This software is offered as an improvement with respect to PHYSICS (created by Vernier Software) and to DataMate (Texas Instruments). It was created as a joint effort of two Italian teacher’s associations (AIF and ADT), within a project (IRDIS) partially funded by Italian Ministry of Education.

**Improvements with respect to Physics Software (Vernier)**

1) Saving data into a Data variable named by the user (not only the “cbldata”, where a single set can be saved) and saving modified data in SELECT REGION into a Data variable different from the current one.

2) Retrieving data not only from CBL/LabPro, but also from the archive (choosing from a list).

3) Handle saved data also in the absence of CBL/LabPro, without information on the probe setup previously used in data taking.

4) Reduction of the amount of memory used by data taken at excessively high rate (decimation).

5) Noise reduction in a graph (smoothing) for any selected list.

6) Linear calibration of any sensor, and calibration of generic probe with definition of units.

7) Time derivatives performed on any list at request, not only on position data collected by Motion Detector.

8) Plot of any list versus any other list, as well as best fit at choice (linear, power, exponential, sinusoidal getting amplitude, phase and period).

9) Shift and scale data (linear transformation) for easier post calibration and generic data handling for any list.

10) Choice for archiving data to save memory.

11) Change sign of X axis when using SONAR, and calibrate by entering a value for room temperature.

12) Choice of number of digit displayed for curve coordinates.

13) Implementation of new probes.

14) Recovery from error condition: Some “crashes” of the calculator (from which the user could exit only using the command “2nd QUIT” and by re-loading the application) are here avoided. For example when choosing by mistake, in SELECT REGION, identical values for Lower bound and Upper bound the application does not freeze. Now the user is constraint to choose Upper bound > Lower bound to exit the dialog.

**Improvements with respect to DataMate Software**

1) Time derivatives performed on any list at request, not only on position data collected by Motion Detector.

2) Plot of any list versus any other list, as well as best fit at choice (linear, power, exponential, sinusoidal getting amplitude, phase and period).

3) Noise reduction in a graph (smoothing) for any selected list.
4) Linear calibration of any sensor, and calibration of generic probe with definition of units.
5) Time derivatives performed on any list at request, not only on position data collected by Motion Detector.
6) Plot of any list versus any other list, as well as best fit at choice (linear, power, exponential, sinusoidal getting amplitude, phase and period).
7) Shift and scale data (linear transformation) for easier post calibration and generic data handling for any list.
8) Change sign of X axis when using SONAR, and calibrate by entering a value for room temperature.
9) Choice of number of digit displayed for curve coordinates.
10) Implementation of new probes.

A brief description of SCIENCE

Starting by typing SCIENCE () in the command line leads to the first screen that let you select the graphic calculator version in use (for display optimization) and then a splash screen declares the version of the software:

```
Choose calc. model:
1: TI89
2: TI92+
3: Voyage200

SCIENCE for CBL or LabPro
and Graphic Calculators
TI89, TI92Plus, Voyage200
Version 1/2003

[ENTER]
```

Pressing the ENTER key brings to the MAIN MENU:

```
1:SET UP PROBES
2:COLLECT DATA
3:ANALYZE
4:TRIGGERING
5:ZERO PROBES
6:RETRIEVE DATA
7:SAVE/DELETE
8:QUIT Science

****MAIN MENU****
```

**Probe Setup**

The first option SET UP PROBES, brings to one of the following windows: the first when CBL is not properly linked to the calculator (e.g. when connectors are not fully inserted) or the second when the connection is OK.
In the first case, after re-checking the link, choosing option 1: TRY AGAIN we get:

or, choosing option 2: RUN WITHOUT CBL/LabPro we get the second window and we start a virtual SETUP, (we will see later that this may be necessary in order to handle data previously saved in a Data variable with Physics Software, or Data files taken with another graphic calculator).

By choosing option 3: RETURN TO MAIN we get back to Main Menu.

Once the number of probes has been chosen, another window asks the type of probes from a list:

Option 8: MORE offers a further choice among other probes:
With 8: RETURN we get back to the first probe list.

When selecting an analog probe a window opens prompting for the first available channel:

![Probes menu](image)

Connect probe to channel 1.

The option VOLTAGE ±10V refers to the TI standard Voltage probe that measures positive or negative voltages up to 10V referred to ground, the option Diff VOLTAGE refers to the probe measuring voltages not referred to ground (between –6V and +6V), while the option PROBE 0-5V refers to a generic analogic probe with positive output referred to ground up to 5V, that may be calibrated to measure any physical quantity (when this option is selected a window prompt for a label to be used for Y axis).

The software includes the default calibration values for all the probes, but most values may be changed, by selecting this option at the prompted window:

![Calibration options](image)

Some probes (Temperature, Microphone) cannot be recalibrated, and generally it is a good choice to accept first for any probe the default calibration values.

The calibration should be carried out after having verified, with MONITOR INPUT, that the measured values are not correct (i.e. the used probes is not that for which default values were given). There are in fact several different probes commercially available, with different calibration parameters.
Calibration may be performed in two different ways: when you can provide in the laboratory two known values of the physical quantity to be measured you choose 1: CALIBRATE NOW. A window then appears showing the first sensed voltage value and prompts for the corresponding value in the preferred units. A second window follows prompting for the second value.

At the end the calibration parameters are (intercept B and slope A of equation Y=AX+B).

Alternatively you may perform the calibration by entering known values for the two parameters (2: KNOWN VALUES), e.g. the intercept and the slope obtained in a previous calibration.

In the case of the position sensor (SONAR) a different window appears.
Here you may accept the default calibration, that assumes the value 344 m/s for sound speed (to convert the sonar output, corresponding to measurements of time intervals, into distance values: this calibration correspond to a room temperature of 22 °C). Otherwise you may enter a temperature value closer to the actual ambient temperature, obtaining a more precise calibration. For example a change in room temperature of about 10 degrees (up to 30˚C or down to 10˚C) introduce a systematic error in the computation of distance, velocity and acceleration of about 2%..

You may also choose to change the sign of the distance axis:

By exiting from this window you return to the main menu.

Some probes require to select the chosen span or sensitivity (that sometime is set through a switch on the probe): for example the Force Sensor, the accelerometer Low-G, 25-G; the Magnetic Fiels Sensor, the Light Sensor.
For some probes you may choose the unit of measurement (e.g., pressure in ATM, mm Hg), the probe type (e.g., type of light probe) or the span (e.g., for rotary sensor: ±1 turn, ±10 turns...).

**FORCE SENSOR**

Set switch on the probe when not using TI Light Probe

**ACCELEROMETER**

Set the switch on the Rotary Encoder

**ROTARY ENCODER**

**PRESSURE UNITS**

**Probe Code**

*Sensitivity > Span*
Data acquisition

From Main Menu the option 2: COLLECT DATA let us choose among various acquisition procedures:

1: MONITOR INPUT show the values measured by the active channels with a frequency of about 1Hz. No data is saved.

2: TIME GRAPH save data as a function of time. This option brings to the following windows:

prompting for the sampling interval (in seconds) and number of sample to be taken.

After the total acquisition time is displayed, a possibility of correcting the given values is offered:

The next window shows in certain conditions (single probe, no trigger, sampling time not too short and not too long), offering to draw the graph after the acquisition (NON-LIVE DISPLAY) or during acquisition (LIVE DISPLAY). In the second case we must type in the minimum and maximum value expected for the measured signal.
After the SETUP is finished the following window tells that acquisition may start:

![Image]

READY EQUIPMENT.
PRESS [ENTER] TO BEGIN COLLECTING DATA.

At the end of the acquisition a window shows where the data are saved. Typically: time in L1, channel 1 in L2, channel 2 in L3, and channel 3 in L4.

With motion detector (or CBR), we have:

![Image]

When motion detector is used together with two more probes: time is in L1, channel 1 in L2, channel 2 in L3, distance in L4, the velocity in L5 and acceleration L6.

When two or three identical probes are used, a different choice is offered: we may see on a single graph two or three curves (by choosing “BOTH” or “ALL” respectively).
Now we may choose to save data on a variable archived, by selecting the option 7: **SAVE/DELETE** from the MainMenu.

On option 1: SAVE appears a window, with a pop-up menu, that let us overwrite an existing variable DATA or save the last data with a new name. Selecting ELSE another window (Filelist for SAVE) appears, while selecting EXIT we return to the Main Menu without saving.

In case you want to save your data replacing those contained in a previously saved file you select the name of this file, and no typing is required. To avoid saving we may also leave blank the name-field and press ENTER.

We suggest to use names made of at least 4 characters (but not more than 8 characters!!). For example names to be avoided (because reserved to SCIENCE) are: a, b, c, d, fl, g, gt, h, i, j, k, l, lp, n, o, p, q, s, sw, t8, tp, vf, vl, w, xq, yq, θ.

The saved files contain also the PROBE SETUP used by CBL, stored in column 7: in this way the analysis will not require to remember the used setting. The data may be saved as archived file (stored in FLASH ROM) or as normal file in RAM: the second choice allows modifying the data but it reduces the RAM available for the graphing calculator. It is normally better to archive data (they may be later UN-archived in VAR-LINK mode).
Choosing option 2: DELETE we may delete old files (without exiting the application to reach VARLINK mode): a window allows to select from a list the file to be deleted.

Choosing ELSE we may type-in a name different from those shown in the list. This let us load or delete also files produced by PHYSICS software, or imported from different graphic calculators. In order to load files not included in the list we must remember their name: if they were produced by PHYSICS software we may repeat a virtual setup and save them again, to link permanently the correct setup

3: TRIGGER/PROMPT is used to perform experiments where the value of the independent variable is typed from keyboard and the dependent variable is measured by the probe.

4: TRIGGER (2 probes) this option let us sample manually each active channel (2 or more probes must be used). Pressing TRIGGER on CBL starts the acquisition.

**Triggering**

On the MAIN MENU the option 4: TRIGGERING offers the following choices:

With option 1: MANUAL acquisition starts by pressing the button TRIG on CBL. With option 2: CHANNEL 1 or 3: CHANNEL 2 acquisition starts when the corresponding signal (CH1 or CH 2) reach a given value requested in a following dialog. With option 4: OFF all the previous choices are cancelled.
Zero Probes

The option 4: ZERO PROBES on the Main Menu offsets the intercept value of the probe calibration in order to zero the signal in a particular experimental condition. It opens the following window:

to select the channel corresponding to the probe to be zeroed one by one (CH1, CH2, CH3 MOTION), or all together (option 5). Zeroing must obviously be performed after probe calibration.

Data retrieving

The option 6: RETRIEVE DATA on the Main Menu offers two possibilities:

the first is to retrieve data saved within CBL/LabPro (last acquisition) the second is to retrieve a Data file previously saved in the calculator archive. If the archived file was saved by PHYSICS software (or imported from another calculator or PC) we must first perform a virtual SETUP, simulating an acquisition equal to that made when the file was saved (same probes on the same channels). The present version saves within each data file also the set-up configuration used for that acquisition.

When using this option a pop-up menu let us select a file from a list:
Choosing EXIT we go back to the MAIN MENU, with ELSE a new window let us type in the name of an old version (or imported) Data file. When these converted files have been saved, they will appear in the list. If the name typed-in does not exists we jump back to Main Menu.

**Data Analysis**

From Main Menu we may choose option 3: ANALYZE that offers many possibilities for data handling:

1: **PLOT/FIT** menu offers two sub-menu: GRAPH menu and FIT menu:

Choosing the GRAPH menu you are prompted to choose the X and Y variables from various lists. The List 1 may have either the time values for each value collected by different probes, or the values manually entered in the TRIGGER/PROMPT mode.

and then you choose among different plot styles:

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* GRAPH or FIT ? *

Choosing the GRAPH menu you are prompted to choose the X and Y variables from various lists. The List 1 may have either the time values for each value collected by different probes, or the values manually entered in the TRIGGER/PROMPT mode.

and then you choose among different plot styles:
The FIT menu allows a best fit of the data (chosen from any list) by a function selected in the second window. For example to linear interpolate the force vs distance values obtained with a mass-spring oscillator and force probe and sonar, we choose for X the Sonar, and for Y the channel 1:

Here the slope $A$ of the fitting line is the elastic constant of the used spring. In the case of sinusoidal fit we get screens like the following ones:

The next window ask for possible plot of the fitting function with different values of the calculated parameters.

If we choose YES, after showing the data, by pressing ENTER we are asked to select the parameter we want to change. The next window prompts for a new value and then the plot is redrawn. The fitting function is stored in the Y1= function, for further use even after exiting SCIENCE.

**2: STATS/INTEGRAL**: this option displays the following window:
that allows statistical data handling or integral calculations
Option 1: STATISTICS calculates average, minimum, maximum, standard deviations for a
selected region of the displayed plot.
Once chosen from a list the plot of interest one must select a region by placing the cursor at the
lower limit (1st BOUND), by pressing ENTER a vertical cross line appears and one must
similarly choose the upper limit (2nd BOUND). (Note that you may select 2nd bound lower than
1st bound)

After a second ENTER the values are calculated and displayed on the screen.

Option 2: INTEGRATE is used to integrate a selected region of the graph. The integrated area is
marked by vertical lines

Pressing ENTER the area value is displayed.
3: RESCALE GRAPH changes the scale of a plot chosen from a list. After choosing the list (which is displayed to allow a different choice) you choose RETURN: then three options are available:

Option 1: AUTOSCALE assumes, as bounds the maximum and minimum values of x and y (default option when a graph is drawn the first time).
Option 2: X SCALE prompts for the minimum and maximum x values. Option 3: Y SCALE prompts for the minimum and maximum x values.

4: SELECT REGION allows to select a region from a graph and to save only selected data in a separate Data file.

5: VIEW TIME-GROUPH allows to display graphs of the data as functions of time.
This window shows an optional style of graph that can be displayed using TI92+ or Voyage200 (TI89 has too small LCD to display all these labels). If the user delete the “comment” symbol in the third line of subroutine SZAXIS, the first time a graph is displayed the values (close to the small arrows) of the graph bounds are shown.

```
Prgm
©If tp=4
©Goto fine
```

**6:DATA HANDLING:** This is a new option in the menu ANALYZE that allows several kinds of data processing: With DERIVATIVES the first and second time derivatives are calculated for any selected list. SMOOTHING allows to choose a filtering of data (made by a moving average on three points) that can be repeated at pleasure, for heavy filtering. DECIMATION allows to reduce the dimension of large data files (e.g. taken at too high data rate). ZERO LIST 1 resets to zero the origin of the time axis in data files saved after SELECT REGION. Linear Transf. allows a linear transformation of data (e.g. for data recalibration after collection).

When 1: DERIVATIVES is selected, a window prompt to choose the channel corresponding to the signal to which the calculation must be applied: the list with values of first and second time derivative are calculated and placed in list L5 and L6, respectively.
If you change your mind you may choose EXIT, leaving data unmodified. The time derivatives are calculated by incremental differences, using for the first derivative the algorithm \( v_i = (x_{i+1} - x_{i-1}) / 2Dt \), and for the second derivative \( a_i = (x_{i+1} - 2x_i + x_{i-1}) / (Dt)^2 \). In this way the smoothing is minimised.

By choosing option 2: **SMOOTHING**, we access the menu for selecting the channel (CH1, CH2, CH3, Sonic or Derivative 1\textsuperscript{st} or 2\textsuperscript{nd}) to which we will apply the moving average by the algorithm:

\[
<x_i> = (x_{i+1} + x_i + x_{i-1}) / 3
\]

Choosing option 3: **DECIMATION**, the number of points in the data set is reduced by keeping one point every N existing. We are asked to input the N value from keyboard and from all the lists N-1 points are deleted every N.

Once finished the decimation we are back to the menu ANALYZE, where the option 6: **VIEW GRAPH**, will display the new graphs.

Choosing option 4: **ZERO LIST 1** the first value of the list is subtracted from all value in that list.

Choosing option 5: **Linear Transf** prompts for a shift A that is added to each value of the selected list, and then prompts for a scale factor B: the linear transformation is

\[
X_{\text{OUT}} = B \times (X_{\text{IN}} + A)
\]
For example we may choose to convert values of the voltage measured by a generic sensor into values of a given quantity, when the conversion factor is known, or to flip the direction of the distance axis when using the sonar (if we forgot to do it when setting the SONAR). Note that if we want to offset the data of a **negative** quantity, we must use the **“minus”** key (-) (not to be confused with the “difference operator key”) in front of the A value. This choice was made in order to speed-up the procedure of “Y” shift when zeroing the sensor was forgotten.

**7: N.Digits** This menu allows the user to choose the number of digits displayed on the graph screens when reading the coordinates in TRACE Mode (the default value mode is FIX 3, that sometime is not sufficient to resolve interesting values for xc or yc).