ARM Aerial Vehicles Program

Flight Planning for the Indirect and Semi-Direct Aerosol Campaign (ISDAC)

Jason Tomlinson
Pacific Northwest National Laboratory

ARM Science Team Meeting
March 11th, 2008
Norfolk, VA

Overview

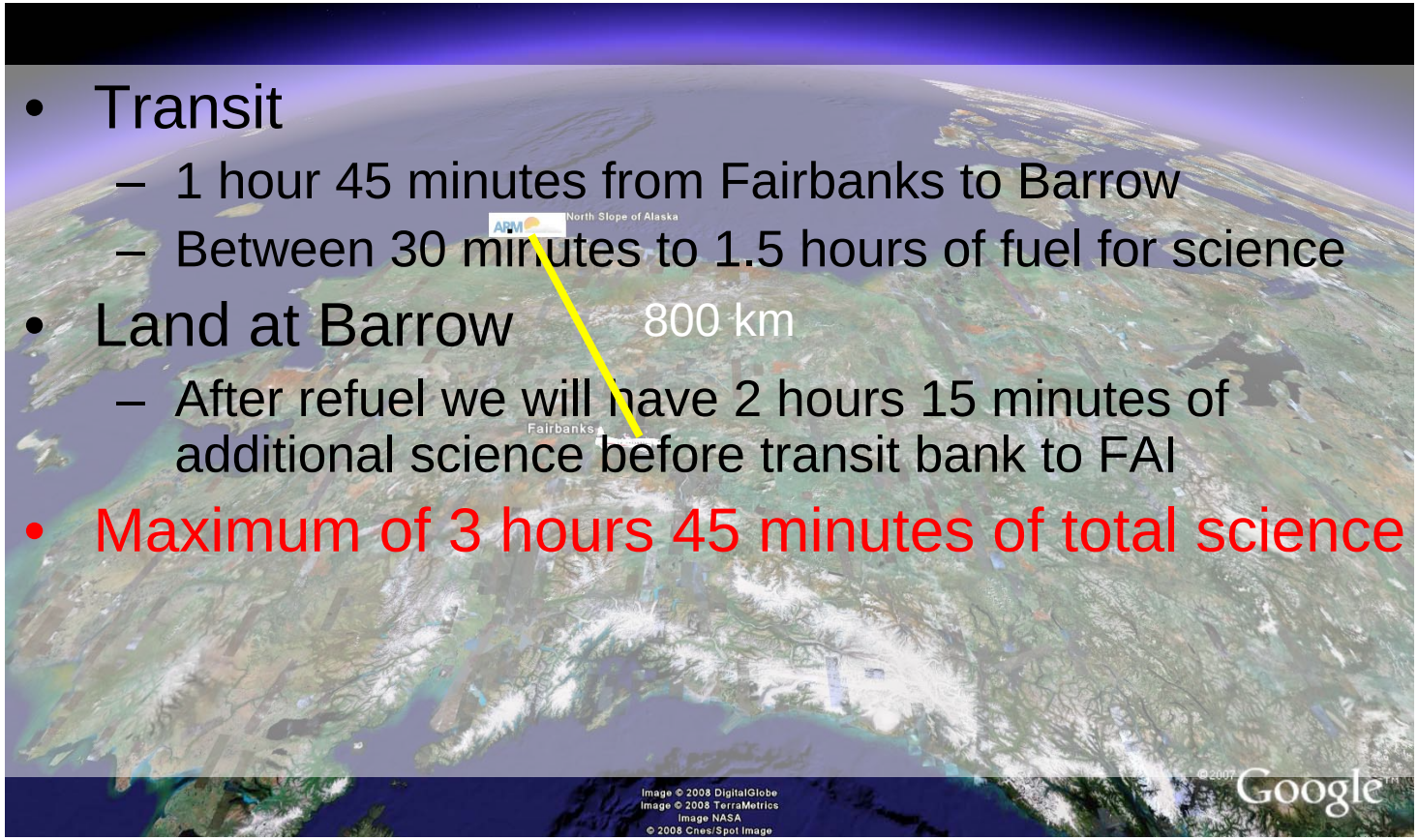
- ISDAC will occur from April 1st to April 30th
- EC/NRC Convair

Aerial Vehicles Program

Overview

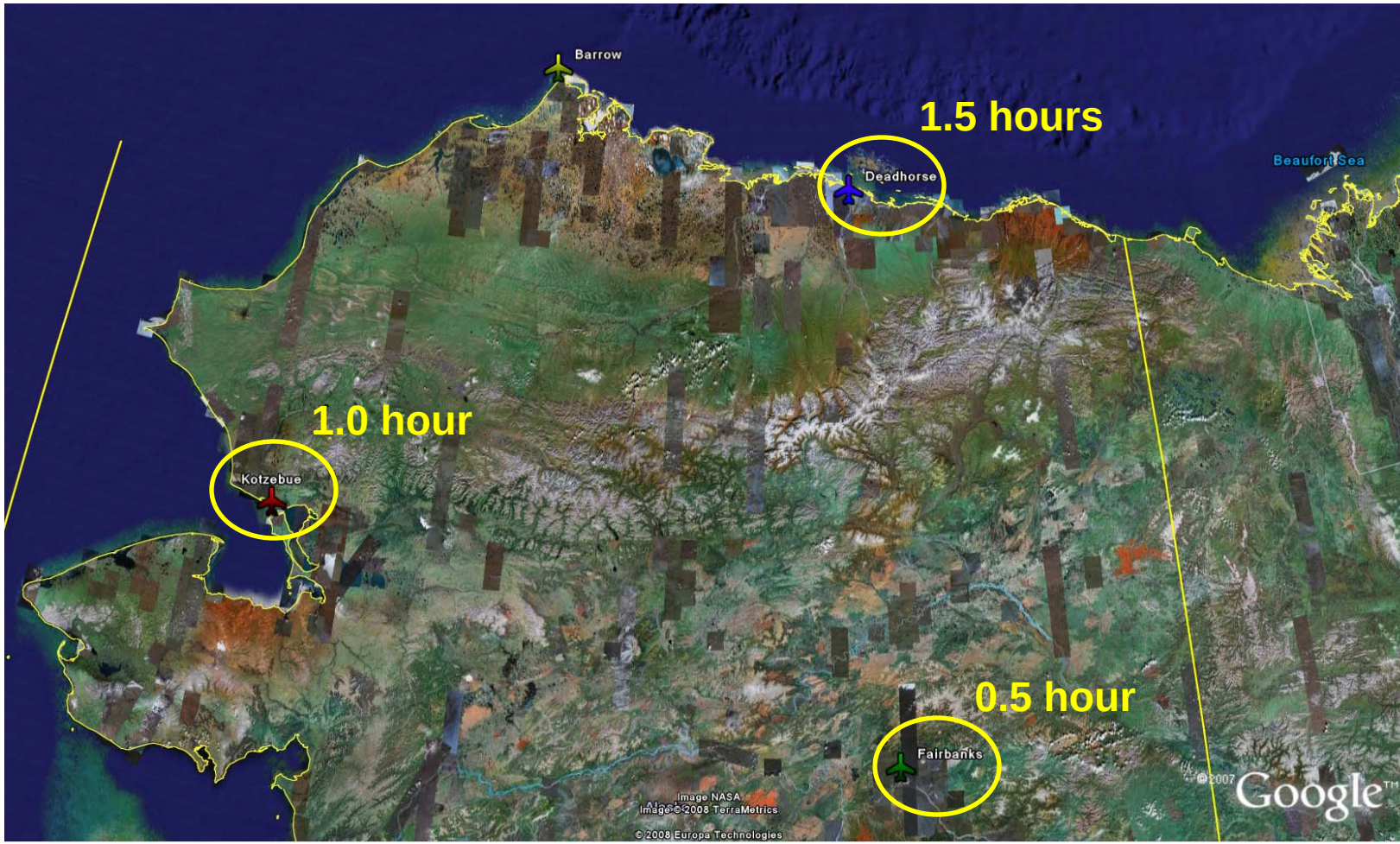
- ISDAC will occur from April 1st to April 30th
- EC/NRC Convair
  - Full suite of instruments capable of aerosol, gas, and ice phase measurements
- 94 Available flight hours
  - Roughly 12 flights with 2 to 3 occurring per week
- Each flight will hopefully have 2 segments
- Several opportunities for comparisons with the A-train satellites

Flight Overview



- Transit
  - 1 hour 45 minutes from Fairbanks to Barrow
  - Between 30 minutes to 1.5 hours of fuel for science
- Land at Barrow
  - After refuel we will have 2 hours 15 minutes of additional science before transit bank to FAI
- Maximum of 3 hours 45 minutes of total science

Aerial Vehicles Program



Pacific Northwest National Laboratory
Operated by Battelle for the U.S. Department of Energy
Office of Science
U.S. DEPARTMENT OF ENERGY

Flight Overview

15:00 (day before flight, C-580 may be airborne): Meteorological briefing for all ISDAC participants

15:30: flight decision-making group (includes off-duty flight crew if C-580 airborne); if next day is suitable, preliminary flight plan produced. alert all crew and instrument support of possible flight;

06:00 (day of flight): meteorological briefing for mission scientists; preliminary flight plan reviewed

07:00: brief flight crew on expected mission profile; official flight plan produced; pull aircraft out of hangar

07:15: scientific crew and instrument support on aircraft preparing for mission

09:15: final ‘go/no-go’ decision from flight decision-making group

09:30: all non-crew members off the aircraft – doors closed

09:45: takeoff Fairbanks

11:25: commence measurements over ARM site

12:45: landing Barrow after flight #1

Flight Overview

13:00: NRC/EC flight director contacts flight decision-making group in Fairbanks for guidance on second flight

13:45: doors closed

14:00: takeoff Barrow for flight #2

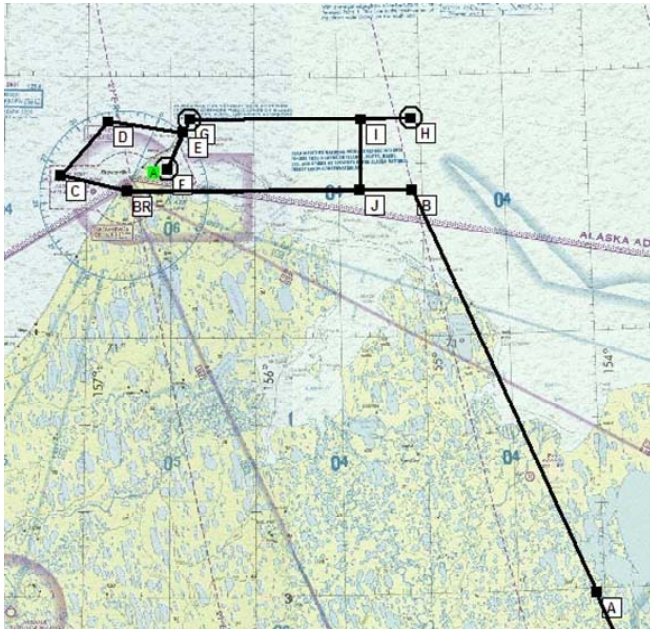
14:18 -14:36: A-Train overpasses near Barrow (April 1, 3, 10, 12, 17, 19) or start measurements over ARM site without A-Train

16:50: start transit back to Fairbanks

18:30: land Fairbanks

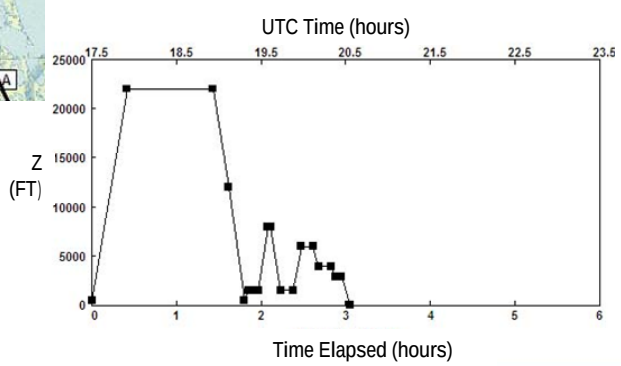
19:00: Flight debrief and plans for next day announced/discussed

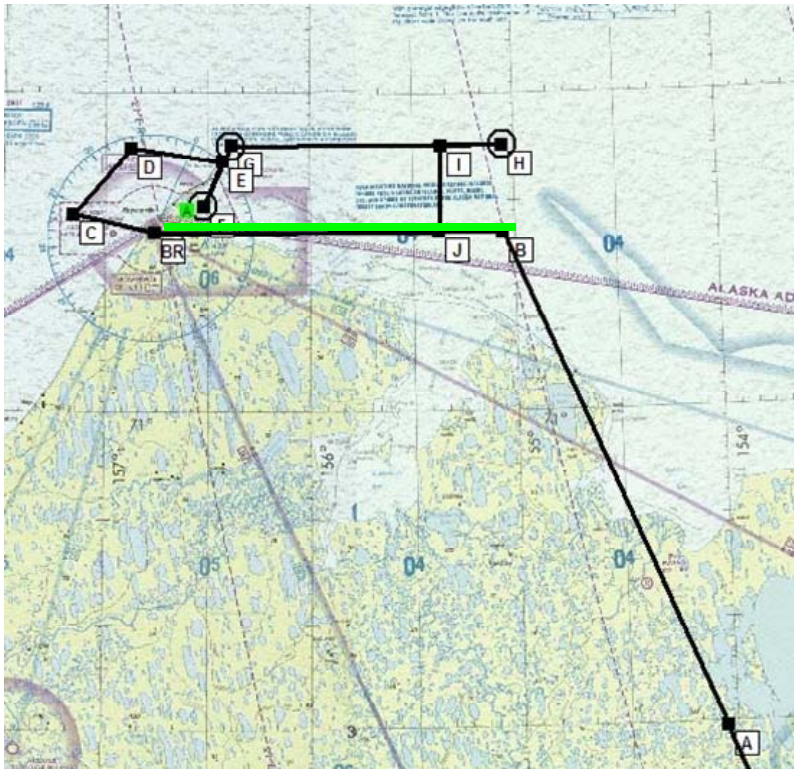
Example Flight Plan



Total Distance (nm): 686.89 Total ETE (min): 182.9

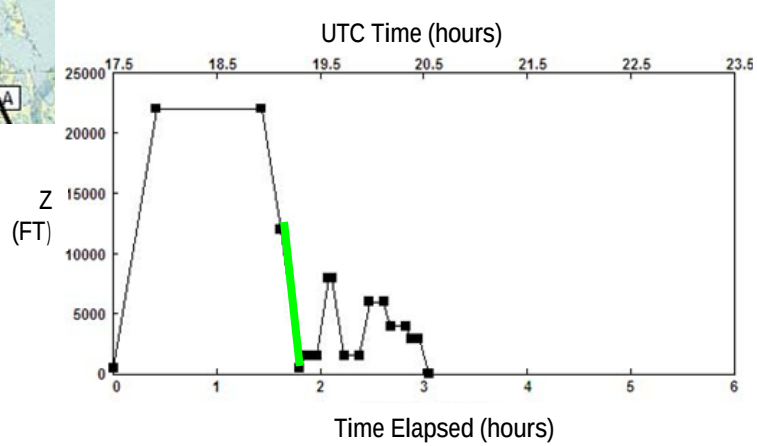
WP	Time Elapsed	LAT	LON	ALT (ft)	SPD (kts)	HDG	Dist (nm)	ETE (min)
FA	00:00:00	64deg 49min	-147deg 51min	434				
FA1	00:25:00	66deg 06min	-149deg 09min	22000	200.0	316.2	83.35	25.0
A	01:26:06	70deg 30min	-154deg 00min	22000	280.0	316.8	285.10	61.1
B	01:37:07	71deg 17min	-155deg 03min	12000	280.0	315.4	51.42	11.0
BR	01:48:08	71deg 17min	-156deg 46min	500	180.0	249.1	33.04	11.0
C	01:50:43	71deg 19min	-157deg 10min	1600	180.0	262.0	7.79	2.6
D	01:53:28	71deg 25min	-156deg 53min	1600	180.0	20.5	8.21	2.7
E	01:56:21	71deg 24min	-156deg 26min	1600	180.0	77.5	8.64	2.9
F	01:57:51	71deg 20min	-156deg 31min	1600	180.0	181.8	4.53	1.5
F	02:04:51	71deg 20min	-156deg 31min	8000	180.0	spiral	21.00	7.0
G	02:06:56	71deg 25min	-156deg 23min	8000	180.0	3.8	6.24	2.1
G	02:13:56	71deg 25min	-156deg 23min	1600	180.0	spiral	21.00	7.0
H	02:22:26	71deg 25min	-155deg 03min	1600	180.0	69.0	25.53	8.5
H	02:28:26	71deg 25min	-155deg 03min	6000	180.0	spiral	18.00	6.0
G	02:36:57	71deg 25min	-156deg 23min	6000	180.0	249.0	25.53	8.5
G	02:40:57	71deg 25min	-156deg 23min	4000	180.0	spiral	12.00	4.0
H	02:49:27	71deg 25min	-155deg 03min	4000	180.0	69.0	25.53	8.5
H	02:52:27	71deg 25min	-155deg 03min	3000	180.0	spiral	9.00	3.0
I	02:54:24	71deg 25min	-155deg 21min	3000	180.0	248.6	5.85	1.9
J	02:57:06	71deg 17min	-155deg 22min	3000	180.0	159.7	8.11	2.7
BR	03:02:54	71deg 17min	-156deg 46min	44	280.0	249.1	27.04	5.8



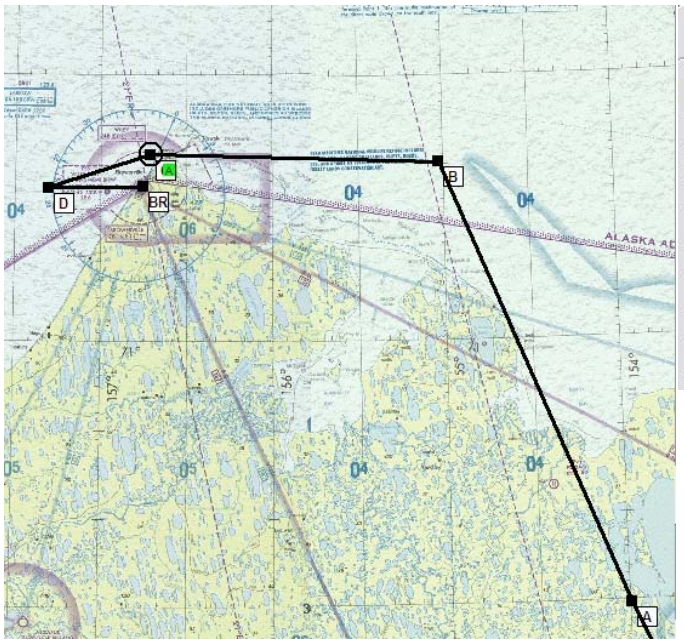


Total Distance (nm): 686.89 Total ETE (min): 182.9

WP	Time Elapsed	LAT	LON	ALT (ft)	SPD (kts)	HDG	Dist (nm)	ETE (min)
FA	00:00:00	64deg 49min	-147deg 51min	434				
FA1	00:25:00	66deg 06min	-149deg 09min	22000	200.0	316.2	83.35	25.0
A	01:26:06	70deg 30min	-154deg 00min	22000	280.0	316.8	285.10	61.1
B	01:37:07	71deg 17min	-155deg 03min	12000	280.0	315.4	51.42	11.0
BR	01:48:08	71deg 17min	-156deg 46min	500	180.0	249.1	33.04	11.0
C	01:50:43	71deg 19min	-157deg 10min	1600	180.0	262.0	7.79	2.6
D	01:53:28	71deg 25min	-156deg 53min	1600	180.0	20.5	8.21	2.7
E	01:56:21	71deg 24min	-156deg 26min	1600	180.0	77.5	8.64	2.9
F	01:57:51	71deg 20min	-156deg 31min	1600	180.0	181.8	4.53	1.5
F	02:04:51	71deg 20min	-156deg 31min	8000	180.0	spiral	21.00	7.0
G	02:06:56	71deg 25min	-156deg 23min	8000	180.0	3.8	6.24	2.1
G	02:13:56	71deg 25min	-156deg 23min	1600	180.0	spiral	21.00	7.0
H	02:22:26	71deg 25min	-155deg 03min	1600	180.0	69.0	25.53	8.5
H	02:28:26	71deg 25min	-155deg 03min	6000	180.0	spiral	18.00	6.0
G	02:36:57	71deg 25min	-156deg 23min	6000	180.0	249.0	25.53	8.5
G	02:40:57	71deg 25min	-156deg 23min	4000	180.0	spiral	12.00	4.0
H	02:49:27	71deg 25min	-155deg 03min	4000	180.0	69.0	25.53	8.5
H	02:52:27	71deg 25min	-155deg 03min	3000	180.0	spiral	9.00	3.0
I	02:54:24	71deg 25min	-155deg 21min	3000	180.0	248.6	5.85	1.9
J	02:57:06	71deg 17min	-155deg 22min	3000	180.0	159.7	8.11	2.7
BR	03:02:54	71deg 17min	-156deg 46min	44	280.0	249.1	27.04	5.8

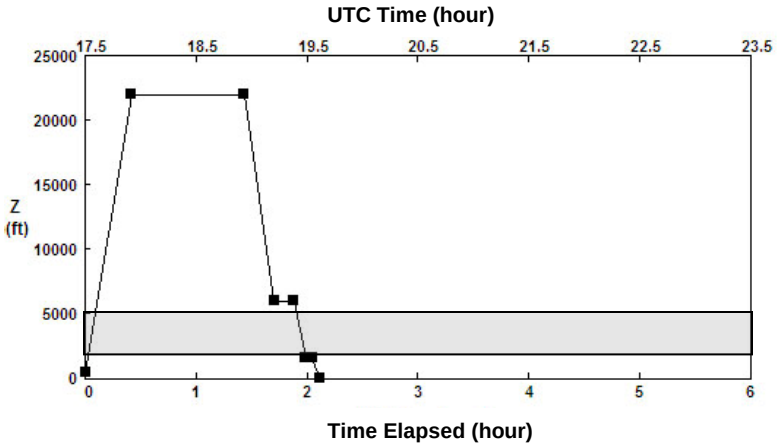


Example Flight Plan 1a (FAI)

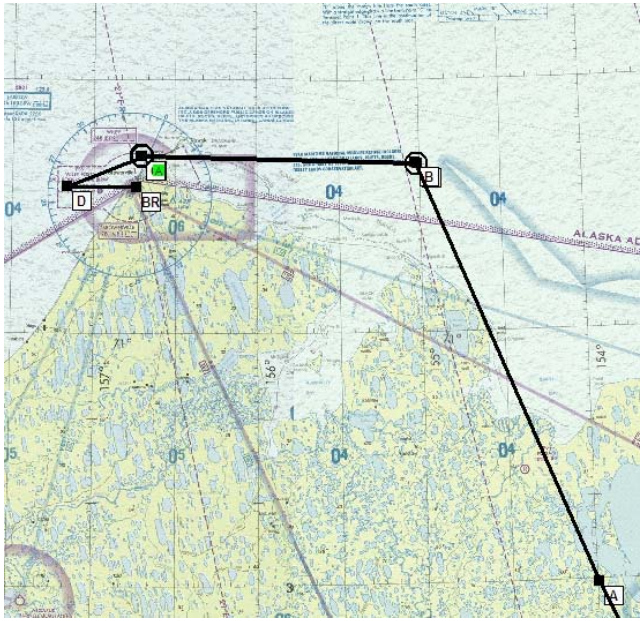


Total Distance (nm): 495.46 Total ETE (min): 126.6

WP	Elapsed UTC	LAT	LON	ALT (ft)	SPD (kts)	HDG	Dist (nm)	ETE (min)
FA	00:00:00	64.815	-147.856	434				
FA1	00:25:00	66.096	-149.150	22000	200.0	316.2	83.35	25.0
A	01:26:06	70.500	-154.000	22000	280.0	316.8	285.10	61.1
B	01:42:15	71.332	-155.030	6000	200.0	317.0	53.85	16.2
C	01:53:00	71.351	-156.710	6000	180.0	251.0	32.27	10.8
C	01:59:00	71.351	-156.710	1600	180.0	spiral	18.00	6.0
D	02:03:03	71.288	-157.311	1600	180.0	231.0	12.14	4.0
BR	02:06:38	71.290	-156.752	44	180.0	68.5	10.76	3.6

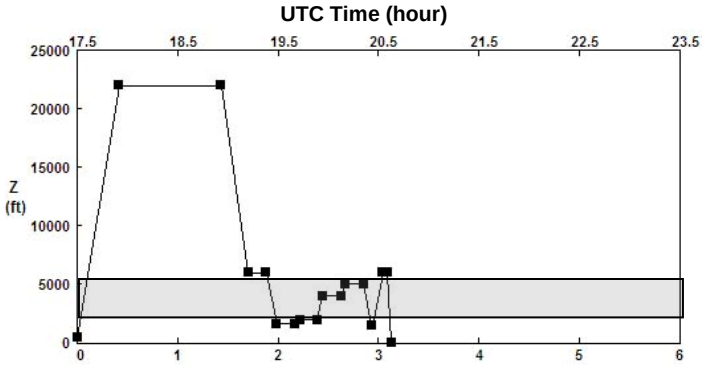


Example Flight Plan 1b (PASC)

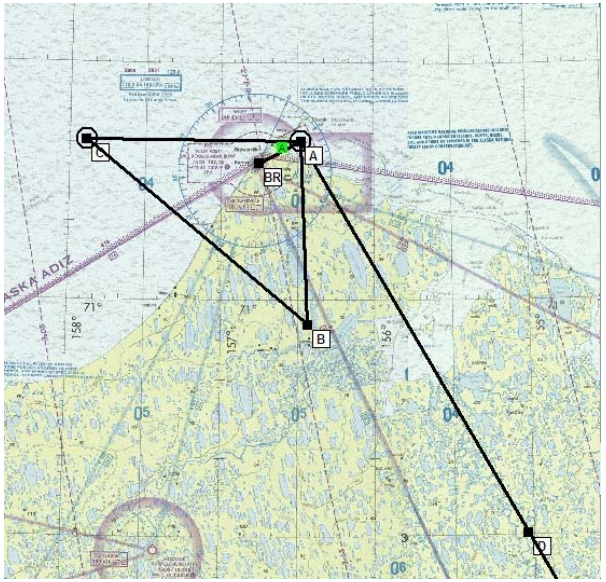


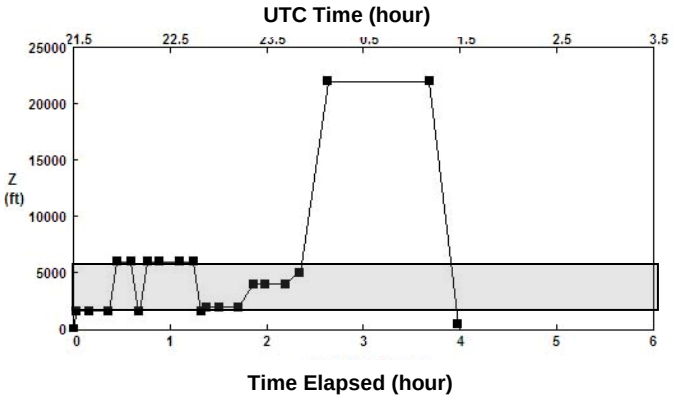
Total Distance (nm): 679.78 Total ETE (min): 188.1

WP	Elapsed UTC	LAT	LON	ALT (ft)	SPD (kts)	HDG	Dist (nm)	ETE (min)
FA	00:00:00	64.815	-147.856	434				
FA1	00:25:00	66.096	-149.150	22000	200.0	316.2	83.35	25.0
A	01:26:06	70.500	-154.000	22000	280.0	316.8	285.10	61.1
B	01:42:15	71.332	-155.030	6000	200.0	317.0	53.85	16.2
C	01:53:00	71.351	-156.710	6000	180.0	251.0	32.27	10.8
C	01:59:00	71.351	-156.710	1600	180.0	spiral	18.00	6.0
B	02:09:49	71.330	-155.022	1600	180.0	71.2	32.43	10.8
B	02:12:49	71.330	-155.022	2000	180.0	spiral	9.00	3.0
C	02:23:36	71.349	-156.704	2000	180.0	251.0	32.32	10.8
C	02:26:36	71.349	-156.704	4000	180.0	spiral	9.00	3.0
B	02:37:22	71.330	-155.022	4000	180.0	71.0	32.32	10.8
B	02:40:22	71.330	-155.022	5000	180.0	spiral	9.00	3.0
C	02:51:09	71.349	-156.704	5000	180.0	251.0	32.32	10.8
C	02:56:09	71.349	-156.704	1500	180.0	spiral	15.00	5.0
C	03:02:09	71.349	-156.704	6000	180.0	spiral	18.00	6.0
D	03:05:21	71.289	-157.169	6000	180.0	226.9	9.64	3.2
BR	03:08:05	71.290	-156.745	44	180.0	68.6	8.17	2.7



Example Flight Plan 2

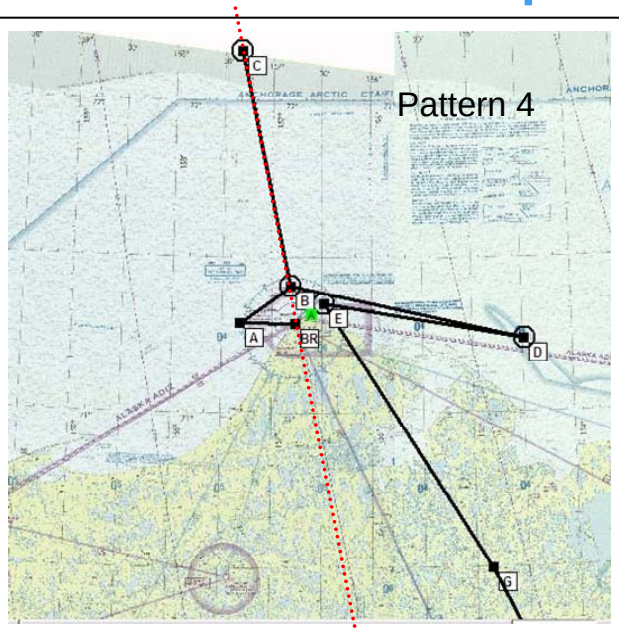




Total Distance (nm): 856.91 Total ETE (min): 238.7

WP	Elapsed UTC	LAT	LON	ALT (ft)	SPD (kts)	HDG	Dist (nm)	ETE (min)
BR	00:00:00	71.288	-156.758	44				
A	00:02:00	71.335	-156.483	1600	180.0	40.8	6.01	2.0
B	00:09:44	70.949	-156.439	1600	180.0	156.9	23.19	7.7
C	00:21:54	71.336	-157.890	1600	180.0	288.5	36.48	12.2
C	00:26:53	71.336	-157.890	6000	180.0	spiral	14.95	5.0
A	00:35:53	71.335	-156.483	6000	180.0	69.1	27.01	9.0
A	00:40:52	71.335	-156.483	1600	180.0	spiral	14.95	5.0
A	00:45:51	71.335	-156.483	6000	180.0	spiral	14.95	5.0
B	00:53:35	70.949	-156.439	6000	180.0	156.9	23.19	7.7
C	01:05:45	71.336	-157.890	6000	180.0	288.5	36.48	12.2
A	01:14:45	71.335	-156.483	6000	180.0	69.1	27.01	9.0
A	01:19:44	71.335	-156.483	1600	180.0	spiral	14.95	5.0
A	01:22:43	71.335	-156.483	2000	180.0	spiral	8.97	3.0
B	01:30:27	70.949	-156.439	2000	180.0	156.9	23.19	7.7
C	01:42:37	71.336	-157.890	2000	180.0	288.5	36.48	12.2
A	01:51:37	71.335	-156.483	4000	180.0	69.1	27.01	9.0
B	01:59:21	70.949	-156.439	4000	180.0	156.9	23.19	7.7
C	02:11:31	71.336	-157.890	4000	180.0	288.5	36.48	12.2
A	02:20:31	71.335	-156.483	5000	180.0	69.1	27.01	9.0
D	02:37:36	70.511	-155.041	22000	200.0	129.2	56.96	17.1
FA1	03:40:50	66.096	-149.150	22000	280.0	132.7	295.07	63.2
FA	03:58:41	64.815	-147.856	434	280.0	136.2	83.34	17.9

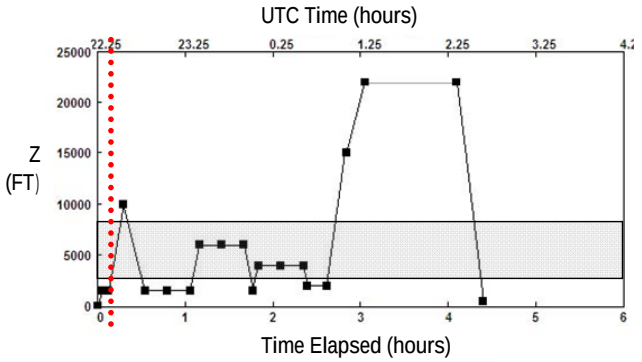
Example Flight Plan



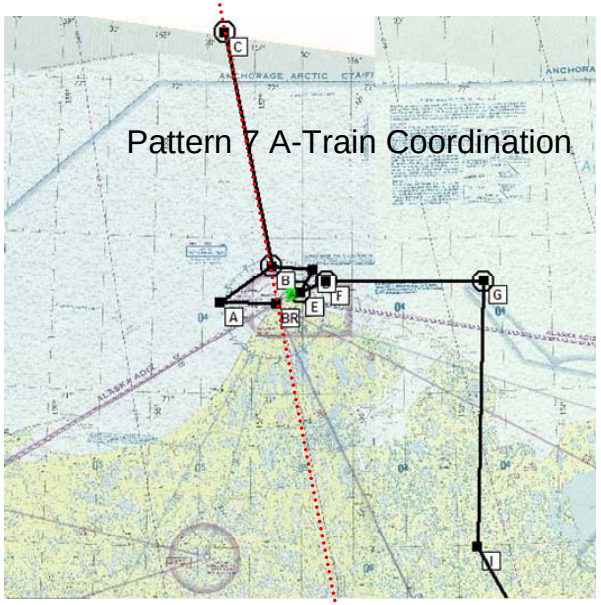
- Spiral synchronized with overpass
- Boundary layer
- In cloud

Total Distance (nm): 946.47 Total ETE (min): 263.5

WP	Time Elapsed	LAT	LON	ALT (ft)	SPD (kts)	HDG	Dist (nm)	ETE (min)
BR	00:00:00	71deg 17min	-156deg 46min	44				
A	00:03:35	71deg 18min	-157deg 19min	1500	180.0	250.2	10.73	3.6
B	00:07:37	71deg 25min	-156deg 49min	1500	180.0	33.2	12.09	4.0
B	00:17:37	71deg 25min	-156deg 49min	10000	180.0	spiral	29.99	10.0
C	00:32:53	72deg 09min	-157deg 19min	1500	180.0	327.0	45.80	15.3
B	00:48:09	71deg 25min	-156deg 49min	1500	180.0	147.0	45.80	15.3
D	01:03:33	71deg 15min	-154deg 28min	1500	180.0	81.7	46.20	15.4
D	01:09:33	71deg 15min	-154deg 28min	6000	180.0	spiral	18.00	6.0
B	01:24:57	71deg 25min	-156deg 49min	6000	180.0	261.7	46.20	15.4
C	01:40:13	72deg 09min	-157deg 19min	6000	180.0	327.0	45.80	15.3
C	01:46:13	72deg 09min	-157deg 19min	1500	180.0	spiral	18.00	6.0
C	01:50:13	72deg 09min	-157deg 19min	4000	180.0	spiral	12.00	4.0
B	02:05:29	71deg 25min	-156deg 49min	4000	180.0	147.0	45.80	15.3
D	02:20:53	71deg 15min	-154deg 28min	4000	180.0	81.7	46.20	15.4
D	02:23:53	71deg 15min	-154deg 28min	2000	180.0	spiral	9.00	3.0
E	02:37:00	71deg 21min	-156deg 29min	2000	180.0	258.9	39.37	13.1
E	02:50:00	71deg 21min	-156deg 29min	15000	180.0	spiral	39.00	13.0
G	03:03:02	70deg 30min	-154deg 49min	22000	280.0	126.5	60.82	13.0
FA1	04:05:40	66deg 06min	-149deg 09min	22000	280.0	133.6	292.30	62.6
FA	04:23:32	64deg 49min	-147deg 51min	434	280.0	136.2	83.35	17.9



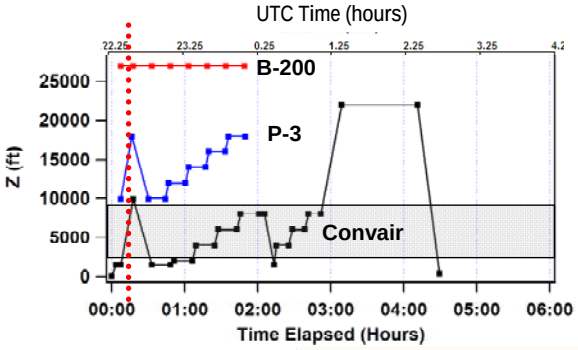
Example Flight Plan



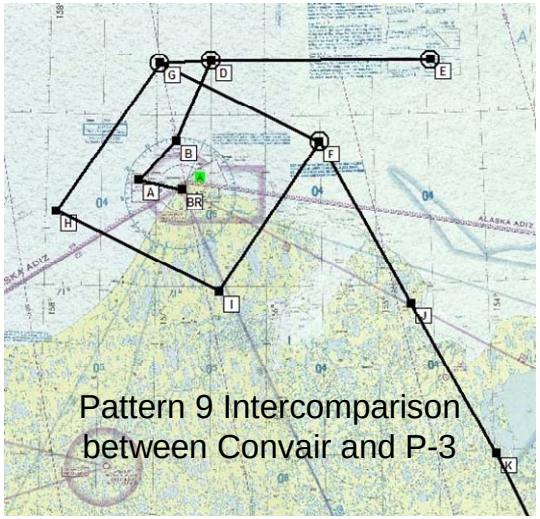
Total Distance (nm): 942.30 Total ETE (min): 267.7

WP	Time Elapsed	AT	LON	ALT (ft)	SPD (kts)	HDG	Dist (nm)	ETE (min)
BR	00:00:00	71deg 17min	-156deg 46min	44				
A	00:03:35	71deg 18min	-157deg 19min	1500	180.0	250.2	10.73	3.6
B	00:07:37	71deg 25min	-156deg 49min	1500	180.0	33.2	12.09	4.0
B	00:17:37	71deg 25min	-156deg 49min	10000	180.0	spiral	29.99	10.0
C	00:32:53	72deg 09min	-157deg 19min	1500	180.0	327.0	45.80	15.3
B	00:48:09	71deg 25min	-156deg 49min	1500	180.0	147.0	45.80	15.3
B	00:51:09	71deg 25min	-156deg 49min	2000	180.0	spiral	9.00	3.0
C	01:06:25	72deg 09min	-157deg 19min	2000	180.0	327.0	45.80	15.3
C	01:09:25	72deg 09min	-157deg 19min	4000	180.0	spiral	9.00	3.0
B	01:24:41	71deg 25min	-156deg 49min	4000	180.0	147.0	45.80	15.3
B	01:27:41	71deg 25min	-156deg 49min	6000	180.0	spiral	9.00	3.0
C	01:42:57	72deg 09min	-157deg 19min	6000	180.0	327.0	45.80	15.3
C	01:45:57	72deg 09min	-157deg 19min	8000	180.0	spiral	9.00	3.0
B	02:01:13	71deg 25min	-156deg 49min	8000	180.0	147.0	45.80	15.3
D	02:03:53	71deg 24min	-156deg 24min	8000	180.0	73.9	8.03	2.7
E	02:05:36	71deg 20min	-156deg 31min	8000	180.0	188.4	5.11	1.7
E	02:13:36	71deg 20min	-156deg 31min	1500	180.0	spiral	24.00	8.0
F	02:15:25	71deg 22min	-156deg 16min	4000	180.0	45.7	5.46	1.8
G	02:25:32	71deg 21min	-154deg 41min	4000	180.0	69.8	30.38	10.1
H	02:28:32	71deg 21min	-154deg 41min	6000	180.0	spiral	9.00	3.0
F	02:38:40	71deg 22min	-156deg 16min	6000	180.0	249.8	30.38	10.1
F	02:41:40	71deg 22min	-156deg 16min	8000	180.0	spiral	9.00	3.0
G	02:51:47	71deg 21min	-154deg 41min	8000	180.0	69.8	30.38	10.1
I	03:07:11	70deg 30min	-154deg 49min	22000	200.0	161.9	51.29	15.4
FA1	04:09:49	66deg 06min	-149deg 09min	22000	280.0	133.6	292.30	62.6
FA	04:27:40	64deg 49min	-147deg 51min	434	280.0	136.2	83.35	17.9

- Spiral coordinated with NASA P-3 and synchronized with overpass
- Boundary layer
- In cloud



Example Flight Plan

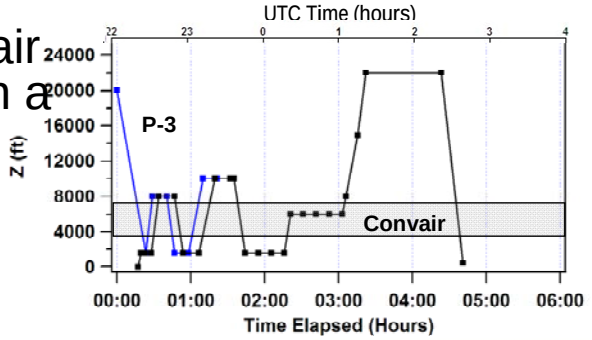


Pattern 9 Intercomparison between Convair and P-3

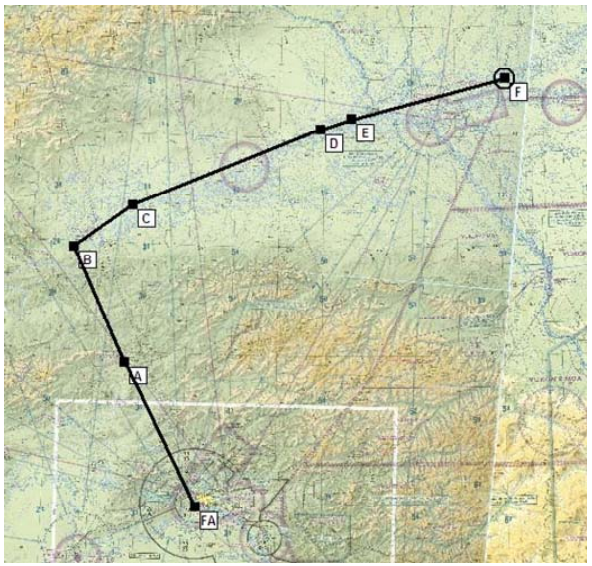
Total Distance (nm): 937.93 Total ETE (min): 264.1

WP	Time Elapsed	LAT	LON	ALT (ft)	SPD (kts)	HDG	Dist (nm)	ETE (min)
BR	00:17:00	71deg 17min	-156deg 46min	44	180.0	260.6	7.77	2.6
A	00:19:35	71deg 19min	-157deg 10min	1600	180.0	22.0	9.49	3.2
B	00:22:45	71deg 26min	-156deg 49min	1600	180.0	2.3	15.39	5.1
D	00:27:53	71deg 40min	-156deg 30min	1600	180.0	spiral	18.00	6.0
D	00:33:53	71deg 40min	-156deg 30min	8000	180.0	69.6	38.51	12.8
E	00:46:43	71deg 39min	-154deg 28min	8000	180.0	spiral	21.00	7.0
E	00:53:43	71deg 39min	-154deg 28min	1600	180.0	249.6	38.51	12.8
D	01:06:33	71deg 40min	-156deg 30min	1600	180.0	69.6	38.51	12.8
E	01:19:23	71deg 39min	-154deg 28min	10000	180.0	249.6	38.51	12.8
D	01:32:14	71deg 40min	-156deg 30min	10000	180.0	245.7	9.03	3.0
G	01:35:14	71deg 39min	-156deg 59min	10000	180.0	spiral	27.00	9.0
G	01:44:14	71deg 39min	-156deg 59min	1600	180.0	193.2	31.56	10.5
H	01:54:45	71deg 13min	-157deg 55min	1600	180.0	94.7	31.85	10.6
I	02:05:22	70deg 59min	-156deg 26min	1600	180.0	13.5	31.51	10.5
F	02:15:53	71deg 25min	-155deg 30min	1600	180.0	spiral	15.00	5.0
F	02:20:53	71deg 25min	-155deg 30min	6000	180.0	275.5	31.28	10.4
G	02:31:18	71deg 39min	-156deg 59min	6000	180.0	193.2	31.56	10.5
H	02:41:50	71deg 13min	-157deg 55min	6000	180.0	94.7	31.85	10.6
I	02:52:27	70deg 59min	-156deg 26min	6000	180.0	13.5	31.51	10.5
F	03:02:57	71deg 25min	-155deg 30min	6000	180.0	spiral	9.00	3.0
F	03:05:57	71deg 25min	-155deg 30min	8000	200.0	130.6	32.41	9.7
J	03:15:40	70deg 57min	-154deg 43min	15000	280.0	131.3	30.24	6.5
K	03:22:09	70deg 30min	-154deg 00min	22000	280.0	136.8	285.10	61.1
FA1	04:23:15	66deg 06min	-149deg 09min	22000	280.0	136.2	83.34	17.9
FA	04:41:06	64deg 49min	-147deg 51min	434				

- NOAA P-3 and Convair will take turns flying in a cloud deck over the Beaufort Sea

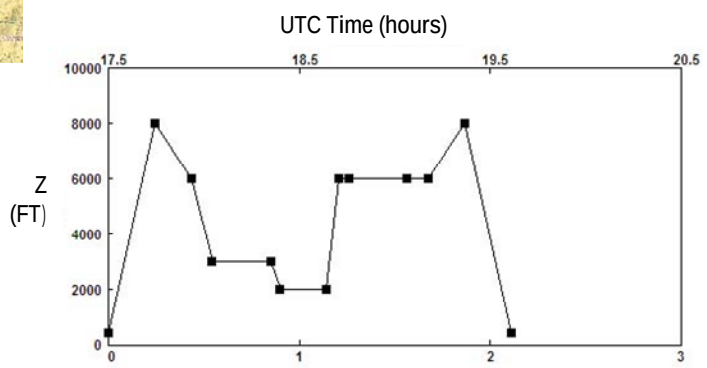


Example Flight Plan



Total Distance (nm): 380.04 Total ETE (min): 126.7

WP	Time Elapsed	LAT	LON	ALT (ft)	SPD (kts)	HDG	Dist (nm)	ETE (min)
FA	00:00:00	64deg 49min	-147deg 51min	434				
A	00:14:39	65deg 28min	-148deg 40min	8000	180.0	311.1	43.96	14.7
B	00:26:09	65deg 59min	-149deg 18min	6000	180.0	312.5	34.49	11.5
C	00:32:42	66deg 11min	-148deg 40min	3000	180.0	31.0	19.65	6.6
D	00:51:06	66deg 32min	-146deg 33min	3000	180.0	45.9	55.19	18.4
E	00:54:09	66deg 35min	-146deg 11min	2000	180.0	50.6	9.15	3.1
F	01:08:32	66deg 46min	-144deg 25min	2000	180.0	54.8	43.16	14.4
E	01:12:32	66deg 35min	-146deg 11min	6000	180.0	spiral	12.00	4.0
D	01:15:35	66deg 32min	-146deg 33min	6000	180.0	230.6	9.15	3.1
C	01:33:59	66deg 11min	-148deg 40min	6000	180.0	225.9	55.19	18.4
B	01:40:32	65deg 59min	-149deg 18min	6000	180.0	211.0	19.65	6.6
A	01:52:02	65deg 28min	-148deg 40min	8000	180.0	132.5	34.49	11.5
FA	02:06:41	64deg 49min	-147deg 51min	434	180.0	131.1	43.96	14.7



Aerial Vehicles Program

Courtesy: U.S. Department of Energy's Atmospheric Radiation Measurement Program