Cologne Game Lab

Master Thesis

Space Debris: History, Analysis and Implementation of a Web - Based Visualization System

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Declaration of Authorship

I, Aleksandra ZARICHIN, declare that this thesis titled, "Space Debris: History, Analysis and Implementation of a Web - Based Visualization System " and the work presented in it are my own. I confirm that:

- Where any part of this thesis has previously been submitted for a degree or any other qualification at this University or any other institution, this has been clearly stated.
- Where the thesis is based on work done by myself jointly with others, I have made clear exactly what was done by others and what I have contributed myself.

Signed:

Date:

"There are two educations. One should teach us how to make a living and the other how to live."

John Adams

Abstract

Space Debris became a huge and dangerous problem. For that reason this Master Thesis allows people to get more knowledge about the vast amount of the human made objects flying currently all over around the Earth. At first, I'm trying to explain and give some more information of the history of the Space Debris problem. Also how the people started to track the Space Debris and why it is important to track it. Further, I propose a method how to effectively visualize space objects including space debris. The method that I propose includes a possibility to search specific space objects by name or category which are displayed with their orbits, movements and current position. Moreover with this research and implementation, the specialist researches, can contribute with their researches and collecting information which would help to find some a solution for this problem.

Acknowledgements

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Chapter 1

Introduction

Space junks or space debris are unwanted objects or rubbish which are left floating in space. It is classified into two different categories, orbital debris and meteoroids. Meteoroids are the "natural substance" in space, including fragment of asteroids and bits of comets. The meteors are in the orbit around the sun, while most artificial debris is in the orbit around the Earth. Orbital debris are man-made objects that are left in space, caused by a variety of reasons[1] (see Figure 1.1). The population of orbital debris comprises of different types of objects created in different ways, from highly energetic disintegration of spacecraft to slow diffusion of liquid metal. This includes the non-functional spacecraft and inactive satellites

[1] Mark Garcia. *Space Debris and Human Spacecraft*. und. Text. Apr. 2015. URL: http://www.nasa.gov/mission_pages/station/news/orbital_debris.html (visited on 11/16/2016).

FIGURE 1.1: Man made objects that are left in the space

which ended their travels, and fragments of collisions, erosions and explosions in the orbit. Space debris is usually located in the low Earth orbit called LEO from approximately 300 to 2,000 km above the surface of the earth. These objects stay in the orbit for a long time, and their movement can hardly be decelerated and controlled. The medium Earth orbit called MEO is a geocentric orbit at a distance of 2000 km to 35,786km. The high Earth Orbit is a geocentric Orbit with a height that exceeds 35,786km[2].

[2] *Space debris*. en. 2016. URL: http://www.space.com/16518-space-junk.html (visited on 10/22/2016).

It is assumed that more than 170 million pieces of debris with a size of less than 1 cm are existing in the orbit of the earth, while there are approximately 670,000 pieces of debris with a size of 1 to 10 cm and approximately 29,000 pieces of debris that are so small that they cannot be monitored. The object's direction of movement in the orbit is another problem[3]. In many cases, pieces of the orbital debris fly towards others which move in the opposite direction. Thereby, the probability for emergence of collisions increases and the result could be explosive.

1.1 Space Trash, it's everywhere

Slowly but constantly, the space in the orbit around the earth started to be polluted. Ever since, these events repeated (by launching new satellites and explosions of space crafting the orbit), the creation of space debris has started (see Figure 1.2). These objects, artificial debris from space, pollute the space maybe irrevocably and threaten the human activities in space. However, what poses the most serious threat to space missions is the debris which cannot be monitored. This was stated

[3] *Orbital Debris*. und. Text. Apr. 2015. URL: http://www.wikivisually.com/wiki/Orbital-debris/1 (visited on 11/16/2016).

by Nicholas Johnson, a chief scientist working on the field of space debris in NASA. The issue of space junk is more complex than the issue of satellites. NASA likes to call this "orbital debris" which refers to all artificial objections in the earth orbit that are not used for a specific purpose. Another important fact is that the origin of the orbital debris may be a result of a mission, an accident or deliberate human action[4].

FIGURE 1.2: Space junk is everywhere

NASA's preferred terminology "orbital debris" is defined as all human objects in orbit about the earth which have lost their value or usefulness. The debris may originate in one of three ways : mission-related operations, accidents or international creation.

[4]Mark Garcia. *Space Debris and Human Spacecraft*. und. Text. Apr. 2015. URL: http://www.nasa.gov/mission_pages/station/news/orbital_debris.html (visited on 11/16/2016).

1.2 Tracking Space Debris

The common way to detect and monitor orbital debris is by using radars and telescopes. In the period of April 1984 to January 1990, a lot of information was obtained about debris. This was achieved by NASA's Long Duration Exposure Facility which made as much as 32,422 orbits around the earth in the period of 5.7 to 6 years that it spent in low earth orbit. The satellite had a length of 9 meters and a diameter of 4.3 meters, and surrounded by flat panels[5].

It is understandable that the monitoring of artificial orbital debris is an expensive process which implies a lot of resources, a lot of equipment and appropriate space objects which would be able to provide information on certain events in space. For such monitoring purposes, ground based radars and optical sensors are applied. More specifically, ultra-high frequency (UHF) radars are used for constant monitoring, while super high frequency (SHF) radars are used for the monitoring of very small debris and this type provides more accurate and specific data. In addition, space surveillance of orbital debris is performed whit space-based sensors. One form of useful

[5] D Mehrholz et al. "Detecting, tracking and imaging space debris". In: *ESA Bulletin(0376-4265)* 109 (2002), pp. 128–134.

equipment that is being used in space includes special spacecraft equipment with panels that are collecting informations and additional passive monitors. The obtained informations about the number and the nature of impacts that such satellites have experienced is a very good reference about the quantity of debris pieces which can hardly be detected by others sensors[6].

Tracking radars are applied in order to get more accurate measurements of the important indicators such a speed, direction and range. Some tracking radars operate mechanically, equal as phased array radars are able to track electronically[7].

Orbital debris is responsible for numerous problems, which can be classified into four different directions. First this refers to collisions caused by spacecraft or debris which result damages or destruction of the spacecraft or even creation of additional debris. Second, Orbital debris often misguides space scientists because confusion emerges when pieces of debris are mistaken for other events. Sometimes this prevents the accurate identification of other phenomena. Third, Orbital debris has reflections on astronomy as well, because the trails

[6] *Space Debris - A Guide*. URL: http://www.spaceacademy.net.au/watch/debris/gsd/gsd.htm (visited on 11/16/2016).

[7] *Space Debris - A Guide*. URL: http://www.spaceacademy.net.au/watch/debris/gsd/gsd.htm (visited on 11/16/2016).

of debris are clearly displayed on astronomical images. Furthermore, space debris creates transient events in astronomy because it is reflected on transmitters twice, to Earth and in to space. In addition, orbital debris causes a more expressed background sky glow. Orbital debris has other effects as well, such as radiation that may be caused by some debris especially large pieces[8].

[8] *Space Debris - A Guide*. URL: http://www.spaceacademy.net.au/watch/debris/gsd/gsd.htm (visited on 11/16/2016).

Chapter 2

Analysis of Space Debris - Theoretical part

2.1 History of Collisions

Donald J. Kessler is the first American astrophysicist and former scientist at NASA, who started to consider and research the effects of the space debris as early as in the seventies of the past century. Donald J. Kessler is very experienced in the field of orbital debris, meteoroids and interplanetary dust. He started working at NASA when he schematically represented the interplanetary meteoroid surrounding. Due to his knowledge in these modelling techniques, he was more prepared for research of artificial satellites in the earth orbit. He projected that the quantity of artificial space debris would be higher than the quantity of natural meteoroids. This claim was supported whit evidence and it was a solid ground for the commencement of the operation of NASA's Orbital Debris Program Office at the Johnson Space Center in 1979[1]. Within this engagement he was dedicated to the development of advanced models of orbital debris. He worked on practical trials, experiments and on the analysis of numerous findings which he used in order to come to new conclusions. In addition, he held lectures, workshops and gatherings focused on orbital debris, and he suggested economic solutions for the environment. He also took apart in different reviews, in the country and abroad, which gradually led to the forming of the inter-Agency space debris Coordination Committee (IADC). This agency is primarily focused on all matters related to orbital debris[2].

In his publication titled "Collision frequency of Artificial Satellites: The Creation of a Debris Belt , which was published in 1978" -[3] and which is also known as the Kessler syndrome

[1] *The Kessler Syndrome Explained*. URL: http://www.spacesafetymagazine.com/space-debris/kessler-syndrome/ (visited on 11/16/2016).

[2] Donald J Kessler et al. "The kessler syndrome: implications to future space operations". In: *Advances in the Astronautical Sciences* 137.8 (2010), p. 2010.

[3] *The Kessler Syndrome Explained*. URL: http://www.spacesafetymagazine.com/space-debris/kessler-syndrome/ (visited on 11/16/2016).

or Kessler effect, Donald J. Kessler explains the favorable and unfordable circumstances which will prevail in our orbit due to the presence of space debris. The Kessler syndrome is an occurrence which happens when several major collisions, due to the density of objects in the low earth orbit, cause a sequence of a new collisions whereby the dangerous debris in the orbit increases. After this scenario, a s the number of satellites increases, there will be a moment when many satellites will be destroyed due to collision whit stray fragments from the space debris and this would continue as a domino effect[4].

In the period from 1968 to 1985, America and the Soviet Union launched many anti-satellite weapons(ASATs). The soviet version was designed in order to explode close to its target, while the american system did not have explosives with it. However, it was designed to destroy its goal with a direct strike. Until 1990 several such tests created 7 percent registered orbital debris, while the number of smaller and unregistered debris was unknown. In the last US ASAT test, in 1985, a rocket plane started to destroy the non-functional American satellites in the relatively low orbit of 525 km. Until January

[4]Paula H. Krisko. "NASA's New Orbital Debris Engineering Model, ORDEM2010". In: *NASA* (). URL: http://hdl.handle.net/2060/20100001666.

1, 1998, all except 8 of 285 pieces of space debris fell out of the orbit(see Figure 2.1) (see Figure 2.2).

In 2007 China launched anti-ballistic weapon in order to destroy its non-operating weather satellite Fengyun-1C. This collision happened at an elevation of 863 km and it created more than 3000 parts of space debris which will be dangerous for navigation for decades. Ten days after the test the debris was spread throughout the orbit, and three years after, they were spread at an elevation from 175 to 3,600 km[5].

The first major collision of artificial satellites happened on 10.02.2009 at the altitude of 789km in the Earth orbit. The collision was between the satellites Iridium 33 with a weight of 560kg and Cosmos -2251 with a weight of 950kg at a speed of a 42,120 km/h. Iridium 33 belonged to the American company Iridium Satellite LLC and it was one of the 66 satellites of this company which was engaged in satellite telephony. It was launched in 1997. Cosmos-2251 is a Russian communications satellite and it flied without control. According to the calculations, these two satellites were supposed to pass each other, however at the moment when they passed each other, Iridium

[5]Loretta Hall. "The History of Space Debris". In: *NASA* (). URL: http://commons.erau.edu/cgi/viewcontent.cgi?article=1000&context=stm (visited on 11/16/2016).

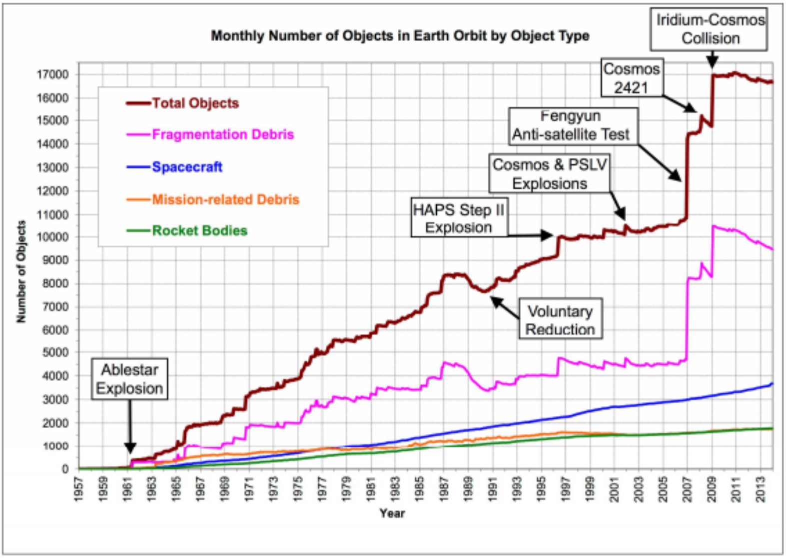

FIGURE 2.1: Catalogued space debris overtime. Image credit: NASA, annotated by Mika McKinnon

33 stopped transmitting signals. After the collision, our orbit became richer for approximately 1,600 new fragments which dispersed and increased the number of space debris in the orbit. With the analyses from 2010 it was concluded that 20 percent of them will stay in the orbit for 30 years, and most of them will descend through the orbit(see Figure 2.2)[6].

[6]Donald J. Kessler and Burton G. Cour-Palais. "Collision Frequency of Artificial Satellites: The Creation of a Debris Belt". In: *Journal of Geophysical Research* 83 (1978), pp. 2637–2646. DOI: 10.1029/JA083iA06p02637.

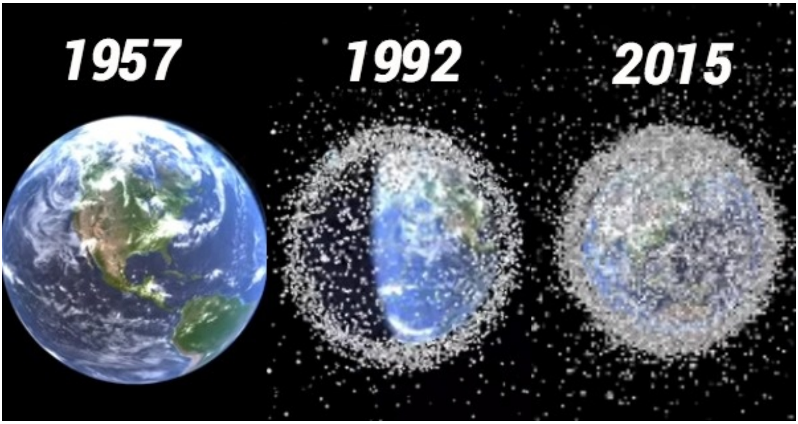

FIGURE 2.2: Space junk is growing up from 1957 to 2015

2.2 Importance of tracking Space debris

There are several reasons we need to take a look at. According to suggestions of the European Space Agency there are currently around 170.000.000 pieces of space debris bigger then 1mm, 750.000 pieces of them bigger than 1cm and around 29.000 pieces even bigger than 10cm. The most parts doesn't seem very big if we are seeing that situation with our "normal" view. But what we definitely need to consider is that the space debris is moving with speeds up to 36.000km/h. That means, something like a small piece of 1cm can produce a damage like a small grenade to every flying object in the orbit[7].

We need to find solutions for a full tracking of our space debris for several reasons. One of them is the already explained risk that is existing due to eventual damages for satellites and spaceships.

Another reason we need to see is the danger for the humans on earth. The small pieces of space debris from 1mm up to 1cm burn in the atmosphere before they are able to reach the ground comparable to a meteoroid shower. But bigger parts of space debris like old gas tanks from space ships for example are much bigger and in their own way very dangerous because of their size and weight. They are too big to burn completely in the atmosphere, so they will after they continued following their first orbit be slowed down from the thin rest of the atmosphere and finally fall down to the ground. Parts of that size and weight are a big risk for humans and animals[8].

One further point is that the favorite orbits for satellites

[7] "Gefahr durch Weltraumschrott: Deutsche Forscher planen gezielte Überwachung ab 2018". In: (). URL: http://info.kopp-verlag.de/neue-weltbilder/neue-wissenschaften/andreas-von-r-tyi/gefahr-durch-weltraumschrott-deutsche-forscher-planen-gezielte-ueberwachung-ab-2-18.html (visited on 11/29/2016).

[8] "Weltraummüll: Entstehung, Vermeidung und Gefahren". In: (). URL: http://lexikon.astronomie.info/satelliten/spacedebris/ (visited on 11/25/2016).

and spaceships will be very dangerous and full of space debris in the future. For example the height of 750-800km that is currently very popular due to the cheap cost, as also the height around 36.000km is popular for the geostationary positions. If we are not tracking the space debris perfect, we will have need to spend a lot of more money to secure the satellites and space ships and exploring our orbit and using the benefits we receive due to that science will be much more expensive than in the past[9].

2.3 Literature Review

Space Debris has become a real threat for the Earth. For that reason, there are already existing projects for the visualization of space debris. Some of the existing projects are showing just a part of the specific information or another type of visualization.

For example there is a project called Stuffin.space , that is a great example of what we are trying to do in our project. Stuffin.Space project is developed by NASA. Allows users to see exactly what objects are floating around there giving their

[9] "Weltraumschrott bedroht Satelliten: Das All braucht eine Müllabfuhr". In: (). URL: http://www.n-tv.de/wissen/Das-All-braucht-eine-Muellabfuhr-article17538521.html (visited on 11/25/2016).

location, orbit and speed. Moreover, this project gives us a possibility to generate groups of debris, whereby they will be displayed with their orbits[10].

Another project is a website providing mainly satellite tracking Services named N2YO. This project with the help of google maps allows users to see a specific satellite, its position at the moment and the country which it is bypassing at the specific moment. Also N2YO shows us in detail the speed of movement the elevation, the inclination and the altitude. N2YO is even called Live real time satellite. Moreover in this web site project the users have a possibility of alerting tools where the user can select different alerts : space station prediction by voice , space station notification tool or sending alerts by email or sms[11].

The California Institute of Technology had created an application where they have developed a very complex system of visualization. After the installation the user has the possibility to choose what he wants to see: for example Earth, Solar system, Exoplanets. When the user selects the eyes on the Earth, he has the possibility to see the visualization of the

[10] *Stuff in Space*. URL: http://stuffin.space (visited on 11/25/2016).
[11] "Live Real Time Satellite Tracking and Prediction". In: (). URL: http://www.n2yo.com/ (visited on 11/25/2016).

global temperature, carbon dioxide, carbon monoxide, see level, soil moisture, water and ice and also some missions. Moreover, when the user is selecting some mission, also is selection one satellite, and developing the mission of the satellite with short information box[12].

The next already existing project is ISS tracker. This web site is created for non-profit educational development. It allows the public a glimpse of what the astronauts in the International Space Station would see when gazing upon the Earth. The ISS tracker is tracking just the ISS satellites, with the real position and information of the speed, latitude, longitude.

Another project from where we get some visualization ideas is 100, 000 stars. This project is developed from the Data Arts Team at Google. 100,000 stars is a Google Experiment that uses real data derived from multiple star catalog. Users can zoom inside the solar system out to the Milky Way galaxy. Each provided star is clickable and giving as an info box with information. In this visualization the user has also possibility to go to other planets. This project is created at 15 November 2012[13] .

[12] "Jet Propulsion Laboratory". In: (). URL: http://eyes.nasa.gov/ (visited on 11/25/2016).

[13] "Chrome Experiments: 100,000 Stars". In: (). URL: http://stars.chromeexperiments.com/ (visited on 11/12/2016).

2.4 Analysis

Space debris is a real danger for the planet Earth because the Earth's orbit is very polluted. The resolution of this problem of space debris requires undertaking of a long-term plan. Even if the current number of pieces of space debris is bearable in the long run, the problem will increase. The management of space debris requires a long-term perspective and it is a challenge and an opportunity to preserve the environment for the future generations. The orbital debris is a long -term care for the society and measures are necessary for its improved modeling, better measurement, regular updates, and as well other activities in order to characterize better the long-term evolution in the environment.

The large countries in the world want to resolve the problem with orbital waste and numerous researches and projects have started in order to eliminate this problem. One of the ways to the orbit is to launch satellites in the high orbit or by means of sensors and lasers, the non-functional satellites can be descended into the low orbit and the earth gravity can pull them towards the earth[14].

[14] *Space trash is a big problem. These economists have a solution.* URL: https://www.washingtonpost.com/news/wonk/wp/2013/10/24/space-

The danger of orbital debris is basically a long-term problem of the environment and it should be treated as such a problem. Although the risk is limited at the moment, in the following period it will become dangerous for any spacecraft, the astronauts and the artificial satellites which are very important in today's society. In a time of globalism, where information and data is an important resource in the entire human life, the transfer of information should be quick, secure and available from everywhere. This is enabled by satellite communications and they transfer data and information from any part of the world regardless of the weather conditions and the costal-political views. Of course they are also very important in science and many achievements that were impossible in the past, are now possible with their assistance. The investment in artificial satellites is economically feasible because the income of the companies which provide satellite services is high, however also has high strategic relevance because of the increased protection of the earth against specific danger. The sooner efficient reduction of orbital debris is provided at all heights, the less drastic and expensive will be the future activities in the society. Such planning would require a great effort from all

is-filling-up-with-garbage-heres-why-we-should-tax-it/ (visited on 11/16/2016).

economic and political creators, as well as appropriate technical support.

Chapter 3

Implementation of the system - Practical part

The German Aerospace Center (DLR) is engaged in a wide range of research and development of a lot of national and international projects, including aeronautics, traffic, energy and security. The Implementation of web- based Space Debris Visualization system is part of the project named the Backend catalog of "Relational Debris Information" - called BACARDI. The backend catalog of Relational Debris Information is the DLR's approach to a space debris database. The Visualization of this catalog should be developed to allow the user to see satellites and debris objects with their orbits and interact with them from a web browser.

3.1 Goals

Space debris has become one of the key topics in the space industry due to the catastrophic effects if not avoided. As the number of space debris increases, either due to nature or man-made reasons, more accurate models and predictions must be developed.

The implementation of space debris is a very complex method to be improved. Our goal is to introduce to the public, how much and what kind of trash our Earth is surrounded by. With this project we may get a better understanding and maybe we will find a solution how to clean it.

Moreover, the goal of this project is to propose some methods to deal with the problem of space debris. Also to get more knowledge with better eye visualization in order to protect our Earth of unwanted meteors.

3.2 Methods and Tools

3.2.1 JavaScript

Java Script is a programing language which was introduced in 1995 as a way to add programs to web pages to Navigator browser. Since then the language has been adopted by all other major graphical web browser. The JavaScript language has made modern application possible, with which you can interact directly, without doing a page reload for every action[1]. JavaScript only executes on the page(s) that are on your browser window at any set time. When the user stops viewing that page, any scripts that were running on it are immediately stopped. This language helps a lot in the Web based industry.

3.2.2 Three.js

The implementation of the Space Debris Visualization System requires installation of a Web API called WEBGL. WebGL (Web Graphics Library) is a JavaScript API for rendering interactive 3D computer graphics and 2D graphics within any compatible web browser without the use of plug-ins. Moreover, for better visualization and flexibility we are also using one library called Three.js. Three.js is a JavaScript 3D Library which makes WebGL much simpler[2]. With this library which contains a lot of functions and classes which are easy to handle, it gives us an opportunity to create a big Visualization System.

[1] Marijn Haverbeke. *Eloquent javascript: A modern introduction to programming*. No Starch Press, 2014.
[2] *Three.js*. en. 2017. URL: https://threejs.org/docs/ (visited on 01/01/2017).

Moreover Three.js makes things easier, for example the implementation of the scene graph, rendering API . Also Three.js is helping us to provide the support for the common 3D file formats (obj, collada).

3.2.3 Blender

Blender is a professional free and open-source 3D computer graphics software. It supports the entirety of the 3D pipeline-modeling, rigging, animation, simulation, rendering, compositing and motion tracking, even video editing and game creation[3]. We are using blender to create satellite models that are displayed inside the visualization.

3.3 Implementation details

At first the project will upload all satellites which are collected in our database. After uploading the satellites the first thing that is visualized is the Earth and dots, where each dot represents one space object. In our database there are approximately 15,000 pieces of space debris that need to be generated and loaded (see Figure 3.1). For that particular reason, the dis-

[3] *Blender*. en. 2017. URL: https://www.blender.org/features/ (visited on 01/01/2017).

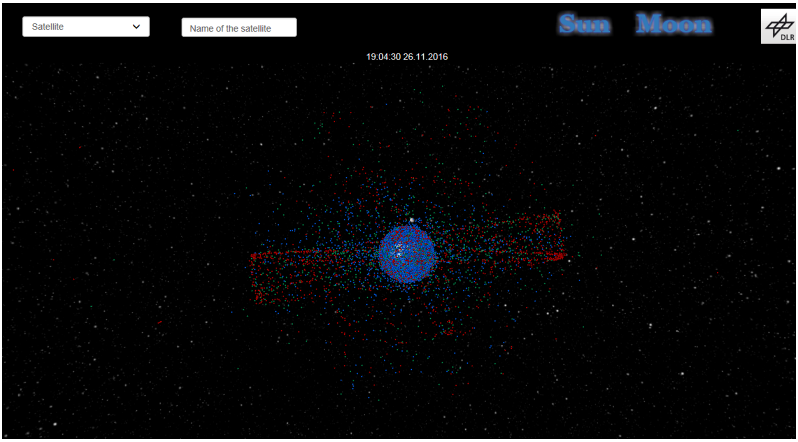

FIGURE 3.1: Visualization of the Earth and the satelittes

playing and the visualization on the screen might take some time. However, after generating and loading the database, the user can click on every piece of space debris which is moving around the Earth. In addition, the user has the possibility to play throughout the space and to become more familiar with the satellites and the space debris all around. With that option, the user can collect information about it. On the other hand, when the user clicks on some satellite, an automatically generated form from the database appears on the left side, with a detailed info box where the user can obtain information about the desired satellite. The user can perform additional research and more knowledge could be obtained not only with the info box but also with a search of satellites by indicating a specific name, country, altitude, and type. In the first case, by giving a specific name, our code searches through our database, then the camera moves and goes to the desired satellite. Moreover, the type of satellites which are above that specific country is also presented. In addition, the user has a possibility to choose between two types of visualization.

- The first visualization is the selection of a specific type of satellite. Only the selected group of satellites will be displayed on the screen. As an example on the picture below is shown just the payload (see Figure 3.2). This feature might help some people who are performing a research only on a specific type of satellite.
- The second type of visualization has one difference compared to the first type. The selected type is displayed even with their orbits (see Figure 3.3). However, due to this huge amount of satellites with orbits, the visualization might take some time to be displayed on the screen.

3.3.1 Reading and generating data

Our database contains more than 15,000 datas of debris and satellites. For tracking the satellites we are using the standard

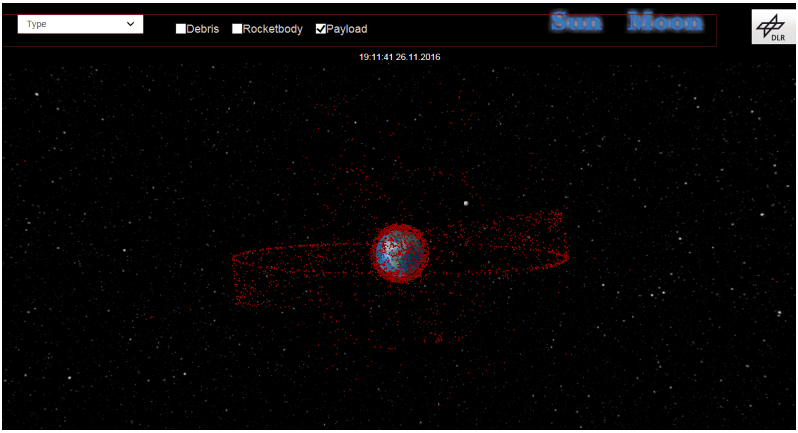

FIGURE 3.2: Visualization of type 1

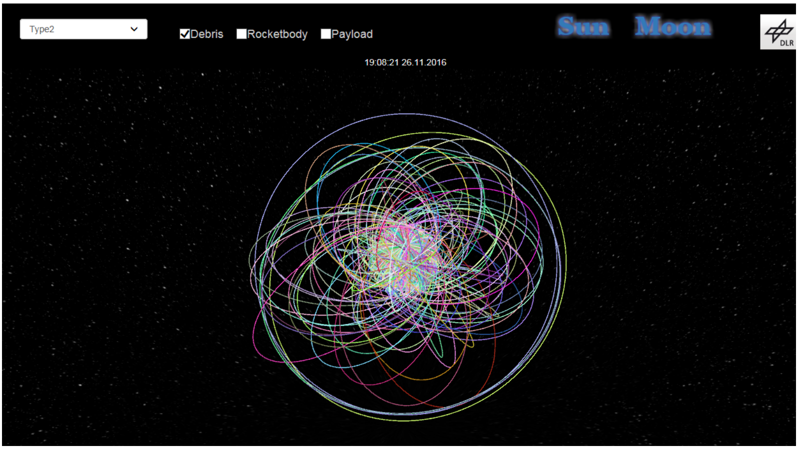

FIGURE 3.3: Visualization of type 2

mathematical model to describe a satellites orbit, called two line elements (TLE). Two line elements (TLE) are processed by a computer tracking software program, that gives us prediction for viewing time and position. Also we are using the library satellite.js which is a modular set of functions for SGP4 and SDP4 propagation of TLEs[4].With this two line elements database , we can read the position , in that moment , their movements, names and inclination. The format uses two lines on 80-columm ASCII (see Figure 3.4). The TLE format is a de facto standard for distribution of an earth-orbiting object. TLE can describe the trajectories only of the Earth - orbiting objects.


```
{
    "INTLDES": "98067A",
    "OBJECT_NAME": "ISS (ZARYA)",
    "OBJECT_TYPE": "PAYLOAD",
    "TLE_LINE1": "1 25544U 98067A   16081.83534722  .00006832  00000-0  10999-3 0  9990",
    "TLE_LINE2": "2 25544  51.6421 133.6858 0001946 345.4502   4.5206 15.54219105991388"
},
```


FIGURE 3.4: Picture from our database as an example of two line elements

3.3.2 Computation of the space object's current position

For generating the current position of the space objects, we are using ECI(Earth-centered inertial). ECI coordinate system also

[4]Shashwat Kandadai. *GitHub - shashwatak/satellite-js: Modular set of functions for SGP4*. en. URL: https://github.com/shashwatak/satellite-js (visited on 01/03/2017).

is defined as a Cartesian coordinate system, where the coordinates (positions) are defined as the distance from the origin along the three orthogonal axes[5] (see Figure 3.5).

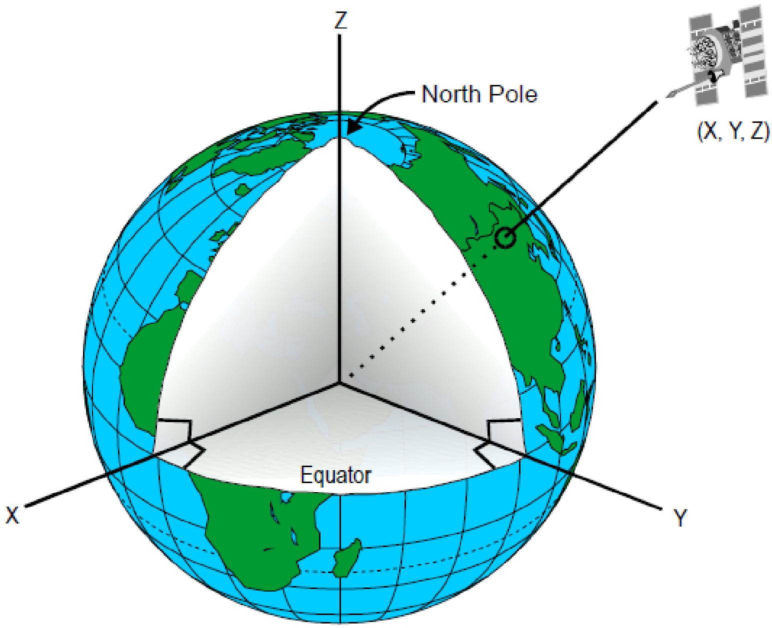

FIGURE 3.5: ECI(Earth-centered inertial) Credits:U.S. Department of Transportation Federal Aviation Administration - Airway Facilities Division - FAA

[5] *Orbital Coordinate Systems, Part I By Dr. T.S. Kelso*. en. 1995. URL: https://www.celestrak.com/columns/v02n01/ (visited on 01/03/2017).

Moreover we are using one function called vecFromLatLong where converts a position given latitude, longitude and distance to earth center (in 1000 km) to ECI coordinates(see Figure 3.6).

```
function getSatelliteOrbit(nowTime, satrec , orbitMaterial) {
    var julianDateNow = jday(nowTime.getUTCFullYear(),
            nowTime.getUTCMonth() + 1,
            nowTime.getUTCDate(),
            nowTime.getUTCHours(),
            nowTime.getUTCMinutes(),
            nowTime.getUTCSeconds());
    julianDateNow += nowTime.getUTCMilliseconds() * 1.15741e-8; //days per millisecond

    var timeSinceEpochMinutes = (julianDateNow - satrec.jdsatepoch) * 1440.0; //in minutes

    // time to make an orbit in minutes
    var orbitTimeMinutes = (Math.PI * 2.) / satrec.no;

    var nEvents = 300;
    var deltaT = orbitTimeMinutes / nEvents;

    // create orbit geometry
    var geometry = new THREE.Geometry();
    for (var i = 0; i <= nEvents; ++i) {
        var pv = satellite.sgp4(satrec, timeSinceEpochMinutes + i * deltaT);
        var pos = pv.position;
        geometry.vertices.push(new THREE.Vector3(pos.x / 1000., pos.y / 1000., pos.z / 1000.));
    }

    var satOrbit = new THREE.Line(geometry, orbitMaterial);
    return satOrbit;
}
```

FIGURE 3.6: The used function for converting latitude, longitude and distance

The ECI coordinate system is often used as the common coordinate system when performing coordinate transformations. For this case for the computation we are using the satellite.js library , which is generating the calculation automatically[6].

[6]Shashwat Kandadai. *GitHub - shashwatak/satellite-js: Modular set of functions for SGP4*. en. URL: https://github.com/shashwatak/satellite-js (visited on 01/03/2017).

3.3.3 Computation of the orbits

In order to get the orbit of the satellite we are using Julian Day Number(JDN) and the geometry of x, y, z axes (see Figure 3.7). Julian date or day number is the number of elapsed days since the beginning of a cycle of 7,980 years invented by Joseph Scaliger in 1583. The purpose of the system is to make it easy to compute an integer (whole number) difference between one calendar date and another calendar date[7]. Here we compute the period of the orbit with the satellite.js library[8], we subdivide the period in e.g. 300 times, then for each time we compute the position and in the end we connect the positions to create an orbit geometry.

3.3.4 3D Visualization

In order to get better visualization, we have created some 3D models. The 3D modeling in general makes the product design process more efficient. For creation of the 3D models we used Blender. With this feature we wanted to optimize the satellites, so that the user can see exactly what the satellites

[7] *Julian Date*. en. URL: https://www.defit.org/julian-date/ (visited on 01/05/2017).

[8] Shashwat Kandadai. *GitHub - shashwatak/satellite-js: Modular set of functions for SGP4*. en. URL: https://github.com/shashwatak/satellite-js (visited on 01/03/2017).

```
function getSatelliteOrbit(nowTime, satrec , orbitMaterial) {
    var julianDateNow = jday(nowTime.getUTCFullYear(),
            nowTime.getUTCMonth() + 1,
            nowTime.getUTCDate(),
            nowTime.getUTCHours(),
            nowTime.getUTCMinutes(),
            nowTime.getUTCSeconds());
    julianDateNow += nowTime.getUTCMilliseconds() * 1.15741e-8; //days per millisecond

    var timeSinceEpochMinutes = (julianDateNow - satrec.jdsatepoch) * 1440.0; //in minutes

    // time to make an orbit in minutes
    var orbitTimeMinutes = (Math.PI * 2.) / satrec.no;

    var nEvents = 300;
    var deltaT = orbitTimeMinutes / nEvents;

    // create orbit geometry
    var geometry = new THREE.Geometry();
    for (var i = 0; i <= nEvents; ++i) {
        var pv = satellite.sgp4(satrec, timeSinceEpochMinutes + i * deltaT);
        var pos = pv.position;
        geometry.vertices.push(new THREE.Vector3(pos.x / 1000., pos.y / 1000., pos.z / 1000.));
    }

    var satOrbit = new THREE.Line(geometry, orbitMaterial);
    return satOrbit;
}
```

FIGURE 3.7: The Function where we are creating the Orbit of the Satellites

look like. Our 3D models have not more than 30 polygons (see Figure 3.8). On our 3D model are implemented specific textures, which are fitting perfectly to get better view on how they are looking in reality. Our textures are pictures, which are free licensed for using it(see Figure 3.9).

3.3.5 Visualization of the Earth

We have created a visualization of the Earth which is the first visualization that is shown after the site gets open. Moreover, for the visualization of the Earth, we are using simple texture for the Earth. On the top of that, we adjust the Earth with

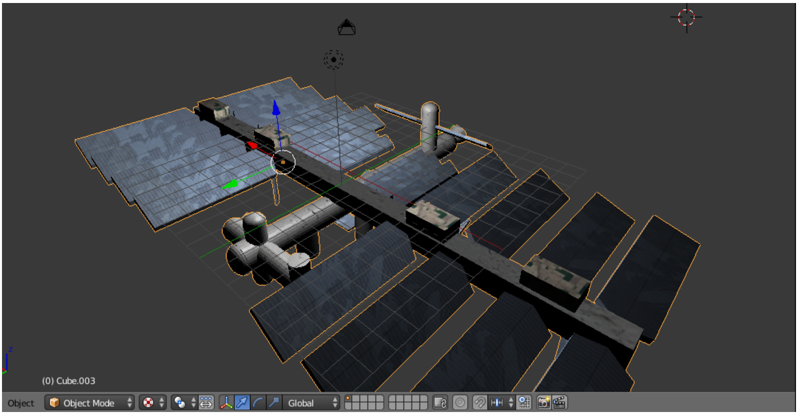

FIGURE 3.8: 3D Module of satellite created in Blender. Credits: Aleksandra Zarichin

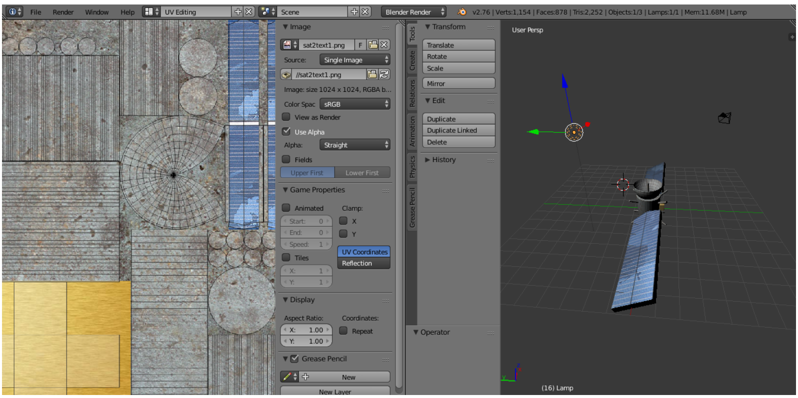

FIGURE 3.9: 3D Module of satellite with implementation of textures. Credits: Aleksandra Zarichin

small detail, which is uploading virtual Clouds that they are moving around the Earth (see Figure 3.10). The Earth rotates in the ECI coordinate system around the z-axis. The rotation is according to the current time.

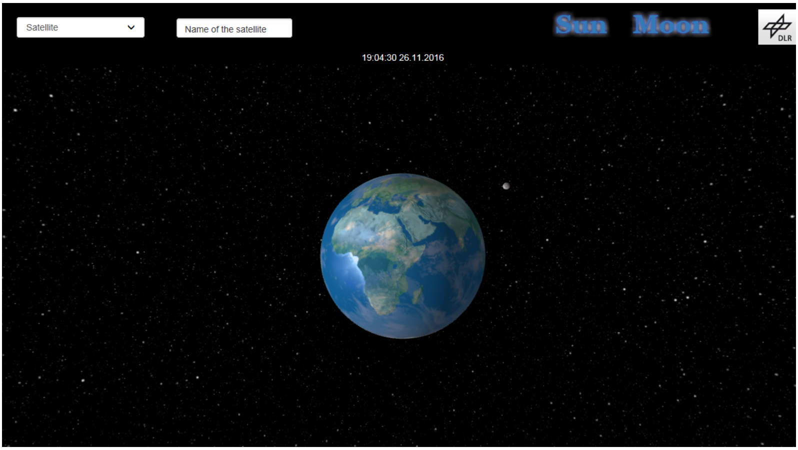

FIGURE 3.10: Visualization of the Earth

3.3.6 Visualization of the Moon and Sun

Additionally, we have developed even visualizations of the Sun and the Moon. They are displayed according to the real distance from the Earth, so the user has the opportunity to see how the space thrash looks like from that distance. According to the big distance between the Earth and the Sun, the camera at that point moves faster, and stops when the Sun is reached. For better visualization of the Sun we have added a lens, where we can see when we are on the direction to the sun with the camera. With these adjustments we are getting a better view and visualization of the Sun (see Figure 3.11). For the visualization of the Moon, we used the same sphere as the Earth, but with the real dimensions and shapes. The Moon has his own texture, where the texture is loaded with the start of the project. Also for this visualization we have created an info box, where we can get some information about their distance, their movement and a small description of them.

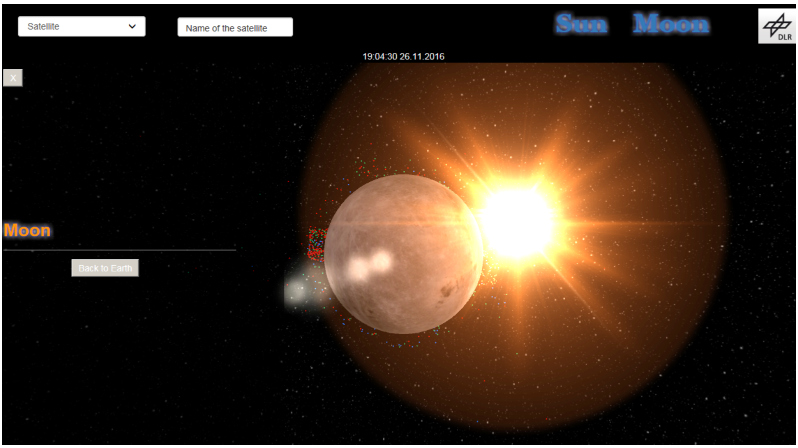

FIGURE 3.11: Visualization of the Moon

3.4 Collecting information and generating infobox

In this part, as I mentioned above, we are trying to present an information box, where we are generating every detail from our database. The info box contains (see Figure 3.12):

International Designator (Int'l designator) The International Designator is an international naming convention for satellites. It comprises of 3 parts: launch of the year, a 3-digit incrementing launch of that year and up to 3-letter code which represents the sequential identifier of a piece of a launch. The international designator is also known as COSPAR designator and in the United States as NSSDC ID[9].

Type Our data base contains 3 types of satellites. One of the types is PAYLOAD, we generate approximately 3,663 payloads. The second type is DEBRIS, we generate approximately 9,965 debris. The third type is ROCKET BODY, with approximately 1,777 rocket bodies.

[9] "Aerospace : Definition of Reentry Terms". In: (). URL: http://www.aerospace.org/cords/reentry-predictions/reentry-term/ (visited on 10/25/2016).

Apogee The apogee in satellite communication means that the satellites orbits are around the Earth, however not in the exact center of the orbital pattern. That means that when the satellite is at the furthest point from Earth, it is at the apogee of the orbit.

Perigee The perigee in satellite communication is the opposite of the apogee. This means that when the satellite is at the closest point from Earth, it is at the perigee of the orbit.

Inclination The Angle of Inclination is the third parameter that describes the orbit data of satellites. That means that the angle of inclination is the angle between the equatorial plane and the orbit of the satellite[10].

Altitude The Altitude is the distance between the Earth and the satellite.

Velocity The velocity represents the velocity of movement of the satellite around the Earth. That value in our data base is calculated in kilometers per second.

[10]Swinburne University of Technology. "COSMOS - The SAO Encyclopedia of Astronomy: Orbital Inclination". In: (). URL: http://astronomy.swin.edu.au/cosmos/O/orbital+inclination (visited on 11/16/2016).

Period When the satellite travels around the Earth, it needs to travel in a certain orbiting radius and period to maintain the orbit. The period of a satellite is the time that it takes for the satellite to make one complete circle around the Earth. There is a special mathematical formula for the calculation of the period.

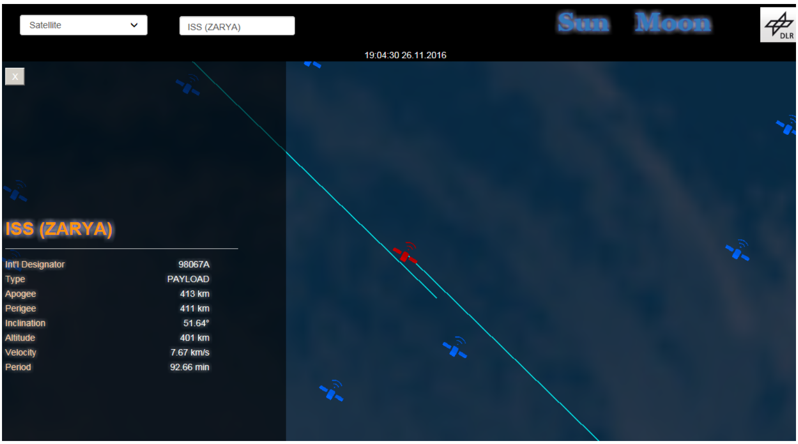

FIGURE 3.12: Information box generated

3.5 User specific 3D models of satellites

At this point we are giving an opportunity to the user to be creative, and a place where he can upload his own satellites. This can also be competitive for the users as an example who will have a better designed satellite, that would also help us to make our Visualization Space Debris System bigger. However, the user cannot upload big 3d models, which means every model has it's limit of polygons. That means that the file of the module .OBJ cannot be more than 100MB. Moreover, with this limitation we are challenging the users even more and also we are protecting our Web Visualization Space Debris system of crashing or being extremely slow. This is also one point that need's to be resolved in the future: the optimization of our system.

3.5.1 Registration and Log In

For better controlling we have created a registration part where the user can register personally. The registration part is created with the JavaScript library called Bootstrap.js, where the user must put his user data as Name, Surname, Date of birth, Email address and password. After the registration the user can log into his account. By entering the username and the password, the user has a possibility to control his account and to upload his own 3D models of satellites. Moreover, with this we provide the user even to be competitive. And with this help, maybe one day the Bacardi project can be one of the biggest real 3D visualization systems.

3.5.2 Data storage

After uploading the 3D models the user has created his own folder where he can upload all of his own models. Moreover, the user must put the name and the type of the debris or satellite on the place where he uploads the model. In that point where the user is putting the name and type of the debris or a satellite, he is creating a 3D model with a special name that contains the name and the type of the debris or the satellite. For example: iss-debris.obj. This created file with the name and type helps our database to recognize which kind of satellite it is and on which place it should be showed.

Chapter 4

Discussion

The implementation of the Space debris visualization system is quite complex because it is a matter of a complex system for visualization. For that reason, this implementation has its advantages and disadvantages compared to the above mentioned existing projects.

One of the advantages is that we are trying to provide 3D models. Form the above mentioned projects we have just one project that is providing 3d models. The California Institute of Technology provides the visualization of 3D satellites, but it is an application that is different from ours. One of the main differences for example is that we provide web services, on the other hand NASA's EYE provided an application. Moreover even this future has his own disadvantages to the reason that we offer 3D models. One of the disadvantages is that by providing 3D models for web service, the site can take some time to be visualized. Also that is one of our futures, to improve the speed of our site. Moreover, the use of models led to other disadvantages. In this case the user cannot put 3D module with a lot of polygons that means that the 3D module file must be with less MB. Otherwise the site can be extremely slowly and that can bring us to a point where the user will be not satisfied.

What will happen if some users have the same modules?

At this point when more users have the same modules, that are containing the same name and type the system will recognize the first that was uploaded. This is also a point which will be discussed in the future. Probably we need to create a list of which satellites or debris are still available or another option would be to put them randomly.

Another advantage is that we offer a search by a country. This research brings us to an opportunity to search and take a note for the satellites that are above the wanted country. With this advantage the possibility to take a note, we can prevent bigger collisions or at least getting more knowledge about it for example selection of a country we have in the project N2YO. For that reason we wanted to have one project where we can have all possibilities to help to the researcher people.

Another advantage is that we offer different type of visualization. For example searching by groups with their orbits or without. This advantage again led us to one disadvantage that we need to work on in the future: The fluency and speed of the loading site. This future is developed also in Stuffin.Space where the user can select just group of debris.

Furthermore, another advantage is that we offer to the user is to see how the Earth is looking with all space debris from the Sun or Moon. The project from Google Chrome experiment 100,000 gives us this idea for creation of the view from the Sun and Moon.

4.1 Futures

The visualization of a Space debris system is just a prototype. Moreover, there are many improvements which should be realized. The first one of them is the improvement of the project speed. This implies also an improvement of the fluently of uploading new models. The view of that improvement is that every registered user has his automatically created folder in the project, where his models will be uploaded. For this reason, the visualization of the space debris system really needs to be improved in terms of speed and fluently of the site. Moreover, with this successful improvement, we get to a point where we can offer the users creating models with more polygons.

Furthermore, another feature which should be implemented is the improvement of creation and visualization of orbits. That means now when the user is making a search "by type2", that means by visualizing the selected group together with their orbits, the site needs some time to visualize them. Another feature is perhaps better visualization of the Sun and the Moon. There is an existing Webgl google experiment, as I mentioned above on the project created from Google Chrome App 100,000 stars where we can see a very good and clean visualization. By seeing that project we got a lot of ideas which could be implemented. Also visualization of other planets, the Milky Way and so on. Furthermore, it also needs to be improved in terms of the security of the data base and the registered users. Moreover, that means creation of powerful control of authentication. In addition, the probability of collisions could also be implemented in this project. As I mentioned above, the knowledge about collisions is very important, because in this way we can also protect the Earth. With this implementation the user will have a possibility to take a note, probably even to change the color of the debris for better control. With all of these improvements, we are increasing the possibility that maybe one day this project could be one of the biggest real visualization space debris systems.

Chapter 5

Conclusion

This visualization gives us an opportunity to get more knowledge about the danger the Earth can be in. More over with this research and implementation, the specialist researches for this above mentioned problem, can contribute with their researches, so maybe one day we can have a better system to protect our Earth.

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This thesis is dedicated to my family.
For their endless love, support and encouragement!!!