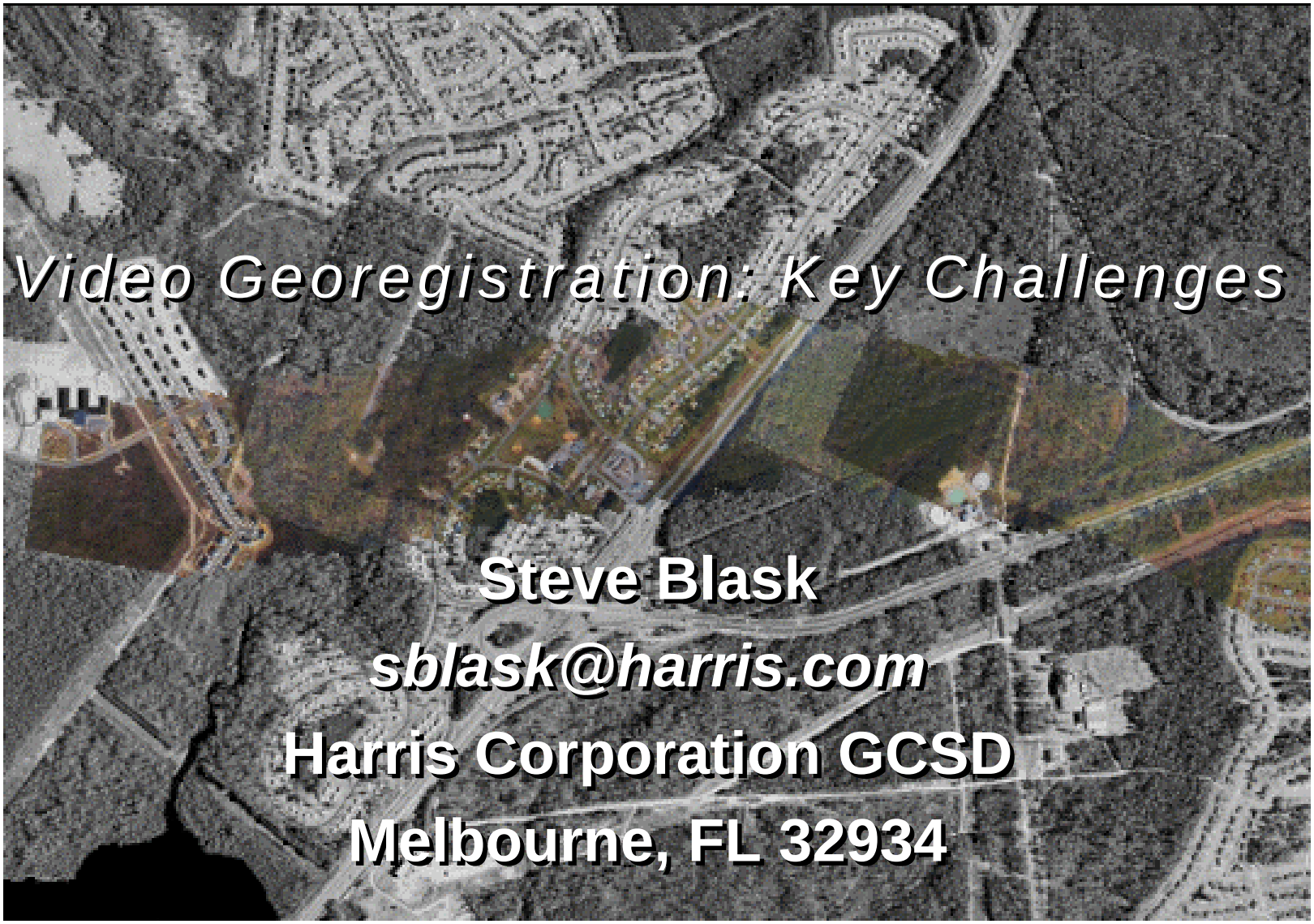

Video Georegistration: Key Challenges

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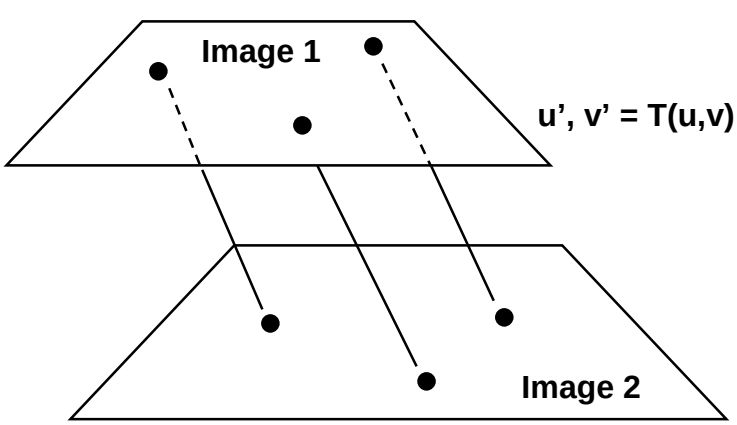
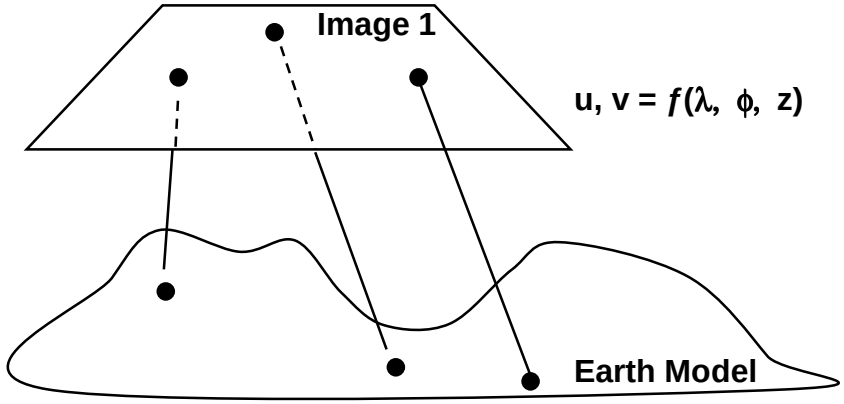
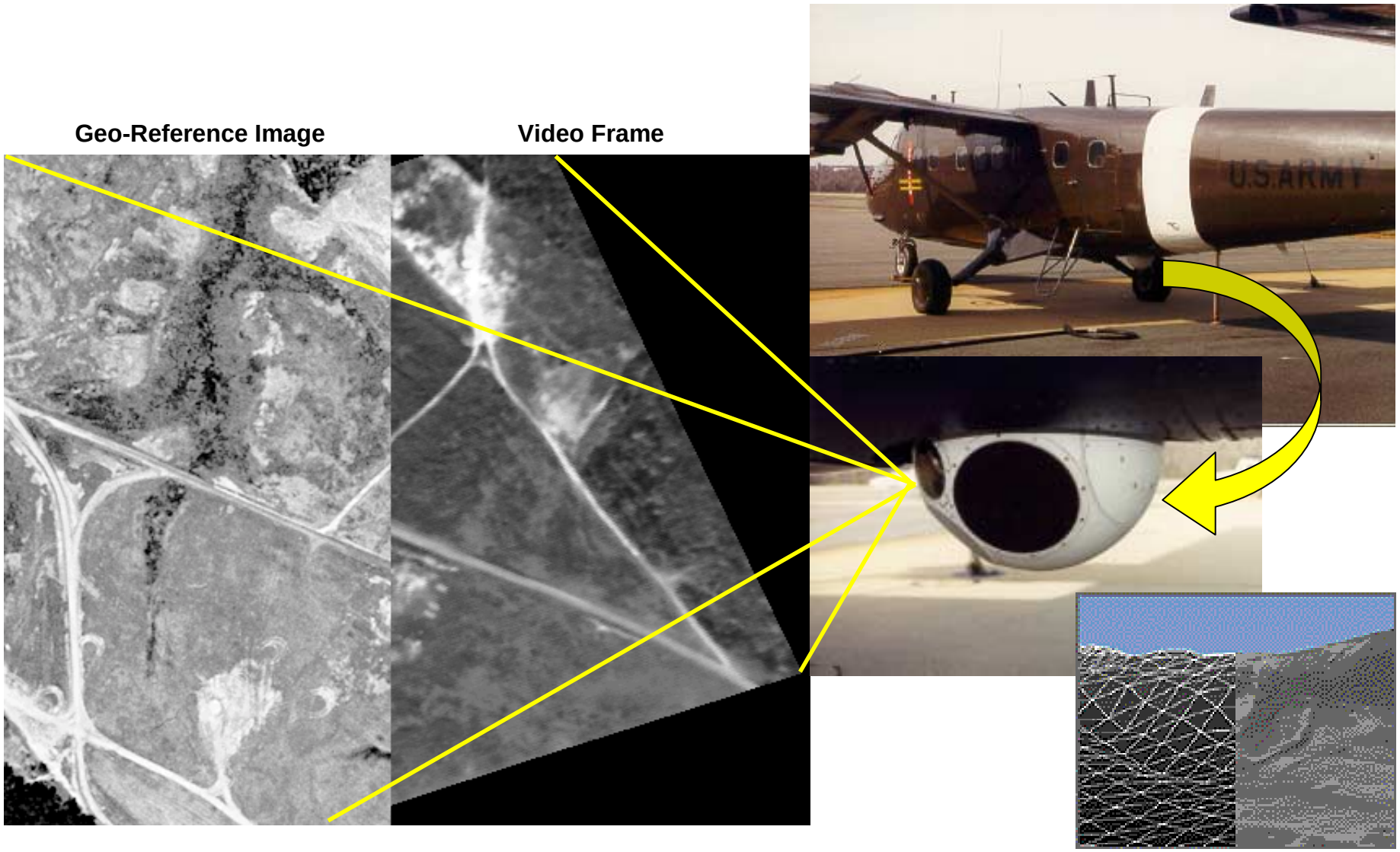
Definitions

- Registration: image to image alignment
  - Find pixel-to-pixel correspondences between images collected at different times, by different sensors, or from different view points, and derive or improve estimate of transformation **T**
- Georegistration: image to Earth alignment
  - Find pixel-to-point location correspondences between imagery and the surface of the Earth, and derive or improve estimate of ***f***
  - One means: transfer high geodetic accuracy from controlled reference imagery and Digital Elevation Model (DEM) to video



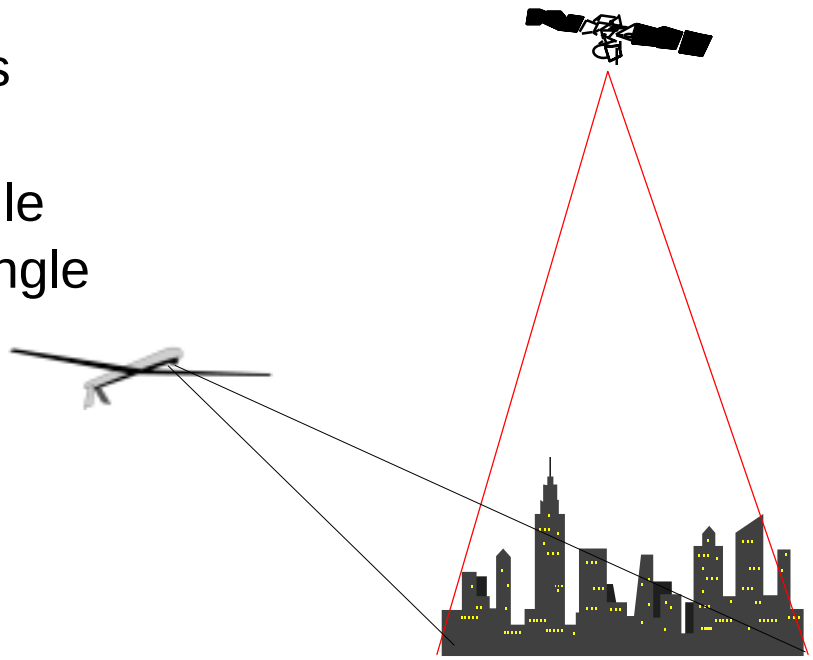


Impact of Exploitation Support Data Errors



Real World Airborne Video Georegistration

- Must deal with complex distortions
  - Minimize to simplify correspondence and improve global accuracy
- Must be robust and efficient
  - Exploit redundancy
  - Enforce global consistency
- Must deal with real world effects
  - Clouds, obscuration
  - Differences in collection angle
  - Differences in illumination angle
- Must be insensitive to
  - Image quality
  - Scene content
  - Sensor modality
  - Disparities in resolution



VG Performance Factors

- An exhaustive multivariate search space

pattern appearance
  - the presence and distribution of distinctive pattern structure in the scene, "scene content"

terrain type
  - 3D relief (flat, rolling, rugged)
  - surface coverage

video quality
  - resolution, spectral band
  - SNR, blur, sharpness, contrast
  - compression artifacts

reference imagery quality
  - age
  - geo-location precision, GSD

video-reference differences
  - season, weather, time of day
  - camera differences
  - feature content & shape changes

viewing geometry / telemetry
  - altitude, focal length, GSD
  - look angle (obliquity)
  - scan pattern

quality of ESD
  - telemetry accuracy, rate, timestamp

quality of DEM
  - post density, accuracy
  - bald earth vs. visible surface
  - age

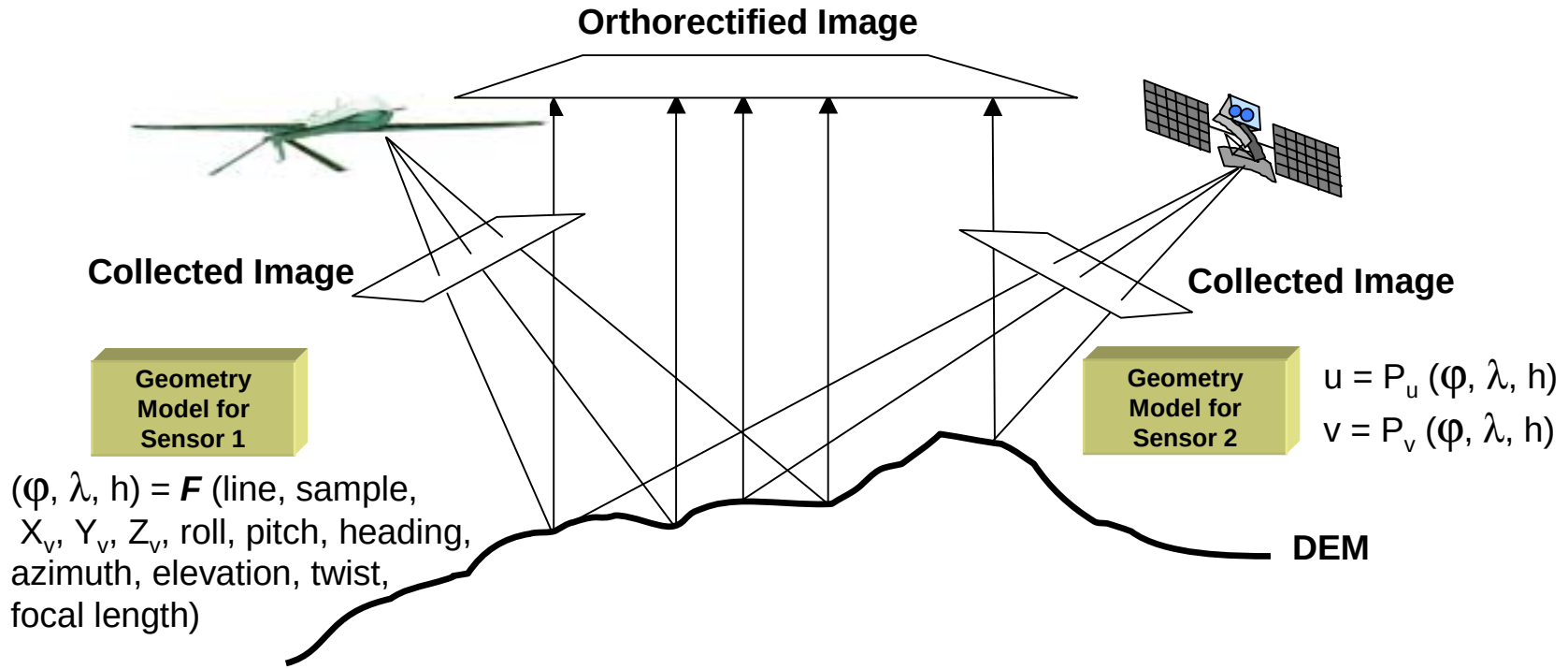
match measure/approach
  - gradient
  - correlation
  - point based or higher order features

optimization methods/approach
  - conjugate gradient, Kalman filter, Levenberg-Marquardt, Gauss-Newton

Question 3a

- Does ESD (Telemetry) really help register video with the reference image and DEM?

  We use *a priori* knowledge of each sensor imaging event and a Digital Elevation Model (DEM) to project imagery to the 3D terrestrial surface



Question 3a

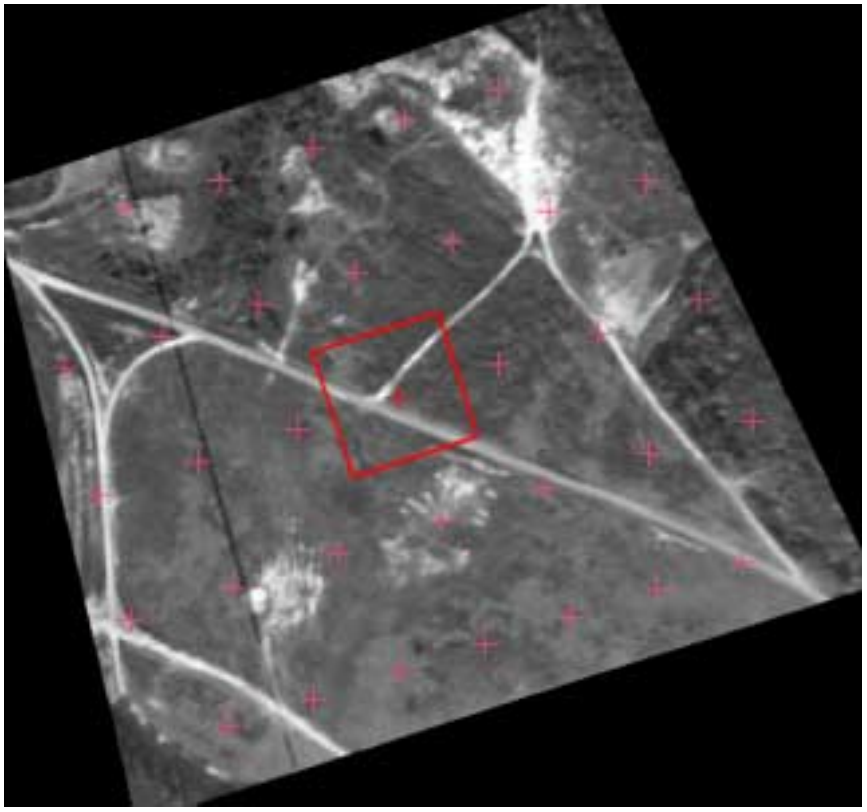
- Does ESD (Telemetry) really help register video with the reference imagery and DEM?
  - Greatly reduces search space (9 parameter airborne sensor model in our application)
  - Reduces amount of ref data preprocessing that may otherwise need to be done (e.g., feature extraction & geometric hashing that might otherwise be necessary for landmark recog.)
  - Availability of ESD is one simplifying assumption that is realistic for many operational systems!

Question 3b

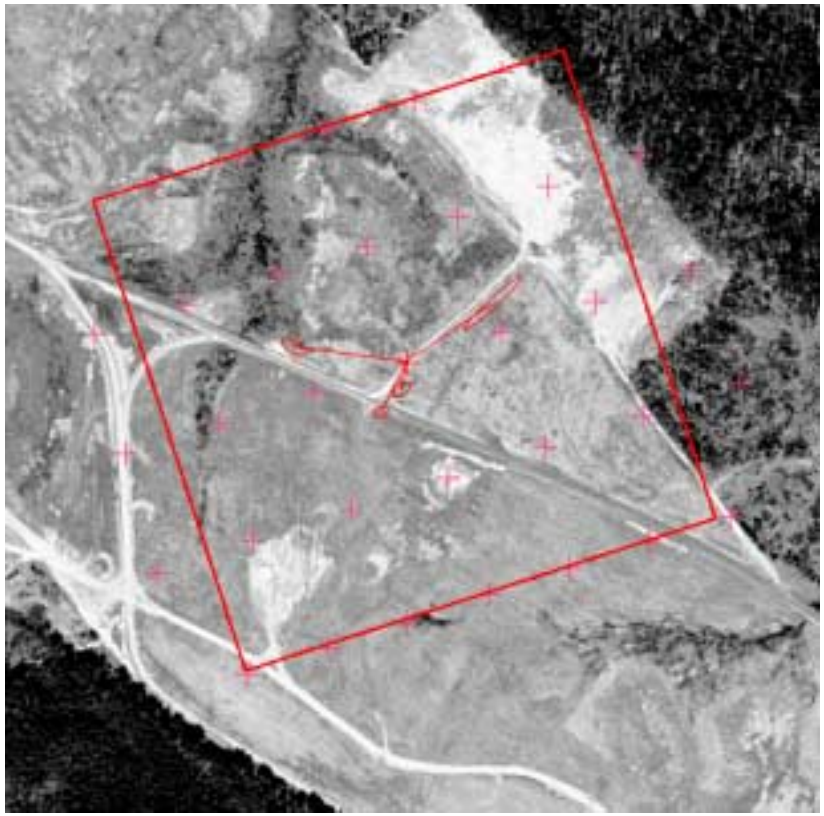
- What are the hard problems in this area?
  - Unknown or unstable ESD / video time synchronization
  - Low reporting rate or missing telemetry parameters
  - Large error covariances for too many parameters (makes search space prohibitively large)

Question 6a

- Does correlation still play an important role in registration?



Video Mission Image



Geo-Reference Imagery

Question 6a

- Does correlation still play an important role in registration?
  - Yes! Image patches are readily available, compact, information-rich features.
  - Robust correspondences are possible if scale, rotation, and 3D perspective differences have been reduced and global consistency is enforced.
  - Correlation in edge space accommodates different imaging modalities (EO, IR, SAR, etc.)
  - Iterative processing of the resolution levels of a Gaussian pyramid enables refinement of the alignment solution.

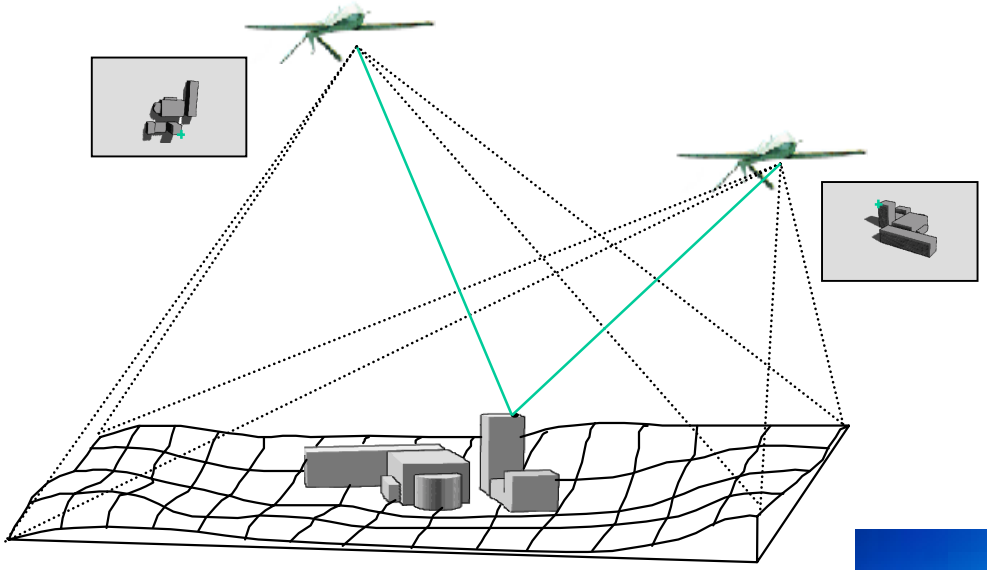
Question 6b

- Has anything new happened in the past 50 yrs?
  - Before computers, correlation was not practical
  - Fast hardware solutions made it ubiquitous in machine vision applications (Cognex's hammer)
  - Mutual Information approach lauded by the medical imaging community is more robust w.r.t. rotation and other distortions that cause 2D correlation to fail, but is computationally more expensive

Question 8

- What is the role of image features in video reg.?
  - Necessary for registration in urban areas and other complex 3D environments (2D correlation becomes very difficult in the presence of viewpoint uncertainty)
  - 2D-to-3D feature correspondences can be directly employed by resection algorithms (Stamos & Allen, “Automatic Registration of 2-D with 3-D Imagery in Urban Environments”, ICCV’01 Poster Session 4)
  - Have proven to be useful for pose refinement (Hsu et al., CVPR’00)

Questions 8&9



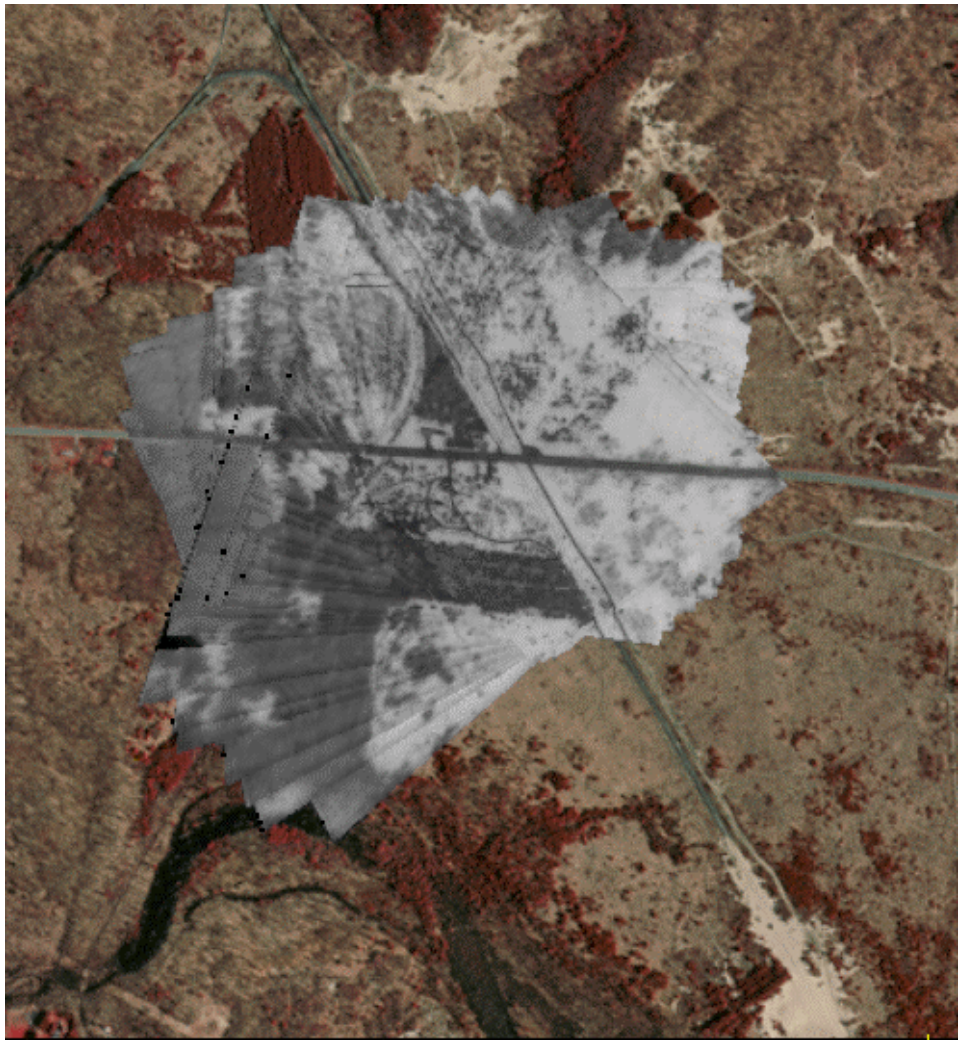
Question 9

- What are the next important unsolved problems?
  - Fully autonomous urban scene georegistration
    - regularity of structure (city block, bldg windows)
    - high edge content (too many (!) features)
  - Fully autonomous georegistration of video from platforms with no ESD or large ESD errors
  - Registration of airborne and ground-based views

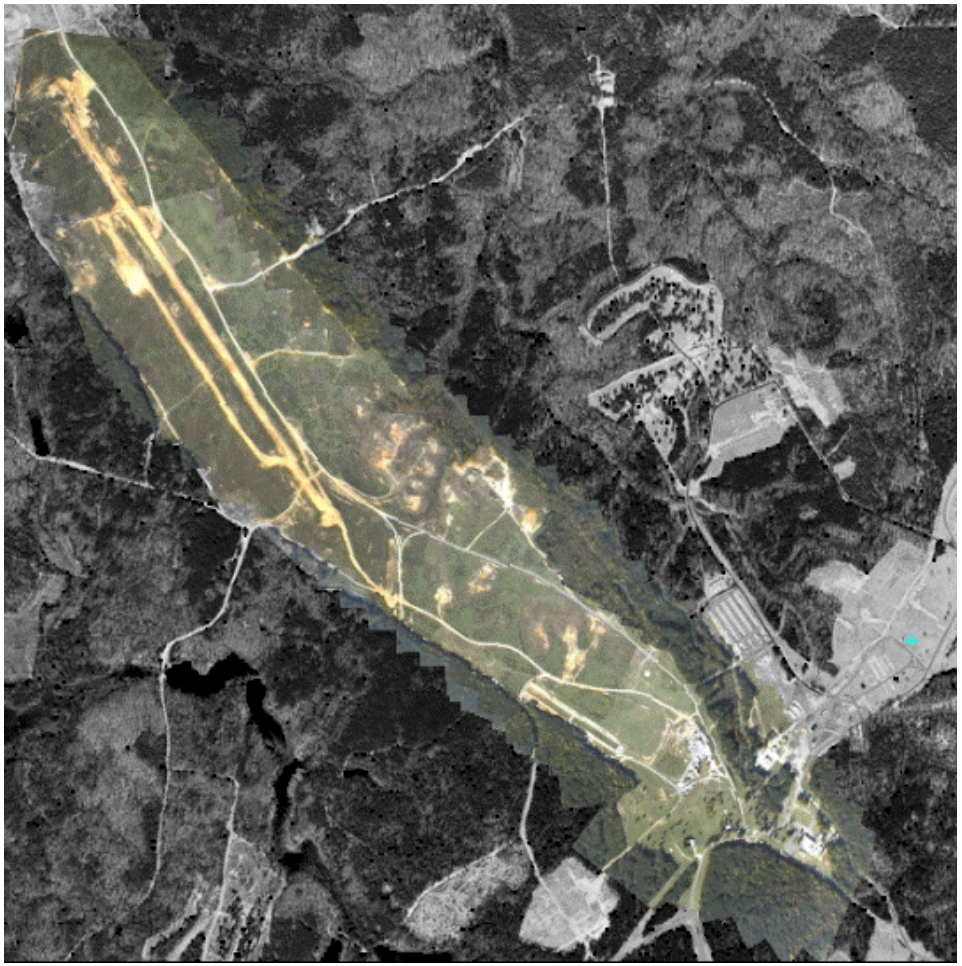
Question 10

- Successful solutions and approaches
  - Depression angle $\in$ [30°,90°], correlate in orthorectified scene space
  - Depression angle $\in$ [0°,30°], correlate in video frame scene space
  - Edge space to fuse different image modalities
  - Global consistency of local matches
  - Iterative refinement (2D image, 3D DEM, N parms)
  - Bundle adjust to bridge poor scene content
  - Bundle adjust to accommodate zooming
  - Rigorous error propagation

Question 1: Orthomosaic Stills & Movies



Greyscale to Color Infrared



Color to Panchromatic