Landing on a comet! The Rosetta project.

Scenario based on the latest news of Rosetta's expedition. How students can learn through the great achievements of European Space Agency (ESA).

Rosetta's travel in space and the landing of Philae on comet 67P give us the opportunity to learn Newton's Laws and to find as real researchers the acceleration of gravity of the comet. The scenario is finalized using various ICT tools.

Goal of this scenario:

We try to implement new ideas and good practices in the science's school curriculum in secondary education using inquiring based learning.

The scenario has two important aspects: On one hand we try to stimulate the learning process with innovative techniques in the class such as simulations, on the other hand students learn not only the very important physical laws but also the latest scientific achievements in space science.

Learning objectives:

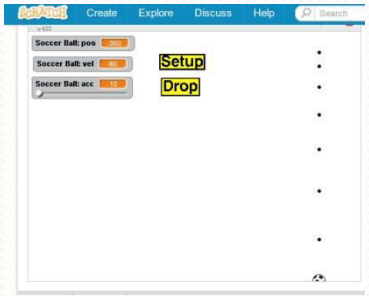
- Inquiring based learning.
- Working into teams. Learn to cooperate.
- Searching on the web, learn to find the necessary info.
- Understand Newton's Laws and corresponding equations of motion.
- Playing and learning through ICT tools: Interaction Physics, Scratch application, Craters simulator, Trajectory web-tool (all freeware).
- Approach the same problem from different views.
- Working as a researcher, testing parameters, exploring different aspects of the problem and find specific value of the acceleration of gravity that is very near to the real value according to references.

Phase A: Introduction to the problem

- Organization of the class into teams.
- Presentation of ESA's latest achievement through a video. Search in general @youtube for esa + rosetta
- http://rosetta.esa.int
- http://www.esa.int/education
- Discussion: Teacher shows using the videos what actually happened and what we want to explore in this project.

Phase B: Playing & collection of data

- The teacher uses the main concepts of the curriculum (Newton's first and second law, equations of motion of a free fall of an object and motion with constant acceleration/deceleration).
- After the introduction of theory and explanation of the physical laws we use the link



http://scratch.mit.edu/projects/13276910

where students play with the free fall of an object. Changing the parameter of the acceleration observe the different track of the object and can see how velocity changes in each case. This activity is a precursor of the next phase where students have to play with a different educational tool.

Next, the class is working into teams as follows:

- 1st team: Collection of information concerning the problem using the internet.
- 2nd team: Students keep the necessary info through reliable sites.
- 3rd team and 4th team (one team is working versus to the other through a dialogue): Decision of which physical quantities are needed for the specific project.
- Discussion.

In the next slide we show some sites where we can found the necessary information:

- http://rosetta.esa.int/
- http://www.quora.com/Can-you-tell-me-everything-about-the-Rosetta-mission
- http://m.space.com/27788-philae-comet-landing-bounce-photos.html
- Students find: "Further analysis indicated that the lander had bounced twice and landed three times; the first bounce (with a **velocity of 0.38 m/s, compared to 1 m/s incoming lasted two hours and may have been 1 km (0.62 mi) high, the second (at 0.03 m/s) lasted seven minutes**. The initial bounce was the largest in history at 1 kilometre (0.62 mi), because of the very low gravity on the comet. *Philae* sits askew, leaning on a rock in partial darkness as much as a kilometre from the first landing spot at an unknown location. At first it was thought that it sat on just two legs; ESA later determined that the lander sits on all three legs "

Useful quantities:

- Philae perform 2 bounces until its final destination on the comet 67P/Churyumov–Gerasimenko (67P).
- Rosetta left Philae 22,5 Km above the surface of 67P.
- Philae reach 67P for the first time with a velocity υ=1 m/s
- Philae did not stayed in the comet. Philae perform its first bounce with a velocity υ=0.38 m/s, 1Km high and lasted approximately 2 hours.
- The second bounce lasted 7 min with an initial velocity υ=0.03 m/s.

Phase C: Some Physics! Activity #1

Students find the acceleration of gravity as Philae falls on the comet using the physical laws. If we assume deceleration with constant g after the first bounce till the maximum height, we can calculate g as follows: (υ=0, υ_0=0.38 m/s, t=1h)

$$\upsilon = \upsilon_0 - g \cdot t \Leftrightarrow 0 = 0.38 - g \cdot 60 \cdot 60 \Leftrightarrow$$

$$g = 1.05 \cdot 10^{-4} m/s^2$$

but we can also calculate g using: υ_0=0.38 m/s, t=1h,h=1Km

$$h = \upsilon_0 \cdot t - \frac{1}{2} g t^2 \Leftrightarrow g = 2 \cdot \frac{\upsilon_0}{t} - 2 \cdot \frac{h}{t^2} \Leftrightarrow g = 2\frac{0.38}{3600} - 2\frac{1000}{3600^2} \Leftrightarrow$$

$$g = 0.56 \cdot 10^{-4} m/s^2$$

Or we can find g through the second bounce:
(υ=0, υ_0=0.03 m/s, t=3.5min)

$$\upsilon = \upsilon_0 - g \cdot t \Leftrightarrow$$

$$0 = 0.03 - g \cdot 3.5 \cdot 60 \Leftrightarrow$$

$$g = 1.42 \cdot 10^{-4} m/s^2$$

Therefore we found using physical laws that g is around to 10^{-4} m/s² . Now it's time to find g with different method: Simulation with Interaction Physics. At first we perform some tests:

Phase C: Activity #2 working as a researcher

Students use *Interaction Physics software* and try to simulate the landing of Philae. Some tests are needed:

i) In the gravitational homogenous field $g=9{,}81\ m/s^2$

ii) In the gravitational homogenous field $g=1\ m/s^2$

iii) In the gravitational homogenous field $g=10^{-3} m/s^2$

iv) Using gravitational interaction between Philae and comet (as it is in the real world)

The scope of this activity is to find the acceleration of gravity of the comet **using different method** (comparing to activity #1).

The steps (i), (ii) and (iii) or possibly with other values of acceleration of gravity are needed to test our parameters and to connect with the free fall as we had in Phase B.

In the following simulations of Interactive Physics:

Activity #2:
We set in simulations the real mass of Philae and the mass of comet:

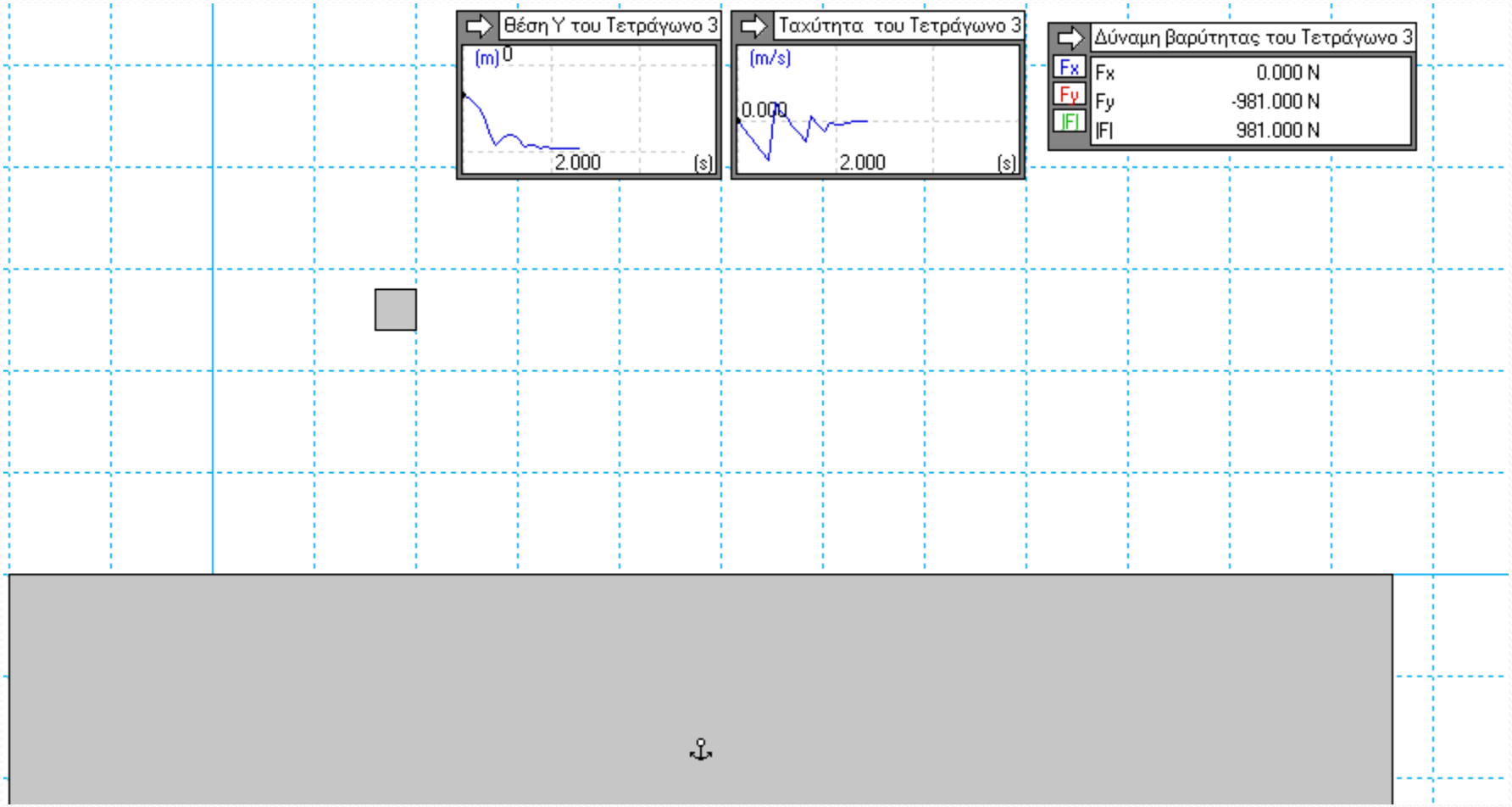
- m_{philae}=100 Kg
- m_{comet}=10^{13} Kg

For the comet is assumed:

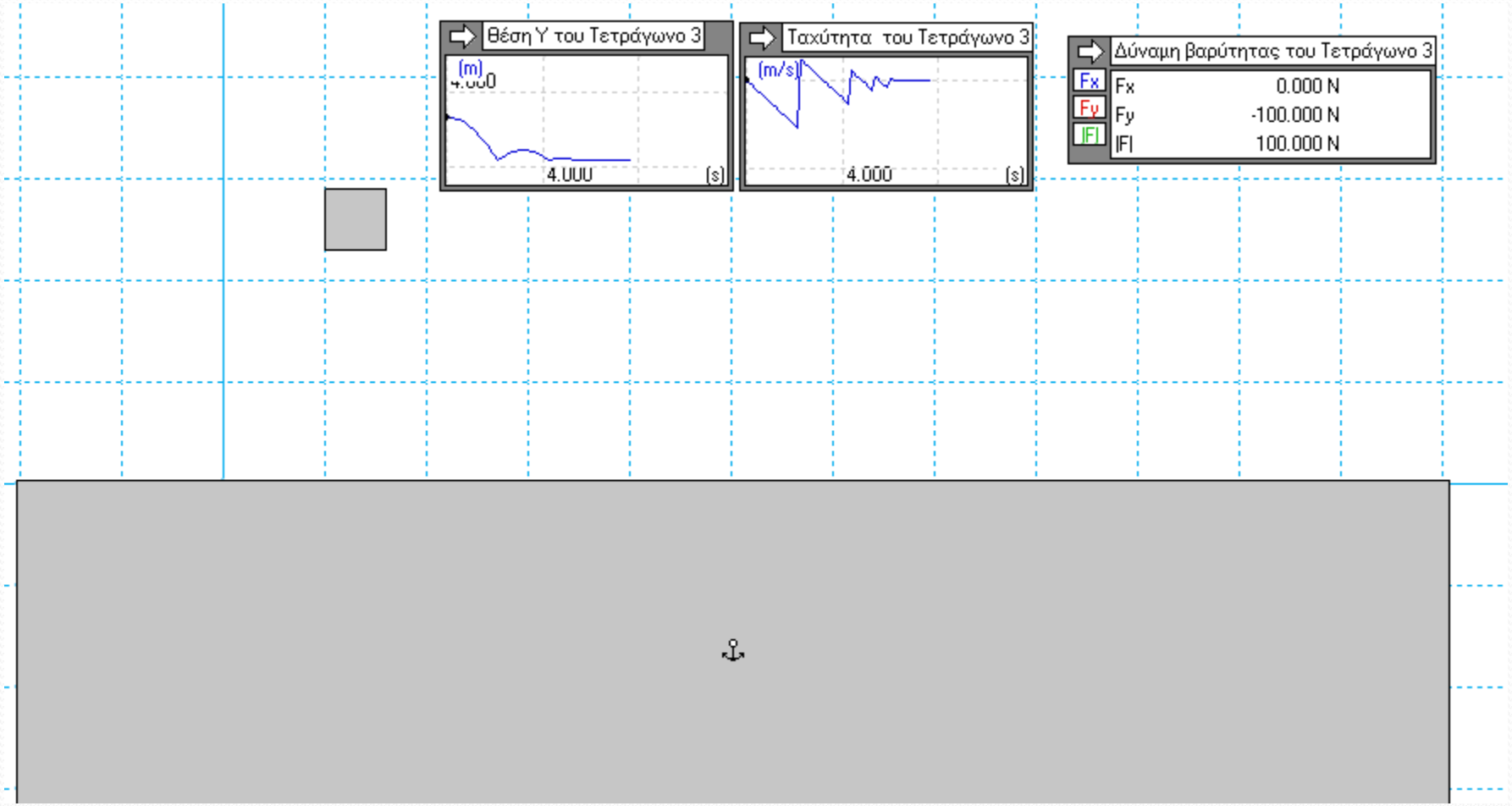
- is not rotated
- the gravitational field is vertical
- its shape is a rectangular box.

The boxes in following graphs shows y(t), υ_y(t), F(t) (from left to right) for the Philae.

Interaction Physics: Philae landing on the comet: (i) Free fall with $g=9,81 m/s^2$

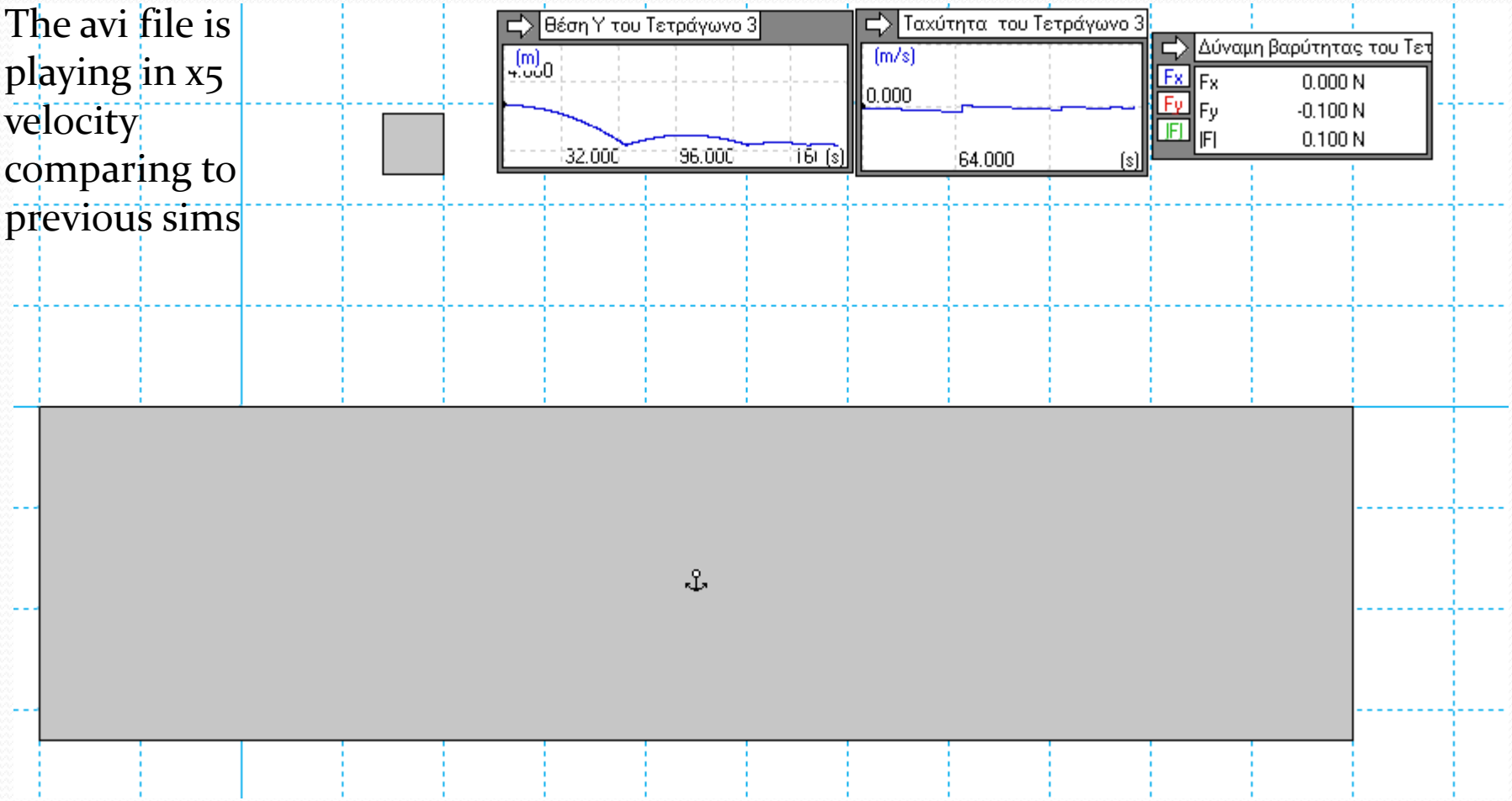


Interaction Physics: Philae landing on the comet: (ii) Free fall with g=1m/s^2



Interaction Physics: Philae landing on the comet: (iii) Free fall with g=0.001m/s^2

The avi file is playing in x5 velocity comparing to previous sims



Simulation in realistic dimensions, simulation (iv):

- Now we perform a simulation using a spherical comet with radius of 1 Km (real dimensions of the comet are:

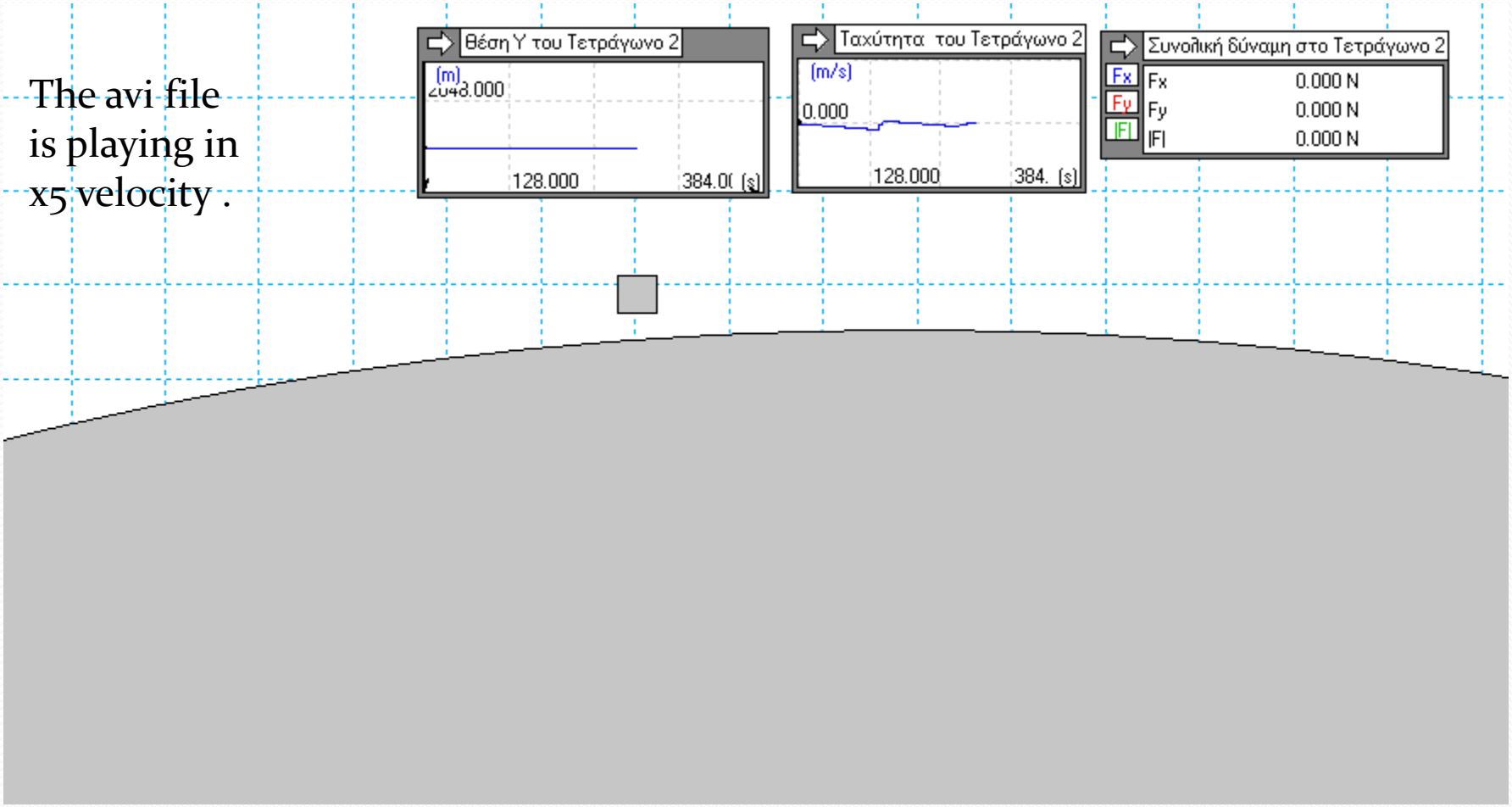
  4,1km x 3,2 km x 1,3 km.
- In the previous simulations Philae falls due to homogenous gravity field. In this simulation we activate the planetary interaction through the 2 objects (Philae and comet) and as the simulation runs the total force on Philae is computed. Using this result we derive g.

$$F = G\frac{m_{philae}m_{comet}}{r_{ph,com}^2} = gm_{philae} \Leftrightarrow g = \frac{F}{m_{philae}}$$

This actually holds, the masses are attracted to each other through the Newton's law of universal gravitation.

(iv): the simulation derives F=0.066N thus g=6,6*10^{-4}m/s^2

The avi file is playing in x5 velocity .



Comparison of g's using physics laws and IPs simulations.

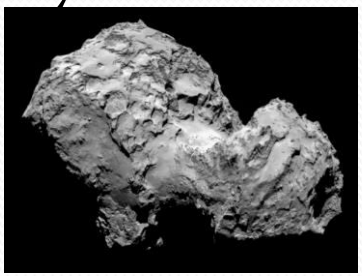
Physical Laws	Interaction Physics
$g \approx 10^{-4} m/s^2$	$g = 6{,}6 \cdot 10^{-4} m/s^2$

Very good agreement between the two different methods that students use. Very good agreement also with the actual value see: http://spacenews.com/42527european-spacecraft-touches-down-on-comet/ (where Philae weight on 67P is like 1 g mass comparing to Philae weight on earth that is m=100Kg. This gives acceleration of gravity on comet $g=10^{-4}$ m/s^2)

Real facts vs. our findings

- The gravity on comet is very low and changes as Philae moves from the one side to the other side of the comet.
- The actual shape of the comet is anomalous therefore the gravity field in not homogenous.
- Also comet is rotating and we didn't take it into consideration.
- We assumed deceleration for Philae after the bounces.

Nevertheless in the last simulation where the gravity enters from the planetary interaction between Philae and 67P we found an acceleration of gravity very near to reality!



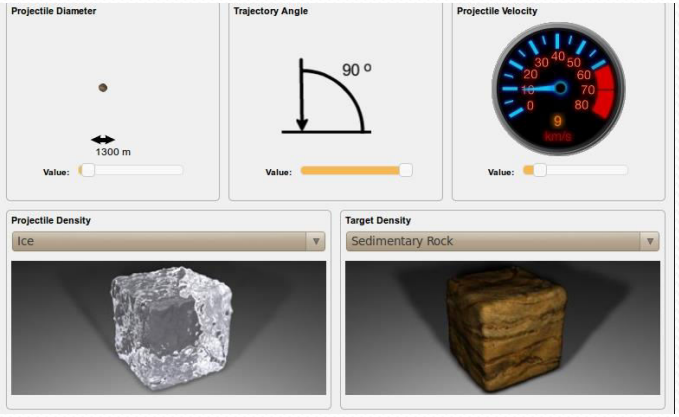
Phase D: Activities for craters and trajectories of comets. Activity #3: Craters

- #3 Craters: What will happen if the comet 67P fall on Earth?

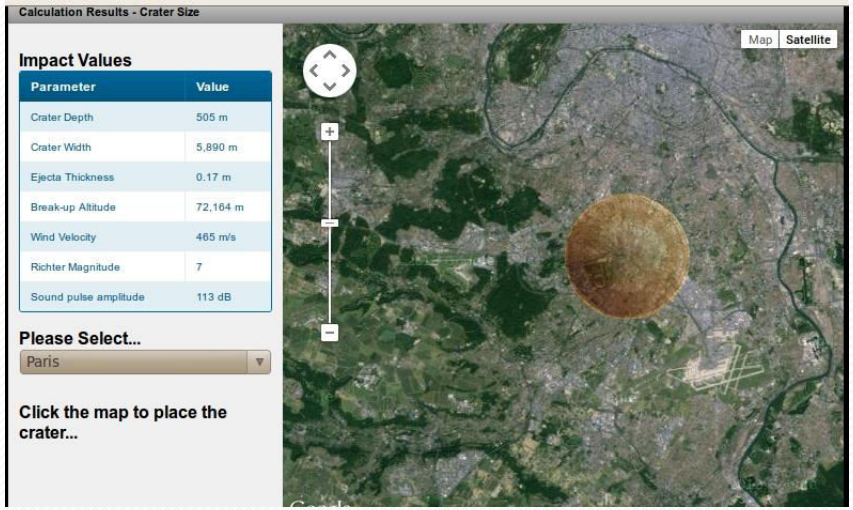
We use the go-lab approved software:

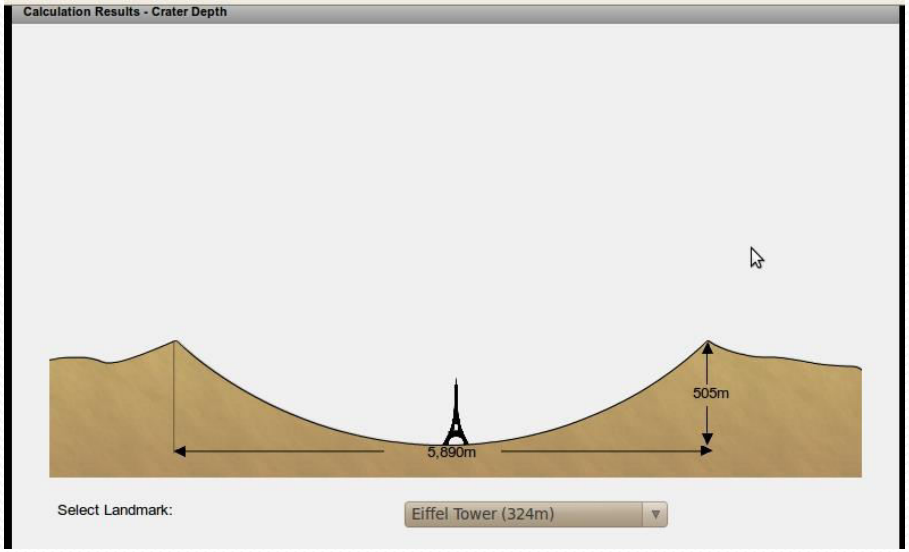
Craters on Earth and Other planets:

http://education.down2earth.eu



The impact of comet in Paris!





Some numerical results

Calculation Results - Data View

About Your Projectile

Parameter	Value
Mass	1.15×10^{12} kg
Projectile Velocity	9 km/s
Trajectory Angle	90^{o}
Projectile Density	1,000 kg/m^3
Target Density	2,500 kg/m^3
Fireball Radius	0.00 km

Damage at 32 km from crash site

Multistory wall-bearing buildings will collapse

Wood frame buildings will almost completely collapse

Multistory steel-framed office-type buildings will suffer extreme frame distortion, incipient collapse

Small bridges will collapse

Glass windows will shatter

Cars and trucks will be overturned and displaced, requiring major repairs

Impact Energy

Parameter	Value
Kinetic Energy	4.66×10^{19} J
Impact Energy	4.56×10^{19} J
How frequent?	143,610 yrs

What happens to the impactor?

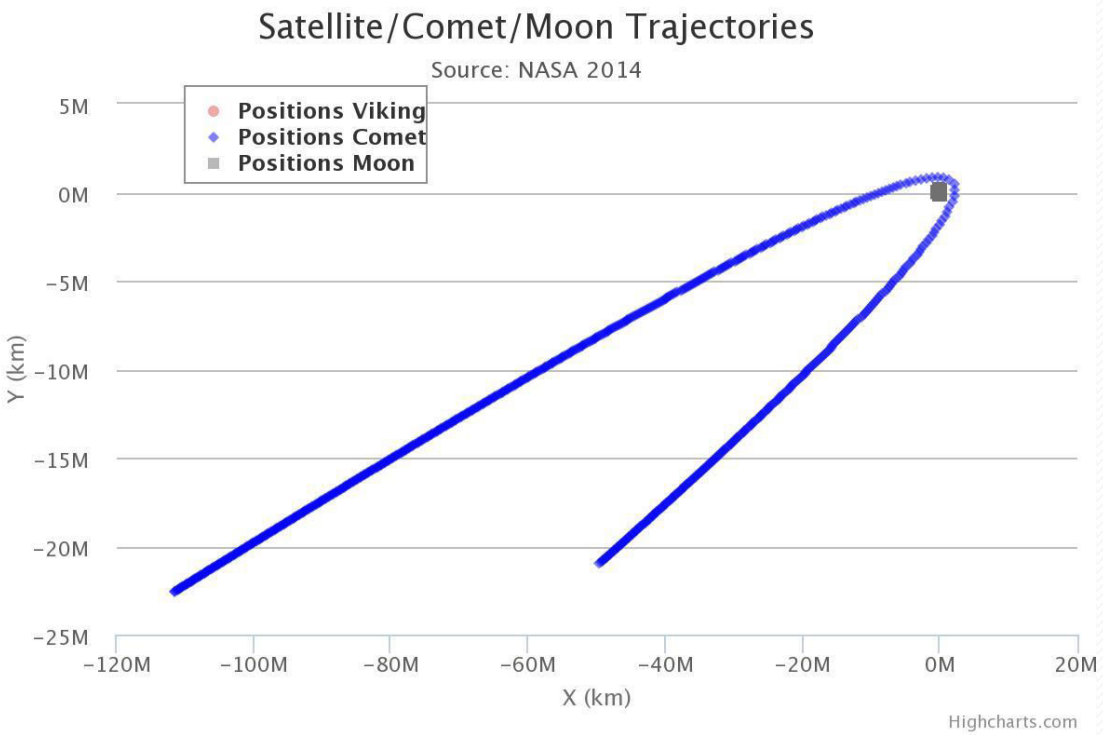
The projectile reaches the ground in a broken condition. The mass of the projectile strikes the surface at a velocity of 8.91 km/s

Is a fireball seen?

Parameter	Value
Not applicable	Not applicable

Activity #4: the trajectory of a comet

How about the trajectory of a comet in the planetic systems?
Using the Satellite/Moon/Comet Trajectories educational tool:
http://graasp.epfl.ch/sharedapp/1073c0fd5e959e19ef6bc6c93acfc0713beb03d8



Phase E: Conclusions

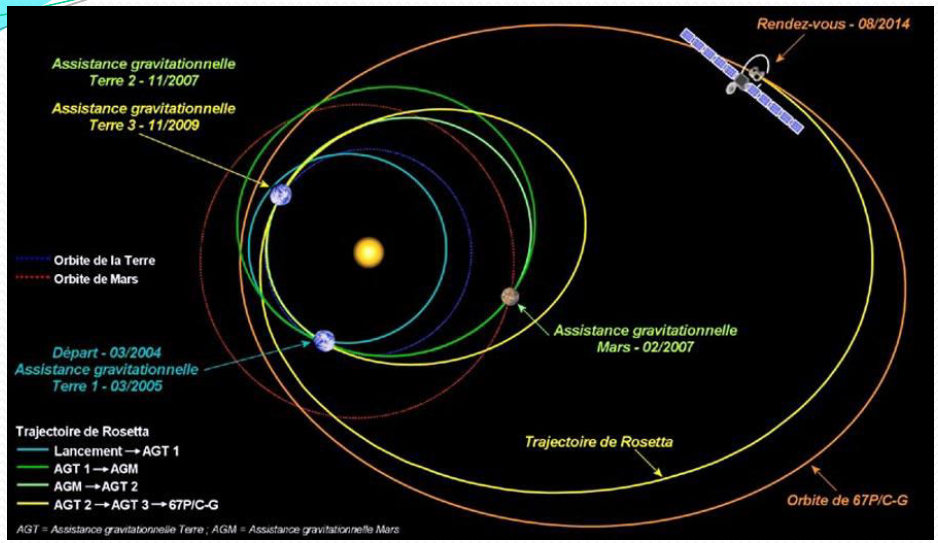
- Discussion about the final results and outcomes.
- Final presentation from students. Learning to make successful presentations. Students make a poster with pictures and their findings.
- Summary of the project.
- Conclusions

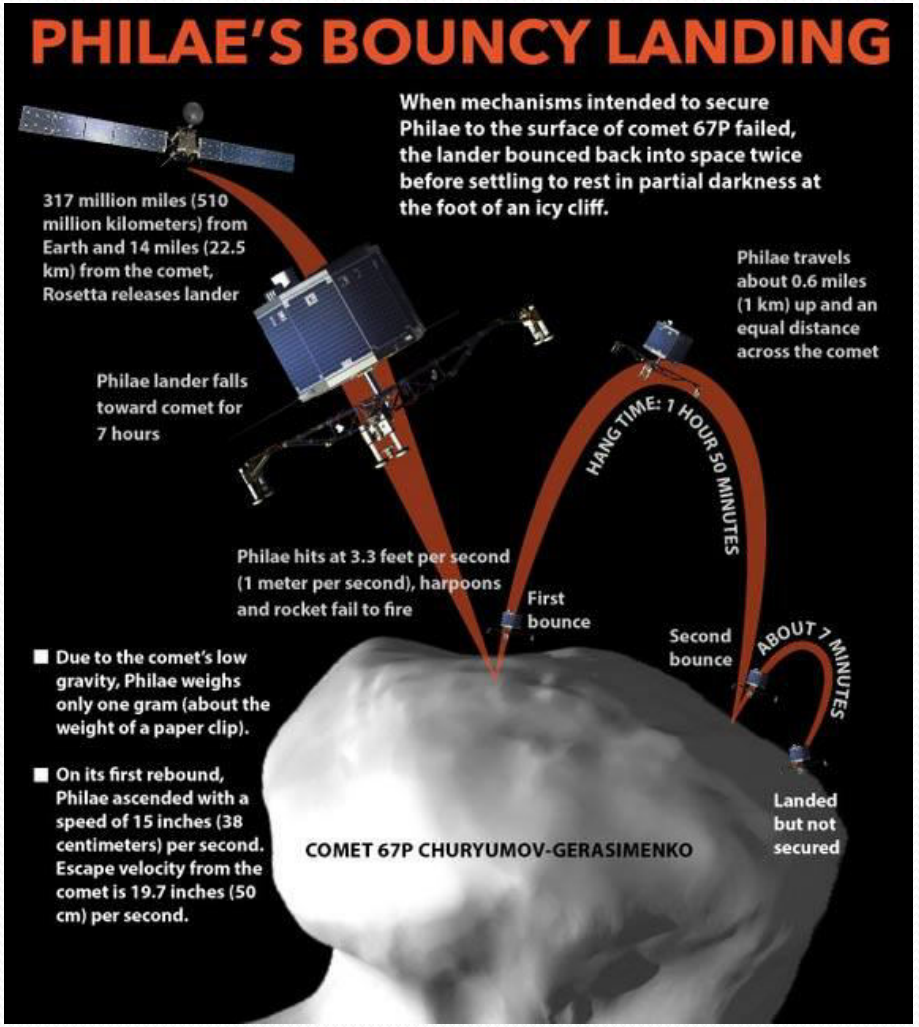
Conclusions -1-

- Students learn through different activities Newton's laws of motion.
- Students learn a very important achievement of European Space Agency that is the Rosetta landing (Philae) on comet 67P.
- Students find the necessary info from the web.
- Students work as a real researchers and test the parameters of the problem in order to find the acceleration of gravity on comet 67P using theory and simulations (free software).
- Students finally conclude through different methods.
- Students playing with other activities as well acquiring a spherical knowledge about comets and space in general.

Conclusions -2-

- Using Inquiring based learning students can work in a problem and learn how to solve it following simple but important steps.
- Collaboration in class is very effective and gives the possibility to learn one student from the other.
- Teacher introduce challenging problem that gives inspiration to the students.
- Discussions with students throughout the activities in order to make them come to conclusions on their own.
- Preparing presentation gives the ability to the students to understand the new information and to make it their own.
- Through all the above that we mention, students learn how they can learn, using various different tools, questioning, exploring, testing, verifying or discarding, critically thinking.


Rendez-vous - 08/2014
Assistance gravitationnelle Terre 2 - 11/2007
Assistance gravitationnelle Terre 3 - 11/2009
Orbite de la Terre
Orbite de Mars
Assistance gravitationnelle Mars - 02/2007
Départ - 03/2004
Assistance gravitationnelle Terre 1 - 03/2005
Trajectoire de Rosetta
Lancement → AGT 1
AGT 1 → AGM
AGM → AGT 2
AGT 2 → AGT 3 → 67P/C-G
Trajectoire de Rosetta
Orbite de 67P/C-G
AGT = Assistance gravitationnelle Terre ; AGM = Assistance gravitationnelle Mars


PHILAE'S BOUNCY LANDING
When mechanisms intended to secure Philae to the surface of comet 67P failed, the lander bounced back into space twice before settling to rest in partial darkness at the foot of an icy cliff.
317 million miles (510 million kilometers) from Earth and 14 miles (22.5 km) from the comet, Rosetta releases lander
Philae lander falls toward comet for 7 hours
Philae travels about 0.6 miles (1 km) up and an equal distance across the comet
HANG TIME: 1 HOUR 50 MINUTES
Philae hits at 3.3 feet per second (1 meter per second), harpoons and rocket fail to fire
First bounce
Second bounce
ABOUT 7 MINUTES
Landed but not secured
Due to the comet's low gravity, Philae weighs only one gram (about the weight of a paper clip).
On its first rebound, Philae ascended with a speed of 15 inches (38 centimeters) per second. Escape velocity from the comet is 19.7 inches (50 cm) per second.
COMET 67P CHURYUMOV-GERASIMENKO