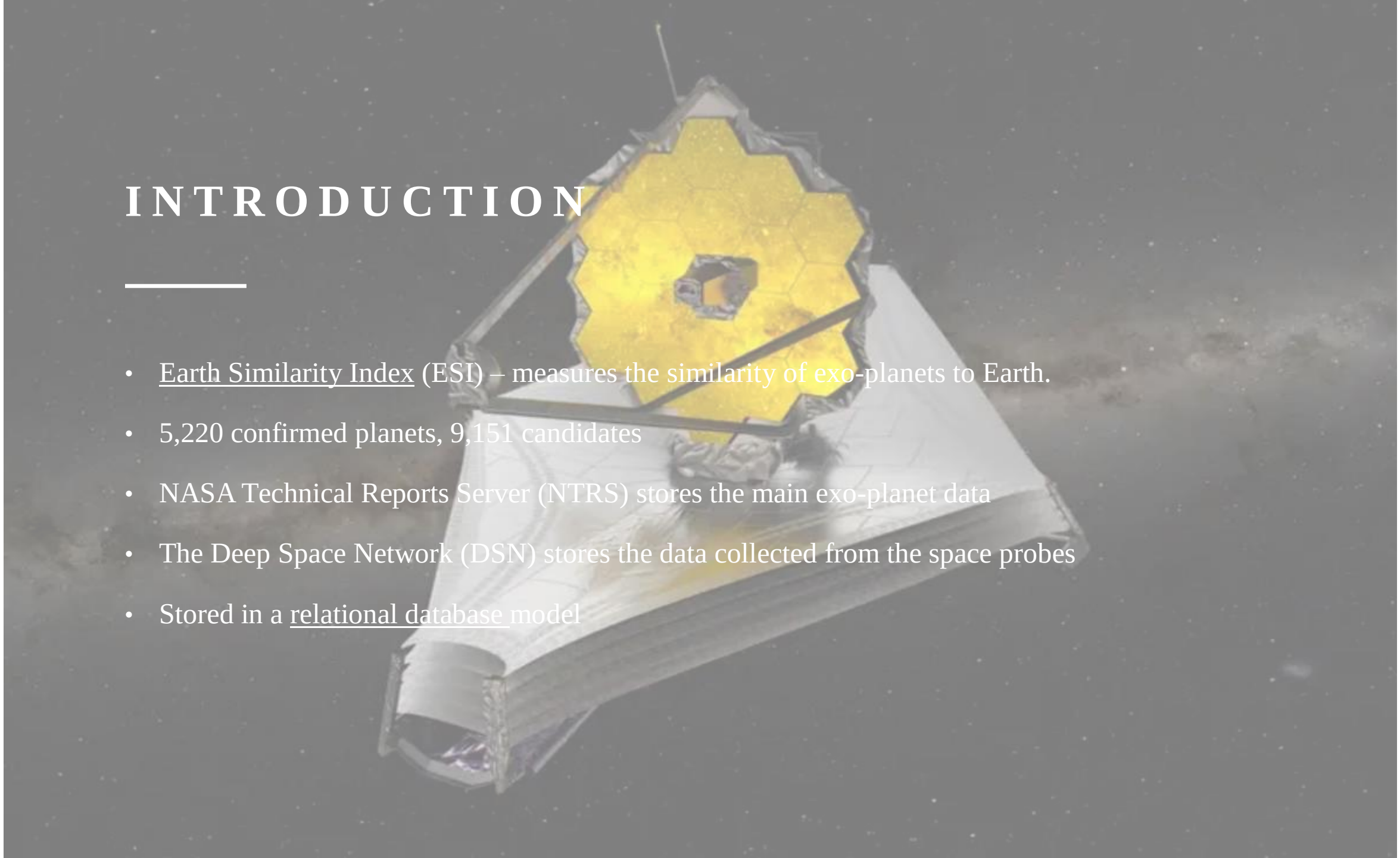
NASA'S EXO-PLANET DATABASE ANALYSIS

By Naga Jyothi Madamanchi



INTRODUCTION

- Earth Similarity Index (ESI) – measures the similarity of exo-planets to Earth.
- 5,220 confirmed planets, 9,151 candidates
- NASA Technical Reports Server (NTRS) stores the main exo-planet data
- The Deep Space Network (DSN) stores the data collected from the space probes
- Stored in a relational database model

THE 4 ESI VARIANTS

- NASA’s Standard ESI
- NASA’s Weighted ESI
- Derived Custom ESI
- Derived Revised ESI

STANDARD ESI

- Measures 2 factors: stellar flux, and planet radius
- The first of NASA's ESI equations
- Earth's radius (Re) and stellar flux (Fe) serve as baseline

Standard ESI:

$$\mathrm{ESI}(F,R) = 1 - \sqrt{\frac{1}{2}\left[\left(\frac{F-Fe}{F+Fe}\right)^2 + \left(\frac{R-Re}{R+Re}\right)^2\right]}$$

Highest ESI: Teegarden's Star B = 0.9502

WEIGHTED ESI

- 5 variables: stellar flux, radius, density, escape velocity, and temperature
- Each variable has weights
- More accurate than Standard ESI

Weighted ESI variables:

Variables	Weights
Flux	1
Radius	0.57
Density	1.07
Escape Velocity	0.70
Temperature	5.58

Weighted ESI:

$$\mathrm{ESI}(F,R,D,E,T) = 1 - \sqrt{\frac{1}{5}\left[\left(\frac{F-Fe}{F+Fe}\right)^2 + (0.57)\left(\frac{R-Re}{R+Re}\right)^2 + (1.07)\left(\frac{D-De}{D+De}\right)^2 + (0.70)\left(\frac{E-Ee}{E+Ee}\right)^2 + (5.58)\left(\frac{T-Te}{T+Te}\right)^2\right]}$$

Highest ESI: Teegarden's Star B = 0.9636

CUSTOM ESI

- First of my own derived test ESI equations
- 9 variables in total, unweighted

Variables: Flux, Radius, Gravity, Planet Mass, Temperature, Star Temperature, Star Mass, Orbital Period, Density.

Custom ESI:

$$\mathrm{ESI}(F,R,G,M,T,K,S,O,D) = \prod_{i=1}^{9}\left(1-\left|\frac{x_i - x_{io}}{x_i + x_{io}}\right|\right)$$

Highest ESI: Venus = 0.7996

REVISED ESI

- Weighted variant of the Custom ESI
- Accounts factors such as temperature and star mass more heavily

Revised ESI variables:

Variables	Weights
Flux	3.2
Radius	0.57
Gravity	4.75
Planet Mass	0.4
Temperature	10.58
Star Temperature	1
Star Mass	1
Orbital Period	1
Density	2.8

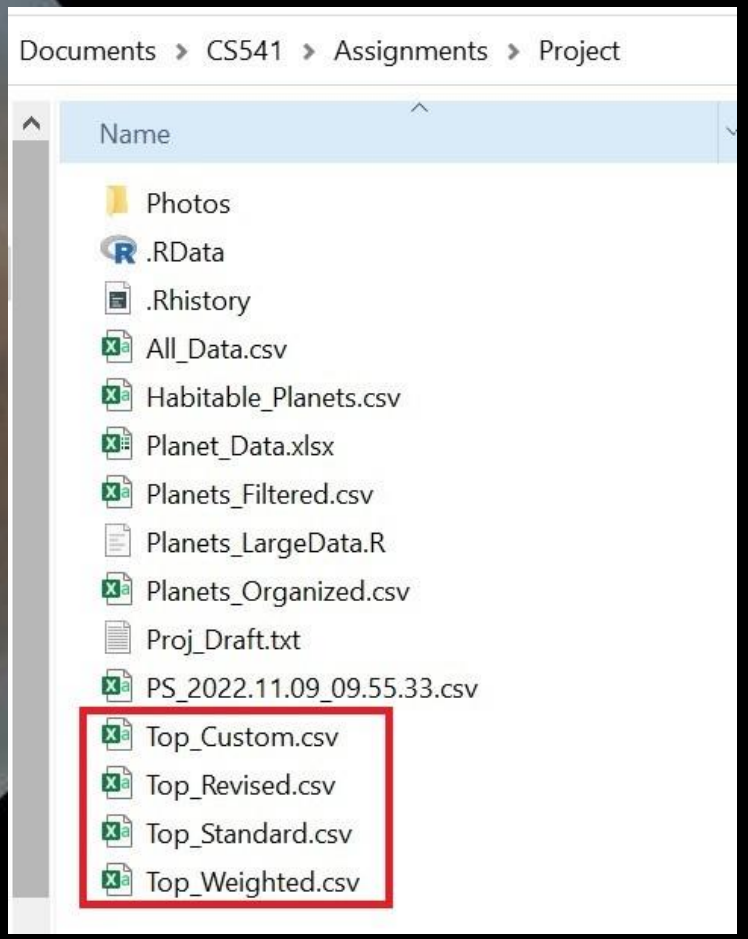
Revised ESI:

$$\mathrm{ESI}(F,R,G,M,T,K,S,O,D) = \prod_{i=1}^{9}\left(1-\left|\frac{x_i - x_{io}}{x_i + x_{io}}\right|\right)^{\frac{wi}{9}}$$

Highest ESI: Kepler-452 B = 0.8478

CODING SETUP

- Downloaded NASA's exoplanet catalog as a .csv file
- Installed R language and R studio to process database
- Filtered out unnecessary columns, 92 was the initial amount
- Filtered out blank data to make ESI calculations possible



RStudio

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Go to file/function | Addins | Project: (None)

Planets_LargeData.R | topstandard | topweighted | topcustom | toprevised | revised

Source on Save | Run | Source

```
1  #installs the necessary packages to read .csv files
2  #install.packages("tidyverse")
3  library(tidyverse)
4
5  #creates a planets variable to read the .csv file into a large data table
6  planets <- read.csv(file="PS_2022.11.09_09.55.33.csv", skip=96, sep=",")
7
8  #creates a filtered variant of table above, -c skips over certain columns
9  filtered <- read.csv(file="PS_2022.11.09_09.55.33.csv", skip=96, sep=",")[-c(2:11,13:19,21:27,29:40,42:44,46:51,53:55,56:59,61:9
10
11 #generates a .csv file from the filtered data
12 write.csv(filtered, "Planets_Filtered.csv", row.names=FALSE)
13 #reads the .csv file of filtered data
14 averages <- read.csv(file="Planets_filtered.csv", sep=",")
15
16 #filters out any nulls or zeros one column at a time
17 library(dplyr)
18 orbit <- subset(averages, !is.na(pl_orbper))
19 radius <- subset(orbit, !is.na(pl_rade))
20 mass <- subset(radius, !is.na(pl_bmasse))
21 flux <- subset(mass, !is.na(pl_insol))
22 temperature <- subset(flux, !is.na(pl_eqt))
23 startemp <- subset(temperature, !is.na(st_teff))
24 starmass <- subset(startemp, !is.na(st_mass))
25
26 #imports smaller .csv file with habitable planets
27 habitable <- read.csv(file="Habitable_Planets.csv", sep=",")
28 #appends habitable graph to star mass graph
29 organized <- rbind(habitable, starmass)
30
31 #exports organized .csv data
32
33
```

19:41 (Top Level) R Script

Console | Terminal | Background Jobs

R 4.2.2 · C:/Users/Administrator/Desktop/Documents/CS541/Assignments/Project/

```
Platform: x86_64-w64-mingw32/x64 (64-bit)

R is free software and comes with ABSOLUTELY NO WARRANTY.
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'help.start()' for an HTML browser interface to help.
Type 'q()' to quit R.

[Workspace loaded from C:/Users/Administrator/Desktop/Documents/CS541/Assignments/Project/.RData]

> |
```

Environment | History | Connections | Tutorial

154 MiB | List

R | Global Environment

Data

averages	33719 obs. of 8 variabl…
custom	313 obs. of 14 variables
escape	313 obs. of 10 variables
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.RData	4.3 MB
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~$Planet_Data.xlsx	165 B
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RStudio

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Planets_LargeData.R | topstandard | topweighted | topcustom | toprevised | revised

Source on Save | Run | Source

```
31 #exports organized .csv data
32 write.csv(organized, "Planets_Organized.csv", row.names=FALSE)
33
34 #creates renamed table
35 oldnames = c("pl_name", "pl_orbper", "pl_rade", "pl_bmasse", "pl_insol", "pl_eqt", "st_teff", "st_mass")
36 newnames = c("Planet_Name", "Orbit_Period", "Planet_Radius", "Planet_Mass", "Stellar_Flux", "Temperature", "Star_Temperature", '
37 renamed <- organized %>% rename_at(vars(oldnames), ~ newnames)
38 #removes duplicates
39 nodups <- renamed %>% distinct(Planet_Name, .keep_all=TRUE)
40
41 #adds columns based on calculations
42 planetdensity <- nodups %>% mutate(Planet_Density=(5.51*(4.19*(Planet_Mass/((4/3)*(22/7)*(Planet_Radius^3))))))
43 escape <- planetdensity %>% mutate(Escape_Velocity=(11.186*(0.7072*sqrt((Planet_Mass*2)/Planet_Radius))))
44 gravity <- escape %>% mutate(Gravity=(9.82*(Planet_Mass/(Planet_Radius)^2)))
45
46 #ESI variants analysis
47 #ESI Standard
48 standard <- gravity %>% mutate(ESI_Standard=
49 (1-sqrt((1/2)*(((Stellar_Flux-1)/(Stellar_Flux+1))^2+
50                ((Planet_Radius-1)/(Planet_Radius+1))^2))))
51 #ESI Weighted
52 weighted <- standard %>% mutate(ESI_Weighted=
53 (1-sqrt((1/5)*(((Stellar_Flux-1)/(Stellar_Flux+1))^2+
54         (0.57*((Planet_Radius-1)/(Planet_Radius+1))^2)+
55         (1.07*((Planet_Density-5.51)/(Planet_Density+5.51))^2)+
56          (0.7*((Escape_Velocity-11.186)/(Escape_Velocity+11.186))^2)+
57         (5.58*((Temperature-288)/(Temperature+288))^2)))))
58 #ESI Custom
59 custom <- weighted %>% mutate(ESI_Custom=
60 (1-sqrt((1/9)*(((Stellar_Flux-1)/(Stellar_Flux+1))^2+
61                ((Planet_Radius-1)/(Planet_Radius+1))^2+
62
63
```

90:35 (Top Level) R Script

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```
66                ((Star_Mass-1)/(Star_Mass+1))^2+
67                ((Orbit_Period-365)/(Orbit_Period+365))^2+
68                ((Planet_Density-5.51)/(Planet_Density+5.51))^2))))
69  #ESI Revised
70  revised <- custom %>% mutate(ESI_Revised=
71  (1-sqrt((1/9)*((3.2*((Stellar_Flux-1)/(Stellar_Flux+1)))^2)+
72                (0.57*((Planet_Radius-1)/(Planet_Radius+1)))^2)+
73                (4.75*((Gravity-9.82)/(Gravity+9.82)))^2)+
74                (0.2*((Planet_Mass-1)/(Planet_Mass+1)))^2)+
75                (10.58*((Temperature-288)/(Temperature+288)))^2)+
76                ((Star_Temperature-5778)/(Star_Temperature+5778))^2+
77                ((Star_Mass-1)/(Star_Mass+1))^2+
78                ((Orbit_Period-365)/(Orbit_Period+365))^2+
79                (2.8*((Planet_Density-5.51)/(Planet_Density+5.51)))^2)))))
80
81  #exports all usable .csv data
82  write.csv(revised, "All_Data.csv", row.names=FALSE)
83
84  #gets top 10 from each analysis
85  topstandard <- revised[-c(13:15)] %>% arrange(desc(ESI_Standard)) %>% slice(1:11)
86  topweighted <- revised[-c(12,14:15)] %>% arrange(desc(ESI_Weighted)) %>% slice(1:11)
87  topcustom <- revised[-c(12:13,15)] %>% arrange(desc(ESI_Custom)) %>% slice(1:11)
88  toprevised <- revised[-c(12:14)] %>% arrange(desc(ESI_Revised)) %>% slice(1:11)
89
90  #generates .csv files from top 10s
91  write.csv(topstandard, "Top_Standard.csv", row.names=FALSE)
92  write.csv(topweighted, "Top_Weighted.csv", row.names=FALSE)
93  write.csv(topcustom, "Top_Custom.csv", row.names=FALSE)
94  write.csv(toprevised, "Top_Revised.csv", row.names=FALSE)
95
96  #rm (remaned) #removes any unneeded table
```

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EXPORT INTO GABEN

- ESI equations used to create 4 sub tables from the main filtered table
- The main table and the 4 ESI tables were exported as .csv files
- The .csv files were transferred over to the ”CS541” folder in the Gaben server
- Made backup of data in hard drive due to possible SQL data corruption

RELATIONAL DIAGRAM

- The original raw .csv file is the source of all the data
- "Habitable Planets" contains supplemental habitable exo-planet data
- Column names differ between "Habitable Planets" and the filtered "Data with No Blanks"
- Identifying relationship because of difference between those two tables

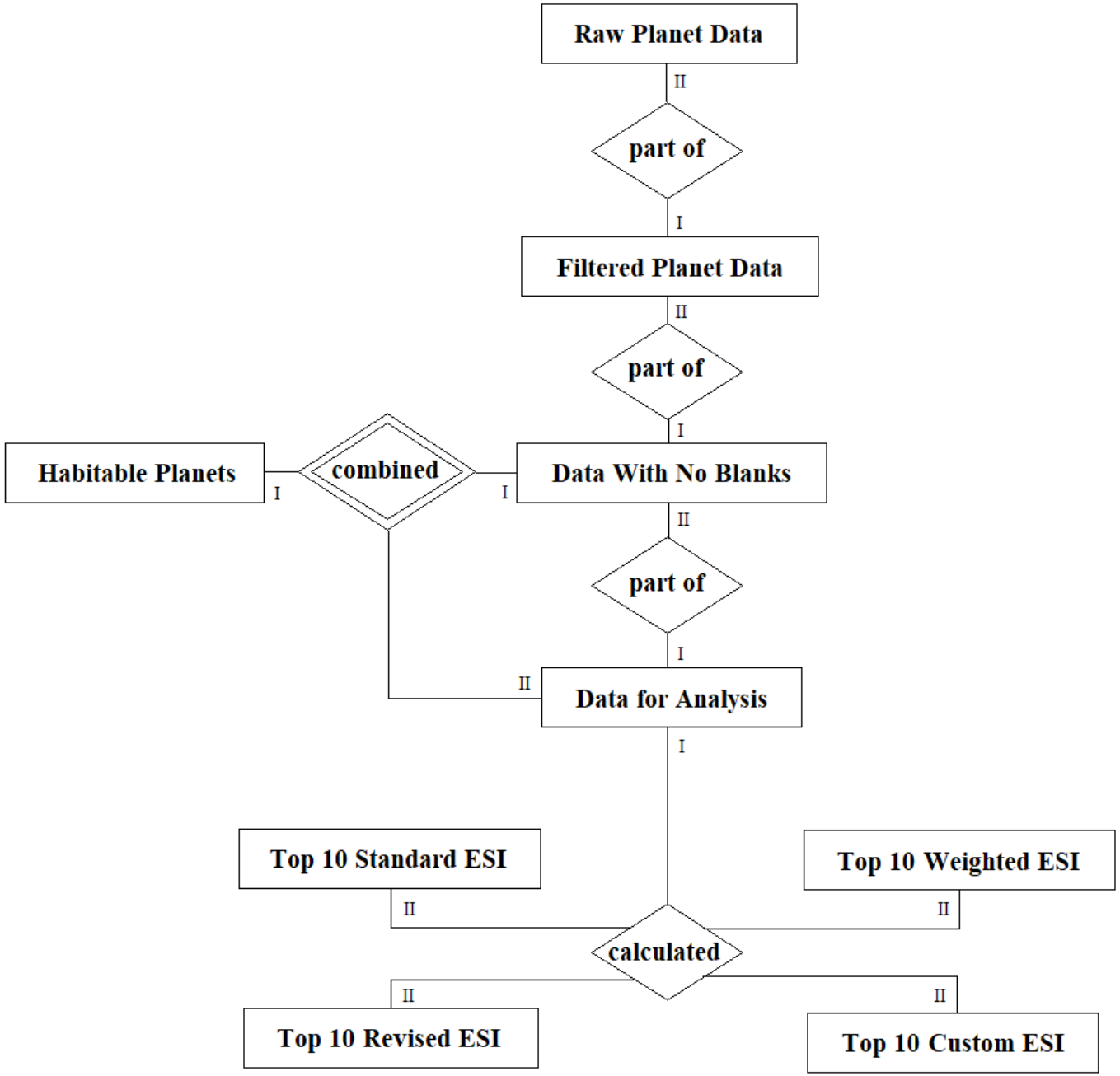
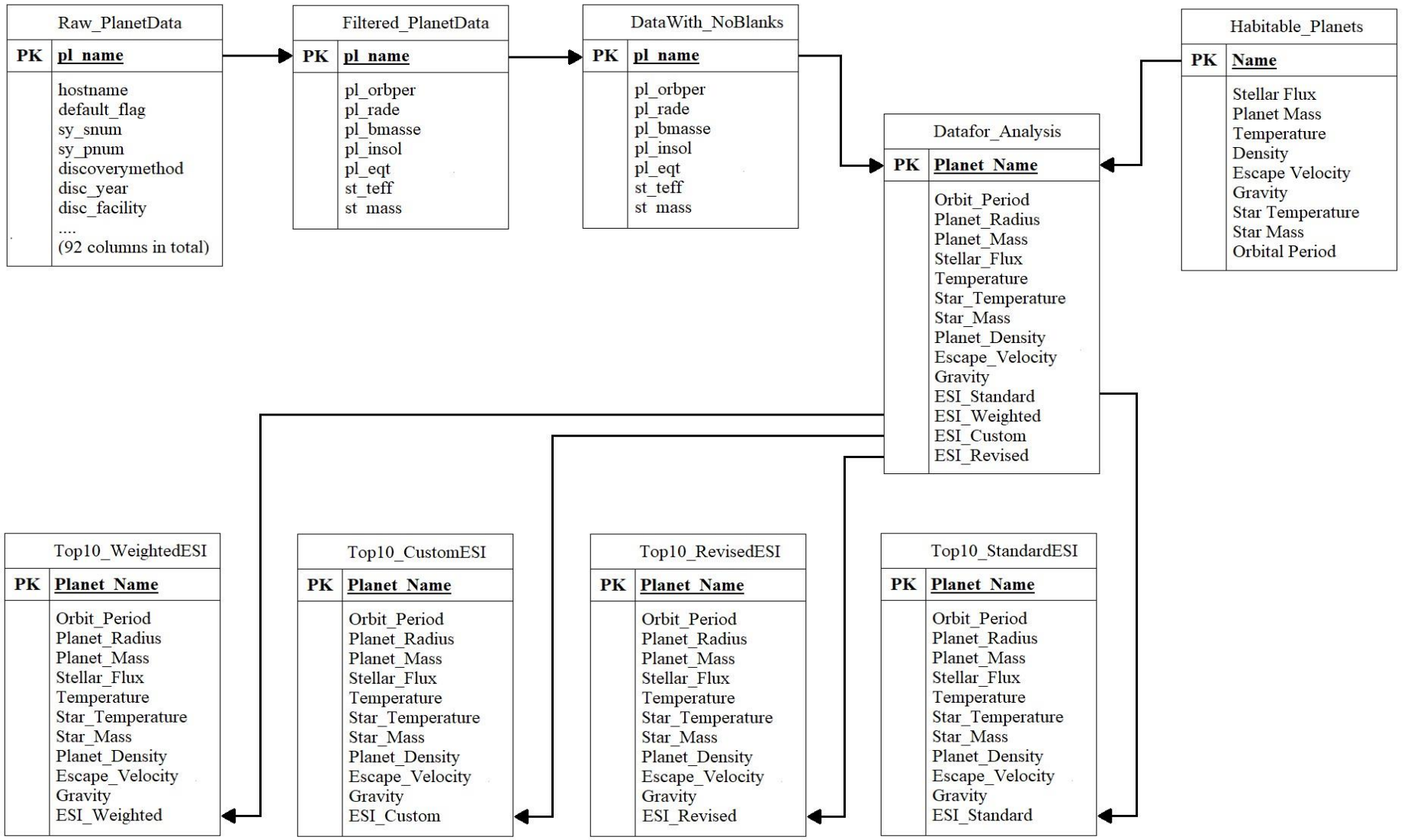


TABLE LAYOUT



INSERTION INTO SQL

```
CREATE TABLE `alldata` (
  `pname` varchar(20) NOT NULL,
  `operiod` real DEFAULT NULL,
  `radius` real DEFAULT NULL,
  `pmass` real DEFAULT NULL,
  `flux` real DEFAULT NULL,
  `temp` real DEFAULT NULL,
  `sttemp` real DEFAULT NULL,
  `stmass` real DEFAULT NULL,
  `density` real DEFAULT NULL,
  `velocity` real DEFAULT NULL,
  `gravity` real DEFAULT NULL,
  `standard` real DEFAULT NULL,
  `weighted` real DEFAULT NULL,
  `custom` real DEFAULT NULL,
  `revised` real DEFAULT NULL,
  PRIMARY KEY (`pname`)
) ENGINE=MyISAM DEFAULT CHARSET=utf8;


BULK INSERT alldata
from 'All_Data.csv'
with (firstrow = 2,
      fieldterminator = ',',
      rowterminator='\n',
      batchsize=313,
      maxerrors=10);
```

Scre

```
mysql> describe alldata;
+----------+-------------+------+-----+---------+-------+
| Field    | Type        | Null | Key | Default | Extra |
+----------+-------------+------+-----+---------+-------+
| pname    | varchar(20) | NO   | PRI | NULL    |       |
| operiod  | double      | YES  |     | NULL    |       |
| radius   | double      | YES  |     | NULL    |       |
| pmass    | double      | YES  |     | NULL    |       |
| flux     | double      | YES  |     | NULL    |       |
| temp     | double      | YES  |     | NULL    |       |
| sttemp   | double      | YES  |     | NULL    |       |
| stmass   | double      | YES  |     | NULL    |       |
| density  | double      | YES  |     | NULL    |       |
| velocity | double      | YES  |     | NULL    |       |
| gravity  | double      | YES  |     | NULL    |       |
| standard | double      | YES  |     | NULL    |       |
| weighted | double      | YES  |     | NULL    |       |
| custom   | double      | YES  |     | NULL    |       |
| revised  | double      | YES  |     | NULL    |       |
+----------+-------------+------+-----+---------+-------+
15 rows in set (0.02 sec)
```

Screenshot

ESI SQL QUERIES

- Added columns to the main Data for Analysis table
- SQL query uses planet name for the “group by” function
- Example below uses Standard ESI equation to create “esistandard” column

Standard ESI:

$$\mathrm{ESI}(F,R) = 1 - \sqrt{\frac{1}{2}\left[\left(\frac{F-Fe}{F+Fe}\right)^2 + \left(\frac{R-Re}{R+Re}\right)^2\right]}$$

```
SELECT pname, (1-SQRT((1/2)*(POWER((flux-1)/(flux+1),2)+
              POWER((radius-1)/(radius+1),2))))
              as esistandard
FROM alldata
Group by pname;
```

R AND SQL COMPARISON

```sql
SELECT pname, (1-SQRT((1/2)*(POWER((flux-1)/(flux+1),2)+
              POWER((radius-1)/(radius+1),2))))
              as esistandard
FROM alldata
Group by pname;

SELECT pname, 1-SQRT((1/5)*(POWER((flux-1)/(flux+1),2)+
              (0.57*POWER((radius-1)/(radius+1),2))+
              (1.07*POWER((density-5.51)/(density+5.51),2))+
              (0.7*POWER((velocity-11.186)/(velocity+11.186),2))+
              (5.58*POWER((temp-288)/(temp+288),2))))
              as esiweighted
FROM alldata
Group by pname;

SELECT pname, 1-SQRT((1/9)*(POWER((flux-1)/(flux+1),2)+
              POWER((radius-1)/(radius+1),2)+
              POWER((gravity-9.82)/(gravity+9.82),2)+
              POWER((mass-1)/(mass+1),2)+
              POWER((temp-288)/(temp+288),2)+
              POWER((sttemp-5778)/(sttemp+5778),2)+
              POWER((stmass-1)/(stmass+1),2)+
              POWER((operiod-365)/(operiod+365),2)+
              POWER((density-5.51)/(density+5.51),2)))
              as esicustom
FROM alldata
Group by pname;

SELECT pname, 1-SQRT((1/9)*(3.2*(POWER((flux-1)/(flux+1),2))+
              (0.57*POWER((radius-1)/(radius+1),2))+
              (4.75*POWER((gravity-9.82)/(gravity+9.82),2))+
              (0.2*POWER((mass-1)/(mass+1),2))+
              (10.58*POWER((temp-288)/(temp+288),2))+
              POWER((sttemp-5778)/(sttemp+5778),2)+
              POWER((stmass-1)/(stmass+1),2)+
              POWER((operiod-365)/(operiod+365),2)+
              (2.8*POWER((density-5.51)/(density+5.51),2))))
              as esirevised
FROM alldata
Group by pname;
```

```r
#ESI variants analysis
#ESI Standard
standard <- gravity %>% mutate(ESI_Standard=
(1-sqrt((1/2)*(((Stellar_Flux-1)/(Stellar_Flux+1))^2+
               ((Planet_Radius-1)/(Planet_Radius+1))^2))))
#ESI Weighted
weighted <- standard %>% mutate(ESI_Weighted=
(1-sqrt((1/5)*(((Stellar_Flux-1)/(Stellar_Flux+1))^2+
         (0.57*((Planet_Radius-1)/(Planet_Radius+1))^2)+
         (1.07*((Planet_Density-5.51)/(Planet_Density+5.51))^2)+
          (0.7*((Escape_Velocity-11.186)/(Escape_Velocity+11.186))^2)+
         (5.58*((Temperature-288)/(Temperature+288))^2)))))
#ESI Custom
custom <- weighted %>% mutate(ESI_Custom=
(1-sqrt((1/9)*(((Stellar_Flux-1)/(Stellar_Flux+1))^2+
               ((Planet_Radius-1)/(Planet_Radius+1))^2+
               ((Gravity-9.82)/(Gravity+9.82))^2+
               ((Planet_Mass-1)/(Planet_Mass+1))^2+
               ((Temperature-288)/(Temperature+288))^2+
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               ((Star_Mass-1)/(Star_Mass+1))^2+
               ((Orbit_Period-365)/(Orbit_Period+365))^2+
               ((Planet_Density-5.51)/(Planet_Density+5.51))^2))))
#ESI Revised
revised <- custom %>% mutate(ESI_Revised=
(1-sqrt((1/9)*((3.2*((Stellar_Flux-1)/(Stellar_Flux+1)))^2)+
               (0.57*((Planet_Radius-1)/(Planet_Radius+1)))^2)+
               (4.75*((Gravity-9.82)/(Gravity+9.82)))^2)+
               (0.2*((Planet_Mass-1)/(Planet_Mass+1)))^2)+
               (10.58*((Temperature-288)/(Temperature+288)))^2)+
               ((Star_Temperature-5778)/(Star_Temperature+5778))^2+
               ((Star_Mass-1)/(Star_Mass+1))^2+
               ((Orbit_Period-365)/(Orbit_Period+365))^2+
               (2.8*((Planet_Density-5.51)/(Planet_Density+5.51)))^2)))))
```
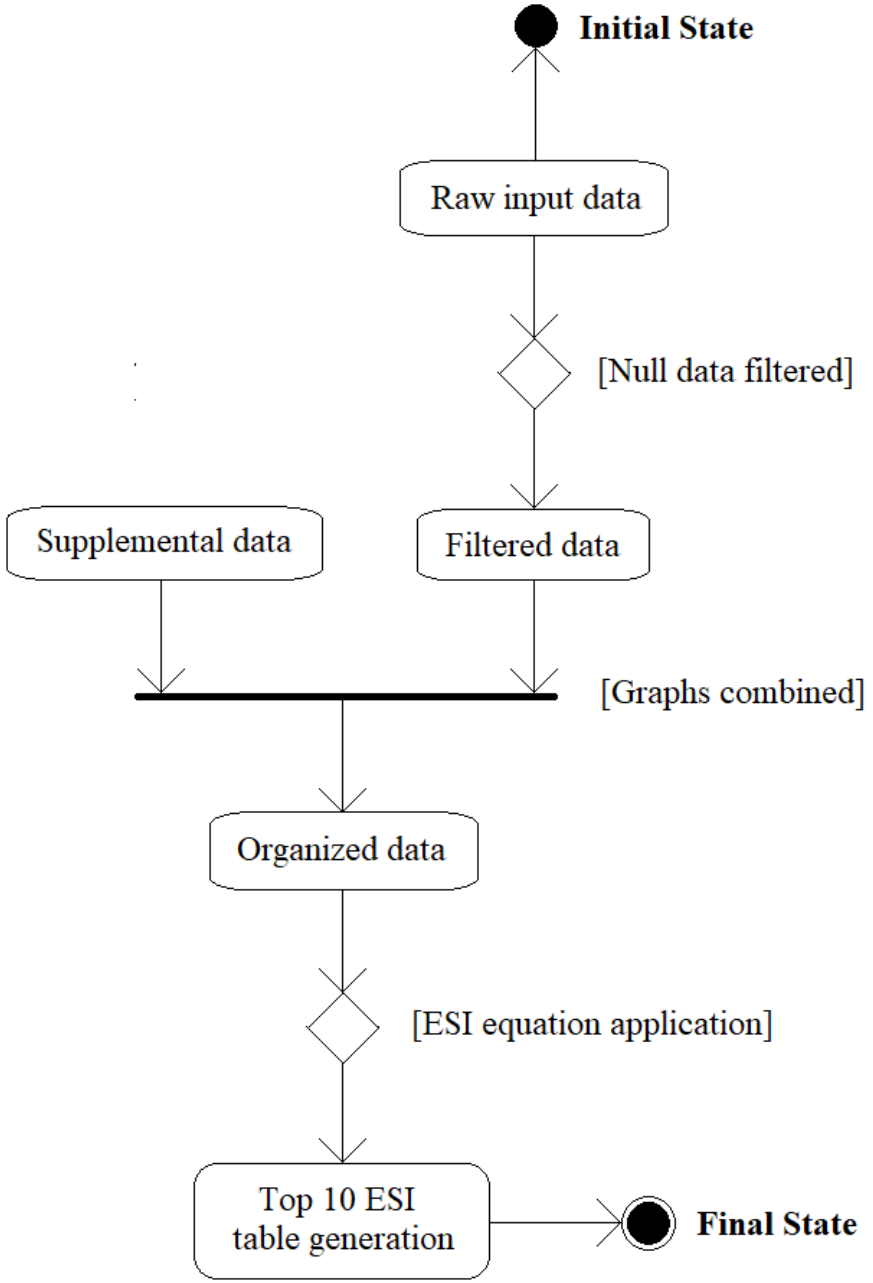
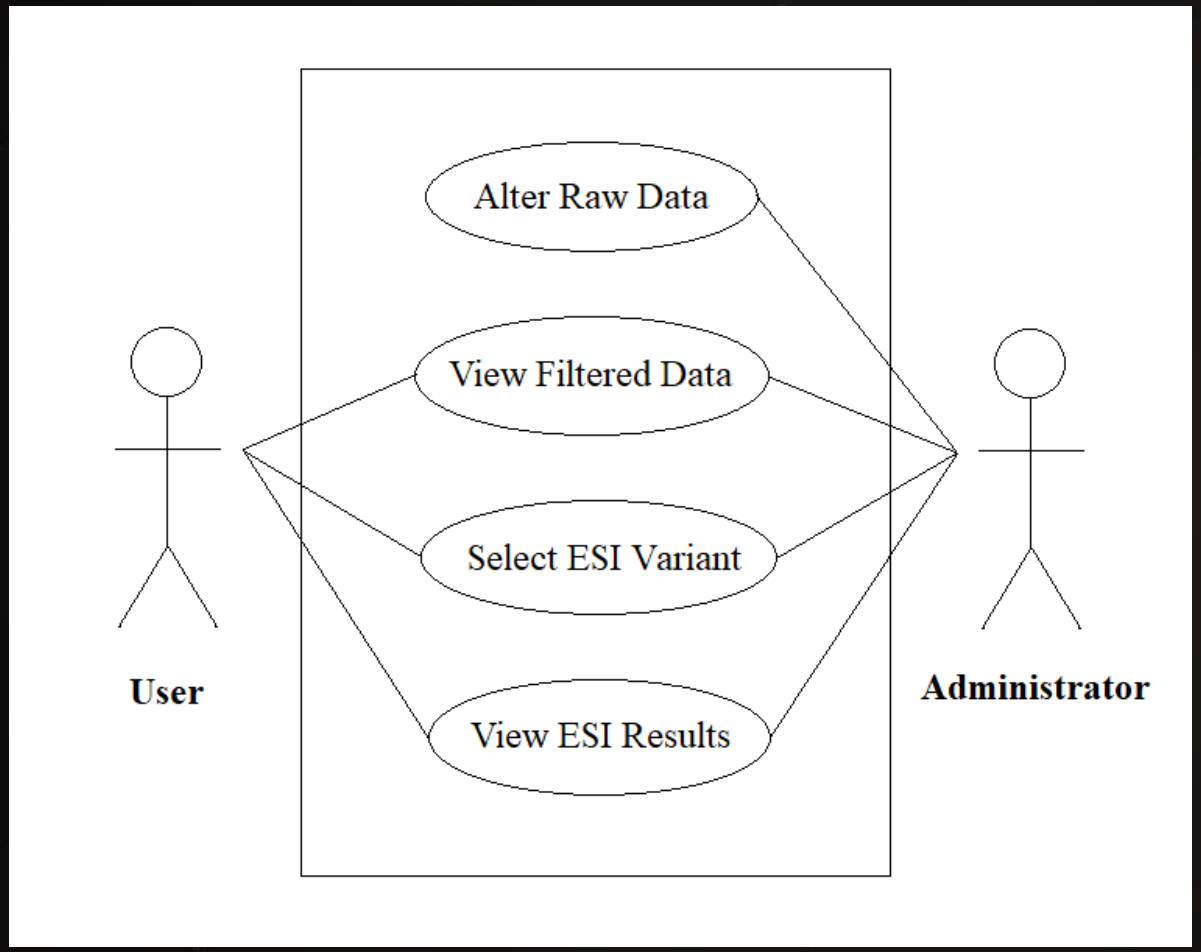

SOFTWARE DESIGN DIAGRAM

- Initial state is the downloaded NASA data
- Final state is the generation of 4 top 10 ESI variant tables



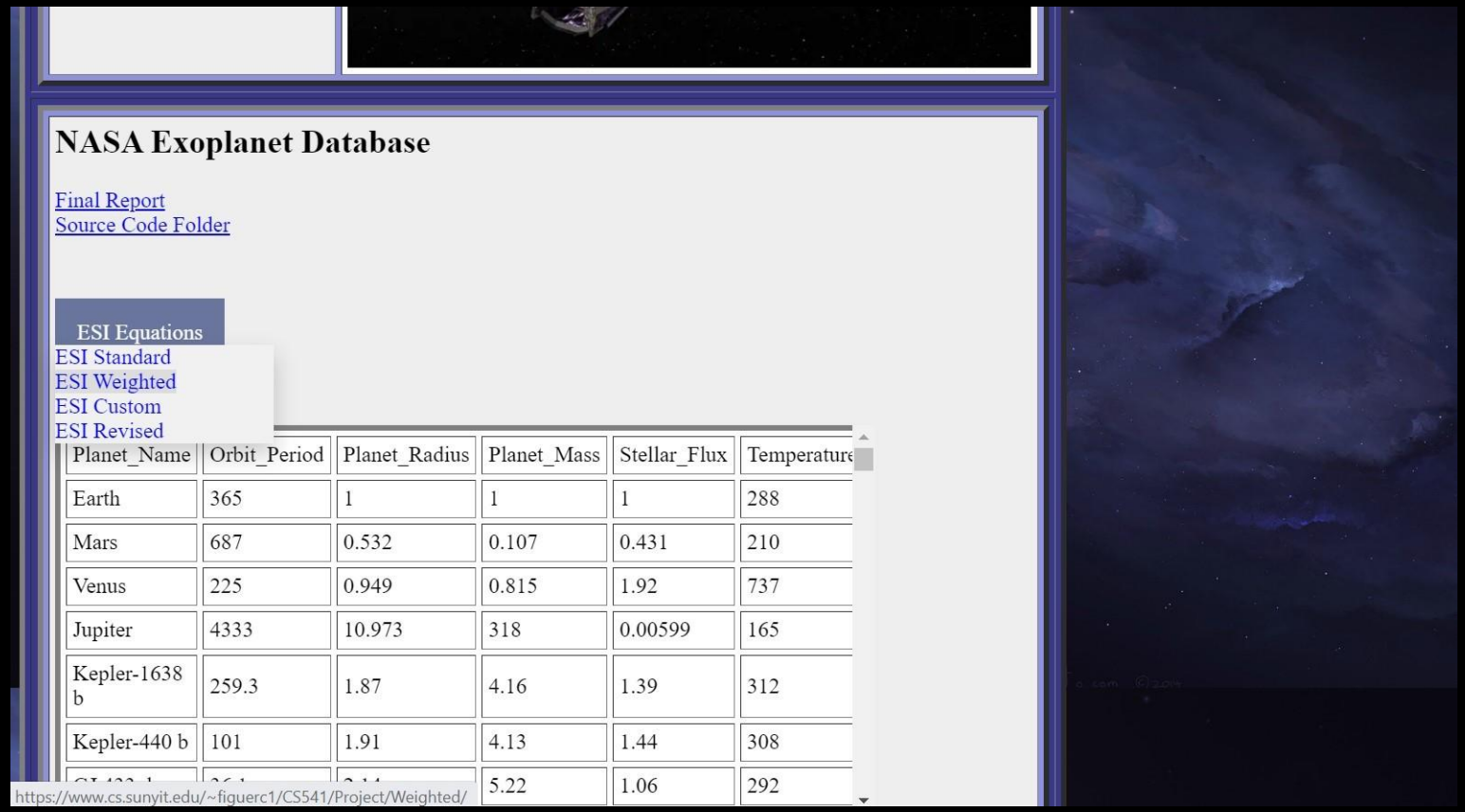
CASE DIAGRAM

- Simple user interface
- Options include selection and comparison of the ESI variants
- Uses CSS to create menu
- PHP to display tables



WEBSITE DEMO

- Link: https://www.cs.sunyit.edu/~madaman1/CS541/Project/



CHALLENGES OF CODING

- No direct link to NASA's database server
- Problem connecting R to Gaben server
- Possible permissions restriction
- Needed to copy .csv files into Gaben
- Renamed index HTML file to PHP

```
:~/www/CS541/Project$ nano index.html
:~/www/CS541/Project$ ls
 index.html      Top_Revised.csv   Top_Weighted.csv
 Top_Custom.csv  Top_Standard.csv
:~/www/CS541/Project$ mv index.html index.php
:~/www/CS541/Project$ ls
 index.php       Top_Revised.csv   Top_Weighted.csv
 Top_Custom.csv  Top_Standard.csv
:~/www/CS541/Project$
```

```
96  #rm (remaned) #removes any unneeded table
97
98  #import for exportation of data into SQL server
99  #install.packages("RODBC")
100 library(RODBC)
101
102 #writes tables into SQL database
103 sqlSave(revised, all_data, rownames = FALSE)
104 revised <- DBI::dbConnect("Driver={SQLServer};Server=10.156.192.30;Uid=f
105
```

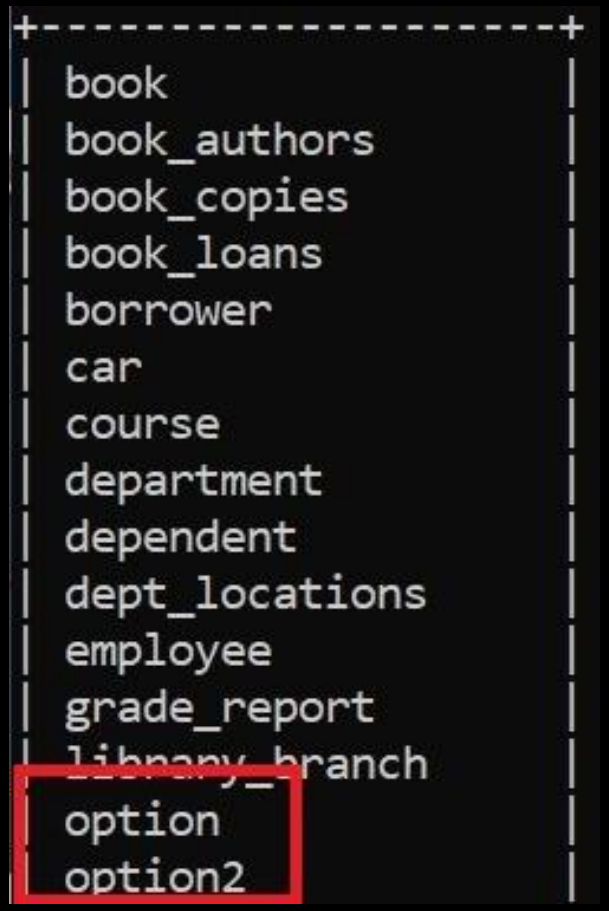
103:1 (Top Level)

Console | Terminal | Background Jobs

R 4.2.2 · C:/Users/Administrator/Desktop/Documents/CS541/Assignments/Project/

```
> revised <- DBI::odbcConnect("Driver={SQLServer};Server=10.156.192.30;Uid=figu
Error: 'odbcConnect' is not an exported object from 'namespace:DBI'
> #writes tables into SQL database
> sqlSave(revised, all_data, rownames = FALSE)
Error in sqlSave(revised, all_data, rownames = FALSE) :
  first argument is not an open RODBC channel
> revised <- odbDriverConnect("Driver={SQLServer};Server=10.156.192.30;Uid=figu
Error in odbDriverConnect("Driver={SQLServer};Server=10.156.192.30;Uid=figuerc
  could not find function "odbDriverConnect"
```

DATABASE CORRUPTION



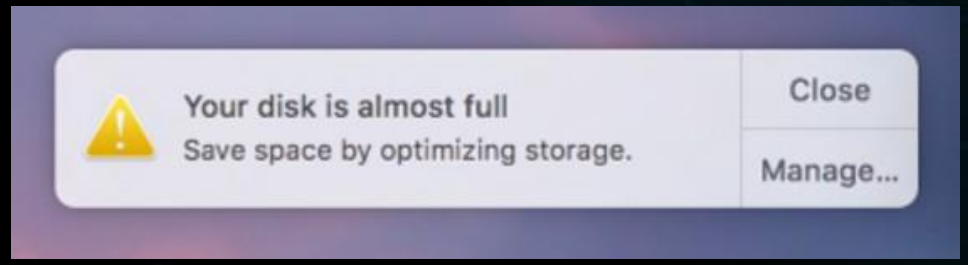
```
+--------------------+
| book               |
| book_authors       |
| book_copies        |
| book_loans         |
| borrower           |
| car                |
| course             |
| department         |
| dependent          |
| dept_locations     |
| employee           |
| grade_report       |
| library_branch     |
| option             |
| option2            |
```

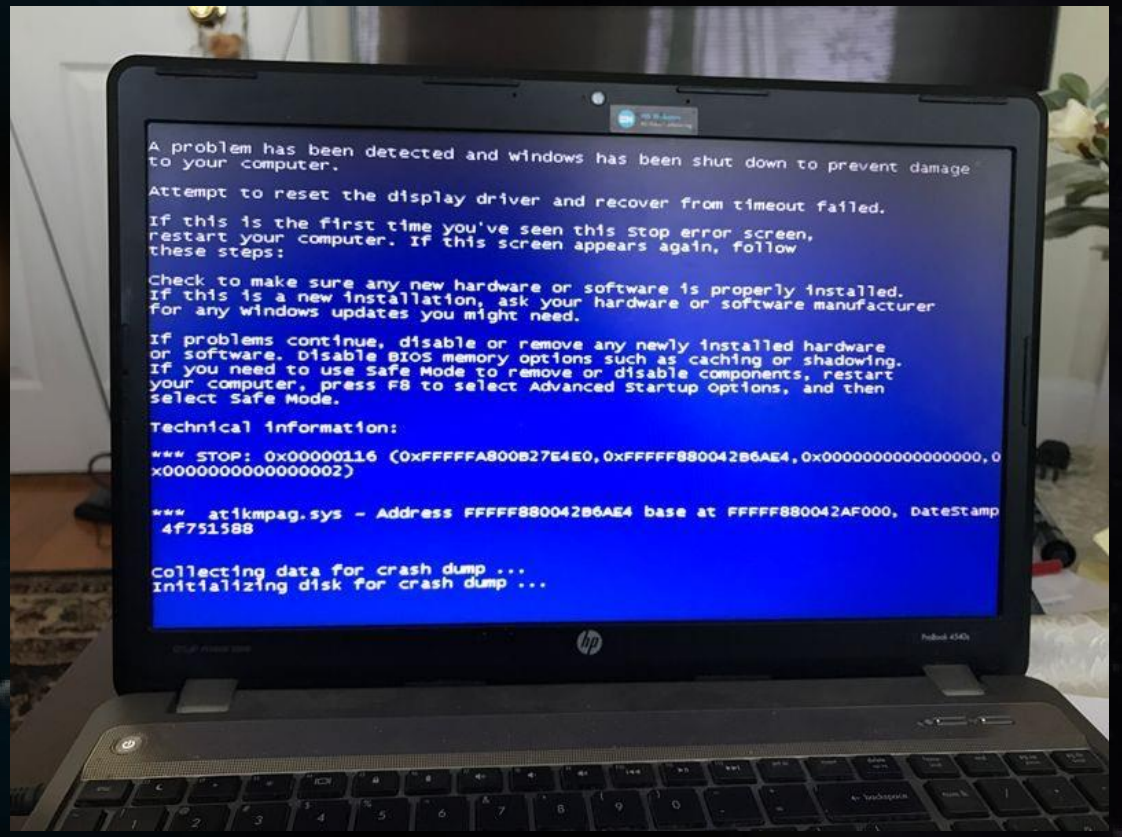
```
mysql> describe option2
    -> ;
+-------------+-------------+------+-----+---------+-------+
| Field       | Type        | Null | Key | Default | Extra |
+-------------+-------------+------+-----+---------+-------+
| serial_no   | varchar(25) | NO   | PRI |         |       |
| option_name | varchar(20) | NO   | PRI |         |       |
| price       | varchar(10) | YES  |     | NULL    |       |
+-------------+-------------+------+-----+---------+-------+
3 rows in set (0.01 sec)
```

```
| price       | varchar(10) | YES  |     | NULL    |       |
+-------------+-------------+------+-----+---------+-------+
3 rows in set (0.01 sec)

mysql> describe option;
ERROR 1064 (42000): You have an error in your SQL syntax; chec
 for the right syntax to use near 'option' at line 1
mysql>
```

WHY NO MORE ATTEMPTS?

- Windows PC broke down
- Stuck working with Mac with limited storage





SOURCES

- [1] https://exoplanets.nasa.gov/discovery/exoplanet-catalog/
- [2] https://phl.upr.edu/projects/habitable-exoplanets-catalog
- [3] https://phl.upr.edu/projects/earth-similarity-index-esi
- [4] https://interestingengineering.com/science/earth-similarity-index-where-could-we-livebesides-earth
- [5] http://www.imatheq.com/imatheq/com/imatheq/math-equation-editor.html
- [6] https://www.upi.com/Science_News/2017/02/08/NASA-Red-dwarf-habitable-zones-maynot-be-so-habitable/2881486579322/
- [7] https://www.geeksforgeeks.org/how-to-display-data-from-csv-file-using-php/
- [8] https://www.w3schools.com/howto/howto_css_dropdown.asp
- [9] https://popsql.com/learn-sql/sql-server/how-to-import-a-csv-in-sql-server
- [10] https://stackoverflow.com/questions/7367750/average-of-multiple-columns