STA 160 Midterm Report Codes

May 7, 2022

1 An Analysis of NASA Asteroids dataset

1.1 Data Preparation/Inspection

```
[1]: import pandas as pd
     import seaborn as sns
     import matplotlib.pyplot as plt
     import numpy as np
     import scipy.stats as stats
     %matplotlib inline
     nasa_df = pd.read_csv (r'nasa.csv')
     nasa_df.head(10)
```

```
[1]:   Neo Reference ID     Name  Absolute Magnitude  Est Dia in KM(min)  \
    0           3703080  3703080                21.6            0.127220
    1           3723955  3723955                21.3            0.146068
    2           2446862  2446862                20.3            0.231502
    3           3092506  3092506                27.4            0.008801
    4           3514799  3514799                21.6            0.127220
    5           3671135  3671135                19.6            0.319562
    6           2495323  2495323                19.6            0.319562
    7           2153315  2153315                19.2            0.384198
    8           2162463  2162463                17.8            0.732074
    9           2306383  2306383                21.5            0.133216

       Est Dia in KM(max)  Est Dia in M(min)  Est Dia in M(max)  \
    0            0.284472         127.219879         284.472297
    1            0.326618         146.067964         326.617897
    2            0.517654         231.502122         517.654482
    3            0.019681           8.801465          19.680675
    4            0.284472         127.219879         284.472297
    5            0.714562         319.561887         714.562102
    6            0.714562         319.561887         714.562102
    7            0.859093         384.197891         859.092601
    8            1.636967         732.073989        1636.967205
    9            0.297879         133.215567         297.879063

       Est Dia in Miles(min)  Est Dia in Miles(max)  Est Dia in Feet(min)  …  \
    0               0.079051               0.176763            417.388066  …
    1               0.090762               0.202951            479.225620  …
    2               0.143849               0.321655            759.521423  …
    3               0.005469               0.012229             28.876199  …
    4               0.079051               0.176763            417.388066  …
    5               0.198566               0.444008           1048.431420  …
    6               0.198566               0.444008           1048.431420  …
    7               0.238729               0.533815           1260.491809  …
    8               0.454890               1.017164           2401.817627  …
    9               0.082776               0.185093            437.058960  …

       Asc Node Longitude Orbital Period  Perihelion Distance  Perihelion Arg  \
    0          314.373913     609.599786             0.808259       57.257470
    1          136.717242     425.869294             0.718200      313.091975
    2          259.475979     643.580228             0.950791      248.415038
    3           57.173266     514.082140             0.983902       18.707701
    4           84.629307     495.597821             0.967687      158.263596
    5          178.971951     556.160556             0.577800      198.145969
    6          178.971953     556.160544             0.577800      198.145960
    7          112.562984     502.808758             0.680905      288.374651
    8           80.211132     447.837013             0.872705      353.422394
    9            2.613682     299.535161             0.393040      253.765937

       Aphelion Dist  Perihelion Time  Mean Anomaly  Mean Motion  Equinox  \
    0       2.005764     2.458162e+06    264.837533     0.590551    J2000
    1       1.497352     2.457795e+06    173.741112     0.845330    J2000
    2       1.966857     2.458120e+06    292.893654     0.559371    J2000
    3       1.527904     2.457902e+06     68.741007     0.700277    J2000
    4       1.483543     2.457814e+06    135.142133     0.726395    J2000
    5       2.069265     2.458009e+06    354.237368     0.647295    J2000
    6       2.069265     2.458009e+06    354.237396     0.647295    J2000
    7       1.794045     2.458242e+06    186.776932     0.715978    J2000
    8       1.418397     2.458222e+06    182.236432     0.803864    J2000
    9       1.359211     2.457901e+06    119.861382     1.201862    J2000

       Hazardous
    0       True
    1      False
    2       True
    3      False
    4       True
    5      False
    6      False
    7      False
    8      False
    9       True
```

```
[10 rows x 40 columns]
```

[2]:
```python
print(nasa_df.shape)
nasa_df.describe()
```

```
(4687, 40)
```

[2]:
```
       Neo Reference ID          Name  Absolute Magnitude  Est Dia in KM(min)  \
count      4.687000e+03  4.687000e+03         4687.000000         4687.000000
mean       3.272298e+06  3.272298e+06           22.267865            0.204604
std        5.486011e+05  5.486011e+05            2.890972            0.369573
min        2.000433e+06  2.000433e+06           11.160000            0.001011
25%        3.097594e+06  3.097594e+06           20.100000            0.033462
50%        3.514799e+06  3.514799e+06           21.900000            0.110804
75%        3.690060e+06  3.690060e+06           24.500000            0.253837
max        3.781897e+06  3.781897e+06           32.100000           15.579552

       Est Dia in KM(max)  Est Dia in M(min)  Est Dia in M(max)  \
count         4687.000000        4687.000000        4687.000000
mean             0.457509         204.604203         457.508906
std              0.826391         369.573402         826.391249
min              0.002260           1.010543           2.259644
25%              0.074824          33.462237          74.823838
50%              0.247765         110.803882         247.765013
75%              0.567597         253.837029         567.596853
max             34.836938       15579.552413       34836.938254

       Est Dia in Miles(min)  Est Dia in Miles(max)  Est Dia in Feet(min)  \
count            4687.000000            4687.000000           4687.000000
mean                0.127135               0.284283            671.273653
std                 0.229642               0.513496           1212.511199
min                 0.000628               0.001404              3.315431
25%                 0.020792               0.046493            109.784247
50%                 0.068850               0.153954            363.529809
75%                 0.157727               0.352688            832.798679
max                 9.680682              21.646663          51114.018738

       …  Semi Major Axis  Inclination  Asc Node Longitude  Orbital Period  \
count  …      4687.000000  4687.000000         4687.000000     4687.000000
mean   …         1.400264    13.373844          172.157275      635.582076
std    …         0.524154    10.936227          103.276777      370.954727
min    …         0.615920     0.014513            0.001941      176.557161
25%    …         1.000635     4.962341           83.081208      365.605031
50%    …         1.240981    10.311836          172.625393      504.947292
75%    …         1.678364    19.511681          255.026909      794.195972
max    …         5.072008    75.406667          359.905890     4172.231343
```

```
       Perihelion Distance  Perihelion Arg  Aphelion Dist  Perihelion Time  \
count          4687.000000     4687.000000    4687.000000     4.687000e+03
mean              0.813383      183.932151       1.987144     2.457728e+06
std               0.242059      103.513035       0.951519     9.442264e+02
min               0.080744        0.006918       0.803765     2.450100e+06
25%               0.630834       95.625916       1.266059     2.457815e+06
50%               0.833153      189.761641       1.618195     2.457973e+06
75%               0.997227      271.777557       2.451171     2.458108e+06
max               1.299832      359.993098       8.983852     2.458839e+06

       Mean Anomaly  Mean Motion
count   4687.000000  4687.000000
mean     181.167927     0.738242
std      107.501623     0.342627
min        0.003191     0.086285
25%       87.006918     0.453289
50%      185.718889     0.712946
75%      276.531946     0.984669
max      359.917991     2.039000

[8 rows x 35 columns]
```

- Dataset includes 4687 observations and 40 columns.
- The mean values of each column are less than their median values.
- There are large differences between the values of 75% quantile and maximum in several columns: ‘Est Dia in M(min)’, ‘Est Dia in M(max)’, ‘Est Dia in Feet(min)’, and etc.
- There is a reasonable doubt that some values are outliers.
- The dataset includes the information about the geometry of the asteroid and its path and speed.

[3]:

```
nasa_df.info()
```

```
<class 'pandas.core.frame.DataFrame'>
RangeIndex: 4687 entries, 0 to 4686
Data columns (total 40 columns):
 #   Column                        Non-Null Count  Dtype
---  ------                        --------------  -----
 0   Neo Reference ID              4687 non-null   int64
 1   Name                          4687 non-null   int64
 2   Absolute Magnitude            4687 non-null   float64
 3   Est Dia in KM(min)            4687 non-null   float64
 4   Est Dia in KM(max)            4687 non-null   float64
 5   Est Dia in M(min)             4687 non-null   float64
 6   Est Dia in M(max)             4687 non-null   float64
 7   Est Dia in Miles(min)         4687 non-null   float64
 8   Est Dia in Miles(max)         4687 non-null   float64
 9   Est Dia in Feet(min)          4687 non-null   float64
 10  Est Dia in Feet(max)          4687 non-null   float64
 11  Close Approach Date           4687 non-null   object
 12  Epoch Date Close Approach     4687 non-null   int64
 13  Relative Velocity km per sec  4687 non-null   float64
 14  Relative Velocity km per hr   4687 non-null   float64
 15  Miles per hour                4687 non-null   float64
 16  Miss Dist.(Astronomical)      4687 non-null   float64
 17  Miss Dist.(lunar)             4687 non-null   float64
 18  Miss Dist.(kilometers)        4687 non-null   float64
 19  Miss Dist.(miles)             4687 non-null   float64
 20  Orbiting Body                 4687 non-null   object
 21  Orbit ID                      4687 non-null   int64
 22  Orbit Determination Date      4687 non-null   object
 23  Orbit Uncertainity            4687 non-null   int64
 24  Minimum Orbit Intersection    4687 non-null   float64
 25  Jupiter Tisserand Invariant   4687 non-null   float64
 26  Epoch Osculation              4687 non-null   float64
 27  Eccentricity                  4687 non-null   float64
 28  Semi Major Axis               4687 non-null   float64
 29  Inclination                   4687 non-null   float64
 30  Asc Node Longitude            4687 non-null   float64
 31  Orbital Period                4687 non-null   float64
 32  Perihelion Distance           4687 non-null   float64
 33  Perihelion Arg                4687 non-null   float64
 34  Aphelion Dist                 4687 non-null   float64
 35  Perihelion Time               4687 non-null   float64
 36  Mean Anomaly                  4687 non-null   float64
 37  Mean Motion                   4687 non-null   float64
 38  Equinox                       4687 non-null   object
 39  Hazardous                     4687 non-null   bool
dtypes: bool(1), float64(30), int64(5), object(4)
memory usage: 1.4+ MB
```

- Dataset has 4 types of data; 1 boolean, 30 float, 5 integer, and 4 object values.
- None of the variables has missing values.

[4]:
```
nasa_df.Hazardous.unique()
```

[4]:
```
array([ True, False])
```

[5]:
```
nasa_df.Hazardous.value_counts()
```

[5]:
```
False    3932
True      755
Name: Hazardous, dtype: int64
```

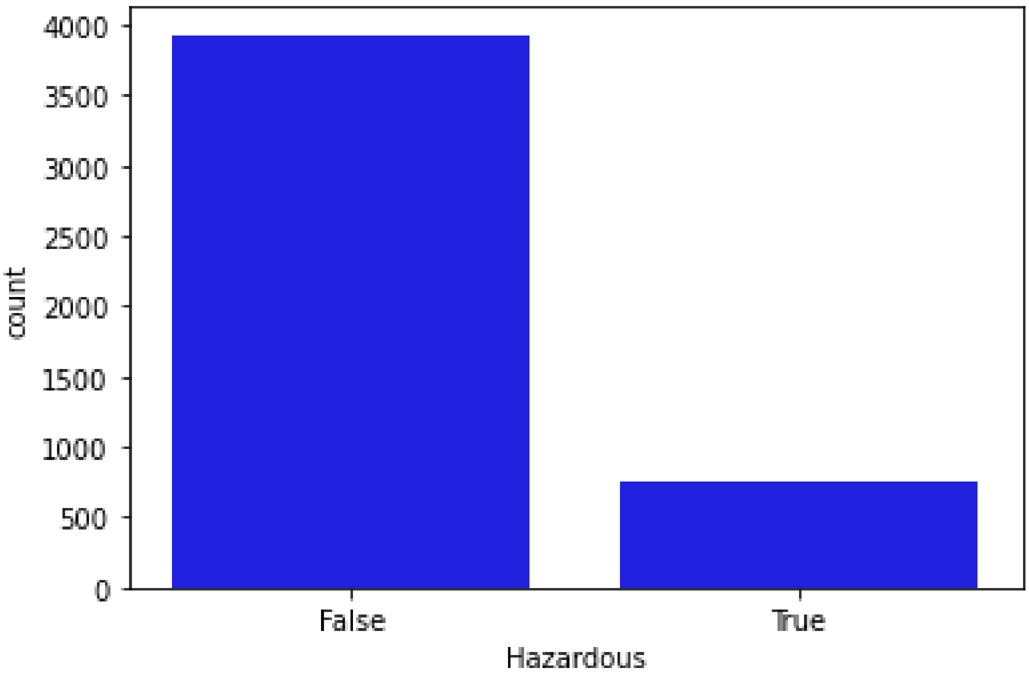
- The target/dependent variable, 'Hazardous', is a boolean variable.

- There are 3932 observations considered as not hazardous and 755 of the observations are harzardous.

[6]:
```
#Counts of hazardous vs not-hazardous  (seems to be more non-hazardous than␣
↪hazardous)

sns.countplot(nasa_df['Hazardous'], color = 'blue')
```

```
/Applications/anaconda3/lib/python3.8/site-packages/seaborn/_decorators.py:36:
FutureWarning: Pass the following variable as a keyword arg: x. From version
0.12, the only valid positional argument will be `data`, and passing other
arguments without an explicit keyword will result in an error or
misinterpretation.
  warnings.warn(
```

[6]:
```
<AxesSubplot:xlabel='Hazardous', ylabel='count'>
```



False : $\frac{3932}{4687} = 83.9\%$
True : $\frac{755}{4687} = 16.1\%$

[7]:
```
nasa_df.corr()
```

[7]:
```
                                Neo Reference ID      Name  Absolute Magnitude  \
Neo Reference ID                        1.000000  1.000000            0.602381
Name                                    1.000000  1.000000            0.602381
Absolute Magnitude                      0.602381  0.602381            1.000000
```

```
Est Dia in KM(min)                   -0.499821 -0.499821           -0.613482
Est Dia in KM(max)                   -0.499821 -0.499821           -0.613482
Est Dia in M(min)                    -0.499821 -0.499821           -0.613482
Est Dia in M(max)                    -0.499821 -0.499821           -0.613482
Est Dia in Miles(min)                -0.499821 -0.499821           -0.613482
Est Dia in Miles(max)                -0.499821 -0.499821           -0.613482
Est Dia in Feet(min)                 -0.499821 -0.499821           -0.613482
Est Dia in Feet(max)                 -0.499821 -0.499821           -0.613482
Epoch Date Close Approach             0.186513  0.186513            0.168621
Relative Velocity km per sec         -0.165032 -0.165032           -0.376853
Relative Velocity km per hr          -0.165032 -0.165032           -0.376853
Miles per hour                       -0.165032 -0.165032           -0.376853
Miss Dist.(Astronomical)             -0.155782 -0.155782           -0.339117
Miss Dist.(lunar)                    -0.155782 -0.155782           -0.339117
Miss Dist.(kilometers)               -0.155782 -0.155782           -0.339117
Miss Dist.(miles)                    -0.155782 -0.155782           -0.339117
Orbit ID                             -0.651200 -0.651200           -0.575668
Orbit Uncertainity                    0.611205  0.611205            0.677764
Minimum Orbit Intersection           -0.158673 -0.158673           -0.488235
Jupiter Tisserand Invariant          -0.004854 -0.004854            0.238702
Epoch Osculation                      0.006023  0.006023           -0.116087
Eccentricity                         -0.125071 -0.125071           -0.361359
Semi Major Axis                       0.035865  0.035865           -0.212437
Inclination                          -0.175461 -0.175461           -0.459632
Asc Node Longitude                   -0.026381 -0.026381           -0.011470
Orbital Period                        0.040058  0.040058           -0.206774
Perihelion Distance                   0.130486  0.130486            0.086966
Perihelion Arg                       -0.007669 -0.007669            0.031784
Aphelion Dist                         0.006318  0.006318           -0.256169
Perihelion Time                       0.003031  0.003031           -0.115855
Mean Anomaly                         -0.051685 -0.051685           -0.049401
Mean Motion                          -0.020719 -0.020719            0.195652
Hazardous                            -0.269028 -0.269028           -0.325522

                              Est Dia in KM(min)  Est Dia in KM(max)  \
Neo Reference ID                       -0.499821           -0.499821
Name                                   -0.499821           -0.499821
Absolute Magnitude                     -0.613482           -0.613482
Est Dia in KM(min)                      1.000000            1.000000
Est Dia in KM(max)                      1.000000            1.000000
Est Dia in M(min)                       1.000000            1.000000
Est Dia in M(max)                       1.000000            1.000000
Est Dia in Miles(min)                   1.000000            1.000000
Est Dia in Miles(max)                   1.000000            1.000000
Est Dia in Feet(min)                    1.000000            1.000000
Est Dia in Feet(max)                    1.000000            1.000000
Epoch Date Close Approach              -0.094121           -0.094121
```

```
Relative Velocity km per sec            0.242141            0.242141
Relative Velocity km per hr             0.242141            0.242141
Miles per hour                          0.242141            0.242141
Miss Dist.(Astronomical)                0.188027            0.188027
Miss Dist.(lunar)                       0.188027            0.188027
Miss Dist.(kilometers)                  0.188027            0.188027
Miss Dist.(miles)                       0.188027            0.188027
Orbit ID                                0.724089            0.724089
Orbit Uncertainity                     -0.399488           -0.399488
Minimum Orbit Intersection              0.257904            0.257904
Jupiter Tisserand Invariant            -0.133582           -0.133582
Epoch Osculation                        0.061582            0.061582
Eccentricity                            0.216623            0.216623
Semi Major Axis                         0.121224            0.121224
Inclination                             0.259450            0.259450
Asc Node Longitude                      0.036558            0.036558
Orbital Period                          0.118314            0.118314
Perihelion Distance                    -0.071866           -0.071866
Perihelion Arg                         -0.019577           -0.019577
Aphelion Dist                           0.151836            0.151836
Perihelion Time                         0.062167            0.062167
Mean Anomaly                            0.031455            0.031455
Mean Motion                            -0.104350           -0.104350
Hazardous                               0.132424            0.132424

                              Est Dia in M(min)  Est Dia in M(max)  \
Neo Reference ID                      -0.499821          -0.499821
Name                                  -0.499821          -0.499821
Absolute Magnitude                    -0.613482          -0.613482
Est Dia in KM(min)                     1.000000           1.000000
Est Dia in KM(max)                     1.000000           1.000000
Est Dia in M(min)                      1.000000           1.000000
Est Dia in M(max)                      1.000000           1.000000
Est Dia in Miles(min)                  1.000000           1.000000
Est Dia in Miles(max)                  1.000000           1.000000
Est Dia in Feet(min)                   1.000000           1.000000
Est Dia in Feet(max)                   1.000000           1.000000
Epoch Date Close Approach             -0.094121          -0.094121
Relative Velocity km per sec           0.242141           0.242141
Relative Velocity km per hr            0.242141           0.242141
Miles per hour                         0.242141           0.242141
Miss Dist.(Astronomical)               0.188027           0.188027
Miss Dist.(lunar)                      0.188027           0.188027
Miss Dist.(kilometers)                 0.188027           0.188027
Miss Dist.(miles)                      0.188027           0.188027
Orbit ID                               0.724089           0.724089
Orbit Uncertainity                    -0.399488          -0.399488
```

```
Minimum Orbit Intersection          0.257904          0.257904
Jupiter Tisserand Invariant        -0.133582         -0.133582
Epoch Osculation                    0.061582          0.061582
Eccentricity                        0.216623          0.216623
Semi Major Axis                     0.121224          0.121224
Inclination                         0.259450          0.259450
Asc Node Longitude                  0.036558          0.036558
Orbital Period                      0.118314          0.118314
Perihelion Distance                -0.071866         -0.071866
Perihelion Arg                     -0.019577         -0.019577
Aphelion Dist                       0.151836          0.151836
Perihelion Time                     0.062167          0.062167
Mean Anomaly                        0.031455          0.031455
Mean Motion                        -0.104350         -0.104350
Hazardous                           0.132424          0.132424

                             Est Dia in Miles(min)  Est Dia in Miles(max)  \
Neo Reference ID                         -0.499821              -0.499821
Name                                     -0.499821              -0.499821
Absolute Magnitude                       -0.613482              -0.613482
Est Dia in KM(min)                        1.000000               1.000000
Est Dia in KM(max)                        1.000000               1.000000
Est Dia in M(min)                         1.000000               1.000000
Est Dia in M(max)                         1.000000               1.000000
Est Dia in Miles(min)                     1.000000               1.000000
Est Dia in Miles(max)                     1.000000               1.000000
Est Dia in Feet(min)                      1.000000               1.000000
Est Dia in Feet(max)                      1.000000               1.000000
Epoch Date Close Approach                -0.094121              -0.094121
Relative Velocity km per sec              0.242141               0.242141
Relative Velocity km per hr               0.242141               0.242141
Miles per hour                            0.242141               0.242141
Miss Dist.(Astronomical)                  0.188027               0.188027
Miss Dist.(lunar)                         0.188027               0.188027
Miss Dist.(kilometers)                    0.188027               0.188027
Miss Dist.(miles)                         0.188027               0.188027
Orbit ID                                  0.724089               0.724089
Orbit Uncertainity                       -0.399488              -0.399488
Minimum Orbit Intersection                0.257904               0.257904
Jupiter Tisserand Invariant              -0.133582              -0.133582
Epoch Osculation                          0.061582               0.061582
Eccentricity                              0.216623               0.216623
Semi Major Axis                           0.121224               0.121224
Inclination                               0.259450               0.259450
Asc Node Longitude                        0.036558               0.036558
Orbital Period                            0.118314               0.118314
Perihelion Distance                      -0.071866              -0.071866
Perihelion Arg                            -0.019577              -0.019577
Aphelion Dist                              0.151836               0.151836
Perihelion Time                            0.062167               0.062167
Mean Anomaly                               0.031455               0.031455
Mean Motion                               -0.104350              -0.104350
Hazardous                                  0.132424               0.132424

                              Est Dia in Feet(min)  …  Inclination  \
Neo Reference ID                         -0.499821  …    -0.175461
Name                                     -0.499821  …    -0.175461
Absolute Magnitude                       -0.613482  …    -0.459632
Est Dia in KM(min)                        1.000000  …     0.259450
Est Dia in KM(max)                        1.000000  …     0.259450
Est Dia in M(min)                         1.000000  …     0.259450
Est Dia in M(max)                         1.000000  …     0.259450
Est Dia in Miles(min)                     1.000000  …     0.259450
Est Dia in Miles(max)                     1.000000  …     0.259450
Est Dia in Feet(min)                      1.000000  …     0.259450
Est Dia in Feet(max)                      1.000000  …     0.259450
Epoch Date Close Approach                -0.094121  …    -0.067337
Relative Velocity km per sec              0.242141  …     0.514657
Relative Velocity km per hr               0.242141  …     0.514657
Miles per hour                            0.242141  …     0.514657
Miss Dist.(Astronomical)                  0.188027  …     0.255828
Miss Dist.(lunar)                         0.188027  …     0.255828
Miss Dist.(kilometers)                    0.188027  …     0.255828
Miss Dist.(miles)                         0.188027  …     0.255828
Orbit ID                                  0.724089  …     0.112125
Orbit Uncertainity                       -0.399488  …    -0.228806
Minimum Orbit Intersection                0.257904  …     0.439867
Jupiter Tisserand Invariant              -0.133582  …    -0.037366
Epoch Osculation                          0.061582  …     0.015879
Eccentricity                              0.216623  …     0.039018
Semi Major Axis                           0.121224  …    -0.030325
Inclination                               0.259450  …     1.000000
Asc Node Longitude                        0.036558  …    -0.029160
Orbital Period                            0.118314  …    -0.032227
Perihelion Distance                      -0.071866  …    -0.046215
Perihelion Arg                           -0.019577  …     0.003301
Aphelion Dist                             0.151836  …    -0.021653
Perihelion Time                           0.062167  …     0.013727
Mean Anomaly                              0.031455  …     0.015743
Mean Motion                              -0.104350  …     0.013188
Hazardous                                 0.132424  …     0.009607

                              Asc Node Longitude  Orbital Period  \
Neo Reference ID                       -0.026381        0.040058
```

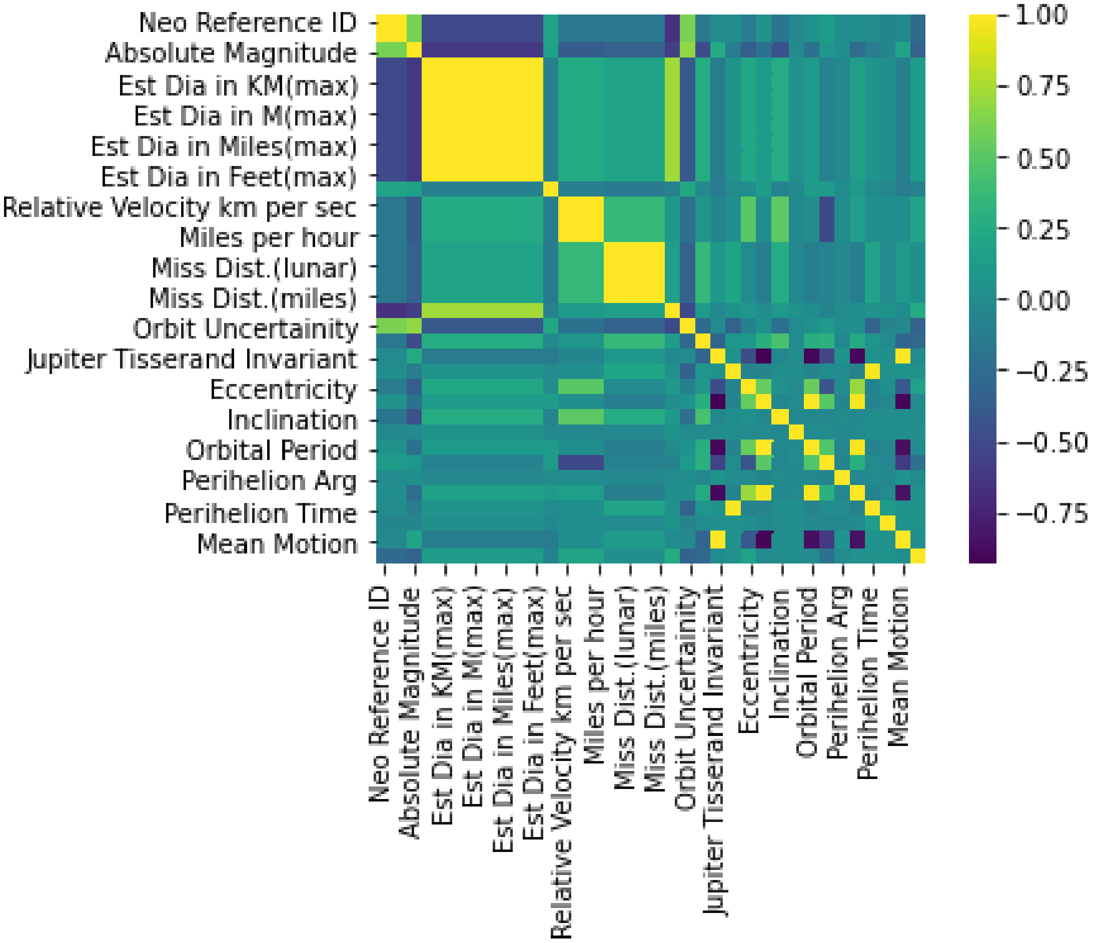
```
Name                                  -0.026381        0.040058
Absolute Magnitude                    -0.011470       -0.206774
Est Dia in KM(min)                     0.036558        0.118314
Est Dia in KM(max)                     0.036558        0.118314
Est Dia in M(min)                      0.036558        0.118314
Est Dia in M(max)                      0.036558        0.118314
Est Dia in Miles(min)                  0.036558        0.118314
Est Dia in Miles(max)                  0.036558        0.118314
Est Dia in Feet(min)                   0.036558        0.118314
Est Dia in Feet(max)                   0.036558        0.118314
Epoch Date Close Approach             -0.019341        0.130175
Relative Velocity km per sec          -0.021301        0.017961
Relative Velocity km per hr           -0.021301        0.017961
Miles per hour                        -0.021301        0.017961
Miss Dist.(Astronomical)              -0.023033       -0.109888
Miss Dist.(lunar)                     -0.023033       -0.109888
Miss Dist.(kilometers)                -0.023033       -0.109888
Miss Dist.(miles)                     -0.023033       -0.109888
Orbit ID                               0.047959        0.002705
Orbit Uncertainity                    -0.009618        0.047535
Minimum Orbit Intersection            -0.008963        0.279885
Jupiter Tisserand Invariant            0.018413       -0.893517
Epoch Osculation                       0.017782       -0.056653
Eccentricity                          -0.015413        0.548521
Semi Major Axis                       -0.011073        0.995248
Inclination                           -0.029160       -0.032227
Asc Node Longitude                     1.000000       -0.009580
Orbital Period                        -0.009580        1.000000
Perihelion Distance                    0.000182        0.467209
Perihelion Arg                        -0.020012       -0.044507
Aphelion Dist                         -0.012245        0.977630
Perihelion Time                        0.020059       -0.058549
Mean Anomaly                           0.029477       -0.025304
Mean Motion                            0.017870       -0.859462
Hazardous                              0.017536       -0.011168

                              Perihelion Distance  Perihelion Arg  \
Neo Reference ID                         0.130486       -0.007669
Name                                     0.130486       -0.007669
Absolute Magnitude                       0.086966        0.031784
Est Dia in KM(min)                      -0.071866       -0.019577
Est Dia in KM(max)                      -0.071866       -0.019577
Est Dia in M(min)                       -0.071866       -0.019577
Est Dia in M(max)                       -0.071866       -0.019577
Est Dia in Miles(min)                   -0.071866       -0.019577
Est Dia in Miles(max)                   -0.071866       -0.019577
Est Dia in Feet(min)                    -0.071866       -0.019577
Est Dia in Feet(max)                    -0.071866       -0.019577
Epoch Date Close Approach                0.131854        0.001834
Relative Velocity km per sec            -0.506978       -0.002913
Relative Velocity km per hr             -0.506978       -0.002913
Miles per hour                          -0.506978       -0.002913
Miss Dist.(Astronomical)                -0.079937       -0.021483
Miss Dist.(lunar)                       -0.079937       -0.021483
Miss Dist.(kilometers)                  -0.079937       -0.021483
Miss Dist.(miles)                       -0.079937       -0.021483
Orbit ID                                -0.063884        0.001338
Orbit Uncertainity                       0.107946        0.016307
Minimum Orbit Intersection               0.299991       -0.029130
Jupiter Tisserand Invariant             -0.537884        0.064496
Epoch Osculation                         0.000093       -0.006703
Eccentricity                            -0.412612       -0.003210
Semi Major Axis                          0.496847       -0.048999
Inclination                             -0.046215        0.003301
Asc Node Longitude                       0.000182       -0.020012
Orbital Period                           0.467209       -0.044507
Perihelion Distance                      1.000000       -0.053090
Perihelion Arg                          -0.053090        1.000000
Aphelion Dist                            0.292995       -0.040477
Perihelion Time                         -0.002854       -0.004517
Mean Anomaly                            -0.047114       -0.027294
Mean Motion                             -0.601118        0.067008
Hazardous                               -0.207027       -0.003865

                              Aphelion Dist  Perihelion Time  Mean Anomaly  \
Neo Reference ID                   0.006318         0.003031     -0.051685
Name                               0.006318         0.003031     -0.051685
Absolute Magnitude                -0.256169        -0.115855     -0.049401
Est Dia in KM(min)                 0.151836         0.062167      0.031455
Est Dia in KM(max)                 0.151836         0.062167      0.031455
Est Dia in M(min)                  0.151836         0.062167      0.031455
Est Dia in M(max)                  0.151836         0.062167      0.031455
Est Dia in Miles(min)              0.151836         0.062167      0.031455
Est Dia in Miles(max)              0.151836         0.062167      0.031455
Est Dia in Feet(min)               0.151836         0.062167      0.031455
Est Dia in Feet(max)               0.151836         0.062167      0.031455
Epoch Date Close Approach          0.114616        -0.015533     -0.026182
Relative Velocity km per sec       0.144782         0.020006      0.017685
Relative Velocity km per hr        0.144782         0.020006      0.017685
Miles per hour                     0.144782         0.020006      0.017685
Miss Dist.(Astronomical)          -0.103231         0.189409     -0.010157
Miss Dist.(lunar)                 -0.103231         0.189409     -0.010157
Miss Dist.(kilometers)            -0.103231         0.189409     -0.010157
Miss Dist.(miles)                 -0.103231         0.189409     -0.010157
```

```
Orbit ID                         0.022269         0.037901      0.048985
Orbit Uncertainity               0.020908        -0.325784     -0.059396
Minimum Orbit Intersection       0.242023         0.080592     -0.013336
Jupiter Tisserand Invariant     -0.887879         0.051994      0.030972
Epoch Osculation                -0.063625         0.977613      0.036881
Eccentricity                     0.701294        -0.064366      0.026161
Semi Major Axis                  0.975326        -0.059303     -0.026319
Inclination                     -0.021653         0.013727      0.015743
Asc Node Longitude              -0.012245         0.020059      0.029477
Orbital Period                   0.977630        -0.058549     -0.025304
Perihelion Distance              0.292995        -0.002854     -0.047114
Perihelion Arg                  -0.040477        -0.004517     -0.027294
Aphelion Dist                    1.000000        -0.064609     -0.017011
Perihelion Time                 -0.064609         1.000000      0.125563
Mean Anomaly                    -0.017011         0.125563      1.000000
Mean Motion                     -0.840166         0.047035      0.035849
Hazardous                        0.040800         0.038113      0.054164

                              Mean Motion  Hazardous
Neo Reference ID                -0.020719  -0.269028
Name                            -0.020719  -0.269028
Absolute Magnitude               0.195652  -0.325522
Est Dia in KM(min)              -0.104350   0.132424
Est Dia in KM(max)              -0.104350   0.132424
Est Dia in M(min)               -0.104350   0.132424
Est Dia in M(max)               -0.104350   0.132424
Est Dia in Miles(min)           -0.104350   0.132424
Est Dia in Miles(max)           -0.104350   0.132424
Est Dia in Feet(min)            -0.104350   0.132424
Est Dia in Feet(max)            -0.104350   0.132424
Epoch Date Close Approach       -0.137663  -0.079020
Relative Velocity km per sec     0.022452   0.191970
Relative Velocity km per hr      0.022452   0.191970
Miles per hour                   0.022452   0.191970
Miss Dist.(Astronomical)         0.104642   0.032407
Miss Dist.(lunar)                0.104642   0.032407
Miss Dist.(kilometers)           0.104642   0.032407
Miss Dist.(miles)                0.104642   0.032407
Orbit ID                        -0.008898   0.247369
Orbit Uncertainity              -0.023776  -0.328721
Minimum Orbit Intersection      -0.290538  -0.288949
Jupiter Tisserand Invariant      0.992680  -0.003404
Epoch Osculation                 0.045812   0.040940
Eccentricity                    -0.394860   0.183269
Semi Major Axis                 -0.901396  -0.010770
Inclination                      0.013188   0.009607
Asc Node Longitude               0.017870   0.017536
```

```
Orbital Period                    -0.859462  -0.011168
Perihelion Distance               -0.601118  -0.207027
Perihelion Arg                     0.067008  -0.003865
Aphelion Dist                     -0.840166   0.040800
Perihelion Time                    0.047035   0.038113
Mean Anomaly                       0.035849   0.054164
Mean Motion                        1.000000   0.013028
Hazardous                          0.013028   1.000000

[36 rows x 36 columns]
```

[8]:

```
sns.heatmap(nasa_df.corr(), vmax = 1, square = True, cmap = 'viridis')
fig=plt.figure(figsize=(30, 90))
plt.show()
```



```
<Figure size 2160x6480 with 0 Axes>
```

- Light shades represents positive correlation while darker shades reppresents negative correlation.

[9]:

```
#cleaning our data (drop repetitive columns keep miles, Est Dia in KM(min)'.
#keep 'Relative Velocity mile per hr','Miss Dist.(miles),'Relative Velocity km␣
 ↪per hr'
nasa_df = nasa_df.drop(columns=['Miss Dist.(kilometers)','Miss Dist.
 ↪(kilometers)','Miss Dist.(lunar)','Miss Dist.(Astronomical)', 'Est Dia in␣
 ↪Feet(max)','Est Dia in Feet(min)','Est Dia in M(min)','Est Dia in␣
 ↪M(max)','Est Dia in KM(max)','Est Dia in KM(min)','Relative Velocity km per␣
 ↪sec','Relative Velocity km per hr'])
```

[10]:

```
#corelation of independent variables with the dependent variable
#want to check which characteristics associated with asteroid being hazardous
nasa_df.corr()[['Hazardous']].sort_values(by='Hazardous', ascending=False)


#We can filter groupby hazardous later and just get the true
```

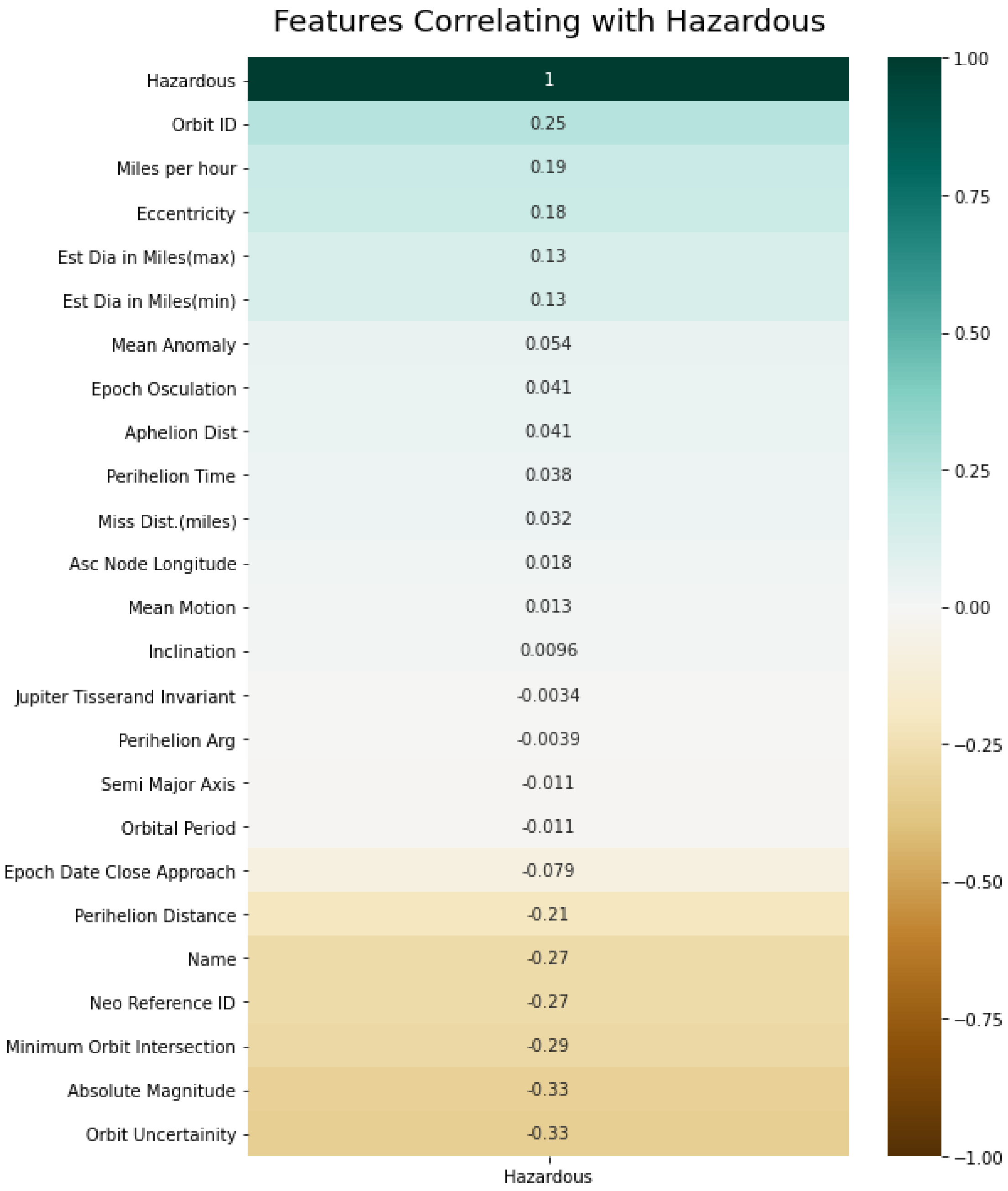
[10]:

```
                              Hazardous
Hazardous                      1.000000
Orbit ID                       0.247369
Miles per hour                 0.191970
Eccentricity                   0.183269
Est Dia in Miles(max)          0.132424
Est Dia in Miles(min)          0.132424
Mean Anomaly                   0.054164
Epoch Osculation               0.040940
Aphelion Dist                  0.040800
Perihelion Time                0.038113
Miss Dist.(miles)              0.032407
Asc Node Longitude             0.017536
Mean Motion                    0.013028
Inclination                    0.009607
Jupiter Tisserand Invariant   -0.003404
Perihelion Arg                -0.003865
Semi Major Axis               -0.010770
Orbital Period                -0.011168
Epoch Date Close Approach     -0.079020
Perihelion Distance           -0.207027
Name                          -0.269028
Neo Reference ID              -0.269028
Minimum Orbit Intersection    -0.288949
Absolute Magnitude            -0.325522
Orbit Uncertainity            -0.328721
```

[11]:

```
#New Heatmap
plt.figure(figsize=(8, 12))
```

```
heatmap = sns.heatmap(nasa_df.corr()[['Hazardous']].sort_values(by='Hazardous',␣
↪ascending=False), vmin=-1, vmax=1, annot=True, cmap='BrBG')
heatmap.set_title('Features Correlating with Hazardous', fontdict={'fontsize':
↪18}, pad=16);
```



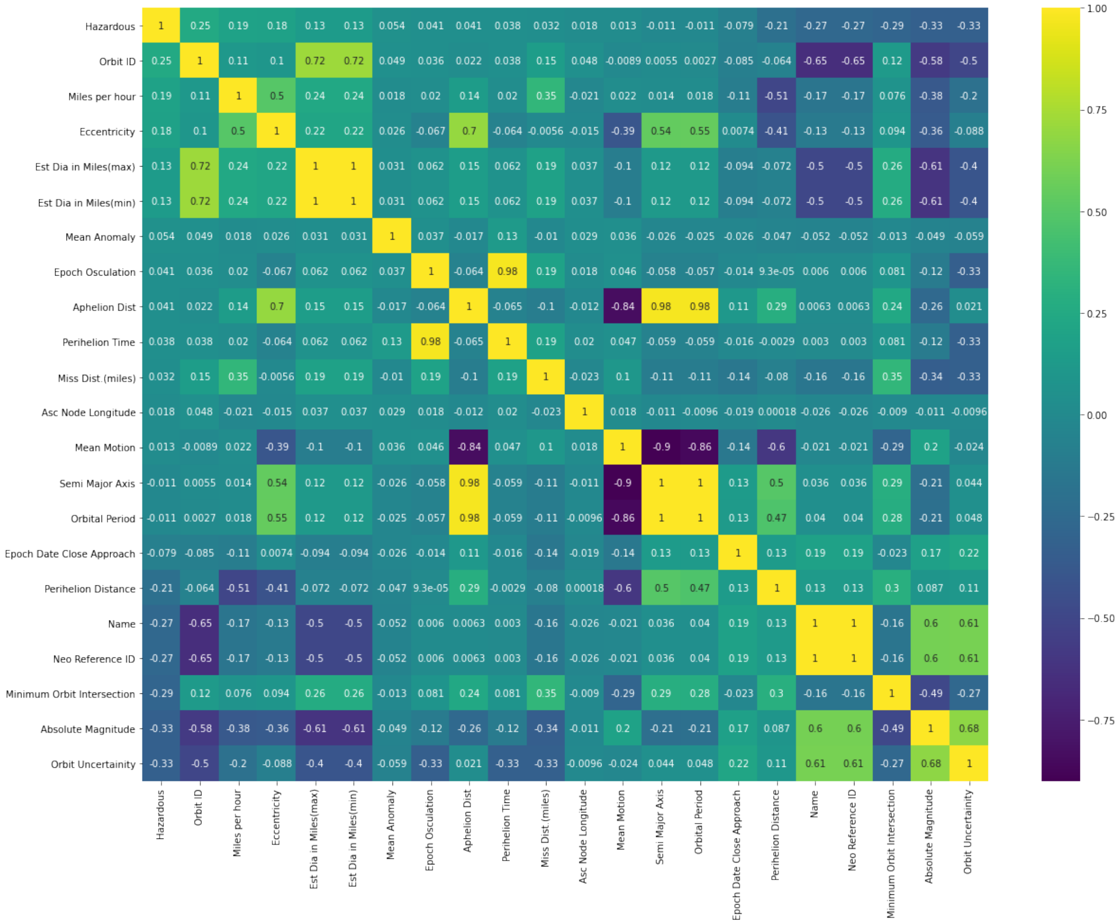
- ‘Inclination’, ‘Jupiter Tisserand Invariant’, and ‘Perihelion Arg’ have almost no correlation with ‘Hazardous’.
- There is no linear relationship between these three predictors so it is safe to drop them.

```
[12]: nasa_df = nasa_df.drop(columns=['Inclination','Jupiter Tisserand␣
       ↪Invariant','Perihelion Arg'])
      nasa_df.corr()[['Hazardous']].sort_values(by='Hazardous', ascending=False)
```

```
[12]:                            Hazardous
      Hazardous                    1.000000
      Orbit ID                     0.247369
      Miles per hour               0.191970
      Eccentricity                 0.183269
      Est Dia in Miles(max)        0.132424
      Est Dia in Miles(min)        0.132424
      Mean Anomaly                 0.054164
      Epoch Osculation             0.040940
      Aphelion Dist                0.040800
      Perihelion Time              0.038113
      Miss Dist.(miles)            0.032407
      Asc Node Longitude           0.017536
      Mean Motion                  0.013028
      Semi Major Axis             -0.010770
      Orbital Period              -0.011168
      Epoch Date Close Approach   -0.079020
      Perihelion Distance         -0.207027
      Name                        -0.269028
      Neo Reference ID            -0.269028
      Minimum Orbit Intersection  -0.288949
      Absolute Magnitude          -0.325522
      Orbit Uncertainity          -0.328721
```

```
[13]: #Harzardous correlation matrix
      k = 22 #number of variables for heatmap
      cols = nasa_df.corr().nlargest(k, 'Hazardous')['Hazardous'].index
      cm = nasa_df[cols].corr()
      plt.figure(figsize=(20,15))
      sns.heatmap(cm, annot=True, cmap = 'viridis')
```

```
[13]: <AxesSubplot:>
```



- ‘Orbit ID’ has strong postive correlation with ‘Est Dia in Miles(max)’ and ‘Est Dia in Miles(min)’.
- ‘Epoch Osculation’ has really strong postive correlation with ‘Perihelion Time’.
- ‘Aphelion Dist’ has strong positive correlation with ‘Eccentricity’, ‘Semi Major Axis’, and ‘Orbital Period’ whearas it has strong negative correlation with ‘Mean Motion’.
- ‘Mean Motion’ also has strong negative correlation with ‘Semi Major Axis’, and ‘Orbital Period’ which are positively correlated with ‘Aphelion Dist’.

[14]:
```
# only consider the columns that have numerical values
# in order to create the box plot and check the outliers
nasa_df_num = nasa_df.drop(columns=['Close Approach Date','Orbiting␣
↪Body','Orbit Determination Date','Equinox','Hazardous'])
```

[15]:
```
nasa_df_num
```

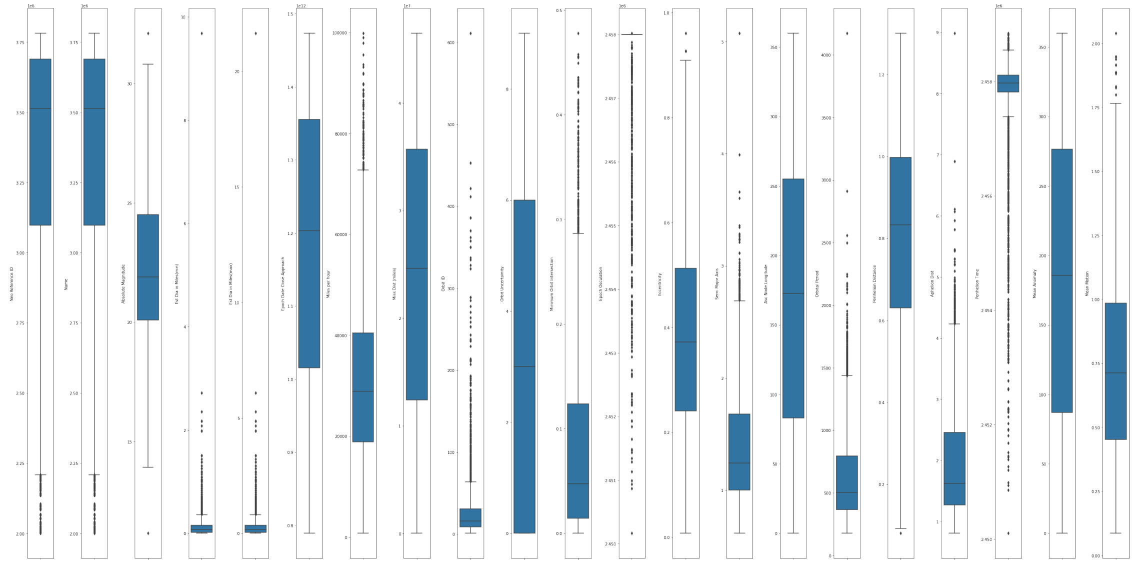
[15]:
```
      Neo Reference ID     Name  Absolute Magnitude  Est Dia in Miles(min)  \
0              3703080  3703080              21.600               0.079051
1              3723955  3723955              21.300               0.090762
2              2446862  2446862              20.300               0.143849
```

```
3              3092506  3092506              27.400               0.005469
4              3514799  3514799              21.600               0.079051
…                …      …                 …                    …
4682           3759007  3759007              23.900               0.027410
4683           3759295  3759295              28.200               0.003784
4684           3759714  3759714              22.700               0.047633
4685           3759720  3759720              21.800               0.072095
4686           3772978  3772978              19.109               0.248946

      Est Dia in Miles(max)  Epoch Date Close Approach  Miles per hour  \
0                  0.176763               788947200000    13680.509944
1                  0.202951               788947200000    40519.173105
2                  0.321655               789552000000    16979.661798
3                  0.012229               790156800000    24994.839864
4                  0.176763               790156800000    22012.954985
…                     …                        …             …
4682               0.061290              1473318000000    49556.875548
4683               0.008460              1473318000000     7214.337772
4684               0.106510              1473318000000    16086.983633
4685               0.161210              1473318000000    25393.489071
4686               0.556661              1473318000000    80409.512650

      Miss Dist.(miles)  Orbit ID  Orbit Uncertainity  …  Epoch Osculation  \
0          3.899334e+07        17                   5  …         2458000.5
1          3.560342e+07        21                   3  …         2458000.5
2          4.736658e+06        22                   0  …         2458000.5
3          2.652237e+07         7                   6  …         2458000.5
4          3.791037e+07        25                   1  …         2458000.5
…                 …       …                 …  …               …
4682       3.844741e+06         4                   8  …         2457637.5
4683       6.013211e+05         2                   6  …         2458000.5
4684       5.671115e+06        17                   6  …         2458000.5
4685       2.423912e+07         6                   5  …         2458000.5
4686       4.298016e+07        13                   6  …         2458000.5

      Eccentricity  Semi Major Axis  Asc Node Longitude  Orbital Period  \
0         0.425549         1.407011          314.373913      609.599786
1         0.351674         1.107776          136.717242      425.869294
2         0.348248         1.458824          259.475979      643.580228
3         0.216578         1.255903           57.173266      514.082140
4         0.210448         1.225615           84.629307      495.597821
…            …              …                 …             …
4682      0.361512         1.161429          164.183305      457.179984
4683      0.073200         1.075134          345.225230      407.185767
4684      0.368055         1.528234           37.026468      690.054279
4685      0.202565         1.486600          163.802910      662.048343
4686      0.405642         1.474045          187.642183      653.679098
```

```
      Perihelion Distance  Aphelion Dist  Perihelion Time  Mean Anomaly  \
0                0.808259       2.005764     2.458162e+06    264.837533
1                0.718200       1.497352     2.457795e+06    173.741112
2                0.950791       1.966857     2.458120e+06    292.893654
3                0.983902       1.527904     2.457902e+06     68.741007
4                0.967687       1.483543     2.457814e+06    135.142133
…                   …            …              …             …
4682             0.741558       1.581299     2.457708e+06    304.306025
4683             0.996434       1.153835     2.458088e+06    282.978786
4684             0.965760       2.090708     2.458300e+06    203.501147
4685             1.185467       1.787733     2.458288e+06    203.524965
4686             0.876110       2.071980     2.458319e+06    184.820424

      Mean Motion
0        0.590551
1        0.845330
2        0.559371
3        0.700277
4        0.726395
…           …
4682     0.787436
4683     0.884117
4684     0.521698
4685     0.543767
4686     0.550729

[4687 rows x 21 columns]
```

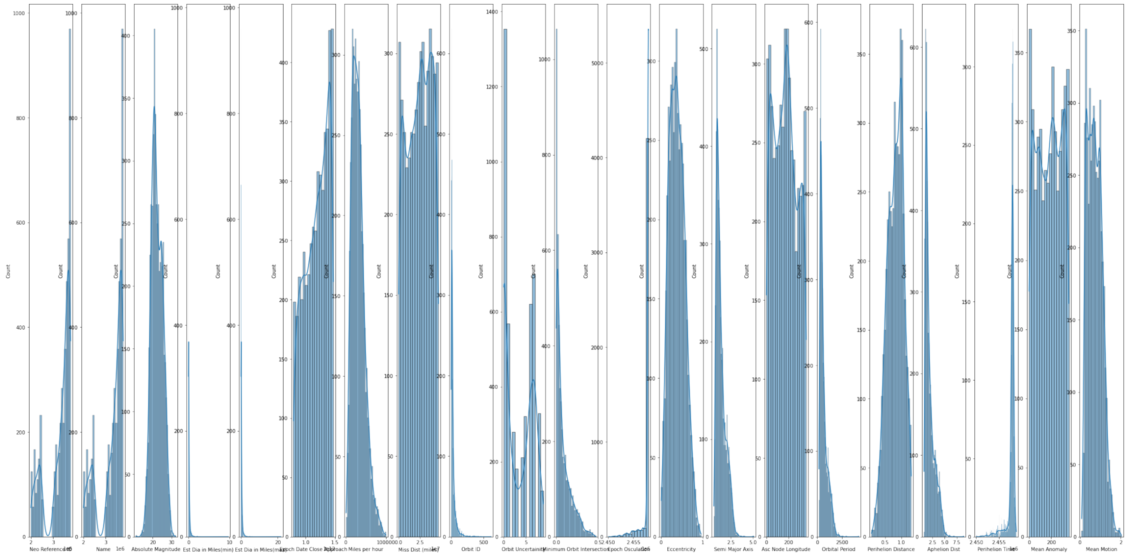
[16]:

```python
# check the outliers
df = nasa_df_num
l = df.columns.values
num_cols = len(l)
plt.figure(figsize=(40,20))
for i in range(0,len(l)):
    plt.subplot(1,num_cols,i+1)
    sns.boxplot(y=df[l[i]])
    plt.tight_layout()
```



- 16 out of 21 variables show outliers.
- The 5 variables with no outliers are ‘Epoch Date Close Approach’, ‘Miss Dist.(miles)’, ‘Orbit Uncertainity’, ‘Asc Node Longitude’, and ‘Mean Anomaly’.

[17]:
```
# Check the asymmetry of the probability distribution
plt.figure(figsize=(40,20))
for i in range(0,len(l)):
    plt.subplot(1,num_cols,i+1)
    sns.histplot(df[l[i]],kde=True)
```



- ‘Absolute Magnitude’ seems to be normally distributed.

[18]:

```
for i in range(0,len(l)):
    skewness = round(stats.skew(df[l[i]]),4)
    print('The skewness of \'%s\' is %f.' % (l[i],skewness))
```

```
The skewness of 'Neo Reference ID' is -1.102200.
The skewness of 'Name' is -1.102200.
The skewness of 'Absolute Magnitude' is 0.193900.
The skewness of 'Est Dia in Miles(min)' is 17.664500.
The skewness of 'Est Dia in Miles(max)' is 17.664500.
The skewness of 'Epoch Date Close Approach' is -0.294900.
The skewness of 'Miles per hour' is 0.887600.
The skewness of 'Miss Dist.(miles)' is -0.102400.
The skewness of 'Orbit ID' is 4.844800.
The skewness of 'Orbit Uncertainity' is 0.154700.
The skewness of 'Minimum Orbit Intersection' is 1.474500.
The skewness of 'Epoch Osculation' is -4.031100.
The skewness of 'Eccentricity' is 0.297300.
The skewness of 'Semi Major Axis' is 1.109600.
The skewness of 'Asc Node Longitude' is 0.087300.
The skewness of 'Orbital Period' is 1.527600.
The skewness of 'Perihelion Distance' is -0.261300.
The skewness of 'Aphelion Dist' is 1.305700.
The skewness of 'Perihelion Time' is -3.723900.
The skewness of 'Mean Anomaly' is -0.034600.
The skewness of 'Mean Motion' is 0.420300.
```

[19]:

```
#print(nasa_df["Hazardous"])
#boolean Hazardous column
nasa_df1 = nasa_df[nasa_df["Hazardous"] == True] #filter by hazardous = True
nasa_df1

#idk if we need this, might also need to get rid of redundant
```

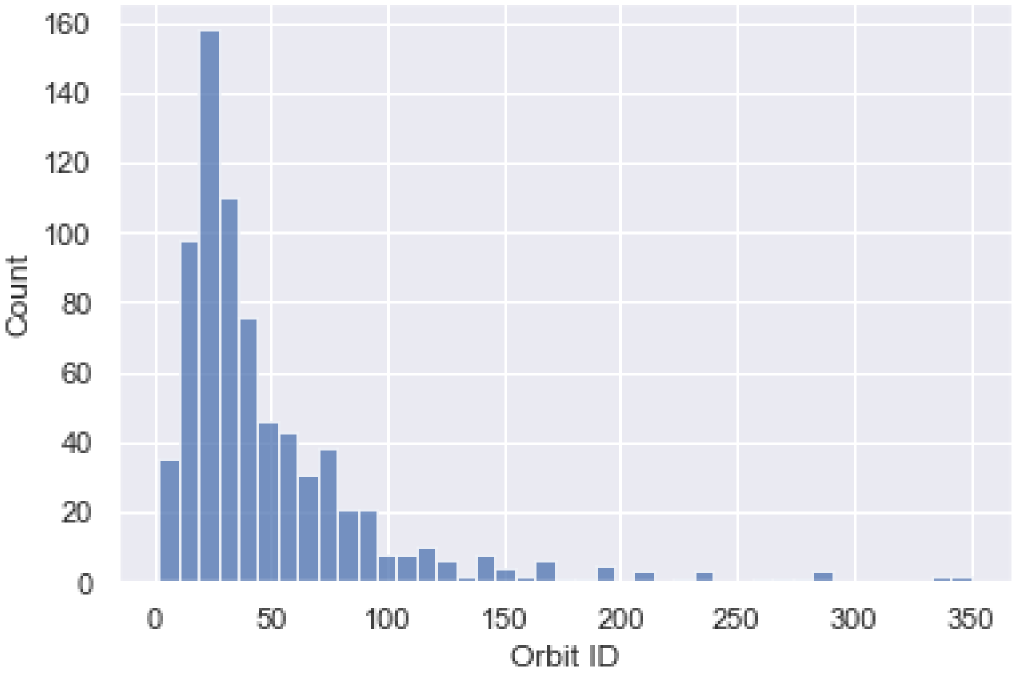
[19]:

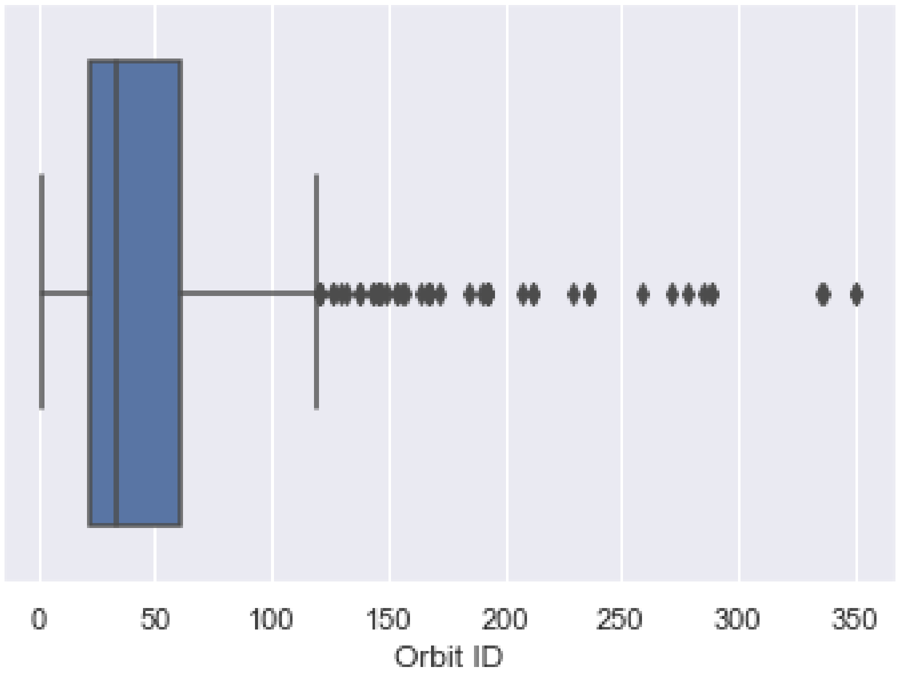
```
      Neo Reference ID     Name  Absolute Magnitude  Est Dia in Miles(min)  \
0              3703080  3703080                21.6               0.079051
2              2446862  2446862                20.3               0.143849
4              3514799  3514799                21.6               0.079051
9              2306383  2306383                21.5               0.082776
22             3005973  3005973                21.7               0.075493
…                  …        …                  …                     …
4662           3744785  3744785                19.3               0.227985
4663           3755345  3755345                21.5               0.082776
4665           2333578  2333578                20.2               0.150628
4668           3475236  3475236                21.6               0.079051
4674           2068346  2068346                16.9               0.688503

      Est Dia in Miles(max) Close Approach Date  Epoch Date Close Approach  \
0                  0.176763          1995-01-01               788947200000
2                  0.321655          1995-01-08               789552000000
4                  0.176763          1995-01-15               790156800000
9                  0.185093          1995-01-22               790761600000
22                 0.168807          1995-02-22               793440000000
…                     …                 …                        …
4662               0.509790          2016-08-08              1470639600000
4663               0.185093          2016-08-08              1470639600000
4665               0.336815          2016-08-15              1471244400000
4668               0.176763          2016-08-15              1471244400000
4674               1.539540          2016-09-08              1473318000000

      Miles per hour  Miss Dist.(miles) Orbiting Body  …  Semi Major Axis  \
0       13680.509944         38993336.0         Earth  …         1.407011
2       16979.661798          4736657.5         Earth  …         1.458824
4       22012.954985         37910368.0         Earth  …         1.225615
9       28855.136987         14111226.0         Earth  …         0.876125
22      63570.358787          4512202.5         Earth  …         0.906734
…              …                 …           …  …              …
4662    51596.244460          5420135.5         Earth  …         1.647586
4663    33004.316467         11229848.0         Earth  …         1.037464
4665    28235.041082         17621348.0         Earth  …         1.573764
4668    38373.479006         36278652.0         Earth  …         1.439534
4674    25139.845771         24667792.0         Earth  …         1.507454

     Asc Node Longitude  Orbital Period  Perihelion Distance  Aphelion Dist  \
0            314.373913      609.599786             0.808259       2.005764
2            259.475979      643.580228             0.950791       1.966857
4             84.629307      495.597821             0.967687       1.483543
9              2.613682      299.535161             0.393040       1.359211
22           342.784208      315.368341             0.119309       1.694158
…                 …             …                  …            …
4662         138.565536      772.450559             0.700571       2.594602
4663         136.762870      385.973723             0.938903       1.136024
4665         169.500723      721.120395             0.980758       2.166770
4668          54.443592      630.857755             0.629932       2.249136
4674         219.394973      676.027851             0.879333       2.135575

      Perihelion Time  Mean Anomaly  Mean Motion  Equinox  Hazardous
0        2.458162e+06    264.837533     0.590551    J2000       True
2        2.458120e+06    292.893654     0.559371    J2000       True
4        2.457814e+06    135.142133     0.726395    J2000       True
9        2.457901e+06    119.861382     1.201862    J2000       True
22       2.453598e+06    303.979299     1.141522    J2000       True
…               …           …          …      …        …
4662     2.458331e+06    205.762131     0.466049    J2000       True
4663     2.457848e+06    142.264753     0.932706    J2000       True
```

```
4665     2.457645e+06    177.326778     0.499223     J2000        True
4668     2.458240e+06    223.131665     0.570652     J2000        True
4674     2.458321e+06    189.232032     0.532522     J2000        True

[755 rows x 26 columns]
```

[20]:

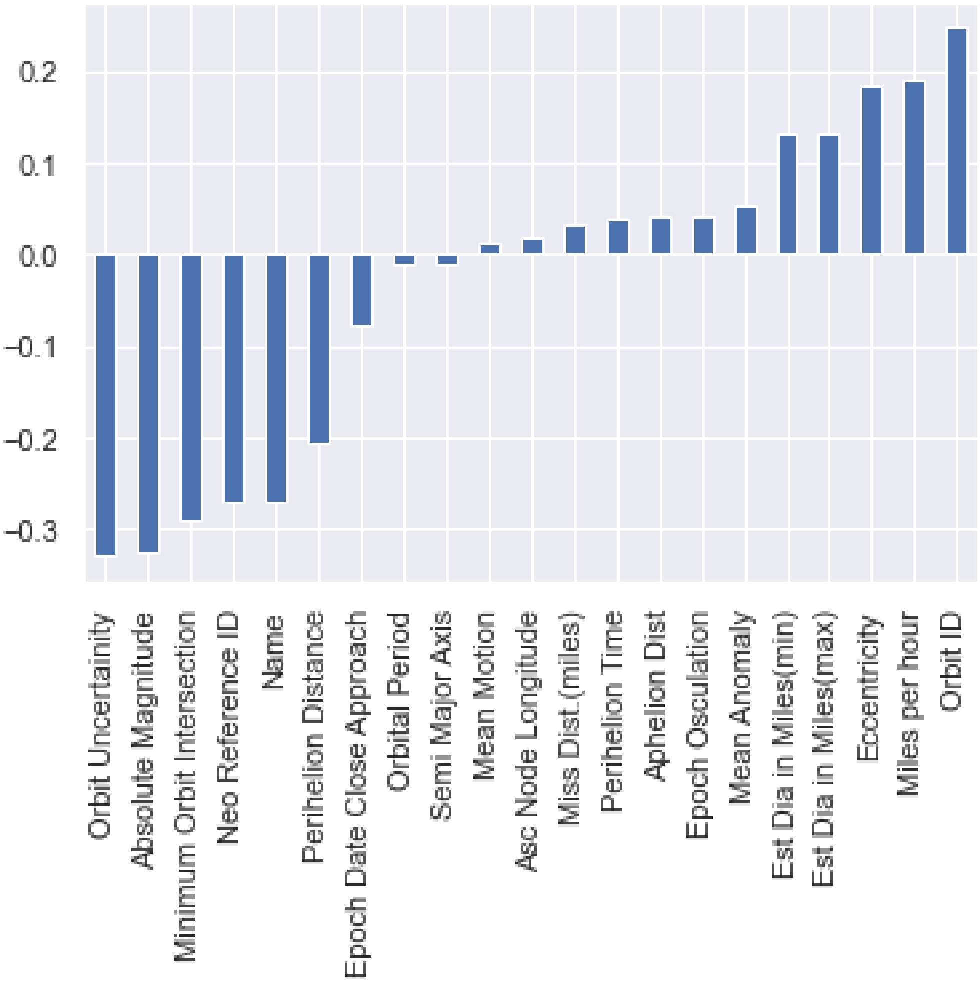
```python
# plot of frequencies of each variable with true as hazardous
# set a grey background (use sns.set_theme() if seaborn version 0.11.0 or above)
sns.set(style="darkgrid")
sns.histplot(data=nasa_df1, x="Orbit ID")
plt.show()

#for true or hazardous asteroids, orbit ID near values 0-100?

ax = sns.boxplot(x=nasa_df1["Orbit ID"])
#or like interpret the boxplot
```





[21]:
```
#count number of Hazardous vs not in dataset, see which one occurs more
print(nasa_df['Hazardous'].value_counts())
#histogram plot to see pairwise correlation with hazardous, get rid of hazardous correlation with itself
nasa_df.corr()['Hazardous'][:-1].sort_values().plot(kind='bar') #sorted values in ascending
plt.show()
#print(nasa_df.corr()['Hazardous'][:-1])
#print(nasa_df.corr()['Hazardous'])
```

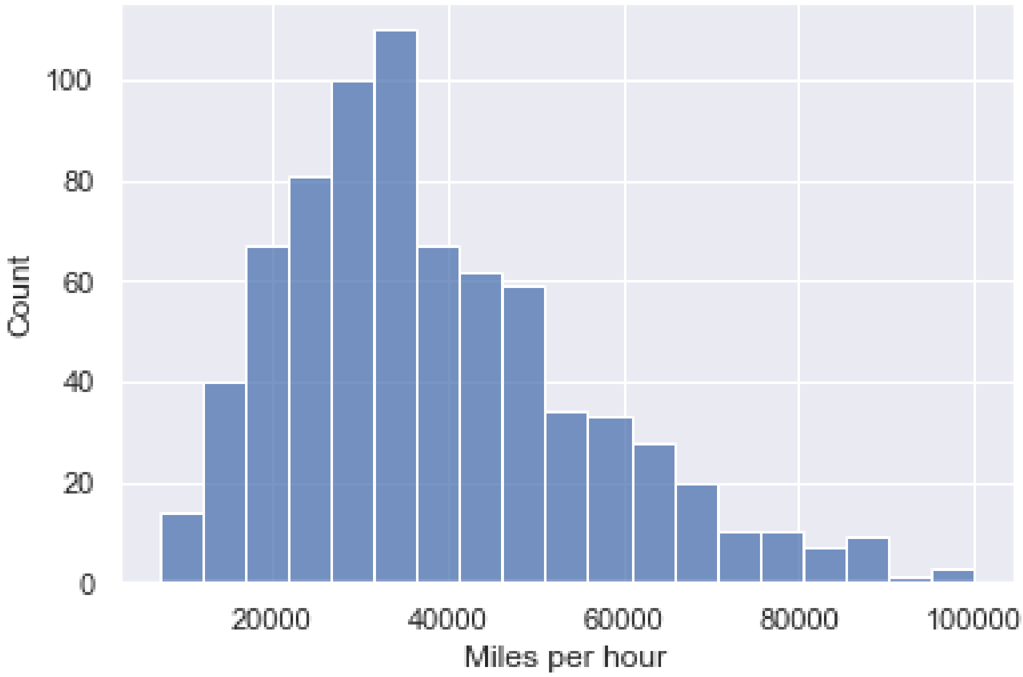
```
False    3932
True      755
Name: Hazardous, dtype: int64
```

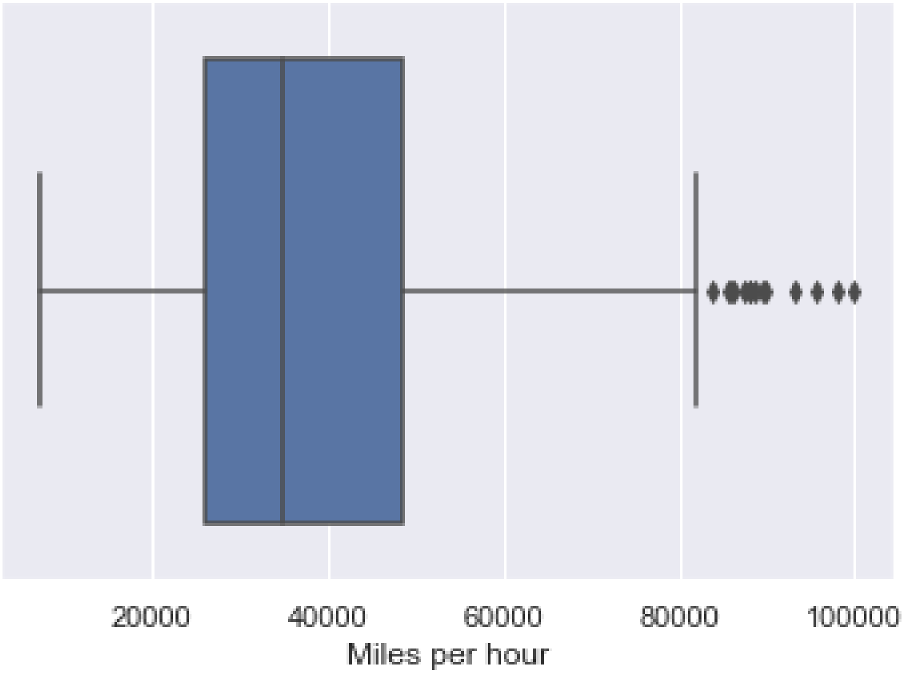


[22]:
```
nasa_df['Equinox'].unique()
```

[22]:
```
array(['J2000'], dtype=object)
```

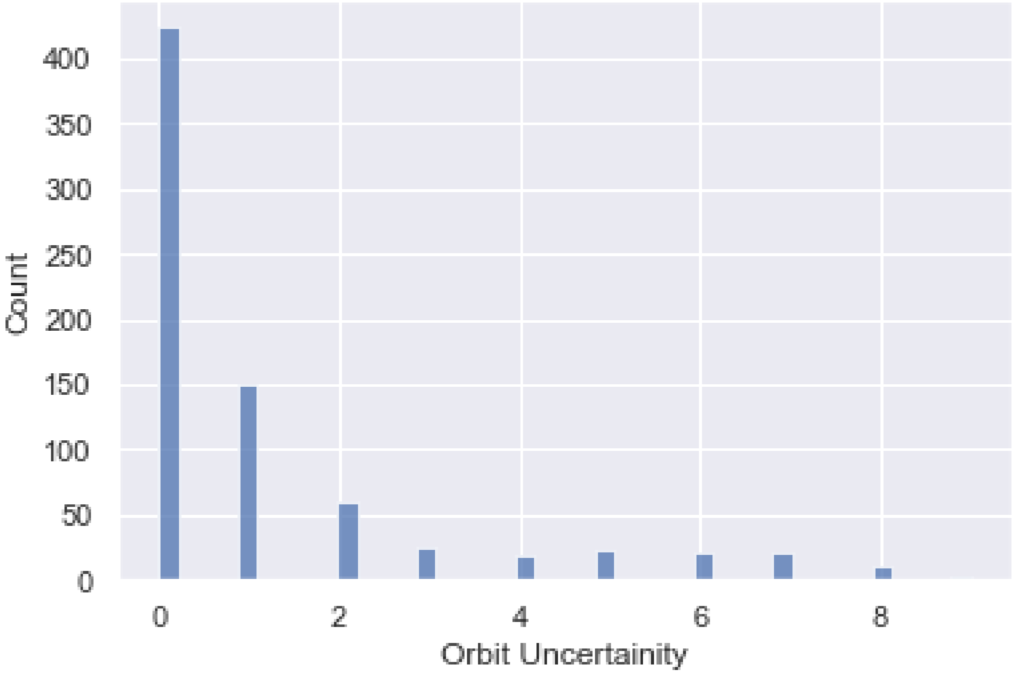
[23]:
```
#More plots occurences of the variables '
# might want to do percentage/proportion of variables and proportion hazarard␣
↪or not hazard
#contingency table for categorical variable'


#can use frequency table showing varibales after filtering true
#ggplot
#contingency table, can do odds ratio, risk comparison
sns.histplot(data=nasa_df1, x="Miles per hour")
plt.show()
ax = sns.boxplot(x=nasa_df1["Miles per hour"])
```

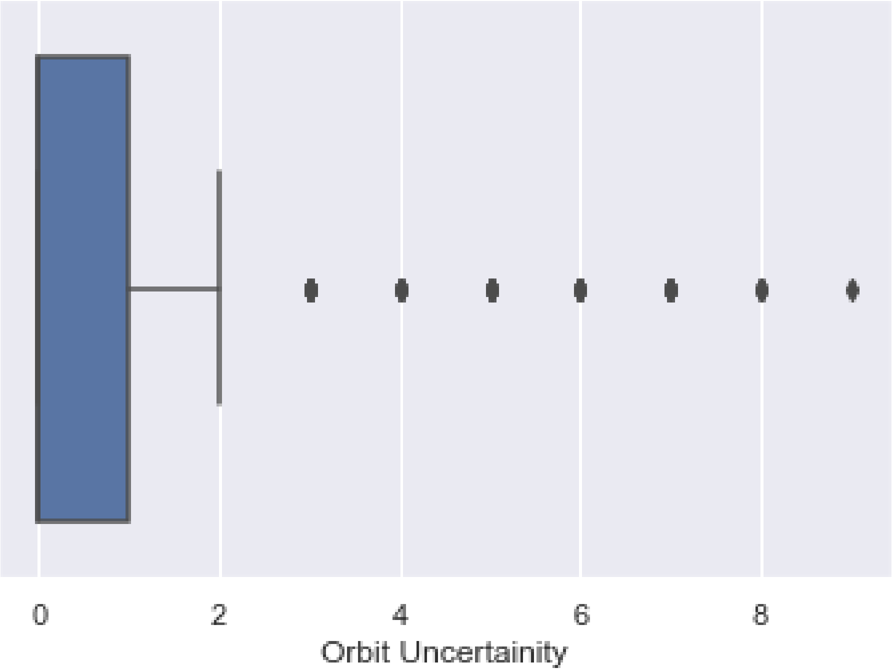

100
80
60
40
20
0
Count
20000
40000
60000
80000
100000
Miles per hour


20000
40000
60000
80000
100000
Miles per hour

[24]:

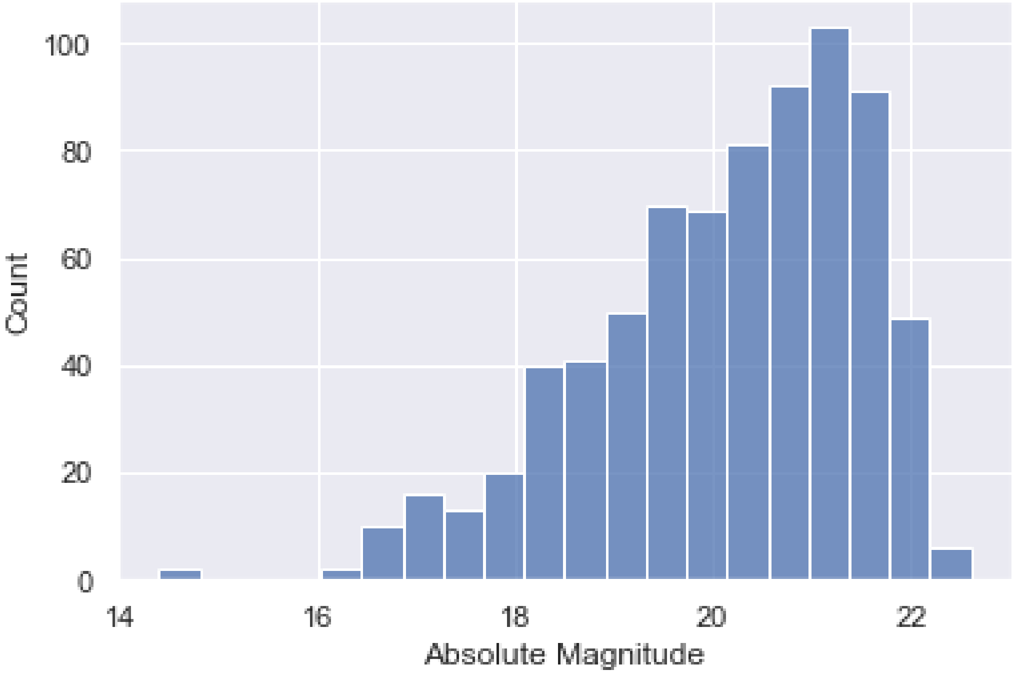
```
sns.histplot(data=nasa_df1, x="Orbit Uncertainity")
plt.show()
ax = sns.boxplot(x=nasa_df1["Orbit Uncertainity"])
```

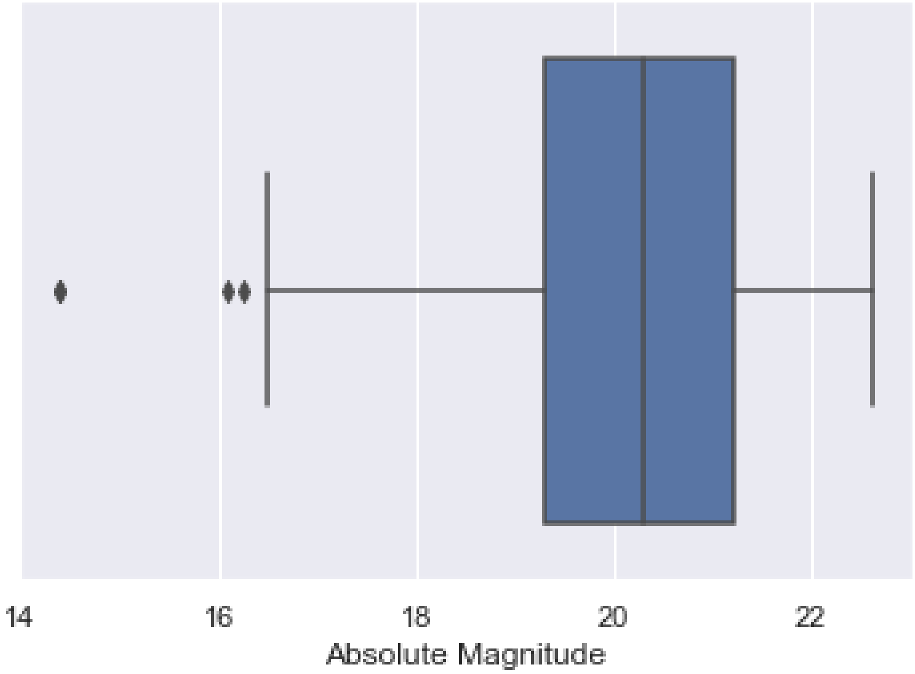




[25]:

```
sns.histplot(data=nasa_df1, x="Absolute Magnitude")
plt.show()
ax = sns.boxplot(x=nasa_df1["Absolute Magnitude"])
```





1.1.1 Hierarchical Clustering

[26]:

```
#using the same dataset that we used for the Machine Learning models
my_data = nasa_df[['Orbit Uncertainity', 'Miles per hour', 'Absolute␣
 ↪Magnitude', 'Hazardous']].copy()
my_data
```

[26]:

```
      Orbit Uncertainity  Miles per hour  Absolute Magnitude  Hazardous
0                      5    13680.509944              21.600       True
1                      3    40519.173105              21.300      False
2                      0    16979.661798              20.300       True
3                      6    24994.839864              27.400      False
4                      1    22012.954985              21.600       True
…                    …               …                   …          …
4682                   8    49556.875548              23.900      False
4683                   6     7214.337772              28.200      False
4684                   6    16086.983633              22.700      False
4685                   5    25393.489071              21.800      False
4686                   6    80409.512650              19.109      False

[4687 rows x 4 columns]
```

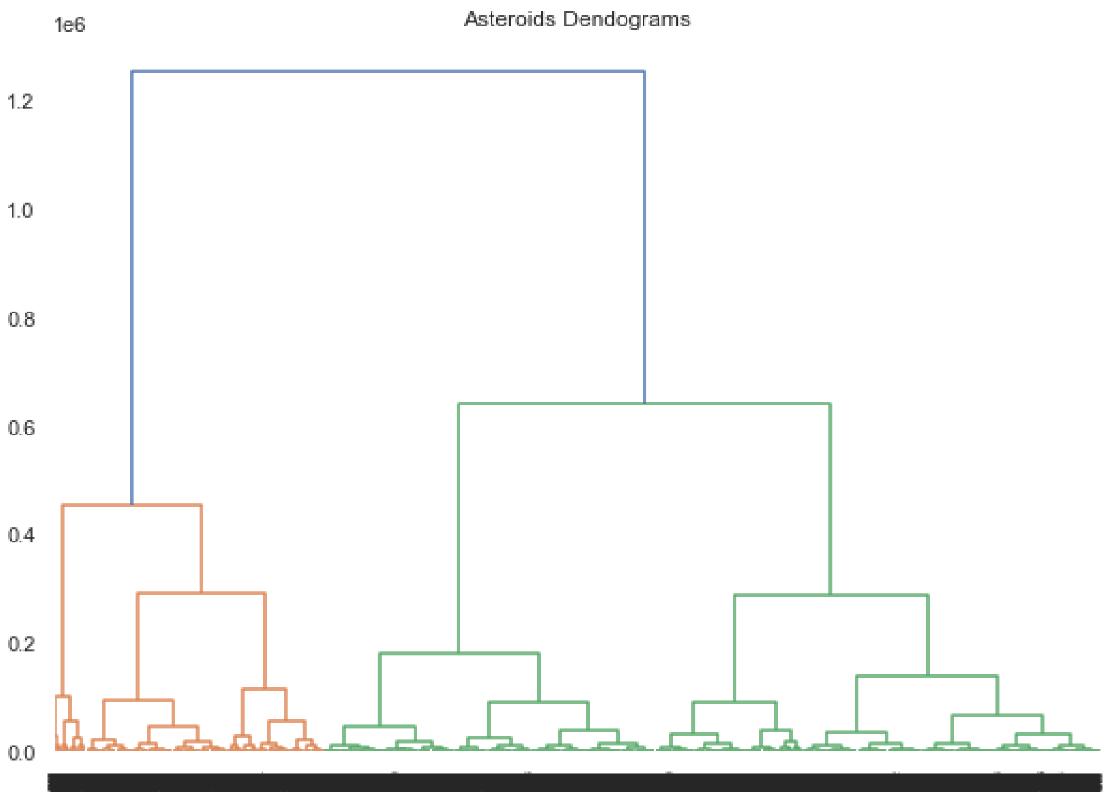
- This dataset has four colunms: Orbit ID, Miles per hour, Eccentricity, and Hazardous.
- We remove Orbit ID and Hazardous columns to view the results in 2D feature space.

[27]:

```
data = my_data.iloc[:,1:3].values
```

[28]:

```
import scipy.cluster.hierarchy as shc

plt.figure(figsize=(10, 7))
plt.title("Asteroids Dendograms")
dend = shc.dendrogram(shc.linkage(data, method='ward'))
```



[29]:

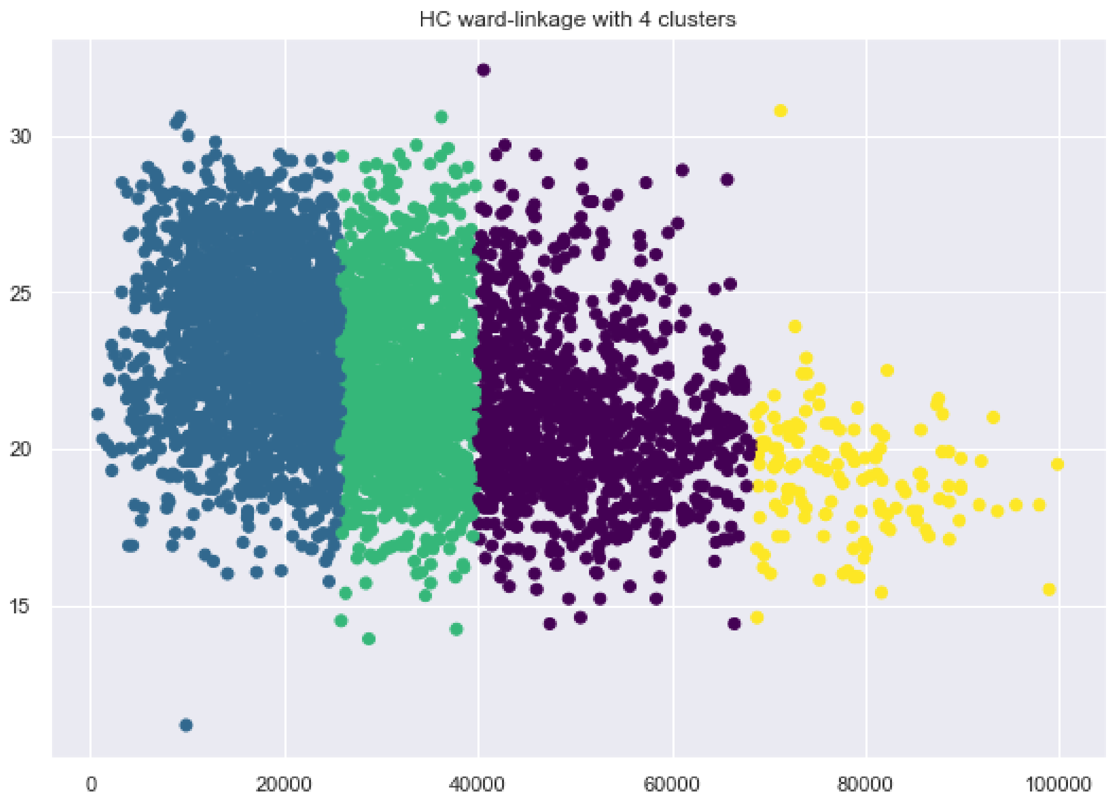
```
from sklearn.cluster import AgglomerativeClustering

HCward = AgglomerativeClustering(n_clusters=4, linkage='ward')
HCward.fit_predict(data)
```

[29]:

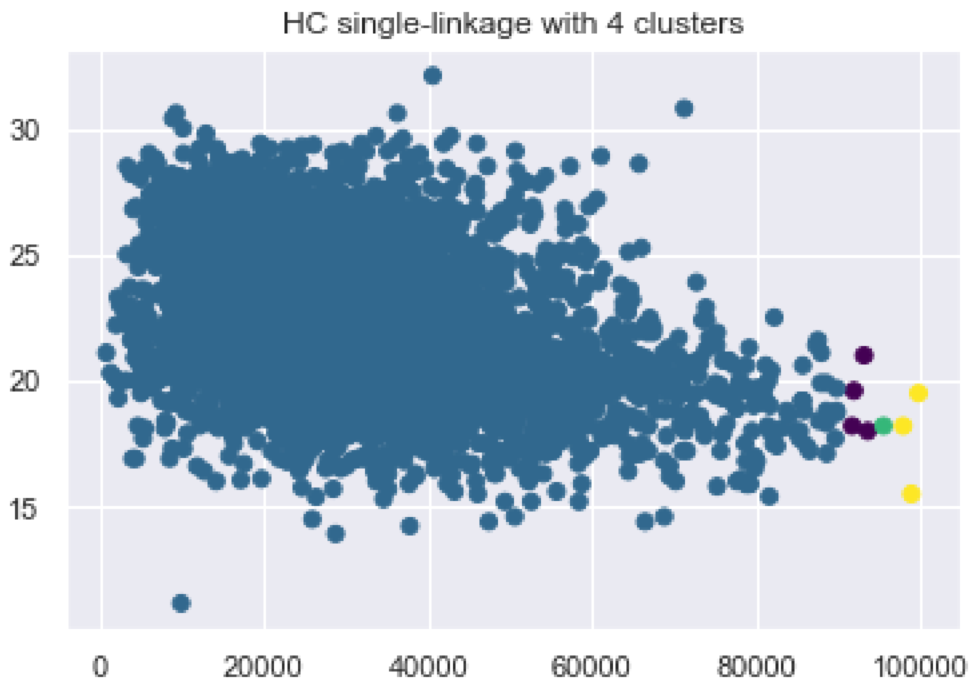
```
array([1, 0, 1, …, 1, 1, 3])
```

[30]:

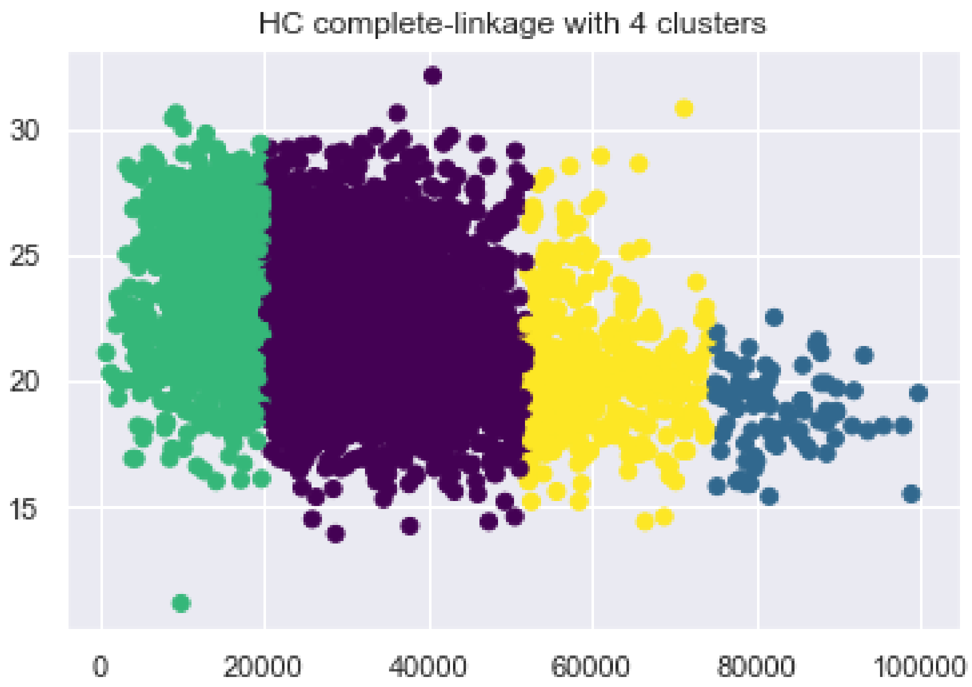
```
plt.figure(figsize=(10, 7))
plt.scatter(data[:,0], data[:,1], c=HCward.labels_, cmap='viridis')
plt.title('HC ward-linkage with 4 clusters')
plt.show()
```



```
[31]: HCsingle=AgglomerativeClustering(n_clusters=4, linkage='single')
      HCsingle.fit_predict(data)
      plt.scatter(data[:,0], data[:,1], c=HCsingle.labels_, cmap='viridis')
      plt.title('HC single-linkage with 4 clusters')
      plt.show()
```



[32]:
```
HCcomplete=AgglomerativeClustering(n_clusters=4, linkage='complete')
HCcomplete.fit_predict(data)
plt.scatter(data[:,0], data[:,1], c=HCcomplete.labels_, cmap='viridis')
plt.title('HC complete-linkage with 4 clusters')
plt.show()
```



1.2 MACHINE LEARNING MODELS

[33]:

```
import sklearn
from sklearn.model_selection import train_test_split
from sklearn.model_selection import ShuffleSplit
from sklearn.model_selection import GridSearchCV
from sklearn.neural_network import MLPClassifier
from sklearn.neighbors import KNeighborsClassifier
from sklearn.linear_model import LogisticRegressionCV
from sklearn.tree import DecisionTreeClassifier
from sklearn.metrics import plot_confusion_matrix
```

[34]:

```
X=np.asarray(my_data[['Orbit Uncertainity', 'Miles per hour', 'Absolute␣
 ↪Magnitude', 'Hazardous']])
Y=my_data['Hazardous']

X_train, X_test, Y_train, Y_test = train_test_split(X, Y, random_state=42)
```

1.2.1 Multi-Layer Perceptron (MLP)

[35]:

```
cv = ShuffleSplit(n_splits=5, test_size=0.3, random_state=1)

param_grid_mlp = {
    'hidden_layer_sizes': [5,10,15,(5,5),(5,10),(100,15),(100,)],
    'activation': ['relu', 'sigmoid'],
    'solver': ['adam'],
    'alpha': [5e-4, 1e-4, 0.005, 0.001],
    'max_iter':[300,500]
}

X=np.asarray(my_data[['Orbit Uncertainity', 'Miles per hour', 'Absolute␣
 ↪Magnitude', 'Hazardous']])
Y=my_data['Hazardous']

X_train, X_test, Y_train, Y_test = train_test_split(X, Y, random_state=42)

gridSearch_data1 = GridSearchCV(MLPClassifier(), param_grid_mlp, cv=cv,
                         scoring='accuracy', verbose=2, n_jobs=-1)
gridSearch_data1.fit(X_train, Y_train)
print('Score: ', gridSearch_data1.best_score_)
print('Parameters: ', gridSearch_data1.best_params_)
```

```
Fitting 5 folds for each of 112 candidates, totalling 560 fits
Score:  0.8400000000000001
Parameters:  {'activation': 'relu', 'alpha': 0.0005, 'hidden_layer_sizes': 10,
'max_iter': 300, 'solver': 'adam'}
```

```
/Applications/anaconda3/lib/python3.8/site-
packages/sklearn/model_selection/_search.py:918: UserWarning: One or more of the
test scores are non-finite: [0.82881517 0.83146919 0.84       0.83829384
0.83924171 0.6092891
 0.70218009 0.62369668 0.55507109 0.83829384 0.84       0.7163981
 0.76511848 0.83374408 0.70767773 0.81763033 0.42957346 0.42521327
 0.71601896 0.77800948 0.58028436 0.55563981 0.83791469 0.66218009
 0.84       0.84       0.75393365 0.83033175 0.83886256 0.80227488
 0.82104265 0.82805687 0.7636019  0.72265403 0.84       0.84
 0.69630332 0.69137441 0.70236967 0.56436019 0.70957346 0.7236019
 0.55829384 0.57364929 0.83753555 0.83905213 0.82597156 0.73611374
 0.84       0.69308057 0.70236967 0.82976303 0.70900474 0.70312796
 0.84       0.7014218         nan        nan        nan        nan
        nan        nan        nan        nan        nan        nan
        nan        nan        nan        nan        nan        nan
        nan        nan        nan        nan        nan        nan
        nan        nan        nan        nan        nan        nan
        nan        nan        nan        nan        nan        nan
        nan        nan        nan        nan        nan        nan
        nan        nan        nan        nan        nan        nan
        nan        nan        nan        nan        nan        nan
        nan        nan        nan        nan]
  warnings.warn(
```

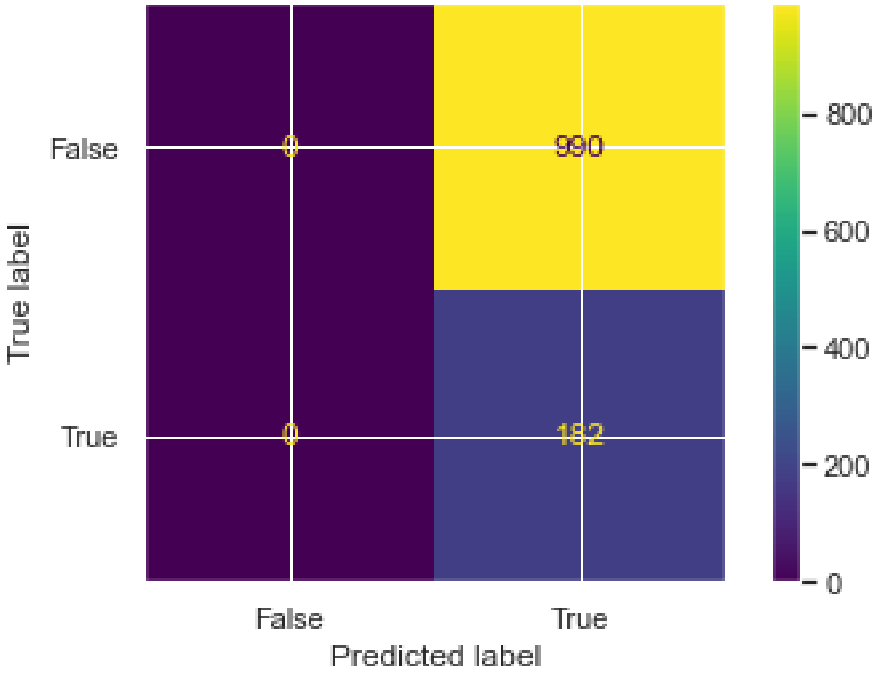
1.2.2 K-Neighbors

[37]:
```
cv = ShuffleSplit(n_splits=5, test_size=0.3, random_state=1)

param_grid = {
    'n_neighbors': [3, 5,7,9],
    'weights': ['uniform', 'distance'],
    'algorithm': ['auto', 'ball_tree', 'kd_tree', 'brute']
}

gridSearch = GridSearchCV(KNeighborsClassifier(), param_grid, cv=cv,␣
 ↪scoring='accuracy', verbose=2, n_jobs=-1)
gridSearch.fit(X_train, Y_train)

print('Score: ', gridSearch.best_score_)
print('Parameters: ', gridSearch.best_params_)
```

```
Fitting 5 folds for each of 32 candidates, totalling 160 fits
Score:  0.8288151658767774
Parameters:  {'algorithm': 'auto', 'n_neighbors': 9, 'weights': 'uniform'}
```

[38]:
```
plot_confusion_matrix(gridSearch_data1, X_test, Y_test)
```

[38]:
```
<sklearn.metrics._plot.confusion_matrix.ConfusionMatrixDisplay at
0x7fb79a57d5b0>
```



1.2.3 Naive Bayes Classifier

[39]:

```
from sklearn.naive_bayes import GaussianNB
#clf = GaussianNB()
#nb_model = clf.fit(X_train,y_train)
#print("Accuracy of Naive Bayes of test set:",nb_model.score(X_test,y_test))
#print("Accuracy of Naive Bayes of train set:",nb_model.score(X_train,y_train))

cv = ShuffleSplit(n_splits=5, test_size=0.3, random_state=1)

param_grid = {
    'var_smoothing': [1e-9, 1e-7],
}

gridSearch = GridSearchCV(GaussianNB(), param_grid, cv=cv, scoring='accuracy',␣
 ↪verbose=2, n_jobs=-1)
gridSearch.fit(X_train, Y_train)

print('Score: ', gridSearch.best_score_)
print('Parameters: ', gridSearch.best_params_)
```

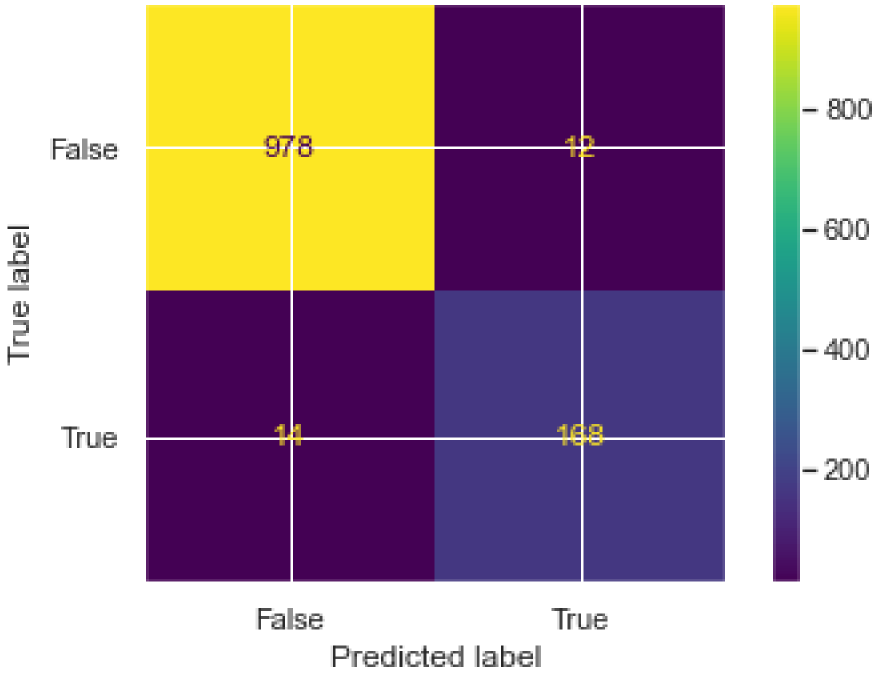
```
Fitting 5 folds for each of 2 candidates, totalling 10 fits
Score:  0.9759241706161138
Parameters:  {'var_smoothing': 1e-09}
```

[40]:

```
plot_confusion_matrix(gridSearch, X_test, Y_test)
```

[40]:

```
<sklearn.metrics._plot.confusion_matrix.ConfusionMatrixDisplay at
0x7fb79a50e7f0>
```



1.2.4 SVM

```
[42]: from sklearn.svm import SVC
      clf = SVC(kernel = 'rbf')
      svm_model = clf.fit(X_train,Y_train)
      print("Accuracy of SVM of test set:",svm_model.score(X_test,Y_test))
      #print("Accuracy of Decision Tree of train set:",svm_model.
       ↪score(X_train,Y_train))
```

```
Accuracy of SVM of test set: 0.8447098976109215
```

1.2.5 Logistic Regression

```
[43]: from sklearn.linear_model import LogisticRegression
      clf = LogisticRegression()
      lg_model = clf.fit(X_train, Y_train)
      #rint("Accuracy of train:",lg_model.score(X_train,y_train))
      print("Accuracy of test:",lg_model.score(X_test,Y_test))
```

```
Accuracy of test: 0.8387372013651877
```