Space Mission Design Tool For Knowledge Management

Designing a knowledge management system for Space Mission Design.

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November, 2020

A written report on the work made as SSERD interns.

Acknowledgements

Firstly, we would like to thank our mentor's Vishnu and Rashika for guiding us throughout the project. We will miss Vishnu's wide range of suggestions.
We would also like to thank our coordinator Anisha for helping us to glide through the internship smoothly.
Also, we would like to thank the entire SSERD team for helping us in all possible ways to complete our project by providing us with all the required resources.
Finally, special thanks to Mr Pavan Kumar AV for guiding us through all the necessary requirements for building our career.

Abstract

Our work as the STARS team and as part of the SSERD internships program consisted of designing and building a tool that can help space mission designers on giving them insights on what are the technologies, modules of experimentation and instruments most suitable for their specific goals and restrictions.

The main characteristic of this tool is that it works by pulling data from a database that consists of multiple experiments from different space missions, categorized by several factors such as status, country, date, etc. The tool takes into account user inputs and matches them with the experiment that most closely resembles the user's restrictions and objectives.

We hope that this tool will facilitate the work of mission designers when deciding what kind of technology, manufacturer, materials, etc. will be used for their mission.

This document will provide a thoroughly description and explanation of how the thought process of coming up with this idea came to be, as well as the data collection, database creation, design, development and implementation of the tool in order to better understand its scope and limitations as well as its functionalities, characteristics and areas of improvement.

Contents

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Introduction

1.1 | Antecedents

Space mission design can be a very time-consuming and difficult problem, often taking several years in the mission development process and allocating a lot of resources, specially when the technology and knowledge of similar missions are not of easy access to the designers.
This is a problem we have experience first-hand. At the SPES mission (Mexico), the mission design process, which consisted of brainstorming possible mission use cases, researching about the technology available, realizing feasibility studies and proving the viability of the mission took about 4 to 7 months from the total of the project timeline. And this is not the only case. World-renowned space agencies have often dealt with the same problem. In an average mission, NASA can spend up to decades planning and designing the mission, often working on several prototypes simultaneously, each with slightly different instruments. An example of one of NASA's missions is shown in Figure 1.1.
This long process often comes because of the fact that space agencies tend to re-invent from scratch the instruments of a particular mission (although this is not the norm anymore and agencies are turning more and more into outsourcing the design and manufacturing processes to third parties, as well as to re-utilize old concepts both flight-proven and unproven). A new way of starting the mission design for a spacecraft is needed. This new way can help connect and share knowledge similar technologies and limitations between different companies and space agencies, in order to reuse old, proven concepts for in different missions.

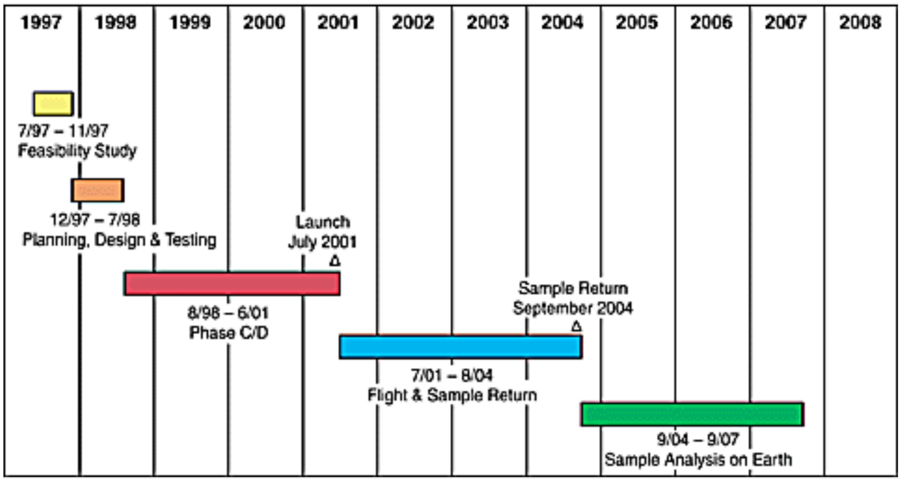


Figure 1.1: NASA mission timeline for the Genesis Mission. The mission design process alone took two years.

1.2 | Aims, Objectives and Possible Solutions

The objective of this internship project was to provide a solution to this problem, thus reducing time and monetary resource allocation into the mission design process and making it a more versatile and streamlined process.

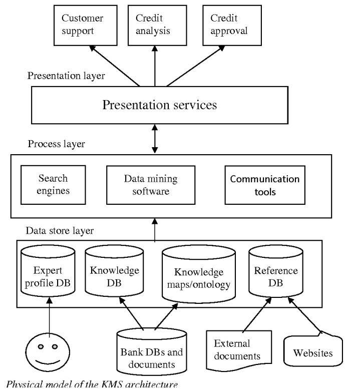
For this, the team discussed several possible solutions, from interactive dashboards, web pages and a couple other innovative solutions. Said that, it is important to mentioned that the team had two big constraints: time and human resources, thus we had to choose a solutions that best fitted our needs and constraints.

After some brainstorming, the best choice was to design a Knowledge Management System or KMS. These systems are designed to create, share, use and manage the knowledge and information of an organization or group of organizations in order to improve performance, give competitive advantage, innovate, integration and continuous improvement of systems and projects and most importantly **share the lessons learned and technologies used by other teams.**

In other words, a Knowledge Management System is a solution implemented in order to **share lessons learned, technologies, intellectual properties and other information that could eventually reduce work loads on other teams in the future**, which is exactly what we needed. *See image* 1.2.

Once the solution we wanted to implement was identified, the next stage was to decide whether to use an existing solution and adapt it to our specific needs or build ours from scratch. After a thoroughly analysis the team decided that a custom made tool designed and implemented from scratch would better fit our requirements due to the extreme level of specialization required (space missions).

(a) Logic model of a KMS



(b) Typical KMS Architecture

Figure 1.2: Conceptual models of a classic Knowledge Management System.

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Proposed Solution

As specified in last chapter, we decided to create a KMS solution from scratch that would fit our specific needs. In order to create this, we first needed to create a strong solid data warehouse to work on.

2.1 | Database Creation

A KMS works by pulling data from a database based on specific inputs that the user will introduce, such as filters, constraints and requirements. In order to successfully use the system, a solid database needed to be created. This is the most fundamental part of the solution, thus it was the most time-consuming stage of the project.
In order to make the data accessible, it must be formatted in an optimized way that facilitates searching and handling the information. We designed our main database considering these concepts. The database consists of 37 data points, each selected in order to optimize search results, bring the most information about the instrument and provide mission designers with the best data quality available.

The architecture of the database is presented in the following chart:

Data point	Description
ID	ID Number on the registry
Instrument Name	Name of the Instrument
Instrument Acronym	Acronym of the instrument (Optional)
Instrument Description	Brief description of the instrument
Objective	Tag for the objective of the instrument
Task 1	Tag 1 for ease of search of the instrument
Task 2	Tag 2 for ease of search of the instrument
Task 3	Tag 3 for ease of search of the instrument
Task 4 (Optional)	Tag 4 for ease of search of the instrument
Instrument Mass (kg)	Total mass (Weight) of the instrument in kgs
Instrument size (X) cm	Length of the instrument on its X axis in cm
Instrument size (Y) cm	Length of the instrument on its Y axis in cm
Instrument size (Z) cm	Length of the instrument on its Z axis in cm
Power (Watt)	Power consumption of the instrument in Watts
Instrument cost (USD)	Cost of development of the instrument (Optional)
Component 1	Main component of the instrument
Component 2	Main component of the instrument
Component 3	Main component of the instrument
Stage of the mission	Stage of the mission in which the instrument is being used
Manufacturer	Company in charge of designing or manufacturing the instrument
Operator	Operator of the mission
Mission	Name of the mission
Mission Destination	Celestial body in which the mission is operating
Mission Objective	Brief description of the objective of the mission.
Mission Type	Orbiter, lander or rover
Orbit Perigee (If applicable)	Perigee of the orbit (For orbiters only)
Orbit Apogee (If applicable)	Apogee of the orbit (For orbiters only)
Inclination (If Applicable)	Inclination of the orbit (For orbiters only)
Orbit Type (If Applicable)	Type of orbit (For orbiters only)
Year Launched	Year when the mission was launched
Status	Status of the mission (Successful, unsuccessful, operating, etc)
Country	Country of origin of the instrument
Image	URL with an image of the instrument
Sources	Sources of the information

2.1.1 | Data Collection

Once the data points that were more representative for a mission designer were identified, we started building the database. We faced two main problems while doing so, which slowed down our progress and represented significant bottlenecks.

The first one is the availability of the data: each space agency and private company has a different way to communicate their progress and their discoveries with the public (some do not even do so, since most of their intellectual property is a trade secret, is protected by their country's government or just was not made publicly available).
This presented a huge issue while building the database and that still affects the system, since the least data the solution has available to work with, the less accurate the results will be. One example of this is the 'Instrument Cost' column. This information is one of the most valuable to a mission designer, since very often their most constraint limitation is the budget available for the mission. Said that, only a handful of missions (or even instruments from a single mission) have this data available for public access.

The second problem we faced while building the database was the infinite amount of possible combinations between tasks, as well as one instrument serving for several objectives. This means that, for example, one camera can be useful for taking photos of the surface, but can also be helpful for creating 3D maps of the terrain and also for detecting weather conditions on the planet.
This means that we will have several 'tags' or tasks for the same instrument and may overpass our four-tasks limit, plus, it is possible that there will be a lot of tags for every function each instrument delivers, so the search process can be more time-consuming than planned.

Another bottleneck we experiences was the fact that each space agency has a different format to display its information, making it impossible to automate the information extraction process and making the process extremely time consuming. Some agencies use clear tables with relevant and technical information and data, while others display their findings in papers and academic journals, so the information extraction process has to be done manually while reading the entire paper. *See figure 2.2*

All these problems (and probably a lot more) as well as their possible solutions will be addressed on the 'Future Implementations' section of this document.

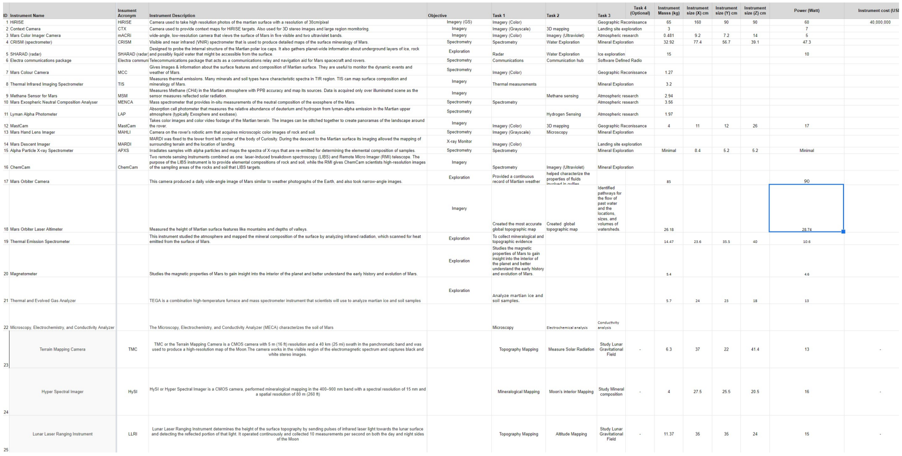
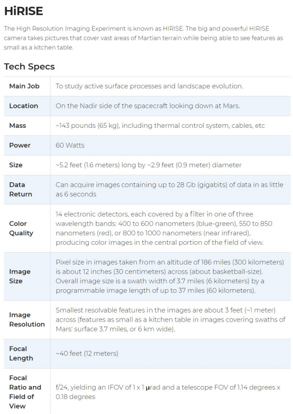


Figure 2.1: Example of the final database format used.



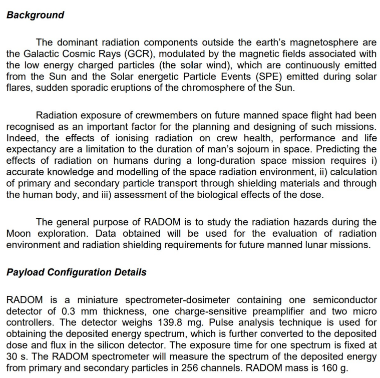
HiRISE

The High Resolution Imaging Experiment is known as HIRISE. The big and powerful HIRISE camera takes pictures that cover vast areas of Martian terrain while being able to see features as small as a kitchen table.

Tech Specs

Main Job	To study active surface processes and landscape evolution.
Location	On the Nadir side of the spacecraft looking down at Mars.
Mass	~143 pounds (65 kg), including thermal control system, cables, etc
Power	60 Watts
Size	~5.2 feet (1.6 meters) long by ~2.9 feet (0.9 meter) diameter
Data Return	Can acquire images containing up to 28 Gb (gigabits) of data in as little as 6 seconds
Color Quality	14 electronic detectors, each covered by a filter in one of three wavelength bands: 400 to 600 nanometers (blue-green), 550 to 850 nanometers (red), or 800 to 1000 nanometers (near infrared), producing color images in the central portion of the field of view.
Image Size	Pixel size in images taken from an altitude of 186 miles (300 kilometers) is about 12 inches (30 centimeters) across (about basketball-size). Overall image size is a swath width of 3.7 miles (6 kilometers) by a programmable image length of up to 37 miles (60 kilometers).
Image Resolution	Smallest resolvable features in the images are about 3 feet (~1 meter) across (features as small as a kitchen table in images covering swaths of Mars' surface 3.7 miles, or 6 km wide).
Focal Length	~40 feet (12 meters)
Focal Ratio and Field of View	f/24, yielding an IFOV of 1 x 1 µrad and a telescope FOV of 1.14 degrees x 0.18 degrees

(a) Technical data sheet



Background

The dominant radiation components outside the earth's magnetosphere are the Galactic Cosmic Rays (GCR), modulated by the magnetic fields associated with the low energy charged particles (the solar wind), which are continuously emitted from the Sun and the Solar energetic Particle Events (SPE) emitted during solar flares, sudden sporadic eruptions of the chromosphere of the Sun.

Radiation exposure of crewmembers on future manned space flight had been recognised as an important factor for the planning and designing of such missions. Indeed, the effects of ionising radiation on crew health, performance and life expectancy are a limitation to the duration of man's sojourn in space. Predicting the effects of radiation on humans during a long-duration space mission requires i) accurate knowledge and modelling of the space radiation environment, ii) calculation of primary and secondary particle transport through shielding materials and through the human body, and iii) assessment of the biological effects of the dose.

The general purpose of RADOM is to study the radiation hazards during the Moon exploration. Data obtained will be used for the evaluation of radiation environment and radiation shielding requirements for future manned lunar missions.

Payload Configuration Details

RADOM is a miniature spectrometer-dosimeter containing one semiconductor detector of 0.3 mm thickness, one charge-sensitive preamplifier and two micro controllers. The detector weighs 139.8 mg. Pulse analysis technique is used for obtaining the deposited energy spectrum, which is further converted to the deposited dose and flux in the silicon detector. The exposure time for one spectrum is fixed at 30 s. The RADOM spectrometer will measure the spectrum of the deposited energy from primary and secondary particles in 256 channels. RADOM mass is 160 g.

(b) Academic paper

Figure 2.2: Completely different ways in which space agencies display their data makes automatic data extraction extremely difficult.

2.2 | User Experience Design

The main reason this tool is being designed in the first place is to enable mission designers to access information quickly and easily. Because of this, human-data interaction, simple and to-the-point user experience and a straightforward interface are key points for a successful implementation of the system. To do this, methodologies and guidelines of good interface design practices were followed to facilitate said interaction. Likewise, a lot of time was designated solely to discuss about the best way to bring the tool to the user. *(See Figure 2.3)*. Among the options considered were desktop apps, web pages, tablet and mobile apps, etc, among others. Likewise, there was a lot of discussion about the programming environment, Integrated Development Environment (IDE) or tool that would be used for the development of the system.

2.2.1 | Tool Prototyping

Based on our two main restrictions (human resources and time constraints) we decided to go for a progressive web app and avoid entirely the development of a mobile app on Xcode for iOS or any similar IDEs (although they are extremely more powerful than the solution we ended up using, it would also mean taking way longer to develop the tool as planned).
The two developing tools we ended up using were Microsoft PowerApps for its extremely flexible workflow and exhaustive documentation online *(See Figure 2.4)* and GlideApps, for its super easy and user-friendly way to build web apps, as well as because of the fact that the entire back-end could be made using simple Google spreadsheets (which we were already suing for building the database), so at the end that was the tool we ended up using. Once all the aforementioned factors were clear to the team, the development process started. We made several prototypes to test out the best way in which the user could get the info.

2.2.2 | Tool Development

After prototyping and coming up with the best practices and tools to develop the system, the process became very straightforward. The entire development process was migrated into GlideApps and we worked on a single Google Sheets database (which as mentioned before, also worked as our back-end).
The main way GlideApps work is to utilize data stored in different cells and columns both for its inputs and outputs, as well as for some scripting. We also took advantage of the extreme flexibility of Google Sheets to run SQL Queries inside a typical spreadsheet formula and using data stored on cells as its parameters. So for example, if we had an input from the user that wanted to be filtered out in say Column 'A' of the 'INPUTS' sheet from our Google Sheets file and wanted to display it on another sheet where the app could read it, we just executed the following script:

```
=QUERY(
    DATA!A1:AK111, "
        SELECT *
```

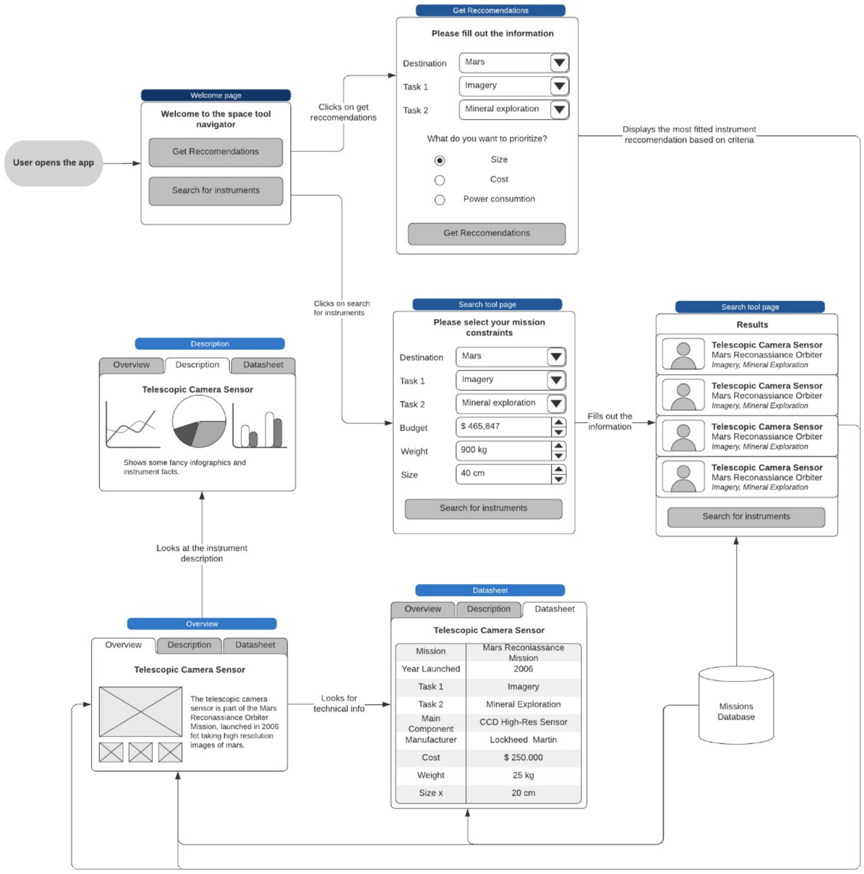


Figure 2.3: Several prototypes and wireframes were made to test the best way the user can interact with the tool.

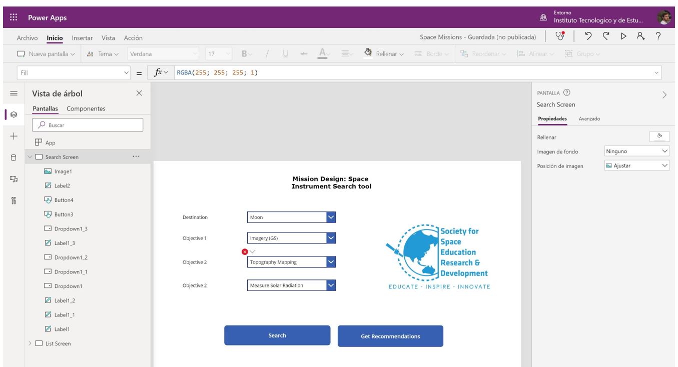


Figure 2.4: First prototype of the tool made in Microsoft PowerApps. Eventually we moved the development into GlideApps.

```
        WHERE F = '"&INPUTS!A2&"' " , 1
    )
```

And we can just keep adding filters with the 'AND' or 'OR' SQL functions, depending of our needs, as so:

```
=QUERY(
    DATA!A1:AK111, "
        SELECT *
        WHERE F = '"&INPUTS!A2&"'
        AND G = '"&INPUTS!B2&"'
        AND U = '"&INPUTS!C2&"'
        OR AE = '"&INPUTS!D2&"'
        OR W = '"&INPUTS!E2&"'
        " , 1
    )
```

Where the data in the 'DATA' sheet would be filtered out based on the user inputs in the 'INPUTS' sheet that the app would use as the parameters to run the SQL query and display them in the according sheet to be read out by the app.

2.2.3 | App Design

Having all the back-end design figured out, the next part was to make the app look good to the user and polish some detail in the way the information is displayed. This is exactly why we made all those prototypes earlier, since it saved us a lot of time in this section of the development. Basically the entire app ended up as follows:

Home Page: Here the user will enter its inputs based on the restrictions the specific mission would have. We ditched completely the welcome page and just keep the inputs page. (See Figure 2.5)

Results Page: Once the filters are specified by the user, the necessary operations will be made in order to show the user the most relevant results to its mission restrictions.

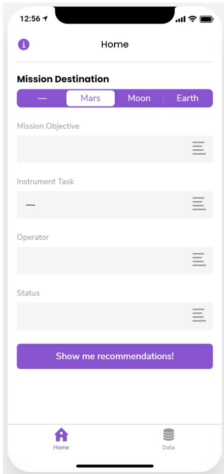


Figure 2.5: Home screen and input fields.

There is a lot of information displayed on this screen such as the name, acronym, operator, manufacturer and instrument objective, cramped in a small footprint with a friendly and aesthetic design. There is also an option to add as favorites to see later. (See Figure 2.6)

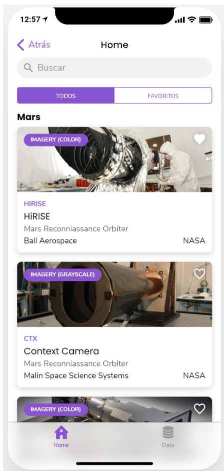


Figure 2.6: Results page and relevant information.

Instrument Page: When the user selects a specific instrument, a new page will be created with a larger image and all the available data for that specific instrument. It also contains some graphics in order to make it easier for the user to grasp the data. (See Figure 2.7)

Data Page: The app also has a specific function in which the user can search an

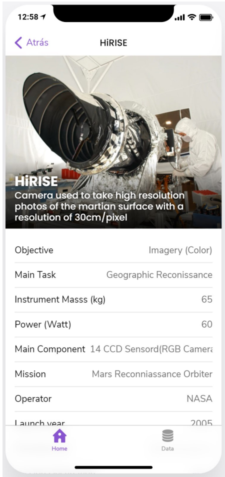


Figure 2.7: Instrument page with all the available information.

instrument by its name, country or basically any data available just by start typing the input on the search bar. Although it is a more inexact way to search for an instrument (since there are basically no filters applied and all results are mixed) it is a nice way for the user to explore all the collected data. (See Figure 2.8)

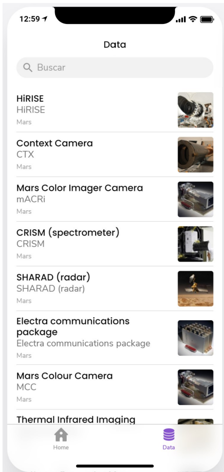


Figure 2.8: In the data page, the user can freely search for any instrument.

3

Conclusions, Lessons Learned and Areas of Improvement

This internship was full of challenges, goals to meet and deadlines to follow. However, as with any project, there were also problems to be solved and sacrifices to be made. In the end, everything was worth it because of the lessons and experience acquired, as well as the feeling of seeing the finalized working tool. That said, there were still areas of opportunity and improvement which are planned to be attacked in the future.

3.1 | Conclusions

In the end, the app developed throughout the course of this internship met the initial objectives to perfection, which were:

- To Survey past, present and future space missions and try to co-relate their mission objectives with each of the instruments used.
- To develop a solution which includes the database of major instruments used in payloads available in space industries.
- To help the space mission design analyst to get a first-hand idea about the possible instruments that can be selected for payload once the destination of mission is decided.

We hope that future mission designers can make use of this tool to ease their workflow and save time, manpower and economic resources in the process. Likewise, it is expected that new generations will be constantly updating the information with new data and space missions (both new and existing that need to be included in the database) as well as to keep adding features, destinations and fixing bugs so that the tool can be constantly improving.

3.2 | Lessons Learned

Throughout this internship internship, the team was able to put in practice skills that usually are not related with space development such as database creation (and administration), SQL Scripting and data recollection as well as working with an app development workflow and using user experience design methodologies all this with the end goal of using these skills in a way that can be helpful in a space-related context (in this case mission design).

We also learned that teamwork can be difficult, especially when working remotely (and in some cases from the other side of the world). The internship had a lot of challenges and situations we had to solve together by prioritizing tasks, delegating specific tasks or taking though decisions.

3.3 | Areas of Improvement

Finally, as with any piece of software, there are always areas for improvement and opportunity and this case is no different. Throughout this project the team detected many cases of possible improvement that, due to either time and tight deadlines, lack of people in the team or lack of knowledge on the subject, so we could not address them correctly. There were also some ideas and features we came up with that also were not able to implement properly.
Among these features and bugs we detected were the following:

- Optimize search results in order to more precisely filter out and display the results and relevant data to the user.
- Optimize the link between the app and the database in order to reduce the lag between the user inputs and the information being displayed (reduce it from a couple seconds to a couple ms).
- Make the app more responsive and compatible with a wider range of devices.

- Add more registries to the database and connect other public databases.
- Reduce the search categories (such as Task1, Task2, etc.) to a reasonable number and group similar instruments in the same categories.
- Add more filters in order to the user to search for more specific space missions.
- Rate each instrument based on the user search criteria and display it in a user-friendly way.
- Add more visual information like graphs, charts and other media in order to make the information more digestible to the user.
- Allow the user to add more data to the database (maybe from their own missions or missions the user is interested in) in a user-friendly way, without the need to access the database itself and modify its registry.

We hope these areas of improvement and new features can be addressed in the future either by the same team or new teams interested in the project, in order to release new app versions in the future.