STRUCTURE OF SLICER .DAT FILES:

The SLICER .dat data files are derived from the standard Laser Altimeter Processing Facility .geo files which include geolocation results and instrument data. Automated last return detection software is applied to the backscatter waveform to identify the start, peak, and end of the last return, inferred to be from the ground. In addition, invalid laser shots in the .geo files (no range data, cloud returns and/or noise above an elevation threshold set above the highest expected ground, noise below an elevation threshold set below the lowest expected ground, and shots with anomalously low or high start pulse energy) are excluded. The inclination and azimuth of the transmit pulse are also derived from the .geo roll, pitch and yaw data, simplifying correction for waveform slant range distances. The diameter of each laser footprint, based on an approximate laser divergence and the ranging distance, is also provided.

The .dat file structure was created to be compatible with the BORIS data archive established for the BOREAS boreal forest project, and thus all parameters are stored as scaled long integers or bytes. The .dat files contain all SLICER parameters relevant to the end-user, but exclude .geo engineering parameters not directly relevant to end use applications.

SLICER .dat file structure
file naming convention: YYMMDDLL.DAT
(e.g., 96072904.DAT is flight line 4 acquired on July 29, 1996)
binary files created on a SUN workstation

Parameter	Stored As	Bytes	Scale Factor	Scale Factor Precision	Output As	Bytes
header record:						
tiu_bin	long	4	none	-	long	4
dig2wf_average	long	4	none	-	long	4
wvfm_bins	long	4	none	-	long	4
numshots	long	4	none	-	long	4
Header Record Total:		16				16
data records:						
shotnum	long	4	none	-	long	4
beam	long	4	none	-	long	4
starten	long	4	none	-	long	4
gpstime	long	4	1.00E+04	double flt	double flt	8
diameter	long	4	1.00E+06	float	float	4
azimuth	long	4	1.00E+06	float	float	4
inclination	long	4	1.00E+06	float	float	4
latitude	long	4	1.00E+06	double flt	double flt	8
longitude	long	4	1.00E+06	double flt	double flt	8
elevation*	long	4	1.00E+06	float	float	4

grndstart	long	4	1.00E+06	float	float	4
grndpeak	long	4	1.00E+06	float	float	4
grndend	long	4	1.00E+06	float	float	4
waveform	byte array	600	none	-	byte array	600
Data Record Total:		652				664

* the maximum elevation value stored as a long word and scaled by 1.00E+06 is 2147 m. This maximum elevation is adequate for the BOREAS data set and most other SLICER missions. However, elevations on flight days 950919, 950920, and 950924 over Mt. Saint Helens and Mount Rainier exceed this limit. The elevation scale factor for these three flight days was changed to 1.00E+04.

Parameter	Description
header record:	
tiu_bin	waveform bin corresponding to Time Interval Unit stop-trigger event
dig2wf_average	number of digitizer bins averaged together to form a waveform bin; the digitizer sampling rate yields 0.1112 m per digitizer bin
wvfm_bins	number of bins stored per waveform
numshots	number of data records (laser shots) in the file
data record:	
shotnum	laser shot number from the .geo source file
beam	cross-track beam position: 1 (left) to 3 or 5 (right) in scan mode; 0 in profile mode
starten	energy of transmitted laser pulse (very noisy measure inuncalibrated units)
gpstime	time of laser pulse transmission (seconds past GPS midnight)
diameter	diameter of footprint = range x 0.02 mrad (approx.) laser divergence (m); diameter at distance where Gausssian energy falls off to $1/e^2$ that of center
azimuth	azimuth of the laser pointing vector (degrees from north, 0 to 360 clockwise)
inclination	inclination of the laser pointing vector (degrees from horizontal; 90 = vertical)
latitude	latitude of the footprint at highest detected surface (degrees N in WGS-84)
longitude	longitude of the footprint at highest detected surface (degrees E in WGS-84)
elevation	elevation of the highest detected surface (meters w.r.t. WGS-84 ellipsoid)
grndstart	distance along laser vector from elevation to inferred start of ground return (m)
grndpeak	distance along laser vector from elevation to peak of ground return (m)
grndend	distance along laser vector from elevation to end of ground return (m)
waveform	raw return amplitude (uncalibrated units) per waveform bin

The end of the last return (grndend) in the .dat files is determined by a threshold method. The threshold is derived on a per shot basis by establishing the mean and maximum background noise occurring in the waveform record. If there are sufficient bins in the waveform prior to tiu_bin to adequately characterize the noise, this region is used.

Otherwise, the last 5% of the waveform record is used. A potential error is introduced by using the end of the return to define the noise level if a greatly broadened signal, such as from very tall trees, extends all the way to the end of the waveform record. The end-of-signal threshold level for a waveform is set to some scaling factor times the maximum noise in the sampled bin region. The scaling factor is adjusted depending on desired detection sensitivity (a higher scaling factor causes less false triggers on noise but more misses of small ground returns, whereas a smaller scaling factor causes more false triggers on noise but fewer misses of small ground returns). The appropriate scaling factor is determined based on visual examination of ground profile results for a selected set of test cases. If the waveform bins were derived from the digitizer bins without averaging, three or four adjacent waveform bins are summed together prior to establishing the shot noise level in order to increase the waveform signal-to-noise. The effective resolution of the ground distance measurements (grndstart, grndpeak, and grndend) is thus tripled to 0.3336 m or quadrupled to 0.4448 m. After threshold determination of grndend, the peak of the ground return is determined to be the location where the first change from negative slope to positive slope occurs prior to grndend (i.e., where the derivative of the waveform crosses 0). A threshold based on the noise level is also used here to exclude peaks of very small amplitude. The start of the ground return (grndstart) can not be uniquely determined from the waveform record because vegetation directly above the ground can cause return signal that is not distinctly separated from the beginning of the ground return. Identification of the start of the ground return is accomplished by using the width of the return pulse from grndpeak to grndend. This width for the back half of the pulse is multiplied by a constant scaling factor, to account for the non-symmetric character of the Raleigh-shaped SLICER transmit pulse, in order to derive the width of the front half of the pulse. The scaling factor is determined from impulse response reflections from smooth water surfaces and is varied from mission to mission to account for the changing quality of the transmit pulse. With this technique, returns from vegetation directly above the ground should be separated from the ground return. This pulse width determination of the start of the ground return is noisy, at the sub-meter level, due to the sensitivity of the grndend threshold determination. The grndend threshold technique is sensitive to the asympoptic fall-off in energy of the transmit-pulse trailing edge, and to the potential presence of a variable amplitude backporch during periods of non-optimal beam quality.

In some instances of very low return amplitudes throughout the waveform the algorithm described above finds no signal above the grndend detection threshold. In those instances, the grnd start, grndpeak, and grndend positions are assigned to the last three bins at the end of the waveform as a flag to indicate failure to detect any waveform signal above threshold. In data sets where tall trees cause some signals to extend to the end of the waveform, the grnd positions are placed just after the tiu_bin position when no grndend is detected. In other instances of low ground return amplitudes, the threshold method misses the ground return but identifies a higher canopy return as the ground return. In some rare cases, the grndend position is properly identified but the grndpeak position misses the maximum ground return and instead identifies a maximum return from a higher canopy layer. The grndstart position is then placed higher up into the canopy by the pulse width method. A final error is the identification of waveform noise occurring after, and thus below, the ground surface as the ground return. These various anomolous ground return detections are usually readily

identified by examing a profile plot of the canopy top, grndstart, grndpeak, and grndend elevations.

The above described determination of the ground return position fails for saturated ground returns. In saturated cases, the threshold determination of grndend often corresponds to a small detector ringing peak after the return. Software checks are included that attempt to minimize detection of these false peaks. Also, because the saturated peak does not have a well defined inflection point, grndpeak is simply set to the mid-point of the saturation. Thus, the grndpeak to grndend width does not have physical significance. In these cases, grndstart is defined to be the point prior to grndpeak at which the slope of the waveform record decreases below a constant, but arbitrary, magnitude. The cutoff slope magnitude is selected so that the resulting grndstart positions look qualitatively correct. The resulting determination of grndstart is less accurate and more noisy than in non-sturated cases. Also, the grndstart technique for saturated returns will not effectively separate returns from vegetation directly above the ground. However, in most cases saturation of the ground return occurs where the surface is unvegetated and the intensity of the transmit pulse reaching the ground is not diminished by any overlying vegetation.