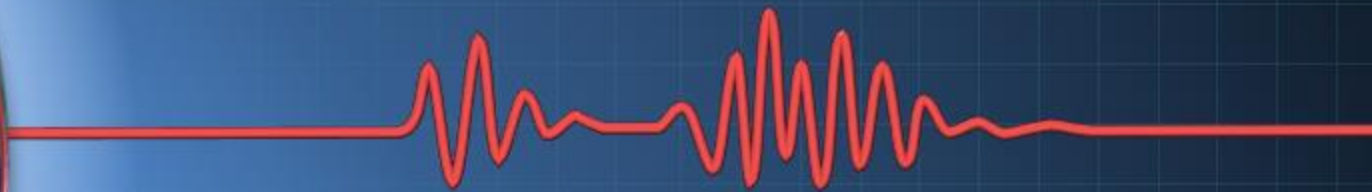


Jonathan David
Clément Le Marquis
Mickael Renault

Building a vertical motion seismometer

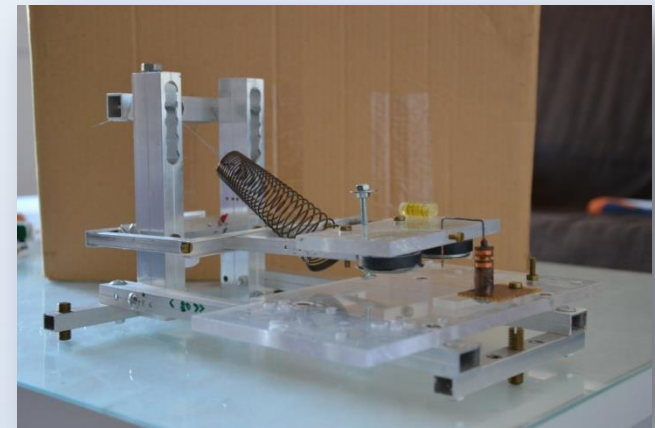


with



- **I) Project management**
- **II) Seismic sensor and analog acquiring system**
- **III) Digital data transmission and user interaction**
- **IV) Future directions**
- **V) Conclusion**

- Erasmus+ Project
- Low cost seismometer
- Existing mechanical part
- Digital processing with a Raspberry Pi B+



Building a seismometer

- Timing plan (Schedule)

2014	Novembre	Présentation du projet		
		21 nov. 2014 RDV Préparatoire M. Luc Deneire	04 déc. 2014 Présentation du Projet à GéoAzur	
2015	Décembre	Etudes Bibliographiques		
		Approche sismologie / sismométrie / mécanique		12 déc. 2014 Cours de sismométrie M. Robert Pillet
		Etude du modèle, choix du sismomètre		
		Etude du modèle de convertisseur, et codage		
	Janvier	Etude des cartes existantes et leur configuration		8 jan. 2015 Réunion de projet au CIV, cours de sismologie et rencontre avec les élèves
		Etude des librairies pythons orientées sismométrie		
		Etude des coûts, Précision du cahier des charges		
		Choix / préparation des composants		
	Février	Etudes des capteurs de vitesse et de déplacement du marché	Etudes des Filtres, techniques de rétroactions et amplificateur	Choix et commande de la carte programmable
		Contact des industriels du secteur		Etude comparative des outils de mesure du temps
2015	Mars	Etude de faisabilité et de viabilité de la conception d'un capteur par nos soins	Etude comparative des convertisseurs adaptés au projet	Choix des composants numériques : output, connectique...
		Prototype		
	Avril	Configuration, Amélioration, Etalonnage des capteurs Présence de M. Pillet	Installation et paramétrage de la carte Raspberry Pi	
			Développement du programme d'acquisition, de filtrage numérique, de compression et d'encodage des données	
2015	Mai	Conception des circuits d'implémentation de chaque capteur Présence de M. Pillet	Paramétrage et simulation de la contre- réaction du système	Développement de l'interface utilisateur Implémentation du convertisseur Analogique - Numérique
		29 mai 2015 : Visite des élèves du CIV à Polytech, bilan sur l'avancement du projet		

Communication constante et partage d'informations sur l'avancement du projet
avec les élèves du CIV grâce au site internet conçu pour l'occasion :
www.tess-erasmus.fr

- Working Plan :

- Analog part :

- Sensor
- Control loop feedback

- Numeric part :

- Data acquisition
- User interface

Cost analysis

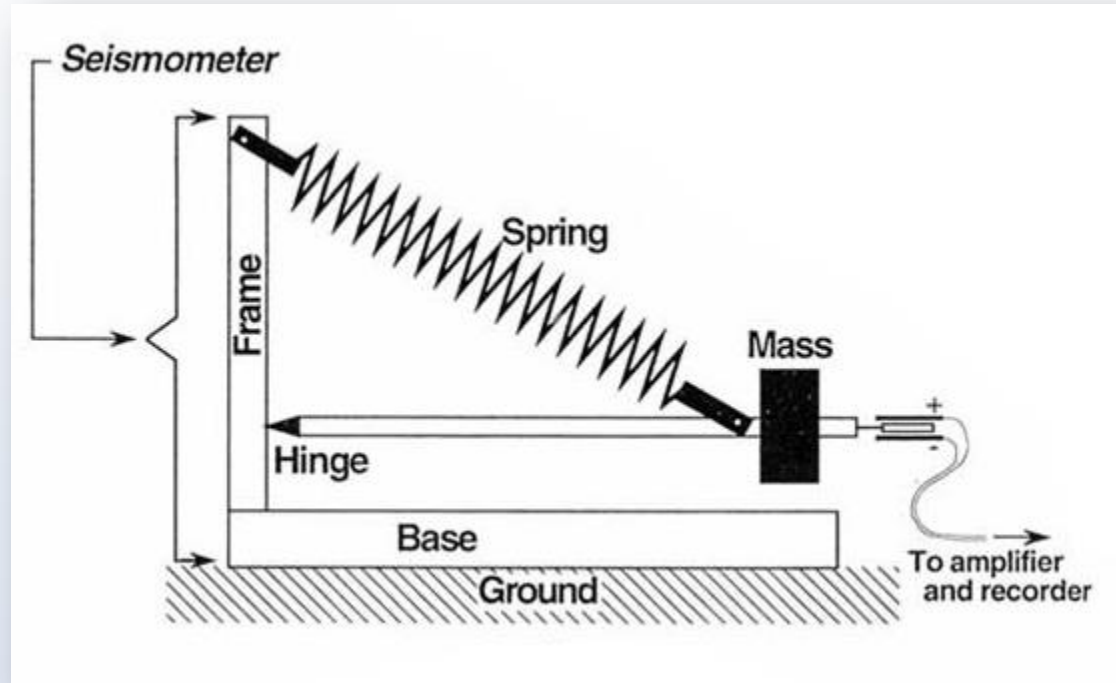
Objective budget : about 200€.

Estimated budget : 180€

We have worked with a handmade sensor. Professional sensor with high sensitivity costs at least 1000€.

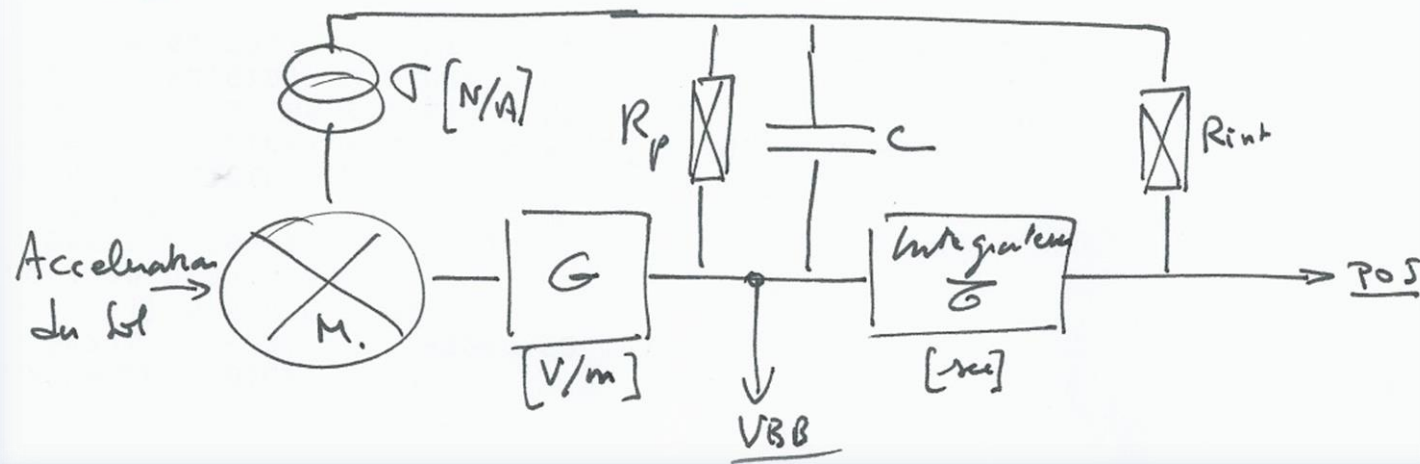
The seismometer

A. Mechanical part



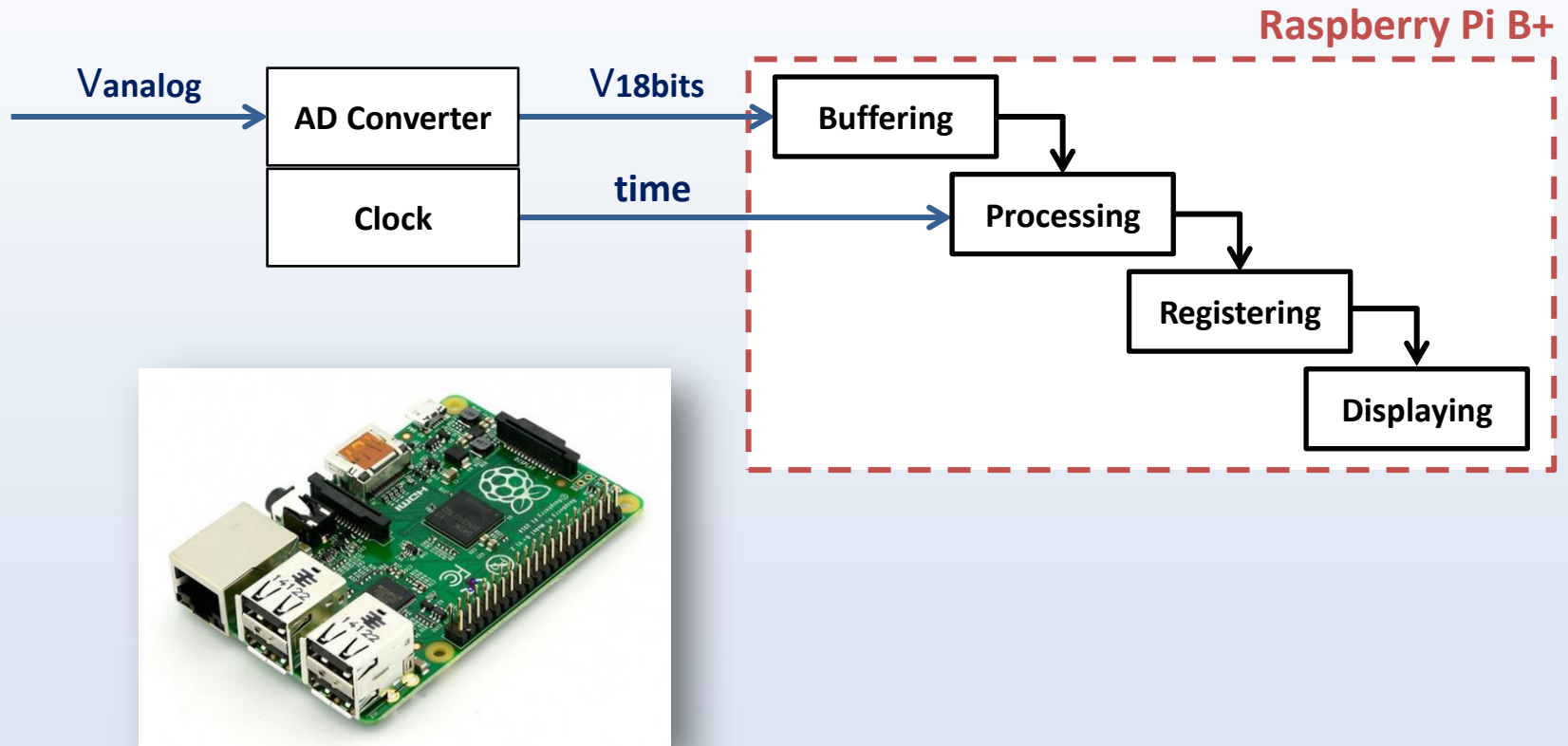
Building a seismometer

B. Analog Part



The seismometer

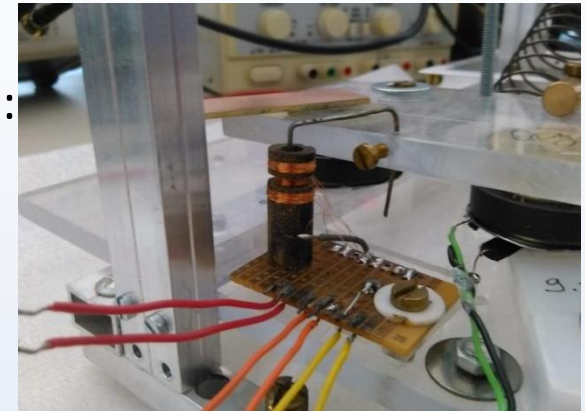
C. Numeric part



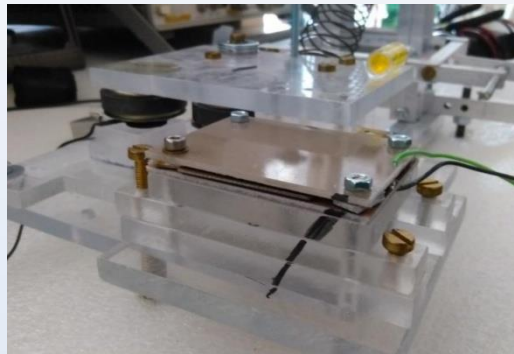
A. Seismic sensor

Using Displacement sensors :

- Inductive (LVDT) :



- Capacitive :



- Optical :



B. Implementation

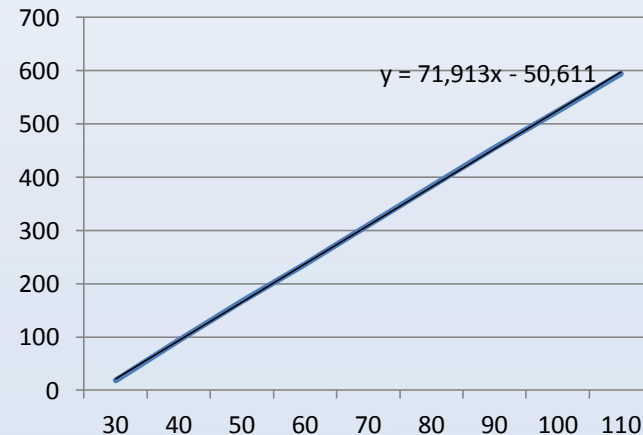
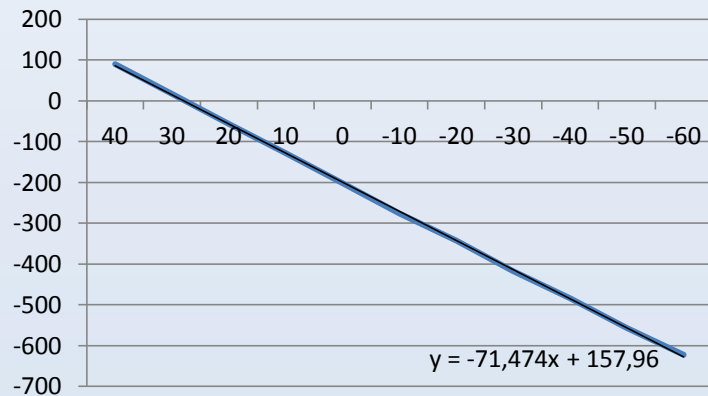
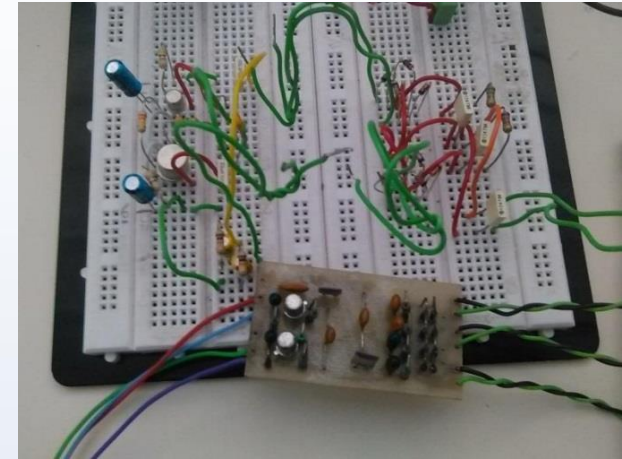
LVDT :

Left part creates current injected in the primary

Right part acquires the position of the mass

Characteristics :

Linearity : 1cm



Building a seismometer

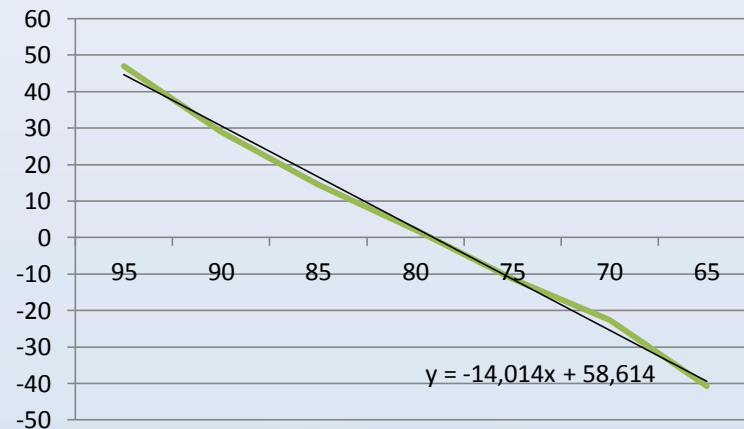
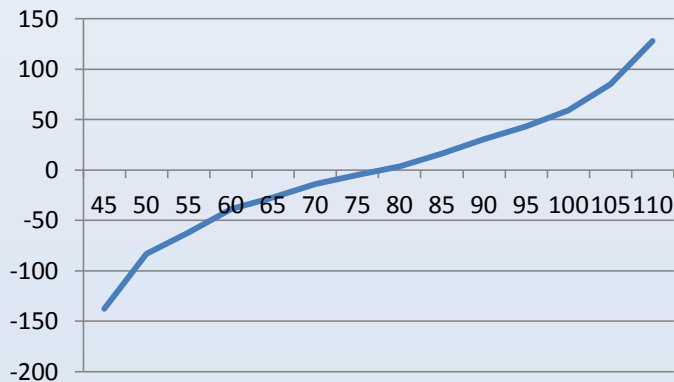
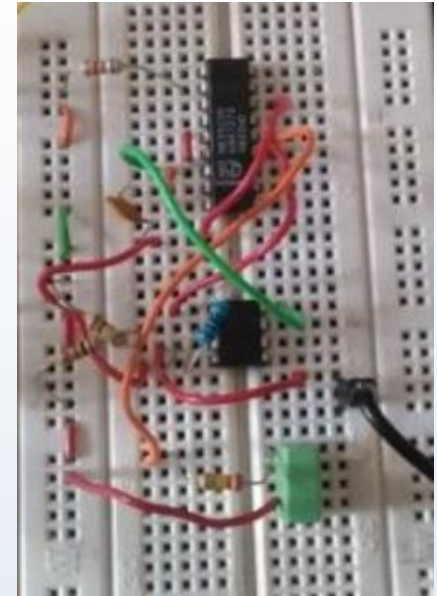
B. Implementation

Capacitive :

Using a NE5521 microchip

Characteristics :

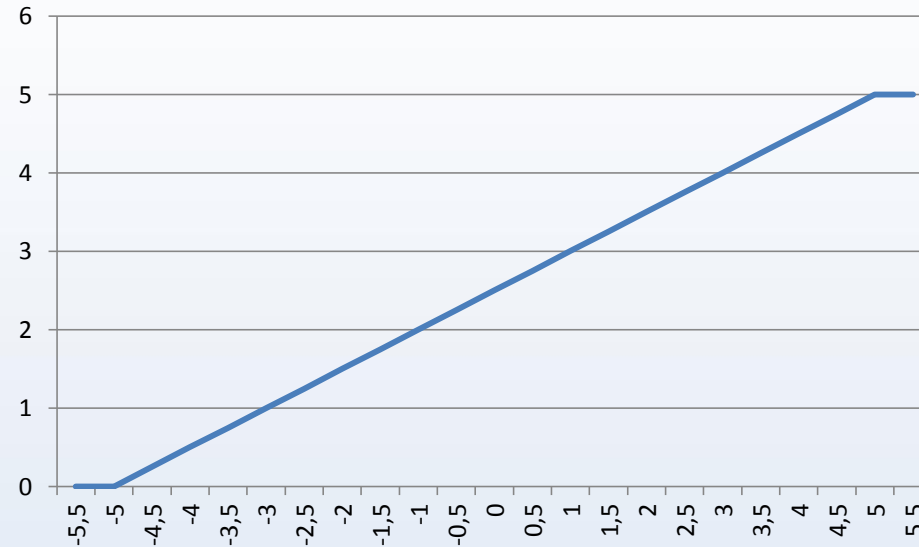
Linearity : 3mm



Building a seismometer

C. Comparison

Optical :
Linearity : 1 cm



Measure : capacitive < LVDT

Linearity : capacitive < LVDT ~ optical

Cost : capacitive = LVDT

=> LVDT is the best solution

Building a seismometer

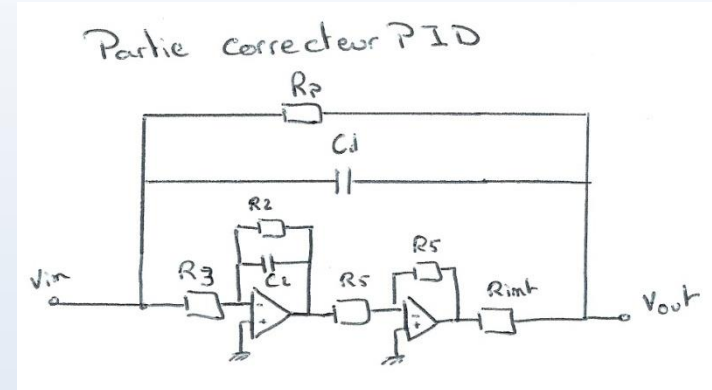
D. Control loop feedback

- Objective
 - Avoid intempestive oscillations of the mass

We have created a PID controller :

Effects of increasing a parameter independently^[13]

Parameter	Rise time	Overshoot	Settling time	Steady-state error	Stability ^[11]
K_p	Decrease	Increase	Small change	Decrease	Degrade
K_i	Decrease	Increase	Increase	Eliminate	Degrade
K_d	Minor change	Decrease	Decrease	No effect in theory	Improve if K_d small



- Modeling
 - Hand schema , Math simulation (Matlab) , Electrical simulation (Cadence)

D. Control loop feedback

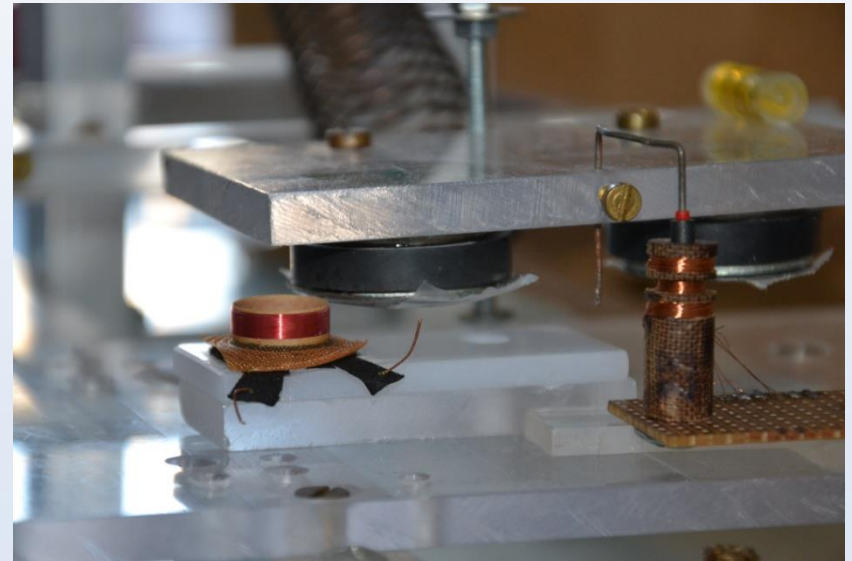
- Forcer

Transform current in movement.

Function on the principe of magnetism.

Characteristic :

$\Sigma = 1.1 \text{ N/A}$

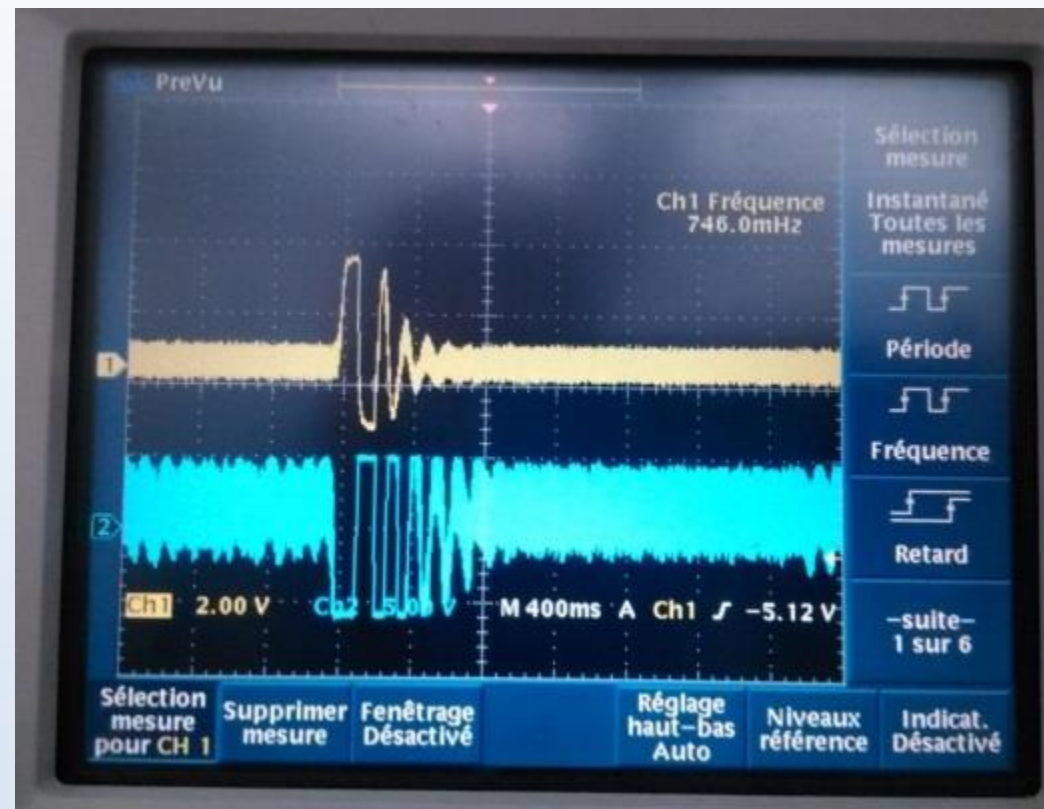


E. Complete analog part test

We have put each part of the seismometer together (mechanical sensor and control loop feedback) and run a test.

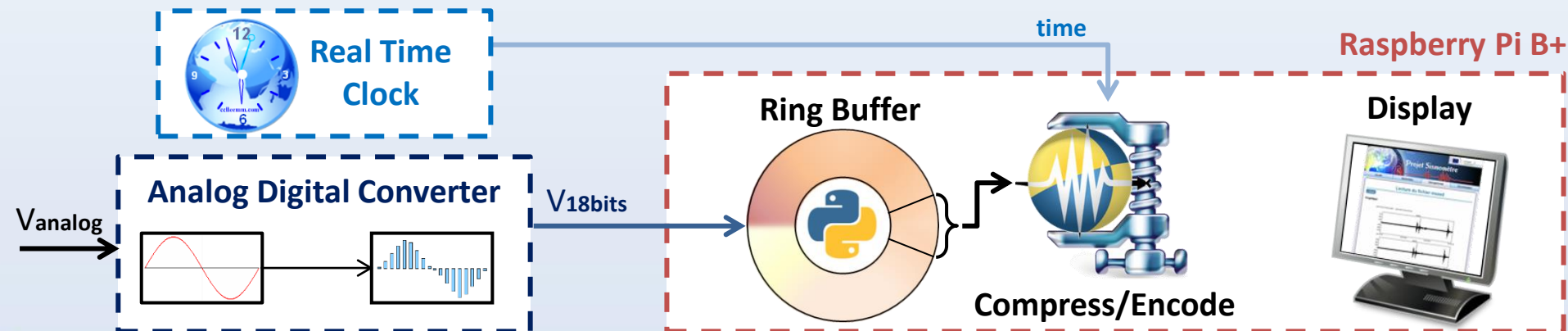
We have punched the table and monitoring the time response of the seismometer

In yellow the position mass signal
In blue the equivalent of the current injected in the forcer



A. Digital process

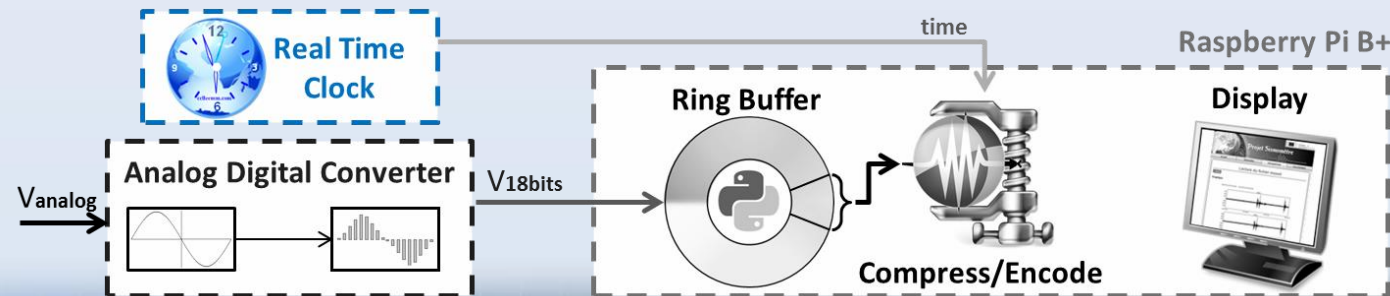
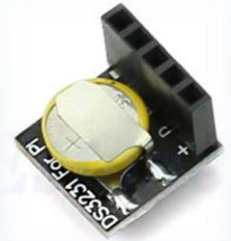
- Analog Digital Converter
- Real Time Clock
- Raspberry Pi B+



Building a seismometer

B. Real Time Clock

- Solution to keep time while system is off
 - Choice between GPS module or RTC module
 - GPS gives time and location, auto-adjusted
 - RTC cheap and accurate : DS3231 $\pm 2\text{ppm}$ $\rightarrow$ max 2,6s/month
- $\rightarrow$ Best compromise : RTC with DS3231 chip (1,73€ with shipping)



Building a seismometer

C. Analog Digital Converter

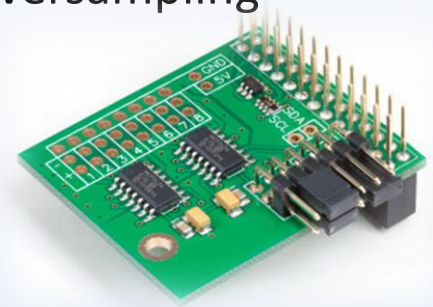
- Why choose a Sigma Delta converter ?
 - Oversampling and averaging for best estimations
 - We can use low resolution ADC if we use enough oversampling

16+ bits resolution

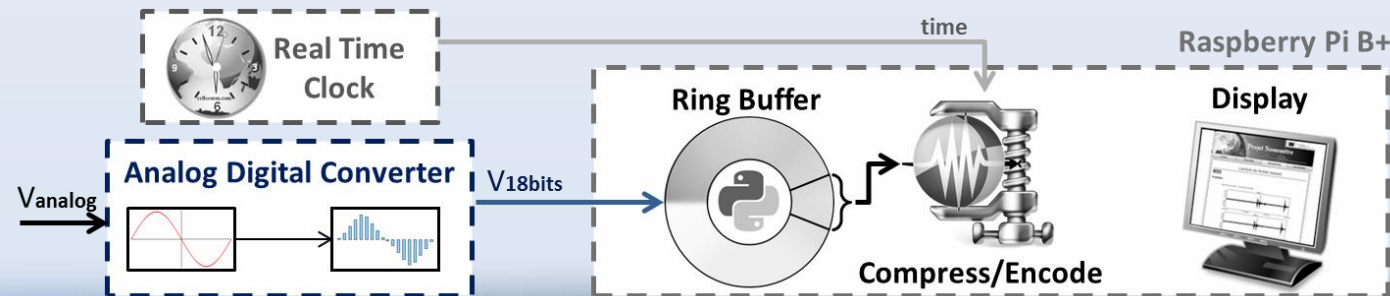
At least 2 channels

Minimal data rate : 125 SPS

Transmission protocol : I2C or SPI



→ AB Electronics Delta Sigma Pi (33€ with shipping)

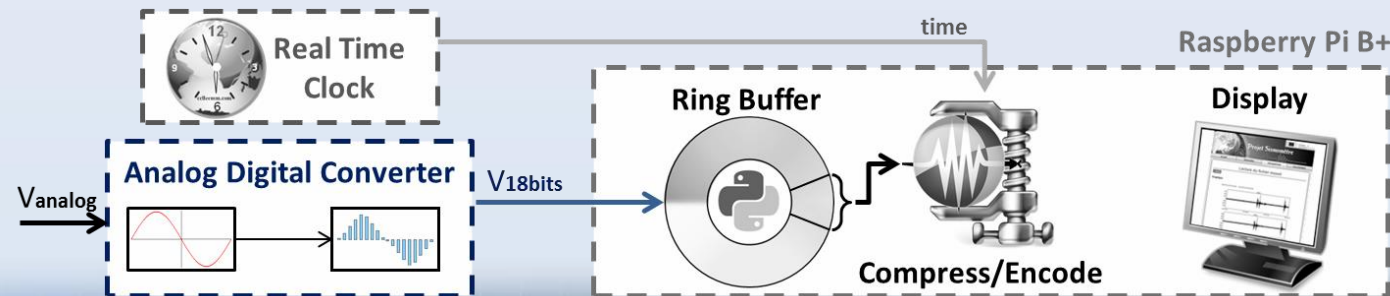
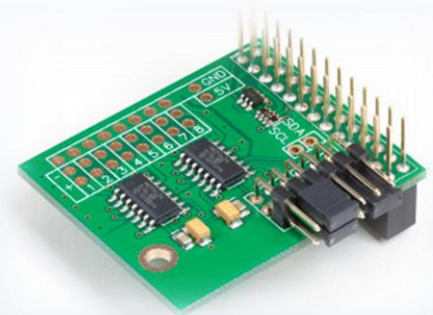


Building a seismometer

C. Analog Digital Converter

AB Electronics Delta Sigma Pi : Features

	Minimal specifications	Delta Sigma Pi
Resolution	16 bits	18 bits
Channels	2	8
Data rate	125 SPS	260 SPS
Transmission protocol	I2C or SPI	I2C (5V 100mA)
Additional features		- Integrated Programmable Gain amplifier (1,2,4, or 8) - One-shot or continuous conversion options



Building a seismometer

D. Ring Buffer

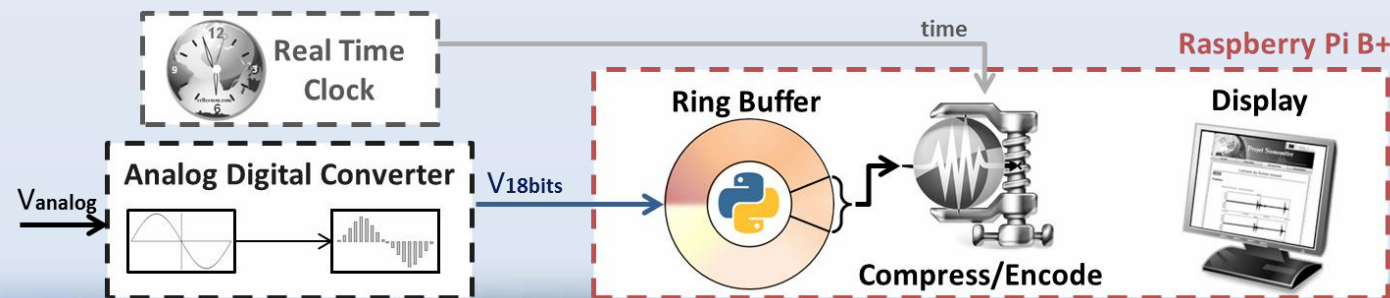
- Continuous reception
- Limited space
- Python 2.7 script for data acquisition on Raspberry Pi B+
 - Best compatibility with seismological tools
 - Integrated in Raspberry Pi : GPIO and I2C control



→ Ring Buffer

with  NumPy

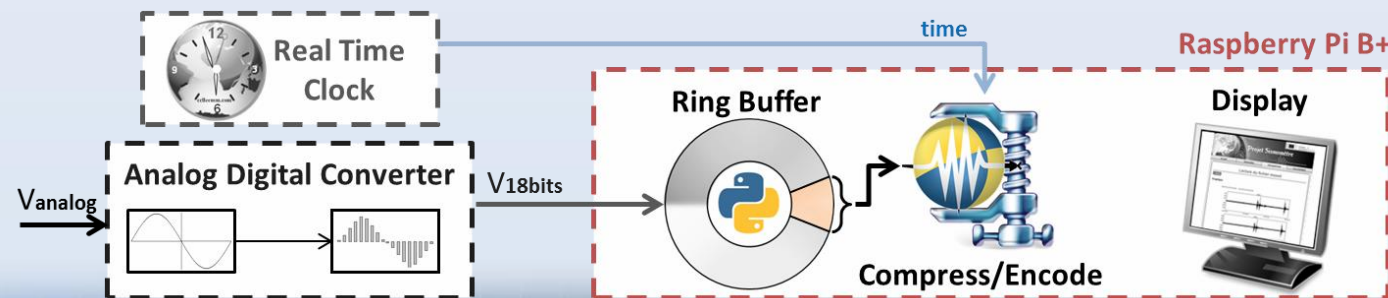
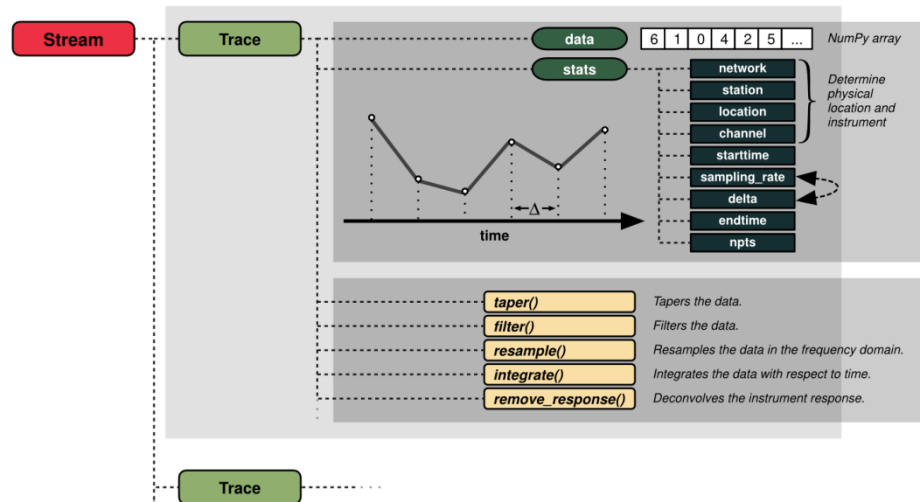
Data rate	Resolution	Duration	Allocated memory
125 SPS	18 bits	24 H	48,6 MB



Building a seismometer

E. Compress and encode

- Register data stream every 30s
- Trace object : [data, metadata]
 - RTC time (of start / end)
 - Characteristics of record
 - Characteristics of seismometer
 - Various filtering functions
- Stream object : [Trace1, Trace2]
 - Position and speed of mass
- Save Stream to MSEED and PNG



Building a seismometer

F. User Interface

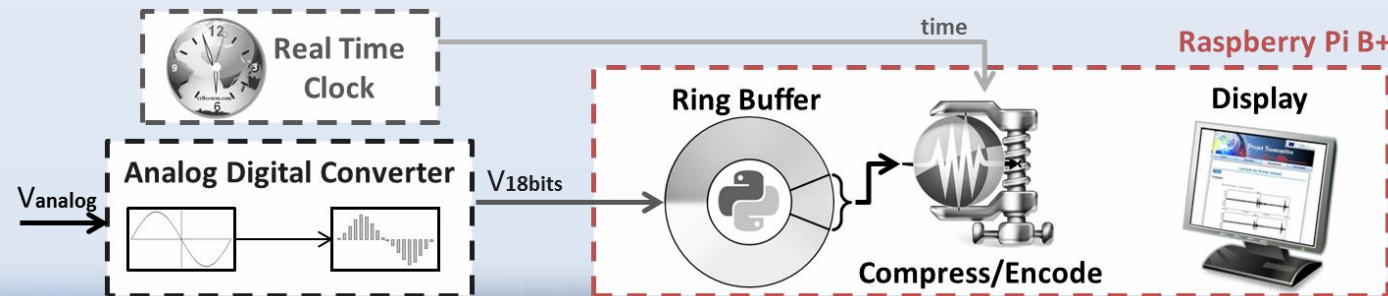
Objective : Avoid misunderstanding instruction and unsafe manipulation



Web Application Interface to replace LXTerminal :

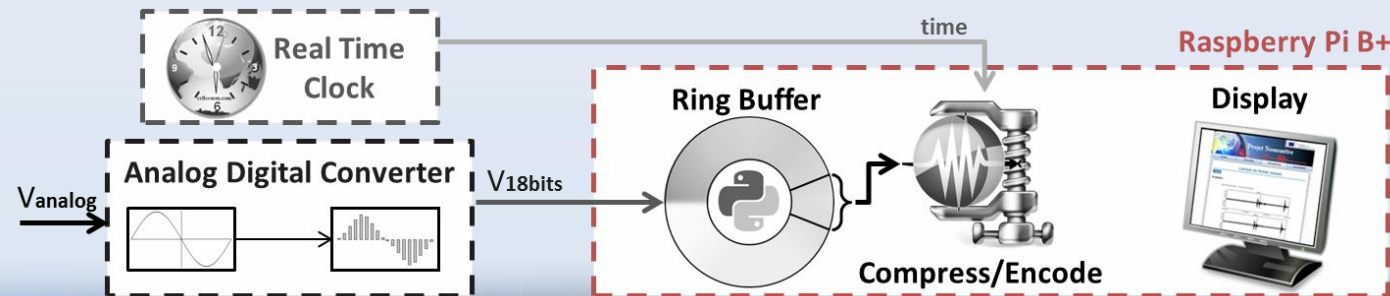


- PHP scripts, HTML and CSS rendering
- PHP call to Python recording script
- Enlarge local server accesses to execute our program
- Display seismograms, system informations, documentation



Building a seismometer

F. User Interface



Building a seismometer

A. Improve feedback circuit

- Maybe develop a numeric feedback on the seismometer. This has never been done because of the time of conversion A/D and D/A
- Give the feedback more adaptive, with different choice of gain.
- Improve the work done on the modelisation of the seismometer.

B. Reduce instrument self noise

- Decrease the impact of noise : Filtering , Better choice of component
- Optimisation of the placement of the component (E.M.C)

C. Switch to Raspberry Pi 2

	Raspberry Pi B+	Raspberry Pi 2
Released	July 2014	February 2015
SOC	Broadcom BCM2835	Broadcom BCM2836
CPU	700MHz Single-Core ARM11	900MHz Quad-Core ARMv7
SDRAM	512 Mo	1 Go
Price	35€ (found now with a discount)	35€



Building a seismometer

D. Working with threats

- Threats : Advantage of multiple cores systems
- Smoother multitasking : Recording script and web interface
- More efficiency with I2C data transmission
- 900MHz → a faster Python 2.7 script execution



- Diversity of working areas
 - High accuracy sensor
 - Feedback circuit
 - Analog to Digital Conversion
 - Data processing
 - User interface through Web Application
- Organisation :
 - Working Plan
 - Timing Plan
 - Team work and tasks division

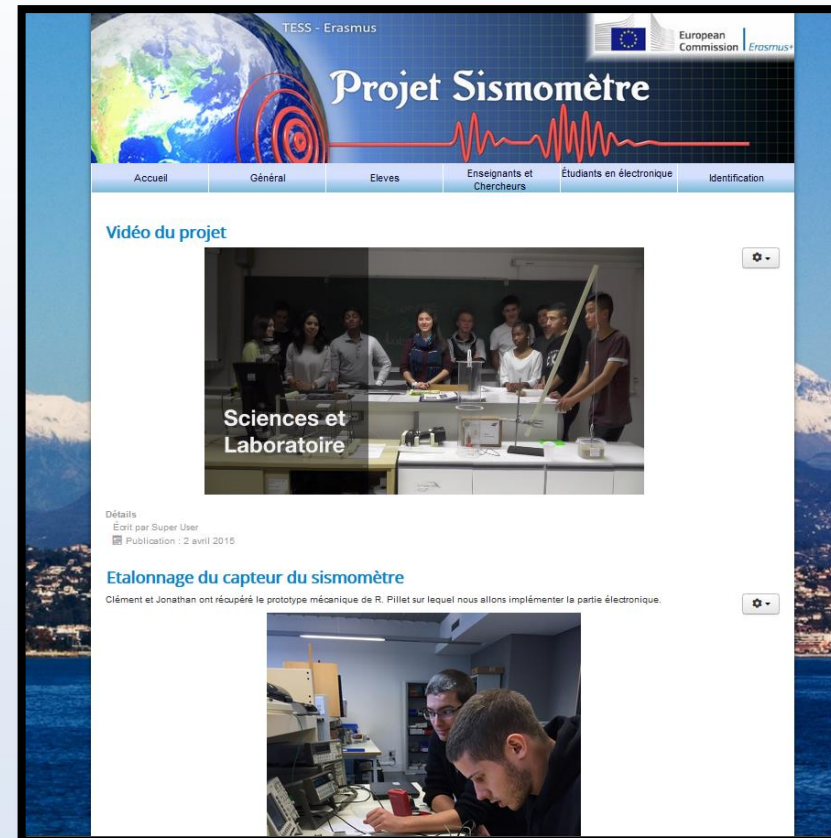


Communication

- Web platform to share the progresses :

www.tess-erasmus.fr

- CIV student access
- Teacher access
- Electronic student access
- Public access



Building a seismometer

Thanks for your attention

30

Do you have any questions ?



Building a seismometer

TESS – Erasmus+