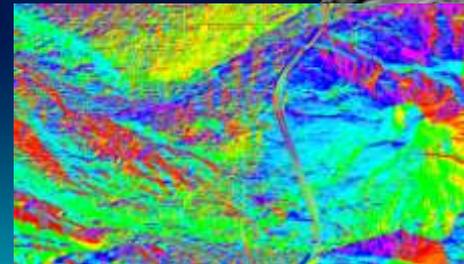
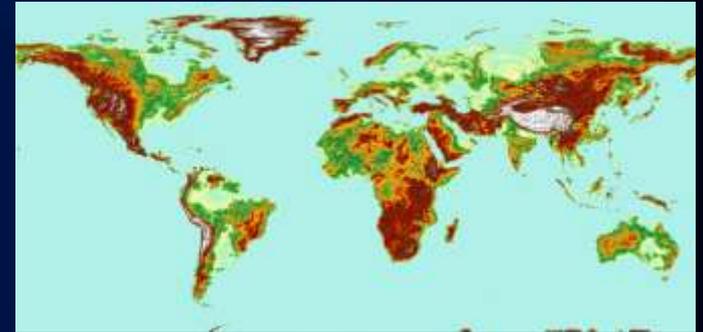


Managing & Serving Elevation Data

Uses of Elevation

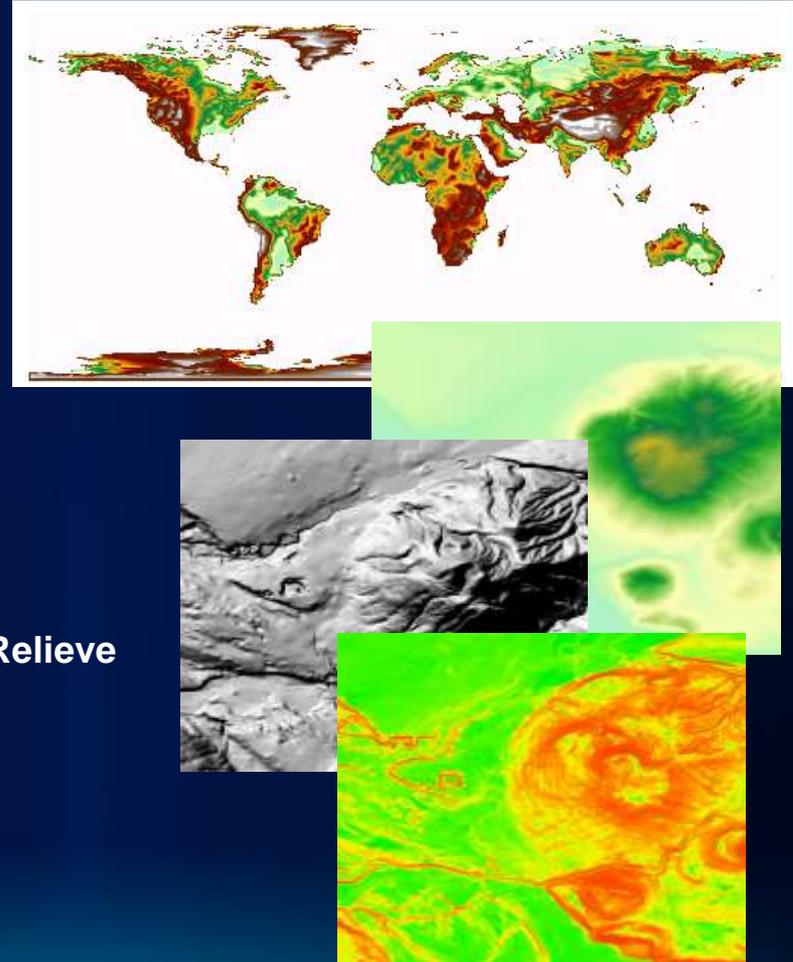
- As Elevation
- 3D Visualization
- Shaded Relief – cartographic
- Aspect – Agriculture
- Slope – Land subsidence, off-road mobility analysis
- Profiles – Planning pipelines, drainage
- Viewshed – Visibility analysis
- Orthorectification
- Difference/Volume – Tree Height
- Change – Ground movement



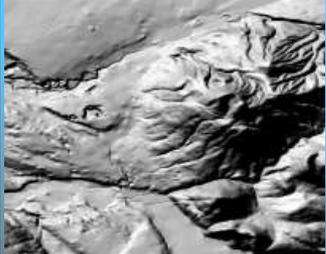
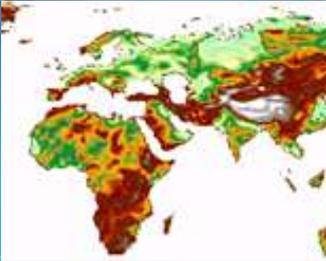
World Elevation

Elevation for the complete globe

- **Multi Source**
 - GTOPO, SRTM,
 - USGS NED (1 and 1/3 arcsecond)
 - Lidar for sample areas
 - EGM2008 Geoid model
- **Services**
 - Elevation Orthometric & Ellipsoidal
 - Hill Shade, Slope, Aspect, Shaded Relief
- **Tasks**
 - Profile, Viewshed, Contour



Demo: World Elevation Service



Data Sources

- **GTOPO – 30-arc second (1km)**
- **SRTM – Shuttle Mission Topography Mission - 3-arc sec (90m)**
- **ASTER – GDEM – 1-arc sec (30m)**
- **NED – 1-arc sec (30m) & 1/3-arc sec (10m)**
- **Intermap, SPOT, other....**
- **Photogrammetry – Correlation or point capture**
- **LiDAR**
- **Bathymetry**
- **Sonar**
- **From Contour, vector sources**

Varying Horizontal and Vertical accuracies (LE90 CE90)

Data Structures

- **Gridded Rasters**

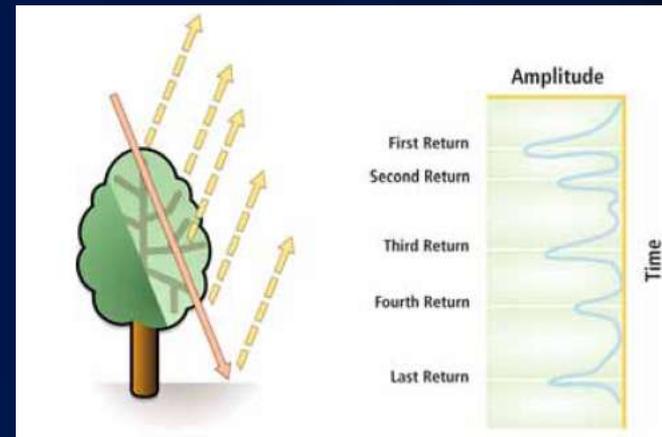
- GRID, TIF, FLT, ASCII DEM, IMG, BAG*, HRE
-
- INTEGER vs. FLOAT

- **Irregular**

- Terrain, LAS, MG4 LiDAR, BAG, ASCII XYZ, 3D SHP
- ...

LiDAR (Light Detection and Ranging)

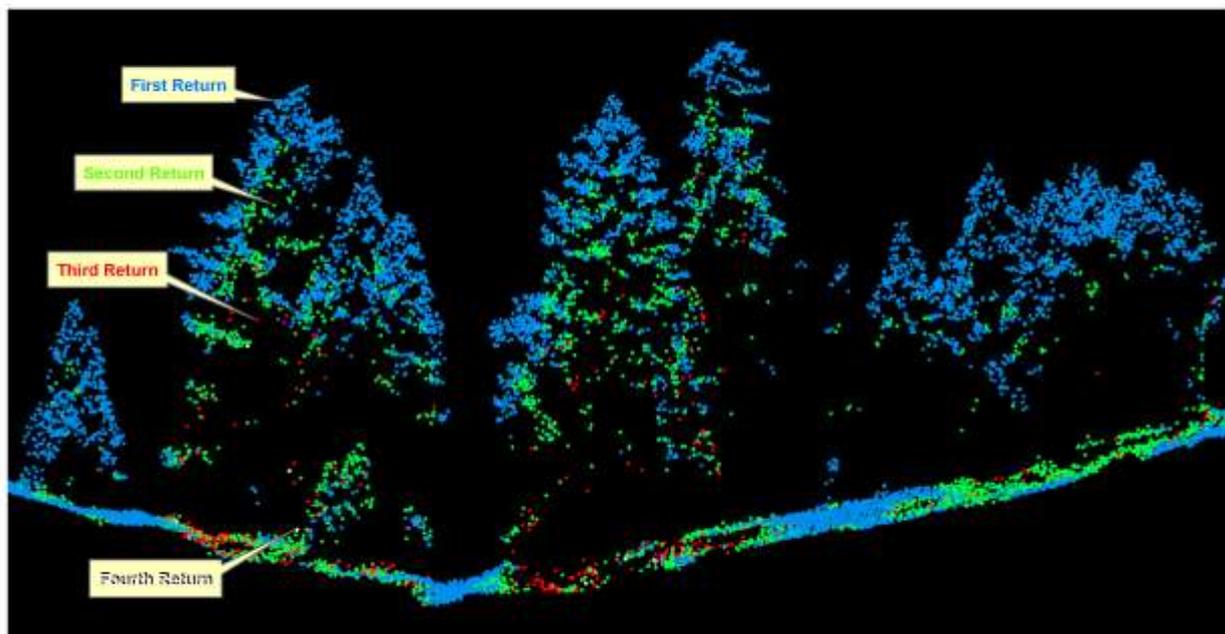
- Laser based
- High Density, High Accuracy
- Partially penetrates canopy
- LAS 1.2 - ASPRS
- Include classification



Classification Value	Meaning
0	Created, never classified
1	Unclassified1
2	Ground
3	Low Vegetation
4	Medium Vegetation
5	High Vegetation
6	Building
7	Low Point (noise)
8	Model Key-point (mass point)
9	Water

Lidar Data

Very rich, but contains a lot of data not required for many applications

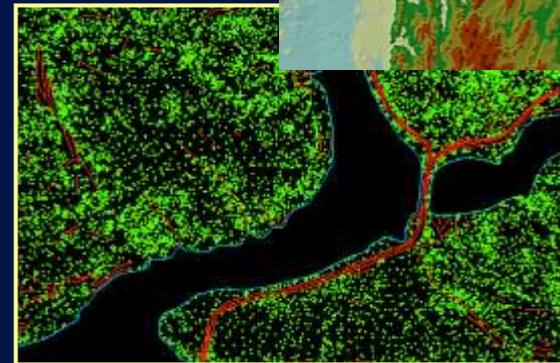
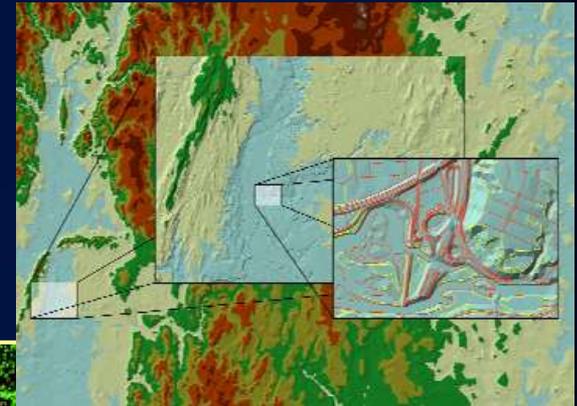


Terrain Dataset

Multi-resolution surface created from measurements stored in feature classes

- **MassPoints (LiDAR), Breaklines,**
Spot heights, Polygons, ...
- **Stored in the geodatabase**
- **Schema: Defines feature class participation**
- **On-The-Fly TIN**
- **Multi-resolution**
- **Highly scalable**
- **Attributes**
- **Editable, Versioned**

Points and
Breaklines



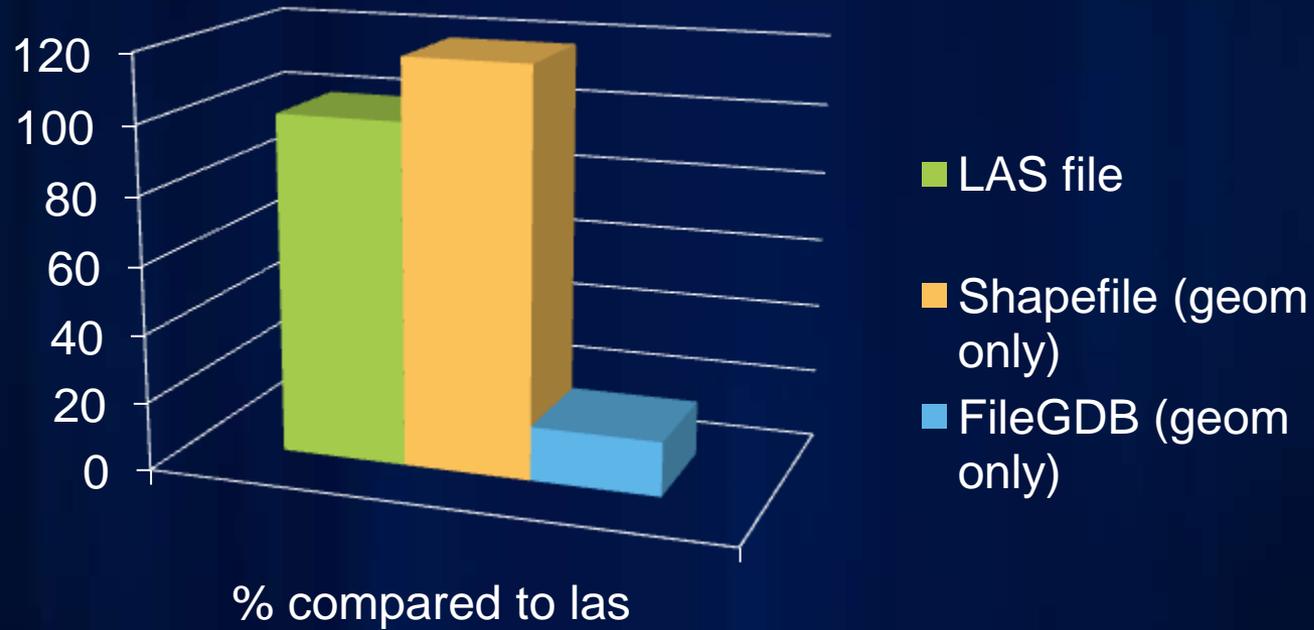
Terrain Pyramids



Requires multiple terrains to represent multiple surfaces

Options to support decision makers

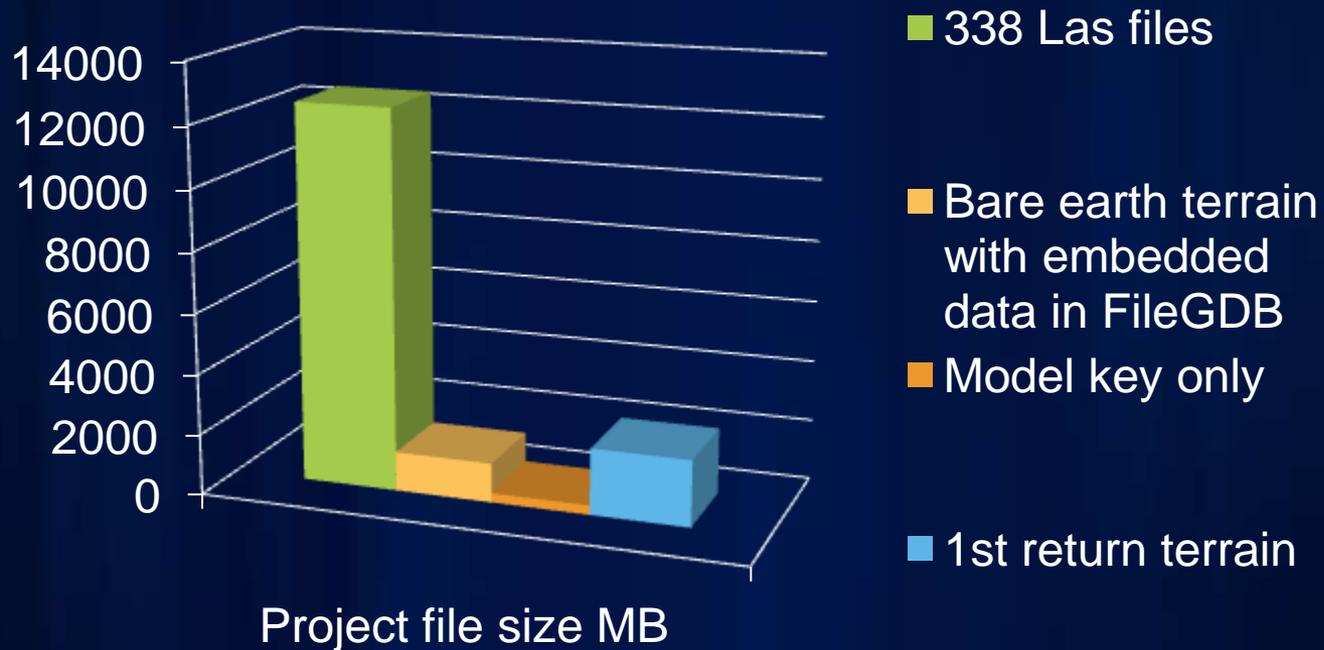
Massive data sets with ArcGIS



...ArcGIS Lidar management is also scalable

Options to support decision makers

Massive data sets with ArcGIS (project comparison)



...leverage GIS for your Lidar management

Raster / Grid

For Elevation; Generally a Derivative

- **Advantages**

- Simplest representation
- Highly scalable
- Fast access
- Compact (through compression)

198.5	180.6	158.7	146.8	189.8	206.8	185.4
181.9	112.2	143.8	184.0	113.1	240.1	141.6
94.5	178.3	178.2	149.8	108.7	238.3	213.9
91.0	106.8	184.3	158.1	234.5	117.7	243.5
97.8	69.4	149.8	90.9	132.6	80.8	204.8
149.5	77.0	100.8	122.6	145.7	122.0	120.7
140.7	59.0	68.5	99.9	162.0	203.4	101.4

- **Disadvantages**

- Loss of original point data, breaklines
- Require multiple rasters for different classifications, attributes



Note ArcGIS enables multi-resolution rasters

Traditional method of Managing Elevation

- **Data Management**
 - **Project wise**
 - **Separate datasets**

- **Analysis**
 - **Project wise**
 - **Merge together required sources**

User Requirements

- **Visualization – Human understanding**
 - Hillshade, Slope, Aspect
- **Analysis – Extracting Knowledge**
 - Visibility, Viewshed, Contours
 - User only gets results
- **Directly using Elevation – Specialized Apps**
 - Othophoto generation
 - Interactive Analysis
- **Data download & export – For specialized apps.**

User Requirements – By Data Type

- **Terrain Model (Ground) – Vast Majority**
 - Hydrographic Modeling, Contours, Ortho
 - Varying accuracy requirements, but need constraints
- **Surface Model (First Return)**
 - Volume computations, Tree Heights, Some Viewshed
- **Full form Lidar**
 - Domain specific applications

Recommendations

- **Store original (and archive duplicates)**
 - LAS
 - Geometries
 - Rasters
- **Server Rasters as Image Services**
- **Create Terrain for Terrain Model - Project wise**
- **Create Raster from Terrain**
 - Multi-resolution according to source
 - Add to Image Service
- **Create Raster surface from Lidar Surface**
 - Create and serve Image Service
- **Create GeoProcessing based on Raster and/or Terrain**
- **Enable Download of original source**

Data Management Requirements

- **Enable Multiple use**
- **Reduce Storage**
- **Single Service from multiple sources**
 - **Simplifies data management and dissemination**
- **Create Derived Service for different**
 - **Visual representations**
 - **Orthometric vs Ellipsoidal**
 - **Surface Elev. (DSM) vs. Ground Elev, (DEM)**
- **Set up server side analysis services**

ArcGIS 10

Provides A Complete Geospatial Platform

Integrating Geospatial Knowledge . . .
. . . From Many Sources



Making GIS Available to Everyone

Manage, Disseminate, Visualize, Analyze

Imagery is Core to GIS



- ArcGIS enables you to:

Manage, Disseminate, Visualize and Analyze



all forms of imagery

- Platform for complete Imagery Solutions
- Mosaic Datasets are the optimum model of managing and serving imagery and rasters
- Maximizing the Value of Imagery

ArcGIS – For Image Data Management

Storage, Catalog, Metadata & Process

- Workstation User
“What do I have? How can I easily work with it?”
- Organizations with collections of processed imagery
“How can I server my elevation data to multiple users?”
- Enterprises collecting new imagery
“How do I process and serve new elevation that we acquire?”

Catalog all available data

Make it quickly accessible in the required form



Mosaic Dataset

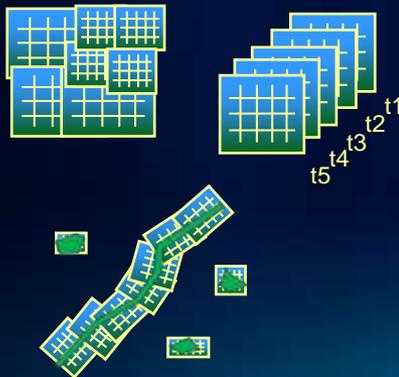
Optimum Model for Image Data Management

- Within ArcGIS Desktop (Editor/Info)
- Quickly Catalog
 - All raster datasets including elevation
 - Imagery from different sensors
- Define – In Geodatabase
 - Metadata
 - Processing to be applied
 - Default viewing rules
- Access – In all ArcGIS applications
 - As Image
 - Dynamic Mosaic , Processed on-the-fly
 - As Catalog
 - Footprints, Detailed metadata



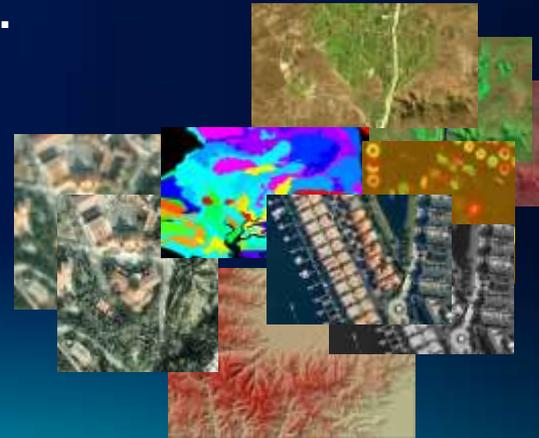
Dynamic Mosaicking

- Merge multiple sources
 - Projections
 - Formats
 - Bit Depths
 - Pixel Sizes
- User defined ordering



On-The-Fly Processing

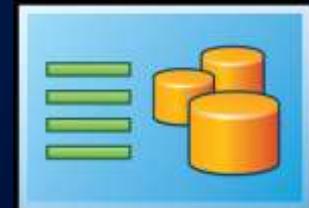
- Process image as accessed
 - Stretch, Extract Bands
 - Clip, Mask
 - Reproject, Orthorectify, Pan Sharpen
 - Vegetation Index, Classify
 - Shaded Relief, Slope, Aspect
 - Color Correction
 - ...



Metadata

Should be obtained for all sources

- Horizontal projection and datum
- Vertical datum and unit
- Horizontal accuracy as CE90, Vertical as LE90
- Ground or Surface?
- Data source
- NoData definition
- Ground sample distance
- Data raw or resampled?



Pre-Processing – Elevation data in raster format

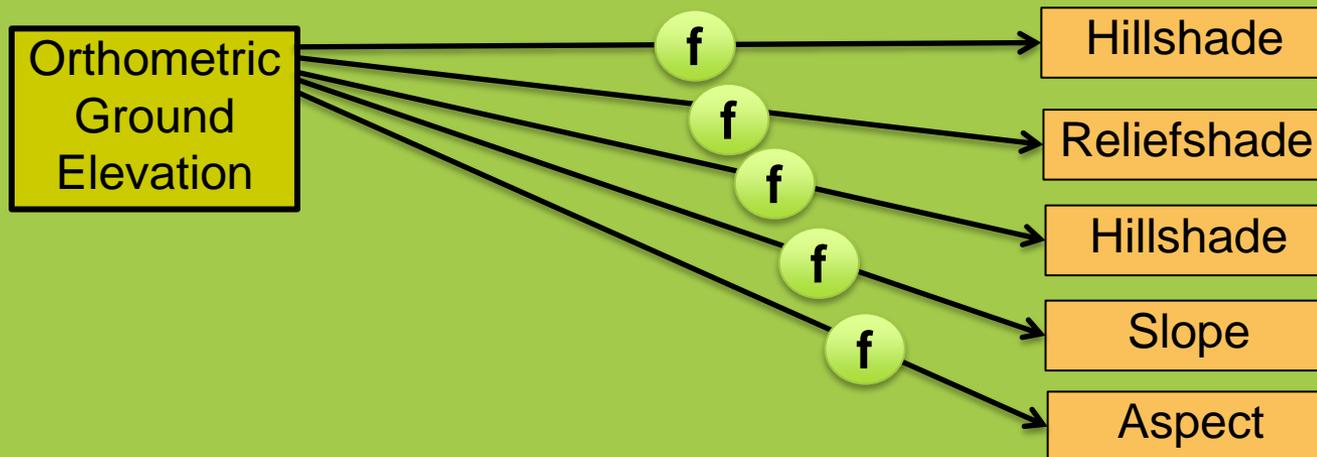
- Do NOT re-project! (will be done OTF if required)
- Optimum format TIF w/ LZW compression
- Some formats (ASCII DEM, GRID) should be converted
- Special formats: HDF, NETCDF. May be better to convert
- Larger datasets (NCols>5000), better to have pyramids (OVR)
- If NCols > 5000 and not tiled, consider reformatting
- JPEG2000 possible, but w/ decompression cost penalty

- Terrain/LiDAR processing discussed later

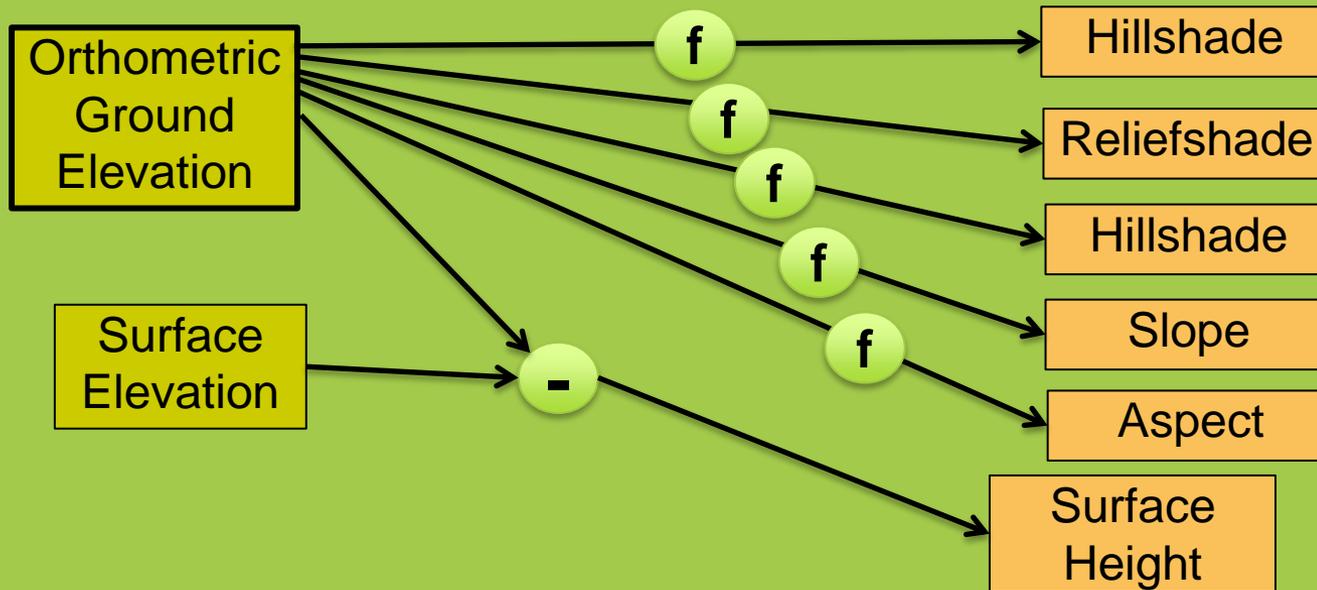
Mosaic Datasets and Services to Create

Orthometric
Ground
Elevation

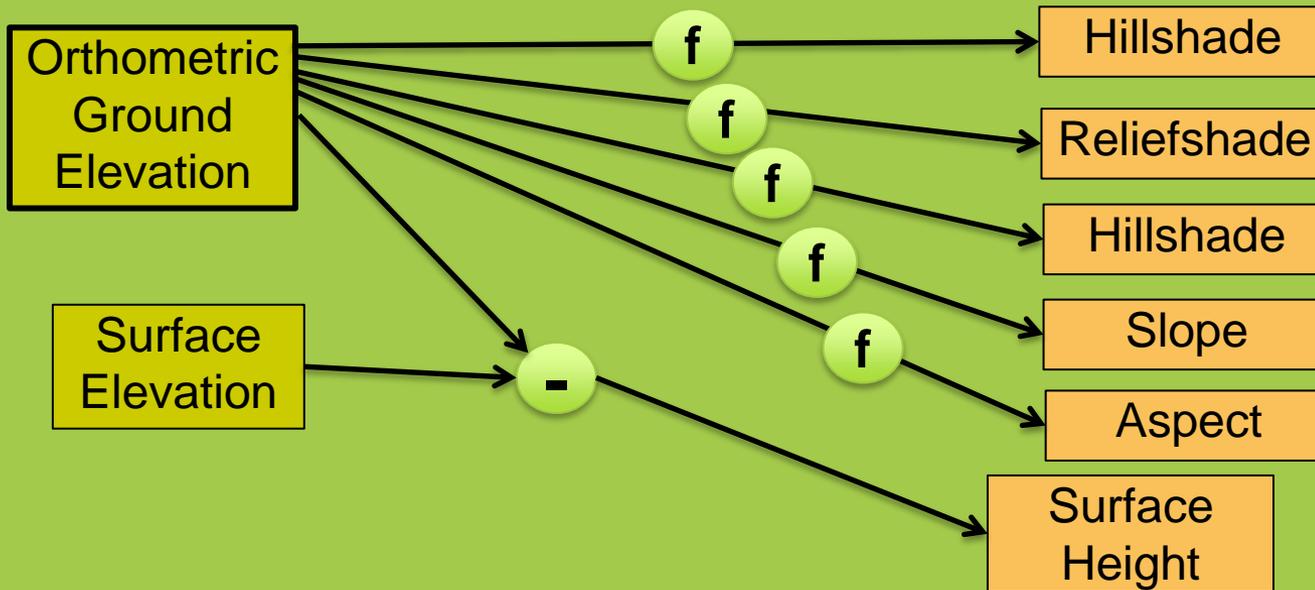
Mosaic Datasets and Services to Create



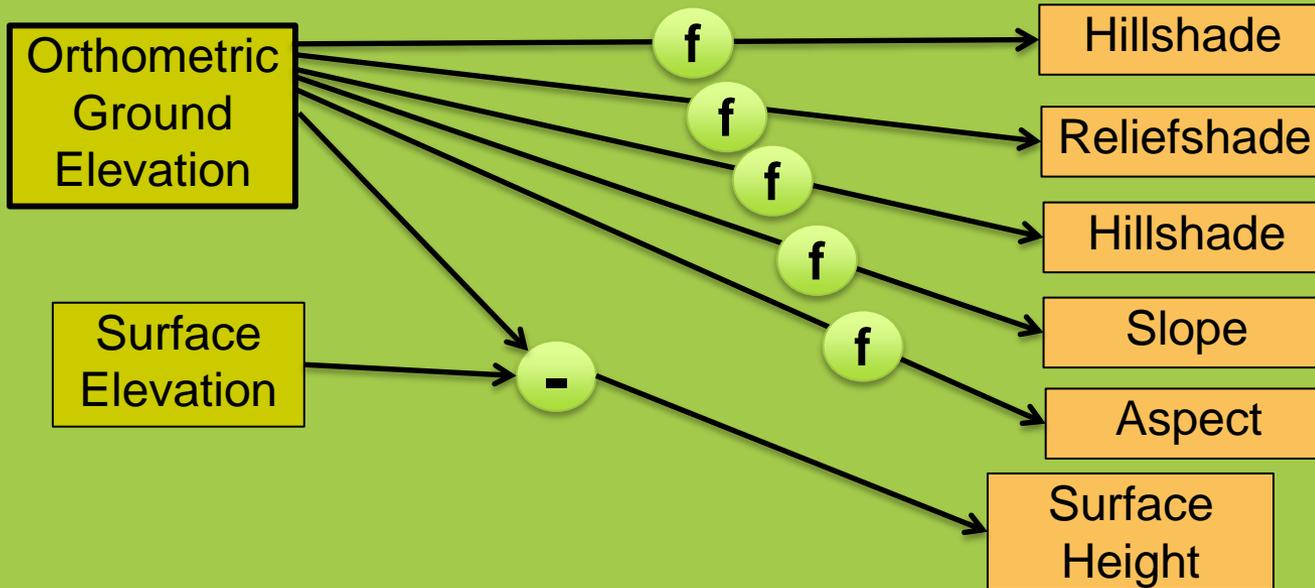
Mosaic Datasets and Services to Create



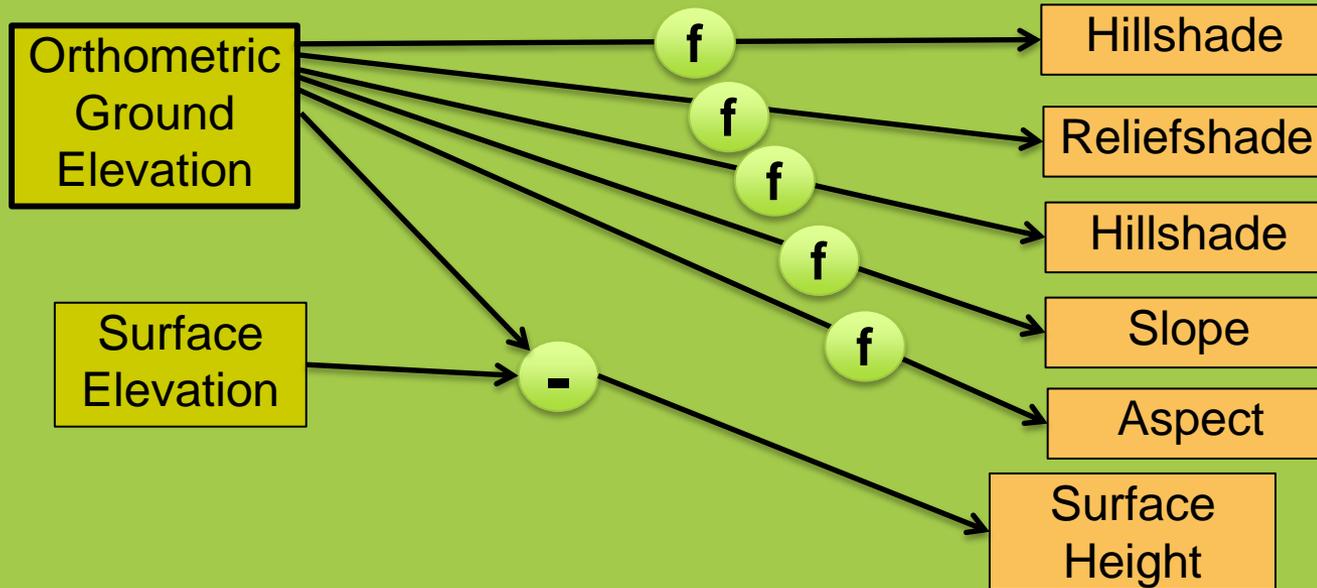
Mosaic Datasets and Services to Create



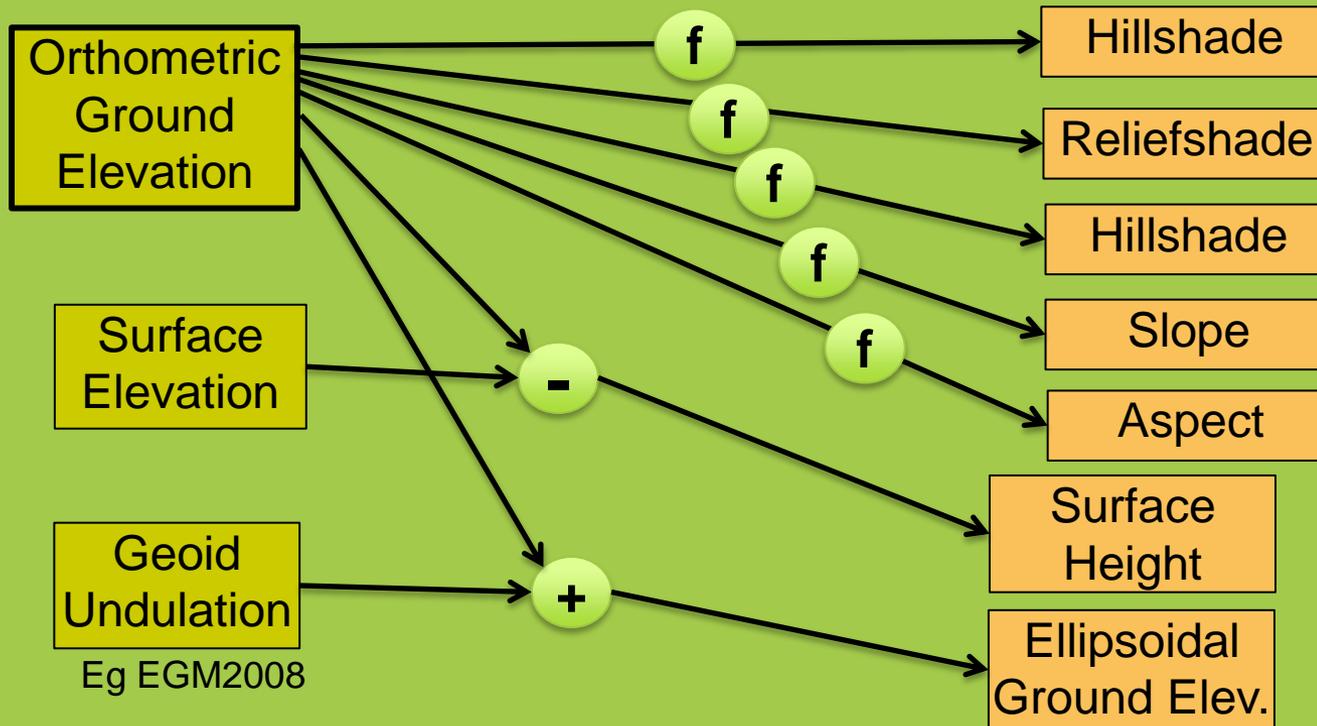
Mosaic Datasets and Services to Create



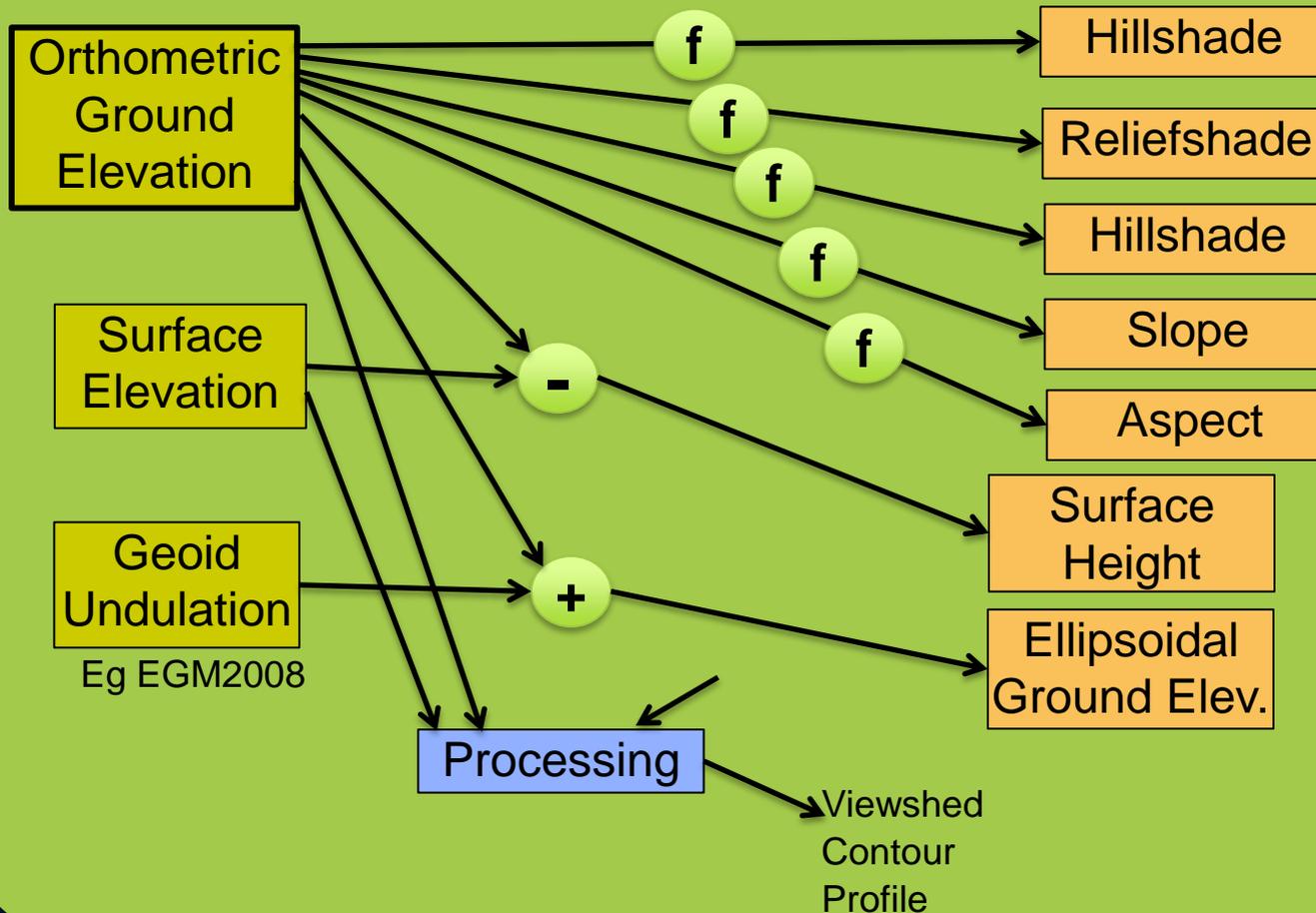
Mosaic Datasets and Services to Create



Mosaic Datasets and Services to Create

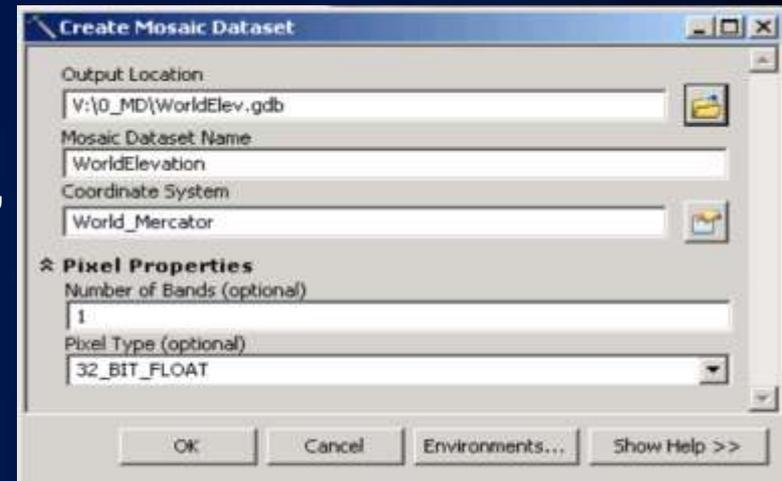


Mosaic Datasets and Services to Create



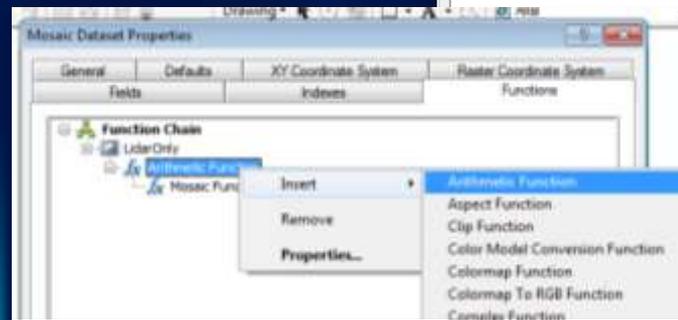
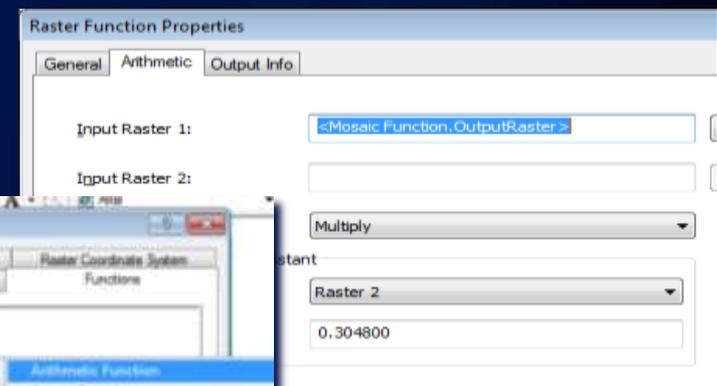
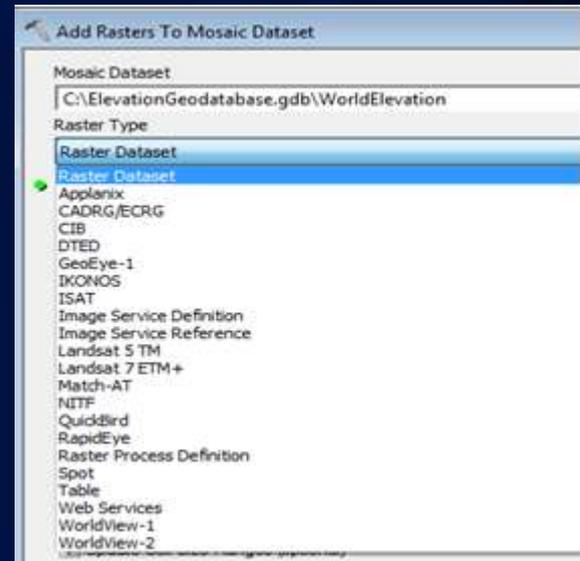
Mosaic Dataset Design

- **Create Master Mosaic Dataset for Orthometric Ground Elevation**
 - Projection (for management and overviews) – World Mercator?
 - Ensure type = float
- **Create suitable Metadata attributes**
 - Horiz_CE90, Vert_LE90, Source, “Best”
- **Separate Mosaic Dataset for**
 - Surface (e.g. LiDAR First Return)
- **Create Reference / Derived Mosaic Datasets**



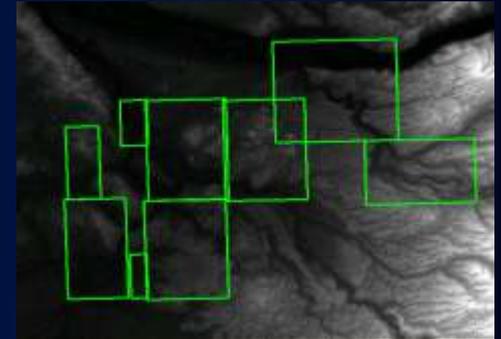
Data Ingest

- Use suitable Raster Type
 <Raster Dataset>
- Consider create new Mosaic Dataset for each source, QC and then add to master
- Convert units when necessary
 (scale/offset)



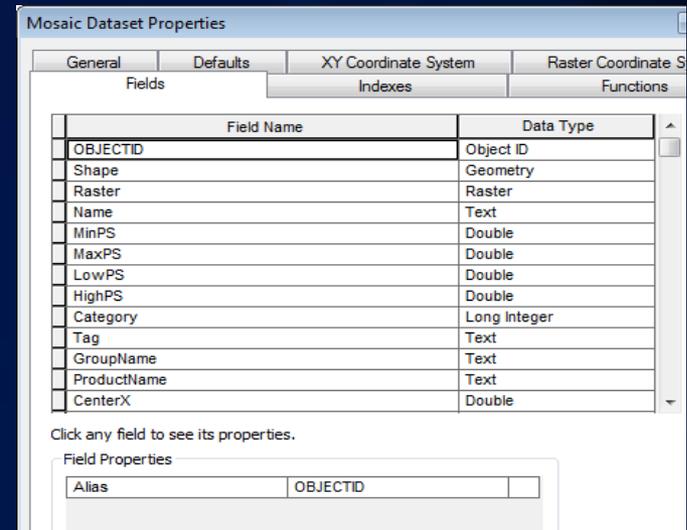
NoData – Pixels / Areas with No Value

- **Use NoData Value – Raster Property**
 - **Use NoData Mask – Some image formats**
 - **Define Mask Value or Range - Functions**
 - **Define Footprint - Build Footprint tool - Recommended**
-
- **Options for Oceans/Seas**
 - **NoData**
 - **0 (Global dummy image with value=0)**
 - **Bathymetric**



Mosaic Dataset Properties

- Set “Best” = most accurate (Vert_LE90 or LoPS) on top
- LZ77 compression for transmission
- Set allowable mosaic methods to: ByAttribute, Locked
-
- Set MinPS = 0 for all datasets



Overviews

- Define provide fast access to small scales
- Can be generated – from primary data
- Advantageous to use global data sources such as SRTM and GTOPO to mitigate the requirement for creating overviews
- Review NoData values in overviews

Creating Reference Mosaic Datasets

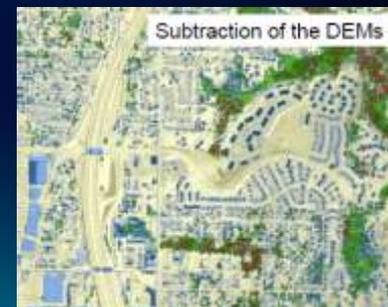
- **Hill Shade, Slope, Aspect**
 - Add Function
 - Change Compression for transmission (JPEG)
 - * there exists also a Derived method
- **Geoid**
 - Need Geoid Undulation model eg EGM2008
 - As single file or Mosaic Dataset
 - Ellipsoid height = Optometric + Geoid Undulation
- **Height**
 - Height = (First Return – Bare Earth)



-



=



Optimization & Maintenance

- **New data can be added as required to master**
- **Reference Mosaic Datasets are automatically updated**
- **Consider optimizing formats**
- **If a lot of Nodata Areas**
 - **Consider to generate tiles to minimize NoData processing**

Applications using Elevation based Image Services

- **Serve Visualization**
 - Direct use of Hillshade, Slope, Aspect
- **Directly Using Elevation**
 - Client downloads source data for local processing
 - Recommendation: Try to minimize this usage mode
- **Serve Analysis Results**
 - Tools to perform on-demand analysis on server
 - Viewshed, Profile, Contours
- **In any of 3 uses above, client application can be:**
 - ArcGIS (for further technical analysis)
 - Other web apps (ArcExplorer, custom apps, etc.)

GeoProcessing with Image Services

- **Requirement: Perform analysis on multi-resolution data**
- **Example: Calculate viewshed, contours**
- **Options:**
 - **User download full resolution source elevation data**
 - Need client capable of processing
 - Too expensive in data transfer
 - **Publish GeoProcessing service**
 - Accessible as a service
 - Requires server to extract required pixels from image Service
 - What Cell Size?
 - Impractical to do Viewshed of Himalayas using 2ft spacing

GeoProcessing Image Service Options

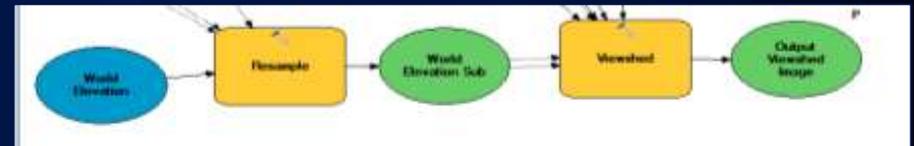
- **MakeImageServiceLayer**

- Initialization will look to complete service
 - Set MaxRows/Cols = Extent/Base PixelSize
- Input to tool is URL
- Sampling = Nearest Neighbor



- **Resample**

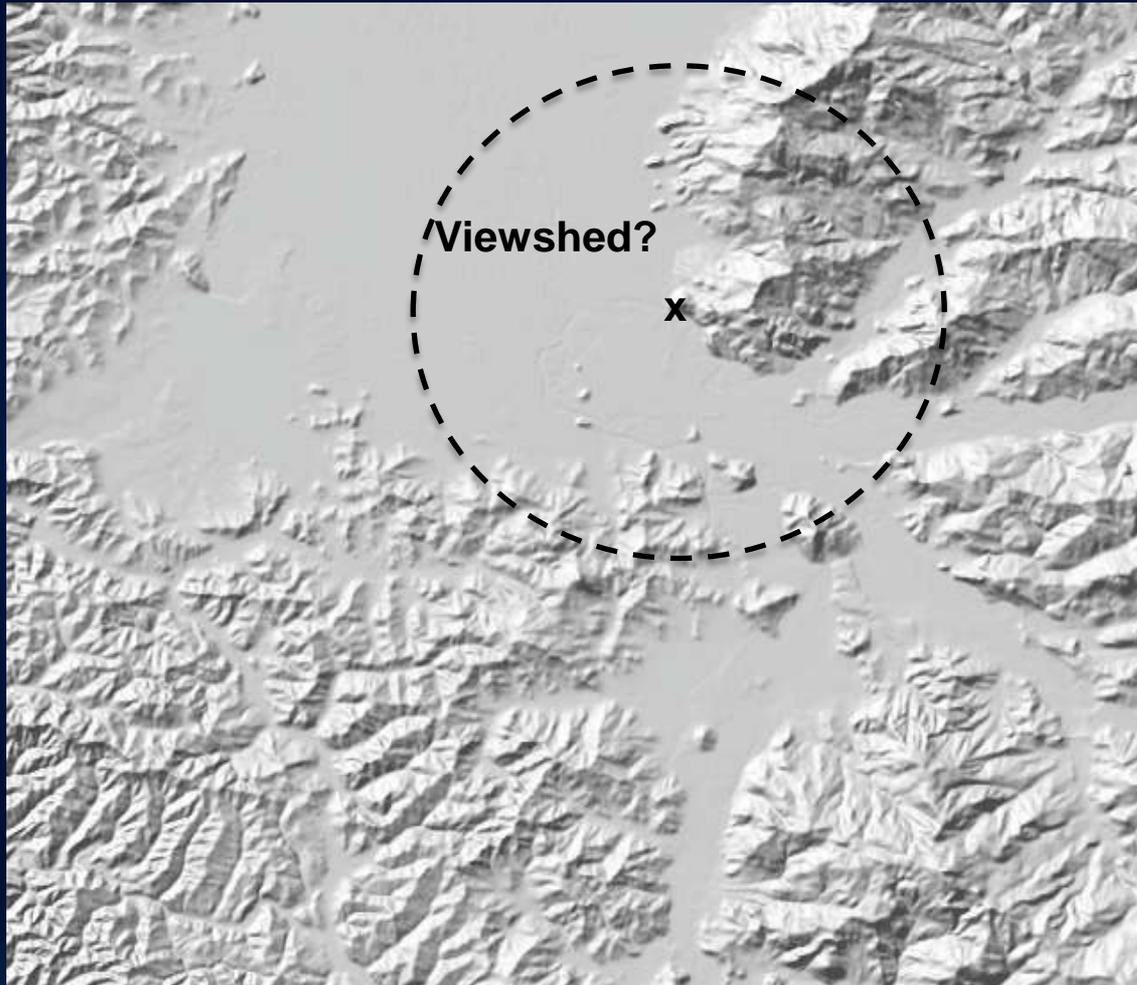
- Server read & resample only what is required for Analysis
- Input to tool is image service layer in ArcMAP document
- Sampling method can be defined



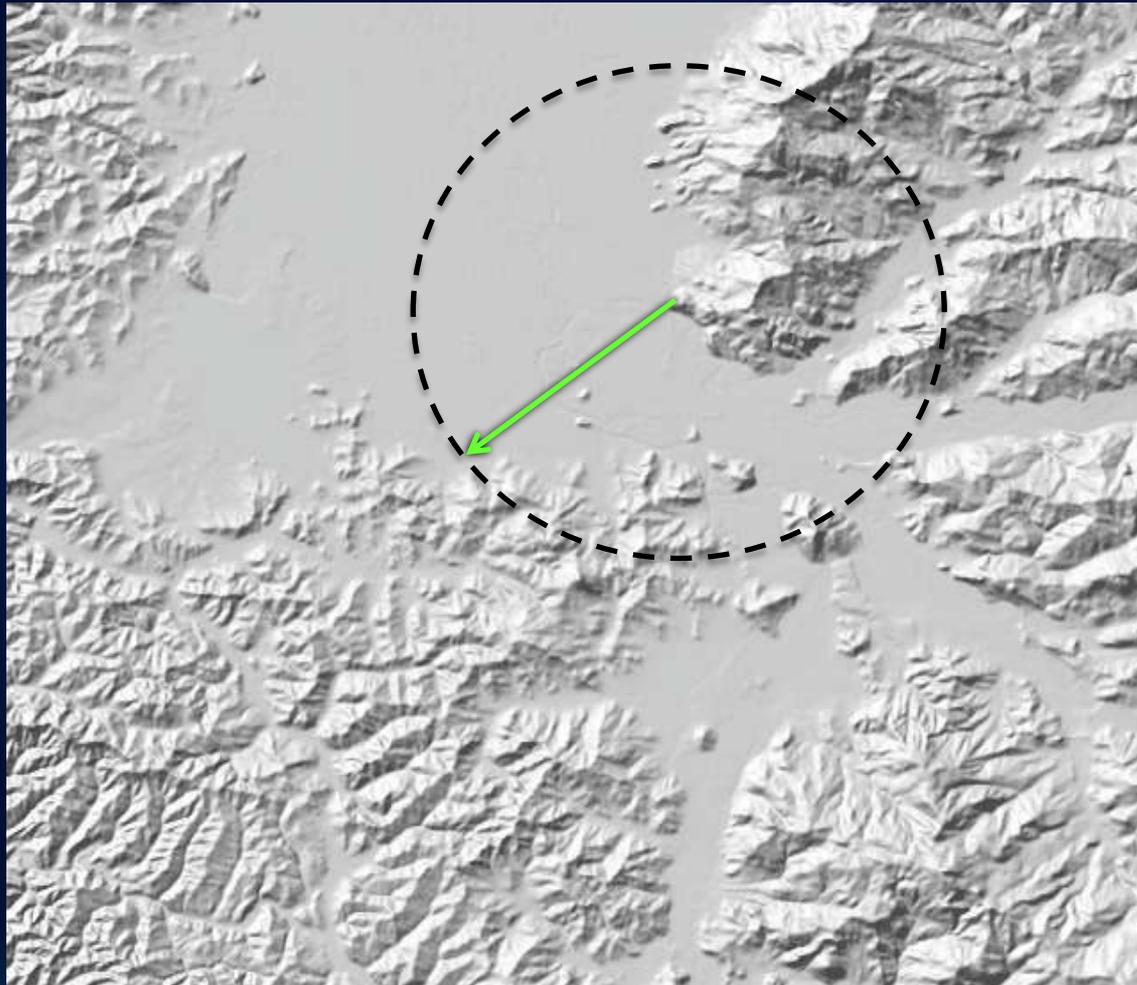
- **Download**

- Can avoid sampling
- Query source and download required data (with clipping)
- Merge sources according to user's rules
- More complex to process, download may be slow

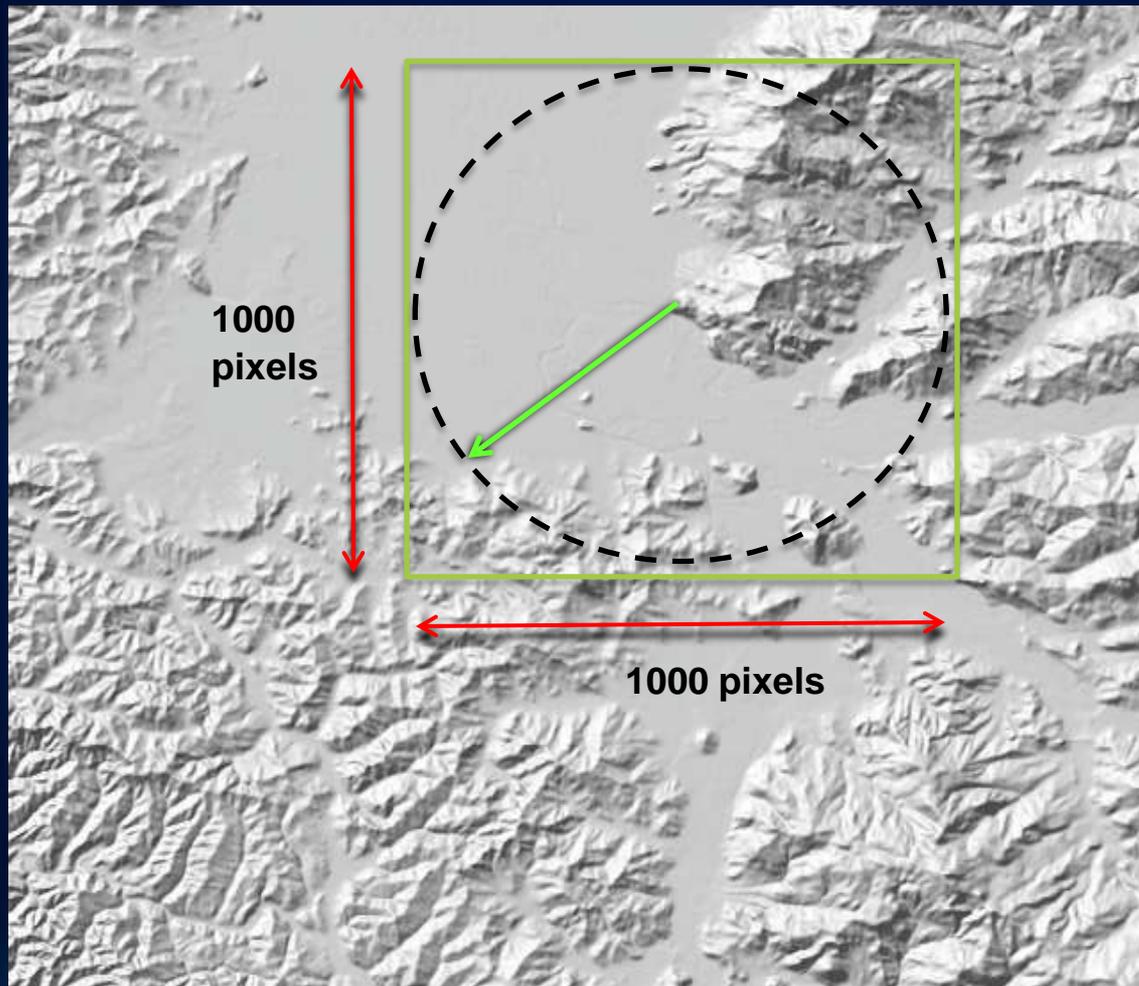
Viewshed region of interest



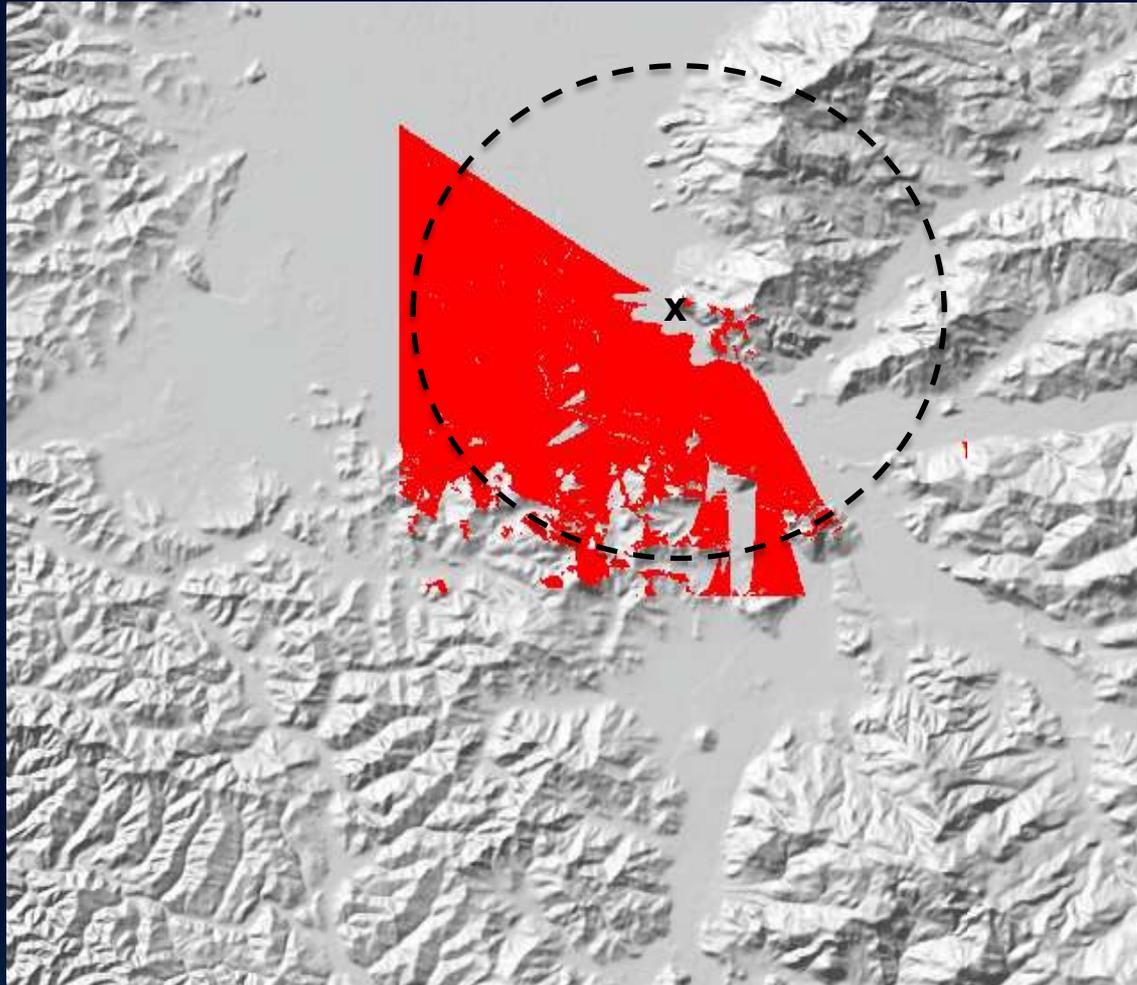
Viewshed region of interest



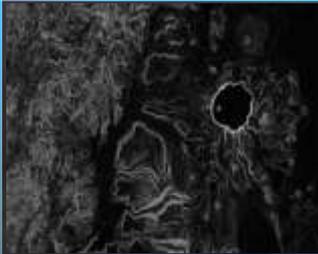
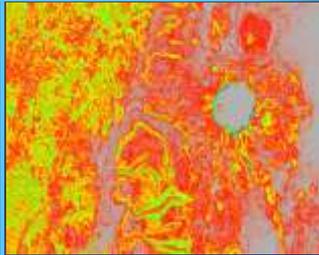
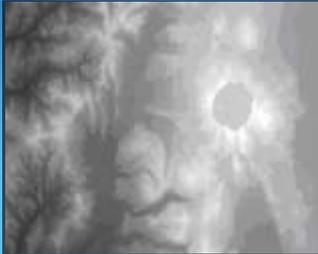
Viewshed region of interest



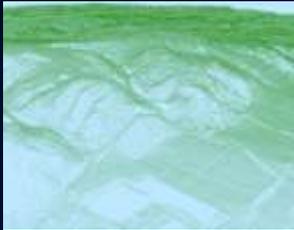
Viewshed region of interest



Demo – GeoProcessing with Image Services



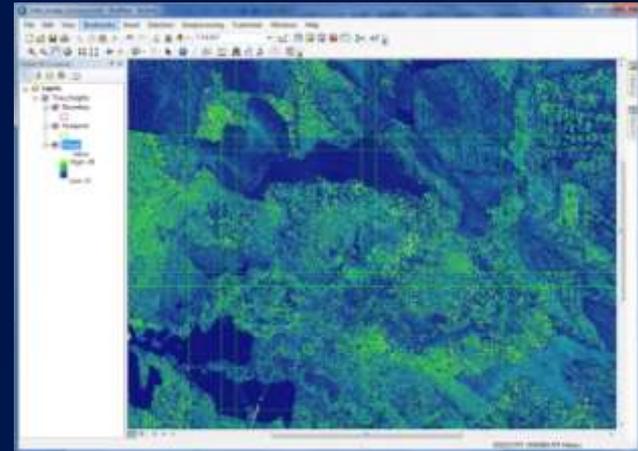
3D visualization and Analysis



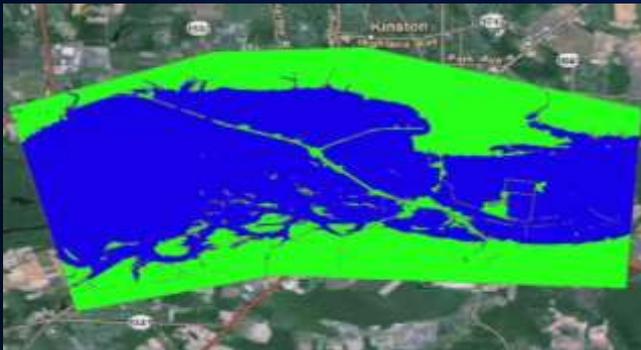
Point cloud



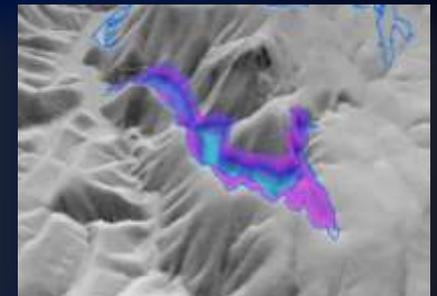
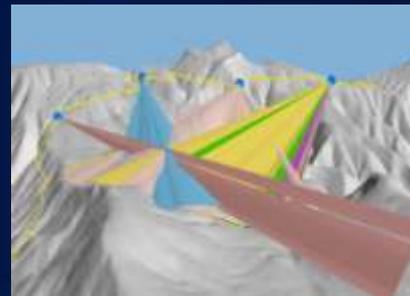
Intensity



Forest inventory



Flood plain

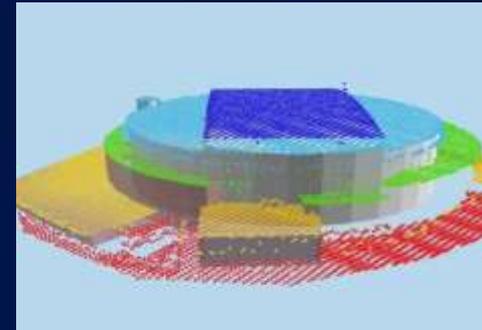


3D Viewshec

3D visualization and Analysis



Derive buildings height



Extract simple geometry



Parade route analysis



Skyline analysis



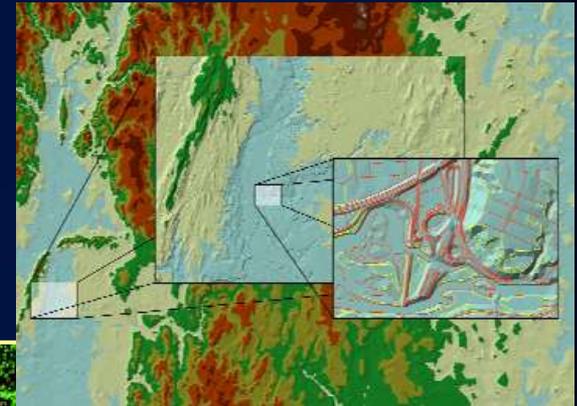
Volumetric Shadows

Terrain Dataset

Multi-resolution surface created from measurements stored in feature classes

- MassPoints (LiDAR), Breaklines, Ppot heights, Polygons, ...
- Stored in the geodatabase
- Schema: Defines feature class participation
- On-The-Fly TIN
- Multi-resolution
- Highly scalable
- Attributes
- Editable, Versioned

Points and
Breaklines



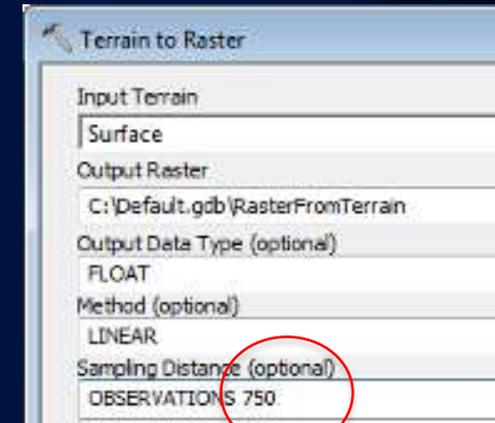
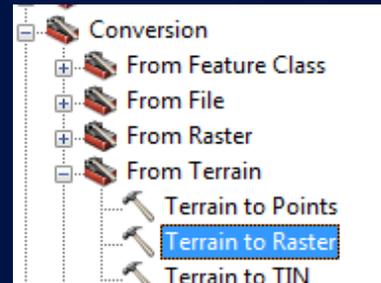
Terrain Pyramids



Rasterizing Terrain

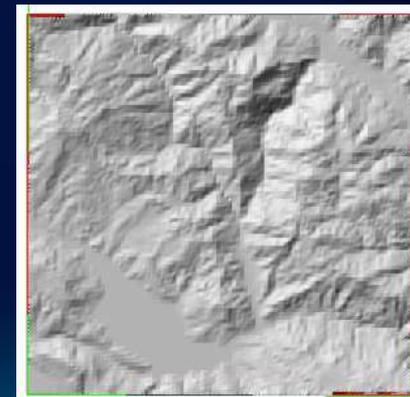
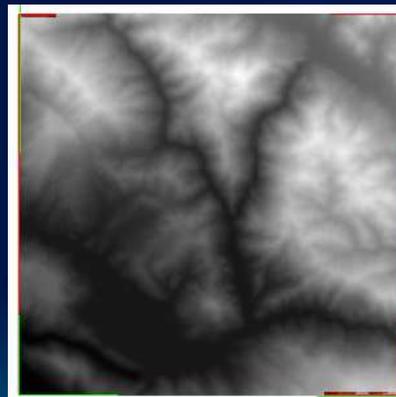
- Easily convert Terrain datasets to Raster

- Size based on Point spacing
- TIF with LZW
- NoData / Boundaries



- Considerations

- Have overlap in tiles (20 pixels)



Rasterizing LiDAR

- Import *LAS to Multi-point*; Then, two methods:

(1) Raster via Terrain

- Point File Information (Avg. point spacing)
- Terrain Wizard; 2 Terrains for First and Last (Ground) Return
- NoData “holes” filled by TIN
- QC and Edit → Terrain to Raster (previous slide)

(2) Interpolate Multi-point directly to Raster

- *Point to Raster*; Set Point Set cell size to 4x avg. point spacing
- Filter to remove holes: `Con(IsNull("INPUTRASTER"), FocalStatistics("INPUTRASTER", NbrRectangle(3,3, "CELL"), "MEAN", "DATA"), "INPUTRASTER")`

- 3rd Party Tools

- Eg LP360 (QCoherent)

- Considerations

- Have overlap in tiles (20 pixels)

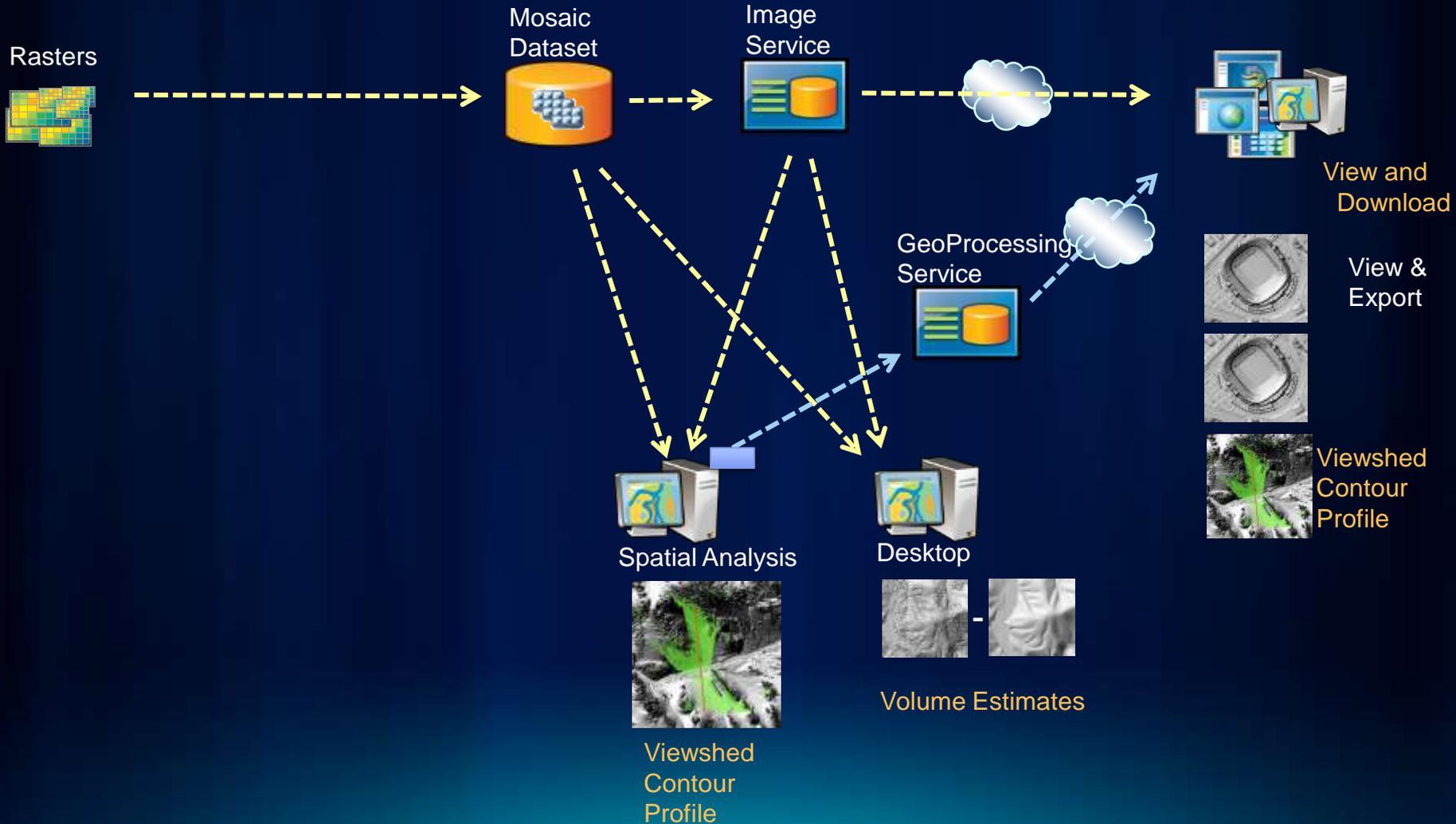
Including Terrain and Lidar



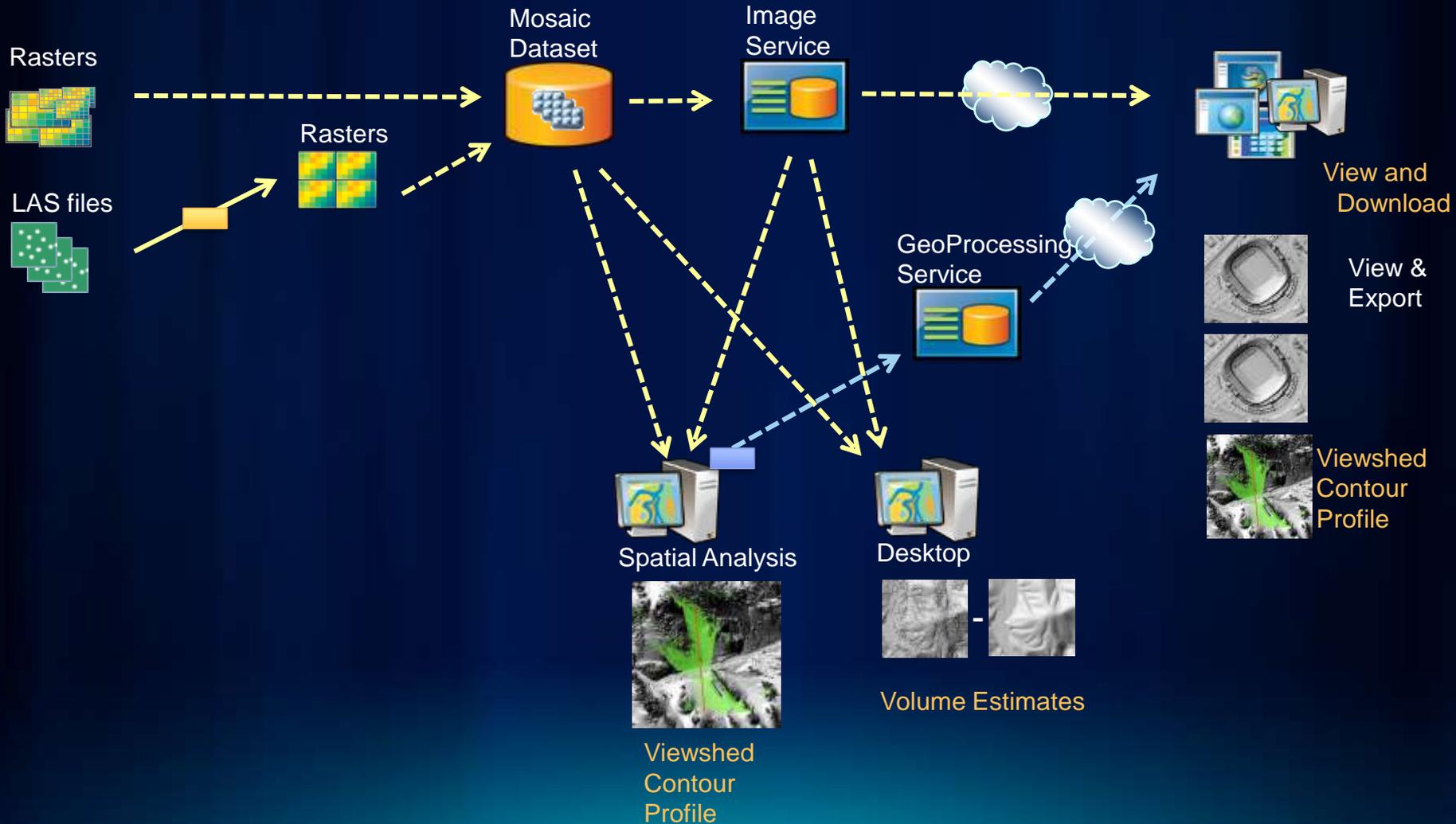
Including Terrain and Lidar



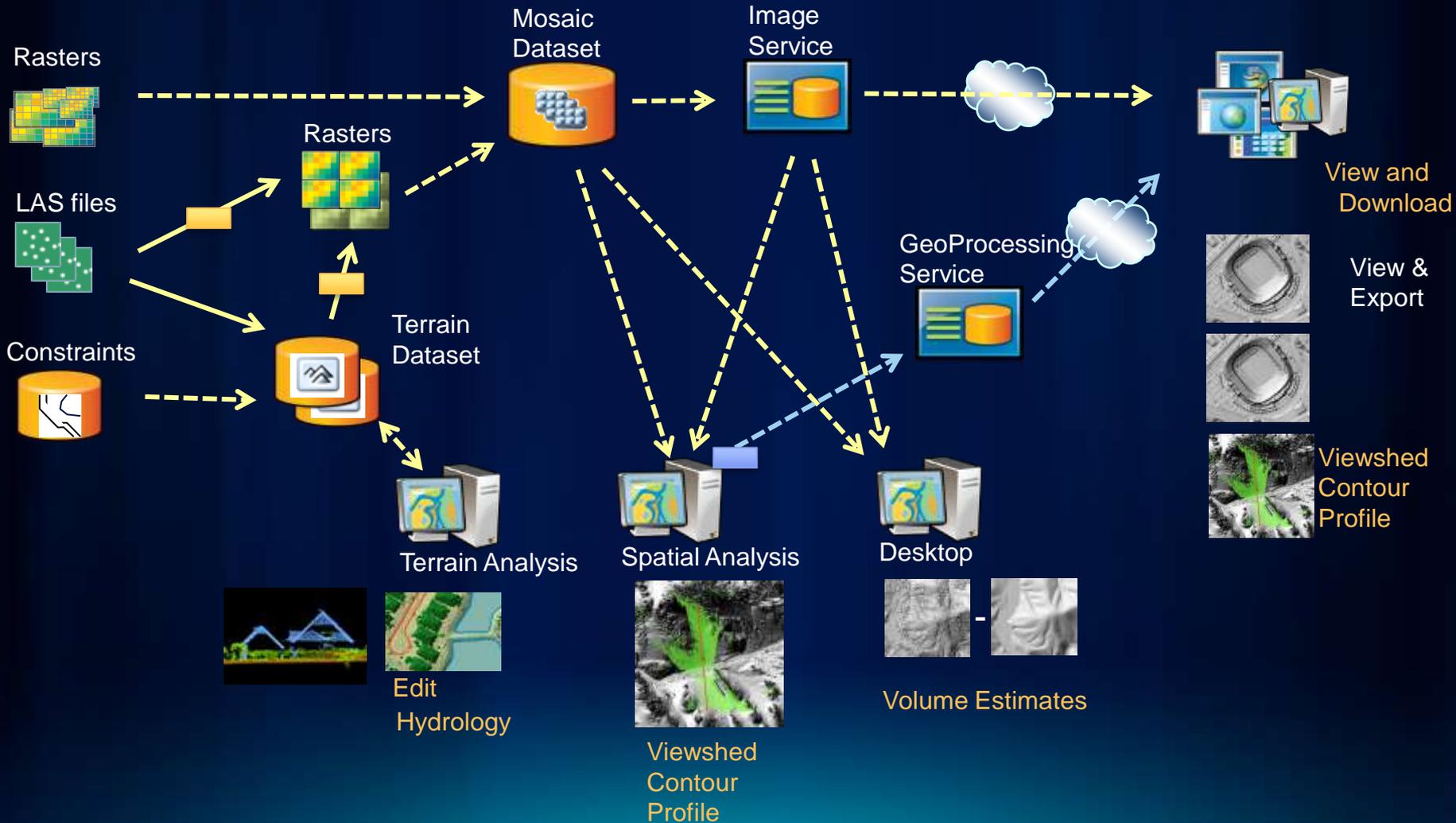
Including Terrain and Lidar



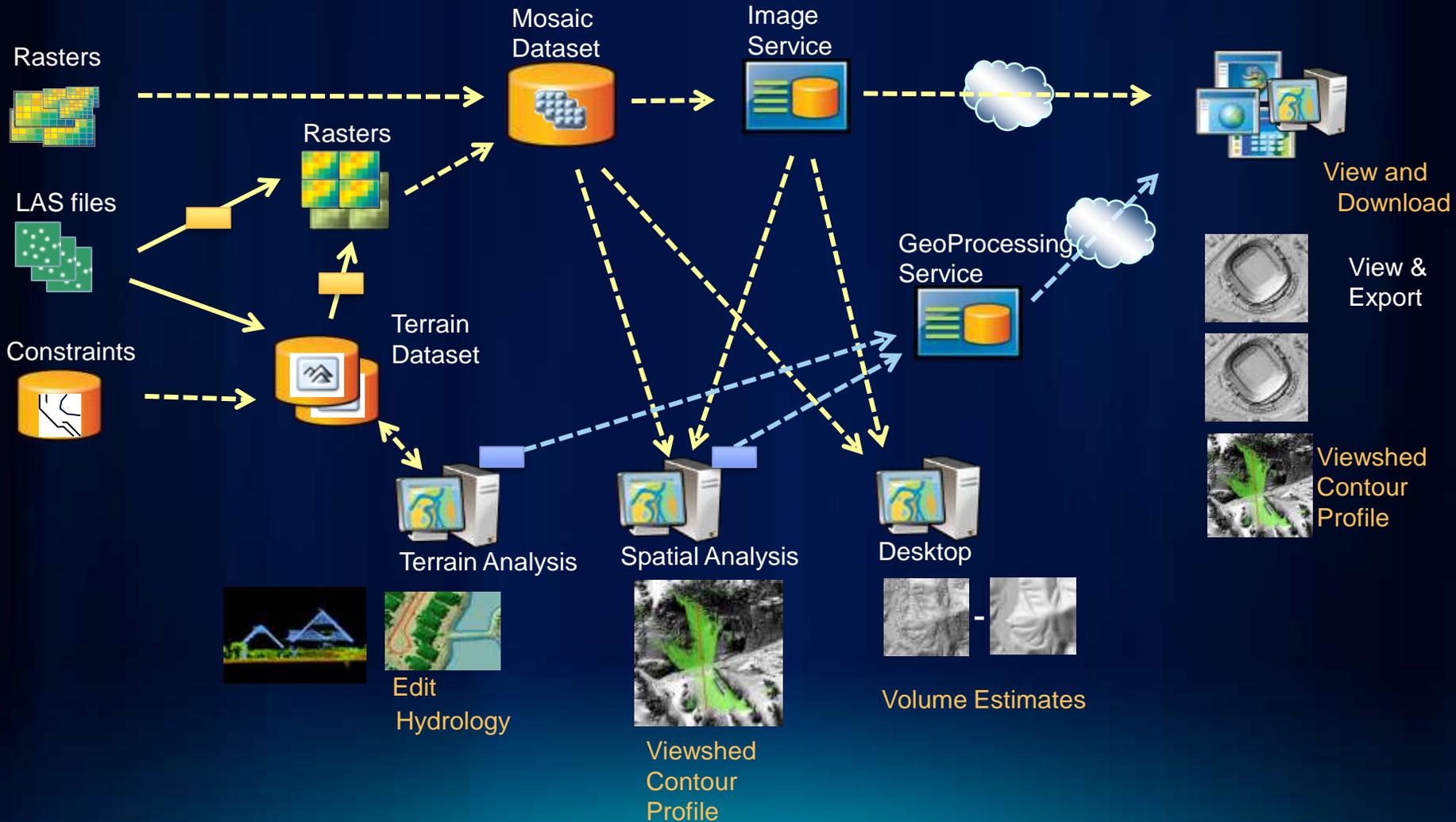
Including Terrain and Lidar



Including Terrain and Lidar



Including Terrain and Lidar



Merging Terrain, Lidar and Raster

- **Use Image Services to make elevation accessible**
- **For Each Terrain / Las**
 - **Create Polygons that define extents and cell size for each raster**
- **Use Model to generate/regenerate rasters**
- **Add/Synchronize with Mosaic Dataset**
- **Server GeoProcessing Tools for Analysis**
 - **Use Mosaic Dataset as source**
 - **According to requirements use Raster or Terrain**

Elevation Summary

- **Making elevation accessible increases value**
- **Keep primary source and optimized derived products**
- **Manage individual projects**
 - **Create**
 - **Maintain metadata**
- **Server combined projects as Image services**
 - **Provides majority of use requirements**
 - **Acts as a catalog for more advanced processing**
- **Utilize GeoProcessing**
 - **Create processes that return required information**
- **Enable download for specific applications**

ArcGIS – A Platform for Complete Imagery Solutions

Information Centric Workflows Enable Efficiency & Interoperability

- **ESRI works closely with its partners**
- **ArcGIS provides THE platform**
- **Partners provide domain expertise**

- Automated Feature Extraction
- Multispectral Analysis
- Hyperspectral Analysis
- Radar
- Specialized Sensor Support
- Stereo Display
- ...

Trimble (Applanix)
Microsoft (Vexcel)
DigitalGlobe
Pictometry
RapidEye
GeoEye
SPOT

ITT VIS
Definiens
Clark Labs
Overwatch
BAE Systems



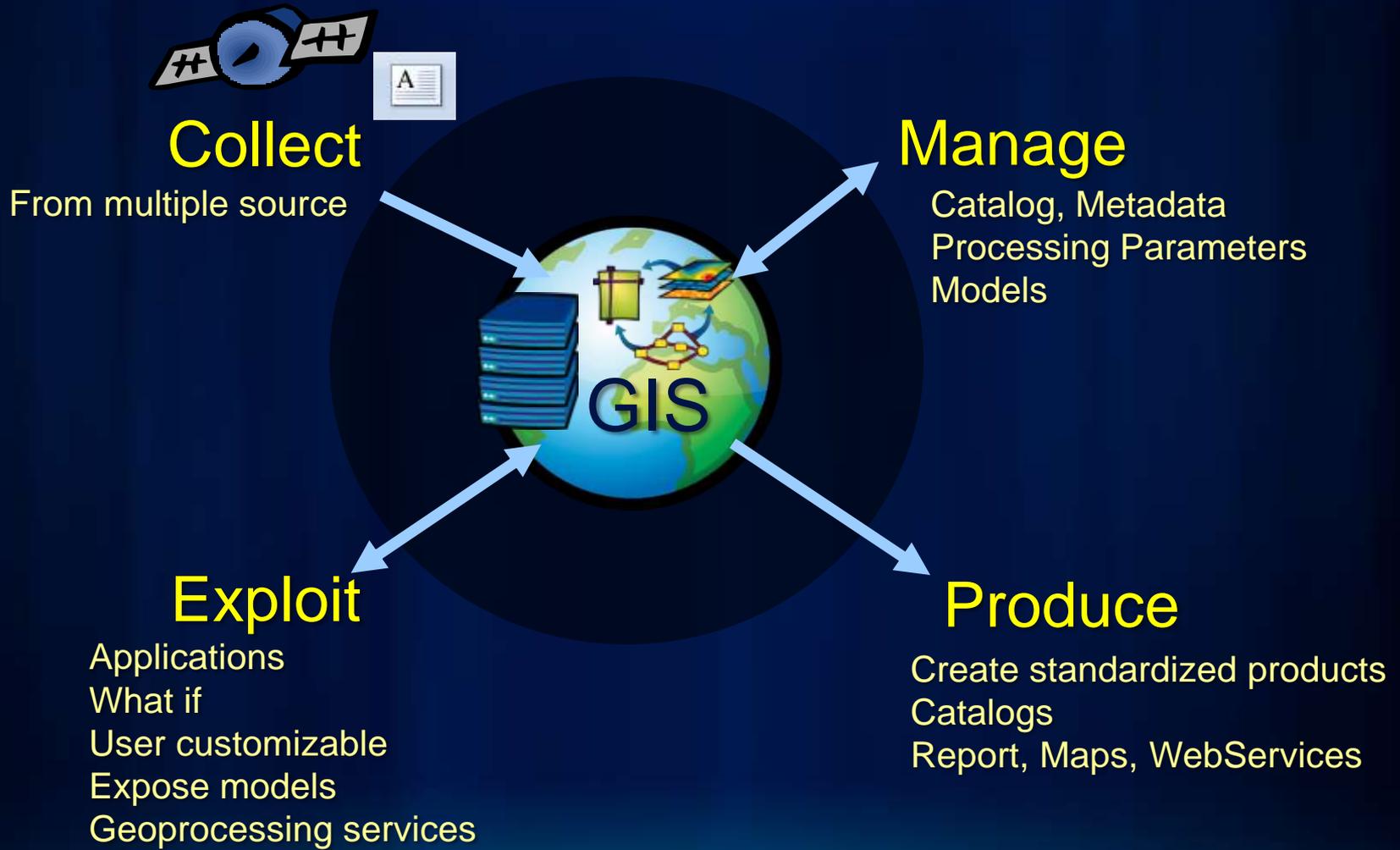
PCI Geomatics
Trimble (Inpho)
LizardTech
i-cubed
MDA

DAT/EM
PurVIEW
TerraGo
Qcoherent

Service partners not listed

Information Centric Approach to Workflows

Making Workflows Transactional



Enable Graded Product

ArcGIS

The Platform for Fully Integrated GIS and Imagery

- Integrating Imagery as core to GIS
- Management, Dissemination, Visualization and Analysis
- Solution for wide range of imagery requirements
- Maximizes the value of imagery

