Verification of the Theory of the Formation of Jupiter Through NASA's Juno Mission

(Technical Paper)

A Look at the Societal Impact and Reasoning Behind the Juno Mission

(STS Paper)

A **Thesis Prospectus Submitted to the**

Faculty of the School of Engineering and Applied Science
University of Virginia • Charlottesville, Virginia

In Partial Fulfillment of the Requirements of the Degree
Bachelor of Science, School of Engineering

Kevin Melloy
STS 4500, Spring 2020

Technical Project Team Members
Kevin Melloy

On my honor as a University Student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments

Signature Kevin Melloy Date 4/28/20
Kevin Melloy 4/28/20

Approved Nathan Brunelle Date 12/14/2020
Nathan Brunelle, Department of Computer Science

Approved ________________ Date 10/9/2020
Toluwalogo B. Odumosu, Department of Engineering and Society

Introduction

Our solar system is comprised of the Sun, the asteroid belt, and eight objects considered to be planets by today's definition of the word, along with some other more minor objects. Each of these planets was formed billions of years ago, to the best of our knowledge. But how were these planets formed? This is a question that has been thought about for decades by astronomers across the world. Over the years, there have been various theories that have been proposed to explain the formation of the planets, with different explanations for terrestrial, the inner, rocky planets, and the Jovian planets, the outer gas giants.

Among all of these planets, Jupiter, the largest in the solar system, is perhaps the most important—aside from the Earth, of course. The reason for this is the fact that Jupiter stands as something of a model for the vast majority of the exoplanets we have discovered so far. This is due to Jupiter being a very generic case of a planet. Jupiter is simply a giant collection of gas with nothing extraordinarily exceptional about it—no rings, not too hot or cold, even its size is not at all unusual when looking beyond the context of our solar system. Because of Jupiter's status as a representative of a plethora of exoplanets, understanding it and how it formed can help us understand planetary formation in general.

This is precisely what NASA's Juno mission was intended to do. On August 5, 2011 the Juno spacecraft was launched as the second installment of NASA's New Frontiers Program. This spacecraft was sent from Earth with the goal of increasing our understanding of Jupiter and how it formed. It would do this by taking measurements of Jupiter's magnetosphere and atmosphere, specifically how much water is in the atmosphere, "which helps determine which planet formation theory is correct (or if new theories are needed)" (NASA). With these measurements, NASA was hoping to either confirm the current leading theory of Jupiter's formation or discover that a new theory was necessary.

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The leading theory of Jupiter's formation is a condensation or "core accretion" theory. The basic idea of this theory is exactly what it sounds like. The core of the planet is formed first. Miniscule dust particles and other materials come together and begin to form a core. As the core grows, the material begins to condense and change into an amalgamation of iron, rock, and other heavy metals. It attracts more material, growing in size, and becoming surrounded in a sphere of ice. Eventually, the core of the planet becomes large enough to begin to pull in gas, in a process is known as "accretion", forming the beginnings of the planet we are familiar with.

Juno would test the validity of this theory by taking measurements of the planet's magnetosphere and atmosphere. These measurements would allow the scientists at NASA to get a better picture of Jupiter's core. If Jupiter's core aligned closely with what we had come to expect based off of the core accretion theory, the leading theory would gain a substantial amount of backing evidence.

The results of the mission, however, were not completely as expected. While Jupiter's core was as rocky and solid as the theory claimed it would be, the size was not at all as anyone would have thought. Going into the Juno mission, the core was expected to be relatively small, less than 10% of the radius of Jupiter. The measurements that the spacecraft took, however, showed that the core was substantially larger than this, making up approximately 30-50% of the planet's radius.

What did these results mean for the theory of planet formation? How do we explain the unexpected findings? Overall, the Juno mission helped greatly to add validity to the core accretion theory of planet formation. To address the massive difference between expected and actual size of the core, other theories have come about. Things like fluid motions within the planet's core or an impact with a large object, such as another planet, are some current theories to explain this discovery. These are some of the theories that I think could be looked into with a technical project.

I believe that comparing the results of the Juno mission—the measurements of Jupiter's atmosphere and magnetosphere—and how they correlate to the leading theories of the planet's formation with the measurements of the magnetosphere and atmosphere of Earth, a planet for which we have a greater understanding of its formation, would lead to some insight into which theories have legitimacy. Obviously, this would not be entirely conclusive, given that Jupiter is a gas giant while the Earth is a terrestrial planet. However, I believe that this would be a good stepping stone for testing the theories of Jupiter's formation.

A brief outline of how I believe this technical project would work is as such: looking at the Earth's magnetosphere and atmosphere, which theories of planetary formation are implied the strongest? Do these theories line up with the most widely accepted theories of the Earth's formation? Using these questions, I would identify if the measurements of the same aspects of Jupiter similarly imply the currently accepted theories of its formation. This would go along with what Lisa Messeri, an Assistant Professor of socioculturual anthropology at Yale University, says about using well understood planets to help us better understand exoplanets: "knowledge of well-studied planets guides the scientist's understanding of newly detected planets" (Messeri).

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What does the Juno mission mean for us as a society though? I think that this mission can mean more to us than simply verifying a current theory and introducing new ones. When applying a non-positivist point of view to the Juno mission, some questions of a subjective nature may come to mind. For example, was this mission worthwhile? Do the benefits of this mission outweigh the costs? How do the results of this mission affect our lives, and how do these effects, if they exist, justify spending all of the resources and time that went into this mission, when they could have very easily been spent on other projects?

These are all questions that I think would be worthwhile to look into and invest in, and I think that the SCOT (Social Construction of Technology) framework can be used in this case. This STS framework, introduced by Trevor Pinch, a Professor of STS at Cornell University, and Wiebe Bijker, looks at different social groups which play a part in the creation, advancement, and use of technology (Pinch, 1987). When looking at scientific projects and missions, such as NASA's Juno, it is easy to focus solely on positivist questions and points of view. The results and findings of such missions are often looked at objectively—the radius is exactly this large, the mass is this much, this validates this theory, this invalidates this theory, and all of these findings lead us to this conclusion. I think other points of view are often overlooked when it comes to scientific projects such as this. We don't often take time to look into how the project affects things other than numbers and theories. I think we as a society would benefit from taking more time and putting more thought into other, less objective, questions when it comes to projects as large scale as investigating the formation of the largest planet in our solar system.

Looking into a project such as Juno using the SCOT framework would allow us to better ask constructivist questions. It is easy to see the positivist benefits of a project such as Juno—obviously the scientific community is benefited—but what about the other users that come into play and are affected by this project? The funding poured into this project had a great impact on the advancement of the technologies used by astronomers, physicists, and mathematicians, among other groups. However, there was very little to be gained by other groups, or even other branches of government operated administrations.

Given a chance to do an STS analysis of NASA's Juno project using the SCOT framework, I would investigate questions like mentioned above. To be honest, to do so would be vastly different from how I believe I have thought about things like this my entire life. I am almost always inclined to look at and interpret things from a positivist lens, but I have learned that this worldview is incomplete. I have learned that a constructivist lens is just as important as a positivist lens. Having learned this, and having learned how to apply the constructivist lens to ask questions I would not normally have thought of, I would seek to research how Juno affected things beyond just the numbers and theories involved. Some questions I would ask would be: what was the funding like for this project? How was the importance and priority of this project determined? What factors led to Juno being deemed more important than other things that the government funding could have gone to?

These and other questions that would be asked in an STS research project on the Juno mission would be asked and investigated. I believe that this would be beneficial to us, as there is no shortage of positivist studies and research projects on topics as scientific as the Juno mission, but the constructivist analyses of things such as this are particularly lacking, with the potential benefits of such analyses mostly left unexplored.

In particular, I would be very curious to observe the discovery of the exceptionally large planetary core of Jupiter from a different lens than has previously been used. Based on NASA's findings and conclusions, we know what to make of the measurements taken by Juno in this regard. However, I think that such a disparity between expected and actual findings can be questioned more significantly when using a constructivist point of view. How much of a disparity between expected and actual is deemed satisfactory to be used as validation of a theory, as was the case with the core accretion theory? If this threshold is too large, would this invalidate past conclusions? Using constructivist philosophies and the SCOT framework on an almost entirely positivist project such as Juno opens up a nearly endless list of important, impactful questions—a list that I believe would be worthwhile to investigate.

References

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