Project D3finite

A glimpse of the world's Satellites

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Satellite image from https://www.wired.com/story/facebook-confirms-its-working-on-new-internet-satellite/

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Overview and Motivation:

There are many implications in the satellite dataset, from general scientific ones to economic, and political ones. The average person has very little knowledge of how they work, how many are above us, and what their purpose is. This project aims to inform the audience as well as pique their curiosity. Many portions of the data involve classifications and distinctions that we found interesting to learn more about and investigate correlations with the more familiar metrics. One such direction is the political aspect, as both country of origin/owner and usage (whether commercial or military) present interesting questions that could be examined with this visualization.

Our visualization features a representation of the earth with satellites in “orbit” around it, an interactive table, a representation chart, and a details pane for specific selections. By displaying multiple representations of the overall data we are able to tell the story of what is in the near-space around our planet, what they’re doing, and how they got there.

Related Work:

One of the ideas that we had involved displaying the satellites in orbital “rings” around the earth, and we found a radial chart that would be perfect for that:

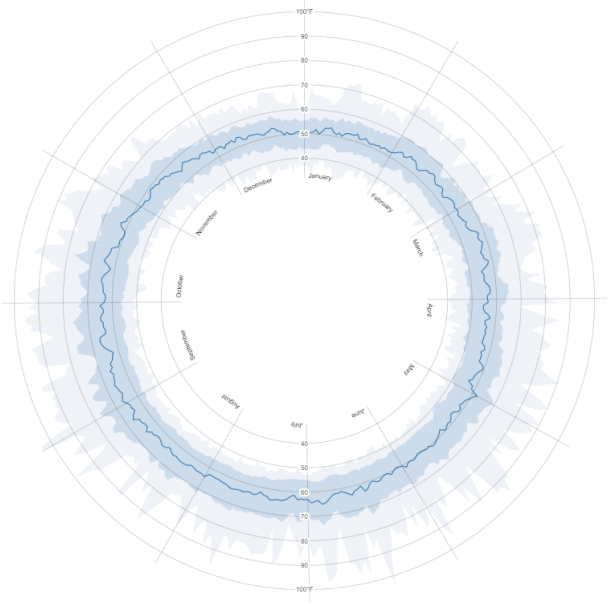
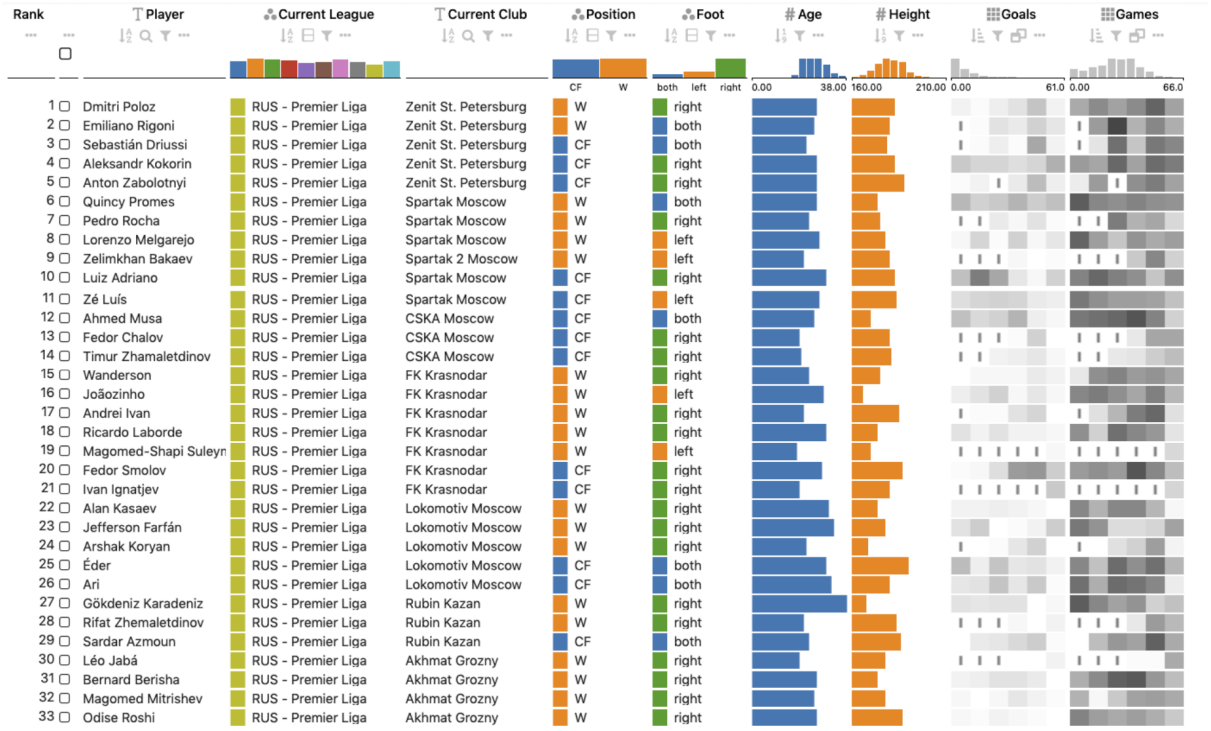


Figure 1.1 - radial chart
Another visualization that we found useful was this table view from a course lecture.



Rank	Player	Current League	Current Club	Position	Foot	Age	Height	Goals	Games
1	Dmitri Poloz	RUS - Premier Liga	Zenit St. Petersburg	W	right				
2	Emiliano Rigoni	RUS - Premier Liga	Zenit St. Petersburg	W	both				
3	Sebastián Driussi	RUS - Premier Liga	Zenit St. Petersburg	CF	both				
4	Aleksandr Kokorin	RUS - Premier Liga	Zenit St. Petersburg	CF	right				
5	Anton Zabolotnyi	RUS - Premier Liga	Zenit St. Petersburg	CF	right				
6	Quincy Promes	RUS - Premier Liga	Spartak Moscow	W	both				
7	Pedro Rocha	RUS - Premier Liga	Spartak Moscow	W	right				
8	Lorenzo Melgarejo	RUS - Premier Liga	Spartak Moscow	W	left				
9	Zelimkhan Bakaev	RUS - Premier Liga	Spartak 2 Moscow	W	left				
10	Luiz Adriano	RUS - Premier Liga	Spartak Moscow	CF	right				
11	Zé Luís	RUS - Premier Liga	Spartak Moscow	CF	left				
12	Ahmed Musa	RUS - Premier Liga	CSKA Moscow	CF	both				
13	Fedor Chalov	RUS - Premier Liga	CSKA Moscow	CF	right				
14	Timur Zhamaletdinov	RUS - Premier Liga	CSKA Moscow	CF	right				
15	Wanderson	RUS - Premier Liga	FK Krasnodar	W	right				
16	Joãozinho	RUS - Premier Liga	FK Krasnodar	W	left				
17	Andrei Ivan	RUS - Premier Liga	FK Krasnodar	W	right				
18	Ricardo Laborde	RUS - Premier Liga	FK Krasnodar	W	right				
19	Magomed-Shapi Suleym	RUS - Premier Liga	FK Krasnodar	W	left				
20	Fedor Smolov	RUS - Premier Liga	FK Krasnodar	CF	right				
21	Ivan Ignatjev	RUS - Premier Liga	FK Krasnodar	CF	right				
22	Alan Kasaev	RUS - Premier Liga	Lokomotiv Moscow	W	right				
23	Jefferson Farfán	RUS - Premier Liga	Lokomotiv Moscow	W	right				
24	Arshak Koryan	RUS - Premier Liga	Lokomotiv Moscow	W	right				
25	Éder	RUS - Premier Liga	Lokomotiv Moscow	CF	both				
26	Ari	RUS - Premier Liga	Lokomotiv Moscow	CF	both				
27	Gökdeniz Karadeniz	RUS - Premier Liga	Rubin Kazan	W	right				
28	Rifat Zhemaletdinov	RUS - Premier Liga	Rubin Kazan	W	right				
29	Sardar Azmoun	RUS - Premier Liga	Rubin Kazan	CF	both				
30	Léo Jabá	RUS - Premier Liga	Akhmat Grozny	W	right				
31	Bernard Berisha	RUS - Premier Liga	Akhmat Grozny	W	right				
32	Magomed Mitrishev	RUS - Premier Liga	Akhmat Grozny	W	right				
33	Odise Roshi	RUS - Premier Liga	Akhmat Grozny	W	right				

Figure 1.2 is from class lecture 15-16-Tables, showing a table layout using bars for visuals

Questions:

Our initial line of questioning revolved around these:

- Do origin countries and purposes relate? - e.g. are most of the USA's satellites commercial?
- Purpose vs. Expected Lifetime.
- Where are satellites launched from?
- What are the most common launch vehicles?
- Where do most satellites reside? Is there a visual "band" that we could explore showing the bulk of most of them?

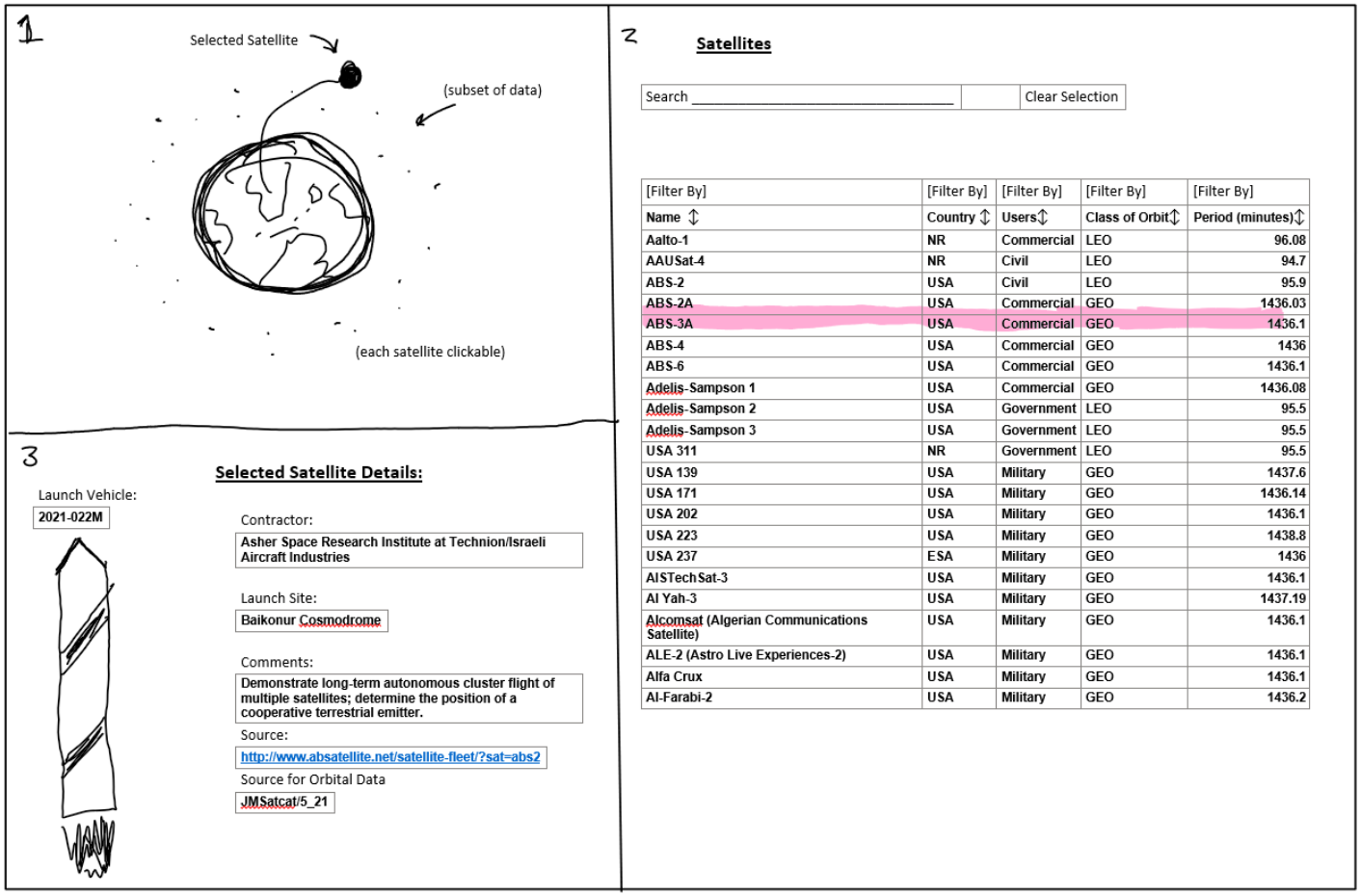
Data:

We found a relatively clean dataset from https://www.ucsusa.org/resources/satellite-database and then pruned it down into a more manageable JSON file using python. We needed to address some "NaN" fields, and we needed to convert the "Launch Date" column to a string

date format. We only selected 28 relevant fields, excluding sources and other data that would be difficult to visualize or was otherwise irrelevant to our project.

Design Evolution:

Initial Idea:

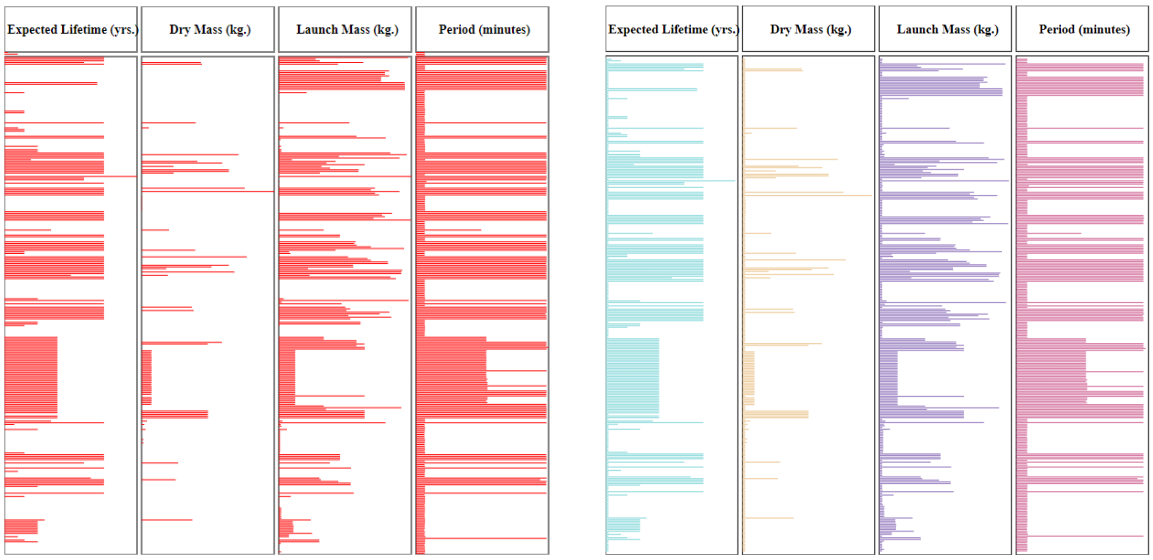


Experimented with various combinations of columns, including using every column in the data. This appears unreasonable, since some columns are missing a majority of values. The column attributes currently displayed are a culmination of what we have decided are very important attributes or are not highlighted in other views in our visualization.

Bar Chart

Experimented with using bars instead of text to display numerical attributes in the table like mass and lifetime, as shown in class lecture (Figure 1.2). So far, we have decided not to use this feature since we are creating a separate bar-chart element which accomplishes the same task. It would be redundant to have both.

The bar chart at the proposal stage includes a single row for each satellite, and is meant to perfectly match whatever data the table is showing in the same order as well. However even at a single pixel height, the chart can't show 100% of the data.

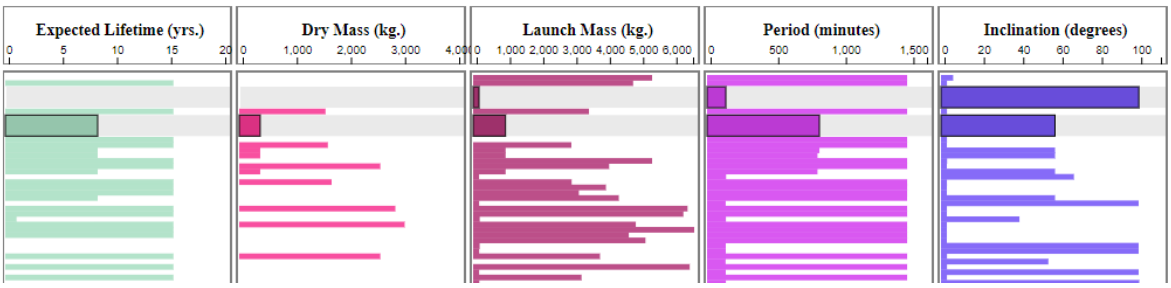


Some of the main issues to deal with in a bar chart representing such a large dataset is including all of the data in a single chart. With 5,500 rows of data, at a single pixel height, that will amount to over 5000 pixels, which is way too much to have on screen at once. Also, just putting the bar chart in without any interaction doesn't provide enough insight and information. The update to the bar chart provided a scrollable window, this means that all of the data can be displayed, but requires using a scrollbar to view all of it. The next feature added was selection highlighting. Selection highlighting is not straightforward for the chart because if each row is only a pixel or two high, there aren't many options for highlighting. So based off one of the examples in the table visualization lecture, we decided to expand the selected row while in line with the other rows by shifting the scale to make room. Basically this stretches the selected row while shrinking all other rows, or if they are already the minimum size, just shifting them down. This technique required careful dynamic scaling of the bar chart to make room, while preserving visibility for all rows, and having nothing occluded. This was made even more complex when adding multiple row selection for comparing two satellites. This is shown below:

One idea that was considered was changing the bars to some other type of symbol, maintaining the same horizontal channel but using a line chart, scatter plot, etc. However these were ruled out for a variety of reasons. First, the line chart would be very confusing given how much back/forth between extremes exists in the data. Also usually a line chart has sufficient space between each mark, but with often needing every row to only have a single pixel breadth this makes a line chart unfeasible. As far as a scatterplot, this is more plausible of an option but it becomes very hard to follow down the line with dots in such vastly different locations and to determine that one point is above or below another without making the dots much wider. This pretty much left the bars.

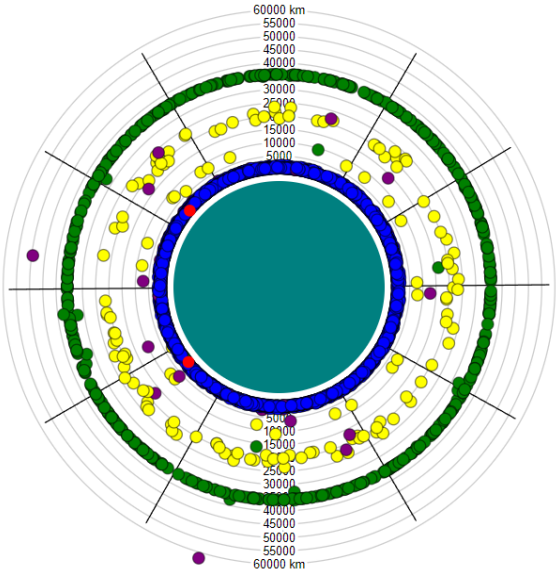
The axes were designed and placed in the header, and the scrolling ability was only applied to the bars, not to the header so that at any scroll position it is possible to see the axes/scale as well as the category.

The final design version only involved minor changes beyond this, first was removing the rows that the data was blank. Originally these were just rendered as-is which usually was a value of zero in the respective category. But this tends to make the data seem less informative, so by removing these rows from the bar chart it presents a more accurate idea of the real values of each satellite. Also the coloring was shifted when items are selected so the selected row(s) appear to stand out more. Also a small but important update when using the scrolling, is that if a selected item from the table is not in the view of the current window of the bar chart, the scroll bar will automatically adjust so the selected item is within view. This can be important when dealing with the unfiltered data and trying to find the row you just selected from the table.

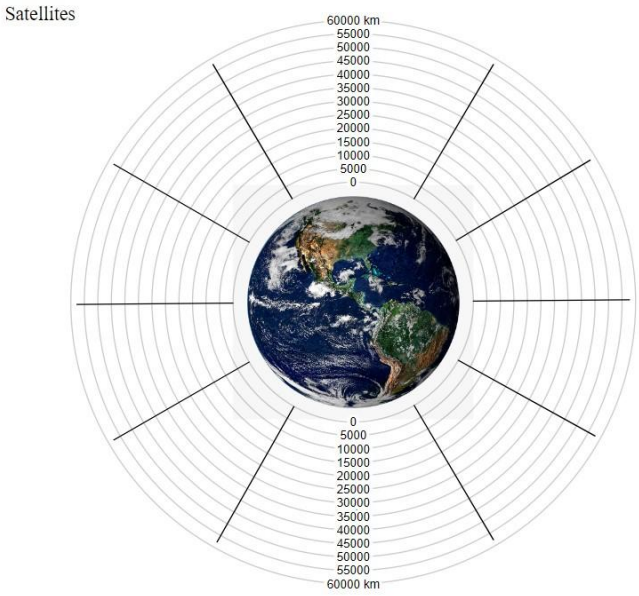


Radial Chart

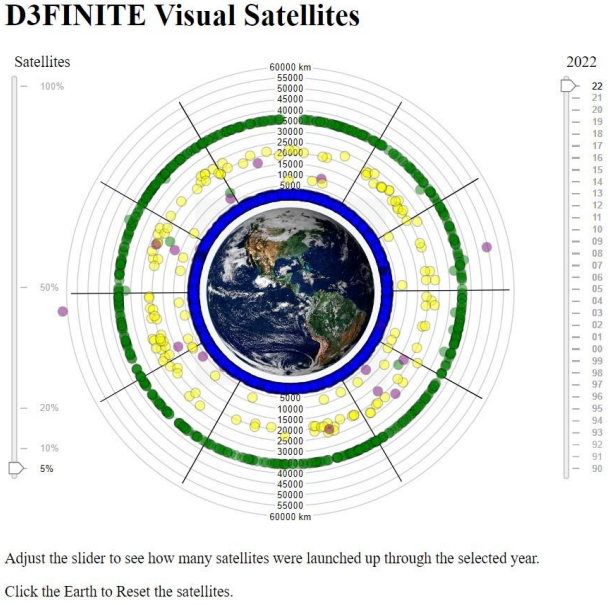
Our initial attempt at creating visual “bands” for the satellite orbits were problematic for a few reasons: We were displaying all of our almost 6000 satellites at the same time, which lowered the clarity of what was going on. Overlap was heavy, and the legends were hard to read.



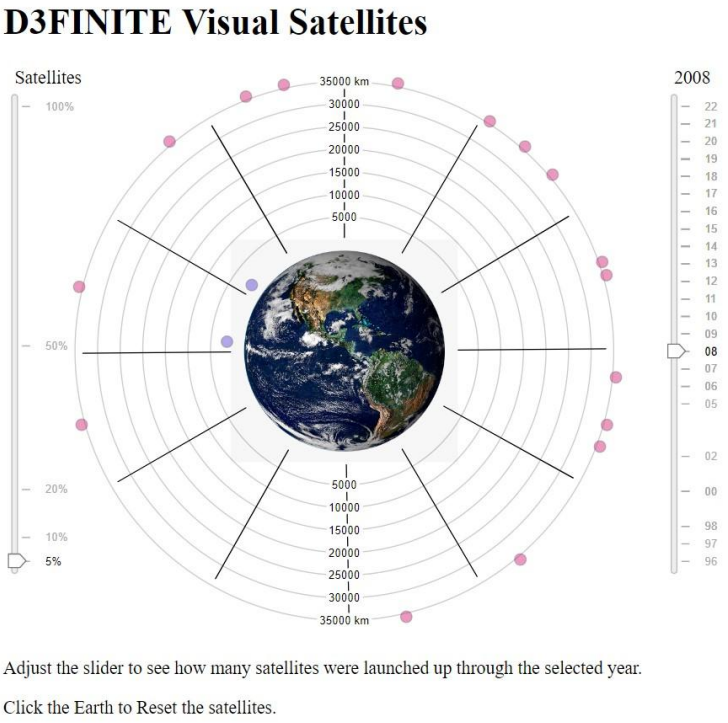
The first improvement was to add in an actual picture of the globe, rather than a teal circle:



We then added sliders to accompany the chart and allow for easier filtering. These were initially below the chart, but in an interest of maintaining compactness and reducing whitespace, we put them on either side. The leftmost slider controls what percentage of our satellites that you wanted to display, and defaulted it at 5%. This decreased load times, allowed for the user to control how dense they wanted the chart to be, and added more interactivity. We added more options on the lower end of the slider simply to encourage more performance friendly rendering.

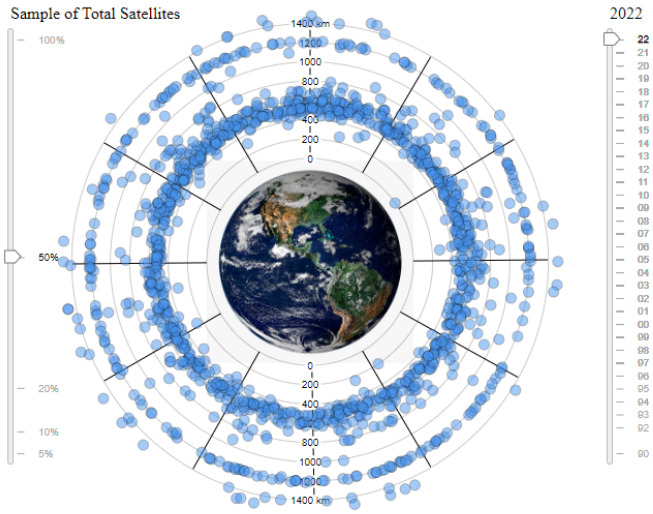


The right slider caps the latest launch year displayed. This defaults to 2022, but can be brought down to show how the orbits around us have changed and become more populated over the last 30 years. We also made the decision to make the year 1990 the oldest possible year. There are some satellites that were launched before then, but they are a minimal part of the dataset, and it kept the slider neat. You can see a good example of this filtering below:

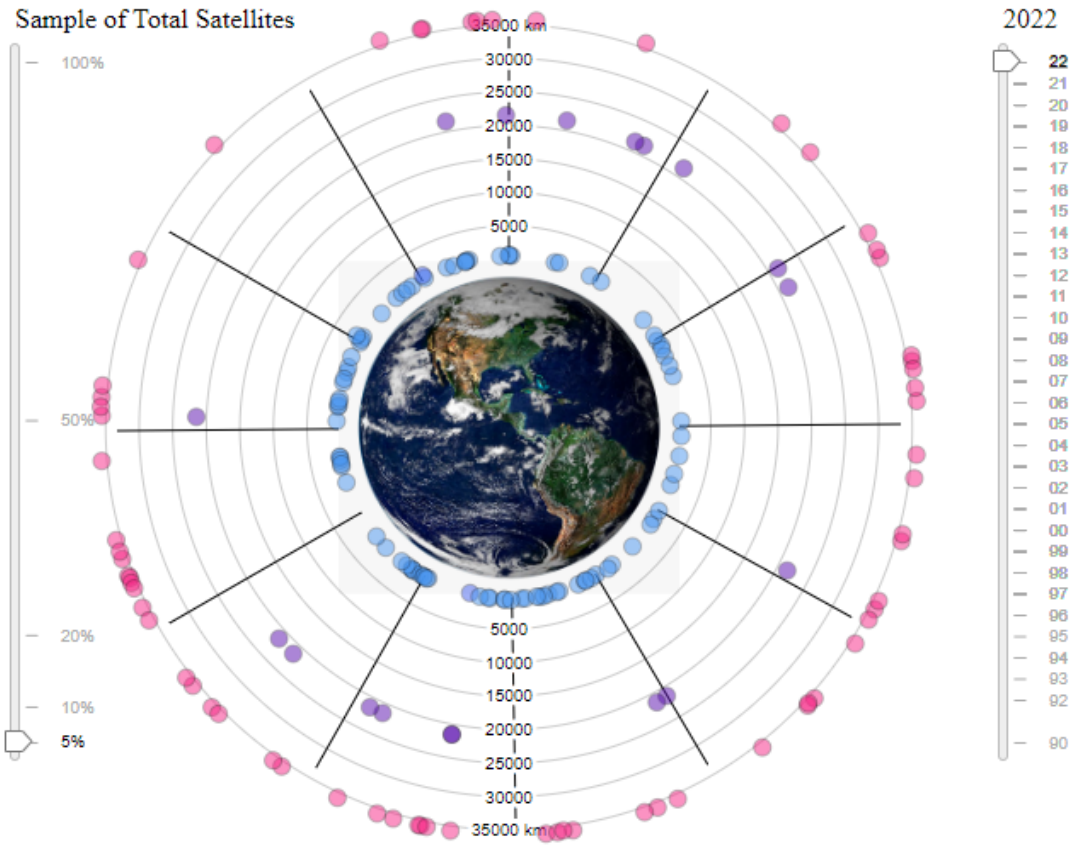


There is also another more subtle change in the above image - we changed the color scheme. Rather than bright, default colors, we found a color scheme we liked, and applied it to each visualization. As before, the color in the radial chart encodes the type of orbit of each satellite, helping to more clearly indicate the different distance “bands” that most of our satellites find themselves in.

We also decided that being able to explore those “bands” in more detail would be a good idea. So clicking on any of the satellites in a given color would zoom in to that band and display them in more detail, and clicking the earth would reset things for you:



At this point, we made a lot of cosmetic changes. The color scheme was updated, the opacity reduced, and the instructions for the chart were added to a greater body of instructions for the whole page at the top of our visualization. This is the final result:

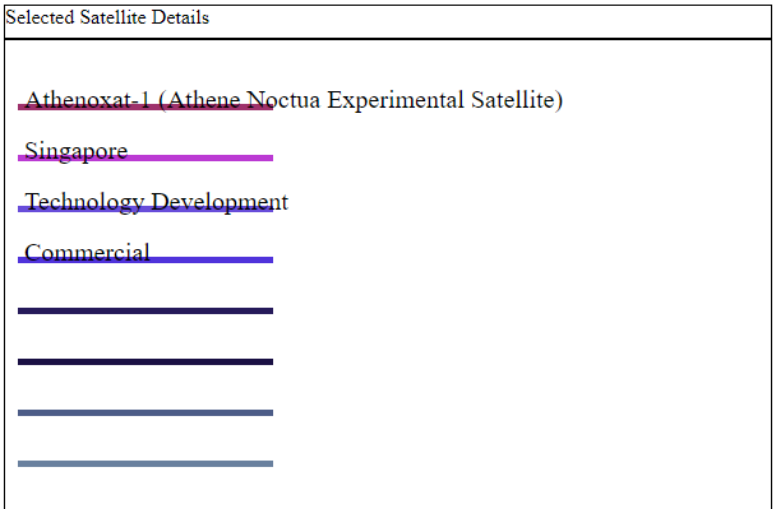


The design for our “orbits” was definitely an evolution of our original idea, but it did turn out a little different. For one thing, we are showing more satellites than we were initially planning on, from 20 to 200. We also aren’t highlighting where they came from on the globe in the center, option for a static image and leaning more into the table and details pane to give more

information. The sliders were an evolution of the design, most likely due to our displaying variable amounts of the backing data.

Details Pane

This first cut at the details section was basically a statically placed “tooltip”. It utilized some of the color encoding for the different categories used in the bar chart, but gave a vertical text layout. The elements and text were all placed via svg, which eventually became constraining for getting all of the wrapping and text handling that would be required. The main issue being that while each text element could be initially spaced easily using d3, if the text value for a particular satellite required multiple lines, it was very difficult to determine that easily. And even more difficulty arose in being able to offset all of the following sections dynamically if an extra line/element was added for overflow.



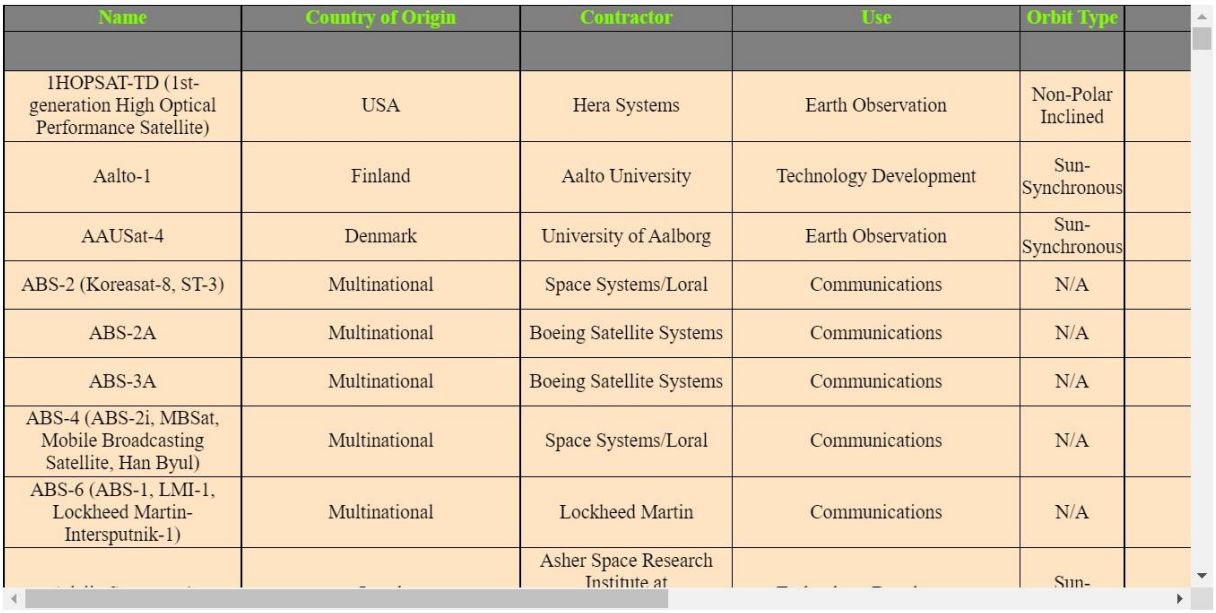
These difficulties were enough reason to go away from the svg layout to the html div layout, and using css styling with word-wrap the sizing and spacing was much easier to handle dynamically. This also allowed easily inserting images, and dividing the area into two columns for satellite comparison. The next update involved the colored bar at the bottom, and instead, converting the entire background to a color based on the category, and lightening the color so it did not impact readability. Finally, to help visualize one of the fields that is very difficult for a regular person to immediately understand/perceive, an image of the launch vehicle was inserted into the details pane to provide a visual representation.

Selected Satellite Details	
Name: Azerspace 2/Intelsat-38	Name: Astra 1KR
Country: Azerbaijan	Country: Luxembourg
Use: Communications	Use: Communications
User: Government	User: Commercial
Launch Site: Guiana Space Center	Launch Site: Cape Canaveral
Launch Date: 09-25-18	Launch Date: 04-20-06
Notes: Host Direct-to-Home (DTH) platforms for Central and Eastern Europe as well as the Asia-Pacific region. Intelsat 38 will also provide connectivity for corporate networks and government applications in Africa.	Notes: 32 Ku-band transponders; direct-to-home broadcast services across Europe.
Launch Vehicle: Ariane 5 ECA 	Launch Vehicle: Atlas 5 

This final version allows for clear comparison between two selected satellites, and presents the information in an aesthetically pleasing form as well.

Interactive Table

The first iteration of the table was just a html table element that displayed text in each box as shown below on the left. The choice was made to include a window cutoff and include a scroll bar for both the x and y axis. Including both scroll bars allows the window to be more compact instead of showing ~5000 rows and ~15 columns all at once. Additionally, adding in the x-axis scroll bar provides the opportunity to keep individual cells larger, so there isn't an unnecessary amount of text wrapping.



Name	Country of Origin	Contractor	Use	Orbit Type	
1HOPSAT-TD (1st-generation High Optical Performance Satellite)	USA	Hera Systems	Earth Observation	Non-Polar Inclined	
Aalto-1	Finland	Aalto University	Technology Development	Sun-Synchronous	
AAUSat-4	Denmark	University of Aalborg	Earth Observation	Sun-Synchronous	
ABS-2 (Koreasat-8, ST-3)	Multinational	Space Systems/Loral	Communications	N/A	
ABS-2A	Multinational	Boeing Satellite Systems	Communications	N/A	
ABS-3A	Multinational	Boeing Satellite Systems	Communications	N/A	
ABS-4 (ABS-2i, MBSat, Mobile Broadcasting Satellite, Han Byul)	Multinational	Space Systems/Loral	Communications	N/A	
ABS-6 (ABS-1, LMI-1, Lockheed Martin-Intersputnik-1)	Multinational	Lockheed Martin	Communications	N/A	
		Asher Space Research Institute at		Sun-	

Sorting:
The next step was to add sorting filters to each of the columns. There were two ideas for sorting, the first being a standalone button for each column. This would be placed in the second row of the table header and would show the sorting order, (ascending/descending), as the text for the button. The second idea was to use the column header cells as the sort buttons instead of having a separate element. This is the idea that was implemented since it would reduce the amount of elements appearing on the page.

Filtering:
There were 3 main designs we considered when creating a way to filter. The first design was a giant table at the top that contained every possible filter, and a corresponding checkbox. The benefit of this design is that it would allow multiple filters to be applied for each category, (i.e. showing both France and UK satellites instead of just one or the other). However, the drawback of this implementation is the size of the filter table, we would have roughly 75-100 different filters.

The second design idea was to have a singular button for each filterable category pictured below.. On each click, the filter would swap, going through each filter option in alphabetical order. This would solve the space issue that the check box table design had, but we would lose the ability to quickly pick filters. We did end up implementing this design, but later scrapped it in favor of the third design idea: A dropdown menu.

Name	Country of Origin	Contractor	Use	Orbit Type	Launch Weight	Expected Lifetime	Launch Site	Launch Vehicle
group	group	group	group	group	group	group	group	group
1HOPSAT-TD (1st-generation High Optical Performance Satellite)	USA	Hera Systems	Earth Observation	Non-Polar Inclined	22	0.5	Satish Dhawan Space Centre	PSLV
Advanced Orion 10 (Mentor, NRO L-44, USA 311)	USA	National Reconnaissance Laboratory (?)	Earth Observation	N/A	5400	N/A	Cape Canaveral	Delta 4 Heavy
Advanced Orion 4 (Mentor, NROL 6, USA 139)	USA	TRW Space and Electronics	Earth Observation	N/A	5200	N/A	Cape Canaveral	Titan IVA
Advanced Orion 5 (Mentor, NROL 19, USA 171)	USA	TRW Space and Electronics	Earth Observation	N/A	5200	N/A	Cape Canaveral	Titan IV
Advanced Orion 6 (Mentor, NRO L-26, USA 202)	USA	National Reconnaissance Laboratory (?)	Earth Observation	N/A	5400	N/A	Cape Canaveral	Delta 4 Heavy
Advanced Orion 7 (Mentor, NRO L-32, USA 223)	USA	National Reconnaissance Laboratory (?)	Earth Observation	N/A	5000	N/A	Cape Canaveral	Delta 4 Heavy
Advanced Orion 8 (Mentor, NRO L-15, USA 237)	USA	National Reconnaissance Laboratory (?)	Earth Observation	N/A	5000	N/A	Cape Canaveral	Delta 4 Heavy

The third design, a dropdown menu, was the idea we decided to implement. The dropdown menu provides compactness in the filtering since it takes up the same space as a button when not expanded to show the filter options. The option to filter using multiple objects from the same category is still not present, but the tradeoff in space and simplification of filtering provides better usability.

ResetFilters

Name	Country of Origin	Contractor	Use	Orbit Type	Launch Weight	Expected Lifetime	Launch Site	Laun Vehi
Advanced Orion 4 (Mentor, NROL 6, USA 139)	USA	TRW Space and Electronics	Earth Observation	N/A	5200	N/A	Cape Canaveral	Titan I
Astra 1G	Luxembourg	Hughes Space and Communications Co.	Communications	N/A	3379	15	Baikonur Cosmodrome	Proton
Anik F1	Canada	Boeing Satellite Systems	Communications	N/A	4710	15	Guiana Space Center	Ariane
Astra 2A	Luxembourg	Hughes Space and Communications Co.	Communications	N/A	3635	15	Baikonur Cosmodrome	Proton
Anik F1R	Canada	EADS Astrium	Communications	N/A	4500	15	Baikonur Cosmodrome	Proton
Astra 1KR	Luxembourg	Lockheed Martin Commercial Space Systems	Communications	N/A	4332	15	Cape Canaveral	Atlas
AMC-1 (Americom 1, GE-1)	USA	Lockheed Martin Commercial Space Systems	Communications	N/A	2783	15	Cape Canaveral	Atlas

The dropdown menu was very difficult to create. On the first instance of the dropdown, it would append multiple copies of the elements into the options. This was resolved by creating a new set of elements based on the data being shown since sets do not allow duplicates like traditional arrays. The second issue that arose was that multi-filtering did not work. This meant we could only filter by one category at a time. To resolve this, we added a new variable that contained metadata describing if an attribute had a filter applied. When a filter was applied, it would stack on top of any other filters already in use instead of overriding the previous filters. The current and complete version acts like an onion, with each filter acting as a layer, and what is shown on the screen is a combination of all the applied filters.

Color:
Originally, arbitrary high contrast colors were chosen so we could easily see distinctions in the code. After we decided on a color palette, we decided to use the darker green/gray colors for the table. Since the other colors from our palette were brighter and more vibrant, we decided it would not be as easy to read text elements in the table.

Feedback:

Below is the feedback we gained from our meeting with our advisor Haihan, and how we addressed it:

- Bar chart is hard to read as a total object (try to subset it)
    - We addressed this by having all four views synched, so the bar chart would only show information that was selected/filtered in the table and radial charts.
- Filter the bar chart with table, randomly pick a subset to start
    - As mentioned above, all four views are synched. We decided to use a random number generator to randomly select 200 satellites to show at the start
- Keep the subset down to 10-30 on bar chart, add in axis and label each bar with the satellite name
    - We decided not to keep the subset down to 30 since we wanted all the views to be synched together, and if we subset something with more than 30 bars, we wouldn't be able to see anything past the first 30. The axis and label for the bars will show up in the details window, showing expanded information of the selected satellites.
- Radial chart, keep subset down to something that doesn't entirely overlap
    - To combat the overwhelming amount of satellites that would be drawn, we decided to start by showing only a subset of 5% of the satellites, with options for users to up the amount of satellites via a slider. This way it is smooth and fast at first, while still retaining the option to view the full dataset.
- For radial chart, try opacity or some density grouping (like clustering some together)
    - We are using opacity in the radial chart to show density of satellites. Each drawn satellite is slightly opaque, so that way when there are multiple satellites in the

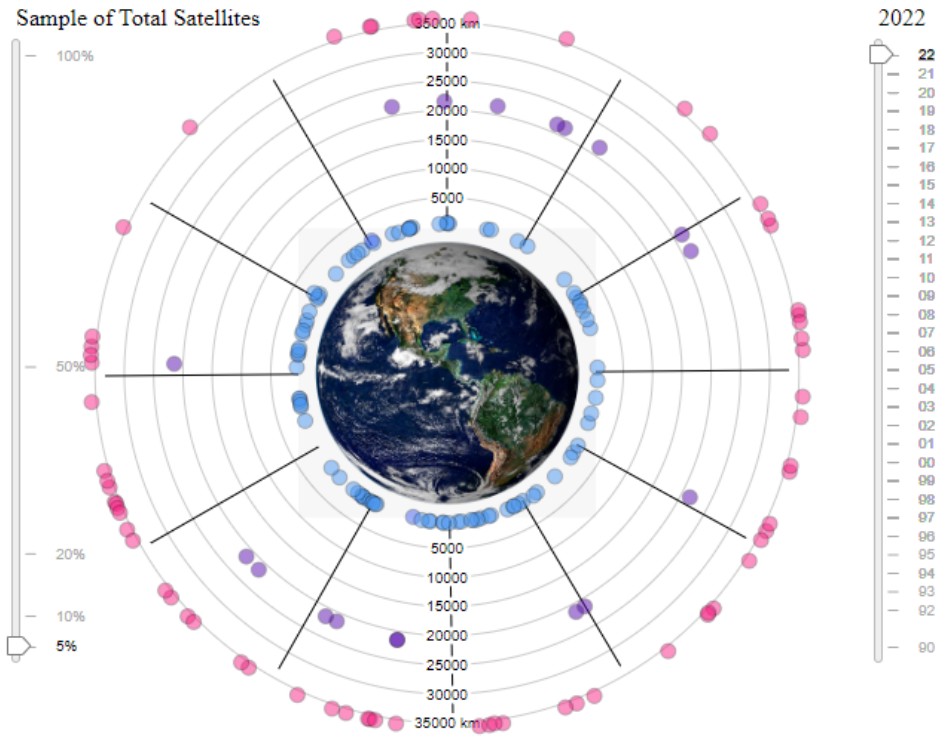
same spot, the color becomes darker, indicating a larger amount of satellites at that location.

- Searches will be the best option to help find specific subsets
    - We decided not to use a search bar since it can be difficult to know what to look for without exploring the data first. Instead we opted for dropdown filters, allowing users to see the options available to them immediately without having to explore the entire dataset.
- Maybe take down the amount of graphical elements that are being drawn
    - This is addressed with the two sliders, one for showing only a percentage based subset, and the other for showing satellites by launch year.
- Maybe add some explanation box/tooltip to show what percentage of satellite sample is being shown in the radial chart
    - We have added a small tooltip explaining how the sliders work for the radial chart
- Add scroll bar to show satellites by launch date
    - This is the other slider that is appended to the right of the radial chart
- Make launch date the color encoding or make expected lifetime or age
    - We decided to instead make the orbit the color encoding since color does not provide a huge variety of options. For launch date or expected lifetime we would need ~20 colors, where we only needed 4 colors for orbit. This means we won't have an overload of indistinguishable colors.
- Flip the axis and circles on radial chart so the axis is readable
    - This has been implemented so the text of the axis shows up on top of the graphical elements in the radial chart.

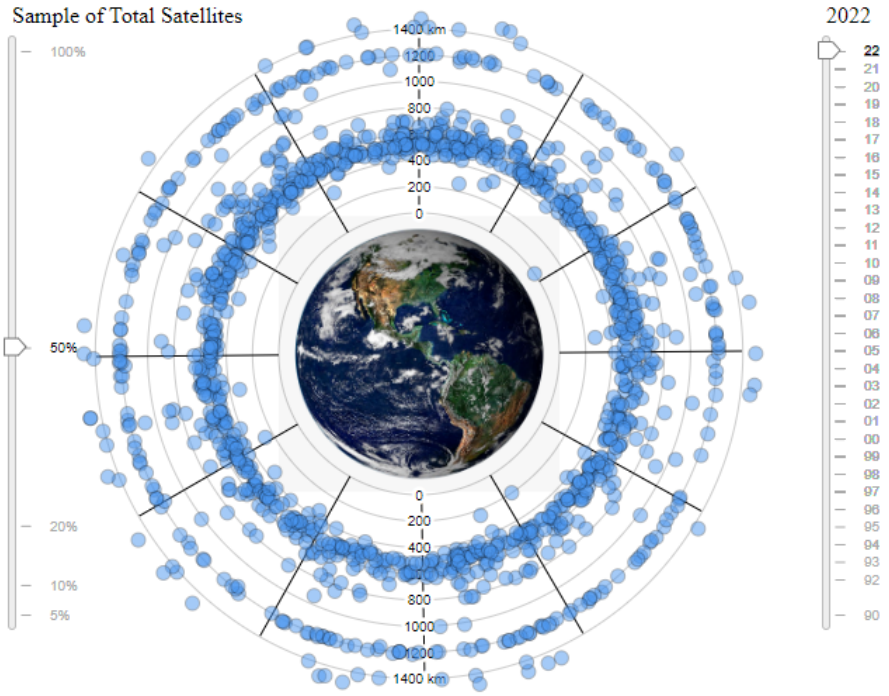
Implementation:

Radial Chart

The main intention of this visualization was to give the viewer a sense of what was in the night sky "above" them. We designed this to focus more on displaying clear groups or "bands" of distance that most of the earth's satellites fall in. The locations are accurate by altitude, but positions are imprecise, falling somewhere along their orbital radius.
The final implementation of the radial orbit chart looks like this:



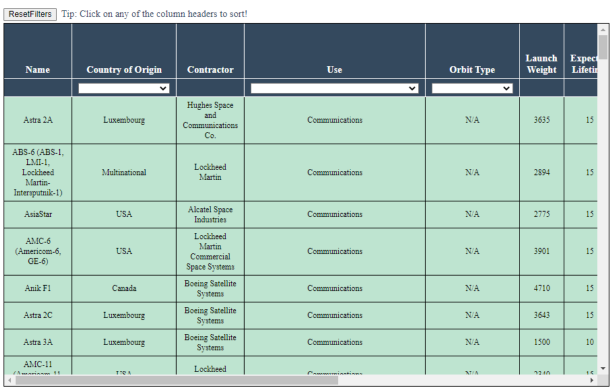
Orbit type is encoded via color for clear distinction. The sliders to the left and right control the volume of satellites displayed and the latest launch year respectively. Each ring around the earth is based on a variable scale depending on what is currently displayed, and shows how far a given satellite is from the earth in kilometers. Clicking on any satellite will zoom into that satellite's orbit and give a closer view like the following:

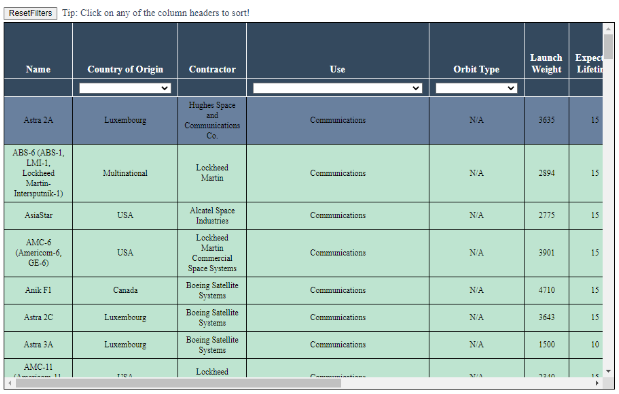


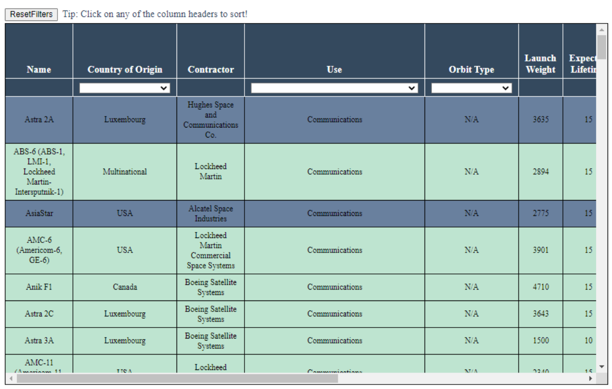
Clicking on earth will reset the visualization to its initial state.
We opted to decrease opacity because it made it easier to see individual satellites and also intensified the effect of clustering - more satellites in a given band are going to make the entire band darker, almost creating a heatmap of sorts.

Table

Selecting:



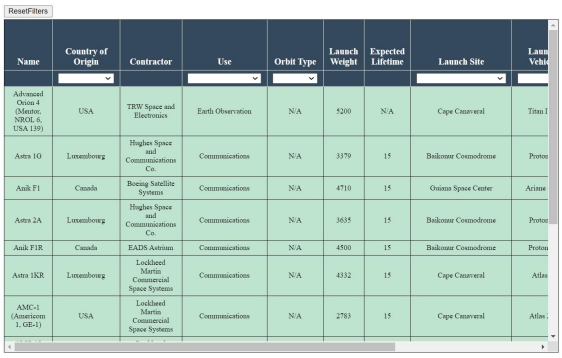




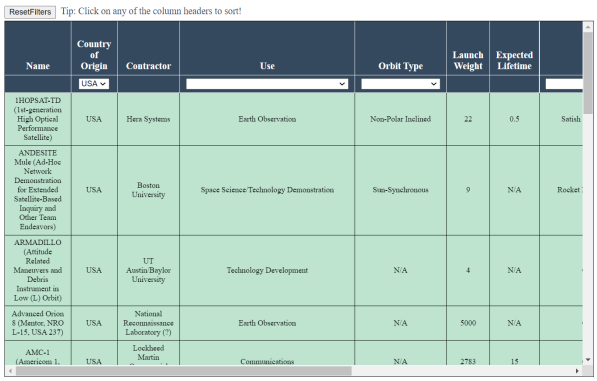
The table view allows users to select specific entries to highlight them in all four views. The table view applies a darker color background over the selected elements. Additionally, there is the option to select up to two satellite entries at a time, showing a comparison in the details and bar chart views.

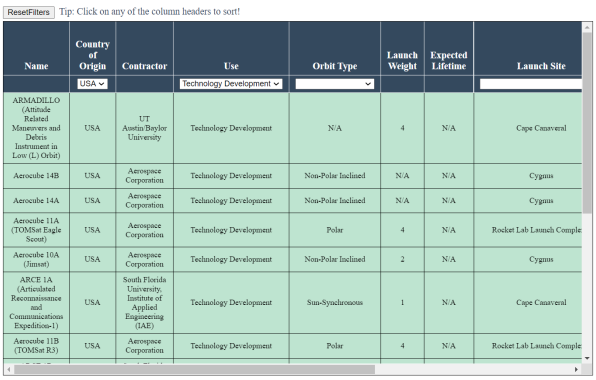
Filtering:

Filtering in the table is demonstrated below. On the left is an image with no filter applied, and on the right is an image of the filtered table



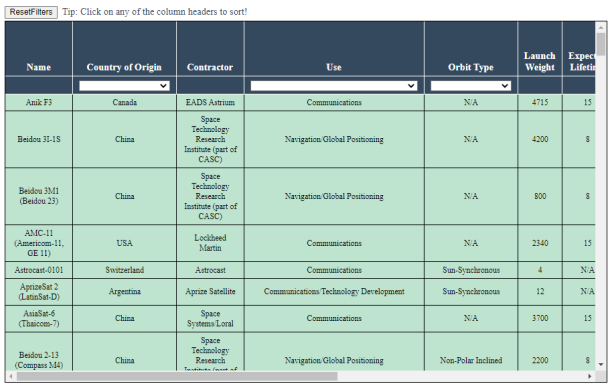
Filtering in the table view is triggered by either an interaction with the radial chart, or by using the dropdown menu filters on the table. There are five categories that allow filtering: Country of origin, use, orbit type, launch site, and launch vehicle. The dropdown menu populates options based on unique values in the current satellite set. Without any filters applied, the table will show all the data, but as filters are applied the set will shrink. This allows layered filtering, for example, we can first filter by the country, selecting USA, then we can filter the USA satellites by use case, like technology. This layered filtering interaction is displayed in the images below. On the left, is the first filtering by USA, and on the right is the second layer of filter by use case.



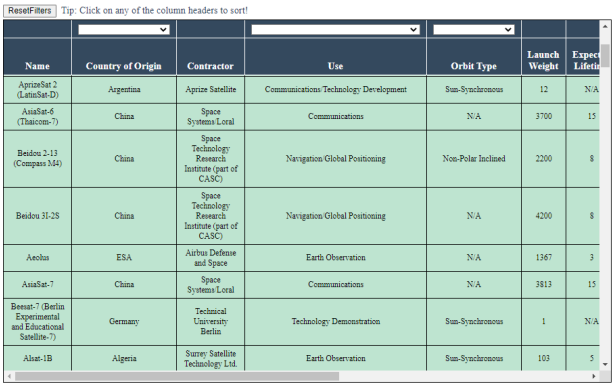


Fitler bar and reset button:

The reset button’s functionality is trivial. Upon clicking the button, all filters in the table will be reset, unwrapping each filter layer. The last major feature of the table is the dropdown filter bar’s placement. The bar moves to the top as the user scrolls down so that way the category names are easier to read when lined up with the table entries. This is imaged below, on the left the unfiltered table, on the right an unfiltered table that has been scrolled to part way down the table.


ResetFilters Tip: Click on any of the column headers to sort!

Name	Country of Origin	Contractor	Use	Orbit Type	Launch Weight	Expec Lifeti
Anik F3	Canada	EADS Astrium	Communications	N/A	4715	15
Beidou 3I-1S	China	Space Technology Research Institute (part of CASC)	Navigation/Global Positioning	N/A	4200	8
Beidou 3M1 (Beidou 23)	China	Space Technology Research Institute (part of CASC)	Navigation/Global Positioning	N/A	800	8
AMC-11 (Americom-11, GE 11)	USA	Lockheed Martin	Communications	N/A	2340	15
Astrocast-0101	Switzerland	Astrocast	Communications	Sun-Synchronous	4	N/A
AprizeSat 2 (LatinSat-D)	Argentina	Aprize Satellite	Communications/Technology Development	Sun-Synchronous	12	N/A
AsiaSat-6 (Thaicom-7)	China	Space Systems/Loral	Communications	N/A	3700	15
Beidou 2-13 (Compass M4)	China	Space Technology Research	Navigation/Global Positioning	Non-Polar Inclined	2200	8


ResetFilters Tip: Click on any of the column headers to sort!

Name	Country of Origin	Contractor	Use	Orbit Type	Launch Weight	Expec Lifeti
AprizeSat 2 (LatinSat-D)	Argentina	Aprize Satellite	Communications/Technology Development	Sun-Synchronous	12	N/A
AsiaSat-6 (Thaicom-7)	China	Space Systems/Loral	Communications	N/A	3700	15
Beidou 2-13 (Compass M4)	China	Space Technology Research Institute (part of CASC)	Navigation/Global Positioning	Non-Polar Inclined	2200	8
Beidou 3I-2S	China	Space Technology Research Institute (part of CASC)	Navigation/Global Positioning	N/A	4200	8
Aeolus	ESA	Airbus Defense and Space	Earth Observation	N/A	1367	3
AsiaSat-7	China	Space Systems/Loral	Communications	N/A	3813	15
Beesat-7 (Berlin Experimental and Educational Satellite-7)	Germany	Technical University Berlin	Technology Demonstration	Sun-Synchronous	1	N/A
Alsat-1B	Algeria	Surrey Satellite Technology Ltd.	Earth Observation	Sun-Synchronous	103	5

Details Pane

No current selection (from table):

Selected Satellite Details

Single satellite selected (from table):

Selected Satellite Details
Name: Beidou DW 39
Country: China
Use: Navigation/Global Positioning
User: Military/Government
Launch Site: Xichang Satellite Launch Center
Launch Date: 10-15-18
Notes:
Launch Vehicle: Long March 3B 

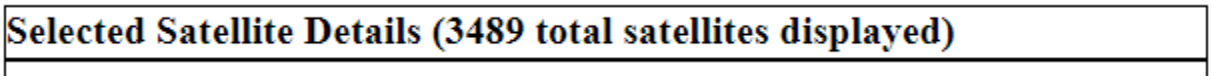
Comparison View (two satellites selected from table):

Selected Satellite Details	
Name: Beidou DW 39	Name: Aerocube 7A
Country: China	Country: USA
Use: Navigation/Global Positioning	Use: Technology Development
User: Military/Government	User: Commercial
Launch Site: Xichang Satellite Launch Center	Launch Site: Vandenberg AFB
	Launch Date: 10-08-15
Launch Date: 10-15-18	Notes:
Notes:	Launch Vehicle: Atlas 5 
Launch Vehicle: Long March 3B 	

The Detail Pane will update upon any satellite selection event from the table. This will pull 8 fields from the satellite data based on the currently selected satellite and display them as text (and image) for each field. The fields/categories are highlighted via background color to easily distinguish the list of attributes and compare between satellites, given there may be

word-wrapping that offsets the height of a given category in the pane. The “Launch Vehicle” category will also load an image of the launch vehicle associated with that particular satellite. Images are taken from wikipedia for the respective launch vehicle. These images are automatically loaded from the “images” folder upon click, so slower internet connections/computers may take some time to load them, but on the computers used to develop, the loading was near-instantaneous. The images are also automatically scaled to fit easily in the detail pane despite the variation in the original sizes. If no image appears with a selected satellite it is because only 95% of the satellites had accompanying images for their launch vehicle, keeping the total number of launch vehicle images down to 29. There were satellites with more obscure launch vehicles and including all of those would more than double the number of images required and only serve an additional 5% of the data points.
The “Notes” section simply lists the comments that were in our original dataset that sometimes accompanied a specific satellite.

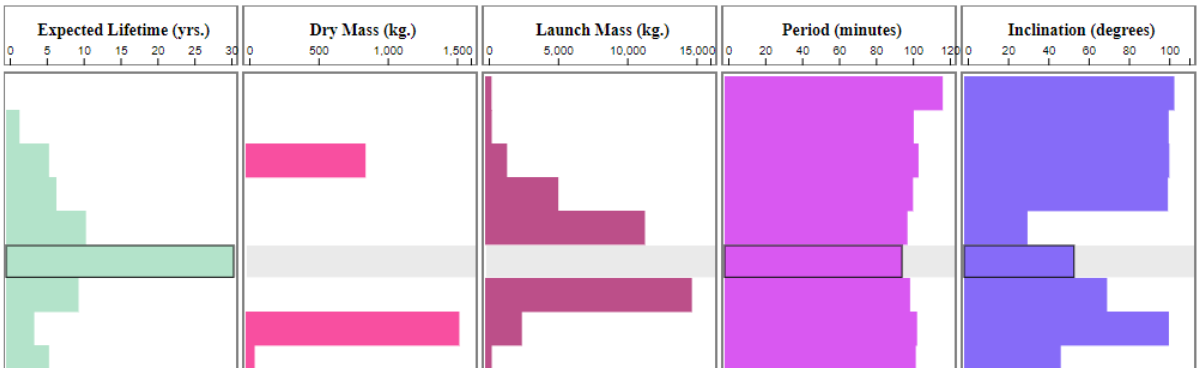
Also the total number of satellites shown across the table, worldview, and bar chart is shown in parentheses in the detail pane:



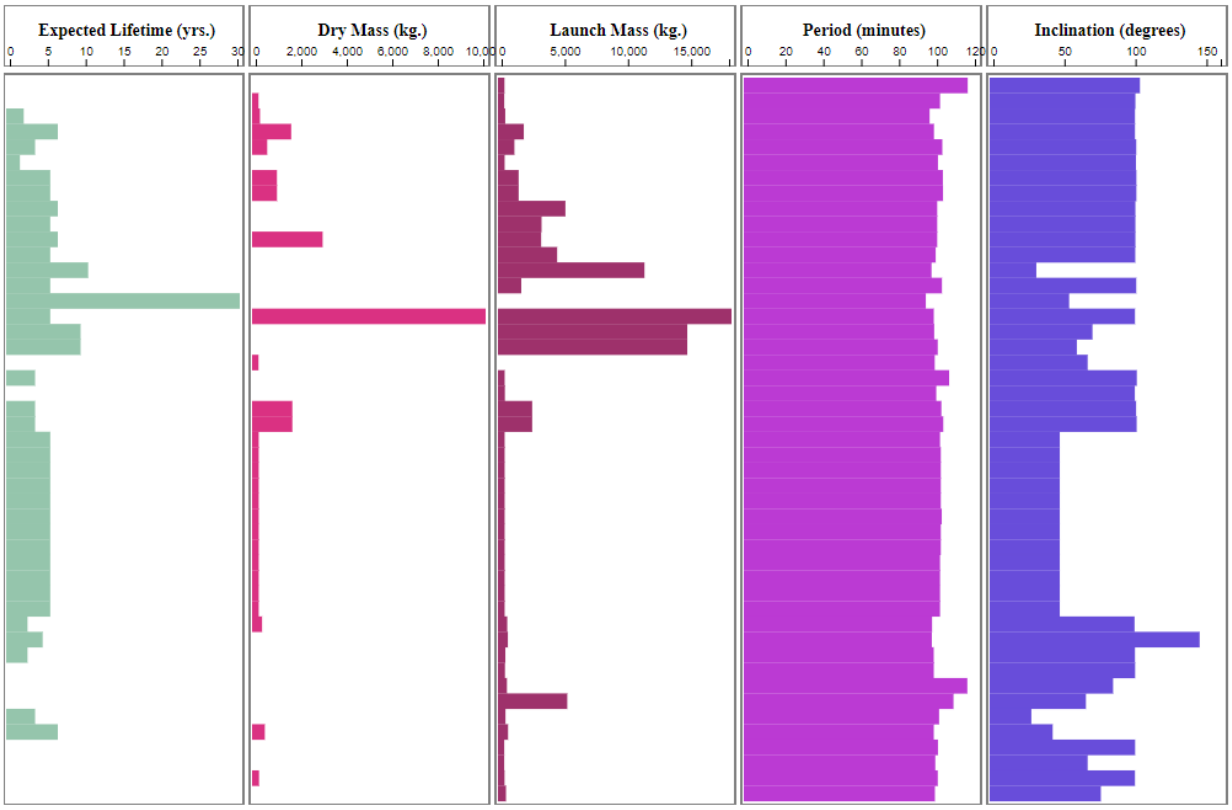
Bar Chart

The bar chart has no directly interactive elements and instead is synced completely with the other elements of the visualization. It will maintain a completely identical list of satellites as the table, in a more condensed form. If the table is sorted, filtered or any row is selected, the chart will mirror that interaction exactly.
In terms of scaling and row representation there are a couple forms the bar chart will take depending on the data selected/filtered.

The first case is Small Grouping (less than 30 total)
This version, every row is scaled so that the total number of rows together will be 600 pixels tall. Selected rows will be enlarged only if the total number of rows is greater than 30. If less than 30 rows, the row height is not changed upon selection, only the color:

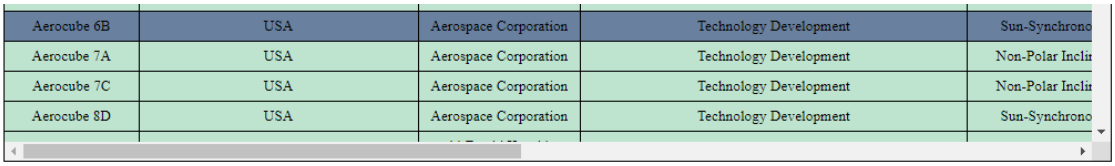


The second case is Medium Grouping (between 31 and 600 satellites)
Here a highlighted row is scaled up upon selection, while all other rows are scaled down to make room for the enlarged/highlighted row.

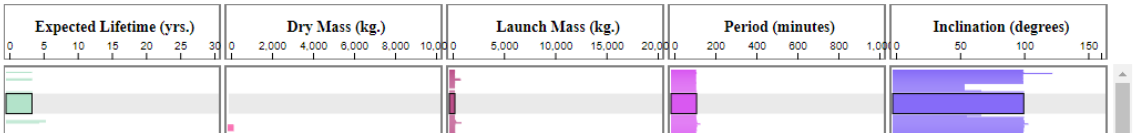


The last case is a large grouping (greater than 600 total satellites):

In this case each row is only a single pixel in height, and a scroll bar appears to allow scrolling to view the entirety of the data. When an item is selected that row is enlarged and the total height of the chart is increased to make room so no occlusion occurs. The rows in a specific column that are blank indicates that there was no recorded data for that field for that specific satellite. The scale/axis in the header is updated dynamically based on the data that is filtered. So when increasing/decreasing the sample size of the data you might observe scale changing, as outlier satellites can cause the range to skew. Selection of a single satellite will cause a single row to be highlighted:

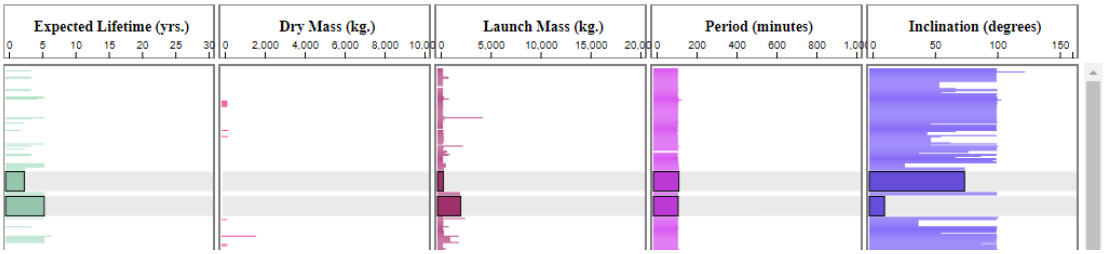


Aerocube 6B	USA	Aerospace Corporation	Technology Development	Sun-Synchrono
Aerocube 7A	USA	Aerospace Corporation	Technology Development	Non-Polar Inclin
Aerocube 7C	USA	Aerospace Corporation	Technology Development	Non-Polar Inclin
Aerocube 8D	USA	Aerospace Corporation	Technology Development	Sun-Synchrono



Also, in the case the total filtered satellite list is over 600 and the scrollbar is present, the selected satellite will be scrolled to so that the selection is shown on the screen regardless of where in the list it is.

When two satellites are selected via the table, both are highlighted in the chart:



This continuity makes it clear what is being selected in the table and allows for quick comparison between two satellites by muting the colors of all rows in the chart and highlighting the rows selected.

Evaluation:

We learned there is significant clustering in the data in the perigee, period and expected lifetime. Among the thousands of data points we have, the majority seem to have similar values for these fields with a smaller portion having variance and spread across the range. Our visualization is able to filter down to more specific pieces of the dataset and it allows for many of our questions to be answered. One such example might be the purpose of most of a country's satellites. We can filter down to that country, a specific use case, and even get specific information down to individual satellites.

Something we learned from our data is that many satellites that are government owned do not have much public information. This led to a reasonably sized subset of our data that contained N/A or unknown values for fields such as use, lifetime, and the additional comments field. To further improve this part of our visualization would be to do a more in depth search for information regarding those satellites, since it is possible our dataset sources did not reach information that was available.

We also learned a lot about the satellites and space industries of other countries/regions of the world. A lot of satellites used various launch methods from NASA but in other parts of the world a lot of rocket designs were reused for almost the entirety of their satellites just with updated versions of the same rocket. From a physics perspective, by sorting by Period it is clear from the bar chart the relationship between inclination and period. This makes sense as the actual length of the orbit and radius of the orbit are related to the inclination angle with respect to the earth. The expected lifetime of satellites doesn't seem to have changed much over the past decade either which was counterintuitive from what we would expect given technology would be expected to improve over time, however the vast majority of satellites maintain close to a 15 year expected lifetime, regardless of owner, launch date or other factors.

The visualization works to express the vastness of the satellites orbiting our planet and the varying countries, sizes, and attributes of the satellites. The comments shown in the "Notes" also provide interesting facts that contribute to the story of how/why the satellites got into their place in the night sky and that fulfills our original goal of learning more about these satellites. The visualization could possibly be improved by showing more group statistics for the filtered group of satellites, possibly a box plot or violin chart. Other improvements could be put in place to implement color more precisely around certain channels of the data, clearly expressing the trends more immediately to the viewer.