# Launch Sites Locations Analysis with Folium

Estimated time needed: **40** minutes

The launch success rate may depend on many factors such as payload mass, orbit type, and so on. It may also depend on the location and proximities of a launch site, i.e., the initial position of rocket trajectories. Finding an optimal location for building a launch site certainly involves many factors and hopefully we could discover some of the factors by analyzing the existing launch site locations.

In the previous exploratory data analysis labs, you have visualized the SpaceX launch dataset using `matplotlib` and `seaborn` and discovered some preliminary correlations between the launch site and success rates. In this lab, you will be performing more interactive visual analytics using `Folium`.

## Objectives

This lab contains the following tasks:

- **TASK 1:** Mark all launch sites on a map
- **TASK 2:** Mark the success/failed launches for each site on the map
- **TASK 3:** Calculate the distances between a launch site to its proximities

After completed the above tasks, you should be able to find some geographical patterns about launch sites.

Let's first import required Python packages for this lab:

```
!pip3 install folium
!pip3 install wget
!pip3 install pandas
```

```
Requirement already satisfied: folium in /usr/local/lib/python3.10/dist-packages (0.18.0)
Requirement already satisfied: branca>=0.6.0 in /usr/local/lib/python3.10/dist-packages (from folium) (0.8.0)
Requirement already satisfied: jinja2>=2.9 in /usr/local/lib/python3.10/dist-packages (from folium) (3.1.4)
Requirement already satisfied: numpy in /usr/local/lib/python3.10/dist-packages (from folium) (1.26.4)
Requirement already satisfied: requests in /usr/local/lib/python3.10/dist-packages (from folium) (2.32.3)
Requirement already satisfied: xyzservices in /usr/local/lib/python3.10/dist-packages (from folium) (2024.9.0)
Requirement already satisfied: MarkupSafe>=2.0 in /usr/local/lib/python3.10/dist-packages (from jinja2>=2.9->folium) (3.0.2)
Requirement already satisfied: charset-normalizer<4,>=2 in /usr/local/lib/python3.10/dist-packages (from requests->folium) (3.4.0)
Requirement already satisfied: idna<4,>=2.5 in /usr/local/lib/python3.10/dist-packages (from requests->folium) (3.10)
Requirement already satisfied: urllib3<3,>=1.21.1 in /usr/local/lib/python3.10/dist-packages (from requests->folium) (2.2.3)
Requirement already satisfied: certifi>=2017.4.17 in /usr/local/lib/python3.10/dist-packages (from requests->folium) (2024.8.30)
Requirement already satisfied: wget in /usr/local/lib/python3.10/dist-packages (3.2)
Requirement already satisfied: pandas in /usr/local/lib/python3.10/dist-packages (2.2.2)
Requirement already satisfied: numpy>=1.22.4 in /usr/local/lib/python3.10/dist-packages (from pandas) (1.26.4)
Requirement already satisfied: python-dateutil>=2.8.2 in /usr/local/lib/python3.10/dist-packages (from pandas) (2.8.2)
Requirement already satisfied: pytz>=2020.1 in /usr/local/lib/python3.10/dist-packages (from pandas) (2024.2)
Requirement already satisfied: tzdata>=2022.7 in /usr/local/lib/python3.10/dist-packages (from pandas) (2024.2)
Requirement already satisfied: six>=1.5 in /usr/local/lib/python3.10/dist-packages (from python-dateutil>=2.8.2->pandas) (1.16.0)
```

```
import folium
import wget
import pandas as pd
```

```
# Import folium MarkerCluster plugin
from folium.plugins import MarkerCluster
# Import folium MousePosition plugin
from folium.plugins import MousePosition
# Import folium DivIcon plugin
from folium.features import DivIcon
```

If you need to refresh your memory about folium, you may download and refer to this previous folium lab:

Generating Maps with Python

## Task 1: Mark all launch sites on a map

First, let's try to add each site's location on a map using site's latitude and longitude coordinates

The following dataset with the name `spacex_launch_geo.csv` is an augmented dataset with latitude and longitude added for each site.

```
# Download and read the `spacex_launch_geo.csv`
spacex_csv_file = wget.download('https://cf-courses-data.s3.us.cloud-object-storage.appdomain.cloud/IBM-DS0321EN-SkillsNetwork/datasets/spacex_launch_geo.csv')
spacex_df=pd.read_csv(spacex_csv_file)
```

Now, you can take a look at what are the coordinates for each site.

```
# Select relevant sub-columns: `Launch Site`, `Lat(Latitude)`, `Long(Longitude)`, `class`
spacex_df = spacex_df[['Launch Site', 'Lat', 'Long', 'class']]
launch_sites_df = spacex_df.groupby(['Launch Site'], as_index=False).first()
launch_sites_df = launch_sites_df[['Launch Site', 'Lat', 'Long']]
launch_sites_df
```

| | Launch Site | Lat | Long |
|---|---|---|---|
| 0 | CCAFS LC-40 | 28.562302 | -80.577356 |
| 1 | CCAFS SLC-40 | 28.563197 | -80.576820 |
| 2 | KSC LC-39A | 28.573255 | -80.646895 |
| 3 | VAFB SLC-4E | 34.632834 | -120.610745 |

Next steps: Generate code with launch_sites_df | View recommended plots | New interactive sheet

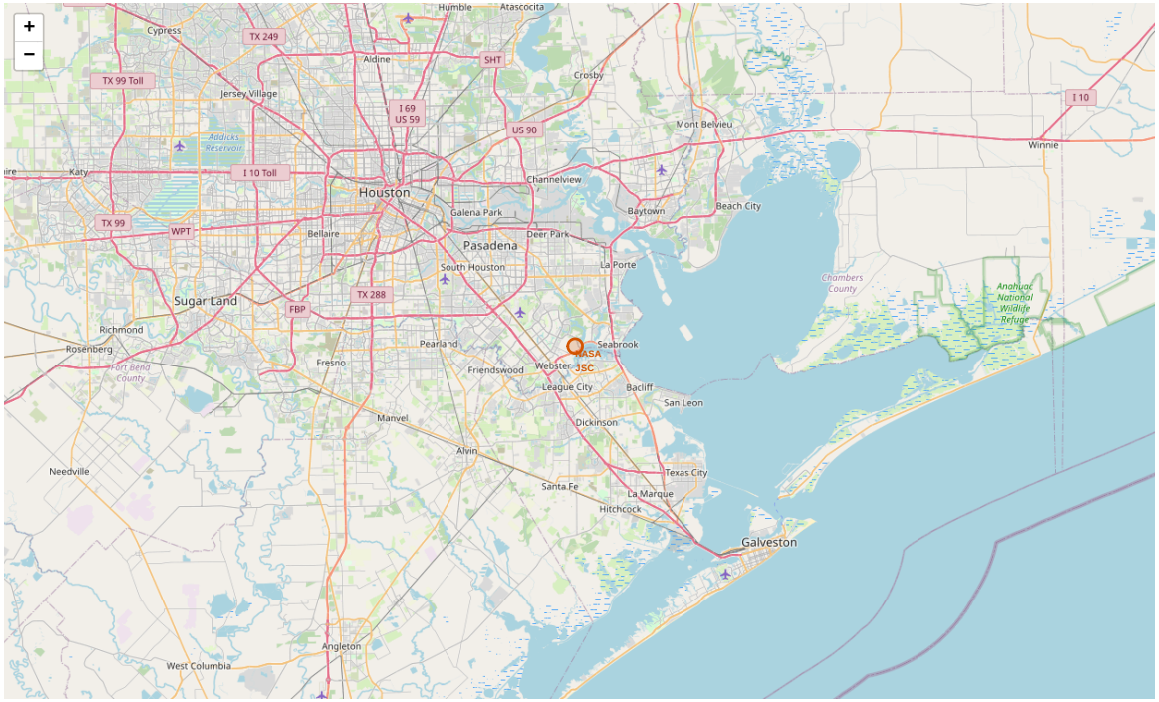
Above coordinates are just plain numbers that can not give you any intuitive insights about where are those launch sites. If you are very good at geography, you can interpret those numbers directly in your mind. If not, that's fine too. Let's visualize those locations by pinning them on a map.

We first need to create a folium `Map` object, with an initial center location to be NASA Johnson Space Center at Houston, Texas.

```
# Start location is NASA Johnson Space Center
nasa_coordinate = [29.559684888503615, -95.0830971930759]
site_map = folium.Map(location=nasa_coordinate, zoom_start=10)
```

We could use `folium.Circle` to add a highlighted circle area with a text label on a specific coordinate. For example,

```
# Create a blue circle at NASA Johnson Space Center's coordinate with a popup label showing its name
circle = folium.Circle(nasa_coordinate, radius=1000, color='#d35400', fill=True).add_child(folium.Popup('NASA Johnson Space Center'))
# Create a blue circle at NASA Johnson Space Center's coordinate with a icon showing its name
marker = folium.map.Marker(
    nasa_coordinate,
    # Create an icon as a text label
    icon=DivIcon(
        icon_size=(20,20),
        icon_anchor=(0,0),
        html='<div style="font-size: 12; color:#d35400;"><b>%s</b></div>' % 'NASA JSC',
        )
    )
site_map.add_child(circle)
site_map.add_child(marker)
```




and you should find a small yellow circle near the city of Houston and you can zoom-in to see a larger circle.

Now, let's add a circle for each launch site in data frame `launch_sites`

*TODO:* Create and add `folium.Circle` and `folium.Marker` for each launch site on the site map

An example of folium.Circle:

`folium.Circle(coordinate, radius=1000, color='#000000', fill=True).add_child(folium.Popup(...))`

An example of folium.Marker:

`folium.map.Marker(coordinate, icon=DivIcon(icon_size=(20,20),icon_anchor=(0,0), html='<div style="font-size: 12; color:#d35400;"><b>%s</b></div>' % 'label', ))`

```
# Initial the map
site_map0 = folium.Map(location=nasa_coordinate, zoom_start=5)
# For each launch site, add a Circle object based on its coordinate (Lat, Long) values. In addition, add Launch site name as a popup label

```

```
#LaunchSite Coordinates
launchsite0=[28.562302, -80.577356]
launchsite1=[28.563197, -80.576820]
launchsite2=[28.573255, -80.646895]
launchsite3=[34.632834, -120.610745]
```

```
#LaunchSite0 circle and popup
# Create a blue circle with a popup label showing its name
circle0 = folium.Circle(launchsite0, radius=50, color='#d35400', fill=True).add_child(folium.Popup('CCAFS LC-40'))
# Create a blue circle  with a icon showing its name
marker0 = folium.map.Marker(
    launchsite0,
```

```
    # Create an icon as a text label
    icon=DivIcon(
        icon_size=(20,20),
        icon_anchor=(0,0),
        html='<div style="font-size: 12; color:#d35400;"><b>%s</b></div>' % 'CCAFS LC-40',
        )
    )
```

```
#LaunchSite1 circle and popup
# Create a blue circle with a popup label showing its name
circle1 = folium.Circle(launchsite1, radius=50, color='#d35400', fill=True).add_child(folium.Popup('CCAFS SLC-40'))
# Create a blue circle  with a icon showing its name
marker1 = folium.map.Marker(
    launchsite1,
    # Create an icon as a text label
    icon=DivIcon(
        icon_size=(20,20),
        icon_anchor=(0,0),
        html='<div style="font-size: 12; color:#d35400;"><b>%s</b></div>' % 'CCAFS SLC-40',
        )
    )

```

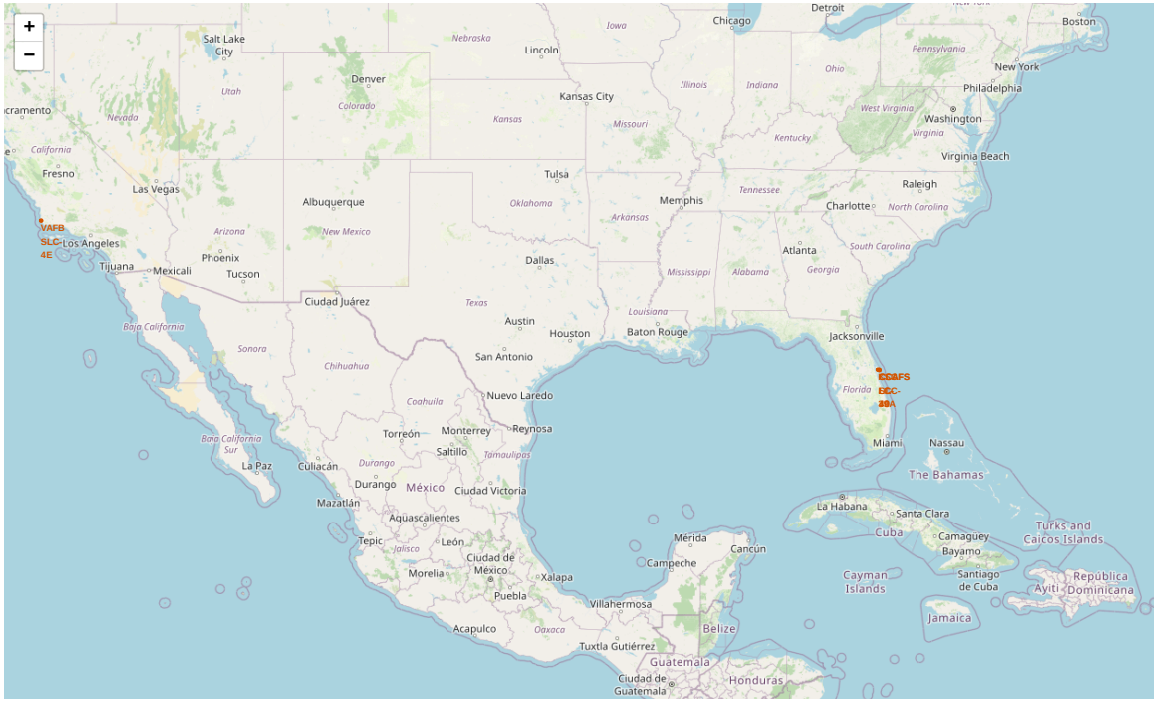
```
#LaunchSite2 circle and popup
# Create a blue circle with a popup label showing its name
circle2 = folium.Circle(launchsite2, radius=50, color='#d35400', fill=True).add_child(folium.Popup('KSC LC-39A'))
# Create a blue circle  with a icon showing its name
marker2 = folium.map.Marker(
    launchsite2,
    # Create an icon as a text label
    icon=DivIcon(
        icon_size=(20,20),
        icon_anchor=(0,0),
        html='<div style="font-size: 12; color:#d35400;"><b>%s</b></div>' % 'KSC LC-39A',
        )
    )
```

```
#LaunchSite3 circle and popup
# Create a blue circle with a popup label showing its name
circle3 = folium.Circle(launchsite3, radius=1000, color='#d35400', fill=True).add_child(folium.Popup('VAFB SLC-4E'))
# Create a blue circle  with a icon showing its name
marker3 = folium.map.Marker(
    launchsite3,
    # Create an icon as a text label
    icon=DivIcon(
        icon_size=(20,20),
        icon_anchor=(0,0),
        html='<div style="font-size: 12; color:#d35400;"><b>%s</b></div>' % 'VAFB SLC-4E',
        )
    )
```

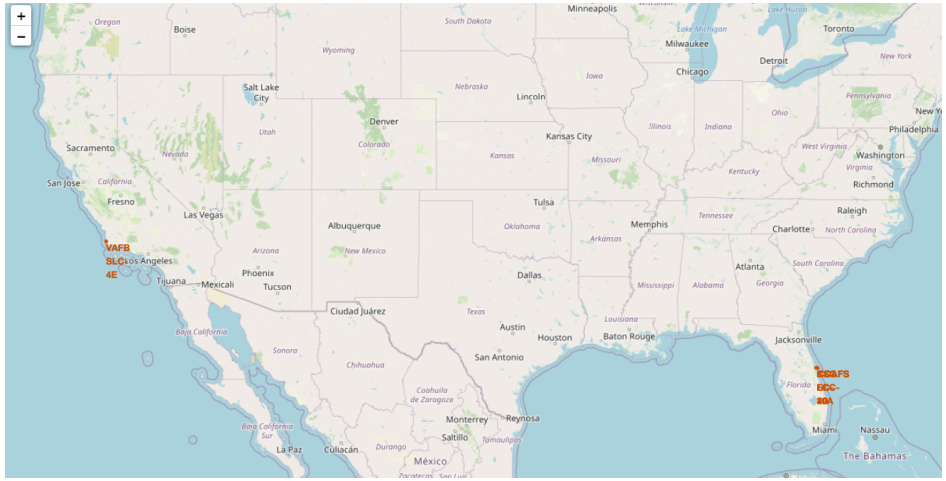
```
# Add each child element individually to the map using a loop
for circle in [circle0, circle1, circle2, circle3]:
    site_map0.add_child(circle)

for marker in [marker0, marker1, marker2, marker3]:
    site_map0.add_child(marker)

site_map0
```




The generated map with marked launch sites should look similar to the following:




Now, you can explore the map by zoom-in/out the marked areas , and try to answer the following questions:

- Are all launch sites in proximity to the Equator line?
- Are all launch sites in very close proximity to the coast?

Also please try to explain your findings.

## Task 2: Mark the success/failed launches for each site on the map

Next, let's try to enhance the map by adding the launch outcomes for each site, and see which sites have high success rates. Recall that data frame spacex_df has detailed launch records, and the `class` column indicates if this launch was successful or not

```
spacex_df.tail(10)
```

| | Launch Site | Lat | Long | class |
|---|---|---|---|---|
| **46** | KSC LC-39A | 28.573255 | -80.646895 | 1 |
| **47** | KSC LC-39A | 28.573255 | -80.646895 | 1 |
| **48** | KSC LC-39A | 28.573255 | -80.646895 | 1 |
| **49** | CCAFS SLC-40 | 28.563197 | -80.576820 | 1 |
| **50** | CCAFS SLC-40 | 28.563197 | -80.576820 | 1 |
| **51** | CCAFS SLC-40 | 28.563197 | -80.576820 | 0 |
| **52** | CCAFS SLC-40 | 28.563197 | -80.576820 | 0 |
| **53** | CCAFS SLC-40 | 28.563197 | -80.576820 | 0 |
| **54** | CCAFS SLC-40 | 28.563197 | -80.576820 | 1 |
| **55** | CCAFS SLC-40 | 28.563197 | -80.576820 | 0 |

Next, let's create markers for all launch records. If a launch was successful `(class=1)`, then we use a green marker and if a launch was failed, we use a red marker `(class=0)`

Note that a launch only happens in one of the four launch sites, which means many launch records will have the exact same coordinate. Marker clusters can be a good way to simplify a map containing many markers having the same coordinate.

Let's first create a `MarkerCluster` object

```
marker_cluster = MarkerCluster()
```

*TODO:* Create a new column in `launch_sites` dataframe called `marker_color` to store the marker colors based on the `class` value

```

# Apply a function to check the value of `class` column
# If class=1, marker_color value will be green
# If class=0, marker_color value will be red

```

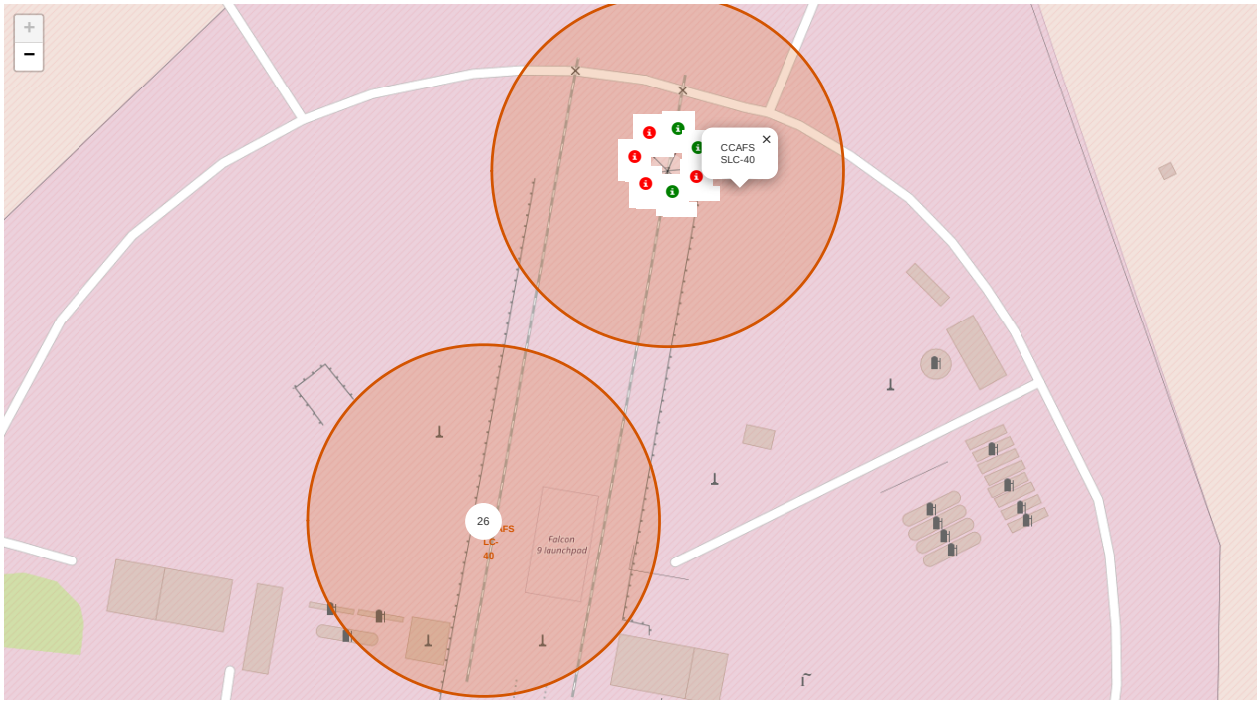
```
# Function to assign color to launch outcome
def assign_marker_color(launch_outcome):
    if launch_outcome == 1:
        return 'green'
    else:
        return 'red'

spacex_df['marker_color'] = spacex_df['class'].apply(assign_marker_color)
spacex_df.tail(10)
```

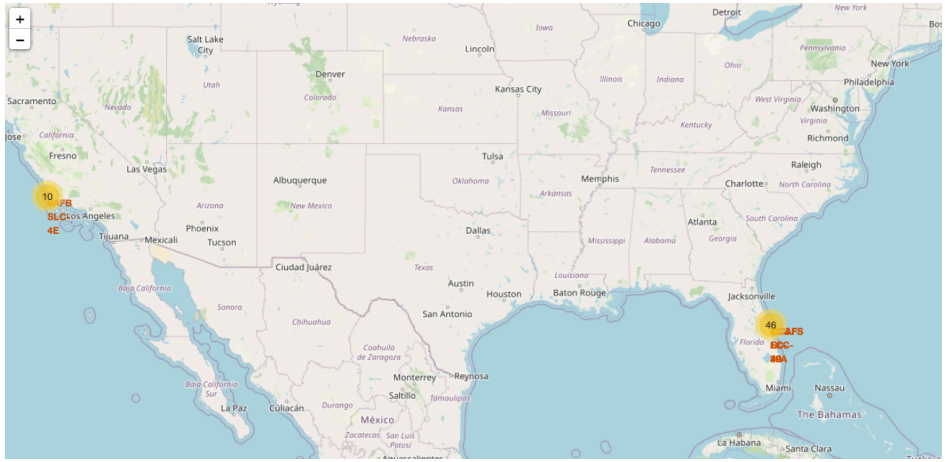
| | Launch Site | Lat | Long | class | marker_color |
|---|---|---|---|---|---|
| 46 | KSC LC-39A | 28.573255 | -80.646895 | 1 | green |
| 47 | KSC LC-39A | 28.573255 | -80.646895 | 1 | green |
| 48 | KSC LC-39A | 28.573255 | -80.646895 | 1 | green |
| 49 | CCAFS SLC-40 | 28.563197 | -80.576820 | 1 | green |
| 50 | CCAFS SLC-40 | 28.563197 | -80.576820 | 1 | green |
| 51 | CCAFS SLC-40 | 28.563197 | -80.576820 | 0 | red |
| 52 | CCAFS SLC-40 | 28.563197 | -80.576820 | 0 | red |
| 53 | CCAFS SLC-40 | 28.563197 | -80.576820 | 0 | red |
| 54 | CCAFS SLC-40 | 28.563197 | -80.576820 | 1 | green |
| 55 | CCAFS SLC-40 | 28.563197 | -80.576820 | 0 | red |

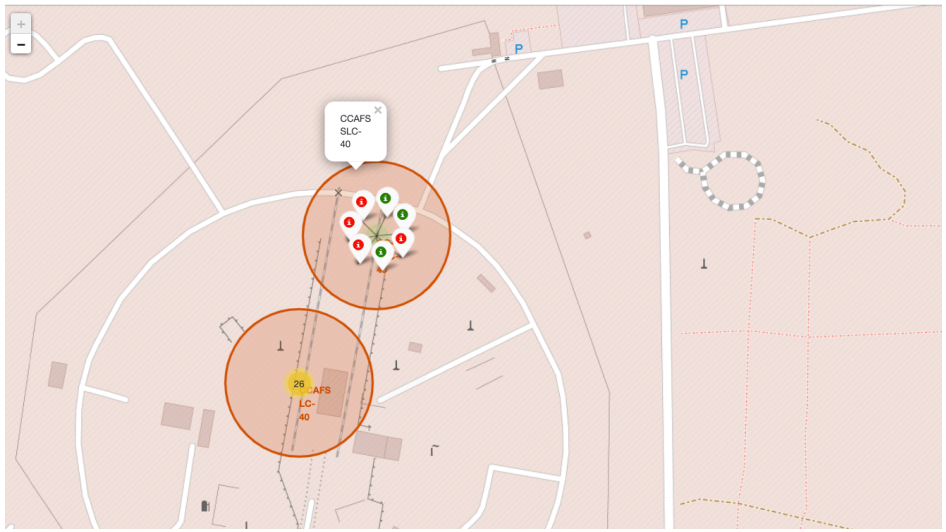
*TODO:* For each launch result in `spacex_df` data frame, add a `folium.Marker` to `marker_cluster`

```
# Add marker_cluster to current site_map
site_map0.add_child(marker_cluster)
# for each row in spacex_df data frame
# create a Marker object with its coordinate
# and customize the Marker's icon property to indicate if this launch was successed or failed,
# e.g., icon=folium.Icon(color='white', icon_color=row['marker_color']
for index, record in spacex_df.iterrows():
    # TODO: Create and add a Marker cluster to the site map
    marker = folium.Marker([record['Lat'], record['Long']], icon=folium.Icon(color='white', icon_color=record['marker_color']))
    marker_cluster.add_child(marker)
site_map0
```




Your updated map may look like the following screenshots:




From the color-labeled markers in marker clusters, you should be able to easily identify which launch sites have relatively high success rates.

## TASK 3: Calculate the distances between a launch site to its proximities

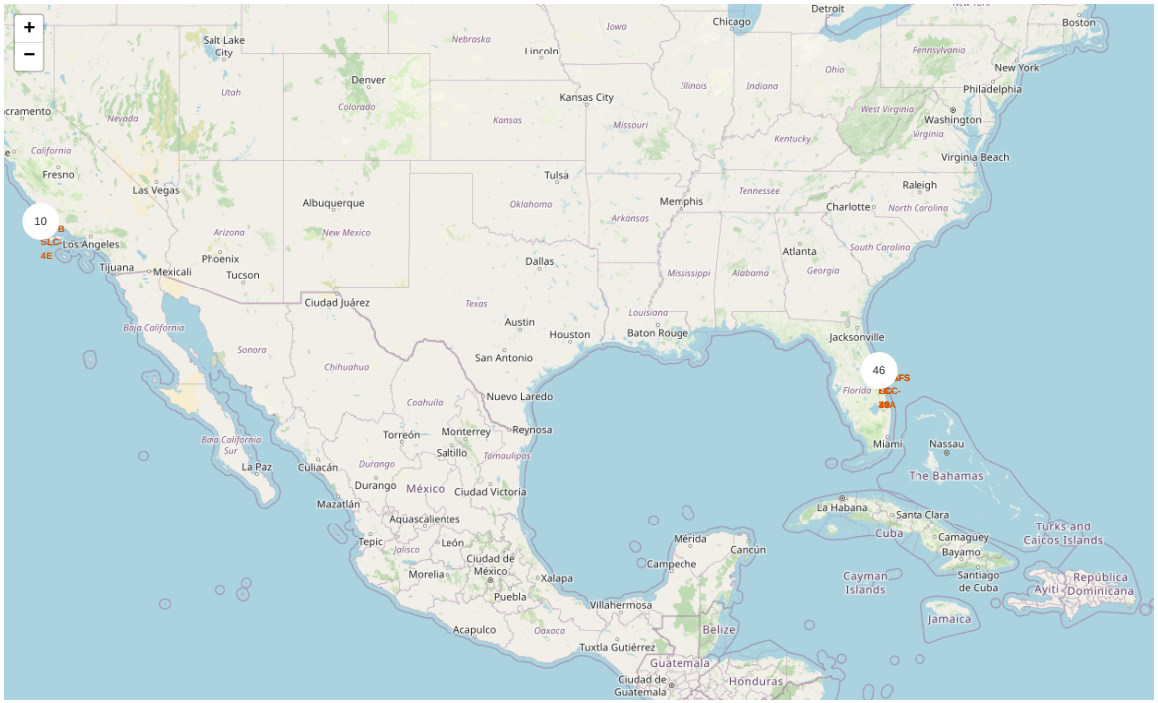
Next, we need to explore and analyze the proximities of launch sites.

Let's first add a `MousePosition` on the map to get coordinate for a mouse over a point on the map. As such, while you are exploring the map, you can easily find the coordinates of any points of interests (such as railway)

```
# Add Mouse Position to get the coordinate (Lat, Long) for a mouse over on the map
formatter = "function(num) {return L.Util.formatNum(num, 5);};"
mouse_position = MousePosition(
    position='topright',
    separator=' Long: ',
    empty_string='NaN',
    lng_first=False,
    num_digits=20,
    prefix='Lat:',
```

```
    lat_formatter=formatter,
    lng_formatter=formatter,
)

site_map0.add_child(mouse_position)
site_map0
```




Now zoom in to a launch site and explore its proximity to see if you can easily find any railway, highway, coastline, etc. Move your mouse to these points and mark down their coordinates (shown on the top-left) in order to the distance to the launch site.

You can calculate the distance between two points on the map based on their `Lat` and `Long` values using the following method:

```
from math import sin, cos, sqrt, atan2, radians

def calculate_distance(lat1, lon1, lat2, lon2):
    # approximate radius of earth in km
    R = 6373.0

    lat1 = radians(lat1)
    lon1 = radians(lon1)
    lat2 = radians(lat2)
    lon2 = radians(lon2)

    dlon = lon2 - lon1
    dlat = lat2 - lat1

    a = sin(dlat / 2)**2 + cos(lat1) * cos(lat2) * sin(dlon / 2)**2
    c = 2 * atan2(sqrt(a), sqrt(1 - a))

    distance = R * c
    return distance
```

*TODO:* Mark down a point on the closest coastline using MousePosition and calculate the distance between the coastline point and the launch site.

```
# find coordinate of the closet coastline
# e.g.,: Lat: 28.56367  Lon: -80.57163
```

```
# distance_coastline = calculate_distance(launch_site_lat, launch_site_lon, coastline_lat, coastline_lon)
```

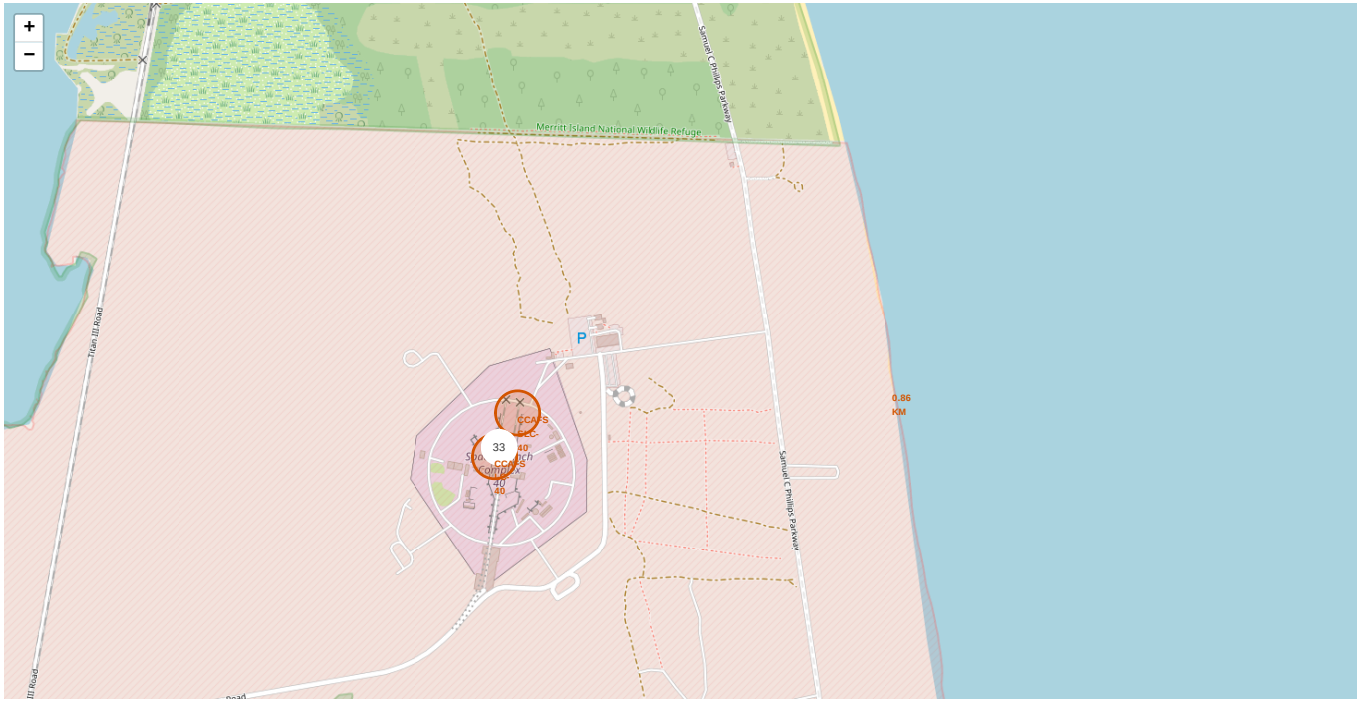
```
coastline_lat = 28.56365
coastline_lon = -80.56808
launch_site_lat = 28.563197
launch_site_lon = -80.576820
distance_coastline = calculate_distance(launch_site_lat, launch_site_lon, coastline_lat, coastline_lon)
distance_coastline
```

```
0.8553124096287662
```

*TODO:* After obtained its coordinate, create a `folium.Marker` to show the distance

```
# Create and add a folium.Marker on your selected closest coastline point on the map
# Display the distance between coastline point and launch site using the icon property
# for example
# distance_marker = folium.Marker(
#    coordinate,
#    icon=DivIcon(
#        icon_size=(20,20),
#        icon_anchor=(0,0),
#        html='<div style="font-size: 12; color:#d35400;"><b>%s</b></div>' % "{:10.2f} KM".format(distance),
#        )
#    )
```

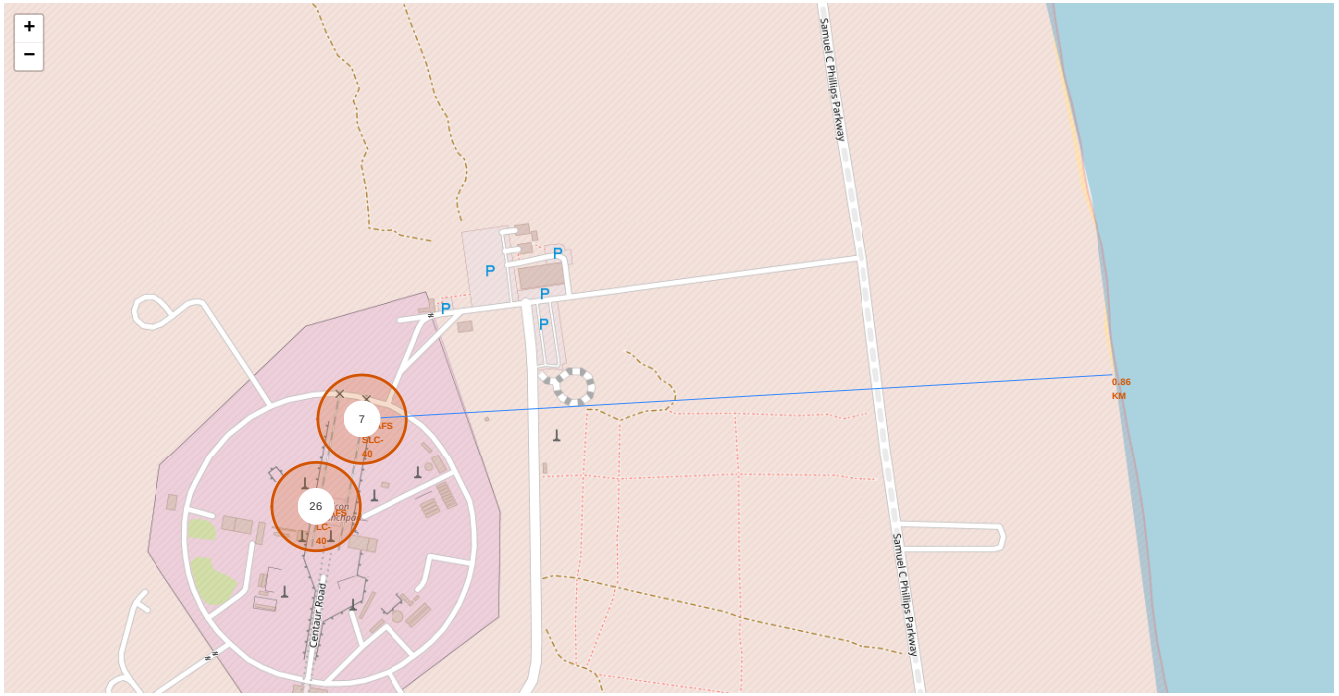
```
distance_marker = folium.Marker(
    [coastline_lat, coastline_lon],
    icon=DivIcon(
        icon_size=(20,20),
        icon_anchor=(0,0),
        html='<div style="font-size: 12; color:#d35400;"><b>%s</b></div>' % "{:10.2f} KM".format(distance_coastline),
        )
    )
site_map0.add_child(distance_marker)
```



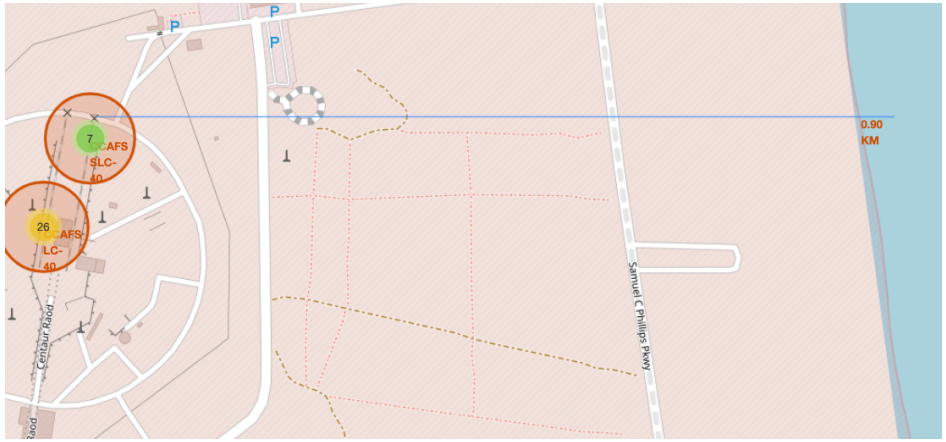

*TODO:* Draw a `PolyLine` between a launch site to the selected coastline point

```
# Create a `folium.PolyLine` object using the coastline coordinates and launch site coordinate
```

```
# create a folium.PolyLine object using the coastline coordinates and launch site coordinate
coordinates = [[launch_site_lat, launch_site_lon], [coastline_lat, coastline_lon]]
lines=folium.PolyLine(locations=coordinates, weight=1)
site_map0.add_child(lines)
site_map0
```



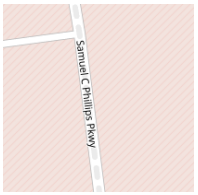

Your updated map with distance line should look like the following screenshot:




*TODO:* Similarly, you can draw a line betwee a launch site to its closest city, railway, highway, etc. You need to use `MousePosition` to find the their coordinates on the map first

A railway map symbol may look like this:


A highway map symbol may look like this:




A city map symbol may look like this:

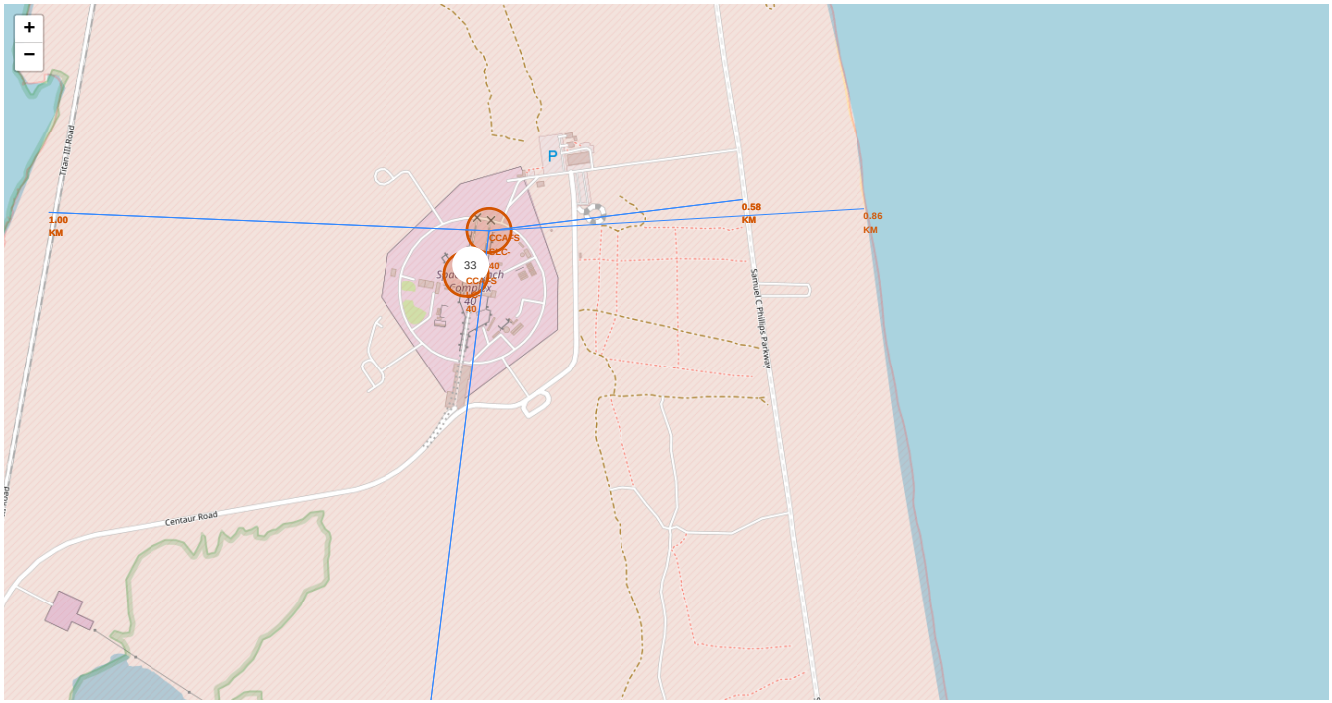

```
# Create a marker with distance to a closest city, railway, highway, etc.
# Draw a line between the marker to the launch site

```

```
#Coordinates for Railway, Highway, City
railway_lat = 28.56357
railway_lon = -80.58708
hwy_lat = 28.56383
hwy_lon = -80.57091
city_lat = 28.38808
city_lon = -80.60154
distance_railway = calculate_distance(launch_site_lat, launch_site_lon, railway_lat, railway_lon)
distance_hwy = calculate_distance(launch_site_lat, launch_site_lon, hwy_lat, hwy_lon)
distance_city = calculate_distance(launch_site_lat, launch_site_lon, city_lat, city_lon)
```

```
#Distance to the closest Railway
distance_marker_railway = folium.Marker(
    [railway_lat, railway_lon],
    icon=DivIcon(
        icon_size=(20,20),
        icon_anchor=(0,0),
        html='<div style="font-size: 12; color:#d35400;"><b>%s</b></div>' % "{:10.2f} KM".format(distance_railway),
        )
    )
site_map0.add_child(distance_marker_railway)
#Distance to the closest Highway
distance_marker_hwy = folium.Marker(
    [hwy_lat, hwy_lon],
    icon=DivIcon(
        icon_size=(20,20),
        icon_anchor=(0,0),
        html='<div style="font-size: 12; color:#d35400;"><b>%s</b></div>' % "{:10.2f} KM".format(distance_hwy),
        )
    )
site_map0.add_child(distance_marker_hwy)
#Distance to city Cape Canaveral
distance_marker_city = folium.Marker(
    [city_lat, city_lon],
    icon=DivIcon(
        icon_size=(20,20),
        icon_anchor=(0,0),
        html='<div style="font-size: 12; color:#d35400;"><b>%s</b></div>' % "{:10.2f} KM".format(distance_city),
        )
    )
site_map0.add_child(distance_marker_city)
#add lines for Railway
coordinates_railway= [[launch_site_lat, launch_site_lon], [railway_lat, railway_lon]]
lines_railway=folium.PolyLine(locations=coordinates_railway, weight=1)
site_map0.add_child(lines_railway)
#add lines for Highway
coordinates_hwy= [[launch_site_lat, launch_site_lon], [hwy_lat, hwy_lon]]
```

```
lines_hwy=folium.PolyLine(locations=coordinates_hwy, weight=1)
site_map0.add_child(lines_hwy)
#add lines for City
coordinates_city= [[launch_site_lat, launch_site_lon], [city_lat, city_lon]]
lines_city=folium.PolyLine(locations=coordinates_city, weight=1)
site_map0.add_child(lines_city)
site_map0
```




After you plot distance lines to the proximities, you can answer the following questions easily:

- Are launch sites in close proximity to railways?
- Are launch sites in close proximity to highways?
- Are launch sites in close proximity to coastline?
- Do launch sites keep certain distance away from cities?

Also please try to explain your findings.

**ANSWERS**

The base chosen was CCAFS SLC-40. Based on this base,

- Launch sites are close to railways. In the map example, CCAFS SLC-40 site is **1 KM** away from the railway.
- Launch sites are close to highways. In the map example, CCAFS SLC-40 site is **0.58 KM** away from the highway.
- Launch sites are close to coastlines. In the map example, CCAFS SLC-40 site is **0.86 KM** away from the coastline.
- Launch sites do keep a certain distance to the city. In the map example, CCAFS SLC-40 site is **19.63 KM** away from the coastline.