# CS0011 Introduction to Computing for Scientists
# Project 1
# Lab 1

## Overview

Consider the following problem:

You are docked at the ISS with your shuttle, the *Knight*, when you receive an alert that space pirates are attacking a currently-unmanned base on Mars. Your intelligence crew reports that the base is reasonably well-protected, but losses will nonetheless result. They estimate losses of $120,000 per day (for this project, we'll be considering only Earth days, 24 hours), until you can reach the base and prevent any further damages. Luckily, Earth and Mars are relatively close to opposition (their closest approach), and as such the distance to travel is only 75,000,000 km.

Given this, your goal is to reach Mars in time to minimize the losses from this attack. Your supervisor approves fuel expenditure up to 100,000 kg (the most that the *Knight* can hold), and asks that you keep total losses (from fuel and damages) to under $70,000,000 if at all possible. Can you do so?

In addition to the above, you may assume the following:

- the *Knight* has a dry weight (mass without fuel) of 100,000 kg
- Acceleration is close to instantaneous and follows the Tsiolkovsky rocket equation

$$v = v_e \ln \frac{m_0}{m_f}, \tag{1}$$

  where $v$ is the velocity of the *Knight*, $v_e$ is the effective exhaust velocity, $m_0$ is the initial total weight of the *Knight* (dry weight plus mass of fuel), and $m_f$ is the dry weight of the *Knight*.
- the *Knight* is powered by a specialized fuel that costs $1,000 per kg
- The engines of the *Knight* can expel its specialized fuel with an effective exhaust velocity of 10,000 m/s
- the *Knight* will travel uninhibited at its intended velocity until it arrives at Mars
- You do not need to consider deceleration upon arrival, nor the cost of fuel to return from Mars (though note that both could be modeled using Tsiolkovsky's equation) You do not need to consider any other costs beside damages from the attack and fuel to make it to Mars.

You will develop a program to determine an effective amount of fuel to bring on the trip. If you bring too much, you may spend too much money on fuel to keep losses below $70 million. If you bring too little, you may not accelerate to a high enough velocity to stop the damages in time.

If it is possible to keep total losses below $70 million, give an amount of fuel that allows you to do so. If not, give an amount of fuel that comes as close as you can, and state the total losses.

# Lab 1

## Part 1: Calculate the velocity

First, we will use Equation 1 to calculate the velocity of the *Knight* given an amount of fuel.

1. If the *Knight* is carrying $x$ kgs of fuel, what is its total weight?
2. Create a variable `fuel` to represent the fuel mass and assign it some value in the range 0 to 100,000.
3. Using Equation 1, the variable `fuel`, and the above information, calculate the final velocity of the *Knight*. You will need to import the `math` package. The function `math.log(x)` calculates $\ln x$ (the natural logarithm of $x$). Assign the velocity to a variable `v`.
4. Print `v` using the `print` function.

Run your program. It should print the velocity resulting from the amount of fuel you chose.

## Part 2: Compute other values

Using the velocity `v` that we have just calculated, we can now calculate the other values we will need for this project.

### Duration

1. Let's call the distance between the Earth and Mars $d$. Given that it has velocity $v$, how long will it take the *Knight* to get to Mars? Consider acceleration to be instantaneous.
2. In your program, use the variable `v` to calculate how long it will take take the *Knight* to get to Mars, in seconds. Note that the distance between the Earth and Mars is given in kilometers. The velocity we've calculated above has units meters per second.
3. Convert this time to days and assign it to a variable `days`.
4. Print `days`.

**Fuel cost** Next, use variable `fuel` to compute the total cost of fuel used. Assign this value to a variable `cost` and then print it.

**Losses from damage** Calculate the losses due to the space pirates' attack before the *Knight* arrives; use the estimated loss per day given by the intelligence crew in the Overview. Assign this value to a variable `loss` and then print it.

**Total value lost** Calculate the total value lost due to the space pirates' attack. This includes both the cost of the fuel and the losses from damage. Assign this value to a variable `net` and then print it.

Run your program to see the velocity, duration, fuel cost, losses from damage, and total value lost for the amount of fuel you chose.

## Part 3: Ask user for input

Now, rather than setting the value of `fuel` in the program, ask the user to enter an amount of fuel in kilograms. Then calculate and print the velocity, duration, fuel cost, losses from damage, and total value lost for this amount of fuel.

*Hint:* What function should you use to ask the user to enter a value? What type is returned by this function? What type does `fuel` need to be to do the computations you've already implemented?

## Part 4: Run some experiments

Finally, use your program from the last part to experiment with different amounts of fuel in order to get an idea of the range of losses we will have to sustain due to the space pirate attack.

Once you have completed all parts of the lab, show your work to the lab instructor.