Satellites - Exploratory Data Analysis with Inference

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Dataset: https://www.kaggle.com/datasets/sujaykapadnis/every-known-satellite-orbiting-earth

Read and clean data

```
import numpy as np
import pandas as pd
import matplotlib.pyplot as plt; plt.rcParams["figure.dpi"] = 144
import seaborn as sns
from matplotlib import ticker
from wordcloud import WordCloud
from datetime import datetime
from matplotlib.patches import Patch
from scipy import stats
```

```
# Check out the columns
df = pd.read_csv('UCS-Satellite-Database-1-1-2023.csv',encoding='windows-1252')
df.info()
```

```
 12  Apogee (km)                       6718 non-null   object
 13  Eccentricity                      6718 non-null   float64
 14  Inclination (degrees)             6718 non-null   object
 15  Period (minutes)                  6674 non-null   object
 16  Launch Mass (kg.)                 6475 non-null   object
 17   Dry Mass (kg.)                   444 non-null    object
 18  Power (watts)                     581 non-null    object
 19  Date of Launch                    6718 non-null   object
 20  Expected Lifetime (yrs.)          4804 non-null   float64
 21  Contractor                        6718 non-null   object
 22  Country of Contractor             6718 non-null   object
 23  Launch Site                       6718 non-null   object
 24  Launch Vehicle                    6718 non-null   object
 25  COSPAR Number                     6718 non-null   object
 26  NORAD Number                      6718 non-null   int64
 27  Comments                          1836 non-null   object
 28  Unnamed: 28                       4 non-null      object
 29  Source Used for Orbital Data      6427 non-null   object
 30  Source                            3209 non-null   object
 31  Source.1                          729 non-null    object
 32  Source.2                          1856 non-null   object
 33  Source.3                          1136 non-null   object
 34  Source.4                          735 non-null    object
 35  Source.5                          554 non-null    object
 36  Source.6                          504 non-null    object
 37  Unnamed: 37                       484 non-null    object
 38  Unnamed: 38                       484 non-null    object
 39  Unnamed: 39                       484 non-null    object
 40  Unnamed: 40                       484 non-null    object
 41  Unnamed: 41                       484 non-null    object
 42  Unnamed: 42                       484 non-null    object
 43  Unnamed: 43                       484 non-null    object
 44  Unnamed: 44                       484 non-null    object
 45  Unnamed: 45                       484 non-null    object
 46  Unnamed: 46                       484 non-null    object
```

```
 64  Unnamed: 64                          484 non-null    object
 65  Unnamed: 65                          484 non-null    object
 66  Unnamed: 66                          486 non-null    object
 67  Unnamed: 67                          484 non-null    object
dtypes: float64(3), int64(1), object(64)
memory usage: 3.5+ MB
```

```
# Show how many elements of each column are NaN
df.isna().sum().head(50)
```

```
Name of Satellite, Alternate Names       0
Current Official Name of Satellite       0
Country/Org of UN Registry               0
Country of Operator/Owner                0
Operator/Owner                           0
Users                                    0
Purpose                                  0
Detailed Purpose                      5551
Class of Orbit                           0
Type of Orbit                          641
Longitude of GEO (degrees)               2
Perigee (km)                             0
Apogee (km)                              0
Eccentricity                             0
Inclination (degrees)                    0
Period (minutes)                        44
Launch Mass (kg.)                      243
 Dry Mass (kg.)                       6274
Power (watts)                         6137
Date of Launch                           0
Expected Lifetime (yrs.)              1914
Contractor                               0
Country of Contractor                    0
Launch Site                              0
Launch Vehicle                           0
COSPAR Number                            0
NORAD Number                             0
Comments                              4882
Unnamed: 28                           6714
Source Used for Orbital Data           291
Source                                3509
Source.1                              5989
Source.2                              4862
Source.3                              5582
Source.4                              5983
Source.5                              6164
Source.6                              6214
Unnamed: 37                           6234
Unnamed: 38                           6234
Unnamed: 39                           6234
Unnamed: 40                           6234
Unnamed: 41                           6234
Unnamed: 42                           6234
Unnamed: 43                           6234
Unnamed: 44                           6234
Unnamed: 45                           6234
Unnamed: 46                           6234
Unnamed: 47                           6234
Unnamed: 48                           6234
Unnamed: 49                           6234
dtype: int64
```

```
# Investigate the unnamed columns unique values - what are these columns for?
eval("[df[f'Unnamed: {i}'].value_counts() for i in range(37,68)]")
```

```
Name: count, dtype: int64,
Unnamed: 57
Estimated    484
Name: count, dtype: int64,
Unnamed: 58
Estimated    484
Name: count, dtype: int64,
Unnamed: 59
Estimated    484
Name: count, dtype: int64,
Unnamed: 60
Estimated                                          484
http://www.orbcomm.com                               2
http://perso.wanadoo.fr/eurospace/espdatabase/       1
Name: count, dtype: int64,
Unnamed: 61
Estimated                                          484
http://nssdc.gsfc.nasa.gov/spacewarn/spx554.html     2
http://nssdc.gsfc.nasa.gov/spacewarn/spx540.html     1
Name: count, dtype: int64,
Unnamed: 62
Estimated                                                    484
http://perso.wanadoo.fr/eurospace/espdatabase/S1119.html       2
Name: count, dtype: int64,
Unnamed: 63
Estimated    484
Name: count, dtype: int64,
Unnamed: 64
Estimated    484
Name: count, dtype: int64,
Unnamed: 65
Estimated    484
Name: count, dtype: int64,
Unnamed: 66
Estimated      484
JMSatcat803      2
Name: count, dtype: int64,
Unnamed: 67
Estimated    484
Name: count, dtype: int64]
```

```
df['Comments'].value_counts().head(20)
```

```
Comments
Lemur surveillance of satellites or LEO.                                                                  86
Sensing surveillance of satellites in LEO.                                                                39
Next generation expected to last to 2030                                                                  30
C surveillance of satellites in LEO.                                                                      18
Remote surveillance of satellites in LEO.                                                                 14
ICEYE surveillance of satellites r  LEO.                                                                  14
High Resolution Optical Imaging                                                                           13
Thought to be for intelligence gathering.                                                                 11
Part of Beidou constellation.                                                                             10
Unknown mission.                                                                                           9
First of planned constellation to cover self-driving cars.                                                 9
ELINT system; wide area ocean surveillance, primarily for the Navy and surveillance of shipping.           8
Store-dump communications for Russian government and military.                                             8
Communications services; part of planned 24-satellite constellation. First commercial satellites.         7
IoT data relay.                                                                                            7
Electronic intelligence gathering (ELINT).                                                                 6
HawkEye surveillance of satellites in LEO.                                                                 6
Radar reconnaissance.                                                                                      6
Collect atmospheric data for weather prediction and for ionosphere, climate and gravity research.         6
ELINT.                                                                                                     6
Name: count, dtype: int64
```

```
df['Source'].value_counts()
```

```
Source
https://spaceflightnow.com/2021/01/24/spacex-launches-record-setting-rideshare-mission-with-143-small-satellites/
74
https://spaceflightnow.com/2021/03/14/spacex-extends-its-own-rocket-reuse-record-on-starlink-launch/
60
https://spaceflightnow.com/2021/04/29/spacex-launches-60-more-starlink-spacecraft-fcc-clears-spacex-to-fly-satellites-at-lower-altitudes/    60
https://spaceflightnow.com/2021/04/07/spacex-launches-its-100th-mission-from-floridas-space-coast/
60
https://spaceflightnow.com/2021/03/11/spacex-adds-more-satellites-to-starlink-internet-fleet/
60

..
https://hiber.global/press/hiber-4/
1
```

```
http://nssdc.gsfc.nasa.gov/spacewarn/spx580.html
1
http://www.hellas-sat.net/
1
http://www.france24.com/en/20091218-france-lauches-spy-satellite-helios-2b-kourou-guiana-military-space-intelligence
1
https://spaceflightnow.com/2020/07/25/china-launches-high-resolution-mapping-satellite/
1
Name: count, Length: 1425, dtype: int64
```

```
# Drop unneeded columns with high nan counts
df = df.drop(labels=[f'Unnamed: {i}' for i in range(37,68)], axis=1)
df = df.drop(labels=['Unnamed: 28'], axis=1)
df = df.drop(labels=['Source','Source.1','Source.2','Source.3','Source.4','Source.5','Source.6'], axis=1)
df = df.drop(labels=[' Dry Mass (kg.) ','Power (watts)'],axis=1)
df.info()
```

```
<class 'pandas.core.frame.DataFrame'>
RangeIndex: 6718 entries, 0 to 6717
Data columns (total 27 columns):
 #   Column                              Non-Null Count  Dtype
---  ------                              --------------  -----
 0   Name of Satellite, Alternate Names  6718 non-null   object
 1   Current Official Name of Satellite  6718 non-null   object
 2   Country/Org of UN Registry          6718 non-null   object
 3   Country of Operator/Owner           6718 non-null   object
 4   Operator/Owner                      6718 non-null   object
 5   Users                               6718 non-null   object
 6   Purpose                             6718 non-null   object
 7   Detailed Purpose                    1167 non-null   object
 8   Class of Orbit                      6718 non-null   object
 9   Type of Orbit                       6077 non-null   object
 10  Longitude of GEO (degrees)          6716 non-null   float64
 11  Perigee (km)                        6718 non-null   object
 12  Apogee (km)                         6718 non-null   object
 13  Eccentricity                        6718 non-null   float64
 14  Inclination (degrees)               6718 non-null   object
 15  Period (minutes)                    6674 non-null   object
 16  Launch Mass (kg.)                   6475 non-null   object
 17  Date of Launch                      6718 non-null   object
 18  Expected Lifetime (yrs.)            4804 non-null   float64
 19  Contractor                          6718 non-null   object
 20  Country of Contractor               6718 non-null   object
 21  Launch Site                         6718 non-null   object
 22  Launch Vehicle                      6718 non-null   object
 23  COSPAR Number                       6718 non-null   object
 24  NORAD Number                        6718 non-null   int64
 25  Comments                            1836 non-null   object
 26  Source Used for Orbital Data        6427 non-null   object
dtypes: float64(3), int64(1), object(23)
memory usage: 1.4+ MB
```

```
# Investigate the unique values in several columns
df['Purpose'].value_counts()
```

```
Purpose
Communications                                4812
Earth Observation                             1142
Technology Development                         366
Navigation/Global Positioning                  141
Space Science                                   98
Technology Demonstration                        42
Earth Science                                   22
Surveillance                                    14
Navigation/Regional Positioning                 13
Unknown                                         10
Earth Observation/Navigation                     9
Space Observation                                9
Earth Observation/Technology Development         7
Communications/Maritime Tracking                 5
Communications/Technology Development            5
Earth Observation                                4
Earth Observation/Communications                 2
Earth/Space Observation                          2
Mission Extension Technology                     2
Technology Development/Educational               2
Space Science/Technology Development             1
Technology  Development                          1
Earth Observation/Communications/Space Science   1
Earth Science/Earth Observation                  1
Educational                                      1
Communications/Navigation                        1
```

```
Earth Observation/Space Science                     1
Platform                                            1
Earth Observation/Earth Science                     1
Space Science/Technology Demonstration              1
Satellite Positioning                               1
Name: count, dtype: int64
```

```
df['Detailed Purpose'].value_counts()
```

```
Detailed Purpose
Optical Imaging                                          470
Electronic Intelligence                                  129
Meteorology, Automatic Identification System (AIS)       128
Radar Imaging                                             86
Earth Science                                             58
Meteorology                                               50
Automatic Identification System (AIS)                     36
Hyperspectral Imaging                                     21
Multispectral Imaging                                     20
Internet of Things (IoT)                                  19
Earth Science/Meterology                                  18
Radar Imaging (SAR)                                       15
Amateur Radio                                             14
Infrared Imaging                                          12
Radar Imaging/Earth Science                                8
Video Imaging                                              7
Data Relay                                                 7
Radio Spectrum Monitoring                                  5
Early Warning                                              5
Imaging                                                    5
Radio Frequency Monitoring                                 4
Optical                                                    3
Technology Development                                     3
Optical Imaging/Automatic Identification System (AIS)      3
Meteorology/Earth Science                                  3
Maritime Surveillance                                      3
Optical Imaging/Meterology                                 3
Maritime Observation                                       2
Optical Imaging (video)                                    2
Synthetic Aperture Imaging                                 2
Multi-Spectral Imaging                                     2
Navigation                                                 2
Synthetic Aperture Radar (SAR)                             2
Infra-Red Imaging                                          2
Optical, Near-Infrared                                     1
Microwave Radiometer                                       1
Optical/Hyperspectral Imaging                              1
Radar Imaging/Electronic Intelligence                      1
Situational Awareness                                      1
Laser Imaging                                              1
Surveillance                                               1
Optical/Video Imaging                                      1
X-ray Astronomy                                            1
ADS-B Receiver                                             1
Thermal Imaging                                            1
Subsurface Imaging                                         1
Optical Imaging                                            1
Optical Stereo Imaging                                     1
AI Remote Sensing                                          1
Optical Imaging/Meteorology                                1
Signals Intelligence                                       1
Optical Imaging/Infrared Imaging                           1
Name: count, dtype: int64
```

```
df['Expected Lifetime (yrs.)'].value_counts()
```

```
Expected Lifetime (yrs.)
4.00     2872
5.00      704
15.00     423
3.00      246
2.00      122
8.00       84
12.00      83
10.00      83
7.00       77
1.00       26
14.00      15
18.00      13
13.00      12
11.00       6
16.00       6
```

```
20.00       5
9.00        5
0.50        4
6.00        4
0.25        3
1.50        2
30.00       2
7.25        2
17.00       1
25.00       1
2.50        1
12.50       1
4.50        1
Name: count, dtype: int64
```

```
df['Date of Launch'].value_counts()
```

```
Date of Launch
13-01-2022    93
24-01-2021    91
30-06-2021    78
14-03-2021    63
13-06-2020    60
              ..
16-06-2004     1
29-10-2000     1
23-11-2009     1
30-11-2009     1
09-01-2012     1
Name: count, Length: 1187, dtype: int64
```

```
df['Operator/Owner'].value_counts().head(50)
```

```
Operator/Owner
SpaceX                                                                      3349
OneWeb Satellites                                                            502
Planet Labs, Inc.                                                            195
Chinese Ministry of National Defense                                         147
Spire Global Inc.                                                            127
Ministry of Defense                                                          113
Swarm Technologies                                                            84
Iridium Communications, Inc.                                                  75
Chang Guang Satellite Technology Co. Ltd.                                     53
National Reconnaissance Office (NRO)                                          50
China Academy of Space Technology (CAST)                                      49
Spacex                                                                        46
Indian Space Research Organization (ISRO)                                     46
SES S.A.                                                                      46
European Space Agency (ESA)                                                   40
ORBCOMM Inc.                                                                  35
Intelsat S.A.                                                                 34
DoD/US Air Force                                                              34
Globalstar                                                                    33
Satellogic S.A.                                                               30
EUTELSAT S.A.                                                                 29
US Air Force                                                                  26
National Aeronautics and Space Administration (NASA)                          24
ICEYE Ltd.                                                                    20
O3b Networks Ltd.                                                             20
China Aerospace Science and Technology Corp. (CASC)                           19
Kepler Communications                                                         19
Shanghai Academy of Spaceflight Technology                                    18
Gonets Satcom                                                                 18
China National Academy of Sciences (CNSAS)                                    18
China Satellite Communication Corp. (China Satcom)                            16
Guodian Gaoke                                                                 15
Aerospace Corporation                                                         15
Russian Satellite Communications Company                                      14
Japan Aerospace Exploration Agency (JAXA)                                     14
National Reconnaissance Office (NRO)/US Air Force                             14
BlackSky Global                                                               14
Chinese Academy of Sciences                                                   13
Unknown                                                                       12
Kleos Space                                                                   12
HawkEye 360                                                                   12
National Reconnaissance Office (NRO)/US Navy                                  12
Technical University Berlin                                                   12
Tyvak Nanosatellite Systems, Inc.                                             12
EUMETSAT (European Organization for the Exploitation of Meteorological Satellites)    12
Telesat Canada Ltd. (BCE, Inc.)                                               12
Cabinet Satellite Intelligence Center (CSIC)                                  11
Echostar Satellite Services, LLC                                              11
```

```
Sky Perfect JSAT Corporation                                                    10
China Meteorological Administration                                             10
Name: count, dtype: int64
```

```
len(df['Operator/Owner'].unique())
```

```
639
```

```
df['Users'].value_counts()
```

```
Users
Commercial                         5272
Government                          541
Military                            443
Civil                               154
Government/Commercial                97
Military/Commercial                  81
Military/Government                  56
Government/Civil                     44
Military/Civil                        7
Government/Military                   4
Commercial/Civil                      4
Civil/Government                      4
Civil/Military                        3
Commercial/Military                   2
Commercial                            1
Government                            1
Civil/Commercial                      1
Government/Commercial/Military        1
Commercial/Government                 1
Military                              1
Name: count, dtype: int64
```

```
df['Launch Mass (kg.)'].value_counts().head(50)
```

```
Launch Mass (kg.)
260      2962
148       503
227       434
4         206
10        186
2         113
1          77
860        75
6          64
9          53
100        52
5          47
45         45
3          41
700        39
280        39
800        35
300        30
500        27
5,000      25
1,000      23
8          23
80         23
12         22
43         22
15         22
1,415      21
2,500      20
55         20
110        17
20         17
2,300      16
50         16
40         16
4,200      15
4,500      15
95         14
650        13
1,600      13
3,200      13
2,217      13
3,000      12
172        12
1,630      12
723        12
```

```
225        11
70         11
42         11
5,200      11
4,000      11
Name: count, dtype: int64
```

```
len(df['Launch Mass (kg.)'].unique())
```

```
567
```

```
df['Type of Orbit'].value_counts()
```

```
Type of Orbit
Non-Polar Inclined       3740
Sun-Synchronous          1510
Polar                     748
Equatorial                 38
Molniya                    23
Deep Highly Eccentric       9
Elliptical                  8
Cislunar                    1
Name: count, dtype: int64
```

```
df['Period (minutes)'].value_counts() # Need to convert to float
```

```
Period (minutes)
95.6      1262
95.4      1020
91.5       511
1436.1     198
94.5       170
          ...
115.89       1
115.87       1
116.02       1
98.35        1
106.59       1
Name: count, Length: 579, dtype: int64
```

```
df['Eccentricity'].describe()
```

```
count    6718.000000
mean        0.391619
std        14.122881
min        -0.033400
25%         0.000202
50%         0.000329
75%         0.000943
max       575.000000
Name: Eccentricity, dtype: float64
```

```
index_to_drop = df[df['Eccentricity'] < 0].index # There is one entry with a negative eccentricity. Eccentricity is always n
df = df.drop(index=index_to_drop)
```

```
# Organize Users
df['UsedCivil'] = df['Users'].str.contains('civil', case=False)
df['UsedCommercial'] = df['Users'].str.contains('commercial', case=False)
df['UsedGovernment'] = df['Users'].str.contains('government',case=False)
df['UsedMilitary'] = df['Users'].str.contains('military',case=False)
```

```
# Remove commas from mass and convert to float
df["MassKg"] = df['Launch Mass (kg.)'].str.replace(",","").astype(float)
df['MassKg'].value_counts()
```

```
MassKg
260.0     2962
148.0      503
227.0      434
4.0        206
10.0       188
          ...
1955.0       1
1064.0       1
4860.0       1
3695.0       1
```

```
2110.0       1
Name: count, Length: 565, dtype: int64
```

```
# Remove commas from period and convert to float
df['PeriodMinutesFl'] = df['Period (minutes)'].str.replace(",","").astype(float)
df['PeriodMinutesFl'].head()
```

```
0      96.08
1      94.70
2      95.90
3    1436.03
4    1436.10
Name: PeriodMinutesFl, dtype: float64
```

```
# One entry had year '018' - change it to 2018
df['Date of Launch'][330] = '11/29/2018'
```

```
<ipython-input-24-e69d93b61add>:2: SettingWithCopyWarning:
A value is trying to be set on a copy of a slice from a DataFrame

See the caveats in the documentation: https://pandas.pydata.org/pandas-docs/stable/user_guide/indexing.html#returning-a-view
  df['Date of Launch'][330] = '11/29/2018'
```

```
# Extract year from date of launch and save as new column
df['LaunchYear'] = pd.DatetimeIndex(df['Date of Launch']).year
```

```
# Calculate expected mission end year
df['ExpectedEndYear'] = df['LaunchYear'] + df['Expected Lifetime (yrs.)']
```

```
# One inclination entry contains a comma and one is 'USA' - drop them
inc_drop = df[(df['Inclination (degrees)'].str.contains(",")) | df['Inclination (degrees)'].str.contains('USA')].index
df = df.drop(index=inc_drop,axis=0)
```

```
# Convert inclination to float
df['InclinationDeg'] = df['Inclination (degrees)'].astype(float)
```

```
df['LaunchDate'] = pd.to_datetime(df['Date of Launch'],format='mixed')
```

Descriptive questions

What time range does the dataset include?

```
print(f"This dataset covers the years {min(df['LaunchYear'])} to {max(df['LaunchYear'])}.")
```

```
This dataset covers the years 1974 to 2022.
```

How many satellites are currently orbiting Earth?

```
expected_ended = df[df['ExpectedEndYear'] < 2024]
print(f'There are at least {len(df)-len(expected_ended)} active satellites orbiting Earth.')
```

```
There are at least 6004 active satellites orbiting Earth.
```

How many satellites are no longer operational?

```
print(f'{len(expected_ended)} satellites from this dataset are likely decommissioned, or {round(100*len(expected_ended)/len(
```

```
710 satellites from this dataset are likely decommissioned, or 10.6% of the total.
```

What is the average lifespan of the satellites?

```
avg_lifespan = df['Expected Lifetime (yrs.)'].mean()
print(f'The average satellite lifetime is {round(avg_lifespan)} years.')
```

```
The average satellite lifetime is 6 years.
```

How many satellites are used for Earth observation purposes?

```
earth_obs = df[df['Purpose'].str.contains("earth observation", case=False)]
num_earth_obs = len(earth_obs)
print(f'{num_earth_obs} satellites are used for Earth observation, which is {round(100*num_earth_obs/len(df),1)}% of the tot
```

```
1165 satellites are used for Earth observation, which is 17.4% of the total.
```

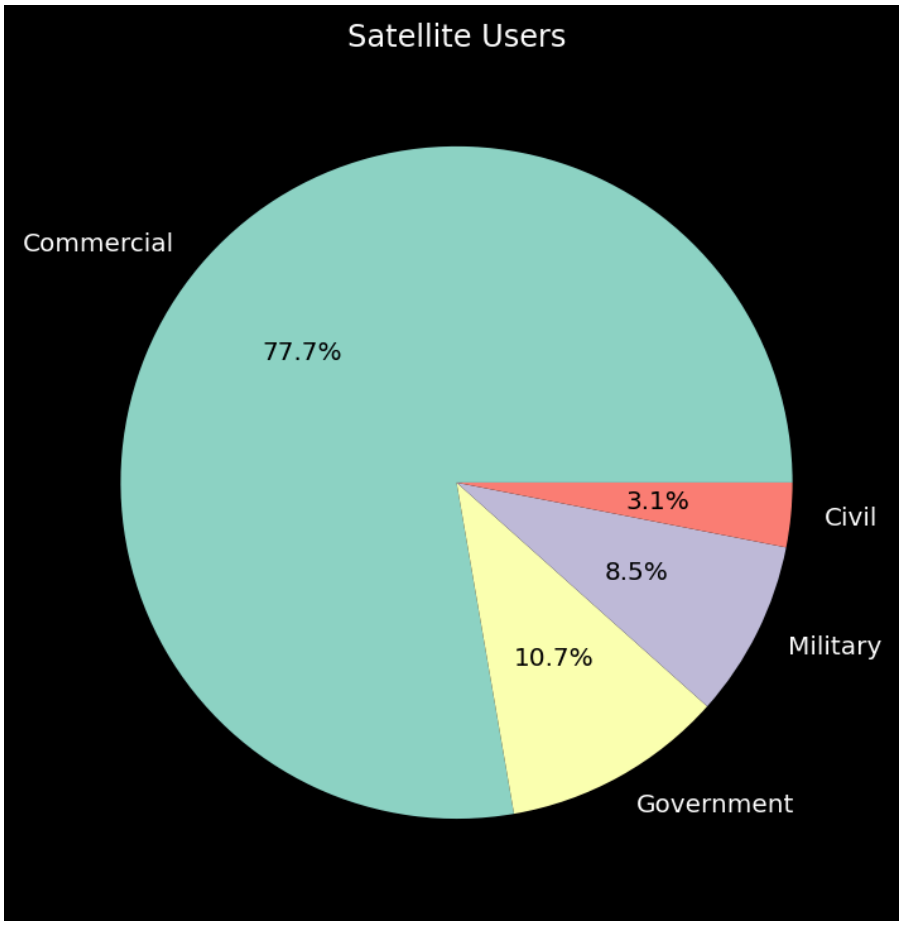
What is the average mass of the satellites?

```
avg_mass = df['MassKg'].mean()
print(f'The average satellite mass is {round(avg_mass)} kg.')
```

```
The average satellite mass is 666 kg.
```

What is the breakdown of satellite users by sector?

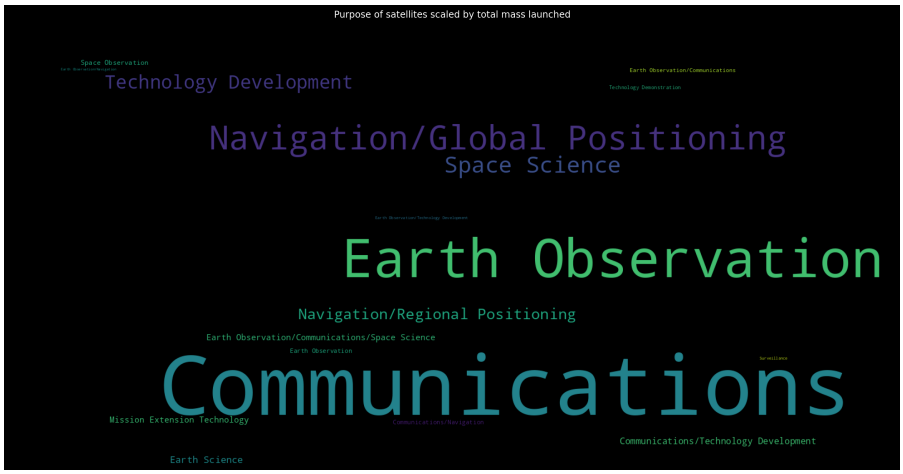
```
used_percent = []
cats = ['UsedCommercial', 'UsedGovernment','UsedMilitary', 'UsedCivil']
for x in cats:
  used_percent.append(100*sum(df[x])/len(df))
plt.style.use("dark_background")
plt.figure(figsize=(6,6))

# https://matplotlib.org/stable/gallery/pie_and_polar_charts/pie_and_donut_labels.html#sphx-glr-gallery-pie-and-polar-charts-
def func(pct):
    absolute = int(np.round(pct/100.*np.sum(used_percent)))
    return f"{pct:.1f}%"


# https://stackoverflow.com/questions/27898830/python-how-to-change-autopct-text-color-to-be-white-in-a-pie-chart
_, _, autotexts = plt.pie(labels=['Commercial','Government','Military','Civil'],x=used_percent, autopct=func)
for autotext in autotexts:
    autotext.set_color('black')

plt.title('Satellite Users')
plt.show()
```



What are the satellites' primary purposes?

```
def plot_word_cloud_dict(d, title):
  wordcloud = WordCloud(collocations=False,width=1600, height=800, prefer_horizontal=1).generate_from_frequencies(d)

  # plot the WordCloud image
  plt.figure(figsize=(16,8))
  plt.imshow(wordcloud)
  plt.axis("off")
  plt.tight_layout(pad = 0)
  plt.title(title)
  plt.show()
```

```
mass_purpose_df = df[['Purpose','MassKg']].groupby(['Purpose']).sum()
mass_purpose_df = mass_purpose_df[mass_purpose_df['MassKg'] > 0]
mass_purpose_df['MassKg'] = mass_purpose_df['MassKg'].astype(int)
mass_purpose_dict = mass_purpose_df.to_dict(index=['Purpose'])['MassKg']
mass_purpose_dict

plot_word_cloud_dict(mass_purpose_dict,'Purpose of satellites scaled by total mass launched')
```



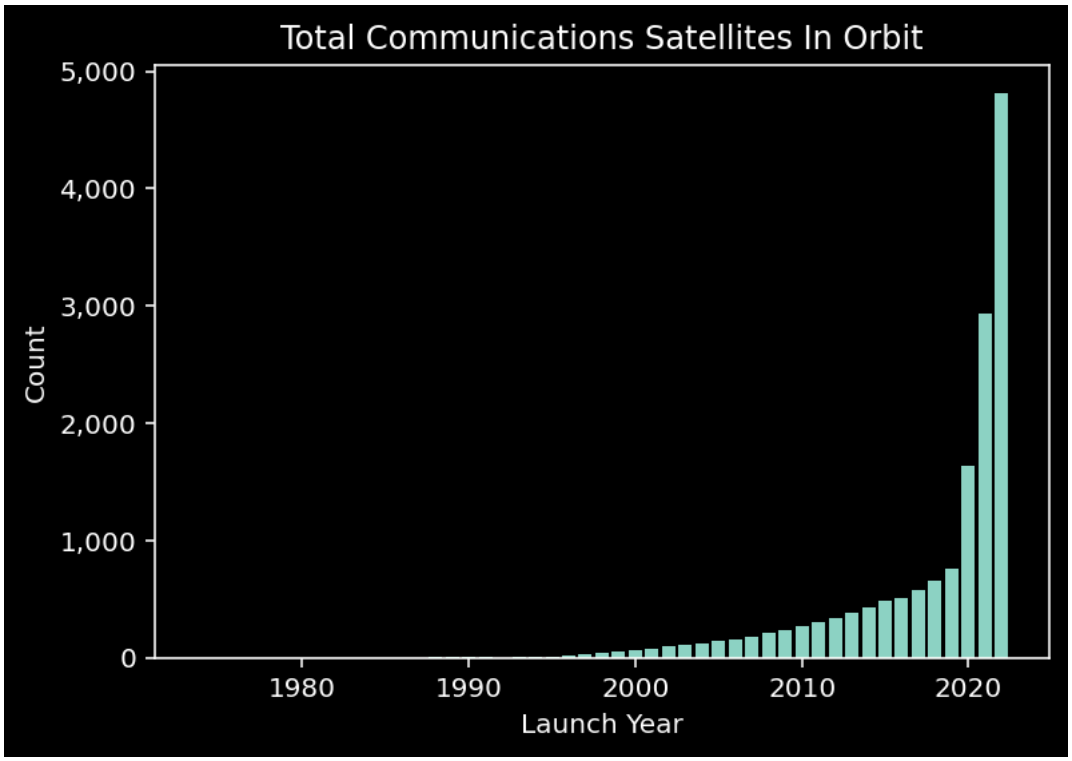
What is the distribution of satellites by their launch year?

```
# First count number of launches of each type of satellite to date
df['AggValue'] = 1
has_launch_date_df = df.dropna(subset='LaunchYear')
has_launch_date_year_counts = has_launch_date_df.pivot_table(values='AggValue', index='LaunchYear', columns='Purpose', aggfu
end_counts = has_launch_date_year_counts[has_launch_date_year_counts.index == 2022]
end_counts = end_counts.sort_values(by=2022,axis=1,ascending=False)
end_counts
```

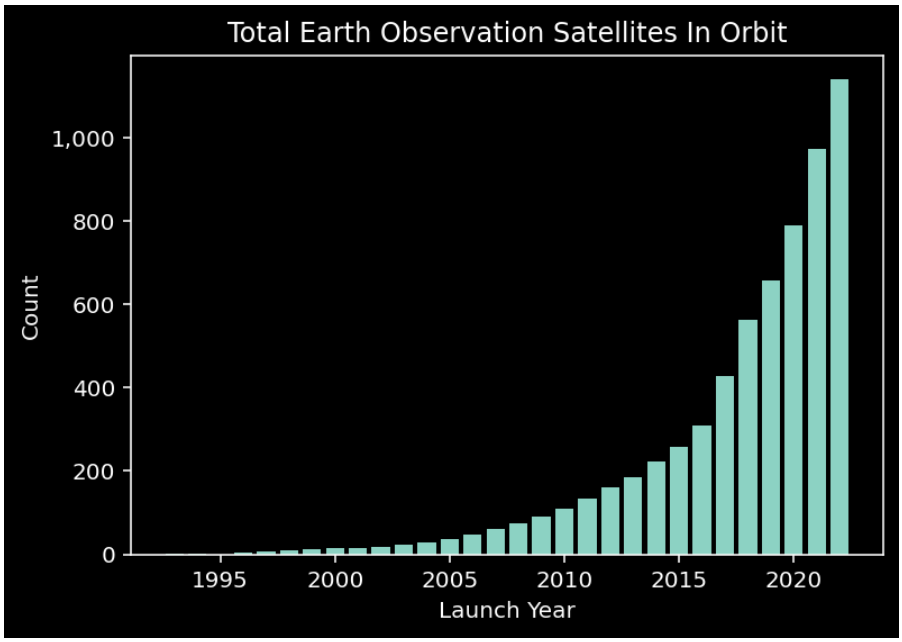
Purpose	Communications	Earth Observation	Technology Development	Navigation/Global Positioning	Space Science	Technology Demonstration	Earth Science	Surveillance	Unknow
LaunchYear									
2022	4811.0	1139.0	366.0	141.0	98.0	42.0	22.0	14.0	10

1 rows × 31 columns

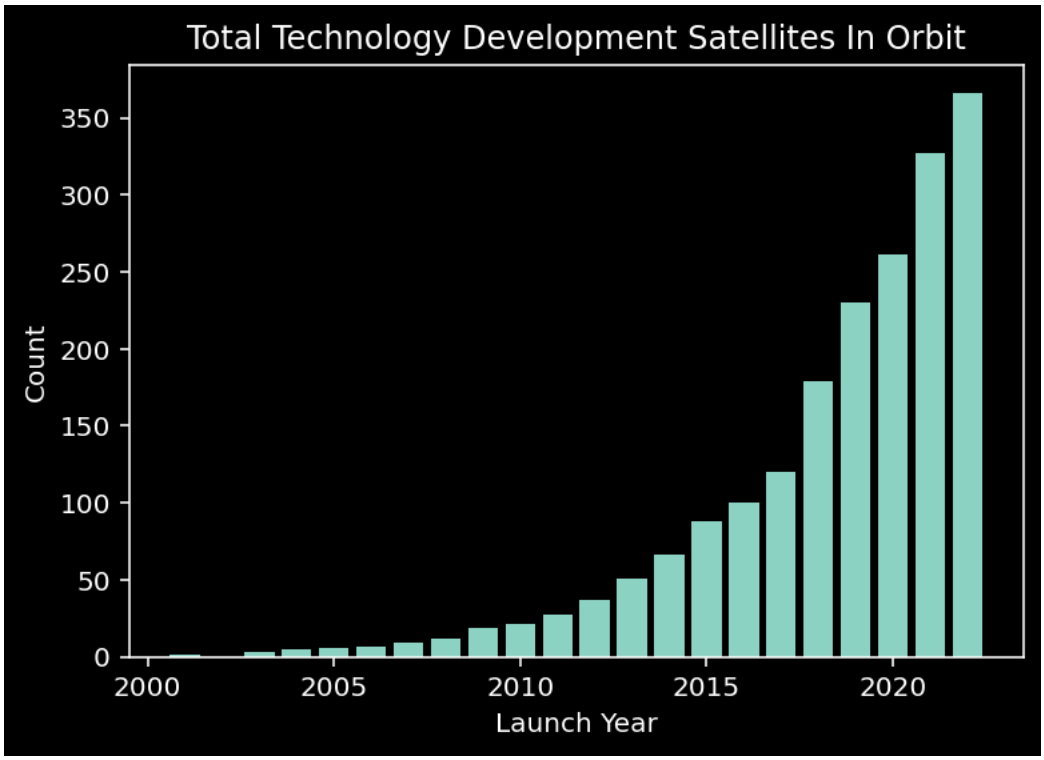
```
# Now plot total satellites in orbit over time for each top category
fig, ax = plt.subplots(figsize=(6, 4))
plt.bar(x=has_launch_date_year_counts.index, height=has_launch_date_year_counts['Communications'])
plt.xlabel('Launch Year')
plt.ylabel('Count')
plt.title('Total Communications Satellites In Orbit')
plt.style.use("dark_background")
# https://stackoverflow.com/questions/25973581/how-to-format-axis-number-format-to-thousands-with-a-comma
thousands_format = ticker.StrMethodFormatter('{x:,.0f}')
ax.yaxis.set_major_formatter(thousands_format)
plt.show()
```



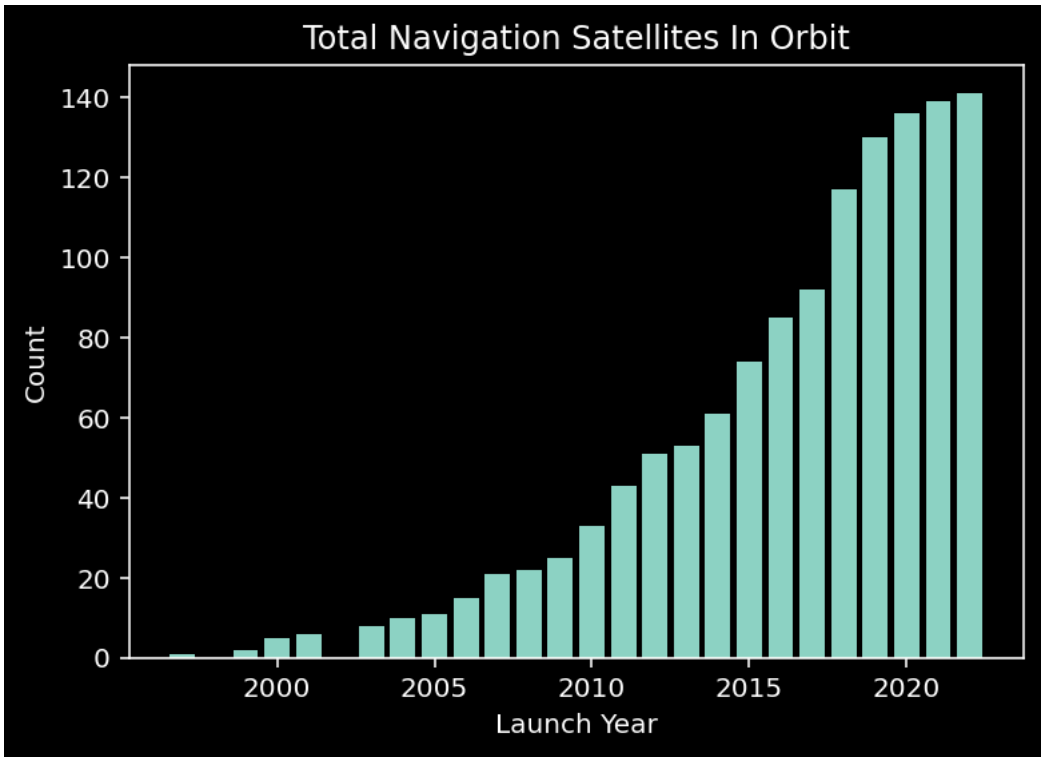

```
fig, ax = plt.subplots(figsize=(6, 4))
plt.bar(x=has_launch_date_year_counts.index, height=has_launch_date_year_counts['Earth Observation'])
plt.xlabel('Launch Year')
plt.ylabel('Count')
plt.title('Total Earth Observation Satellites In Orbit')
plt.style.use("dark_background")
ax.yaxis.set_major_formatter(thousands_format)
plt.show()
```




```
fig, ax = plt.subplots(figsize=(6, 4))
plt.bar(x=has_launch_date_year_counts.index, height=has_launch_date_year_counts['Technology Development'])
plt.xlabel('Launch Year')
plt.ylabel('Count')
plt.title('Total Technology Development Satellites In Orbit')
plt.style.use("dark_background")
ax.yaxis.set_major_formatter(thousands_format)
plt.show()
```



```
fig, ax = plt.subplots(figsize=(6, 4))
plt.bar(x=has_launch_date_year_counts.index, height=has_launch_date_year_counts['Navigation/Global Positioning'])
plt.xlabel('Launch Year')
plt.ylabel('Count')
plt.title('Total Navigation Satellites In Orbit')
plt.style.use("dark_background")
ax.yaxis.set_major_formatter(thousands_format)
plt.show()
```

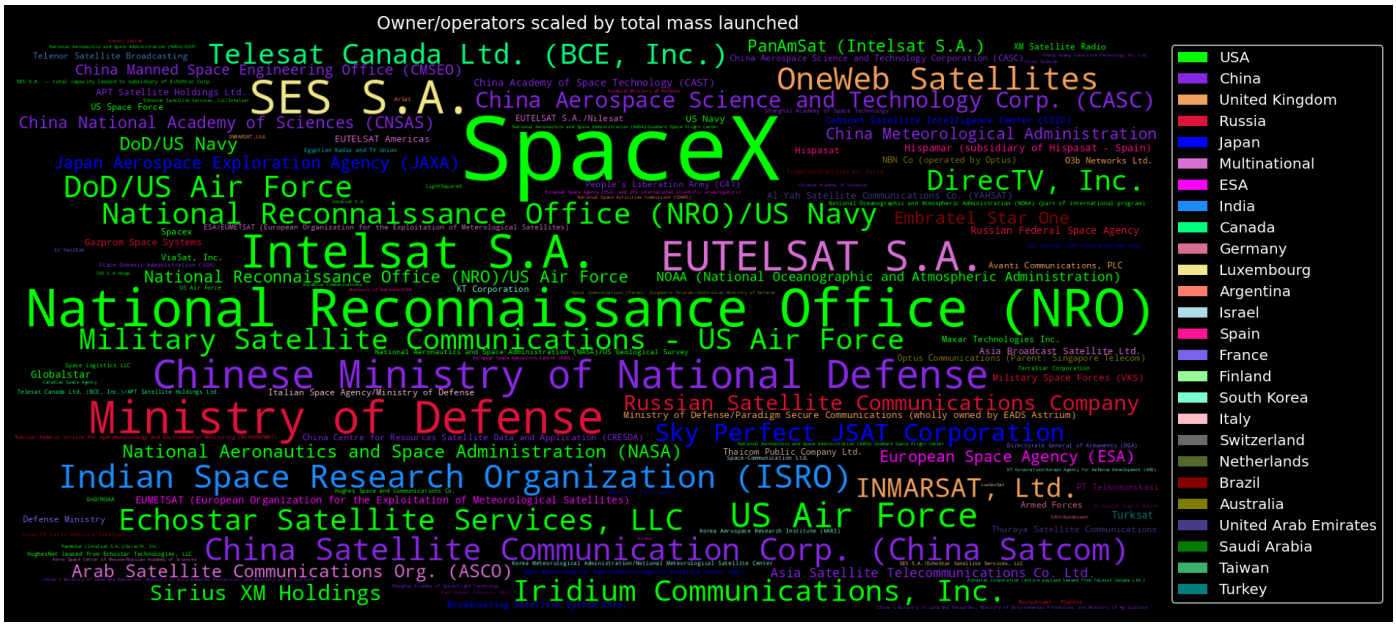


Who operates/owns most of the satellites?

```
countries = df['Country of Operator/Owner'].value_counts()
top_countries = countries[:35]
# need to map each name to a different color
palette = ['#00ff00',
           '#8a2be2',
           '#f4a460',
           '#dc143c',
           '#0000ff',
           '#da70d6',
           '#ff00ff',
           '#1e90ff',
           '#00ff7f',
           '#db7093',
           '#f0e68c',
           '#fa8072',
           '#b0e0e6',
           '#ff1493',
           '#7b68ee',
           '#98fb98',
           '#7fffd4',
           '#ffc0cb',
           '#696969',
           '#556b2f',
           '#8b0000',
           '#808000',
           '#483d8b',
           '#008000',
           '#3cb371',
           '#008080',
           '#4682b4',
           '#9acd32',
           '#00008b',
           '#7f007f',
           '#d2b48c',
           '#ff4500',
           '#00ced1',
           '#ffa500',
           '#ffd700']

countries_colors = dict(zip(top_countries.keys(),palette))

df['Color'] = df['Country of Operator/Owner'].map(countries_colors)

# https://stackoverflow.com/questions/61919884/mapping-wordcloud-color-to-a-value-for-sentiment-analysis
# https://stackoverflow.com/questions/70883110/python-wordcloud-how-to-make-the-word-colour-based-on-a-data-column
class SimpleGroupedColorFunc(object):
    """Create a color function object which assigns EXACT colors
       to certain words based on the color to words mapping
       Parameters
       ----------
       color_to_words : dict(str -> list(str))
         A dictionary that maps a color to the list of words.
       default_color : str
         Color that will be assigned to a word that's not a member
         of any value from color_to_words.
    """

    def __init__(self, words_to_colors, column1, column2, default_color):
        self.word_to_color = words_to_colors
        self.default_color = default_color
        self.column1 = column1
        self.column2 = column2

    def __call__(self, word, **kwargs):
        return self.word_to_color.get(df[df[self.column1] == word][self.column2].value_counts().keys()[0], self.default_colo
```

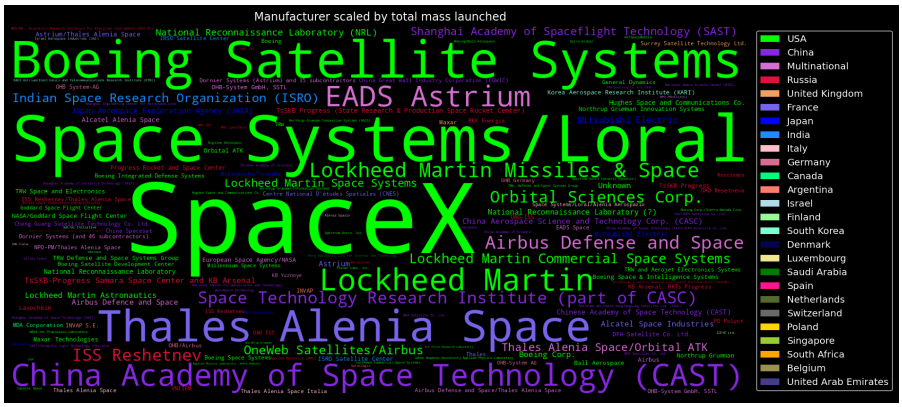
```
def plot_word_cloud_dict_colormapped(d, color_fun, title, offset):
  wordcloud = WordCloud(collocations=False,width=1600, height=800, prefer_horizontal=1, min_font_size=6).generate_from_frequ
  wordcloud.recolor(color_func=color_fun)
  # plot the WordCloud image
  plt.figure(figsize=(14,10))
  plt.imshow(wordcloud)
  plt.axis("off")
  plt.title(title)
  legend_elements = [Patch(facecolor=list(color_fun.word_to_color.values())[:26][i],label=list(color_fun.word_to_color.keys(
  plt.legend(handles=legend_elements,bbox_to_anchor=(offset, 1))
  plt.show()
```

```
mass_owner_df = df[['Operator/Owner','MassKg']].groupby(['Operator/Owner']).sum()
mass_owner_df = mass_owner_df[mass_owner_df['MassKg'] > 0]
mass_owner_df['MassKg'] = mass_owner_df['MassKg'].astype(int)
mass_owner_dict = mass_owner_df.to_dict(index=['Operator/Owner'])['MassKg']
mass_owner_dict

grouped_color_func_owner = SimpleGroupedColorFunc(countries_colors, 'Operator/Owner', 'Country of Operator/Owner', '#000000'

plot_word_cloud_dict_colormapped(mass_owner_dict,grouped_color_func_owner,'Owner/operators scaled by total mass launched', 1
```



Who manufactured most of the satellites?

```
mass_contractor_df = df[['Contractor','MassKg']].groupby(['Contractor']).sum()
mass_contractor_df = mass_contractor_df[mass_contractor_df['MassKg'] > 0]
mass_contractor_df['MassKg'] = mass_contractor_df['MassKg'].astype(int)
mass_contractor_dict = mass_contractor_df.to_dict(index=['Contractor'])['MassKg']
mass_contractor_dict

replacement_dict = {
    'UK': 'United Kingdom',
    'International': 'Multinational',
    '/Italy': 'Italy',
    '/Thales Alenia Space': 'France',
    'France/Italy': 'Multinational',
    'France/UK/Germany/Spain':'Multinational',
    'Germany/UK':'Multinational',
    'France/UK/Germany':'Multinational',
    'Russia/France':'Multinational',
    'Germany/UK/Italy':'Multinational',
    'United States':'USA',
    'Denmark/Canada':'Multinational'
}

df['Country of Contractor'] = df['Country of Contractor'].replace(replacement_dict)

contractor_countries = df['Country of Contractor'].value_counts()
top_contractor_countries = contractor_countries[:33]
top_contractor_countries

# Maintain the color coding for countries and add other needed ones
extra_colors = {
'Denmark':'#06064c',
'Belgium':'#9d9452',
'Ukraine':'#b46fa9',
'Lithuania':'#4de091'
# '#5ac3de',
# '#07bf65',
# '#2340d2',
# '#445990',
# '#f829e9',
# '#8aa6ea',
}

palette2 = [(countries_colors[x] if x in countries_colors else extra_colors[x]) for x in top_contractor_countries.keys()]
contractor_countries_colors = dict(zip(top_contractor_countries.keys(),palette2))

grouped_color_func_contractor = SimpleGroupedColorFunc(contractor_countries_colors, 'Contractor','Country of Contractor', '#

plot_word_cloud_dict_colormapped(mass_contractor_dict, grouped_color_func_contractor,'Manufacturer scaled by total mass laun
```



Which country has launched the most satellites?

```
# has_launch_date_df = df.dropna(subset='LaunchYear')
has_launch_date_country_counts = has_launch_date_df.pivot_table(values='AggValue', index='LaunchYear', columns='Country of O

end_country_counts = has_launch_date_country_counts[has_launch_date_country_counts.index == 2022]
end_country_counts = end_country_counts.sort_values(by=2022,axis=1,ascending=False)
end_country_counts

usa_tot = end_country_counts.iloc[0,0]
others_tot = end_country_counts.iloc[0,1:].sum()

used_percent = [usa_tot/(usa_tot+others_tot),others_tot/(usa_tot+others_tot)]

plt.style.use("dark_background")
plt.figure(figsize=(6,6))

# https://matplotlib.org/stable/gallery/pie_and_polar_charts/pie_and_donut_labels.html#sphx-glr-gallery-pie-and-polar-charts
def func(pct):
    absolute = int(np.round(pct/100.*np.sum(used_percent)))
    return f"{pct:.1f}%"


# https://stackoverflow.com/questions/27898830/python-how-to-change-autopct-text-color-to-be-white-in-a-pie-chart
_, _, autotexts = plt.pie(labels=['USA','Other countries'],x=used_percent, autopct=func)
for autotext in autotexts:
    autotext.set_color('black')

plt.title('Most satellites are US-owned')
plt.show()
```


Most satellites are US-owned