# Visualization of Reported UFO Sightings

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Fig. 1. UFOs are "proved beyond reasonable doubt": A rotating "glowing aura" traveling at high speeds that was captured from a Navy F/A-18 Super Hornet. [6]

**Abstract**—Reports of unidentified flying objects (*UFOs*) have sparked amateur research, government investigations, and large popular interest in the last five decades. Most reported UFOs are later identified as natural phenomena or conventional objects. However, there is a considerable body of reports about objects that are not identified, which are often rumored as claims of observations of extraterrestrial crafts, raising questions about life on other planets and extraterrestrials visiting Earth. Scientists in their majority have naturally greeted the topic with skepticism but it widely recognized that answering these questions would be of great importance and a step towards understanding the universe. We provide an interactive visualization of the reported UFO sightings in the United States in the period of 1964-2017, aiming to help any interested user explore these sightings.

**Index Terms**—Visualization, Map, Interactivity, Unidentified Flying Object, UFO, United States.

## 1 Introduction

An unidentified flying object (UFO) is a perceived object in the sky that is not readily identified. The term UFO (initially, *UFOB*) appeared in 1953 when the United States Air Force used it to describe "any airborne object which by performance, aerodynamic characteristics, or unusual features, does not conform to any presently known aircraft or missile type, or which cannot be positively identified as a familiar object" [4]. Since the 1950s, UFOs have become a major subject of interest in the popular culture and an inspiration for several movies and books [5]. The reason for this is the fact that UFOs are linked to rumored extraterrestrial aircrafts, and if this were true it would suggest that extraterrestrials have visited our planet.

Although UFOs are largely connected to this theme, it is true that for most of the reported cases the objects are identified to be ordinary or to be caused by natural phenomena after careful investigation. Most commonly, UFOs are identified to actually be astronomical objects, aircrafts, balloons (e.g. weather, research balloons), atmospheric or light phenomena (e.g. clouds, mirages), other atmospheric objects (e.g. birds), or, in some rare cases, hoaxes. The percentage of reports of objects that remain unidentified lies between 5% and 20% [4]. However, this is a large enough percentage to spur a significant amount of government research and funds as well as scientific attention.

Of the most recently revealed government programs on UFOs is the

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U.S. Defense Department's *Advanced Aerospace Threat Identification Program* [6]. The program, which was led by military intelligence official Luis Elizondo, investigated evidence of UFOs and extraterrestrial life from 2007 to 2012, with an annual budget of 22 million dollars. In 2012 it was shuttered due to a change in the department's funding priorities, but Elizondo oversaw UFO investigations until this past October. He is convinced that this is a matter of importance and even contends that UFOs are "proved beyond reasonable doubt" (Fig.1). As for the scientific community, the recent *Breakthrough Listen Program* [7], located in the Astronomy Department of the University of California, Berkeley, is the most scientifically comprehensive search for intelligent extraterrestrial communications in the Universe to date [8]. It counts 100 million dollars in funding and it became more publicly known due to the statements of renowned physicist Stephen Hawking on alien life and his support of the program [9].

It is clear that the subject is controversial but, at the same time, most would agree that it requires research and attention. Therefore, it is important that there is a general awareness of the subject to the public. To this end, we created an interactive web-based visualization that allows the user to explore reports of sightings in the United States. It is intended to be pleasing and to give an overview of the reported sightings in the United States throughout the years, as well as the ability to drill down in order to explore characteristics of more specific areas and sightings.

The data we are using is posted on the website of the National UFO Report Center, whose head is Peter Davenport. The Center's website provides an online form as well as a hotline for reports of UFO sightings and these reports are annotated by Peter Davenport himself before they are posted in the database. Each report includes the date and time of the sighting, its duration, shape, location, and description summary (possibly including notes of Peter Davenport in double parentheses), as well as the date the report was posted.

Table 1. Data attributes

| Term | Type of Variable | Example |
|---|---|---|
| Date | quantitative | 1/12/10 21:30 |
| City | categorical | Fairbanks |
| State | categorical | AK |
| Shape | categorical | Disk |
| Duration | quantitative | about 1.5 minutes |
| Summary | | "We saw..." |
| Date Posted | quantitative | 1/12/2012 |

## 2 Related Works

**Visualizations of the UFO dataset:** The dataset we are using has been popular on Kaggle which led two data visualization experts, Pooja Gandhi and Adam Crahen, to use it in their DuoDare project on their DataDuo blog [3]. The DuoDare was a project where each month one of the two experts would choose a dataset and call the other on a battle for the best visualization. The two visualizations that the experts came up with for this dataset included, among others, interactive maps, area charts, bar charts, and calendar heat-maps. Both visualizations as well as our own include a map of the United States. In Pooja Ghandi's visualization a point on the map corresponds to an area and hovering over the point shows a moving tooltip of the number of sightings that have been reported in that area. In Adam Crahen's visualization each point corresponds to a single sighting and hovering over the point shows the details of the sighting. Adam Crahen's visualization includes a calendar heat-map, which also allows the user to click on a particular year/month/weekday/hour and filter the sightings she sees. Pooja Ghandi's visualization includes an area chart of the number of sightings through the years and allows the user to filter the data over time by hovering over a particular vertical line on the area chart. This action also updates a donut chart showing the number of sightings in that year as a percentage over the total number of sightings. In addition to these, it includes two horizontal bar charts showing the five locations/shapes with the highest number of sightings, as well as two visualizations regarding the top five countries besides the United States with the highest number of sightings.

In our visualization we use the same encoding as Adam Crahen for the overview task, i.e. we use a map where each point corresponds to a sighting. However, instead of showing a static map of all the points, we populate the map over time. The user can pause this procedure by clicking on the time-slider. This allows her to explore more patterns about the way the sightings occur over the years, on top of giving an overall picture of the sightings, whereas the other two visualizations only use filtering to allow the user to explore these patterns. As an extra overview feature, we color each state based on the number of sightings that have occurred in that state. In addition, our visualization is different from the other two since it also supports drilling down in the data. It allows the user to choose a particular state to see the sightings of that state in more detail and it shows a line chart of the number of sightings of the state over time (instead of the area chart Pooja Gandhi used for a similar task). Finally, it allows the user to brush over an area in the state, thus selecting a group of sightings, and it updates the line chart of the sightings over time based on these sightings only. We believe that this additional exploration based on the state and area is more intriguing and would make the visualization more interesting and enjoyable to the user. We base this on the fact that our visualization supports the task of "What sightings have happened in my area?" which is a common question when thinking about this subject.

**Visualizing geographic spatial data:** Since we have geographic spatial data, we chose a map to represent them. There are several types of maps, based on the type of surface the Earth is projected on. There are three main types of projections: cylindrical, conical, and azimuthal [10]. Although cylindrical projections incur a significant amount of distortion ( [11]), the Mercator map, which corresponds to a cylindrical projection, is the most popular type of map. Since it is more important that the user is familiar with what they are seeing than deriving exact conclusions on the data, we chose to use the Mercator map.

## 3 Process

In this section we focus on the steps that we took to successfully create our project. Many of the steps were prescribed for us beforehand as requirements for the final project for our data visualization course.

**Initial data selection:** With requirements for a class project already available to us, this dataset became appealing to us for its cleanliness and public availability. The key requirements were that we make an interactive, web-based visualization with at least two different visual encodings and two features from brushing and linking, overview, and details-on-demand. The existing visualizations of this data we found [3] left the option to incorporate brushing and linking of time with the spacial data as well as a few other features as a novel direction to head in. We found the whole subject to be amusing and felt a broad audience would be able to have fun exploring an interactive visualization of these data.

**Interview with field expert:** Having decided to use the the National UFO Report Center's dataset for our project, we conducted a phone interview with its head, Peter Davenport to help us understand his website and dataset better. The current iteration of the website was set up in 1995 and hosts approximately 145,000 alleged sightings, with a noticeable uptick since the option to report a sighting via the internet became available. Currently there is a weekly UFO update on Coast to Coast AM radio and the website boasts many details with images of suspected sightings, however no visualizations of the dataset as a whole. After this interview we were able to decide which tasks were most important for us to satisfy in our visualization (see 3.1).

**Prototyping workflows and refinements to the website based on feedback:** Based on the tasks outlined in 3.1, we each created different sketches that we discussed extensively with each other as well as with the teaching staff before incorporating the best features of those

sketches into a final workflow to keep as a goal. Further along the way, there was an interactive feature testing session where we tested a basic D3 prototype of our visualization with our classmates. The feedback we gathered served to help us tailor the design to users less familiar than ourselves, by for example, including text that explicitly tells the user when certain areas are clickable. We noticed that test subjects would sometimes not realize that a feature existed if they were not explicitly told about it.

### 3.1 Task Analysis

The main purpose of this project is to serve as a way to explore the data hosted on the National UFO Report Center's website. The dataset hosted there is massive and hard to understand without performing analytics. The domain tasks our visualization supports are in Table 2 and are further explained below.

Table 2. Domain Tasks

| Task | Abstraction |
|---|---|
| Observe how the UFO sightings occur throughout the years | Present |
| Observe all UFO sightings of a particular year and specific details (such as shape) | Discover |
| Curiosity stimulation | Enjoy |
| Look for areas with high number of sightings | Search/Explore |
| Are there clusters of UFO sightings according to geographic area? | Cluster |
| Learn details of sighting | Retrieve Value |
| Did sightings of specific durations have other details in common (eg shape) | Correlate |
| What states have the most sightings each year? | Find Extremum |
| What year has the most sightings? | Find Extremum |

**Observe how UFO sightings occur throughout the years**: This task is supported by two visualizations on the webpage. Firstly there is a zoomable timeline (shown in figure 2) where you can select a range of years in the lower timeline and see the upper timeline update. This interactivity enables a user to present the overall trend of the number of sightings skyrocketing as reporting became easier and popular culture made more people familiar with the idea that there was a secret conspiracy to suppress news of such sightings.

Additionally the map of the US allows a user to observe sightings occur over the years using the slider and further see their spatial distribution across the country, the durations of the sightings, and the shapes reported.

**Observe all UFO sightings of a particular year**: The slider above the map enables this task. Just slide the dot to the year desired and then a user can hover his mouse over a sighting to see details. Aggregate details pertaining to that year also appear as before in the scatterplot and donut chart on the right of the map.

**Curiosity Stimulation**: The webpage is designed in a way to entice a user to read background information and then hopefully engage with the interactivity in the visualizations. The overall layout of the website flows like an article with visualizations embedded to give the user perspective before engaging with the tools. There is purposefully a small bar chart showing the total number of visualizations by state to give the user a taste of the rest before he continues to scroll down.

**Look for areas with high number of sightings and detect clustering**: The map allows the user to search and explore as well as click to zoom in closer on a particular area to examine areas of interest, particularly areas with high numbers of sightings. Since the map shows a point for every reported sightings by geographic area, people are excellent at then detecting clusters of sightings.

**Learn details fo sightings**: Every point on the map has a tooltip which displays details of a particular sighting when the cursor is held over the point.

Fig. 2. Interactive timeline of UFO sightings from 1910-2014

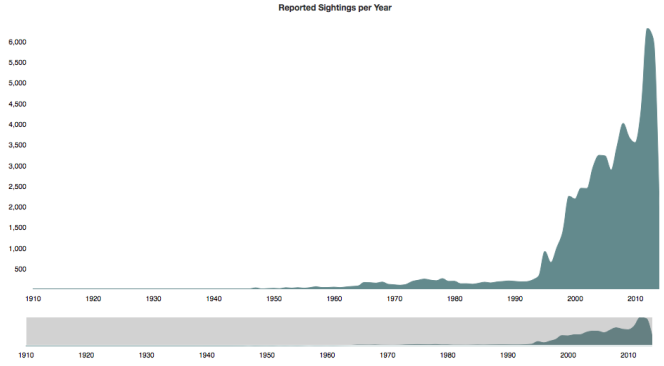
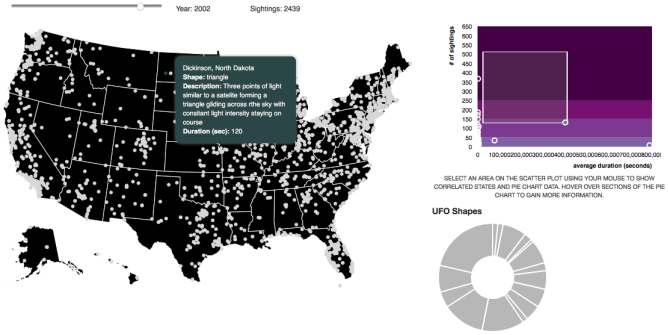



Fig. 3. Interactive national map of sightings with year slider bar and brushable chart of durations and donut chart of shapes of sightings




**Did sightings of specific durations have other details in common**: The brushable scatterplot allows a user to select points with a similar duration and see the donut chart update. This could make more apparent if there are certain shapes in common to sightings that have particular durations.

**What states have the most sightings each year**: Finding these extrema is simple by using the year slider and the map. Also the initial bar chart at the top of the page shows the states by total number of sightings which is a similar metric.

**What year has the most sightings**: To the right of the year slider displays the total number of sightings reported that year. The interactive timeline, however, likely is more useful for this task and allows the user to put a years total number of sightings in context with the years before and after it.

## 4 Design

Our final visualization shows the data in many different ways, all including interactivity to different degrees, which allows the user to decide which path through the story they want to take. When they first load the page, however, they are greeted by a clean layout, banner, and a cheesy UFO GIF. This serves to make the page seem inviting and encourage the user to read the motivation and explore the tools we designed. Our first visualization is also visible near the top, which shows the number of reporting sightings over the history of our dataset; this is the highest level of looking at the data that we encoded. The user can hover the mouse over a bar and see a tooltip display the number of sightings in that state in total from 1910-2014.

After reading what is immediately visible, any user will notice that there is more material cut off at the bottom of the screen. This is important because it makes the fact that they can simply scroll continuously down the page to keep exploring - they don't have to click through any new pages. This will likely lead them to discover our next interactive feature by accident. The next visualization (Figure 2) shows the reporting sightings per year and allows the user to zoom in and

brush the data that they are interested in seeing; there are two ways to brush down the data; on the time series and on the chart itself. If a user is casually scrolling down the page, they will likely inadvertently discover that scrolling the mouse while the cursor is hovering over the time series chart will cause it to zoom in. This is a good thing because then they will start to realize that all the visualizations have an interactive feature and will not miss them by moving too quickly.

Our final visualization (Figure 3) appears shortly after a little more text, and it shows the geo-location of each individual sighting during the selected year. The user selects the year using the slider above the map, which populates using points in the exact geo-location. The choropleth map shows the number of sightings, which links in color scheme to the graph to the right. In this graph, the points indicate states, and the axis reflect the number of sightings versus average duration. The map also has an on-click feature, which allows the user to drill down to a state level for more discernibility with the data points and ease of access in reading and using the tooltip. The donut plot shows the proportion of shapes sighted, either by year on a national level, using the brushed data from the scatter plot, or the state data, depending on how the user chooses to interact.

This visualization was built using HTML, CSS, JavaScript, and several open-source projects including D3 v4, d3-queue. Moment JS, topojson, Underscore JS, Bootstrap, and nodejs.

## 5 Discussion

### 5.1 Reflection

The main purpose of this project is to serve as a way to explore the data hosted on the National UFO Report Center's website. The dataset hosted there is massive and hard to understand without performing analytics, so any visual representation of the data would be useful to someone interested. Fortunately the data was extremely well formatted and easy to access and work with - one of the major motivating factors to our choosing to work with it. The related work with this data could also be improved with further interactivity and so this project seemed a good fit for our class. Now that it is complete it is clear that this visualization was an improvement on the existing ones that work with this dataset.

An effective method we used to pick our design was study the related work for features that we liked and features we would have liked that were missing. We immediately liked the use of a map and overlaying of the spacial data of the sightings, but due to the large number of points, we were able to know from the beginning that we wanted to incorporate a feature that lets a user zoom in on the map and see sightings over a smaller area. We also decided that the slider at the top to view sightings by year would de-clutter the data as well, and reflecting on the finished product seems to confirm that it was a good decision.

Looking back at all the initial design sketches, they were overall useful to have done, but only with discussion and editing. We had 4 initial design sketches to work off of, and none were constrained by implementation limitations or the actual data. Some of the initial design sketches had a separate window appearing when you clicked on a state, and would display sightings across all years from 1910-2014 on that state. It turned out that it was easy to underestimate the volume of data we would be representing. Combining all the sketches forced us to focus on what limitations we might encounter when implementing an idea. Therefore we found that creating a single workflow to work towards to be valuable in the design phase. It forced all of us not only to ultimately agree on a single design but also to make that design more representative of what would be feasible to create in a limited timeframe.

Usability testing was the last milestone before completing development of our visualization. We had classmates from our visualization class test our prototype and studied how they approached the tool as well as solicited feedback from the subjects. This visualization is mostly geared to anyone interested in exploring the data, so there is no particular ideal test user. Thus user testing was not a critical phase for our development since we could test the tool on our own along the way. There was, however, a few things in particular that we included as a direct result of studying how test users approached our website. We decided to include more explicit instructions to users on the website that they could click on the map to zoom in and brush points in the lower scatter plot and see the correlated states and pie chart data showing the shapes of the sightings. Without explicit instructions, some users didn't know these features existed or would only discover them after a long time. Since the user testing phase was very easy to conduct, we found the whole process well worth doing and overall helpful.

### 5.2 Future Work

This paper focused on the UFO data we worked with, the tasks we sought to implement, and the visualization design that resulted from these requirements as well as through acquired feedback. There are many features we would like to be able to include in the future, however. Among the most interesting would be to associate historical weather data with the dates of the alleged UFO sightings. Additionally, plotting sources of red flags such as airports or weather balloons would be of use in explaining a large number of sightings. The biggest challenge at the moment is acquiring a suitable dataset containing this information in a reasonable format.

## 6 Conclusion

We created a web-based interactive visualization providing a novel view of data originally gathered by the National UFO Report Center of thousands of alleged UFO sightings around the country. We incorporated interactivity tools such as brushing and linking to make it easier to dynamically view reported sightings on a United States map and select only reports within years ranges of interest. This allows a map to be less cluttered than existing maps and thus also allows for details-on-demand to be easier to use as there is less ambiguity of where a user is pointing. We use an appealing color palate for the task at hand and create an environment that is amusing and engaging to users interested in understanding the scale of belief in conspiracies or UFOs.

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