordered set of four numbers.

1. PIXXEL OVERVIEW

This document describes Pixxel satellite imagery and platform products. It is intended for users of satellite imagery interested in working with Pixxel's product offerings.

1.1. COMPANY OVERVIEW

Pixxel is a space data company, building a constellation of hyperspectral Earth imaging satellites and the analytical tools to mine insights from that data. The constellation is designed to provide global coverage every 24 hours, with the aim of detecting, monitoring, and predicting global phenomena.

1.2. DATA PRODUCT OVERVIEW

Pixxel currently provides these data products:

VNIR Imagery	SWIR imagery
Hyperspectral Visible and Near Infrared (VNIR) Product (470-900 nm) from the Technology Demonstrator satellites and Firefly satellites upon launch in 2024	Hyperspectral Short Wave Infrared (SWIR) Product (900-2500 nm) from the Honeybee satellites upon launch in 2025

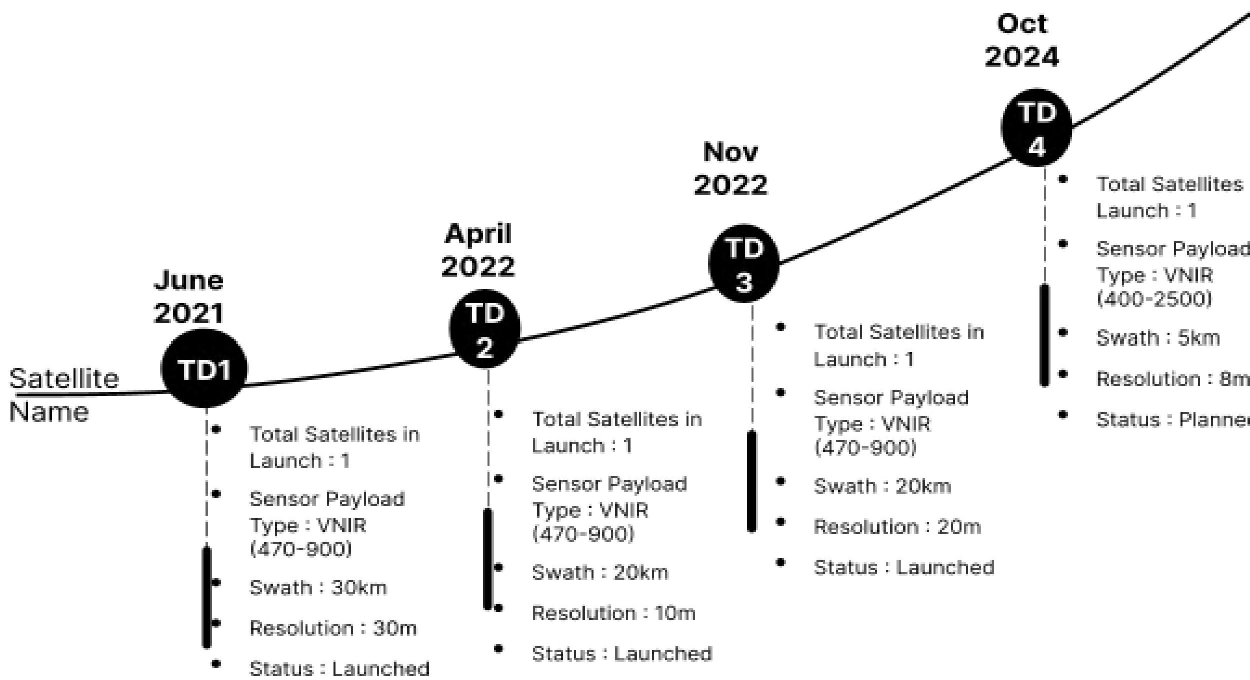
Upon launch of the Firefly and Honeybee constellations, the data can be provided either as a VNIR or SWIR product separately or as a combined product.

1.3. PIXXEL CONSTELLATION OVERVIEW

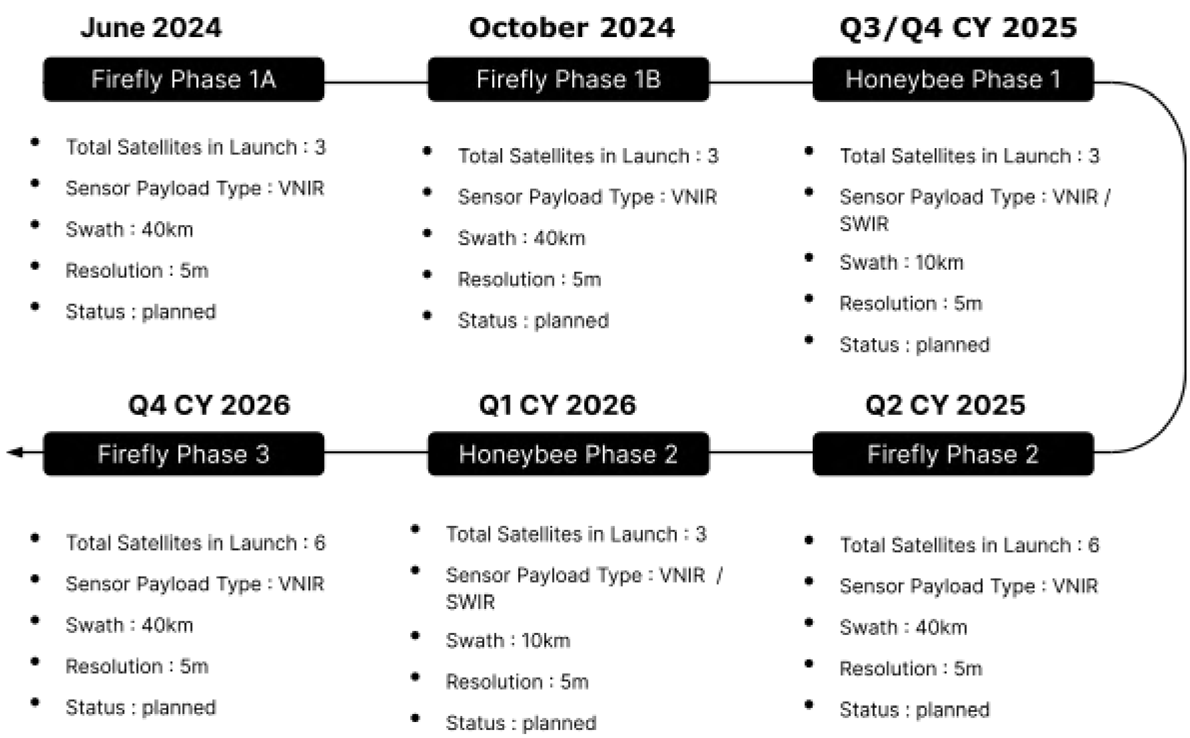
Satellite	Wavelength range	Spatial Resolution (GSD)	Status
Tech Demo - 1	470-900 nm (VNIR)	30m	Launched and operational
Tech Demo - 2	470-900 nm (VNIR)	10m	Launched and operational
Tech Demo - 4	470-2500 nm (VNIR/SWIR)	8m	To launch in Q4 2024
Fireflies	470-900 nm (VNIR)	5m	To launch in Q2 2024
Honeybees	470-2500 nm (VNIR/SWIR)	5m	To launch in H2 2025

1.4. PIXXEL CONSTELLATION LAUNCH ROADMAP

Tech Demo Satellite Launch Plan:



Commercial Constellation Launch Plan:



1.5. PIXXEL TECH DEMO SATELLITES AND SENSOR OVERVIEW

Parameters	Tech Demo 1	Tech Demo 2	Tech Demo 4
Ground Spatial Distance (GSD)	32 m (from a reference 510 km altitude)	9.8 m (from a reference 500 km altitude)	8 m
Swath	30 km	19.6 km	5 km
Wavelength Range	470 - 900 nm	470 - 900 nm	400 - 2500 nm
Orbit	Sun Synchronous Orbit (SSO), 98° inclination	Sun Synchronous Orbit (SSO), 97.4° inclination	Sun Synchronous Orbit (SSO), 97.6° inclination
Altitude	350 - 550 km (declines naturally throughout its lifetime)	350 - 550 km (declines naturally throughout its lifetime)	500 - 550 km (subject to change)
Equator Crossing Time	2:30 PM	11:00 AM	10:30 - 11 AM (subject to change)
Total available bands	161 bands	150 bands	468 bands
Total selectable bands (per acquisition)	67 bands	67 bands	200 bands
Off-nadir angle (ONA)/slew	+/- 20°	+/- 20°	+/- 20°
Revisit time	7 days	7 days	Every 14 days to 21 days
Cloud cover thresholds	<20%	<20%	20% TBD
Imagery bit depth	10 bits of dynamic range, stretched to fill a 16 bit container	10 bits of dynamic range, stretched to fill a 16 bit container	10 bits of dynamic range, stretched to fill a 16 bit container

1.6. PIXXEL COMMERCIAL CONSTELLATION AND SENSOR OVERVIEW

Parameters	Firefly Constellation	Honeybee Constellation
Ground Spatial Distance (GSD)	5 meters	5 meters
Swath	40 km	10 km SWIR 30 km VNIR
Wavelength range	470 - 900 nm	470 - 2500 nm
Total available bands	~160 bands	~160 VNIR, ~100 SWIR
Total selectable bands	~50 bands	Total: 72, VNIR - 46, SWIR - 26
Orbit	Sun Synchronous Orbit (SSO), 97.65° inclination	Sun Synchronous Orbit (SSO), 97.45° inclination
Altitude	565 km	550 km (TBD)
Equator Crossing Time	10 - 11 AM	10 - 11 AM
Off-nadir angle (ONA)/slew	+/- 20° (+/-10° recommended)	+/- 30° (+/-10° recommended)
Revisit time	1 - 4 days	1 - 4 days
Cloud cover thresholds	<20%	<20%
Imagery bit depth	10 bits of dynamic range, stretched to fill a 16 bit container	10 bits of dynamic range, stretched to fill a 16 bit container

2. TECH DEMO SATELLITES AND SENSOR CHARACTERISTICS

2.1. TECHNOLOGY DEMONSTRATOR 1 (30M) SATELLITE AND SENSOR

The technology demonstration satellite 1 (D2) is equipped with a prototype hyperspectral imager capable of capturing 161 bands in the 470-900 nm range at a 16-meter GSD and 32-meter pixel size. This single prototype satellite is limited in its capture and downlink capabilities, which can result in longer capture times than the planned Firefly and Honeybee constellations which are composed of six satellites each.

Mission Characteristics

<table>
<tr><th>Parameters</th><th>Tech Demo 1</th></tr>
<tr><td>Ground Spatial Distance (GSD)</td><td>30 meters (from a reference 510 km altitude)</td></tr>
<tr><td>Swath</td><td>30 km</td></tr>
<tr><td>Wavelength range</td><td>470 - 900 nm</td></tr>
<tr><td>Orbit</td><td>Sun Synchronous Orbit (SSO), 98° inclination</td></tr>
<tr><td>Altitude</td><td>350 - 550 km (declines naturally throughout its lifetime)</td></tr>
<tr><td>Equator Crossing Time</td><td>2:30 PM</td></tr>
<tr><td>Band Information</td><td>Bandwidths: 2nm - 11 nm
Range: 467.9 nm - 899.2 nm, 161 hyperspectral bands
<table>
<tr><th>Band Group</th><th>Number of Bands</th><th>Approximate range</th><th>Average Bandwidth</th></tr>
<tr><td>Blue
(450 - 500)</td><td>9</td><td>471.5 - 500.5 nm</td><td>3.1</td></tr>
<tr><td>Green
(500 - 570)</td><td>21</td><td>501.5 - 568.5 nm</td><td>2.9</td></tr>
<tr><td>Yellow - Orange
(570 - 620)</td><td>19</td><td>571.0 - 620.5 nm</td><td>7.8</td></tr>
<tr><td>Red
(620 -700)</td><td>26</td><td>625.0 - 699.0 nm</td><td>5.6</td></tr>
<tr><td>Red-Edge
(700 - 750)</td><td>16</td><td>703.0 - 750.0 nm</td><td>4.7</td></tr>
<tr><td>NIR
(750 - 900)</td><td>54</td><td>753.5 - 896.0 nm</td><td>7.8</td></tr>
</table>
</td></tr>
<tr><td>Total available bands</td><td>161 bands</td></tr>
<tr><td>Total selectable bands</td><td>67 bands</td></tr>
<tr><td>Off-nadir angle (ONA)/slew</td><td>+/- 20°</td></tr>
<tr><td>Revisit time</td><td>7 days</td></tr>
<tr><td>Cloud cover thresholds</td><td><20%</td></tr>
<tr><td>Imagery bit depth</td><td>10 bits of dynamic range stretched to fill a 16-bit container</td></tr>
</table>

2.2. TECHNOLOGY DEMONSTRATOR 2 (10M) SATELLITE AND SENSOR CHARACTERISTICS

The technology demonstration satellite 2 (Shakuntla) is equipped with a prototype hyperspectral imager capable of capturing 150 bands in the 470-900 nm range at a 10-meter GSD. This prototype satellite is limited in its capture and downlink capabilities, which can result in longer capture times than the planned Firefly and Honeybee constellations.

Mission Characteristics

<table>
<tr><th>Parameters</th><th>Tech Demo 2</th></tr>
<tr><td>Ground Spatial Distance (GSD)</td><td>9.8 meters (from a reference 500 km altitude)</td></tr>
<tr><td>Swath</td><td>19.6 km</td></tr>
<tr><td>Wavelength range</td><td>470 - 900 nm</td></tr>
<tr><td>Orbit</td><td>Sun Synchronous Orbit (SSO), 97.4° inclination</td></tr>
<tr><td>Altitude</td><td>350 - 550 km (declines naturally throughout its lifetime)</td></tr>
<tr><td>Equator Crossing Time</td><td>11:00 AM</td></tr>
<tr><td>Band Information</td><td>Bandwidths: 2nm - 11 nm
Range: 469.9 nm - 894.0 nm, 150 hyperspectral bands
<table>
<tr><th>Band Group</th><th>Number of Bands</th><th>Approximate range</th><th>Average Bandwidth</th></tr>
<tr><td>Blue
(450 - 500)</td><td>9</td><td>470.0 - 497.0 nm</td><td>2.9 nm</td></tr>
<tr><td>Green
(500 - 570)</td><td>20</td><td>501.0 - 570.0 nm</td><td>2.4 nm</td></tr>
<tr><td>Yellow - Orange
(570 - 620)</td><td>15</td><td>573.5 - 620.0 nm</td><td>3.9 nm</td></tr>
<tr><td>Red
(620 -700)</td><td>28</td><td>623.0 - 698.0 nm</td><td>4.0 nm</td></tr>
<tr><td>Red-Edge
(700 - 750)</td><td>17</td><td>702.0 - 750.5 nm</td><td>3.3 nm</td></tr>
<tr><td>NIR
(750 - 900)</td><td>55</td><td>753.5 - 894.0 nm</td><td>5.5 nm</td></tr>
</table>
</td></tr>
<tr><td>Total available bands</td><td>150 bands</td></tr>
<tr><td>Total selectable bands</td><td>67 bands</td></tr>
<tr><td>Off-nadir angle (ONA)/slew</td><td>+/- 20°</td></tr>
<tr><td>Revisit time</td><td>7 days</td></tr>
<tr><td>Cloud cover thresholds</td><td><20%</td></tr>
<tr><td>Imagery bit depth</td><td>10 bits of dynamic range stretched to fill a 16-bit container</td></tr>
</table>

2.3. TECHNOLOGY DEMONSTRATOR 4 (8M) SATELLITE AND SENSOR CHARACTERISTICS

The technology demonstration satellite 4 is equipped with a prototype hyperspectral imager capable of capturing 200 bands in the 400-2500 nm range at an 8-meter GSD. This prototype satellite is limited in its capture and downlink capabilities, which can result in longer capture times than the planned Firefly and Honeybee constellations.

Mission Characteristics

Parameters	Tech Demo 4
Ground Spatial Distance (GSD)	8 meters
Swath	5 km
Wavelength range	400 - 2500 nm
Orbit	Sun Synchronous Orbit (SSO), 97.6° inclination
Altitude	500 - 550 km (subject to change)
Equator Crossing Time	10:30 - 11 AM (subject to change)
Total available bands	468 bands
Total selectable bands	200 bands
Off-nadir angle (ONA)/slew	+/- 20°
Revisit time	Every 14 days to 21 days
Cloud cover thresholds	20% TBD
Imagery bit depth	10 bits of dynamic range, stretched to fill a 16-bit container

3. FIREFLY CONSTELLATION AND SENSOR OVERVIEW

The Firefly satellites are planned to be launched in 2024. The sensors on these satellites are equipped to provide hyperspectral imagery of 160 bands in the 470-900 nm range at a 5-meter GSD.

Mission Characteristics

PARAMETERS	FIREFLY CONSTELLATION
Ground Spatial Distance (GSD)	5 meters
Swath	40 km
Wavelength range	470 - 900 nm
Band Information	Bandwidths: 2nm - 11 nm Range: 467.9 nm - 902.6 nm, 161 hyperspectral bands
Total available bands	~160 bands
Total selectable bands	~50 bands
Orbit	Sun Synchronous Orbit (SSO), 97.65° inclination
Altitude	565 km
Equator Crossing Time	10 - 11 AM
Off-nadir angle (ONA)/slew	+/- 20° (+/-10° recommended)
Revisit time	1 - 4 days
Cloud cover thresholds	<20%
Imagery bit depth	10 bits of dynamic range, stretched to fill a 16-bit container

4. HONEYBEE SATELLITE CONSTELLATION AND SENSOR CHARACTERISTICS

The Honeybee satellites are planned to be launched in 2025. The sensors on these satellites are equipped to provide hyperspectral imagery of 260 bands in the 470 - 2500 nm range at a 5-meter GSD.

Mission Characteristics

PARAMETERS	HONEYBEE CONSTELLATION
Ground Spatial Distance (GSD)	5 meters
Swath	10 km SWIR 30km VNIR
Wavelength range	470 - 2500 nm
Total available bands	160 VNIR, 100 SWIR
Total selectable bands	Total: 72, VNIR - 46, SWIR - 26
Orbit	Sun Synchronous Orbit (SSO), 97.45° inclination
Altitude	500 - 550 km
Equator Crossing Time	10 - 11 AM
Off-nadir angle (ONA)/slew	+/- 30° (+/-10° recommended)
Revisit time	1 - 4 days
Cloud cover thresholds	<20%
Imagery bit depth	10 bits of dynamic range, stretched to fill a 16-bit container

5. PRODUCT PROCESSING

5.1. IMAGE PROCESSING LEVELS

Name	Description	Product Level
Bottom of Atmosphere (BOA) reflectance	This is radiometric, geometric, and atmospheric (aerosol and water vapor) corrected BOA reflectance data. The image is orthorectified and projected to WGS84 projection. The data is available in a geoTIFF file format (accompanied by additional metadata). The pixel reflectance values are linearly scaled between 0 - 50000. Thus to convert the image to 0-1 reflectance range, all the pixel values must be divided by 50000.	L2A
Top of Atmosphere (TOA) reflectance	This is radiometric, and geometric corrected TOA reflectance data. The image is orthorectified and projected to WGS84 projection. The data is available in a geoTIFF file format (accompanied by additional metadata). The pixel reflectance values are linearly scaled between 0 - 50000. Thus to convert the image to 0-1 reflectance range, all the pixel values must be divided by 50000.	L1C
Top of Atmosphere (TOA) radiance	This is radiometric, and geometrically corrected TOA radiance (also termed at-sensor radiance) data. The image is orthorectified using a customer-requested projection. The data is available in a geoTIFF file format (accompanied by additional metadata). This level may be available on request. The pixel values are not scaled and the values have radiance units - $W \cdot m^{-2} \cdot sr^{-1} \cdot \mu m^{-1}$	L1B (available upon request)

5.2. IMAGE PROCESSING AND CORRECTION

The image processing workflow consists of four major steps - radiometric correction, geometric correction, atmospheric correction, and quality analysis. Before radiometric correction, the raw data downlinked from the satellite is converted to an L0 level for long-term storage. The L0 level data is then used for radiometric correction where DN numbers are converted to radiance, and basic striping and high-frequency noises are removed from the data. This data is called L1A. Post L1A, a geometric correction model is applied to georeference, orthorectify the data, and stored as level L1B. L1B data is used by Pixxel's internal atmospheric correction model and is converted to TOA reflectance (L1C) and BOA reflectance (L2A) data sequentially. Upon completion, a quality analysis and quality check are performed on each image, observations are recorded and data is stored for delivery. Figure 4.2 illustrates the image processing method. Table 4.2 describes each block in the flowchart.

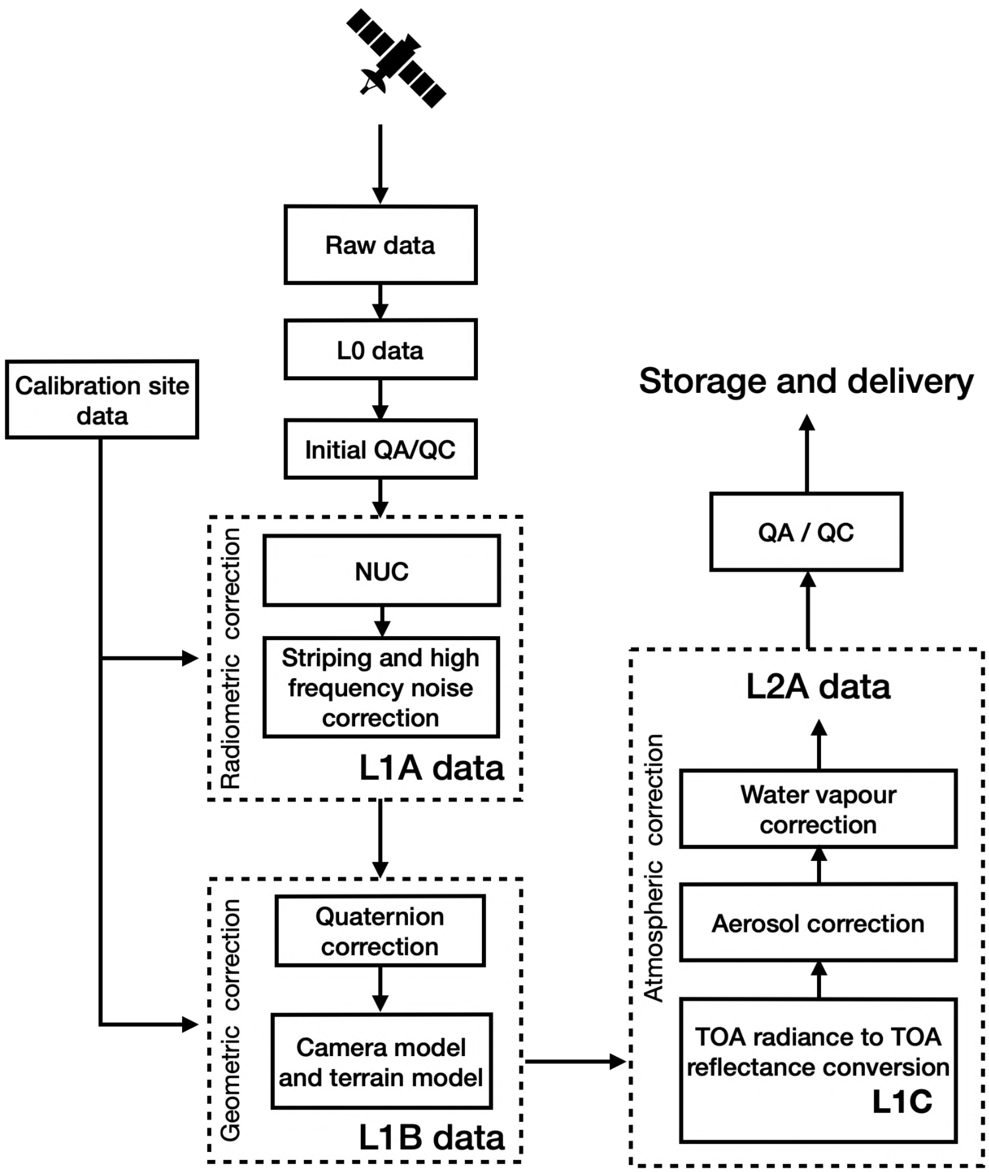


Figure 4.2: Image processing pipeline flowchart

Table 4.2: Image processing steps

Raw data	This is raw data downlinked from the satellite.
L0 data	This level is for long-term archive of the raw data with additional information added at a ground station.
NUC correction	NUCs stands for non-uniformity coefficients which are calculated during pre-launch calibration and used on the satellite data to convert DN numbers to radiance.
Striping and high-frequency noise correction	Minor striping noise and high-frequency noise present in the data post-NUC implementation are corrected through a filtering approach.
Camera model-based geometric correction	A custom-written camera model is used to project an L1A pixel to a stated height above the ellipsoid, returning the latitude and longitude at that depth into the scene.
Orthorectification	Orthorectification is performed by using the aforementioned camera model and Copernicus DEM/terrain models. The output image of this step is termed level L1B.
TOA radiance to TOA reflectance	The georeferenced and orthorectified TOA radiance image is converted to a TOA reflectance image using extraterrestrial solar irradiance, Earth-Sun distance, and solar zenith angle. This TOA reflectance data level is termed L1C.
Aerosol correction	The L1B and L1C data are used to estimate and correct the effects of aerosol using Pixxel's in-house pHSICOR model. This step removes the haze effect from the image and makes the image visibly clear.
Water vapor correction	Water vapor correction helps in correcting spectral bands in the water absorption regions centered around 950 and 1150 nm. The output image of this step is termed level L2A.
QA/QC	The L2A, L1C, and L1B data go through automated and random manual quality assessments, and the spectral and geometric quality observations are recorded.

5.2.1. L1A Processing: Initial Radiometric Interpretation & Correction

To create calibrated hyperspectral products (Pixxel L1B, L1C, and L2A) suitable for use as Analytics Ready Data (ARD), an initial L1A pre-processing step is conducted to eliminate predictable image artifacts. Radiometric correction coefficients (NUC) are calculated pre-launch and their accuracy is validated on-orbit using collects over established vicarious sites such as RadCalNet and FLARE sites.

All Pixxel satellite images are collected at a bit depth of 10 bits per pixel. Once on the ground, the images are converted to 16-bit format. On-ground image processing involves applying radiometric correction coefficients to convert the pixel Digital Numbers (DNs) from the sensor to absolute at-sensor radiance units.

The pixel values of Pixxel's L1A product represent absolute calibrated radiance units for the image.

5.2.2. L1B Processing: Geometric Correction

Further radiometric processing (L1C, L2A) requires accurate georeferencing. L1B processing orthorectifies all bands using a calibrated camera model and a terrain model. Geolocation is computed photogrammetrically, and good band-to-band registration is obtained.

The initial attitude data received from the satellite has poor accuracy due to hardware limitations. This creates a noticeable geolocation error that must be addressed before L1B processing. To rectify this, Pixxel bands are registered against Sentinel-2 reference images to recover an “adjusted pointing” that would lead to the same geolocation upon projection. A proprietary, multi-channel registration technique is employed where four Pixxel bands in a collection are simultaneously registered to the corresponding four 10-meter bands [blue, green, red, NIR] of a contemporaneous Sentinel-2A or 2B truth ortho. The registration creates tie points for those four bands which are then fed into a least squares fit that deduces the adjusted pointing. This "corrected quaternion list" is then stored for all subsequent product generation. This process is as accurate as the truth orthos, which themselves typically have an absolute geolocation accuracy of around 12 meters CE90.

Also relevant is the geometric accuracy of the terrain model (DEM) used during orthorectification. Freely available, 30-meter Copernicus DEMs have a horizontal accuracy of 6 meters or a 1/5th of a posting. Vertical accuracy for the DEM is about 4 meters or 1/7th of a posting.

The output of L1B processing is a multiband geoTIFF, complete with geospatial headers that specify the projection and extent. The map projection can be anything but is defaulted to geodetic (EPSG:4326). The hyperspectral stack is trimmed to the common overlap region of all bands. A configurable value is used to fill areas outside the projection. The bit depth is made 16-bit just prior to saving the file.

5.2.3. L1C Processing: Radiance to Reflectance Conversion

To generate the L1C scaled product from Pixxel's L1B radiance values, parameters such as Earth-Sun distance, extraterrestrial solar irradiance, and solar zenith angles are considered for calculation using the following formula:

$$Ref_{L1C} = \frac{Rad_{L1B} * \pi * dist_{ES}^{2}}{E_{sun} * cos(\theta_{s})}$$

where,

Ref_{L1C} = Top-of-atmosphere Reflectance

Rad_{L1B} = Top-of-atmosphere Radiance

$dist_{ES}$ = Earth-Sun distance ratio in astronomical unit for a given acquisition date

E_{sun} = Extraterrestrial Solar Irradiance

θ_{S} = Solar Zenith angle in degrees

The above formula assumes that the targets are Lambertian in nature and BRDF effects of the target are not taken into consideration.

The delivered Pixxel L1C product is then scaled between 0-50000 values, where 0 is for 0 reflectance and 50000 represents 100% reflectance (i.e. 1). Thus, to convert pixel values of L1C product to TOA reflectance, the pixel values are to be multiplied by a reflectance scaling factor of 2e-5, as provided in the corresponding metadata XML file, as:

$$Ref = Pixel_{L1C} * ReflectanceScalingFactor$$

$$where,\ Pixel_{L1C} = L1C\, product\, pixel\, value \text{ and } ReflectanceScalingFactor = 2 * 10^{-5}$$

5.2.4. L2A Processing: Atmospheric Correction

To generate a bottom-of-the-atmosphere (BOA) L2A product, Pixxel L1C products are atmospherically corrected using Pixxel's copyrighted atmospheric correction software - pHSICOR. The software accounts for aerosols and water vapor content in the atmosphere and their variations with the altitude. Based on libRadtran look-up-tables, popular approaches such as Dark-Dense Vegetation and novel methods such as the Water Absorption Strength Ratio were used in combination to estimate the BOA products. Some limitations of the model are:

- The current version of the atmospheric correction model does not correct for oxygen absorption bands around 760 nm.
- The surface BRDF effects have not been accounted for.

5.3. PRODUCT METADATA

Each of the image products contains an image file in geoTIFF format, an RGB composite thumbnail of the image in JPEG format, a footprint, and a bounding box in geoJSON format. Each of the products is also accompanied by a metadata file in XML format, with the following parameters:

PARAMETER	DATA TYPE	DESCRIPTION
Satellite Details		
Satellite	string	The satellite ID to which the image product belongs. Satellite ID "Pixxel-TD1 '' indicates the image product belongs to Pixxel's TD1 satellite.
Sensor Name	string	Field indicates the name of the imaging sensor. For Pixxel's TD1, the hyperspectral imager is the 'VNIR' sensor.
Image Product Details		
Product Files	string	List of all the filenames included in the image product including image file, metadata, bounding box, and header files.
Image Acquisition Details		
Acquisition Datetime	string	Date and time in UTC format at the time of image acquisition.
Altitude	number	Height of the satellite in units of kilometers at the time of image acquisition.
Columns	number	Number of columns of the image product, or alternatively called samples.
Earth Sun Distance Ratio	number	Earth-Sun distance in astronomical units depending on the image acquisition day.
Image ID	string	Image ID is unique to each image from the sensor, which also indicates the Tile Strip number. All communication with Pixxel about the image has to be referred to the image ID.
Number of bands	number	Indicates the number of bands available in the image product.
Rows	number	Number of rows of the image product or scan lines.
Satellite Look Angle	number	Angle between the satellite's pointing direction and nadir in units of decimal degrees.

PARAMETER	DATA TYPE	DESCRIPTION
Scene Center Lat	number	Geographic latitude of the center pixel of the scene in units of decimal degrees using the WGS84 standard of reference.
Scene Center Lon	number	Geographic longitude of the center pixel of the scene in units of decimal degrees using the WGS84 standard of reference.
Sun Azimuth Angle	number	Azimuth angle of the Sun's position at the time of image acquisition in units of decimal degrees.
Sun Elevation Angle	number	Elevation angle of the Sun's position at the time of image acquisition in units of decimal degrees.
Spectral Bands Information		
Bands UID	string	IDs unique to each band and are used for reference when communicating with Pixxel.
Bandwidth	number	Refers to the full width at half maximum (FWHM) of the corresponding band in nanometers.
Central Wavelength	number	Central wavelength of the corresponding band in nanometers.
Layer	number	Indicates the layer number of the band in the image product. For example, if the image product contains band UIDs starting from B7, B8, and B11, band B7 is layer 1 and B11 is layer 3 in the image product.
Solar Irradiance	number	Indicates the solar spectral irradiance values for the corresponding bands in Watts per square meter per micrometer ($W/m^2/\mu m$).
Status	boolean ('0' or '1')	Field indicates if the corresponding band is available in the image product.
Processed Image Details		
Acknowledgment	string	Acknowledgment of open-source software used to create the image products.
Bottom Right Lat	number	Latitude of the bottom right corner of the image in decimal degrees. The latitude also forms the lower bound of the image
Bottom Right Lon	number	Longitude of the bottom right corner of the image in decimal degrees. The longitude also forms the right bound of the image
Cloud cover	number or string	Denotes the percentage of pixels in the image classified as cloud mask. This feature is currently unavailable and the value is assigned as 'NA'.

PARAMETER	DATA TYPE	DESCRIPTION
Created time	string	Date and time in UTC format at the time of image product creation.
Data type	string	Type of data representation of each pixel such as unsigned integer 16-bit data.
DEM	string	Source of Digital Elevation Models used for terrain correction.
Map Projection	string	Refers to the Geographic Coordinate System (GCS) used for the image product.
No data	number	All pixels having value 0 should be ignored in image processing. These may be found on the edge of the image.
Output Quantity	string	Denotes per pixel output radiometric measurement in reflectance or radiance.
Processing Level	string	Indicates the image product's processing level (such as L1C, L2A) and the corrections applied to the product.
Processing Software	string	Indicates Pixxel copyrighted processing software, "pHSICOR", used to create image products.
Reflectance addition factor	number	An additional factor to be added to the pixel values before scaling it by the reflectance scaling factor.
Reflectance scaling factor	number	Scaling factor to bring the per pixel reflectance values to the 0.0 - 1.0 range. The reflectance scaling factor must be multiplied by the pixel value to get reflectance.
Spatial Resolution	number	Spatial resolution of the image denoting the Ground Sampling Distance (GSD) in meters.
Top Left Lat	number	Latitude of the top left corner of the image in decimal degrees. The latitude also forms the upper bound of the image.
Top Left Lon	number	Longitude of the top left corner of the image in decimal degrees. The longitude also forms the left bound of the image
Unit	string	Unit of the output radiometric measurement per pixel.

An ENVI-compatible header file is also created from the metadata with the following parameters:

Acquisition time	File type	Samples
Band names	FWHM	Sensor type

Bands	Header offset	Solar irradiance
Byte order	Interleave	Sun Azimuth
Coordinate system string	Lines	Sun elevation
Data ignore value	Map info	Wavelength
Data type	Reflectance scale factor	Wavelength units

The description of each of the listed attributes can be found in the official documentation for [ENVI header files].

6. IMAGE QUALITY ATTRIBUTES

6.1. ABSOLUTE GEOLOCATION ACCURACY (CE90)

Any lingering geometric errors from the corrected quaternion list and DEM combine during L1B orthorectification. For a Pixxel band that completes processing, a final product CE90 of ~12 meters can be expected. This would be just over 1 pixel for TD2 and about half a pixel for TD1.

Any image without a corrected quaternion list cannot be processed through L1B orthorectification. There are currently three classes of images in this category: those tasked more than 10 degrees off-nadir, those with more than 20% cloud cover, and those with extended stretches of featureless scene content.

6.2. BAND-TO-BAND REGISTRATION

Given that the hyperspectral camera is calibrated, all spectral bands have an image-to-ground projection that is mutually consistent to better than 1 pixel (90th percentile). Products that complete L1B processing have scene content well suited to correlation, and so tend to have good band-to-band metrics. Barring any SNR issues that would preclude accurate correlation, a final product band-to-band registration of at least 1.0 pixels (90th percentile) should be expected.

To monitor and verify this aspect of product quality, band-to-band registration metrics are collected after L1B processing. By explicitly correlating patches of L1B ortho between the first and last bands (which have the most time between them), any lingering, consistent band-to-band misregistration equal to or greater than 1.0 pixels would be detected and flagged for manual review.

7. IMAGE ORDER, DELIVERY & INSIGHTS

7.1. OVERVIEW

7.1.1. Order, Delivery & Insights Generation

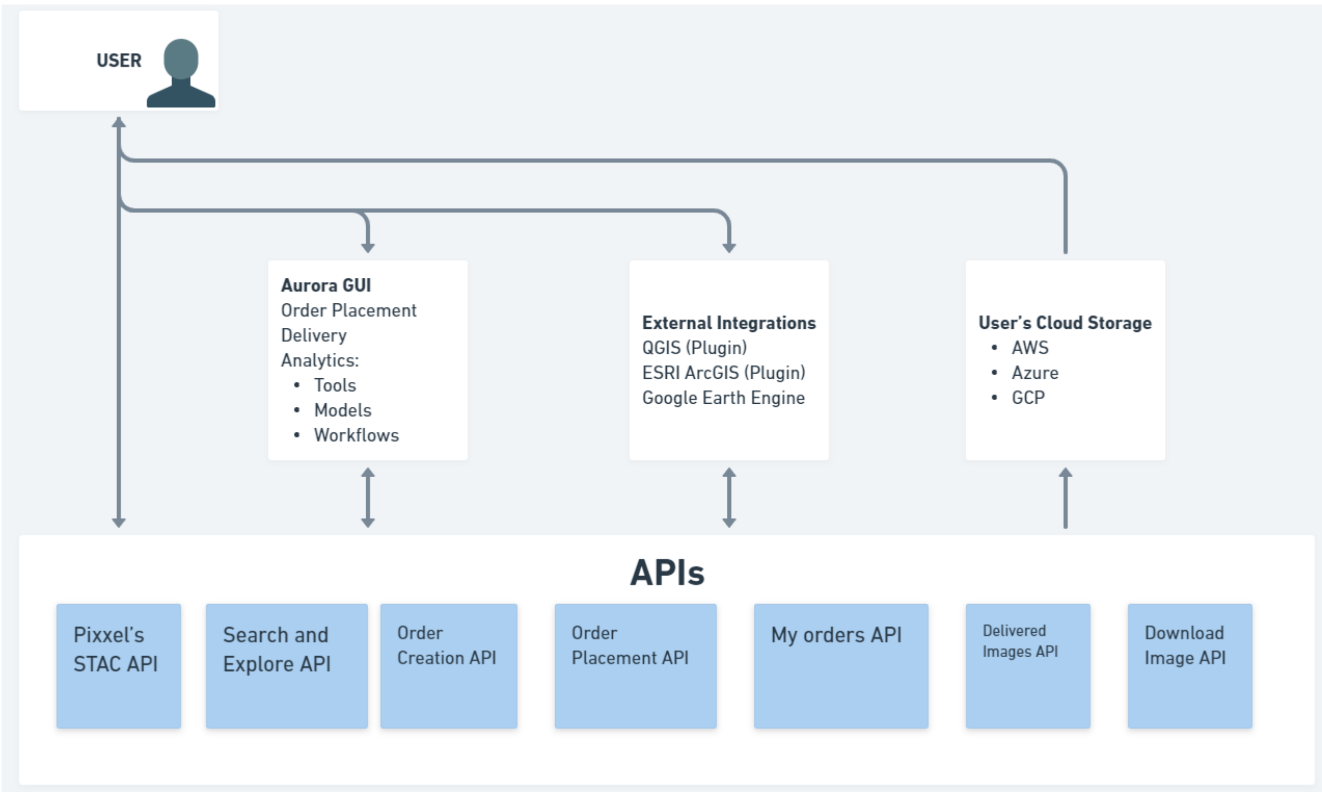


Figure 6.1

7.1.2. About Aurora Platform

At Pixxel, It's not enough for us to simply deliver satellite images to users. We believe it's crucial to provide users with the necessary tools to effectively work with imagery and other data, enabling users to derive insights seamlessly on a single platform without any hassle. In alignment with this objective, we enable our customers with Aurora – an all-inclusive platform catering to a wide range of tasks within the remote sensing and geospatial analytics domain. The Aurora platform will offer a seamless user experience, empowering individuals and organizations to accomplish various tasks. These tasks include ordering, tracking, and receiving satellite imagery for specific regions, importing and analyzing diverse datasets using advanced analytics and machine learning models, and obtaining valuable insights, alerts, and recommendations. Furthermore, the platform will facilitate tracking actions based on recommendations and monitoring their impact. Additionally, we provide a chat-based interface on the platform for users to interact with the platform in natural language.

Pixxel's Aurora Platform provides the following functionalities:

Dashboard to Search and Explore:

- Provides an overview of recent user activities, notifications, and a quick search bar.
- Initiate searches, access saved projects, and track orders right from the dashboard.

- Discover a vast collection of available satellite imagery datasets in the catalog section.
- Keywords, locations, and date range searches to find relevant imagery.
- Imagery search is enabled by on-map drawing tools, or uploading a geometry file (shapefile, geoJSON, KML, or WKT) designating an AOI.
- Search results are displayed in a user-friendly grid format, featuring thumbnail previews and key metadata.

Order, Track, and Download:

- Easily compile a collection of selected images in cart for ordering.
- Download chosen images in various formats tailored to user needs.
- User-defined status notifications for orders.
- Integration with payment gateways.
- Access to Image Catalog

Analytics Tools:

- Users can visualize selected imagery on an interactive map.
- Imagery layers can be overlaid on a basemap with contextual information.
- Tools for zooming, panning, and toggling layers enhance the map exploration experience.
- Measurement tools for distance, area, and perimeter calculations directly on the map.
- Spectral Indices, Split Compare View

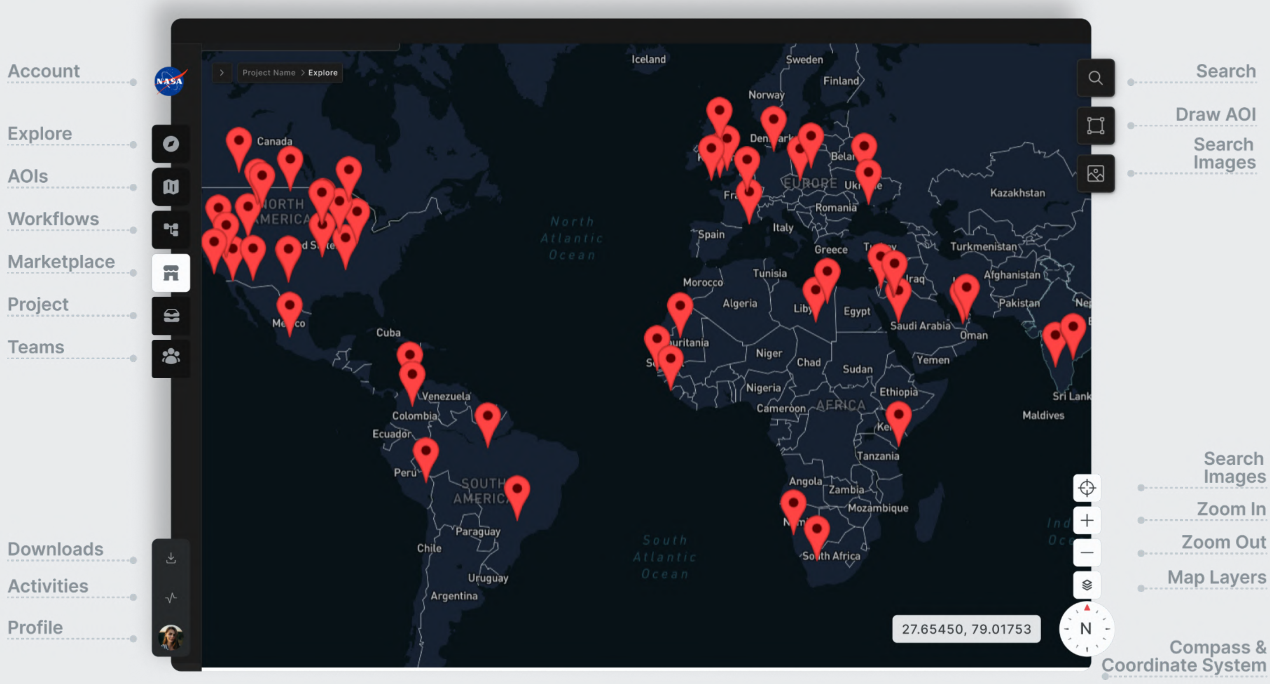
Model Marketplace, Insights, and Workflows:

- On-the-fly image analysis, enhancement, land cover classification, and change detection.
- Basic image processing using tailored workflows, and predefined, or user-defined algorithms.
- *Insight-generation Toolkit*: Build custom workflows and generate insights using models available in Aurora's Model Marketplace.
- Aurora will provide performance for user availability, the functional integrity of applications, security and protection of information, access ease, and integrability.

Quick Glimpse of Platform

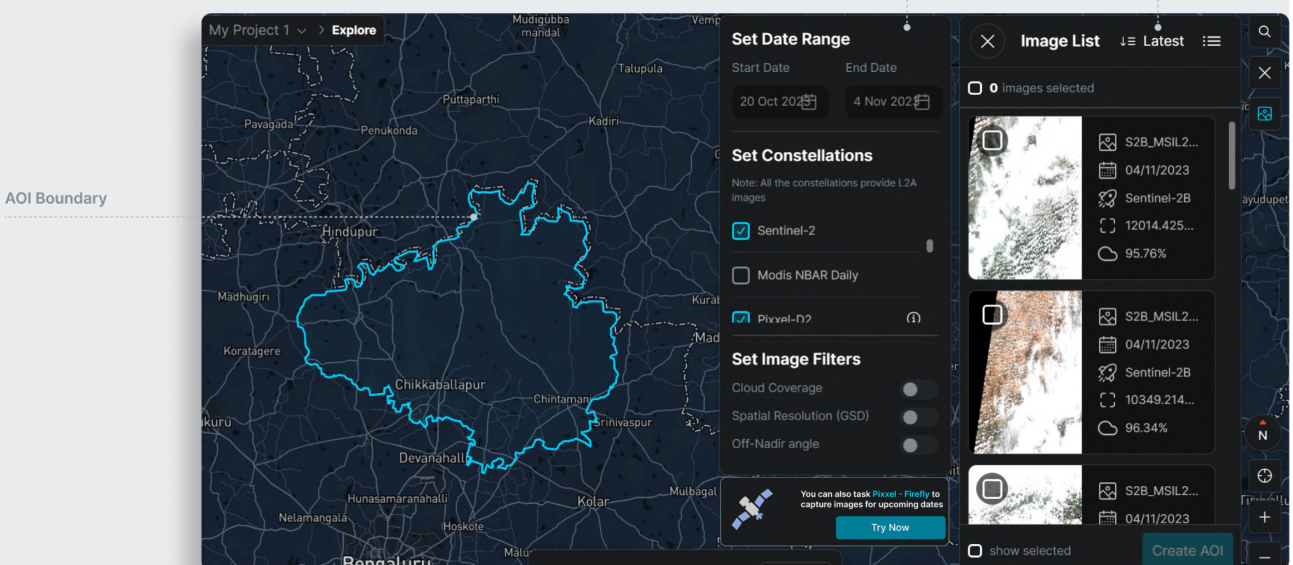
Explore Screen (Dashboard)

The Explore screen comprises mainly the world map with a few important functions. You can access the left sidebar to navigate across Aurora and on the right, you can search desired location, images and create AOI.



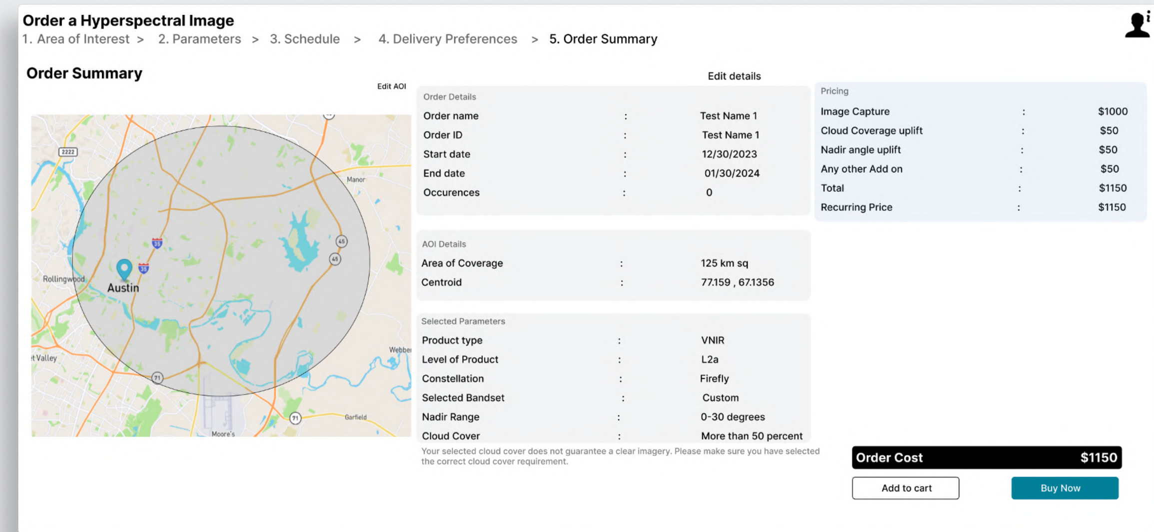
Area of Interest

It is the crucial initial step in remote sensing, involving the creation and utilization of a defined polygon boundary in various file formats to specify the area of interest.



Order Summary Screen (Order Desk)

You reach this screen when you have provided all the requirements to task a satellite for image capture.



Order Status Screen (Order Desk)

This screen provides the status of all the orders that are in pipeline or succeeded for the user.

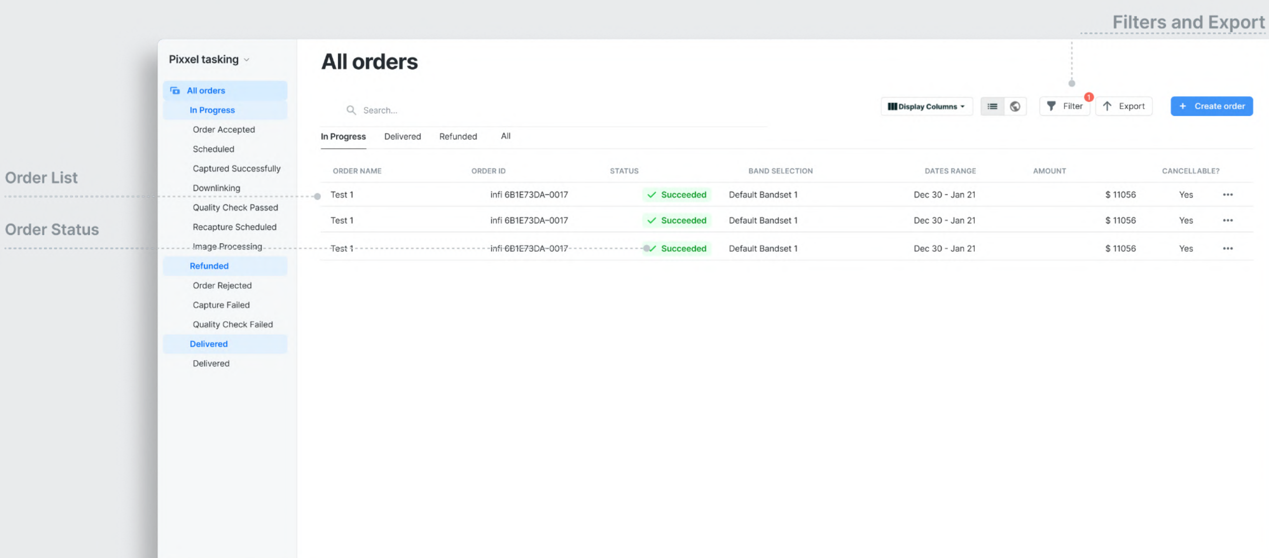
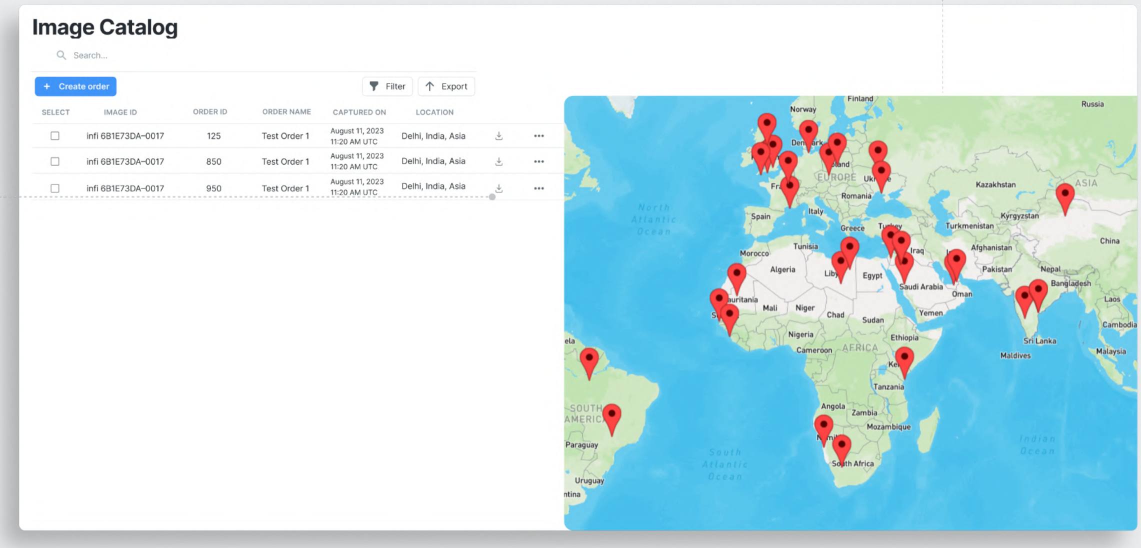


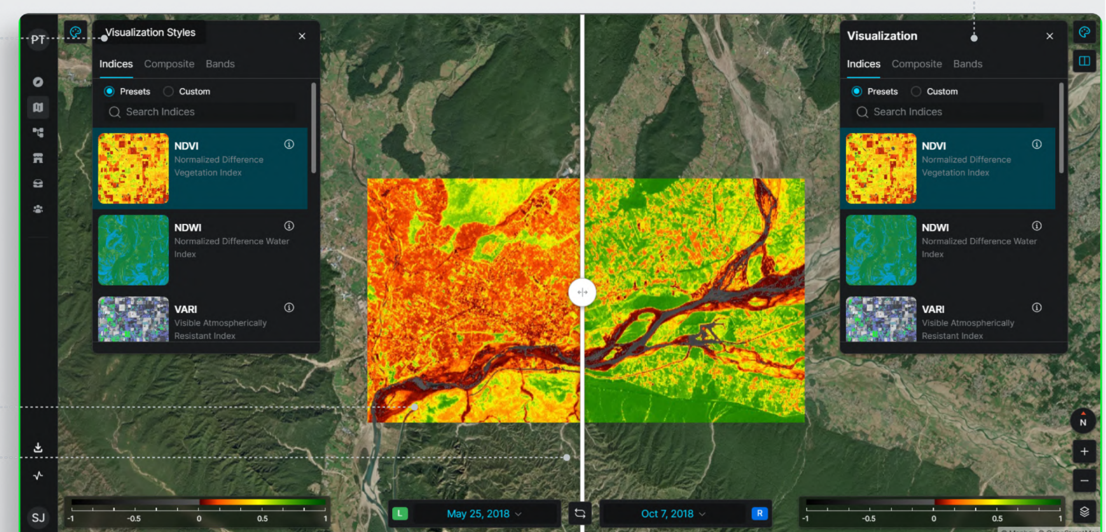
Image Catalog Screen (Order Desk)

This screen is the catalog of all the images ordered by the user which are delivered successfully. Here, user can find all the tasked images as well as images purchased from archives.



Area of Interest (AOI)- Split Compare

Split comparison is a widely used feature in geospatial analysis. As you might have understood from the name, this feature helps you compare two raster files in a split view.



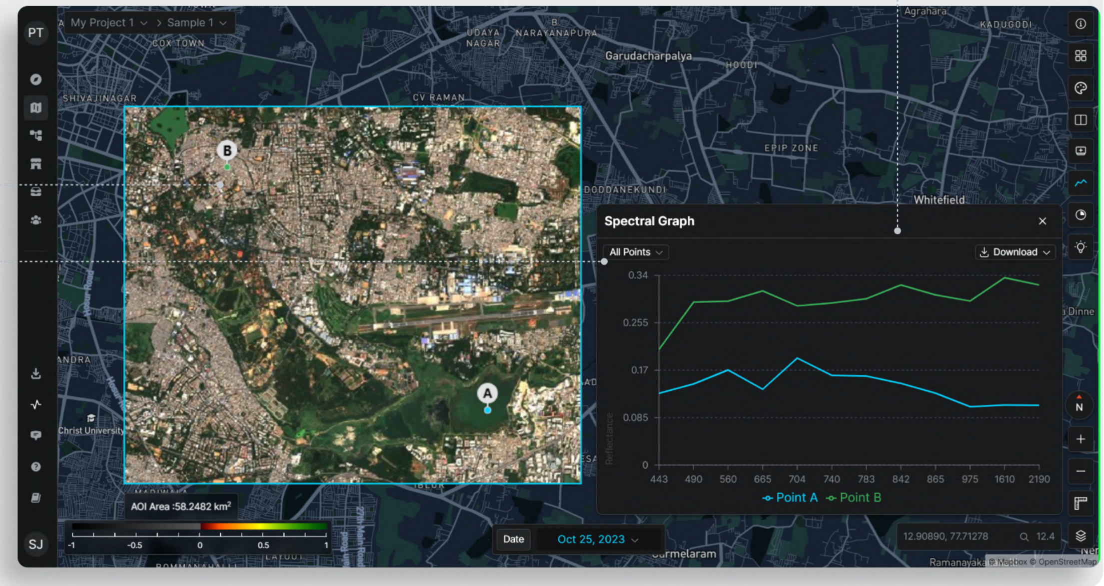
Area of Interest (AOI)- Spectral and Temporal Graph

The temporal graph represents the temporal changes of a specific location or region over time and spectral graphs are used to compare the different pixels' spectral characteristics in the AOI

Spectral Graph

AOI created

Points Selected



Workflow- Canvas

It is used for streamlining data extraction and analysis through a visually designed, automated sequence of activities.

Workflow Canvas

Create your workflow on this canvas

Node Library

Drag and Drop your Data and Processing Blocks to create Workflow

Run

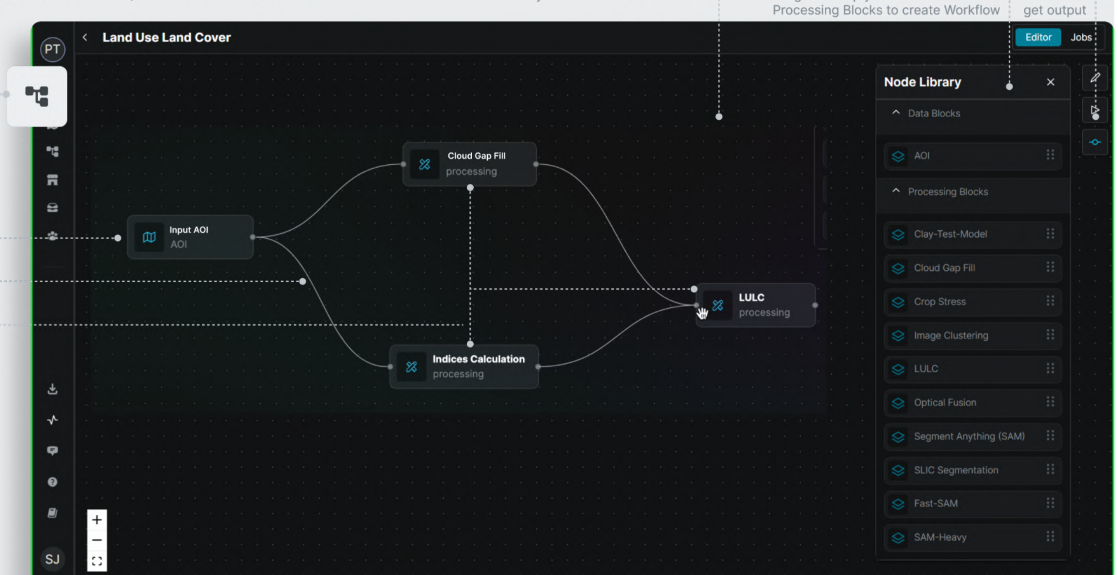
Click to get output

Workflow(s) button

Data Block

Connect the blocks

Processing Block

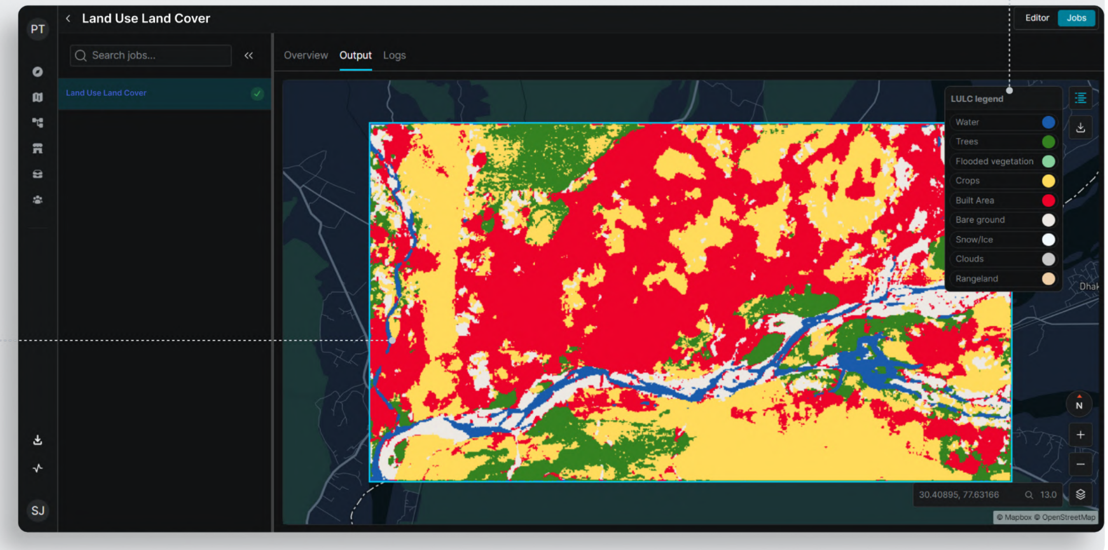


Workflow- Land Use Land Cover Output

The Land Use Land Cover (LULC) model for satellite images enables users to classify and understand the types of land activities and covers, facilitating detailed analysis and insights into environmental changes or urban development.

LULC Output Legend

AOI- LULC Output



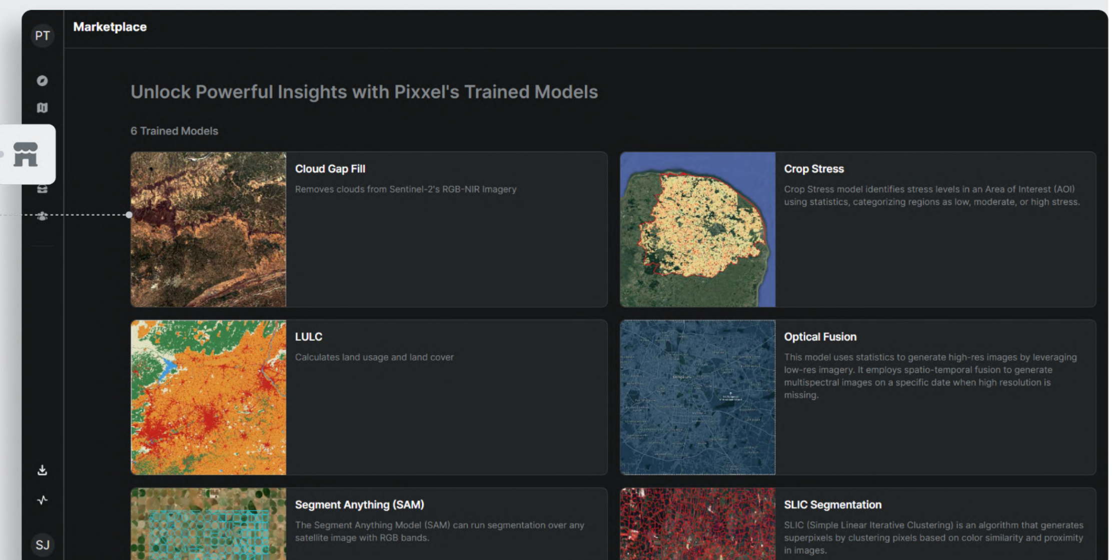
Marketplace

It is an online store where you can find models and run them on different satellite images to get needed analysis.

Marketplace button

Model Cards

Platform provides users with a list of models that you can choose to analyze the satellite images as per your need



7.2. EXPLORE PIXXEL ARCHIVES

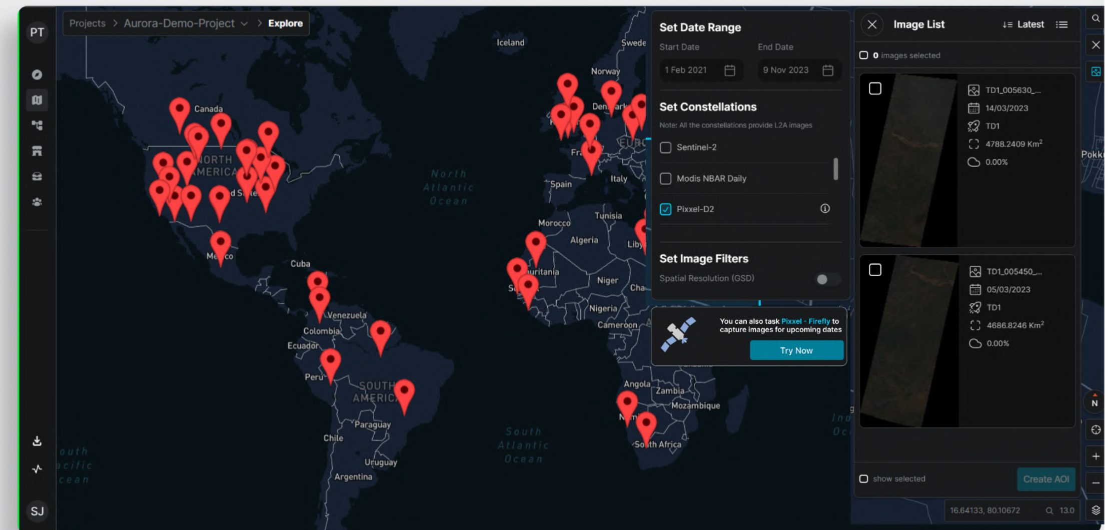
With the Explore feature, users can:

- Search available imagery based on filters such as date, location, sensor, resolution, cloud cover, and any other relevant metadata.
- Retrieve detailed information about specific imagery, including acquisition parameters and processing details.
- Generate map visualizations by overlaying satellite imagery/thumbnails onto basemaps.

7.2.1. Explore Archives using Aurora GUI

Explore Archives (Pixxel-D2 Satellite)

User can explore Pixxel's Satellites for the archived data and can order the image from this screen.



7.2.2. Pixxel's STAC API [Cosmos]

Pixxel STAC API includes 3 types of APIs:

1. Catalog API
2. Collections API
3. Items API

Catalog API: Catalog to list Pixxel's Hyperspectral Images

This API contains a catalog of all the satellites provided by Pixxel.

Sample Request

```
curl --location 'https://d-platform-gateway.pixxel.dev/cosmos/api/v1/catalogs' \
--header 'Authorization: Bearer
eyJhbGciOiJSUzI1NiIsImtpZCI6ImxjN29RV25SNFFoOE5Yal9VeGVKbWROTGJkX0RkNHVSZUxBMWVmUGZPZkUiLCJ
```

0eXAiOiJKV1QifQ..xAMIQ5wmV4pgPEE5UcTKIJwgTmAg9xREdPzAj47USKCcjy6ddAbl8YMadXTT5Jp5tHdyQbIS5IqSn
lmKP_3uIORF3XziAA6oEt-bCWDRmPsT8UuUxj_Lj9ubbw7ffZDb61IBKJbhJ2jNFundQ6B7b7IzuTnw569JDYJn-XBiQPO
od3869RS9XkMkZvHGmXlu4aeceZqQpiFkYMVurTKYbvV71v-tz_QUszRCJnHXg4wxCvDvY0MuwqLGDK0cellsXje3CB
OC9NRLp6oxsOByXy2LMZvMuT68gMYprlYmaYUMH0QfM9CO-GZaQG1ICFh45-yzupEhbtFv7i3dIOMb5A'

Snippet of response of Catalog API (for reference)

Unset


```
[
    {
        "id": "pixxel-td1",
        "type": "Catalog",
        "title": "",
        "stac_version": "1.0.0",
        "description": "A STAC for pixxel-td1 imagery",
        "created_at": "2023-08-01T13:15:31.578209Z",
        "updated_at": "2023-10-19T07:46:28.189152Z",
        "links": [
            {
                "rel": "root",
                "href": "http://cosmos.platform.svc.cluster.local/api/v1",
                "type": "application/json",
                "title": ""
            },
            {
                "rel": "parent",
                "href":
"http://cosmos.platform.svc.cluster.local/api/v1/catalogs",
                "type": "application/json",
                "title": ""
            },
            {
                "rel": "collections",
                "href":
"http://cosmos.platform.svc.cluster.local/api/v1/catalogs/pixxel-td1/collection
s",
                "type": "application/json",
                "title": "child"
            },
            {
                "rel": "self",
                "href":
```


Collections API: Lists all the collection of Pixxel's satellites

This API contains the availability of different levels of images present for all the pixxel's satellites. Eg: L1C, L2A etc.

Sample Request

```
curl --location 'https://d-platform-gateway.pixxel.dev/cosmos/api/v1/collections' \
--header 'Authorization: Bearer
eyJhbGciOiJSUzI1NiIsImtpZCI6ImxjN29RV25SNFFoOE5Yal9VeGVKbWROTGJkX0RkNHVSZUxBMWVmUGZPZkUiLCJ
0eXAiOiJKV1QifQ..xAMIQ5wmV4pgPEE5UcTKIJwgTmAg9xREdPzAj47USKCcjy6ddAbl8YMadXTT5Jp5tHdyQbIS5IqSn
lmKP_3uIORF3XziAA6oEt-bCWDRmPsT8UuUxj_Lj9ubbw7ffZDb61IBKJbhJ2jNFundQ6B7b7IzuTnw569JDYJn-XBiQPO
od3869RS9XkMkZvHGmXlu4aeceZqQpiFkYMVurTKYbvV71v-tz_QUszRCJnHXg4wxCvDvY0MuwqLGDK0cellsXje3CB
OC9NRLp6oxsOByXy2LMZvMuT68gMYprlYmaYUMH0QfM9CO-GZaQG1lCFh45-yzupEhbtFv7i3dIOMb5A'
```

Snippet of response of Collections API (for reference)

Unset


```
[{"id":"pixxel-td2-l2a","type":"Collection","stac_extensions":null,"
stac_version":"1.0.0","description":"This collection contains L2A
images","title":"","catalog":"","created_at":"2023-08-10T11:34:40.85
5238Z","updated_at":"2023-08-10T11:34:40.855238Z","providers":[{"des
cription":"Pixxel is a space data company","name":"Pixxel
Space","roles":["producer"],"url":"https://pixxel.space"}],"extent":
{"spatial":{"bbox":[[14.950201,-23.741091,76.419757,30.527516]]},"te
mporal":{"interval":[["2022-11-23T08:54:15Z","2023-05-09T06:17:48Z"]
]}},"license":"proprietary","summaries":{},"links":[{"rel":"root","h
ref":"http://cosmos.platform.svc.cluster.local/api/v1","type":"appli
cation/json","title":""},{"rel":"parent","href":"http://cosmos.platf
orm.svc.cluster.local/api/v1/collections","type":"application/json",
"title":""},{"rel":"items","href":"http://cosmos.platform.svc.cluste
r.local/api/v1/collections/pixxel-td2-l2a/items","type":"application
/json","title":"child"},{"rel":"self","href":"http://cosmos.platform
.svc.cluster.local/api/v1/collections/pixxel-td2-l2a","type":"applic
ation/json","title":""}]},{"id":"pixxel-td1-l1c","type":"Collection"
,"stac_extensions":null,"stac_version":"1.0.0","description":"This
collection contains L2A
images","title":"","catalog":"","created_at":"2023-08-10T06:10:15.69
5342Z","updated_at":"2023-08-10T06:10:15.695342Z","providers":[{"des
cription":"Pixxel is a space data company","name":"Pixxel
Space","roles":["producer"],"url":"https://pixxel.space"}],"extent":
{"spatial":{"bbox":[[-120.10315,-35.807841,150.484904,56.082381]]},"
```


Items API: Lists all the images of each satellite of Pixxel

This API contains all the images across Pixxel's satellites comprising all data levels (L1c, L2a, etc) of the image.

Sample Request

```
curl --location 'https://d-platform-gateway.pixxel.dev/cosmos/api/v1/collections/pixxel-td1-l2a/items' \
```

--header 'Authorization: Bearer eyJhbGciOiJSUzI1NiIsImtpZCI6ImxjN29RV25SNFFoOE5Yal9VeGVKbWROTGJkX0RkNHVSZUxBMWVmUGZPZkUiLCJ0eXAiOiJKV1QifQ.eyJleHAiOjE2OTk1MTk4OTgsImdlbiI6InN5c3RlbSIsImlhdCI6MTY5OTUxNjI5OCwiaXNzIjoiZnJvbnRpZXIb7IzuTnw569JDYJn-XBiQPOod3869RS9XkMkZvHGmXlu4aeceZqQpiFkYMVurTKYbvV71v-tz_QUszRCJnHXg4wxCvDvY0MuwqLGDK0cellsXje3CBOC9NRLp6oxsOByXy2LMZvMuT68gMYprlYmaYUMH0QfM9CO-GZaQG1lCFh45-yzupEhbtFv7i3dIOMb5A'

A snippet of the response of Collections API (for reference)

```
Unset
{"type":"FeatureCollection","features":[{"id":"TD1_005440_20230304_L2A_20230329
_03001064","type":"Feature","collection":"pixxel-td1-l2a","stac_version":"1.0.0
","stac_extensions":["https://stac-extensions.github.io/eo/v1.1.0/schema.json",
"https://stac-extensions.github.io/projection/v1.1.0/schema.json"],"bbox":[54.2
30314,23.746464,54.768692,24.578086],"geometry":{"type":"Polygon","coordinates"
:[[[54.230314,24.578086],[54.230314,23.746464],[54.768692,23.746464],[54.768692
,24.578086],[54.230314,24.578086]]]},"properties":{"datetime":"2023-03-04T11:04
:49Z","created":"2023-03-29T13:30:32Z","platform":"TD1","instruments":["VNIR"],
"gsd":30,"proj:epsg":4326,"view:sun_elevation":42.15,"view:sun_azimuth":235.14}
,"assets":{"B012":{"href":"s3://pixxel-td1/pixxel-td1-l2a/TD1_005440_20230304_L
2A_20230329_03001064/B012.tif","type":"","title":"B012","roles":null,"eo:bands"
:[{"name":"B012","common_name":"","central_wavelength":490,"fwhm":0}]},"B012-co
gs":{"href":"s3://pixxel-td1/pixxel-td1-l2a-cogs/TD1_005440_20230304_L2A_202303
29_03001064/B012.tif","type":"","title":"B012-cogs","roles":null,"eo:bands":[{"
name":"B012","common_name":"","central_wavelength":490,"fwhm":0}]},"B013":{"hre
f":"s3://pixxel-td1/pixxel-td1-l2a/TD1_005440_20230304_L2A_20230329_03001064/B0
13.tif","type":"","title":"B013","roles":null,"eo:bands":[{"name":"B013","commo
n_name":"","central_wavelength":493,"fwhm":0}]},"B013-cogs":{"href":"s3://pixxe
l-td1/pixxel-td1-l2a-cogs/TD1_005440_20230304_L2A_20230329_03001064/B013.tif","
type":"","title":"B013-cogs","roles":null,"eo:bands":[{"name":"B013","common_na
me":"","central_wavelength":493,"fwhm":0}]},"B014":{"href":"s3://pixxel-td1/pix
xel-td1-l2a/TD1_005440_20230304_L2A_20230329_03001064/B014.tif","type":"","titl
e":"B014","roles":null,"eo:bands":[{"name":"B014","common_name":"","central_wav
elength":497,"fwhm":0}]},"B014-cogs":{"href":"s3://pixxel-td1/pixxel-td1-l2a-co
gs/TD1_005440_20230304_L2A_20230329_03001064/B014.tif","type":"","title":"B014-
cogs","roles":null,"eo:bands":[{"name":"B014","common_name":"","central_wavelen
gth":497,"fwhm":0}]},"B015":{"href":"s3://pixxel-td1/pixxel-td1-l2a/TD1_005440_
20230304_L2A_20230329_03001064/B015.tif","type":"","title":"B015","roles":null,
"eo:bands":[{"name":"B015","common_name":"","central_wavelength":500.5,"fwhm":0
}]},"B015-cogs":{"href":"s3://pixxel-td1/pixxel-td1-l2a-cogs/TD1_005440_2023030
4_L2A_20230329_03001064/B015.tif","type":"","title":"B015-cogs","roles":null,"e
o:bands":[{"name":"B015","common_name":"","central_wavelength":500.5,"fwhm":0}]
},"B017":{"href":"s3://pixxel-td1/pixxel-td1-l2a/TD1_005440_20230304_L2A_202303
29_03001064/B017.tif","type":"","title":"B017","roles":null,"eo:bands":[{"name"
:"B017","common_name":"","central_wavelength":505,"fwhm":0}]},"B017-cogs":{"hre
f":"s3://pixxel-td1/pixxel-td1-l2a-cogs/TD1_005440_20230304_L2A_20230329_030010
```

7.2.3. API to Search and Explore Archives of Pixxel's Hyperspectral Images:

This API provides a mechanism to search and explore all the archives of Pixxel's hyperspectral images. Users will get a list of images based on the input filters and then can create an order based on that list.

Users can provide their AOI in terms of latitude and longitude as a request for the above API along with some filters like cloud coverage percentage, off-nadir angle, etc.

The output of this API is a list of images applicable for filters provided in the request. Users can choose images from this list and pass in the Order Creation API to create an order.

Sample Request

```
curl --location 'https://p-platform-gateway.pixxel.dev/lens/api/v1/search' \

--header 'Content-Type: application/json' \
--header'Authorization:Bearer
eyJhbGciOiJSUzI1NiIsImtpZCI6ImxjN29RV25SNFFoOE5YaI9VeGVKbWROTGJkX0RkNHVSZUxBMWVmUGZPZkUiLCZvHGmXlu4aece
ZqQpiFkYMVurTKYbvV71v-Xje3CBOC9NRLp6oxsOByXy2LMZvMuT68gMYprlYmaYUMH0QfM9CO-GZaQG1ICFh45-yzupEhbtFv7i3d
IOMb5A' \
--data '{
  "start_date": "2023-10-26T09:29:59.652Z",
  "end_date": "2023-11-10T09:29:59.652Z",
  "satellites": [
    {
      "satellite_id": "Pixxel-Tech-Demo-1",
      "collection_id": "Pixxel-Tech-Demo-1-l2a"
    }
  ],
  "filters": [
    {
      "id": "eo:cloud_cover",
      "min": 0,
      "max": 100
    },
    {
      "id": "gsd",
      "min": 0,
      "max": 500
    },
    {
      "id": "off_nadir",
      "min": 0,
      "max": 100
    }
  ],
  "geometry": {
    "type": "Polygon",
    "coordinates": [
      [
        [
          -102.429055626998,
          34.24935725683071
        ],
        [
          -102.429055626998,
          34.231334710970195
        ],
        [
          -102.39815657914643,
          34.231334710970195
        ],
        [
          -102.39815657914643,
          34.24935725683071
        ],
        [
          -102.429055626998,
          34.24935725683071
        ]
      ]
    ]
  }
}'
```

Sample Output

{

"S2A_MSIL2A_20231101T173451_R055_T13SGT_20231101T232414": {
"constellation": "Pixxel Tech Demo 1",
"datetime": "2023-11-01T17:34:51.024Z",
"eo:cloud_cover": 0.010524,
"geometry": {
"type": "Polygon",
"coordinates": [
[
[
-102.8266544,
34.3223732
],
[
-101.6347407,
34.2954057
],
[
-101.673258,
33.3067898
],
[
-102.8515624,
33.3327745
],
[
-102.8266544,
34.3223732
]
]
]
},
"instruments": [
"msi"
],
"platform": "Pixxel Tech Demo 1",
"preview_url":
"https://d-platform-gateway.pixxel.dev/api/stac/v1/collections/pixxel-td1-l2a/items/S2A_MSIL2A_20231101T173451_R055_T13SGT_20231101T232414&resampling_method=nearest&assets=visual&bidx=1%2C2%2C3",
"proj:epsg": 32613,
"stac_url":
"https://d-platform-gateway.pixxel.dev/api/stac/v1/collections/pixxel-td1-l2a/items/S2A_MSIL2A_20231101T173451_R055_T13SGT_20231101T232414"
},
"S2A_MSIL2A_20231101T173451_R055_T13SGU_20231102T004118": {
"constellation": "Sentinel 2",
"datetime": "2023-11-01T17:34:51.024Z",
"eo:cloud_cover": 0.014512,
"geometry": {
"type": "Polygon",
"coordinates": [
[
[
-102.8028976,
35.2231329
],
[
-101.5980052,
35.1952508
],
[

-101.6382697,
34.2068165
],
[
-102.8289365,
34.2336951
],
[
-102.8028976,
35.2231329
]
]
]
},
"instruments": [
"msi"
],
"platform": "Pixxel-Tech-Demo-1",
"preview_url":
"https://d-platform-gateway.pixxel.dev/api/stac/v1/collections/pixxel-td1-l2a/items/S2A_MSIL2A_20231101T173451_R055_T13SGU_20231102T004118&resampling_method=nearest&assets=visual&bidx=1%2C2%2C3",
"proj:epsg": 32613,
"stac_url":
"https://d-platform-gateway.pixxel.dev/api/stac/v1/collections/pixxel-td1-l2a/items/S2A_MSIL2A_20231101T173451_R055_T13SGU_20231102T004118"
}

7.3. IMAGE ORDERING

7.3.1. Ordering Overview

The catalog in Pixxel's Aurora platform includes Pixxel's hyperspectral imagery from Tech Demo & Commercial Satellites and other open-source datasets (i.e. Sentinel, Landast, etc).

Users can buy Pixxel's archived hyperspectral images from the STAC catalog and can also place an order for new Pixxel hyperspectral images by tasking Pixxel satellites using Aurora.

1. Enables order placement for specific satellite images or predefined image packages.

2. Selection of imaging parameters such as sensor, resolution, AOI, and window time.

3. Make a payment through the payment gateway integration.

Aurora provides multiple ways of ordering, tasking, payment, and receiving an order using one or more of the following:

1. Ordering on the UI

2. Ordering through Aurora APIs

3. QGIS and ArcGIS (Esri) Plugins

Steps for ordering an Image from Aurora

1. Explore the archives (already downlinked images) or task the satellite for a new image

2. Pay for the image (not applicable for open-source imagery)

3. Track delivery status

4. Customize image delivery method

Things to note before placing an order:

Minimum Order Size:

Pixxel accepts all orders with a minimum size of 100 sq km with each additional unit of 100 sq km. Eg: If a user places an order for a 70 sq km area, it will be charged for 100 sq km.

Mosaicking:

Mosaicking is a concept where multiple images of the same date are stitched into a single image. Users can choose whether or not to receive images mosaicked.

Large Area Deliveries:

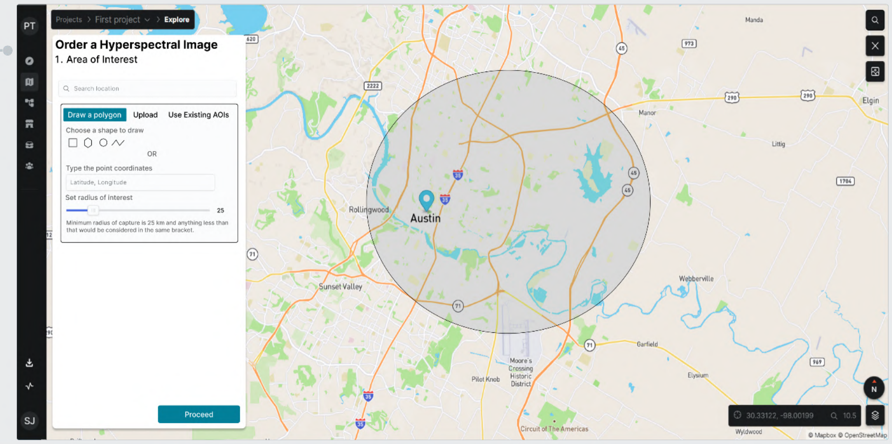
Large area deliveries are handled by stitching images of multiple small areas and creating a single image of that area.

7.3.2. Order Using Aurora

1

Define AOI

Choose between, Drawing an AOI, Uploading or Using an Existing AOI

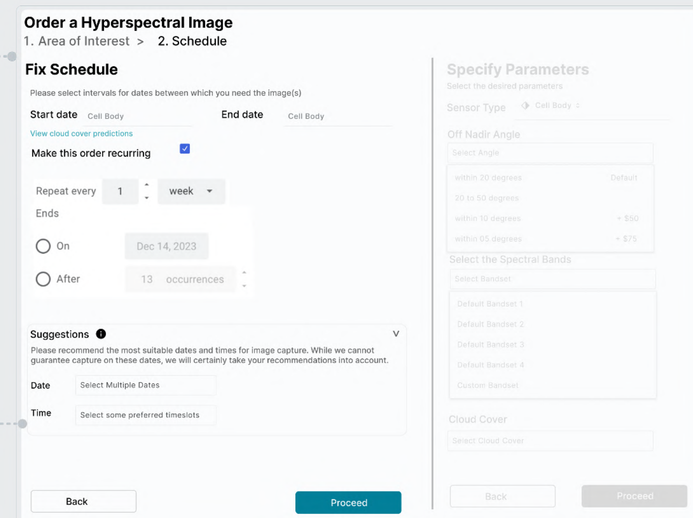


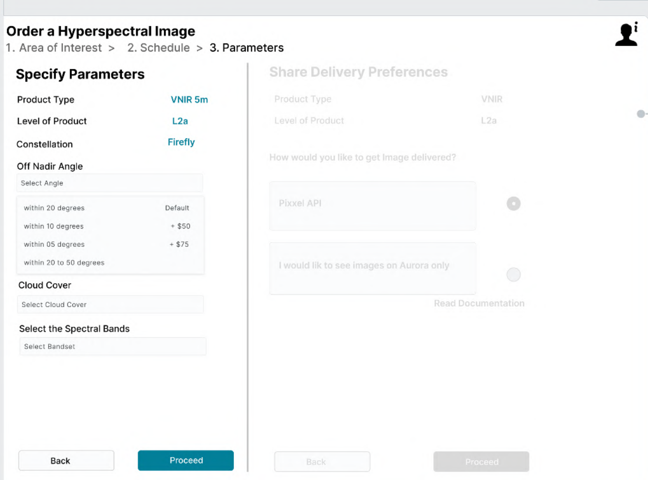
2

Fixing the Schedule

Detail out the date and recurrences for the image tasking

Date & Time Suggestions

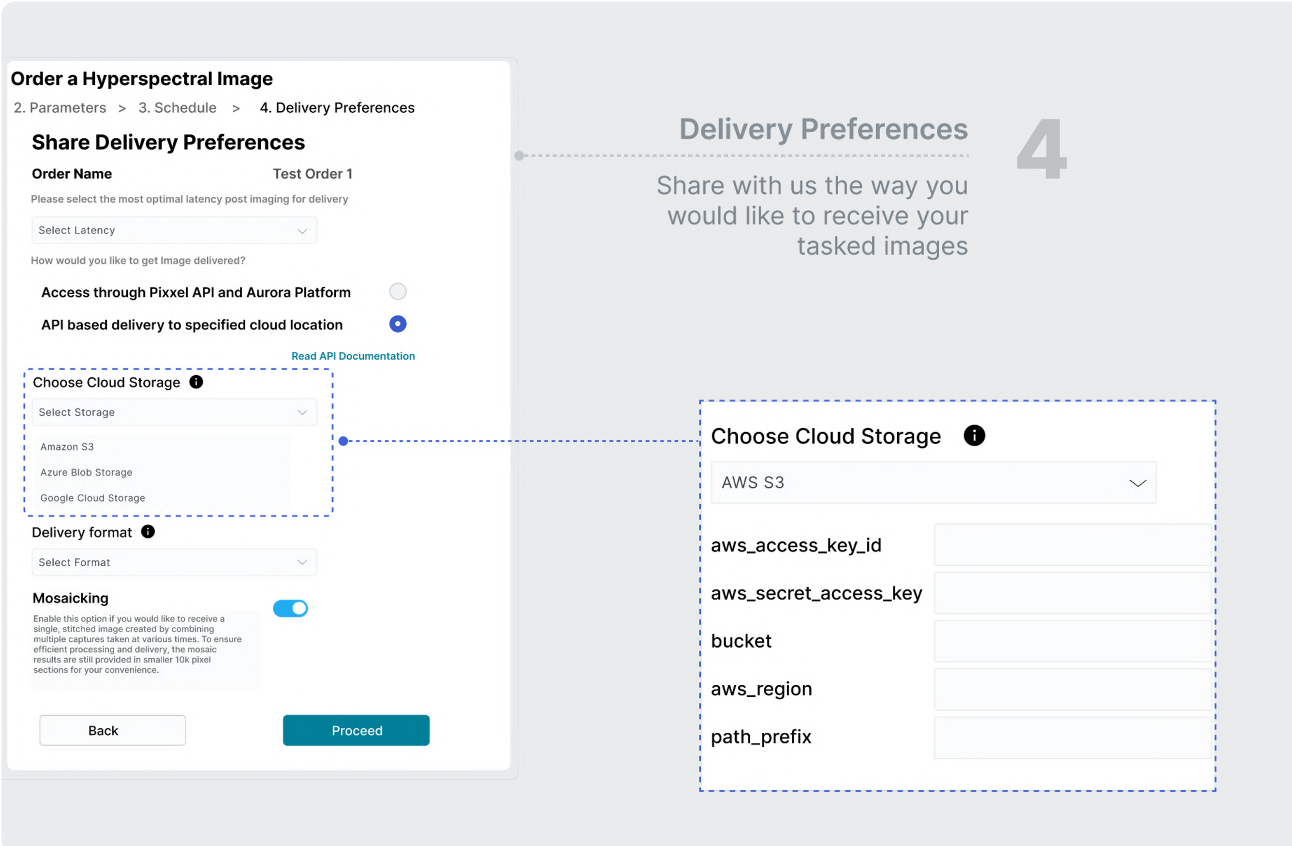


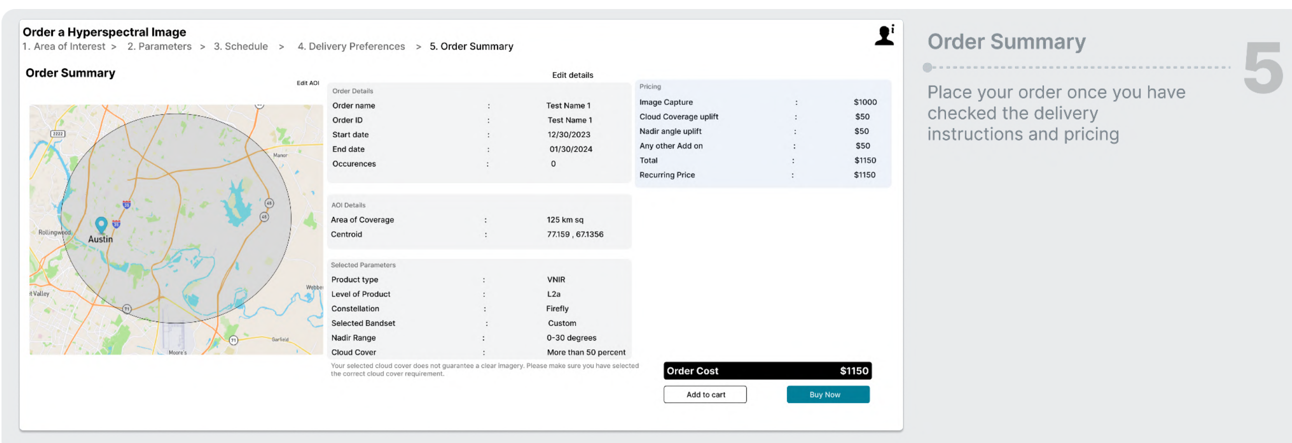


Specifying the Parameters

3

Select various parameters that should be taken care of while capturing the image





7.3.3. Order using APIs

Aurora provides multiple APIs to order an image. Steps for ordering an image are:

1. Exploring archives or task a capture
2. Creating an order and getting the price
3. Placing an order successfully

Order Creation API

This API is used for creating an order on Aurora. It can be used either to order an archive image or task the satellite for a new image.

- Users can also configure delivery location and notification webhook (if the user wants to get notified about the order status in their system) as optional parameters.
- Users can also enable/disable email status notifications.

In the API request payload, users can choose either archive or schedule to create an order. For archive, only archive_image_id needs to be passed and for schedule, all the fields in "schedule" need to be passed.

The output provides the quotation for the image requested or scheduled along with an order_id. Users need to pass this order_id in place order API to place the order.

Sample Request

```
curl --location 'https://p-platform-gateway.pixxel.dev/orderdesk/order' \

--header 'Authorization: Bearer xxx' \
--header 'Content-Type: application/json' \
--data '{
  "AOI": {
    "geometry": {
      "type": "Polygon",
      "coordinates": [
        [
          [
            -102.429055626998,
            34.24935725683071
          ],
          [
            -102.429055626998,
            34.231334710970195
          ],
          [
            -102.39815657914643,
            34.231334710970195
          ],
          [
            -102.39815657914643,
            34.24935725683071
          ],
          [
            -102.429055626998,
            34.24935725683071
          ]
        ]
      ]
    },
    "product_type": "VNIR 5nm",
    "level_of_product": "L2a",
    "constellation": "Firefly",
    "off_nadir_angle": 50,
    "cloud_cover": 40,
    "spectral_bands": [
      "B01",
      "B02",
      "B09"
    ],
    "mosaicking": true,
    "name": "Test Order",
    "mode_of_delivery": "s3",
    "s3_delivery": {
```

```
        "access_key": "xxx",
        "secret_key": "xxx",
        "bucket": "xxx",
        "folder": "path/",
        "provider_name": "aws/azure"
      },
            "Email":True,
      "webhook_notification_delivery": {
        "url": "https://company.notificarion/webhook"
      },
      "type_of_image": "archive/schedule",
      "archive_image_id": "xxx",
      "schedule": {
        "start_date": "2021-01-01",
        "end_date": "2022-01-01",
        "recurring": true,
        "repeats": "4",
        "end_on": "2022-01-01",
        "end_after": 15
      }
    }
}
'
```

Sample Response


```
{

  "product_type": "VNIR 5nm",
  "level_of_product": "L2a",
  "constellation": "Firefly",
  "off_nadir_angle": 50,
  "cloud_cover": 40,
  "order_id": "asd",
  "total_amount": 1230,
  "discount" : 140 ,
  "tax": 50
  "amount to be paid": 1140,
  "status": "10"

}
```


Order Placement API

This API enables users to place the order by taking order_id from Create Order API as an input.

To use this API, users need to have sufficient balance in their Aurora account or else an order will not be placed.

As an output response, either 200 or 400 will be shown depending on the wallet of the user.

Sample Request

```
curl --location 'https://p-platform-gateway.pixxel.dev/orderdesk/order/place' \

--header 'Content-Type: application/json' \
--data '{
  "order_id": "xxxx"
}
```

Sample Response


```
{
   "status": 400,
   "message": "No amount"
}

{
   "status": 200,
   "message": "Order placed"
}
```


7.3.4. Order using Plugins inside other GIS Tools

ArcGIS Pro:

Aurora Add-ons (**Plugin**) for ArcGIS will enable users to directly get data from the Aurora database on ArcGIS Pro and use it according to their needs. The following features can be used with the ArcGIS Pro Plugin:

- Easily discover, preview, order, and download satellite imagery available on Aurora directly on ArcGIS Pro. This includes access to Pixxel's hyperspectral images via Aurora's database and also to other open source datasets integrated on Aurora like Sentinel, Landsat, etc. Users will need to install the plugin on ArcGIS to get a custom UI.
- This plugin provides the ability to use all filters applicable on Aurora for downloading or ordering an image.
- Satellite tasking can also be performed using the ArcGIS Pro plugin directly. Users can easily task Pixxel's satellites by providing inputs on ArcGIS Pro and receive delivery through the plugin.

QGIS:

The Aurora QGIS **Plugin** provides access to Pixxel's satellite imagery directly from QGIS.

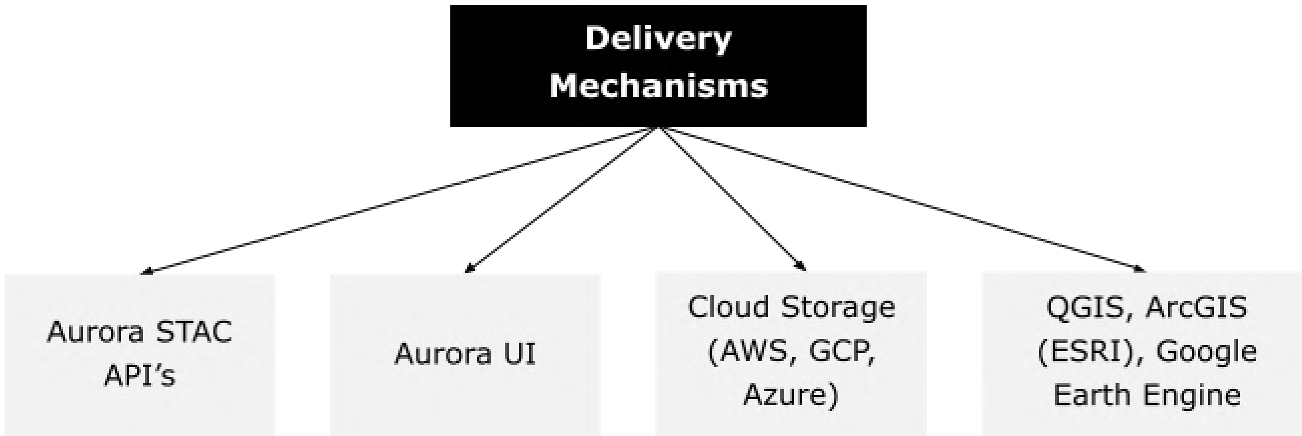
- To order Pixxel's imagery for use in QGIS, specify the area of interest (AOI) to filter the search.
- Users can search, discover, and download Aurora's imagery database and send tasking coordinates to Aurora's Orderdesk for on-demand imagery captures.

7.4. IMAGE DELIVERY

Aurora provides users with options to retrieve imagery in various standard formats like geoTIFF.

7.4.1. Different Delivery Mechanisms

There are multiple ways by which a user can request the image they have ordered as depicted below.



Users can choose any of the above delivery mechanisms for their images at the time of order placement. They can either choose Aurora APIs/UI or Cloud Storage platforms when ordering.

By using a set of delivery APIs or UI, users can easily track their order status, see their delivered images, and download their images.

7.4.2. Delivery Package

After successful download of the images via any method, users will receive a delivery package as a .zip file.

The .zip delivery package encapsulates the ordered satellite image products, following a structured naming convention and containing essential contents. Each .zip package is organized with a clear hierarchy, ensuring ease of use and data management.

File Naming Conventions

Files within the .zip package are named using a systematic approach. Generally, names include vital information such as acquisition date, image ID, and sensor type.

File naming format:

<satelliteName>_<imageID>_<acquisitionDate>_<productLevel>_<productCreationDate>_<spatialResolution><imageProcessingVersion>

Sample file: TD1_004190_20221222_L1C_20230131_03001074

Contents of Image Products

The .zip package contains the following key components:

Imagery Files: The primary satellite image files, often in formats such as geoTIFF or Cloud Optimized GeoTIFF (COG). These files represent the acquired imagery at the specified resolution.

Metadata File: A metadata XML file accompanying the imagery, detailing acquisition parameters, geolocation data, and processing information.

Thumbnail: A smaller version of the image, providing a quick preview of the content.

Footprint: The footprint information provides the geographic extent of the captured image. It defines the spatial boundaries of the imaged area, enabling users to precisely locate and contextualize the data within their geographical context. This information is typically available in a standardized geospatial format, i.e., geoJSON.

.

7.4.3. Delivery using Aurora GUI (Graphical User Interface)

Users can easily obtain their ordered images via Aurora User Interface.

After ordering the image successfully, users can check their order status and can see all the delivered images in the images catalog screen.

Order Status Screen

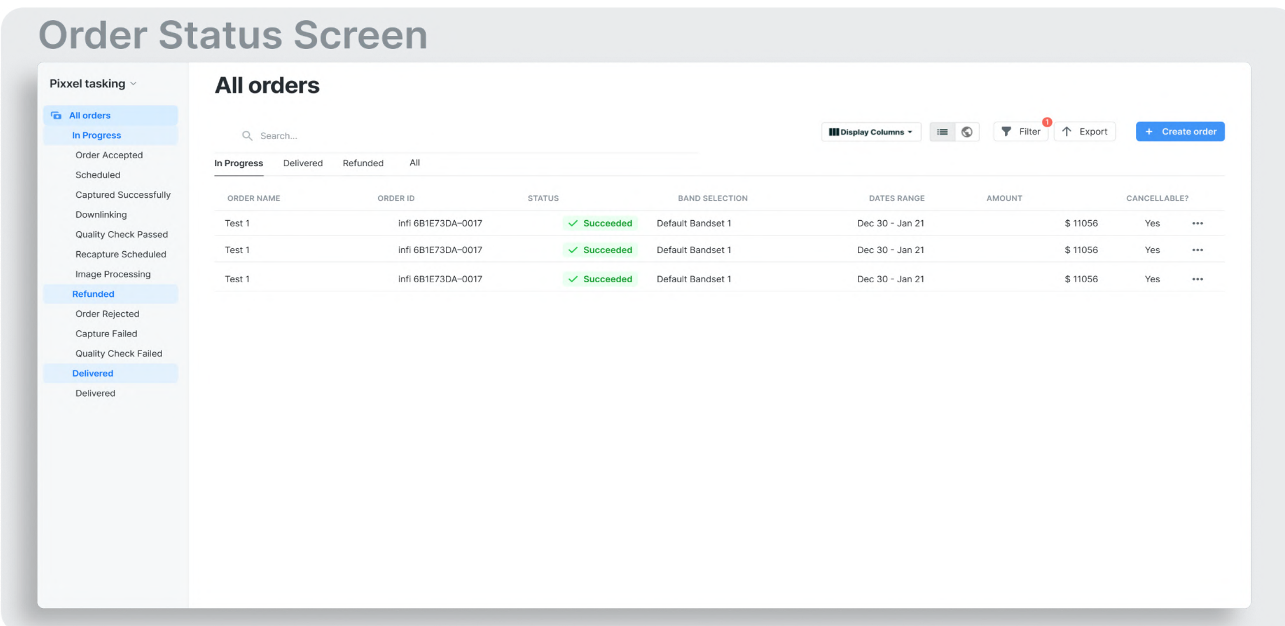
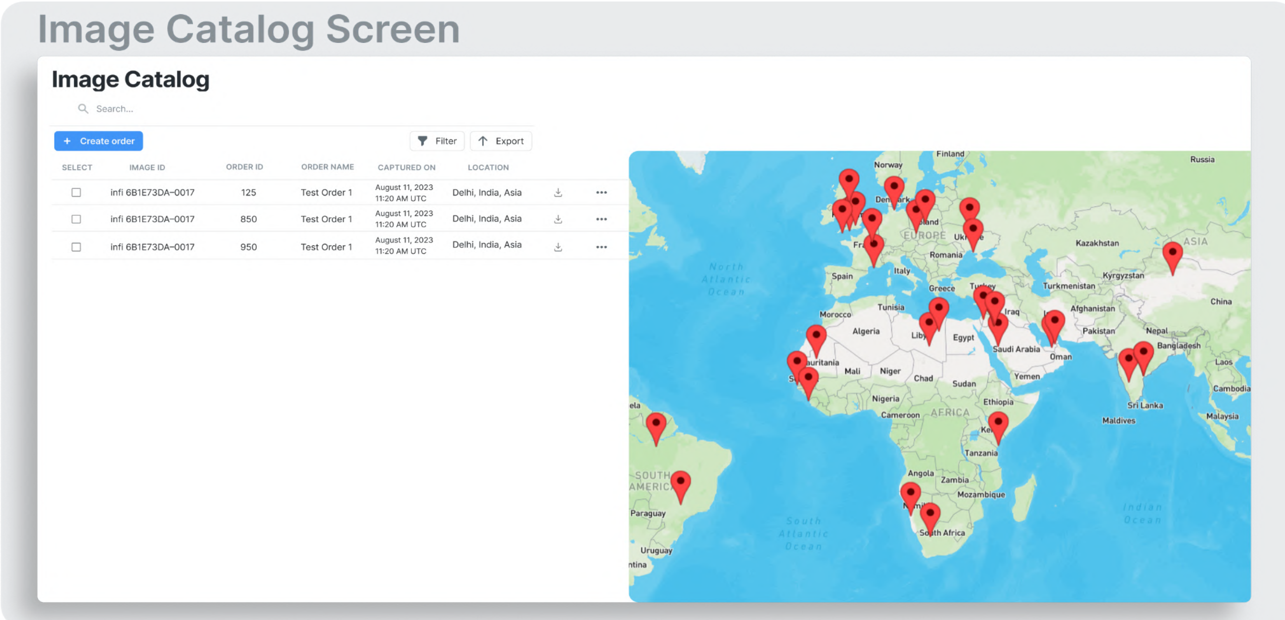


Image Catalog Screen

Users can come on this screen and easily select the image and can download it with a click of a button.



7.4.4. Delivery using APIs

The following APIs can be used to track order status, and get all purchased images available for a particular user along with an option to download selected images. There are three APIs for these operations:

1. List Order API
2. Delivered Images API
3. Download Images API

List Order APIs

This API provides the flexibility to view all the orders and their status on Aurora. The user needs to provide an order ID as input and will receive the status of that ID.

Order id is optional, without this field, all the orders will be fetched with their status as a response.

Sample Request

```
curl--location'https://p-platform-gateway.pixxel.dev/orderdesk/orders' \

--header 'Content-Type: application/json' \
--data '{
  "order_id": "xxx"
}'
```

Sample Response

```
{

  "orders": [
    {
```

```
      "org_id": "xxx",
      "product_type": "VNIR 5nm",
      "level_of_product": "L2a",
      "constellation": "Firefly",
      "off_nadir_angle": 50,
      "cloud_cover": 40,
      "order_id": "xxx",
      "name": "Test Order",
      "total_amount": 1230,
      "discount": 10,
      "tax": 10,
      "paid_amount": 10,
      "status": "InProgress"
    },
    {
      "org_id": "xxx",
      "product_type": "VNIR 5nm",
      "level_of_product": "L2a",
      "constellation": "Firefly",
      "off_nadir_angle": 50,
      "cloud_cover": 40,
      "order_id": "xxx",
      "name": "Test Order",
      "total_amount": 1230,
      "discount": 10,
      "tax": 10,
      "paid_amount": 10,
      "status": "InProgress"
    }
  ]
}
```


Delivered Images API

This API contains a list of all the images applicable for a user. Users can choose the image that is required to download and use that as input in the Download Image API.

Order_id is an optional parameter, if not provided, a list of all the images in the order will be given as output.

Sample Request

```
curl--location'https://p-platform-gateway.pixxel.dev/orderdesk/image' \

--header 'Content-Type: application/json' \
--data '{
  "order_id": "xxx"
}'
```

Example Output


```
{

  "S2A_MSIL2A_20231101T173451_R055_T13SGT_20231101T232414": {
    "order_id": "xxx", // extra key
    "constellation": "Pixxel Tech Demo 1",
    "datetime": "2023-11-01T17:34:51.024Z",
    "eo:cloud_cover": 0.010524,
    "geometry": {
      "type": "Polygon",
      "coordinates": [
        [
          [
            -102.8266544,
```

```
                34.3223732
              ],
              [
                -101.6347407,
                34.2954057
              ],
              [
                -101.673258,
                33.3067898
              ],
              [
                -102.8515624,
                33.3327745
              ],
              [
                -102.8266544,
                34.3223732
              ]
            ]
          ]
        },
        "instruments": [
          "msi"
        ],
        "platform": "Pixxel-Texh_Demo-1",
        "preview_url":
"https://d-platform-gateway.pixxel.dev/api/stac/v1/collections/pixxel-td1-l2a/items/S2A_MSIL2A_20231101T173451_R055_T13SGT_20231101T232414&resampling_method=nearest&assets=visual&bidx=1%2C2%2C3",
        "proj:epsg": 32613,
        "stac_url":
"https://d-platform-gateway.pixxel.dev/api/stac/v1/collections/pixxel-td1-l2a/items/S2A_MSIL2A_20231101T173451_R055_T13SGT_20231101T232414"
      },
      "S2A_MSIL2A_20231101T173451_R055_T13SGU_20231102T004118": {
            "order_id": "xxx", // extra key
        "constellation": "Pixxel Tech Demo 1",
        "datetime": "2023-11-01T17:34:51.024Z",
        "eo:cloud_cover": 0.014512,
        "geometry": {
          "type": "Polygon",
          "coordinates": [
            [
              [
                -102.8028976,
                35.2231329
              ],
              [
                -101.5980052,
                35.1952508
              ],
              [
                -101.6382697,
                34.2068165
              ],
              [
                -102.8289365,
                34.2336951
              ],
              [
                -102.8028976,
                35.2231329
              ]
            ]
          ]
        },
        "instruments": [
          "msi"
```

```
        ],
        "platform": "Pixxel-Texh_Demo-1",
        "preview_url":
"https://d-platform-gateway.pixxel.dev/api/stac/v1/collections/pixxel-td1-l2a/items/S2A_MSIL2A_20231101T173451_R055_T13SGU_
20231102T004118&resampling_method=nearest&assets=visual&bidx=1%2C2%2C3",
        "proj:epsg": 32613,
        "stac_url":
"https://d-platform-gateway.pixxel.dev/api/stac/v1/collections/pixxel-td1-l2a/items/S2A_MSIL2A_20231101T173451_R055_T13SGU_
20231102T004118"
    },
```

Download Image API

This API allows users to generate a downloadable link for the image ID provided from the above output.

Sample Request

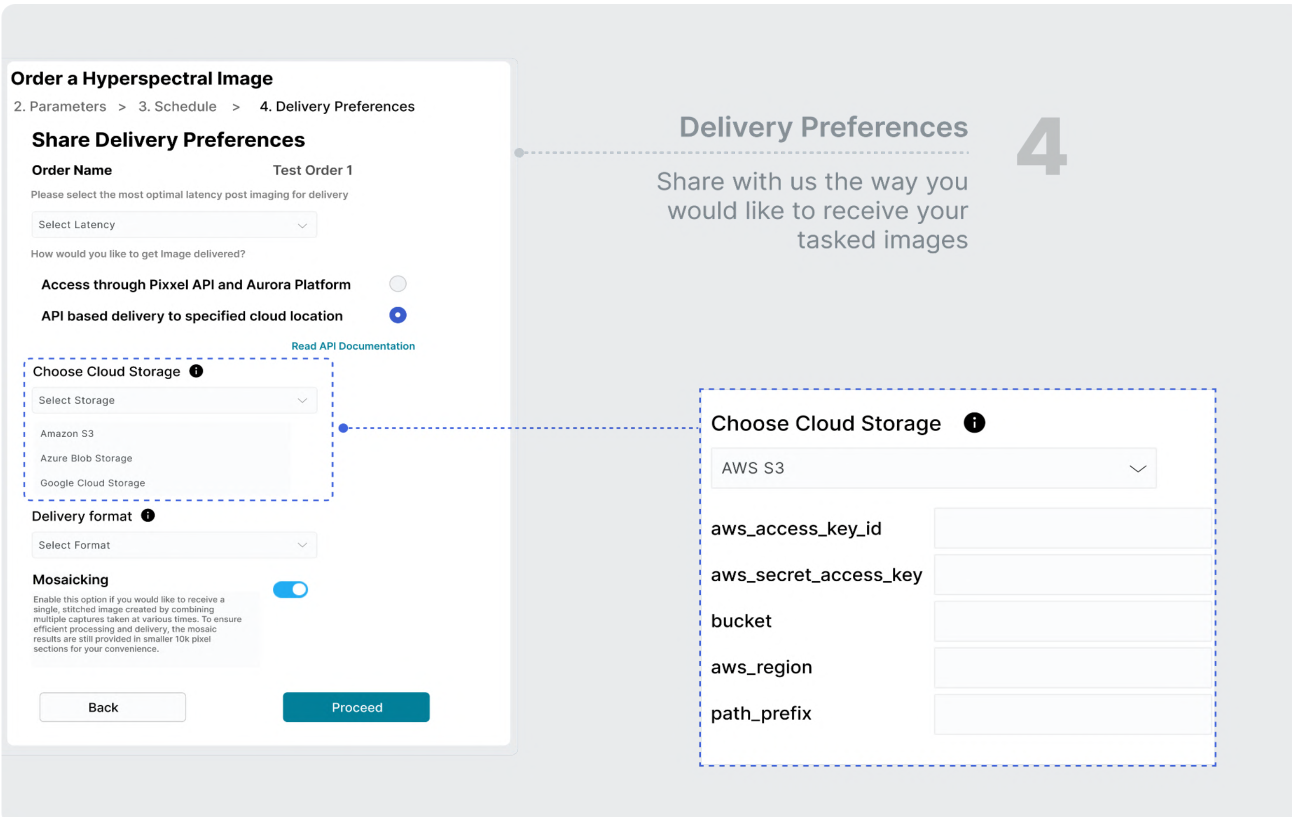
```
curl --location 'https://p-platform-gateway.pixxel.dev/atlas/image/download' \
--header 'Content-Type: application/json' \
--data '{
    "platform": "Pixxel-Tech-Demo-1",
    "image_id": "xxx"
}'
```

Sample Response

```
{
    "url": "https:pixxel.com/download_file"
}
```

7.4.5. Delivery to Cloud Storage Locations like AWS, Azure, or Google Cloud

Users can configure their choice of cloud storage platforms at the time of order placement either through the API or on the UI. The configuration for the API is covered in the **Order Creation API** section. UI screenshots can be found below.



Users will be notified when their order will be successfully delivered to their chosen cloud storage either via an email or by updating their notification API at the time of order creation.

7.4.6. Delivery to Other GIS Tools

ArcGIS Pro:

Users can track the status of their orders and download their orders on this platform only.

QGIS:

Users can track the status of their orders and download their orders on this platform only.

Google Earth Engine:

Users can visualize Aurora's imagery on Google Earth Engine (GEE) without going through the hassle of downloading and uploading images on GEE.

Users can connect GEE directly to Aurora's Delivery APIs and get images delivered on GEE for further processing. For images to be delivered to GEE, users must already have the image purchased on Aurora with the image ID.

However, discovering, ordering images, and tasking Pixxel's satellites is not supported on GEE.

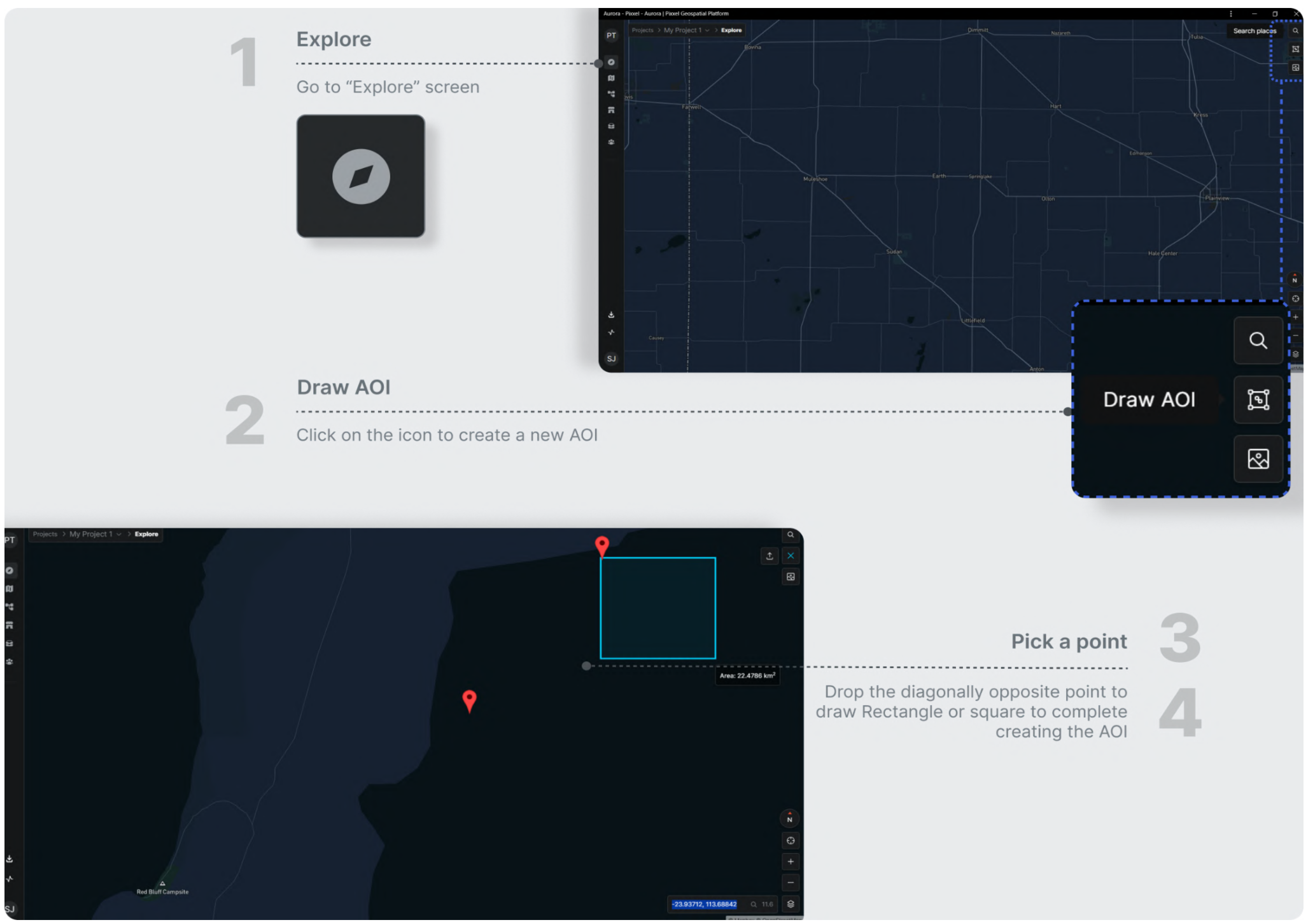
7.5. ANALYTICS / INSIGHTS GENERATION USING AURORA

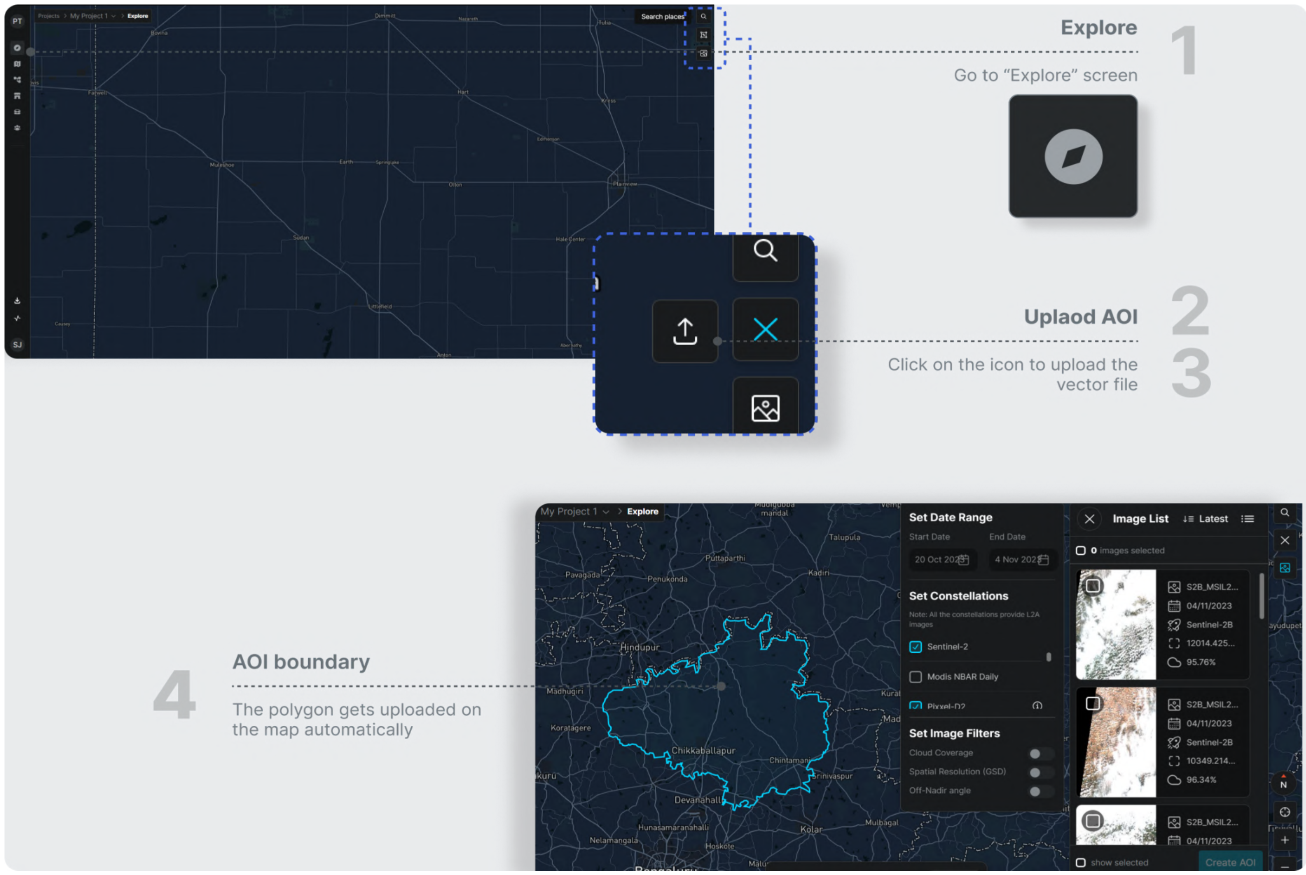
7.5.1. Area of Interest

AOI Creation

Aurora provides users with an option to **draw an AOI boundary** as well as **upload an AOI boundary.** Users can effortlessly migrate their already drawn AOI polygon file from any other software to Aurora. Aurora offers support for all major vector file formats such as **GeoJSON, SHP, KML, and GPKG**. Uploading an AOI boundary supports all types of polygon files, given that they are continuous.

Apart from Pixxel's **Hyperspectral Satellites** like D2 and Shakuntala, users can also access multispectral images offered by other Earth observation missions. These missions include Sentinel-1, Sentinel-2, MODIS, Landsat, and Hyperion. Once a user has drawn the AOI boundary, users can choose the dates & constellations that suit their needs, and filter out the best images with filters such as cloud coverage, spatial resolution (GSD), and off-nadir angle.





📓 An image may not cover the whole AOI. Therefore we use mosaicked images to analyze the AOI. What is a mosaic?

In remote sensing imagery, a "mosaic" refers to an image or dataset created by combining multiple individual images to form a seamless, continuous representation of a larger area. Mosaicking is a common technique used in remote sensing to create more comprehensive and coherent views of the Earth's surface.

Assets Created for Area of Interest

In certain instances, satellite images are not directly used for AOI analysis, rather, mosaics are used. There are two types of mosaics formed during the AOI generation. Users will find assets with naming conventions below:

- **Date_mosaic.tif:** The images users selected while creating an AOI are called tiles. For larger AOIs, it will overlap on the multiple tiles captured on the same date. Date_Mosaic is created from the overlapping tiles of the same date from the user-selected tiles, mosaicked into a single image. The purpose of creating this mosaic is to enhance user experience while performing analysis by making it easier to visualize and analyze the data collectively.

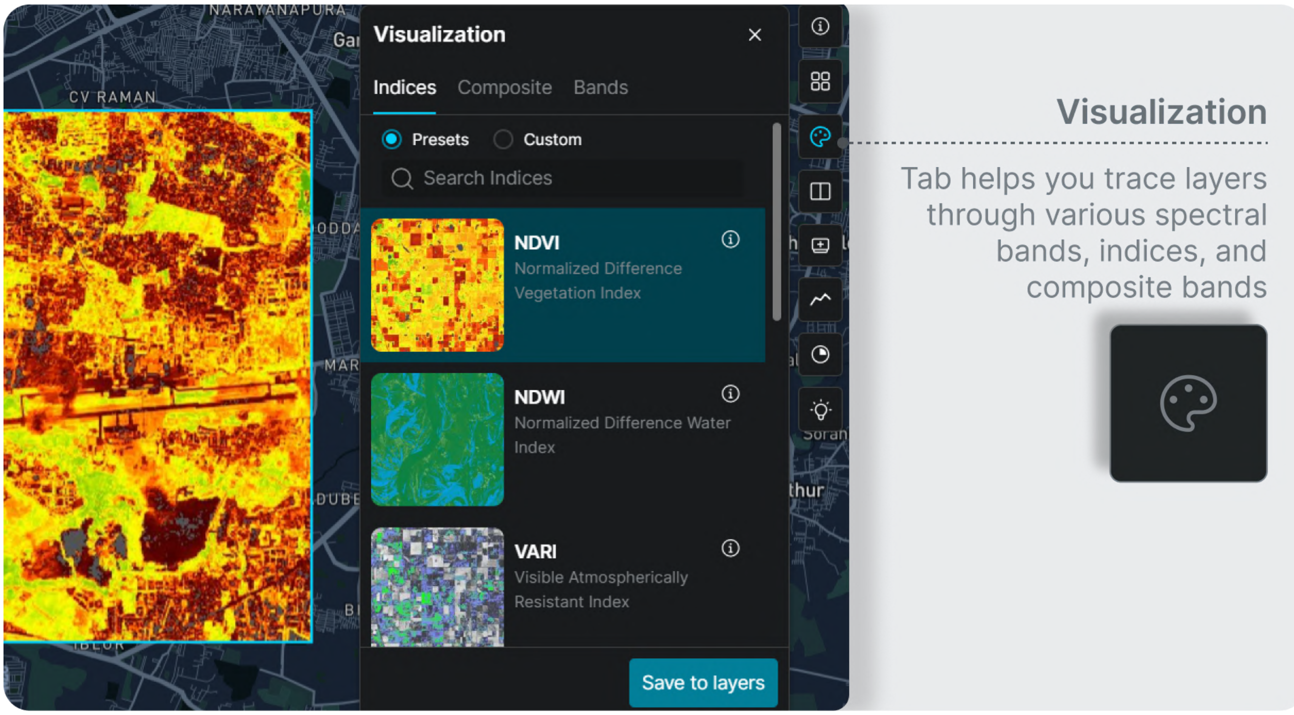
  Date_mosaic formed, in this case, might not cover the whole AOI if the image tiles combined do not cover the AOI.

- **Latest_data.tiff:** The Latest_data is a mosaic created using the latest imagery from the selected tiles such that it covers the entirety of the AOI. If a user selects images from 2 dates, but the image(s) from the latest date covers the whole AOI, then, the Latest_data.tiff will be a raster clipped to the AOI from that image(s) itself. In another scenario, if the AOI is completely covered by the two tiles corresponding to different dates but covered partially by the individual tiles, the Latest_data.tiff is created by mosaicking these two tiles corresponding to different dates.

7.5.2. Analytics Tools

1. Visualization Styles

In remote sensing imaging, layers can represent different spectral bands or wavelengths. These layers help build a comprehensive view of the scene being observed. The visualization tab helps users trace these layers through various **Spectral bands, Indices, and Composite bands**.



Indices

Users can use a spectral index to derive valuable information by the ratio of spectral bands or by applying operations on these bands. Aurora offers users two types of indices, preset indices and custom indices.

Preset Indices:

Users can use commonly used preset indices in addition to creating and downloading a layer using an index.

Vegetation: NDVI, TVI, NDMI, GNDVI, EVI, EVI2, Rededge2

Agriculture and Crop Growth: MTVI2, NDRE, RECI, SIPI, ARVI, RENDVI, PSRI, GCI, CVI

Soil Moisture: MSAVI 2, MSI, SAVI

Waterbody Coverage: NDWI

Heat Stress: NBRI

Oil and Gas: OSI

Urban Planning: NDBI

Environmental Change: NDDI, GEMI, NDSI

Custom Indices:

Since indices are ratios of spectral bands or normalized differences of spectral bands, users can create custom indices for specific use cases. Aurora gives users the freedom to experiment or customize how they use spectral data. Users can use the following options to create custom indices.

- Normalized difference index
- Band Difference
- Band Ratio
- Custom Input

Composite Bands

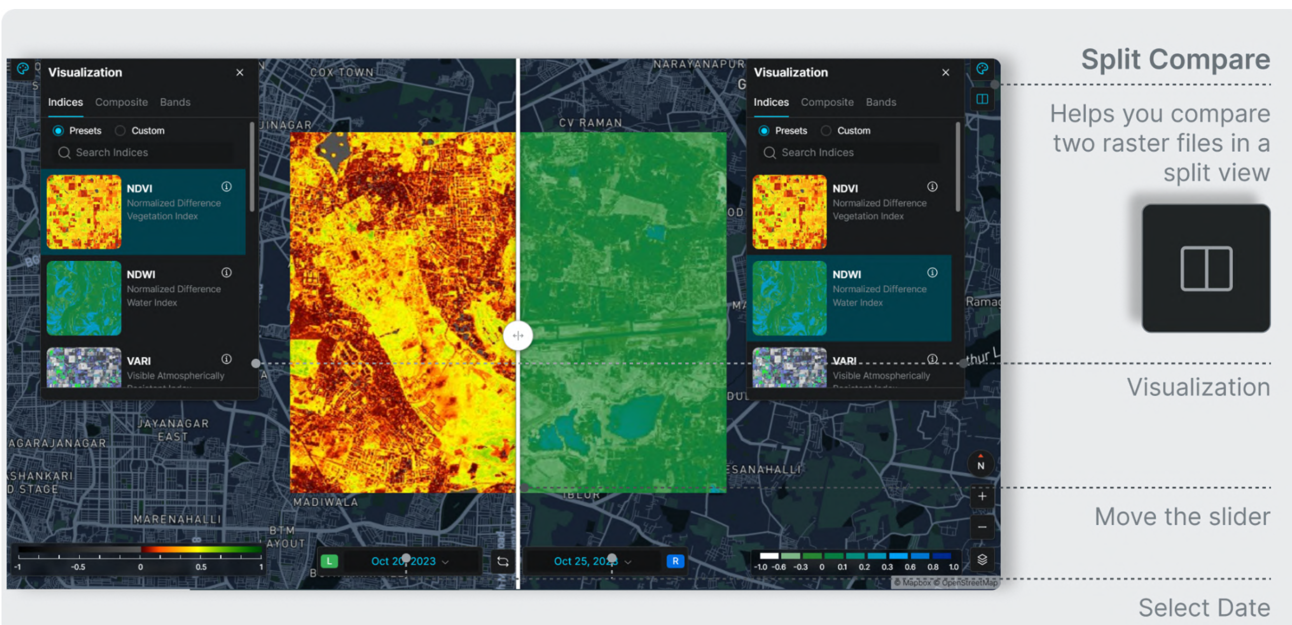
False Composite Bands are a common way to analyze the information by enhancing particular sensitive bands specific to any use case. Users can use this feature to create Composite RGB bands based on their requirements and the availability of bands from the given constellation/satellite.

Bands

Apart from indices and setting composite bands, users can view all the bands captured in the satellite image one by one. Each band visualization provides the spatial distribution of spectral information in the image.

2. Split Compare

Split comparison is a widely used feature in geospatial analysis. As evident from its name, this feature helps users compare two raster files in a split view. Aurora provides users with an option to choose between visualization styles of the raster on each side of the slider.



3. Spectral and Temporal Graph

Spectral Graph: In multispectral or hyperspectral imagery, each pixel contains information from multiple bands across the electromagnetic spectrum. Plotting these pixel values for a selected location or the mean of the pixel values for a selected area across these bands is referred to as a spectral graph. It helps to understand how the pixel characteristics vary across the bands. These spectral graphs are also used to compare the different pixels' spectral characteristics in the AOI.

Temporal Graph: The temporal graph represents the temporal changes of a specific location or region over time. Satellite collects the imagery across multiple timestamps, plotting the information across time allows for the analysis of changes in land cover, vegetation, and other features over time and interprets trends over time.

4. Labeled Dataset

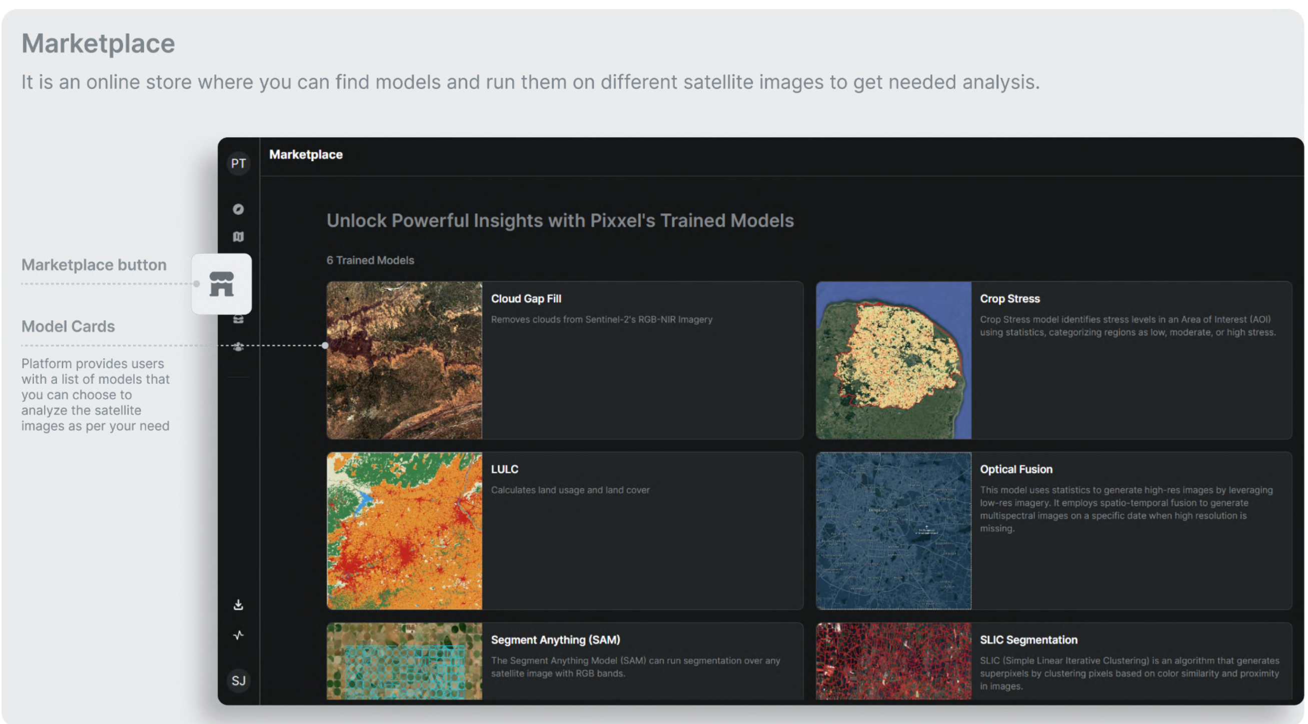
Aurora provides users with an option to create multiple labeled datasets which can be used further for different purposes like model training. Aurora uses the Segmentation model to segment the image based on pixel similarity. Some segments can be labeled into different classes and color maps. These labeled datasets can be used for further classification techniques.

7.5.3. Model Marketplace

Aurora provides users with varying machine learning and statistics models to derive valuable information from an AOI. Model Marketplace is a one-stop solution to find all the models available and the necessary details for each one. Moreover, users can put newly created and trained models on Aurora, for other users to utilize.

Please refer to the below list of models. This list will continue to evolve as demand for new models is added to the market.

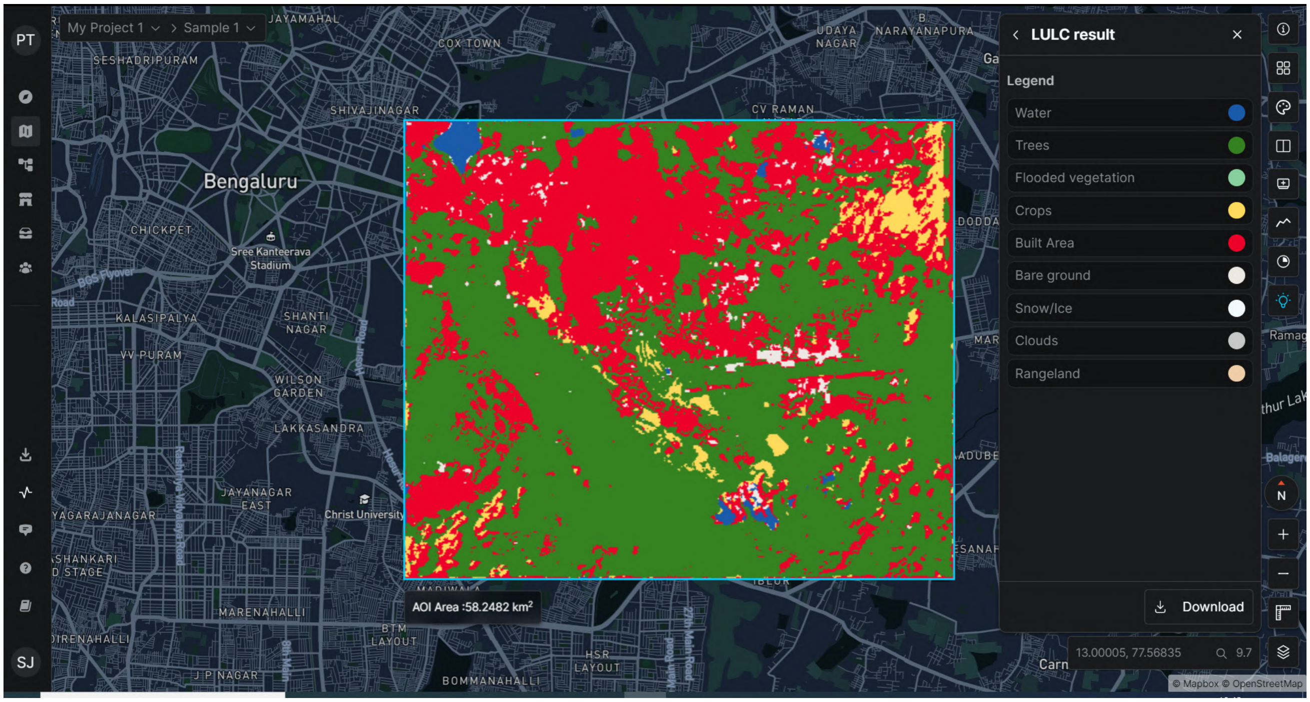
- Land Use/Land Cover (LULC)
- Change Detection with Quantified Numbers
- Optical Fusion
- Farm Boundary Detection
- Crop Type Classification
- Crop Stress
- Crop Biophysical and Biochemical Parameters
- Crop Growth Monitoring
- Crop Species Identification
- Crop Yield Estimation
- Forest Biomass Estimation
- Water Quality Monitoring
- Mineralogy
- Algal Bloom Monitoring
- Forest Pest Detection
- Segmentation Models
- Image Clustering
- Principal Component Analysis
- Cloud Gap Fill



7.5.4 Insights and Workflows in Aurora

1. Insights in Aurora

This feature enables users to generate instant insights for their given AOI. The objective of the insights function is to experiment and analyze the data quickly, whereas workflows follow a more detailed approach.

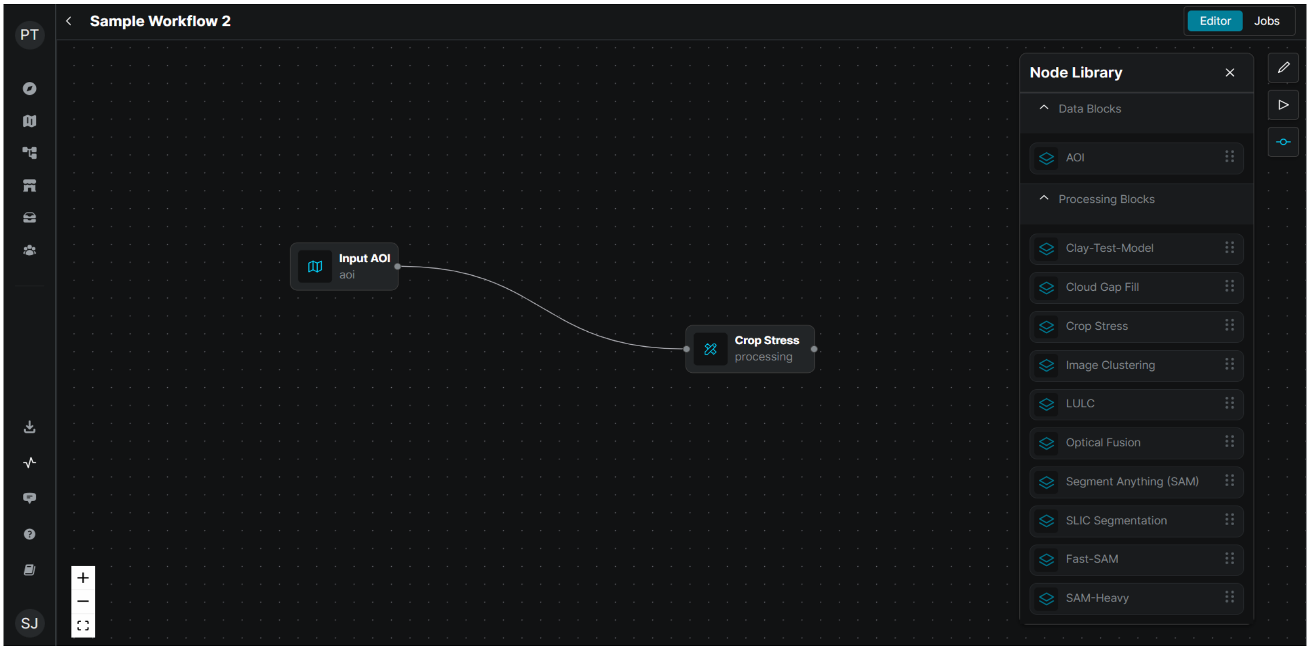


2. Workflow and Jobs

The workflow section allows users to experiment and derive necessary information from an AOI through various in-house machine learning and statistical models.

Workflow:

A workflow refers to a structured sequence of activities that can be created and managed within the platform. Workflows in Aurora are meant to automate the process of data extraction and analyses by visually designing an efficient process using data and processing blocks.



Data Blocks:

Data blocks represent the input data or information that is required for the workflow. This includes the AOI users create comprising images selected. Data blocks serve as the starting point for the workflow, providing the initial dataset on which the workflow's operations will be performed.

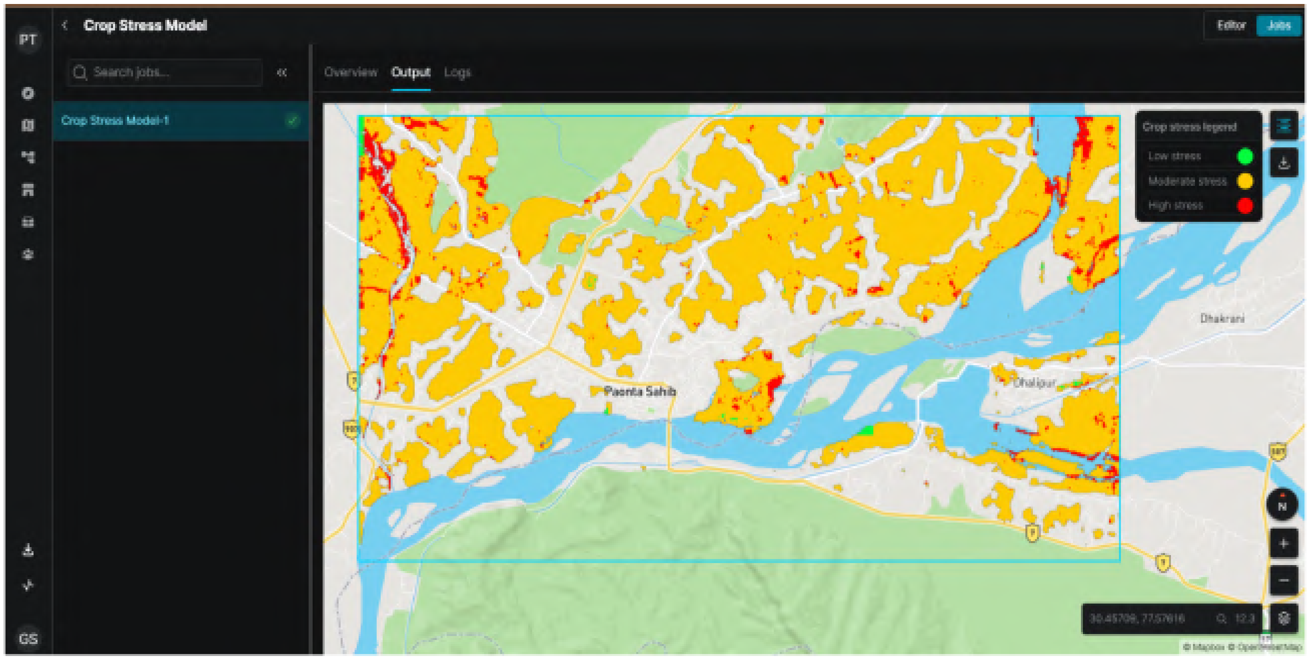
Processing Blocks:

Processing blocks represent the operations or tasks that are to be applied to the input data. These operations include all the models and tools offered by Aurora. Processing blocks determine how the data is modified, analyzed, or processed within the workflow.

Jobs:

Workflows are run to produce output where each instance when the workflow is run is called a Job. Jobs allow users to run the workflows repeatedly, eliminating the need to create the same workflow for each data block or processing block. Jobs are further divided into three tabs: Overview, Output, and Logs.

Sample Output


PT
Crop Stress Model
Editor
Jobs
Search jobs...
Overview
Output
Logs
Crop Stress Model-1
Crop stress legend
Low stress
Moderate stress
High stress
Paonta Sahib
Dhakrani
Dhalipur
GS