Determination of Landing Parameters of High Performance Aircraft Using a Photogrammetric Approach

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ABSTRACT

Photogrammetry is used as a structural test program to determine landing parameters for F18 aircraft. Parameters such as horizontal speed, sink, pitch and roll rates are determined with high accuracy. Procedures are developed to relate this information to stress for the under carriage support structure. Photogrammetric procedures are discussed along with the post processing of the photogrammetric data.

1.0 INTRODUCTION

Photogrammetry lends itself very well to Aerospace applications. Our first photogrammetric aerospace application involved monitoring flight parameters of Remote Piloted Vehicles during the 1970's. Later in 1980 we started to apply photogrammetry for aircraft crash analysis and later to quality assurance of aircraft manufacturing, in particular the F18 Hornet Aircraft.

1.1 Project Definition

The study undertaken involved photography of F-18 aircraft within three seconds prior to WOW (weight on wheels) and -.5 seconds after WOW with medium format cameras. Utilizing close range terrestrial photogrammetry the following parameters such as sink and horizontal speed, pitch, roll angles and rates were to be accurately measured.

1.2 Background

The project task was in support of the International Follow On Structural Test Program (IFOSTP). Discrepancies between the available Maintenance Signal Data Recording System (MSDRS) and actual occurrence have been noticed when comparing landing parameters with an independent high sampling pulse code modulated (pcm) data source from the Canadian Air Force Aerospace Engineering Test Establishment (AETE) flight test program. It was found that the aircraft's vertical velocity at weight on wheels appears to be largely overestimated by the MSDRS. Actual values were found to be 40 to 70 percent less than the MSDRS estimate. The likely reason is that the MSDRS computer algorithm for Vv yields the largest value out of the two seconds preceding WOW. While United States Navy (USN) pilots literally drop at constant sink rates on carrier decks Canadian Forces pilots "check" their landings in the last few seconds to reduce ground impact. At present, structural life estimates of the F-18 undercarriage and support structure is based on McAir calculations and tests conducted for the USN and make use of CF MSDRS data. The life obtained is thus likely to be overly conservative. Photogrammetry proved to be the best test alternative considering the time frame for acquiring the test information.

2.0 COMPUTER SIMULATION

Due to the varying situations and applications that may be encountered in a close range photogrammetric survey, a computer simulation of the survey is an invaluable tool. In this case, the coordinates of designated locations on the aircraft were generated. By assuming the locations of the expected camera station coordinates and orientation parameters, the photo coordinates of a point are generated synthetically. In order to provide a realistic simulation, these synthetic photo coordinates are disturbed (usually by a random number generator). This has the effect of synthetically introducing random errors into the system that are expected to occur in practice. By processing this data through the bundle adjustment program, various configurations of targeted points, camera station locations and control point information can be examined with respect to the achievable and expected accuracy. The simulated data indicated that overall accuracies would be from 17 to 24 mm. for the sequences from 3.5 seconds to WOW.

3.0 INTIAL FIELD PREPARATION

The cameras selected for the photogrammetric monitoring were Hulcher model 108 70 mm camera with a maximum frame rate of 20 frames per second and shutter speeds up to 1/4000 of a second. All cameras were equipped with a 165mm lens. The cameras were calibrated and checks were made for film flattening at the higher speeds.

During the preliminary discussions for this project we considered type of cameras to be used, frame rate, and problems of synchronizing the cameras. In addition, simulations were analyzed for possible camera locations and target and camera distances. Several tests were made with the Hulcher camera to test for non-mechanical or non-electrical synchronization. These tests include the use of a Flash or strobe, Argon pulse flash and lights. As a backup Canadian air force personnel developed a rotating mechanical target large enough to viewed by several cameras. The target was tested and proved quite effective (Figure 1). The overall accuracy would be dependent on the ability of the cameras synchronizing.

In addition video was used to supplement some landing sequences.

3.1 Initial Photogrammetric Work

Convergent photography was taken of a CF18 aircraft on the ground at a distance of less than 10 meters as shown in Figure 2. The images were processed through our Bundle adjustment program, this provided a very accurate control reference for the aircraft. The control values would be used to determine accuracy and check data for the ground to air photography of the CF18 aircraft.

An arbitrarily defined survey system was established and control targets were placed and surveyed within the field of view as described by the simulation.

Since the purpose of the study was determining landing parameters we wanted the data to describe at best typical landings. It was for this reason that the pilots were not briefed on what we were doing to avoid the possibility of altered landing procedures. All film was processed on site.

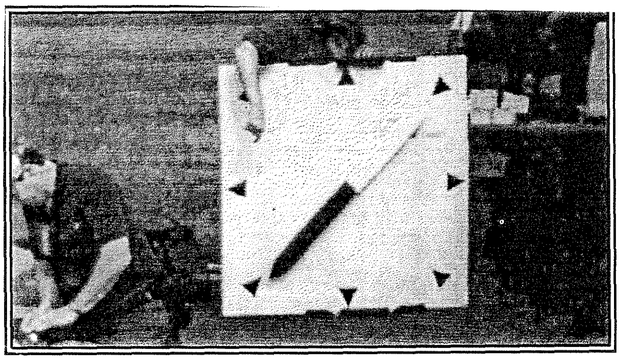

Figure 1.

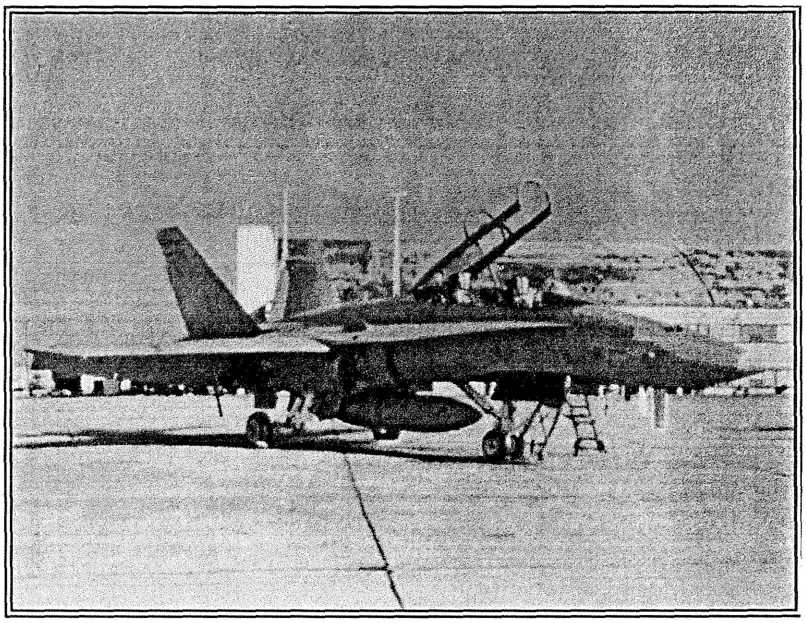

Figure 2.

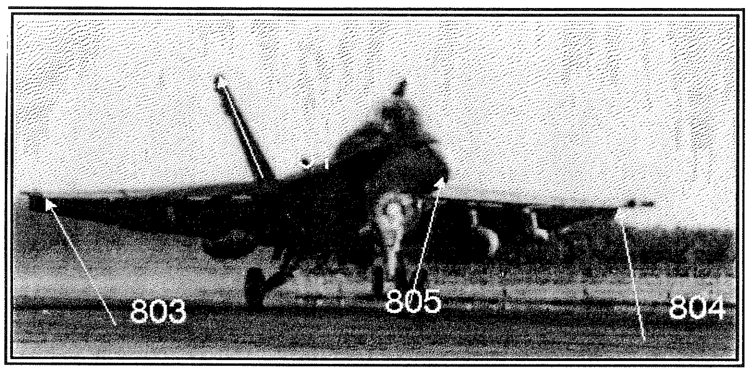

Figure 3.

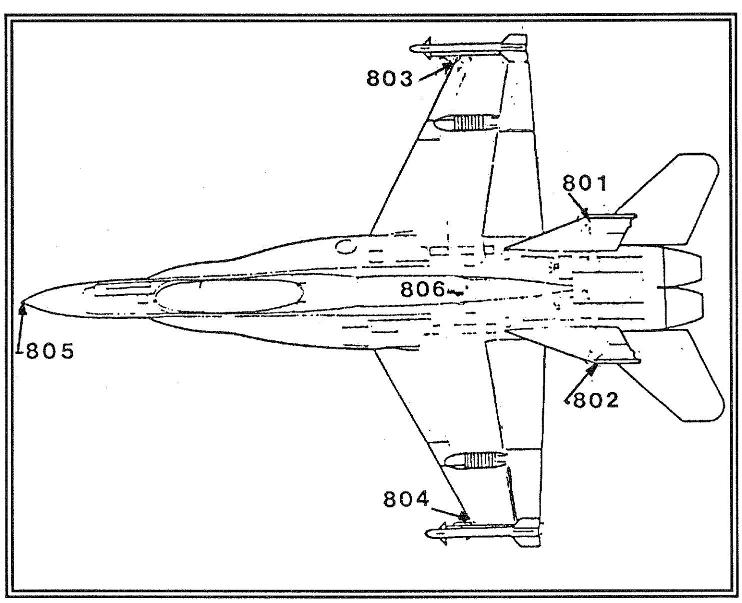

Figure 4.

Table 1. Sample Test data.

IFOSTP F18 TEST

	Analysis Time	Hoziz Speed (Kts)	Sink Speed (ft/sec)	Roll Angle (Deg)	Pitch Angle (deg)	Pitch Rate (deg/s)
	wow - 3.25 sec			1.095	1.616	
	wow - 2.75 sec	137.42	15.67	0.181	2.168	1.102
	wow - 2.25 sec	136.50	14.11	-0.719	2.513	0.690
	wow - 1.75 sec	135.80	14.34	-0.332	3.009	0.992
	wow - 1.25 sec	135.43	13.81	-0.488	4.034	2.051
	wow - .75 sec	135.10	11.91	-0.869	4.700	1.332
	wow - .25 sec	135.50	8.23	-0.045	5.019	0.637
	wow -					
	wow + .25 sec	134.95	-0.05	0.221	1.825	-3.193
MEAN		135.81	11.15	-0.120	3.110	0.516
STDV		0.87	5.49	0.631	1.318	1.703
	wow - 3.25 sec			0.387	4.026	
	wow - 2.75 sec	138.40	8.14	0.638	4.380	0.708
	wow - 2.25 sec	137.80	6.04	-1.276	4.758	0.757
	wow - 1.75 sec	137.50	5.95	-1.748	4.721	-0.076
	wow - 1.25 sec	137.10	5.72	-1.568	5.159	0.877
	wow - .75 sec	136.50	4.44	-1.681	5.143	-0.033
	wow - .25 sec	136.14	4.63	0.542	5.642	1.000
	wow -					
	wow + .25 sec	134.28	1.53	0.246	4.396	-2.493
MEAN		136.82	5.21	-0.558	4.778	0.106
STDV		1.35	2.02	1.095	0.521	1.224
	wow - 3.25 sec			-0.392	4.668	
	wow - 2.75 sec	135.87	7.35	-0.357	4.587	-0.161
	wow - 2.25 sec	134.80	7.03	0.060	5.190	1.203
	wow - 1.75 sec	134.47	6.16	-0.301	5.439	0.498
	wow - 1.25 sec	133.89	5.22	0.377	5.270	-0.338
	wow - .75 sec	134.02	4.95	0.970	5.012	-0.516
	wow - .25 sec	133.61	4.34	0.201	4.879	-0.266
	wow -					
	wow + .25 sec	132.99	1.53	-0.809	2.986	-3.786
MEAN		134.23	5.22	-0.031	4.754	-0.481
STDV		0.93	1.97	0.554	0.771	1.575
	wow - 2.75 sec			0.181	2.361	
	wow - 2.25 sec	135.94	7.88	-0.924	3.361	2.000
	wow - 1.75 sec	137.10	8.02	-0.904	3.182	-0.358
	wow - 1.25 sec	136.01	7.30	-0.698	4.131	1.898
	wow - .75 sec	137.40	6.10	0.884	4.076	0.110
	wow - .25 sec	136.89	4.23	0.980	3.656	-0.840
	wow -					
	wow + .25 sec	134.31	-0.05	0.256	3.842	1.177
MEAN		136.27	4.78	-0.028	3.076	0.570
STDV		1.13	3.53	0.755	1.368	1.123
	wow - 3.25 sec			3.189	2.060	
	wow - 2.75 sec	144.46	12.29	2.773	2.397	0.674
	wow - 2.25 sec	143.60	11.05	1.844	3.434	2.074
	wow - 1.75 sec	143.30	9.37	0.920	4.115	1.362
	wow - 1.25 sec	142.68	7.07	0.990	4.516	0.802
	wow - .75 sec	142.37	4.77	2.271	4.261	-0.510
	wow - .25 sec	143.15	3.88			
	wow -					
	wow + .25 sec	139.83	1.73	-1.433	2.051	
MEAN		142.77	7.16	1.319	2.854	0.629
STDV		1.46	3.92	1.529	1.526	0.889

4.0 DATA REDUCTION

All film was sorted and catalogued for each event. Every event was recorded with the aircraft number, date, film roll, runway, and landing time. This was required since all data was to be compared with the aircraft MSDRS computer data.

Film frames were sorted, starting from WOW every .5 of a second to 3.0 seconds before WOW. The film frame from each camera for each epoch of the event was measured on a PASS 2000 system, in addition to scanned images that were measured with our Digtab_Plus IP soft copy system. Control values were measured along with 5 points on the aircraft as illustrated in Figures 3 and 4.

During this study WOW is defined as the point at which the smoke from the undercarriage tires is visible on the film frame. The point is thus defined for each camera to within one twentieth of a second. This point is not necessarily the point at which the WOW flag in the aircraft recording system is displayed.

Three dimensional coordinate data were computed for the reference points shown in Figure 3 and 4. The data was transformed and compared to values obtained from the ground based photogrammetry.

Utilizing the three dimensional coordinate data obtained points on the aircraft mid point 806 was computed for each epoch and event.(Figure 4.) The point 806 is very close to the CG of the aircraft (35 inches aft) and directly in line with the main undercarriage. Since the point 806 is so close to the aircraft's CG it was used for the determination of airspeed and sink speeds found in Table 1.
Airspeed was calculated using the distance travelled over the time taken between the epochs. The sink speed is calculated using the elevation differences taken between the epochs at point 806. The airspeed is displayed in Table 1. in Knots per second and sink speed has been reduced to feet per second.

4.1 Accuracies of the final landing parameters

After reviewing the data epochs within some events show forward and sink speeds, not having a smooth trend. This was caused by synchronization problems within the cameras and to poor image quality. In addition problems were encountered with film flattening, or consistency of film flattening during the exposures. The percentage difference between the airspeed and sink speeds are consistent and the problem occurs over the entire frame.

As described, the frames were additional matched utilizing the timing target in each frame. The film rebate on some cameras was wider so there was a difference between the overall frame count.

If the camera synchronization is out by a half frame or 1/40 sec. then the aircraft would have travelled forward by .87 meters. This is equivalent to 3.4 knots in the speed calculation.(** Table 1.)

The reference points coordinate accuracy is 25 mm in the object space. Frames were read every .5 seconds, a typical aircraft vertical movement in .5 seconds is 1.3 meters this provides a percentage of accuracy of 2 percent. This equates to an accuracy of .2 ft/sec in sink speed.

Figure 5.

5.0 CONCLUSION

The purpose of this study was to provide a reasonably detailed analysis of the adaptability of photogrammetric mensuration procedures for determination of landing parameters of F18 aircraft. The photogrammetric data extraction process proved to be advantageous and cost effective.

The landing parameters determined by photogrammetry was compared to the MSDRS data, the epochs compared within 10 percent. This comparison it quit good, one has to consider that the WOW flag from the MSDRS data is not necessarily the same that is used for the photogrammetry. In addition even the frames that showed slight synchronization problem's data plotted to a XY plot show the same trend.

Approximately 70 100 foot rolls of film were taken at the site. The cameras were mounted along the side of the active runway within a fairly difficult working environment (Figure 5). There were hundreds of takeoff and landings with various (armed) military aircraft. Communication and team liaison were very important, especially for coordinating photography and safety reasons, every item had to be secured and removed from the site at the end of the day's photography.

I would like to thank the personnel at Canadian Air Force Test & evaluation lab for there support during this project.

6.0 REFERENCE

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