Outline of steps necessary to process imagery in Leica Photogrammetry Suite

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1. Get all the necessary imagery and information
   (a) Historical imagery – high-resolution scans, 600 dpi/ppi or better, 8-bit grayscale
      i. Lists of historical aerial images can be found online, and map libraries can scan things for you (potentially costs $$$)
      ii. Make sure the photos more than cover your area of interest
      iii. Overlapping photos are very helpful
      iv. Even if you will not be mosaicing the results, you should still use at least three photos for the orthorectification to ensure that you get a good result
   (b) Flight metatdata: flight height and camera focal length
      i. Sometimes hard to find, try entering filename into a search engine, or try UCSB map library or UCB map library
   (c) Horizontal reference imagery, e.g. NAIP – must be orthorectified and georeferenced.
      i. Cal Atlas has NAIP, GIF has a shapefile of the key to the names of the tiles
      ii. Note: one trick when there are not many good ground control points (e.g. heavily and continuously forested locations), you can use a hillshade made from the DEM to locate canyons and other topographical features which may work as a horizontal referece.
   (d) Vertical reference imagery – DEM, 10m is better than 30-m
      i. Cal Atlas has 10-m DEMs for California, and a key for these as well.
2. Pre-process imagery
   (a) Clip reference imagery using ArcGIS (but make sure your DEM and horizontal reference definitely cover all the area you need for the historical images; making the DEM bigger than necessary is okay but it can't be too small or orthorectification won't work)
   (b) If you will mosaic the historical images, crop the outer edges of the photo with fiduciary marks and where the image is very distorted
   (c) Set up a file system with folders for originals, pre-processed files, orthorectified files, mosaiced files, etc. Otherwise use a very clear file naming system – you will end up with many, many files!
   (d) Tip: try to use the same format for all the raster files (DEM, NAIP, etc) – Erdas Imagine (.img) or ESRI GRID, for example. LPS can read either, but you have to be constantly switching the 'file type' back and forth.
3. Start and set up LPS
   (a) Start menu>AllPrograms>Leica Geosystems>Leica Photogrammetry Suite 9.1> Leica Photogrammetry Suite 9.1
   (b) Set file destinations: ERDAS IMAGINE window>Session>Preferences; then Category>User Interface & Session
      i. Set Default Data Directory to the folder where your images to be orthorectified are
      ii. Set Default Output Directory to the folder where you want your orthorectified files to end up
      iii. User Save
4. Set up a new Blockfile: Project Manager>File>New
   (a) Set up camera
      i. Model Setup>Geometric Model Category>Camera
      ii. Model Setup>Geometric Model>Non-Metric Camera>OK
   (b) Set up horizontal and vertical references according to the geographical metadata in your

reference imagery (e.g. NAIP, DEM from USGS)

i. Block Property Setup>Reference Coordinate System:Horizontal>Set
ii. Projection Chooser>Standard

e.g. Categories: UTM GRS 1980 NAD83 North
e.g. Projection: UTM Zone 10 (For Northern California) or UTM Zone 11 (For Southern California)

iii. Block Property Setup>Reference Coordinate System:Vertical>Set…
iv. Elevation Info Chooser:

e.g. Spheroid Name: GRS 1980
e.g. Datum Name: NAD83, Elevation Units: meters. Elevation Type: height

v. Block Property Setup>Next

(c) Set Frame (image) specific information: use default values EXCEPT (use information according to your flight metadata):
  i. Average Flying Height (meters): 2500
  ii. Edit Camera>Focal Length (mm): 209.55 (for 8.25 inch focal length, use 152.4 mm for 6 inch focal length)

5. Import historical aerial photos
  (a) Edit>Add Frame
    i. Image File Name: navigate to your historical photo files. You can select multiple by holding SHIFT.
    ii. Change the ImageID to match the flight line/photo number (or some other more useful code than the default).
  (b) Edit>Compute Pyramid Layers
    i. Generate Pyramid Layers for>All Images without Pyramids
  (c) Edit>Frame Editor
    i. Non-Metric Camera Frame Editor>Interior Orientation>Pixel size in x direction (microns): 42.33 (for 600 ppi scans)
    ii. Non-Metric Camera Frame Editor>Interior Orientation>Pixel size in y direction (microns): 42.33 (for 600 ppi scans)
    iii. Check "Apply to all Frames" or hit Next button until it is grayed out
6. Collecting Control Points (points (a) through (e) below are buttons)
  (a) Set up Point collection tool:
    i. Edit>Point Measurement…>Classic Point Measurement Tool
    ii. Set automatic Z updating
    iii. Set automatic x,y drive
    iv. Set Vertical Reference
      A. Vertical Reference Source >Vertical Reference Source> DEM
      B. Set pull down menu: 'Find DEM', navigate to appropriate source (Navigate to and set DEM, Files of Type: GRID, .img)
      C. Click OK
    v. Set Horizontal Reference
      A. Horizontal Reference>GCP Reference Source>Check Image Layer, then OK, and set NAIP
    vi. tips: save often! Create a new version of the blockfile after collecting 30 points
  (b) Collect control points for first image

i. Check "Use viewer as reference" (left display will show the horizontal reference photo)
ii. in the right-hand viewer, choose the first photo to be georeferenced. Choose one for which it will be easy to locate control points.
iii. Use the 'add' button to create a new control point. Tip: make sure the point you want to set is highlighted in the table. Even clicking the 'add' button may not automatically select the new point in the table.
iv. Use the "+" button to locate the highlighted control point in one of the viewers. You will have to click it again to locate it in the other viewer. Remeber, make sure you have clicked the "add" button before you use the "+" button, or you will move the highlighted control point, which will be the last one you located!
v. Hint: good control points include road intersections or unique curves, buildings, rock outcrops, and clumps of trees (not typically individual trees, but clumps in a particular pattern). Zoom in close enough to place the points in the center of the tree or the edge of the road.
vi. After 3 control points are collected, the automatic x,y drive will activate. You can tell how well your control points are doing by how accurate the x,y drive's guess is: you place the point in one viewer, and you see approximately the same location in the other viewer before you've placed the point.
vii. You can click and drag the control points if you need to correct them.
viii. After adding 15-20 control points, you can move on to the next image. Points should be evenly distributed throughout the image as much as possible.

(c) Collecting points for the second (and later) images

i. Uncheck "Use viewer as reference" button.
ii. Add the second image to the right viewer
iii. add the first image (the one you just finished collecting control points for) to the left viewer
iv. select a point in the left viewer and locate that point in the right. Select the point in the table of points, then click the "+" button, and locate the point in the new image (the right image) Hint: here you should NOT be using the "add" button.
v. Use the table of points to make sure you've located all the points that the two images have in common. Hint: when you are done with this image pair, leave a point selected that does not lie off the edge of one of the images. This makes it hard to locate where you are.
vi. Capture points in common between the two images even if you do not have the horizontal reference point for them.
vii. Register the new tie points by checking "Use viewer as reference". Locate the new points from the historical image in the modern horizontal reference.
viii. Collect new points for the new historical image which cover a new area of the horizontal reference (not overlapping with the first historical image)
ix. Continue to do this until you have collected points for all images you intend to georegister (at least 3)
x. Save this version of your blockfile, use a new version for the next step.

7. Auto-generation of tie points

(a) Change point type to "Full" and Usage to "Control"

i. Right click on a number in the 'Point#' column>Select All
ii. Right click on 'None' in the 'Type' column, change to 'Full'
iii. Right click on 'Tie' in the 'Usage' column, change to 'Control'

(b) Set automatic tie properties: keep all defaults except:
i. Automatic Tie Point Generation Properties>Distribution>Intended Number of Points/Image>40
ii. Click the Run button

(c) New points are Type: None and Usage: Tie
(d) check a few of the points for accuracy

8. Triangulation
(a) Open the "Aerial Triangulation" options dialog box
(b) Change or confirm the following settings:
i. General>Check on Compute Accuracy for Unknowns
ii. Advanced Options>Check on Use Image Observations of Check Points in Triangulation
iii. Advanced Options>Blunder Checking Model>Advanced robust checking

(c) Update Z points
i. Select all points: Right click on a number in the 'Point#' column>Select All

(d) Run triangulation & review results, and repeat as necessary
i. Click the cyan triangle to run triangulation
ii. When the Triangulation summary window appears, click the "Review" button
iii. Sort points in descending order by Total RMSE: Right click a cell in the 'Row #' column>Sort…>Total RMSE, Descending
iv. Check on points with RMSE above 50 or 100
v. You can deactivate these points and then click "Re-Run Triangulation", but try not to deactivate too many points – check them in the point collection tool to see if you can locate them better. Especially try not to remove the manually-collected points.
vi. Make sure to check both the "Ground Points" and "Image Points" for high RMSE
vii. You will likely re-reun the triangulation multiple times until you no longer have points with high RMSE
viii. Try to get your total RMSE less than 5, but if it's greater than 20 you really need to go check your control and tie points.

(e) Click the "Accept" button. (If you forget this, triangulation won't take effect and ortho-resampling in the next step will fail.)
(f) Save the Error report. In particular the total RMSE is important for reporting.

9. Ortho-resampling
(a) Exit the point collection tool, and click the "Start Ortho Resampling Process" button (the icon looks like the old Microsoft Windows icon) and set these settings:
i. General>Output File Name: (*.img) -Update file name and output location (if necessary)
ii. General>DTM Source>DEM
iii. General> Output Cell Sizes -round X & Y cell sizes up
iv. Advanced>Check Ignore Value 0.00000
v. Advanced>Cubic Convolution

(b) Add the images one at a time (Don't use "Add multiple")

(c) Click "OK" (don't use "Batch")
(d) Check resampled images in ArcMap or ERDAS' Viewer
  i. In ERDAS viewer, you can overlay the orthorectified image with the horizontal reference, and use the "Swipe" utility to see if features line up well.
  ii. SFEI's definitions of "Location Certainty":

Typical horizontal offset for a flat area:	≤5m	(=Loc_Cert: Extra High)
Maximum horizontal offset for a flat area:	≤15m	(=Loc_Cert: Extra High)
Typical horizontal offset for a hilly area:	≤15m	(=Loc_Cert: Extra High)
Maximum horizontal offset for a hilly area:	≤50m	(=Loc_Cert: High)

10. Mosaicing
(a) ArcGIS and ERDAS both have mosaicing functions.
  i. ERDAS will treat 0 values as transparent, so you will need to adjust your raster
  ii. ArcGIS has a mosaic dataset data type, and can also create mosaics with many options for how to blend edges. Preferred.
(b) Regardless of whether you mosaic your orthorectified images, you should keep the individual images for analysis as well.

Note that it is best to do triangulation and ortho-resampling on only one flightline at a time.