ERUPTION!

A VOLCANIC CRISIS SIMULATION

INTRODUCTION

Eruption! is a model or simulation in the form of a computer program, which simulates a fifty day period of volcanic activity at a potentially hazardous volcano. The volcanic activity leads up to a 'volcanic crisis,' a situation in which lives may be endangered. The immediate goal of the model is to instruct students in the hazards associated with volcanic eruptions and in the basic theory of eruption prediction. You will learn through playing roles of people directly concerned with the volcano's activity, to absorb the information and order it into a rational pattern, and finally to act on the interpretation of the meaning of the information.

All data and action within the model are predicted upon the premonitory activity that often precedes a volcanic eruption. All volcanic activity is driven from a look-up table that indicates what is to occur at each step. The volcanic activity used in the simulation is based upon our current understanding of what occurs within a volcano before and during an eruption. As magma moves toward the surface of the earth within a volcano, changes occur at the surface. The changes that take place at the volcano give clues as to what the magma under the surface is doing. Most activity precursory to an eruption cannot be sensed directly. Instead, sensitive instruments and techniques are used to detect unrest. Various types of data are gathered and interpreted by volcanologists in light of past activity. Different types of monitoring techniques are linked to different aspects of volcanic unrest, thus scientists must make judgments concerning the most useful monitoring program as they institute it. Read the last few pages of this handout ("Technical Information") to get a better idea of what is going on.

Once the simulation starts, the volcano will begin to show signs of activity. Three types of activity can occur:

1) **Steam Plumes**, completely benign phenomena that indicate magma is close to the surface and degassing, or vaporizing water within the shallow subsurface. These show up on your screen as white clouds coming from the center of the volcano.

2) **Rockfalls / Avalanches**, which indicate that the upper summit region of the volcano is becoming unstable because of the intrusion of a cryptodome near the surface, or because of the extrusion of a true dome at the surface. These show up as small brown blocks coming from the center of the volcano.

3) **Pyroclastic Flows and Lahars**, which are the potentially dangerous phenomena that can destroy villages and cause loss of life. The flows extend to different distances from the volcano, and can potentially be erupted in any direction. Those playing the simulation are to direct their energies at avoiding the effects of these flows. These appear as large red swaths of color that advance away from the volcano, and toward the villages.

THE PLOT

Given their budget as determined by the governor, the Volcanologists must collect data, interpret it and determine the volcano crisis code (Red for extreme danger, immediate evacuation recommended; Orange for high activity, state of readiness recommended; Yellow, for low activity, little chance of dangerous eruption; Green for no or background activity, i.e. that which would occur during times of quiescence). Once a code is chosen, the villagers can choose to respond by evacuating or by protecting village structures. The press meanwhile should be gathering as much information as possible form the volcanologists to convey this to the villagers, and help them to understand the motivation for the crisis code values. Keep the province within budget, save life and property, and maintain the governor's popularity.

THE CLOCK IS TICKING!

After all of the computers are logged-in, the game will begin when any one of the computers starts the simulation. The simulation covers 50 days of activity, but is accelerated to take approximately 1 hour. Every player (computer) is in charge of at least one village. Initially all of the money in the simulation is in the hands of the governor. Each user begins with $0, as indicated by the money display in the upper right corner of the window. Each user is responsible for requesting their own share of funds from the governor.

To Request Funds from the governor :

- Click and hold down the mouse on the $ in the lower right corner. This will bring up a pop-up menu.
- To request money, select **Request $** and type in the amount that you need. Then press the "**Do it"** button. This will submit the request to the governor. Now you must wait for the governor to receive the request and to act on it. If the governor decides to send you money, it will transfer automatically into your account. The balance in your account is shown in the top right portion of the screen.
- In the event of a budget crisis you can return money to the general fund. To do this, select **Return $,** type in the amount you want to return, and **"Do it"**.

It is important to realize that the villages will lose some people and property to the devastating effects of the volcano. What you should attempt to do is to minimize that impact by evacuating your people and by protecting your property. Keep in mind that the amount of money available is **limited**, so be careful how you spend! The list below includes the cost of different items in this simulation. If you use all of your money before the simulation ends, your people may starve to death even if they are not killed by deadly pyroclastic flows!

COST SUMMARY

Villagers : Evacuation: **$4** per villager. While evacuated, villager computers are automatically assessed **$1 per person per day for food and lodging**
Reinhabitation: **$2** per villager
Property Protection : **$1 per $100,000 value** of buildings in village

Volcanologists :

Buy Seismometer : $20,000	Repair Seismometer : $10,000
Buy COSPEC : $20,000	Repair COSPEC : $10,000
Buy Geodimeter : $20,000	Repair Geodimeter : $10,000
Plot a graph : $100	

Press :

No costs : Free Press!

SPECIFIC INFORMATION : Villagers, Volcanologist, Press, and Governor

VILLAGERS:

- The villagers, unfortunately, know little about volcanoes, governing, or the press; yet they must stay safe from the first, and deal with the last two. They must base their decisions for action completely on what others - particularly the press - tell them, and on their own visual observations of the volcano from the village.
- Each villager window displays all the villages around the volcano. Villages which belong to a user appear white on their computer, while villages belonging to other users are maroon colored (dark).
- The villagers must request funds from the governor (see above).
- The volcanologists will be evaluating the severity of the overall situation using their sophisticated equipment and expertise. They will assign levels of risk to each of the villages; theses levels of risk may change throughout the simulation depending on the activity of the volcano. The following colors that represent levels of hazard will appear as borders around you villages when the volcanologists assign them:
    - **Condition Red** : Highest risk from eruption; damage likely
    - **Condition Orange** : Damage / loss of life possible
    - **Condition Yellow** : Some chance of damage / loss of life
    - **Condition Green** : No risk
- You must decide what to do : Nothing, Evacuate some people, Protect property, or Reinhabit the village.
- **To either protect property or evacuate:**
    - Click and hold the mouse on the village of interest
    - A pop-up menu will appear. Your choices are: Evacuate, Reinhabit, and Protect. Whichever you choose, type in the number you need to evacuate, reinhabit, or protect and then press **"Do it"**. Protected village structures cannot be damaged by flows. Another effect of protection of structures is an increased protection of the villagers, but there is an element of risk involved, since the model considers that at different times of day people will not be in structures. If you evacuate people, it costs money to evacuate them AND to feed them during the duration of evacuation (a daily expense). It also costs money to reinhabit the village. See "Cost Summary" above.

- In the lower left corner you will see a **Newspaper icon** whenever there is a news release that you have not yet read. Click on it to read the latest news as reported by the press.

PRESS

- The press is responsible for keeping the public informed. They obtain information from the scientists through press conferences. They must choose the right questions to ask to ascertain the state of the volcano. They pass their interpretations on to the villagers and governor in news reports. Ideally, the volcanologists will be able to answer questions in such a way that the press can understand. Then the press must inform the public, yet not create a panic. The press hold considerable power, but only if it is used correctly will disaster be averted.
- You may **only** communicate verbally with the volcanologists!
- **To activate the newspaper:**
  - Click on the newspaper icon in the lower right-hand corner of the screen.
  - A text processor will be opened in which stories can be written after consulting with the volcanologists.
    - The thin, upper portion of the text editor is for the article's Headline
    - The larger, lower portion is for the main body of the article.
    - Once an article is finished, click Send to distribute the article to all parties involved.

VOLCANOLOGIST

- The volcanologists need to do as much research as possible to try to predict over the short-term, or forecast over the long-term what the volcano will do.
- **Task 1** : **Understand the introductory text material** on volcanoes and volcanic hazards (refer to last page of this handout).
- **Task 2 : Initiate a volcano monitoring program**. For this you have three tools available for purchase : Seismometer (measures and plots Seismicity), COSPEC (measures and plots SO_2 data), and Geodimeter (measures and plots Deformation). See the "Cost Summary" for prices for these instruments. You choose which instrument to purchase and when.
  - To do plot the data that an instrument is gathering, click on the "**Graph**" icon in the lower left-hand corner. While the computer is graphing the data your cursor will look like a graph. When it returns to the normal mouse pointer,

you know that graphing is complete. Remember, it costs $100 to graph any set of data!

- Pay attention to the instruments: **watch for when they break because of volcanic activity**. If an instrument breaks, you will not have any data from that machine for the time period during which it was out-of-commission. So, it is in your best interest to keep an eye on whether or not they are all working.

- **Task 3 : Interpret the Data** : You must interpret the data that you gather from the volcano monitoring program. Once a consensus is reached, then you should inform the press of your interpretation of the state of the volcano.
- **Task 4 : Warn the Villages** : You are responsible for alerting the villagers to the risk that each village faces. You will do this by **assigning a color code** for each village based on your interpretation of the meaning of your monitoring data.
  - Click and hold down the pointer on a village
  - A pop-up menu will appear with the following options:
    - **Condition Red** : Highest risk from eruption; damage likely
    - **Condition Orange** : Damage / loss of life possible
    - **Condition Yellow** : Some chance of damage / loss of life
    - **Condition Green** : No risk
  - After choosing one of these conditions, the selected village will be marked with the risk color on every computer in the simulation.
- Clicking on the newspaper icon will bring up the latest edition of Eruption! Today, the official periodical of the Eruption! simulation.

GOVERNOR

- You know you are the governor if you have a phone icon in the lower right corner of the screen. There is only one governor.
- Your primary role is **control of the budget** for the community of villages. You will be receiving requests for funds as well as pleas for help from the villages and volcanologists. You must weigh their requests carefully.
- You are the ultimate decision maker: you control the money available to the villages and to the volcanologists. You decide if the volcanologists should get extra money for research. You decide which villages will need money for evacuation, food, reinhabitation, and protection of property. The governor is also in charge of contacting the military if transportation is needed for evacuation. BUT the provincial budget is limited, so be prudent in your distribution of funds. Another thing to think

about : the governor has to worry about re-election so you must keep the villagers as happy as possible.

- Whenever someone makes a request for funds the "**Governor Window**" will appear on the screen. You can also bring up this window by clicking on the phone icon in the lower right corner of the screen.
    - **Send Funds:** By using this button you will send the entire amount requested.
    - **Send Other Amount** : Type in a different amount to send, then press "Send Funds"
    - **Double click on a request** : This is a shortcut to sending the full amount requested.
    - **Later** : This will close the governor's window until you open it later.

TECHNICAL INFORMATION

DEFORMATION

Deformation, or displacement of the Earth's surface, consists of movements that are almost always difficult to detect by the human eye. The displacements can be vertical or horizontal and can be measured to high precision by the use of sensitive instruments. With respect to volcanic activity, as magma begins to push toward the surface within a volcano, the volcano bulges outward and upward, and cracks or fissures may develop or become wider. Whatever the deformation, it is important to monitor because it could give an indication of an impending eruption.

CRUST DISPLACEMENT

One way of measuring displacement is with **geodimeters**. These sensitive devices measure the distance between two points. The geodimeter is situated at one particular point. A laser beam is emitted from the geodimeter, hits a retroreflector at a second point, and returns to a recording device on the geodimeter. The distance between the points is measured from the time that it took for the beam to make a round trip between instrument and reflector. This technique works best if you have a network of points that keep track of the deformation occurring on all parts of the volcano.

If the distance between two points changes with time, then the earth between the two points is deforming. Such deformation can be caused by the motion of the tectonic plates, but also by magma movement. On volcanoes, it has been shown that as the deformation rate increases, the probability of an eruption increases. Constant, steady displacements do not generally signify that an eruption is imminent, as they are often caused by tectonic forces rather than magma movement.

SULFUR GAS EMISSIONS

As magma nears the surface of a volcano, gasses begin to leak from the cracked surface. Sulfur dioxide is one of the main gasses that escapes. The amount of gas can be measured by a device called a **correlation spectrometer** or **COSPEC**. An increase in the amount of gas emitted can signify an increase in the activity of a volcano, or the approach of magma toward the surface.

EARTHQUAKES

As magma nears the surface and the surface deforms, earthquakes are generated. The more magmatic activity there is, the more earthquakes there are. By keeping track of the number

of earthquakes through time, one can get a reasonable idea of the degree of volcanic unrest. Although large earthquakes can be felt, the vast majority of smaller earthquakes are only detected with sensitive equipment. A **seismometer** is usually used to measure and record the seismic activity at a volcano. Constant monitoring is needed to keep volcanologists up to date.

Although there are unusual types of earthquakes peculiar to volcanoes that signify particular types of activity, we will not be distinguishing between them. The number of earthquakes within given time spans is all that we will use in the simulation. A change in the number of earthquakes will signify a change in the activity at the volcano. However, bear in mind that during a volcanic crisis, seismic (earthquake) activity can essentially become continuous for great lengths of time, so that separate earthquakes cannot be distinguished. This is known as **harmonic tremor**. Tremor characterizes active volcanoes, and usually occurs during an eruption. Tremor may also precede an eruption, so it is a good idea to watch for it if the proper data are available.

DEBRIS AVALANCHES

Flows of rock material and debris downslope are called **avalanches**. With increased activity at a volcano, earthquakes and ground instability can cause such flows. Rocky material is often loosened by ground instability or shaking, and then flows short distances. Debris avalanches, if sufficiently large, can be seen by anyone watching the volcano, and can signify an increase in the activity of the volcano if they are repeated. They are not measured by any device, but it is useful to watch for them as another indication of unrest.

GAS AND STEAM PLUMES

Visible emissions of steam and other gasses, called **steam plumes**, can be seen by all. As ground movement increases, cracks appear form which gasses escape. If steam plumes become visible or increase in frequency or size, then volcanic unrest is increasing. Steam plumes are like debris avalanches in that they can be observed unaided. Again like avalanches, their occurrence should be remembered when considering what the volcano might do.

HAZARD MAPS

Maps of a volcano with potential hazards indicated are called hazard maps. A great deal of painstaking research is needed to produce a hazard map, and such a map cannot always be completely accurate. Many factors need to be analyzed in the construction of the map, but especially the past history of the volcano as indicated by the ages of deposits formed by the different destructive volcanic phenomena. An understanding of what type of hazard could extend its effects to a given locality can be gained by interpreting what has happened at the locality in the past.

Student Survey for ERUPTION !

Now that you have participated in a simulation of a volcanic eruption, answer the following questions. Use **coherent sentences**. **Grammar and handwriting count!**

Question 1.

What was your role in the simulation ? (circle no more than 2)

Governor Press Volcanologist Villager

Question 2.

If you worked with a partner (or partners), what did each of you do during the simulation? (Ex. I did most of the communicating with the governor, my partner watched the screen) **Be specific!**

Question 3.

What were your goals? Did you meet those goals? Why or why not?

Question 4.

If you could do this over again, what would you do differently?

Question 5.

What is your opinion about communities that are located in hazard-prone areas? (This includes hazards other than volcanoes) What can you do to minimize your risk from natural disasters?