



# Workflows for Aerial Frame Cameras

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ESRI USER CONFERENCE

# Objectives

- **Manage and share collections of imagery from aerial frame cameras**

- **Professional digital cameras**

- Metric lens, precise positioning with GPS & IMU

(see separate sessions)

- Applicable to professional oblique cameras – multiple sensors

- Scanned historical aerial photos include this workflow, w/ more preprocessing steps

- ⊘ **Uncalibrated frame cameras on unmanned aerial systems (UAS) or drones**

- **Intent is to manage & process single images from a *frame* sensor**

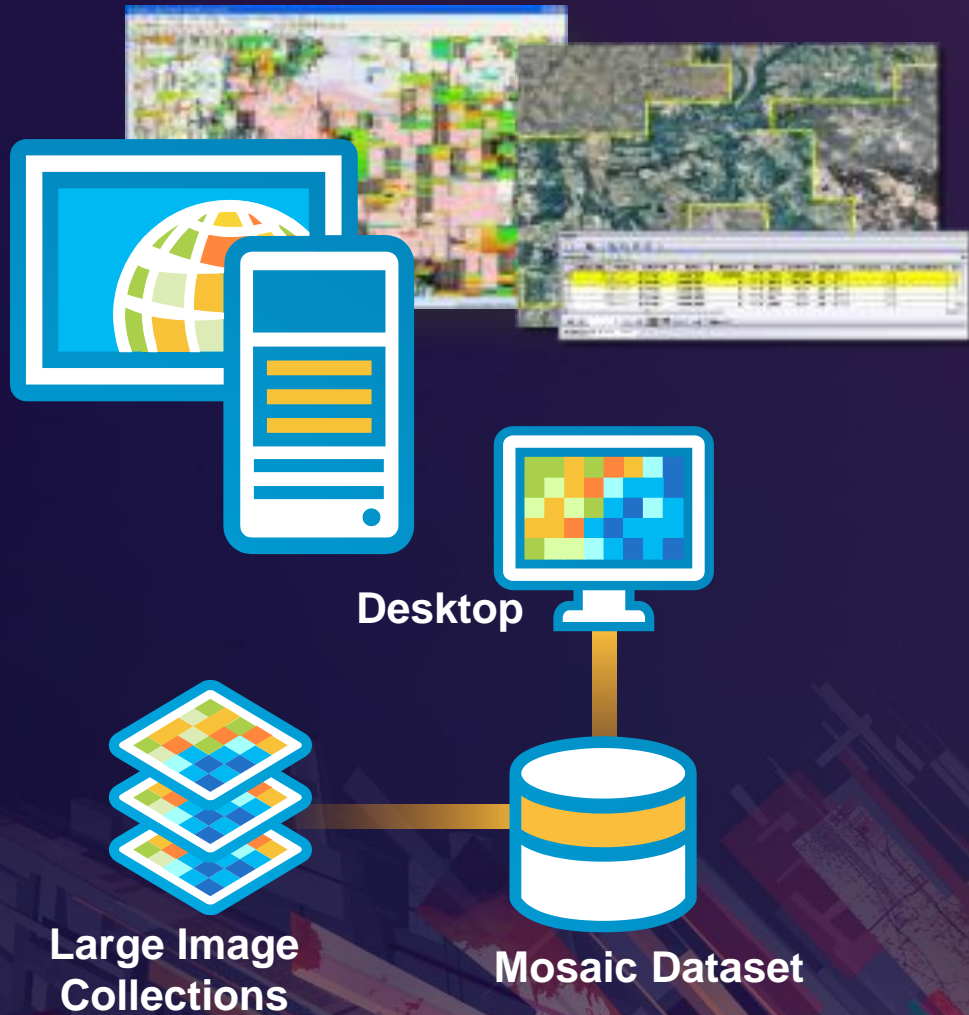
- ⊘ **Satellite imagery – different sensor model (use proper Raster Type)**

- ⊘ **Aerial line scanners (ADS 40/60/80) – unique geometry, hardware-specific workflow**

- ⊘ **Preprocessed Orthophotos require a different workflow**

# Image Management Workflow Using Mosaic Datasets

Highly Scalable, From Small to Massive Volumes of Imagery



## Create Catalog of Imagery

- Reference Sources
- Ingest & Define Metadata
- Define Processing to be Applied

## Apply:

- On-the-fly Processing
- Dynamic Mosaicking

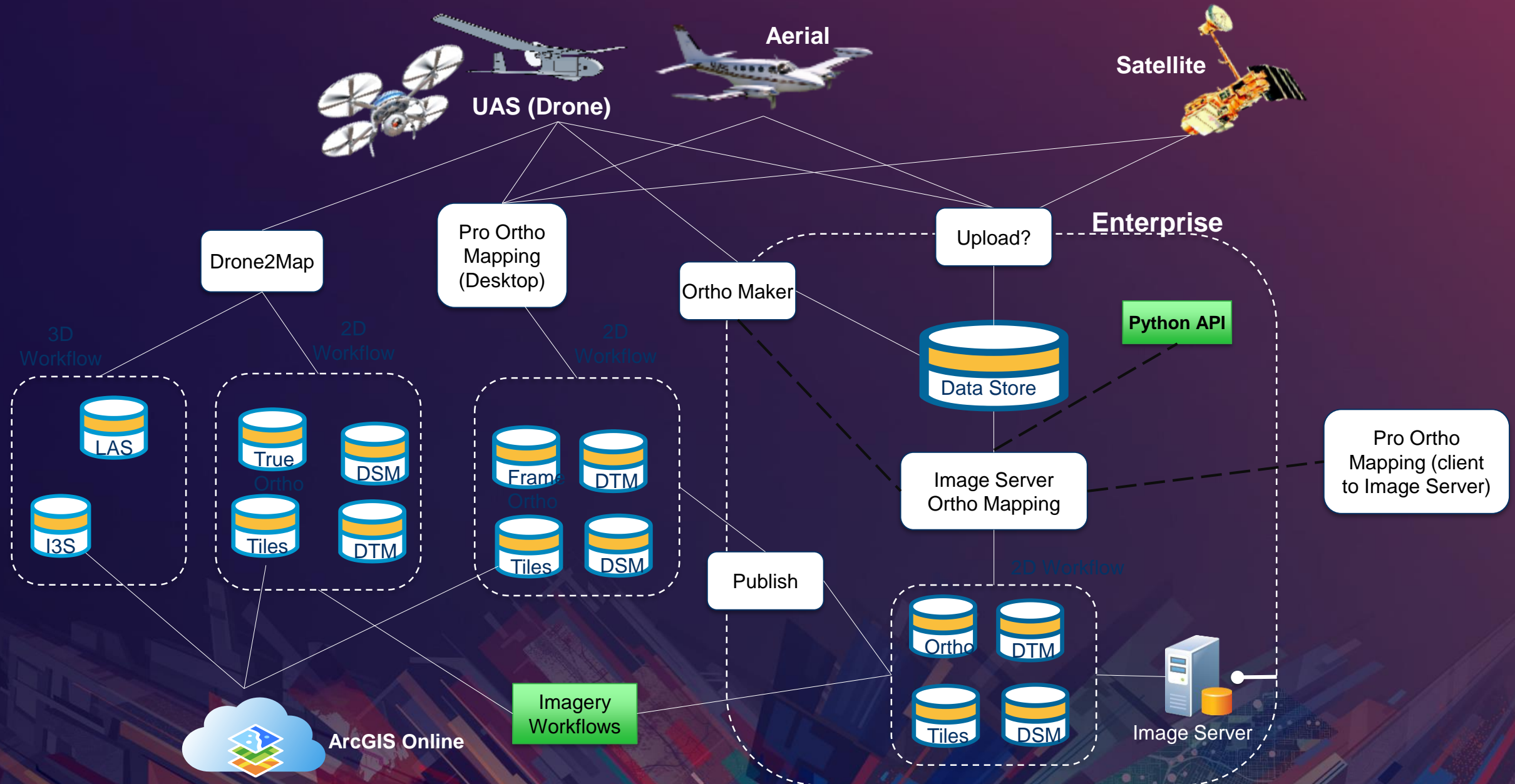
Access as Image or Catalog

# Advantages

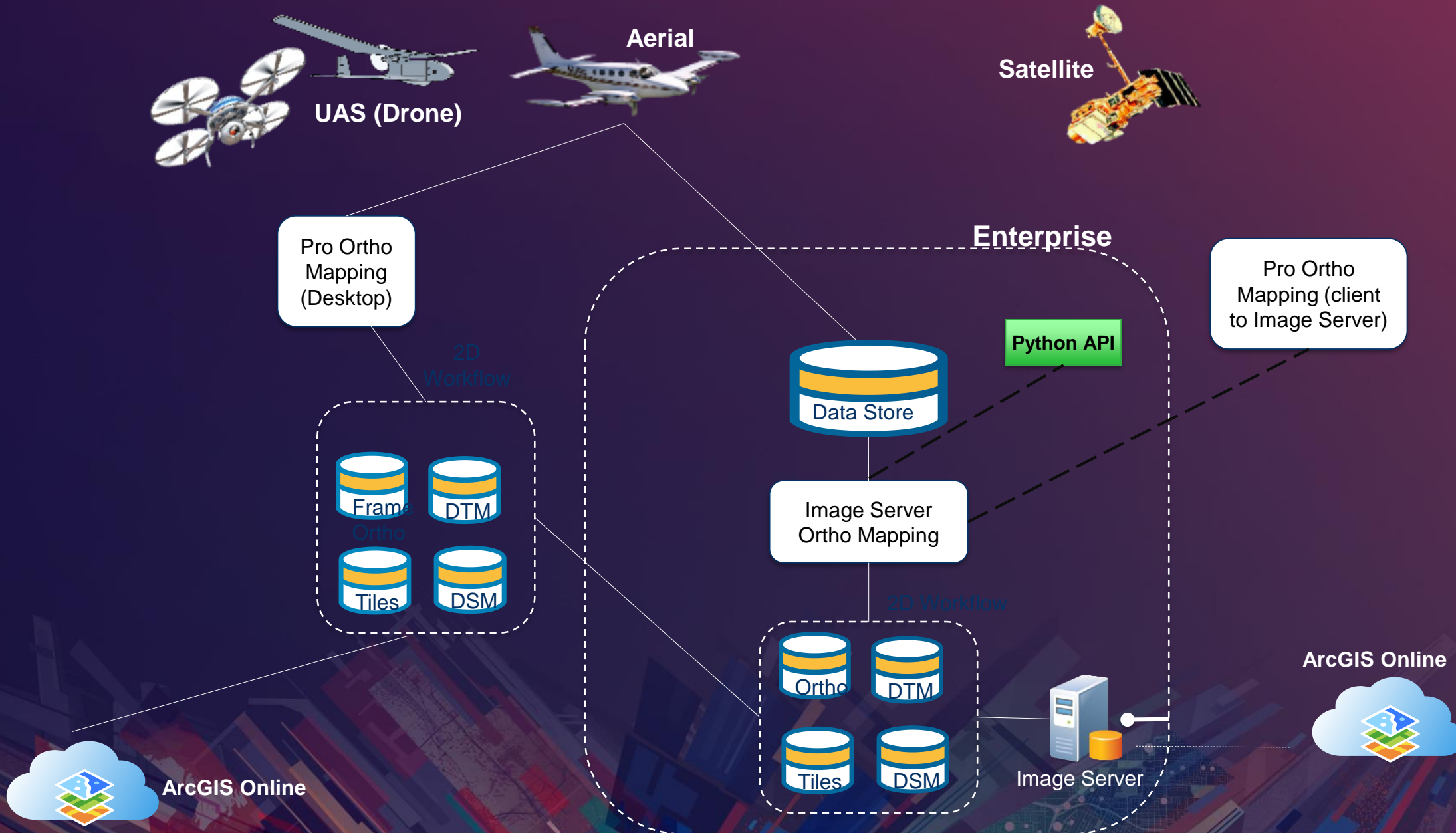
On-the-fly orthorectification, dynamic mosaics via Mosaic Dataset

- Can be 'on demand' and avoid output of duplicate pixels
- Bring overlapping images to foreground
- Navigate on map, but view in image coordinates (unprojected) for best clarity
- 3D mensuration
- Stereo viewing

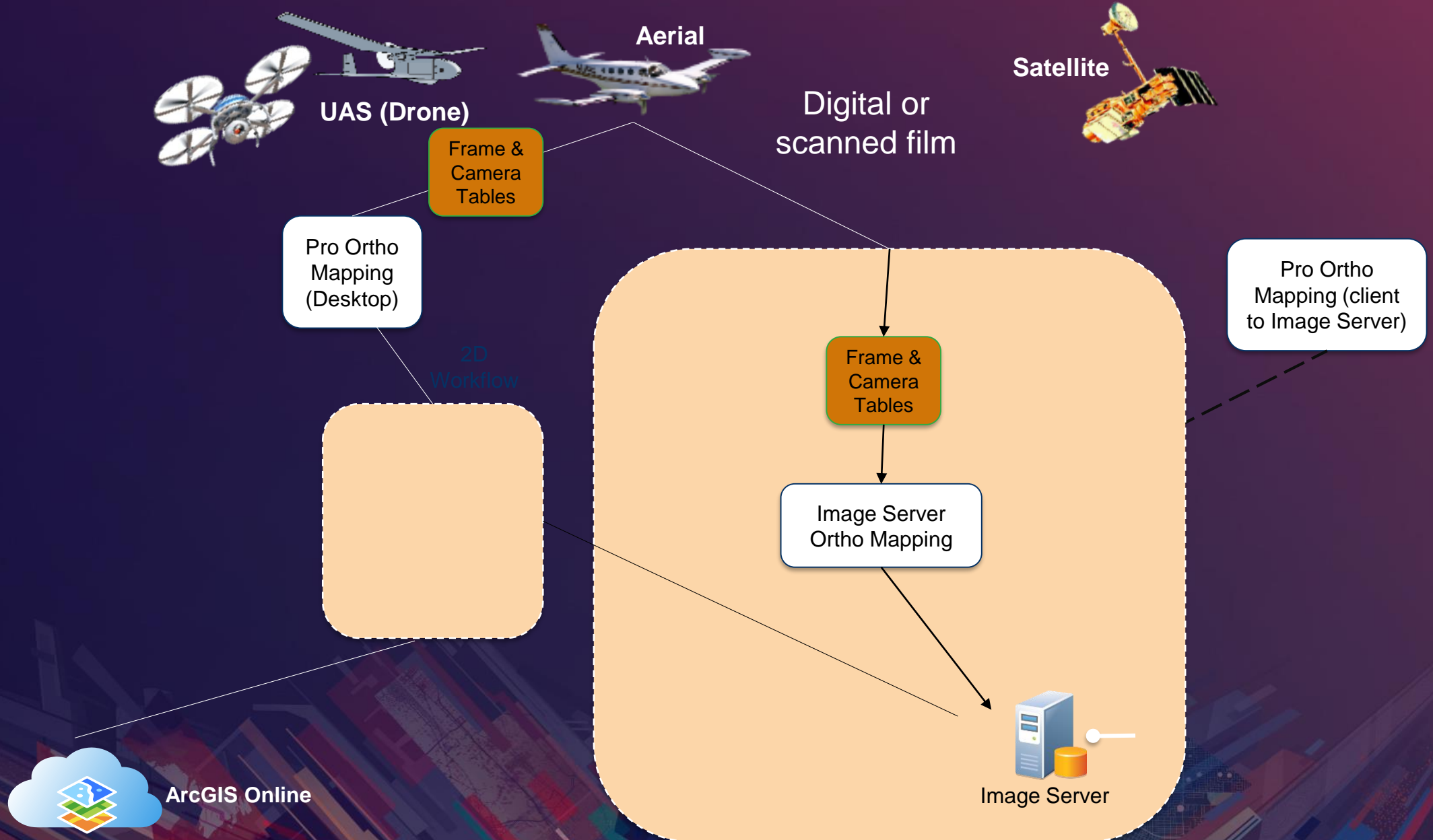
# Ortho Mapping workflows in the ArcGIS Platform



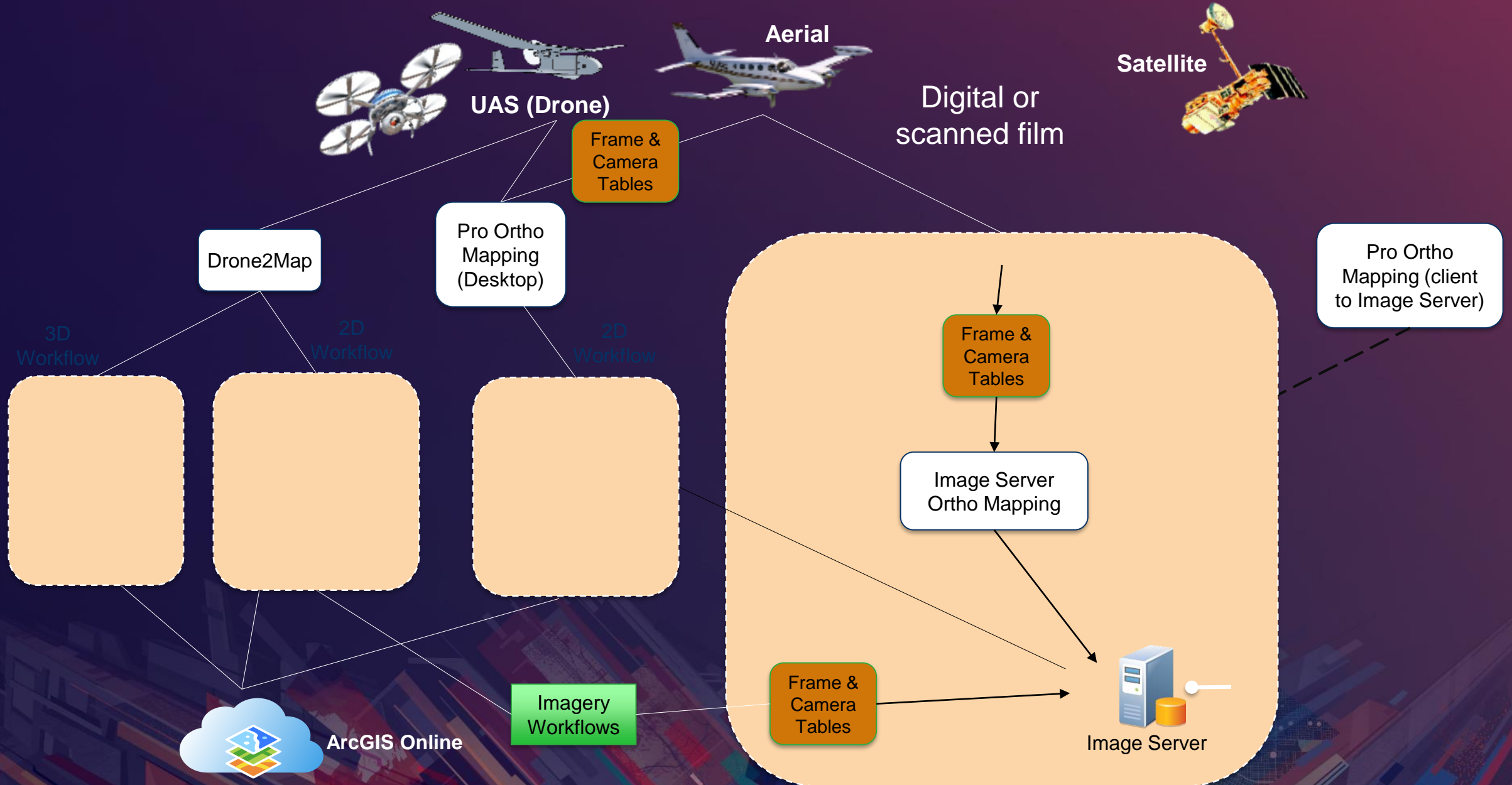
# Geometric processing – workflows for aerial cameras



# Frame Camera raster type (interior/exterior orientation)



# Frame Camera raster type (interior/exterior orientation)

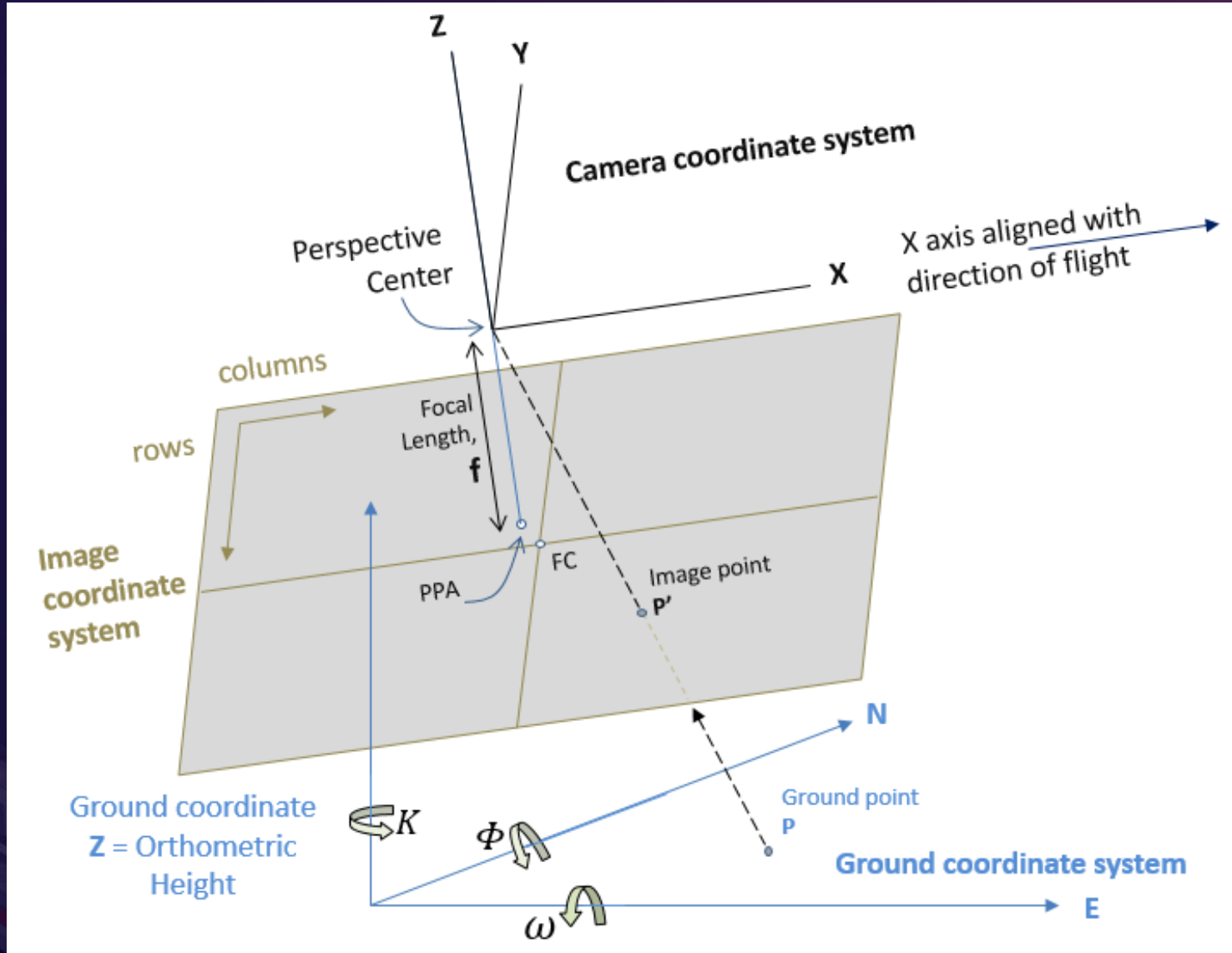




## Support for frame imagery data

- **Use Mosaic Dataset to manage both film and digital frame camera data**
- **A generic solution to support any frame camera**
- **Required information:**
  - **Interior orientation (camera parameters)**
  - **Exterior orientation (unique frame parameters)**

# Frame Camera geometry for Photogrammetry in ArcGIS



<http://esriurl.com/FrameCameraDetailDoc>

# Basic workflow in ArcGIS

Frame imagery *including* the Frame Camera raster type

- Create Mosaic Dataset
- Use the appropriate Raster Type to ingest imagery based on available orientation data
  - Applanix, Match-AT, ISAT
  - Frame Camera** *(added at 10.3.1)*
- Populate integrated metadata into Mosaic Dataset
  - Sensor location (x,y,z) and orientation (o,p,k)
  - Other metadata may be added to facilitate management & analysis
- If accurate → proceed to using orthorectified imagery
- If approximate → proceed with **Ortho Mapping workflow**

# Two approaches

Specifically for the Frame Camera raster type

- **Image collections with complete orientation parameters**

- LeadAir
- UltraCam
- etc.

→ **Generate Frames and Cameras tables from calibration report, etc.**

- **Orientation parameters generated by software**

- OrthoMapping in ArcGIS Pro
- Drone2Map
- Pix4D Mapper™
- etc.

→ **Generate Frames and/or Cameras table from exported project report.**

## Prepare inputs for *Frame Camera* Raster Type

- **Consolidate exterior/Interior orientation parameters**
  - GPS file
  - Camera file
  - Frame parameters file (\*.txt, \*.csv, or \*.xml)
- **Create Frames table and Cameras table**
  - Format the orientation parameters per *Frame Camera* raster type schema
  - Supports radial distortion correction
  - Works for any camera
  - Input format can be csv/txt/feature class/GDB table

See in ArcGIS Help System:  
<http://esriurl.com/FrameSchema>  
<http://esriurl.com/CameraSchema>

# Frame Camera Raster Type – Exterior orientation

## Frames table

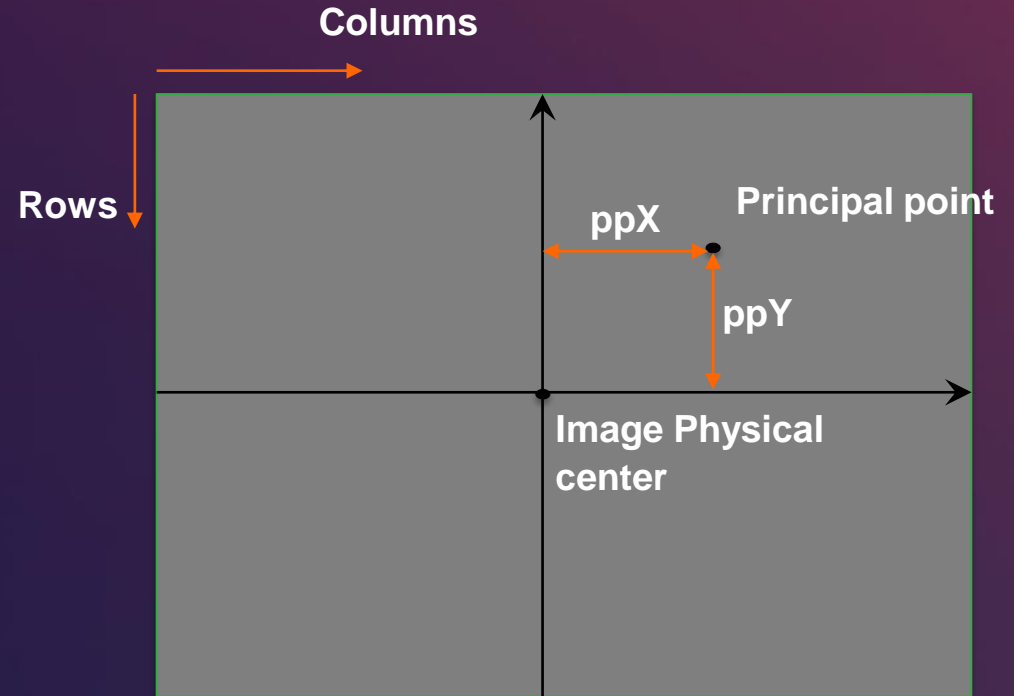
- Required: PerspectiveX/Y/Z and image path (relative or absolute)
- Omega/Phi/Kappa
- Spatial Reference System (SRS)
- Add raster info fields to speed up ingest process
  - NCols, NRows, NBands, PixelType

NCols	NRows	NBands	PixelType	SRS
10328	7760	3	8_BIT_UNSIGNED	32617
10328	7760	3	8_BIT_UNSIGNED	32617
10328	7760	3	8_BIT_UNSIGNED	32617

PerspectiveX	PerspectiveY	PerspectiveZ	Omega	Phi	Kappa
461681.6722	3158470.35	809.574638	-0.064682	-0.139704	-179.71770
461683.087	3158371.445	811.472574	-0.028823	-0.063748	-179.64660
461682.6709	3158272.916	811.971936	-0.105496	0.456202	-179.51621
461682.0233	3158173.322	812.724519	-0.080568	0.000266	-179.54476
461681.5294	3158074.227	813.701214	-0.0777	0.206639	-179.64853
461681.6746	3157975.307	814.514642	-0.052909	0.052173	-179.56249
461682.6923	3157876.594	815.005899	-0.020786	-0.014977	-179.84698
461684.4121	3157777.858	814.663818	-0.035867	-0.058924	-179.74516
461685.7635	3157679.019	813.618601	-0.037719	0.139921	-179.61517
461685.702	3157580.669	811.834429	-0.056909	0.199438	-179.73050

# Frame Camera raster type – Interior Orientation in *Cameras* table

- Focal length & principal point position
- Pixel size
- Affine transformation (Camera to Image)
- Fiducial locations **New at Pro 2.2**
- Konrady distortion model
  - Radial (Konrady)/Decentering correction



$$x_{corrected} = x(1 + k_1r^2 + k_2r^4 + k_3r^6)$$

$$y_{corrected} = y(1 + k_1r^2 + k_2r^4 + k_3r^6)$$

FocalLength	Principal X	Principal Y	A0	A1	A2	B0	B1	B2	Konrady	DistortionType
79887.2	-13.3	-54.6	-26852.8	5.2	0	20176	0	-5.2	0;0.000006203849275567615;0.0000000015076531614740 2;0.00000000000003426861243162828;0	Konrady

*Cameras table (10.5 or earlier, MUST be named simply "Cameras")*

# How to compute A0, A1, A2, B0, B1, B2

- Calculate affine transformation matrix

- Inputs:

- Number of Columns and Rows (for the image file on disk),
- Pixel size (on the sensor)

- Calculate [A0, A1, A2; B0, B1, B2]

- Used to transform coordinates from *image space* (column, row) to *camera space*.

$$C = ((\text{cols}/2) - 0.5) * PS$$
$$R = ((\text{rows}/2) - 0.5) * PS$$

$$A0 = -C$$

$$A1 = PS$$

$$A2 = 0$$

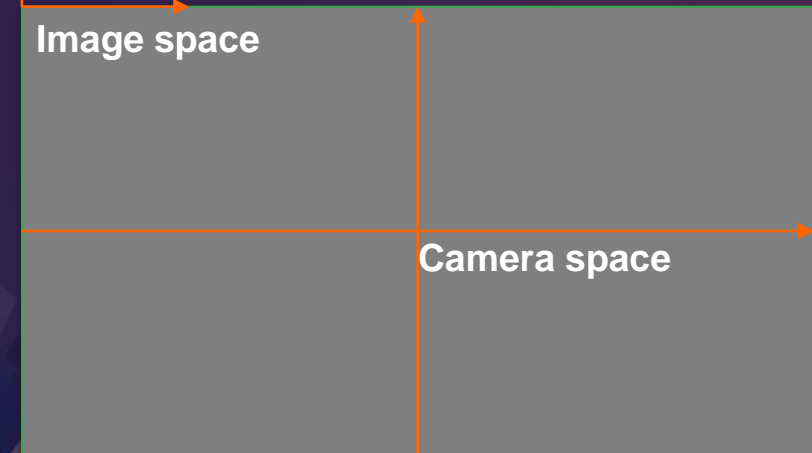
$$B0 = R$$

$$B1 = 0$$

$$B2 = -PS$$

where PS is camera's film pixel size in microns.

A0	A1	A2	B0	B1	B2
-26852.8	5.2	0	20176	0	-5.2
-26852.8	5.2	0	20176	0	-5.2
-26852.8	5.2	0	20176	0	-5.2
-26852.8	5.2	0	20176	0	-5.2
-26852.8	5.2	0	20176	0	-5.2

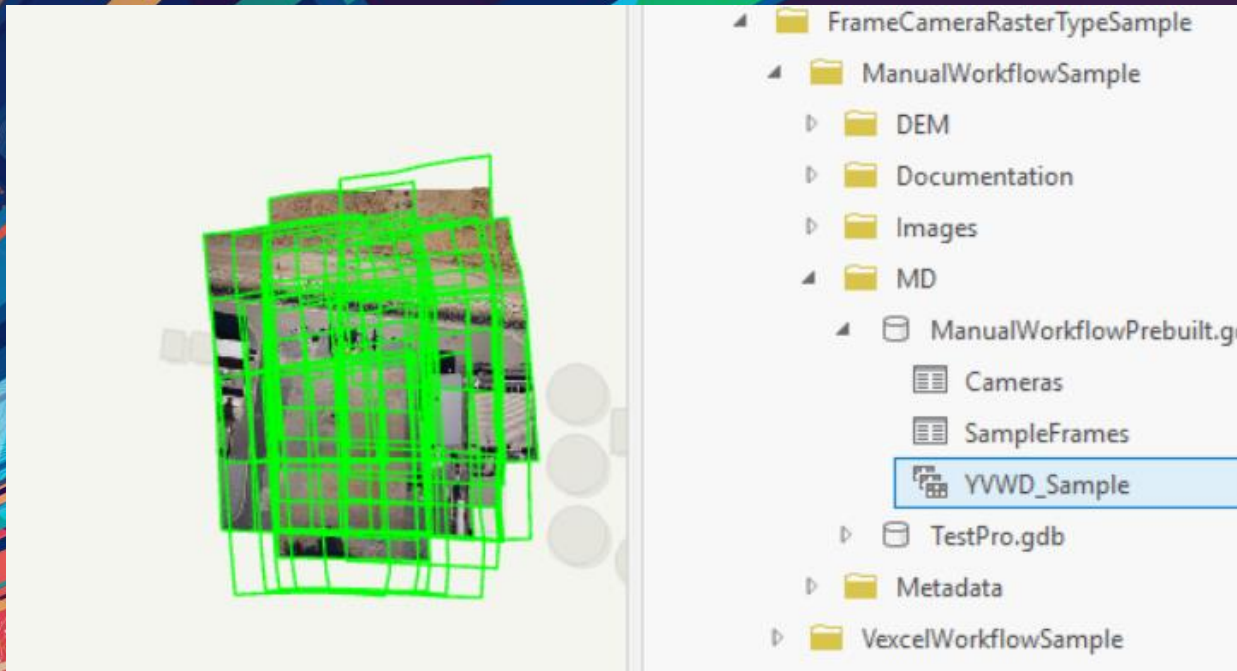


Spreadsheet available from Esri



# Mosaic Dataset workflow

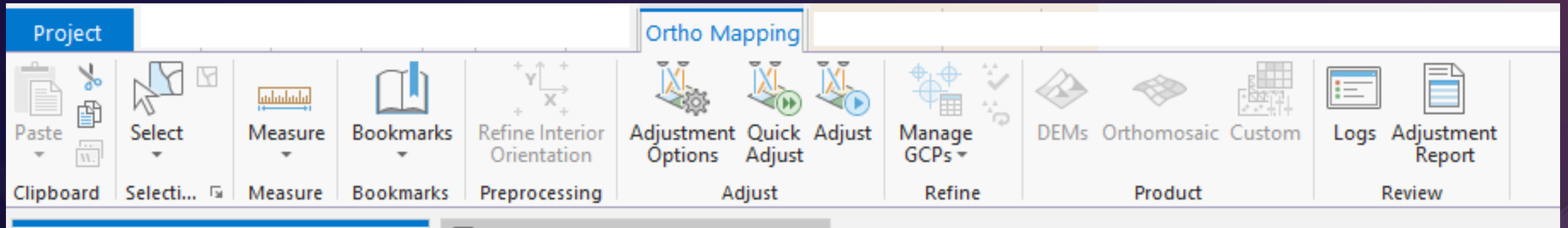
Demo



<http://esriurl.com/FrameCameraSample>

# Frame Camera input to Ortho Mapping in ArcGIS Pro

- Frame Camera raster type generates orthorectified images on-the-fly
- Accuracy dependent on camera parameters & DEM
- To improve accuracy:
  - Aerial Triangulation & Bundle Block Adjustment → OrthoMapping in ArcGIS Pro



# Oblique Image support

- **Frame Camera raster type is oblique aware**
  - **Sensor Azimuth** - indicate camera horizontal direction (0 ~ 360)
  - **Sensor Elevation** – indicate camera vertical direction (0 ~ 90)
- **Query these values to determine**
  - **Whether a image is oblique**
  - **The image's look angle**
- **Web Appbuilder “Oblique Viewer” widget**
  - **Create comprehensive web app to view oblique images from frame camera image service**
  - **Perform mensuration**

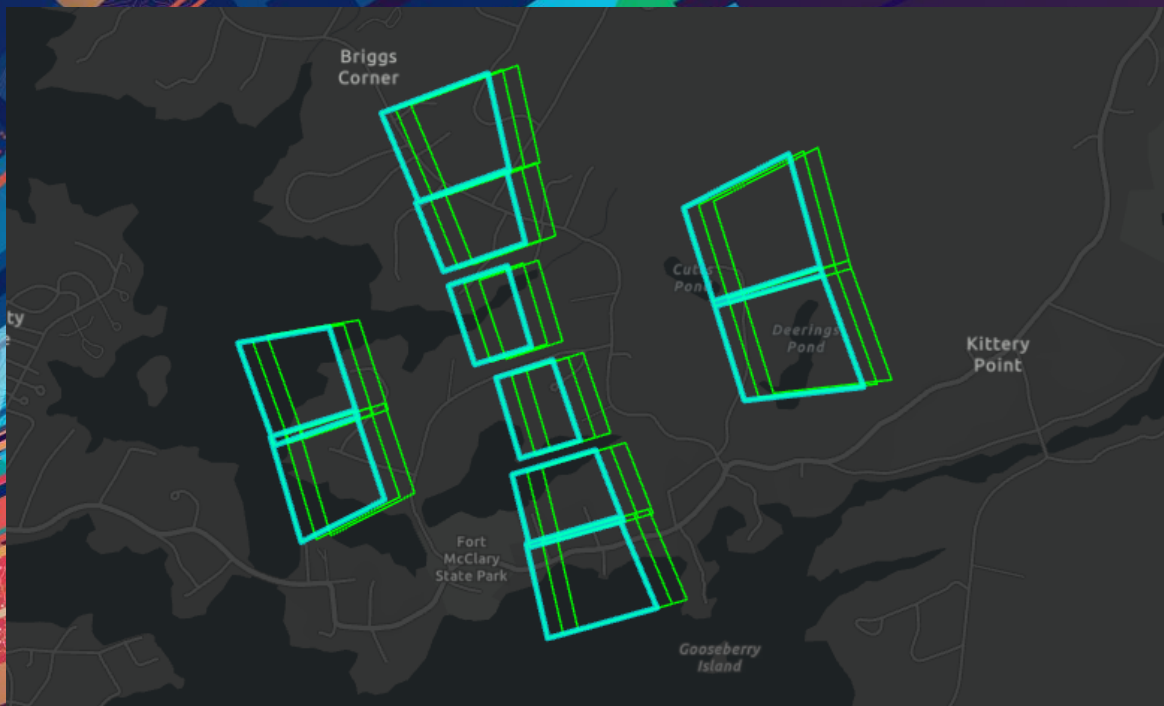
Sensor Azimuth	Sensor Elevation
358.63081	89.932621
11.414397	89.929006
357.567056	89.924382
10.65224	89.933026
349.311434	89.933089
358.810121	89.904169
12.167622	89.917067
357.734182	89.917796
8.229158	89.915742
1.35762	89.911365
359.515553	89.916027

# Best Practice Recommendations

- **Focus on Frames table first**
  - Are your images on the correct continent? State? County?
- **Cameras table: F and A0..B2**
  - **DISTORTION TERMS ZERO**
  - Are images 2x, 10x the wrong size?
    - (if close but wrong, it could be Z value in Frames table)
  - Are images rotated?
    - A0..B2
- **Apply DEM**
  - Orthometric or ellipsoidal height?
- **LAST: add and resolve distortion terms**

# Oblique Camera Imagery

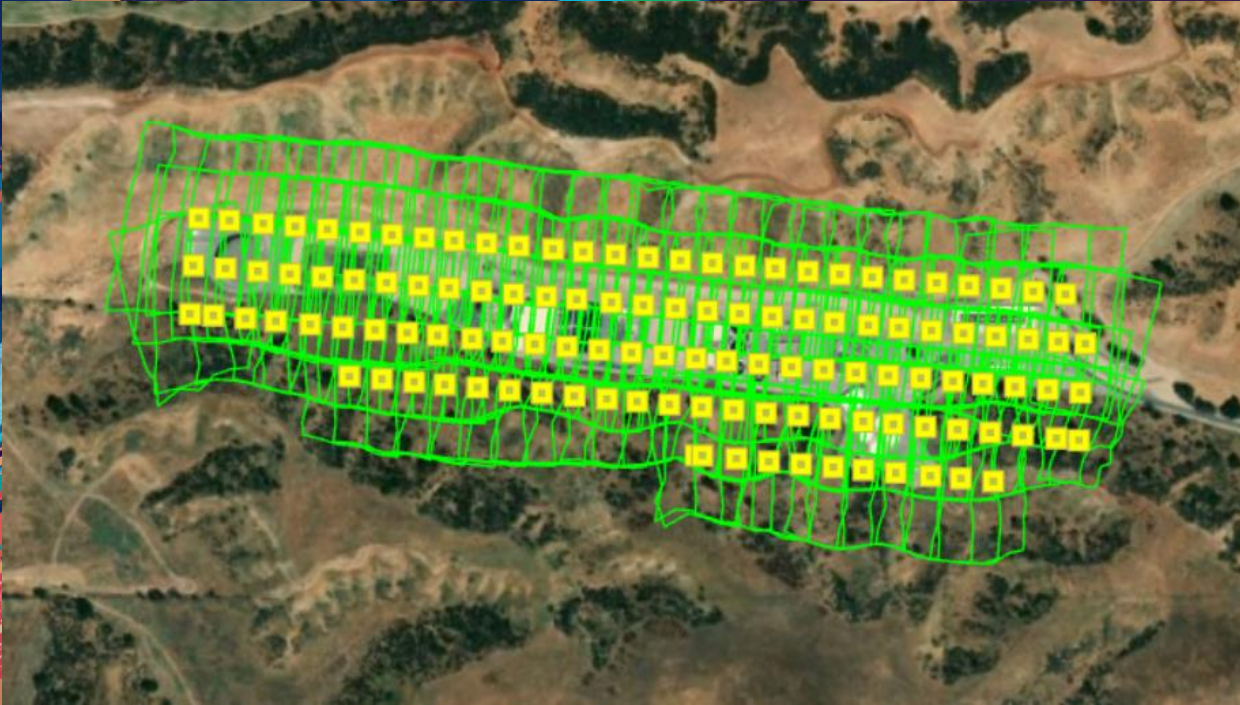
Demo



Imagery courtesy of Aeroptic, LLC, a KeyW Company

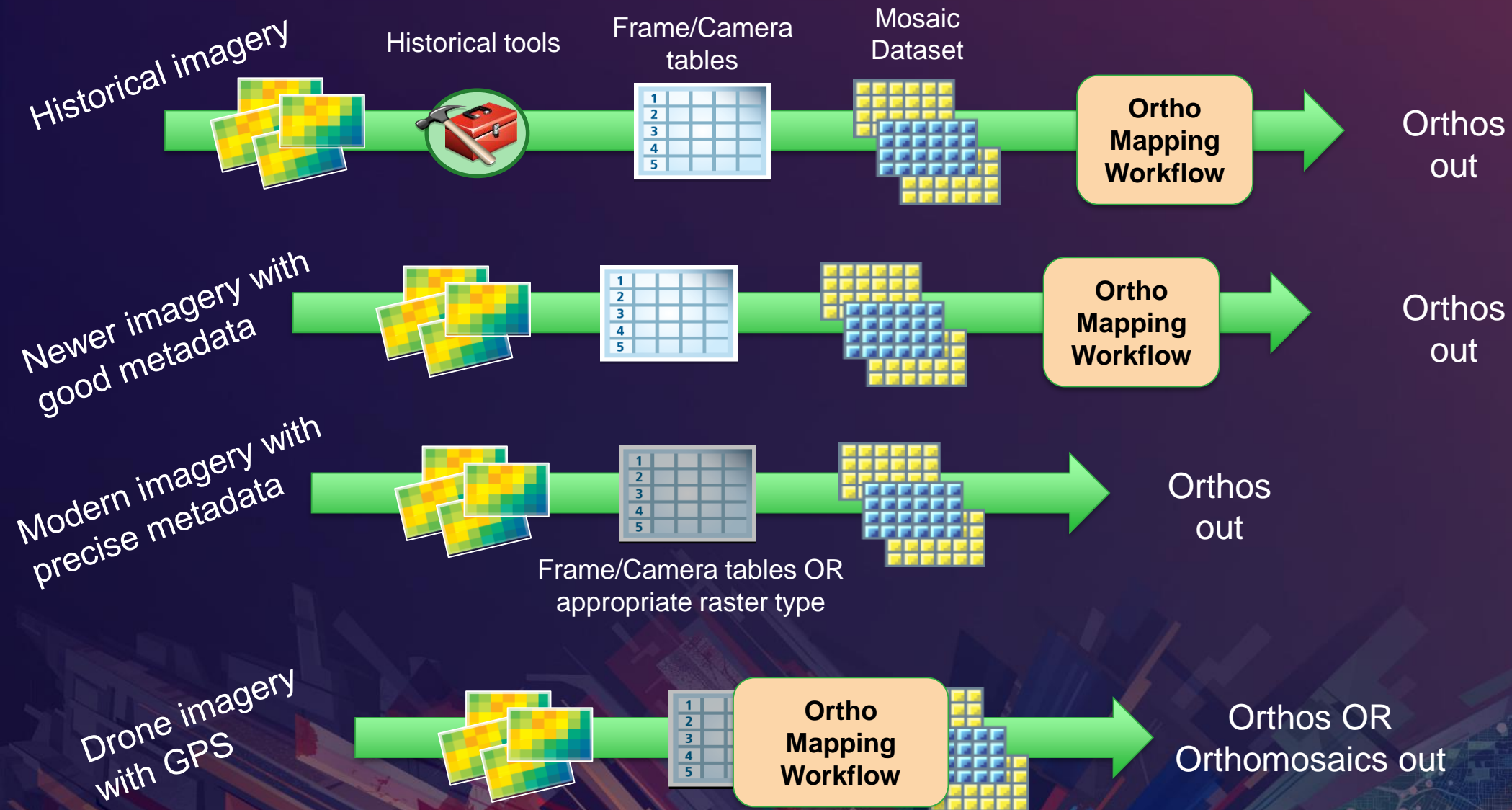
# What about Drones?

OrthoMapping in ArcGIS Pro  
Standalone processing in Drone2Map

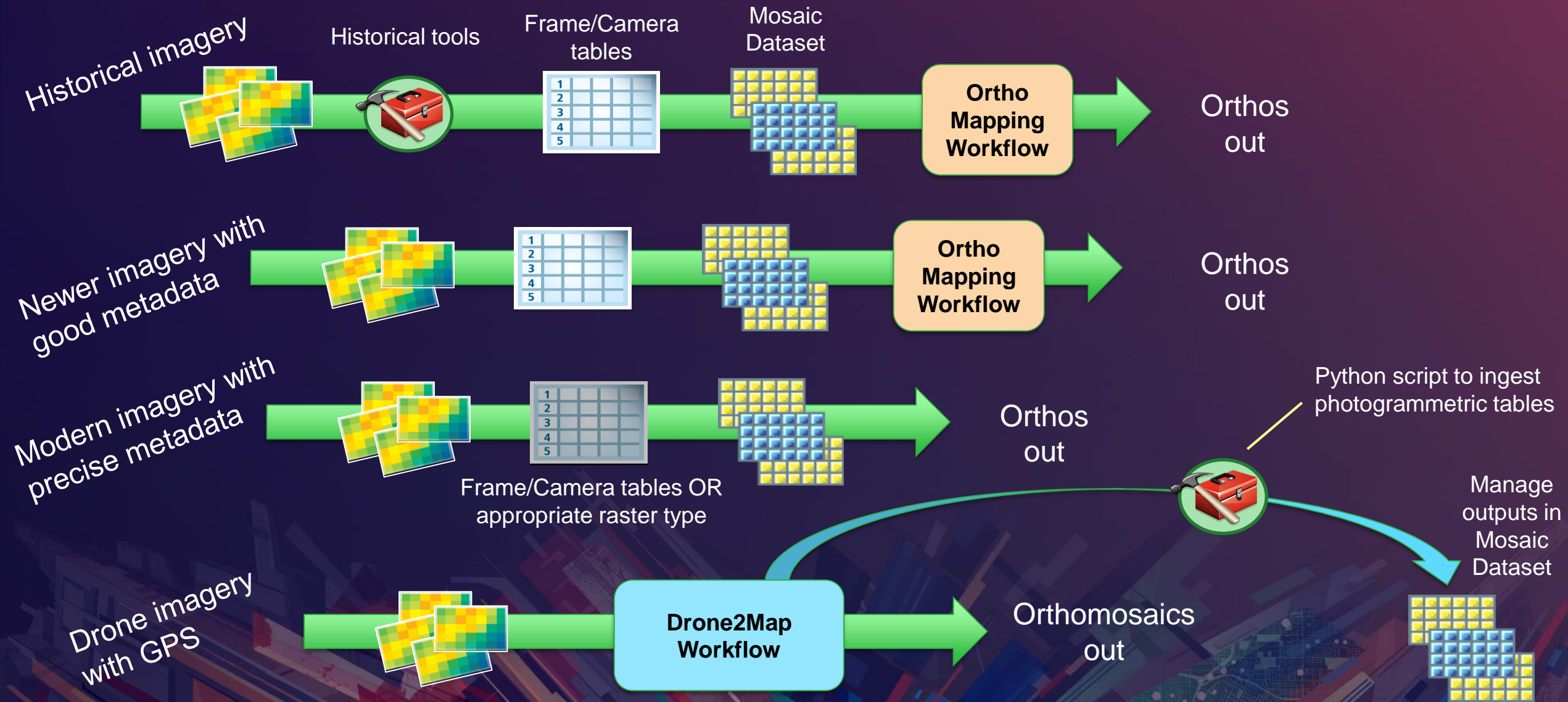


Frame Camera model is applicable, but largely hidden from the user

# Overview of alternative Frame Camera workflows



# Overview of alternative Frame Camera workflows





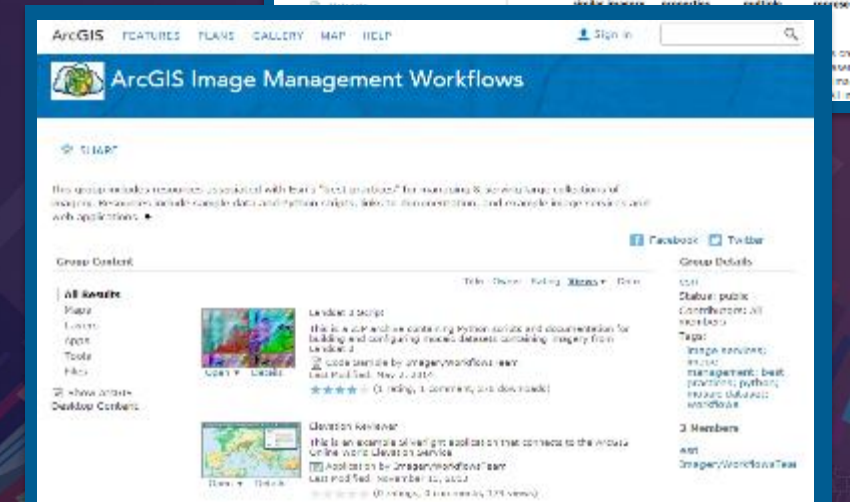
# Summary – and links to further information

*Best Practice Workflows for Image Management*

Our focus was on creating the mosaic dataset for a single data collection using the *Frame Camera Raster Type*...

For more info re: data management & automation:

- Landing page <http://esriurl.com/ImageManagement>
- Guidebook in Help System <http://esriurl.com/6007>
- ArcGIS Online Group <http://esriurl.com/6539>
  - Downloadable scripts & sample data
- Recorded webinar: <http://esriurl.com/LTSImgMgmt>





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