ESRI
EXTERNAL

Oriented Imagery Catalog Schema

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380 New York Street
Redlands, California 92373-8100 USA
909 793 2853
info@esri.com
esri.com

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This document applies to Oriented Imagery 1.1.2. Oriented Imagery and associated tools are currently provided as a prototype and for testing only. The functionality has not been exhaustively tested and is not currently covered under ArcGIS support. Please address questions or suggestions related to this workflow to Esri Community or to ImageManagementWorkflows@esri.com.

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Overview

We refer to "oriented" imagery as nontraditional mapping imagery. Such imagery may include street-side imagery taken from a mobile platform, close-range inspection images (e.g., transmission towers, bridge repairs) captured using drones or underwater rovers, or smartphone pictures taken by workers in the field. It also includes many forms of oblique imagery for viewing the different sides of buildings—in property assessment or for the inspection of power lines, for example. Such imagery is not typically suitable or desired for orthorectification due to a number of factors, including high oblique orientation (camera field of view partially or completely above the horizon), insufficient metadata, confusing content in the background, and/or subject matter with significant vertical structure. Although the ArcGIS mosaic dataset has robust support for nadir and low oblique imagery, the data model is not suitable for many forms of oriented imagery.

This document defines a schema for describing an oriented imagery catalog (OIC) for use in the ArcGIS platform. The OIC is defined as a JSON that references a point-based feature service that defines the camera location and orientation as well as metadata. The design should allow for scaling to many millions of images in a single catalog.

The OIC is used to find appropriate imagery for any location and enable an indication of the image coverage. The imagery should then be displayed, and if the accuracy of the orientation is sufficient, provide a mapping between ground features and image features as well as the ability to take measurements, superimpose the display of features into the images, or annotate and record features in the image with the location in map space also being recorded.

The range of applications includes 2D web maps, 3D scenes, mobile apps, and desktop applications such as ArcGIS Pro.

Oriented Imagery is primarily intended to support applications with the camera aimed near the horizon or oblique views but can also be used for nadir imagery.

Imagery requirements

Minimum requirements

This document presumes the existence of individual images with metadata describing the approximate camera location as well as orientation, hence the term *oriented* imagery. Additional metadata and more accurate orientation can be included for more advanced functionality. Geotagged imagery is defined as a subset of oriented imagery that has location but no orientation. It is supported but cannot provide any mensuration and can only provide limited navigation capabilities.

Camera support

Oriented Imagery is designed to support the following types of cameras:

- **Frame cameras.** This includes most drone and aerial imagery, typically with a field of view of about 70 degrees or smaller. Most digital cameras and video fall into this category.
- **Wide-angle or fish-eye cameras.** These typically have a greater than 70-degree field of view.

- **Omnidirectional cameras.** Panoramic, spherical, catadioptric, and fish-eye cameras are included in this category.
- **Synthetic omnidirectional cameras.** These have properties similar to an omnidirectional camera, but with a field of view typically created by processing the input from multiple images into a virtual image that typically has a predefined direction and distortion. These images are defined by methods including single frame, equirectangular images, and cube images.

Image structure

The images may be a single image, as in the case of a frame camera, or they may be made up of multiple images that need to be stitched together or images that have been processed to represent a single, stitched image (e.g., equirectangular images and cube images). Various stitching methods are supported.

Image format

A variety of formats are supported. These include simple browser-readable JPEG/PNG files, as well as formats such as MRF that are optimized for cloud storage. Additionally, the imagery can be accessed from tile services or image services. Tile services provide a predefined tiling scheme where each tile can be accessed as a URL. Image services enable dynamic requests for a specified area of interest (AOI) and resolution and return only the pixels required.

Metadata

Metadata about the imagery is required. This not only includes the location of the imagery but also various attributes that define the orientation, view angles, and a wide range of attributes about each camera. A generic view of the data structure indicates that each image has a wide range of standardized parameters that define all properties, such as location, orientation, and image-specific metadata. Such metadata is provided as a point-based feature service that enables the image for an AOI to be efficiently queried and key attributes returned. In a typical scenario, the feature service is created from a collection of imagery and its attributes. Oriented imagery also provides support for image services sourced from a mosaic dataset of oblique imagery. This enables an image service to be directly referenced in an Oriented Imagery application, removing the requirement for a separate point-based feature service. Alternatively, an oriented imagery point-based feature service can define the image orientation with the imagery being read from an image service by making use of the ICS export capability.

Oriented imagery catalogs

Data structure

An oriented imagery catalog (OIC) is defined by a JSON data structure that defines key properties as well as a reference to the image-specific metadata. The key properties not only include generic parameters but also define defaults and variables. The use of the default and variables can significantly reduce the number of attributes required to define a collection of imagery with similar properties. If all the images in a collection of imagery have the same field of view, this can be defined in the OIC JSON file and need not be defined for each image. Similarly, if part of the URL to the imagery is always the same, this can be defined as a variable to reduce redundancy in the database.

Approximate versus accurate georeferencing

A key principle in the OI design is to enable both approximate and accurate georeferencing. The accuracy of the georeferencing is highly dependent on the calibration of the camera and knowing the camera parameters and auxiliary data, such as a digital terrain model (DTM) or depth image. To enable support for a wide range of accuracies while still enabling simple implementation, the georeferencing is split into two parts. One set of georeferencing is always required and provides georeferencing accuracy suitable for the determination of the appropriate image location and navigation. This provides approximations to the image2ground and ground2image transforms and is typically not sufficient for any mensuration. An optional second set of georeferencing can define accurate transformation that can be used to define accurate mensuration and associated accuracies.

Security

Security is handled at the OIC and feature service level. This means that the OIC JSON contains all the information required to access the imagery and a link to the service that provides image-specific metadata. In a typical implementation, the OIC is defined as an item in ArcGIS Online (or your ArcGIS Enterprise portal) and users that have access to this can access the key properties including a reference to the feature (or image service) that defines the camera-specific data. This feature service may be a direct URL to a service or an item in ArcGIS Online (or your ArcGIS Enterprise portal) such that only users that have access to the service can access the imagery. This enables the inclusion of views or similar into the feature service so that users can access only specific subsets of the whole. It is typically assumed that if the OIC item can be accessed, then the imagery can also be accessed; i.e., the feature service will typically point directly to a URL that enables access to the imagery. It is possible to include additional authentication to allow access to the imagery.

The client application therefore needs access to the OIC item, the feature service providing metadata, and the imagery. Access to the pixels can be directly from cloud storage or using a tile service API. One recommended way of providing access to the imagery is to put the data in an obfuscated cloud storage location such that access is not specifically authenticated but access to the URL is assumed to be equivalent to accessing the data source. Such a system enables massive volumes of imagery to be accessed while simplifying access control.

Licensing

Oriented Imagery is controlled through the use of an OI API that is used in both web and desktop applications. This API should limit capability depending on the user's subscription level in ArcGIS Online. Access to imagery and navigation is open. Access to simple mensuration requires the Viewer User Type. Access to a collection of features requires the Editor User Type. Access to any authoring capability requires the Creator User Type.

Third-party integration

It is realized that some third parties have very advanced navigation and mensuration capabilities. In many cases, this may be beyond the capabilities of the existing OIC viewer. Oriented Imagery was designed to enable the integration of such applications so long as they conform to a specified API. It is required that the key metadata for each image is defined in an OIC.

Modes

Oriented Imagery has many modes that are controlled by the OIC. This allows great flexibility while providing simplicity for the end users, but can create complexity for the authoring of OICs and the software development. The following information attempts to define the different modes.

The OIC can refer to a feature service or image service as the source of metadata that defines the location and orientation for all images. If defined by a feature service, the location of the images for navigation is determined by attributes of the service. The mensuration capabilities are determined based on availability of approximate orientation, more accurate sensor-specific orientation, or by a third-party viewer API.

If the source is an image service, then the navigation, image access, and mensuration are defined by the image service.

If the source is a feature service, then the imagery can be accessed multiple ways, including direct access to imagery in web-accessible storage, access using a tile server, or access via an image service. It is possible to *define* the geometry using a feature service, but *access* the pixels via image coordinate system (ICS) requests to an image service. In this case, the image service only needs to contain imagery, no georeferencing is required. Such an image service can be very quick to implement, provides on-the-fly clipping of the imagery, and can take advantage of the image service's access control.

As mentioned above, the georeferencing of the imagery for navigation purposes is defined in the feature by attributes. These provide only a limited level of accuracy. The attributes can also define a collection of sensor-specific parameters that can be used to provide more accurate mensuration.

Third dimension

Determining a relationship between image space and ground space requires a definition of three dimensions in both ground and image space as well as a transformation between them. A typical image does not have a third dimension, so one needs to be defined. This third dimension can be defined for each image in one of two ways:

DEM—Digital elevation model that is defined in map space. For any defined x,y location, the DEM should provide a height. Based on x,y,z + the ground2image transform, the appropriate pixel in image space can be identified. Having a DEM (and ground2image transform) for an image means that for any point on the map, the associated image location can be found. Going from image2ground is more complex and can only be achieved iteratively while needing to make assumptions on the form of the DEM. For many applications, no DEM is known, and ground needs to be approximated by the height of the camera above a flat terrain.

Depth Image—For images that are collected at the same time as data is collected by a lidar system or other system that measures the suitable geometry between frames, a depth image can be defined. If such an associated image exists, then the transform from image space to ground space is simplified to a single equation, but transformation of ground features to image locations is not uniquely defined and must be solved iteratively. A depth image is important for more accurate mensuration in complex terrains.

Oriented Imagery attempts to support both methods of defining the third dimension.

Integration with artificial intelligence

In addition to providing navigation and mensuration capabilities for oriented imagery, OICs are also designed to be used as the source for applications requiring image-based feature identification. As a catalog, an OIC can be used to define what imagery should be submitted to artificial intelligence (AI) algorithms but, more importantly, to transform labels and features from image space to ground space for additional spatial processing.

Camera position and orientation

By default, the x,y position of the point feature defines the location of the camera in a suitable coordinate system. This may be a projected coordinate system, such as universal transverse Mercator (UTM) or web Mercator, or geographic coordinates. It is assumed that the y-axis is toward north.

This location is primarily used to aid in the search for the appropriate images to display. As clarified later, the location of the camera may also be offset from this location.

If defined, the z-value of the point is assumed to be that of the camera location and may be defined by orthometric or ellipsoid height as part of the coordinate system. As will become apparent, the z-value is only used to show the location of the camera in 3D environments and is not necessarily used to define the location of objects in the image or the visible extent of the image.

The camera orientation is described in terms of **CamHeading**, **CamPitch**, and **CamRoll** ("cam" to clearly differentiate from orientation of the aircraft/vehicle body). These angles describe the camera orientation relative to a local projected coordinate system and refer to the point between the camera position and a point running through the center of the image.

Camera orientation is described as follows:

- The initial camera orientation is with the lens aimed at nadir (negative z-axis), with the top of the camera (columns of pixels) pointed north and rows of pixels in the sensor aligned with the x-axis of the coordinate system.
- The first rotation (**CamHeading**) is around the z-axis (optical axis of the lens), positive rotations **clockwise** (left-hand rule) from north.
- The second rotation (**CamPitch**) is around the x-axis of the camera (rows of pixels), positive **counterclockwise** (right-hand rule) starting at nadir.
- The final rotation (**CamRoll**) is a second rotation around the z-axis of the camera, positive **clockwise** (left-hand rule).

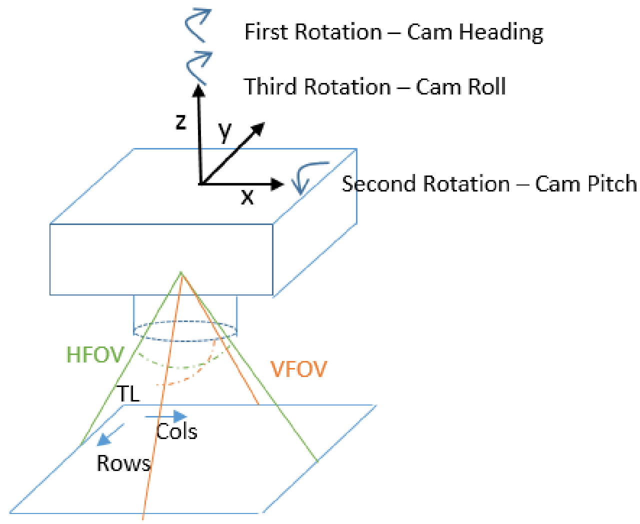


Figure 1

Example orientations

- The camera pointing down with the rows of pixels going from west to east would have the orientation 0,0,0.
- Rotating the camera 90 degrees so that the pixels go from north to south would be 90,0,0.
- Rotating the camera to the horizon would have the orientation 90,90,0.
- Rotating the camera counterclockwise by 20 degrees would result in an orientation of 90,90,20.

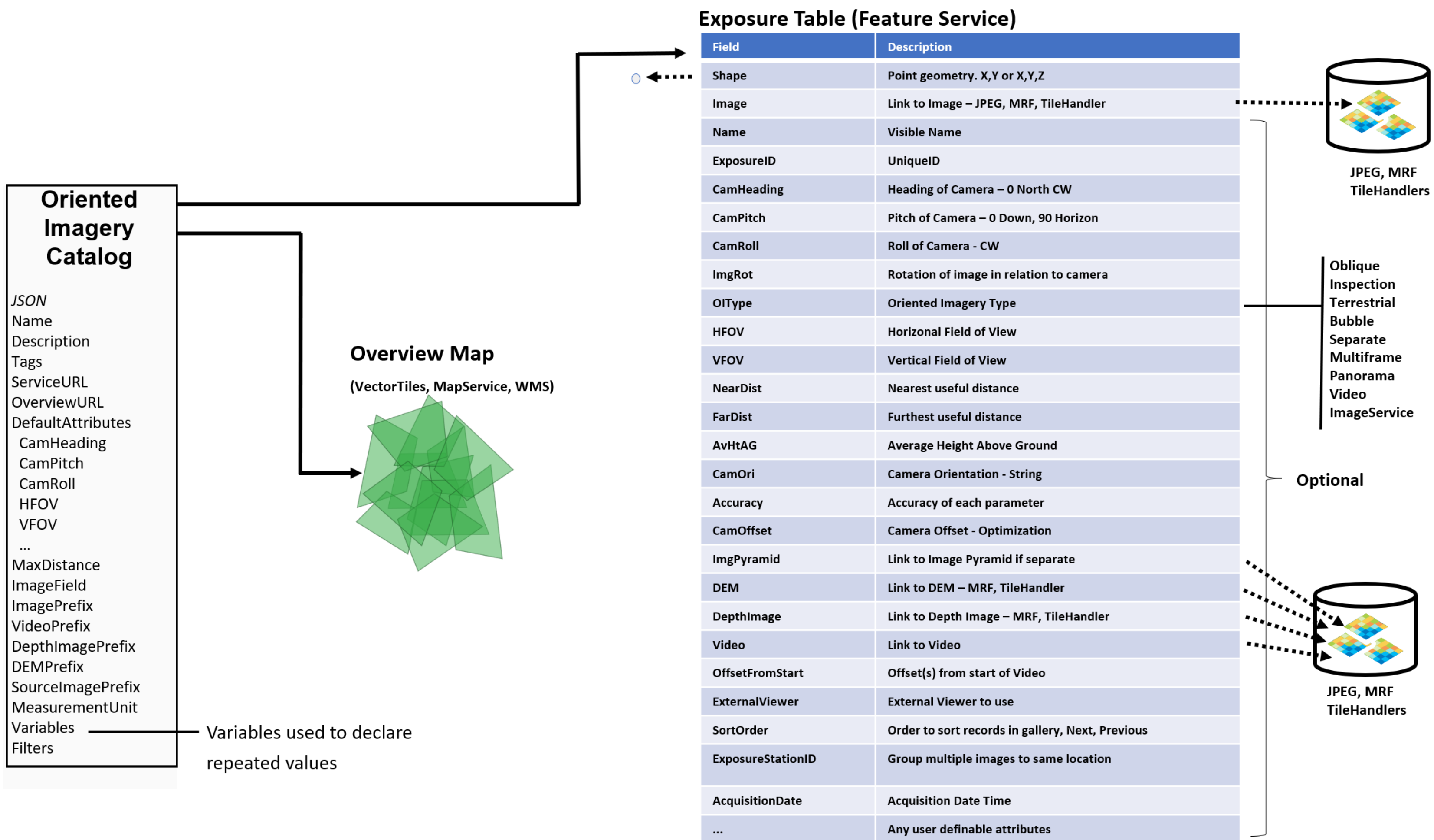
In most applications, the roll angle is 0. The roll angle is used to indicate that the camera body is rotated around the lens axis and is required to determine the correct pixel-to-image relationship.

In some cases, the image is rotated with respect to the camera. This is handled by the ImgRot field. Horizontal field of view (HFOV) and vertical field of view (VFOV) should be that of the camera and should not change based on the roll angle.

Note that omega, phi, and kappa, the classic photogrammetric definitions for angles, are not used, as they are not suitable for imagery directed at the horizon.

Oriented imagery catalog schema

The structure of the oriented imagery catalog is summarized by the following:



Field	Description
Shape	Point geometry. X,Y or X,Y,Z
Image	Link to Image – JPEG, MRF, TileHandler
Name	Visible Name
ExposureID	UniqueID
CamHeading	Heading of Camera – 0 North CW
CamPitch	Pitch of Camera – 0 Down, 90 Horizon
CamRoll	Roll of Camera - CW
ImgRot	Rotation of image in relation to camera
OIType	Oriented Imagery Type
HFOV	Horizonal Field of View
VFOV	Vertical Field of View
NearDist	Nearest useful distance
FarDist	Furthest useful distance
AvHtAG	Average Height Above Ground
CamOri	Camera Orientation - String
Accuracy	Accuracy of each parameter
CamOffset	Camera Offset - Optimization
ImgPyramid	Link to Image Pyramid if separate
DEM	Link to DEM – MRF, TileHandler
DepthImage	Link to Depth Image – MRF, TileHandler
Video	Link to Video
OffsetFromStart	Offset(s) from start of Video
ExternalViewer	External Viewer to use
SortOrder	Order to sort records in gallery, Next, Previous
ExposureStationID	Group multiple images to same location
AcquisitionDate	Acquisition Date Time
...	Any user definable attributes

Figure 2

Generic Model

Used for Search and Non Precise Viewing

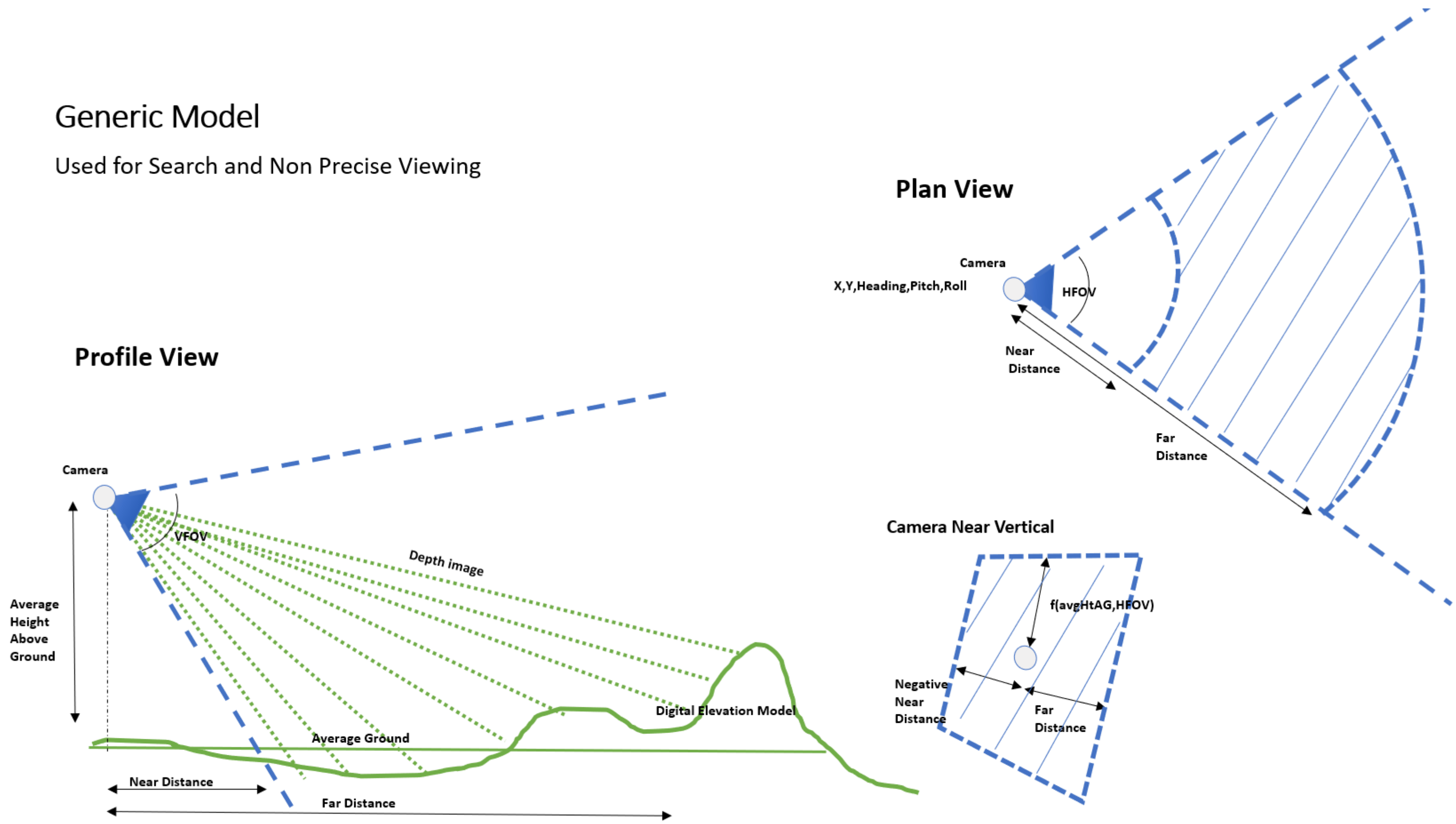


Figure 3

Oriented Imagery Exposure Table

This section defines field names, types, and default values in the feature class/service. Note that the primary use for this metadata is an efficient search capability to enable a user to quickly find and display images covering a site of interest and so includes a number of approximations. An optional CamOri field is provided to support precise measurements and can include accurate metadata (e.g., focal length, lens distortion) to enable more accurate measurements. This separation of approximate and precise metadata enables the support of an extensive range of imagery types.

Field name <default values in brackets>

- **Shape geometry X,Y—**Defined location of the camera. See also "CamOffset" attribute below. Optionally may also be x,y,z.
- **Name (optional)—**Name given to the raster and may be displayed for identification purposes. It may not be unique. It should not include the file extension.
- **ExposureID (optional)—**String maximum 50 characters—String that can be used as a unique identifier for the specific camera exposure. This is used to link any feature captured from the image back to the specific image. When features are captured using Oriented Imagery feature capture tools, the features are attributed with an Image URN that often contain this value. The Image URN value recorded is determined as follows: If the Exposure Table (that forms the OIC) has a GUID, then this should be used. Else, if the OIC contains an ExposureID field, then this should be used. Otherwise, the Image URN is set as follows:

  Name + "|" +
  Right (Name+"|"+ServiceName+"|"ObjectID, 50)
  where ServiceName is the service name (excluding \feature\...)
  Note: if Name is undefined, then this would be right("|"+ServiceName+"|"ObjectID, 50)
  On the creation of an OIC, some sources may already have unique IDs that are used to uniquely identify the image and so can be put in the ExposureID field.

- **Image—**Reference to the image. This can be one of the following:
  - URL to a web accessible image file (including extension) in cloud storage. Initial supported formats are: JPEG or MRF. MRF provides a cloud-optimized, multiresolution, tiled format for faster access. JPEG may also be used but may not be optimum, especially for larger files. See notes below on ImgPyramid field that can be used to provide multiresolution access.
  - Local file path to a JPEG image(Works only in ArcGIS Pro Add-In).
  - In some managed (database only) implementations, image may refer to a binary large object (BLOB) in which the image is stored. This may be applicable in offline mobile type applications.
  - May also refer to different services. Currently, three services are supported. The URL needs to be prefixed with an identifier that indicates the type of file service and the schema used. The following notation should be used:

    ArcGIS ImageServer
    A|ImageServiceURL|ObjectID|Col|Row—ArcGIS Image Server.
    A—Identifier.
    ImageServiceURL—URL to the image services (excluding Export).
    ObjectID—ObjectID of the image. The API will construct the URL to enable specified rows/columns to be returned.

Col—Number of columns (image width).
Row—Number of rows (image height).

TileService
T|ZSTS|Col|Row|URL or T|ZSTS|URL.
T—Identifier.
ZSTS—Defines scale factor, number of levels, and tile size.
Col—Number of columns (image width) (In case of cube images, specify the width of one face in cube).
Row—Number of rows (image height).
For example, 42512 defines that there are 4 levels of zoom each with a factor of 2, and the tile size is 512. Only the following are supported: Number of Levels 1–9; zoom factors 2,3; tile sizes 256,512.
URL is URL to the tile service using the following notation to define the location of a tile:
|z|—zoomLevel
|x|—col
|y|—row
|f| or |F|—For cubemap (360) images. F denotes the face of the cube. Valid values are f,r,b,l,u,d or F,R,B,L,U,D.

Example: Tile url—esri.com/Tiles/ImageID/|z|/|x|/|y|.jpg
The Oriented Imagery API will replace |z|with the valid zoom level value, |x| with the appropriate column value, and |y| with the row value.

Feature Image Attachments
FA
FA – Identifier
Attachments are images that are included on feature layers. Attachments allow you to store images in the geodatabase and access the images in more ways.

- **SourceImage (optional)—**Similar to image but used to point to a local source. This should only exist in the authoring components when imagery is local. Should not be included in the published services. Enables the authoring tools to keep track of local and web accessible versions of the images.
- **AcquisitionDate (optional)—**DATE field. An important attribute for many applications. Also used to support temporal imagery search or filtering. Allows optional recording of date only or may also include time of day, as required by the application. Note that all dates and times should be relative to UTC.
- **CamHeading** <default = -999>. Defined above, in degrees. CamHeading = 0 means the top of the camera is oriented toward the north, or CamHeading = 90 means the top of the camera is oriented toward the east. Value should be between 0 and 360. A negative value or NULL indicates that orientation is not known, such as for georeferenced imagery.
- **CamPitch** <default = 90>. Defined above, in degrees. CamPitch = 90 means the camera is viewing toward the horizon. 0 indicates straight down.
    - The default value is based on the context of "inspection/street view" (non-nadir mapping) imagery.
    - Drone imagery may be at a range of oblique angles and, if nadir, would require a value of 0.

- For inspection imagery, CamPitch > 90 may occur.
- A negative value is allowed but is equivalent to using CamHeading + 180 and CamPitch + 180.

- **CamRoll** <0>. Defined above, measured in degrees. CamRoll will typically be near 0. CamRoll is used to account for +/- 90-degree rotations in the camera housing.
- **ImgRot—**Orientation of the image. The orientation of the camera relative to the scene, when the image was captured. Default is <0>. This rotation is added in addition to Roll. Value can be from 0 to 360. Negative values are allowed.
- **HFOV** <60>. Horizontal field of view, measured in degrees. This typically refers to the FOV for the row direction of the camera but may be the column direction if the CamRoll is +/- 90. The value can be estimated based on the focal length of the camera and CCD (image sensor) width.
    - HFOV ≈ 2*atan(sensor_width/(2*focallength))
- **VFOV** <40>. Horizontal field of view, measured in degrees. Typically refers to the HOV for the column direction of the image but may not be if CamRoll is +/- 90. The value can be estimated based on the focal length of the camera and CCD height.
    - VFOV ≈ 2*atan(sensor_height/(2*focallength))
- **AvgHtAG** <1.8>. Average height (m) above ground of the camera. For aerial or drone imagery, this is equivalent to the flying height above ground. For indoor imagery, this is the height above the appropriate floor. For inspection imagery, it is the height above the base of the appropriate feature. The value is used to determine the visible extent of the image, so large values will result in a greater view extent. It is also used to help estimate the location of an object of known relative coordinates in the image. It can be used to enable identification of an appropriate image when using multiple images of tall objects.
- **FarDist** <20>. Furthest usable distance from the camera position of the imagery in meters.
    - This value is used for searching on a 2D map; e.g., click on the map, "Do I have an image that shows this location?" Beyond this distance, the answer may be technically yes, but it's beyond the distance for the image to be usable for detailed inspection or interpretation (a judgment based on the application).
    - For close-range applications, the value is typically set manually versus calculated; e.g., for close-range inspection, this may be ~5 m; for street view imagery, perhaps ~20 m; for structural inspection/damage assessment from a drone, ~50 m.
    - If nadir, then set FarDist = AvgHtAG*sin(VFOV/2).
    - FarDist should always be >0.
- **NearDist** <0>. Nearest usable distance of the imagery in meters. For imagery that is near nadir, the value can be negative, indicating that the x,y location of the camera is covered by the image.
    - If nadir, then set NearDist = -AvgHtAG*sin(VFOV/2).
- **OIType (optional)—**Oriented Imagery type, string to define type of imagery
    - **O—**Oblique—Frame image from aerial or drone sensor
    - **I—**Inspection—Frame image with feature of interest near camera
    - **T—**Terrestrial (Default)—Typical frame imagery taken at street level
    - **B—**Bubble—A single stitched panorama image with 360-degree view (equirectangular image—photosphere)

Figure 4

- **S—**Six separate images stitched together to form a cube. Order of images should be [Front, Right, Back, Left, Down, Up], and front face of the cube should have CamHeading = 0; Cubemap image—a cube with six faces.
  Example
  
  Figure 5
- **D—**Multiple frame images taken from the same location, pointing in different directions but considered a group. Order of images should be [Front, Right, Back, Left, Down, Up], and front face of the cube should have CamHeading = 0; Cubemap image—a cube with six faces.
  Example—Image URL of front face (provided in Image field):
  http://s3.amazonaws.com/sample_F.png
  It should have _F at the end. API will append a character at the end of the string to get all the faces of the cube.
  For Front, it will create the URL http://s3.amazonaws.com/sample_F.png.
  For Right, it will create the URL http://s3.amazonaws.com/sample_R.png.
  For Back, it will create the URL http://s3.amazonaws.com/sample_B.png.
  For Left, it will create the URL http://s3.amazonaws.com/sample_L.png.
  For Down, it will create the URL http://s3.amazonaws.com/sample_D.png.
  For Up, it will create the URL http://s3.amazonaws.com/sample_U.png.
  These URLs should exist in the same location.
  (Note that these names may change.)
- **P—**Panorama—HFOV >4x VFOV. Equirectangular—photosphere.

Figure 6

- **V—**Video. Image may or may not exist. Video field should define location of video.
- **A—**ArcGIS Image Server—Defines that mensuration should be achieved using ArcGIS Image Server. This can be used to change the functionality of the client app.

- **ExternalViewer—**A string value indicating that the image should be opened in an external viewer. Value typically exists as a variable in the OIC file. If the value is null or does not match any variable defined in the OIC file, then the image is opened in oriented imagery viewer.
- **SortOrder—**Optional LongInteger. A number used to define the order of the imagery and to enable gallery type applications, where users make a selection and go from one image to the next, typically along a street or down a power line or pipeline. If undefined, then AcquisitionDate is used so long as it exists and includes time; otherwise, ObjectID is used.
- **CamOffset (optional)—**String of two or three comma-delimited values (dx,dy,dz) that define the actual camera location relative to the feature point. The use of this is primarily for oblique imagery with longer focal lengths. It enables smaller search distances to be used when identifying a suitable image for a location. When determining the extent and positioning of the camera, the application must add these values to the feature location to determine the camera location. Note that the units are defined in that of the feature service; i.e., if the service is measured in feet, then this unit is in feet.
- **Accuracy (optional)—**Comma-delimited string of values with the following order: StdDevXY(m), StdDevZ(m), StdDevHeading(deg), StdDevPitch(deg), StdDevRoll(deg), StdDevDistNear(m), StdDevDistFar(m), StdDevElevation(m). Default or 0 defines unknown. These are used to indicate the accuracy of the orientation measurements and to control how the location cursors are displayed. If undefined, the position cursors should indicate very approximate positions. StdDevXY,Z are the standard deviation of the camera location. StdDevHead,Pitch,Roll are the standard deviation of angles. StdDevDistNear,Far are the standard deviation of the distance measurements for measurements at the near distance and far distance when using a depth image. It is assumed that measurement accuracy changes linearly with distance. Note that if near distance is negative, then StdDevDistNear may also be negative.
- **ExposureStationID (optional)—**Long integer that can be used to associate multiple images taken at the same location. This can be used to aid in editing such as that if the location of the camera is moved, all the points with the same ExposureStationID are also moved.
- **ImgPyramids (optional)—**Optimization field providing information on the approximate size of the image and the possible availability of reduced-resolution JPEG versions that can be used to enable faster access to thumbnails of the full image. The field is a comma-delimited string of integers defining the approximate number of columns (or rows) of the image width and availability of a reduced-resolution image. The image size is defined as the round (cols|rows/100); i.e., an image with 5,550 columns would be defined as 56. Subsequent numbers define the availability, approximate size, and name of reduced-resolution versions. The URL to the reduced-resolution versions are assumed to be the same as the full-resolution

version but with the file extension replaced by _XXXX.jpg. For example, if the ImageRef was http://a.com/img/D023.jpg and had a size of 5,550 columns, then a string of the form 55,20,5 would indicate the following images also exist:
http://a.com/img/D023_20.jpg has about 2,000 columns or rows,
http://a.com/img/D023_5.jpg has about 500 columns or rows.
The application can now access the appropriate image for display depending on the display window size and zoom ratio.
Note that although MRF files will typically have internal pyramids, such small JPEG files may still be used to increase performance, as small JPEG files can be accessed as single get requests.

- **DEM (optional)—**Defines the Digital Elevation Model to be used to compute the ground to image transform for cases where no height information is available. Note that if a depth image exists it will be used for all image to ground transforms, but if one does not exist then the DEM will be used.

  ArcGIS ImageServer for Height
  I|PS|ImageServiceURL—ArcGIS Image Server|RenderingRule
  I—Identifier
  PS—Pixel size in meters
  ImageServiceURL—URL to the image services (excluding Export)
  Based on the coverage, the system should extract a terrain model of defined pixel size covering the possible image extent and use that to define elevation.
  RenderingRule (optional)—Rendering Rule defined on the service

  ArcGIS Tile ImageServer for Height
  E|ImageServiceUrl—ArcGIS Cached Image Services|LOD
  E—Identifier
  ImageServiceUrl—URL to the cached image service
  LOD (optional)—Level of Detail (max LOD Level). Tile will be retrieved from this level or below.

  MRF|LERC for Height
  URL—URL to MRF|LERC file
  Source can be image service, tile cache image service, MRF, or LERC.

- **DepthImg (optional)—**Used to define the depth dimension. Depending on the application, different methods are appropriate. Defining a depth image has a significant effect on the measurement taken from the image. If Undefined or 0, then distance of the object from the camera is computed purely from AvgHtAG and camera angles, which will assume the ground is flat (or will use the DEM described above if defined).
  The default notation is to define a URL to a web accessible image that provided depth information for the pixels. The extent of the image is assumed to be the same extent as the primary image, although it may have a different number of rows and columns. This URL may differ from image to image, or many images may reference the same depth image.

  The following notations are used to define different ways of representing plane depth:

  MRF|LERC|PNG for Depth
  URL—URL to MRF|LERC|PNG file

Simple Plane

P|A,H,V

P- Identifier

Define distance as P|A,H,V were A is distance to center of image and H and V are the vertical and horizontal deviations (in deg) from a plane that is parallel to the camera. Currently, we don't support both H and V parameters together. In most cases V=0. Hence, we only use one of the angels with preference to the Vertical angle.

Distance is computed as

If V != 0

$D = A * ((\cos(V-V_{ang}) + \sin(V_{ang}) * \sin(-V))/(\cos(V- V_{ang}) * \cos(V_{ang}) * \cos(H_{ang})))$

Else if H != 0

$D = A * ((\cos(H-H_{ang}) + \sin(H_{ang}) * \sin(-H))/(\cos(H- H_{ang}) * \cos(H_{ang}) * \cos(V_{ang})))$

Else

$D = A / (\cos(H_{ang}) * \cos(V_{ang}))$

Where H_{ang} = HFOV*Abs(Col-(NCols/2)), V_{ang} = VFOV*Abs(Row-(NRows/2))

TileService

T|ZSTS|URL

T—Identifier

ZSTS—Defines scale factor, number of levels, and tile size

Example: 42512 defines that there are 4 levels of zoom, each with a factor of 2, and the tile size is 512. Only the following are supported: Number of Levels 1–9; zoom factors 2,3; tile sizes 256,512.

URL is URL to tile service using the following notation to define the location of tile:

|z|—zoomLevel

|x|—col

|y|—row

|f| or |F|—For bubble images. F denotes the face of the cube. Valid values are f,r,b,l,u,d or F,R,B,L,U,D.

Example: Tile url—https://esri.com/PanoramaTiles/ImageID/|z|/|x|/|y|.jpg

The Oriented Imagery API will replace |z|with valid zoom level value, |x| with appropriate column value, and |y| with row value.

Note that such tiles services are assumed to return PNG files that have elevation encoded.

It is often possible to define a depth image as a single value (e.g., some inspection imagery) or a plane (e.g., oblique imagery of a flat terrain), but this is not yet supported.

- **CamOri (optional)—**Detailed camera orientation, stored as a comma-delimited string. This field provides support for more accurate measurements, depending on the application.
  The first number indicates the type. Over time, many different types may exist. Some applications may only support some of the types.

Type 1—Heading, Pitch, Roll
Value ordering:
1|WKID_H|WKID_V|X|Y|Z|H|P|R
or
1|WKID_H|WKID_V|X|Y|Z|H|P|R|A0|A1|A2|B0|B1|B2|FL|PPX|PPY|K1|K2|K3|P1|P2

- WKID_H—WKID for horizontal coordinate system
- WKID_V—WKID for vertical coordinate system. Can be undefined but must be same unit as the WKID_H.
- X,Y,Z—Camera center coordinate (perspective point)
- H,P,R—Heading, pitch, roll—Define as in key attributes
- A0 A1 A2 B0 B1 B2 Affine transformation parameters to camera center in the ground to image direction (i.e., A0 and B0 are offsets in cols and rows, and A1,B2|A2,B1 are 1/pixel size in microns.)
- FL—FocalLength in microns
- PPX,PPY—PrincipleX,PrincipleX—Principal point offset in X and Y from camera center in microns
- K1,K2,K3—Conrady distortion coefficients
- P1,P2—Tangential distortion coefficients

Type 2—Omega, Phi, Kappa
Value ordering:
2|WKID_H|WKID_V|X|Y|Z|O|P|K
or
2|WKID_H|WKID_V|X|Y|Z|O|P|K|A0|A1|A2|B0|B1|B2|FL|PPX|PPY|K1|K2|K3|P1|P2

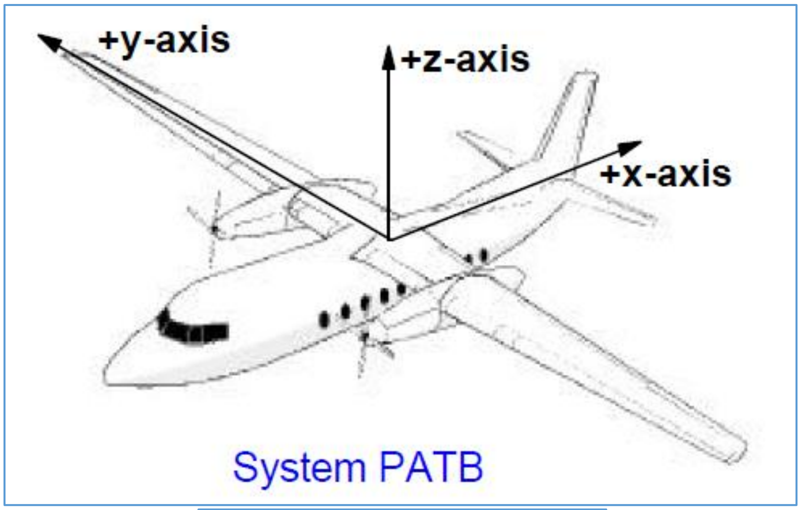
- WKID_H—WKID for horizontal coordinate system of the point
- WKID_V—WKID for vertical coordinate system of the point
- X,Y,Z—Camera center coordinate (perspective point)
- O,P,K—Omega, phi, kappa
- A0 A1 A2 B0 B1 B2—Affine transformation parameters to camera center (i.e., A0 and B0 are offsets in cols and rows, and A1,B2|A2,B1 are 1/pixel size in microns.)
- FL—FocalLength in microns
- PPAX,PPAY—Principal point offset in X and Y from camera center in microns
- K1,K2,K3—Conrady distortion coefficients
- P1,P2—Tangential distortion coefficients

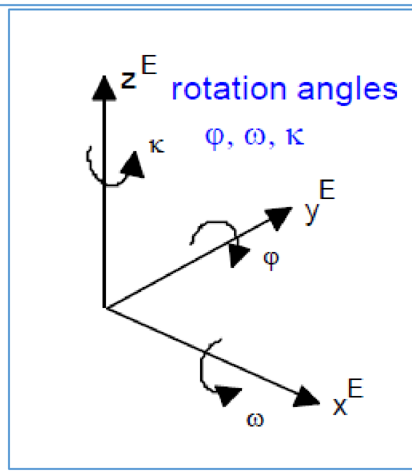
Type 3—Yaw, Pitch, Roll
Value ordering: 3|WKID_H|WKID_V|X|Y|Z|Y|P|R

- WKID_H—WKID for horizontal coordinate system of the point
- WKID_V—WKID for vertical coordinate system of the point
- X,Y,Z—Camera center coordinate (perspective point)
- Y,P,R—Yaw, Pitch, Roll

Note- Type 3 is currently only valid for 360 images.

Omega, Phi, Kappa
Omega, Phi, Kappa angles define the rotation between a projected coordinate system and the image coordinate system. It is mostly used in photogrammetry software.





All rotations are measured positive counterclockwise. For rotations performed in the sequence of Omega first, then Phi, then Kappa, the resulting rotation matrix **R** is

R = $R_X(\omega)R_y(\varphi)R_z(\kappa)$

$$\mathbf{R} = \begin{bmatrix} \cos\varphi\cdot\cos\chi & -\cos\varphi\cdot\sin\kappa & \sin\varphi \\ \cos\omega\cdot\sin\chi+\sin\omega\cdot\sin\varphi\cdot\cos\chi & \cos\omega\cdot\cos\chi-\sin\omega\cdot\sin\varphi\cdot\sin\chi & -\sin\omega\cdot\cos\varphi \\ \sin\omega\cdot\sin\chi-\cos\omega\cdot\sin\varphi\cdot\cos\chi & \sin\omega\cdot\cos\chi+\cos\omega\cdot\sin\varphi\cdot\sin\chi & \cos\omega\cdot\cos\varphi \end{bmatrix}$$

Yaw, Pitch, Roll

Yaw (ψ) is measured positive clockwise while Pitch (θ) and Roll (ϕ) are measured positive counterclockwise. For rotations performed in the sequence of Yaw first, then Pitch, then Roll, the resulting rotation matrix **R** is

R = $R_z(\psi)R_y(\theta)R_x(\phi)$

$$
\mathbf{R} = \begin{vmatrix} \cos\psi * \cos\theta & \sin\psi * \cos\phi + \cos\psi * \sin\theta * \sin\phi & \cos\psi * \sin\theta * \cos\phi - \sin\psi * \sin\phi \\ -\sin\psi * \cos\theta & \cos\psi * \cos\phi - \sin\psi * \sin\theta * \sin\phi & -\sin\phi * \cos\psi - \sin\psi * \sin\theta * \cos\phi \\ -\sin\theta & \cos\theta * \sin\phi & \cos\theta * \cos\phi \end{vmatrix}
$$

OIC properties

Each OIC is defined by a properties JSON that is referenced as a file or an item in ArcGIS Online. In the OIC management tools in ArcGIS Pro, this file also defines the key properties.

The file should have the extension .oic

Following is the data structure:

```
{
	"type": "OIC",
	"version": "1.0",
	"properties": {
		"Name": "",
		"Description": "",
		"Tags": "",
		"ServiceURL": "",
		"OverviewURL": "",
		"DefaultAttributes": {
			"CamHeading": "",
			"CamPitch": "",
			"CamRoll": "",
			"HFOV": "",
			"VFOV": "",
			"AvgHtAG": "",
			"FarDist": "",
			"NearDist": "",
			"OIType": "",
			"SortOrder": "",
			"CamOffset": "",
			"Accuracy": "",
			"ImgRot": "",
			"CamOri": "",
			"ImgPyramids": "",
			"DepthImg": "",
			"ExternalViewer": ""
		},
		"About": "",
		"ImageField": "",
		"ImagePrefix": "",
```

```
		"VideoPrefix": "",
		"DepthImagePrefix": "",
		"DEMPrefix": "",
		"SourceImagePrefix": "",
		"MaxDistance": "",
		"MeasurementUnit": "meter",
		"TimeUnit": "days",
		"Credentials": {
			"Username": "",
			"Password": ""
		},
		"Variables": {},
		"Filters": {},
		"Copyright": {
			"text": "",
			"url": ""
		}
	}
}
```

Notes

Name—Name of the Oriented Imagery catalog.

Description—Short description of the Oriented imagery catalog.

Tags—Tags used to aid identification

ServiceURL—URL to the feature service that defines the points and attributes.

OverviewURL—URL to the vector tile cache, map service, Web Map Service (WMS), or Web Map Tile Service (WMTS) or service item used to provide an overview of the image coverage. This is used only as a display of coverage and is not queried.

DefaultAttributes—Define defaults for each field if undefined or NULL in the feature class.

About—Help document. The format of the file should be .html.

ImageField—If defined, then the name of the field to be used as the Image Field

ImagePrefix—Prefix to be added to start of image name. Typically used to define the root URL for the image.

VideoPrefix—Prefix to be added to start of video name. Typically used to define the root URL for the video.

ExternalViewer—JSON object containing the wrapperUrl and config. This is a typical example of where a variable would be defined:$_cyclo_$

DepthImagePrefix—Prefix to be added to start of depth image name. Typically used to define the root URL for the image.

DEMPrefix—Prefix to be added to start of DEM name. Typically used to define the root URL for the image.

SourceImagePrefix—Prefix to be added to start of source image name. Typically used to define the local network or path where the images are stored. Does not exist as part of the service.

MaxDistance—Maximum search distance to be used while querying the service specified in ServiceURL.

MeasurementUnit—Valid values are meter or feet. Mensuration results will be shown in the unit defined here. Default is m.

TimeUnit—Valid values are days, weeks, months, or years. Time selector tool in the viewer will filter images based on the TimeUnit value defined here.
Credentials—Credentials required to access imagery served using TileService. Basic authentication method is used to access such imagery.
Copyright—Define copyright/attribute text to display on image

Filters—There is often a necessity to subset an OIC. A typical example is the street view imagery taken over multiple years where the user wants to see imagery only for a specific year. Another example may be imagery for a building at different floors, where users want to see only imagery for a specific floor. This can be handled by defining a set of filters in the OIC JSON as follows:

```
{
	"filters": {
		"All": "1=1",
		"2016": "Where Year = 2016",	//* Replace these with appropriate statements *//
		"2014": "Where Year = 2014",
		"Old": "Where Year<2014"
	}
}
```

The OIC API will list the defined filters in their respective order and labels.

Variables—The number of records in the feature service can become very large, and there are many cases where parameters may need to be changed depending on a user. An example is an access key that may be embedded as part of a URL. This key may need to change over time or be specific to a user. To enable this, the concept of variables is used.
Any string attribute value may have one or more variables defined using the notation $_Variable_$; e.g., URL = $_Path_$/MyDirectory/A.JPG?/$_tag_$
As each attribute is read, any text between $_ and _$ will be replaced by a variable in the OIC. If no corresponding variable is defined, it is excluded.
Note: Variables should not be used in attributes that are searched, e.g., AcquisitionDate.

Variables are defined as JSON as follows:

```
{
	"variables": {
		"cyclo": {
			"wrapperUrl": " ",
			"config": {
				"username": "aad",
				"password": "asdasd",
				"apiKey": "asdasdasdasdasd"
			}
		},
		"path": "C:/temp"
	}
}
```

Defaults are values to be used in place of attribute fields. Each image is initiated with these default values, and then the defaults are replaced by any value in the attribute table.

This provides a much more compact method of defining OIC, as only the values that vary from camera to camera need to be defined in the attribute table.

Note that values such as AcquisitionDate do not have defaults, as they are used as query fields.

These properties need to be refined. Names will be refined based on ArcGIS Online naming conventions.