

Eglin Air Force Base Measurement Report



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Introduction

This report is a summary of the V-STARS work carried out at the Air Force Armament Museum and the Mass Properties unit at Eglin Air Force Base, Florida. The surveys were undertaken as part of Phase 2 of SBIR AF01-259. Two objects were measured as part of the evaluation. The measurements were completed using the V-STARS INCA camera system, PRO-SPOT, and accessories.

Measurement requirements are outlined below.



V-STARS with INCA camera.

Requirements

Object 1 – MK84 Bomb

The following requirements were stipulated.

1. Use PRO-SPOT target projection system to collect patches of dense point data.
2. Use V-STARS/M and probes to collect edge of part and supplemental data.
3. Combine data into one unified model.
4. Use GeoMagic to create surfaces from point data.



Object 2 – F-105

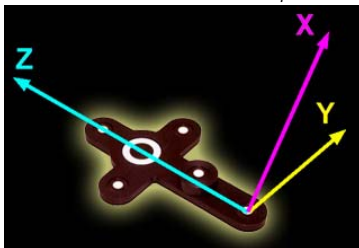
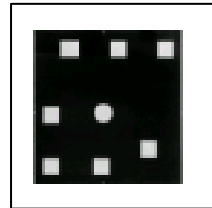
The following requirements were stipulated.

1. Use PRO-SPOT target projection system to collect patches of dense point data over as much of the surface as possible.
2. Combine data into one unified model.
3. Use hand-held probes to measure specific features that can't be targeted.
4. Use GeoMagic to create surfaces from point data.



Measurement Procedure

Data collection is accomplished in two major stages. In the first, an array of retro-reflective targets is placed on the object. These targets may be a combination of single retro-reflective stick-ons; adhesive strips of targets, and bushing targets used in tooling holes. Additionally, it is necessary to use a number of coded targets (right). Coded targets are found automatically in the imagery and as such, serve to automate the measurement procedure. The initial coordinate system and approximate scale is established with the **AutoBar** (left). The AutoBar, a cross-shaped fixture with five targets of known coordinates, is attached on or near the measured object, preferably in a highly visible location. To scale a photogrammetric measurement, there must be at least one known distance between measured targets. This is typically accomplished by placing a targeted invar scale bar in the survey. For redundancy, multiple scale bars were used in each of the measurements described below. Finally, the coordinates of all targets are determined using the single-camera **V-STARS/S** system.



determined using the single-camera **V-STARS/S** system.

In the second stage of data collection, the targets surveyed with the **V-STARS/S** system serve to establish the position and orientation of the two-camera **V-STARS/M** system used for real-time data acquisition.

Real-time measurement is performed with either the PRO-SPOT projector or with hand held probes. Using a slide with an imprinted dot pattern containing as many as 22,179 points, the PRO-SPOT projects the point pattern onto the surface

of an object. The two cameras of the V-STARS/M system fire simultaneously with the projector and the dot pattern is imaged from both cameras. The dots are then triangulated to obtain their three-dimensional coordinates.

Measuring with the hand held probes is as simple as pointing the cameras roughly at the area of interest, placing the probe on the point of interest and pressing the hand held trigger. Each camera images the probe, determines the type of probe being used and sends this information to the system laptop. V-STARS then takes this data and computes the XYZ location of the probe tip. Up to 16 different probes are available. Each of these has a unique pattern of dots and is automatically identified by the system. The probes also have a variety of tips available. The probes typically come with a 3mm or 6mm ball tip. Scribe tips are also available.



Once all the points of interest are measured, the cameras are simply moved to the next position. Camera re-orientation is carried out automatically. The cameras orientate themselves during each point measurement, which means that the cameras or the object can be vibrating without any ill effect to the resulting point data.

Results – MK84 Bomb

VSTARS/S Survey

3mm codes were used on the bomb surface and 6mm codes on the floor immediately surrounding the bomb. The network consisted of 156 codes, various stick-on targets, and 4 scale bars. A total of 187 images were taken of the MK84. The photography for the object was completed in approximately 20 minutes. Camera station locations for the measurement are shown in Figure 1 below. Also shown is a sample intersection pattern for a point. Each of the green lines represents an observation to that point from the corresponding camera station.

The following is a summary of the measurement statistics from the VSTARS/S measurement of the MK84.

No. of photos		187
No. of points		183
No. of scales		4
Scale Agreement (inch)		0.0012
Accuracy RMS (inch) X,Y,Z	X	0.0005
	Y	0.0011
	Z	0.0006

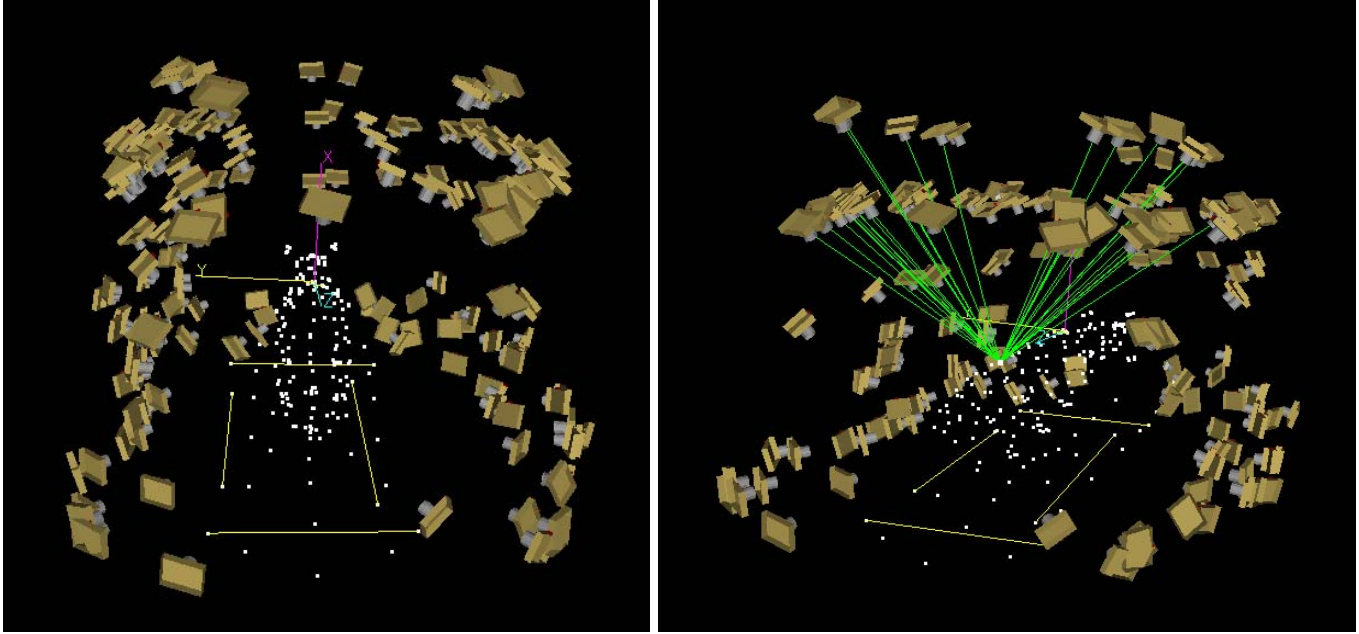


Figure 1: Control points established on MK84 Bomb with **VSTARS/S** system. These points are used in turn for the orientation of the **VSTARS/M** system during real-time data acquisition. Camera stations and scale bars are also shown. Green rays illustrate intersection geometry for an individual point in the left image.

Surface Measurement with VSTARS/M System

PRO-SPOT

The **PRO-SPOT** and two **INCA** cameras were configured on a stable bar which was in turn mounted on a rolling Genie lift (Figure 2). The entire camera-projector configuration can be raised to a height of 10.5 feet and rotated in azimuth and elevation. A slide with 22,179 points was utilized with the projector. The cable box and laptop were placed on a separate rolling cart and moved along behind or beside the lift as it was moved around the object. This became difficult with little space to move between the bomb, the mass properties table, and the wall on the opposite side. Also, cables

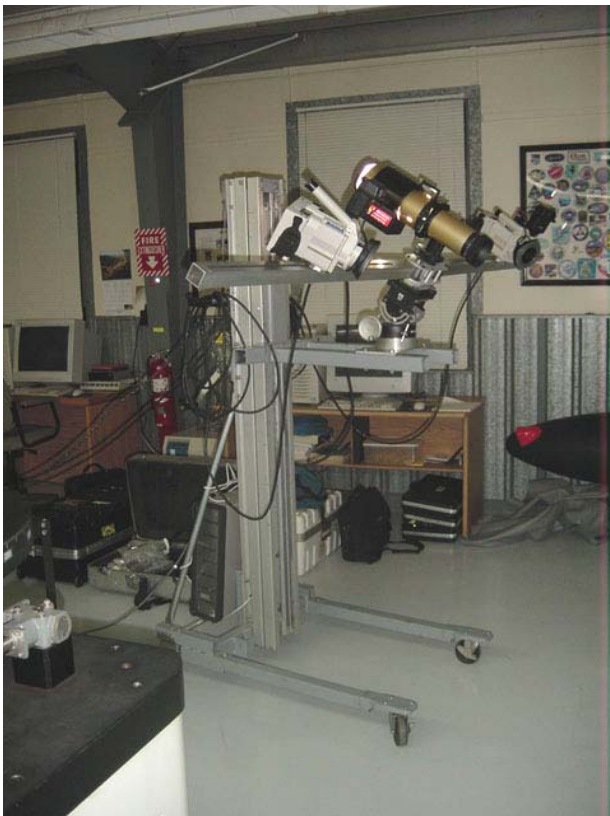


Figure 2: Genie lift with mounted PRO-SPOT and INCA cameras.

became tangled around various objects. These things aside, the lift was still more convenient than tripods as the height and aim of the entire setup could be adjusted very quickly.

56 epochs of data PRO-SPOT data were collected in approximately six hours. This is considerably longer than what would normally be required and result from newly found software problems which have since been corrected.

Probe

Approximately 475 points were measured on the MK84 bomb in approximately one hour using the VSTARS/M system with handheld probes (Figure 3).

Points were probed on antenna features at the fore and aft of the bomb. Additional probed features included the edge of one fin, the nose cap, the support lug on top of the bomb, a section seam at the aft, and a line of points along the entire bottom centerline of the bomb which couldn't be collected with the PRO-SPOT.

The final point cloud shown in Figure 4 contains 383,094 points. It was created with 52 of the 56 epochs collected and includes probe data. Note that this is raw data before cleanup in GeoMagic.

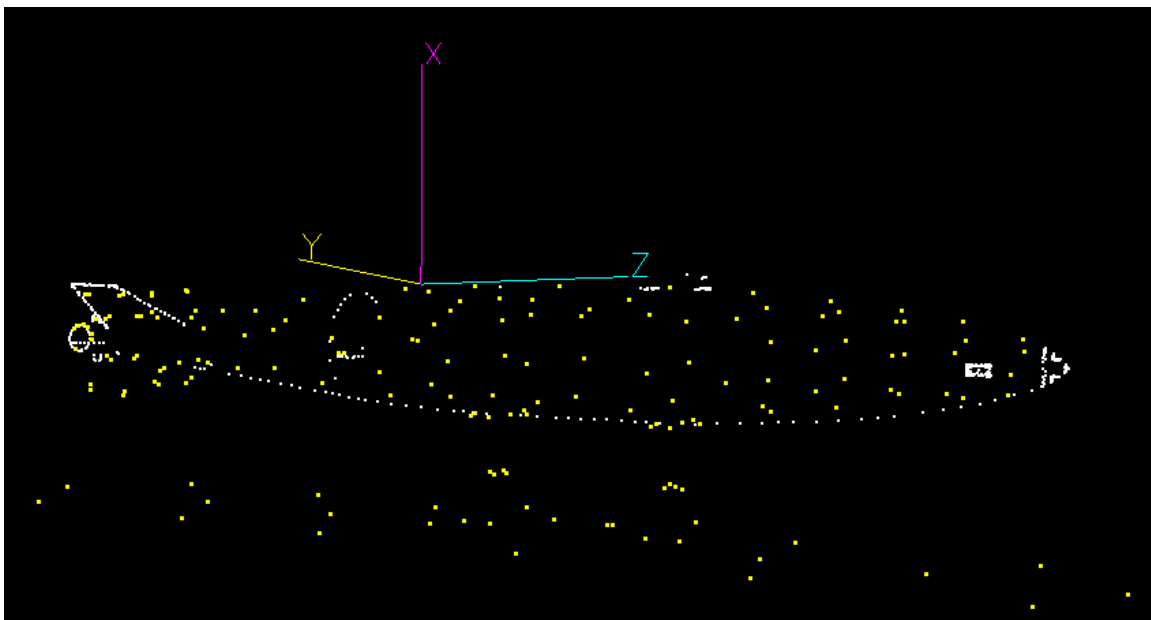


Figure 3: Probe points on the MK84 bomb are seen in white; yellow points serve as control for orientation of the VSTARS/M system.

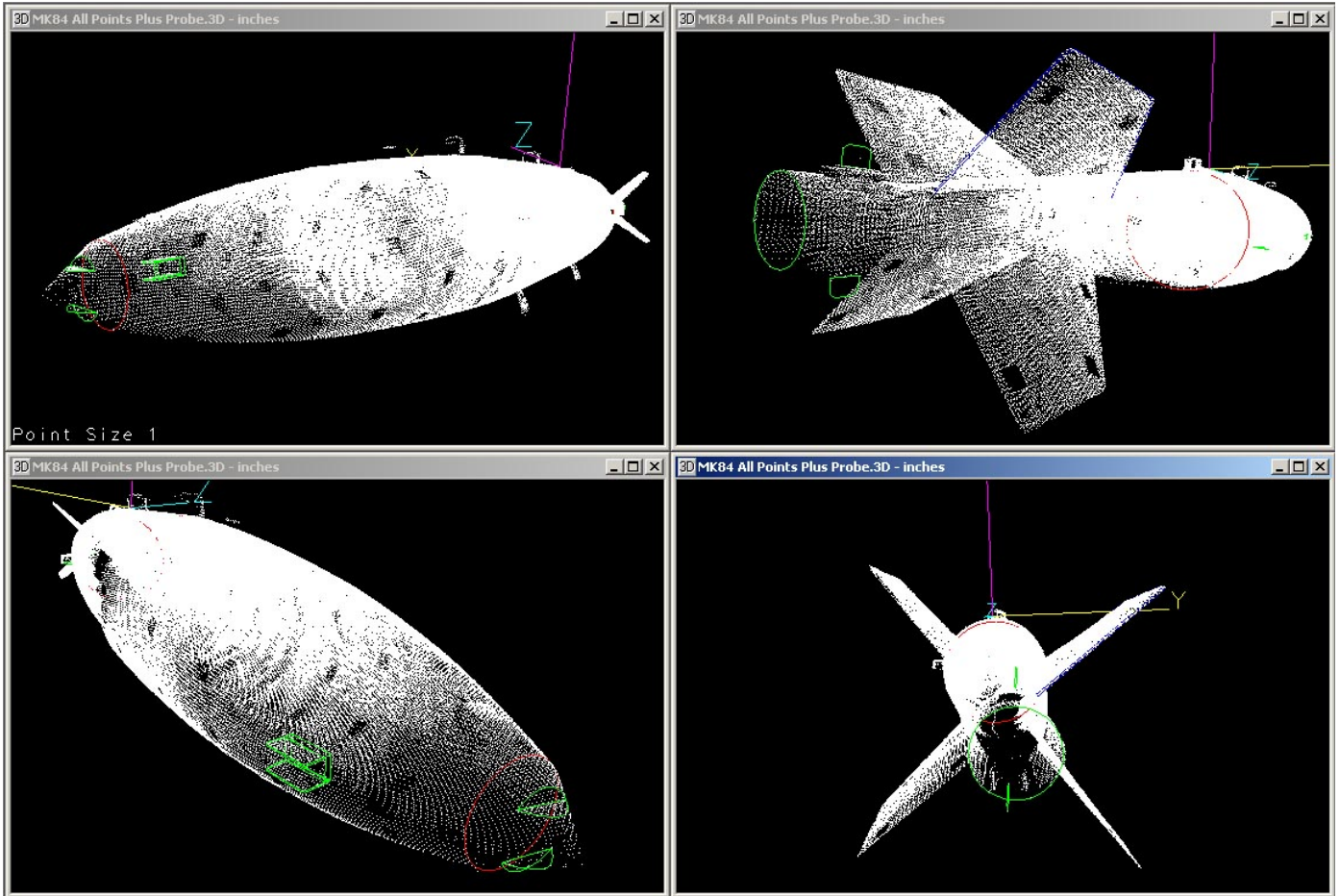


Figure 4: MK84 bomb data. 383,094 points, including probe data. Note this is raw data before cleanup with GeoMagic.

Results – F105 Aircraft

VSTARS/S Survey

Due to scheduling at the museum we had less time to work than we had anticipated. Additionally, the F-105 in the museum is surrounded by many displays, some moveable, some not. Although we initially thought that we would measure all or most of the plane, it became clear due to the obstructions and time limitations that we would have to settle on a particular area and stick to it. It was decided to do the port side of the aircraft, from mid-cockpit to just behind the trailing edge of the wing. We would cover the fuselage as high as we could reach, the underside of the wing, the inside of the strut, and as much as the top of the wing as possible. As the Genie lift goes only to 10.5 feet, it was unlikely that we would cover much of the upper wing surface.

The aircraft was targeted in approximately two hours. The network consisted of 180 codes, about 160 stick-on targets, and three scale bars. As target adhesive

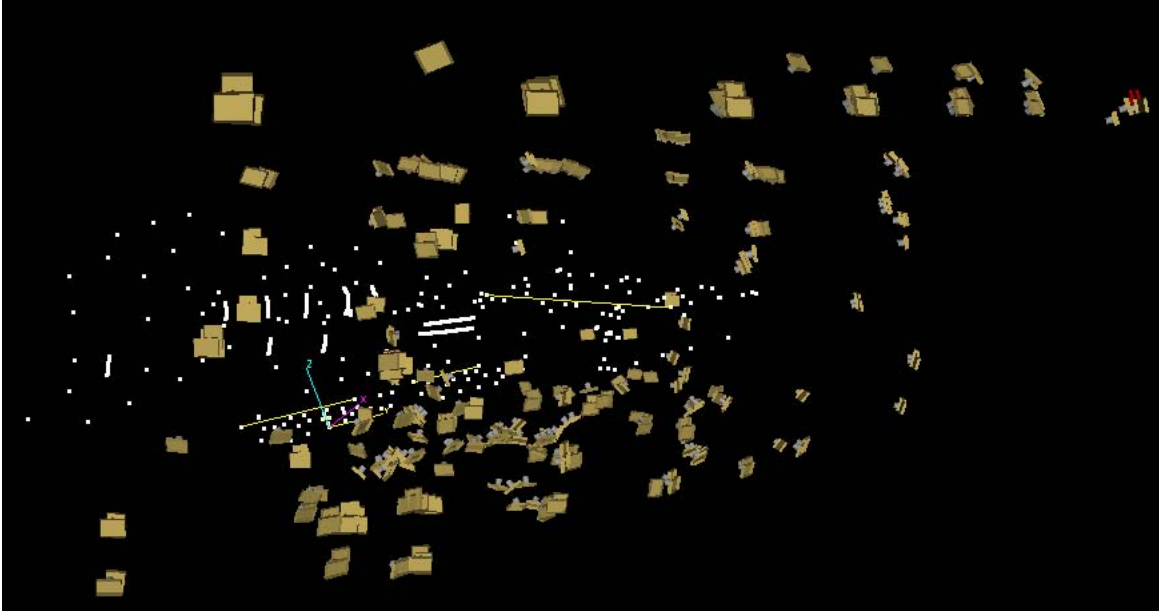


Figure 5: Control points established on F-105 aircraft by VSTARS/S survey. Camera stations are also shown.

couldn't be applied directly to the aircraft surface, drafting tape was put down first and the targets placed on the tape. Photography was completed in 30 minutes. Images were acquired from the museum floor, the second floor balcony, and from a 10 foot ladder. The resulting point cloud and camera stations are shown in Figure 5.

The following is a summary of the measurement statistics from the F-105 survey.

No. of photos	291	
No. of points	360	
No. of scales	3	
Scale Agreement(inch)		0.0022
Accuracy RMS(inch) X,Y,Z	X	0.0012
	Y	0.0009
	Z	0.0006

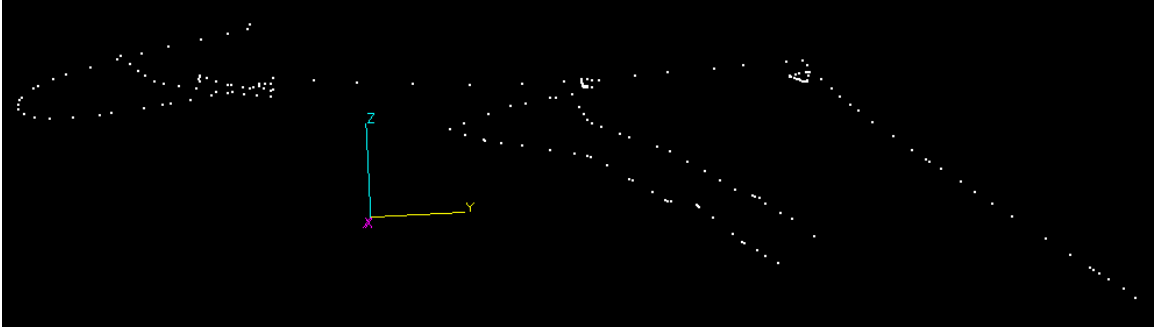


Figure 6: Probe points on F-105.

Surface Measurement with VSTARS/M System

PRO-SPOT

The **PRO-SPOT** and two **INCA** cameras were again configured on the rolling Genie lift. The 22,179 point slide was utilized again with the projector. The cable box and laptop were placed on a separate rolling cart and moved along behind or beside the lift as it was moved around the object. For four hours on Wednesday and seven hours on Thursday, over 300 epochs of surface data were captured.

Probe

Approximately 190 points were measured on the F-105 in approximately one hour using the VSTARS/M system with handheld probes. Points were probed on the air intake, spoiler, the flap trailing edge, wheel-well edges, and the wing root. Probe points are shown in Figure 6 above.

The final point cloud shown in Figure 7 consists of 609,688 points. Again, note that this is raw data before cleanup in GeoMagic.

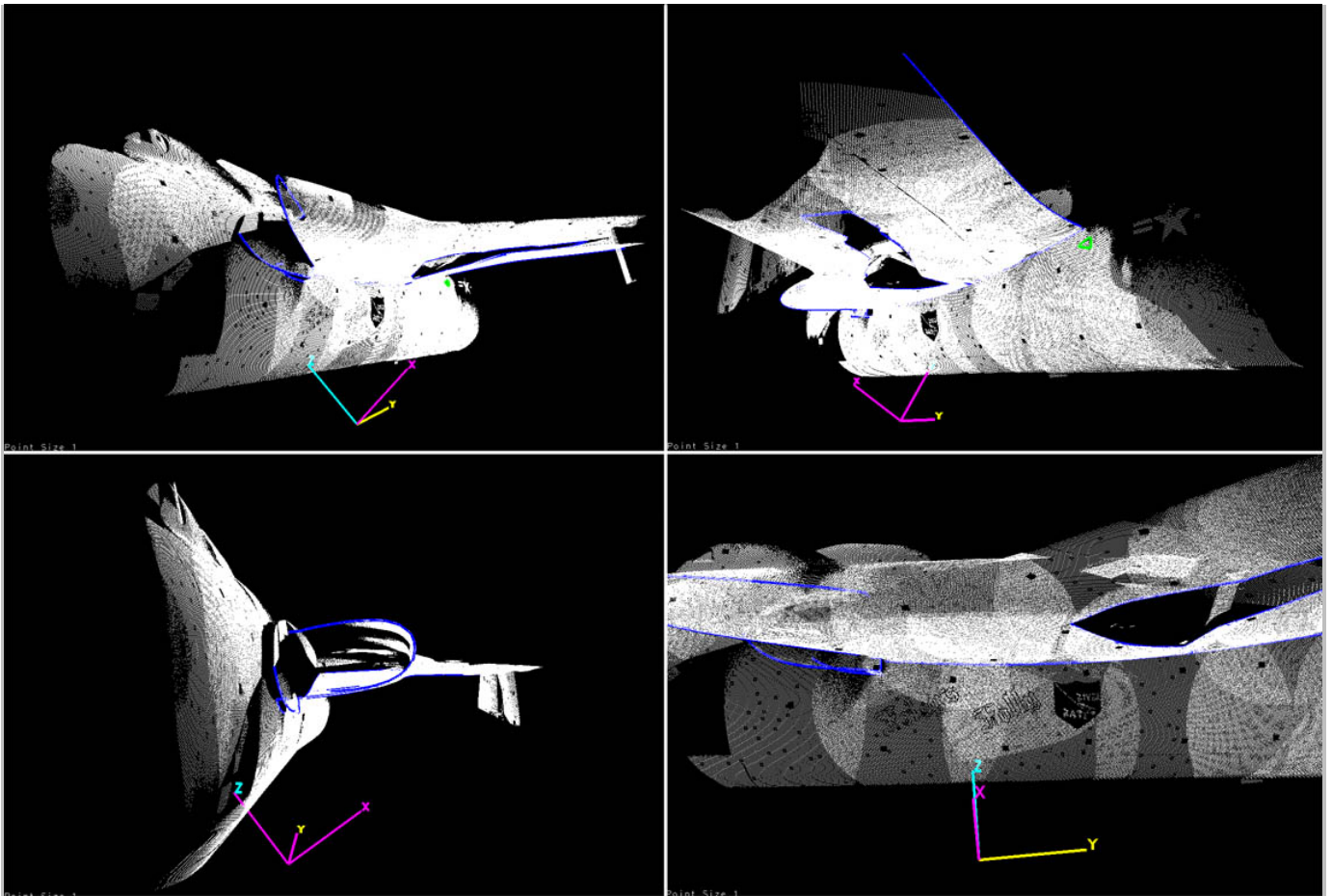


Figure 7: F-105 Data; 609,688 points.