# N.E.R.D.S
# New Mexico
# Supercomputing Challenge
# Final Report
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Team 95
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**Executive Summary:**

Our project was to develop tools and programs to simulate a constellation of radar satellites to track and gather data on hurricanes. We were inspired by the devastating effects of hurricane Katrina and other hurricanes. Although Katrina's amount of damage was not solely based on the poor information, better and more timely information about the hurricane it would have saved lives and reduced damage. Improved prediction of hurricanes intensities and paths would allow emergency officials to better distribute their resources. Current weather satellites do not provide sufficient information for prediction of hurricanes direction of intensity. Our objective was to develop tools for designing a constellation of satellites that could gather the necessary data for effective hurricane prediction models. To achieve this goal, we used the program, Satellite Tool Kit (STK) to model satellites as well as hurricanes. It addition to STK, we wanted to create at least one C++ program to determine the size of the satellite's footprint and sensor range.

We call our system N.E.R.D.S (Near Earth RaDar Satellites). Current weather satellites don't measure wind speed and precipitation rate needed for accurate hurricane intensity and path prediction. Radar carrying satellites can provide this information, but there is only one operating at this time, that is CloudSat. To provide global coverage and frequent revisit times a constellation of radar carrying satellites would be needed.

**Statement of Problem:**

In order to gather sufficient data for short term hurricane predictions a constellation of satellites needs to be designed which covers the hurricane latitudes and sees the hurricanes at least every few hours.

**Description of Method:**

To do what we have done required the information our mentor provided us as well as the use of the pre-existing program STK. From there we used C++ to develop our own tools to quickly gather the satellites altitude, slant range, and footprint.

Mr. Keenan provided us with the most efficient altitudes (700km to 1000km) as well as the maximum angle (60 degrees) they can view from. Besides this key information we also expanded our vocabulary when referring to satellites.

*FOOTPRINT*: a footprint is the circle on the ground that the satellite's radar can see. It can also be referred to as a ground track.

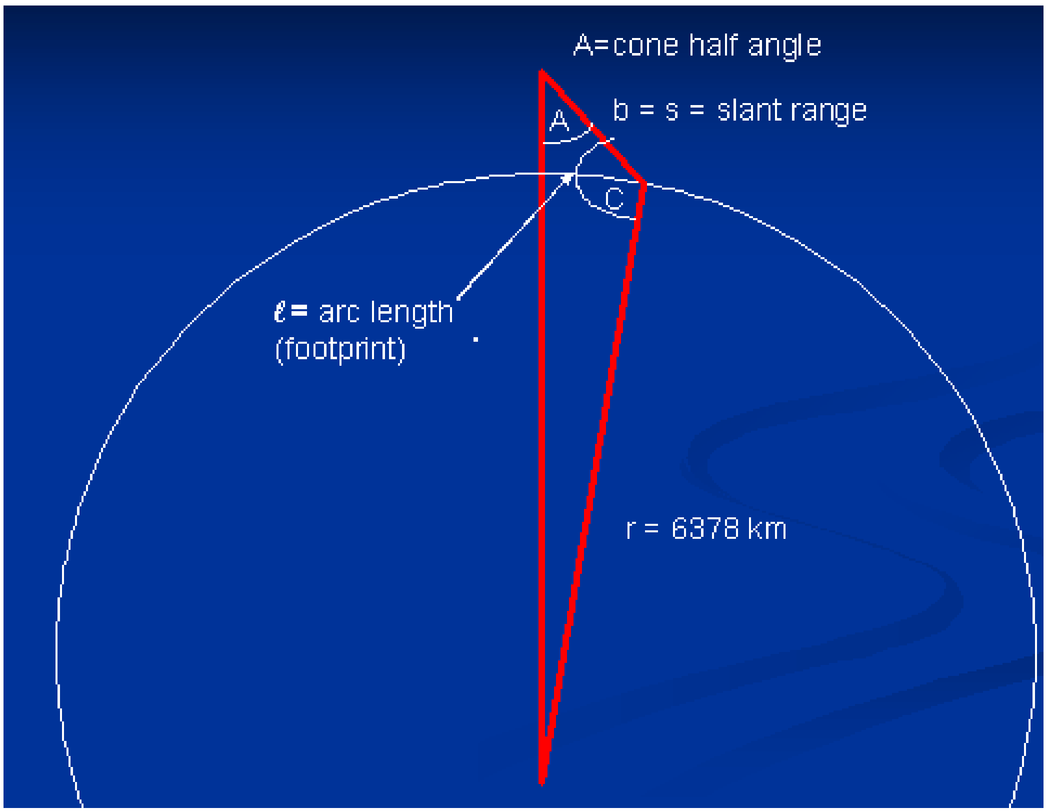
*CLOUDSAT*: Cloudsat is a satellite orbiting the earth now. It uses radar technology to gather information on clouds. It is one satellite in a system of 5, but is the only one that is equipped with radar.

*NEAR EARTH RADAR SATTELIETS*: A near earth satellite flies significantly closer to earth than a geo-synchronous satellite. It is usually a few 100 to a few 1000 kilometers of the earth. Each orbit takes and average of 100 minutes.

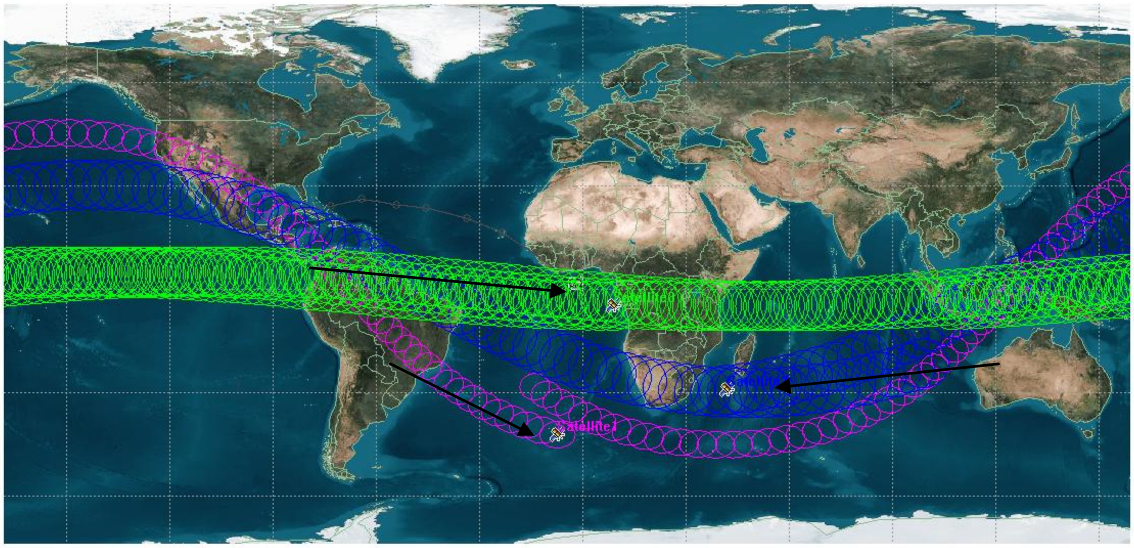
*ACCESS*: An access is a list of times generated by STK. STK documents all the times in which a satellites radar comes in contact with the hurricane or ground station. STK then puts this information on a list, known as an access. We have used the access to determine the most efficient satellite constellation.

*SLANT RANGE*: Distance from the satellite to a point on the ground. It is used to determine the capability of the radar on the satellite. The maximum slant range drives the design of the radar.

*CONE HALF ANGLE*: Angle created by the altitude and the slant range.




STK is a program that models satellites and ground vehicles among other things. You can create several different satellites, and satellite constellations. You can set the path of the satellite by imputing the altitude and degree off the equator. You can create ground vehicles by imputing latitude and longitude of the path. Using STK, we created five different constellations. We compared all of these systems and found the best to be a constellation of three satellites, two flying at the same degree off the equator, in opposite directions. The last one flies at a much smaller angle.



Our programming language was C++. With it, we were able to develop two tools to calculate the slant range and footprint of the satellites at various heights and angles. This allows anyone to simply input the altitude and angle desired to get back the footprint and slant range it would be at the specified settings.

Hard Math:

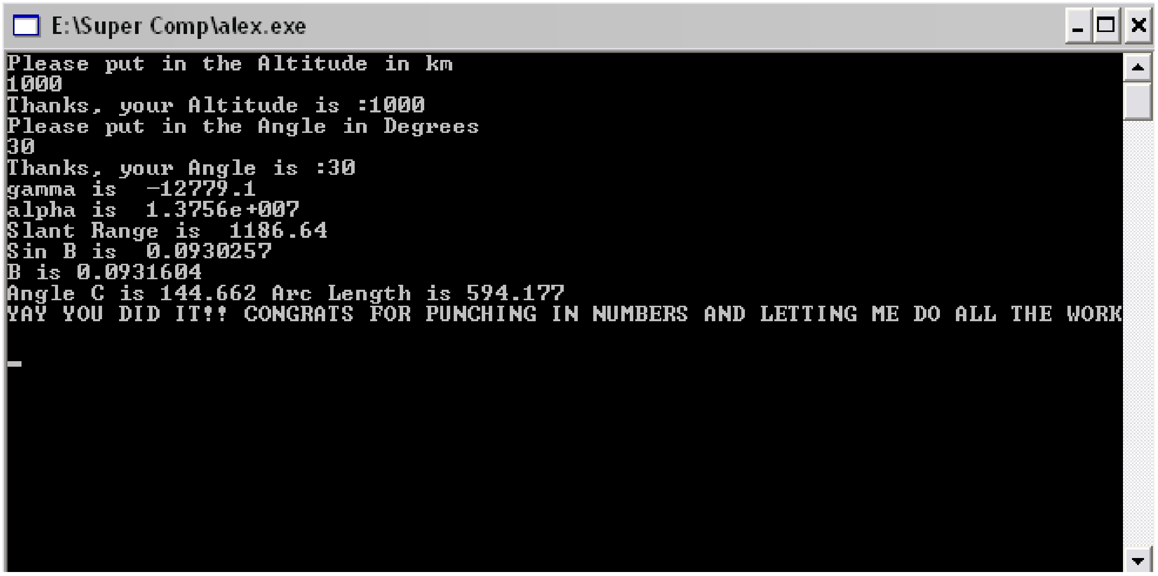
Law of cosines: $a2 = b2 + c2 – 2*b*c*cos(A)$

Law of sines: $a/(sin(A)) = b/sin(B) = c/sin(C)$

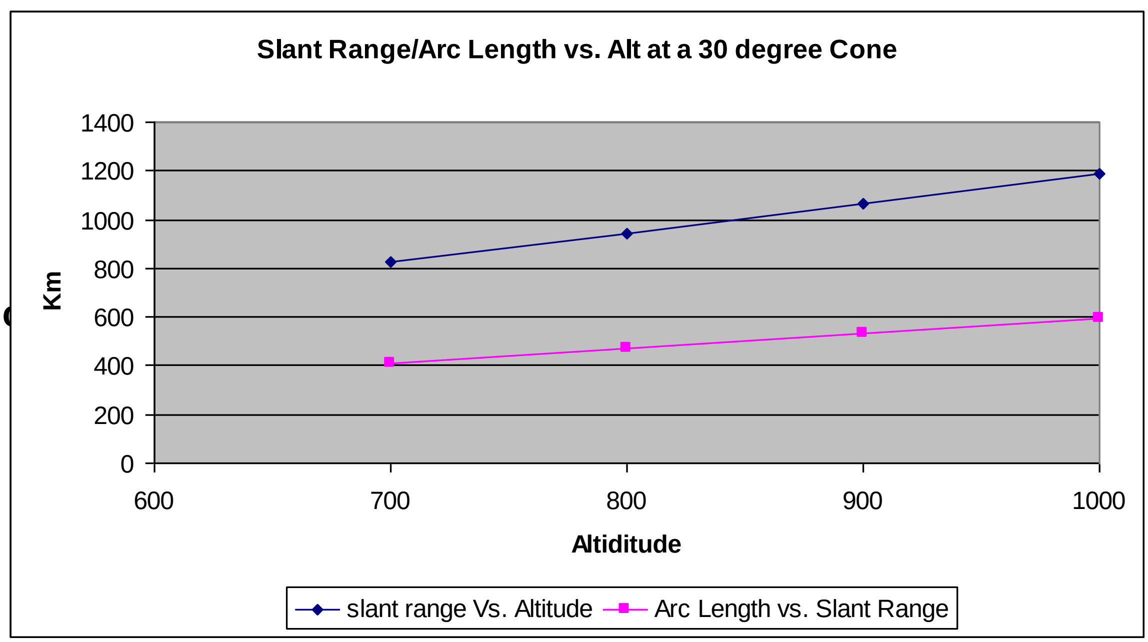
$a*x2 + b*x + c = 0$, then $x = [ -b + sqrt(b2 – 4*a*c) ] / (2*a)$

or $x = [ -b - sqrt(b2 – 4*a*c) ] / (2*a)$

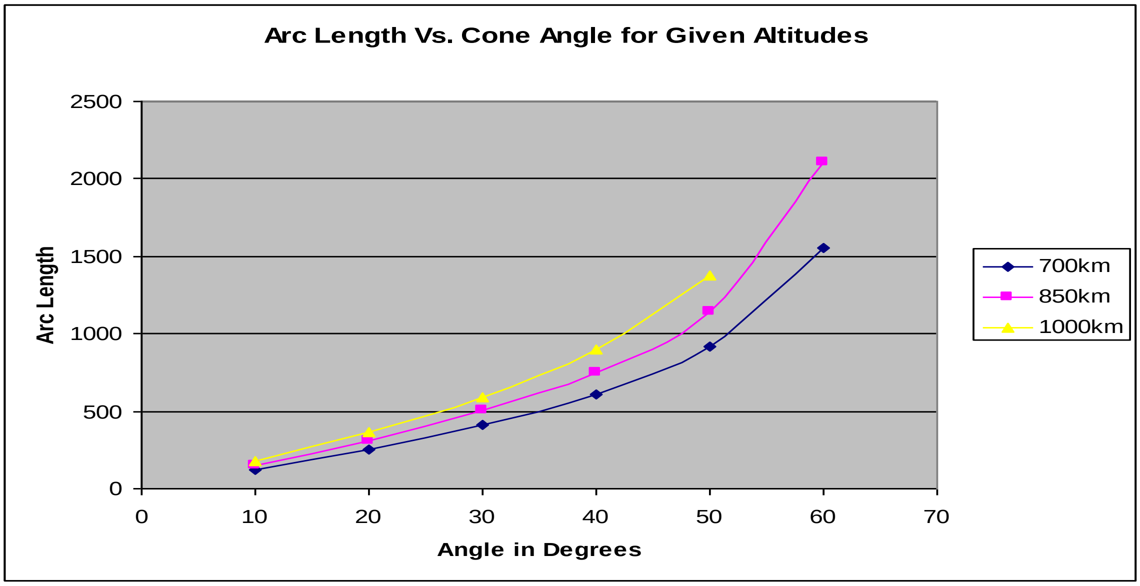
Easy Math:




After getting the information from the program we compiled it into easy to understand graphs.




This graph represents the slant range and arc length at a satellites maximum footprint of 30 degrees. As shown the graph clearly increases as one goes up in altitude.




This graph represents what would happen if the radar system was and expand to a larger footprint. As of now we cannot go past 30 degrees. This graph demonstrates the effectiveness if we were to expand that field of vision.

**Conclusion/Analyzes:**

Our team made great progress throughout the year. We achieved our set goals to find which system of satellites was most accurate under our set limitations (Altitude between 700 and 1000km and degrees up to 30). Our guide lines for most effective were: the amount on time the satellite saw a hurricane and the amount of time the hurricane saw the ground control. We also managed to create a tool to quickly calculate the footprint and slant range. Although our team did not achieve all we wanted to it was great experience and we feel that we have all learned a lot about satellites and teamwork.

**Refrences:**

| **Rank** | **Hurricane** | **Year** | **Category** | **Damage In Millions** |
|---|---|---|---|---|
| **1** | **Andrew (SE FL, SE LA)** | **1992** | **5** | **26,500** |
| **2** | **Charley (SW FL)** | **2004** | **4** | **15,000** |
| **3** | **Ivan (AL/NW FL)** | **2004** | **3** | **14,200** |
| **4** | **Frances (FL)** | **2004** | **2** | **8,900** |
| **5** | **Hugo (SC)** | **1989** | **4** | **7,000** |
| **6** | **Jeanne (FL)** | **2004** | **3** | **6,900** |
| **7** | **Allison (N TX)** | **2001** | **TS** | **5,000** |
| **8** | **Floyd (Mid-Atlantic & NE U.S.)** | **1999** | **2** | **4,500** |
| **9** | **Isabel (Mid-Atlantic)** | **2003** | **2** | **3,370** |
| **10** | **Fran (NC)** | **1996** | **3** | **3,200** |
| **11** | **Opal (NW FL, AL)** | **1995** | **3** | **3,000** |
| **12** | **Frederic (AL, MS)** | **1979** | **3** | **2,300** |
| **13** | **Agnes (FL, NE U.S.)** | **1972** | **1** | **2,100** |

**http://www.nhc.noaa.gov/pastcost.shtml**

**Significant Achievement:**

We developed a program that calculated slant range and cone angle as a function of satellite altitude.

We created five different scenarios in STK. All of these varying scenarios were used to write our programs, and to find the most efficient constellation**.**

**Acknowledgments:**

We would like to thank a number of people for their assistance and guidance during the time of this program.

Thank you Mr. McBeth, for organizing the supercomputing challenge. With out your help, we would not have been able to have this fun experiacne. You gave us mental support when we were going crazy, and were always there to talk to.

Also thanks to:

Mr Donald Keenan, with out your guidance, we would be lost in space.

Bob Anderson for your wonderful help with the confusing language of C++.

Kim Hughes for your wonderful help with the confusing language of English.

Mrs. Cheryl Luera, Mrs. Sam Simms, and Mrs. Gayla Walden for review our power point in February; you were able to give us great information and help us fill our 30 minute time slot.

And finally, all our family and friends who did not deserve to be named; you make us laugh.

Thank you all. You have made this a wonderful, beneficial experience.

We love you all!