# Extended Reality 3D Model Application in Space Exploration and Planetary Habitation Mikhail Nikolaenko, Computer Science; Project Advisor: Dr. Ming Tang

## Abstract:

This proposed project incorporates the use of data science, astronomy, and VR to create a visually interactive learning tool for students, academics, enthusiasts, and professionals alike to learn about areas of space exploration that will be easily accessible to anyone with a VR device such as an Oculus Quest 2. The application will include an **accurate mapping** of different celestial bodies such as planets and stars, and the model will be **fully interactable** through functions such as scaling, time manipulation, and highlighting. The uses of this proposed application range from basic elementary applications (e.g. learning about our solar system in astronomy courses) to astronomical data research (e.g. viewing spectra of celestial objects found by Gaia).

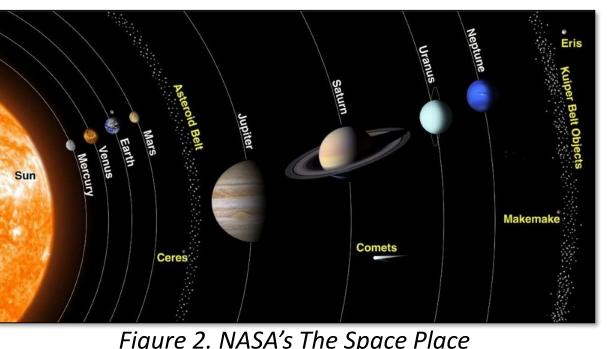
## Intro:

## Why?

- > Combine multiple interdisciplinary skills, such as data science, XR technologies, software development, astronomy/astrometry to create an interactive space education application. Current 3D models exist, but not to this proposed scale, accuracy, or interactivity; Example:
- NASA's "Eyes on exoplanets" contains around 1000 exo-planets.<sup>1</sup>
- > Databases exist but are too difficult to understand for non-professional individuals. (see Figure 1) > 2D Diagrams often don't present the scale of distances and objects (see Figure 2)

	Α	В	С	D	E	F	G	н	l. I	J	κ	L	М	N	0	Ρ	Q	R	S	T	U	V	W
1	solution_id	source_id	random_index	ref_epoch	ra	ra_error	dec	dec_error	ra_dec_corr	astrome	ast	astrea	stroi	astror	astron	astrom	astrometr	astrometr	astrometi	r astrometr	astrometr	astror	match
2	1.64E+18	6.91E+18	644618244	2015	312.1157554	3.956163569	-3.74035	1.404508	0.99665	62	0	62	0	0	0		0.374397	3.284118	FALSE	1.235849	2.662341	2	9
3	1.64E+18	6.91E+18	668015830	2015	312.1343319	4.045969091	-3.73963	1.437343	0.99665	62	0	62	0	0	0		0.432068	5.060065	FALSE	1.349939	2.566972	2	10
4	1.64E+18	6.91E+18	609250353	2015	312.138582	25.93889781	-3.73706	11.68324	-0.70815	25	0	25	0	0	0		1.58134	1.509319	FALSE	1.34948	0.121771	2	6
5	1.64E+18	6.91E+18	393393107	2015	312.1311733	24.81927117	-3.73526	11.17584	-0.7076	24	0	23	0	1	0		1.258626	1.049244	FALSE	1.164136	0.12126	2	6
6	1.64E+18	6.91E+18	241639886	2015	312.1346758	23.95391504	-3.73385	10.81131	-0.70745	25	0	25	0	0	0		1.077916	0.451322	FALSE	1.090901	0.091946	2	6
7	1.64E+18	6.91E+18	1083380421	2015	312.1281074	25.14685086	-3.73342	11.34067	-0.709	27	0	26	0	1	0		0.619861	0.287113	FALSE	1.047695	0.154572	2	6
8	1.64E+18	6.91E+18	991794988	2015	312.1124316	21.8538572	-3.73633	9.027788	-0.971	45	0	45	0	0	0		0	0	FALSE	1	0.04592	2	7
9		6.91E+18		2015	312.1067336	3.185126924	-3.7317	1.153372	0.98335	71			0	0	0		0.275343	0.335408	FALSE	1.029765	0.684084	2	9
10		6.91E+18		2015	312.1088187	24.87797005	-3.73645	11.22071	-0.70905	27	-		0	0	0		0	0	FALSE		0.160893	2	6
11		6.91E+18		2015	312.1248386				0.99885		-	79	0	0	0			49.05027	FALSE		4.96576	2	10
12		6.91E+18		2015	312.122955	4.348196974	-3.72973	1.572403	0.9986	79	0		0	0	0		0.468832	107.589	FALSE	2.989277		2	10
13	1.64E+18	6.91E+18	772363589	2015	312.1257629	3.255037154	-3.72333	1.183533	0.98385	71	0		0	1	0		0.682951	2.391867	FALSE	1.206762	0.67239	2	9
14		6.91E+18		2015	312.1433811	2.950897397		1.080953	0.96435	62	-		0	0	0		0	0	FALSE		0.423741	2	9
15	1.64E+18	6.91E+18	200796881	2015	312.1499471	3.205912033	-3.72236	1.167898	0.98425	62			0	0	0		0	0	FALSE	1	0.849971	2	9
16	1.64E+18	6.91E+18	346699479	2015	312.1425548	3.189075215	-3.71974	1.150169	0.9797	62	0	61	0	1	0		0.20585	0.167672	FALSE	1.015331	0.652856	2	9
17	1.64E+18	6.91E+18	822965385	2015	312.1533747	3.999442966	-3.7072	1.428178	0.99085	62	0	62	0	0	0		0.890556	17.25141	FALSE	2.045433	0.958729	2	10
18	1.64E+18	6.91E+18	669911155	2015	312.1355708				-0.9706	43			0	0	0		0	0	FALSE	1	0.043236	2	8
19	1.64E+18	6.91E+18	1065804604	2015	312.1317649	21.91959742	-3.70926	9.055514	-0.96975	41	0	41	0	0	0		0	0	FALSE		0.050853	2	7
20	1.64E+18	6.91E+18	340485901	2015	312.133152	25.22884576	-3.70803	11.3763	-0.70905			27	0	0	0		0.60432	0.226551	FALSE	1.046984	0.189226	2	6
21	1.64E+18	6.91E+18	904055603	2015	312.1467259	4.978188083	-3.71137	6.757577	0.8818	35	0	35	0	0	0		1.076909	9.604273	FALSE	1.190646	0.211329	2	7
22	1.64E+18	6.91E+18	270927225	2015	312.1467864	25.59407409	-3.70701	11.54443	-0.7092	27	0		0	0	0		0	-5.36E-16	FALSE		0.180802	2	6
23	1.64E+18	6.91E+18	1019462870	2015	312.0594665	24.09072374	-3.7663	10.87785	-0.7079	27			0	0	0		1.618732	1.035805	FALSE	1.206155		2	5
24		6.91E+18		2015	312.0690109				0.7405	45	0	44	0	1	0				FALSE		0.075135	2	7
25	1.64E+18	6.91E+18	468420179	2015	312.066464	14.75689289	-3.75232	18.78226	0.98675	44	0	44	0	0	0		0.589283	1.700937	FALSE	1.158783	0.713022	2	7
26	1.64E+18	6.91E+18	252634356	2015	312.0474497	3.715399972	-3.75798	1.343479	0.9969		0		0	0	0		0.484194	9.923437	FALSE	1.534219	2.549269	2	10
27	1.64E+18	6.91E+18	810786160	2015	312.0460114	21.84225026	-3.75484	9.025407	-0.97045	36	0	35	0	1	0		1.506641	1.2437	FALSE	1.091057	0.047559	2	6
28	1.64E+18	6.91E+18	282940965	2015	312.0564258	4.170324317	-3.75063	1.512999	0.9967	71	0	71	0	0	0		0.568451	32.5803	FALSE	2.516543	2.56468	2	9
29	1.64E+18	6.91E+18		2015	312.0583843	3.09602411	-3.74098	1.254902	0.8766	51	0	51	0	0	0		1.874051	6.897879	FALSE	1.668933	0.149312	2	8
20	1 645/10	6 01C±10	720002705	2015	212 0702200	2 752055001	2 72750	1 262407	0 009/15	01	0	01	0	0	0		0 421769	26 4995	EALCE	2 0012	4 501054	2	11

Figure 1. CSV File containing Gaia Release 3 data



## Methods:

### Software:

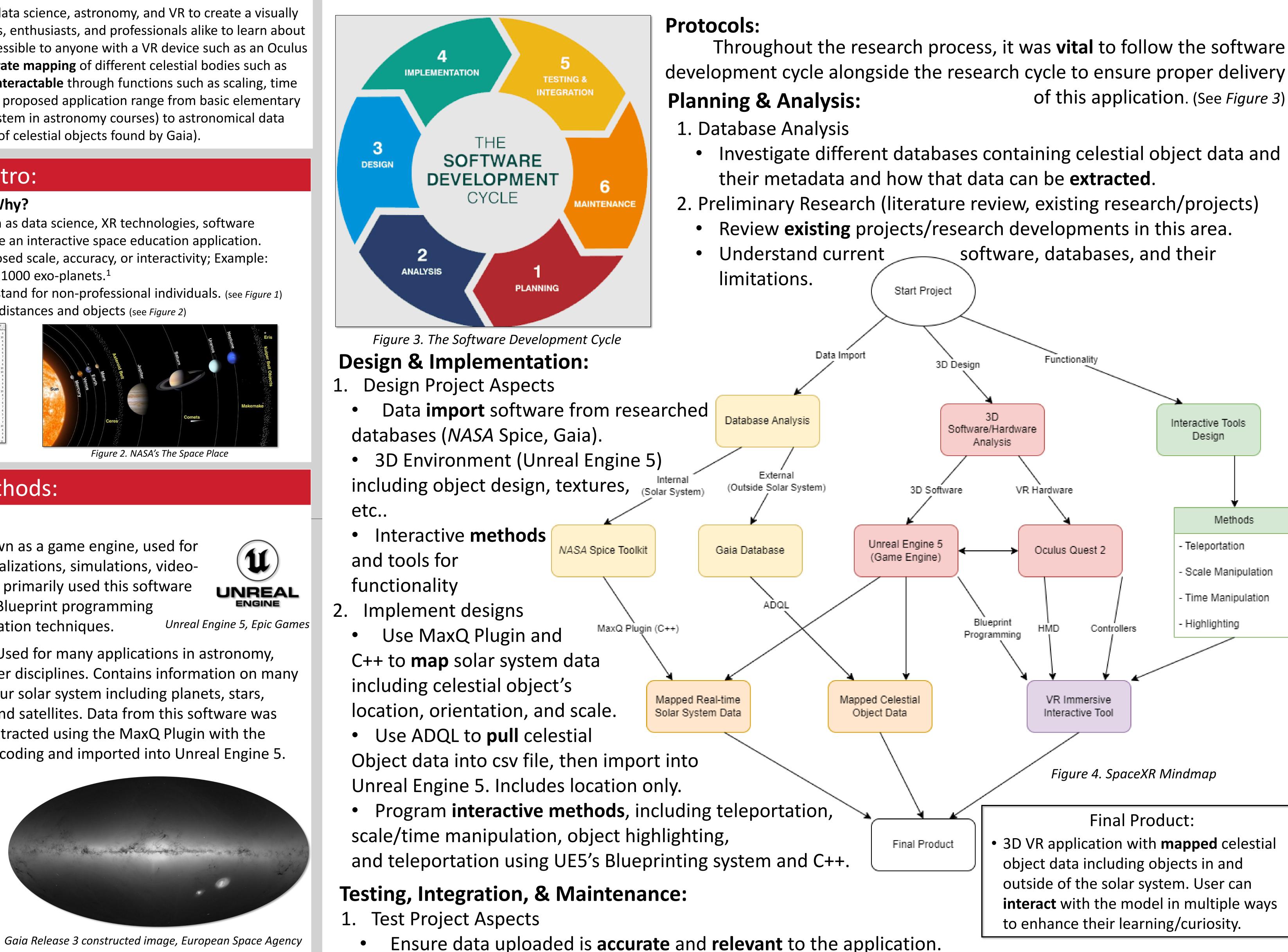
Unreal Engine 5 (UE5): Commercially known as a game engine, used for many applications involving real-time visualizations, simulations, videogames, VR development, etc.. This project primarily used this software with the combination of custom C++ and Blueprint programming techniques, algorithms, and data manipulation techniques.



NAIF, creator of SPICE

Nasa SPICE Toolkit: Used for many applications in astronomy, astrometry, and other disciplines. Contains information on many celestial objects in our solar system including planets, stars, asteroids, comets, and satellites. Data from this software was programmatically extracted using the MaxQ Plugin with the combination of C++ coding and imported into Unreal Engine 5.

Gaia Database: The largest, most accurate mapping of the Milky Way Galaxy created by the *European Space* Agency. This database contains information on distant celestial objects via the Gaia Satellite. Data was programmatically extracted using the ADQL language into a csv file, then imported into Unreal Engine 5 Hardware:





Oculus Quest 2, Meta

Oculus Quest 2: VR HMD (headset) with controllers is used for many applications involving gaming, 3D visualization, virtual reality, etc.. The Interactivity of this hardware was programmed using C++ and UE5's Blueprinting system to create an interactive and functional application.



- 2. Maintain Program Integrity
  - Polish bugs, details, and overall look of the application.
  - Move onto the next software development cycle step to **complete** the cycle.

## Process:

Test different cases of **interactivity** in multiple combinations to ensure intended functionality.

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## **Results:**

**Outcome:** 

- $\succ$  3D VR Application that runs on Oculus Quest 2.
- > Incorporates data on different celestial objects in and outside of the solar system.

Figure 5. Imported Gaia Stars, SpaceXR



- > Includes multiple interactive tools such as teleportation, scale manipulation, and time manipulation.
- > Base software allows for **new data** to be pushed into the application.

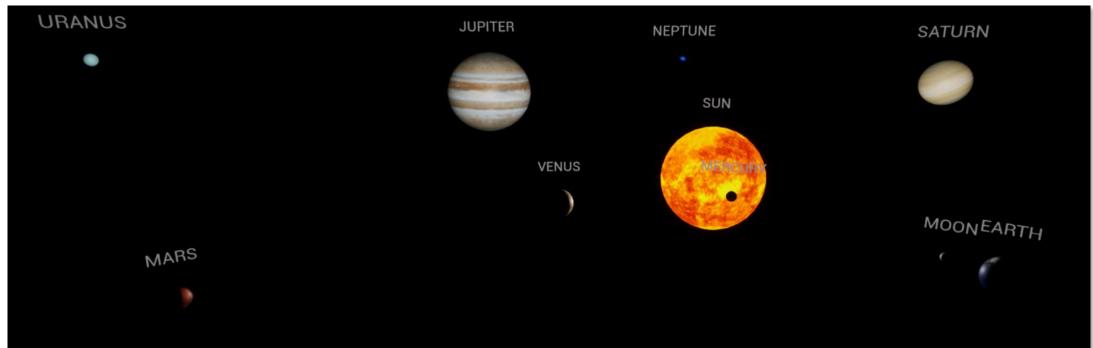


Figure 6. Solar System, SpaceXR

# Conclusion:

## Findings:

- Data on celestial objects exist and can be accurately modeled in a 3D software if **given** proper metadata, such as inclination, declination, and parallax.
- Modern game engines such as Unreal Engine 5 with custom programming can handle thousands of objects with metadata in real-time.

## **Future Directions:**

- Expanding current solar system model to other celestial objects other than planets and the sun.
- > Incorporating other **databases** for external objects, such as the Dark Energy Survey
- Incorporating artificial intelligence to determine habitability and/or other factors associated with celestial objects.

# References & Acknowledgments:

	Acknowledgements:
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	<u>External Celestial Data:</u> This work has made use of data from the European Space Agency (ESA) mission Gaia ( <u>https://www.cosmos.esa.int/gaia</u> ), processed by the Gaia Data Processing and Analysis Consortium (DPAC, <u>https://www.cosmos.esa.int/web/gaia/dpac/consortium</u> ). Funding for the DPAC has been provided by national institutions, in particular the institutions participating in the Gaia Multilateral Agreement.
	<u>Internal Solar System Data:</u> Acton, C.H.; "Ancillary Data Services of NASA's Navigation and Ancillary Information Facility;" Planetary and Space Science, Vol. 44, No. 1, pp. 65-70, 1996. DOI 10.1016/0032-0633(95)00107-7
	Charles Acton, Nathaniel Bachman, Boris Semenov, Edward Wright; A look toward the future in the handling of space science mission geometry; Planetary and Space Science (2017); <u>DOI 10.1016/j.pss.2017.02.013</u>
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