PHYSICAL DIGITAL LIMITED

CUSTOMER : Amalgam Fine Model Cars & BBMF (RAF)
PROJECT : Supermarine Spitfire MkIIa – P7350
CASE STUDY TYPE : Reverse Engineering & Digital Archiving
SYSTEMS USED : GOM (ATOS IIe + III Triple Scan, TRITOP, Touch Probe)

In order to create a highly accurate scale model of a MkIIa Spitfire, Physical Digital were commissioned by Amalgam Fine Model Cars to digitise an original. The aircraft, which is based at the Battle of Britain Memorial Flight (BBMF), RAF Coningsby, in Lincolnshire is the last remaining example of an airworthy MkIIa that saw active service in the Battle of Britain. The digital data was also presented to the BBMF for digital archiving, to be used as reference if the aircraft was ever damaged. A combination of photogrammetry, Touch Probe and 3D optical scanning was used to capture surface data.

Project Background

Physical Digital, and their GOM optical scanning technology, have been used for past projects by Amalgam who are aware of the reduction in time and cost in using accurate scan data to reverse engineer their models. Physical Digital have a long running relationship with Amalgam and have been responsible for the digitising of many cars available in their range including the Bugatti 57SC , Ferrari 250 California Spider , 1930 Mercedes Bens SSK Counttrossi, Lamborghini, Jaguar XK 120 , Lotus 38 and many others.

Amalgam Fine Model Cars creates the highest quality model cars and yachts. It supplies the majority of Formula 1 teams and performance car manufacturers with large-scale models. In most cases, these models are available to owners, personalised to match the exact specification of their real car.

The Amalgam brand has steadily grown to become synonymous with exceptional hand-made models, created by a highly skilled, passionate team in very concise, limited editions. As a result of this success Amalgam has now decided to create aircraft to the same stunning detail. A decision was made to begin the new range with a MkIIa Spitfire; the only remaining example of this aircraft is currently flown by the BBMF.

Aircraft History

P7350 is the oldest airworthy Spitfire in the world and the only Spitfire still flying today to have actually fought in the Battle of Britain. She is believed to be the 14th aircraft of 11,989 built at the Castle Bromwich 'shadow' factory, Birmingham. Entering service in the August of 1940, she flew in the Battle of Britain serving with 266 Squadron and 603 (City of Edinburgh) AuxAF Squadron. Whilst serving with the latter at Hornchurch, on or about 25 October 1940, she was involved in a combat with Bf 109s and forced to crash land. She was quickly repaired at No 1 Civilian Repair Unit, Cowley, and flew again on 15 November, only 3 weeks after the crash landing; repaired bullet holes can still be seen on her port wing. She subsequently served operationally with 616 and 64 Squadrons. After April 1942 she was relegated to support duties serving with the Central Gunnery School and 57 OTU and ending her operational career with 19 MU. During the War, 'P7' suffered three 'Cat B' flying accidents (at Tangmere, Hornchurch and Sutton Bridge).

(Extract from: www.raf.mod.uk/bbmf/theaircraft/spitfirep7350.cfm)

BBMF History

Fig 1.0

Today the Battle of Britain Memorial Flight is a household name, however it has gone from being a loose collection of 'obsolete types' tucked away in various hangars, to a dedicated unit with its own headquarters, entrusted with caring for priceless assets of British aviation heritage.

On 15th September 1957, the first commemorative flypast took place over Westminster Abbey for Battle of Britain Day, with the Hurricane LF363 and Spitfire TE330. During 1959 the Flight lost its Spitfire XVIs altogether due to a series of accidents and reliability problems.

After filming for the 1969 classic *Battle of Britain* was completed, The BBMF was presented with Spitfire MkIIa P7350. This was – and still is – the world's oldest airworthy example of its type and a genuine combat veteran of the Battle of Britain.

November 1973 saw the arrival of the Lancaster PA474 which was officially transferred from Waddington, Lincolnshire, where it had been refurbished and looked after by station personnel. Less than two years later, it was announced that the BBMF was moving from Coltishall to Coningsby in Lincolnshire. Another aircraft joined the flight in July 1993 when the Douglas Dakota III ZA947 arrived.

Records show that for many years after its formation the Flight conducted relatively low-key operations; typically making 50-60 appearances per season, a situation that continued into the mid-1960s. By the early 1990s this had trebled and demand for participation by the Flight's aircraft was continuing to grow. In 1996 individual aircraft appearances exceeded 500 and by 2003 tasking rose to over 700 individual aircraft appearances. Last year the BBMF was tasked with 950 individual aircraft appearances at 612 separate events. These events included 118 air displays and 494 fly pasts.

Objectives

- Accurately measure the aircraft using TRITOP and ATOS systems
- Capture of all data needed for recreation of scale model
- Scan of movable/control surface in extreme positions for archiving
- Scan of cockpit showing positions of vital components
- Deliver Amalgam data for modelling process
- Deliver original .STL data to BBMF for archiving

Fig 2.0

Data Capture Process

The digitising was carried out in the storage and maintenance hanger at RAF Coningsby in Lincolnshire. The RAF base is fully operational with four squadrons of Eurofighter typhoons based there and over 10 BBMF aircraft. It is also home to the visitor centre where the public can take a tour of the hanger. It was vital to cause as little disruption to the daily tasking as possible, this was possible due to the portability of the equipment used and the ability to work in environments that other hardware would find difficult. The process took three days to complete with the aircraft handed back to the BBMF as presented.

The aircraft was positioned in a maintenance bay *(Fig 1.0)*.

Three systems were used to capture the necessary data for this project: GOM TRITOP, GOM ATOS and GOM touch probe.

1. TRITOP

The spitfire was prepared for the data capture process. Coded and un-coded markers were applied to the airframe *(Fig 2.0)*. The un-coded markers are placed directly on the airframe; these are non-corrosive low strength adhesive stickers which can easily be removed at the end of the process. For this project 5mm diameter markers were used to create the framework *(Fig 2.0 & 2.1).* Using two certified scale bars within the photogrammetry system Physical Digital could verify a global accuracy < 0.02mm/m^3 for this project.

Using this file as a main reference file, Physical Digital are able to move surfaces into alternative positions and scan these within the same project using the global alignment. This method was used to capture the control surfaces (Ailerons, Rudder and Elevators) in their extreme positions, to be used by the model makers to accurately recreate the deflection angles of these control surfaces. The same method was also used for the cockpit canopy in open and closed positions.

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 (Fig 2.2), 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 .

Fig 2.1

Fig 3.0

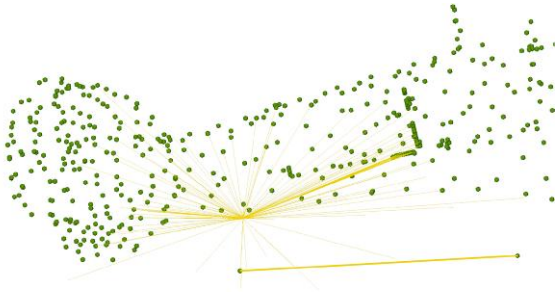

Fig 2.2

2. ATOS

Fig 3.1

The TRITOP file was imported into the ATOS scanning software *(Fig 3.0)*, for use as a reference frame. Physical Digital then began to scan the main airframe using a GOM ATOS III Triple Scan (Supplied by GOM UK). The second system (GOM ATOS IIe) was used to capture the moveable surfaces using the same alignment as the airframe *(Fig 3.3).* The simultaneous use of two systems, although not necessary, enabled Physical Digital to significantly reduce the time scale of the project *(Fig 3.1).*

The data was converted into individual polygon meshes for each component and each position *(Fig 3.2 & 3.3)*. The data from the two systems was compiled into a single project and the mesh was checked for any errors. The files were post processed to a manageable size and presented to the BBMF for digital archiving. The mesh was thinned whilst remaining sympathetic to curvature and the .STL file was delivered to Amalgam for use in creating the scale model.

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.

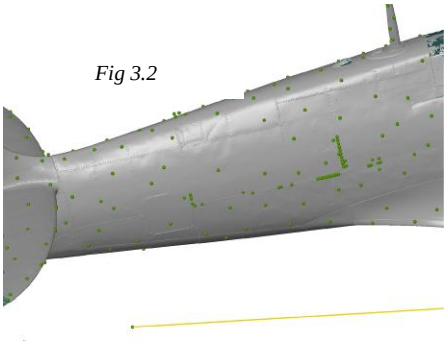

Fig 3.2

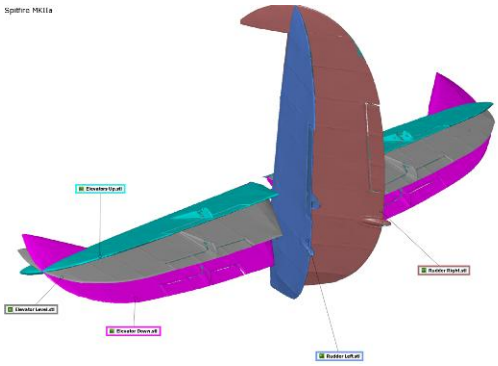

Fig 3.3

3. Touch Probe

The optically tracked touch probe was used to determine the location of the complex bubble shaped canopy glass *(Fig 4.1)*; this method was chosen as an alternative to using excess polish on the transparent surface. These points can then be turned into a mesh in the post processing stage and added into the project.

Fig 4.1

Fig 4.0

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. (Fig 4.0)

Summary

Physical Digital completed the scanning of the aircraft in the agreed three day timescale; capturing all necessary data for Amalgam to recreate a detailed model whilst maintaining the high level of accuracy necessary for archiving this priceless historical aircraft. Using GEOMAGIC software Physical Digital reverse engineered CAD models which can be produced from the scan data. This process can then be used to recreate components and tooling for worn, broken, damaged, hand modified parts which do no correctly represent the 2D line drawing or CAD models. Physical Digital are also able to analyse and redesign these components making them stronger, lighter and safer by utilising computed simulations and modern material properties.

Achievements

- Quick and accurate capture of all surfaces
- Minimal disruption to normal RAF operations
- Collection of movable/control surfaces for archiving
- Delivery of mesh to Amalgam for creation of model
- Delivery of mesh to BBMF for reference and archiving

Project Completed by

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