Creating Terrain in Flight Simulator 2000

Introduction
This document describes how to create custom terrain for use in Flight Simulator 2000. It covers the following topics:

- Tools provided for Creating Terrain
- Creating a Terrain File
- Using the Level of Detail (LOD) Directive
- Using Scaled Elevation Values
- Using Multiple Overlapping Source Files
- Naming Convention for Terrain Textures

Tools Provided For Creating Terrain
Along with this document, we have provided the following tools for use in creating custom terrain with digital elevation data:

- resample.exe
- tmfcompress.exe
- tmfmerge.exe
- tmf2bgl.exe

We've also included in this document some examples of .INF files for you. These INF files are based on 100 meter DEM data. Note that higher resolutions in either elevation or texture data can seriously affect Flight Simulator 2000's performance, depending on the system configuration of the machine running the simulation.

Creating a Terrain File
The typical steps to creating a Flight Simulator 2000 Terrain File are as follows:
1. Acquire raw digital elevation data.
2. Create an .INF file for the raw data.
3. Run RESAMPLE.EXE on the raw data to create a TMF file.
4. Run TMFCOMPRESS.EXE to compress the file (optional).
5. Run TMFMERGE.EXE to merge 2 or more TMF files together if desired.
6. Run TMF2BGL.EXE to convert the TMF into a BGL file.

1) Getting Data for Use With the Terrain SDK

There are a number of places to get digital elevation data. Most terrain data available for free over the Internet is typically stored in formats such as the USGS DEM (Digital Elevation Model) ASCII, USGS TAR, or USGS Spatial Data Transfer Standard (SDTS) formats. All source data is expected to use USGS84 projection.

For example, here's a link to the USGS 100 meter DEM for the entire United States of America. Just click on the area of DEM you want:

http://edcwww.cr.usgs.gov/glis/hyper/guide/1_dgr_demfig/index1m.html

A DEM provides a digital representation of a portion of the earth's elevation points over a two dimensional surface. A DEM is generated by sampling an array of elevation values derived from topographic maps, aerial photographs, or satellite images.

The raw data used when creating terrain for Flight Simulator 2000 must be in a binary file format, with each elevation point (measured in meters above mean sea level) being assigned a 16-bit integer, the LSB (least significant byte) listed first, followed by the MSB (most significant byte).

Note: The USGS DEM and SDTS formats are not compatible with the terrain tools included with this document, but there are converters available for free on the websites offering the data that will convert the data to a compatible binary form.
For example, check out the **read_dem.exe** tool that's available for download at http://dbwww.essc.psu.edu/notes/utilities.html. After using this tool, you should be good to go to run the output DEM data through our SDK tools.

Once the binary information is acquired, it must be converted into a format that Flight Simulator 2000 can use. The next section discusses the conversion process for elevation data.

2) Creating an .INF File

The raw elevation data you wish to convert must be defined in an .INF file used by RESAMPLE.EXE. The .INF file specifies the latitude/longitude bounding area of the data, as well as the resolution of the data.

Note: You'll often find that the source files you acquire come with a header file. This header file will provide the information needed for some sections of the .INF file such as the bounding area.

The following page shows a sample .INF entry for the Mt. Rainier, Washington State area:

```
===================================================================
[Destination]
      ; LOD = {Auto, 0..n}
      ; LOD = Auto tells the resampler to pick the closest LOD to the
      ;source
      ;cell size.  Specifying a number will force an LOD.  This can
      ;be used for undersampling or oversampling.

      LOD   = Auto

      DestDir            = "tmf"
      DestBaseFileName   = "rainier"
      UseSourceDimensions = 1

[Source]
      Type              = ElevS16LSB
      SourceDir         = "x:\dem"
      SourceFile        = "dem_100m_mtrainier"
      Lat               = 46.99916666667
      Lon               = -121.9466666667
      NumOfCellsPerLine = 457
      NumOfLines        = 375
      CellXdimensionDeg = 0.0008333333333333
      CellYdimensionDeg = 0.0008333333333332
      ScaleinMeters     = 1.0
=====================================================================
```

Definitions

LOD	The LOD directive means "Level of Detail" and tells the resampler the desired resolution of the destination file. **LOD = Auto** means pick a resolution closest to the raw data's resolution. Custom LOD settings are described in Advanced Topics.
DestDir	The directory in which to place the file created by the resampler.
DestBaseFileName	The name given to the file created by the resampler.
UseSourceDimensions	Tells the resampler to use the latitude and longitude specified in the [Source] section as the limits of the bounding area. **Note:** The UseSourceDimensions directive is only supported with single source .INF files. If the [destination] section doesn't specify a latitude/longitude resampling area, then the area is assumed to be the entire earth.
Type	The default type value. This should remain as ElevS16LSB unless you know your data is in big endian format. **ElevS16MSB** -- 16 bit signed elevation data with the most signification byte first. **ElevS16LSB** -- 16 bit signed elevation data with the least signification byte first.
SourceDir	The directory where the raw data is stored.
SourceFile	The file containing the raw data.
Lat	The latitude of the northwest corner of the bounding area
Lon	The longitude of the northwest corner of the bounding area
NumOfCellsPerLine	The number of data values per line (columns)
NumOfLines	The number of lines of data (rows)
CellXdimensionDeg	The distance between each elevation post in the X-axis in decimal degrees or fraction of a degree. If you are using one degree data (digital information that covers an area of one degree of latitude by one degree of longitude), you divide one by the NumOfCellsPerLine value to derive CellXdimensionDeg. This entry can also be in scientific notation (example: 8.3263946711074104912572855953372e-4).
CellYdimensionDeg	The distance between each elevation post in the Y-axis in decimal degrees or fraction of a degree. If you are using one degree data (digital information that covers an area of one degree of latitude by one degree of longitude), you divide one by the NumOfLines value to derive CellYdimensionDeg. This entry can also be in scientific notation (example: 8.3263946711074104912572855953372e-4).
ScaleinMeters	Tells the resampler what the measurement convention was in the source file. If the source file was in feet, this value would equal the decimal fraction of a meter that represents one foot.

This file specifies that the raw data is DEM. The spacing between each elevation post is 0.0008333333333333, or about 100 meters along the X and Y-axis.

When the resampler reads this .INF file, it searches for the raw data in a file called "dem_100m_mtrainier" located in a directory called "x:\dem". The .INF file also specifies a destination filename and directory.

"UseSourceDimensions = 1" tells the resampler to use the latitude and longitude specified in the [Source] section of the .INF file. It is possible to specify a different resampling bounding area. Instead of specifying "UseSourceDimensions = 1" you may specify the latitude and longitude of the resampling area with these statements:

```
NorthLat =
SouthLat =
EastLong =
WestLong =
```

With multiple source files, you must specify the bounding area using the lat/long switches above.

3) Using the Resampler

After creating the .INF file for your DEM data, you must run the resampler to create a .TMF file.

Resample.exe is run with the following command line format:

Resample [-i, -q, ?] **file1.INF** [file2.INF…fileN.INF]

-i ignores all but the last [destination] section
-q runs in quiet mode
? prints a help message

The resampler is very easy to use. Simply run it and specify one or more .INF files. Multiple .INF files are allowed because it is possible for the [source] and [destination] sections to be in separate files. This is convenient when you want to generate different resolutions of data from a single source file or to generate one destination file from multiple sources of different resolution. Simply build an .INF file for the source data and multiple .INF files with [destination] sections for each destination file.

The resampler can also process more than one source file. Multiple source files can be specified in one of two ways, the first being multiple source .INF files each specifying a source file, and the second being one .INF file listing multiple source files as follows:

```
===================================================================
[Source]
      Type              = MultiSource
      NumberOfSources   = 3

[Source1]
      Type              = ElevS16LSB
      SourceDir         = "x:\dem"
      SourceFile        = "dem_w180n90"
      CellType          = S16LSB
      NullCellValue     = -9999
      Lat               = 90
      Lon               = -180
      NumOfCellsPerLine = 4096
      NumOfLines        = 4096
      CellXdimensionDeg = 0.0146484375
      CellYdimensionDeg = 0.010986328125
      ScaleinMeters     = 1.0

[Source2]
      Type              = ElevS16LSB
      SourceDir         = "x:\dem"
      SourceFile        = "dem_w120n90"
      CellType          = S16LSB
      NullCellValue     = -9999
      Lat               = 90
      Lon               = -120
      NumOfCellsPerLine = 4096
      NumOfLines        = 4096
      CellXdimensionDeg = 0.0146484375
      CellYdimensionDeg = 0.010986328125
      ScaleinMeters     = 3.280

[Source3]
      Type              = ElevS16LSB
      SourceDir         = "x:\dem"
      SourceFile        = "dem_w060n90"
      CellType          = S16LSB
      NullCellValue     = -9999
      Lat               = 90
      Lon               = -60
      NumOfCellsPerLine = 4096
      NumOfLines        = 4096
      CellXdimensionDeg = 0.0146484375
      CellYdimensionDeg = 0.010986328125
      ScaleinMeters     = 3.280
===================================================================
```

By default, the resampler scans each .INF file on the command line, collecting information from each [source] section it encounters. Once a [destination] section is found, it proceeds with the resampling process. If more [source] sections are thereafter encountered, they are treated as a separate job and these sections will be used when the next [destination] section is encountered.

If the **-i** switch is specified, resample ignores all but the last [destination] section.

4) Using the Compression Utility

Once the resampler has been employed to create .TMF files, you can compress those files. This is done with TMFCOMPRESS.EXE.

Tmfcompress.exe is run with the following command line format:

tmfcompress source.tmf [source2.tmf] dest.tmf

TMFCOMPRESS produces a compressed .TMF file from an uncompressed file. The utility can take a long time to run if the .TMF file is large.

5) Using the Merge Utility

TMFMERGE.EXE is used to merge several .TMF files together into one .TMF file. If two or more .TMF files contain elevation data for the same geographical location, the data from the last .TMF file listed on the command line will be the one used. This situation may occur when you're using multiple source files that overlap a particular geographic area.

TMFMERGE.EXE is run with the following command line format:

tmfmerge dest.tmf source1.tmf [source2.tmf] [sourceN.tmf]

5) Converting TMF Files to BGL Files

To use the new terrain data you have created, you must convert the .TMF files to .BGL files. This is done with TMF2BGL.EXE.

Tmf2bgl.exe is run with the following command line format:

tmf2bgl inputfile.tmf outputfile.bgl

TMF2BGL converts a .TMF file into a .BGL file. Flight Simulator 2000 requires terrain files to be in .BGL format to use them.

6) Using Your Files in Flight Simulator 2000

Once the custom terrain data has been created, a configuration file called Scenery.CFG in Flight Simulator 2000 must be edited to allow the program to load and use the new terrain data. The procedure is as follows:

Create a directory that has a scenery and texture subdirectory in it. Example:
c:\custom
c:\custom\scenery
c:\custom\texture

Copy the custom terrain .BGL files into the scenery directory.

Edit the Scenery.CFG file in the Flight Simulator 2000 folder and add a new area at the end with layer number = 2 or higher. The layer number must be greater than 1 so that your custom terrain takes precedence over the default terrain. Make sure that the area number is greater than the last area number listed. For example, if the last area was 72, then add the following lines:

[**Area.073**]
Title=My custom terrain
Local=c:\custom
Active=TRUE
Layer=073

When Flight Simulator 2000 is started, it will read in all of the default terrain and then read in the new terrain, overwriting in memory any data that has already been read in. Note that terrain in Flight Simulator 2000 is layered and the highest resolution data will be made available over lower resolution data.

Using the Level of Detail (LOD) Directive
The LOD directive determines the resolution of the resampled elevation data. The .TMF files store elevation data in quadrants. Each LOD level represents a division by 2 in the east/west and north/south directions.

The following table details the LOD values and the corresponding latitude/longitude spans for each quadrant. Find the Sample Size in meters that you desire and then look up the LOD value to the left of that value. This is the LOD value that you type into your .INF file.

LOD	Sample Size Meters	Lat Deg Boundries	Lon Deg Boundries	Span Meters
0	39136.2	90	120	10018863
1	19568.1	45	60	5009431
2	9784.0	22.5	30	2504716
3	4892.0	11.25	15	1252358
4	2446.0	5.625	7.5	626179
5	1223.0	2.8125	3.75	313089
6	611.5	1.40625	1.875	156545
7	305.8	0.703125	0.9375	78272
8	152.9	0.3515625	0.46875	39136
9	76.4	0.17578125	0.234375	19568
10	38.2	0.087890625	0.1171875	9784
11	19.1	0.043945313	0.05859375	4892
12	09.6	.021972656	0.029296875	2446
13	4.8	0.010986328	0.014648438	1223
14	2.4	0.005493164	0.007324219	612
15	1.2	0.002746582	0.003662109	306

Using Scaled Elevation Values

Flight simulator 2000 supports scaled elevation values. The elevation resampler provides a capability whereby very precise elevation values can be specified at the expense of the range of these values. By default, the resampler expects elevation values to be in increments of 1 meter. However, with the BaseValue and FractionBits directive, it is possible to specify different scalings for source and/or destination data.

For example, say you had source data with very precise elevation measurements of a given area, with measurements being precise to within 128th of a meter. Since elevation values are represented as a signed 16-bit integer, the range of values a given integer can express is -32768 to 32767. As stated above, the resampler's default behavior is to assume the given elevation values to be in meters which means the default range of values is -32768 meters to 32767 meters.

If you set the FractionBits directive to 1 in the [source] section of the .INF file, the resampler knows that the source data is in the form of "15.1" numbers. This means that each number has 15 bits reserved for the whole number part and 1 bit reserved for the fractional part.

With a single bit used for fractions, a number can be precise to within one-half (since the first place-value after the decimal point in a binary number represents one-half). From this, it is evident that a 15.1 number is more precise than a 16-bit integer, however its range is half of a 16-bit integer. The range of a 15.1 number is -16384 to 16383.5. Each increment to the number represents an increment by 1/2. So, a "1" means 1/2 meter. A "2" means 1 meter. A "3" means 1.5 meters", and so on.

Getting back to our example, we have source data precise to 128th of a meter. This means that a "1" equals 1/128th of a meter. A "2" equals 2/128th of a meter, and so on. To represent the example data properly, we need to specify 9 bits for the whole number part and 7 bits for the fraction part, or a "9.7" number. We do this with the following directive:

```
=================================================================
[source]

FractionBits = 7
=================================================================
```

Since 9 bits are reserved for the whole number part, the range is -512 to 511.984375. This is a fairly narrow range. Unless the area on the earth represented by this data is below 512 meters (and above -512 meters), there would be a problem representing the magnitude of the elevations. An elevation of 1000 meters, for example, cannot be expressed with a "9.7" scaled number. It is outside of the range. To solve this problem, the directive "BaseValue" can be used to define a "zero point" for the elevation values. For example, if the following is specified:

```
=================================================================
[source]

FractionBits = 7
BaseValue = 1000
=================================================================
```

A value of zero in the source data means 1000 meters. A value of 1 means 1000 + 1/128th of a meter (or 1000.78125).

The FractionBits and BaseValue directives can be used in either the [source], [destination], or both sections. In the case where these directives specify different scalings in the [source] and [destination] sections, the resampler will attempt to form the source scale to the destination scale. If a loss of precision occurs, the resampler will print out an error message.

Using Multiple Overlapping Source Files

Another useful feature of the resampler is the ability to merge different resolutions of elevation data as it resamples. This is best explained with an example.

The Mt. Rainier data shipped with Flight Simulator 2000 has a resolution of approximately 75 meters. This data extends over an area that spans 4 quadrants at LOD = 9 (see Using the Level of Detail (LOD) Directive section above for further info).

However, the data does not completely cover these quadrants. There are parts of the quadrants that contain no data.

Since the resampler's output consists of quadrants at a given LOD, the resulting .TMF file produced by resampling the Mt. Rainier data alone will result in a steep cliff around the Mt. Rainier area. This cliff exists because the data does not completely cover the quadrants containing the Mt. Rainier data. When used in the game, the cliffs will be obvious because there will be a gap between the surrounding quadrants containing 1 kilometer data and the partially filled quadrants containing 75 meter data.

To fix this problem, the resampler allows for multiple source files to be specified. For example:

resample mtrainier.inf 1km.inf

If the file **mtrainier.inf** contains:

```
====================================================================
[Destination]
      ; LOD = {Auto, 0..n}
      ; LOD = Auto tells the resampler to pick the closest LOD to the
      ;     source cell size.  Specifying a number will force an LOD.
      ;     This can be used for undersampling or oversampling.

      LOD   = Auto

      DestDir            = "_tmf"
      DestBaseFileName   = "rainier"
      UseSourceDimensions = 1

[Source]
      Type               = ElevS16LSB
      SourceDir          = "x:\dem"
      SourceFile         = "dem_100m_mtrainier"
      NullCellValue      = -9999
      Lat                = 46.99916666667
      Lon                = -121.9466666667
      NumOfCellsPerLine = 457
      NumOfLines         = 375
      CellXdimensionDeg = 0.0008333333333333
      CellYdimensionDeg = 0.0008333333333332
====================================================================
```

And if the file **1km.inf** contains:

```
==================================================================
[Source]
      Type              = ElevS16LSB
      SourceDir         = "x:\dem"
      SourceFile        = "dem_w180n90"
      CellType          = S16LSB
      NullCellValue     = -9999
      Lat               = 90
      Lon               = -180
      NumOfCellsPerLine = 4096
      NumOfLines        = 4096
      CellXdimensionDeg = 0.0146484375
      CellYdimensionDeg = 0.010986328125
==================================================================
```

The resulting .TMF file will have 1 kilometer resolution data in the areas not filled in by the Mt. Rainier data. This happens because the command line order defines a priority for the data. Since the Mt. Rainier data is specified first in the command line, it takes precedence over the data that follows in the command line. The result of this behavior is that data values outside the extent of the Mt. Rainier data will come from the data specified by the 1km.INF file.

The final result will be a .TMF file with 75-meter data in the Mt. Rainier area and 1 km data around it, extending to the quadrant boundary. This .TMF file will merge seamlessly with the 1 kilometer data of the earth shipped with Flight Simulator 2000.

Terrain Texture Naming Convention

This section describes the naming convention used by Flight Simulator 2000 for terrain textures. The naming convention follows this format:

OOOB2SU1

- The first three numbers "000" are the numeric value for a given texture.
- A "B" followed by a number (e.g., B2), denotes the latitude band in which the texture resides.
- The next two letters (SP, SU, FA, WI, HW) represent the seasonal variation of the tile.
- The last number (1) denotes which variation the texture is.

There are some gaps in the numbering system like the one seen between 011B2SU1 and 013B2SU1. These textures are not mapped anywhere, and are not displayed by the terrain engine.

There are five possible latitude bands, numbering from 1-5. They start at the equator, (band 1) and proceed northward to the pole (band 5). The southern hemisphere uses the corresponding numbers (band 5 at the equator to band one at the South Pole).

There are five seasons: Spring (SP), Summer (SU), Fall (FA), Winter (WI), and Hard Winter (HW). The difference between the two winter textures; WI and HW are mainly visual (snow in HW) and when they are displayed in the game.

Almost all terrain textures have variations: a unique texture that tiles in all four directions to the other textures sharing that numeric value (example: 013B2SU3 and 013B2SU1 tile to each other, whereas 021B2SU5 and 021B2SU5 do not tile to each other).

Texture	**Texture Name**	**Number of Variations**
Water	000B2SU1.bmp	1
Ice	001B2SU1.bmp	5
Desert	002B2SU1.bmp	7
Semi Desert Shrub	003B2SU1.bmp	7
Geometric Crop	004B2SU1.bmp	7
Non Geometric Crop	005B2SU1.bmp	5
Grassland	006B2SU1.bmp	7
Non Geometric Crop And Town	008B2SU1.bmp	7
Grass And Shrub	009B2SU1.bmp	7
Grass Crop Shrub	010B2SU1.bmp	7
Woody Savanna	011B2SU1.bmp	7
Tundra	013B2SU1.bmp	5
Woody Tundra	014B2SU1.bmp	5
Wooded Swamp	016B2SU1.bmp	5
Mire Bog Fen	017B2SU1.bmp	5
Wetland Marsh	018B2SU1.bmp	5
Evergreen Tropical Forest	019B2SU1.bmp	5

Degraded Evergreen Tropical Forest	020B2SU1.bmp	5
Deciduous Tropical Forest	021B2SU1.bmp	5
Conifer Boreal Forest	022B2SU1.bmp	5
Mixed Boreal Forest	023B2SU1.bmp	7
Evergreen Conifer Forest	024B2SU1.bmp	5
Evergreen Conifer Forest and Field	025B2SU1.bmp	7
Deciduous Conifer Forest	026B2SU1.bmp	7
Mixed Forest	027B2SU1.bmp	7
Evergreen Broadleaf Forest	028B2SU1.bmp	7
Large City Urban Grid Wet	029B2SU1.bmp	7
Large City Urban Grid Dry	030B2SU1.bmp	7
Large City Urban Non Grid Wet	031B2SU1.bmp	7
Large City Urban Non Grid Dry	032B2SU1.bmp	7
Medium City Urban Grid Wet	033B2SU1.bmp	7
Medium City Urban Grid Dry	034B2SU1.bmp	7
Medium City Urban Non Grid Wet	035B2SU1.bmp	7
Medium City Urban Non Grid Dry	036B2SU1.bmp	7
Large City Suburban Grid Wet	037B2SU1.bmp	7
Large City Suburban Grid Dry	038B2SU1.bmp	7
Large City Suburban Non Grid Wet	039B2SU1.bmp	7
Large City Suburban Non Grid Wet	040B2SU1.bmp	7
Medium City Suburban Grid Wet	041B2SU1.bmp	7
Medium City Suburban Grid Dry	042B2SU1.bmp	7
Medium City Suburban Non Grid Wet	043B2SU1.bmp	7
Medium City Suburban Non Grid Dry	044B2SU1.bmp	7
Small City Suburban Grid Wet	045B2SU1.bmp	7
Small City Suburban Grid Dry	046B2SU1.bmp	7
Small City Suburban Non Grid Wet	047B2SU1.bmp	7
Small City Suburban Non Grid Dry	048B2SU1.bmp	7
Large City High rise	049B2SU1.bmp	5
Semi desert sage	050B2SU1.bmp	7
Shrub evergreen	051B2SU1.bmp	7
Hot And Mild Grasses And Shrubs	052B2SU1.bmp	7
Polar And Alpine Desert	055B2SU1.bmp	5
Rock	056B2SU1.bmp	7