



## MEMORANDUM

**To:** Mission Critical Chemistry Team Members

**CC:**

**From:** Director of Physics Subdivision

**Date:** October 16, 2003

**Re:** Fuels

The physics team assigned to the Mission Critical Chemistry project has done an analysis of the rocket characteristics, and created a flight simulator for the mission to Mars.

### **Rocket Characteristics**

The fuel is stored in two towers, one for the oxidant and one for the reductant. Each tower may contain up to  $6,100,000 \text{ cm}^3$  of fuel. (The volume of fuel is one of the launch parameters.)

The fuel is delivered into the reaction area through nozzles that control the fuel flow. The nozzles can deliver flow rates of up to  $25,000 \text{ cm}^3/\text{sec}$ . (This is one of the launch parameters.)

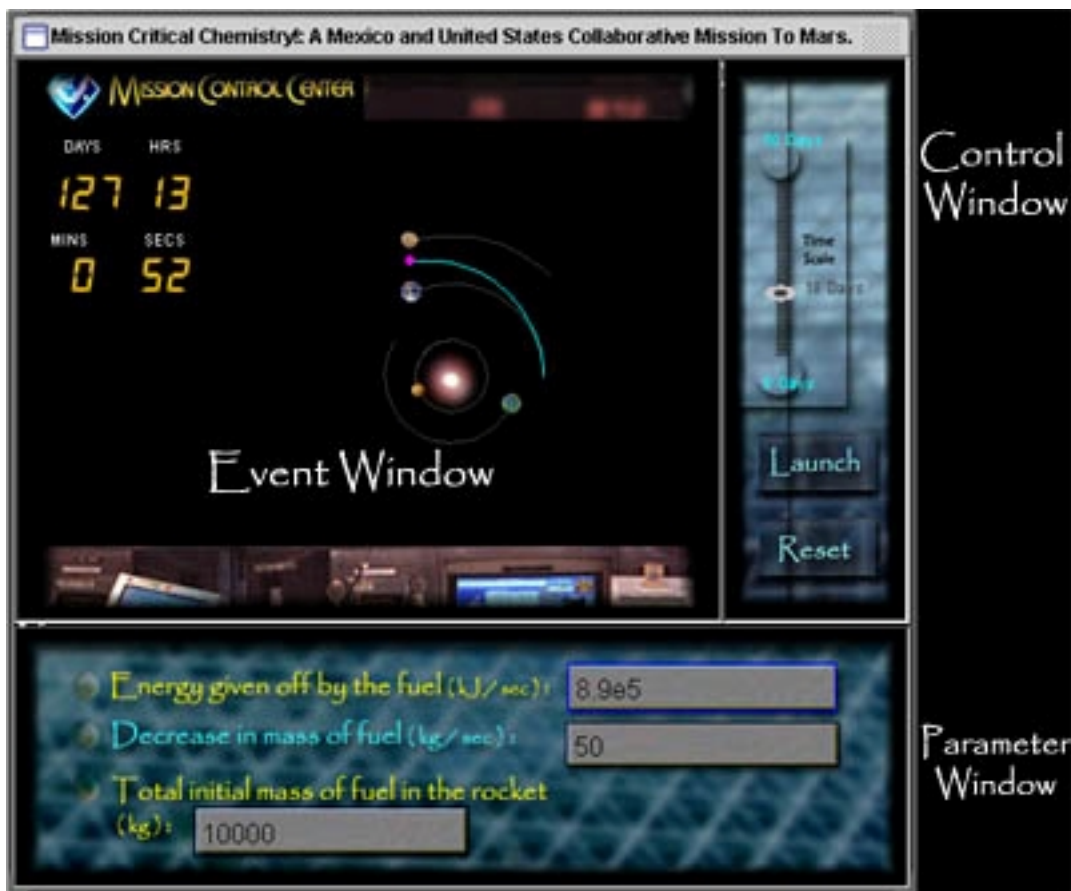
### **Using the Trajectory Simulator**

The Trajectory Simulator allows you to determine the amount of fuel necessary to reach Mars. This simulator shows the path of the rocket as it leaves Earth and heads to Mars. On our launch date, Mars will be 45 degrees ahead of Earth, so the simulation always starts with the planets in this configuration. The trip should take approximately 190 days.

The simulation takes three parameters:

- Energy given off by the fuel reaction, in kJ/sec
- Loss in mass of fuel, in kg/sec
- Initial mass of fuel, in kg

The simulation assumes that the rockets burn until the fuel is completely consumed, so the burn time is given by  $(\text{Initial mass of fuel})/(\text{Loss in mass of fuel})$ .



The Simulator consists of three windows: the Event Window, the Control Window, and the Parameter Window.

When you first start the simulator, it will have the following default parameters:  
 Energy given off by the fuel reaction =  $8.9 \times 10^5$  kJ/sec (this means  $8.9 \times 10^5$ )  
 Loss in mass of fuel = 50 kg/sec  
 Initial mass of fuel = 10000 kg

These default parameters will not lead to a successful mission. To see this:

- Click on the Launch Button in the Control Window to launch your rocket and follow its trajectory as it leaves earth and heads towards Mars. The Event Window will show a schematic of the inner planets from Mercury to Mars, and the rocket, shown as a pink dot.
- Use the slider above the launch button to speed up or slow down the simulation. You may want to increase the speed as you become familiar with the simulator.

The following steps will allow you to see a successful mission:

- Increase the initial mass of fuel in the rocket to 15000. In the Parameter Window, click on the blank that corresponds to that parameter and edit the value. Note that the parameter boxes do not have a cursor (just start typing to see that you are in the desired box).

- Hit the Reset button in the Control Window. This returns the planets to their pre-launch configuration, with Mars 45° ahead of Earth.
- Hit the Launch button, to see a trajectory that uses these new parameters. (Since the parameters are not read until you hit the Launch button, you can hit the Reset button either before or after entering new values.) With these new parameters, your mission should succeed and you should get a message indicating you successfully reached Mars.

## Troubleshooting

Here are some suggestions for identifying and overcoming problems that may arise while using the simulator.

- If you do not have enough energy to break free of the gravitational force of Earth, the simulator will say “Not enough energy to achieve escape velocity”. You might try increasing either the amount or energy content of your fuel.
- If you are having trouble reaching Mars, note that as you increase the amount of fuel, you get more energy from the fuel reaction, but the rocket must carry more mass on its journey. For certain fuels, the energy content of the fuel is simply not sufficient to allow the rocket to reach Mars. For instance, try the following parameters:
  - Energy given off by the fuel reaction = 4e5 kJ/sec
  - Loss in mass of fuel = 50 kg/sec
  - Initial mass of fuel = any value
 If you run into this situation for a certain choice of fuels, you might try identifying a better combination of fuels.
- If you put in any zero or negative parameters, the simulator will issue a warning when you hit launch.
- If the outcome is not at all what you expected, check for typographical errors in your input parameters, for example 8,9e8 instead of 8.9e8 (comma instead of period).
- If this simulator, or any other Java software, won't respond or behaves erratically, hold down the control key (Ctrl) and hit your browser's refresh button. If that does not work, try closing and restarting your browser.