MultiGrad 601

Version 1.05

User's Manual

GEOMAR SOFTWARE INC.
Tel: 905.306.9215

E-mail: geomar@geomar.com
Web: www.geomar.com

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Geomar Software Inc.
899 Runningbrook Drive
Mississauga, Ontario, Canada L4Y 2S4
Tel: 905 306 9215
e-mail: geomar@geomar.com
web: www.geomar.com

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Introduction 1

The Geomar MLgrad601 Data Logging System consists of a data logging program MLgrad601 and associated PC computer data processing program MultiGrad601. The data acquisition program MLgrad601 is designed for various field computers operating under Windows 2000/XP/7.

The program MultiGrad601 is used to process data files recorded under the control of program MLgrad601. It recognizes data file formats created with various versions of MLgrad601 automatically.

1.1 About the MultiGrad601

The program MultiGrad601 is a Windows based program for IBM PC compatible computers operating under Windows 2000/XP and Windows 7. The program MultiGrad601 is designed to process data collected by a field computer under the control of program MLgrad601. The program can be used to position array of Grad601 sensors based on real time GPS data and the system geometry, results are written into XYZ type of file suitable as an input to various mapping systems. The program allows you also to convert data to ASCII text file format, to position field comments, and to correct created XYZ files for a delay (lag) caused by the system time constant.

Main function of this program is to position Bartington Grd601 sensors based on the recorded GPS position, the instant heading of the system, the configuration of the system, and several user specified filters. Configuration of the system is described by offsets of the GPS antenna from the reference point 0,0 located at the center of the left side of the Grad601 array sensors. The program calculates real position of the instrument based on specified GPS antenna offset and direction of the movement. However, it is highly recommended that GPS antenna is placed as close as possible to the center of Grad601 sensors array as this configuration provides the best accuracy. Optionally elevation data can be written to the output file. The program corrects elevation data for the GPS antenna height. The program can process seven different NMEA GPS messages recorded by data acquisition software MLgrad601: a pair GGA/GSA, GGA, POS, LLK, LLQ, GLL, and GGK (Trimble and Leica versions). In addition program handles interface of Leica Robotics Total Station (RTS) TPS1100 and TPS1200, as well as Trimble RTS supporting stream of pseudo-GGA staement.

The MultiGrad601 uses data files in MLgrad601 format which have extension name MGR. These are binary files with a record length of 27 bytes terminated by Line Feed

character. These files must not be edited using standard text editors, in case the binary data file is saved in a text editor then data file may be corrupted.

One sample MLgrad601 data files 082212A.MGR is included on the program disk. They allow the user to become familiar with running the MultiGrad601 program.

1.2 Contents of MultiGrad601 Distribution Disk

Program MultiGrad601 is supplied on one CD disk. Disk contains following files and directories:

SetupML601	-	setup program for MultiGrad601
Documentation	-	directory containing all MLgrad601 and MultiGrad601, and other Geomar manuals in PDF format.
MLgrad601	-	MLgrad601 version of data acquisition program

1.3 MultiGrad601 Software Installation

The MultiGrad601 uses a setup program to load files onto your computer. The following section describes the installation process. To install MultiGrad601: Insert the MultiGrad601 CD disk into computer CD disk drive. Exit all Windows applications before installing the program. Locate SetupML601.exe in Windows Explorer (Figure 1.1) or in Windows XP use the Windows File Manager, select **Run** from the **File** menu.

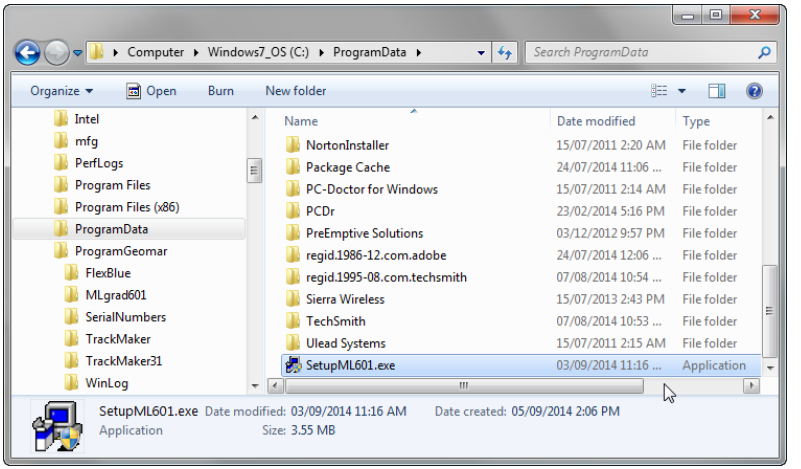


Figure 1.1: Run Dialog window

Browse for the file SetupML601.exe in the directory of the diskette. Click **OK** to launch the Setup program. Once the Setup determines your computer configuration the Welcome window opens (Figure 1.2).

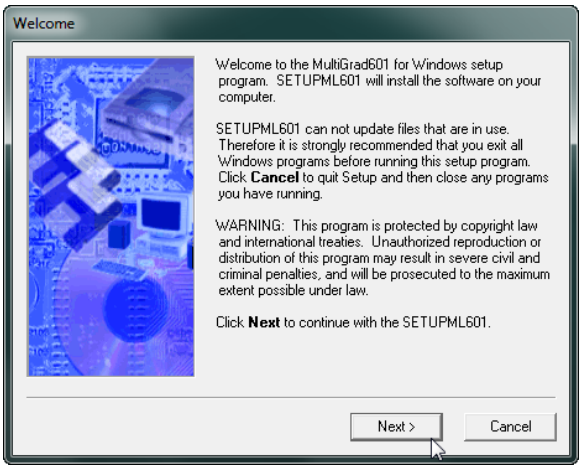


Figure 1.2: Welcome window

Read the text and click the **Next** button. The Serial Number window will be displayed (Figure 1.3).

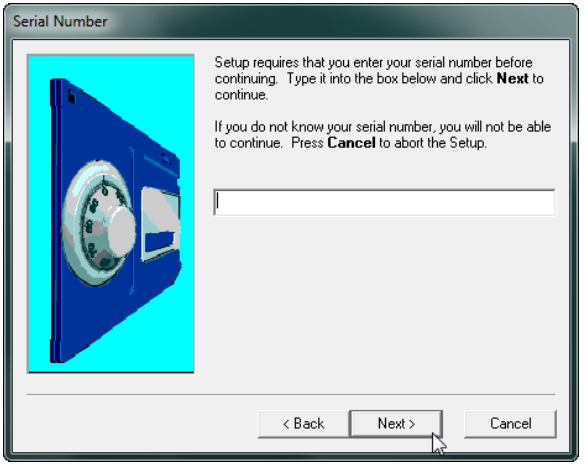


Figure 1.3: Serial Number window

In case the software is supplied with USB security key (dongle) or the software is provided without Serial Number (info is printed on the distribution CD) the Serial Number window will be not displayed, otherwise please type the Serial Number into the provided box and press the **Next** button. (If you do not know the Serial Number, you will not be able to continue.) The Installation Directory window opens (Figure 1.4).

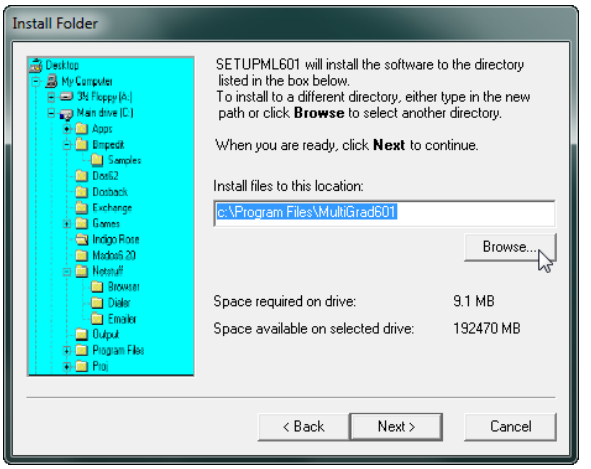


Figure 1.4: Installation Directory window

The default directory is C:\Program Files\MultiGrad601. Click the **Next** button to install the program to this directory. If you wish to install MultiGrad601 to another directory, click the **Browse** button, and the Browse for Folder window will open (Figure 1.5).

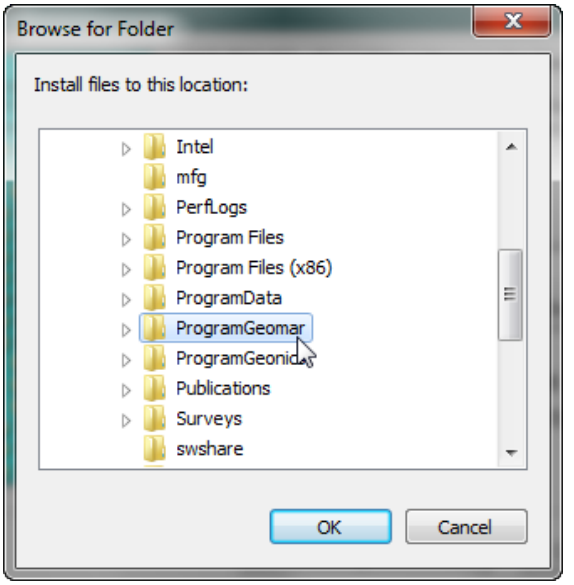


Figure 1.5: Select Installation Directory window

Select a target directory (folder) and click **OK**. The Browse for Folder window closes, and the Installation Directory window opens with the selected directory listed. Click the **Next** button. The Select Short cut Folder window opens (Figure 1.6).

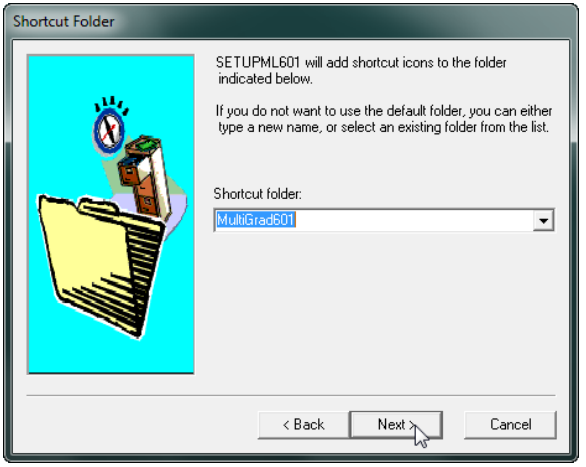


Figure 1.6: Select Shortcut Folder window

The setup program will create a MultiGrad601 menu item in the Program menu accessible by clicking **Start**. If you do not want to use the proposed folder, you can either enter a new name, or select an existing folder from the list. Click **Next** and the Ready to Install window will follow (Figure 1.7).

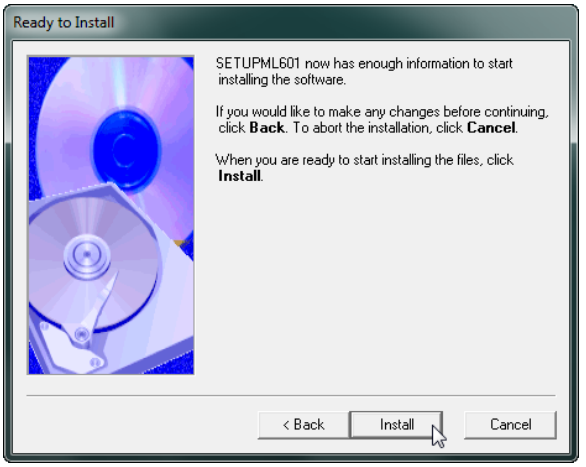


Figure 1.7: Ready to Install window

In case you would like to make any changes before the installation, click **Back**. To abort installation click **Cancel**. If you are ready to start installation, click **Finish**. The installation progress bar will appear.

The Installing Files window with a progress bar displays the percentage of the installation completed. When finished, the following window will appear (Figure 1.8).

Figure 1.8: Finished window

Click **Finish** to end installation. SetupML601 creates a MultiGrad601 program group and places **MultiGrad601** and **Uninstall** items and icons into it (Figure 1.9). The setup program creates also a **MultiGrad601** menu item in the Program menu accessible by clicking **Start**. A reminder to restart the system will be displayed at the end of the setup program if necessary. The destination directory that was chosen earlier contains program files and sample data files.

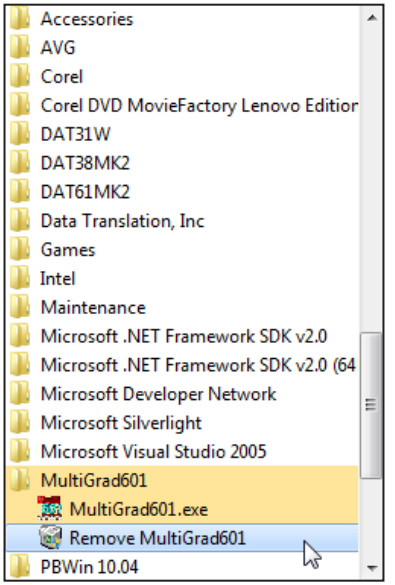


Figure 1.9: MultiGrad601 and Remove the program items

1.4 Program Overview

Start the MultiGrad601 by double clicking the MultiGrad601 icon in the **Start|Programs** menu, in Windows Explorer, or on the desktop if a shortcut was created. At the start, MultiGrad601 displays the following screen (Figure 1.10):

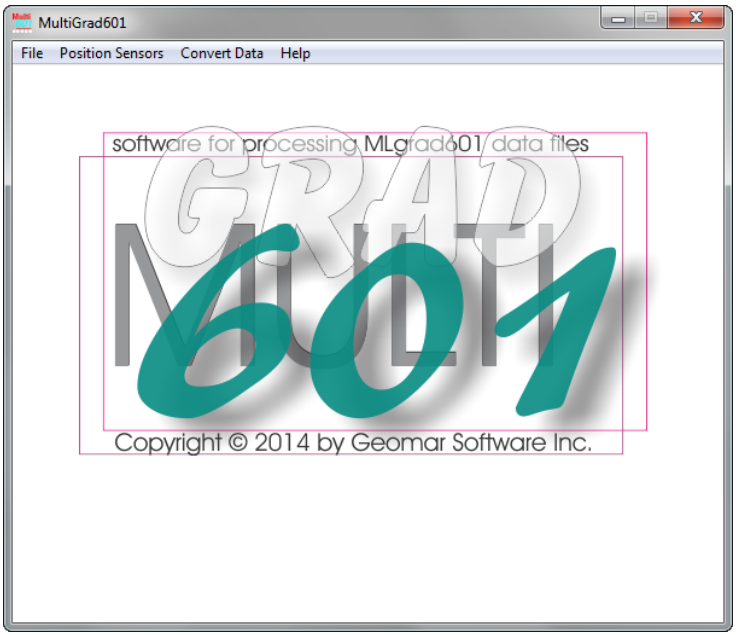


Figure 1.10: MultiGrad601 Main Screen

The MultiGrad601 is a menu driven program. Most of menus items are disabled till a data file is loaded in to the program. A short description of the possible menu options is given below.

File Menu

The File Menu is shown in Figure 1.11. Functions accessible from this menu allow you to load data file, to save data set, to save data set under different file name (Save As), to remove loaded data from the program memory (Close), to edit data parameters, to display two dimensional layout of selected XYZ file, and exit the program.

When program starts most of items in File menu are disabled. As soon as data file is selected and data is loaded to the program memory the program displays information related to data file contents, Figure 1.12. When the OK button on the MultiGrad601 window is clicked, the window disappears and the program replaces graphic splash

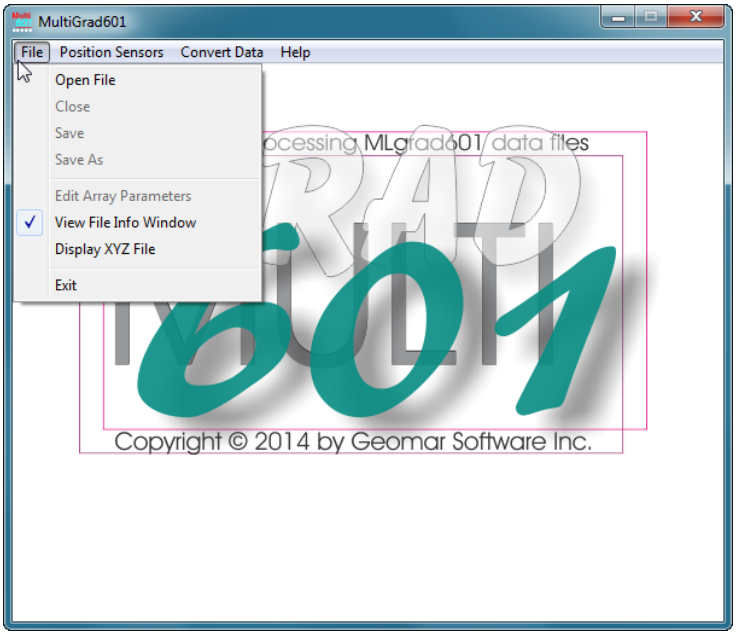


Figure 1.11: MultiGrad601 File menu

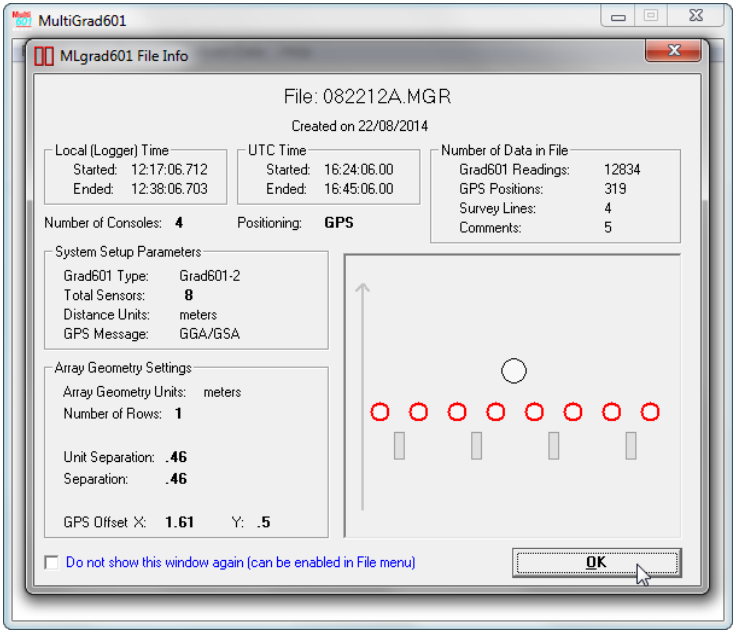


Figure 1.12: MultiGrad601 Main Screen after Loading data file

screen by name of the loaded file, its date of creation, number of data and GPS readings it contains, and by the layout of the Grad601 sensors (Figure 1.13). At the same time remaining items in the File menu are enabled.

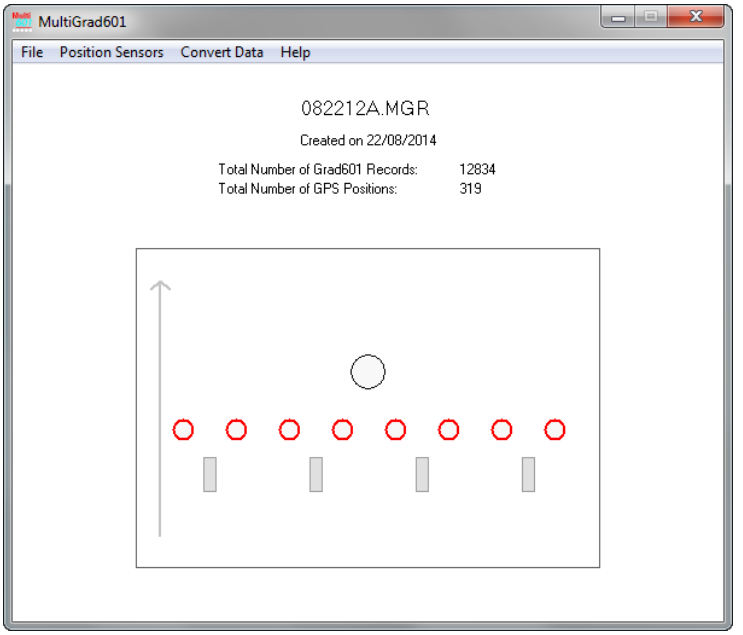


Figure 1.13: Layout of the MultiGrad601 Main Screen after Data File is Loaded

The MultiGrad601 does not allow to overwrite original data file. The Save option is enabled only when not original data file (i.e. with edited parameters or previously Saved As) was loaded or after option Save As was used. When original data file is selected the name of the file and date of the creation is displayed at the top of the screen. In case when not original file was loaded then the current file name is displayed, followed by an original date of creation and original file name, for example: "Created on 06/02/2014 as 060202A.MGR".

The information displayed by the MultiGrad601 main screen contains data file name and number of readings, and system geometry. Detailed information as well as possibility of adjustment of some parameters can be displayed by clicking on the Edit Array Parameters item located in the File menu. The Edit Array Parameters window will be displayed (Figure 1.14). The window displays entire information about loaded data set and settings used during data acquisition. Several parameters: Array Geometry Units, Unit Separation, sensors Separation, GPS antenna offsets, Grad601 type (cannot be changed in the current version), GPS statement to be used during data processing, as well as Distance Units can be adjusted using the Edit Array Parameters window (see Figure 1.14).

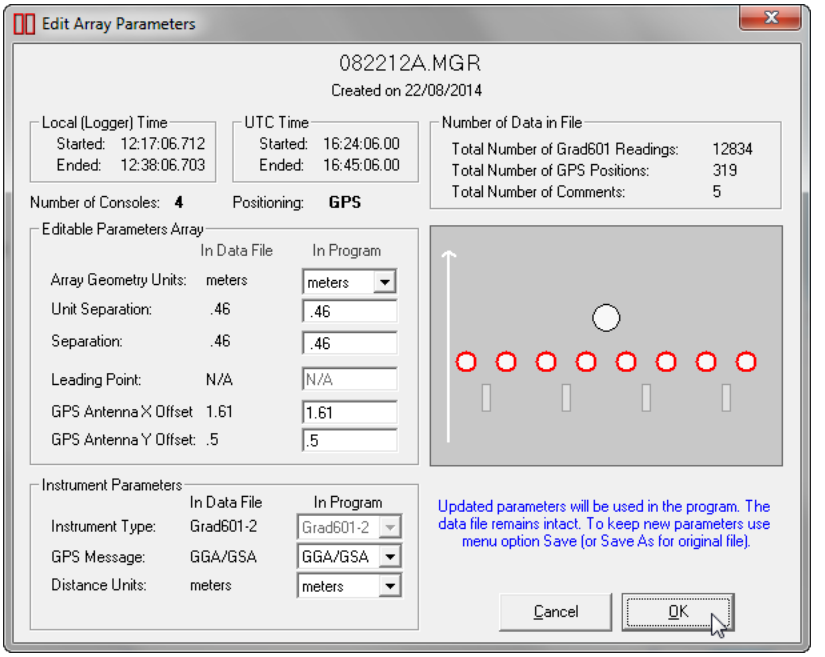


Figure 1.14: Edit Parameters window

Position Readings Menu

The Position Sensors menu represents the main function of the program: positioning of the Grad601 sensors based on the system geometry and GPS positioning (Figure 1.15).

The Position Sensors using MLgrad601 Data File item allows you to position sensors based on Real Time GPS data embedded in MLgrad601 file, as well as on several user specified settings and filters for GPS signal quality. The program can also include elevation data in the output file.

Convert Data Files Menu

The Convert Data menu has four functions available. The menu is shown in Figure 1.16.

The first item, MLgrad601 Files to ASCII Format allows you to convert data files to ASCII text format. This file can be simply used to examine data in text mode, or it can be easily converted to other formats if required.

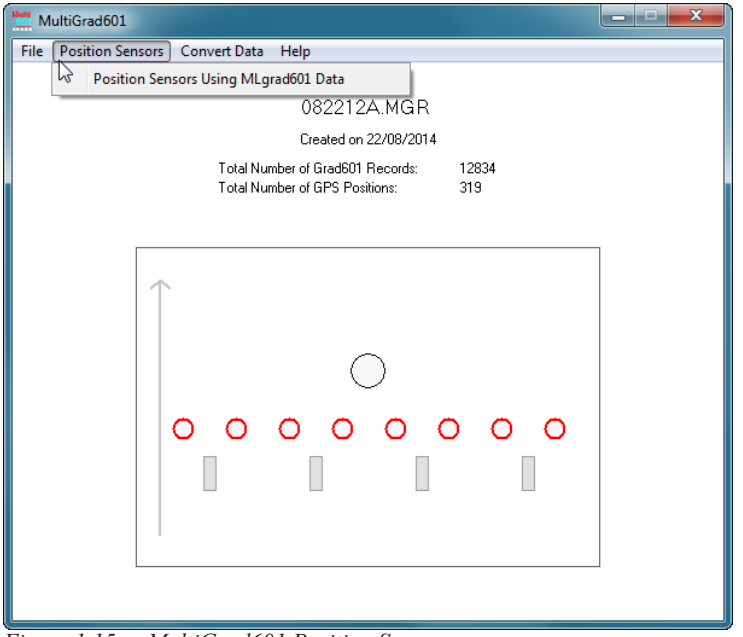


Figure 1.15: MultiGrad601 Position Sensors menu

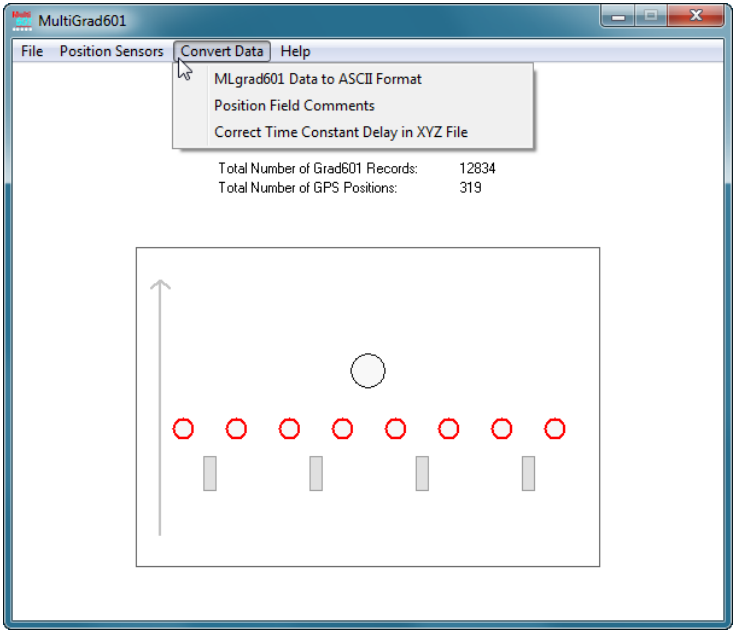


Figure 1.16: MultiGrad601 Convert Data menu

The second item of the Convert menu, Retrieve and Position Field Comments allows you to filter out and position field comments entered by the operator during the survey.

The last option of the Convert menu, Correct Time Constant Delay in XYZ Files can be used to correct the effect of the system (combined Grad601 and GPS receiver) time constant delay in two dimensional XYZ files generated during positioning Grad601 data.

Help Menu

Item "About" is the only available option in this menu. It displays name and version of the program, as shown in Figure 1.17. Help function is not available in this version of the MultiGrad601.

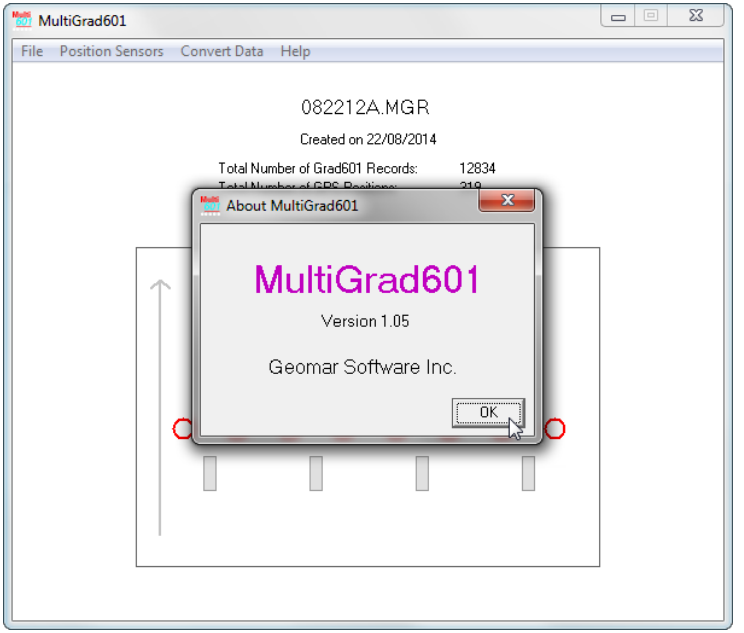


Figure 1.17: About MultiGrad601 window

A detailed description of the function of each menus item is provided in relevant sections of the manual.

File Menu 2

File menu of MultiGrad601 program is shown in Figure 2.1. There are several items associated with the File menu:

- Open File (loads MLgrad601 data file to the program memory),
- Close (closes current data set),
- Save (saves data to the same file, disabled if original data file loaded),
- Save As (saves data to a file with different file name),
- Edit Array Parameters (changes parameters in loaded data set),
- View File Info Window (enables/disables a File Info after loading data file),
- Display XYZ File (displays layout of stations in XYZ file),
- Exit (terminates MultiGrad601 program).

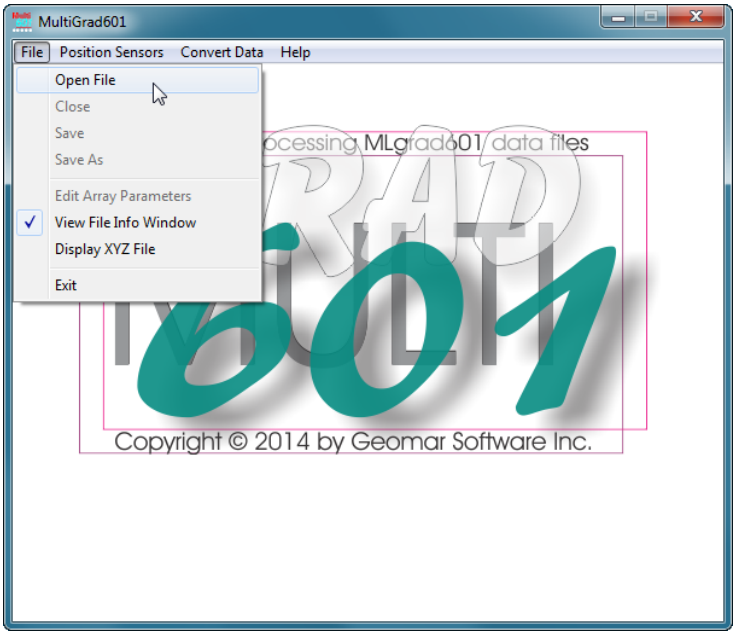


Figure 2.1: MultiGrad601 File menu

When program starts most of items in the File menu are disabled. They are enabled automatically as soon as data file is loaded in to the program memory.

The general rule of the MultiGrad601 software is that the program cannot overwrite original file name. In order to Save file, the original file name must be "Saved As" first. The program tags such file and menu item Save is enabled. At further runnings when the "Saved As" file will be loaded item Save will be enabled automatically.

2.1 Open File

The Open File option allows you to load MLgrad601 data file to the program memory. Select **File|Open File** from the main program menu, as shown in Figure 2.1. After the selected menu item is clicked the Select MLgrad601 Input File window will be displayed in the centre of the screen, Figure 2.2.

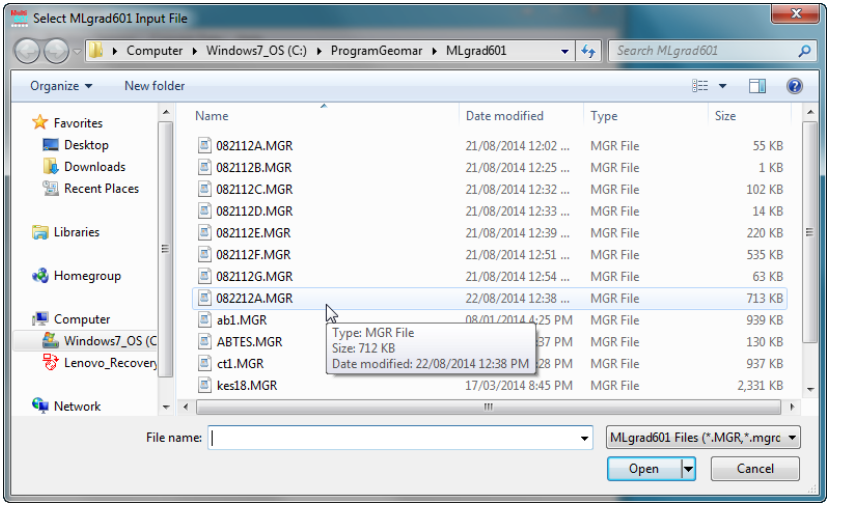


Figure 2.2: Select MLgrad601 Input File window

The window lists files with extension name MGR. Select a file name and click the **Open** button. The Select MLgrad601 File window will close and the progress bar will appear in the center of program's main window indicating percentage of loaded file (Figure 2.3).

As soon as data file is loaded to the program memory the program displays a window labeled MLgrad601 File Info (Figure 2.4) with the information related to data file contents.

The MLgrad601 File Info window displays the most important parameters of the entered data file. At the top of the window the current file name, date of file and optionally original file name (as entered in the field), and start and end times in local time (field computer clock) and UTC time (GPS time in NMEA messages) are displayed. On the right side, in the frame labeled **Number of Data in File** a total number of Grad601 readings, number of GPS positions recorded, number of survey lines, and comments entered in the field are given. In the frame labeled **System Setup Parameters** listed are: number of Grad601 sensors in array and Grad601 Type, Distance Units, and type of used GPS NMEA message. The frame labeled **Array Geometry Settings** contains: Array Geometry Units, Number of Sensors, Sensor Separations (Unit Separation and Separation),

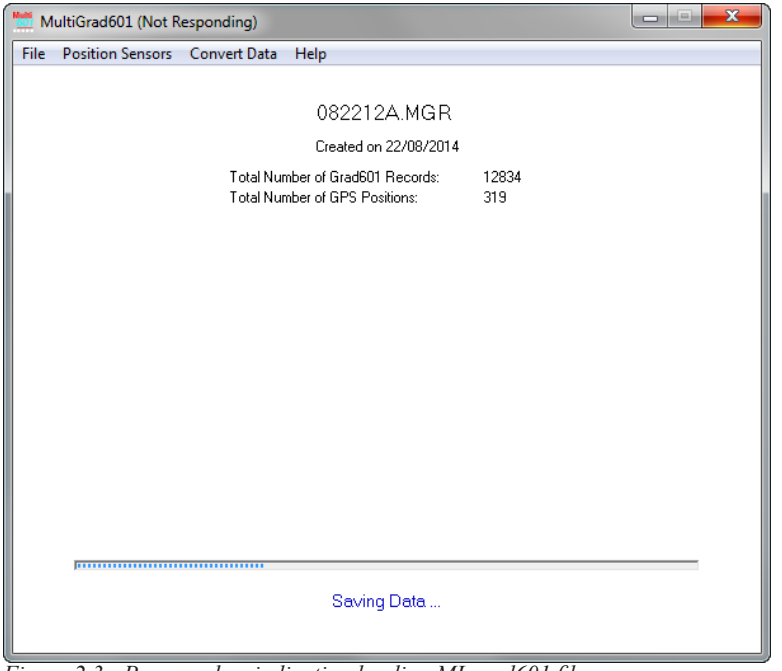


Figure 2.3: Progress bar indicating loading MLgrad601 file

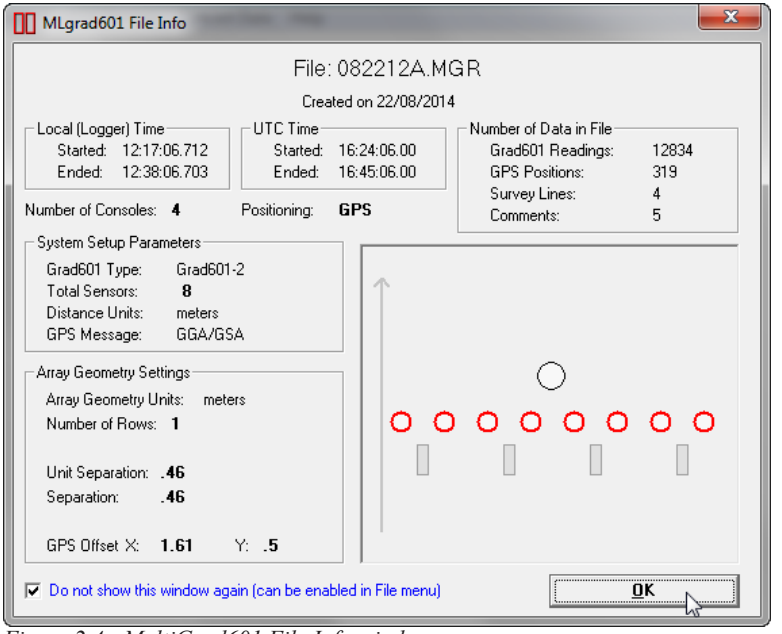


Figure 2.4: MultiGrad601 File Info window

and GPS X and Y offsets (in Distance Units). The bottom right section of the window contains actual layout of sensor as described by GPS antenna offsets and sensors Separations.

The MLgrad601 File Info window can be deactivated (not displayed every time file is loaded) by checking button located at the bottom of the window and labeled **Do not display this window ...** . This can be also enabled and disabled at any time by checking File menu item **View File Info Window**. After clicking on the button OK (or pressing Enter key) the window disappears.

As soon as the button OK is clicked (or ENTER key is pressed) the window disappears, the splash graphic on the main window disappears and it is replaced by the loaded file name, its date of creation, number of data points, and layout of the system geometry (Figure 2.5). At the same time remaining items in the File menu (and items in other menus as well) are enabled and the Open File item is disabled.

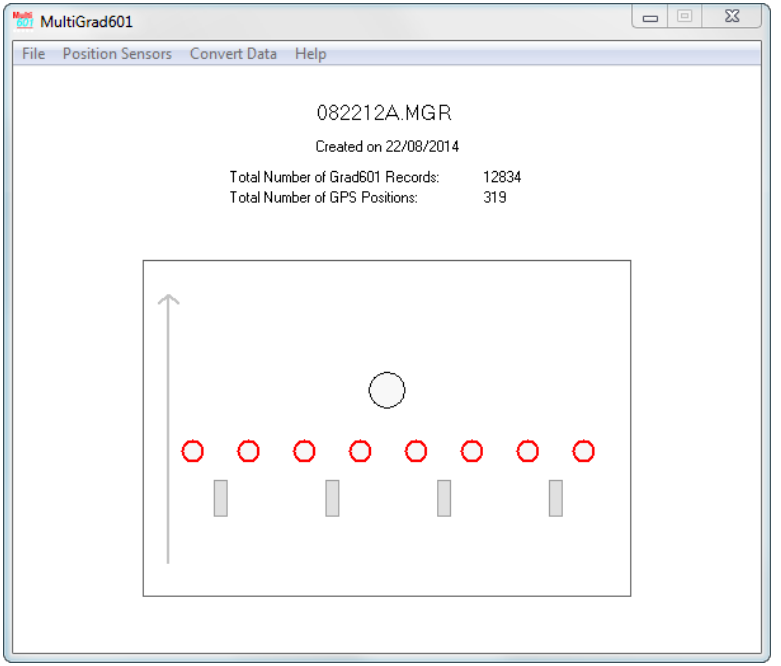


Figure 2.5: MultiGrad601 Main Screen after data file is loaded

When original data file is selected the name of the file and date of the creation is displayed at the top of the screen. In case when not original file was loaded then the current file name is displayed, followed by an original date of creation and original file name, for example: "Created on 06/03/2007 as 030610A.MGR", (see Figure 2.6).

At this point loaded data can be used for further data processing.

2.2 Save, Save As, Close

As it was mentioned data can be saved only if the data file was previously Saved As. This assures that the original data file will not be overwritten, i.e. with edited parameters. The File menu item **Save** is enabled only when other than original data file is loaded. The indication that file was previously Saved As is given at the top of the screen, under currently loaded file name label "Created on 22/08/2014 as 082212A.MGR" provides information that the original file name was 082212A.MGR (Figure 2.6). Otherwise this label would provide only date of the created file (see Figures 2.5 and 2.7).

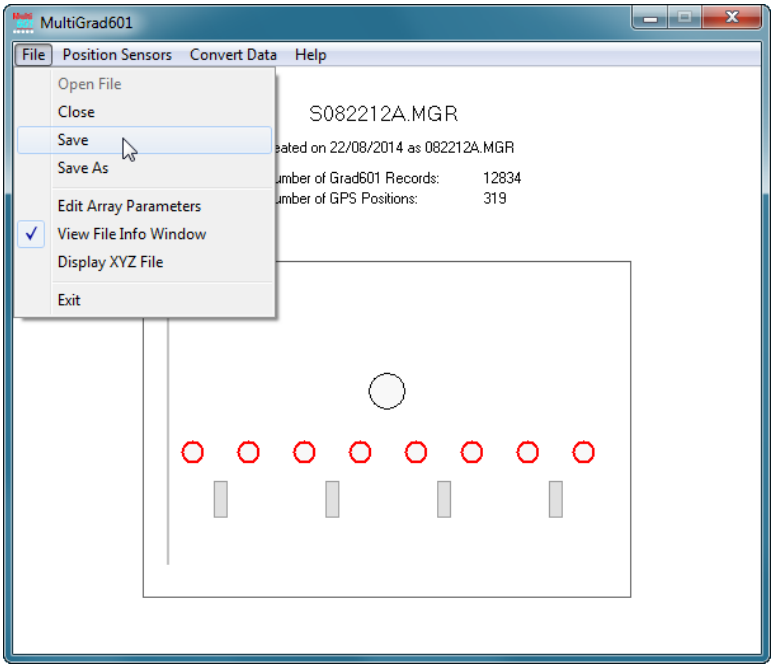


Figure 2.6: MultiGrad601 Main Screen with item Save enabled after not original file was loaded

The File menu item labeled **Save As** allows you to save any data set. Select **File|Save As** from the program main menu (see Figure 2.7). After the selected menu item is clicked, the Save As MLgrad601 Input File window will be displayed in the centre of the screen, Figure 2.8.

This option is useful when working with data files created in Windows 7/XP based computer. During data acquisition the Windows system creates files that are not organized according to time stamp sequence. When such file is loaded, first it is sorted by the program. The option Save As will save data in organized format, and therefore loading

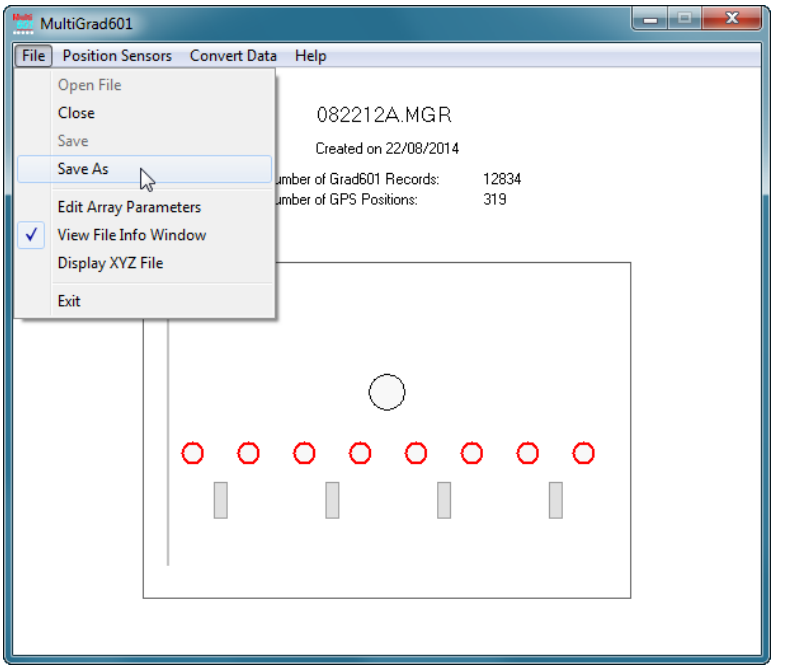


Figure 2.7: MultiGrad601 Screen with loaded original data file, disabled Save option, and selected Save As item

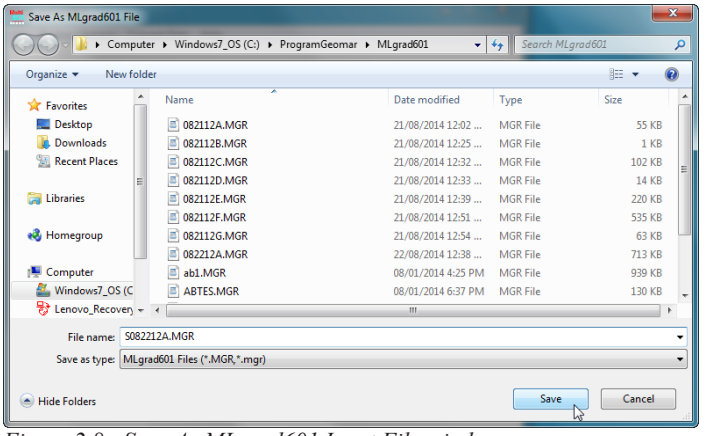


Figure 2.8: Save As MLgrad601 Input File window

previously saved file will be faster (since sorting is not necessary). The program recognizes sorted files automatically.

After the file is saved with Saved As option the Main Screen of MultiGrad601 will be updated, and file name will placed at the top of the screen and the item **Save** in the File menu will be enabled, Figure 2.9 (compare with Figure 2.7).

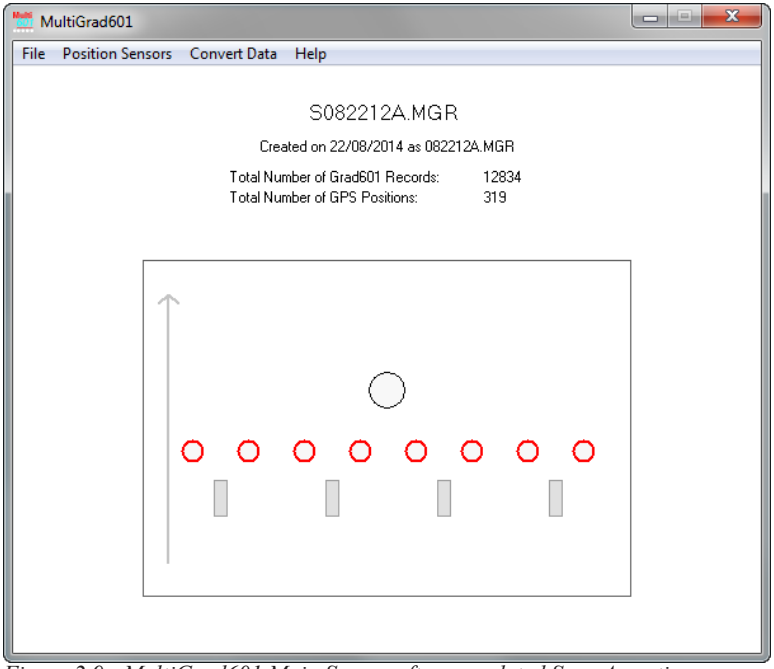


Figure 2.9: MultiGrad601 Main Screen after completed Save As option

Clicking on the **Close** item in File menu will remove data set from the program memory, the Main Screen will display splash graphic and the menu item Open File will be enabled. This action allows you to load another MLgrad601 data file.

2.3 Edit Array Parameters

Several parameters entered during the field work can be modified during data processing. Click on the **Edit Array Parameters** item in the File menu and the Edit Array Parameters window will appear (Figure 2.10). The Edit Array Parameters window is also available in Position Readings options.

The window displays parameters that the user can edit as well as other general information about loaded data set. Parameters that can be edited are divided in to two groups. The first group is located in a window frame labeled **Array Parameters** and contains: Array Geometry Units, Sensors Separations, GPS X and Y offsets. The second group labeled **Instrument Parameters** contains: Instrument Type, GPS Message, and Distance Units. If all parameters were correctly specified in the field then clicking on **OK** or **Cancel** button will accept these entries. In case some of the parameters require modification

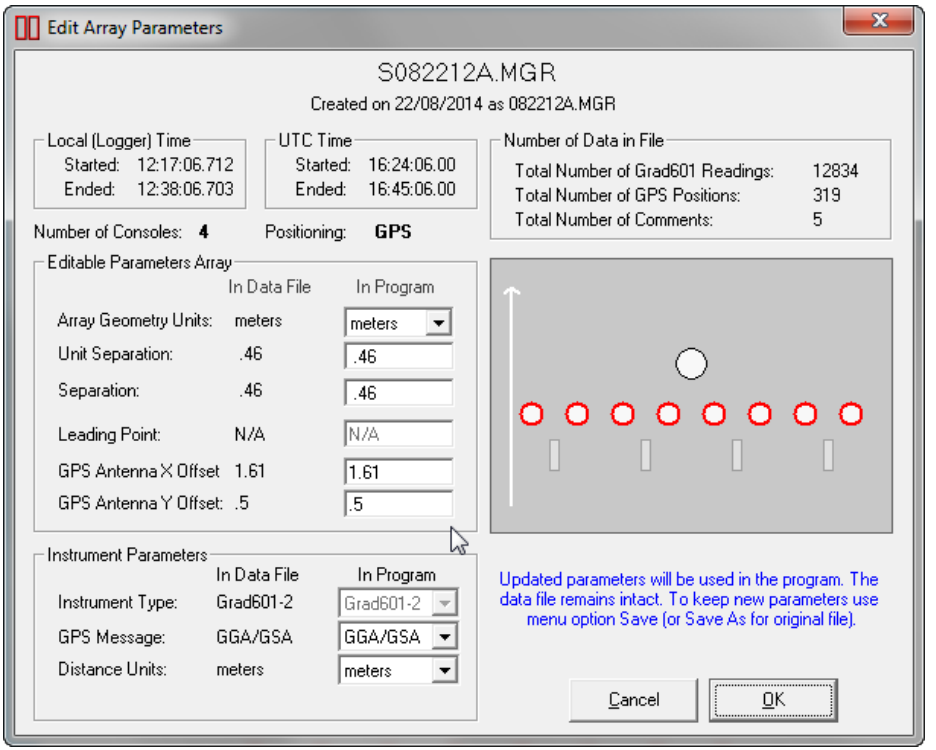


Figure 2.10: Edit Array Parameters window

they can be entered in appropriate text boxes located under label **In Program**, original parameters (as entered in the field) are displayed below label **In Data File**. Values for Sensors Separation and GPS X and Y Offsets must be entered in appropriate test edit boxes, while remaining parameters can be selected from combo list boxes.

A relatively large portion of the Edit Array Parameters window is occupied by the Preview window displaying current layout of the system geometry (Sensor Separation and GPS antenna offsets). This preview window is updated in real time reflecting any changes entered in the Array Parameter fields . Example of MLgrad601 File Info window with modified parameters for GPS antenna location is shown in Figure 2.11.

Clicking on the **OK** button will accept any changes, clicking on the **Cancel** button will cause the program to use initial parameters (state when window was displayed). After buttons **OK** or **Cancel** are clicked the Edit Array Parameter window will disappear.

Any updates in this window are valid only for duration of the program. The data file will remain the same unless it is **Saved** or **Saved As** in the File menu.

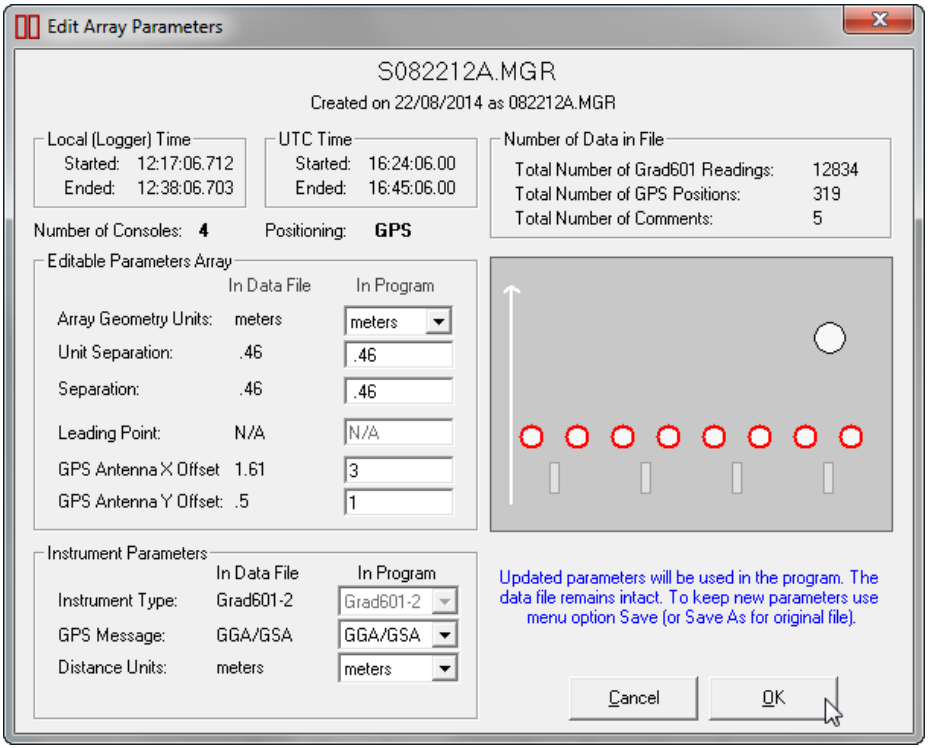


Figure 2.11: Modified parameters in Edit Parameters window

2.4 Display XYZ File

The Display XYZ File option allows you to display two dimensional layout of stations in a selected XYZ file. Select **File | Display XYZ File** from the main program menu, as shown in Figure 2.1. The Select XYZ to Open window will appear.

The window lists files with extension name XYZ. Select a file name and click the **Open** button. The Select XYZ to Open window will close, the file will be loaded and two dimensional image will be displayed (Figure 2.12).

The image displayed in the Plot XYZ window shows the spatial layout of stations to scale, based on the station coordinates as written in the selected XYZ file.

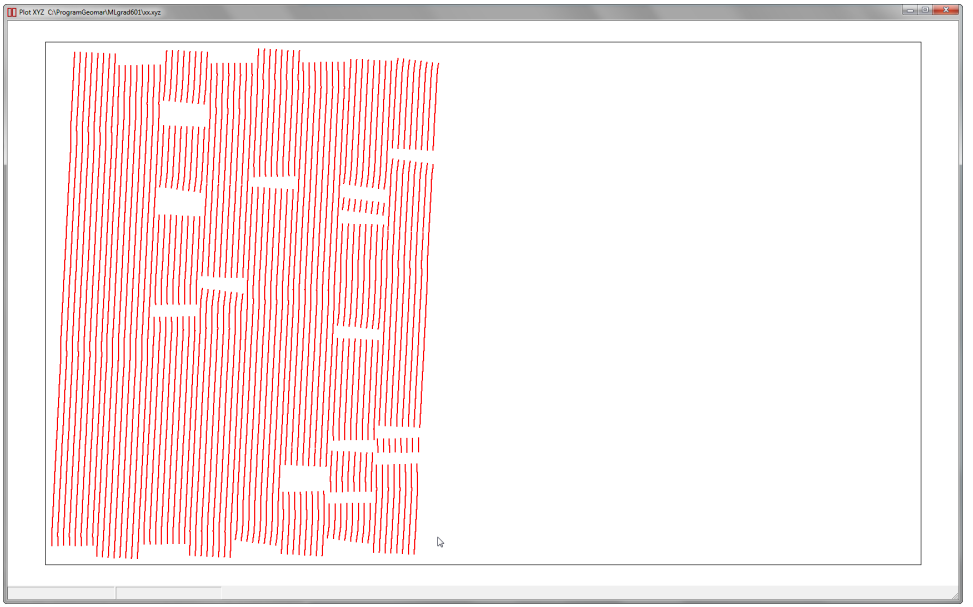


Figure 2.12: Two dimensional layout of stations in XYZ File

Position Readings 3

Positioning of the Grad601 sensors in the array is the main function of the MultiGrad601. Location of each gradiometer probe is calculated based on the recorded GPS position, instant heading of the system, and the system geometry which is described by the location of GPS antenna and separation between sensors.

Description of functions involved in positioning sensors is preceded by a short description of the array geometry. For more detailed description of Grad601 sensors setup and survey procedure see Chapter 6 of MLgrad601 manual.

3.1 The MLgrad601 Array Geometry

The instrument array consists of two sensors. The reference point 0, 0 of the array is located at the center of the left edge of the left sensor (Figure 3.1). Sensors are numbered from the left while facing the direction of the array movement, or they can be named as Left (Sensor #1) and Right (Sensor #2) for each console. This procedure of naming (numbering) is very important since positioning of sensors calculated from one GPS antenna bases on this assumption. For surveys carried out along grid (without GPS receiver) this method of numbering particular Grad601 sensors will be used in specifying the position of the survey line for each sensor.

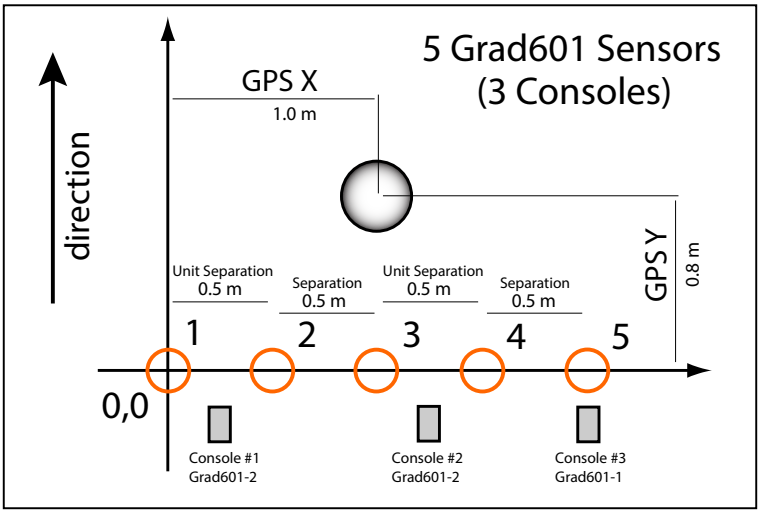


Figure 3.1: The Grad601 Sensors and GPS antenna geometry

The main result of the described method of numbering Grad601 sensors in the array is that the system can not change its orientation. The left sensor (Sensor #1) must remain in this position (related to direction of moving) during collection of data to one data file. This means that the Grad601 array can not be pushed toward the fence or building, and then towed away from an obstruction. If the survey is conducted along a grid, without GPS positioning, the above method can be omitted, however the operator has to keep track of sensor locations for each survey line.

GPS antenna can be placed anywhere, however to achieve higher accuracy for the calculated positions of each coil the GPS antenna must be placed as close to the center of the system as possible (Figure 3.2). Location of GPS antenna is described by two parameters, offsets in X and Y directions (while facing direction of the movement) from the reference point 0,0 (see Figure 3.1).

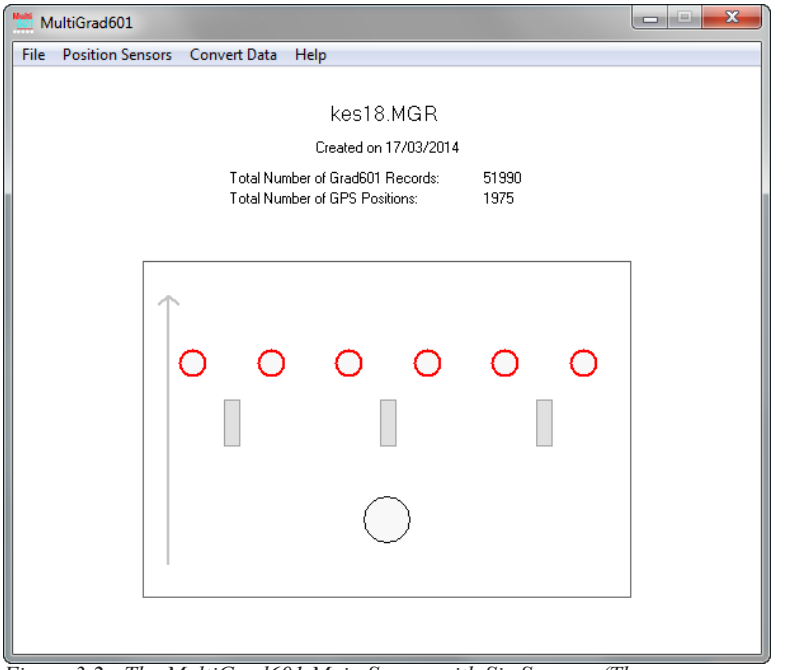


Figure 3.2: The MultiGrad601 Main Screen with Six Sensors (Three Consoles) and GPS Antenna Located in the Center, behind the System (Negative GPS Y offset)

In summary, geometry of the Grad601 system is described by location of GPS antenna (offsets X and Y), separation between unit sensors and separation between units belonging to neighbouring consoles (in most cases both types of separation are equal), and array units (selected in the data acquisition program).

3.2 Positioning Readings Using MLgrad601 Data File

After a data file is loaded the MultiGrad601 main window displays the current file name, date of file creation and optionally original file name (as entered in the field), number of instrument readings and GPS positions, and layout of the system (Figure 3.2).

The Position Readings Using MLgrad601 Data option allows you to position Grad601 stations based on Real Time GPS data which were recorded in MLgrad601 data file during the survey. Select **Position Sensors|Position Readings Using MLgrad601 Data Files** from the main program menu, as shown in Figure 3.3.

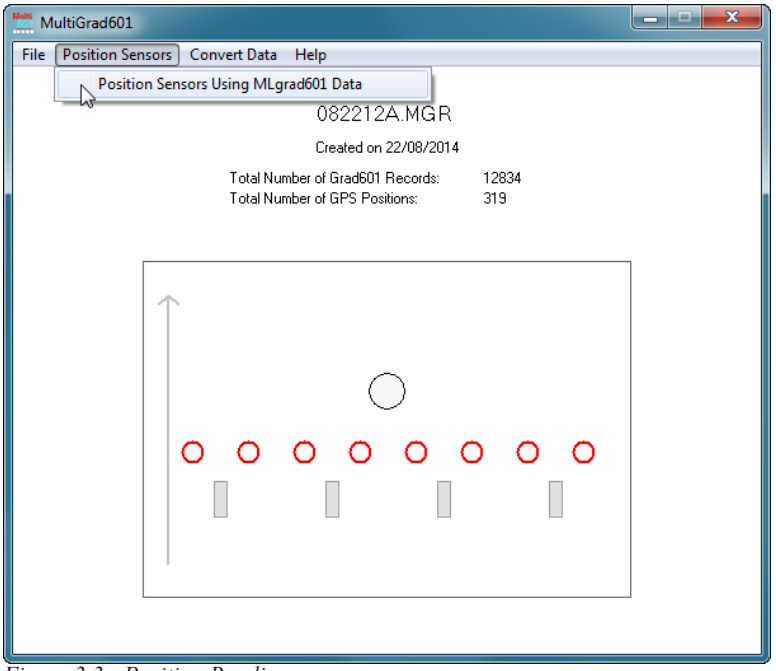


Figure 3.3: Position Readings menu

After the selected menu item is clicked the Position Grad601 Readings Using MLgrad601 Data File window will be displayed in the centre of the screen, Figure 3.4.

Parameters in Positioning Readings Using MLgrad601 Data File Dialog

Several parameters which affect the contents and format of the created output (XYZ) file must be specified. These are the XYZ output file name, parameters describing contents and format of the created file and parameters related to electromagnetic as well as to GPS data.

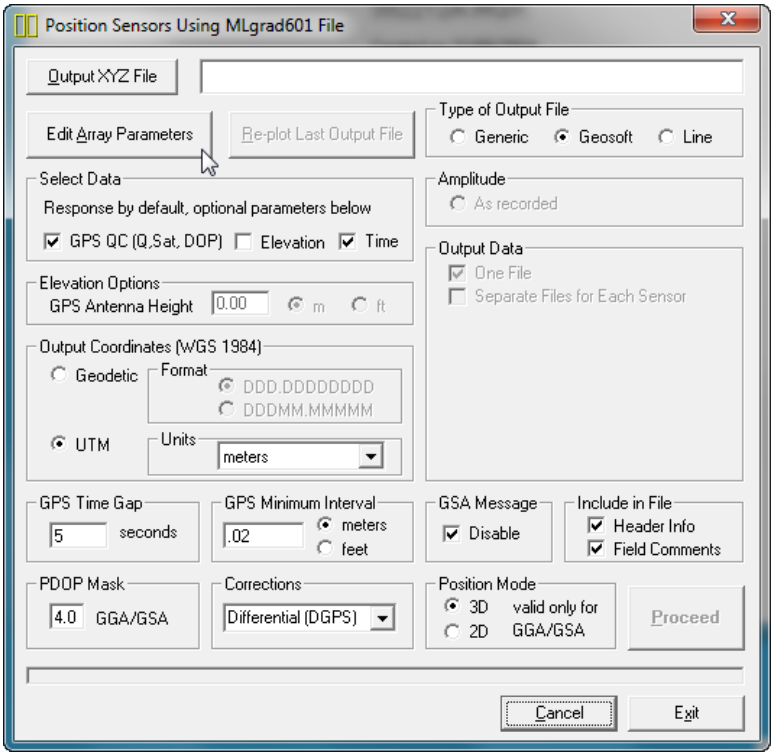


Figure 3.4: Position Sensors Using MLgrad601 File window

Edit Array Parameters

The MultiGrad601 uses settings and parameters as encoded in the data file. In case some parameters were wrongly entered in the field it is possible to change them using Edit Array Parameters option (the same option is available in the File menu of the MultiGrad601 main screen). Click on the **Edit Array Parameters** button and the Edit Array Parameters window will appear (Figure 3.5).

The window displays parameters that the user can edit as well as other general information about loaded data set. Parameters that can be edited are divided in to two groups. The first group is located in a window frame labeled **Array Parameters** and contains: Array Geometry Units, Unit Separation and Separation, GPS X and Y offsets. The second group labeled **Instrument Parameters** contains: Instrument Type, GPS Message, and Distance Units. In case some of the parameters require modification they can be entered in appropriate text boxes located under label **In Program**, original parameters (as entered in the field) are displayed below label **In Data File**. Values for Sensors Separation and GPS

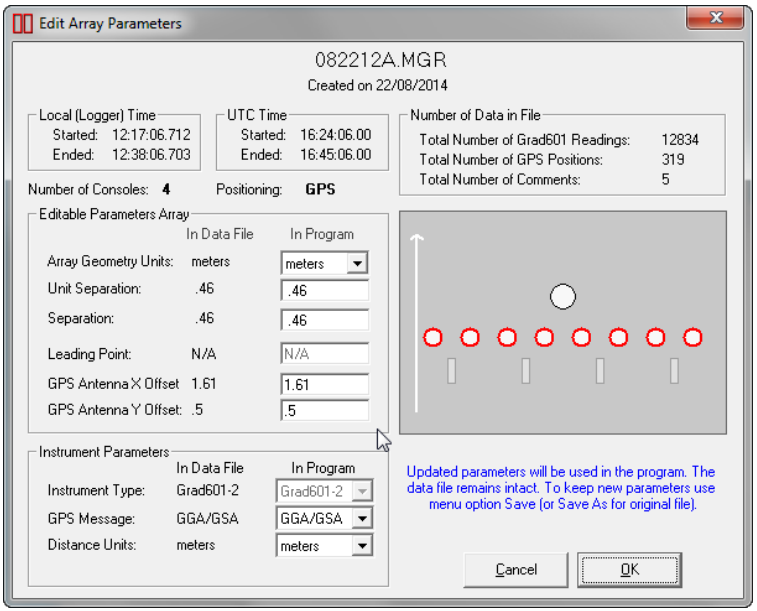


Figure 3.5: Edit Array Parameters window

X and Y Offsets must be entered in appropriate test edit boxes, while remaining parameters can be selected from combo list boxes.

A relatively large portion of the Edit Array Parameters window is occupied by the Preview window displaying current layout of the system geometry (Sensor Separation and GPS antenna offsets). This preview window is updated in real time reflecting any changes entered in the Array Parameter fields . Example of MLgrad601 File Info window with modified parameters for GPS antenna location is shown in Figure 3.6 (compare with Figure 3.5).

Clicking on the **OK** button will accept any changes, clicking on the **Cancel** button will cause the program to use initial parameters (state when window was displayed). After buttons **OK** or **Cancel** are clicked the Edit Array Parameters window will disappear.

Any updates in this window are valid only for duration of the program. The data file will remain the same unless it is **Saved** or **Saved As** in the File menu.

Please note that parameter Instrument Type can be changed only if wrong setting was selected during the field work for employed console (Early or Late). Each type of console is physically different and this entry cannot change readings from one type to another, it can only be used to specify correct type connected to the field computer.

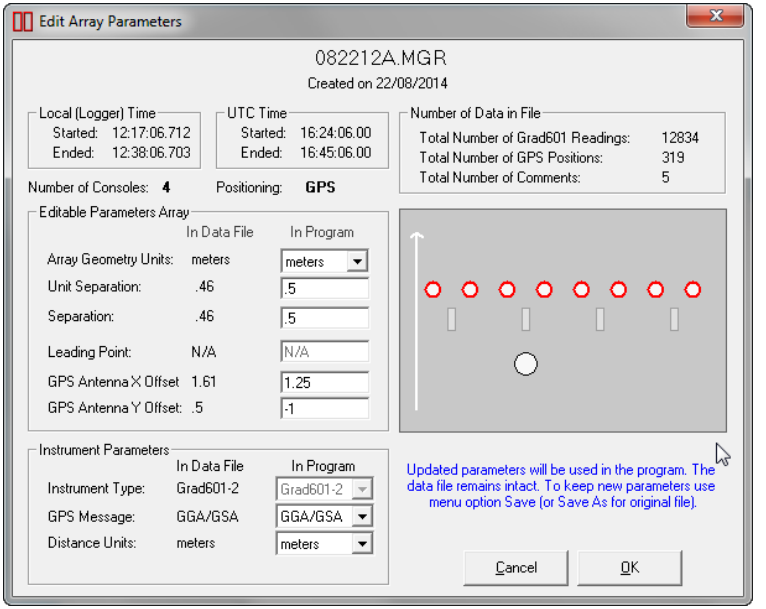


Figure 3.6: Modified parameters in Edit Array Parameters window

Output File

Click on the **Output XYZ File** button. The Select Output File window is displayed (Figure 3.7).

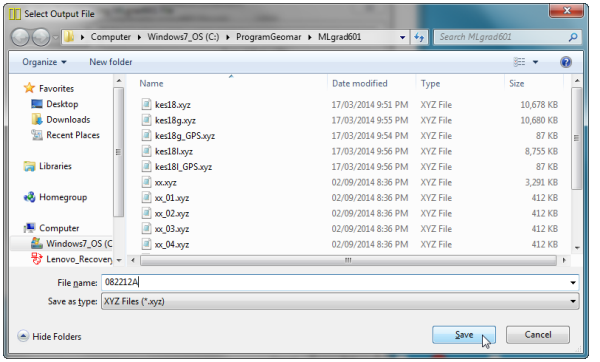


Figure 3.7: Select Output File window

Select a file name and click the **Save** button. The Select XYZ File window will close and the selected file name will be displayed beside the **Output XYZ File** button in the Position Grad601 Readings Using MLgrad601 File window.

When Output file is specified the **Proceed** button in the Position Sensors Using MLgrad601 File becomes active (Figure 3.8).

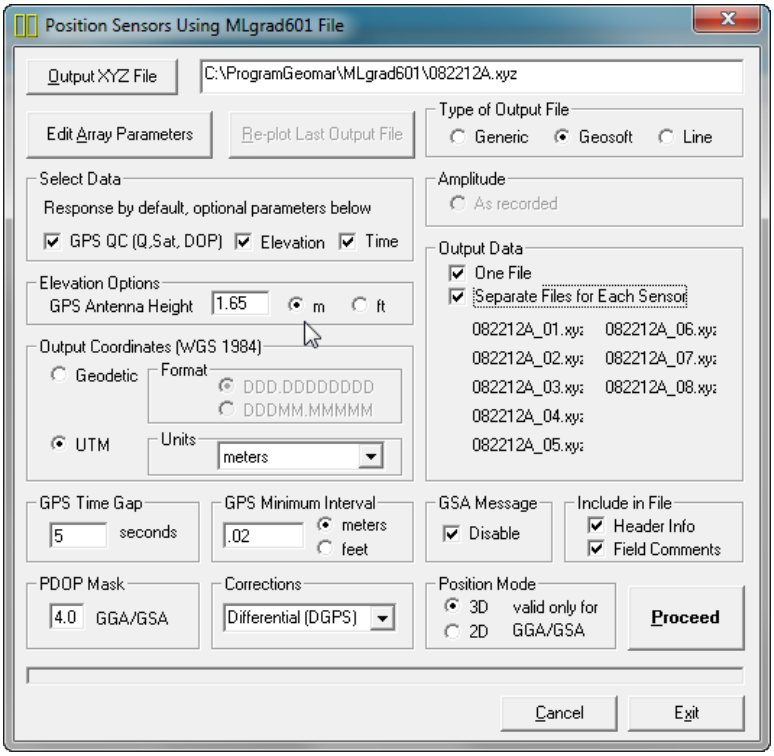


Figure 3.8: Position Sensors Using MLgrad601 File window

Select Data

The MLgrad601 response for given sensor is always placed in XYZ file. Three optional data can be written in the output file. These are GPS QC parameters (Quality Indicator, PDOP or equivalent, number of satellites), Elevation, and Time Stamp for each reading. To select optional parameters in XYZ file click on desired check buttons labeled **GPS QC**, **Elevation**, and **Time**.
Data is always placed in the created XYZ file in the following order: X coordinate (Easting or Longitude), Y coordinate (Northing or Latitude), Grad601 response, three GPS QC parameters (Quality Indicator, PDOP or equivalent, Number of Satellites), Elevation, and Time Stamp.
If parameter Header Info in Include in File section is checked a line listing all parameters in the file will be placed as a header for each created XYZ file.

If the check box labeled **Elevation** is clicked (checked) then a text box labeled **Antenna Height** and two radio buttons labeled **m** and **ft** become active in the section labeled **Elevation Options**. The text box labeled Antenna Height allows

you to enter correction for Elevation data. The Antenna Height corresponds to the distance between ground surface and GPS antenna. If Antenna Height is set to zero then elevations for the GPS antenna (not the ground surface) are written to the output file. Two radio buttons labeled **m** (meters) and **ft** (feet) allows you to specify units for elevation data placed in the output file. It is assumed that Antenna Height parameter is entered in units specified by these radio buttons.
Elevation values base on the recorded GPS data. Therefore Elevations will not be written to the file if the NMEA message GLL was used during the survey. Message GLL does not contain elevation data.

Type of Output File

Check the option appropriate for the contouring software used. The Generic option will create a four or more column file without any text strings. This file can be used as an input file for many contouring packages (including Surfer). Geosoft format will cause the program to write Line # at the beginning of each survey line.

Include in File

This section contains two check boxes labeled **Header Info** and **Field Comments**. When Header Info box is checked the file will contain a header listing type of coordinates and names of data contained in each column of created XYZ file. Checking box labeled Field Comments will cause the program to write text of all field comment (entered by the operator during the survey) in to the created file.

Output Coordinates

Positions can be written in the output file as geodetic (geographical) coordinates (Latitude/Longitude) or they can be converted to UTM coordinates. The program uses the WGS1984 datum. To select coordinates click **Geodetic** or **UTM** radio buttons (Figure 3.9).

Geodetic coordinates, Latitude and Longitude are given in degrees. They can be written in two formats DD.DDDDDDDD or DDMM.MMMMM (native format found in NMEA GPS messages). To select which format click the appropriate radio button in Format section located at the radio button labeled Geodetic. This section is active only when radio button Geodetic is selected (Figure 3.9).

UTM coordinates can be generated in meters, feet, or US Survey feet. To select units for UTM coordinates select proper parameter from the combo box located in the Units section located at the UTM radio button (Figure 3.9). This combo box is active only when radio button labeled UTM is selected.

GPS Time Gap

Differentially corrected GPS data often has gaps, due to differences in the constellation of satellites visible to two (fixed and moving receivers), lack of beacon signal, surveying near trees, buildings, and other elevated obstructions. These gaps are filled by MultiGrad601 with the assumption that the GPS receiver speed is essentially constant and that it moves along a straight line during the gaps.

The **GPS Time Gap** parameter specifies the maximum time during which the Grad601 data will be linearly interpolated between two GPS positions. Enter this parameter (in seconds) in the edit box labeled **seconds** in the GPS Time Gap section (Figure 3.9). In most cases a value 2 to 3 times larger than the GPS data acquisition frequency is adequate, however the user has to determine this value based on the survey specific conditions and requirements. To ignore effect of this parameter enter a large number of seconds (i.e. 300 or more) as GPS Time Gap parameter.

GPS Minimum Interval

The **GPS Minimum Interval** parameter specifies the minimal distance between two GPS stations that will be used in interpolation. If this distance is smaller than the specified GPS Minimum Interval, then all Grad601 readings located between these two stations will be ignored. This parameter is useful in cases when the operator stops for a moment and data are collected in one point. Limited accuracy of GPS positioning will create randomly distributed positions in area adjacent to the stationary location of the system. If MultiGrad601 will calculate positions of sensor in case offset values (GPS X and/or GPS Y Offsets) are different than zero, positions of the Grad601 will have quite large variations associated with apparent change of direction of the survey line caused by randomly close spaced GPS positions. In most cases a value 2 or 3 times smaller than average distance between two GPS stations is adequate, however the user has to determine right value for this parameter which will depend on survey conditions and first of all accuracy of the employed GPS receiver. To ignore the effect of this parameter and to use all stations during creating XYZ file (i.e. during testing when GPS antenna is stationary) set this parameter to zero.

Enter the GPS Minimum Interval in the edit box and check one of the two radio buttons labeled **meters** and **feet** (indicating distance unit) in the GPS Minimum Interval section (Figure 3.9).

GSA Message

This parameter is used to disable GSA message. This is to be used only if the operator has specified in the data acquisition program (MLgrad601) that the

GPS Message will be pair GGA/GSA and for any reason message GSA was not recorded. In such case the MultiGrad601 will search for GPS quality information contained in not recorded GSA statement and it would conclude that GPS readings are invalid. Disabling GSA message in this situation causes that the program will use only information available from GGA message.

PDOP Mask

The PDOP Mask is used to filter quality of GPS positions. The index called PDOP (Position Dilution of Precision) measures the strength of satellite coverage for a given area. PDOP is affected by the number of satellites visible and their relative positions in the sky. The smaller the number of PDOP the stronger the satellite coverage is. When there are more than 5 satellites widely spaced visible, the PDOP is 4 or less. However, when there are less satellites visible, or they are unevenly spaced in the sky, PDOP values can be 6 or higher. In most cases, the PDOP in open sky is less than 3, and most accuracies given for many GPS systems are given for this norm. The index called GDOP covers time accuracy in addition, while the index HDOP is related only to horizontal position fix (it is used when message GGA was selected). Refer to GPS documentation and literature for more information related to error sources of GPS positioning.
The section PDOP Mask may differ depending on GPS NMEA message used. It is related to PDOP parameter if GGA/GSA, POS, or GGK was employed during the survey, to HDOP if GGA was used, to GDOP if LLK was used during the survey, and it is invalid if GLL or LLQ message was used.
Enter the PDOP (HDOP or GDOP) value in the edit box in the PDOP Mask section, Figure 3.9. All positions (as well as Grad601 readings) associated with GPS data of higher than specified value of this index will be ignored.

Corrections

Select type of differentially corrected position data to be used during the creation of XYZ file in the combo list box labeled Corrections. Five types of GPS corrections are given: **Raw (GPS)**, **Differential (DGPS)**, **Differential (RTK 3)**, **Differential (RTK 4)**, and **Differential (RTK 5)**. Last three types of RTK (real time kinematic) corrections are available only in high end of GPS receivers and differently named depending on manufacturer, however in NMEA specifications they indicate Quality Parameter 3, 4, and 5. When **Raw** is selected, both differentially corrected and raw GPS data are used to calculate positions of Grad601 stations.

Position Mode

This option is valid only if the pair GGA/GSA messages were used during data collection. If radio button labeled 3D is checked then GPS data in mode 3D are

used, while when radio button 2D is checked then program uses 2D as well as 3D mode of GPS data.

It should be noted that if any NMEA message indicates that GPS position (fix) is invalid this data is ignored by the MultiGrad601.

Creating XYZ Files With Positioned Readings

When all parameter are set and output file name is specified, the **Proceed** button is activated in the Position Sensors Using MLgrad601 File window. After you click the **Proceed** button, the program begins to filter loaded data, calculates Grad601 stations positions based on the recorded GPS readings, instant heading, and other specified parameters, and writes results to the XYZ output file. A progress bar at the bottom of the screen shows the percentage of the file processed (Figure 3.9).

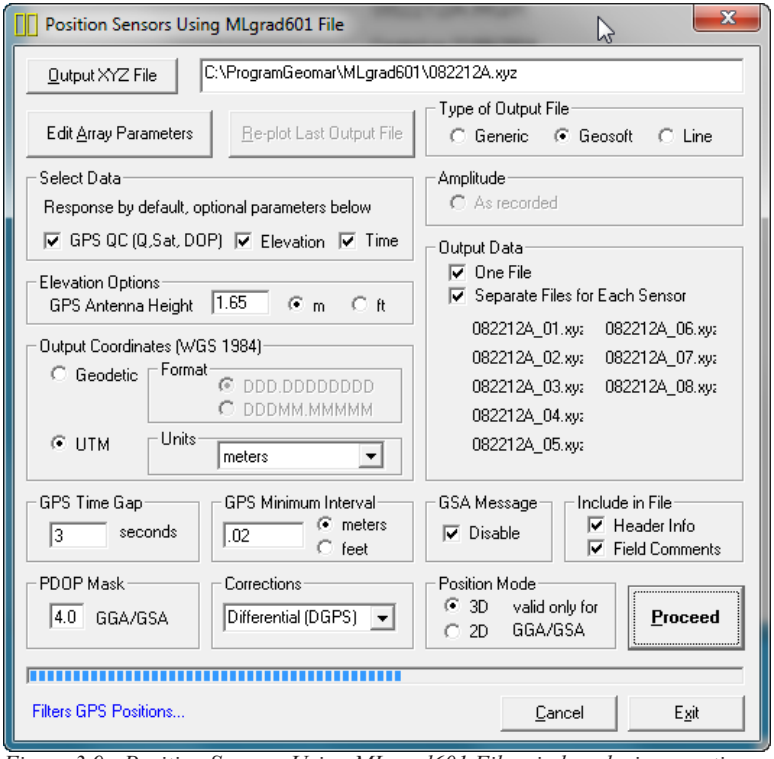


Figure 3.9: Position Sensors Using MLgrad601 File window during creating XYZ file

The speed of this operation depends on the size of the input file. After the output XYZ file is created a two dimensional layout of the survey is displayed (Figure 3.10).

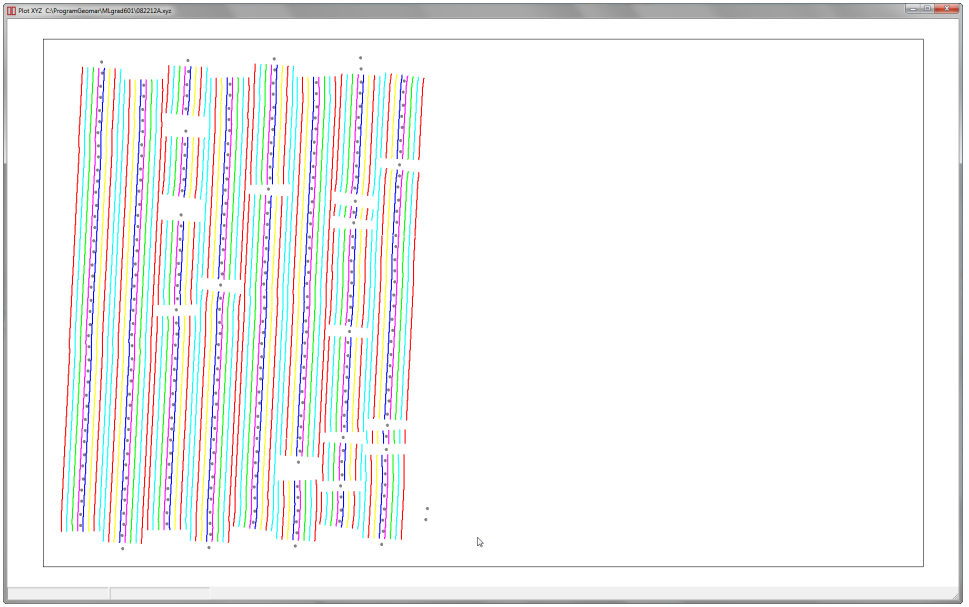


Figure 3.10: Two dimensional layout of stations taken with eight Bartington Grad601 sensors array. The GPS X = 1.75 m (center along X) and Y offset = 0.5 m (GPS antenna was located 0.5 m in front of the center of the array of sensors while facing direction of the array movement).

The image displayed in the Plot XYZ window shows the spatial layout of stations to scale, based on the station coordinates as written to the created file. The display has fixed colours. GPS positions are marked by larger grey dots while the Grad601 stations are plotted by smaller red dots. This plot window can be closed by clicking on **Close** button (located in the top right corner of the window).

After the Plot XYZ window is closed a button **Replot Last Output File** becomes active and the layout of data can be examined again. However, at this time original GPS positions will not be displayed and only instrument positions will be represented by red dots on the screen. Files created by this portion of the program can be also viewed at any time using the **File|View XYZ File** menu.

After the file is created and its layout is examined it is possible (if required) to recreate XYZ file with changed system geometry parameters. To do this, click **Edit Array Parameters** button, the Edit MLgrad601 File Parameters window will appear again. After changes are done, click the **Proceed** button to repeat procedure of creating XYZ file. See example in Figure 3.11 where GPS antenna location was changed as compared to case shown in Figure 3.10.

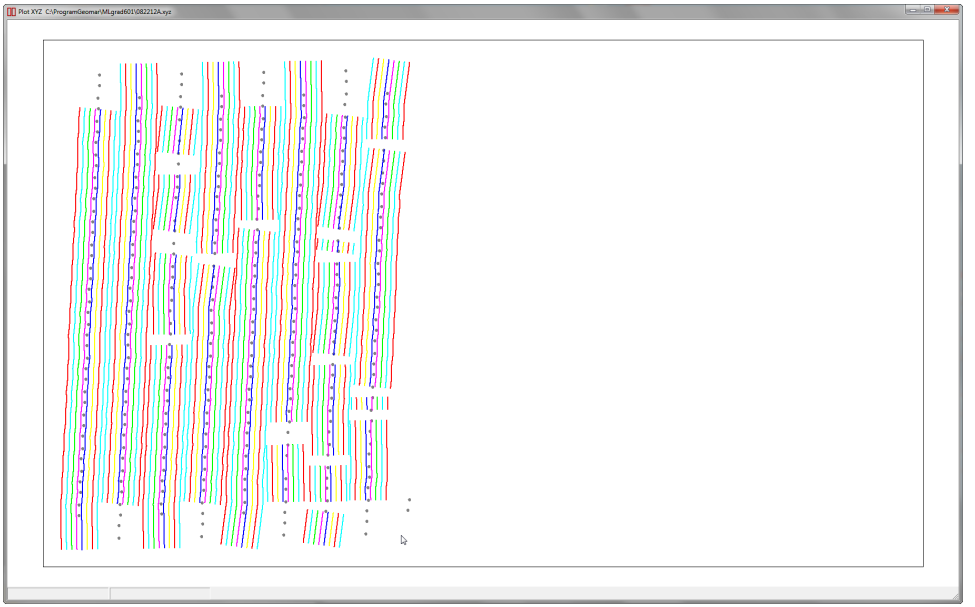


Figure 3.11: Two dimensional layout of stations taken with eight Bartington Grad601 sensors array. The GPS X = 1.75 m (center along X) and Y offset = 2.0 m (GPS antenna was located 2.0 m in front of the center of the array of sensors while facing direction of the array movement).

If the input file does not contain sufficient GPS information, or parameters are not correctly selected, the program will display a warning message (or window containing two dimensional layout will be blank), and the program will pause operation till the **OK** button is clicked in the warning window (or Cancel X button on the window).

This message may indicate lack of GPS data in the file, however in most cases it reflects lack of GSA messages when GGA/GSA was selected in the data acquisition program (check Disable GSA Message), raw positions only when Differential button is checked, too small value specified in GPS Time Gap section, etc..

Convert Data Files

4

Convert menu of MultiGrad601 program allows you to convert the MLgrad601 binary file to other formats. There are three items associated with the Convert menu (Figure 4.1):

- convert MLgrad601 file to general format ASCII file,
- retrieve and position field comments from MLgrad601,
- correct system time constant delay in XYZ files.

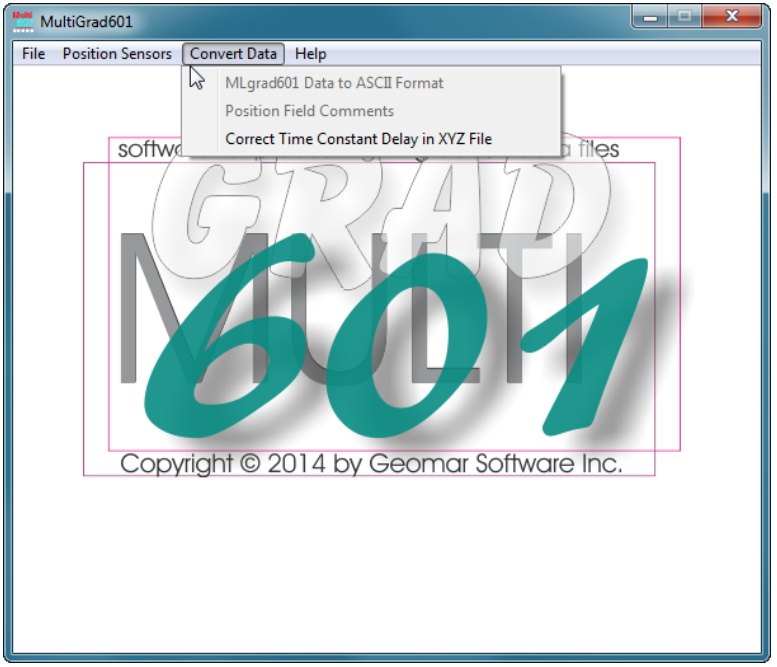


Figure 4.1: Convert Data Files menu

Files converted to general ASCII format can be easily reformatted and used by other software. While retrieving comments from MLgrad601 file, the program retrieves text of the comment and their position based on neighbouring GPS records. Correct Time Constant Delay item provides correction for specified time constant delay of the system (instrument specific time constant combined with GPS latency). Any XYZ file containing sequential time stamp column can be corrected while using this option.

It should be noted that two first items of Convert Files menu are disabled. They are enabled automatically after the MLgrad601 data file is loaded in File menu (Figure 4.2).

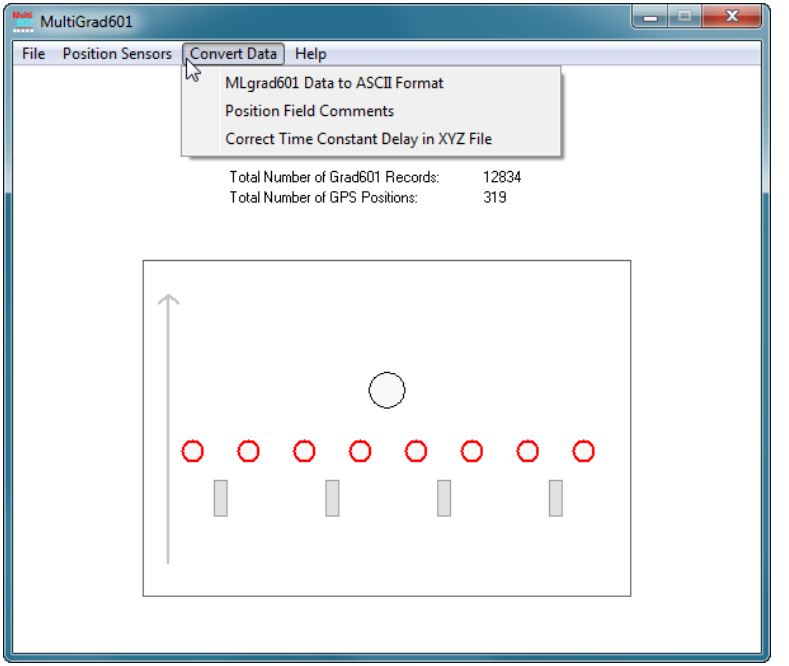


Figure 4.2: Convert Data Files menu after MLgrad601 file is loaded to the program

Selected examples of file formats created by MultiGrad601 are given in Appendix B of this manual.

4.1 Convert MLgrad601 Data to ASCII Format

The Convert MLgrad601 Data to ASCII Format option allows you to convert MLgrad601 binary files to ASCII format, which can be viewed with any text editor and then easily converted to the other format. Select **Convert|MLgrad601 to ASCII Format** from the main program menu, as shown in Figure 4.2.

After the selected menu item is clicked the Convert MLgrad601 Files to ASCII Format window will be displayed in the centre of the screen, Figure 4.3.

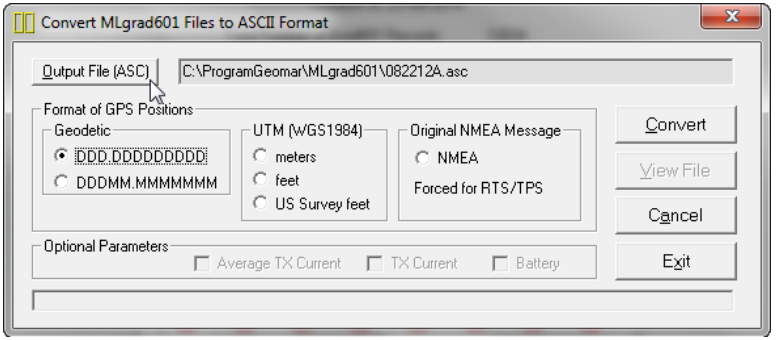


Figure 4.3: Convert MLgrad601 Files to ASCII Format dialog

Parameters in Convert MLgrad601 Data to ASCII Format Dialog

Several parameters which affect the contents and format of the created output (ASC) file must be specified. These are the ASCII file name, and Format of GPS Positions (coordinates format or original NMEA statement). The External Sensor option is not used in this version of the program.

Output File

Click on the **Output File** button. The Select Output File window is displayed (Figure 4.4).

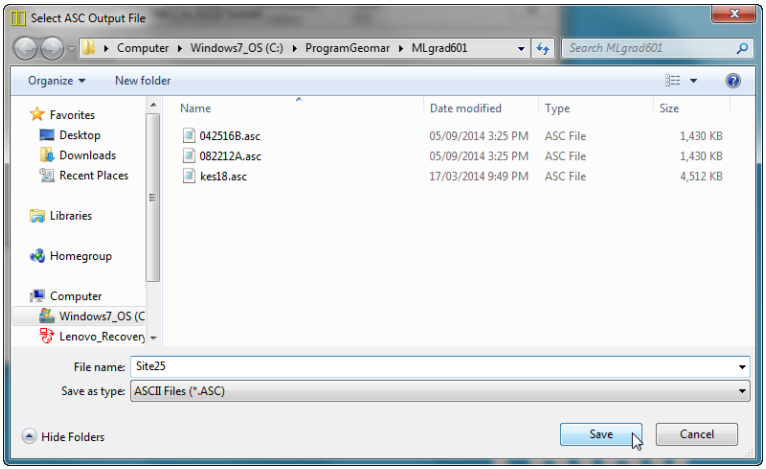


Figure 4.4: Select ASC Output File window

Select a file name and click the **Save** button. The Select ASC Output File window will close and the selected file name will be displayed beside the **Output File (ASC)** button in the Convert MLgrad601 Files to ASCII Format window.

When Output file is specified the **Convert** button in the Convert MLgrad601 Data to ASCII Format window becomes active.

Format of GPS Positions

Positions can be written in the output file as geodetic (geographical) coordinates (Latitude/Longitude), they can be converted to UTM coordinates, or written to file as original NMEA messages (exactly as streamed by a GPS receiver). The program uses the WGS1984 datum. To select coordinates click the appropriate radio buttons in the sections labeled **Geodetic** or **UTM** (Figure 4.3).

Geodetic coordinates, Latitude and Longitude are given in degrees. They can be written in two formats DD.DDDDDDDD or DDMM.MMMMM (native format found in NMEA GPS messages). To select which format click the appropriate radio button in the section labeled **Geodetic** (Figure 4.3).

UTM coordinates can be generated in meters, feet or US Survey feet. To select units for UTM coordinates click one of the radio buttons located in the Units section located at the UTM radio button (Figure 4.3).

Converting MLgrad601 Data to ASCII Format

When all parameter are set and output file name is specified, the **Convert** button is activated in the Convert MLgrad601 Data to ASCII Format window. After you click the **Convert** button, the program begins to read the data, converts data to ASCII format and writes results to the output file. A progress bar at the bottom of the screen shows the percentage read (Figure 4.5).

The speed of this operation depends on the size of the input file. After the output file is created the **View Converted File** button becomes active. Clicking on this button will display first 63 Kilobytes of the created file.

The created file contains Grad-601 readings, GPS positions, and entire information related to the instrument and survey settings. Readings are written in the ASCII file in the following order: Grad-601 console number, Station number, Sensor #1 (Left) data, Sensor #2 (Right) data, and time stamp. Example of the output file in ASCII format is given in Appendix B.

Clicking **Cancel** button will clear text box at **Output File** button. Click on **Exit** button to close the Convert MLgrad601 Data to ASCII Format window.

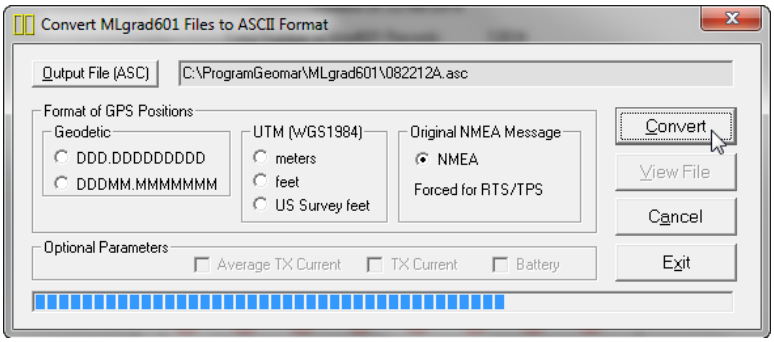


Figure 4.5: Convert MLgrad601 Files to ASCII Format dialog during data processing

4.2 Retrieve and Position Field Comments

The Retrieve and Position Field Comments option allows you to convert retrieve field comments from MLgrad601 binary files. At the same time the program assigns GPS positions to indicate where these comments were entered by the operator. The position can be assigned either as a GPS position preceding or position following the comment entry. The resulting output file consists of coordinates and corresponding text of the comment. Select **Convert|Retrieve and Position Field Comments** from the main program menu, as shown in Figure 4.2.

After the selected menu item is clicked the Position Comments Recorded in MLgrad601 File window will be displayed in the centre of the screen, Figure 4.6.

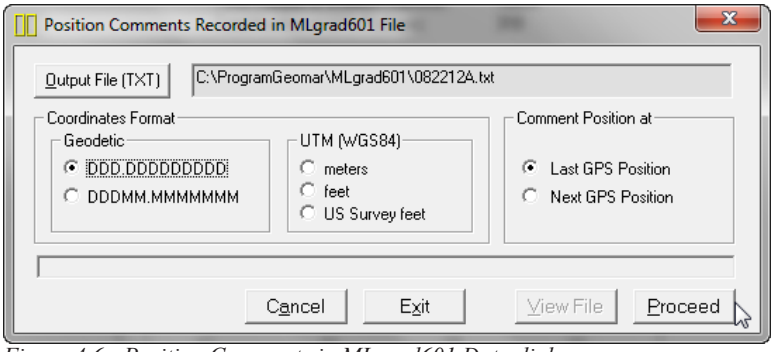


Figure 4.6: Position Comments in MLgrad601 Data dialog

Several parameters which affect the contents and format of the created output (TXT) file must be specified. These are the output file names, coordinates format, and indicating type of position of the comment - using a preceding or following GPS reading.

Output File (TXT)

Click on the **Output File (TXT)** button. The Select Output File window is displayed (Figure 4.7).

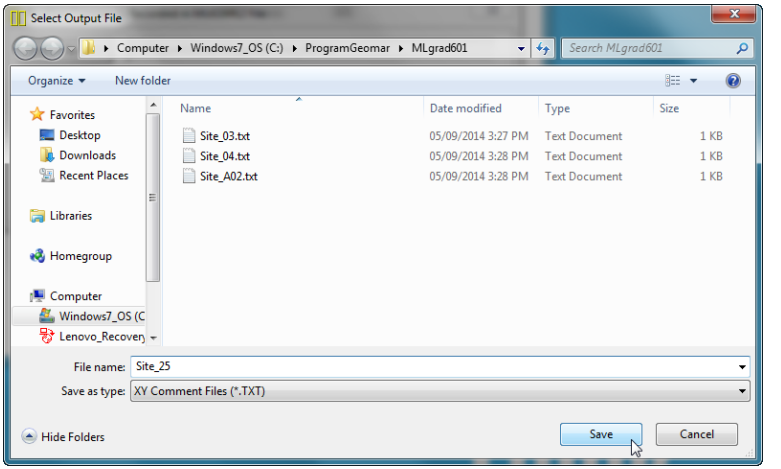


Figure 4.7: Select Output File window

Select a file name and click the **Save** button. The Select Output File window will close and the selected file name will be displayed beside the **Output File (TXT)** button in the Position Comments Recorded in MLgrad601 File window.

When both, Input and Output files are specified the **Proceed** button in the Position Comments Recorded in MLgrad601 File window becomes active.

Coordinates Format

Positions can be written in the output file as geodetic (geographical) coordinates (Latitude/Longitude) or they can be converted to UTM coordinates. The program uses the WGS1984 datum. To select coordinates click the appropriate radio buttons in sections labeled **Geodetic** or **UTM** (Figure 4.6).

Geodetic coordinates, Latitude and Longitude are given in degrees. They can be written in two formats DD.DDDDDDDD or DDMM.MMMMM (native

format found in NMEA GPS messages). To select which format click the appropriate radio button in section labeled **Geodetic** (Figure 4.6).

UTM coordinates can be generated in meters, feet or US Survey feet. To select units for UTM coordinates click one of the radio buttons located in the Units section located at the **UTM** radio button (Figure 4.6).

Comment Position at

This section specifies how GPS positions are assigned to the comment. There are two choices: Comment can be assigned to the last position that was recorded by the MLgrad601 program, or to the position that follows comment entry. In most cases any choice is right since comments are usually taken while collecting data (including GPS positions) and during comment entry operator stops recording for a moment. However the option **Last GPS Position** appears to be more natural since after the comment entry the operator may stop taking readings and later continue survey from other location.

To select comment position option click one of the radio buttons labeled **Last GPS Position** and **Next GPS Position** located in the Comment Position at section of the window (Figure 4.6).

Positioning Comments Recorded in MLgrad601 File

When all parameter are set and input and output file names are specified, the **Proceed** button is activated in the Position Comments Recorded in MLgrad601 File window. After you click the **Proceed** button, the program begins to read the input file, converts data to ASCII format and writes results to the output file. A progress bar at the bottom of the screen shows the percentage read (Figure 4.8).

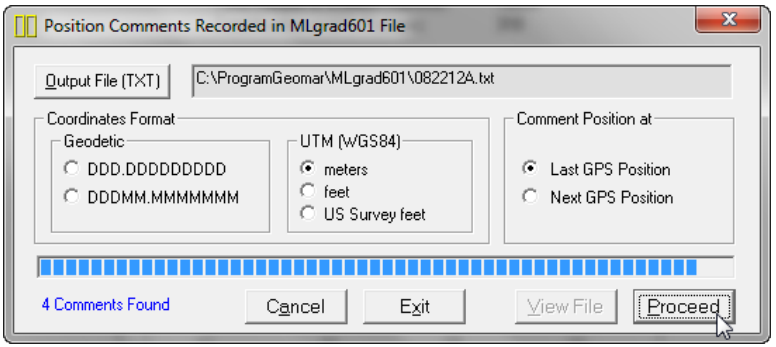


Figure 4.8: Position Comments Recorded in MLgrad601 File dialog during data processing

The speed of the operation depends on the size of the input file. After the output file is created the **View File** button becomes active. Clicking on this button will display first 63 Kilobytes of the created file.

The created file contains GPS positions in the first two columns followed by the text of comment as recorded in the field. Example of the output file containing comments is given in Appendix B.

Clicking **Cancel** button will clear text boxes at the **Output File (TXT)** button. Click on **Exit** button to close the Position Comments Recorded in MLgrad601 File window.

4.3 Correct Time Constant Delay in XYZ File

This option allows for the system time constant delay correction. The procedure acts on two dimensional, GPS positioned data.

While the Grad-601 time constant can be given by manufacturer the time constant of the combined Grad-601 and GPS receiver system is a function of these two devices. The easiest method to determine the time constant of the system is to survey a known buried pipe. After the proper time constant delay correction is applied the linear anomaly associated with the pipe should be free of any “hearing bone” effect. Another method to determine the time delay is to survey a few lines (in two directions) with varying speeds over the same small metallic target. When displaying the image the anomaly associated with the sample target may be slightly displaced or extended in size on neighboring lines. After the correct time constant for the system is determined the anomaly should be at the same location for each survey line.

Since the image of two dimensional data can be displayed in a mapping system (after griding) the procedure can be time consuming, however it only needs to be done once for a given GPS receiver and Grad-601 system.

In order to apply the correction the generated XYZ file must have time stamps. In the event input file does not have time stamp at each reading the program will display a warning message.

The correction acts on any XYZ type of file so care should be taken that data is not corrected twice.

To access this option select **Convert|Correct Time Constant Delay in XYZ File** in the menu (Figures 4.1 or 4.2). The Correct Time Constant Delay window will appear on the screen (Figure 4.9).

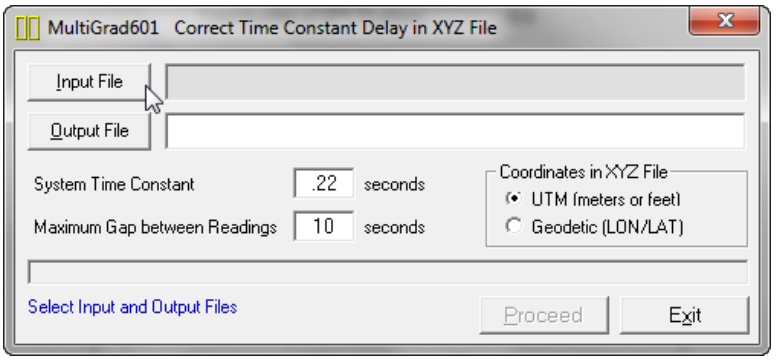


Figure 4.9: Correct Time Constant Delay in XYZ File dialog

Parameters in Correct Time Constant Delay Dialog

Several parameters which affect the contents of the created output (XYZ) file must be specified. These are the Input and Output XYZ file names, System Time Constant, Maximum Gap between Readings, and type of coordinates in the input XYZ file.

Input File

Click on **Input File** button. The Select Input XYZ File window is displayed (Figure 4.10).

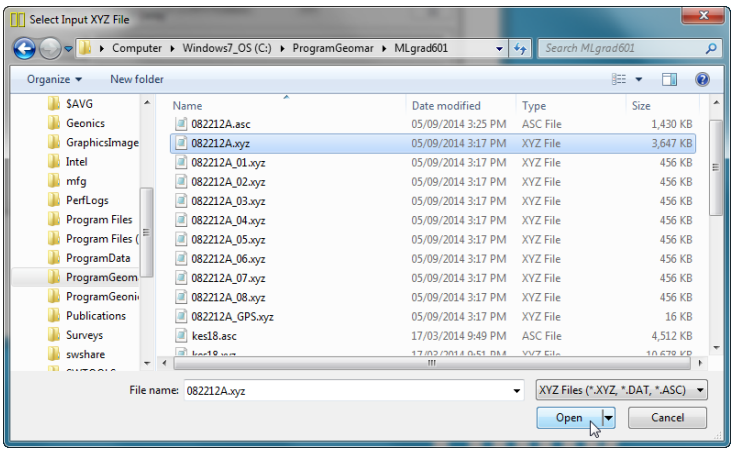


Figure 4.10: Select Input XYZ File window

The window lists files with extension names XYZ, DAT, and ASC. Select a file name and click the **Open** button. The Select Input XYZ File window will close and the selected file name will appear next to the **Input File** button in the Correct Time Constant Delay window.

Output File

Click on the **Output File** button. The Select XYZ File window is displayed (Figure 4.11).

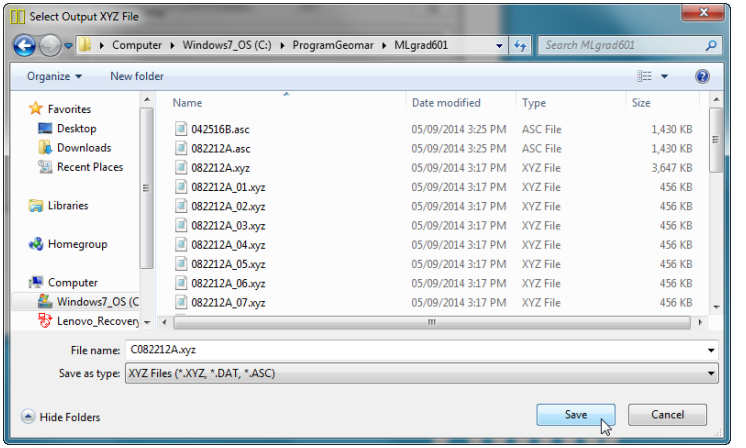


Figure 4.11: Select Output XYZ File window

As a default the Input File name with prefix C is given. Accept the default, enter, or select a file name and click the **Save** button. The Select Output XYZ File window will close and the selected file name will be displayed beside the **Output File** button in the Correct Time Constant Delay window.

When Input and Output files are specified the **Proceed** button in the Correct Time Constant Delay window becomes active (Figure 4.12).

System Time Constant

Time delay 0.4 seconds is given as a default. This value can be changed (0 to 2 seconds), however the user should experiment before choosing a final value.

Maximum Gap Between Readings

This parameter specifies the maximum time during which the magnetic data will be treated as continuous data set. If the gap between two stations is larger than specified maximum gap the station that follows the gap will be assumed the first station of a new line.

Enter this parameter (in seconds) in the edit box labeled Maximum Gap between Readings. In most cases a value 2 to 3 times larger than the GPS acquisition frequency is adequate.

Coordinates in XYZ File

Specify type of coordinates in the input file. The output file will be written with the same type of coordinates.

Creating XYZ File With Time Delay Corrections

When all parameter are set and input and output file names are specified, the **Proceed** button is activated in the Correct Time Constant Delay window. After you click the **Proceed** button, the program begins to read and analyze the input file. A label Analyzing File is displayed at the bottom of the window. The program then calculates corrections for each station based on the instant velocity of the system at each station. A progress bar at the bottom of the screen shows the percentage read (Figure 4.12).

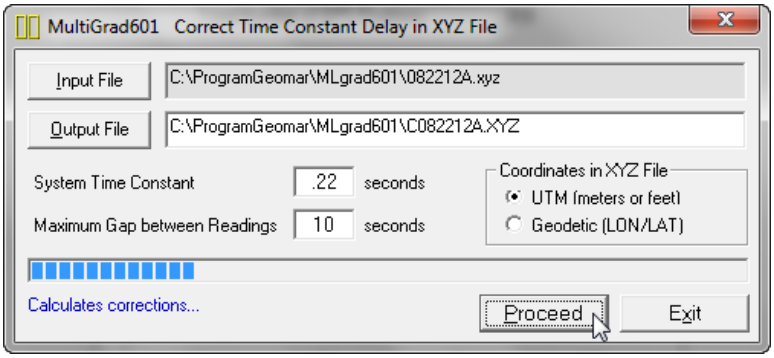


Figure 4.12: Correct Time Constant Delay in the XYZ File dialog during data processing

If the input file does not contain time stamp information, the program will display a warning message, and it will pause operation till the **OK** button is clicked in the warning window.

MLgrad601 Data File

A

A.1 Description of MLgrad601 Data File Format (MGR)

Each record created by the MLgrad601 program for Windows 7/XP contains 27 characters, including line feed at the end of each record.

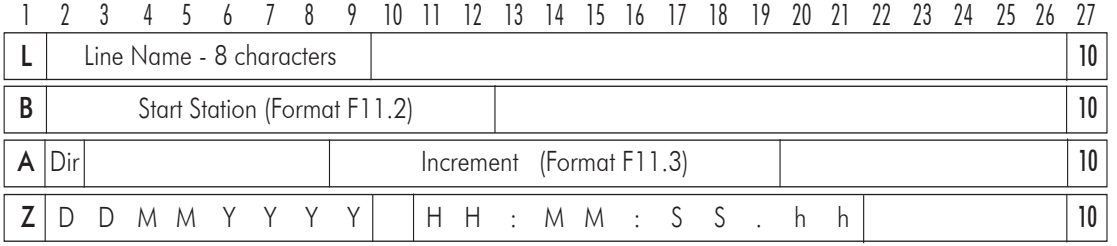
Header of the file contains 6 records starting with characters M, H, and four records starting with G.

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
M	L	G	6	0	1			W	1	0	6	Survey Type			UT		IM		IS	AU						10
H		File Name										C1	C2	C3	C4	C5	C6		TG		C7	C8	C9				10
G	GPS X Offset (F7.3)							GPS Y Offset (F7.3)							NC	MN	GP		CO	NG						10
G	not used							not used																		10
G	not used							not used																		10
G	Unit Separation (F7.3)							Separation (F7.3)																		10

ML601	-	identification of program file
W106	-	version number (V1.06)
Survey Type	-	GPS (if GPS Input Enabled) or GRD (grid)
UT	-	unit type (0 = meters, 1 = ft, 2 = US Survey ft)
IM	-	survey mode (fixed 0 = Auto)
IS	-	not used (fixed =2)
AU	-	array units (0=m, 1=cm, 2=feet, 3=inch)
File Name	-	file name, maximum 8 characters
C1 to C9	-	type of Grad601 for each console (=1 Grad601-1, =2 Grad601-2)
TG	-	File tag (space=original, 1=Saved As / edited)
GPS X Offset	-	Offset of GPS antenna in X direction
GPS Y Offset	-	Offset of GPS antenna in Y direction
NC	-	total number of consoles in the array (1 to 9)
MN	-	leading unit (1 to 9 sensor, 0 for center)

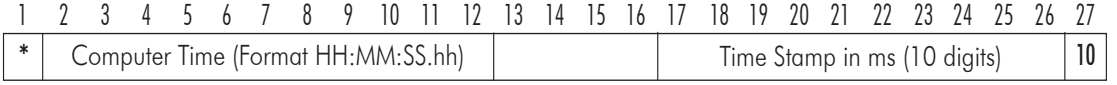
GP	-	type of GPS NMEA message (0 = GGA/GSA, 1= GGA, 2 = POS, 3 = LLK, 4=LLQ, 5=GLL, 6 = GGK, 7 = Leica TPS, 8 = pseudo GGA)
CO	-	coordinates (not used in this version)
NG	-	number of GPS receivers (not used in this version)
Unit Separation	-	separation between sensors of the same console
Separation	-	separation between sensors of neighbouring consoles
10	-	Line Feed character

Header at the start of survey line (contains four records starting with L, B, A, and Z)



Line Name	-	Line Name, maximum 8 characters
Start Station	-	Start Station for the Line, format F11.2
Time	-	Time when Line was created in milliseconds
Dir	-	Direction of the Line (E, W, N, or S)
Station Inc.	-	Station Increment, format F11.3
Date	-	Date when Line was created, format DD-MM-YYYY
Time	-	Time when Line was created, format HH:MM:SS.hh
10	-	Line Feed character

Timer Reset



Indicates reset time of the program timer. This record links timer in milliseconds and computer time (local time) in format HH:MM:SS.hh. This record is written to the file each time after the program switches from the Stand By to Log mode. In case when data are taken continuously the timer is automatically reset every hour.

Reading

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
I	$	P	B	A	R	,	Left Sensor				,	Right Sensor				Time Stamp in ms (10 digits)										10

I - indicator of reading start, one ASCII character. Number of the ASCII character represents the Grad601 console number in array. Console #1 is indicated by character T (ASCII number 84). Following constants are added to each of this number (84) to indicate other instruments in the array:

Grad601 Console #1	**0**
Grad601 Console #2	**+32**
Grad601 Console #3	**+128**
Grad601 Console #4	**+160**
Grad601 Console #5	**-64**
Grad601 Console #6	**+67**
Grad601 Console #7	**+84**
Grad601 Console #8	**+101**
Grad601 Console #9	**-24**

$PBAR - original indicator of Grad601 string (not used)
, - comma separator
Left Sensor - 4 digits, reading of the Left Sensor connected to console
Right Sensor - 4 digits, reading of the Right Sensor connected to console (spaces if Grad601-1 with one sensor is used)
Time - time stamp of the reading in milliseconds, this is time elapsed from the start (creation) of the current data. The time in milliseconds can be linked with the computer local time by using Times in lines B and Z of Line Header.
10 - Line Feed character

Comment

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
C	Comment (maximum 11 characters)															Time Stamp in ms (10 digits)										10

New Station

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
S	New Station (Format 11.2)															Time Stamp in ms (10 digits)										10

Records starting with X
Several informative records, for example X$STARTED indicates start of Logging mode, X$PAUSED indicates Pause (activated by Pause key stroke), etc.

GPS Data Message Records

Each GPS record (GGA Message) is broken in to several 25 characters strings and placed in the MLgrad601 data file which contains 27 characters records, including one character indicator and line feed at the end of each record. The GPS sequence starts at the line which contains the character @ as the first character, then records that contain a continuation of the same message start with the character **#**. The GPS sequence ends with a line starting with the character **!**. The last line contains sequential number of GPS recorded position and a logger time stamp for the given GPS reading. A sample of the GPS message written in MLgrad601 format is given below.

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
@	$	G	P	G	G	A	,	h	h	m	m	s	s	.	s	s	,	d	d	m	m	.	m	m	m	10
#	m	m	,	s	,	d	d	d	m	m	.	m	m	m	m	m	,	s	,	n	,	q	q	,	p	10
#	p	.	p	,	s	a	a	a	a	a	.	a	a	,	u	,	±	x	x	x	x	.	x	,	M	10
#	,	s	s	s	,	a	a	a	*	c	c	CR	LF													10
!	0	0	4	3	5												Time Stamp in ms (10 digits)									10

The GPS sequence may contain 4 to 7 records. The components of the GGA message may differ in length, however they are placed in the same number of columns. Refer to Appendix B (section B.2) for the definition of each component of the GGA data message. Other available GPS messages in NMEA format, GSA, POS, LLK, LLQ, GLL, and GGK, are recorded similarly. The structure of these NMEA sentences is given in section B.2 of Appendix B.

If the Checksum in NMEA message is invalid then starting character @ is replaced by **?**, and **#** is replaced by " (ASCII character code 34). The starting character of Time Stamp record **!** remains the same.

A.2 Example of MLgrad601 Data File

The MLgrad601 data file records are written in binary format, therefore characters may have a different shape when displayed or printed, depending on particular video or printer settings.

```
MLG601  W106GPS0 0 20
H 082212A   222200   000
G  1.610  0.500410 01
G
G
G  0.460  0.460
L3.00
B    -137.00
AS            1.000
Z22082014 12:17:03
*12:17:03.078       4576351
t$PBAR,  44,  66    4579580
ô$PBAR,  74,  28    4579580
I$PBAR,  89,  58    4579580
O$PBAR,  57,  80    4579596
t$PBAR,  44,  78    4579674
ô$PBAR,  74,  49    4579674
I$PBAR,  89,  79    4579674
O$PBAR,  57,  62    4579705
t$PBAR,  45,  66    4579768
ô$PBAR,  75,  29    4579768
I$PBAR,  90,  59    4579768
O$PBAR,  65,  68    4579799
t$PBAR,  50,  70    4579861
ô$PBAR,  78,  36    4579861
I$PBAR, 101,  66    4579877
O$PBAR,  62,  62    4579892
ô$PBAR,  77,  29    4579955
t$PBAR,  48,  66    4579955
I$PBAR,  96,  59    4579970
O$PBAR,  35,  76    4579986
ô$PBAR,  65,  45    4580064
t$PBAR,  30,  76    4580064
I$PBAR,  60,  75    4580064
O$PBAR,  39,  73    4580080
@$GPGGA,162406,4336.8685,N
#,07937.7241,W,8,12,2.0,20
#1.2,M,-35.4,M,,*7C
!             0     4579986
ô$PBAR,  67,  41    4580158
t$PBAR,  33,  73    4580158
I$PBAR,  66,  71    4580158
O$PBAR,  73,  67    4580173
ô$PBAR,  82,  34    4580251
t$PBAR,  55,  69    4580251
I$PBAR, 111,  64    4580251
O$PBAR,  68,  67    4580267
ô$PBAR,  79,  34    4580345
t$PBAR,  52,  69    4580345
I$PBAR, 104,  64    4580345
O$PBAR,  52,  80    4580376
ô$PBAR,  72,  49    4580438
t$PBAR,  41,  78    4580438
I$PBAR,  82,  79    4580454
O$PBAR,  59,  61    4580470
t$PBAR,  46,  65    4580532
ô$PBAR,  76,  27    4580532
I$PBAR,  93,  57    4580548
O$PBAR,  78,  73    4580563
t$PBAR,  58,  73    4580641
.................
```

File Formats

B

B.1 Description of MLgrad601 File in ASCII Format

The MLgrad601 data file converted to ASCII format is in text format, it can be edited in any text editor. The format of the file is self explanatory.

The file starts with a header block, which starts with the line **MLgrad601 File Header** and it ends with line **End of file header**. The file header includes: MLgrad601 version number, type of positioning, distance units, name of current and original data file (as entered during the survey), list of consoles with number of sensors, separation between same console sesors (Unit Separation), separation between neighbouring consoles (Separation), GPS NMEA message type, GPS antenna X and Y offsets, Leading Point (sensor number or 0 if center of array), and sequence of parameters in every reading line.

The file contains at least one survey line (even if survey lines are not used with GPS positioning). Each survey line starts with a Line Header Block. The Line Header Block contains four lines describing: survey line name, start station, station increment, date (MM/DD/YYYY) and time (HH:MM:SS) of line creation.

Lines containing readings start with one of the console number indicator: 1 to 9, and it is followed by one or two numbers of sensors belonging to the console. Console and sensors identifier is followed by four columns: station number, Sensor #1 (Left) response, Sensor #2 (Right) response, and local time stamp (format HH:MM:SS.ttt).

Line that starts with C corresponds to field comment, and line that starts with N indicates entry of New Station.

GPS data consists of one or two lines starting with GP and GQ. Line containing GP is always present and it contains position, while line starting with GQ corresponds to quality of GPS reading.

Line that starts with GP contains position, UTC time, and local time. If Geodetic Coordinates were selected the position is indicated by Latitude and Longitude. In case when UTM coordinates were selected the position is described by UTM Zone number, East-

ing and Northing (see example of the file below). The second line that starts with GQ describes quality of GPS position and it contents depends on the NMEA message used during the survey. In the example of the file GQ statement is given for NMEA message pair GGA/GSA and contains: Position Quality, status of differential corrections, and index PDOP. For other NMEA messages contents of line starting with GQ may differ.

Line containing GPS position may also include original NMEA message if this option was selected in Convert MLgrad601 File to ASCII Format window (as in the example below).

Example of MLgrad601 files in ASCII format

```
MLgrad601 File Header   Version W1.06
Positioning: GPS          Distance units: meters
Instrument Type: Grad601-2  Survey Mode   : Auto
Current Data File  : 082212A.MGR
Original Data File : 082212A.MGR
# of Consoles :  4   # of Sensors: 8
Console #1:  2 sensors
Console #2:  2 sensors
Console #3:  2 sensors
Console #4:  2 sensors
Separation between sensors for the same console:  .46
Separation between neighboring consoles sensors:  .46
GPS Message   : GGA/GSA
GPS Antenna X offset:  1.61
GPS Antenna Y offset:  .5
Leading Sensor: 1
Readings in the following order:
Console#, Probe_1# & Probe_2#, Stn, Rdg_1, Rdg_2, Time
End of file header

Survey Line      : 3.00
Start Station    : -137.00
Station Increment: 1.000
Date: 22/08/2014  Time: 12:17:03
End of Survey Line header
2  3 & 4      -133.000   48.00    66.00     12:17:06.682
1  1 & 2      -133.000   96.00    59.00     12:17:06.697
3  5 & 6      -133.000   35.00    76.00     12:17:06.712
$GPGGA,162406,4336.8685,N,07937.7241,W,8,12,2.0,201.2,M,-35.4,M,,*7C       12:17:06.712
4  7 & 8      -132.000   65.00    45.00     12:17:06.790
2  3 & 4      -132.000   30.00    76.00     12:17:06.790
1  1 & 2      -132.000   60.00    75.00     12:17:06.790
3  5 & 6      -132.000   39.00    73.00     12:17:06.807
4  7 & 8      -131.000   67.00    41.00     12:17:06.885
2  3 & 4      -131.000   33.00    73.00     12:17:06.885
1  1 & 2      -131.000   66.00    71.00     12:17:06.885
3  5 & 6      -131.000   73.00    67.00     12:17:06.900
4  7 & 8      -130.000   82.00    34.00     12:17:06.978
2  3 & 4      -130.000   55.00    69.00     12:17:06.978
1  1 & 2      -130.000  111.00    64.00     12:17:06.978
3  5 & 6      -130.000   68.00    67.00     12:17:06.993
4  7 & 8      -129.000   79.00    34.00     12:17:07.072
2  3 & 4      -129.000   52.00    69.00     12:17:07.072
1  1 & 2      -129.000  104.00    64.00     12:17:07.072
3  5 & 6      -129.000   52.00    80.00     12:17:07.103
4  7 & 8      -128.000   72.00    49.00     12:17:07.165
2  3 & 4      -128.000   41.00    78.00     12:17:07.165
1  1 & 2      -128.000   82.00    79.00     12:17:07.180
3  5 & 6      -128.000   59.00    61.00     12:17:07.197
2  3 & 4      -127.000   46.00    65.00     12:17:07.258
```

```
4  7 & 8      -127.000   76.00    27.00     12:17:07.258
1  1 & 2      -127.000   93.00    57.00     12:17:07.275
3  5 & 6      -127.000   78.00    73.00     12:17:07.290
2  3 & 4      -126.000   58.00    73.00     12:17:07.368
4  7 & 8      -126.000   84.00    41.00     12:17:07.368
1  1 & 2      -126.000  117.00    71.00     12:17:07.368
3  5 & 6      -126.000   42.00    61.00     12:17:07.383
4  7 & 8      -125.000   68.00    28.00     12:17:07.461
2  3 & 4      -125.000   35.00    66.00     12:17:07.461
1  1 & 2      -125.000   70.00    58.00     12:17:07.461
3  5 & 6      -125.000   40.00    78.00     12:17:07.476
4  7 & 8      -124.000   67.00    47.00     12:17:07.555
2  3 & 4      -124.000   33.00    77.00     12:17:07.555
1  1 & 2      -124.000   67.00    77.00     12:17:07.555
3  5 & 6      -124.000   77.00    72.00     12:17:07.570
4  7 & 8      -123.000   84.00    40.00     12:17:07.648
2  3 & 4      -123.000   58.00    73.00     12:17:07.648
1  1 & 2      -123.000  117.00    70.00     12:17:07.648
3  5 & 6      -123.000   36.00    59.00     12:17:07.680
4  7 & 8      -122.000   65.00    26.00     12:17:07.743
2  3 & 4      -122.000   30.00    64.00     12:17:07.743
1  1 & 2      -122.000   61.00    56.00     12:17:07.743
3  5 & 6      -122.000   37.00    73.00     12:17:07.773
4  7 & 8      -121.000   66.00    41.00     12:17:07.835
2  3 & 4      -121.000   31.00    74.00     12:17:07.835
1  1 & 2      -121.000   63.00    71.00     12:17:07.851
3  5 & 6      -121.000   40.00    83.00     12:17:07.866
4  7 & 8      -120.000   67.00    52.00     12:17:07.944
2  3 & 4      -120.000   33.00    80.00     12:17:07.944
1  1 & 2      -120.000   67.00    82.00     12:17:07.944
3  5 & 6      -120.000   73.00    71.00     12:17:07.960
4  7 & 8      -119.000   82.00    39.00     12:17:08.038
2  3 & 4      -119.000   55.00    72.00     12:17:08.038
1  1 & 2      -119.000  111.00    69.00     12:17:08.038
3  5 & 6      -119.000   67.00    83.00     12:17:08.055
4  7 & 8      -118.000   79.00    52.00     12:17:08.133
2  3 & 4      -118.000   51.00    80.00     12:17:08.133
1  1 & 2      -118.000  103.00    82.00     12:17:08.133
3  5 & 6      -118.000   35.00    50.00     12:17:08.148
4  7 & 8      -117.000   65.00    16.00     12:17:08.225
2  3 & 4      -117.000   30.00    58.00     12:17:08.225
1  1 & 2      -117.000   60.00    46.00     12:17:08.225
3  5 & 6      -117.000   66.00    72.00     12:17:08.241
4  7 & 8      -116.000   79.00    40.00     12:17:08.319
2  3 & 4      -116.000   51.00    73.00     12:17:08.319
1  1 & 2      -116.000  102.00    70.00     12:17:08.319
3  5 & 6      -116.000   44.00    47.00     12:17:08.350
4  7 & 8      -115.000   69.00    13.00     12:17:08.413
2  3 & 4      -115.000   36.00    56.00     12:17:08.413
1  1 & 2      -115.000   73.00    43.00     12:17:08.428
3  5 & 6      -115.000   42.00    73.00     12:17:08.444
4  7 & 8      -114.000   68.00    41.00     12:17:08.506
2  3 & 4      -114.000   35.00    73.00     12:17:08.523
1  1 & 2      -114.000   70.00    71.00     12:17:08.523
3  5 & 6      -114.000   50.00    59.00     12:17:08.538
4  7 & 8      -113.000   71.00    25.00     12:17:08.616
2  3 & 4      -113.000   40.00    64.00     12:17:08.616
1  1 & 2      -113.000   80.00    55.00     12:17:08.616
3  5 & 6      -113.000   51.00    74.00     12:17:08.631
4  7 & 8      -112.000   72.00    43.00     12:17:08.709
2  3 & 4      -112.000   41.00    74.00     12:17:08.709
1  1 & 2      -112.000   82.00    73.00     12:17:08.709
3  5 & 6      -112.000   71.00    81.00     12:17:08.724
$GPGGA,162408,4336.8690,N,07937.7241,W,8,12,2.0,201.2,M,-35.4,M,,*72     12:17:08.724
4  7 & 8      -111.000   81.00    50.00     12:17:08.802
2  3 & 4      -111.000   54.00    79.00     12:17:08.802
1  1 & 2      -111.000  108.00    80.00     12:17:08.802
3  5 & 6      -111.000   58.00    72.00     12:17:08.818
4  7 & 8      -110.000   75.00    40.00     12:17:08.896
2  3 & 4      -110.000   45.00    73.00     12:17:08.896
1  1 & 2      -110.000   91.00    70.00     12:17:08.896
.....................................................
```

B.2 Retrieved and Positioned Field Comments

File containing retrieved and positioned comments starts with a header indicating name of the original MLgrad601 data file. This is followed by coordinates and text of comment enclosed in double quotes. Coordinates can be written in UTM or Geodetic format. Column one includes Easting or Longitude, and second column contains Northing or Latitude. The optional, fourth column of the file includes local time.

Example of file containing positioned comments (Geodetic coordinates)

```
Comments in Data File  : 082218A.MGR
  -79.610851833    43.609890333  "Stake#10"      18:17:41.934
  -79.610850500    43.609890167  "Stake#20"      18:29:32.187
  -79.610833500    43.609879500  "Stake#30"      18:29:36.834
  -79.610833500    43.609879500  "Stahe#40"      18:29:41.974
  -79.610833500    43.609879500  "WoodPile"      18:29:47.636
  -79.610835167    43.609885833  "Fence"         18:37:11.833
```

B.3 Output File (XYZ)

The output XYZ file may be written in two output formats: Generic, Geosoft, and Line type of XYZ file. The only difference between these two formats is that Geosoft format contains line labeled Line # at the beginning of each survey line. The Line Format is prepared for other mapping/processing software.

The One File option contains all sensors, starting with sequence for Sensor#1, and then segments for following Sensors are written in order. If Separate Files option was selected then number of created XYZ files is equal to number of sensors in the array, and each file contains coordinates and data only for one sensor.

Coordinates can be written in UTM or Geodetic format. Column one includes Easting or Longitude, and second column contains Northing or Latitude. The third column represents response of one of sensors. The optional columns that include Elevation, three GPS QC parameters (Quality Indicator, PDOP, Number of Satellites), and a reading time stamp (local time) are always placed as last columns in the file.

The XYZ file may also contain field comments. All lines containing description text start with character "\" with the exception of label Line# if Geosoft data type is used. If the Include Header Info option was used then each file contains header fully describing XYZ file contents. See the example of the XYZ file given below. This sample file is in UTM coordinates and it contains elevation data.

Example of XYZ file created by MLgrad601 (One File - contains all sensors)

```
//MLgrad601   # of Sensors: 8, UTM zone = 17, Datum: WGS1984
//Easting [m], Northing [m], Rdg[nT/m], Quality, Sat., HDOP, Elev[m], Time
//Grad601 Sensor: #1
//Grad601 Sensor #1, UTM zone = 17, Datum: WGS1984
//Easting [m], Northing [m], Rdg[nT/m], Quality, Sat., HDOP, Elev[m], Time
Line 3.00
     610648.297    4829965.343    60.00   8  12   2.00   199.550    12:17:06.790
     610648.297    4829965.386    66.00   8  12   2.00   199.550    12:17:06.885
     610648.296    4829965.429   111.00   8  12   2.00   199.550    12:17:06.977
     610648.295    4829965.472   104.00   8  12   2.00   199.550    12:17:07.072
     610648.294    4829965.522    82.00   8  12   2.00   199.550    12:17:07.180
     610648.294    4829965.566    93.00   8  12   2.00   199.550    12:17:07.275
     610648.293    4829965.608   117.00   8  12   2.00   199.550    12:17:07.368
     610648.292    4829965.652    70.00   8  12   2.00   199.550    12:17:07.461
     610648.291    4829965.694    67.00   8  12   2.00   199.550    12:17:07.555
     610648.291    4829965.738   117.00   8  12   2.00   199.550    12:17:07.648
     610648.290    4829965.781    61.00   8  12   2.00   199.550    12:17:07.743
     610648.289    4829965.831    63.00   8  12   2.00   199.550    12:17:07.851
     610648.289    4829965.874    67.00   8  12   2.00   199.550    12:17:07.944
     610648.288    4829965.917   111.00   8  12   2.00   199.550    12:17:08.038
     610648.287    4829965.960   103.00   8  12   2.00   199.550    12:17:08.133
     610648.286    4829966.003    60.00   8  12   2.00   199.550    12:17:08.226
     610648.286    4829966.046   102.00   8  12   2.00   199.550    12:17:08.319
     610648.285    4829966.096    73.00   8  12   2.00   199.550    12:17:08.428
     610648.284    4829966.140    70.00   8  12   2.00   199.550    12:17:08.523
     610648.283    4829966.182    80.00   8  12   2.00   199.550    12:17:08.616
     610648.283    4829966.226    82.00   8  12   2.00   199.550    12:17:08.709
     610648.282    4829966.276   108.00   8  12   2.00   199.550    12:17:08.802
     610648.281    4829966.329    91.00   8  12   2.00   199.550    12:17:08.896
     610648.280    4829966.382   107.00   8  12   2.00   199.550    12:17:08.991
     610648.279    4829966.443    68.00   8  12   2.00   199.550    12:17:09.099
     610648.278    4829966.495    84.00   8  12   2.00   199.550    12:17:09.192
     610648.277    4829966.547    68.00   8  12   2.00   199.550    12:17:09.286
     610648.277    4829966.600    63.00   8  12   2.00   199.550    12:17:09.381
     610648.276    4829966.652    94.00   8  12   2.00   199.550    12:17:09.474
     610648.275    4829966.705    92.00   8  12   2.00   199.550    12:17:09.567
     610648.274    4829966.766    78.00   8  12   2.00   199.550    12:17:09.676
     610648.273    4829966.819   108.00   8  12   2.00   199.550    12:17:09.771
     610648.272    4829966.871    77.00   8  12   2.00   199.550    12:17:09.864
     610648.271    4829966.923   113.00   8  12   2.00   199.550    12:17:09.957
     610648.270    4829966.975   104.00   8  12   2.00   199.550    12:17:10.050
     610648.269    4829967.028    81.00   8  12   2.00   199.550    12:17:10.144
     610648.269    4829967.081    73.00   8  12   2.00   199.550    12:17:10.239
     610648.268    4829967.142    73.00   8  12   2.00   199.550    12:17:10.347
     610648.267    4829967.194    92.00   8  12   2.00   199.550    12:17:10.440
     610648.266    4829967.247    63.00   8  12   2.00   199.550    12:17:10.534
     610648.265    4829967.299    91.00   8  12   2.00   199.550    12:17:10.629
     610648.264    4829967.351    65.00   8  12   2.00   199.550    12:17:10.722
     610648.263    4829967.395   113.00   8  12   2.00   199.550    12:17:10.815
     610648.263    4829967.445    68.00   8  12   2.00   199.550    12:17:10.924
     610648.262    4829967.489   115.00   8  12   2.00   199.550    12:17:11.019
     610648.261    4829967.532    62.00   8  12   2.00   199.550    12:17:11.112
     610648.260    4829967.576    80.00   8  12   2.00   199.550    12:17:11.205
     610648.260    4829967.619    83.00   8  12   2.00   199.550    12:17:11.298
     610648.259    4829967.662   116.00   8  12   2.00   199.550    12:17:11.392
     610648.258    4829967.706    92.00   8  12   2.00   199.550    12:17:11.487
     610648.257    4829967.756   101.00   8  12   2.00   199.550    12:17:11.595
     610648.257    4829967.799    75.00   8  12   2.00   199.540    12:17:11.688
     610648.256    4829967.843    91.00   8  12   2.00   199.556    12:17:11.782
     610648.255    4829967.887    83.00   8  12   2.00   199.553    12:17:11.877
     610648.255    4829967.930    95.00   8  12   2.00   199.554    12:17:11.970
     610648.254    4829967.973   101.00   8  12   2.00   199.549    12:17:12.063
     610648.253    4829968.024    86.00   8  12   2.00   199.544    12:17:12.173
     610648.252    4829968.067    60.00   8  12   2.00   199.545    12:17:12.266
     610648.252    4829968.110    96.00   8  12   2.00   199.541    12:17:12.360
     610648.251    4829968.154    94.00   8  12   2.00   199.533    12:17:12.453
     610648.250    4829968.197    73.00   8  12   2.00   199.534    12:17:12.546
     ..........................................
```

Example of XYZ file created by MLgrad601 (Separate File - Sensor #3)

```
//Grad601 Sensor #3, UTM zone = 17, Datum: WGS1984
//Easting [m], Northing [m], Rdg[nT/m], Quality, Sat., HDOP, Elev[m], Time
Line 3.00
     610649.217    4829965.358    30.00   8  12   2.00   199.550    12:17:06.790
     610649.216    4829965.401    33.00   8  12   2.00   199.550    12:17:06.885
     610649.216    4829965.444    55.00   8  12   2.00   199.550    12:17:06.977
     610649.215    4829965.487    52.00   8  12   2.00   199.550    12:17:07.072
     610649.214    4829965.530    41.00   8  12   2.00   199.550    12:17:07.165
     610649.214    4829965.573    46.00   8  12   2.00   199.550    12:17:07.258
     610649.213    4829965.624    58.00   8  12   2.00   199.550    12:17:07.368
     610649.212    4829965.667    35.00   8  12   2.00   199.550    12:17:07.461
     610649.211    4829965.710    33.00   8  12   2.00   199.550    12:17:07.555
     610649.211    4829965.753    58.00   8  12   2.00   199.550    12:17:07.648
     610649.210    4829965.796    30.00   8  12   2.00   199.550    12:17:07.743
     610649.209    4829965.839    31.00   8  12   2.00   199.550    12:17:07.835
     610649.208    4829965.889    33.00   8  12   2.00   199.550    12:17:07.944
     610649.208    4829965.932    55.00   8  12   2.00   199.550    12:17:08.038
     610649.207    4829965.975    51.00   8  12   2.00   199.550    12:17:08.133
     610649.206    4829966.018    30.00   8  12   2.00   199.550    12:17:08.226
     610649.206    4829966.061    51.00   8  12   2.00   199.550    12:17:08.319
     610649.205    4829966.104    36.00   8  12   2.00   199.550    12:17:08.413
     610649.204    4829966.155    35.00   8  12   2.00   199.550    12:17:08.523
     610649.203    4829966.198    40.00   8  12   2.00   199.550    12:17:08.616
     610649.203    4829966.241    41.00   8  12   2.00   199.550    12:17:08.709
     610649.202    4829966.291    54.00   8  12   2.00   199.550    12:17:08.802
     610649.201    4829966.344    45.00   8  12   2.00   199.550    12:17:08.896
     610649.200    4829966.397    53.00   8  12   2.00   199.550    12:17:08.991
     610649.199    4829966.449    34.00   8  12   2.00   199.550    12:17:09.084
     610649.198    4829966.510    42.00   8  12   2.00   199.550    12:17:09.192
     610649.197    4829966.563    34.00   8  12   2.00   199.550    12:17:09.286
     610649.196    4829966.615    31.00   8  12   2.00   199.550    12:17:09.381
     610649.196    4829966.667    47.00   8  12   2.00   199.550    12:17:09.474
     610649.195    4829966.720    46.00   8  12   2.00   199.550    12:17:09.567
     610649.194    4829966.772    39.00   8  12   2.00   199.550    12:17:09.661
     610649.193    4829966.825    54.00   8  12   2.00   199.550    12:17:09.754
     610649.192    4829966.886    38.00   8  12   2.00   199.550    12:17:09.864
     610649.191    4829966.939    56.00   8  12   2.00   199.550    12:17:09.957
     610649.190    4829966.991    52.00   8  12   2.00   199.550    12:17:10.050
     610649.189    4829967.043    40.00   8  12   2.00   199.550    12:17:10.144
     610649.188    4829967.096    36.00   8  12   2.00   199.550    12:17:10.239
     610649.188    4829967.148    36.00   8  12   2.00   199.550    12:17:10.332
     610649.187    4829967.209    46.00   8  12   2.00   199.550    12:17:10.440
     610649.186    4829967.262    31.00   8  12   2.00   199.550    12:17:10.534
     610649.185    4829967.314    45.00   8  12   2.00   199.550    12:17:10.629
     610649.184    4829967.367    32.00   8  12   2.00   199.550    12:17:10.722
     610649.183    4829967.410    56.00   8  12   2.00   199.550    12:17:10.815
     610649.183    4829967.453    34.00   8  12   2.00   199.550    12:17:10.908
     610649.182    4829967.497    57.00   8  12   2.00   199.550    12:17:11.002
     610649.181    4829967.547    31.00   8  12   2.00   199.550    12:17:11.112
     610649.180    4829967.591    40.00   8  12   2.00   199.550    12:17:11.205
     610649.180    4829967.634    41.00   8  12   2.00   199.550    12:17:11.298
     610649.179    4829967.677    58.00   8  12   2.00   199.550    12:17:11.392
     610649.178    4829967.721    46.00   8  12   2.00   199.550    12:17:11.487
     610649.177    4829967.764    50.00   8  12   2.00   199.550    12:17:11.580
     610649.177    4829967.815    37.00   8  12   2.00   199.550    12:17:11.688
     610649.176    4829967.858    45.00   8  12   2.00   199.550    12:17:11.782
     610649.175    4829967.902    41.00   8  12   2.00   199.550    12:17:11.877
     610649.174    4829967.945    47.00   8  12   2.00   199.550    12:17:11.970
     610649.174    4829967.988    50.00   8  12   2.00   199.550    12:17:12.063
     610649.173    4829968.032    43.00   8  12   2.00   199.550    12:17:12.156
     610649.172    4829968.083    30.00   8  12   2.00   199.550    12:17:12.266
     610649.171    4829968.126    48.00   8  12   2.00   199.550    12:17:12.360
     610649.171    4829968.169    47.00   8  12   2.00   199.550    12:17:12.453
     610649.170    4829968.212    36.00   8  12   2.00   199.550    12:17:12.546
     610649.169    4829968.256    30.00   8  12   2.00   199.550    12:17:12.640
     610649.169    4829968.300    32.00   8  12   2.00   199.550    12:17:12.735
     610649.168    4829968.345    55.00   8  12   2.00   199.550    12:17:12.828
     ..........................................
```

Example of XYZ file created by MLgrad601 (Line Format)

```
MLgrad601   # of Sensors: 8, UTM zone = 17, Datum: WGS1984
Easting [m], Northing [m], Rdg[nT/m], Quality, Sat., HDOP, Elev[m], Time

Line 3.00 - Sensor #1

s       610648.26     4829967.84     60.00   8  12   2.00   199.550    12:17:06.790
        610648.26     4829967.89     66.00   8  12   2.00   199.550    12:17:06.885
        610648.25     4829967.94    111.00   8  12   2.00   199.550    12:17:06.977
        610648.25     4829967.98    104.00   8  12   2.00   199.550    12:17:07.072
        610648.25     4829968.03     82.00   8  12   2.00   199.550    12:17:07.180
        610648.25     4829968.08     93.00   8  12   2.00   199.550    12:17:07.275
        610648.25     4829968.13    117.00   8  12   2.00   199.550    12:17:07.368
        610648.25     4829968.17     70.00   8  12   2.00   199.550    12:17:07.461
        610648.25     4829968.22     67.00   8  12   2.00   199.550    12:17:07.555
        610648.25     4829968.26    117.00   8  12   2.00   199.550    12:17:07.648
        610648.25     4829968.31     61.00   8  12   2.00   199.550    12:17:07.743
        610648.25     4829968.36     63.00   8  12   2.00   199.550    12:17:07.851
        610648.25     4829968.41     67.00   8  12   2.00   199.550    12:17:07.944
        610648.25     4829968.45    111.00   8  12   2.00   199.550    12:17:08.038
        610648.25     4829968.50    103.00   8  12   2.00   199.550    12:17:08.133
        610648.25     4829968.54     60.00   8  12   2.00   199.550    12:17:08.226
        610648.24     4829968.59    102.00   8  12   2.00   199.550    12:17:08.319
        610648.24     4829968.64     73.00   8  12   2.00   199.550    12:17:08.428
        610648.24     4829968.69     70.00   8  12   2.00   199.550    12:17:08.523
        610648.24     4829968.73     80.00   8  12   2.00   199.550    12:17:08.616
        610648.24     4829968.78     82.00   8  12   2.00   199.550    12:17:08.709
        610648.24     4829968.83    108.00   8  12   2.00   199.550    12:17:08.802
        610648.25     4829968.89     91.00   8  12   2.00   199.550    12:17:08.896
        610648.25     4829968.94    107.00   8  12   2.00   199.550    12:17:08.991
        610648.25     4829969.01     68.00   8  12   2.00   199.550    12:17:09.099
        610648.25     4829969.06     84.00   8  12   2.00   199.550    12:17:09.192
        610648.26     4829969.11     68.00   8  12   2.00   199.550    12:17:09.286
        610648.26     4829969.17     63.00   8  12   2.00   199.550    12:17:09.381
        610648.26     4829969.22     94.00   8  12   2.00   199.550    12:17:09.474
        610648.27     4829969.28     92.00   8  12   2.00   199.550    12:17:09.567
        610648.27     4829969.34     78.00   8  12   2.00   199.550    12:17:09.676
        610648.27     4829969.40    108.00   8  12   2.00   199.550    12:17:09.771
        610648.27     4829969.45     77.00   8  12   2.00   199.550    12:17:09.864
        610648.28     4829969.51    113.00   8  12   2.00   199.550    12:17:09.957
        610648.28     4829969.56    104.00   8  12   2.00   199.550    12:17:10.050
        610648.28     4829969.62     81.00   8  12   2.00   199.550    12:17:10.144
        610648.29     4829969.67     73.00   8  12   2.00   199.550    12:17:10.239
        610648.29     4829969.74     73.00   8  12   2.00   199.550    12:17:10.347
        610648.29     4829969.79     92.00   8  12   2.00   199.550    12:17:10.440
        610648.29     4829969.84     63.00   8  12   2.00   199.550    12:17:10.534
        610648.30     4829969.90     91.00   8  12   2.00   199.550    12:17:10.629
        610648.30     4829969.95     65.00   8  12   2.00   199.550    12:17:10.722
        610648.30     4829970.00    113.00   8  12   2.00   199.550    12:17:10.815
        610648.30     4829970.05     68.00   8  12   2.00   199.550    12:17:10.924
        610648.31     4829970.09    115.00   8  12   2.00   199.550    12:17:11.019
        610648.31     4829970.13     62.00   8  12   2.00   199.550    12:17:11.112
        610648.31     4829970.18     80.00   8  12   2.00   199.550    12:17:11.205
        610648.31     4829970.22     83.00   8  12   2.00   199.550    12:17:11.298
        610648.31     4829970.26    116.00   8  12   2.00   199.550    12:17:11.392
        610648.32     4829970.31     92.00   8  12   2.00   199.550    12:17:11.487
        610648.32     4829970.36    101.00   8  12   2.00   199.550    12:17:11.595
        610648.32     4829970.40     75.00   8  12   2.00   199.550    12:17:11.688
        610648.32     4829970.44     91.00   8  12   2.00   199.550    12:17:11.782
        610648.33     4829970.49     83.00   8  12   2.00   199.550    12:17:11.877
        610648.33     4829970.53     95.00   8  12   2.00   199.550    12:17:11.970
        610648.33     4829970.57    101.00   8  12   2.00   199.550    12:17:12.063
        610648.33     4829970.62     86.00   8  12   2.00   199.550    12:17:12.173
        610648.33     4829970.67     60.00   8  12   2.00   199.550    12:17:12.266
        610648.34     4829970.71     96.00   8  12   2.00   199.550    12:17:12.360
        610648.34     4829970.75     94.00   8  12   2.00   199.550    12:17:12.453
        610648.34     4829970.80     73.00   8  12   2.00   199.550    12:17:12.546
        610648.34     4829970.84     60.00   8  12   2.00   199.550    12:17:12.640
        ........................................
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Selected NMEA Messages

C

GGA Data Message

The GGA message contains the GPS position information and it is the most widely used NMEA data message. This message takes the following form:

$GPGGA,hhmmss.ss,ddmm.mmmmm,s,dddmm.mmmmm,s,n,qq,pp.p,saaaaa.aa,u,
±xxxx.x,M,sss,aaaa*cc<CR><LF>

Definition of GGA message component:

hhmmss.ss	UTC time in hours, minutes, seconds of the GPS position
ddmm.mmmmm	Latitude in degrees, minutes, and decimal minutes
s	s=N or s=S, for North and South latitude
dddmm.mmmmm	Longitude in degrees, minutes, and decimal minutes
s	s=E or s=W, for East and West longitude
n	Quality indicator, 0 = no position, 1 = raw, no differentially corrected position, 2 = differentially corrected position (DGPS), 4 = Real-time kinematic, fixed integers, 5 = Real-time kinematic, float integers, 9 = position computed using almanac information
qq	Number of satellites used in position computation
pp.p	HDOP = 0.0 to 99.9
saaaaa.aa	Antenna altitude
u	Altitude units, M=meters
±xxxx.x	Geoidal separation (requires geoidal height option)
M	Geoidal separation units, M = meters
sss	Age of differential corrections in seconds
aaaa	Base station identification
***cc**	Checksum
<CR><LF>	Carriage return and Line feed

GSA Data Message

The GSA message contains active satellites and PDOP value. The GSA message is given in the following form:

$GPGSA,c1,d1,d2,d3,d4,d5,d6,d7,d8,d9,d10,d11,d12,d13,f1,f2,f3*cc<CR><LF>

Definition of GSA message components:

c1	Mode, M = manual, A = automatic
d1	Mode, 2 = 2D, 3 = 3D
d2-d13	Satellites used in position computation (range 0 to 32)
f1	PDOP (range 0 to 99.9)
f2	HDOP (range 0 to 99.9)
f3	VDOP (range 0 to 99.9)
***cc**	Checksum
<CR><LF>	Carriage return and Line Feed

POS Data Message

The POS message contains the GPS position information and PDOP value. The POS message is given in the following form:

$PASHR,POS,n,qq,hhmmss:ss,ddmm.mmmmm,s,dddmm.mmmmm,s,saaaaa.aa,seeeee, ttt,ggg,svvv,pp,hh,vv,tt,vvvv*cc<CR><LF>

Definition of POS message components:

n	Quality indicator, 0 = no differentially corrected position, 1 = differentially corrected position
qq	Number of satellites used in position computation
hhmmss:ss	UTC time in hours, minutes, seconds of the GPS position
ddmm.mmmmm	Latitude in degrees, minutes, and decimal minutes
s	s=N or s=S, for North and South latitude
dddmm.mmmmm	Longitude in degrees, minutes, and decimal minutes
s	s=E or s=W, for East and West longitude
saaaaa.aa	sensor computed altitude
seeeee	reserved

ttt	True track/true course over ground in degree
ggg	Speed over ground (knots)
svvv	Vertical velocity (decimeters per second)
pp	PDOP - position dilution of precision (00 to 99)
hh	HDOP - horizontal dilution of precision (00 to 99)
vv	VDOP - vertical dilution of precision (00 to 99)
tt	TDOP - time dilution of precision (00 to 99)
vvvv	firmware version ID
***cc**	Checksum
<CR><LF>	Carriage return and Line feed

LLK Data Message

The LLK (Leica Local Position and GDOP) message provides position in local coordinates in meters and GDOP value. The LLK message is given in the following form:

$GPLLK,hhmmss.ss,ddmmyy,xxxx.xxxx,M,xxxx.xxxx,M,x,x,xx.xx,xxxx.xxxx,M, *cc<CR><LF>

Definition of LLK message components:

hhmmss.ss	UTC time in hours, minutes, seconds of the GPS position
ddmmyy	UTC date (day, month, year)
xxxx.xxxx	Grid Easting, meters
M	Meters (fixed text “M”)
xxxx.xxxx	Grid Northing, meters
M	Meters (fixed text “M”)
x	Quality indicator, 0 = not valid, 1 = GPS Nav Fix (no differentially corrected position), 2 = DGPS Fix (differentially corrected position), 3 = RTK Fix
x	Number of satellites used in computation,
xx.xx	GDOP
xxxx.xxxx	Height, meters
M	Meters (fixed text “M”)
***cc**	Checksum
<CR><LF>	Carriage return and Line feed

LLQ Data Message

The LLQ (Leica Local Position and Quality) message provides position in local coordinates in meters and position quality in meters. The LLQ message is given in the following form:

$GPLLQ,hhmmss.ss,ddmmyy,xxxx.xxxx,M,xxxx.xxxx,M,x,x,xx.xx,xxxx.xxxx,M, *cc<CR><LF>

Definition of LLK message components:

hhmmss.ss	UTC time in hours, minutes, seconds of the GPS position
ddmmyy	UTC date (day, month, year)
xxxx.xxxx	Grid Easting, meters
M	Meters (fixed text "M")
xxxx.xxxx	Grid Northing, meters
M	Meters (fixed text "M")
x	Quality indicator, 0 = not valid, 1 = GPS Nav Fix (no differentially corrected position), 2 = DGPS Fix (differentially corrected position), 3 = RTK Fix
x	Number of satellites used in computation,
xx.xx	Position quality, meters
xxxx.xxxx	Height, meters
M	Meters (fixed text "M")
***cc**	Checksum
<CR><LF>	Carriage return and Line feed

GLL Data Message

The GLL message takes the following form:

$GPGLL,ddmm.mmmmm,s,dddmm.mmmmm,s,hhmmss.ss,s*cc<CR><LF>

Definition of GLL message component:

ddmm.mmmmm	Latitude in degrees, minutes, and decimal minutes
s	s=N or s=S, for North and South latitude

dddmm.mmmmm	Longitude in degrees, minutes, and decimal minutes
s	s=E or s=W, for East and West longitude
hhmmss.ss	UTC time in hours, minutes, seconds of the GPS position
s	Status, A = valid, V = invalid
***cc**	Checksum
<CR><LF>	Carriage return and Line feed

GGK Data Message

The GGK message contains the GPS position, Time, Date, Position Type, and DOP information. The GGK shown below is not a standard NMEA data message and it is used in several Trimble GPS receivers. If this message is used as a standard NMEA statement by a given GPS receiver it starts with $GPGGK and contains GDOP instead of DOP.

TrackMaker software automatically recognizes which type of GGK message is used.

The Trimble proprietary type of GGK message takes the following form:

$PTNL,GGK,hhmmss.ss,ddmmyy,ddmm.mmmmmmmm,s,dddmm.mmmmmmmm,s,n,qq,p.p,EHT-aa.aaa,M*cc<CR><LF>

Definition of GGK message component:

hhmmss.ss	UTC time in hours, minutes, seconds of the GPS position
ddmmyy	Date
ddmm.mmmmmmmm	Latitude in degrees, minutes, and decimal minutes
s	s=N or s=S, for North and South latitude
dddmm.mmmmmmm	Longitude in degrees, minutes, and decimal minutes
s	s=E or s=W, for East and West longitude
n	GPS Quality indicator, 0 = fix not valid or not available, 1 = Autonomous GPS fix, no differentially corrected position, 2 = differential, floating carrier phase integer based solution (FLOAT), 3 = differential, fixed carrier phase integer-based solution (FIXED), 4 = differential, code phase only solution (DGPS)
qq	Number of satellites used in fix

p.p	DOP of fix
EHT-aa.aaa	Ellipsoidal height of fix
M	unit of measure for ellipsoidal height in meters
***cc**	Checksum
<CR><LF>	Carriage return and Line feed