NASA
Light Detection and Ranging (LIDAR)
Digital Elevation Data Products

Solicitation # RFO 13-SSC-O-02-40

Pre-Mission Plan Report

Mt. Rainier Project Area

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January 2003

TerraPoint™

Table of Contents

Introduction

The pre-mission planning report consists of information about fligtlines and flightline planning, estimated weather and operating conditions, ground control points and reference maps of the Mt. Rainier project area performed under Solicitation # RFO 13-SSC-O-02-40.

Anticipated Operating Conditions

Weather

TerraPoint anticipates that weather conditions will have the most direct impact on the ability to acquire LIDAR data in the Mt. Rainier project area. Conditions in the upper elevations will most likely prevent capture of 100% of the data in this flying season.

December 2002

Winter flying season 2002 / 2003 is anticipated to be an El Nino year which means wetter but warmer than usual conditions for the NW coast and west coastal zones. If temperatures do remain normal, then there will be a higher chance of large snow fall in the Mt. Rainier area early in December than normal.

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Seattle Area

- About 40 °F
- 6 inches of precipitation
- Strong winds keeping skys clear
- normal to above normal precipitation, above normal temperatures, clouds, rain, wind, and very little sunshine

Sky Conditions	Expected for Dec 2002
Sunny	3 days
Partly-Cloudy	8 days
Cloudy	20 days
Rain	50% of days
Snow	5% of days

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Mt. Rainier Area

- While snow starts to fall in earnest in November it can fall at anytime and at any elevation in the month of October.
- Anticipated 16 inches of snow fall between 2500 and 5000 ft. Above 5000 ft 60 inches of snow fall accumulation.
- Afternoon pass temperatures 30 to 35. Wind in the passes west 5 to 15 mph.

January 2003

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Seattle Area

- Mid 40 °F
- 8 inches of precipitation
- Strong winds gusting to 20 knots out of the south keeping skys clear
- Normal to above normal precipitation, above normal temperatures with sunny and partly-cloudy days outnumbering cloudy days.

Sky Conditions	Expected for Jan 2003
Sunny	7 days
Partly-Cloudy	3 days
Cloudy	20 days
Rain	40% of days
Snow	8% of days

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Mt. Rainier Area

- Daily temperatures are expected to be in the upper 30 ° F to lower 40° F.
- Precipitation below 2500 ft is expected to be about 6 inches.
- Precipitation between 2500 ft and 5000 ft is expected to be around 20 inches.
- Snow fall accumulation above 5000 ft is expected to be 80 inches.

Ground Control Points

A series of ground control points are surveyed for their use as calibration check points. These points are at a calibration site that is flown over at the start and end of every mission to collect data. Orthometric, Ellipsoidial, and height above the geoid are all recorded for these calibration points.

The kinematic GPS acquired with the LIDAR data on each flight will be processed with GPS from the base station installations at this site. Any base stations to be used in missions are operated continuously. The base station in nearest proximity to the flight lines completed during a mission will be used as the Master station for the GPS processing to determine aircraft position.

Calibration Ground Control Points

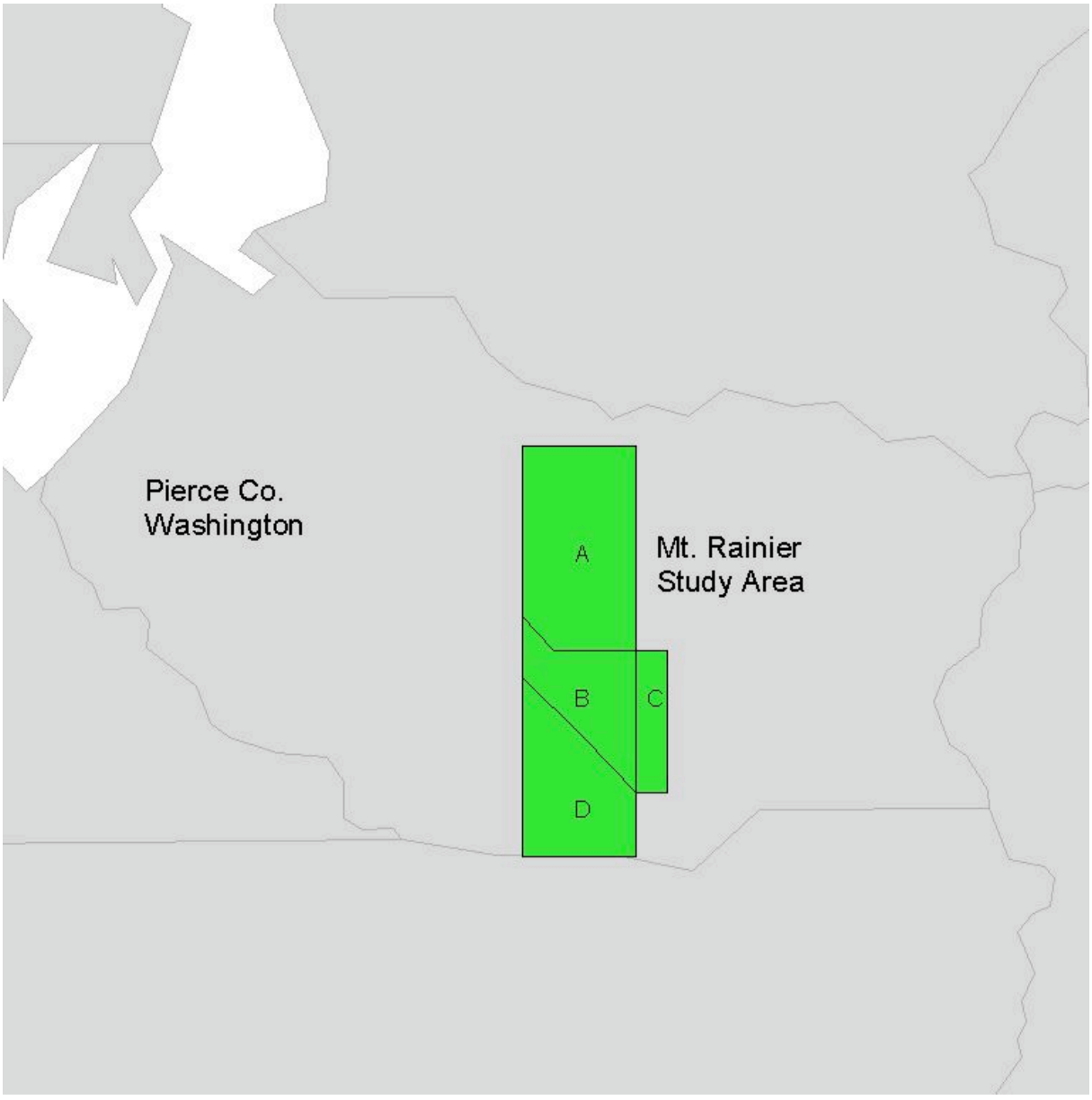
Id	Latitude	Longitude	Ortho	Geoid	Ellipsoid
1	47.26964064	-122.57474660	89.335	-22.589	66.746
2	47.26959668	-122.57432330	89.423	-22.589	66.835
3	47.26963431	-122.57388870	88.947	-22.589	66.358
4	47.27068285	-122.57351330	88.427	-22.588	65.839
5	47.27113021	-122.57343640	88.338	-22.588	65.750
6	47.27167000	-122.57405270	89.228	-22.588	66.640
7	47.27237472	-122.57396690	89.157	-22.588	66.569
8	47.27309267	-122.57391320	89.395	-22.588	66.808
9	47.27337826	-122.57367800	88.612	-22.588	66.025
10	47.27379813	-122.57362750	88.532	-22.588	65.945
11	47.27409731	-122.57352680	88.290	-22.587	65.702
12	47.27442990	-122.57377200	88.476	-22.587	65.889
13	47.27459615	-122.57434360	87.795	-22.587	65.208
14	47.27342348	-122.57451760	88.465	-22.588	65.877
15	47.27251374	-122.57469460	88.768	-22.588	66.180
16	47.27169706	-122.57455400	89.103	-22.588	66.515
17	47.27122775	-122.57452140	89.211	-22.588	66.623
18	47.27048444	-122.57460690	89.249	-22.588	66.660
3A	47.27027029	-122.57358760	88.265	-22.588	65.676
A1	47.26988504	-122.57447480	96.844	-22.589	74.255
A2	47.26986633	-122.57424700	102.684	-22.589	80.096
A3	47.26984657	-122.57402040	96.884	-22.588	74.296
A4	47.27018142	-122.57396040	96.907	-22.588	74.319
A5	47.27020056	-122.57418700	102.668	-22.588	80.080
A6	47.27021953	-122.57441480	96.865	-22.588	74.277
B1	47.27027356	-122.57390240	97.217	-22.588	74.629
B2	47.27025472	-122.57367970	96.514	-22.588	73.925

Id	Latitude	Longitude	Ortho	Geoid	Ellipsoid
B3	47.27102831	-122.57353970	96.521	-22.588	73.933
B4	47.27104699	-122.57376230	97.201	-22.588	74.613
C1	47.27188565	-122.57435190	93.479	-22.588	70.891
C2	47.27187494	-122.57422000	94.102	-22.588	71.514
C3	47.27282482	-122.57404920	94.116	-22.588	71.528
C4	47.27283536	-122.57418110	93.509	-22.588	70.921
D1	47.27350483	-122.57405670	92.862	-22.588	70.275
D2	47.27348796	-122.57385450	92.862	-22.588	70.274
D3	47.27389792	-122.57378120	96.698	-22.588	74.111
D4	47.27430860	-122.57370660	92.864	-22.587	70.276
D5	47.27432547	-122.57390880	92.870	-22.587	70.283
D6	47.27391482	-122.57398270	96.706	-22.588	74.118

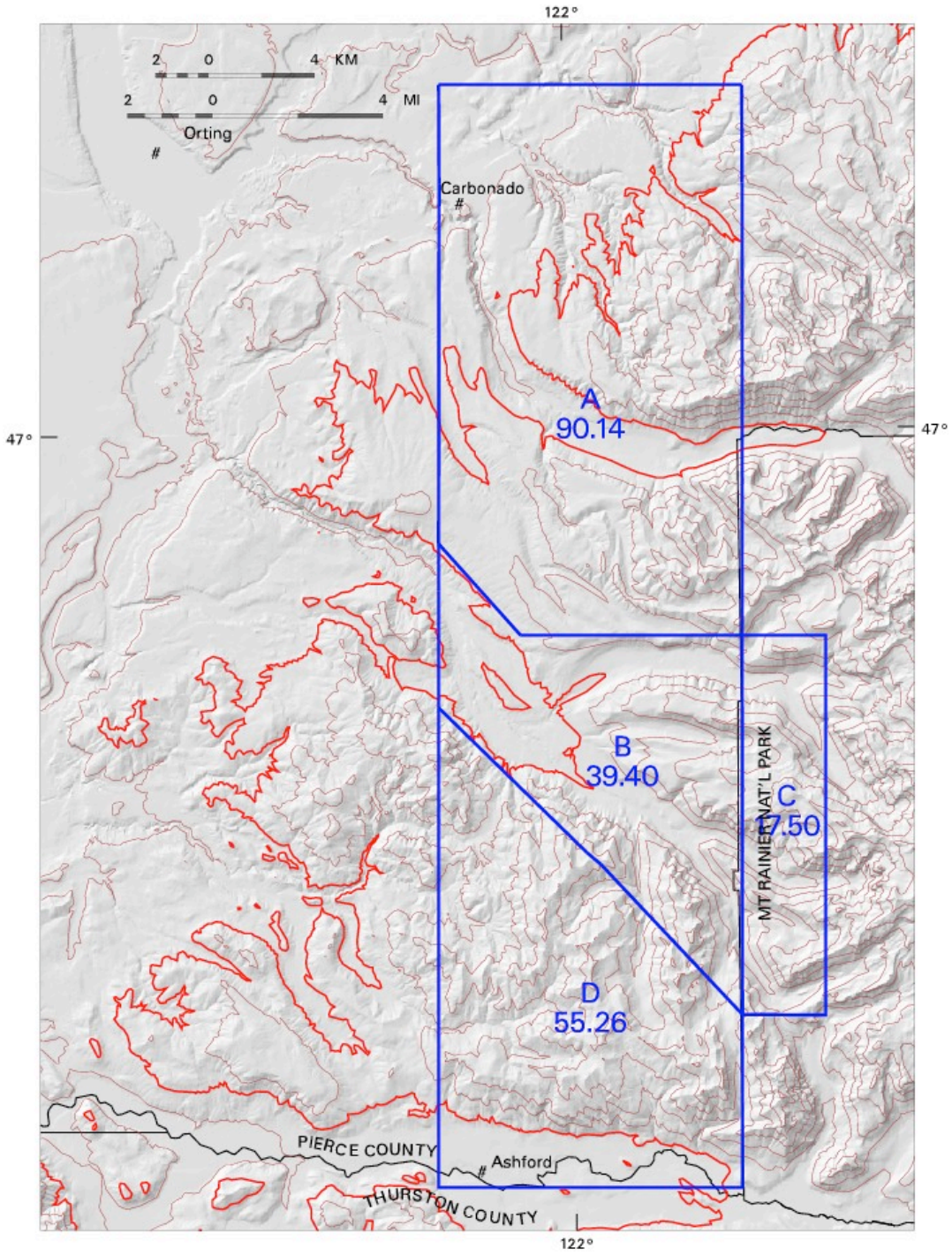
Maps of Study Area

The Mt. Rainier study area is locatied in the central eastern part of Pierce county in Washington state, USA. The study zone runs north to south along the western edge of the Cascade range containing Mt. Rainier. The study area is divided into four sections, A, B, C, and D. The following image shows the study area in relation to Pierce County.

Mt. Rainier Study Area



West Rainier Seismic Zone Project Area
(image provided by NASA)



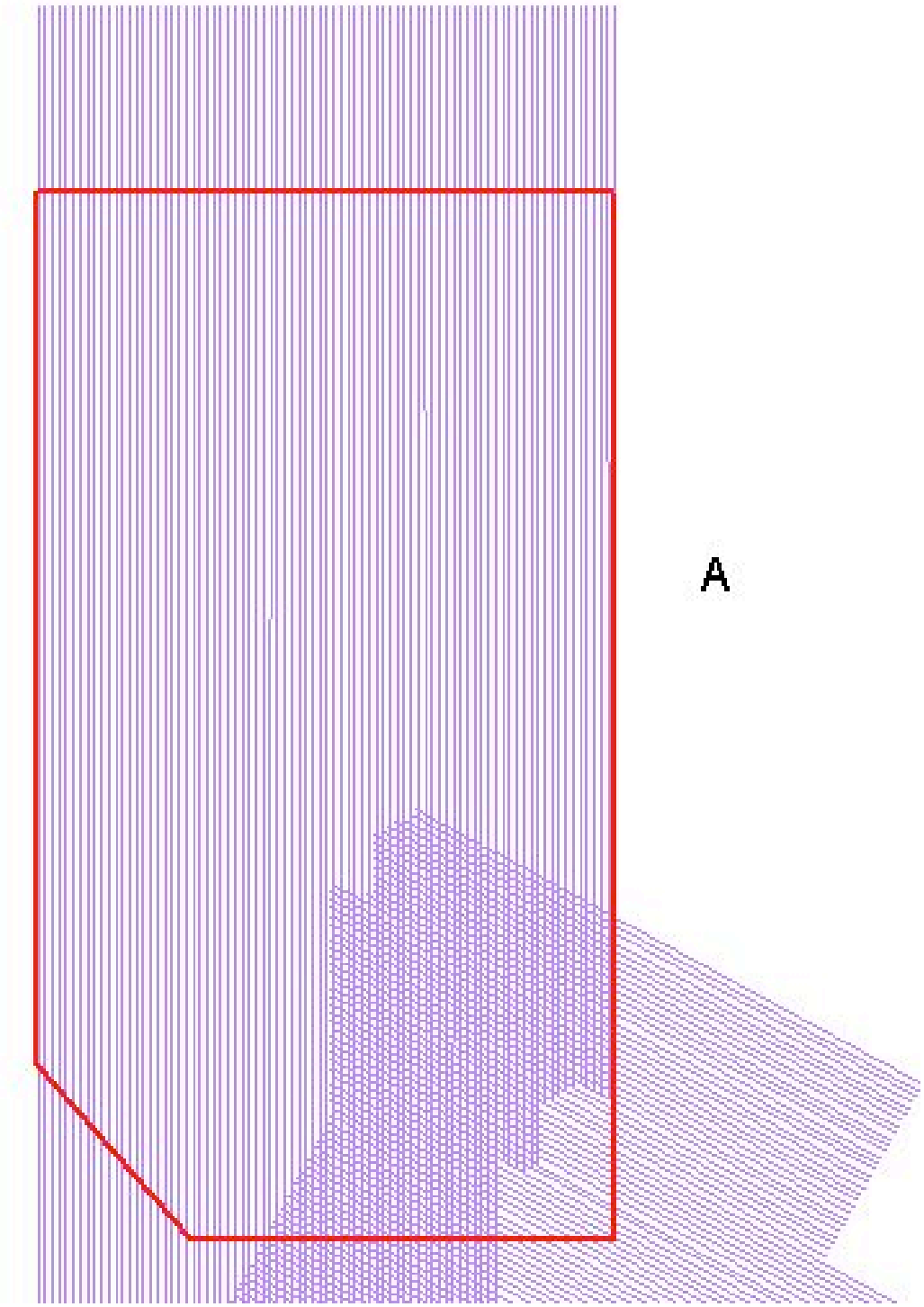
Planned Flight Paths

LIDAR data acquisition flight lines have been created for each sub part of the Mt. Rainier project area. Flight lines and cross flight lines have been created to minimize the impact of steep terrain during data acquisition and to meet data density requirements.

Flightline Parameters are:

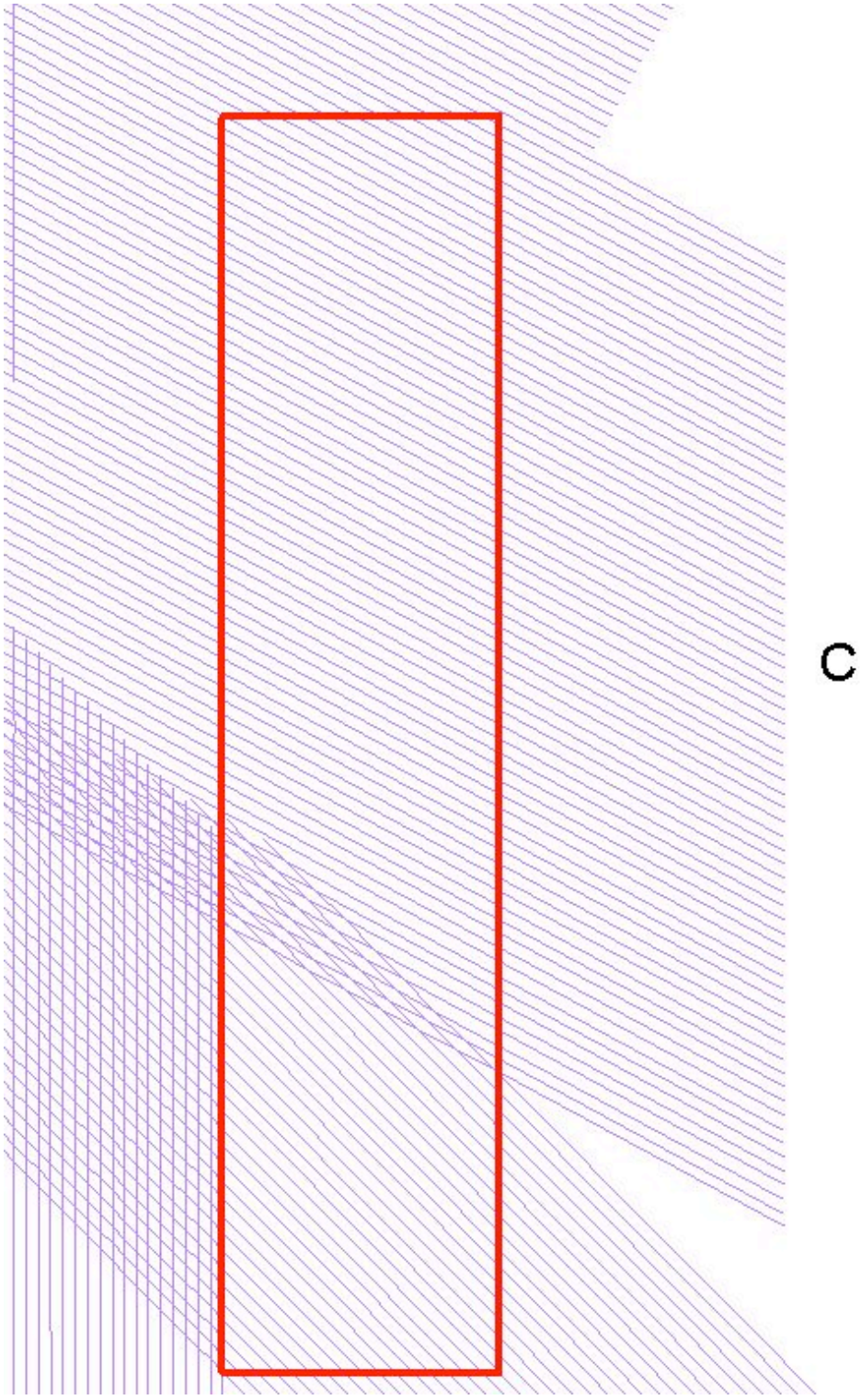
Parameter	Value
Nominal Flying Height (AGL)	3000 ft
Flightline Overlap	70%
Nominal Point Spacing	1.5 m
Flightline length (average)	12,340 m

Flightlines Area A

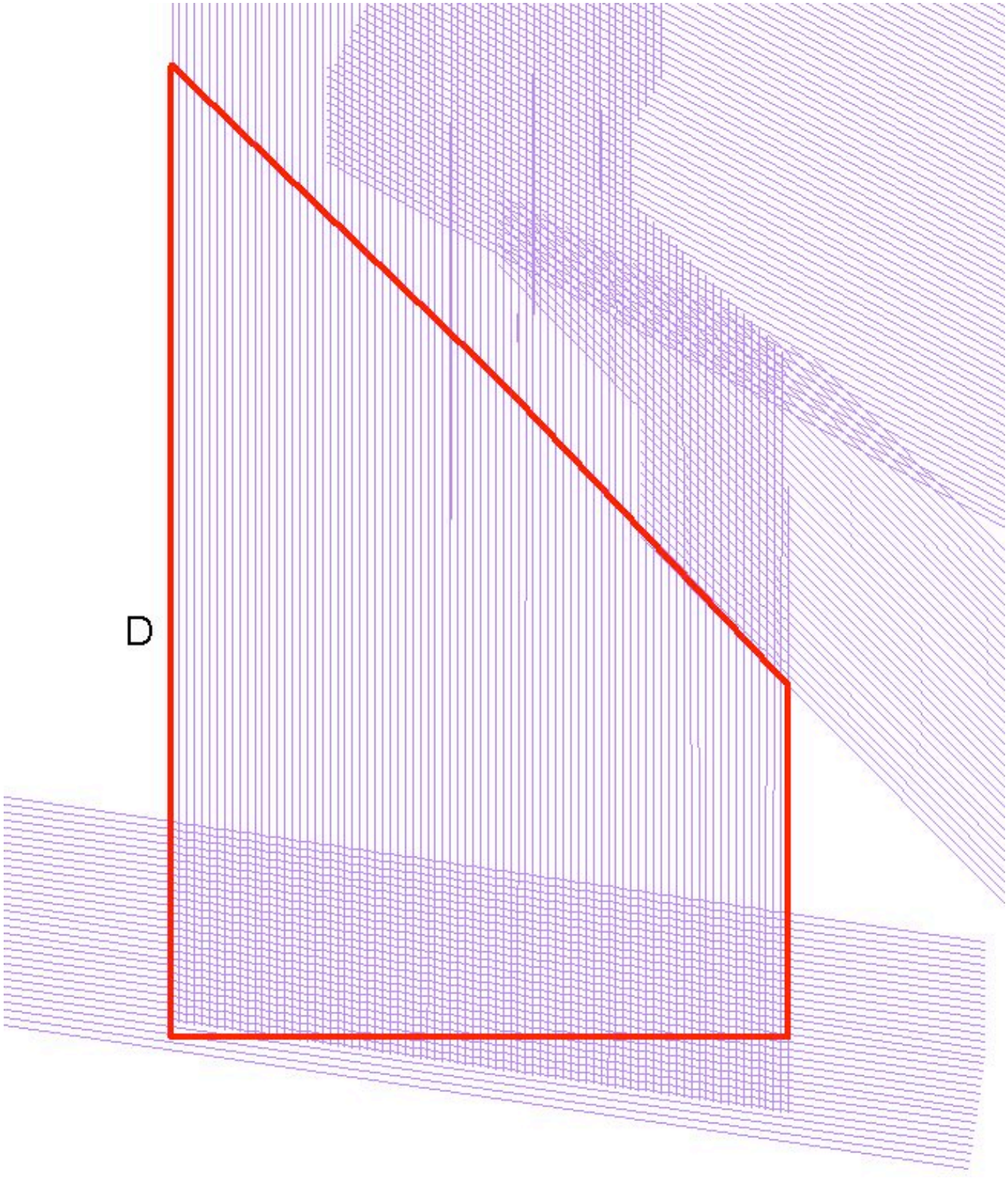


Flightlines Area B

Flightlines Area C



Flightlines Area D



Clarification provided by TerraPoint by email on February 3, 2003.

The nominal point density is uniform for all areas A-D.
The flight lines for the low density areas were originally specified for a nominal altitude of 3000 ft AGL and 70% overlap. The high overlap percentage was used to meet the specification for double coverage of all project areas, taking into consideration such factors as aircraft roll, yaw and line following errors. The actual flight line generation process produced a line spacing of 140 m (~75% overlap). Since the total swath from 3000 ft is 594 m, that results in a point density 4.24 times the density of an individual flight line.

In our proposal, we conservatively specified our point spacing as 1.5 m. With operating conditions of 3000 ft AGL and 130 knots ground speed, the nominal point spacing is actually 1.4 m. This gives a density of 1 shot per 1.96 sq m. When the overlap discussed above is taken into consideration, the density becomes 4.24 points per 1.96 sq m, or 2.16 shots per sq m. Since this satisfies the specification for the high density areas as well as the low density areas, it was decided to use the same flight line spacing throughout the project area.

This point density calculation is purely theoretical, however, and the density of first returns we actually achieve varies as a function of altitude, ground speed, vegetation type, etc., etc. To monitor our actual point density, we developed an application that analyzes a 5 km by 5 km tile and counts the number of first returns inside each 10 m by 10 m area within that tile. We use 100 sq m evaluation areas rather than individual 1 sq m areas to provide reasonable statistical coverage of the data. This approach was discussed in an earlier telecon with Dave and Ralph, who seemed comfortable with the philosophy at that time.

We analyzed the first return point density for some of the initial missions and found quite good results. The table below presents the results in terms of the specifications for the higher density areas B and C. These areas are required to achieve an average point density of 2 returns per sq m, and no less than 0.8 returns per sq m. The table reports Mean, Min and Max point densities as well as the percentage of areas with a density greater than the average density specification, between the average and minimum specification, and below the minimum specification. As seen in the table below, all except one tile (105195570) exceed the average density specification of 2 returns per sq m. A more detailed analysis of this tile indicated particular areas with low point density, and a reflight of the deficient areas was ordered to increase the final point density. Even with the somewhat lower average point density in this tile, however, there were no 100 sq m areas where the point density fell below the minimum specification of 0.8 returns per sq m. Note that the maximum density values

exceed the nominal 2.16 shots per sq m due to additional flight line overlaps in certain areas.

Density Report Based On 5k Tile at 95th Percentile

	(Points/m^2)					
Tile	Mean	Min	Max	>=2.0	0.8-2.0	<0.8
105215570	2.0	1.4	4.2	44.44%	55.56%	0.00%
105210570	2.1	1.5	4.3	64.35%	35.65%	0.00%
105205570	2.1	1.5	3.8	60.75%	39.25%	0.00%
105200570	2.1	1.5	3.6	58.48%	41.52%	0.00%
105195570	1.9	1.3	3.5	28.58%	71.42%	0.00%
105190570	2.2	1.5	6.3	57.09%	42.91%	0.00%
105185570	2.3	1.6	4.6	73.07%	26.93%	0.00%
105180570	2.2	1.6	4.8	69.28%	30.72%	0.00%

The same tiles were then analyzed in terms of the lower density specifications for areas A and D. These areas required an average point density of 1 return per sq m, and no less than 0.4 returns per sq m. As seen in the table, the point density in each 100 sq m area within every tile exceeds the average density specification, and none of them have areas falling below the minimum density specification. In fact, none of them have areas falling below the average density specification.

Density Report Based On 5k Tile at 95th Percentile

	(Points/m^2)					
Tile	Mean	Min	Max	>=1.0	0.4-1.0	<0.4
105215570	2.0	1.4	4.2	100.00%	0.00%	0.00%
105210570	2.1	1.5	4.3	100.00%	0.00%	0.00%
105205570	2.1	1.5	3.8	100.00%	0.00%	0.00%
105200570	2.1	1.5	3.6	100.00%	0.00%	0.00%
105195570	1.9	1.3	3.5	100.00%	0.00%	0.00%
105190570	2.2	1.5	6.3	100.00%	0.00%	0.00%
105185570	2.3	1.6	4.6	100.00%	0.00%	0.00%
105180570	2.2	1.6	4.8	100.00%	0.00%	0.00%

This analysis confirms that we are achieving results in compliance with the contract specifications in areas B and C, and far exceeding the specifications for areas A and D. We will monitor and report the achieved point density for the remaining missions to ensure continued compliance with these specifications.