Experimental Methods to Evaluate Science Utility Relative to the Decadal Survey

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1.0 Introduction

The driving factor for competed missions is the science that it plans on performing once it has reached its target body. These science goals are derived from the science recommended by the most current Decadal Survey. This work focuses on science goals in previous Venus mission proposals with respect to the 2013 Decadal Survey. By looking at how the goals compare to the survey and how much confidence NASA has in the mission's ability to accomplish these goals, a method was created to assess the science return utility of each mission. This method can be used as a tool for future Venus mission formulation and serves as a starting point for future development of create science utility assessment tools.

2.0 Background

The Planetary Science decadal survey, created by the United States Research Council, is a publication that outlines key questions to be answered in terms of planetary science and presents mission ideas that would best accomplish this task. The most recent decadal survey, "Visions and Voyages for Planetary Science in the Decade 2013-2022," was published in 2011 and will have an effect on upcoming announcements of opportunities and therefore mission proposals. The science goals in most proposals are based on the most recent decadal survey at the time of writing and the proposals stress their ability to address the science goals established in the decadal survey. Because science merit is a major factor in NASA's evaluation of mission proposals, it is beneficial to assess the degree to which prior mission concepts address the objectives presented in the most recent Decadal Survey. The results of this research will be used to assess the potential impact of the 2013 Decadal Survey in formulating future missions.

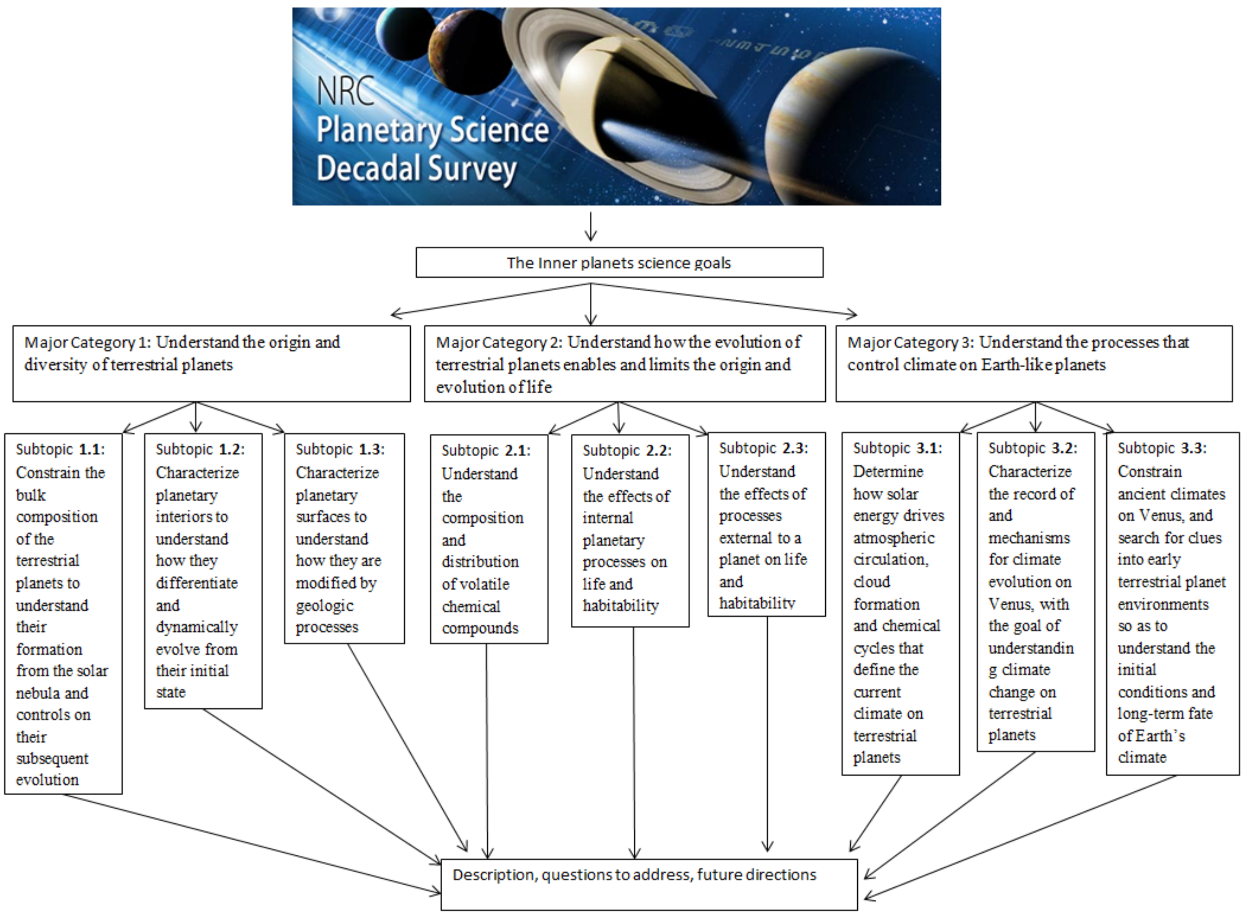
3.0 Objectives

1. Assess the main goals of the 2013 Decadal Survey with respect to Venus.
2. Create algorithms to assess the degree to which proposed science meets the goals established in the 2013 Decadal survey.
3. Create algorithms to calculate execution scores based on NASA debriefs.
4. Create algorithms to calculate overall scientific utility.
5. Look at trends with respect to science, cost, proposal category, and execution for selected data set.

4.0 Approach

I chose Venus for this study because of my interest in the planet and to focus on a manageable set of goals from the Decadal Survey (which addresses all planetary bodies in detail). This limited the number of proposals to be examined and provided a common background for the study. Further, this research examines proposals submitted in 2009 and 2010 to ensure that the most recent findings in Venus science were reflected in the proposals.

A five step process was used to reach the objectives set forth for this analysis. The first step was to take the inner planets section in the Decadal Survey and break it down into the major goals that it addresses. The decadal survey is broken up first into three main subsections. Each of these subsections is then broken up into three subtopics each. This structure and the exact topics can be seen in the following table.

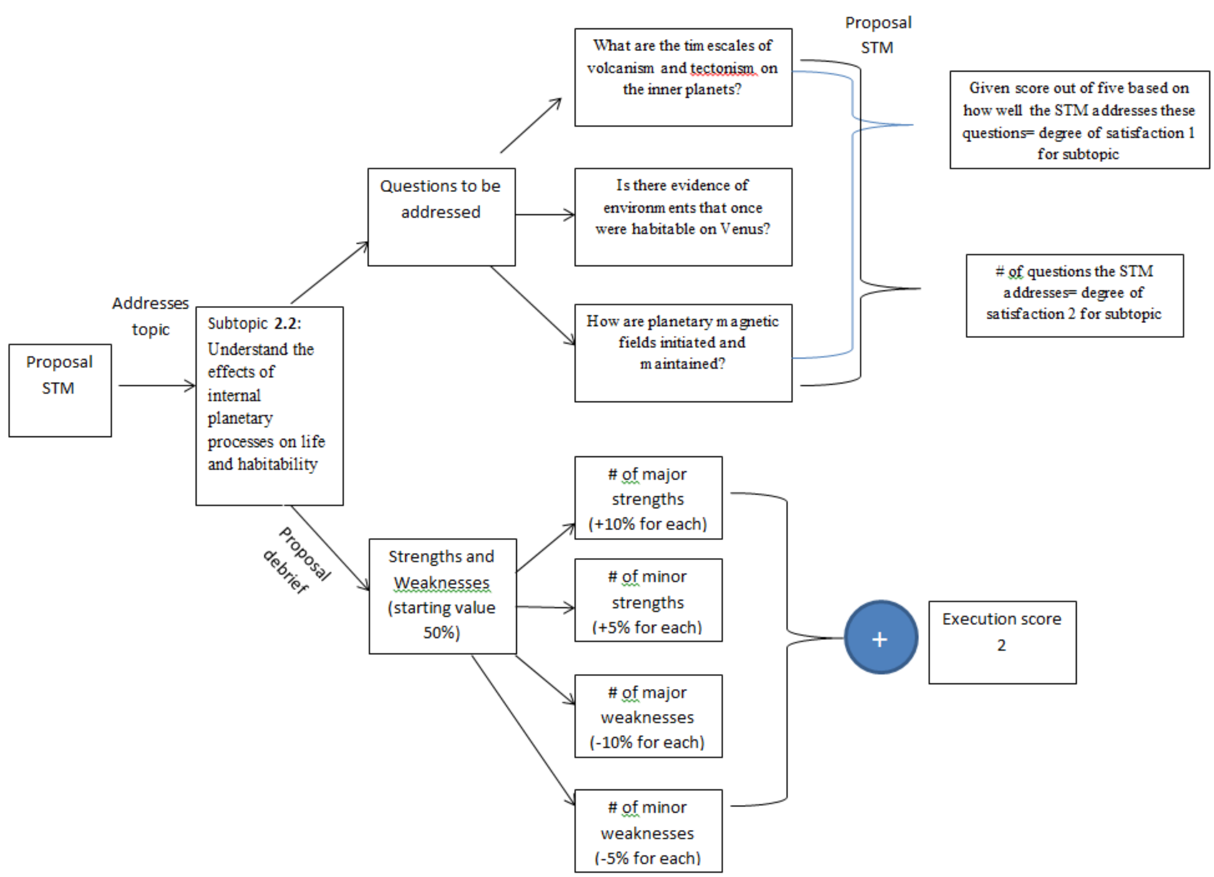


Each of the nine subtopics gives a broad overview of the subjects that should be addressed when looking at the inner planets, questions to be answered and further directions for research.

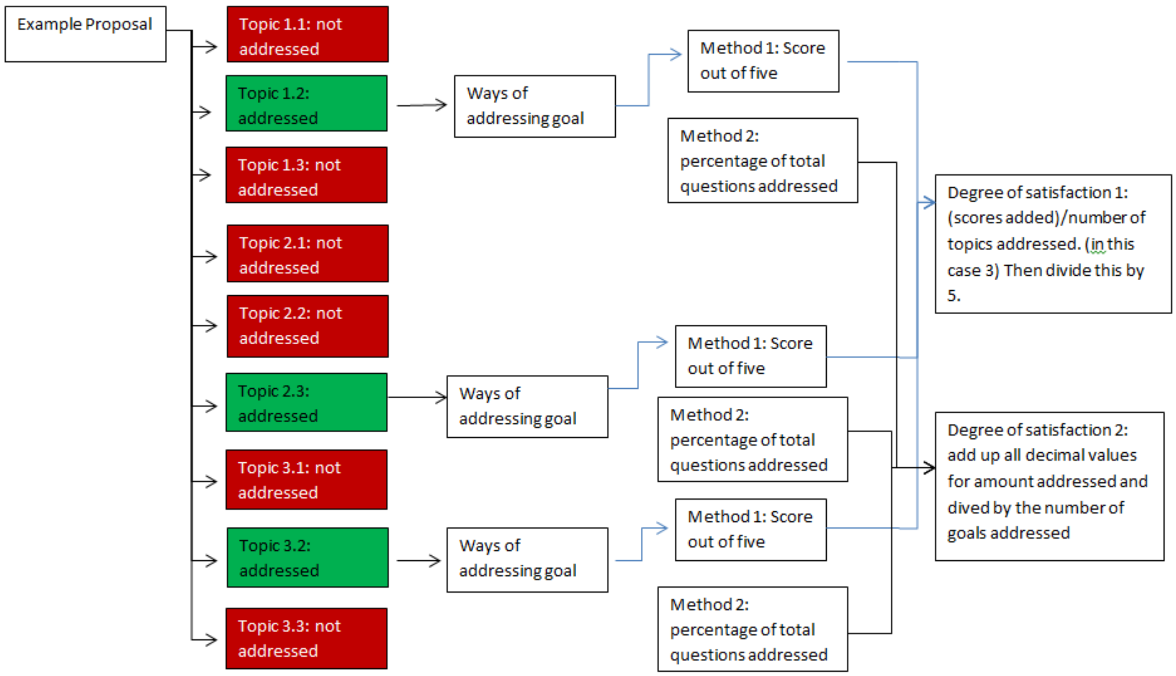
The next step was to take the four proposals that fit the previously mentioned criteria and examine their Science Traceability Matrices (STMs). An STM is a table included in proposals that shows the science questions and goals of the mission and how the mission will address each of these goals.

Many STMs list the exact measurements the mission plans to make and with what instrument for each goal. The purpose of this step was to match the proposed science goals of each mission to the nine decadal survey topics.

The third step was to take each goal that the proposal addresses and analyze how completely it addresses that goal. Even though the decadal survey goals break down the decadal survey into more concise categories, each is still somewhat broad. In the decadal survey, each goal is followed by a set of questions to be addressed that all together encompass the entire goal. To assess the degree to which each proposal addresses each goal, information on the methods of addressing these topics were pulled out. Then, two methods of analysis were used. First, each goal was looked at and, based on the proposals' way of addressing it, was given a score of 1 to 5, with 5 being the highest. Then for each proposal, the scores received for each goal were added up and divided by the number of goals it addressed. Then that number was divided by 5 to get a percentage. This would be the proposal's Degree of Satisfaction-1. The second method was to look at each individual question mentioned for each topic and figure out what percentage of questions were addressed in each topic. Then all of these decimal values were added up and divided by the number of goals addressed. The following chart illustrates the processes of getting the degree of satisfaction scores for one topic.



To calculate the final degree of satisfaction scores, you take all of the scores per topic, add them and divide by the number of goals addressed. The following table is an overview.



The fourth step was to use the feedback given in the NASA debriefs to determine the confidence NASA has in the proposal's science goals. Once again two different methods were used to evaluate this "execution score." Before each method could be implemented, the NASA debriefs were analyzed and the comments relating to science goals were extracted. They were also sorted based on whether it was a major strength, minor strength, major weakness, or minor weakness. The first method involved taking all of the science goal comments and getting a score based on how many were strengths and weaknesses. First, it was decided that major comments would be twice as influential as minor comments. The first step was to take twice the number of major strengths and subtract twice the number of major weaknesses. Then this was added to the number of minor weaknesses subtracted from the number of minor strengths. This would give you the initial score which could be anywhere from plus or minus two times the total number of science goal related comments. Therefore execution score 1 was determined by the equation:

$$\frac{2(\text{total}) + 2(\#MS - \#MW) + (\#mnS - \#mnW)}{4(\text{total})}$$

The second method used involved correlating the science goal debrief comments to the individual topics taken from the decadal survey. After they were correlated, a system was used that looked at each individual goal separately. For each goal, the execution score began at 50. For every major strength relating to the topic 10 was added and for every minor strength 5 was added to this score. On the other hand, for every major weakness relating to the topic 10 was subtracted and for every minor weakness 5 was subtracted to this score. For each goal, the score had to be between 0 and 100. These scores were added for all addressed goal in the proposal and then divided by the number of goals addressed to get execution score two. An illustration of this method follows:

Proposal	Goals addressed	Strengths	Weaknesses	Confidence percentage
Proposal 1	2.2	**Major strength 1 (add 10%)** **Major strength 2 (add 10%)** Minor strength 1(add 5%)	Minor weakness 1 (subtract 5%) Minor weakness 2 (subtract 5%)	65%
	3.1	**Major strength 1 (add 10%)**	**Major weakness 1 (subtract 10%)** **Major weakness 2 (subtract 10%)** **Major weakness 3 (subtract 10%)** Minor weakness1 (subtract 5%)	25%

→ Execution score: (.65 + .25)/2= **.45**

This method can also be seen in the table at the bottom of page 4.

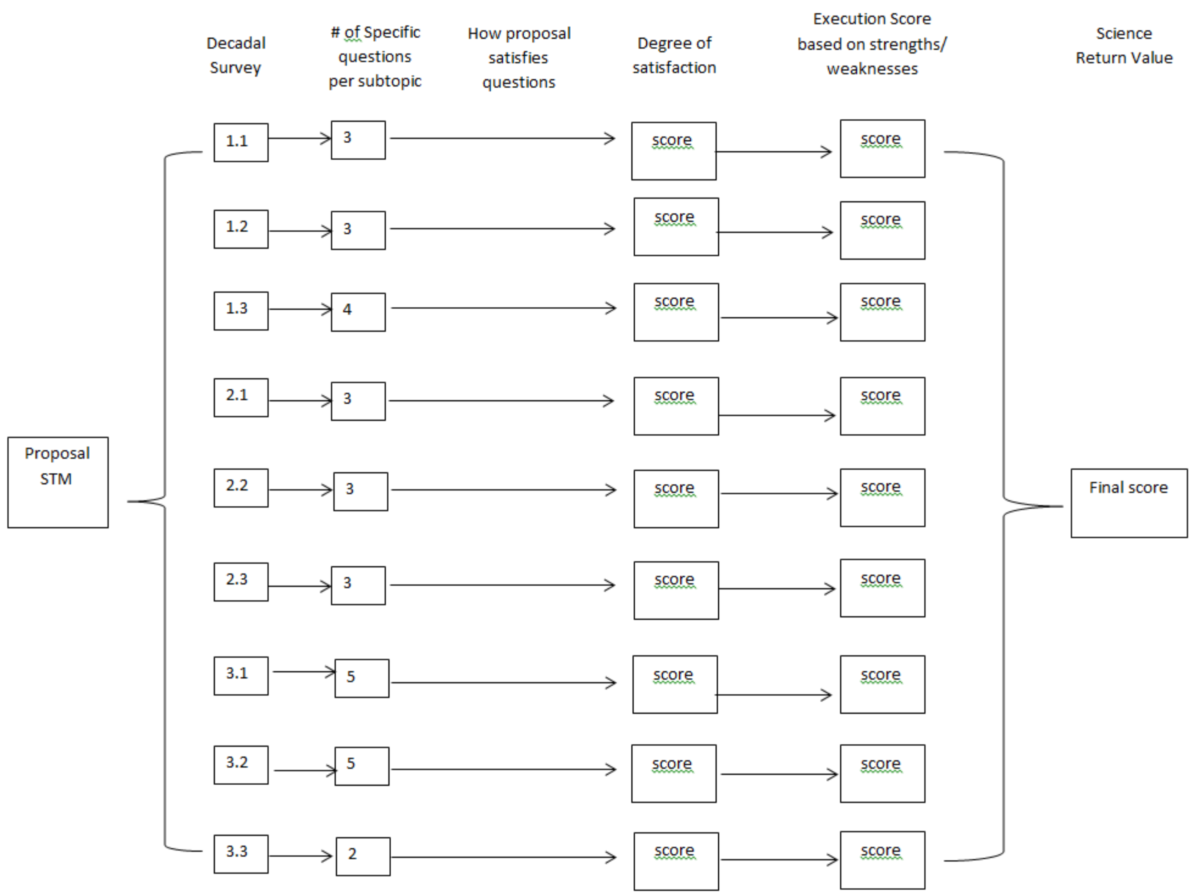
The fifth and final step was to take the results from the previous three steps to determine overall science return value. Two science return values were generated. The first is a score with respect to the entire decadal survey. This was determined by the following equation:

(number of science goals addressed / 9) * degree of satisfaction * execution score = science return value with respect to the entire decadal survey.

The second science return value is with respect to only the goals the proposal addresses. This was determined using the following equation:

degree of satisfaction * execution score = science return value with respect to goals proposal addresses

As a summary, the following charts shows this five step process:



First the proposal's STM is evaluated based on the decadal survey topics. Based on the number of specific questions addressed, the proposal receives a Degree of Satisfaction score. Then you take the execution score and combine it with the Degree of Satisfaction score to get the science return value.

The numbers that were generated were then evaluated with respect to the categories they were classified as by NASA and by the overall response to the proposal. Conclusions were drawn about the significance of the decadal survey in proposal writing and about the trends seen in previous Venus mission proposals.

5.0 Results

The result of this work was a basic model for determining the science return value of a proposal after it has been reviewed by NASA. This model takes the entire decadal survey and determines how much of the goals in it are addressed by the proposal and then how well that is addressed. The scores for the four proposals I evaluated are shown below:

Proposal	# of goals addressed	degree of satisfaction for goals addressed by STM #1	degree of satisfaction for goals addressed by STM #2	execution score 1	execution score 2	science return utility for goals addressed based on execution score 1	science return utility for goals addressed based on execution score 2
Mission 1	4	0.45	0.39	0.644	0.5625	0.2898	0.253
Mission 2	5	0.56	0.452	0.5	0.42	0.28	0.2352
Mission 3	2	0.5	0.465	0.6375	0.625	0.3188	0.3125
Mission 4	7	0.742	0.777	0.611	0.75	0.4534	0.5565

6.0 Discussion

The results seem to be reasonable and expected values.

[Redacted due to competition sensitive information]

It is important to note that the work that was done for this project is simply a starting model that can be used for future works. The most important outcome is the structure of the model, not the actual numbers. The proposals were used to test out the methods and determine the usefulness.

7.0 Conclusions

This task was a starting block for future efforts that could be useful in evaluating proposed mission concepts. Its main purpose was to look at science goals for Venus and determine how well previous proposals have addressed these goals. The resulting method has the potential to become a useful tool in mission formulation.

Many of the steps involved in creating the equations used to assess science return utility required some interpretation of the proposals on my part. For example, even the first step of deciding which goals were addressed by the STM required some interpretation. I used the new decadal survey as my basis and the goals were written in the writer's own way, sometimes without the survey in mind. This forced me to match them up to the best of my ability. This leaves some room for error in this process. Therefore, in the future it would be beneficial if a Venus scientist could be the one using this process to assess science return utility. Someone who knows the science and the planet well could come up with a much more accurate number which would be beneficial in the future.

Another future suggestion would be to take what I have created and make it into a method that can assess science return utility before the proposal is submitted to NASA. At the moment, this method can only be used after the fact because expected utility is calculated using NASA debriefs. If a different method of calculating expected utility was devised, proposal writers could potentially receive a science score before the proposal is submitted and perhaps attempt to improve their science if the number is insufficient.

Finally, an ambitious suggestion would be to take this model for Venus related proposals and apply it to create models for missions going to other planetary bodies. If a very accurate model for Venus can be developed, why stop there? By creating methods for assessing science utility in any proposal, proposal writers would have a very useful tool that could give them a slight advantage and help improve the science sections in their proposals.

Throughout this process I've learned about the science measurements that have already been performed, are currently being performed, and would be ideal to perform in the future on Venus. I have gained a deeper understanding of how NASA views science goals. I look forward to future Venus missions and I am very happy knowing this work could be used as a tool during their formulation.

8.0 Acknowledgments

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9.0 Bibliography

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2. [Competition sensitive - information removed]

3. [Competition sensitive - information removed]

4. [Competition sensitive - information removed]

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7. [Competition sensitive - information removed]