

Creativity and motivation in teaching maths, science and technology  
21 – 24 October 2010, Olomouc, Czech Republic  
<http://letsdoit.upol.cz>



# DATA LOGGING

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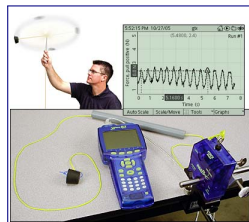
**Let's do it**  
**CREATIVELY**



This project has been funded with support from the European Commission.  
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# Workshop outline

- 1 Why data logging?
- 2 The Pros and Cons in education
- 3 Various solutions
- 4 First steps with Vernier
- 5 Experiments
  - Pressure change with altitude
    - Faculty building
    - RCO Olomouc
    - Sněžka mountain
  - Workplace 1: „bats“
  - Workplace 2: Force sensor
  - Workplace 3: Competition of thermometers
  - Workplace 4: Oscillations with photogate
  - Workplace 5: pressure
- 6 „Logger“ from Your computer
- 7 References



# Data logging

- **Wikipedia:** „A data logger (also datalogger or data recorder) is an electronic device that records data over time or in relation to location either with a built in instrument or sensor or via external instruments and sensors.“
- data loggers typically deployed and left unattended to measure and record information for the duration of the monitoring period  $\implies$  this allows e.g. for a comprehensive, accurate picture of the environmental conditions being monitored (air temperature, pressure, relative humidity, ...) – who uses „weather station“?
- used in a practical life, industry



Flight data recorder  
and cockpit voice  
recorder

# The Pros (+ for teaching): the main advantages

- huge demonstration meter, connecting to computer and overhead projector – visible for the entire class
- all data can be stored in tables and graphs (USB cable, memory card), use MS Excel, Openoffice Calc, GNUPlot, etc.
- the sensors can be shared by physics, chemistry, biology (etc.) teachers
- quite easy to transfer from one classroom to another
- easy portability allows outdoor measurement (trips, excursions)
- multipurpose equipment, one tool for more tasks, consistency, control



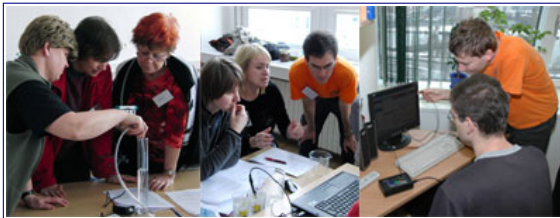
# The Pros (+ for teaching): the main advantages

- multipurpose equipment, one tool for more tasks, consistency, control
- several sensors simultaneously  $\Rightarrow$  see the chart using the relationships between measured variables, **analysis tools** (statistics, curve-fitting, Fourier analysis, calculating the area under the graph, ...)
- recording very fast processes (lasting a few milliseconds), also slow and long processes (measurement running all day)
- interesting sensors (more than 50 with Vernier) – acceleration, pH, concentration of carbon dioxide, spectrophotometer, ...
- you enjoy the measurement, part of the **community**



# The Cons and risks (– for teaching)

- money – do not grow on trees
- overuse – it should be combined with the traditional methods, **not replace** them – chalk, PET bottles, balls, ...
- not a magic box, just a tool – work must be done by students



# Various solutions

- do-it-yourself
- *PASCO scientific* (Roseville, California, USA), Paul A. Stokstad in a garage in 1964
- *Vernier Software & Technology* (Beaverton, Oregon, USA), David and Christine Vernier (former teachers), founded in 1981
- *LogIT* (Norfolk, Britain), DCP Microdevelopments founded in 1981
- ... ???

**PASCO**



**LogIT**  
world



# Vernier

## Data-Collection Technology

COMPUTERS + HANDHELDS



[www.vernier-intl.com](http://www.vernier-intl.com)



Chemistry | Physics | Biology | Biotechnology | Engineering | Physical Science  
Math | Environmental | Water Quality | Earth Science | Physiology | Middle School



CATALOGUE  
**2010**





ORDER CODE  
**LABQ**

## Breakthrough data-collection technology—the Vernier LabQuest®

Presenting the most powerful and intuitive interface for science education. Engage your students with hands-on science in your classroom or in the field.

Use it as a standalone device or as a computer interface with our award-winning *Logger Pro* software. Created with today's classroom in mind, you will love its durability, vivid color touch screen, and ease of use. And, of course, since it was developed by Vernier, it is backed by comprehensive curriculum, a generous warranty, and legendary support.

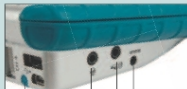


### Six sensor ports

- Provides maximum versatility
- Compatible with your existing Vernier sensors

### Computer interface

Connect LabQuest to a Windows or Macintosh computer via USB to collect data in *Logger Pro*.



**Stylus**

**Audio in**

**Power**

Connect to power and recharge LabQuest's built-in battery

### Audio out

Use audio out to connect headphones or speakers




**SD/MMC card slot**

**USB Peripherals expansion**

Connect to a printer, Flash drive, or other devices using USB

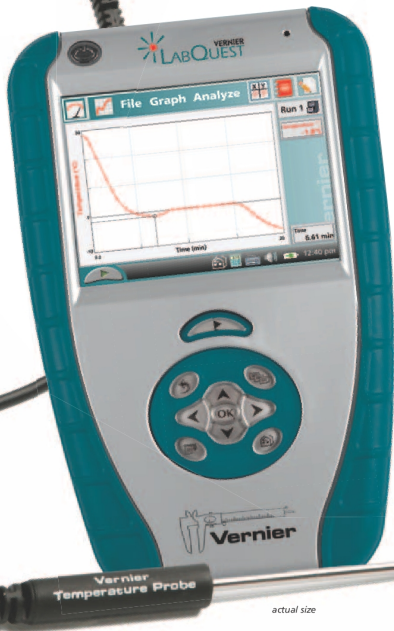
# \$448

Included with LabQuest: LabQuest unit; power adapter; USB cable; CD containing *Logger Lite* software, LabQuest reference guide, Flash introduction, LabQuest Emulator Software; Quick-Start Guide; 2 Styluses; Stylus tether



**TECHNICAL SPECIFICATIONS**

SCREEN SIZE	7 cm x 5.3 cm
SCREEN RESOLUTION	320 x 240 color graphic display
WEIGHT	350 g
INPUT METHOD	Touch screen, on-screen keyboard, attach an external keyboard, or buttons
CPU	416 MHz Application Processor
SAMPLING RATE	100,000 samples per second
STORAGE	40 MB built-in, SD/MMC card slot for expandability
BATTERY	Lithium-ion rechargeable
DURABILITY	Water resistant and will withstand a fall from a classroom lab bench



ORDER CODE  
**LABQ**

## Key Features:

- Sample data at 100,000 samples per second
- Download over 400 teacher-tested experiments FREE using the Lab Organizer
- Get started quickly with free Logger Lite software
- Choose from 66 compatible sensors
- Buy with confidence knowing LabQuest is backed by a 5-year warranty



MultiMedia & Internet@Schools



## Built Tough

Meet our durability testers. Students are tough. We built the Vernier LabQuest interface with rugged reliability in mind. The Vernier LabQuest is designed to withstand a fall from a lab bench. It is splash resistant and holds a battery charge for your entire school day. So go ahead—teach your young scientists about real-world data analysis. Vernier will be there to support you with tough technology. [Note: some sensors and types of experiments require more power than others, so a brief mid-day charge may be necessary.]

### Environmental Specifications:

- 0 – 70°C
- Splash and moisture resistant
- Rugged enclosure with rubber molding for shock absorption



### Print Directly from LabQuest

LabQuest can print directly to most HP printers. Simply connect LabQuest to the printer with a standard USB cable and choose Print from the File menu. Choose full-color or grayscale, and you'll get a full-size print in moments. See [www.vernier.com/labqprinters](http://www.vernier.com/labqprinters) for details.

### NEW WiFi USB Adapter

Add wireless connectivity to your LabQuest with the Vernier WiFi USB Adapter. See our web site [www.vernier.com/labqwifi](http://www.vernier.com/labqwifi) for details.



### ORDER CODE WIFI-USB



ORDER CODE  
LQ-LAN

### LabQuest Lanyard

This lanyard connects to the back of your LabQuest and gives students even more freedom to explore. Best of all, you don't have to worry about students dropping their interface during field studies.

### ORDER CODE LQ-CRG



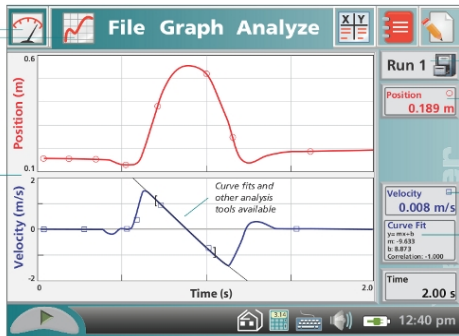
### NEW LabQuest Charging Station

Multi-bay charging capability for your LabQuest

Want a way to charge and store your LabQuests? The LabQuest Charging Station is the perfect solution. Each charging station has four charging slots. LEDs on the charging station indicate the charging status. The compact design uses desk space efficiently. Because the charger holds four LabQuests, it is easy and affordable to accommodate small and large lab setups.

Quick access to graphs, tables, and meters

One or two high resolution plots of data are displayed in real time.



Multiple runs can easily be stored and recalled later.

Live display of sensor data

Curve fit statistics are displayed.

## Built-In Software

### ANALYSIS FEATURES

- Perform linear and curve fits
- Draw a prediction before collecting data
- Display two graphs at once
- Display a tangent line on the graph
- Autoscale
- Integral function
- Statistics

### BUILT-IN APPLICATIONS

- Stopwatch
- Periodic table
- On-screen keyboard
- Scientific calculator
- Audio Function Generator
- Power Amplifier (requires Vernier Power Amplifier)

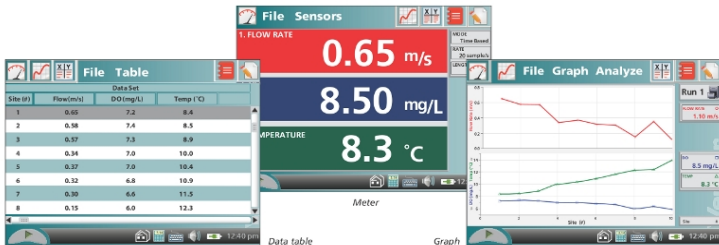
### OTHER GREAT FEATURES

- Export data to Logger Pro
- More than 100 preloaded lab instructions from Vernier's popular lab books
- Notes field
- Voice annotation with internal microphone
- Find slopes, fit a line to a portion of your data, and display position data and its derivatives

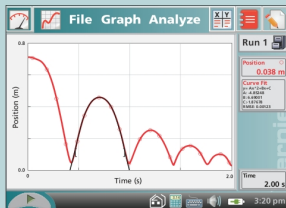
## One-Touch Simplicity

The LabQuest Graphing and Analysis Application gives your students real-time graphing capabilities in a handheld device. It's powerful—yet beautifully simple.

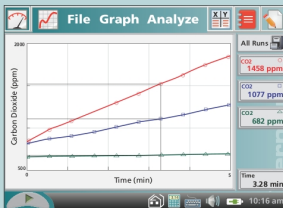
Your students can collect data and view them in a Meter, Data Table, and Graph View.



## Data analysis and other applications at your fingertips



Collect position data. Show students how the ball bounces and fit a curve to your data.



Collect and display data for several sensors or runs on one graph.

On-board Periodic Table

Audio Function Generator

Use LabQuest as a stopwatch

On-board scientific calculator

\* Screen shots shown at 300 dpi print quality. Actual screen resolution on the LabQuest is 320 x 240 color graphic display.



ORDER CODE  
LQ-MINI

## Powerful. Affordable. Easy to Use.

LabQuest Mini brings the power of Vernier's award-winning LabQuest technology to teachers who don't need the versatility of a standalone device. The perfect solution for educators collecting data with a computer, LabQuest Mini interfaces with Logger Pro software for unparalleled power, analysis, and curricular support.

### Key features include:

- 100 kHz maximum sampling rate gives you the unrivaled power of LabQuest
- Five sensor ports give you the flexibility to choose from 54 compatible sensors.
- Logger Lite software gets your students collecting, graphing and analyzing data. And the best part? It is free with purchase.



## Five Total Sensor Ports



### Three Sensor Ports

For use with 48 compatible sensors such as temperature, pH, and Gas Pressure Sensors.



### Two Digital Sensor Ports

For use with motion detectors, photogates, radiation monitors, rotary motion sensors, and drop counters.

## Collecting data exclusively on computers or netbooks?

LabQuest Mini may be perfect for you!

- Comes with FREE Logger Lite Software to get your students quickly collecting and analyzing data.
- Looking for more advanced features than Logger Lite provides? Our award-winning Logger Pro 3 software provides advanced analytical features including video analysis. See pp. 14–17 for additional details.
- Use with over 16 Vernier lab books covering core topics in Biology, Chemistry, Earth Science, Environmental Science, Physical Science, Physics, Physiology, and Water Quality.

**\$203**

## Go! LINK<sup>®</sup> VERNIER

### USB Interface

A quick and affordable way to get started with data-collection technology.

- Single-channel interface connects any one of 46 Vernier sensors to your computer's USB port. (See list of sensors.)
- Dozens of experiments from our popular lab books can be conducted using Go!Link.

#### Go!Link, ORDER CODE GO-LINK

Includes Logger Lite Software

#### Teacher Pack of 8 Go!Links, ORDER CODE GL-TP

Includes Logger Lite Software



# \$78

## FREE Logger Lite Software

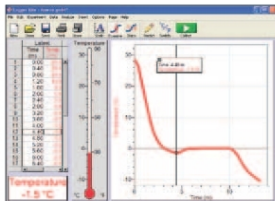
### Real-Time Graphing

Go!Link, Go!Temp and Go!Motion include Logger Lite software with purchase.



Rather than tell students that water changes state at 0°C, let them see it for themselves! You can also investigate magnetic fields, gravity, and force with hands-on exploration and activities to help reinforce scientific concepts.

- Collect data using one or more sensors
- Calculate statistics
- Store runs
- Annotate graphs
- Print graphs
- Write reports
- Easily export data and graphs
- And much more!



Want to import experiment movies and synchronize data with video? You'll want Logger Pro.

### Logger Pro 3

Logger Pro 3 software, ORDER CODE LP

For more advanced software features, buy just one copy—site license for ALL school and students' personal computers is included! See pp. 14–17 for details.

### GO! LINK COMPATIBLE SENSORS

SENSOR	CODE	SENSOR	CODE	SENSOR	CODE
Accelerometers		Gas Pressure Sensor	GPS-BTA	Respiration Monitor or Belt (Requires GPS-BTA)	RMB
25-g Accelerometer	ACC-BTA	Hand Dynamometer	HD-BTA	Salinity Sensor	SAL-BTA
Low-g Accelerometer	LGA-BTA	Hand-Grip Heart Rate Monitor	HGH-BTA	Soil Moisture Sensor	SMS-BTA
Barometer	BAR-BTA	Instrumentation Amplifier	INA-BTA	Sound Level Meter	SLM-BTA
Blood Pressure Sensor	BPS-BTA	Ion-Selective Electrodes		Spirometer	SPR-BTA
Charge Sensor	CRG-BTA	Ammonium Ion-Selective Electrode	NH4-BTA	Temperature Probes	
CO <sub>2</sub> Gas Sensor	CO2-BTA	Calcium Ion-Selective Electrode	CA-BTA	Extra-Long Temperature Probe	TPL-BTA
Colorimeter	COL-BTA	Chloride Ion-Selective Electrode	CL-BTA	Infrared Thermometer	IRT-BTA
Conductivity Probe	CON-BTA	Nitrate Ion-Selective Electrode	NO3-BTA	Stainless Steel Temperature Probe	TMP-BTA
Current Probe	DCP-BTA	Light Sensor	LS-BTA	Surface Temperature Sensor	STS-BTA
Differential Voltage Probe	DVP-BTA	Magnetic Field Sensor	MG-BTA	Thermocouple	TCA-BTA
Dissolved Oxygen Probe	DO-BTA	O <sub>2</sub> Gas Sensor	O2-BTA	Wide-Range Temperature Probe	WRT-BTA
Dual-Range Force Sensor	DPS-BTA	ORP Sensor	ORP-BTA	Turbidity Sensor	TRB-BTA
EKG Sensor	EKG-BTA	pH Sensor	PH-BTA	UVA Sensor	UVA-BTA
Electrode Amplifier	EA-BTA	<b>NEW</b> pH Sensor, Tris-Compatible Flat	FPH-BTA	UVB Sensor	UVB-BTA
Flow Rate Sensor	FLO-BTA	Relative Humidity Sensor	RH-BTA	Voltage Probe	VP-BTA
Force Plate	FP-BTA				



a



b



c

**a. Voltage Probe, ORDER CODE VP-BTA**

The Voltage Probe can be used to study voltages produced by simple voltaic cells (like the lemon battery at the right), for simple electric circuit labs, or to do battery life studies.

Shown here with a Go!Link USB interface and Logger Lite software (included FREE with purchase). See page 12 for more information.

Go!Link, ORDER CODE GO-LINK

**b. Motion Detector, ORDER CODE MD-BTD**

The Motion Detector can be used to study the motion of a cart on a ramp or a ball tossed into the air. You can also use it to teach your students how graphs work by having them try to move in front of the motion detector to match a distance vs. time or velocity vs. time graph.

- Measure objects as close as 15 cm to the detector and as far away as 6 m.
- Pivoting head and rubber feet for ease of use

**c. Light Sensor, ORDER CODE LS-BTA**

Our Light Sensor approximates the human eye in spectral response and can be used over three different illumination ranges, which you select with a switch. Use it for inverse square law experiments or for studying polarizers, reflectivity, or solar energy.

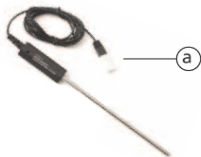


*Experiment 33 from Physical Science with Vernier, Measuring the voltage of a lemon battery, "Lemon Juice" Lab*



*Collecting data with a Light Sensor*





### a. Wide-Range Temperature Probe

ORDER CODE **WRT-BTA**

Our newest temperature probe features a wide temperature range, from  $-20^{\circ}\text{C}$  to  $330^{\circ}\text{C}$ . The high upper limit of the sensor allows for melting point determinations of many organic compounds. Not only does it have a wider range, but it uses RTD (Resistance Temperature Detection) technology to establish a  $\pm 0.1^{\circ}\text{C}$  accuracy throughout its temperature range, as well as excellent stability and repeatability. Each unit is individually calibrated. See page 114 for more details.

### b. Electrode Support, ORDER CODE: ESUP

Our Electrode Support is a great complement to the Vernier Stir Station, as well as a perfect holder for many sensors. It is built to connect to all standard ring-stand posts; its large-handled locking nut keeps your sensors firmly in place. The larger opening (13 mm in diameter) is perfect for our pH, ISE, Conductivity, and ORP sensors. The smaller opening (5 mm) is designed to hold our Stainless Steel Temperature Probe or the Vernier GoTemp.

### c. Thermocouple, ORDER CODE TCA-BTA

This sensor uses type-K thermocouple wire to measure temperatures over the range of  $-200$  to  $1400^{\circ}\text{C}$ . It can be used to measure flame temperatures as high as  $1400^{\circ}\text{C}$ , or liquid nitrogen temperatures at  $-196^{\circ}\text{C}$ . The Thermocouple has an internal ice-point compensation chip, so you do not need to place a reference wire in an ice-water bath. You can simply use one measuring lead to take temperature readings. Each Thermocouple is individually calibrated.



### Nuclear Radiation with Vernier lab book

ORDER CODE **NRV**

Six ready-to-use experiments. Also includes a CD with word-processing files for experiments, so you may easily edit labs to fit your style. More on page 82.

### Digital Radiation Monitor,

ORDER CODE **DRM-BTD**

See page 110.



#### LabQuest for Chemistry

- Durable and splash-resistant
  - Easy to use with color touch screen navigation
  - Built-in lab instructions
  - Voice and text annotations for field work
- See pp. 3-9 for more information.

Conducting a distillation using LabQuest and a Wide-Range Temperature Probe



## Global Positioning Systems (GPS)

### a. Vernier GPS Sensor

ORDER CODE **VGPS**

The Vernier GPS Sensor (Global Positioning System) collects location data such as latitude, longitude, and altitude right on your LabQuest or computer. This small, lightweight sensor connects directly to the USB port and works with LabQuest App and Logger Pro software. See a real-time graph of latitude vs. longitude, or export the data to various mapping programs such as Google Maps or ArcGIS.

With the GPS Sensor, LabQuest can record your location as you measure water quality at various sites along a stream, then map the data via Logger Pro.

Physics students can use a LabQuest and GPS Sensor to track location vs. sensor data, such as acceleration, in a car or train. Logger Pro can export a color-coded track for display to a map.

### b. Garmin eTrex Venture HC

ORDER CODE **GAR-VENTHC**

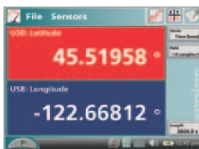
The eTrex Venture HC features include:

- A high-sensitivity GPS receiver for peak performance in any environment.
- Built-in basemap containing lakes, rivers, cities, interstates, national and state highways, railroads and coastlines.
- 256-color, sunlight-readable display makes it easy to distinguish map details—even in bright sunlight.
- Location data from the Garmin eTrex Venture HC can be transferred to Logger Pro.

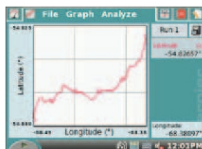


### MORE ONLINE

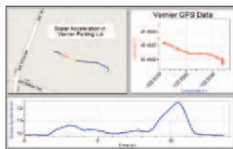
For a complete list of compatible GPS models, visit [www.vernier.com/gps](http://www.vernier.com/gps)



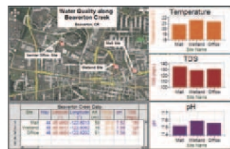
LabQuest showing latitude and longitude



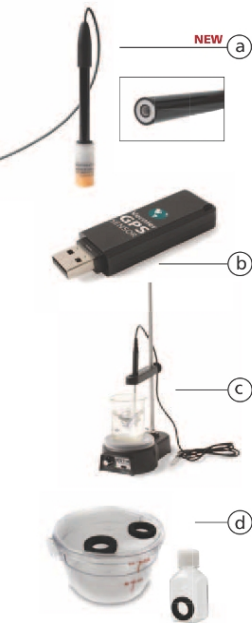
LabQuest graphing the path of a bus ride in Tierra del Fuego



Visually mapping acceleration using Google Maps and Logger Pro



Logger Pro combines GPS data and water quality sensor data



NEW

a

**a. NEW Tris-Compatible Flat pH Sensor**ORDER CODE **FPH-BTA**

The new Tris-Compatible Flat pH Sensor uses a double-junction electrode, making it compatible with Tris buffers and solutions containing proteins. The flat glass shape also makes it ideal for measuring the pH of semisolids, such as food or soil.

**b. Vernier GPS Sensor**ORDER CODE **VGPS**

The Vernier GPS (Global Positioning System) Sensor collects location data such as latitude, longitude, and altitude right on your LabQuest or computer.

- Record your location as you measure water quality at various sites along a stream.
- Track location vs. sensor data, such as acceleration in a car or train.

**c. Stir Station**ORDER CODE **STIR**

The Stir Station is a high-quality, multi-function magnetic stirrer. The speed can easily be fine-tuned to achieve the desired effect. More on page 37.

- Has a built-in ring stand.
- Runs on batteries or AC power.
- Includes Vernier Microstirrer and traditional stir bar.
- Temperature Probe and Electrode Support shown, but not included.

**d. BioChambers**2000 mL, ORDER CODE **BC-2000**250 mL, ORDER CODE **BC-250**

BioChambers provide a way for both CO<sub>2</sub> Gas and O<sub>2</sub> Gas sensors to be used at the same time in a closed system.

**VERNIER GPS SENSOR**

Connect directly to the USB port of your computer or LabQuest. See page 105 for more information.



#### a. EKG Sensor, ORDER CODE EKG-BTA

The EKG sensor is a biopotential sensor that can be used to record EKGs from the heart and surface EMGs from muscle. Analyze the electrical activity of the heart, compare the activity of muscles, or investigate reflex activity. See page 103 for more details on this sensor.



#### b. Hand Dynamometer

ORDER CODE HD-BTA

The strain-gage based isometric dynamometer can be used to measure grip strength, pinch strength, and perform muscle fatigue studies. Combine the dynamometer with a Vernier EKG sensor (used to measure EMG) to measure maximum grip strength and correlate this with electrical activity of the muscles involved. See page 105 for more details on this sensor.



#### c. Spirometer, ORDER CODE SPR-BTA

Our Spirometer can be used to perform a variety of tests related to air flow and lung volume. The sensor includes a removable flow head (22 mm ID/30 mm OD) for easy cleaning and sterilization and a differential pressure transducer. The Spirometer is designed to make human respiratory measurements at rest and during moderate activity. See page 113 for more details.



#### d. O<sub>2</sub> Gas Sensor, ORDER CODE O2-BTA

The O<sub>2</sub> Gas Sensor measures oxygen concentration in air. Use this sensor to analyze breathing patterns, or combine with a Vernier Spirometer to measure tidal volumes and oxygen concentrations of deeply inhaled and exhaled air. See page 108 for more details of this sensor.

#### e. Other Vernier Biomedical Sensors:

- Blood Pressure Sensor
- Hand-Grip Heart Rate Monitor
- CO<sub>2</sub> Gas Sensor
- Surface Temperature Probe

See pp. 76–77 for additional physiology sensors appropriate for biomedical engineering.



PROJECT LEAD THE WAY  
**PLTW**

**Biomedical Sciences™**  
Program from Project  
Lead The Way

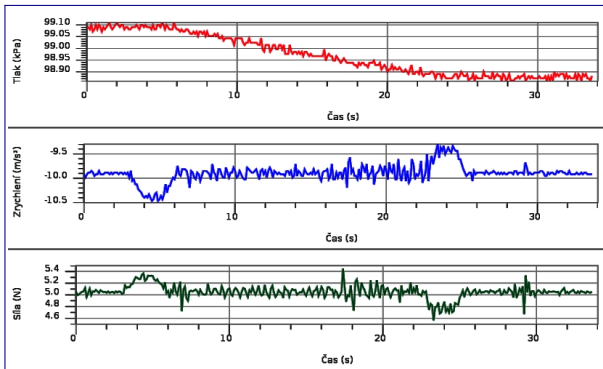
Project Lead The Way is a U.S. organization that works with schools to implement rigorous hands-on, project-based engineering and engineering technology programs. They provide educators with the training and course materials needed to prepare students to be successful in these pursuits. For more information on PLTW, go to [www.pltw.org](http://www.pltw.org)

We have worked with PLTW to integrate our SensorDAQ interface and our physiology sensors into their Biomedical Sciences courseware. For more information, go to [www.vernier.com/pltw](http://www.vernier.com/pltw)



**A FEW EXPERIMENTS ...**

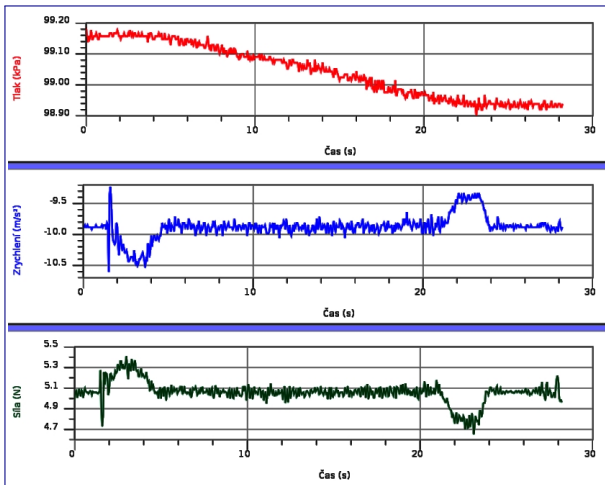
# Lift – faculty building



- 10 or 25 readings per second
- height estimate for 6 floor  
 $\Delta z = 5 \cdot (3,33 + 0,47) \text{ m} \approx 19 \text{ m}$

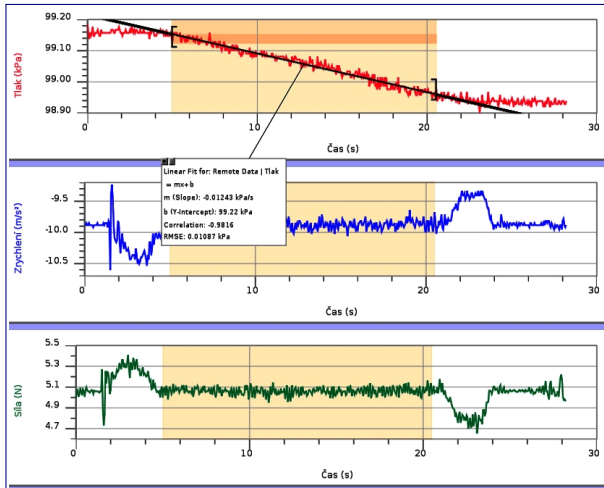
CREATIVELY

# Lift – faculty building



- time  $\Delta t = 18,1 \text{ s} \implies v = 1,04 \text{ m} \cdot \text{s}^{-1}$
- pressure change  $\Delta p = -0,23 \text{ kPa}$ ,  
theoretical value  $\Delta p \approx -0,2185 \text{ kPa}$

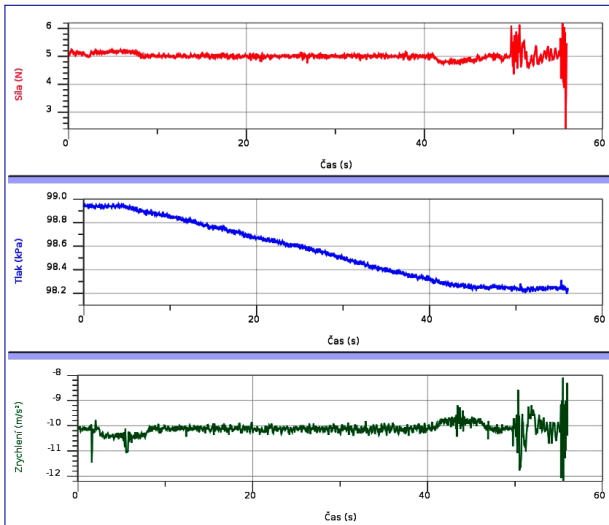
# Lift – faculty building



- linear regression



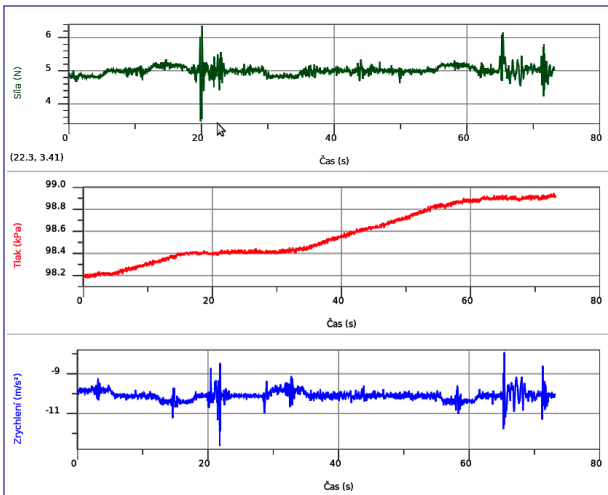
# RCO v Olomouci



[WWW.RCO.CZ](http://WWW.RCO.CZ)

- time  $\Delta t = 45$  s
- velocity  $v \approx 1,5 \text{ m} \cdot \text{s}^{-1}$ , height  $\Delta z \approx 67$  m

# RCO v Olomouci

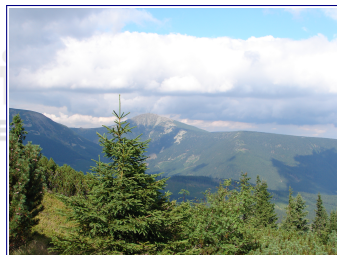
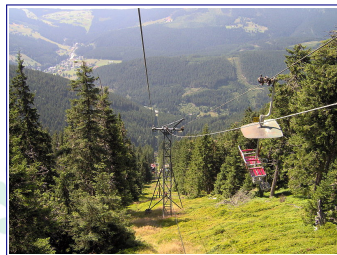
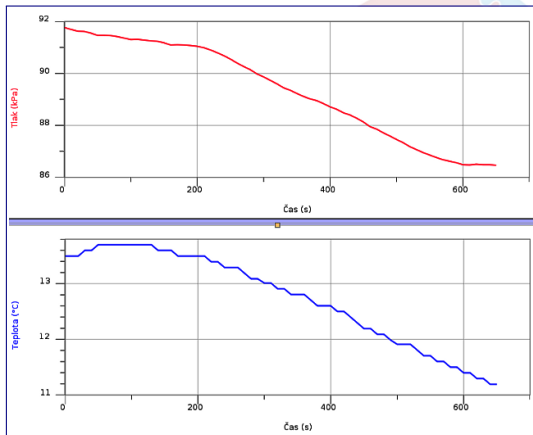


[WWW.RCO.CZ](http://WWW.RCO.CZ)

- one stop on the way down
- $\Delta p = -0,70 \text{ kPa}$ , theoretical value
- $\Delta p \approx -0,78 \text{ kPa}$

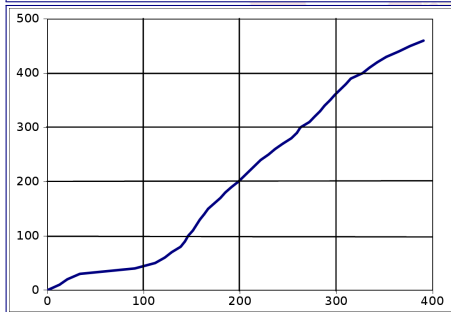
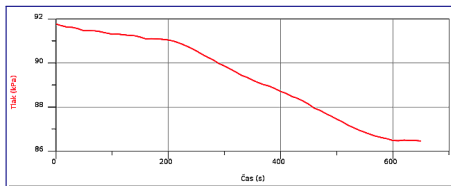
# Sněžka mountain

- holiday trip – cableway
- height  $\Delta h = 1354 - 890 \text{ m} = 464 \text{ m}$
- internal thermometer



# Sněžka mountain

- comparison with the terrain profile (from the map)



- **Motion detector**

- observing oscillations
- measuring people's velocity
- falls and reflections of the ball



- **Dual-range Force sensor**
  - observing oscillations
  - friction measurement



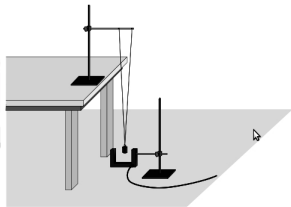
- **Thermometer**

- observe the decline of temperature for dry and wet thermometer
- efficiency of the electric kettle



## • Photogate

- period of the pendulum
- sending balls, combs





# Workplace 5: pressure

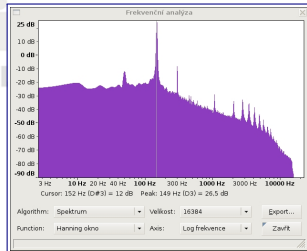
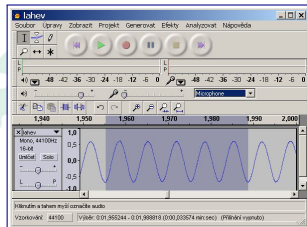
- **Gas pressure sensor**

- hydrostatic pressure in a PET bottle
- change of the atmospheric pressure with the altitude
- Boyle-Marriott's law



# „Logger“ from Your computer

- **freeware** Audacity software
- acoustics, short-times measurements, signal generation
- some possible measurements:
  - velocity of the sound
  - **sound of the bottle** frequency spectrum, glass with water
  - tuning fork sound, damping decrement
  - falls and reflections of the ball
  - differences between phonemes
  - echo (reverberation) in the room
  - sound of the whistles, fillip with one's fingers
  - whirlies

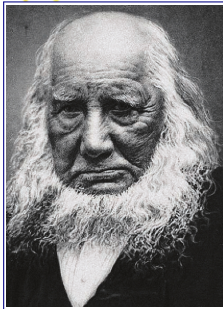
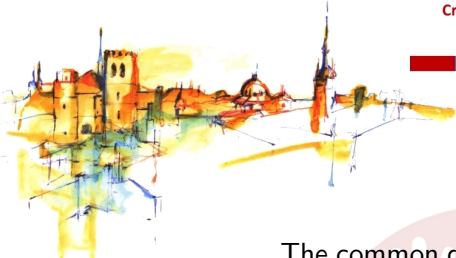


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The common denominator of all Grundtvig's pedagogical efforts was to promote a spirit of freedom, poetry and disciplined creativity, within all branches of educational life.

„A simple, cheerful, active life on earth,  
A cup I'd not exchange for monarch's chalice,..."

*Nikolaj Frederik Severin Grundtvig*  
(September 8, 1783 – September 2, 1872)

