PRA Database Development Project

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1 Abstract

Probabilistic Risk Assessment (PRA) is a systematic and logic-based method used to assess risks associated with a system throughout its life-cycle. Existing PRA data is not centralized, making it difficult to locate specific reliability data. The database development project focused on the consolidation and entry of PRA data obtained from previous JPL flight missions into a database. Existing flight project reliability data was reviewed, standardized, and used as a basis for the database's design in Microsoft Access. The original data was entered into a database with search, compare, and modification capabilities. This new database will support future PRA endeavors.

2 Introduction

The JPL System Reliability Group (5138) supports Flight Projects by reviewing their flight system designs for potential risks, and working with the Projects to identify possible mitigation options to increase their reliability. One way the group achieves this is through Probabilistic Risk Assessment (PRA), which uses statistical methods to evaluate the cause, severity, and frequency of risks associated with components/systems. The use of previous PRA reports to obtain reliability data can be complex, as they can be heavy in documentation and inconsistent in language. As a result, the team has found it difficult to locate specific reliability data, consuming valuable time when performing PRA on recent Projects.

To simplify PRA report analysis, in Summer 2021, reliability data from previous PRA efforts for JPL flight projects were reviewed, assessed, and compiled into a uniform template in Microsoft Excel. These missions were Europa Clipper Mission (ECM), Juno, Kepler, Mars Exploration Rover (MER), Mars Science Laboratory (MSL), Soil Moisture Active Passive (SMAP), and Mars 2020. This project aimed to continue this work, further simplifying PRA data analysis by developing a database.

The chosen database management system for this project was Microsoft Access. It was selected by the System Reliability Group based on its ease of database development and learning curve when compared to other database applications. Access can track changes, back up data automatically, and assign different levels of authority to users.

3 Methods

At the start of the project, a set of desired use cases was provided by the System Reliability Group. In addition to containing the previously compiled data, the database needed to include the ability to be searched, filtered, and modified. Figure 1 explains the use cases in more depth.

Use Case	Functional Objective
Use Case 1a. Search Capability	Be able to output the list of all Projects that used a particular component (e.g., RAD750)
Use Case 1b. Search Capability	Be able to output the list all the components (e.g., RAD750, REU, SDRAM, CMIC, etc.) in the database for a user-specified Project (e.g., Juno) and Subsystem (e.g., C&DH)
Use Case 1c. Search Capability	Be able to search the database by the following additional categories (see below), and output list of associated Projects and their associated reliability data. -- Mission Type (e.g., Orbiter, Lander, Rover, Manufacturer, etc.), -- Body (e.g., Earth, Mars, etc.) -- Any previous failures (Yes or No) -- Hardware Functionality -- Manufacturer
Use Case 1d. Search and Compare Capability	Want ability to compare all the reliability data available for a specified component (e.g., RAD750) used on multiple user-specified Projects (e.g., Juno, M2020, ECM) and generate a table where each column would be a different project, and each row would be the reliability data for that Project for the specified component (e.g., RAD750)
Use Case 2a. Data Entry/Data Modification	Basic capability to enter in new reliability data and/or modify the existing reliability data. Note - Want to keep the original data left intact in the database, and have a separate field to capture any new/modified values (along with the rationale for the new versions)
Use Case 2b. Modify Database with New Projects	Capability to add new Flight Projects to the database, along with their associated reliability data (i.e., to capture the PRA information developed for new/future missions)
Use Case 2c. Modify Database with New Reliability Data Fields	Capability to add new types of reliability data to the database in addition to that in the PRA spreadsheet template. The new fields would be available/linked to each Project, but not necessarily used.

Figure 1: Database Use Cases

The project was split into three primary sections. The first step was to review and organize the compiled PRA information from the Summer 2021 project. This information served as the baseline for the database's design. The second objective was to determine how to organize the information within the database, using relational architecture to simplify data management. The final goal was to build the database's backend and frontend user interface to achieve the specified use cases.

3.1 Data Standardization

To simplify the data importing process, it was important to standardize the PRA data as much as possible. Building on the progress made last year, all existing transcribed sheets were compiled into one master sheet to expedite progress. Standardization steps included transposing all data to match Access' field/record format, eliminating redundant terms used in fields, and splitting certain fields to aid future search, filter, and adding capabilities.

Two additional tables were created to support the existing data. The first table contained additional project-specific information, such as mission type, body, and summary. The second table consisted of the specific and generic element names that element failure descriptions used. These tables were kept separate from the original data to minimize redundancy, but linked using relational architecture.

3.2 Relational Architecture

The purpose of relational architecture is to reduce data redundancy, while also mitigating the risk of human error during data entry. This is achieved by dividing data into small, subject-based tables, placing common fields in related tables, and then defining a relationship between the respective fields. These relationships can be one-to-one or one-to-many. Figure 2 is an example of how relational architecture can simplify data transcription.

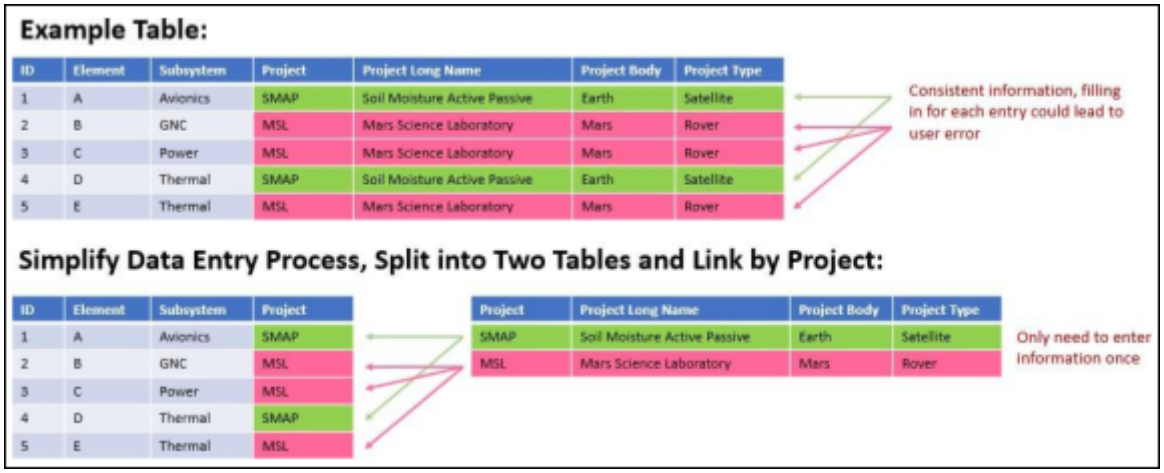

Figure 2: Relational Architecture Example

Relational architecture was implemented using Access's relationship tool. To test its structural validity, the accumulated PRA data was split and imported into the corresponding tables. Then, the full records were reconstructed using a query that pulled data from the tables. Based on the query, the records for each element were successfully imported, thus confirming the relational architecture's structure.

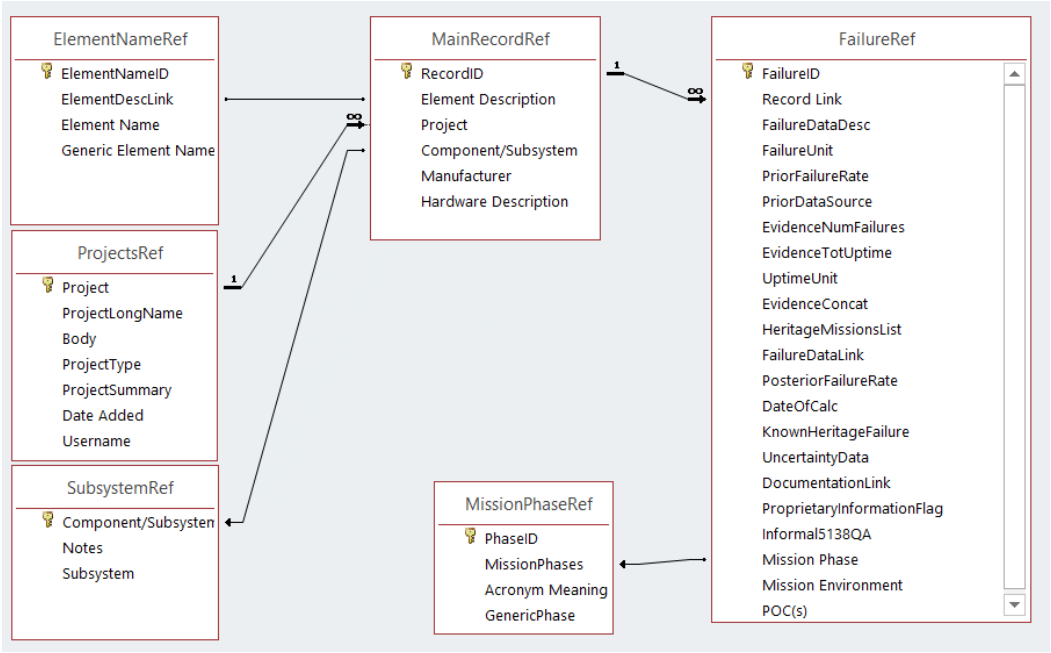

Figure 3: Relational Architecture Design in Access

3.3 User Interface and Backend Development

The user interface was created using forms, which allow users to view, add, and update data. While some capabilities are built in with forms, more complex functions, such as searching based on a user-specified field, require backend development.

Visual Basic for Applications (VBA) was the primary coding language used to implement desired actions. Due to lack of previous experience in VBA, the initial design process was challenging. Whenever a new coding challenge arose, research was conducted to find existing code and functions that may be useful. These resources were documented for future reference.

Throughout the development process, extensive testing and feedback were used to modify the backend design. This included observing how a user would want to interact with the database, as well as taking note of potential edge cases.

```
Private Sub ProjectComboBox_AfterUpdate()
'Set the Subsystem combo box to be limited by the selected Project (FIXED, added quotes around Me.ProjectComboBox)
Me.SubsystemComboBox.RowSource = "SELECT Subsystem " & _
                                 "FROM SubProjPairQuery " & _
                                 "WHERE SubProjPairQuery.[Project] = '" & Me.ProjectComboBox & "'"

Me.SubsystemComboBox.Requery
End Sub


Private Sub searchCmd_Click()
Me.FilterOn = False
Me.Filter = "[Subsystem] like '*" & SubsystemComboBox & "*' And [Project] like '*" & ProjectComboBox & "*'"
Me.FilterOn = True

End Sub

Private Sub SubsystemComboBox_AfterUpdate()
'Set the Project combo box to be limited by the selected Subsystem
Me.ProjectComboBox.RowSource = "SELECT Project " & _
                               "FROM SubProjPairQuery " & _
                               "WHERE SubProjPairQuery.[Subsystem] = '" & Me.SubsystemComboBox & "'"
End Sub
```

Figure 4: Excerpt of VBA Code from the Filter by Project and Subsystem Form

4 Results

The database has five main sections to interact with: the main user interface, summary forms, search and compare forms, data entry and modification forms, and the user guide.

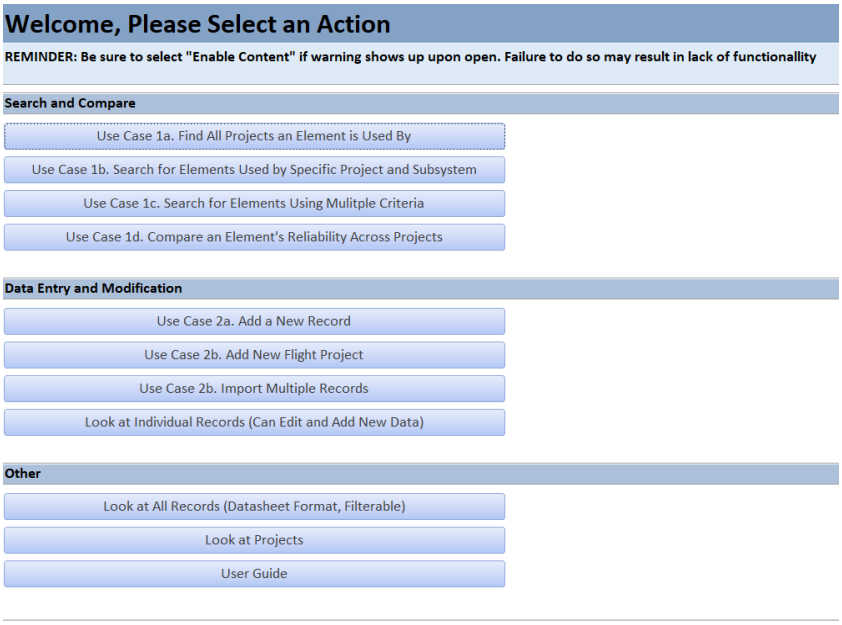

Figure 5: Main User Interface Form

4.1 Main User Interface

The main user interface is the first thing a user sees in the database. It serves as a guide to finding the appropriate form, without having to navigate through the database's objects themselves. Forms are accessible by clicking on their respective button and are sorted by their functionality, which are explicitly stated to improve the user's experience.

4.2 Summary Forms

The summary forms allow users to view one or more records that are in the database. Records can be exported to an Excel Workbook using these forms. Within the database, these forms are strictly for data viewing and exporting purposes, so no information can be modified. However, these forms link to separate forms with modification capabilities.

Singular records can be viewed using the Record Summary Form, which is accessible through two means. The first is directly accessing it through the main user interface, which then allows the user to click through all existing records. The second is to click a record's ID number on a search form, which will then bring the user to all matching data.

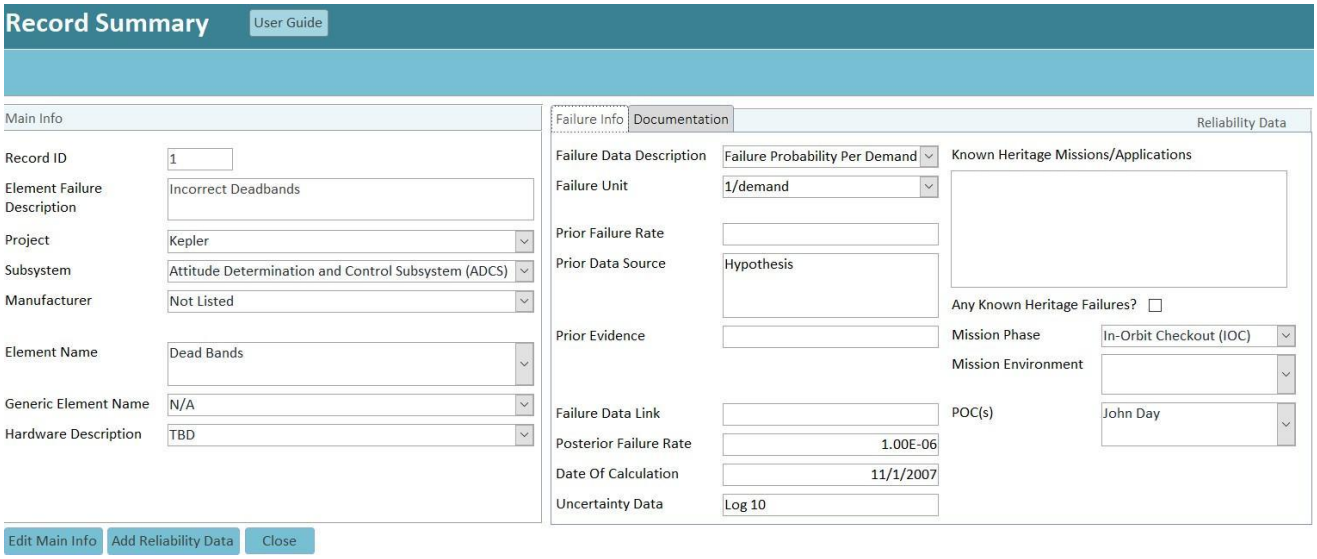

Figure 6: Example of Individual Record Summary

Multiple records can be viewed using the Master Query, which is accessible from the main user interface by selecting the "Look at All Records" button. In this form, all existing data is compiled into a spreadsheet format. From this view, the data can be filtered using the various fields.

RecordID	Element Description	Element Name	Generic Element Name	Project	S
1	Incorrect Deadbands	Dead Bands	N/A	Kepler	Attitude Determinatic
2	ADCS & RCS I/F Board Failure	ADCS & RCS Interface Board	Interface Board	Kepler	Attitude Determinatic
2	ADCS & RCS I/F Board Failure	ADCS & RCS Interface Board	Interface Board	Kepler	Attitude Determinatic
3	Coarse Sun Sensor Failure	Coarse Sun Sensor	Coarse Sun Sensor	Kepler	Attitude Determinatic
4	Attitude Perturbation during Ejection	Attitude	External	Kepler	Attitude Determinatic
5	Inertial Measurement Unit (IMU) Power Converter Failure	Inertial Measurement Unit Power Converter	Inertial Measurement Unit	Kepler	Attitude Determinatic
6	Inertial Measurement Unit (IMU) ESB Fuse Failure	Inertial Measurement Unit ESB Fuse	Inertial Measurement Unit	Kepler	Attitude Determinatic
7	Inertial Measurement Unit (IMU) Gain Drift Failure	Inertial Measurement Unit (IMU)	Inertial Measurement Unit	Kepler	Attitude Determinatic
8	Inertial Measurement Unit (IMU) Scale Factor Drift Failure	Inertial Measurement Unit (IMU)	Inertial Measurement Unit	Kepler	Attitude Determinatic
9	Non-Volatile Memory (NVM) Failure	Non-volatile Memory (NVM)	Memory	Kepler	Attitude Determinatic
10	Reaction Wheel Assembly (RWA) does not survive IOC	Reaction Wheel Assembly	Reaction Wheel	Kepler	Attitude Determinatic
11	Single Board Computer Failure	Single Board Computer	Flight Computer	Kepler	Attitude Determinatic
12	Incorrect Ephemeris or Star Catalog	Ephemeris, Star Catalog	Attitude Estimation Software	Kepler	Attitude Determinatic
13	Bright Body in FOV	Bright Body	Environment	Kepler	Attitude Determinatic
14	Star Tracker Failure	Star Tracker	Star Tracker	Kepler	Attitude Determinatic
15	High Gain Antenna (HGA) Fails	High Gain Antenna (HGA)	Antenna	Kepler	Telecommunications
16	Travelling Wave Tube Amplifier (TWTA) Failure	Travelling Wave Tube Amplifier (TWTA)	Travelling Wave Tube Amplifier	Kepler	Telecommunications
17	Low Gain Antenna (LGA) Failure	Low Gain Antenna (LGA)	Antenna	Kepler	Telecommunications
18	RF NF Failure	RF NF	TBD	Kepler	Telecommunications
19	Small Deep Space Transponder (SDST) Failure	Small Deep Space Transponder (SDST)	Small Deep Space Transponder	Kepler	Telecommunications
20	X-band Coax Switch Failure	X-band Coax Switch	Transfer Switch	Kepler	Telecommunications
21	XEPC Failure	XEPC	TBD	Kepler	Telecommunications
22	Waveguide Transfer Switch (WGS) Failure	Waveguide Transfer Switch (WGS)	Transfer Switch	Kepler	Telecommunications
23	Bus Control Assembly (BCA) Multi-Function Relay Failure	Bus Control Assembly (BCA) Multi-Function Relay	Power Bus Control Electronics	Kepler	Telecommunications
24	Small Deep Space Transponder (SDST) does not survive Launch	Small Deep Space Transponder (SDST)	Small Deep Space Transponder	Kepler	Telecommunications

Figure 7: Excerpt of Master Query

In addition to record summaries, there is an additional form for viewing project summaries. These summaries also include information regarding corresponding records, components, subsystems, and phases.

4.3 Search and Compare Forms

The search and compare forms were designed around use cases 1a-1d. These forms allow users to search the database using the various criteria specified by the project's requirements.

Search fields, drop-down boxes, and option groups were used to collect user-input. These forms are for database navigation and data exporting purposes, so they cannot be used for data entry or modification.

Use cases 1a and 1d filter records based on a user-selected element. All records have an element failure description, as well as a specific and generic element name. To account for this and provide flexibility, three search methods were included. Records can be filtered based on either the specific element, generic element, or a user-entered search term that searches across all element fields.

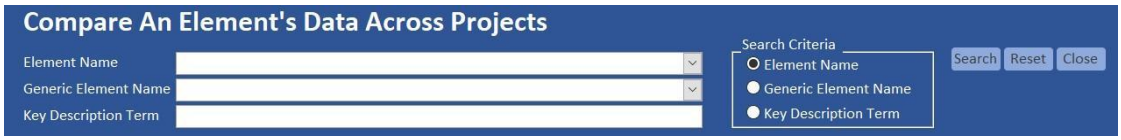

Figure 8: Excerpt of Use Case 1d Form

Use cases 1b and 1c filter records based on multiple criteria, such as project, subsystem, manufacturer, and hardware description. These criteria are filtered using drop-down boxes, whose options are populated based on existing data. To simplify the search process, conditional drop-down boxes were implemented. When an option from one drop-down box is selected, the remaining boxes are filtered to only include options that would return at least one result. For example, use case 1b filters by project and subsystem. If a user selects a specific project, the subsystem's drop-down boxes are filtered to only include the subsystems associated with that project.

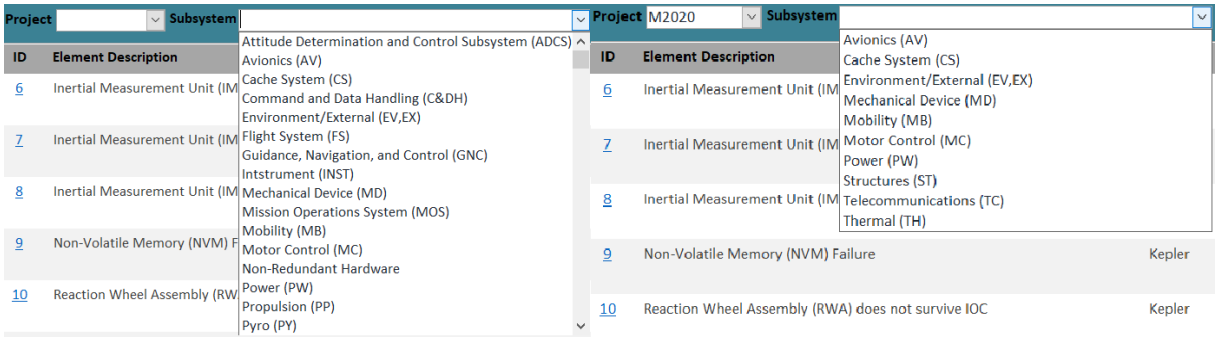

Figure 9: Example of Conditional Drop-Down Box

4.4 Data Entry and Modification Forms

The data entry and compare modification forms were designed around use cases 2a-2c. Records are split into two parts: main record information and reliability data. The former contains fields that would remain constant for a record with multiple sets of reliability data, while latter contains fields that vary.

Users can add individual records to the database using the Add Record form. This form includes numerous safeguards, including checking required fields and data types, limiting certain field choices to drop-down lists, and searching the database to see if a matching record already

exists. If a proposed record passes all required criteria, it is added to the database and all corresponding tables are updated.

To add multiple records at once, users can use the Import Data Form, which contains a specified template for uploading records. When this feature is used, the database imports the user's data into a table separate from the rest of the database and then loops through each record. If a record is valid, it is added to the main database and removed from the imported table. Invalid records are not added to main database. Instead, they remain in the separate table and a comment regarding the cause of import failure is added.

It is important to note that in regards to data modification, no reliability data can be deleted or overwritten. Instead, additional reliability data can be added to an existing record. In contrast, a record's main information can be modified, but this is a permanent revision.

After consulting the System Reliability Group, it was determined that use case 2c, adding new data fields, did not require its own form. This is because new fields can be directly added to existing tables, so adding a form as an intermediary step is unnecessary. In addition, the group does not expect to add new fields often.

4.5 User Guide

A user guide was introduced to assist users with the various forms, in particular the data entry and modification forms. Forms with a user guide have a button located in their header, which will open a pop-up window when clicked. These guides include form overviews and instructions, as well as details on required fields and affected tables.

5 Conclusion

The most significant impact of the PRA Database Development project is that PRA data is now centralized and fully searchable. The database currently contains reliability from seven flight projects: Europa Clipper Mission (ECM), Juno, Kepler, Mars Exploration Rover (MER), Mars Science Laboratory (MSL), Soil Moisture Active Passive (SMAP), and Mars 2020, with data amounting to over 800 records. This consolidation effort will make subsequent PRA efforts more efficient, as engineers in the System Reliability group will have easy access to component reliability values.

Future work would involve implementing additional uses cases such as extrapolating reliability results and calculating failure probabilities for a specified component.

6 Acknowledgments

I would like to thank my mentors, Rob Abelson and Todd Paulos, for giving me this opportunity and supporting me throughout this project. I would also like to thank Andrew Ho for his guidance in understanding PRA data and designing the database. His feedback has been integral to making the database as user-friendly as possible.

This project was carried out at the Jet Propulsion Laboratory, California Institute of Technology, and was sponsored by the JPL Student Internship Program (SIP) and the National Aeronautics and Space Administration (80NM0018D0004).