Process Book

CS 6630

Final Project

Fireballs, Meteorites, and Future Impact Events

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Basic Information

Project Title: Fireballs, Meteorites, and Future Impact Events

Repository: https://github.com/rajathjavali/cs6630nasaproject

Website: https://rajathjavali.github.io/cs6630nasaproject/finalproject/

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Overview and Motivation

Astronomy provides insight into the phenomena that occurs beyond Earth's atmosphere. Our interest in the subject provided the motivation for this project. The objective of our visualization is to learn about the activity in space surrounding Earth by exploring past and potential impact events with meteors. The project covers three sets of data that describe the following: meteorites that were recovered after landing somewhere on Earth; fireballs, also known as bolides, which are defined as very bright meteors that usually explode in the atmosphere; and future potential impact events with Near Earth Objects (NEOs).

The first two datasets allow us to observe past events. The visualization helps us see the number of events per year, and whether there is a pattern in the data such as an increase in events over certain years. Additionally, we can learn more about the types of events that occurred each year. For example, we can count the number of meteorites that fall under a particular classification or the number of fireballs that had a large impact energy. Additionally, we can discover which locations have had the most recorded meteor activity.

For potential future impact events, we are using a dataset from the Center for Near Earth Object Studies at NASA's Jet Propulsion Laboratory. The data describes NEOs, which are defined as comets or asteroids that have an orbit with a close approach to the Earth. Using this data, we can visualize the number of potential impacts for various NEOs, the probabilities of impact, and other characteristics of the NEOs themselves.

Related Work

Inspiration for this project came from personal interest in astronomy as well as the work and research done at NASA. This includes work from the Center for Near Earth Object Studies at NASA's Jet Propulsion Laboratory. Exploring the datasets provided on their website led us to choose the topic of NEOs for our final project.

Questions

The main questions we want to answer with this project include the following:

1. How many meteorite and fireball events have occurred over the years?
2. Which locations have had the most meteorite and fireball activity each year?
3. How do the events compare to each other each year?
4. What do future impact events look like?

Data

We will be using three datasets: meteorite landings, fireball and bolide data, and impact risk data. The first dataset, which describes meteorite landings, can be found at NASA's Open Data Portal by following this link: https://data.nasa.gov/Space-Science/Meteorite-Landings/gh4g-9sfh. The second and third datasets are from the Center for Near Earth Object Studies at NASA's Jet Propulsion Laboratory. The fireball and bolide data can be accessed using the following link: https://cneos.jpl.nasa.gov/fireballs/. The impact risk data comes from the Sentry System at JPL, and the dataset can be found using unconstrained settings for the table at the following location: https://cneos.jpl.nasa.gov/sentry/.

Since the data is already provided through NASA and downloadable in CSV format, we did not expect to do much data cleanup. However, some columns of data needed to be parsed out of the provided string format in order to be used in our project. These included latitudes, longitudes, and years.

To give a narrative of events, we derived the quantity of fireball and meteorite events by counting the number of rows associated with each year. In order to compare meteorite and fireball events to each other, we also needed to filter the data. The meteorite dataset covers dates ranging from the year 860 to 2013, while the fireball dataset ranges from 1988 to 2017. As a result, we centered our visualization on the years where the two datasets overlap: 1988 to 2013. This allowed our project to have a clearer focus for exploring the timeline of past events.

In addition, we needed to process the data for our comparison chart view. In order to compare the large number of events that occur certain years, we needed to arrange the data into a more concise format. This involved counting and sorting the rows into buckets so that we could compare the number of events that fall within a particular category or range of variables such as class, mass, radiated energy, and impact energy.

Exploratory Data Analysis

The visualizations we looked at for inspiration were available at the same locations as our data sources. On the webpage for the fireball data source (https://cneos.jpl.nasa.gov/fireballs/), there is a map that shows each fireball event in the dataset. We built upon this idea by adding additional views that could be linked to the map view in our visualization design. This would allow the data to be more navigable and open to exploration.

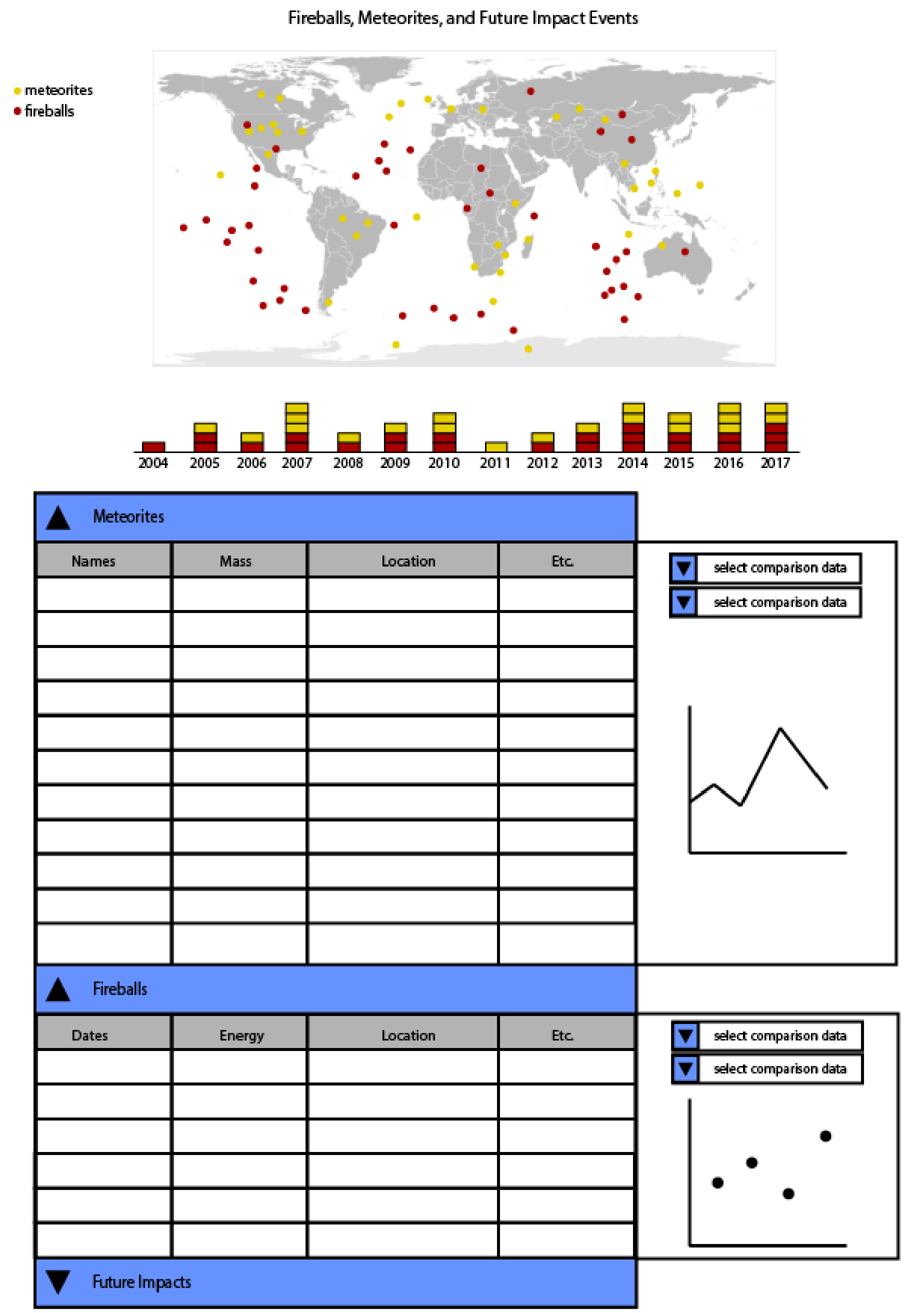
In addition, the meteorite landing data provided a generic interface for exploring the information (https://data.nasa.gov/Space-Science/Meteorite-Landings/gh4g-9sfh/data). Selecting certain options allows the user to choose columns of data to visualize. This provided the inspiration for the expandable table in our design. However, we simplified the interface so that it only uses a line chart, which benefits from the properties of the channel of position.

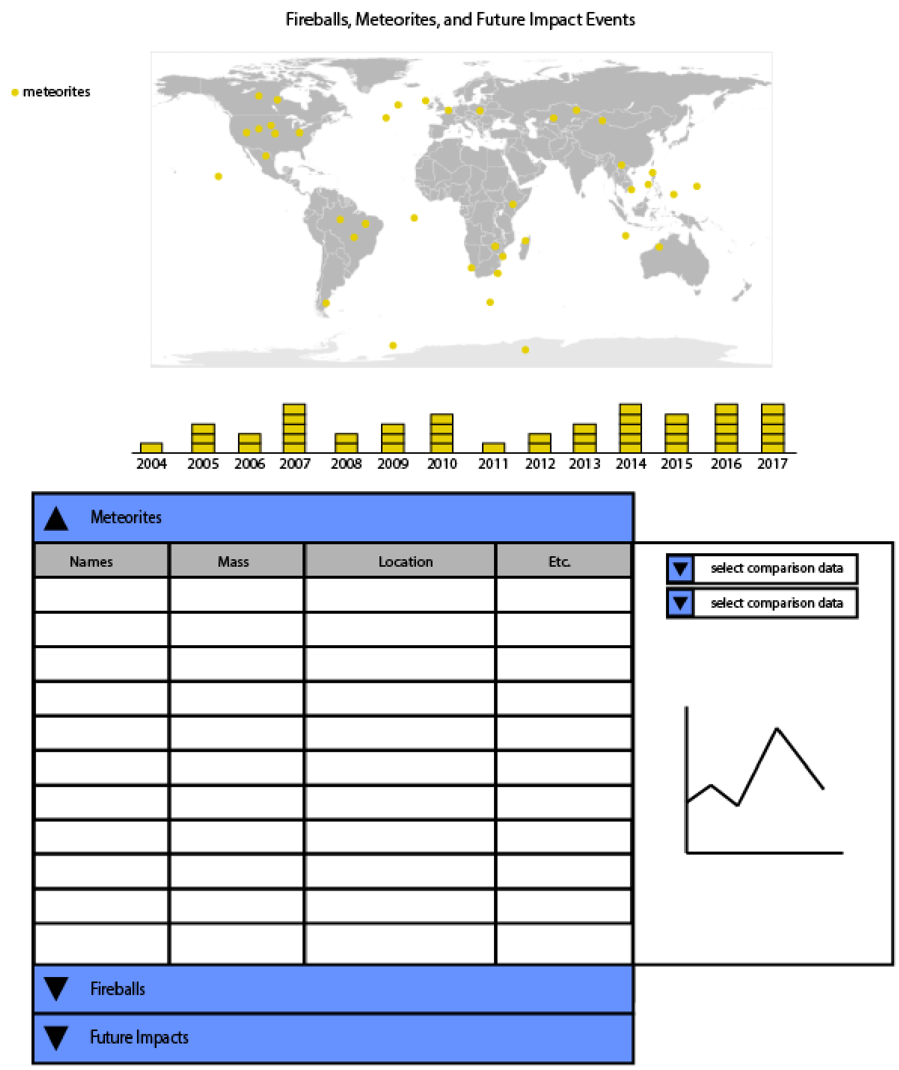
- ## Design Evolution

Proposal Design:

In our proposal, we had four views: a map, a timeline, an expandable table, and a comparison chart. The map visualizes the locations of past meteorite and fireball events by using points on a map that encode the given latitudes and longitudes in each dataset. To differentiate between the type of event displayed on the map, we used two different colors.

Our initial timeline design encoded the number of past meteorite and fireball events every year using bars. The original idea depicted in the image on the right was to represent each individual event as a single rectangular unit stacked on top of each other to form a bar. The idea was inspired by dot chart visualizations.





Our third view was a table that displayed all the numerical data from our three datasets. Upon clicking a category header (Meteorites, Fireballs, or Future Impacts), the table expands to display the rows of data for the selected category. This action also filters the data displayed on the map and timeline such that only the events corresponding to the expanded categories are shown and counted.

Finally, our proposal design included a comparison chart for each table category. These charts help compare data between columns in the expanded table categories. The column of data used in the comparison can be selected using provided dropdown menus.

Additional features in our proposal included linking between views. When hovering over an event in one view, the same event is highlighted in the other three views.

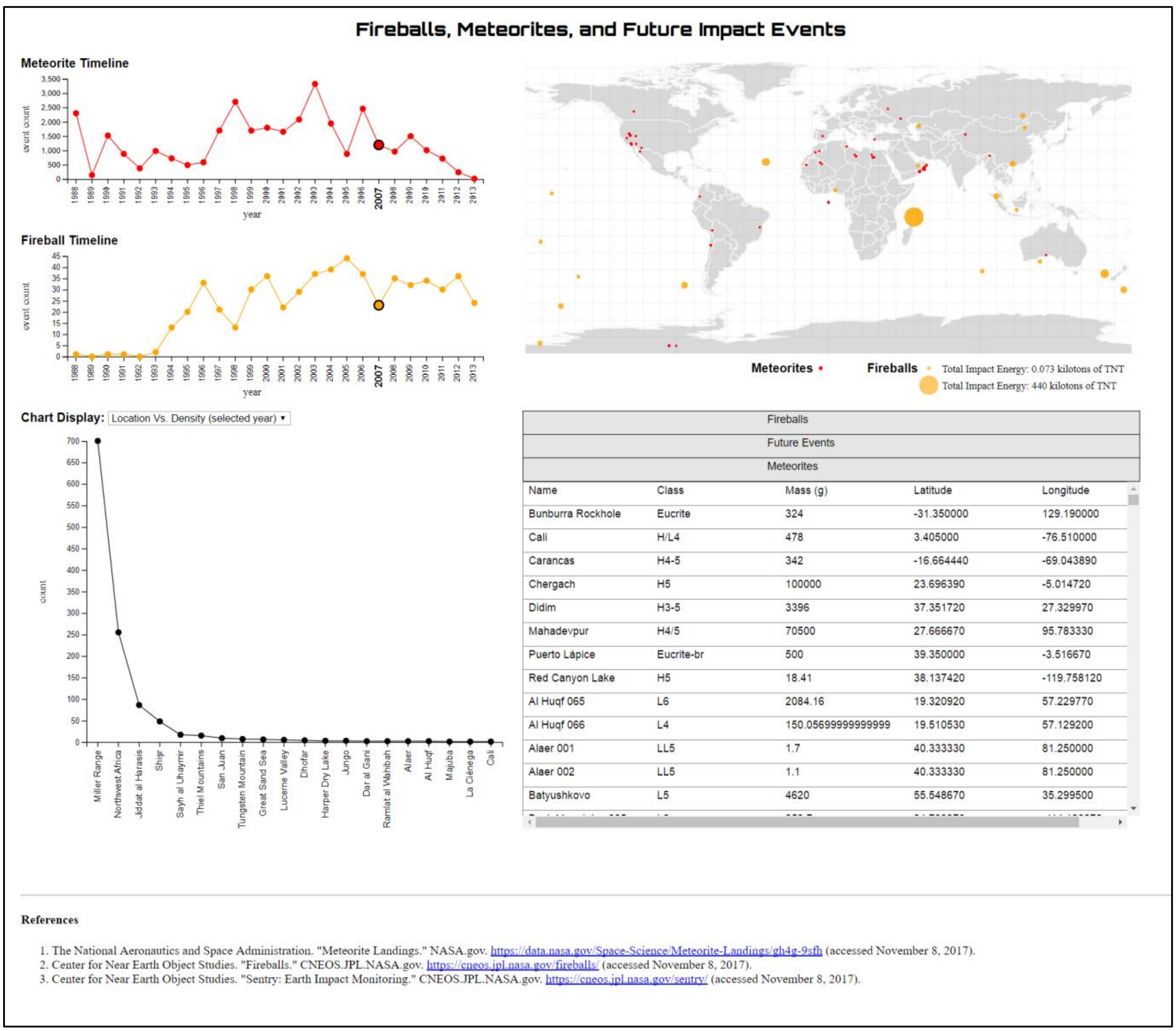
Design Changes:

The first view that changed in our design was the timeline. Instead of using a bar chart to represent the number of events each year, we decided to use a line chart. This is because a line chart uses the channel of position, which is stronger for visualizing data than the length of the bars in a bar chart. Additionally, the lines connecting the points allows us to visualize the rise and fall in the number of events each year.

After processing the data, we also found that the number of meteorite events vastly outnumbered the amount of fireball events each year. As a result, displaying both types of events on the same scale would skew the appearance of one of the datasets. For this reason, we split the timeline into two sections: one for meteorites and one for fireballs. This allowed us to clearly visualize the rise and fall in both meteorite and fireball events each year.

Another change was made to the layout of our design. In our original proposal, each view was stacked on top of each other. The size of the map and timeline pushed the table view out of sight. In other words, the user would have to scroll in order to realize that there was an additional view to explore. For this reason, we moved the timeline next to the map. This allowed the table to be visible as soon as the webpage loads.

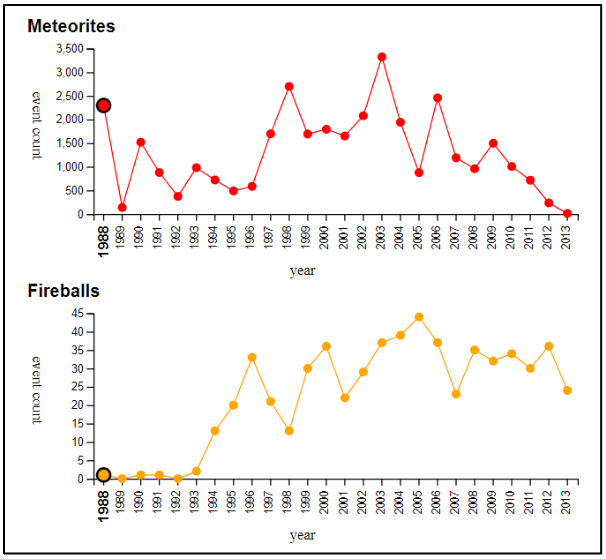
Finally, we moved the comparison chart outside of the table. We realized that the table would be easier to navigate with only one section expanded at a time due to the large number of rows for meteorites and future events. This meant that we did not need to have a separate chart for each expanded category in the table.

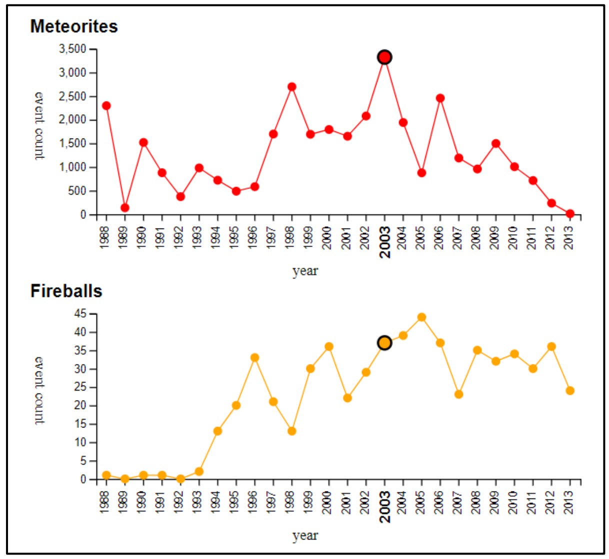


- ## Implementation

Timeline:

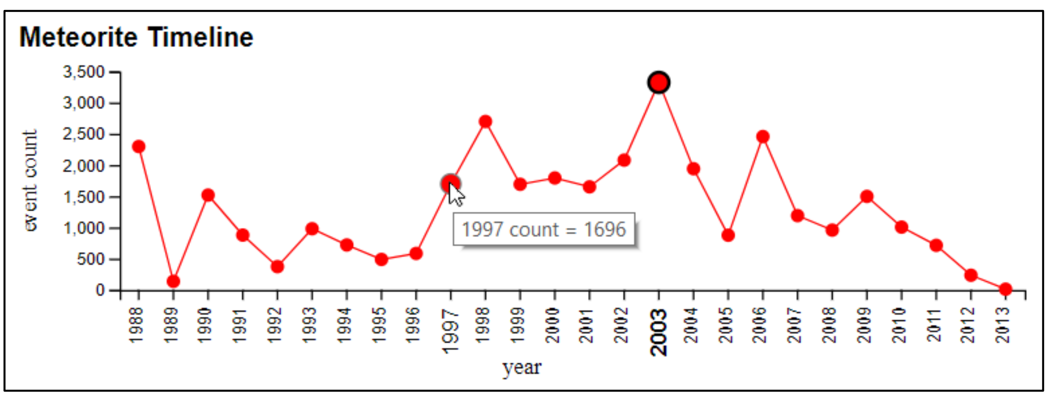
The timeline tells the narrative of past meteorite and fireball events. The line chart visualizes the rise and fall in the number of meteorite and fireball events over the years. This allows users to see that, while the number of meteorite events in the data fluctuates, the number of recorded fireball events appears to rise over time.





The timeline also links to the other views in the visualization. By default, the data displayed on the map, table, and comparison chart is set to the first year in the timeline: 1988. By clicking on either the year text or the point on the line chart associated with a year, users can select which year they want displayed across every view. The size and outline on the point as well as the bolding of the year text denote which year is currently selected. Furthermore, the meteorite timeline is synced to the fireball timeline so that only one year can be selected at a time. This allows the data to be easier to navigate and explore.

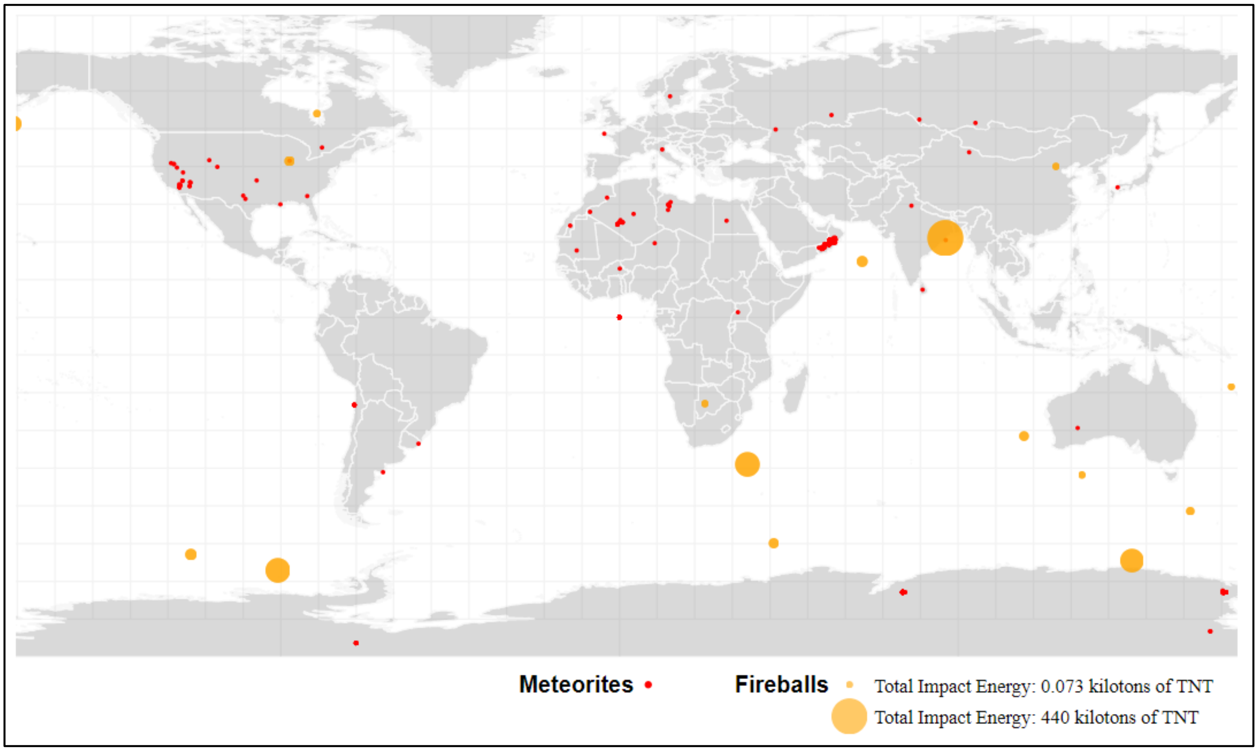
In addition, hovering over a point in the timeline displays a tooltip that allows users to see the actual count of events for that particular year. The image below shows that there were 1,696 meteorite events in 1997. This gives users a more specific look at the change in events over time.



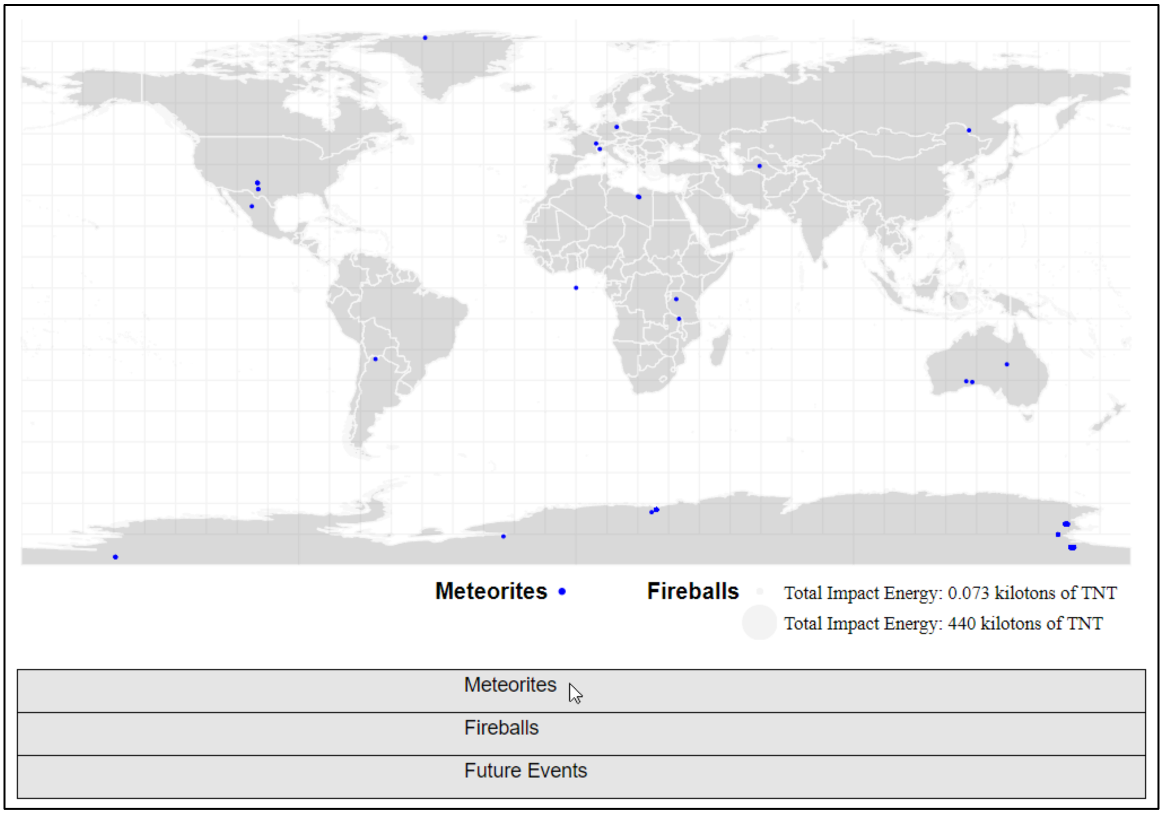
Map:

The map visualizes where past meteorite and fireball events have occurred. It is linked to the timeline so that only events for the selected year are displayed. Meteorites are displayed as red dots, while fireballs are displayed as orange dots. The total impact energy of each fireball event is also encoded into the size of the orange dots, with the smallest size representing the minimum total impact energy found in the data and the largest size representing the maximum total impact energy found in the data.

In this screenshot of the year 2003, users can see that a large number of meteorites were found across the country of Oman while the largest fireball occurred around eastern India.



Additionally, hovering over a category header in the table highlights the same category of event on the map. This allows users to see which type of event they will be exploring in more detail before clicking on that category to expand the table. Screenshots of this interactive feature are presented on the following page.


Meteorites
Fireballs
Total Impact Energy: 0.073 kilotons of TNT
Total Impact Energy: 440 kilotons of TNT
Meteorites
Fireballs
Future Events

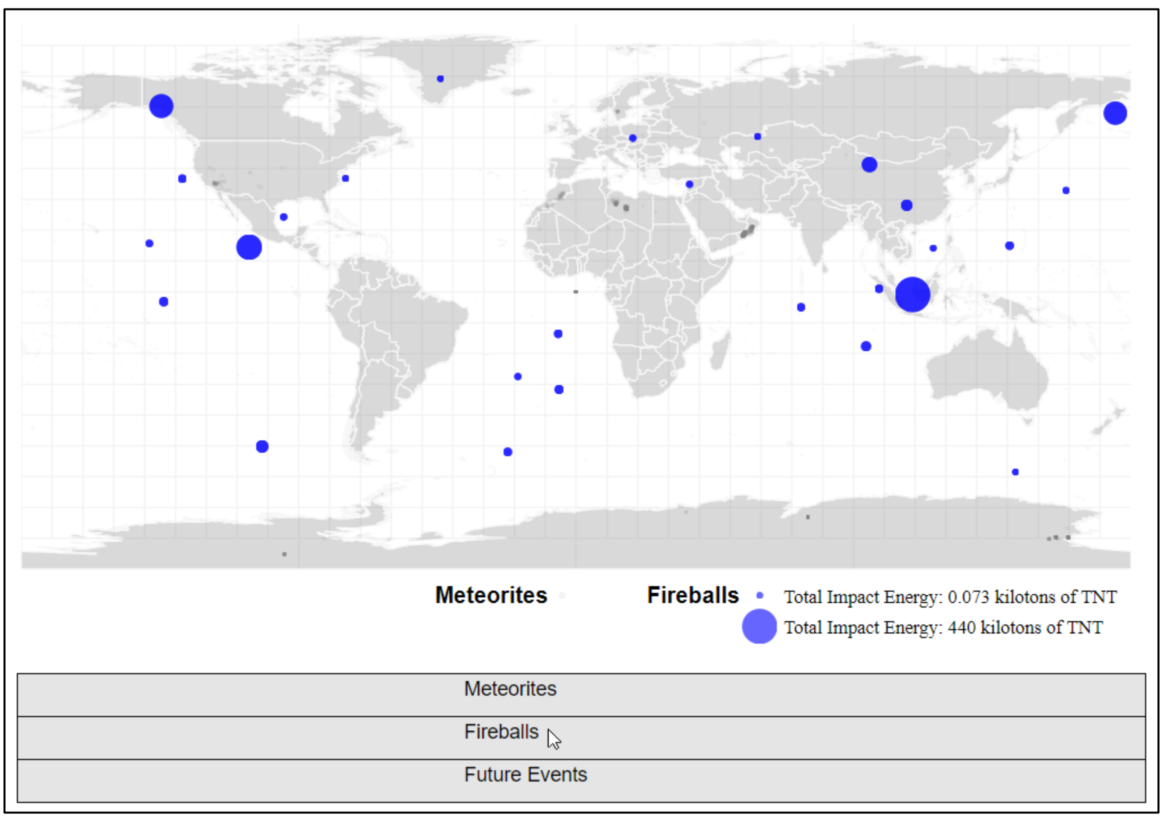
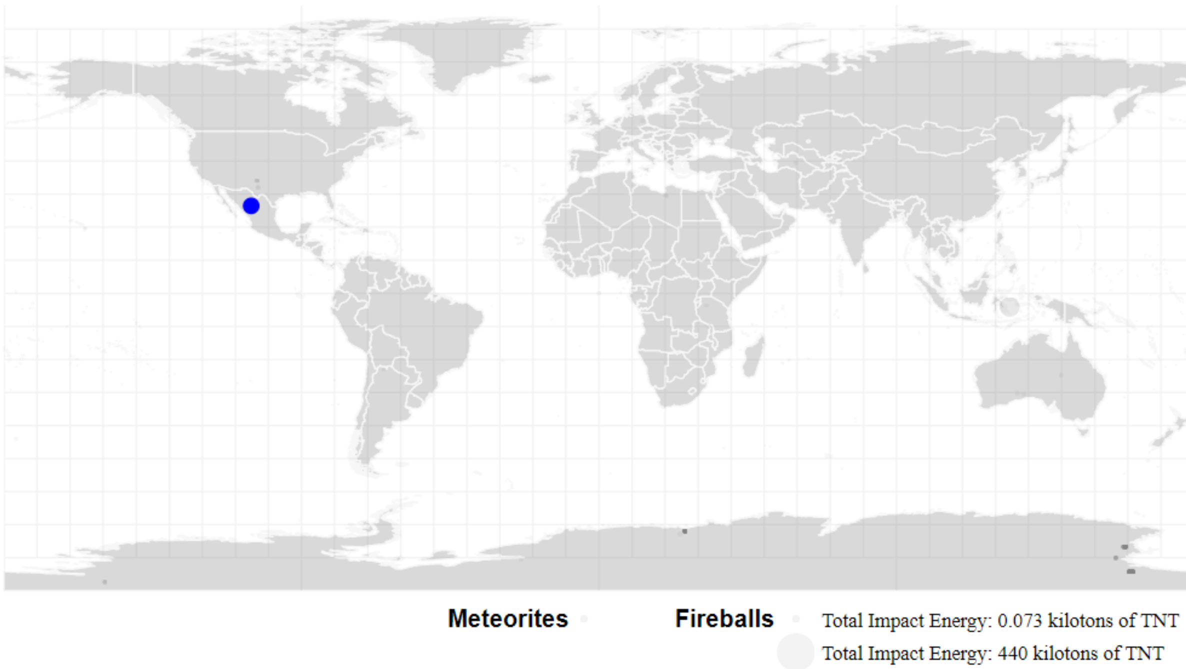

Meteorites
Fireballs
Total Impact Energy: 0.073 kilotons of TNT
Total Impact Energy: 440 kilotons of TNT
Meteorites
Fireballs
Future Events

Table:

The table view allows users to explore each individual event for the selected timeline year. When a user clicks on a category header (Meteorites, Fireballs, or Future Events), the table expands to display a row of numerical data for each event that year. For meteorites, users can view the name, classification, mass, latitude, and longitude. For fireballs, the columns include date, time, altitude, velocity, total radiated energy, total impact energy, latitude, and longitude. For future events, users can explore the object designation, year range, potential impacts, impact probability, velocity, magnitude, estimated diameter, Palermo hazard rating, and Torino hazard rating.

When viewing past meteorite and fireball events, hovering over a row will highlight the corresponding point on the map. This allows users to visualize where each individual event occurred. In the screenshot below, the meteorite Ceniceros is highlighted in the table as well as on the map in northern Mexico.



Fireballs

Future Events

Meteorites

Name	Class	Mass (g)	Latitude	Longitude
Ceniceros	L3.7	1025	26.466670	-105.233330
Chela	H4	2936	-3.666670	32.500000
Chisenga	Iron, IIIAB	3920	-10.059440	33.395000
Palca de Aparzo	L5	1430	-23.116670	-65.100000

In addition, hovering over each column header in the table provides a tooltip with a detailed description of that column. This allows users to better understand the data that they are viewing.

Meteorites

Fireballs

Future Events

Impact Probability (cumulative) - The sum of the impact probabilities of all detected potential impacts. [3]

Object Designation	Year Range	Potential Impacts	Probability	Vinfinity (km/s)
(2010 GZ60)	2017-2116	[illegible]	[illegible]	[illegible]
29075 (1950 DA)	2880-2880	1	1.2e-4	14.10
101955 Bennu (1999 RQ:	2175-2199	78	3.7e-4	5.99
410777 (2009 FD)	2185-2198	7	1.6e-3	15.87
(2017 RH16)	2026-2117	49	8.5e-4	12.78
(2010 AU118)	2020-2112	38	1.8e-8	25.22
(1979 XB)	2056-2113	2	7.4e-7	23.92
(2007 FT3)	2019-2116	165	1.5e-6	17.06
99942 Apophis (2004 MN	2060-2105	12	8.9e-6	5.85
(2000 SG344)	2069-2113	101	2.6e-3	1.36
(2009 JF1)	2022-2022	1	2.6e-4	23.92
(2010 RF12)	2095-2117	63	5.0e-2	5.10
(2006 QV89)	2019-2040	8	5.0e-5	5.16

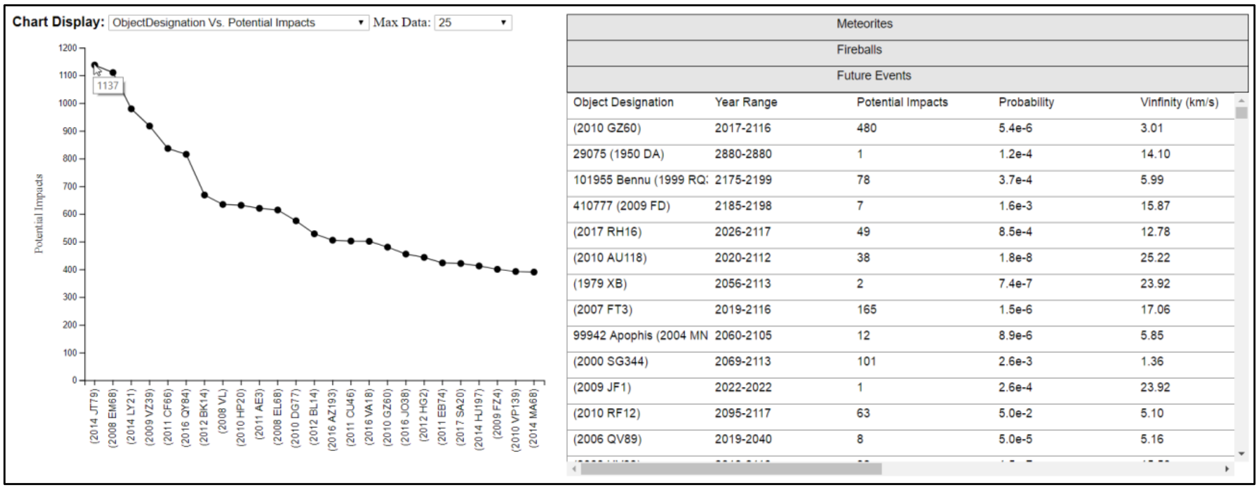
Comparison Chart:

The comparison chart visualizes the numerical data for the expanded category in the table view. After making a selection in the table, users can choose what to display on the chart from the "Chart Display" dropdown menu. For past events (meteorites and fireballs), the data is filtered by the selected year in the timeline. For meteorites, options include the number of meteorites per mass range, the number of meteorites per classification, and the number of meteorites per location. For fireballs, users can select from the number of fireballs per radiated energy range and the number of fireballs per impact energy range.

For future impacts, the selected year in the timeline is not applicable. However, the chart can still be used to explore the number of potential impacts against object designation, the impact probability against object designation, the velocity against object designation, the magnitude against object designation, and the estimated diameter against object designation.

From the "Max. Data" dropdown menu, users can select the number of items to display on the chart. The options are 5, 10, 15, 20, or 25. This allows users to view up to the top 25 items in their data selection in the "Chart Display" dropdown. This gives users the opportunity to "drill down" and specify the amount of detail that they would like to view.

The following image shows that the object (2014 JT79) has the highest number of potential impacts out of the top 25 items. The tooltip displays the actual count of potential impacts: 1,137.



- ## Evaluation

Through our visualizations, we were able to learn more about the datasets in our project. Starting with the timeline, we noticed that meteorite events greatly outnumbered the amount of fireball events. Per year, the meteorite count ranged from 11 to 3,323 while the fireball count varied between 0 and 44. Additionally, the timeline chart showed an increase in fireball events while meteorite events fluctuated. On the map, we saw that meteorites were often recovered from the same areas while fireball events were spread out across the entire globe.

In the table, we explored the numerical details for each type of event. Viewed alongside the comparison chart, we were able to gain further insight into the data. For example, we can figure out how large the majority of meteorites were by expanding the meteorite table and selecting “Number Vs. Mass” from the “Chart Display” dropdown. In a similar fashion, we can find the locations with the most meteorites, how much radiated energy the majority of fireballs had, and the impact energy that the majority of fireballs produced. Looking at the future impact data, we can also find the NEOs with the highest number of potential impacts, impact probability, velocity, magnitude, and estimated diameter.

Using the visualizations, we were able to answer our questions. The line charts in the timeline view allow us to visualize the rise and fall in the number of meteorite and fireball events over the years while the tooltip feature provides us with the actual count. Using the table and comparison chart, we were able to find the locations with the most meteorites each year. Additionally, we could see how the events compared to each other by using the chart to find out where the majority of events fall in terms of variables such as mass for meteorites or radiated energy and impact energy for fireballs. The table and comparison chart were also used to visualize future impact events for different NEOs.

Overall, our visualizations work for exploring the data one year at a time. Using the timeline, users can choose a year they are interested in based on the number of events that occurred. For instance, users can learn about the year with the most meteorites by finding the highest point on the line chart in the meteorite timeline and clicking on it. This selection is then linked to the other views which can be used to further explore the data.

Nevertheless, some improvements could be made to our visualizations. Currently, the map displays all past events as points. However, many of the points overlap each other. While users can still find the locations with the most meteorite events by expanding the meteorite table and selecting “Number Vs. Location” from the “Chart Display” dropdown, the data is not as clear on the map. As a result, the map view could be improved by using saturation to display the density of events in a particular area. Additionally, the columns in the table could have a sorting feature in order to make the data more navigable. Another enhancement that was listed as an optional in our proposal was an animated playback of past events that shows how the data changes over time. However, despite the obstacles we ran into during the project, our visualizations were able to answer the questions we had about our data.