Dynamics of Reaching Earth Orbit

New Mexico
Supercomputing Challenge
Final Report
April 6, 2011

Team 57
Onate & Mayfield High Schools

Team Members:
Austin Kirkpatrick
Arthur T. Kindig

Teachers:
Thomas Kindig

Mentors:
Thomas Kindig

Executive Statement:

Our teams project is called “The Dynamics of Reaching Earth Orbit.” The purpose is to test the efficiency of launching a rocket from different latitudes on the earth. At the equator the earth rotates at 1670 K/h. A rocket launched from the equator may use this rotation velocity to reducing the amount of fuel needed to achieve Escape Velocity (EV), the speed at which it is possible to escape Earth gravity. Our project is to model the fuel required to reach an equatorial orbit from launch points at various latitudes.

To proceed with our project my partner and I had to do several things. We first had to gather information on orbital mechanics. These included the rotation speed of the earth, the speed at which a rocket must obtain to reach LEO (Low Earth Orbit), and the exact speed bonus that is given to a rocket during launch from a given latitude. We began with Tsiolkovsky’s rocket equation. We assumed a rocket and payload with a fixed final mass and with a fuel carrying capacity sufficient to reach orbit from the highest latitude tested. We then spent the next few weeks programming and getting help from programmers and people who had experience doing the challenge. We created a working model to simulate the effects that launching this rocket from various latitudes.

Problem Statement:

The business of transporting objects from Earth to space is subject to geopolitical boundaries, and engineering and safety constraints. In the United States, NASA and the U.S. Air Force have chosen to launch most of their space vehicles from Cape Canaveral Florida. This location is closest to the equator, and is also on the coast of the Atlantic Ocean. Vehicles launched from Cape Canaveral travel to the east as they climb to orbit, out over the ocean where they pose no threat to people and property in the area. That facility is located as 26° 23' N latitude.

Spaceport America in southern New Mexico does provide some safety margin due to the low population density of the area, and the very large White Sands Missile Range. Spaceport America is located at 32° 59' N. latitude. The table below shows that latitude and velocity for various national launch site locations and Spaceport America.

Launch Site	**Latitude**	**Velocity Km/h (Km/s)**
Euro Space (French Guiana)	5° 3' N	1663.34 (0.4620)
Barreira do Inferno (Brazil)	5° 55' S	1660.92 (0.4613)
Xichang Satellite Launch Center (China)	8° 14′ N	1652.62 (0.4591)
Cape Canaveral Florida (U.S.)	26° 23' N	1495.90 (0.4155)
Spaceport America	32° 59' N	1400.69 (0.3892)
Baikonur Cosmodrome (Russia)	45° 57′ N	1161.01 (0.3225)

Comparison of latitude of various launch sites.

In order to reach low earth orbit (LEO) a body must reach a velocity of 17,000km/s. In order to understand how much energy is required to for a rocket to reach orbit, we used the Tsiolkovsky rocket equation. [3]

$$\Delta v = v_e \ln \frac{m_0}{m_1}$$

where:

$m0$ is the initial total mass, including propellant.

$m1$ is the final total mass.

ve is the effective exhaust velocity. ($v_e = I_{sp} \cdot g_0$ where Isp is the specific impulse expressed as a time period)

Δv is delta-v- the maximum change of speed of the vehicle (with no external forces acting)

The Tsiolkovsky rocket equation.

We used derivations of this equation in our model.

As an example of a rocket that was used to reach orbit, the Saturn V carrying a 118,000 kg payload to LEO had a gross mass of 3,038,500Kg. [4]

In order to represent this, we programmed with Relogo of Repast Symphony, within Eclipse.

Method:

In order to effectively model our project, we began with gathering the sufficient research pertaining to our field; The Dynamics of Reaching Orbit. Such research pertaining to the project consisted mainly of rocket science: mathematical models, related projects, physics, and historical background. With information in hand, we were able to establish a firm understanding of the mechanics behind our project and all relevant aspects we may undertake, as well as resources for any more research needed as the project makes progress. For specific parts of the project, it was necessary to go more in depth.

In order to work on the program, we used equations pertaining to rocket efficiency and rocket physics, most notable Tsiolkovsky's Rocket Equation, from research and discerned how to effectively combine them within the programming in order to adequately represent our research. Taking these pieces of information, we incorporated their use to covering the variables to be studied in our project, most notably launching from different latitudes. Ultimately, the program will visually represent, complimented with in flight statistics, the time differences in launch durations resulting from launching from different latitudes. The resulting time, being longer, would reflect that more finances go towards more fuel...and in turn a larger rocket to house the fuel.

Results:

The resulting time expressed from the program is longer from launching at latitudes farther away from the equator. An increase in flight time denotes an increase in fuel required in order to achieve low earth orbit. Cost-wise, this would mean a larger financial cost due to the increase of fuel needed. The increase in fuel in turn could require a higher capacity fuel tank which could alter the entire design of a rocket. From this observation, it would be financially beneficial to launch from latitudes closer to the equator. However, weather and climate decide the safety and validity of a launch, and in generally unfavorable weather and climate along the equator, can result in even greater financial loss.

Conclusion:

Launching a rocket to low earth orbit from the equator creates the least cost, in regards to the flight, as the Earth's rotation offers the most speed bonus at that latitude. Generally, even before a launch may take place, favorable weather conditions must exist. The climate along potential launch sites on the equator is, more often than not , unfavorable for a rocket launch. Even the construction of a launch site along the equator would be difficult due to many factors, not least of which being financial investment.

In order to make a good decision, the risks as well benefits must be fully understood. Balancing cost and safety is the most paramount of these. The simulation of a launch of a rocket to low earth orbit from different latitudes offers a visual understanding of factors associated with choosing a location for a launch site. Therefore, choosing a safer and stable environment...which might not be located along the equator, could be considered more carefully against the cost.

Software and References:

The software that we used to create our program was Repast Symphony as the programming language, and Eclipse as the GUI.

Online Sites:

http://en.wikipedia.org/wiki/Tsiolkovsky_rocket_equation

http://www.aerospaceweb.org/question/spacecraft/q0115b.shtml

http://www.braeunig.us/space/orbmech.htm#launch

http://exploration.grc.nasa.gov/education/rocket/rktrflght.html

http://www.grc.nasa.gov/WWW/K-12/airplane/rockth.html

Significant Achievements:

Our experience with the Supercomputing Challenge has been very beneficial and valuable for our future. In working with the program, we have learned skills that are associated with debugging code and creative thinking used to create the program from the ground up.

People:

Our teacher and mentor is Thomas Kindig, he was very helpful in providing us with information relating to the challenge. He also provided us with sites to help us research our experiment. Ruben Marquez was another very helpful person to our group, he gave us tips on how to improve and debug our program, and also offered us help with our Final report.

Nick Bennett helped us briefly, but gave us the Idea to use Repast Simphony as our choice of program. Richard Oliver also helped by giving us some ideas on how to improve our PowerPoint.