Playbook Table of Contents

Executive Summary .................................................................................................................. iii
Overview ................................................................................................................................. 1
Purpose/Objectives .................................................................................................................. 2
Product Descriptions .............................................................................................................. 3
   Airborne Imagery and Metadata ......................................................................................... 3
   Monterey Flight Plan ............................................................................................................ 3
Data Overview ........................................................................................................................ 5
Software Required .................................................................................................................. 7
   DeltaPan ............................................................................................................................... 7
   F-Planar ............................................................................................................................... 9
Instructions .............................................................................................................................. 10
   Flight Planning .................................................................................................................... 10
   Baseline Image Set .............................................................................................................. 10
Rapid Change Detection, Reporting, and Dissemination ....................................................... 11
   Alternative Approach for Change Detection ...................................................................... 11
ArcGIS Implementation Instructions ..................................................................................... 12
Playbook Directory ................................................................................................................ 19
References .............................................................................................................................. 19

Appendix A: Additional Notes: Instructions for Imagery Providers
   Tasked with Collecting Repeat-Pass Imagery ................................................................. A-1

Appendix B. RELIEF After Action Report ................................................................. B-1

Appendix C. DeltaPan Change Detection User’s Guide ............................................... C-1

Appendix D. F-Planar User’s Guide .................................................................................. D-1
Executive Summary

This playbook provides a description of selected remote sensing imagery and other datasets and products prepared by the NPS/DHS Earthquake Response Project to provide baseline geographic information about critical infrastructural features within the County and City of Monterey. These data are provided on a USB disk drive compatible with MS Windows systems for use by 1st responders and emergency managers as part of Emergency Operations Center resources. This playbook describes the contributions of the Center for Earth Systems Analysis (CESAR) at San Diego State University (SDSU) to the project in the form of refined procedures, tools, and approaches to the collection and analysis of high spatial resolution multitemporal airborne imagery for the purpose of rapidly identifying damage to critical infrastructure in the event of an earthquake in California. The primary purpose of this portion of the project was to advance the capability and demonstrate the effectiveness of the approach for rapid damage assessment.

The objective of this playbook is to introduce first responders and emergency managers to the concepts and tools associated with specialized image collection and processing techniques and rapid change detection for damage assessment. The approach requires specialized equipment and knowledge; therefore, this playbook should be studied and pre-event preparations completed as soon as possible in order to assemble the equipment and understand the full sequence of procedures in preparation for an earthquake or other hazardous event.

For the Monterey area, baseline imagery with 0.5 ft spatial resolution was collected on 12-13 August 2012 for critical infrastructure features identified by the County and City of Monterey. SDSU researchers collaborated with NEOS Ltd. for all aircraft operations and baseline data collection for Monterey. In addition, SDSU collaborated with TerraPan Labs for the creation of a web-based tool for automated image co-registration (alignment of multitemporal images) and georeferencing, automated change detection, change visualization and assessment reporting, and web-based dissemination to a common operating picture. Along with individual image frames prepared and provided for rapid post-earthquake damage assessment, NEOS Ltd. provided an uncontrolled image mosaic for the core urban area of Monterey imaged in August.

The Playbook Directory near the end of this document shows the NPS Earthquake Response Playbook sequence to help put this Playbook into perspective and give an overview of products resulting from this research and some aspects of practical implementation. The content of each Playbook is briefly described; however, users are referred to the specific named and numbered Playbooks for full product descriptions. These provide additional detailed product information, instructions on how to separately utilize the individual products, and how to combine them into an integrated system for improved earthquake response.
Overview

Sponsored by the Department of Homeland Security (DHS) Science & Technology Directorate, the Remote Sensing Center (RSC) at the Naval Postgraduate School (NPS) has developed a series of instructional playbooks designed to assist 1st responders and emergency managers with the use of remote sensing technology for improving earthquake response. This playbook (Playbook #: RSC-04A) describes the use of airborne multitemporal imagery for detailed damage assessment.

Many post-hazard emergency response assessments can benefit greatly from access to high spatial resolution airborne imagery collected and provided to emergency response personnel in near real-time immediately following the disaster. Identification of damage present within post-disaster imagery using visual or in particular semi-automated image analysis, however, can be complicated due to the lack of information about the appearance and characteristics of buildings/infrastructure prior to the disaster (i.e., is the current state different than before). As part of a pilot project funded by the Department of Homeland Security and conducted by the Naval Postgraduate School Remote Sensing Center, researchers with the Center for Earth Systems Analysis (CESAR) at San Diego State University (SDSU) refined procedures, developed tools, and demonstrated the collection and analysis of multitemporal airborne imagery for the purpose of rapidly identifying damage to critical infrastructure in the event of an earthquake in California. The primary purpose of the project was to advance the capability and demonstrate the effectiveness of the approach for rapid damage assessment. Basic capabilities and instructions are described in the main Playbook. Further methods refinement, tool development, and implementation are required for this approach to be fully operational. Some of these are described in Appendix A.

A demonstration of the rapid damage/change assessment approach took place 15-16 August 2012 at Camp Roberts, CA as part of the RELIEF event. The after action report (AAR) for this effort at RELIEF is provided in Appendix B. In addition to the RELIEF demonstration, SDSU researchers and partner NEOS Ltd. collected baseline imagery for the County and City of Monterey to facilitate implementation of these techniques and tools in the event of a major disaster such as an earthquake. Baseline imagery with 0.5 ft spatial resolution was collected on 12-13 August 2012 for prioritized critical infrastructure features identified by the County and City of Monterey.

The core technology facilitating rapid and precise image alignment for near real-time change detection involves returning an aircraft to the same imaging stations in the sky (both horizontally and vertically) over time so that viewing geometries are matched between multitemporal images. The approach for collecting and spatially co-registering multitemporal airborne imagery with high precision is referred to as frame center (FC) matching (Stow et al., 2003; Coulter et al., 2003, Coulter et al., 2005; Coulter et al., 2008; Coulter et al., 2012). When image frames are captured from exactly the same imaging station in the sky between acquisitions, simple techniques may be used to achieve precise alignment between corresponding multitemporal image frames. Matching image stations repeatedly over time is most effectively accomplished through the use of global positioning systems (GPS) to aid aircraft navigation and automated camera triggering at predetermined imaging stations.
Six critical elements of an end-to-end system for rapid aerial image-based assessment are: (1) pre-event planning and baseline data preparation, (2) deployment of an airborne imaging system to capture images at planned image station locations, (3) transmission of image data from airborne platforms to ground-based command and control centers (when possible), (4) precise registration (alignment) of time sequential images so that they may be compared, (5) detection of changes evident within airborne images, and (6) dissemination of derived information to first responders. SDSU researchers collaborated with NEOS Ltd. for all aircraft operations and baseline data collection for Monterey. In addition, SDSU collaborated with TerraPan Labs for the creation of a web-based tool for automated image co-registration (alignment of multitemporal images) and georeferencing, automated change detection, change visualization and assessment reporting, and web-based dissemination to a common operating picture. Wireless data transmission from the aircraft to the ground was not demonstrated for this project. Regarding our commercial partners, NEOS Ltd. utilized commercial-off-the-shelf (COTS) technologies and professional “know-how” to provide advanced and detailed remote sensing information at reduced costs (http://neosltd.com). TerraPan Labs offers a range of mapping and spatial analysis services in addition to sensors and supporting software products (http://www.terrapanlabs.com).

Implementation of the rapid, multiday airborne image assessment approach will require: 1) baseline image sets already collected and provided as part of this project; 2) coordination with an aerial survey/imaging company that has an aircraft ready for rapid deployment as well as a frame-array digital camera system, a capability for GPS-based triggering of the camera, and pre-loaded imaging station waypoints (defining horizontal position and altitude for each image, along pre-defined flight lines), and 3) licensing and use of the web-based tool for automated image co-registration, georeferencing, change detection, change visualization and assessment reporting, and web-based change/damage information dissemination (Appendix C). Air-to-ground wireless data transfer capabilities may be utilized to reduce time associated with image data delivery.

In addition to individual image frames prepared and provided for rapid post-earthquake damage assessment, NEOS Ltd. provided an uncontrolled image mosaic for the core urban area of Monterey imaged in August. This mosaic is ready to use for wide area visual image analysis, as well as for incorporation into GIS data bases.

**Purpose/Objectives**

The objective of this playbook is to introduce County and City of Monterey personnel to the concepts and tools associated with frame center (FC) matched image collection and rapid change detection for damage assessment. This playbook will be useful to emergency response personnel interested in using this specialized method for airborne image collection, pre-processing, change detection and reporting, and dissemination in support of post-disaster damage assessment. The approach requires specialized equipment and knowledge; therefore, this playbook should be studied and pre-event preparations completed as soon as possible in order to assemble the equipment and
understand the full sequence of procedures in preparation for an earthquake or other hazardous event.

There are several components and steps associated with the approach for rapid, high spatial resolution image assessment of post-earthquake damage. These include: pre-event flight planning; baseline image set collection and preparation; aircraft; camera; GPS-based navigation and camera triggering system; and a web-based tool for automated image co-registration, georeferencing, change detection, change visualization and assessment reporting, and dissemination to a common operating picture. Each of these components is listed where appropriate as sub-sections of hardware required, data required, and software required. In addition, further information about software products for flight planning and web-based analysis is provided in the included appendices.

Product Descriptions

Airborne Imagery and Metadata
SDSU in collaboration with NEOS Ltd. collected airborne imagery on 12-13 August 2012 for critical infrastructure sites in the County and City of Monterey. This imagery serves as baseline imagery against which future post-disaster imagery may be compared. Following image collection, SDSU georeferenced the individual airborne image frames (associating real-world coordinates to each image pixel) so that other imagery and GIS data sets may be overlain and locations of ground features extracted. These georeferenced image frames as well as their image station coordinates (and other metadata) are included with the delivery of this playbook to the County and City of Monterey. The image station coordinates from which each image frame was captured are required to collect post-disaster imagery from the same camera stations and to match this imagery to the already collected baseline imagery for the purposes of damage assessment. SDSU also delivered the original, non-georeferenced images as they were captured by the Canon camera; these images are utilized with the DeltaPan tool which simultaneously co-registers and georeferences corresponding multitemporal image frames.

In addition to the Monterey imagery, SDSU collected repeat-pass airborne imagery on 15-16 August 2012 for the NPS RSC demonstration at the RELIEF exercise at Camp Roberts, California. A single flight line was flown several times and at two different altitudes on both days. The flight line was flown at 2650 ft MSL (2000 ft above ground level) for 3-inch spatial resolution imagery, and at 4650 ft MSL (4000 ft above ground level) for 6-inch spatial resolution imagery. These multitemporal images were used at RELIEF to demonstrate rapid post-disaster assessment of change using high spatial resolution imagery. All Monterey data collected by SDSU are found on the distribution disk drive at: "Monterey_Image_Baseline_Data\Monterey_Peninsula_Data-08_Aerial_Photography(SDSU)".

Monterey Flight Plan
The baseline critical infrastructure imagery for Monterey were collected along several flight lines at predetermined camera stations. All images were collected from an altitude of 4500 ft MSL. The flight lines are shown in Figure 1. Parallel flight lines were utilized
to collect images for the core urban area of Monterey (which had a high number/density of critical infrastructure features) and for the Moss Landing power plant. Individual/isolated features such as bridges were imaged using unique flight lines for each feature. The delivered spreadsheet:

\Monterey_Image_Baseline_Data\Monterey_Peninsula_Data-08_Aerial_Photography(SDSU)\Monterey_image_collection_and_critical_infrastructure_information\Aerial_Imagery_Metadata.xlsx

provides image station coordinates and associated flight line numbers for individual imaging stations associated with the flight lines shown in Figure 1. These imaging station coordinates may be revisited for future post-earthquake image collection in order to facilitate automated and detailed change detection using frame center matched images.

Figure 1. Monterey area flight planned lines (shown in blue over lightened National Agriculture Imaging Program mosaic). Blocks with parallel flight lines were used for the downtown Monterey area as well as the Moss Landing power plant. Individual flight
lines were used for bridges and other isolated critical infrastructure features of interest. Some lines were not imaged due to cloud cover.

**Data Overview**

Delivered image data and image metadata products are contained within named subdirectories in the directory

```
\Monterey_Image_Baseline_Data\Monterey_Peninsula_Data-08_Aerial_Photography(SDSU)
```

and include:

1. Monterey and RELIEF airborne image frames as they were captured by the Canon 5D Mark II camera (TIFF and JPEG format) with no georeferencing. The Monterey folder name within the main directory is:

   "Monterey_image_frames_raw_not_georeferenced"

   For the "RELIEF" exercise, the image data are in the directory:

   \Monterey_Image_Baseline_Data\Obispo-Monterey_Counties_Data-09_NPS_Camp_Roberts_Data

2. Monterey georeferenced airborne image frames for selected critical infrastructure features (GeoTIFF format). See Figure 2 and Figure 3 with georeferenced image frames and DOQQ backdrop. The folder name is

   "Monterey_image_frames_georeferenced"
Figure 2. Example of an individual georeferenced SDSU/NEOS image frame displayed on top of a lightened National Agriculture Imaging Program (NAIP) orthorectified mosaic. The spatial resolution of the SDSU/NEOS image is 0.5 ft.
Figure 3. The locations of the georeferenced image frames are shown on a lightened National Agriculture Imaging Program (NAIP) orthorectified mosaic. No images were collected for some flight lines shown in Figure 1 due to complete cloud cover present at the time of imaging.

4) Spreadsheets for Monterey georeferenced image frames that link critical infrastructure features with photo names are located at:

Monterey_Image_Baseline_Data\Monterey_Peninsula_Data-08_Aerial_Photography(SDSU)\Monterey_image_collection_and_critical_infrastructure_information\Critical_infrastructure_information_from_Monterey

5) A spreadsheet for image sets collected at RELIEF that provides approximate aircraft/camera positions at the time of exposure for each image frame (image_collection_information_Aug_15_and_16_at_RELIEF.xlsx). This file is in the folder:

Monterey_Image_Baseline_Data\Obispo-Monterey_Counties_Data-09_NPS_Camp_Roberts_Data\RELIEF_image_collection_information

6) Selected Monterey and RELIEF image-based change detection products, and aerial images utilized to generate these products (Figure 4). The folder names are:

\Monterey_Image_Baseline_Data\Monterey_Peninsula_Data-08_Aerial_Photography(SDSU)\Monterey_example_change_detection_products

and

\Monterey_Image_Baseline_Data\Obispo-Monterey_Counties_Data-09_NPS_Camp_Roberts_Data\RELIEF_example_change_detection_products

"Monterey_example_change_detection_products" and "RELIEF_example_change_detection_products."

7) Monterey image mosaic created by NEOS Ltd (Figure 5). This is an uncontrolled image mosaic provided by NEOS Ltd. There may be offsets between image locations and ground locations because no ground control was used to produce the image. The folder name is:

\Monterey_Image_Baseline_Data\Monterey_Peninsula_Data-08_Aerial_Photography(SDSU)\Monterey_image_mosaics_courtesy_of_NEOS

Software Required

DeltaPan
As part of the SDSU team, Terrapan Labs LLC integrated automated image co-registration procedures and automated change detection procedures on top of an online tool called "pan.io." The tool referred to as DeltaPan enables data visualization, processing, and distribution through a cloud based infrastructure. The developed
software tool extended pan.io functionality to enable rapid visualization of multitemporal imagery, processing and visualization of change detection products, change feature selection, documentation of an analyst’s interpretation of the change, and web-based dissemination of identified change features and notation to a common operating picture. A computer with internet access and an HTML 5 compliant web browser (Google Chrome is recommended) is all that is required to operate the DeltaPan web-based pre-processing, analysis, and dissemination system, making it accessible by distributed analysts. The prototype change detection and visualization tool is available to anyone interested in exploring the images and derived products associated with the August 2012 Monterey and Camp Roberts image collections (see the instructions section of this playbook).
Figure 4. Example imagery and change detection product from Monterey, including: a) Time=1 image, b) Time=2 image, and c) detected changes shown in black on a lightened Time=1 image. Vehicles that moved between Time=1 and Time=2 are detected as change.

Figure 5. Example NEOS mosaic of 0.5 ft spatial resolution airborne imagery collected 12 August 2012.

**F-Planar**

In addition to the creating the change detection and visualization tool leveraging pan.io technology, Terrapan Labs LLC enhanced their rapid flight planning tool, “F-Planar”, to enable the derivation and output of individual image station coordinates for each photo in order to facilitate FC matched image acquisition. In addition, F-Planar was updated to allow the ingestion of previous acquisition locations to enable the generation of Time=2 image station matched flight plans in a variety of standard formats (e.g., TrackAir, GPX, KML, etc.) This software may be used to create new flight plans based on desired image characteristics and a sensor model. However, the flight plan for imaging Monterey critical infrastructure already exists and specific image station coordinates and associated flight line numbers are provided in the spreadsheet described above (Aerial_Imagery_Metadata.xlsx). Further information about the F-Planar software tool and accessing it is provided in Appendix D.
Instructions

Flight Planning
The F-Planar tool is useful for creating new flight plans or for updating existing flight plans. The flight plan for Monterey baseline and repeat pass imaging, however, has already been created and use of F-Planar is not required in order to repeat the image collection that SDSU and NEOS performed on 12-13 August 2012. The F-Planar user interface is shown in Figure 6. Further information about F-Planar is provided in Appendix D.

Baseline Image Sets
Baseline image frames and metadata are deliverable products provided by SDSU and partners that are required in order to perform detailed change detection. These image frames and associated metadata must be available in order to collect and geometrically align post-earthquake image frames to baseline (pre-earthquake) image frames. Examples are shown in Figure 2 and Figure 3. Data are included on the USB project drive in the directories:

\Monterey_Image_Baseline_Data\Monterey_Peninsula_Data-08_Aerial_Photography(SDSU)

And

\Monterey_Image_Baseline_Data\Obispo-Monterey_Counties_Data-09_NPS_Camp_Roberts_Data
Rapid Change Detection, Reporting, and Dissemination using DeltaPan Prototype

The DeltaPan prototype change detection tool based on TerraPan Labs’ Pan.io technology is used to ingest baseline and multitemporal repeat-pass images, co-register the images, perform change detection, visualize detected changes, select change features of interest, document the analyst’s interpretation of the change, and disseminate this information using the internet to a common operating picture.

The full DeltaPan prototype tool is not currently available for public use, but is described here to provide demonstration capabilities. To try DeltaPan with selected Monterey image sets for a demonstration of capabilities, use the Google Chrome web browser and go to http://pan.io/monterey. To try the DeltaPan tool with Camp Roberts image sets, use the Google Chrome web browser and go to http://pan.io/delta. The DeltaPan tool at each of these URLs is preloaded with repeat-pass imagery acquired for Monterey or the RELIEF exercise in August 2012. Using the Google Chrome web browser is recommended when accessing either DeltaPan URL listed above. For any questions regarding the DeltaPan tool, please contact TerraPan Labs LLC at info@terrapanlabs.com. For further information about the DeltaPan tool and accessing the demonstration datasets, see Appendix C.

Alternative Approach for Change Detection

The DeltaPan tool uses a change detection algorithm developed by the Center for Earth Systems Analysis at San Diego State University in order to perform change detection on a frame-by-frame basis. Use of the DeltaPan tool is beneficial because it provides more functionality than simply change detection, including: cloud-based processing, interactive adjustment of change detection parameters, the ability to select change features of interest and document an analyst interpretation of changes, and the ability to disseminate that information over the internet to a common operating picture. The change detection algorithm developed by SDSU may, however, be implemented using other appropriate software packages if that is desired. SDSU developed the algorithm using ERDAS Imagine’s Spatial Modeler, but it can also be implemented using other image processing systems, or ArcGIS. To facilitate this, details of SDSU’s change detection algorithm are schematically described here. The steps required to implement the algorithm with previously co-registered Time=1 and Time=2 image frames are:

1. mask Time=1 and Time=2 images so that only areas common to both have actual data values, and all other areas have digital number (DN) values of zero (i.e., background);
2. mask shadows from both the Time=1 and Time=2 images, setting shaded pixels to a value of zero (background). We used the below condition to identify pixels in shaded portions of the SDSU/NEOS images, where B1 indicates band 1 value, B2 indicates band 2 value, and B3 indicates band 3 value (this approach was derived through understanding of shadow effects in band ratio images and iterative testing);

\[
\text{shadow if } (((((B3/B2)+(B2/B1))-(B3/B1))*100)+100) < 196
\]
3. subtract the masked Time=1 image from the masked Time=2 image;
4. For each difference image pixel from step 3, compute the mean of band 1, band 2, and band 3 difference values; create an initial classification of change by thresholding the mean spectral difference image (from step 4), where change is detected if the mean spectral difference value is less than -50 DN or greater than 50 DN. SDSU indicated “change” with a raster value of one, and “no-change” with a raster value of zero; apply a majority filter to the classified change map from step 5, where a 5x5 window (i.e., kernel) is centered on each pixel and the resulting output value is the majority of the input values. This step operates on both “0” and “1” values, and adds change pixels where the majority is classified as change and removes change pixels where the majority is classified as no-change; apply a “clump” function that groups contiguous “change” pixels into unique sets (or clumps) based upon an 8-neighbor rule (where any neighboring pixel in eight directions may be considered contiguous); apply a “sieve” function that removes change pixel clumps that contain less than 50 contiguous pixels. This step removes isolated, small area changes that are likely noise or not of interest. With 6-inch spatial resolution imagery, this step removes features that are roughly less than 4 ft by 3 ft (assuming a rectangular shape). The product of the sieve function is the final change product.

**ArcGIS Implementation Instructions**

Operationally in ArcGIS, the following steps can be used as an alternative method for change detection comparable to the SDSU approach.

1. Create a subset of a common area of the time 1 and time 2 images.
2. Remove shadows (set as no data).
3. Subtract images to create change detection product.
4. Create mean.
5. Threshold image.
6. Apply a majority filter.
7. Region
8. Mask pixels that are noise.

**Step 1: Create a subset of a common area in the time 1 and time 2 images.**
- Open ArcMap and ArcCatalog by going to Start->All Programs->ArcGIS.
- Click the Add Data button, and navigate to:

    Monterey_Image_Baseline_Data\Monterey_Peninsula_Data-08_Aerial_Photography(SDSU)\Monterey_example_change_detection_products\ERDAS_IMG_Format_georeferenced

The images used for this example are: t1_4494_4513_georef.img -and- t2_4513_georef.img.

**NOTE:** these are referred to as “time1.img” and “time2.img” respectively below.
• In ArcCatalog, right click on a folder of your choice (preferably a folder on your local drive), and click New->Shapefile.

• In the Create New Shapefile window, give the new shapefile a name, and select the Feature Type to Polygon. Click the Edit button and select the coordinate system as NAD 1983 UTM Zone 10N.

• Add the new polygon to ArcMap. You can do this by clicking the Add Data button, or you can drag and drop the shapefile into the map extent.

• Open the Editor toolbar by going to Customize->Toolbars->Edit. The Editor toolbar may already be open.

• On the Editor toolbar click on Editor->Start Editing. In the Create Features window click on the polygon, and under Construction Tools click Rectangle. Draw a polygon over your area of interest. Make sure that this is a common area for both images.

• When you are satisfied with your shapefile, click Editor->Save Edits, then Editor->Stop Editing.

• In ArcCatalog, in the search window, type Clip (Data Management). Double click to open the tool.

• Select the time1.img for your input raster, the polygon from the last few steps for the Output Extent, and select create a file for the Output Raster Dataset. Make sure that the box for “Use Input Features for Clipping Geometry” is checked, and click OK. Repeat this step for the time2.img image.

• In ArcMap, select the shapefile and the two images, right click, and click Remove. Add the clipped images to the map.

Step 2: Remove shadows (set as no data).

• In ArcMap, zoom to an area where there is a shadow. Click Customize->Tools->Image Classification. On the Image Classification toolbar, click the Draw Polygon tool. Draw a polygon around the shadow. Double click to finish. Refer to Figure 7.
Figure 7: Training Sample Manager

- On the Image Classification toolbar, click the Training Sample Manager icon. In the Training Sample Manager window, select the class, and click the Show Statistics icon. You will need to reference the band 1 minimum, and the band 3 mean in the next step.

- In the Search window, type in Raster Calculator. Double click on the tool to open.

Figure 8: Input for Raster Calculator. This is used for shadow detection.
- In the Raster Calculator window use the following parameters for the input expression (refer to figure 8 for the parameters used for this example):

\[(\text{Image} \geq \text{Band 1 Minimum}) \& (\text{Image} \leq \text{Band 3 Mean})\]

- Select an output raster, and click OK.

- Repeat the last two steps for the second image.

- In the Search Window, search for the Set Null (Spatial Analyst) tool. Double click the tool to open.

- For the Input Conditional Raster select one of the shadows raters that were created in the last steps. The Expression should be: “Value = 1”, and the Input False Raster or Constant value is 0. Select an output raster and click OK. Refer to figure 9.

![Set Null Tool](image)

**Figure 9:** Set null tool with the correct input parameters.

- Repeat the last step on the second shadow raster.
• In the Search window, search for Extract by Mask, and open the tool.
• The Input Raster should be the original clipped raster, and the Input Raster or Feature Mask data should be the raster created in the last few steps. Select an output raster. Refer to figure 10. Click OK.

![Extract by Mask tool](image)

Figure 10: Extract by mask tool.

• Repeat the last step on the time 2 image.

**Step 3:**
• Open the Raster Calculator, and subtract the masked time1 image from the masked time 2 image. Expression should look similar to the following:

  "time1-clip-shadows-null-extract.img" - "time2-clip-shadows-null-extract.img"

Select an output raster, and click OK.

**Step 4:**
• In the Search Window, search for the Cell Statistics Tool. Double click to open.

• The Input Raster or Constant Value should be the raster created in step 3. Select an output raster, then make sure the Overlay Statistic is MEAN. Check the box for "Ignore NoData in calculations". Click OK. Refer to figure 11.
Figure 11: Cell Statistics tool.

Step 5:
- Open the Raster Calculator tool. Type in the following expression in the box:

  Image >= 40

  Where Image is the Raster created in step 4. Select an output raster, then click okay.

Step 6:
- In the Search Window, search for Focal Statistics (Spatial Analyst) tool. Double click to open.

- The Input Raster should be the raster from step 5. Select an output raster. Set the Neighborhood to be Rectangle, the Height and Width to be 5, and the Statistics Type to Majority. Check the box for “Ignore NoData in calculations”. Then click OK.

Step 7:
- In the Search Window, search for Region Group (Spatial Analyst). Double click to open the tool.

- The Input Raster should be the raster from step 6. Select an output raster (be sure to use the “.img” extension). Change the Number of Neighbors to Use to EIGHT, and the Zone Grouping Method to WITHIN. Click OK.
Step 8:

- Open the Set Null tool.

- The Input Conditional Raster should be the raster from step 7. The Expression is: “Value” < 50.

  The Input False or Constant Value should be set to 0. Select an output raster, and click okay.

The resulting raster represents areas of change. For this example, the only changed areas are where the cars have moved. This raster can be symbolized to be red (or a bright color), and overlain on a base image or map (Figure 12).

Figure 12: Final change detection product. Areas that are red suggest change.
Playbook Directory

This Playbook is one of a series of Playbooks designed to cover the technical breadth of the NPS-DHS Earthquake Response Project. Each Playbook describes one series of products and its use. These Playbooks can be printed, transmitted electronically as Portable Document Format (PDF) documents, or stored locally on existing emergency management networks, workstations, or mobile devices. The following summarizes the individual Playbooks developed as part of this project and available to emergency responders. See the listed Playbook for specifics and details.

Playbook#RSC-01: NPS-DHS Remote Sensing Project/Products Overview
Playbook documenting project and scope and big picture for other Playbooks

Playbook#RSC-02: Monterey County Baseline Products and Pre-Event Data Processing
Playbook documenting baseline data, preprocessing, use/analysis of basic products

Playbook#RSC-03: Monterey (City) Infrastructure Products
Critical Infrastructure data (location, description, pre-event photos, geolocated imagery frames and metadata)

Playbook#RSC-04A: Airborne Imagery Change Detection Products (SDSU)
Monterey baseline imagery of critical infrastructure, Camp Roberts imagery, and selected change detection example products. Full-Resolution NEOS imagery

Playbook#RSC-04B: NOAA Night Lights/Power Change Detection and Fire Detection Products
Night lights/power and fire detections (NOAA)

Playbook#RSC-05A: Social Networking Products (Ushahidi)
Ushahidi implementation and instructions for Monterey City/County

Playbook#RSC-05B: Social Networking Products (Twitter)
Twitter implementation and instructions for Monterey City/County

Playbook#RSC-06: Mobile Application Damage Assessment Product
Lighthouse damage assessment application download, install, configure, execute

Playbook#RSC-07: Post Event Processing Scenarios Products
LiDAR DEM, DSM, derived products, NAIP/WV-2 Change Detection Examples

Playbook#RSC-08: Soft and Hardcopy Output Products and Distribution
GeoPDF Products, Monterey Map Books, w/National Grid Index, PDF and Printed

Playbook#RSC-09: Common Operating Picture (COP) Products
Sensor Island Common Operating Picture, UICDS to WebEOC Link

Playbook#RSC-10: Systems Integration, Transition, and Training
Hardware/Software Installation Details, Coordination, and Integration
References


Appendix A: Additional Notes: Instructions for Imagery Providers Tasked with Collecting Repeat-Pass Imagery

Hardware Required
Hardware required include: 1) an aircraft, 2) a digital camera system, and 3) a GPS-based navigation and camera triggering system, and 4) a laptop computer for operating the GPS-based navigation and camera triggering system. None of these hardware components are provided.

Aircraft
The aircraft platform that SDSU utilizes for image collection is a low-cost FAA certified light aircraft operated by NEOS Ltd. This aircraft is agile and can be operated with short takeoff and landing distances in the event that local airfields are damaged. The primary consideration for the aircraft is that a camera system can be mounted in or on the aircraft for image capture. Example NEOS aircraft are shown in A-1.

Camera
The digital camera system utilized for rapid damage assessment may be a commercial-off-the-shelf (COTS) camera. For the Monterey baseline imagery and the demonstration at RELIEF, SDSU utilized a Canon 5D Mark II 21 MP camera with a 50 mm lens. Ideally, future image sets that are to be compared to this baseline data set will have similar hardware characteristics (e.g., CCD and lens) so that multi-date image characteristics are as comparable as possible. The Canon 5D Mark II camera is shown in A-2.
GPS-based Aircraft Navigation and Camera Triggering
For GPS-based aircraft navigation and camera triggering, SDSU utilized a NanoTrack system produced by Lead’Air Inc (A-3). This system includes a black box machine that coordinates communication between a GPS receiver, a laptop computer (with specialized software named Tracker for operating the Nanotrack), the camera system, and an optional pilot display. The Tracker software enables an operator to create and/or load predetermined flight lines and waypoints, and is used in conjunction with the Nanotrack system to aid navigation along defined flight lines and trigger the camera during flight at the predetermined imaging stations (and to repeat this over time).

Computers
For the Monterey and RELIEF imaging efforts, SDSU utilized a Dell laptop running Windows 7 operating system to interface with the NanoTrack and collect imagery at predetermined imaging stations.
Data Required
Data required in order to collect post-earthquake imagery from the same image station positions as the baseline imagery are described above in the Data Overview section. These data include camera station positions (horizontal positions as well as altitude) and associated flight line numbers for critical infrastructure features imaged in August 2012. These are provided in an Excel spreadsheet and listed individually for each critical infrastructure feature of interest. Metadata for each image frame include collection date, image names, altitude, heading, and photo position latitude and longitude. The spreadsheet file name is “Aerial_Imagery_Metadata.xlsx” in the directory:
\Monterey_Image_Baseline_Data\Monterey_Peninsula_Data-08_Aerial_Photography(SDSU)\Monterey_image_collection_and_critical_infrastructure_information

Software Required

GPS-based Navigation and Camera Triggering Software
In addition to the F-Planar and DeltaPan software products, software is required to operate the GPS-based navigation and camera triggering system. We used the NanoTrack hardware system by Lead’Air. The software that comes with this system is called Tracker (A-4). Tracker facilitates navigation of the aircraft down predetermined flight paths, triggering of the camera at predetermined imaging stations, and other supporting information (such as velocity, distance/time to next imaging station, etc.). The Tracker software is not provided.

Figure A-4. Tracker software by Lead’Air. The software is in “heads-up” mode, preparing to collect multiple images along a flight line as the aircraft approaches the flight line.
Instructions

Replication of Baseline Image Datasets for Precise Damage Assessment
Following the occurrence of an earthquake, Monterey emergency response agencies have the option to contact NEOS, Ltd (http://neosltd.com) to conduct repeat-pass imaging using the same or similar platforms, cameras and triggering systems. This would enable the most precise change detection products to be generated. The transit time from NEOS aircraft operations in Temecula, CA to Monterey is approximately four hours.

Aircraft, Camera, and GPS-based Navigation and Camera Triggering
Any aircraft may be used to return a camera to imaging stations associated with the baseline image collection. Advantages of a light aircraft such as the NEOS aircraft utilized to collect baseline imagery include low cost, short take-off and landing distances (in case the regional airport runway is damaged), and slow velocity image acquisitions which likely helps a pilot to more precisely match previous flight lines (or at least make flight path corrections in less distance).

We anticipate that any frame array camera may be used to collect post-earthquake imagery. However, in order to match the footprint (or ground coverage) and spatial resolution of the baseline imagery, we recommend using a camera with at least 21MB imaging array size and similar focal length as with the baseline image collection. The baseline image collection utilized a Canon 5D Mark II 21 MP DSLR camera with a 50 mm fixed focal length.

GPS-based navigation and camera triggering may be performed using any system that offers this capability and is integrated with the camera to be used. Integration with the camera system is required so that the system can fire the camera automatically when baseline image stations are passed during the post-earthquake flight.

Repeat-pass Image Collection
Repeat-pass image collection requires precision flying with the aid of the GPS-based navigation and camera triggering system. The NanoTrack that we used provides a display on a laptop or tablet screen that helps the pilot to match altitude and horizontal position along the flight path. If the aircraft deviates from the pre-planned flight path (which is defined by the locations of the predetermined imaging stations), then deviation indicators provide feedback to help the pilot return the planned flight path. Examples of the pilot display are provided in Figure A-4.

Pairing Post-earthquake Imagery with Baseline Imagery
Baseline and post-earthquake (or other disaster) imagery may be paired for change detection using flight line and camera station number information provided with the baseline imagery and repeated for the post-earthquake imagery. This is necessary to begin automated co-registration, change detection, and analysis procedures.
Appendix B: RELIEF After Action Report

JIFX/RELIEF Experiment Number (X-00):

B-11

Experiment Title:

Rapid, High Spatial Resolution Image Assessment of Post-Earthquake Damage

Organization:

San Diego State University Center for Earth Systems Analysis Research (CESAR), TerraPan Labs LLC, and NEOS Ltd. This experiment is part of the Naval Postgraduate School (NPS) - Remote Sensing Center (RSC) Earthquake Response Exercise.

Experiment Lead/Point of Contact:

The experiment lead is Professor Douglas A. Stow, Dept. of Geography, San Diego State University. Fred Kruse is the Naval Postgraduate School point of contact.

Quantitative Results:

Our experiment integrated with several other NPS RSC earthquake response exercises and demonstrated rapid and automated change detection with airborne imagery as part of a post-earthquake disaster response scenario. Airborne imagery captured by a digital color camera mounted on a NEOS Ltd. light sport aircraft platform and resultant change detection products were transferred in electronic form and integrated into the RSC earthquake response system. A single flight line was delineated across the axis of the cantonments area of Camp Roberts and a swath covered by three overlapping images was imaged multiple times on both August 15th and 16th (Figure 1). Each day, the aircraft flew a single flight line six times collecting 3 inch spatial resolution imagery, and three times collecting 6 inch spatial resolution digital color imagery. Three images were collected on each imaging pass, with 100 m spacing between them along the flight line. After the completion of each Imaging pass by the aircraft, participants on the ground at the cantonments site moved several targets to simulate changes, including boxes, tarps, canopies, and strips of strapping and duct tape.

When imaging was complete each morning, the aircraft landed at Paso Robles airport and the digital images and supporting metadata files were delivered to the McMillan Airfield by ground vehicle. Upon arrival at the RELIEF event, the images and associated information about aircraft position and heading at the time of image acquisition were input into an automated workflow which included automated image co-registration (using an algorithm developed and coded from scratch by SDSU/TerraPan participants) and automated change detection (also developed by SDSU/TerraPan participants).
Of the images collected on Wednesday August 15th, 10 pairs of images were found by the automated processing routine to be within a strict 1 m Euclidean distance between imaging stations, and these images were automatically co-registered as the next step in the processing pipeline. Of these 10 pairs, three were not co-registered with sufficient accuracy to perform detailed changed detection as determined by visual inspection in the web-based visualization and analysis tool. This likely resulted from inaccuracy in the results of a student generated automated point matching routine. On the second day, 16 images were found to match within a 1 m threshold. Four of these images were co-registered poorly by the automated co-registration routine, but the remainder were visually accurate, with many seemingly within 2-3 pixel registration accuracy.

Since the same area of ground was imaged by all six passes, we focused on a pair of images for each day that were co-registered within 2 pixel accuracy, selected by quick visual inspection in the web-based viewer (Figures 2-5). On the first day, a total of eight aggregate features changed. Two of these features were not detected. A pile of white boxes, which was stacked in the first frame and knocked down in the second time frame, was not detected likely due to similarity with the bright soil background. Likewise, a person with a low profile was not detected. Some small features such as boxes and peoples shadows were only partially detected, while large changes such as the movement of a car, rotation of a canopy, and slight movement of a blue tarp were reliably detected. Three false detections occurred where shadows moved substantially were highlighted with the default parameters for the change analysis algorithm.

For the Thursday August 16th mission, 10 changes were staged between each pass, for the selected pair of images. All but two of the changes were detected. One was a person that appeared in the frame, and the second was a small teal tarp that was moved. With default parameters on the change analysis algorithm (the parameters are interactively adjustable as part of the demonstration), no false detections occurred and white boxes that were challenging to detect based on Day 1 (Wed.) imagery were well detected. A closing car trunk door was detected,
and the tarps that changed position were well quantified in terms of their shape and area in the image change product.

**Qualitative Results:**

The imaging and change detection demonstration was successful, and results contributed to the larger NPS coordinated earthquake response exercise. Specialized image collection and processing techniques yielded pixel-level spatial co-registration between ultra-high spatial resolution (3-inch) imagery, and the automated change detection routine detected many of the introduced change targets with little false change detection. The automated processes were made possible by server side processing that combined and optimized all automated components. Change detection products were presented in a web-based visualization tool that allowed visual interpretation of the images and change detection results, interactive adjustment of change detection parameters, and submission of change detection results (graphics and text) to the common operating picture of the NPS exercise via GeoRSS feed.

The image-based change detection results that fed into the common operating picture as a GeoRSS feed contributed to the overall situational awareness of the simulated earthquake response event. The efforts of all of the NPS exercise team members made SDSU’s process from image collection to results in a common operating picture seamless.

Mr. Dave Potter with the City of Monterey Emergency Services met individually with Pete Coulter to discuss the technology. Mr. Potter was interested in the capability for rapid image-based change detection, and was very happy that current, 6-inch spatial resolution imagery serving as a baseline for future change detection would be made available to him and his colleagues. During the NPS team presentations Thursday afternoon, Mr. Potter was particularly interested in how well *ad hoc* imaging attempts could perform relative to the repeat pass imaging and facilitate rapid change analysis.

Please document, if applicable, other groups you interacted/collaborated with and what you worked on (please be as descriptive and detailed as possible):

SDSU’s image-based change products were submitted to the NPS common operating picture managed by Peak Spatial Enterprises using their sensor island platform (Figure 6). The change analysis and visualization tool developed by TerraPan Labs, as part of the SDSU team, was used to highlight significant change detections. Then, the tool was used to publish entries to a GeoRSS feed on a TerraPan Labs web server. This GeoRSS feed was monitored by the sensor island software and new entries were displayed on the map in the common operating picture. GeoRSS entries contained descriptive text, change detection image chips, and were referenced to point locations on the map. As an alternative publishing source, the XML file for the GeoRSS feed was also uploaded to a virtual machine hosted on the EOC in a box that NPS managed. This allowed publishing of the GeoRSS over the satellite internet connections hosted by the EOC in a box in the case that the feed could not be updated through standard internet sources.
**Photo/Graphics:**

![Image](image-url)

Figure 2. Review of multitemporal images in web-based change detection and visualization tool. The white box to the right shows the location of the change on a map when connected to high speed internet, but was turned off at RELIEF.

![Image](image-url)

Figure 3. Review of change detection result in web-based change detection and visualization tool. The white box to the right shows the location of the change on a map when connected to high speed internet, but was turned off at RELIEF.
Figure 4. Change detection example from repeat pass images collected Wednesday August 15, 2012.
Figure 5. Change detection example from repeat pass images collected Thursday August 16, 2012.
Figure 6. Example of SDSU’s image-based change detection product in the common operating picture.

Figure 7. SDSU and other participants gathered for the NPS Post Event Imagery and Lidar Analysis training session (Training 6).
Appendix C: DeltaPan Change Detection Tool User’s Guide

Overview
DeltaPan is a prototype change detection tool based on TerraPan Labs LLC’s pan.io technology. It is used to ingest baseline and multitemporal repeat-pass images, co-register the images, perform change detection, visualize detected changes, select change features of interest, document the analyst’s interpretation of the change, and disseminate this information using the internet to a common operating picture. The full DeltaPan prototype tool is not currently available for public use.

Image files in common formats (e.g., Tiff, JPG) and their associated image stations, provided in an ascii text log file or in the image exif, are uploaded to the DeltaPan change detection tool via web interface or through the pan.io desktop utility. This was already completed for the Monterey and Camp Roberts demonstration data. Ingested images are then correlated to existing image frames by spatial proximity and time filters (or by simple cross referencing of image station numbers, as was done for Monterey and RELIEF imaging), enabling automated co-registration of image frames using the San Diego State University developed image co-registration routine. Co-registered images are then visualized through the prototype change detection tool, which displays time 1, time 2, and change products, along with an overview of the location of all image pairs on top of a provided background image or web mapping service.

An analyst can then interactively adjust change detection parameters to highlight features of potential interest. Targets of interest can then be selected by an interactively controlled bounding box and annotations can be entered describing the nature of the identified change. For the purpose of the RELIEF exercise the three image thumbnails (i.e., time 1, time 2, and detected change) were output along with the analyst submitted annotations via GeoRSS, enabling the identified changes to be ingested in the ArcGIS Server based common operating picture. The change detection tool interface is shown in Figure C-1.

The prototype change detection tool with Monterey imagery is available at [http://pan.io/monterey](http://pan.io/monterey). The prototype change detection tool with Camp Roberts imagery is available at [http://pan.io/delta](http://pan.io/delta). The DeltaPan tool at each of these URLs is preloaded with repeat-pass imagery acquired for Monterey or the RELIEF exercise in August 2012. Using the Google Chrome web browser is recommended when accessing either DeltaPan URL listed above. For any questions regarding the DeltaPan tool, please contact TerraPan Labs LLC at info@terrapanlabs.com.

Image files in common formats (e.g., Tiff, JPG) and their associated image station, provided in an ascii text log file or in the image exif, are uploaded to the change detection tool via web interface or through the pan.io desktop utility. Ingested images are then correlated to existing image frames by spatial proximity and time filters (or alternatively by image station identification number), enabling automated co-registration of image frames using the San Diego State University developed image co-registration routine. Co-registered images are then visually interpreted through the prototype change detection tool, which displays Time=1, Time=2, and change products, along
with an overview of the location of all image pairs on top of a provided background image or web mapping service.

Figure C-1. Prototype web-based interactive change detection tool interface.

An analyst may interactively adjust change detection parameters to highlight features of potential interest. Targets of interest can then be selected by an interactively controlled bounding box and text annotations can be entered describing the nature of the identified change. For the purpose of the Monterey exercise the three image thumbnails (i.e., Teim=1, Time=2, and detected change) were output along with the analyst submitted annotations via GeoRSS, enabling the identified changes to be ingested in the ArcGIS Server based common operating picture.

**Display**
The prototype change detection tool interface can be seen in Figure C-1. There are six tiles in the interface. The upper left most tile (i.e., the zoom tile) can be updated to display Time=1, Time=2, or the detection change result overlays on Time=2. The upper right most tile shows the available image pairs and their geographic locations and can be used to select image pairs of interest or navigate the available data. The lower right most tile always shows an overview of Time=1 of the selected image pair, the next tile to right always shows an overview of Time=2 of the selected image pair, the next tile to the right always shows an overview of the detected change results, and the lower right most tile contains the control parameters for the San Diego State University designed
change detection algorithm. The text bar at the bottom of the interface allows notes/text annotations to be entered for an interactively selected thumbnail.

**Controls**

When using the tool, the analyst can type “1” to view the Time=1 image in an interactive map display, “2” to view the Time=2 image (Figure C-2), and “3” to view the change detection image in the interactive map, which allows panning and zooming (Figure C-3).

An overview of the change detection results can be quickly updated and viewed by changing any or all of the 5 parameters (Shadow, Threshold, Majority, Clump, Sieve) for the San Diego State University change detection algorithm using slider controls (Figure C-4). Once the analyst is satisfied with the algorithm parameters, pressing “3” will cause the change product to be computed and displayed on the map. The computation is performed in the analyst’s web browser, as opposed to on the server. This frees up server resources so that thousands of people can potentially view the web tool at the same time without the system suffering a performance hit. However, the analyst needs to have sufficient RAM and CPU resources, otherwise there can be a delay of up to 30 seconds for the change analysis to be computed.

To switch between image pairs, the left and right arrows on the keyboard can be used and the current image pair will be highlighted in green on the map showing camera station locations (Figure C-5).

![Figure C-2 Image “chip” overview, used to select which image will be displayed on the interactive map.](image-url)
Figure C-3. Interactive map display.

Figure C-4. Change detection parameter sliders and overview of results.
Figure C-5 Camera station location map. The currently viewed image pair is selected using the arrow keys.

To report a change detection to the GeoRSS feed the analyst can right click to highlight an area in the map (Figure C-6), and then type a change description in the text submission field (Figure C-7). The “Report Change” Button will submit the report and a link to the GeoRSS feed, which can be viewed from the common operating picture. The selected feature can then be removed from the map display with the “Clear Selection” button.
Figure C-6. Highlighting an area for reporting is done through a right mouse click on the area of interest.

Figure C-7. Reporting a change results to the common operating picture.
Appendix D. F-Planar User’s Guide

F-Planar is an interactive flight planning software for rapidly generating and activating aerial image acquisition plans. As part of this NPS/DHS Earthquake Response Project, TerraPan Labs will make the current version of the F-Planar software license available to the County and City of Monterey. For further information, please visit http://terrapanlabs.com/support or http://fplanar.terrapanlabs.com.

Installation
F-Planar can be downloaded for Windows, Mac, and Linux platforms at http://fplanar.terrapanlabs.com. Enter your username and password or register for an account to download a trial version. Upon downloading the executable file for your platform, you can start F-Planar by opening the application (F-Planar.app on Mac OS X, F-Planar.exe on Windows).

If you have not yet obtained a license for your F-Planar software, you must log in using the username and password you created when registering at http://fplanar.terrapanlabs.com. A trial license valid for 7 days will be downloaded to your machine automatically upon successful login. If you have obtained a license for F-Planar, a permanent license file will be downloaded to your machine automatically upon successful login. You will no longer have to login to the TerraPan Labs license server each time you start the software.

Configuration
You must select the proper aerial platform and sensor model settings for accurate flight planning. The “Platform Settings” tool is located in the upper left corner of the F-Planar software interface. The default system is a LOUIS platform with a LX5 sensor model (Figure D-1). If you have purchased a license for F-Planar, you can add your custom system, calibrate a camera and derive the sensor model, or import a sensor model.

A sensor model consists of the camera matrix, distortion vector, focal length, and sensor dimensions (Figure D-1). The camera matrix is defined as:

\[
\begin{bmatrix}
    fx & 0 & cx \\
    0 & fy & cy \\
    0 & 0 & 1
\end{bmatrix}
\]

where fx and fy are the focal length in pixel units in the x and y axes respectively, and cx and cy are the principal point coordinates. The principal point is the center of the array in an ideal camera model. The distortion vector is defined as:

\[
\begin{bmatrix}
    k1 & k2 & p1 & p2 & k3
\end{bmatrix}
\]

where k1, k2, and k3 are radial distortion coefficients, and p1 and p2 are tangential distortion coefficients. The camera matrix and distortion vector can be calibrated properly and calculated automatically using the “Calibrate New Camera” feature available to licensed Directifi customers.
Open a flight plan
The toolbar at the top of F-Planar allows you to open and save TerraPan Labs F-Planar project files (*.tpf), as well as export to autopilot command formats (e.g., *.fly, KML, GPX, EZTrack).
Backdrop layers

F-Planar comes with a few pre-configured Web Map Service (WMS) layers for display in the “Map View”. However, it is usually advisable to load a detailed backdrop for your study area. Supported backdrop layer data types include GeoTIFF, PNG with world file, and WMS. One benefit of using TIFF files is that you can store them locally on your machine, so with a purchased license for F-Planar you can operate in the field without an Internet connection. Figure D-3 shows the dialogue for loading a GeoTIFF backdrop layer. Basic support for WMS layers is also provided. Figure D-4 shows the dialogue to specify a WMS layer as a backdrop.
Study area
The “Study Area” controls (Figure D-5) allow you to extend the width and length of the flight plan with respect to the Centroid location. You can also control the orientation of flight lines by adjusting the flight heading of the first flight line.

Imaging
The “Imaging” controls of F-Planar allow you to adjust the cruise altitude of your flight, which in turn determines the ground resolution (Figure D-6). In reverse, you may also specify a target ground resolution and the altitude field will be updated automatically for you.

Also in the “Imaging” controls you will find adjustment controls for the sidelap and forward overlap of imaging. The side overlap is calculated based on the camera model for your system, and is dependent on altitude as well. The trigger interval is the time in seconds between each camera trigger, which is directly linked to the forward overlap of subsequent images in a flight line. You may also choose a trigger mode of “Location”, which will trigger the camera sensor at each waypoint instead of on the basis of time. Use “Location” based triggering for planning image station matched flight plans.
Flight

In the F-Planar Flight controls you have control over altitude and flight plan orientation parameters. Flight controls are used largely for programming unmanned flights and have no effect on the configuration of manned flight plans. The status display of F-Planar (Figure D-7) will show the total estimated flight time. Cruise speed must be defined in the platform settings in order to accurately estimate flight times.
Weather

The “Weather” controls allow you to change the heading of your flight plan based on a known wind direction. If you set the “Wind Direction” slider, then click the “Set Heading From Wind” button, your Flight Heading will be adjusted so that aircraft turns are into the wind (Figure D-8). Setting your Flight Heading based on Wind Direction can result in better flight line tracking and tighter turns for UAVs when wind speeds are high for the platform.

![Figure D-8. Wind direction control for changing flight heading](image)

Exporting a flight plan

Click the save as button on the toolbar to save the flight plan you have selected in the “Select Plan” control (Figure D-9). Flight plans can be exported to KML, GPX, ESRI Shapefile, or EZTrack formats.

![Figure D-9 Exporting a flight plan from the F-Planar project to a MicroPilot Fly File (*.fly).](image)
F-Planar project files

To save your project, which could include multiple flight plans, click the save project button in the toolbar and rename the *.tpf file (Figure D-10).

![Save Project Button](image.png)

Figure D-10 Location of the save project tool button.