PHYSICAL DIGITAL LIMITED

CUSTOMER : 2Excel Aviation Ltd
PROJECT : Piper PA-31-310 Navajo Nose Cone
CASE STUDY TYPE : Reverse Engineering
SYSTEMS USED : GOM (ATOS, TRITOP, TOUCH PROBE) GOM INSPECT

In order to install new hardware in the nose cone of a test aircraft, 2Excel Aviation required a new nose cone to be manufactured for their Piper Navajo. Physical Digital's optical scanning technology was utilised to reverse engineer the new component to a high level of accuracy; using a combination of photogrammetry and 3D digitising to capture surface data.

Project Background

Scimitar, formed in 2008 and based at Sywell Aerodrome in Northamptonshire, are the dedicated research and development department of 2Excel Aviation, best known for THE BLADES Aerobatic Display Team. Scimitar design, test and evaluate avionic systems for use in military and civilian applications. The current project involves nose cone mounted instrumentation. To enable them to accurately mount the test system onto the airframe, a new nose cone needed to be manufactured. The final product needed to maintain its original form, to avoid costly CAA recertification, but remove the extrusions from the surface *(Fig 1.0 & 4.1)*. The company requested that the nose cone be symmetrical, as the instruments were sensitive to geometry, whilst still fitting to the original airframe mating surface.

Scimitar have used Physical Digital, and their optical scanning technology for past projects and are aware of the reduction in time and cost in reverse engineering components from scan data.

(Fig 1.0)

Objectives

- Measure the current nose cone and airframe in position using TRITOP Photogrammetry
- Digitise the external surface of the nose cone, 1m of airframe and mating surfaces using ATOS IIe
- Capture critical geometry including locating pins, spheres, hole centres and diameters using Touch Probe
- Align all data to agreed aircraft coordinate system
- Reverse engineer from the scan data, creating a symmetrical nose cone
- Evaluate new CAD model against original scan data

Data Capture Process

The digitising was carried out in the aircrafts storage hanger at Scimitar headquarters in Sywell. This was possible due to the portability of the equipment used and the ability to work in environments that other hardware would find difficult.

Three systems were used to capture the necessary data for this project:

1. TRITOP

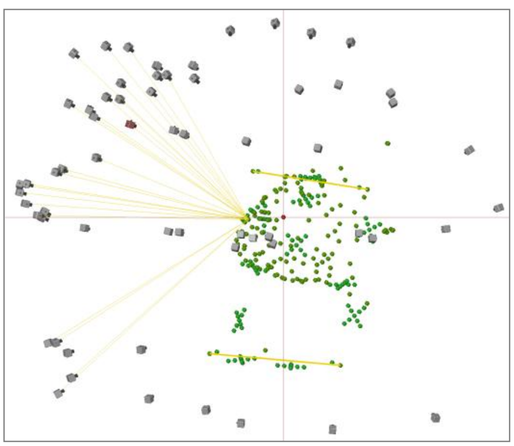
The aircraft was prepared with the current nose cone fitted to the airframe, then coded and un-coded markers *(Fig 3.0 & Fig 1.0)* were applied to, and around, the areas to be captured. Extra markers were applied near the edges of the mating surfaces. This allowed Physical Digital to use the same coordinate system to scan the surface currently hidden inside the airframe.

A total of 49 photos were taken from different angles *(Fig 2.0 & 2.1)*. From this the software calculated the 3D coordinates of all the markers. The accuracy was checked by Physical Digital Engineers and the file saved.

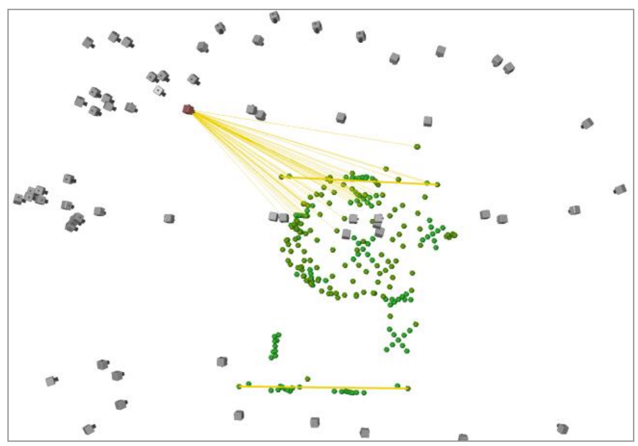
TRITOP - Optical CMM Explained

The TRITOP system takes high resolution 2D images of the object and created an accurate 3D coordinate framework based on digital photogrammetry techniques. Markers are applied (coded and un-coded) to and around the object along with internationally certified scale bars, then multiple photographs are taken from different angles. The software precisely works out the 3D coordinate of the centre of the markers. These coordinates are then used as a reference framework for scanning.

Marker Seen By different Cameras (Fig 2.0)



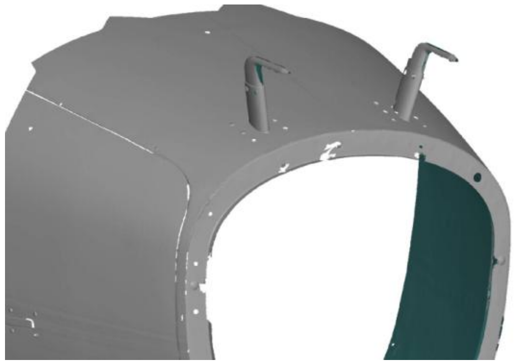
Markers Seen By Single Camera (Fig 2.1)



(Fig 3.0)

2. ATOS

The TRITOP file was imported into the ATOS scanning software, for use as a reference frame. Physical Digital then began to scan the airframe in the assembled state. When all the required data from the exterior was captured, the nose cone was carefully removed and the markers located around the edges were used to align the scan of the once hidden surface. This was repeated on the nose cone using the points on the outside to capture the mating surfaces within the same global alignment system.



The point cloud data was then converted by the software to form a polygon mesh file, the mesh was checked for any errors and post processed to a file size appropriate to the application. The original data was saved in order to produce an inspection report on the new CAD model. For this project .STL file was exported, for use in the available CAE systems.

(Fig 4.0)

(Fig 4.1)

ATOS - 3D Digitising Explained

The ATOS (Advanced Topometric Sensor) system is a white light optical scanner which scans 3D objects and converts the images into a high density point cloud. This allows accurate measurement and capture of the shape and size of almost any object.

The scanning is based on optical triangulation and stereo-viewing. A projector is used to project a striped fringe pattern onto the object surface. These images are captured simultaneously by the cameras from different angles. 3D coordinates are captured fast to a high accuracy; this is repeated for up to seven million points per scan. The captured scan is then automatically integrated into the TRITOP framework; the sensor uses these markers to correctly align each scan. The markers are also used for self calibration and verification and can detect movement and lighting changes which would affect the accuracy.

3. TOUCH PROBE

The optically tracked touch probe was used to determine the location and size of each hole on the airframe and nose cone mounting surfaces *(Fig 4.0)*. Using the touch probe enabled Physical Digital to create direct geometry within the coordinate system of the scan. These can be exported into the CAD software in compatible geometry files. For this project .IGS was used.

(Fig 5.0)

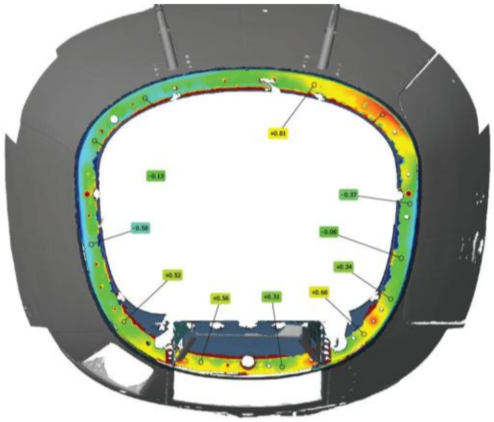
TOUCH PROBE Explained

The GOM touch probe is used for capturing geometry on the object that is being scanned. This handheld probe is optically tracked by the ATOS sensor and calibrated to a high accuracy; it allows movement of both the sensor and probe by using the TRITOP markers to precisely align the data when captured.

Reverse Engineering: Creating CAD Surfaces

The .STL file created from the scan data was imported into the CAD software. Using exact geometry matched (within agreed tolerance) to the mesh, a CAD surface was produced. This was mirrored to create a symmetrical nose cone. The .IGS files from the Touch Probe were then used to trim holes and features in the correct positions within the global coordinate system *(Fig 7.0)*.

When the geometry of the nose cone was complete, the mating surface was assessed to see if a planar surface would correctly fit to the airframe. If this was not the case, a freeform surface would have been applied to the geometrically accurate nose cone. However, when the surface was inspected it was found to be within tolerance and a flat surface was chosen *(Fig 6.0)*.



(Fig 6.0)

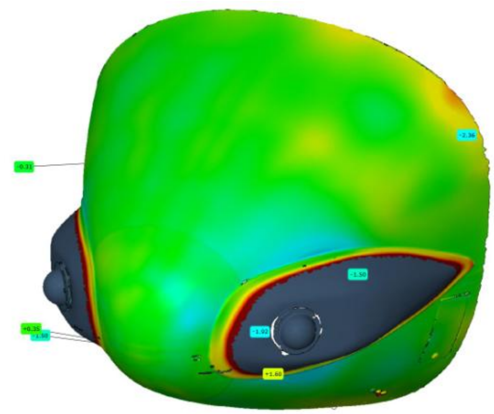
(Fig 7.0)

Inspection & Verification

The final part of the project was to verify the new CAD data against the original scan. Scimitar were keen to keep the new nose as close to the original as possible, whilst removing the features *(Fig 7.0)*. Physical Digital supplied an inspection report using the inspection module of the ATOS Professional software.

The 3D images throughout this case study were taken from the inspection report that was produced.

This graphical representation shows the vector distance between the original scan data and the new CAD model. The green areas are within 1mm of the original. It is interesting to note the red area on the top right: this shows the airframe has been deformed *(Fig 8.0)*. In this project the symmetry was important and the CAD was made slightly smaller to allow manual blending to the airframe.



(Fig 8.0)

A complete set of data was supplied to Scimitar, including:
- Original scan data
- New CAD Model
- Inspection reports
- GOM INSPECT (free inspection software for further analysis)

Achievements

- Quick and accurate capture of all surfaces
- Creation of nose CAD data for use in all future projects
- Reduction in time, compared to traditional methods
- Increases in accuracy, compared to alternative methods
- Final product inspection using Computer Aided Verification

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