A New Capability for Crash Site Documentation

By Major Adam Cybanski, Directorate of Flight Safety, Ottawa

Major Adam Cybanski is the officer responsible for helicopter investigation (DFS 2-4) at the Canadian Forces Directorate of Flight Safety in Ottawa, Canada. He is a tactical helicopter pilot with over 20 years and 2500 hours on fixed and rotary wing aircraft including the CT114 Tutor, CH139 Jet Ranger, CH135 Twin Huey and CH146 Griffon. He completed a tour in Haiti as Night Vision Goggle Specialist and Maintenance Test Pilot, and has managed the CH146 Griffon Full Flight Simulator. He is a graduate of the Aerospace Systems Course and holds a BSc in Computer Mathematics from Carleton University.

Technology has changed dramatically in the last 25 years. The memory storage capacity and speed of seventies era supercomputers like the Control Data 6600 and Cray have been surpassed by the modern cellular telephone. A Samsung *Galaxy 2* or *iPhone 4* has 2000 times the memory and approximately four times the speed of the Cray 1. In addition, the current generation of mobile devices also provide the added capabilities of audio recording, photography, video recording, mobile communications, GPS navigation, and inertial navigation.

Supercomputers

The methodology for documenting a crash site has changed little since the seventies. New flight safety investigators are still taught to take many photos, draw a crash site diagram, and measure everything possible using a ruler and tape measure. One of the reasons this has changed so little over previous decades is because it is effective and fulfills the requirement. The incredible capabilities of consumer technology provide an opportunity to re-examine how we capture a crash site. This is exactly what was done in November 2012.

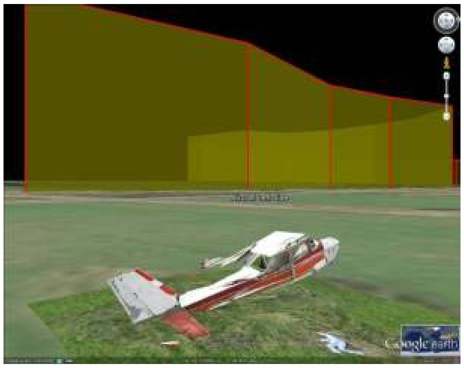
Crash Exercise

A crash site exercise was conducted by DFS in Ottawa, Canada. Wreckage and miscellaneous objects were documented using total station survey equipment, GPS survey equipment, laser scanner, and a phone. A modern cell phone was used to capture high resolution video, GPS-stamped photographs, and to conduct a GPS survey. During the survey, over 400 high resolution photos were taken, and more than 10,000 frames of video were captured by the phone. The data was analyzed in photogrammetry software and integrated into a single 3D site model, which could be examined in *Google Earth*.

Crash Exercise

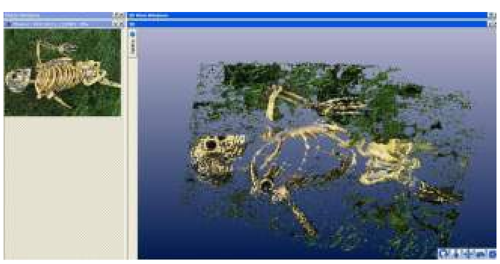
Data Presentation

In the *Google Earth* site model, the simulated radar flight path was added. Representative photos of the site from different viewpoints could be seen by clicking on camera icons dispersed among the site. A 3D model of the crashed aircraft was placed at the correct location, and could be examined from any perspective. Approximate distances could be measured using the ruler tool.



Data Presentation in Google Earth

To illustrate the fine 3D imaging capability for components and remains, several photos of a skeleton were stitched into a 3D point cloud, which could also be examined from any angle. With the addition of a single scale measurement, the measurement between any of the points could be obtained.



3D Point Cloud

Cell Phone Capabilities

A cell phone has many advantages over other methods of crash site capture. It is relatively inexpensive ($500), while surveying equipment or laser scanners can cost up to $85,000. It is available at any electronics store, and there is a very good chance that other people on the investigation will also have similar cell phones, if the investigator's does not work. These phones can be used for taking notes, accessing checklists, sending emails, accessing maps, and many other things. A phone has a fixed focal length lens, which is important. Any time a camera lens is zoomed in or out, it must be recalibrated for photogrammetry. Using a fixed lens, such as in a cell phone, makes measurements from photographs easier and quicker. The resolution of a cell phone (8 Mega pixel) is sufficient for photogrammetry, and 1080p video is more than sufficient for video analysis. By default, most phones stamp their photographs with the time and GPS location. This makes subsequent analysis much easier. Finally, the size of a cell phone is small and portable, which makes it easy to bring to any crash site.

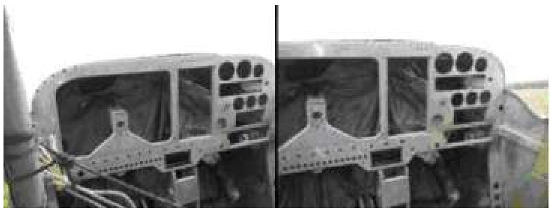
To capture a site, two free *Android* applications were used. Similar programs for the *iPhone* exist. Tina Time-Lapse is a program that automatically takes photos at a predetermined interval. The application was set to take GPS-stamped photos in high resolution every 2 seconds. This meant that a large amount of photos (up to 800 in a 30 minute period) could be taken quickly; simply by pointing the phone in different directions around the crash site. The volume of the phone was increased so that an audible "click" could be heard as each photo was taken. The other application used was Easy Voice Recorder Free. This application was initiated before any pictures were taken which made it easy to produce a running commentary of what was being photographed. This provided easy investigator notes that could be synchronized to each photo taken.

Photogrammetry Overview

Photos were taken at three distinct distances, for three purposes. Close-up photos were taken to capture surfaces and crushed areas, and employed in deep surface analysis to make 3D point clouds of small areas, such as bodies, ground scars, crushed and burnt areas, etc. Medium distance photos were stitched together to make a 3D model of the wreckage. Distant photos were taken that included prominent land features in order to locate the wreckage pieces on the crash site. In addition to the photographs, video was taken of every surface so that nothing would be missed. Capturing the information with the phone was extremely quick, on average 10 photographs per minute.

3D Point Cloud

To capture surfaces in 3D, two overlapping photos are required. The camera must be moved laterally, and not turned between the photographs. If the photos are of a quality that shows sufficient texture, a 3D model can be stitched together in about 30 minutes, once back at the lab. This model is comprised of thousands of measurable points in three dimensions and is the best way to investigate any deformations in the object.



3D Surface Photographs

Wreckage Model

For creating a large 3D wreckage model, many overlapping photos are required as well. The object should be circled from left to right, and the top must be captured. Creating a traditional 3D model is labour intensive and can take several days back at the lab. Identifiable features are marked in overlapping photos. These features (minimum of six on each photograph), allow the software to determine the orientation and location of the camera for each shot, and then calculate the relative location of each feature in space. Joining these points can produce 3D surfaces, which form the basis of the 3D model.

Wreckage Model Photographs

Photogrammetric Survey

To locate the wreckage pieces at the crash site, long-range photos are needed. Photos should include distant objects that can be seen from *Google Earth*, such as large trees, road intersections, towers, etc. Again, identifiable features are marked in each overlapping photograph (minimum of six), both in the foreground and in the background. These features determine the relative camera positions and orientations, and the points can be examined in an application such as *Autocad* to reveal the relative position of objects.

Survey Photograph

In order to easily identify the location of crash components, an *Android* app called *GPS Survey* was used. This provided the position of the principal items, as well as documenting identifiable control features such as a large tower, prominent tree, road intersection and other landmarks. The phone was able to determine the position within a few metres. If extra accuracy was needed, the methodology for differential GPS could be emulated. Continuous logging of GPS signals at one of the identifiable landmarks with a second phone, while conducting the GPS survey, might have further increased measurement accuracy.

GPS Survey

Panoramic View

Panoramic views from inside the cockpit, and between the crash components were also captured and incorporated into the final *Google Earth* project. Double clicking on the aircraft within *Google Earth* takes you inside for panoramic viewing of the controls and cockpit interior. The viewpoint can be slewed left or right, up or down. Overlapping photographs are stitched together and joined at the ends to produce a continuous 360 degree strip. This image can then be formatted so that it can be viewed in a panoramic perspective.

Panoramic Photograph

It is critical to capture an overhead view of the components for situational awareness. This is typically done using aerial photography, but in some cases alternatives may be needed due to aircraft availability, weather, or other factors. An inexpensive UAV (Parrot Drone 2.0) was used along with a rugged camera (GoPro Silver) to capture an overhead view of the wreckage. The relatively small UAV has comprehensive integrated stabilization, and was controlled by the cell phone.

Controlling UAV with Cell Phone

In addition, the UAV transmitted live HD video to the cell phone, which was recorded for later analysis. The live video also aided in effectively positioning the UAV for aerial photos, and could be employed for other purposes, such as aerial search for wreckage.

Aerial View from UAV

Camera Calibration

A camera used by an investigator should be calibrated to improve the accuracy of photogrammetric measurements. This could be done before or after visiting the crash site. A pdf calibration image (showing dots in rows) may be emailed to the investigator. They would print the image onto 8.5 x 11 paper, and then take 8 photos of the paper from different angles. These photos would be sent back to the photogrammetrist, who could use them to improve the precision of crash site measurements. This calibration is not absolutely required for crash site photogrammetry, but improves the accuracy of the resulting calculations.

Camera Calibration Sheet

The final 3D models must be scaled. Without a good scaler, you cannot determine if an object is metres or millimetres across. Ideally, a tape measure should be included in most photos. An investigator can also be photographed for this purpose (if his height is known or subsequently measured), or GPS coordinates from the camera can be employed as a last resort.

Scaling a Photograph

There are several applications available, such as *PhotoModeler* and *iWitness* that can be used to conduct photogrammetric triangulation (surveying). *PhotoModeler* can also create 3D Dense Surface models and 3D wreckage models. The models and photographs were integrated into *Google Earth*, for intuitive analysis by the investigators. There is a free open source application called insight 3D that can be used to learn how to make 3D models from photographs.

Tips for Investigators

The following tips should be considered when preparing to document a crash site:

- Take advantage of the high capacity of memory cards by taking hundreds of GPS-stamped high resolution photos.
- Ensure that prominent features that could be seen in *Google Earth*, are visible in photos when possible.
- Scalers such as a tape measure or measurable objects should be visible in most photos.
- Video record the components so that they are covered from all angles.
- Conduct a GPS survey of the principle components.

Final Thoughts

Photography has been utilized for crash investigation since the dawn of flight safety and will continue to contribute in that vein for the foreseeable future. Photogrammetric analysis may be needed in an investigation, but should not be construed as a routine procedure. It is important that every Flight Safety Officer understand how to capture crash site photos that will yield good results for photogrammetry. This will ensure that photogrammetry will be possible, if needed, and can serve as an excellent back-up to other methods of site capture such as surveys and laser scanning. If done correctly, a modern cell phone can capture an amazing amount of information at a crash site, and should become a critical tool for the modern investigator for years to come.

Afterword

After this paper was written, the author was called out on a helicopter crash investigation. A Smartphone was employed for many purposes, including photographing and videotaping the wreckage and debris fields, making investigation notes, recording witness re-enactment of the event on a tabletop model and in an aircraft cockpit, and for video playback. The utility of this portable and flexible tool will undoubtedly continue to increase with experience and time.