Chapter 11

Terraforming Mars

INTRODUCTION

Managing a planet to keep it fit for life can be a difficult job. Look at the trouble we're having with our own planet. Planetary life (as we know it) requires two main resources from its environment: 1) solar energy; and 2) liquid water. Sunlight is captured by plants, and the sun's heat keeps Earth at a temperature so that liquid water can exist over most of its surface. Liquid water is important as a transport system and reaction medium inside organisms. In our star system, solar energy and liquid water are found in just the right amounts only on Earth. Some creative people think it might be possible to engineer another planet in order to make it suitable for life.

The changing of a lifeless planet to one that is earth-like is called terraforming (after the Latin word 'terra', meaning earth). Re-engineering an entire planet is serious business, and it requires us to know some details about what influences a given planet's environment. Therefore, the purpose of this exercise is to use a computer simulation in an attempt to terraform another planet. In the process, you will need to understand and apply the fundamentals of ecology and planetary environmental management.

DESIGN AND POSITION

A planet's ability to support life has a lot to do with its size, density and its distance form the sun. Below, is a discussion of some of the most important influencing factors.

DENSITY AND ORBITAL PATH

Earth is the densest planet (5.5 g/cm^{3}) in the solar system. Its higher density means the sun's gravity acts strongly on the earth. This has resulted in an orbital path that is close to the sun, but not too close. The earth's close orbit has provided our planet with an ample supply of solar energy in the form of heat and light - hot enough to melt ice, but not too hot that would boil the oceans dry. It is the abundance of liquid water that makes earth unique in its ability to support life. No other planet in our solar system has liquid surface water. If the earth's orbit were much closer to the sun, our liquid water might boil off into steam. If we were much farther away from the sun, our liquid water might freeze. In either case, life either would not be possible, or it would be very much different from what we know.

GREENHOUSE WARMING

An optimum orbital path would keep a planet's temperature just right for liquid water. But what if a planet is a little too far away from the sun, so that it's too cold for liquid water? One solution is for the planet to have a dense atmosphere of thermally insulating gases - like carbon dioxide. Carbon dioxide is what is called a greenhouse gas. It acts like a thermal blanket around the planet, and keeps the sun's incoming heat from escaping. The greenhouse phenomenon is influenced by two factors. They are:

- The proportion of carbon dioxide relative to other gases in the atmosphere. Higher percentage of carbon dioxide, more greenhouse warming.
- The density of the atmosphere. Higher atmospheric pressure, more greenhouse warming.

GRAVITY, AND ATMOSPHERE

Total mass and density contribute to a planet's gravitational pull. Gravity holds gases close to the planet. Holding on to atmospheric gases is difficult for planets close to the sun because these planets are exposed to so much solar energy in the form of heat and the solar wind. So, if a planet is close to the sun, it enjoys being bathed in solar energy, but at a price. If it is to have an atmosphere too, it must be fairly massive and dense in order to generate enough gravity to hold on to its atmosphere. With too little gravity, any gases emitted from the planet's surface will be blown into space by solar wind.

Earth has sufficient gravity to hang on to its atmosphere, in spite of the solar wind's efforts to blow it away. This property has implications when it comes to surface water. It turns out that without an atmosphere, the earth would not have any surface water. The atmosphere exerts pressure (atmospheric pressure - gases pulled toward the planet by gravity) on liquid surface water. This atmospheric pressure reduces liquid water's natural tendency to evaporate. The greater the atmospheric pressure, the less evaporation. Without an atmosphere, all the earth's water would simply evaporate into space. Once a planet has liquid surface water, life is possible.

So, in order for life to exist, a planet needs two main things:

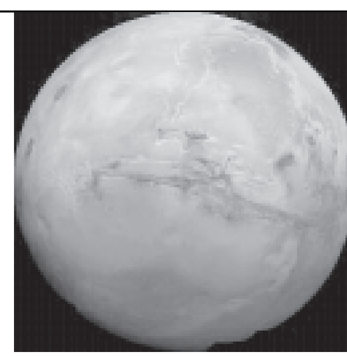
- access to solar energy
- the presence of liquid water.

To summarize, a planet needs:

- to be in close proximity to the sun, but not too close. The sun is a source of energy needed by life. The sun also heats the planet so that water will melt into a liquid.
- liquid surface water. This requires an atmosphere. But, in order to support an atmosphere close to the sun, a strong gravitational pull is required.

What this all means is that in any star system, there may be few or no candidates to support life. In our solar system, the earth is the best candidate, but not the only candidate. There is one other... Mars.

Table 1
Comparing Earth and Mars

	Earth	Mars
		
Mean distance to the sun	1 Astronomical Unit (AU)	1.52 AU
Orbital period	365 days	687 days
Diameter at equator	7,926 miles	4,217 miles
Mass (Earth = 1)	1 Earth mass	0.107 Earth mass
Mean density (water = 1)	5.52	3.94
Max. surface temperature	136° F	80° F
Min. surface temperature	-126° F	-194° F

MARS

See Table 1 for a comparison of Earth and Mars. Mars is the fourth planet from the sun. It is about 50% farther from the sun as the earth. This means it receives less solar energy and tends to be much colder than earth. Mars has a diameter that is about 1/2 of earth's, and a density that is the lowest of the four inner planets. This translates into a much lower gravitational pull. For example, if you weigh 150 pounds on earth, you would weigh only 58 pounds on Mars. This has impacts on Mars' ability to cling to gases, which is to say that it doesn't, very well. The Martian atmosphere is only about 0.75% as dense as the Earth's atmosphere, and 94% of that is carbon dioxide. This thin atmosphere plays a negligible role in keeping the planet warm.

Mars has very little water. Most of it is sealed underground in the permafrost or congregates at the poles in the form of ice, along with frozen carbon dioxide (dry ice).

Although the Martian environment may seem extreme from our point of view here on Earth, when compared to other planets in the solar system, Mars is almost mild — which is why astronomers have wondered for centuries, "Is there life on Mars?"

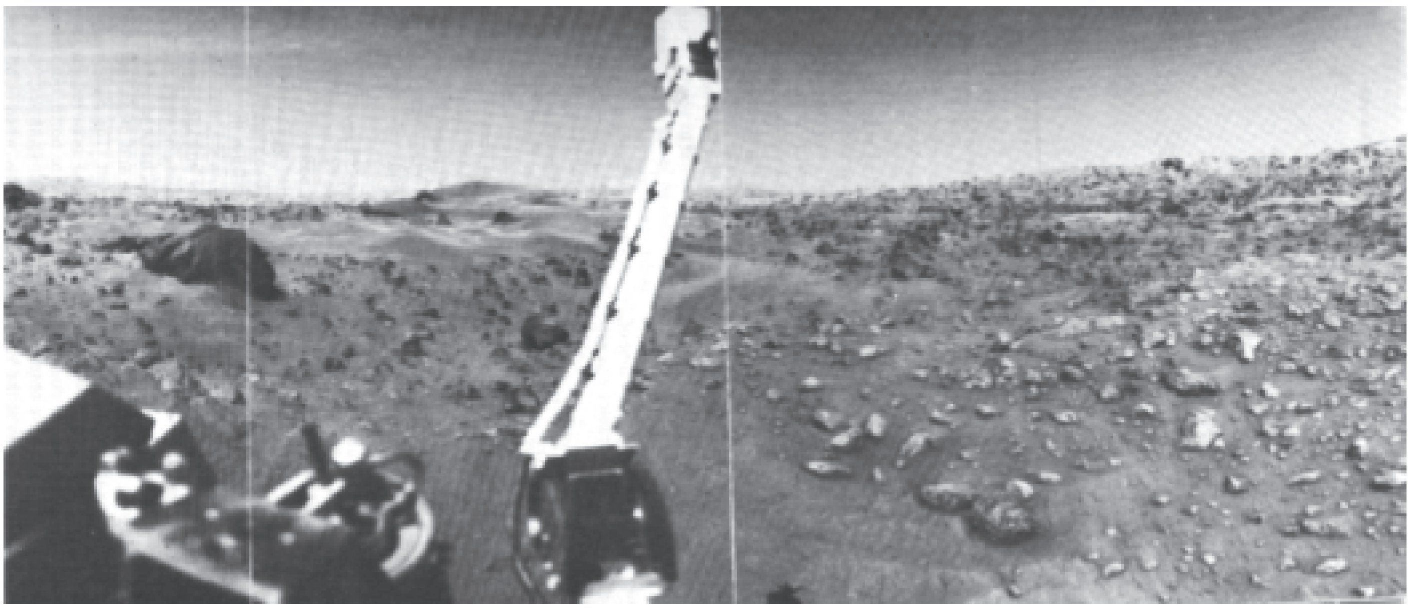


Figure 1. Surface of Mars as seen from a Viking Lander.

Figure 2. Surface of Mars as seen from the Mars Pathfinder.

VIKING AND PATHFINDER MISSIONS

In the summer of 1975, two robot spacecraft were sent toward Mars for the purpose of landing on the planet and taking a looksee. These spacecraft, dubbed Viking 1, and Viking 2, were sent by the National Aeronautics and Space Administration (NASA). Each Viking rocket contained a lander craft that was designed to perform many different scientific investigations on the Martian surface. On July 20, 1976, they made the first soft landing on Mars, and began six months of brilliant exploration. The landers and their lonely orbiters took thousands of photographs and beamed them back to Earth (Figures 1 and 2). They revealed a planet that is more like our moon than Earth. Still, the results of the Viking missions indicated that water must have flowed across the Martian surface many different times in the past. But this is not likely today, or is it?

In the summer of 1997, NASA's Pathfinder mission took pictures of the Martian surface that far surpassed those from the Viking missions.

The Martian landscape is covered with sand, dust and rocks of all sizes. Its atmosphere is thin, yet appears as a haze on the horizon. From the Viking and Pathfinder landers, the vista of Mars looks like a terran desert — and life can exist even in a desert. The Viking landers were equipped to perform many experiments designed to detect signs of life. Most experiments failed to indicate life, but several yielded results that are consistent with the presence of life. So, does life exist there or not? No one knows.

The Viking and Pathfinder missions captured the imaginations of billions of people around the world who thrilled in humankind's newest adventure. They gave us new insights on our own world view, and put in perspective the specialness of earth and the possibilities of beyond. One of these exciting possibilities deals with the potential of terraforming Mars. What would it take to change Mars from a cold and barren rock, to one filled with life?

YOUR ASSIGNMENT

Your group has just been assigned to develop a plan to terraform Mars. Lucky for you, you can use a very cool computer simulation program called SimEarth. Your job is to use SimEarth to teach yourself lessons on how best to go about terraforming Mars.

SimEarth will be running on several computers in the lab. Use SimEarth to try to develop Mars so that it can support advanced human cultures.

Develop a strategy

We suggest you consider a systematic approach. What this means is consider developing a plan before you start fooling with the simulator. We know you want to dive in and see what happens, but that is not an efficient use of limited computer time. Resist temptation. Take a few minutes at the start and plan. A systematic plan should include a series of actions that you intend to take according to a logical sequence.

Keep a log

We want you to keep a log (Table 2) that documents all of your major changes, and the outcome of those actions.

WHAT YOU WILL BE TURNING IN

We want you to prepare a **report of findings**. Make sure you include your log (Table 2). In your discussion section, discuss the following points:

- Why your initial methodology was successful, or not successful.
- What you learned about planetary environmental development and management.
- Your proposal on how best to proceed with the terraforming of Mars.

RUNNING SIMEARTH

SimEarth is a very complex simulator, and you can easily get lost. Don't worry if you do, just call your instructor for help. There is no way you can possibly master the program in the time we have. This is not our expectation. In spite of its high power, SimEarth can be easy to use if you restrict yourself to the necessities. These bare necessities are described below. **Read below instructions first, before launching.**

Graphical User Interface (GUI)

A GUI is a graphical screen that has all sorts of buttons and menus for you to hit with the mouse cursor. You interact with the computer program mostly by moving the mouse around and clicking. The Macintosh computer and Microsoft Windows are popular types of GUIs. For SimEarth, you will use the keyboard some, but the bulk of your work will be with the mouse.

If you have never worked with a GUI before, watch one of your group members for a while, then try it yourself with their help.

Drop Down Menus

There will be a bar near the top of your screen that indicates different categories of menu options. Figure 3 highlights just two of these menu items — “Windows”, and “Graphs”. Move your mouse cursor to the menu item and click with the left mouse button. This action opens a drop down menu. Highlight the one you want and click your left mouse button.

Graphs Menu

The “Graphs” heading provides a drop down menu to check out the status of your world (Figure 3). Use it to get updates on your atmosphere, biome diversity, life form diversity, and technological progress.

Windows Menu

The “Windows” heading provides a drop down menu for your main map windows. It will enable you to open up the “Edit” map, “Terrain” map, and “Globe”.

Edit Map

This map is shown with the heading of “Mars 2.3 Years” in Figure 3. The Edit map is the only map upon which you can make changes directly to your world. You will use this map extensively. The window has a “Toolbar” along the left margin. Tools are accessed by clicking on the tool buttons. The most important of these tools is the “Terraformers” tool.

Terraformers Tool

The uppermost left button on the “edit” map is the terraformers tool. When you click on it a large submenu pops up. This submenu is filled with little toys for you to use on your planet. These are the terraformers. You pick a tool by highlighting it with your mouse cursor and clicking with your left mouse button. Your current tool shows up in the large box on the toolbar.

Once you have picked a tool, then move the cursor over to the map part of the “Edit” map. Simply click your left mouse button to place your object onto the planet.

If you want to remove a terraformer at a later time, you must destroy it with some type of disaster (Disaster tool). One other method that works is to move terraformers on top of other terraformers.

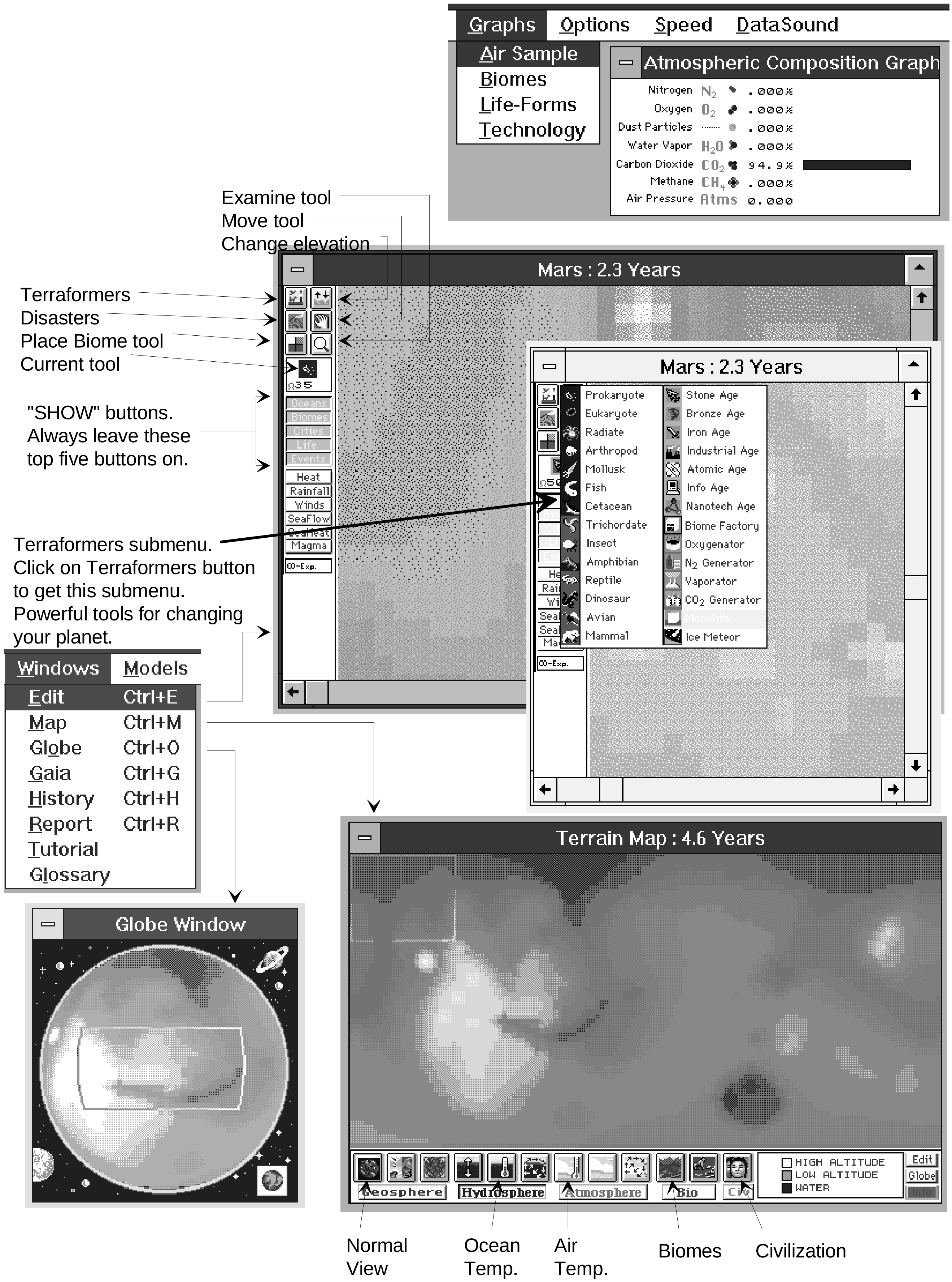


Figure 3. Guide to SimEarth.

Ice Meteor

Use the Ice Meteor to add water to the planet. Make sure your game is not on “pause” (Check the “Speed” menu), otherwise you could add too many ice meteors and flood your planet. If your planet is on “pause”, your planet will not show the effect of the ice meteors.

Don’t get the ice meteor confused with the “regular” meteor accessed through the “Disaster” button.

HINT: Don’t be shy with your planet when it comes to adding water. Remember, this is only make believe. Be bold. Also, more than 2/3 of the Earth’s surface is covered with water.

Generators

You are provided with terrafomers that generate gases in the atmosphere. They include generators for oxygen, nitrogen (N_2), water vapor (Vaporator), and carbon dioxide (CO_2). Use these terraformers to build atmospheric pressure. CO_2 is a greenhouse gas, and is needed as a source of carbon in photosynthesis. Nitrogen adds to atmospheric pressure and is a source of nitrogen for important biomolecules like proteins and DNA. Oxygen is used by animals during cellular respiration. Oxygen also is a very reactive gas, and you could get lots of forest fires if it goes above 25%. Water vapor can be added as a way of encouraging local rainfall. Vaporators are not a good way to add water to your planet.

Biome Factory

Once you think your planet has a hope of supporting life on land, add some Biome Factory terraformers. If your planet can support them, the Biome Factory will automatically start biomes that are most suited to the local environmental conditions. You can also place biomes manually with the “Place Biome” tool.

Life forms

The left column of the Terraformers submenu is devoted to life forms, starting with primitive at the top and working down to most advanced on the bottom. Consider food chain realities before placing life forms. Also, once your planet gains momentum, many of these life forms will begin to emerge on their own.

Civilization

The upper half of the right column on the Terraformers submenu consists of different stages in human civilization. The most primitive is the “Stone Age”, and the most advanced is the “Nanotech Age” which is characterized by molecular construction, molecule-sized machines, and completely automatic production. Your goal is to proceed through all stages of human civilization from stone age to nanotech age.

Terrain Map

The “Terrain Map” shows a flat projection of the entire planet. You cannot edit this map, but you can get a full layout perspective on the status of your world. There are buttons on the bottom of the map that overlay various kinds of information onto the map. They include such information as air temperature, ocean temperature, distribution of different biomes, and distribution of different civilizations. Always click on the left button (on the Terrain map window) to return to normal view.

Globe Window

Use this window only once in a while, because it tends to slow down the simulation. But do use it to get a global view of your Mars. When you are through, close this window by clicking the bar box in the upper left-hand corner of the window. This will automatically close the window. For Microsoft Windows users, choose “Close” from the submenu after clicking the bar box.

Table 2
Log of Results
Terraforming Mars with SimEarth

ACTION	RESULT