Planetary Simulation

This report will run a simulation that assigns system information for every planet in the `planets.xml` database so that we can examine how well the simulation produces socio-industrial codes, population, and HPG status. We run this simulation for the year of 3047 so that we can properly identify clan homeworlds, and only clan homeworlds, as clan foundings.

We use the basic system detailed in *Campaign Operations* to assign these values. However, we have made a variety of tweaks to the system that are detailed below. These tweaks are intended to increase variability and reduce the "chunkiness" of the basic rules, as well as address some areas where the distributions were not producing realistic values.

Changes to Population Generation

Populations are generated in *Campaign Operations* by first calculating a base population number and then multiplying this base number by the sum of a variable number of d6 rolls. There are also "normal" base numbers and "high" base numbers where the high base numbers are produced by rolling a 6 on a single d6.

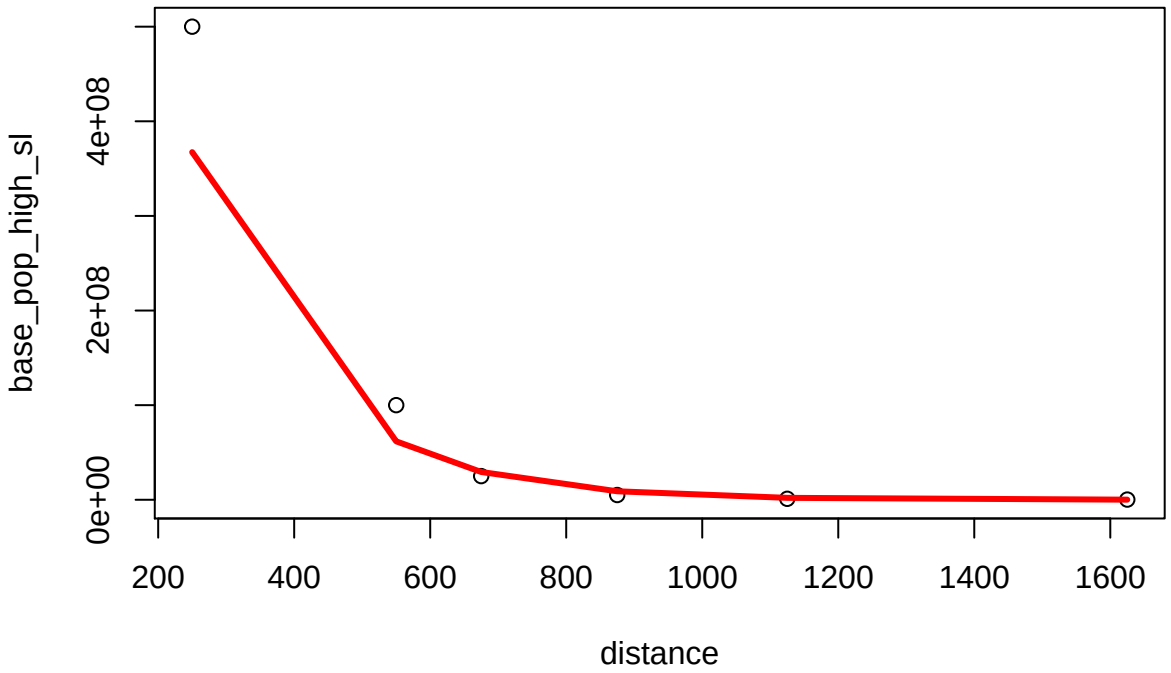
Clan Populations

The numbers for clan populations are extemely small and produce a total clan population well below the 1.2 billion cited in canon. We found that increasing the base numbers to 1 and 5 million for normal and high rolls produced a total clan population very close to 1.2 billion, while still producing clan populations that were much smaller than typical Inner Sphere countries.

Interpolating Base Population Numbers

The table on pg. 123 of *Campaign Operations* gives base population numbers base on bandwidths away from Terra. This makes sense but the use of wide bandwidths produces some pretty chunky variation in population sizes. We used the base numbers and the midpoint of each bandwidth to estimate statistical models that predicted the right base number as a function of light years from Terra. This gives a nice smooth function.

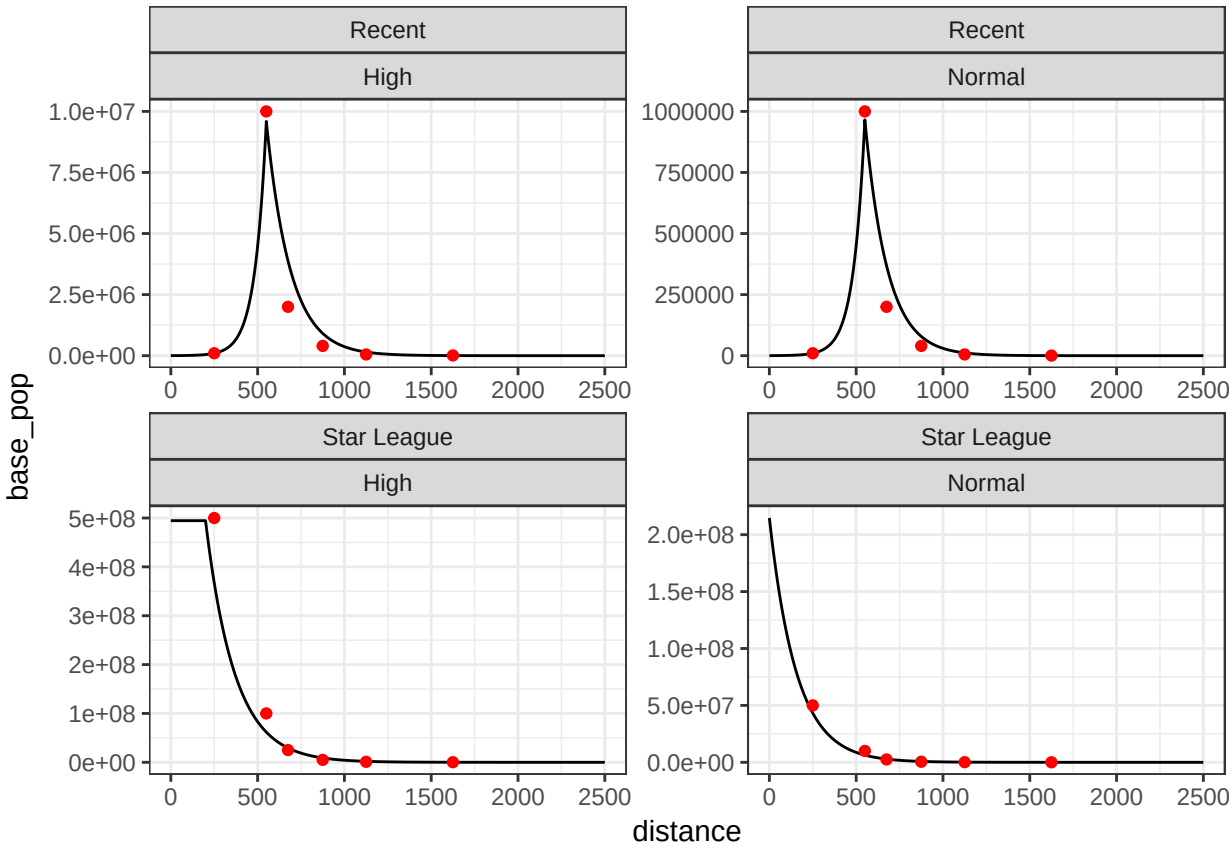
For example, for normal rolls and a star league founding, here are the five base population numbers provided in the book (leaving out the open-ended period past 2000 LY) by the midpoint of LY from Terra for each row.



The line in red shows the fit of a statistical model (in this case, an OLS regression model predicting log of the base number). This line fits the data very well ($R^2=$0.9618694). On the original scale, this formula is:

$$y = (1623754082)(0.9940732)^{(LY)}$$

We estimate both cases of a Star League founding in this way. The model for more recent foundings is more complex because of the peak around 550 light years out. We use spline models with a heavy weight on the peak to fit this model. Finally, because the model for the high star league can produce very high population numbers when you get very close to zero, we cap this base number at 200 LY. So any planet within 200 LY of Terra gets the same value that a planet at exactly 200 LY would get. After all these adjustments, our models for base population are shown below for each case below. The red dots correspond to the base population numbers from *Campaign Operations*.



We also make one other change to population generation. According to the table on pg. 123, more recent foundings only roll 2d6 rather than 4d6 for the random component of population that is multiplied by the base population to get final population. We found that this produced very small numbers for some distant periphery realms like the Hanseatic League because they were being double penalized by the base number roll and the multiplier when founded after the Star League. Therefore we use 4d6 as the base multiplier for all non-clan population multipliers.

Changes to USILR Code Generation

The most important change to the USILR code system is that we apply a gamma distribution to our final result in order to create more variability and smoother distributions of USILR codes. To to this we convert all letter codes to numerical codes (e.g. A,B,C,D,F becomes 5,4,3,2,1). After arriving at a final score α by the methods described in *Campaign Operations*, we then draw from a gamma distribution such that:

$$score \sim gamma(\alpha, \alpha/c)$$

Where c is a constant that allows us to scale the variation up or down. We use $c = 0.2$ for tech ratings and $c = 0.1$ for all other ratings. Because tech ratings play a role in most other codes, we wanted to generate more initial variation there and less variation in later codes. Because the gamma distribution produces a continuous value, we round to the nearest integer and then convert to the appropriate letter (after reducing or increasing numbers that fall outside the range). Mathematially, the mean of this distribution will be equal to α but will allow for some variation above and below. For the mathematically inclined, this approach is identical to fitting a poisson distribution with a mean of α but with underdispersion (smaller variance than the theoretical poisson).

The use of this approach helped to smooth out the distribution of ratings considerably. However the final

results still frequently produced distributions that were too extreme in one direction or the other. The IS for example had almost exclusively A and B tech rated planets with a smattering of a few Cs, while the minor periphery had nearly F on everything for all planets.

One of the nice features of using the gamma distribution described above is that the modifiers described on pg. 126 of *Campaign Operations* no longer have to be whole numbers. If we want to scale down the effect of one thing by 50% we can simply reduce its bonus/penalty from 1 to 0.5. Therefore, we tweaked a variety of numbers to produce smaller differentiation between cases and in particular to not penalize low population size as much. We also increased modifier sizes in a few cases. All of the modifiers we used are described in the tables below.

We also made some additional changes for clan populations. Clan planets are supposedly fairly resource poor and clan populations are small, but supposedly with the strict clan system and high technology skill, the clans have been able to prosper on these planets. We removed all population based modifiers for the clans and also added some flat clan penalties to raw materials and agriculture.

Please also note that we reverse the direction of these modifiers, so that + means higher rating

Technology Modifiers

Base Value=4 (C). We do not use the Advanced or Regressed levels for Tech Rating by random generation.

Condition	Modifier
Star League or earlier	+0.5
Population over 1 billion (non-Clan only)	+1
Clan settlement	+1.5
Minor periphery	-0.25
Population under 100 million (non-Clan only)	-1
Population under 1 million (non-Clan only)	-0.5

Industry Modifiers

Base Balue=2.5 (C-D)

Condition	Modifier
Tech Rating >= B	+0.75
Clan settlement	+1.5
Population over 4 billion (non-Clan only)	+1
Population over 1 billion (non-Clan only)	+1
Population under 100 million (non-Clan only)	-0.5
Population under 1 million (non-Clan only)	-0.25
Tech Rating <= F	-0.75

Output Modifiers

Base Balue=3 (C)

Condition	Modifier
Clan settlement	+0.75
Population over 4 billion (non-Clan only)	+1
Tech Rating >= A	+0.5

Condition	Modifier
Industry Rating >= B	+0.5
Tech Rating <= D	-0.5
Industry Rating <= D	-0.5

Raw Material Modifiers

Base Balue=4 (B)

Condition	Modifier
Clan settlement	-1.5
Tech Rating >= C	+1
Density over 5.5	+1
Population over 3 billion (non-Clan only)	-1
Output Rating >= B	-1
Settled over 250 years ago	-1
Density under 4	-1

Agriculture Modifiers

Base Balue=3 (C)

Condition	Modifier
Clan settlement	-1
Tech Rating >= B	+1
Industry Rating >= C	+1
Tech Rating <= F	-1
Population over 1 billion (non-Clan only)	-1
Population over 5 billion (non-Clan only)	-1
Water Percentage under 50%	-1
Tainted Atmosphere	-1
Toxic Atmosphere	-2

Changes to HPG Generation

Generating Systems

First, we read in the XML file. In order to assign colonization variables, we need to know the:

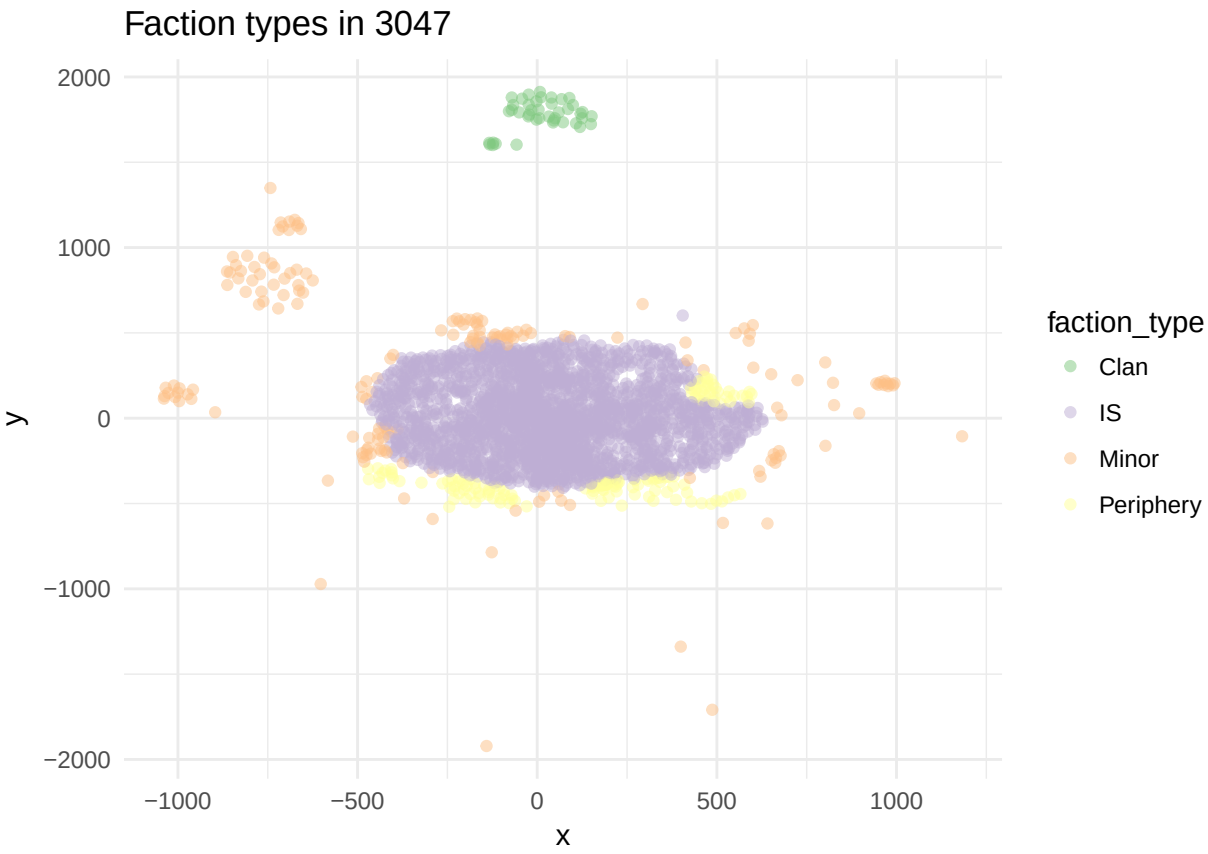
- distance from Terra
- faction type: Inner Sphere, Major Periphery, Minor Periphery, Clan
- year colony founded

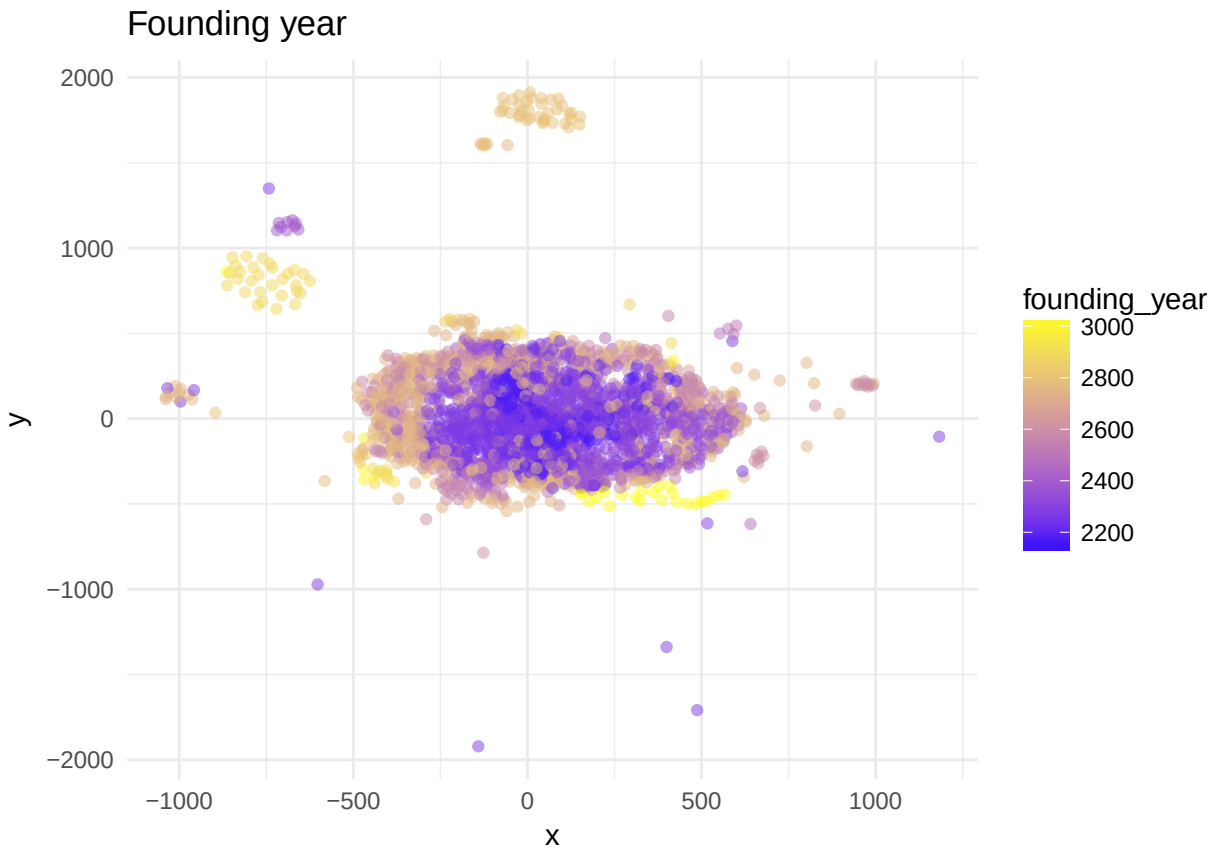
We pull data from year 3047, so that we can derive clan factions by original foundings. We determine original year of colony founding by the first faction change from the default faction of `UND`. We code faction type from specific faction codes. The method used here is not safe to be used if the date is changed from 3047 as we only code factions that existed in 3047, not all possible factions. We remove all factions that were `ABN` (abandoned), `UND`, and `NONE`. This removes all of the Exodus Road planets.

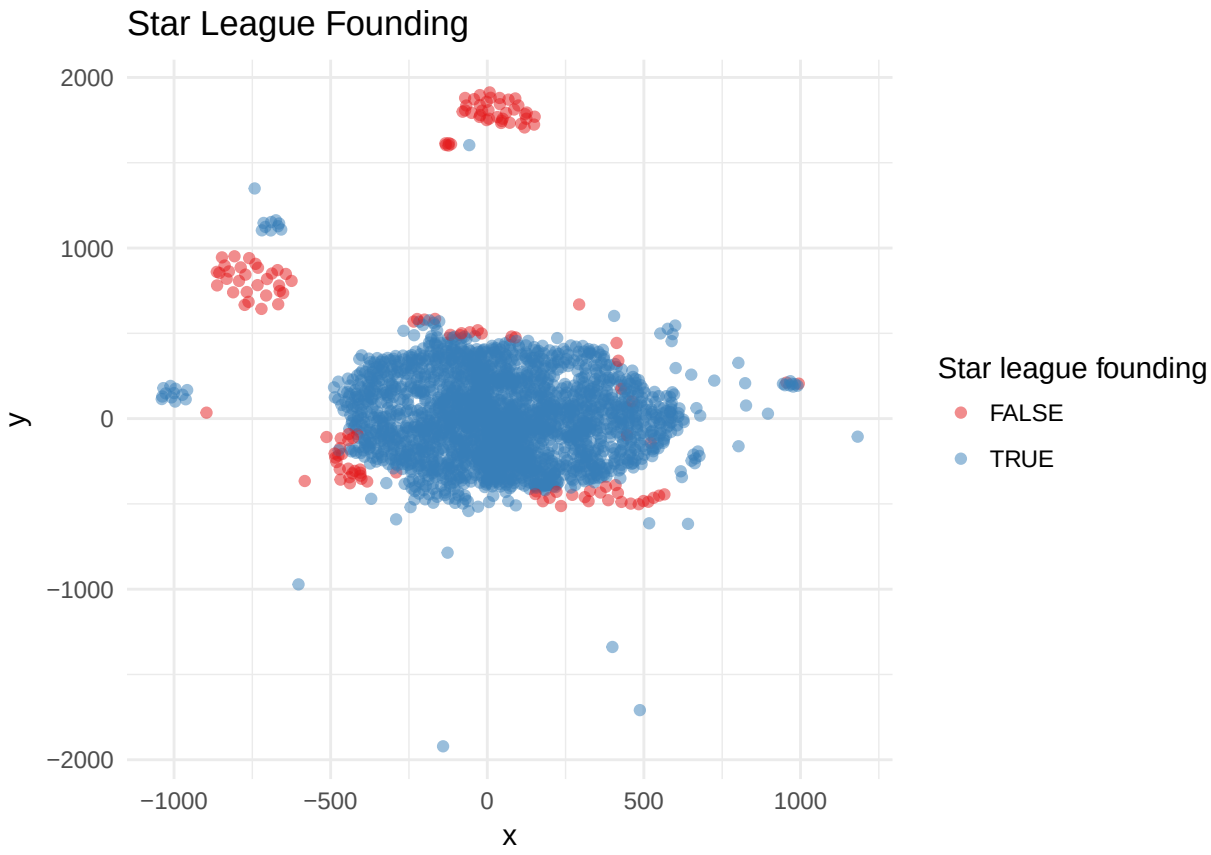
The following cases of planets were missing a founding year:

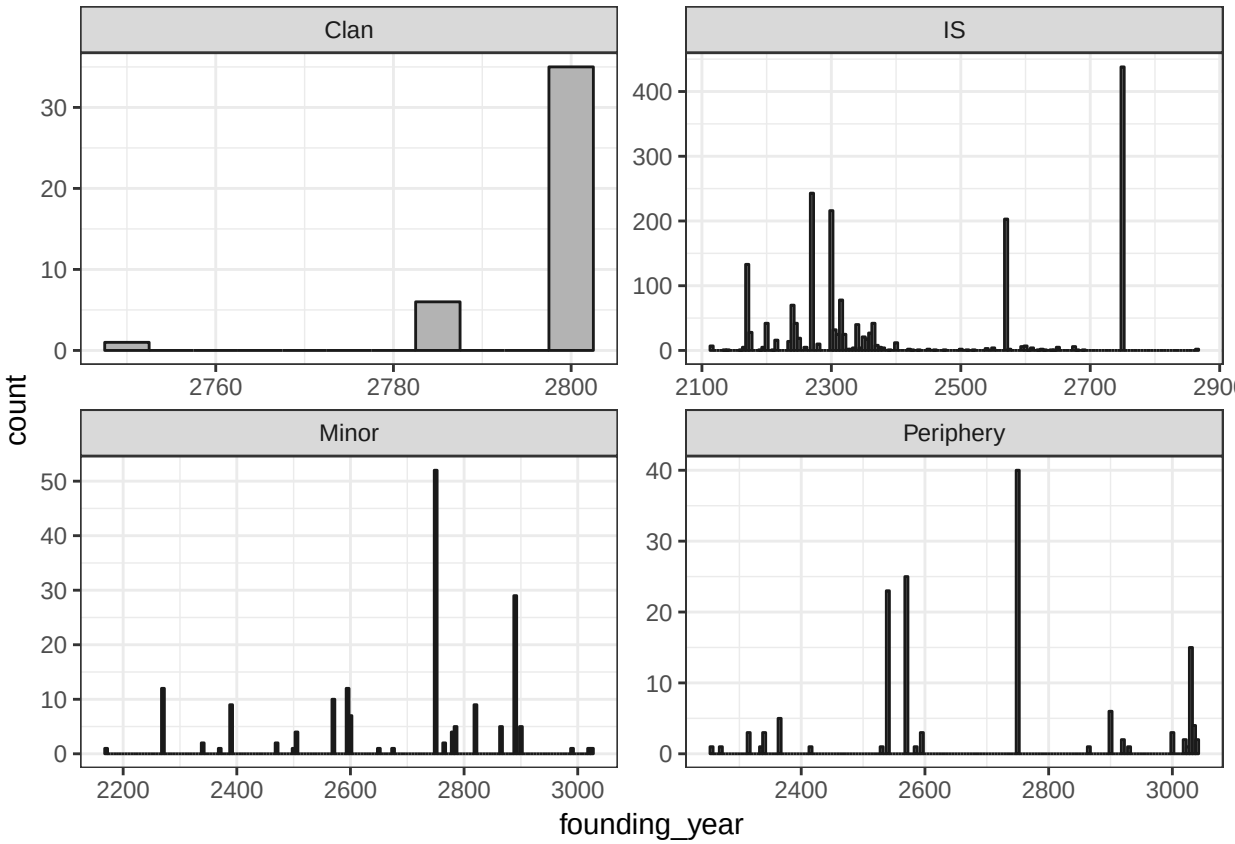
```
##        name       x       y faction  hpg founding_year tech industry  raw
## 2489 Pioche -392.36 -497.51    PIND <NA>            NA <NA>     <NA> <NA>
##      output agriculture distance_terra faction_type
## 2489   <NA>        <NA>       633.6107        Minor
```

After removing missing factions and missing founding year, we have a total of 2275 planets. The maps below show our key independent variable values across diferent planets.




Founding year
2000
1000
0
−1000
−2000
y
−1000
−500
0
500
1000
x
founding_year
3000
2800
2600
2400
2200


Star League Founding
2000
1000
0
−1000
−2000
y
−1000
−500
0
500
1000
x
Star league founding
FALSE
TRUE



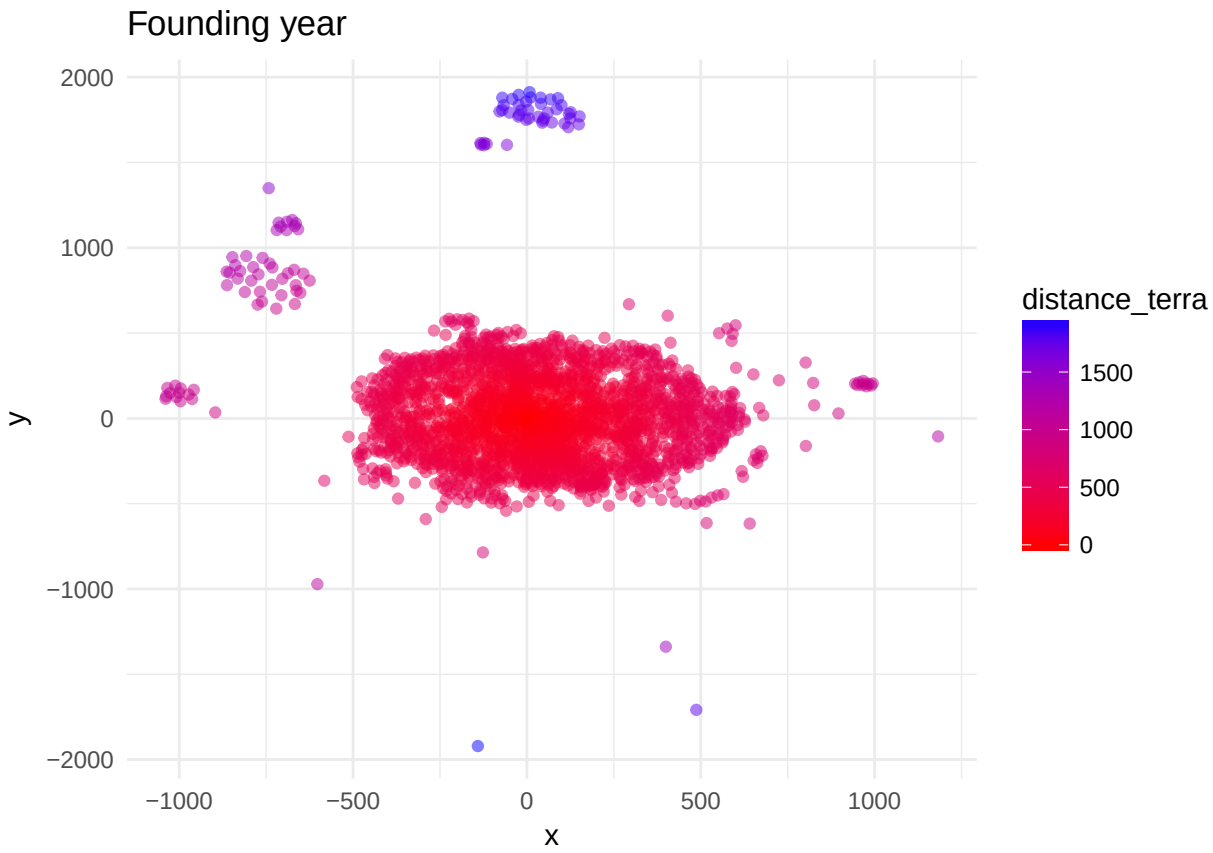
A lot of heaping on some specific founding years. This appears to be a result of using a map data as the founding date if system did not appear on a previous map. We need to distribute those founding years and consider them to be non-canon.

Var1	Freq
2116	1
2117	6
2134	1
2139	1
2160	1
2163	5
2168	1
2170	2
2172	131
2176	27
2177	1
2189	1
2193	3
2194	1
2197	1
2200	42
2212	1
2213	1
2214	1
2215	14
2235	12
2237	2

Var1	Freq
2240	19
2241	27
2242	24
2243	11
2245	20
2247	11
2250	19
2253	1
2259	5
2270	24
2271	232
2278	9
2280	1
2299	4
2300	212
2305	32
2310	25
2314	26
2315	5
2316	1
2317	49
2319	15
2320	1
2322	9
2325	2
2328	1
2330	1
2335	4
2336	1
2338	1
2340	16
2341	28
2343	1
2345	3
2350	21
2355	18
2360	27
2365	4
2367	43
2370	8
2372	1
2375	5
2380	4
2390	1
2392	9
2400	12
2413	1
2418	2
2425	1
2436	1
2450	2
2460	1

Var1	Freq
2471	2
2473	1
2500	3
2504	4
2511	1
2521	1
2531	1
2540	26
2549	1
2550	2
2551	1
2571	238
2573	2
2583	1
2596	20
2597	1
2598	1
2600	13
2605	1
2610	3
2612	1
2620	1
2625	2
2630	1
2640	1
2645	1
2650	6
2673	5
2674	1
2675	1
2680	1
2690	1
2750	531
2765	2
2779	4
2785	4
2786	7
2802	35
2821	1
2822	8
2864	7
2865	1
2891	29
2900	11
2920	2
2930	1
2992	1
3000	3
3020	3
3025	2
3028	13
3030	2

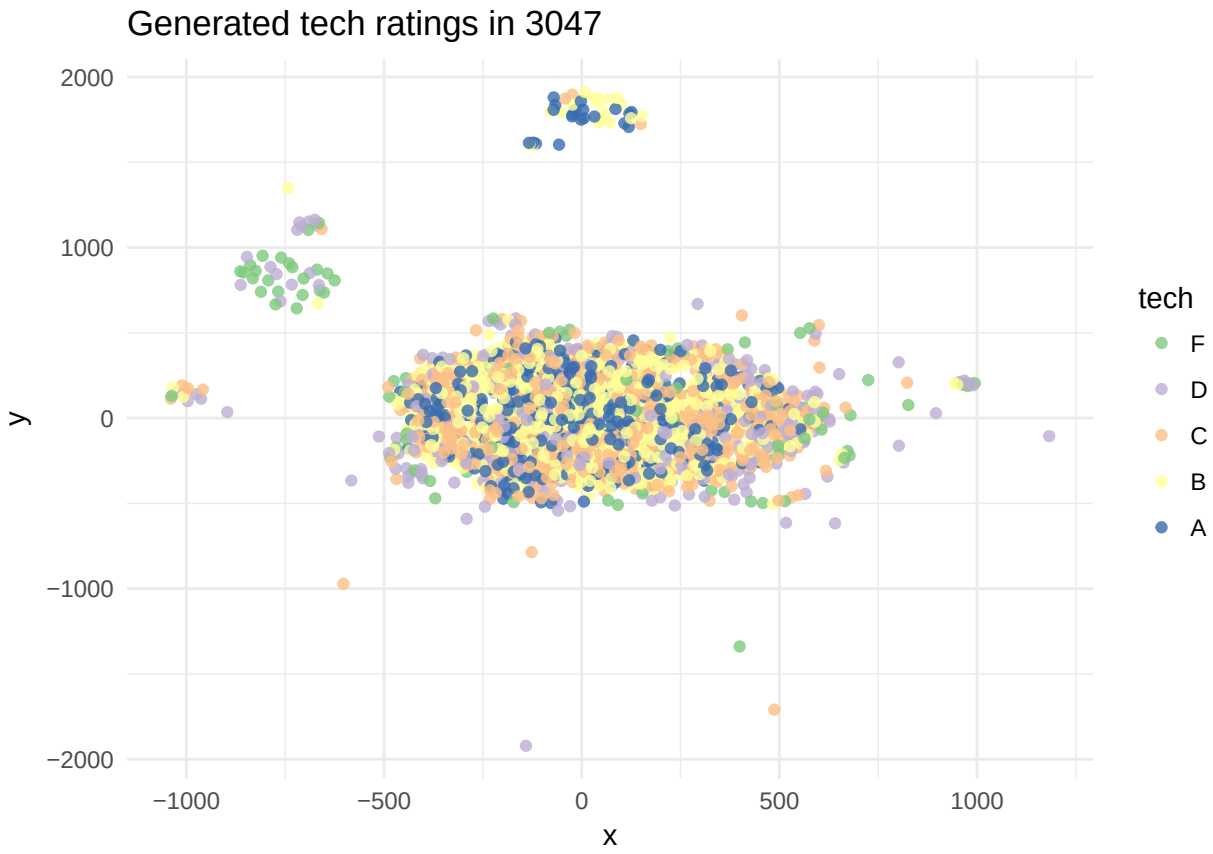
Var1	Freq
3035	4
3040	2

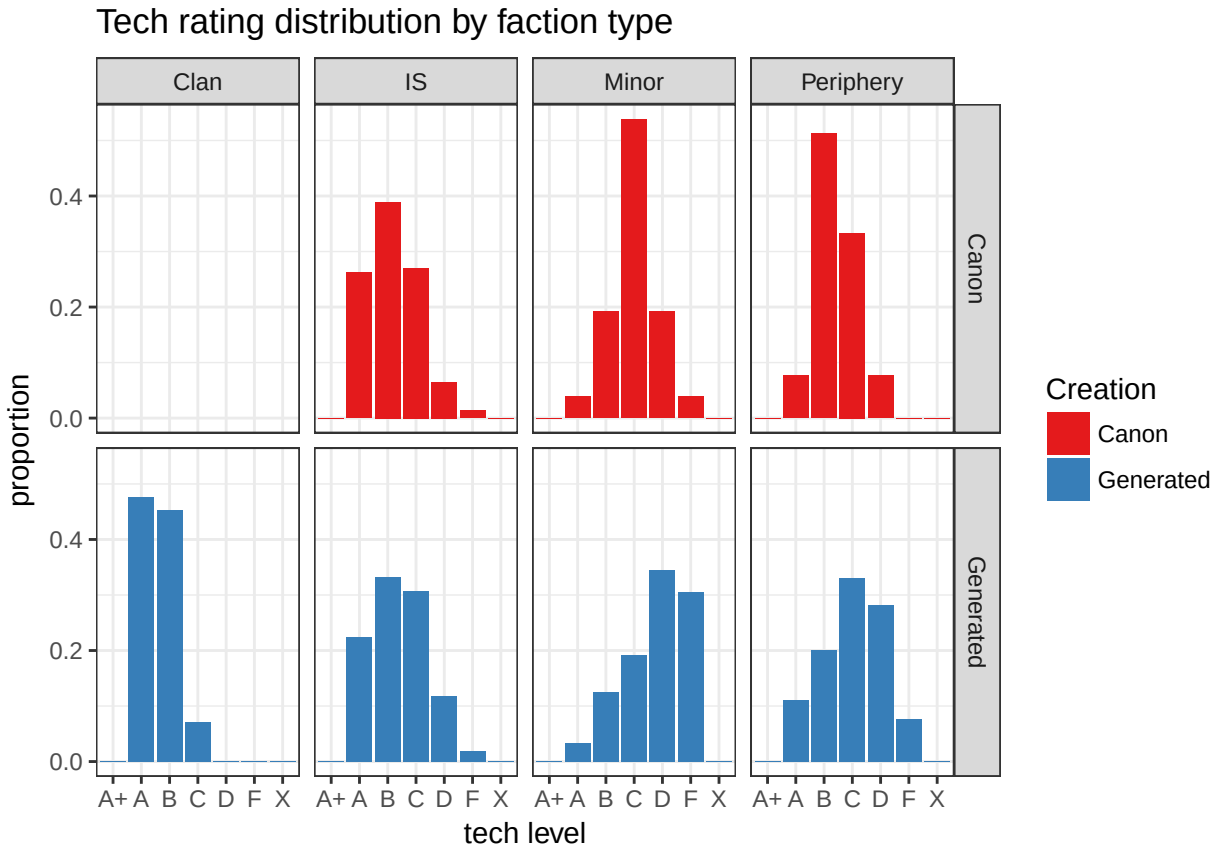


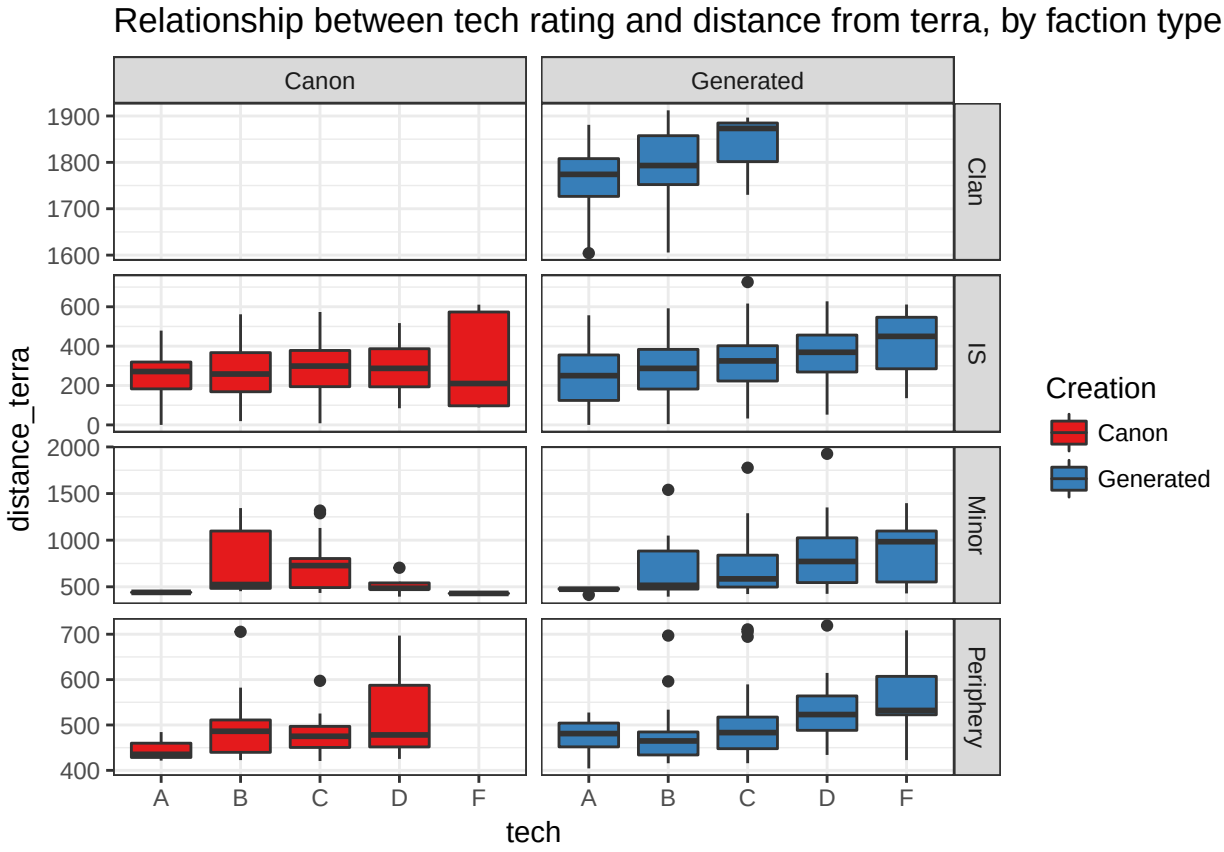
Now, we cycle through every single planet and generate a system complete with astronomical and social data.

Analysis of Generated Results

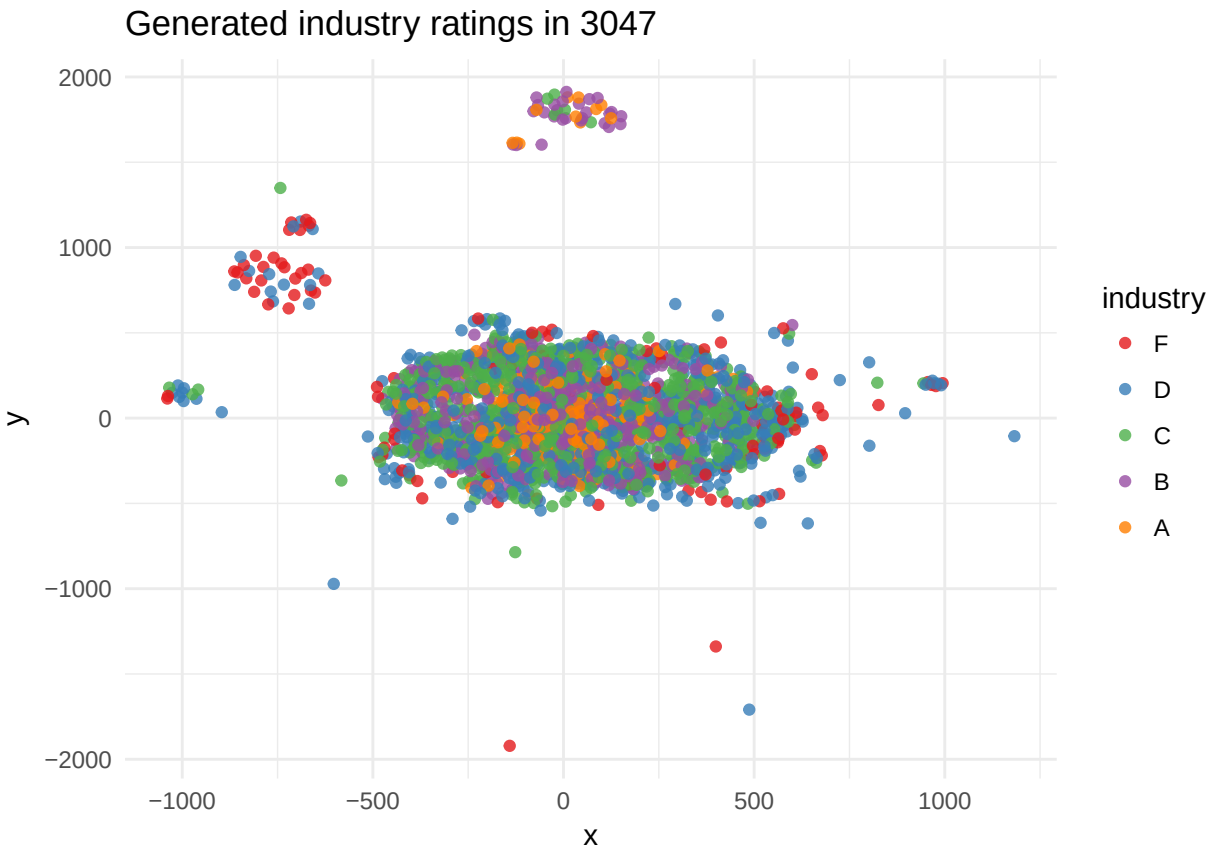
Tech Rating

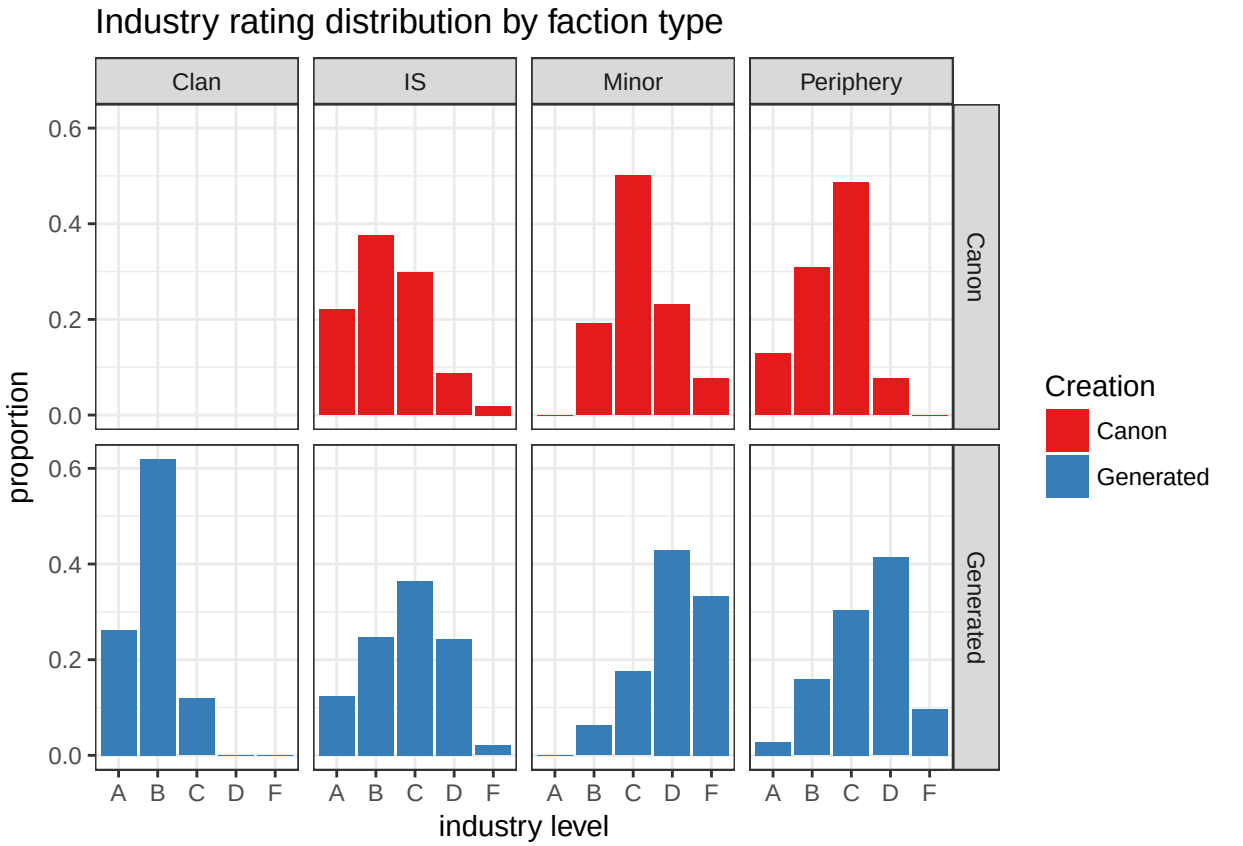


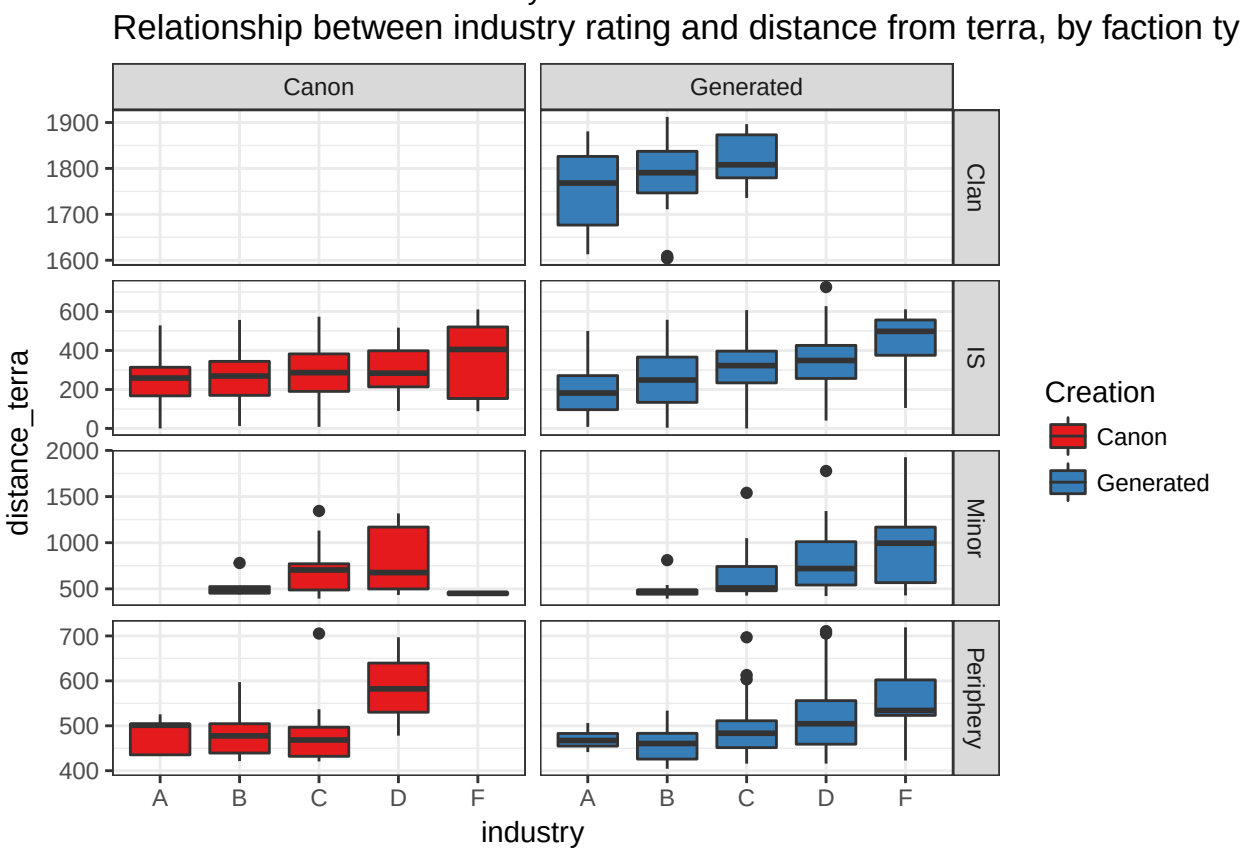

Tech rating distribution by faction type
Clan
IS
Minor
Periphery
Canon
Generated
proportion
0.0
0.2
0.4
A+ A B C D F X
tech level
Creation
Canon
Generated


Relationship between tech rating and distance from terra, by faction type
Canon
Generated
Clan
IS
Minor
Periphery
distance_terra
A B C D F
tech
Creation
Canon
Generated

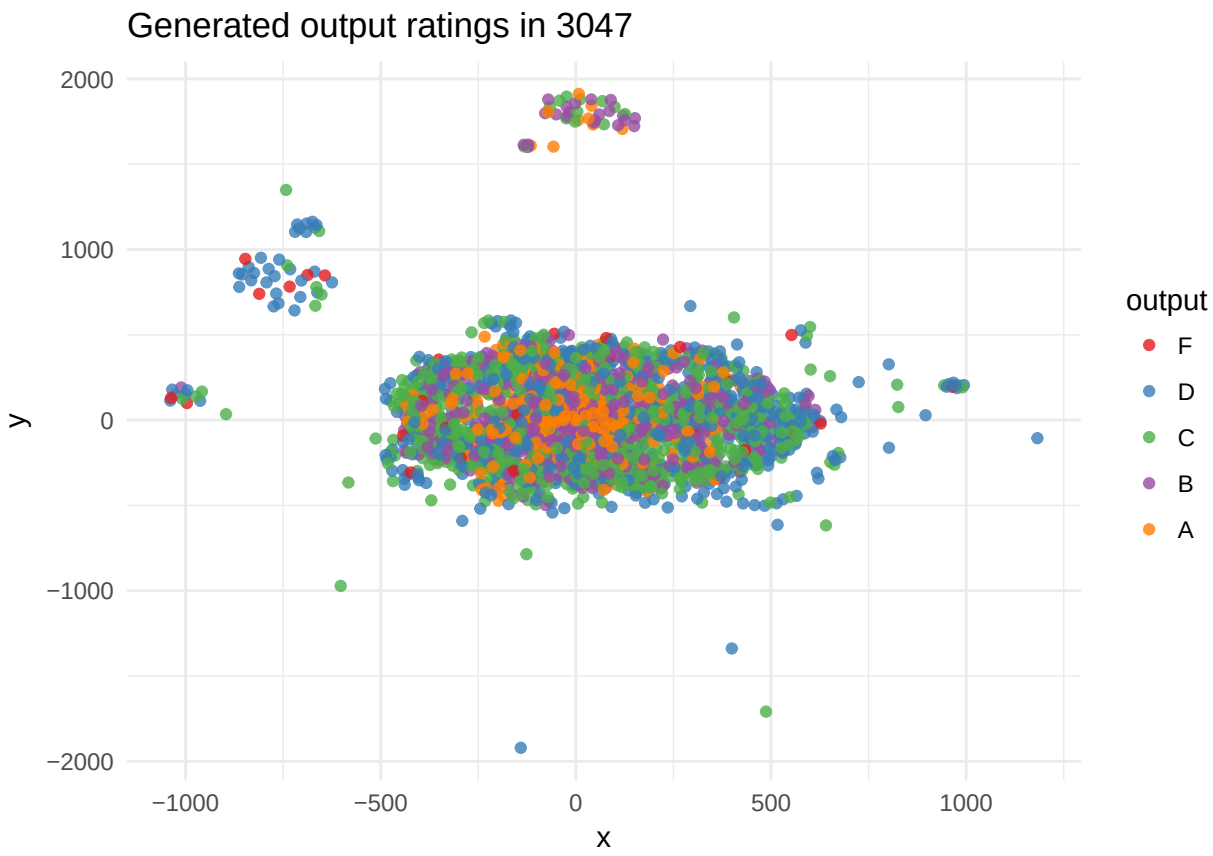
Industry Rating

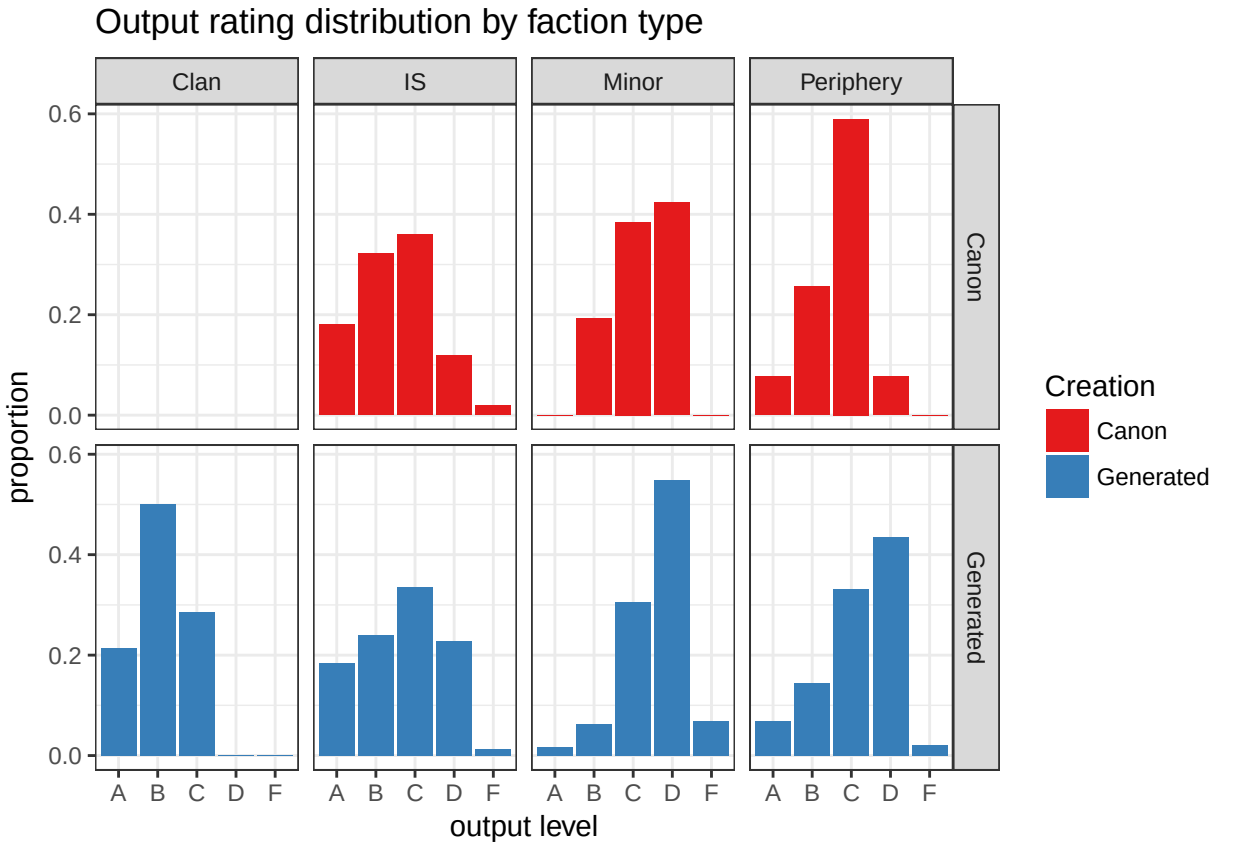


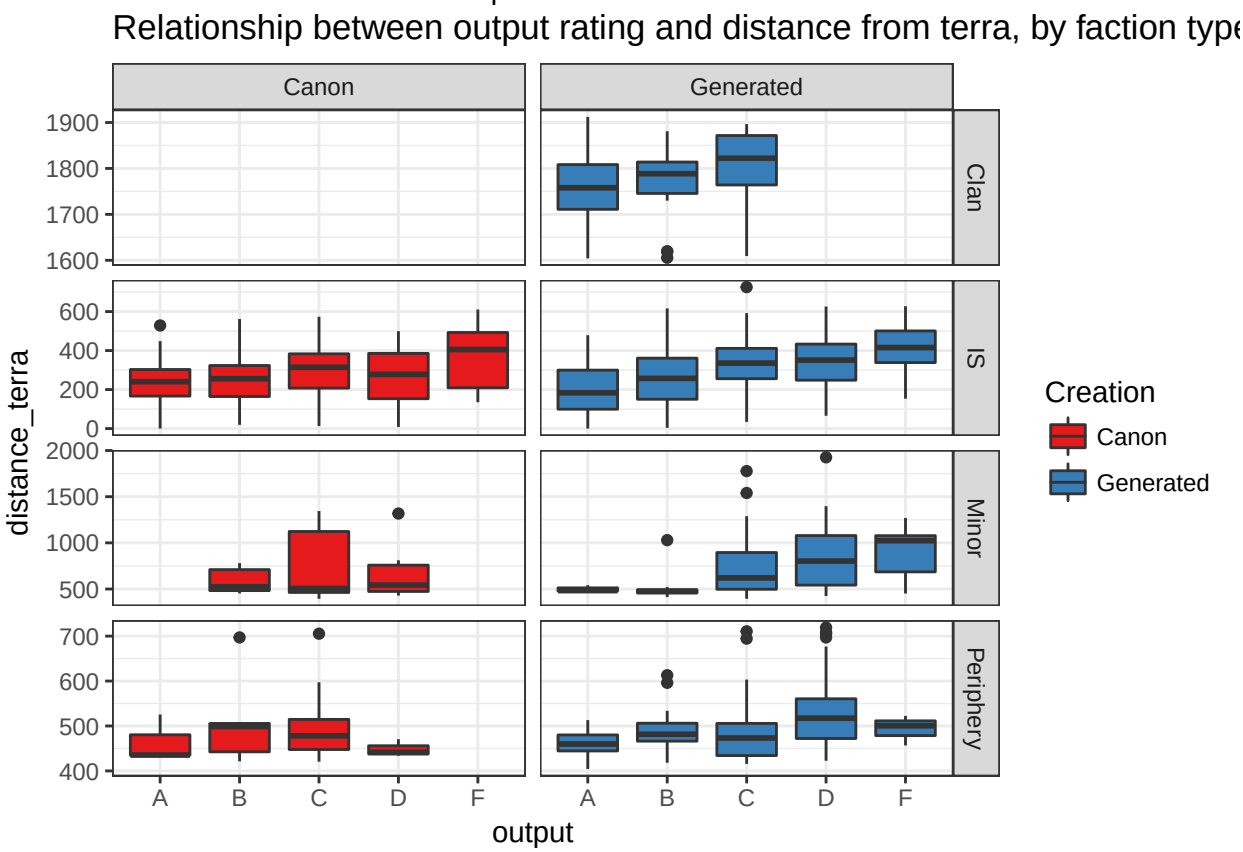

Industry rating distribution by faction type
Clan
IS
Minor
Periphery
Canon
Generated
proportion
0.0
0.2
0.4
0.6
A B C D F
industry level
Creation
Canon
Generated


Relationship between industry rating and distance from terra, by faction ty
Canon
Generated
Clan
IS
Minor
Periphery
distance_terra
A B C D F
industry
Creation
Canon
Generated

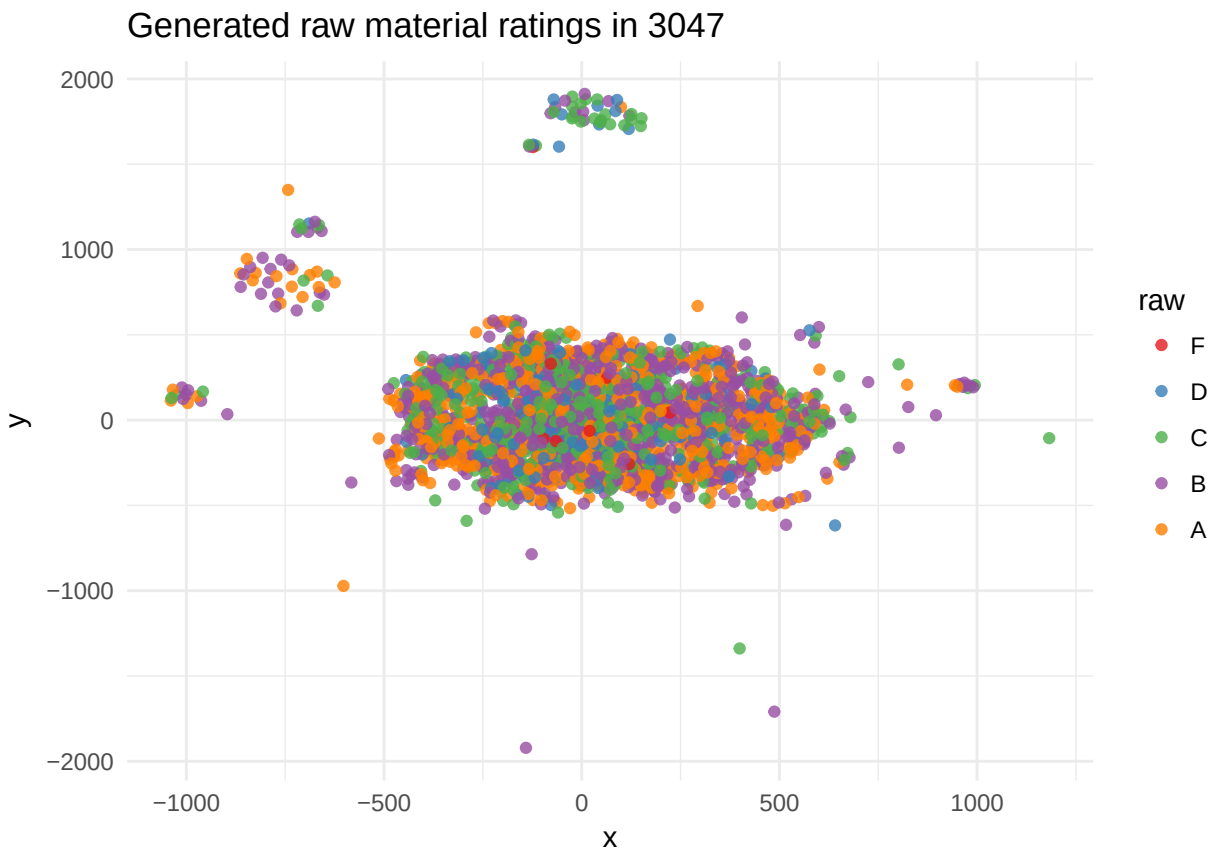
Output Rating

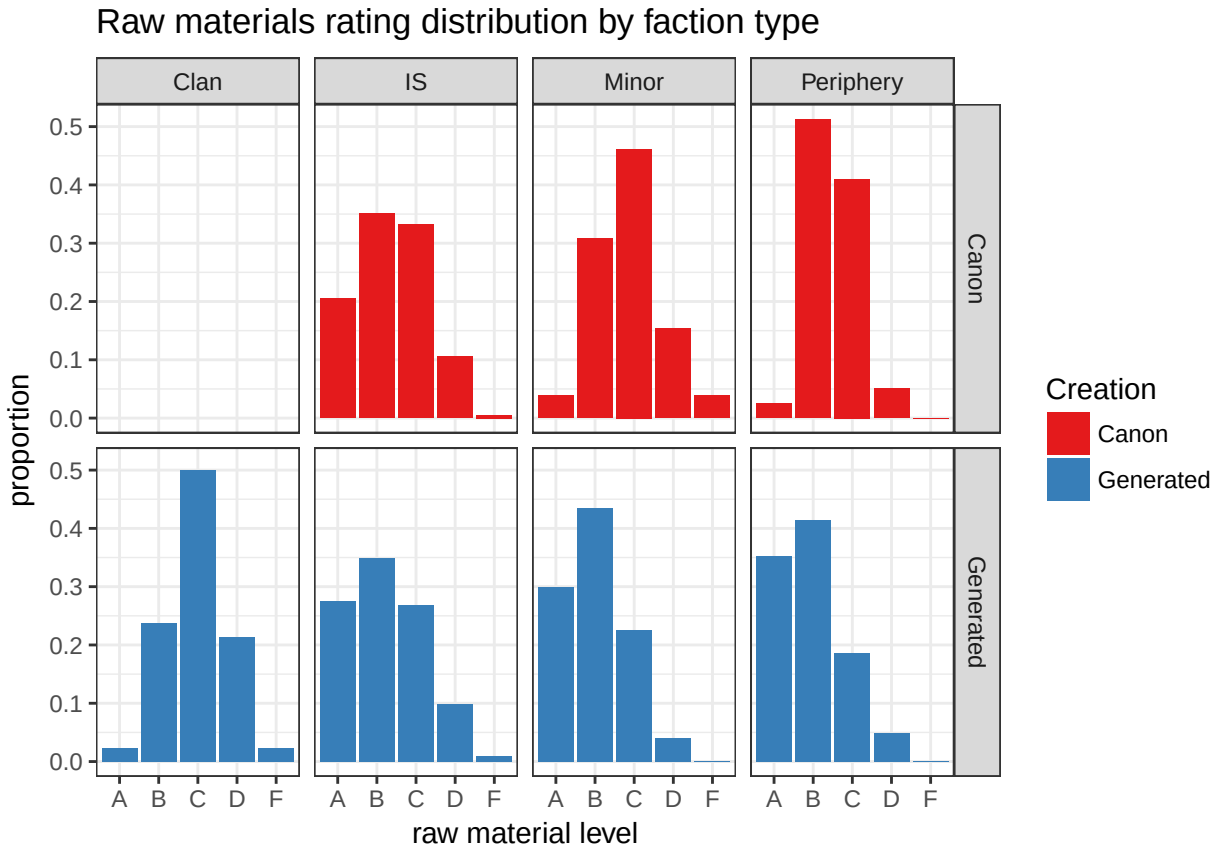


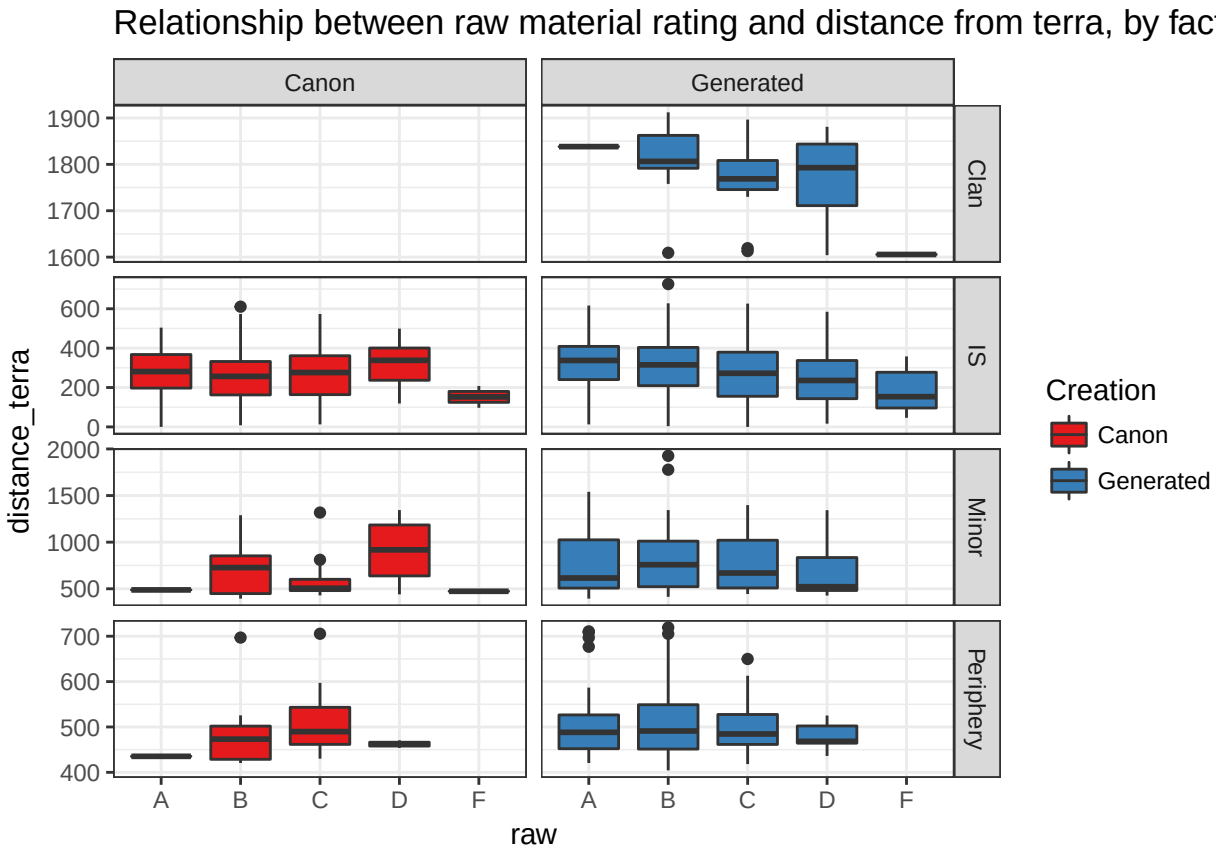

Output rating distribution by faction type
Clan
IS
Minor
Periphery
Canon
Generated
proportion
0.0
0.2
0.4
0.6
A B C D F
output level
Creation
Canon
Generated


Relationship between output rating and distance from terra, by faction type
Canon
Generated
Clan
IS
Minor
Periphery
distance_terra
1600
1700
1800
1900
0
200
400
600
500
1000
1500
2000
400
500
600
700
A B C D F
output
Creation
Canon
Generated

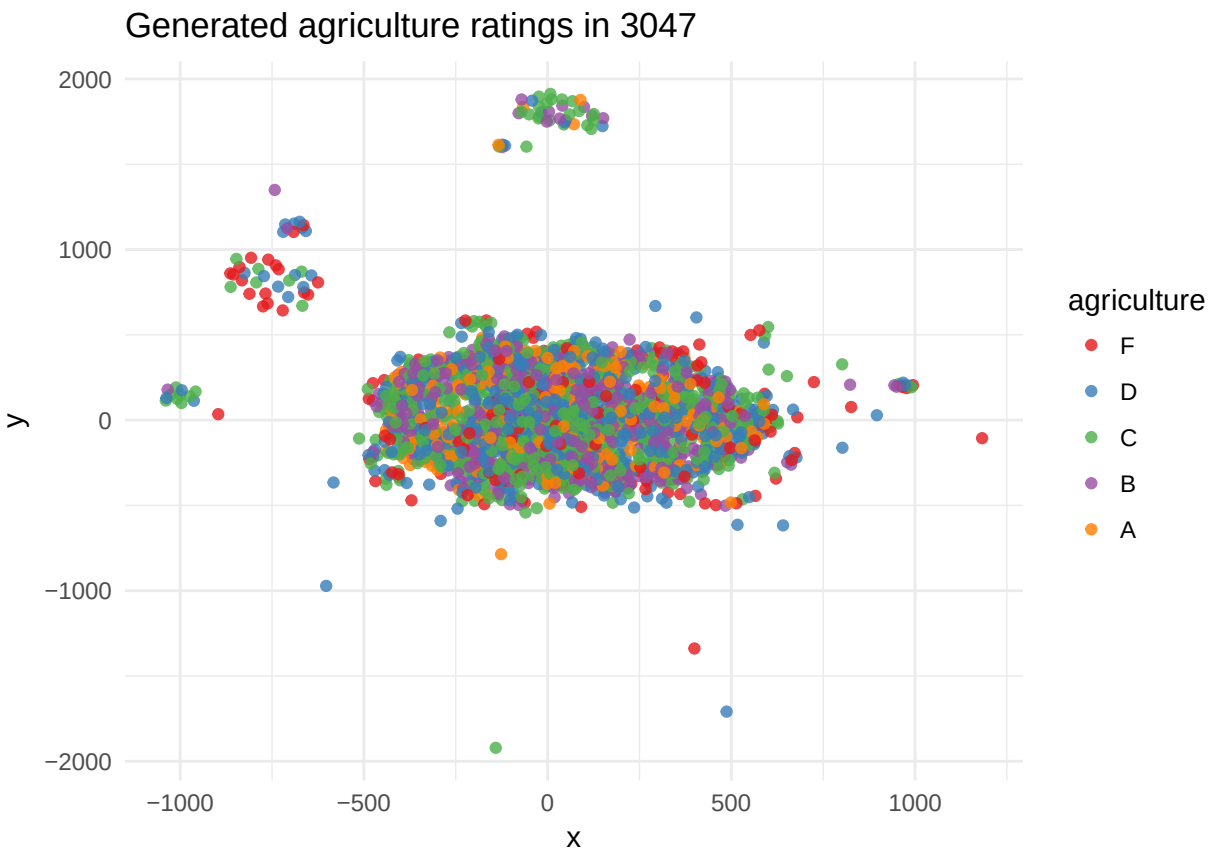
Raw Materials Rating

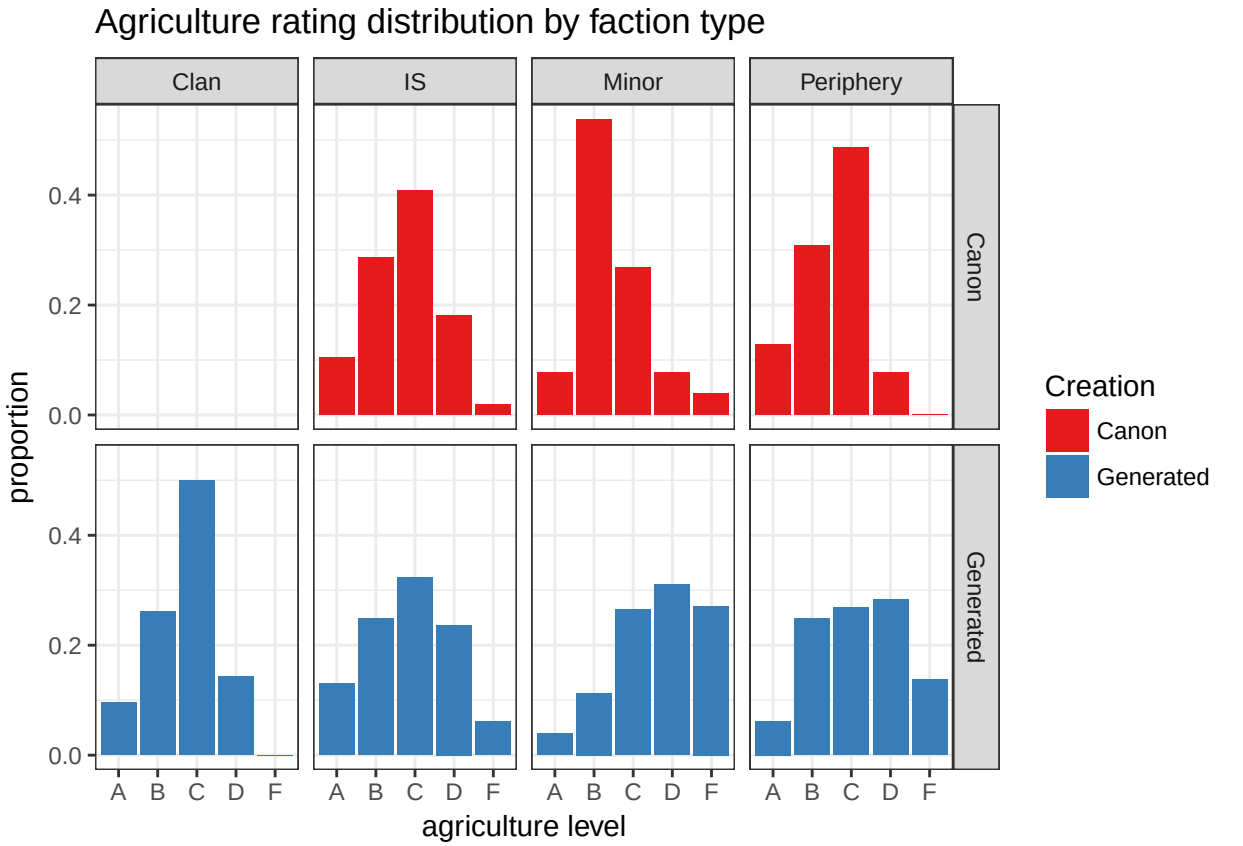


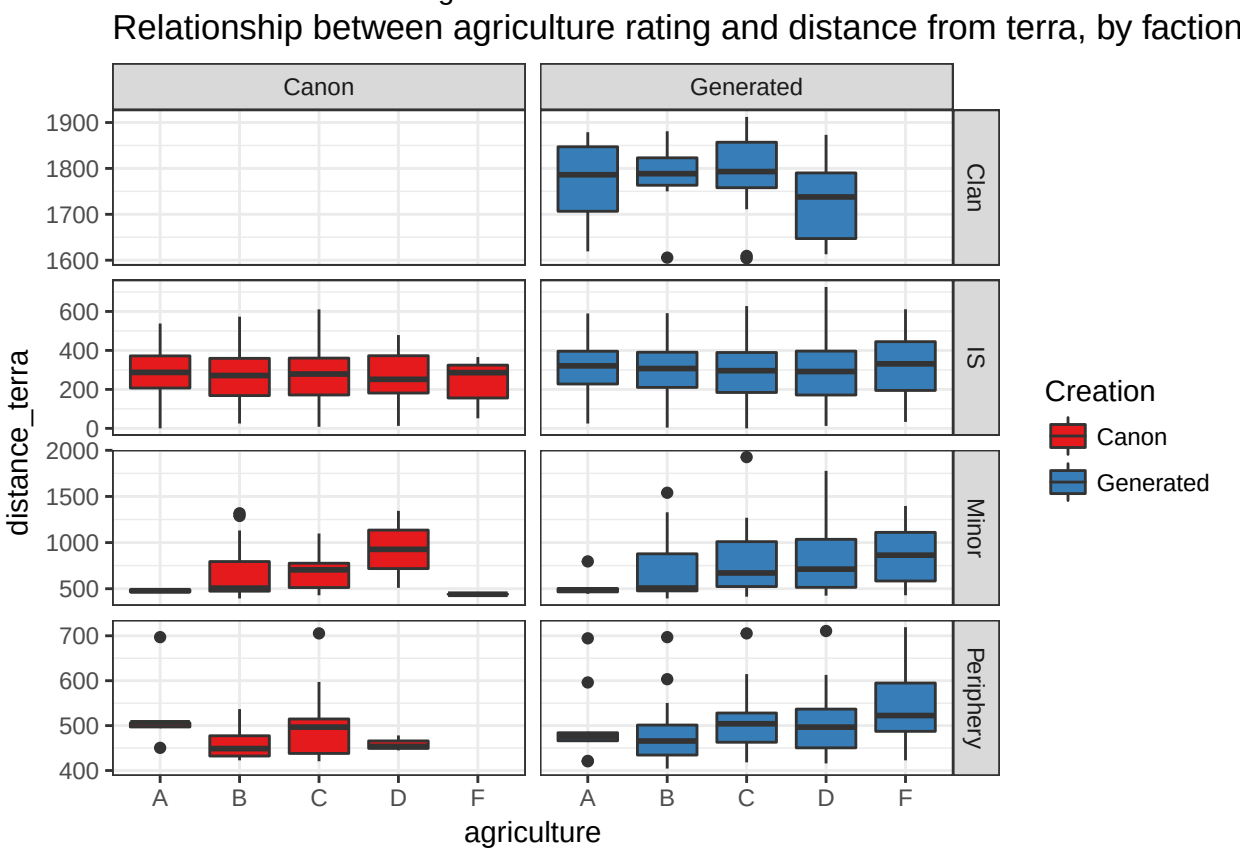

Raw materials rating distribution by faction type
Clan
IS
Minor
Periphery
Canon
Generated
proportion
0.0
0.1
0.2
0.3
0.4
0.5
A
B
C
D
F
raw material level
Creation
Canon
Generated


Relationship between raw material rating and distance from terra, by factic
Canon
Generated
Clan
IS
Minor
Periphery
distance_terra
1600
1700
1800
1900
0
200
400
600
500
1000
1500
2000
400
500
600
700
A
B
C
D
F
raw
Creation
Canon
Generated

Agriculture Rating

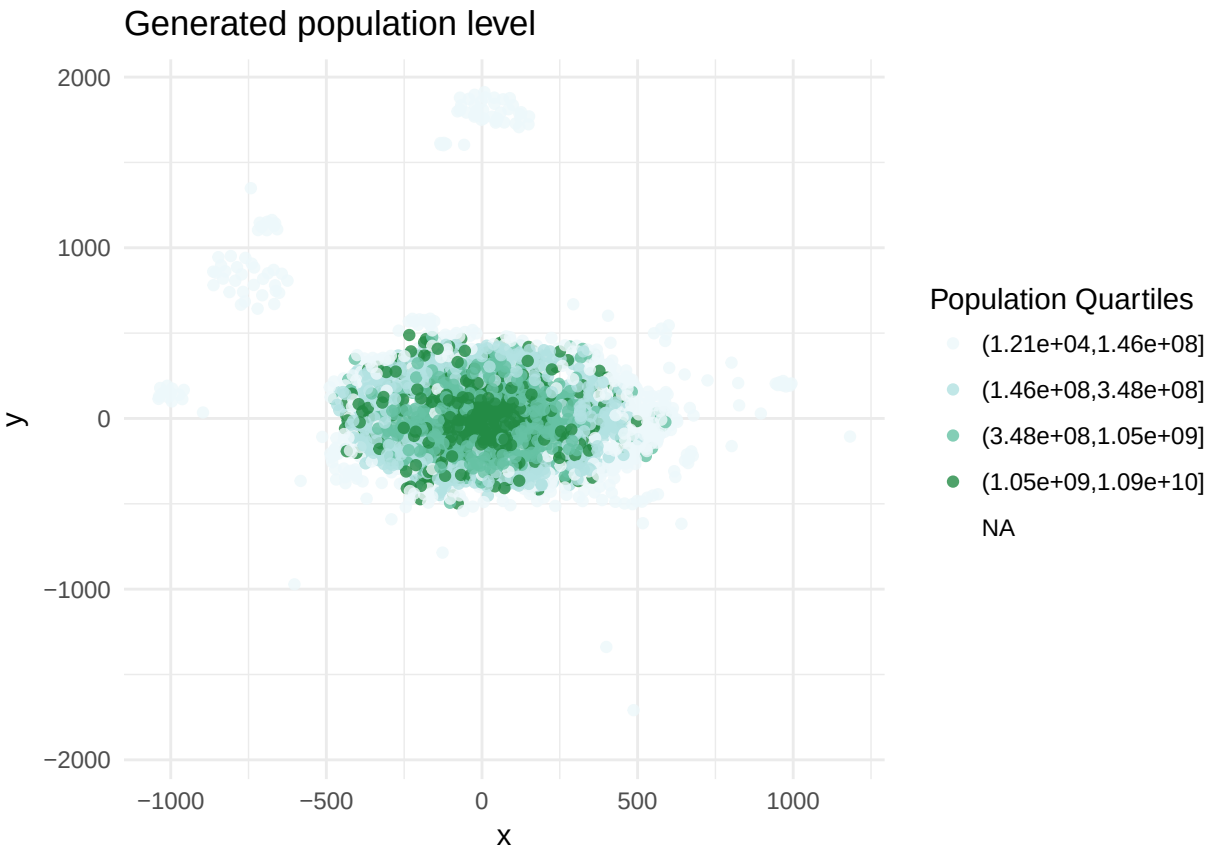



Agriculture rating distribution by faction type
Clan
IS
Minor
Periphery
Canon
Generated
proportion
0.0
0.2
0.4
A
B
C
D
F
agriculture level
Creation
Canon
Generated

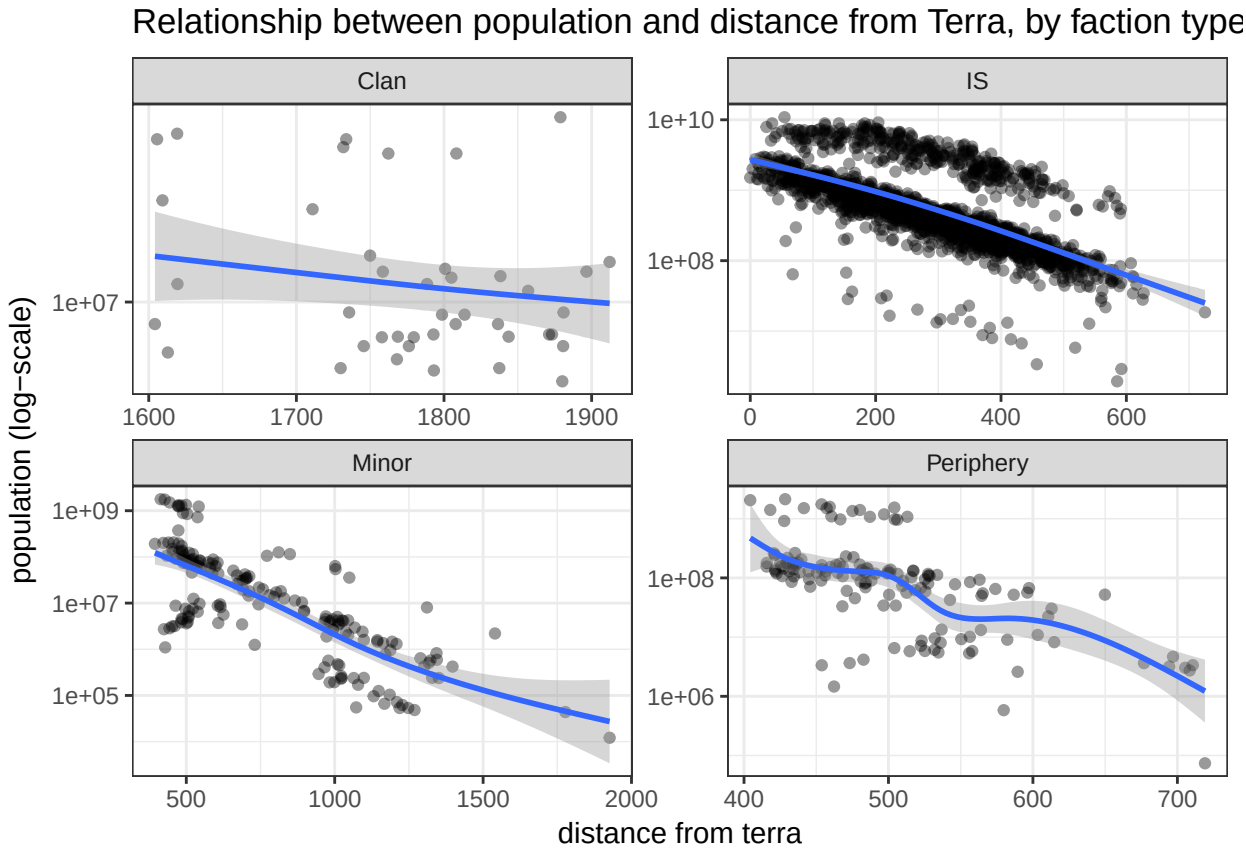

Relationship between agriculture rating and distance from terra, by faction
Canon
Generated
Clan
IS
Minor
Periphery
distance_terra
1600
1700
1800
1900
0
200
400
600
500
1000
1500
2000
400
500
600
700
A
B
C
D
F
agriculture
Creation
Canon
Generated

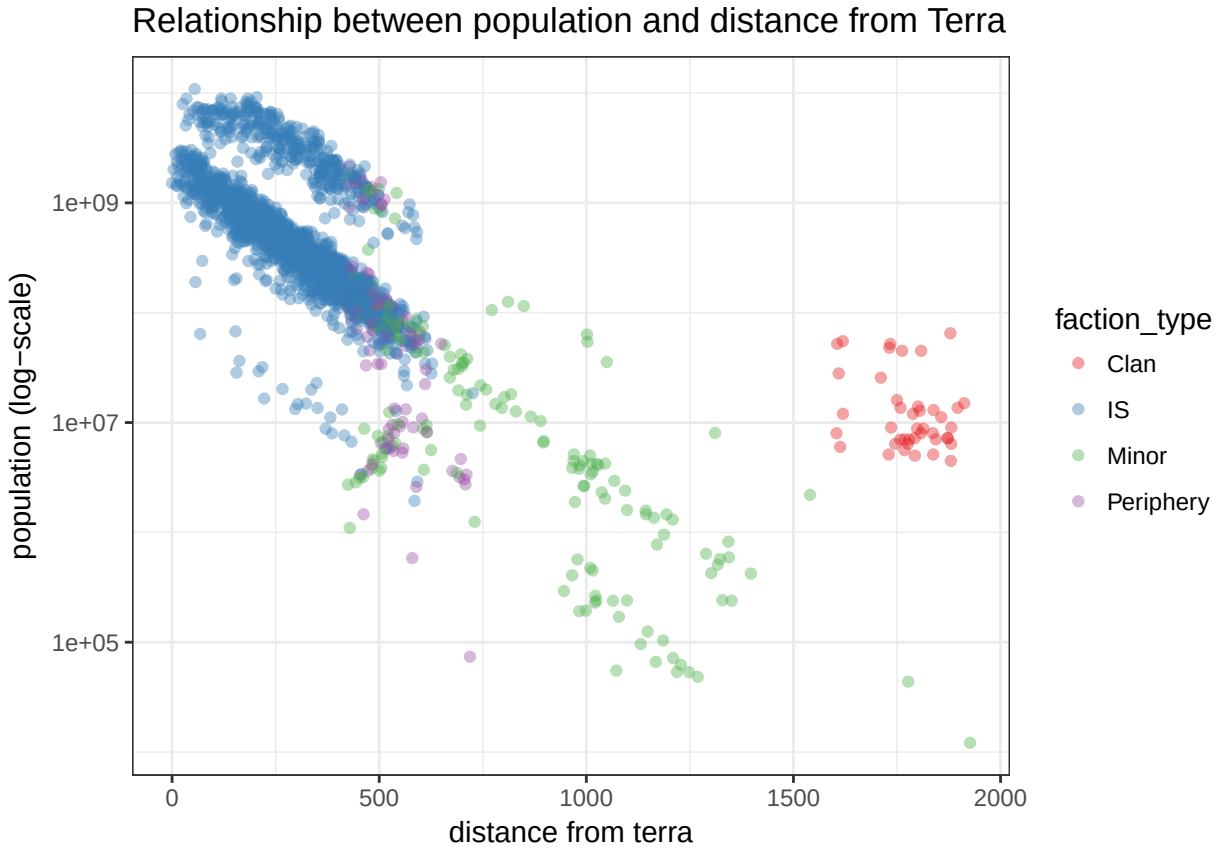
Population

```
## Warning: Removed 1 rows containing missing values (geom_point).
```

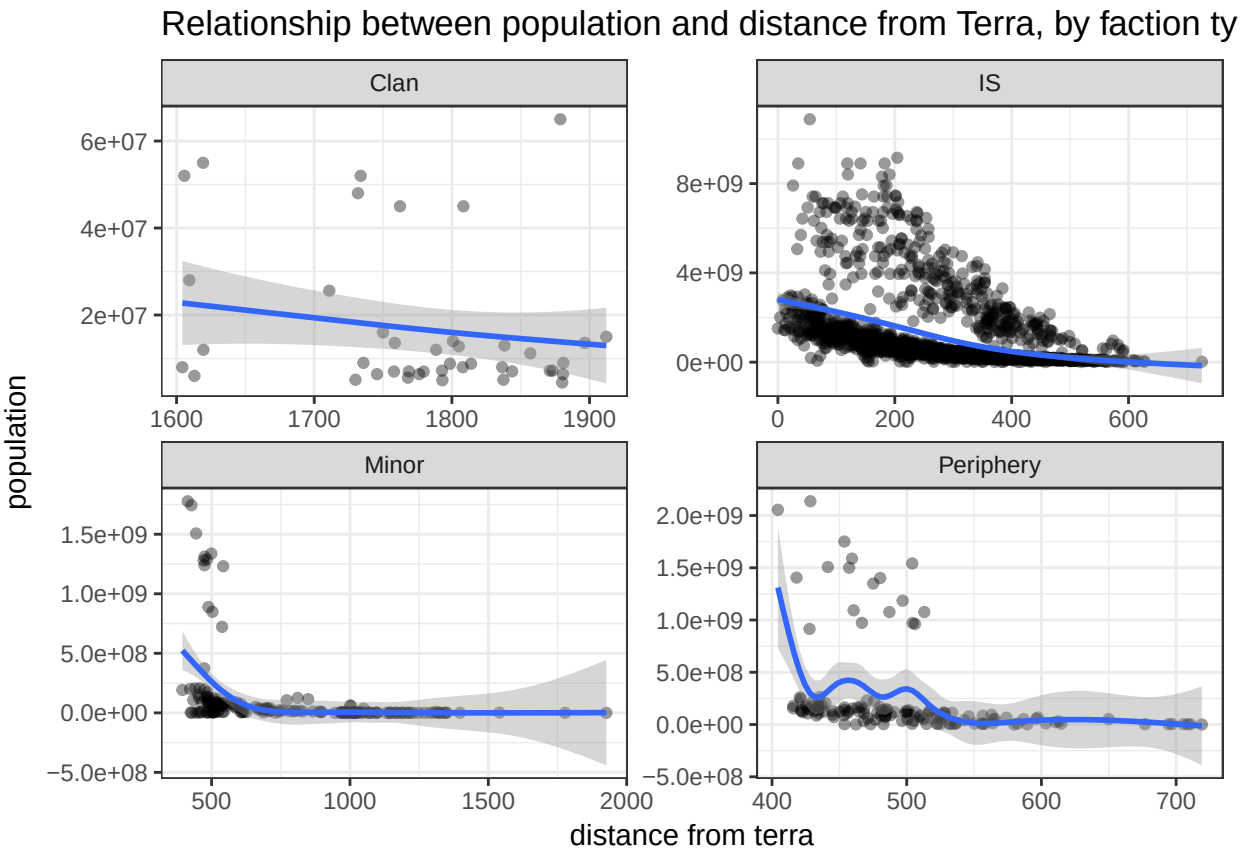


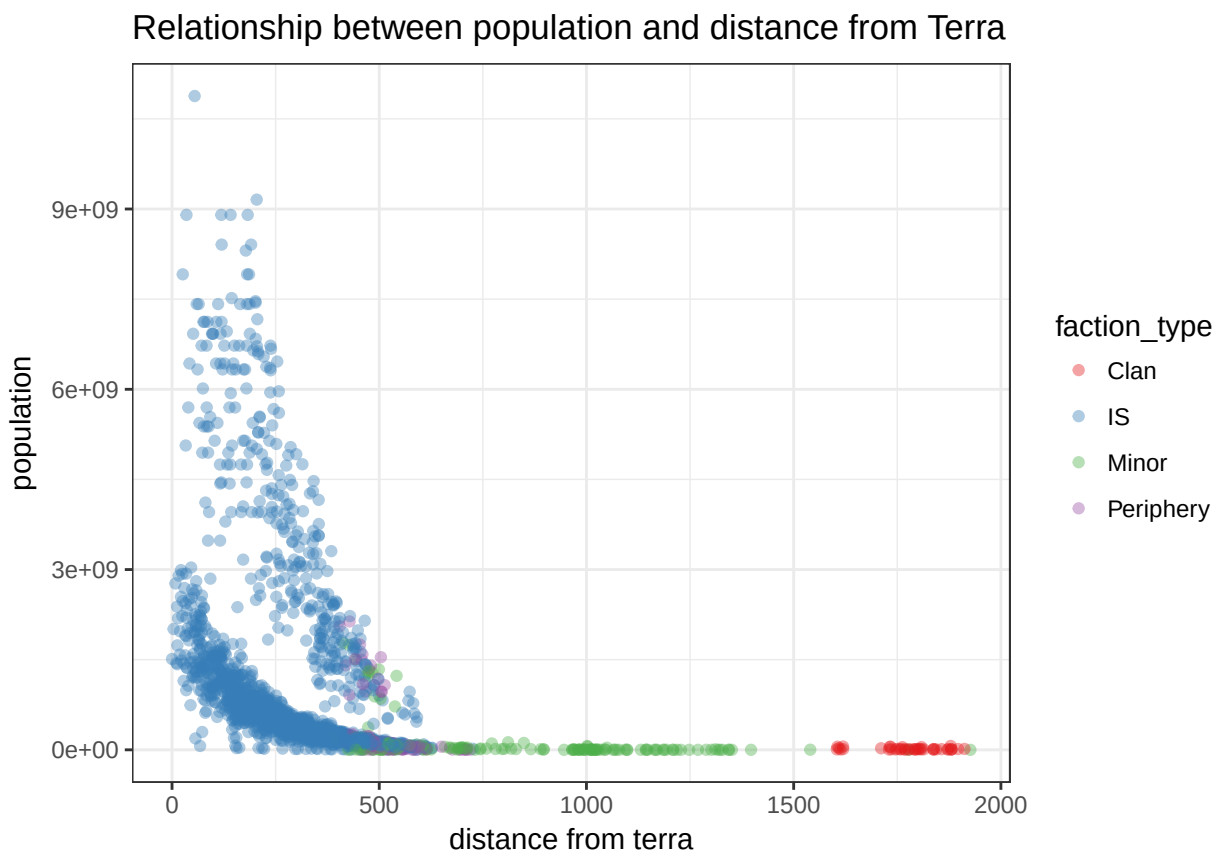

```
## `geom_smooth()` using method = 'gam'
```


Relationship between population and distance from Terra, by faction type
Clan
IS
Minor
Periphery
population (log−scale)
1e+10
1e+09
1e+08
1e+07
1e+06
1e+05
1600
1700
1800
1900
0
200
400
600
500
1000
1500
2000
400
500
600
700
distance from terra

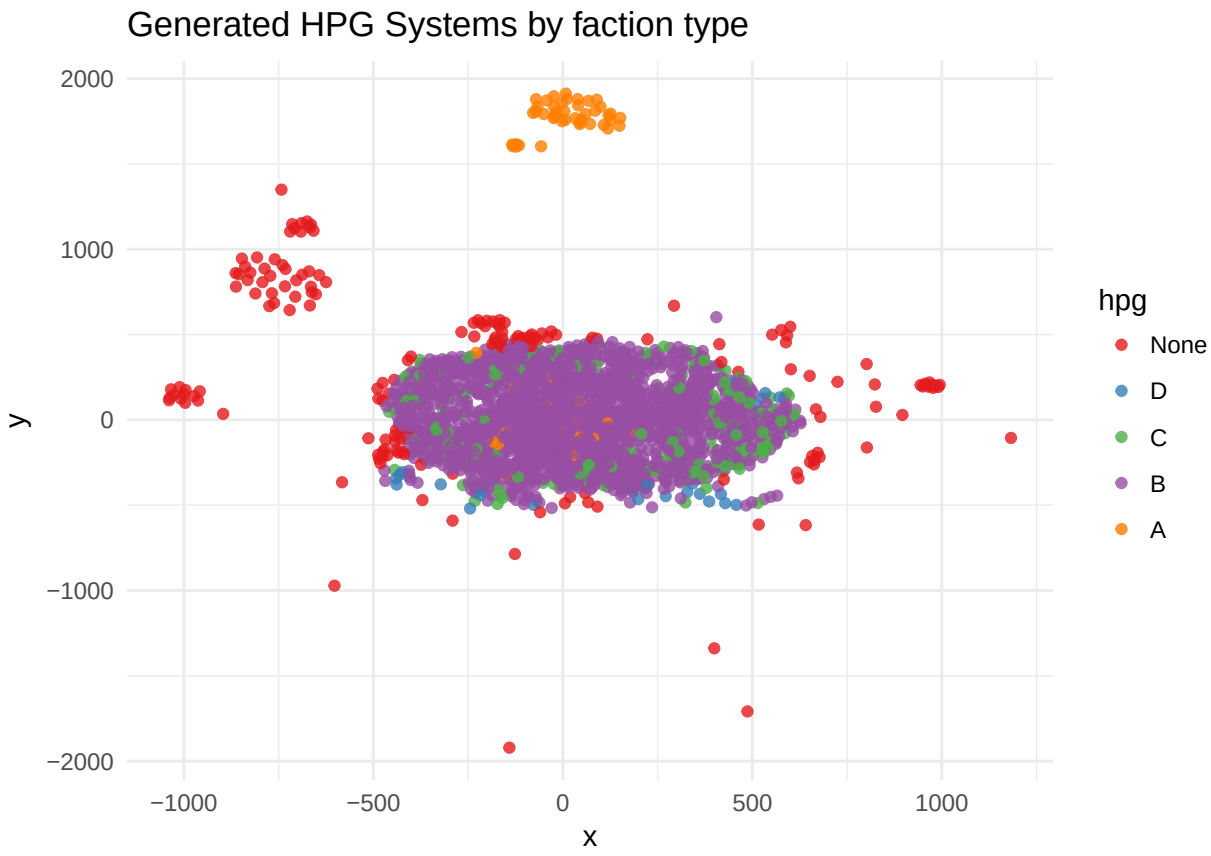

Relationship between population and distance from Terra
population (log−scale)
1e+09
1e+07
1e+05
0
500
1000
1500
2000
distance from terra
faction_type
Clan
IS
Minor
Periphery

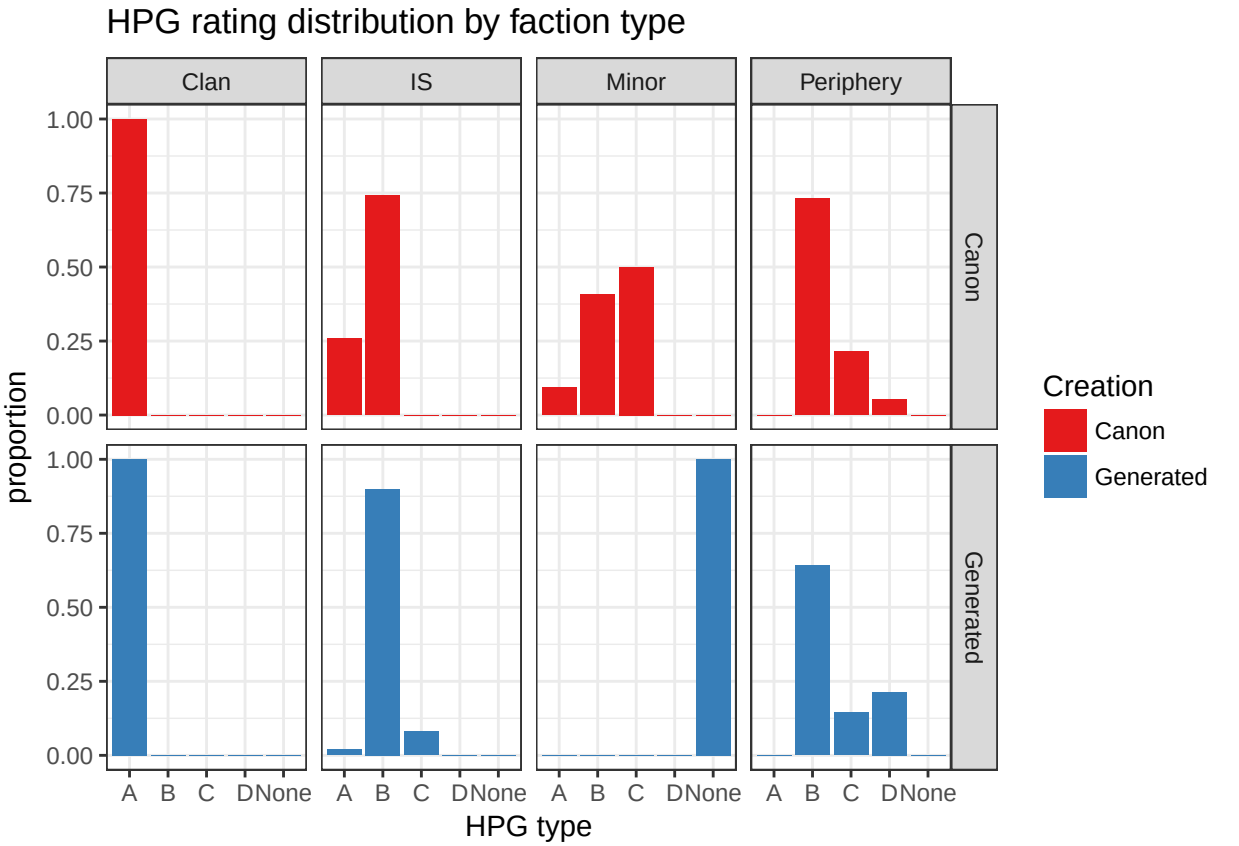
```
## `geom_smooth()` using method = 'gam'
```

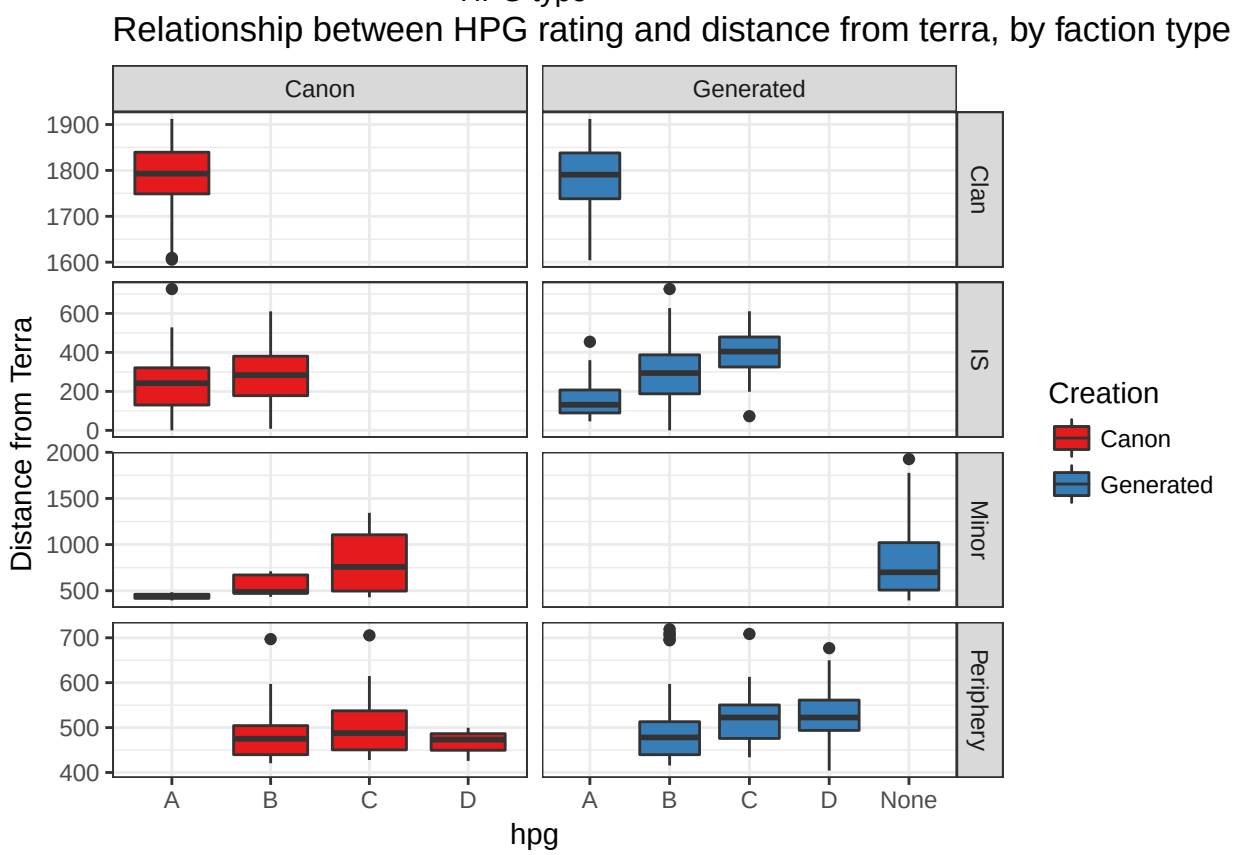



Relationship between population and distance from Terra
population
9e+09
6e+09
3e+09
0e+00
0
500
1000
1500
2000
distance from terra
faction_type
Clan
IS
Minor
Periphery

HPG


Generated HPG Systems by faction type
2000
1000
0
−1000
−2000
y
−1000
−500
0
500
1000
x
hpg
None
D
C
B
A


HPG rating distribution by faction type
Clan
IS
Minor
Periphery
Canon
Generated
proportion
1.00
0.75
0.50
0.25
0.00
A
B
C
DNone
HPG type
Creation
Canon
Generated


Relationship between HPG rating and distance from terra, by faction type
Canon
Generated
Clan
IS
Minor
Periphery
Distance from Terra
1900
1800
1700
1600
600
400
200
0
2000
1500
1000
500
700
600
500
400
A
B
C
D
None
hpg
Creation
Canon
Generated