

Door County, Wisconsin

Airborne GPS and Exterior Orientation Computation Results

Aerial Photographic Project Door County, Wisconsin

EarthData Aviation was requested to collect photography and airborne GPS data to support the photogrammetric mapping of Door County, Wisconsin. The project area was flown in two missions on April 17, 2002 using EarthData Aviation's Navajo Chieftain, tail number N76JN. During the aerial photography, two dual frequency GPS receivers were utilized. One receiver was operated on board the aircraft with the dual frequency antenna located directly over the camera. The shutter output from the aerial camera was directly connected to the receiver. The second receiver was used as a base station. These receivers were in constant operation during the photography mission and GPS phase data was collected at an epoch rate of 1 second.

Details on the mission, camera, and GPS base stations may be found in the attached Overview Report. The National Geodetic Survey (NGS) Data Sheet for the base station "Sturgeon Bay GPS" is attached.

GPS Data Processing

All GPS phase data collected was post processed with continuous kinematic survey techniques utilizing "On the Fly" (OTF) ambiguity resolution. All data was processed forward and reverse and the results from each process were combined to yield the position of the aircraft antenna. All positions are latitude, longitude, and ellipsoidal heights (meters). Attached are charts showing the aircraft trajectory and altitude and forward and reverse processing residuals.

Lift No.	Date	Horizontal Accuracy (cm)	Vertical Accuracy (cm)	Comments
1	4/17/02	10	15	Good quality
2	4/17/02	10	15	Good quality

Orientation Data Processing

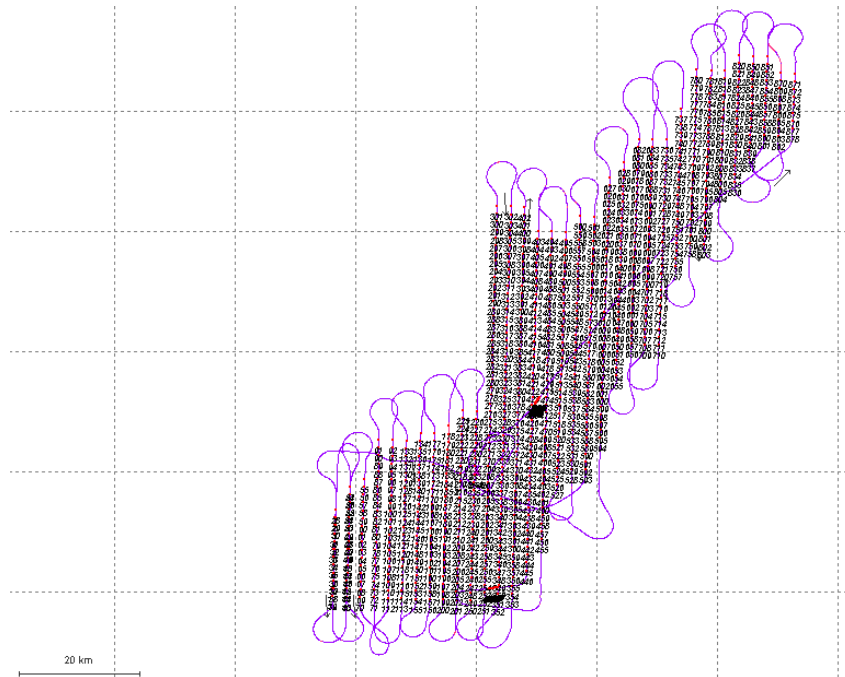
The IMU was used to record precise changes in position and orientation of the camera at a rate of 200 Hz. All IMU data was processed post flight with a Kalman filter to integrate inertial measurements and precise phase differential GPS positions. The resulting solution contains geodetic position, omega, phi, kappa, and time for each photo center.

Exterior Orientation Determination

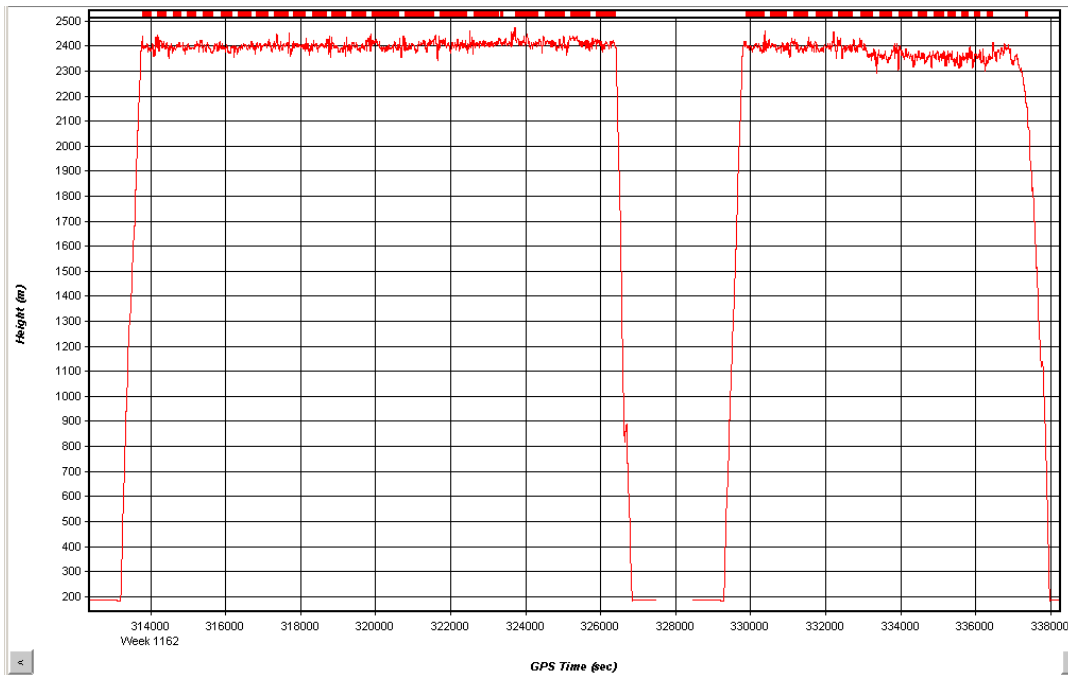
A constant offset exists between the GPS unit, the IMU and the camera focal plane. Furthermore, each unit has its own coordinate reference frame. The GPS operates in the WGS84 coordinate frame, the IMU in the inertial frame, and the camera in its own body reference frame. The

relationship between each of these components is determined through several geodetic processes including: survey measurements on the aircraft, comparison of the position and orientation as computed from an aero triangulation solution over a boresight area, and results from the GPS/IMU solution. This process is performed once for each camera installation.

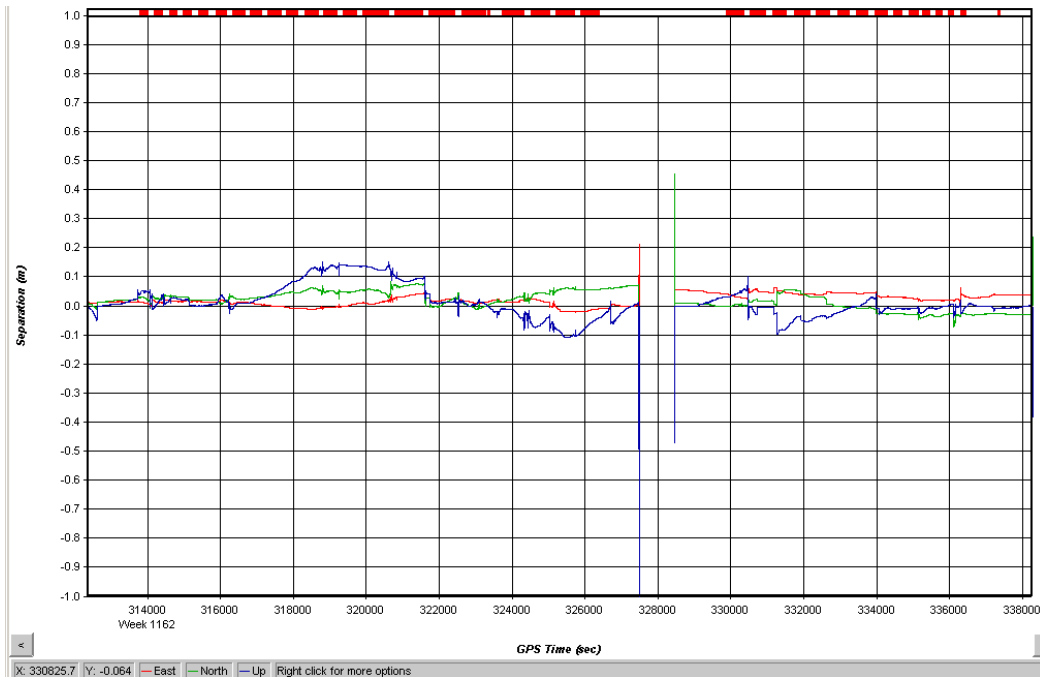
The resultant alignment angles were used in the inertial solution to compute a set of exterior orientation parameters ($X, Y, Z, \omega, \phi, \kappa$) for all photographs.



Aircraft Trajectory
Lifts 1 and 2: April 17, 2002



Altitude Plot
Lifts 1 and 2: April 17, 2002



Forward-Reverse Solution Residual
Lifts 1 and 2: April 17, 2002

Lift 1 Overview Report:

General Information:

EarthData Job 02-1072-EA
 Roll 76584
 Lift No: 1
 Client Job No:
 Client Name: EarthData MD
 Job Name: Door County WI
 State Name: WI

Collection Information:

Date Flown: 4/17/02 Photographer: Lopez
 Film Type: Agfa X-100 Pilot: Stephens
 Lens Number: 13256 - 5242 Inspector: Holloway
 Cal Focal Length: 152.986 Titling Type: ASCOT
 Emulsion 67663032 2003/7 Titling Format: Date Door Co, WI 1:14400 L&F

Aircraft Information:

Aircraft: N76JN Camera: 5242
 Lens: 13256 IMU Serial No: N/A
 Boresite No: N/A Time offset: 0
 Antenna Offset X: 0.00 m Y: 0.03 m Z: 1.46 m
 Information Effective 6/1/01 To: 5/30/02

Base Station Information:

Base Station PM0591
 Base Station Sturgeon Bay GPS
 Latitude: 44 50 10.53283 N
 Longitude: 087 25 34.87193 W
 Ellipsoid Height 183.33 m
 Comment Horiz order A; Ellipsoidal order Third Class I
 Primary airport control station
 NAD 83 (1997)

GPS Quality Information:

X, Y Accuracy <= 8 cm
 Z Accuracy <= 15 cm

Lift 2 Overview Report:

General Information:

EarthData Job 02-1072-EA
Roll 76585
Lift No: 2
Client Job No:
Client Name: EarthData MD
Job Name: Door County WI
State Name: WI

Collection Information:

Date Flown: 4/17/02 Photographer: Lopez
Film Type: Agfa X-100 Pilot: Stephens
Lens Number: 13256 - 5242 Inspector: Novillo
Cal Focal Length: 152.986 Titling Type: ASCOT
Emulsion 67663032 2003/7 Titling Format: Date Door Co, WI 1:14400 L&F

Aircraft Information:

Aircraft: N76JN Camera: 5242
Lens: 13256 IMU Serial No: N/A
Boresite No: N/A Time offset: 0
Antenna Offset X: 0.00 m Y: 0.03 m Z: 1.46 m
Information Effective 6/1/01 To: 5/30/02

Base Station Information:

Base Station PM0591
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DATASHEETS

The NGS Data SheetSee file dsdata.txt for more information about the datasheet.DATABASE = Sybase ,PROGRAM = datasheet, VERSION = 6.61

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1      National Geodetic Survey,   Retrieval Date = JULY 8, 2002
PM0591 *****
PM0591 CBN          -   This is a Cooperative Base Network Control Station.
PM0591 PACS         -   This is a Primary Airport Control Station.
PM0591 DESIGNATION -   STURGEON BAY GPS
PM0591 PID          -   PM0591
PM0591 STATE/COUNTY-   WI/DOOR
PM0591 USGS QUAD    -   STURGEON BAY WEST (1981)
PM0591
PM0591                      *CURRENT SURVEY CONTROL
PM0591
PM0591* NAD 83(1997)- 44 50 10.53283(N)    087 25 34.87193(W)    ADJUSTED
PM0591* NAVD 88      -           220.00    (meters)      721.8    (feet)    GPS OBS
PM0591
PM0591 X            -           203,438.444 (meters)                COMP
PM0591 Y            -      -4,525,999.531 (meters)                COMP
PM0591 Z            -      4,474,592.398 (meters)                COMP
PM0591 LAPLACE CORR-           -1.68    (seconds)                DEFLEC99
PM0591 ELLIP HEIGHT-           183.33 (meters)                GPS OBS
PM0591 GEOID HEIGHT-          -36.67 (meters)                GEOID99
PM0591
PM0591 HORZ ORDER  -   A
PM0591 ELLP ORDER  -   THIRD      CLASS I
PM0591
PM0591.This mark is at Door Co Cherryland Airport (SUE)
PM0591
PM0591.The horizontal coordinates were established by GPS observations
PM0591.and adjusted by the National Geodetic Survey in April 1999.
PM0591
PM0591.The orthometric height was determined by GPS observations and a
PM0591.high-resolution geoid model.
PM0591
PM0591.GPS derived orthometric heights for airport stations designated as
PM0591.PACS or SACS are published to 2 decimal places. This maintains
PM0591.centimeter relative accuracy between the PACS and SACS. It does
PM0591.not indicate centimeter accuracy relative to other marks which are
PM0591.part of the NAVD 88 network.
PM0591
PM0591.The X, Y, and Z were computed from the position and the ellipsoidal ht.
PM0591
PM0591.The Laplace correction was computed from DEFLEC99 derived deflections.
PM0591
PM0591.The ellipsoidal height was determined by GPS observations
PM0591.and is referenced to NAD 83.
PM0591
PM0591.The geoid height was determined by GEOID99.
PM0591
PM0591;
PM0591;SPC WI C      -           North           East           Units   Scale           Converg.
PM0591;UTM 16      -   114,668.001   803,454.950   MT   0.99994095 +1 48 57.3
PM0591;UTM 16      -   4,964,849.530  466,301.264   MT   0.99961396 -0 18 02.2
PM0591
PM0591:
PM0591:SPC WI C      -   Primary Azimuth Mark           Grid Az
PM0591:UTM 16      -   STURGEON BAY GPS AZ MK           020 19 32.7
PM0591:UTM 16      -   STURGEON BAY GPS AZ MK           022 26 32.2
PM0591

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PM0591'TO REACH THE STATION FROM THE JUNCTION OF STATE HIGHWAYS 42 AND 57 AND
PM0591'COUNTY ROADS C AND S IN SOUTHEAST STURGEON, GO NORTH ON COUNTY ROAD C
PM0591'FOR 1.6 KM (1.0 MI) TO A CROSSROAD. TURN LEFT AND GO WEST ON COUNTY
PM0591'ROAD C FOR 2.4 KM (1.5 MI) TO A CROSSROAD. TURN RIGHT AND GO NORTH
PM0591'ON PARK DRIVE FOR 0.7 KM (0.4 MI) TO A PAVED ROAD ON THE RIGHT. TURN
PM0591'RIGHT AND GO EAST ON THE AIRPORT ENTRANCE ROAD FOR FOR 0.3 KM
PM0591'(0.2 MI) TO A PAVED ROAD AND GATE ON THE RIGHT. TURN RIGHT AND GO
PM0591'SOUTH ON THE PAVED ROAD, PASSING THROUGH THE GATE, FOR 0.3 KM
PM0591'(0.2 MI) TO A PAVED ROAD ON THE LEFT. TURN LEFT AND GO EAST ON THE
PM0591'PAVED ROAD AND ALONG A TAXIWAY, PASSING BETWEEN THE HANGARS, FOR 0.1
PM0591'KM (0.1 MI) TO A TAXIWAY. TURN RIGHT AND GO SOUTHWEST ON THE TAXIWAY
PM0591'FOR 0.15 KM (0.09 MI) TO AN APRON, BEAR RIGHT AND CONTINUE SOUTHWEST
PM0591'ACROSS THE APRON FOR 0.1 KM (0.1 MI) AND THE STATION STRAIGHT AHEAD.
PM0591'THE STATION IS LOCATED 51.8 M (169.9 FT) NORTHEAST FROM A CHAINLINK
PM0591'FENCE, 61.3 M (201.1 FT) SOUTHEAST FROM THE SOUTHEAST CORNER OF THE
PM0591'EAA BUILDING, 30.5 M (100.1 FT) SOUTHWEST FROM THE SOUTHWEST EDGE OF
PM0591'THE APRON, 30.5 M (100.1 FT) WEST FROM THE WEST EDGE OF A 3-FOOT
PM0591'SQUARE LIME STONE BLOCK AND IS FLUSH WITH THE GROUND.

PM0591

PM0591

STATION RECOVERY (1997)

PM0591

PM0591'RECOVERY NOTE BY WI HIGHWAY DEPT 1997 (CSM)

PM0591'NOTE--THIS IS THE PRIMARY AIRPORT CONTROL (PAC) STATION FOR THE DOOR
PM0591'COUNTY/CHERRYLAND (SUE) AIRPORT. THE STATION IS LOCATED ABOUT 4.03 KM
PM0591'(2.50 MI) WEST OF STURGEON BAY AND 61.19 KM (38.00 MI) NORTHEAST OF
PM0591'GREEN BAY NEAR THE SOUTHWEST CORNER OF THE DOOR COUNTY CHERRYLAND
PM0591'AIRPORT. OWNERSHIP--DOOR COUNTY. THE AIRPORT MANAGER IS KEITH
PM0591'KASBOHM, TELEPHONE 920 743-3636. TO REACH FROM THE INTERSECTION OF
PM0591'STATE HIGHWAYS 42 AND 57 WITH COUNTY HIGHWAYS C AND S (DULUTH STREET)
PM0591'IN THE WESTERN PORTION OF THE CITY OF STURGEON BAY, GO NORTH 1.61 KM
PM0591'(1.00 MI) ON HIGHWAY C (DULUTH STREET) TO THE INTERSECTION WITH ELM
PM0591'STREET WHERE HIGHWAY C TURNS LEFT, TURN LEFT AND GO WEST 2.42 KM (1.50
PM0591'MI) ON HIGHWAY C TO THE INTERSECTION WITH PARK DRIVE, (THE STATION IS
PM0591'69.2 M (227.0 FT) NORTH OF HIGHWAY C AND 105.35 M (345.64 FT) EAST OF
PM0591'PARK DRIVE) . TO DRIVE TO THE STATION, TURN RIGHT AND GO NORTH 0.64
PM0591'KM (0.40 MI) ON PARK DRIVE TO THE AIRPORT ENTRANCE ON THE RIGHT, TURN
PM0591'RIGHT AND GO EAST-SOUTHEAST 0.16 KM (0.10 MI) ON THE AIRPORT ENTRANCE
PM0591'ROAD TO A GATE ON THE RIGHT AND THE TERMINAL AND AIRPORT OFFICE
PM0591'STRAIGHT AHEAD, TURN RIGHT PASS THROUGH THE GATE AND GO
PM0591'SOUTH-SOUTHWEST 0.32 KM (0.20 MI) ON A PAVED ROAD TO THE HANGER AREA
PM0591'AND AN INTERSECTION NEAR HANGER 55, TURN LEFT AND GO EAST-SOUTHEAST
PM0591'0.08 KM (0.05 MI) ON A ROAD/TAXIWAY PASSING BETWEEN HANGERS 36 AND 37
PM0591'AND THEN BETWEEN HANGERS 18 AND 19 TO A TAXIWAY IN FRONT OF HANGERS 13
PM0591'THROUGH 27, TURN RIGHT AND GO SOUTH-SOUTHWEST 0.24 KM (0.15 MI) ON THE
PM0591'TAXIWAY ADJACENT HANGERS 13 THROUGH 27 TO AN APRON BY HANGER 8,
PM0591'CONTINUE SOUTH-SOUTHWEST 0.08 KM (0.05 MI) CROSSING THE APRON BY
PM0591'HANGER 8 TO THE STATION ON THE LEFT IN A GRASS AREA. THE STATION IS A
PM0591'BRONZE NGS HORIZONTAL CONTROL MARK DISK SET IN THE TOP OF A 40-CM
PM0591'(16-INCH) DIAMETER CONCRETE POST ANCHORED IN A ROCK OUTCROP, IS
PM0591'RECESSED ABOUT 6 CM BELOW THE GROUND SURFACE, AND IS ABOUT LEVEL WITH
PM0591'THE APRON PAVEMENT. THE STATION IS 90.9 M (298.2 FT) EAST OF THE
PM0591'CHAIN-LINK FENCE ON THE EAST SIDE OF PARK DRIVE, 51.9 M (170.3 FT)
PM0591'NORTH OF THE CHAIN-LINK FENCE ON THE NORTH SIDE OF HIGHWAY C, 61.25 M
PM0591'(200.95 FT) SOUTHWEST OF THE SOUTHEAST CORNER OF THE EAA CHAPTER 630
PM0591'MEETING BUILDING, 30.60 M (100.39 FT) SOUTH-SOUTHWEST OF THE
PM0591'SOUTH-SOUTHWEST EDGE OF THE APRON PAVEMENT, 43.35 M (142.22 FT)
PM0591'SOUTHWEST OF THE SOUTHEAST CORNER OF THE APRON PAVEMENT, APPROXIMATELY
PM0591'110 M (360.9 FT) WEST-NORTHWEST OF THE EXTENDED CENTERLINE OF RUNWAY
PM0591'01/19, AND APPROXIMATELY 26 M (85.3 FT) WEST-NORTHWEST OF THE EXTENDED
PM0591'CENTERLINE OF A TAXIWAY PARALLEL TO AND ALONG THE WEST SIDE OF RUNWAY



PM0591'01/19. NO WITNESS POST WAS SET AT THIS STATION. *** retrieval complete.