Framing Science on Social Media to Raise Public Awareness of Space Exploration: A Content Analysis of NASA Mars Mission Videos and Public Responses on YouTube

A Dissertation Presented for the
Doctor of Philosophy
Degree
The University of Tennessee, Knoxville

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December 2017

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ACKNOWLEDGEMENTS

I would like to thank my dissertation Chair, Dr. Carol Tenopir and committee members, Dr. Suzie Allard, Dr. Devendra Potnis, and Dr. Harry Dahms for providing me the right direction, insight, and guidance during my PhD program.

I would also like to thank Dr. Diane Kelly and Dr. Dania Bilal for their understanding, support, help, and encouragement during my moments of struggle.

A special thanks to my family: Dad, Mom, and my brother Prashant for their patience and will to support me in accomplishing this difficult goal.

Finally, this work would not have been possible without the unconditional support, help, and love of my friends. I dedicate this dissertation to my friends who were with me during one of the most challenging experiences of my life. I am deeply grateful and thankful for their presence, patience, insight, trust, emotional support, encouragement, and so much more. I acknowledge my friends Prashasti, Emily, Will, Jim, Sagar, Ritesh, Sumita, Shion, Vishal, Meena, Arvind, Rosann, Sudipta, Ashish, Sucheta, Frank, and LaVerne. Words fail me to describe how much your support means to me. This dissertation is a tribute to all of you.

ABSTRACT

Space exploration has many benefits. However, federal funding for space exploration is declining with each passing year. One of the reasons for the diminishing funding is the lack of public awareness about the value and importance of space research. Public awareness of space exploration is therefore crucial to enhance public interest as well as in drafting important science policy decisions. Social media provides a great opportunity to build this interest among public via various platforms such as YouTube, Facebook, and Twitter. As more and more people use social media to access news information, it plays a significant role in shaping public opinion on important issues. However, each social media platform has unique characteristics and appeals to public in a different manner. It is also important to note that messages framed for each social media platform vary significantly from each other. Therefore, in this dissertation, I explore how space exploration is framed on a social media platform (YouTube) to increase public awareness about space science. I also analyze public comments in response to those videos to understand the trends, patterns, tones, and perceptions of YouTube commenters. Forty-three NASA video transcripts have been analyzed to identify the dominant frames which NASA has used to engage with the public on YouTube and 730 comments have been analyzed to understand the trends, patterns, tones, and perceptions of YouTube commenters. Seven frames have emerged from this study: (1) Science Experiments (2) Curiosity Rover (3) Findings (4) Mars (5) Science Team Characterization (6) Success (7) Communication and Engagement with the Public. Analysis of YouTube comments reveal that majority of the comments posted directly in response to the videos are positive, indicating appreciation and praise for NASA and the space exploration mission. Many negative comments are found to be conspiracy theory related. However, even though these comments attract more discussion, commenters necessarily do not believe these conspiracy theory comments and in turn refute these comments with logical and rational information. Most people use YouTube for asking questions and sharing their knowledge about science and space exploration.

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CHAPTER 1
INTRODUCTION AND GENERAL INFORMATION

Space exploration research has fueled development of numerous radical technologies for the benefit of mankind. Satellite communication, weather forecasting, global positioning systems, CAT scans, cochlear implants, insulin pumps, cordless vacuum cleaners, workout machines, anti-icing systems, and Petroleum Remediation Product (PRP) technology to handle oil spills in the environment are just some of the examples of this endeavor [1] (Heather, 2015). Our day-to-day lives in every sphere be it communication, health and medicine, consumer, home, and recreation, transportation, environment and agriculture resources, or computer and industrial technologies, are highly influenced and dependent on the applications generated due to space exploration research. In such a scenario, maintaining long-term public support, interest, awareness, understanding of space exploration research and its significance are extremely crucial as these missions also incur huge financial investments in the form of income tax from the public. It is also important for public to engage in space policy debates and contribute towards forming space policy decisions. However, studies on public perceptions and opinions on space exploration suggest that in general public knowledge and interest in space programs, activities, and missions remain low (Ehrenfreund, Peter, & Billings, 2010; Nadeau, 2013). This has created a significant impact on the funding of US space exploration research.

One of the main reasons for the lack of public awareness about space exploration programs is the declining interest among public about it (Ehrenfreund et al., 2010).

Researchers have also regarded public interest in space exploration as a complicated issue (Ehrenfreund et al., 2010). Studies show that Americans are in favor of space exploration and NASA "in principle" however they are not in favor of large expenditures towards these space programs and instead believe that federal money should be better spent in other important endeavors such as tackling environmental problems and poverty (Launius, 2003b) . Steinberg (2011) states that even though the public is in favor of space exploration, they still feel that the financial investment by the government in this area is "too high". He furthermore mentions that due to the favorable public opinions on space exploration, there is a slight increase in the funding for space agencies such as NASA every year but the overall percentage of federal budget allocated to NASA is still very small.

Research also shows that some of the factors influencing financial investment in space exploration among the public are political party affiliation, their ideologies, and close ties with deep-seated religious values (Sears,1980). However, a recent study by Nadeau (2013) contradicts these findings and argues that funding decisions about space exploration are not influenced by political affiliation, ideologies or religion. In fact, he argues that scientific literacy is one of the key determinants of funding space exploration among public i.e. increase in scientific literacy among public increases their inclination towards funding space programs. Two of the major goals of NASA in the next few years are to send humans to Mars and the Moon which would require billions of taxpayers' dollars and therefore it is crucial that the public is not only supportive of such goals but

also takes a deeper interest in these goals to understand the risks, complexities, and significance of such efforts for the advancement of human civilization (Dick, 2007). To increase public awareness, interest, and enthusiasm towards space exploration programs and activities, many scholars have emphasized the importance of enhancing science communication with the public (citation). Traditionally, mass media has played a key role in engaging and informing the public about space advancements, importance, and failures and shaping their opinion. However, recent trends suggest a drastic shift in the news consumption habits of younger generation. Reuters Digital Media Report (2015) reveal that most people under 35 prefer social media platforms such as Facebook, Twitter, YouTube, Instagram, and WhatsApp to access news. Smartphones and tablets are the two most popular devices for news access among young users. The report indicates a significant increase in mobile news and a sharp decline in consuming news online on desktop computers. There is also an increase in video news consumption habits among users, especially news clips that provide context or analysis on a text story such as journalist/politician talking to camera or a short interview (59%), news videos that add drama to a story such as eyewitness testimony, raw footage of a news event (52%), and breaking news story (43%). More women (54%) than men (46%) use social media platforms to access news in America (Newman, 2015). These trends suggest that it is important for science agencies and scientists to utilize social media platforms to engage and inform public about space science.

Studies on social media coverage of space exploration information indicate that some platforms such as Facebook, Twitter, and Science Blogs have been explored more

than video based platforms such as YouTube. Some of these studies have examined how the Mars Science Laboratory (MSL) has been framed by Jet Propulsion Laboratory (JPL) on their website and print media (Finn, 2013), how tweets posted by NASA engages adolescents (Lesley, 2014), how space advocacy groups are utilizing social media platforms to raise space awareness (Steinberg, Alles, & Kobrick, 2015), use of Twitter, Facebook, and Science Blogs in space outreach, education and training (Denis, Klein, & Gueguen, 2014) and role of Twitter in popularizing space science (Ryan, 2017). Most of these studies conclude that incorporation of social media platforms to engage with public has positive effects in enhancing space communication, understanding, engagement, and interest in the topic. The results of these studies indicate that the participatory nature of social media platforms not only informs public about space missions but also enables a dialog between scientists and the public in real-time which is extremely favored by the public.

Overall, there is a general lack of studies that explore the role of social media in space communication in both United States and United Kingdom where a significant percentage of people access news online and/or on social media platforms. Research also indicates that communication medium plays a significant role in the communication of messages (Lengel & Daft, 1988) wherein it can improve or hinder effective communication. In addition, portrayal of information is another critical factor in how those messages are perceived (Fat, Sell, Barrowman, & Doja, 2011). Therefore, with the video news consumption on the rise, it is important to explore how space exploration information is framed on YouTube and how it influences public perceptions. This

dissertation investigates YouTube, one of the most popular video-sharing social media platforms and examines how space exploration is portrayed and framed in YouTube videos. As of April 2017, according to Alexa.com, YouTube is the second most popular website in the world. YouTube was founded in the year 2005 and currently has over a billion active users and over 5 billion videos are watched on YouTube every day (Donchev, 2017). Given its tremendous user base and popularity, it would be interesting and important to explore the following two questions:

1.1 Research Questions

RQ1: What frames appear on YouTube in NASA's coverage of Curiosity Rover Mission?

RQ2: What are the different tones and perceptions of YouTube users in response to the Curiosity Rover Mission videos posted by NASA?

CHAPTER 2
LITERATURE REVIEW

2.1 NASA and Space Exploration

2.1.1 Public Opinion on Space Exploration in America

The following paragraphs present an insight into the trends of public opinion in America on various space exploration events since 1957. Some of the most popular space exploration events covered here are: (a) Launch of Sputnik by Soviet Union on October 4, 1957 (b) The Apollo Space Program from 1965-1975 (c) Mars Exploration. I also discuss public opinion on various other issues related to space exploration such as the meaning of space exploration for the public, implications, media coverage on the topic, funding for space exploration, science knowledge/literacy among public, and the future of space exploration. The purpose of reporting an in-depth information about American public opinion on space exploration events here is to provide an idea and background about the thoughts and perceptions of public throughout the history of space missions since 1957 and how they have changed over time with the development of space technology, change in political situation, media coverage, and science literacy.

2.1.1.1 Launch of Sputnik by Soviet Union (1957)

Michael (1960) in his article titled "The Beginning of Space Age and American Public Opinion" presents a comprehensive analysis of the public opinion on the launch of Sputnik, the first artificial satellite by Soviet Union launched on October 4, 1957. Following is a brief discussion of the interesting results presented in his article.

(a) Trends in public opinion before the launch of Sputnik

Six months before the launch, more than 50% of American citizens were not aware of satellites, only 20% indicated having a real understanding of the purpose of the satellites and associated implications and the rest had a rough idea about the technology. The trends suggest men had more knowledge on the issue than women and people who had science education in high school and college were more aware of the launch and its purpose. Public knowledge about Sputnik increased to 18% in June 1957 when respondents in Baltimore indicated some understanding of the term "satellite" and to 59% in the following weeks after the successful launch when respondents mentioned "launch of Sputnik" as the most important thing that has happened in the past three weeks.

(b) Media Coverage

Media coverage on the issue was low. The World Series event was highlighted more than Sputnik except the New York Times which covered the launch and the associated social implications extensively. One of the reasons mentioned to explain the lack of media coverage on Sputnik was due to public's lack of interest in the matter. Public placed more importance on personal problems, and events such as World Series of 1957 than space exploration before Sputnik was launched.

(c) Public Opinion on Satellites and America's Image

According to some of the surveys conducted in the weeks following the launch of Sputnik, a large percentage of the American population (38%) reported having "no opinion" or thoughts about satellites which may be because the news about the launch was still new and people were still processing the meaning and implications of the

satellite launch. However, out of 62% public who expressed their opinions about satellites, majority of them (48%) thought it was due to the "competition between Russia and United States", 19% thought it as a "scientific advance", and 15% thought it was "overrated" and "not important". Another survey conducted three weeks after the launch in Minnesota revealed the percentage of people who thought the launch was due to the competition between Russia and US was about 33% and the percentage of people who thought it was a scientific advancement was only 20%. About 50% of citizens were actually surprised about Russia being able to accomplish such a goal but 44% citizens also reported that they were not surprised about it.

(d) Meaning of Sputnik

When asked about the meaning of Sputnik launch in America, 23% responded that America needed to "catch-up" in education, science, and defense, 18% thought it meant advancement in science and space exploration, 15% thought the launch was a threat to national security, 12% thought it was a sign that Russia was ahead of US in science research and 11% thought that it was "nothing significant". While very small percentage of people thought, it was a good thing (6%) because it gave America a push to focus more on space exploration, 5% thought it was a propaganda and 1% saw it as "an invasion of God's territory which was wrong". The above survey was conducted nationally and we can see that most people in the survey felt the need to focus more on science, education and defense. Although a considerable percentage of people thought it was a scientific advancement, the percentage was still small.

(e) America's Prestige

There was not much difference in the percentage of people who thought that the launch was a serious blow to America's image with 43% reporting "yes" and 46% saying "no" on the issue. More than 60% people thought that "US would make the next great advance." When asked whether America will be able to send a satellite into space in the next 30 days if she wanted, 65% responded "yes" to the question. There was no difference between the percentages of men and women who felt this way. The results also indicate that 67% people with grade school or high school educational qualification said "yes" as well as 57% people with college education also said "yes".

(f) Attitudes Towards the Launch

About 69% people in Minnesota believed that Russia sending the first satellite into space didn't matter a lot whereas 28% thought otherwise. The results of the study also indicate that Americans had not yet understood the magnitude of scientific advancement that had taken place. The attitudes among public suggest "complacency and superiority" about the launch i.e. even though Russia had successfully sent the first artificial satellite into space, the perception was that Americans had nothing to worry about as they would catch-up with Russians quickly and that it was not a matter of serious concern. Public reactions from Sheboygan, Wisconsin, and Gatlinburg, Tennessee reveal denial, complacency, ignorance, ridicule, and lack of depth in understanding the significance of the event, its repercussions on the military, and the society. Around 82% people from the Opinion Research Corporation (ORC) sample believed that even though Russia was ahead at the moment, US would catch-up soon and only 13% respondents thought that

US was seriously lagging behind Russia.

(g) Funding

As far as budget allocation was concerned, 49% of ORC respondents were in favor of keeping the budget at the same level and 37% were in favor of increasing the budget to several billions. However, 71% were opposed to the idea of increment in income taxes to fund the space program and preferred increasing corporation tax as well as reduction in foreign investments.

(h) Space Related Knowledge

The results of the survey indicated that less than 10% of citizens had a clear understanding of concepts such as “centrifugal force” and “gravity”. Only 38% thought that the size of the moon was much smaller than the earth and just 4% of people could provide a correct estimation of distance between earth and the moon. Around 29% had no idea about the distance and 37% thought that the moon was more than 400,000 miles away from earth.

(i) Future of Space Exploration

Close to 50% responded positively towards the idea that man will be able to land on moon before Sputnik was launched as opposed to 37% who responded otherwise. However, after the launch of Sputnik, 50% people in Minnesota thought that it will be possible to get to the moon in the next 25 years whereas 45% said no to the question. A national survey on the same question indicated that 41% people believed humans could go to moon in the next 25 years or less, 48% did not know or considered the idea “silly”. However, the percentage of people who believed humans could go to moon in the next 50

years had increased from 15% in 1949 to 38% in 1955 (which indicates a gradual change in the opinion of people on this matter).

Public opinions on space exploration in this study are described as "sometimes inconsistent" and "frequently illogical". However, one of the main conclusions of the study is that the public were not as "psychologically shocked" and burning with desire to defeat Russia in "space race" as portrayed in the media.

(j) International Public Opinion and Awareness of Space Exploration

According to a World Poll conducted in November 1957, many countries reported extremely high percentages of public awareness regarding Sputnik launch. For instance, over 90% of public in Norway, France, Austria, Belgium, and Germany were aware that the first satellite has been launched in the space and that Russia has accomplished this mission. Over 80% of public were aware of this in Italy and Canada, over 70% public were aware of it in Japan, Britain, and Mexico whereas 57% public were aware of the mission in Brazil (Almond, 1960).

2.1.1.2 Public Perceptions About the Apollo Space Program (1965-1975)

The following paragraphs provide an insight into the public perceptions about the Apollo Space program from 1965 through 1975. Krugman (1977) in his comprehensive study "Public attitudes toward the Apollo Space Program" presents various issues that were responsible for the declining support of the space exploration venture among public. Following is a brief discussion of those factors:

(a) Establishment of NASA

Space exploration events in the US were highly influenced by the successful space missions in Russia. In fact, one of the most important decisions after the launch of Sputnik 1 was to create NASA (National Aeronautics Space Administration). As a result, NASA was officially established approximately a year after Sputnik 1 launch on October 1, 1958. The Apollo Program which consisted of successfully landing a man on the moon was once again a goal set by President Kennedy in response to Yuri Gagarin's (Russian Cosmonaut) first space walk on April 12, 1961.

(b) Funding, Public Opinion, and Space-Race

Public support towards huge government funding for the Apollo Program was low and opposition towards this investment grew more despite extensive media attention given to the program. It is indicated that the number of space probes sent by US in early1960s were much higher than late 1960s and early 1970s. Krugman (1960) states that there were more launches by United States when it was trying to catch-up with Russia and Russia did the same after the successful Apollo Program. However, significant decline in US space probes were caused by the lack of public support in early 1970s after the lunar landing. Public was more concerned about Vietnam War and international conflicts than space exploration in 1960s. Similarly, the main public concerns in 1970s were air and water pollution, economy, crime, drugs and a shift in youth culture.

Surveys between 1955 and 1960 indicate that Russia was thought to be ahead of US in space exploration among Americans. However, between 1960 and 1965, people

believed that US was catching up with Russia and later moved up in the competition. The percentage of people who accepted that moon landing was imminent grew from 15% in 1955 when people thought it was going to happen in the next 50 years to 57% in 1957 when people thought it will take place in the next 20 years to 44% in 1961 when people thought it will happen in the next 5 years or less. The growing number of space probes combined with media attention and President Kennedy's emphasis on the matter influenced the public about the **imminence of lunar landing**.

As far as funding is concerned, a survey conducted in 1965 by AIPO suggests that 42% Americans wanted the funding to stay at the current level, 33% believed that space funding should be slashed, and only 16% believed that it should be increased. Based on the public attitude trend between 1965 and 1975, 32% Americans were in favor of government doing less about space exploration and only 20% were in favor of government doing more towards the cause. Moreover, the **flash fire incident** on January 27, 1967 which resulted in the death of a three men crew for the first manned Apollo Mission also impacted the public support regarding space exploration. The percentage of public who wanted government to "do less" for space exploration increased sharply due to the accident.

However, it is interesting to note that the public support for the government to "do more" about space exploration increased in the next 2 years after the mishap. **Public support reached its peak** when they witnessed the first successful three men crew who went to space for 10 days and came back after completing the mission in October 1968. Even though the moon landing did not take place until July 1969, surveys conducted

during May and November 1968 indicate a sharp increase (33%) in public supporting the government to "do more" with regards to space exploration. However, this increase in public support has been called **"anticipatory"** by the researchers i.e. the curiosity of landing on the moon combined with successful manned spaceflight experiments created a feeling of anticipation among public that moon landing was not a distant dream. Public support in the months before and after the lunar landing increased but the growth in the **support was not extensive** and the support to "do less" increased greatly from 32% in November 1969 to 48% in May 1970, before the second successful moon landing. In the period between 1970 and 1975, public support to "do less" was about to 50% and the interest in doing more for space exploration was about 20% in spite of four successful lunar landings during that period. The anticipation of moon landing was influential in decreasing opposition for the Apollo Program among public in the beginning. The demographic characteristics of public who opposed Apollo Program indicate that **older, less educated people, and women were not in favor** of the program. The people who indicated "do more" saw space exploration as a technological advancement, development, great achievement, and an opportunity to learn more about the universe. The people who indicated "do less" wanted government funding to be used on other important issues, they were more likely to say that space investment is a "waste" and that there was nothing more to accomplish. Even though opposition to the Apollo Program was always there, polarization of public opinion became even more apparent from 1969 to 1972. The TV news coverage and the print media are also considered as important factors affecting public opinion. Public strongly considered investing in the Apollo

Program a waste of resources and the loss of astronaut lives indicated that public was not in favor of paying the price of space exploration with human lives. Positive media coverage on the Apollo Program did not help increase public support. Public was more concerned about national issues at that point of time. Public curiosity declined after the first moon landing as according to them there was very little interest in more lunar landings.

2.1.1.3 Mars Exploration

(a) History of Mars Exploration

Mars has been a planet of interest among public and scientists from the past 6 centuries. Early Mars exploration attempts involved observing the planet in the night sky, describing how it looked, making calculations about its position in the solar system by merely using keen eyesight at first and later via telescopes in 1609, making observations about Martian surface, speculating the length of a day on Mars, wondering possibilities for extraterrestrial life, ice-caps, canals, and speculating about its atmosphere. Each attempt to know Mars added more information, interest, and curiosity about the planet among scientists, public and different countries. Eventually the first space probes to explore Mars were sent by Soviet Union in 1960s named Marsnik 1 and Marsnik 2.

Mars exploration has been a difficult and challenging experience. More than 65% of attempts to explore Mars have resulted in failure with space probes either not being able to leave earth orbit or maintain connection with earth after reaching Mars. There have been three main kinds of space probes sent to explore Mars: (1) Flybys (2) Orbiters (3) Landers and Rovers. The earliest missions to Mars were done by sending flybys

whose main objective was to take pictures of Mars and its surface. For instance, Mariner 3,4, 6, and 7. Flybys helped scientists gather more information about Martian surface and with the development of technology, the second stage of exploration was executed by sending orbiters to Mars. Examples include: Mariner 8 and 9; Viking 1 and 2; Mars Observer, 2001 Mars Odyssey, Mars Reconnaissance Orbiter. The orbiters were technologically superior than flybys i.e. they were designed to enter Mars orbit and gather more precise information such as the presence of canyons, craters, volcanoes, weather patterns, ice-caps, mineral composition, magnetic fields, and gravity on the planet. The third stage of Mars exploration involved scientists sending landers and rovers to Mars. Landers as the name suggests can land on Martian surface and may also carry rovers which can move around Mars and perform various science experiments on the surface. Examples include: Mars Exploration Rovers called Spirit and Opportunity; Mars Science Laboratory Rover called Curiosity. Soviet Union and United States dominated space exploration in 1960s. However, Russia's initial attempts to send flybys were unsuccessful. The first successful flyby, Mariner 4, was sent by United States on November 28, 1964. Mariner 4 sent the first close-up pictures of Mars, detected the presence of carbon dioxide in the Martian atmosphere and a magnetic field on the planet. This was followed by the launch of Viking 1 and 2 in 1975. They were the first two successful space-crafts to land on Martian surface. The main objective behind Viking missions was to investigate the presence of microbes on the planet. The results of these missions remain inconclusive. However, they took over 52,000 images of the planet and studied the Martian weather. The first rover to land successfully on the red planet was

Sojourner in July 1997. The main objective of this mission was to test the feasibility of low-cost space-craft landings on the planet. The 2001 Mars Odyssey lander and orbiter was launched in April 2001. It holds the record for the longest surviving orbiter on Mars (17 years). Its objective was to investigate the clues for the presence of water and volcanic activity on Mars. It also acts as a relay for the existing Mars Science Laboratory mission rover, Curiosity and Mars Exploration Rovers, Spirit and Opportunity. The Mars Exploration Rovers, Spirit and Opportunity were launched in 2003 as part of the robotic space probes to Mars. The primary goals for this mission were to investigate various rocks and soil to find clues about the water activity on Mars. Spirit lasted on Mars for approximately 7 years and eventually lost power resulting in loss of connection with the scientists at NASA. Opportunity on the other hand is still performing experiments on the Martian surface and making observations about its atmosphere and weather patterns.

(b) Curiosity

The Mars Science Laboratory (MSL) Mission is a robotic space probe by Jet Propulsion Laboratory (JPL) at NASA. This mission involved launching a rover named Curiosity to investigate whether Mars had/has a habitable environment, conditions for the presence of microbes, and role of water. Curiosity was launched from Cape Canaveral on November 26, 2011 and it landed on Mars at Gale Crater on August 6, 2012. The rover is collecting information about Mars' climate and geology for the preparation of an eventual manned mission to Mars in 2030s. Curiosity is the largest and most sophisticated rover to have ever landed on Mars. It is 7.2 feet tall, weighs about 2000 pounds and costs $2.5 billion. It is powered via radioisotope thermoelectric generator (RTG) which involves

production of electricity from radioactive isotopes such as Plutonium-238. This helps in providing constant power to Curiosity irrespective of seasons, days, or nights. Curiosity has 17 cameras on it. They are: Hazcams (8); Navcams (4); Mastcams (2); MAHLI (1); MARDI (1); and ChemCam (1). Hazcams also known as Hazard Avoidance Cameras help Curiosity move around the Martian surface autonomously by identifying the safest path to the destination. Navcams also known as Navigation Cameras help Curiosity to move on the ground by taking wide angle pictures to help plan the next movement of the rover. The Mast Cameras enable capturing true-color pictures of the planet which helps in geological analysis. MAHLI stands for Mars Hand Lens Imager and it helps Curiosity to capture microscopic images of the rocks and soil that the rover investigates. MARDI which is the Mars Descent Imager, helped take color pictures of the rover while landing on the surface of Mars. ChemCam which stands for Chemistry and Camera Complex is a collection of remote-sensing instruments on the rover. Among other major instruments on the rover are: REMS (Rover Environmental Monitoring Station); APXS (Alpha Particle X-ray Spectrometer; CheMin (Chemistry and Minerology) instrument; SAM (Sample Analysis at Mars); and RAD (Radiation Assessment Detector). The following Figure 1 and Figure 2 provide a view of Curiosity's Scientific Instruments and Curiosity Rover respectively.

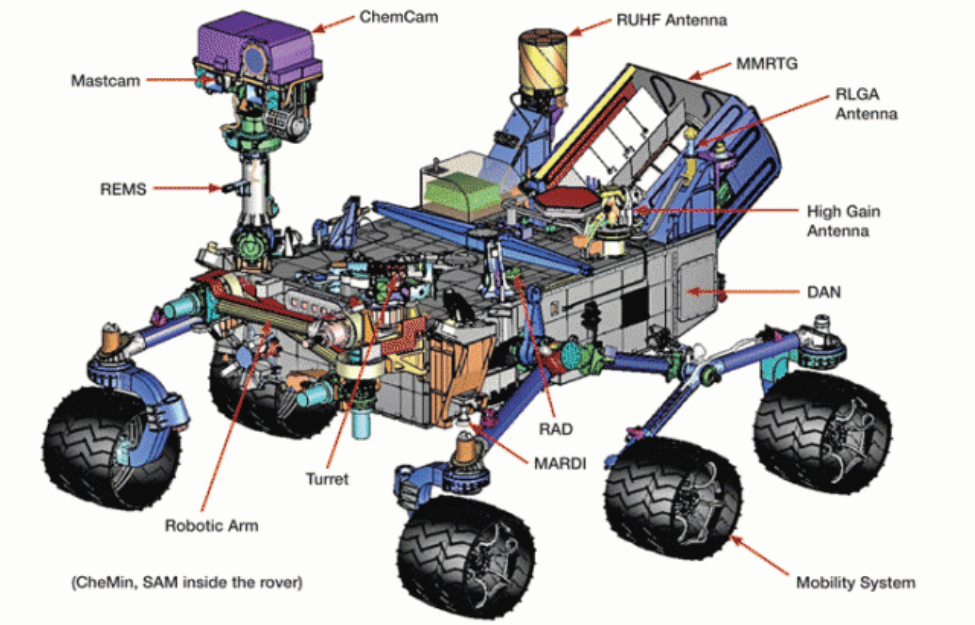

Figure 1: NASA's Curiosity Rover with its Science Instruments

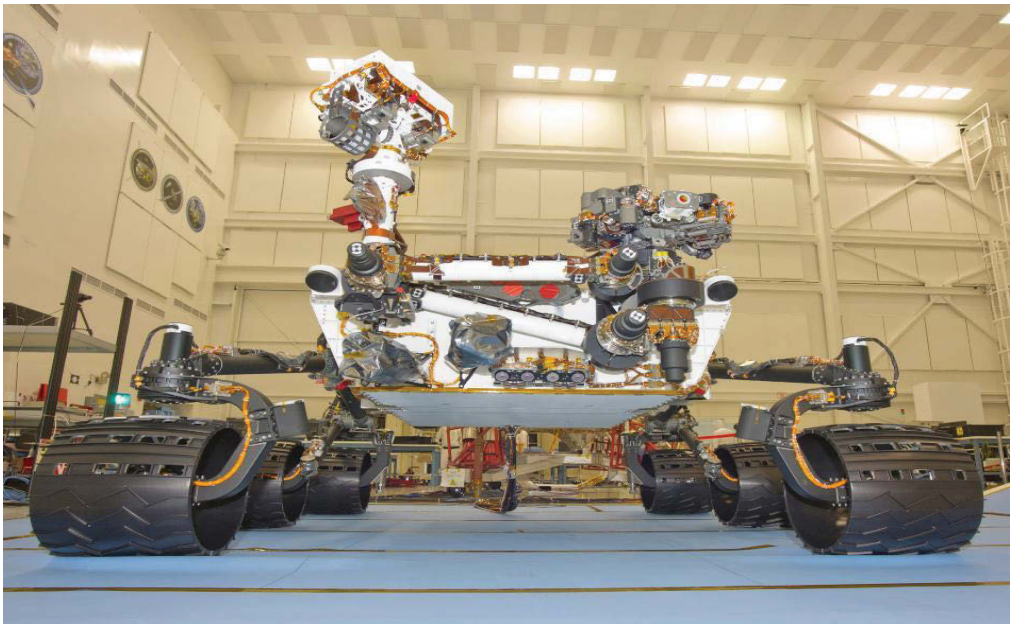

Figure 2: Curiosity Rover, Front View. Courtesy: NASA/JPL-Caltech

(c) Public Perceptions Towards Mars Exploration

People from all over the world have shown strong interest in human exploration of Mars. Around 72 youth delegates from 40 countries signed a "Vision for Human Exploration of Mars" during the United Nations Conference on Exploration and Peaceful Uses of Outer Space, UNISPACE III (Normans Media, 1999). However, public opinions vary in the United States. According to a survey of life scientists, students, and members of Planetary society, public and experts approached Mars Sample Return Mission with uncertainty about the possibilities of life on Mars. Their concerns involved planetary cross contamination and handling of hazardous Martian samples. Despite concerns about the harmfulness of Mars samples, people did not think that it was necessary to abort the mission. Overall NASA was highly trusted to carry out a successful mission but there were mixed feelings about NASA not respecting public values and opinion or honestly informing them about risks from planetary contamination. Space risks and biological contamination were lowest on the list of risks perceived by the public whereas concerns about ozone layer depletion, pesticides in food, and global warming were the issues of deep concerns (Race, 1998; Race, MacGregor, & Slovic, 2000). More recently, in a response to a letter released by President Obama about his admiration for American space exploration and support for the goals of human exploration of Mars, students at the Grand Rapids Community College had mixed feelings about the issue. While some students agreed with Obama's goals and thought that the idea was "interesting", "right thing to do", "an opportunity to improve existing technology and science", some expressed concerns about funding and domestic and global issues (Rios, 2016).

In another survey on a possible Mars Sample Return mission, results indicated that public were not concerned about bringing mars samples back to earth as long as scientists adhered to international standards of safety. But clear communication about what safe containment meant was required for the public by NASA/JPL. Majority of the people supported space research, thought it was necessary to find new planets, resources, and increase scientific knowledge. Public had little knowledge about MSR project. The knowledge they did have was favorable. Even after providing more information about the project, majority of the people supported it. The main concerns raised were about the use of plutonium to send a space-craft on Mars and then leave that plutonium on Mars. Concerns were about accidents involving rockets with Plutonium after take-off on earth. People were opposed to polluting Mars by leaving Plutonium on the planet. Lack of media attention to the issue and lack of communication from NASA were some of the reasons why public was not properly educated about the project. Information campaign in schools, Disney World and McDonalds were suggested to target young kids and families. One of the reasons why public supported Mars Mission was because they thought that earth was being destroyed and Mars was an alternative. People trusted NASA even after previous Mars Climate Orbiter loss. One of the reasons why there was lack of concern among public about this mission was due to less information communicated to them about the project according to the researcher. Out of 70 participants, 60 supported space research. Out of 10 who did not support space research mentioned it was a waste of money and would support it if it cost less. Out of 70, 46 people had not heard about the MSR program and 24 had some idea about it. Even the participants who had heard about

it, knew very little about it and more interesting thing was, only one person was concerned about it. The people who opposed the project did so on the basis of cost and the people who supported the program did so because they just liked the project, thought it was a good use of money and considered it fascinating. Most people preferred communication from NASA via TV and print media (Lofstedt, 2003).

O. Morton (2004) brings up an interesting point. He argues that one of the reasons Mars exploration is appealing to the public is because humans have had the chance to view Mars with just a telescope, they have had the chance to know more about it over the years through pictures, videos, and data shared by science agencies. Mars shares quite a few similarities with earth, it is closer to earth than other planets, and going to mars is a goal that is feasible. The idea of finding life on another planet, the fact that we *can* explore Mars and the similarities that it shares with earth provides a lot of hope to public about Mars exploration.

In a study conducted in Australia between school children aged (11-15) and adolescents with an interest in science aged 18 and above about support for Mars Mission indicated that school children were more likely to believe that life once existed on Mars. They were also more likely to not believe in existence of life and remain undecided. It is interesting to note that school children and adolescents were both in favor of space exploration more than Mars exploration. School children were most concerned about the health issues due to contamination of earth with Mars samples, environmental issues due to contamination of earth, use of nuclear materials as power source for spacecraft, lack of proper quarantine facilities and contamination of Mars. While adults were most

concerned about the contamination of Earth's environment, Mars, and poor quarantine facilities. When inquired about trust in NASA, both school children and adults trusted NASA most on completing a mission successfully, protecting earth, and predicting risks accurately. Both groups showed less trust towards NASA on matters such as protection of Mars, respect towards public opinion, and informing the public honestly about the risks (Joyce, Ferguson, & Weinstein, 2009).

Some of the most cited reasons for exploration in the literature are: Maintaining US leadership in space exploration, practical benefits in the form of spinoffs, and inspiration to the public. An online poll of 1001 respondents over 18 years of age conducted in 2013 found that there is a broad support for mars exploration among public. But the reasons for public support were different than usual. The poll revealed that public supported human exploration of mars to get a better scientific understanding of the planet and to look for the signs of life. Over 50% people believed that these objectives justify human exploration of Mars. About 75% people were in favor of doubling NASA's budget to achieve such a goal once they were informed about the current figures of NASA's budget (a common misconception among public being that NASA's budget is much more than it actually is). Maintaining US leadership was not found as the most important reason for Mars exploration as long as US was participating in the effort. People favored international cooperation and public/commercial partnership in order to achieve the goal, share spinoffs and costs. About 70% Americans, men and women equally, Whites as well as African-Americans believed that humans can walk on mars by 2033 (Carreau, 2013).

With NASA's goals of sending a human crew for Mars exploration in 2030s, there is a dire need of public interest in science education. However, a recent survey of US middle school and high school teachers indicate that only a third of teachers (36%) said that their students show interest towards Science Technology Engineering and Medicine (STEM) education. Space exploration requires a lot of engineers, scientists, doctors, and industry experts at various stages of the mission. A lack of interest in the current and future generations of people in pursuing science education is directly going to affect America's future (Martin, 2017). While this is a problem, majority of teachers also indicated that discussion of space-related careers in classes and exploration of moon once again will encourage students' inclination towards science education. As far as current school curriculum is concerned, 43% teachers mentioned that the existing school curriculum is sufficient to encourage students towards STEM careers while only 23% teachers believed that the current curriculum is sufficient for encouraging students to pursue a career in space exploration (Martin, 2017).

(d) Reasons for Mars exploration

Some of the reasons why Mars exploration is important are: (1) Evidence of water on Martian surface billions of years before its appearance on earth indicates a possibility of life which is worth exploring. (2) It is a big scientific and technological challenge for various countries and people who are curious to know what lies beyond earth. (3) We have already explored Moon, it's time we explored a planet which offers better potential for humanity's future. (4) It will be a source of inspiration for the younger generation to get involved with the mission in various ways and be encouraged about science education

and related careers. (5) Mars has a lot of resources for sustaining life such as water, carbon, nitrogen, hydrogen and oxygen. Mars also experienced similar volcanic and hydrological processes as did earth giving rise to vast mineral ores resources. Although liquid water does not exist on Mars, underground drilling might uncover hot reservoirs of water where life may still exist. It can be a great resource for water and geothermal energy if man ever decides to settle on Mars (Zubrin & Staff, 2005).

2.2 Benefits of Space Exploration on Society

Carl Sagan, famous astronomer, astrophysicist, and science communicator stated that space exploration research enabled development of technology to identify mineral resources, predict storms and earthquakes, satellite communication, and protection of agricultural crops. He asserted that exploring different planets will provide us information about their composition and will help us understand how earth is different from other planets. In doing so, we will learn the delicate "balance" of our own planet and protect it for the future. One of his dreams was to see a rover on Mars and exploration of Titan (Saturn's Moon). He mentioned that space exploration will provide us information about "who we are and where we are" which will enhance our understanding of human civilization. One of his area of interests was to explore the possibility of extraterrestrial life. According to him, presence of extraterrestrial life on any other planet will have the potential to wipe away differences among people on earth based on color, religion, and nationality helping people unite all over the world and confirmation of no life on other planets will also be an important information as it will emphasize the significance and

rarity of life on earth which in turn will have the potential to bring people closer (Reynolds, 1982).

Space exploration research has great astrobiological benefits. Crawford (2010) states that exploration of moon will help scientists understand the origins of life on earth i.e. conditions under which earth started supporting life, exploration of near-earth objects will inform us more about the formation of solar system, human space exploration will enable creation of sophisticated technology to send complicated science equipment into the space for investigation, and it will also help in the creation of powerful space telescopes to probe other planets.

Given the complicated nature of space exploration research, there are various stakeholders involved in the process. Government, space agencies, aerospace industries, entrepreneurs, public, scientific foundations, academia, entertainment industry, and mass and social media are some of the most important stakeholders in this arena (Shaghaghi & Antonakopoulos, 2012). Researchers also argue that a complex mission like Mars exploration will benefit government create a landmark event in the history of mankind and influence public support in the form of votes, space agencies will be able to execute a challenging goal and help preserve jobs in their organization, aerospace industries will be able to create more job opportunities and new technologies, scientific foundations will have enhanced funding, scientists will benefit from the data gathered during the mission to explore Mars and answer some of the key questions about the possibility of life on a different planet (Shaghaghi & Antonakopoulos, 2012).

Space exploration research has provided us several practical and technological benefits over the years. These technologies have improved our **lives, health, and communication processes**. Some of these technologies are: Lasik eye surgery, pacemakers, digital image processing, global positioning satellites (GPS), and collision-avoidance aircrafts (Tyson, 2012). Other examples include neuroArm – world's first robot which performs intense surgeries inside the MRI machines, prevention of bone loss with the use of Biophosphonate which is used to cure elderly patients with osteoporosis as well as astronauts aboard International Space Station who spend months performing experiments but also experience extreme bone loss during the process, growing protein crystals in space helps scientists develop various medicines, development of vaccines, ultrasound technology which reduces the time required to diagnose a patient especially if he or she is in a remote location, development in cancer treatment, and water purification systems all over the world (Thomas, Thumm, & Robinson, 2012). Some of the **earth observation technologies** developed from space exploration research are: Technology to monitor world's sea traffic via International Space Station, detection of locations for natural resources, technology to study natural and man-made disasters such as "earthquakes, volcanic eruptions, floods, fires, hurricanes, and aviation accidents". Data from studying these catastrophes help scientists and government in preventing and minimizing the damage caused by these disasters. Space exploration research also enables technology to monitor various natural and man-made changes on earth which causes drastic climate change. Studying the causes of climate change helps scientists to predict future damages to the environment and device strategies to protect earth. Space

station enables capturing of earth images during disasters such as tsunami and oil spills. Such images are useful for disaster responders on the ground to identify affected areas and take necessary actions to minimize the effect caused by such calamities. Study of coastal regions and coral reefs around the world to protect fisheries and sustain economic development of various countries (Thomas et al., 2012).

2.3 Rationale for Space Exploration

Rationale to justify space exploration have evolved over time. While national pride and prestige used to be the main justifications provided for exploring space during the Cold-War era, more emphasis was given to reasons such as science, economic development, and international cooperation after 1960s (Roy, Gresham, & Christensen, 2000).

Global Exploration Strategy (2007) presents following rationale for exploring space: "(1) New knowledge in science and technology (2) A sustained presence – extending human frontiers (3) Economic expansion (4) Global partnership (5) Inspiration and education". While Dick and Launius (2006) argue that there are five main rationale for spaceflight in America which have been used and modified over time. They are: (1) National pride/prestige/geopolitics (2) Human destiny/survival of the species (3) Commercial and other applications (4) National Security (5) Science and Technology. Selling the idea of space exploration to the public became difficult after the end of Cold War. The end of Cold War meant that there was no urgent need to compete with Russia or any other country for winning the Space-Race. Therefore, justifying the financial cost and need for human exploration in space which is a risky endeavor became exceedingly

difficult (Neal, 2007). Also, NASA was not required to present a rationale for space exploration during Cold-War. Political leaders and media were providing public the reasons for space exploration (Neal, 2007). Cost of space exploration did not matter as much as victory over Russians and the fear of potential attack from Soviet Union due to their advancement in space technology (Neal, 2007). Questions about the future of space exploration, role of NASA and media, and how to garner public support in the absence of Cold War were raised (Neal, 2007).

Literature also suggests that scientists, space agencies, and public were motivated by different reasons to explore space. Public was not convinced of spending billions of dollars for space exploration even for the Apollo Mission (AAAS, 1961). They understood the "practical benefits of technology" aspect of space exploration but administrators at NASA had a different view and rationale for space exploration (AAAS, 1961). For administrators at NASA, advancement in technology, birth of new industries, jobs, strengthening America's economy, and knowing the unknown about universe were more important (AAAS, 1961). Homer E. Nowell, Deputy Director of NASA's Office of Space Flight Programs, mentioned "*Out of the scientific research will come knowledge; knowledge about the universe and its laws; knowledge about the earth upon which we live; its atmosphere, the sun, and the sun's influence on the earth; knowledge about physical life, its origins and fundamental nature…Past experience has shown that the most important benefits of our research are probably unforeseen*"(AAAS, 1961). Scientists who advocate space exploration have provided various reasons to do so. For instance, Tyson (2012) states that exploration of Mars is essential to understand the

reasons behind the loss of water on its surface so we can prevent earth from facing similar situations in the future, asteroids should be explored to understand how to deflect them from colliding with the earth, Venus should be explored to uncover reasons behind extreme high temperatures on its surface and Pluto should be explored to find clues about the origins of solar system. As Carl Sagan once said, "dinosaurs died out because they did not have a space program". It would be silly to face the same kind of extinction despite having the capability to explore space and increase our understanding of the universe.

Scientists also mention that in addition to knowing about our universe, space exploration leads to new information which in turn leads to useful discoveries. Exploration of Jupiter's largest moon, Ganymede reveals the moon might have the largest ocean in the entire solar system containing possibilities of life. Scientists say that the ocean on Ganymede is about 60 miles deep which is about 10 times the depth of oceans on earth (Kramer, 2015). It is not possible to know such facts without exploring space. Crawford (2010) states that "*It is only through space exploration of the universe that we will able to determine the existence, prevalence, and nature of life beyond our own planet…Space technology has the potential to disseminate life outside of earth and play a significant role in the future of life outside earth*."

As we know from public attitudes towards space exploration that NASA enjoys a favorable position among public as an organization and that public supports development of science and technology in general. However, public is not so supportive of spending billions of dollars towards space exploration. Their main reason being the presence of

other high priority earth-based issues such as poverty, lack of education, depletion of resources, economic problems where money and resources should be invested. However, (Tyson, 2012) suggests that instead of questioning the value of spending billions of dollars towards space exploration, public should ask the following questions "*As a fraction of one of my tax dollars today, what is the total cost of US space-borne telescopes and planetary probes, the rovers on Mars, the International Space Station, the recently terminated space shuttle, telescopes yet to orbit, and missions yet to fly? The answer is one-half of a penny.*" He furthermore states that if government could restore the funding for NASA even to the quarter level of what it was during Apollo Era (which was a little over 4 cents on every tax dollar), it will strengthen America's position in world space exploration.

Specific outcomes aside, space exploration also leads to various serendipitous discoveries and inventions which are difficult to predict at the onset of a particular project. For instance, development of technology to detect breast cancer came out of a project to improve the images received from Hubble Telescope and today many people are able to take advantage of this technology (Tyson, 2012). It is important for public who questions investing billions towards space exploration to understand that the solution to solve bigger problems such as poverty, resource depletion, hunger, climate science is not reducing or cutting space budget. Instead, scientists have found numerous ways to improve agriculture, communication, health, climate and hunger issues around the world through the process of space exploration.

Another justification to support space exploration is human space exploration should be done to inspire and motivate public. Some researchers say that presenting technological spinoffs as the rationale for space exploration is not going to motivate public (Pitts, 2003). He says space exploration is about connecting to people in a deeper way. "*What the public seeks is an experience that they can slip into so that they too can experience the wonders of alien realities"*. He calls them "Humane Factors Engineering" which entails exploring space not only as an engineer or scientist but also as a human with his/her artistic perspective involved in the process. He presents examples where Aleksei Leonov carried a colored pencil bracelet and a sketch book with which he drew the horizon of earth as seen from space, permission for women astronauts to carry make-up kits during 80s and 90s on their space mission, astronauts playing with food, enjoying weightlessness, sometimes even dancing. All these experiences make space missions look relatable and humane to public. It is important for public to realize that apart from scientific aspect, space missions also have a humane side.

Dick and Launius (2006) argue that traditional methods to convince public about the value and purpose of space exploration are not going to work. US is not facing a Cold War-like crisis and space advocates need to find different ways to justify space program. He also states that a lot of people are not convinced of the need to send humans to explore space. Therefore, reasons such as human destiny and national prestige fall short of convincing people to support space exploration. In addition, death of astronauts in the Columbia disaster has also influenced public to be cautious about human exploration of space. He concludes that the rationale of national prestige and human destiny are no

longer relevant as they were during the Cold War era. There is a lot of uncertainty about how to convince public about supporting human space exploration.

One of the major criticisms of NASA in the literature is the amount of emphasis given to factors such as national prestige, elitism, and power to justify space programs and placing much less importance on earth-based research. McQuaid (2006) argues that early leaders of NASA have paid more attention to exploring moon, Mars, and other planets instead of focusing on earth as a part of space exploration research. She furthermore states that despite public interest and concerns about earth, pollution and its ecology, despite NASA's one-third budget cut after the Apollo Mission, and despite environmentalism being the national theme in 1970s, NASA did not focus on earth sciences until late 1980s. McQuaid (2006) adds that administrators at NASA avoided opportunities to grow political and public support by engaging in earth applications research and maintained focusing on national prestige and exploration of other planets.

2.4 NASA, Science Communication, and Social Media

2.4.1 Creation of NASA

NASA (National Aeronautics Space Administration) officially began operations on October 1, 1958, almost a year after the first Sputnik launch. Its creation was highly influenced by the space exploration advancements taking place in Soviet Union, especially the launch of first artificial satellite, Sputnik. The main objectives of NASA at the time were: advancement of knowledge about atmosphere and space; advancement of aeronautical vehicles; development and operation of spacecraft; establishing long-range studies of potential benefits from space exploration for peaceful and scientific purposes;

preserving the role of United States as a leader in space exploration and share vital findings with the military; and co-operate with various government agencies with regards to space exploration activities (Dick, 2008).

2.4.2 Need for Public Support

Literature in space communication research suggests various reasons for public support of space exploration activities and NASA. They are: (1) Declining funding for space research (2) Need for public participation in space policy making decisions (3) To prevent loss of trust and resentment towards scientists, science data, and science agencies (4) To raise awareness, significance, and value of work scientists engage in.

2.4.2.1 Declining Funding for Space Research

NASA has made tremendous progress in space exploration. The future goals of NASA involve returning to the moon and a human exploration of Mars by 2030s. However, space exploration is an expensive enterprise and requires billions of dollars, a large portion of which also involves taxpayer's money. The current budget of NASA is $19,508 million which is 0.47% of the federal budget. This is also the lowest percentage of federal budget allocated to NASA since its inception. Public support is crucial in this scenario.

Political affiliation, ideology, and religiosity are some of the most common determinants of public support found in the literature of space exploration. While some researchers agree to that, some have a different perspective. For instance, Cobb (2011) argues that spending may be dependent on value predispositions. According to his study of public opinions from 1973-2010, Republicans are more likely to support space funding

than Democrats. He also says that since Republicans have typically supported NASA and space policy more than democrats, American public may as well adhere to their party affiliation to support or oppose space funding. On the other hand, Jacoby (1994) argues that public support of funding is based on whether spending is proposed for welfare or non-welfare programs. Attitudes toward welfare programs are based on values such as political affiliation, ideology, and religiosity, for non-welfare programs such as NASA funding, support is not formed on the basis of these value predispositions. As per Nadeau (2013) for the public to support increase in budget, factors such as knowledge and opinions about science matter more. White males, with higher socio-economic status, baby-boomers with nostalgia about Apollo mission, fondness for organized science, and post-secondary science education are more likely to support increase in science funding for space agencies.

2.4.2.2 Need for Public Participation in Space Policy Making Decisions

Public participation plays an important role in space policy making decisions. Scholars have emphasized involving public opinion in space policy making due to it being their democratic right; because public can point out certain risks and perspectives that experts might not have considered before; it builds trust and transparency between government and public, and provides an opportunity for diverse opinions to be represented (Entradas, 2016).

Research on this issue suggests that the public is perceived as “curious”, “engaged”, “interested”, “passionate”, “knowledgeable”, and “motivated” in general and scientists do believe that public participation is important for space policy making

decisions. However, despite believing so, a large majority of scientists are against the idea of public participation in space policy formation (Entradas, 2016). The study also indicates that scientists believe the public is not fully informed or educated in specialized areas of science to make an informed decision, they can be easily influenced and manipulated by media and political agendas, pre-existing values and beliefs based on religion, fear, uncertainty might influence their opinion and it is extremely difficult to change those opinions quickly. In this scenario, the government has to make the right decision when it comes to important issues such as space exploration.

2.4.2.2 To Prevent Loss of Trust and Resentment towards Scientists, Science Data and Science Agencies

There is a loss of trust among the public about science data, what scientists do, and towards science agencies. Research suggests that the public is uncertain about NASA respecting their opinion and sharing complete information about risks involved in a given project (Race, 1998; Race et al., 2000). The Public is also vulnerable and can be easily influenced by the media. According to National Research Council's Science Plan 2014, there are three main instances often quoted to show how oversimplification or lack of details about a science topic in the media can create confusion and result in a difference of opinion between public and scientists. First, NASA's announcement about Mars Meteorite ALH84001 providing evidence of life on Mars in 1996 which was highly debated among scientists and the claim not being true stirred a lot of confusion among public. Second, the reasons for demotion of Pluto from planetary status in 2006 were not communicated effectively to the public which led to a huge controversy surrounding the

issue. Third, scientists failed to communicate the uncertainty about the discovery of a planet near the red dwarf star named Gliese 581 in 2010 and the claim was debated by another group of scientists in Switzerland. The declaration by President Bush to explore the Moon by 2020 after the Columbia accident and Congress not funding the mission adequately also indicates that the government is not serious about funding space activities (National Research, 2013). In addition, cancellation of Constellation program by President Obama to save costs for maintaining International Space Station and other projects has filled public with doubts about NASA leadership in space exploration (Nadeau, 2013; National Research, 2013).

2.4.2.4 To Raise Awareness, Significance, and Value of Scientist's Work

Livingston (2006) mentions that scientists need to connect with the public by addressing their concerns regarding space exploration. For instance, many people think that financial investment towards space exploration is a waste of resources. Most likely because it is difficult to see the immediate results and advantages associated with a space mission. However, scientists need to communicate with the public by describing how their money is invested in a "well-designed" space program. He furthermore states that lack of deep understanding about the specifics of the space program and the advantages associated with it creates more misunderstanding among public leading to lack of support or not considering space exploration a top priority for the nation. Communication between scientists and public is key in bridging this information gap.

2.5 Science Communication Via Social Media

Research on space exploration reveals that science communication between scientists and public needs to be addressed. Public opinion about space exploration also suggests that public is not aware about space exploration activities in detail and does not think that it is one of the most important priorities for the country and it is important for scientists to reach out to public to explain the reasons behind such missions (Ehrenfreund et al., 2010).While some researchers suggest that competition with China in space exploration has the potential to stir public interest in space exploration just like it did during Apollo era, some suggest connecting with public through social media, sharing science stories will attract and increase public attention.

Studies suggest it is essential for scientists to reach out to younger generation using social media platforms as the current generation accesses news mostly via these platforms (Trovatello, 2012). One of the most important reasons why social media is preferred over traditional media to access space science updates and information is because social media provides live updates about the activities regarding space exploration combined with astronauts talking to public via international space station, something which traditional media does not offer (Gray, 2014). Some of the advantages listed in favor of the use of social media to communicate about space exploration are: (1) Social media offers many to many communication channels; (2) provides better visibility (3) opportunities for networking; (4) a platform for experimenting with new ideas (4) a platform marketing and promotion (5) enables monitoring of conferences (6) tells public about which news topics are trending (6) enhances communication skills especially

"brevity" in writing (National Research, 2013). It removes the need to use journalists as mediators of science news and information and enables direct communication between public and scientists bridging information gap (Peters, Dunwoody, Allgaier, Lo, & Brossard, 2014). There are also a variety of social media platforms and available features such audio, video, text, and graphics which organizations can use based on their requirements (National Research, 2013). Ryan (2017)also argues that social media and blogs are powerful tools to raise awareness on web especially among youngsters. Although he suggests that social media platforms cannot replace other digital tools but they can complement each other well. He also suggests that each platform should be used for a particular objective depending upon the organization it is being used for. However, there are some challenges in using social media for space outreach and education activities. Researchers argue that one of the risks in using social media platforms such as Facebook and Twitter to engage with the audience is to convert their initial interaction with the issue of space exploration to a long-term engagement with the topic and incorporate them into classroom activities (Denis et al., 2014).

Studies on NASA's use of social media platforms suggest various successful outcomes in terms of increased outreach, understanding, recognition, and involvement with the agency and with space exploration events. For instance, a study on NASA's use of social media (Twitter) suggests that the tweets posted by NASA are very useful in enhancing and improving scientific literacy among adolescents. The results of this study indicate that the tweets are geared towards a general public, promote interactivity with the use of graphics embedded with texts, live streaming of videos, meetings, satellite

images, and science articles. This presence and majority of non-textual content combined with participatory nature of the platform encourages many people to interact with NASA and space exploration activities (Lesley, 2014). McAvinia (2014)argues that YouTube is one of the significant platforms to promote informal science education among adults. According to her study YouTube promotes "public engagement with technology" model where people learn new science information by engaging with the platform, publishers of the video, and other users through comments, likes, and shares rather than merely reading an article from a book which is considered as passive learning. A case study on Yuri's Night space event on social media platforms such as Twitter, Facebook, and YouTube indicates that these platforms have indeed been able to increase public attention and engagement with space exploration (Steinberg et al., 2015).

2.5.1 YouTube

YouTube was founded in 2005. It is one of the most popular social media platforms that supports viewing, uploading, and sharing of user-generated content in the form of videos with the public. According to Alexa, an Internet data analytics company, YouTube is the second most visited social media website in the world. Users of YouTube have grown exponentially since its launch. As of July 2017, YouTube has over a billion subscribers. As of February 2017, around 400 hours of videos were uploaded on YouTube each minute and one billion hours of content were watched on the website every day. YouTube is the most widely accessed social media website by adults between 18-49 years of age than any other cable network in the US. Around 80% of the YouTube viewers are from outside US. It is available in 76 different languages (which covers 95% of the Internet population) and

has local versions in more than 70 countries. Majority of its services for free which makes it immensely popular among masses. YouTube offers features to like, share, and comment on the videos posted by various publishers as well as interact with different users on the website. This ability to interact with people all over the world through videos of shared interests has given rise to a feeling of community and bonding among users. With videos on many topics such as science and technology, news, politics, music, humor, and health, YouTube offers public an opportunity to learn, share knowledge, entertain, and participate in important events all over the world.

2.5.2 YouTube Comments

Research on YouTube comments indicate that an average YouTube comment is "mildly positive", is posted by a 29-year old male, and contains 58 characters (Thelwall, Sud, & Vis, 2012). They also found that positive comments attract fewer replies, and discussions in music, how-to, and comedy videos are the lowest. The study also concluded that religion is the "biggest trigger" of comments. YouTube comments are also influenced by the portrayal of information in the videos where negative portrayal of information is known to generate higher views and comments than positively framed video content (Fat et al., 2011).(Keelan, Pavri-Garcia, Tomlinson, & Wilson, 2007).

CHAPTER 3
FRAMING THEORY

3.1 Introduction

To examine how space exploration was framed on social media during the Mars Science Laboratory Mission, it is important to understand a few key concepts, terms, and methods used in the literature of framing theory. Introduced in 1974 by Erving Goffman, framing or frame-analysis is extensively applied in the field of media studies to understand how news is conveyed by the media emphasizing certain aspects of a social movement or event and how public makes sense of that information.

In this dissertation, space exploration can be considered a social movement and NASA is at the heart of this social movement attempting to frame space exploration for the society. Many scholars have applied frame-analysis to study how public opinions are influenced during a social movement by the news conveyed in the media (Aalai & Ottati, 2014; de Vreese, Boomgaarden, & Semetko, 2011; Terkildsen & Schnell, 1997). Following this particular line of research, I have extended my study to examine how space exploration has been framed on social media by NASA to influence public opinion and garner support by raising awareness about the Curiosity Rover Mission.

3.2 Definition and Meaning

There is no single definition of framing in the literature and most authors have worked towards creating a universal understanding of what it entails, its characteristics, and purpose. Understanding of framing is often left to the "tacit knowledge" of

researchers and audiences. However, some of the most common descriptions of the concept are:

"Framing involves 'selection and salience'. To frame is to select some aspects of a perceived reality and make them more salient in a communicative text, in such a way as to promote a particular problem definition, causal interpretation, moral evaluation, and/or treatment recommendation for the item described." (Entman, 1993)

"Framing is the packaging of messages that resonate with core values and appeal to supporters." (Neal, 2007).

The concept of framing helps us understand "power of a communicating text" (Entman, 1993). According to Entman (1993), frame-analysis reveals how messages conveyed from a sender influence the thinking of the receiver. Furthermore, framing involves constructing or shaping some aspects of an event to make them prominent to the public. Framing of an event may involve definition of a particular issue, identification of the underlying reasons, evaluation based on morals, and/or solutions to the problem (Entman, 1993). Framing provides context to the public about a given issue (Neal, 2007). Frames need to be believable and appealing to the existing public values (Neal, 2007).

3.3 Characteristics of frames

According to Entman (1993), there are four main components of a particular frame: Communicator, Text, Receiver, and Culture. The role of communicators is to make judgements about what to communicate to the public. In this case, NASA, media, and politicians assume the role of communicators deciding how to frame space

exploration for the public. Text conveys frames, often characterized by the presence of certain keywords, phrases, images, or statements for the audience (Entman, 1993). In this dissertation, the transcripts of the NASA/JPL videos contain the frames intended for the public awareness of the MSL mission. The role of receiver is to process and make sense of the frames conveyed to them. However, a receiver's perception or understanding may or may not indicate the same frames as intended by the communicator as everyone views the world with a different perspective. Culture is defined as the set of common frames that is familiar and resonant among the audience. Culture helps public to make sense of a given frame by situating it in common beliefs and values of a social group. Frames can be promoted, criticized, extended, transformed, accepted or rejected during communication (Neal, 2007). Change in situations may result in evolution of a frame (Benford & Snow, 2000). In that case, frames need to be elastic to accommodate new meanings (Benford & Snow, 2000). Frames help shape or restrain public expectations or opinions (Neal, 2007).

3.4 Who creates frames

Social movement activists, politicians, media, national agencies, and public.

3.5 Relevance

Public awareness and support of space exploration is low. Space exploration as an endeavour is becoming extremely expensive every year. In this scenario, major space policy decisions are going to impact the future of Americans as part of their tax will be devoted to space exploration in the long term. Therefore, it is not only important for public to understand where their tax money is being invested but also why it is relevant.

Framing space exploration in a way that resonates with American public and communicating with them on various trusted platforms can generate the depth of public awareness and support that is required for important space policy decisions (Nisbet, 2012). Scientists suggest that information communicated to the public should be tailored according to different platforms (as each platform creates a slightly different impact) and by keeping the variety of audiences in mind. Well researched "metaphors, allusions, and examples" should be used to encourage a different way of thinking about the significance of space exploration (Nisbet, 2012). Frames are important to educate public. Presence of wrong frames creates confusion and lack of trust among public (Nisbet, 2012).

3.6 Framing in Science and its Challenges

Researchers argue that the underlying belief in the scientific community that if public consumes more scientific information and facts via popular sources of news coverage, they will be able to think critically, is not true (Nisbet, 2012). That they will be able to evaluate scientific information just as scientists do and the public distrust in science will reduce is a wrong assumption. Nisbet and Mooney (2007) also argue that public does not consume science news from the media as scientists do. According to them, public is not well informed and driven to evaluate scientific information like scientists. In addition, with the various sources of news and social media platforms available to them, public uses value predispositions such as party affiliation and religious beliefs to form attitudes and opinions about science issues (Popkin, 1991). They are more inclined towards news sources which match their preexisting views on a given topic and thereby reducing the chances to hear and understand opposing viewpoints (Popkin, 1991;

Zaller, 1992). This prevents them from forming an opinion based on hearing different perspectives on a given science issue. Researchers also suggest that only a small fraction of already well-informed public consumes quality scientific information and a large percentage of people either "ignore" or misinterpret scientific news based on their value predispositions (Ho, Brossard, & Scheufele, 2008; Nisbet, 2005, 2012; Popkin, 1991). Frames in this scenario help scientists communicate with the public by providing them a perspective and lens to view a given scientific issue that is meaningful to them. However, as some scientists communicate and try to educate people about science issues that require public attention via resonant frames, there are a group of scientists and political leaders who intentionally frame science with "uncertainty" and "grave economic burden" frames and create doubts in the minds of people (Nisbet, 2012). This is an ongoing struggle.

Literature also suggests that frames vary depending upon a scientific issue (Nisbet & Mooney, 2007). For instance, when communicating about evolution, scientists should focus on positively framed messages without insulting deeply held religious views, thereby respecting the diversity of opinions on this topic (Nisbet & Mooney, 2007). When talking about embryonic stem cell research, frames of "social progress" and "economic competitiveness" have been successful in raising financial support from the public. It is important to note that despite framing issues in ways that resonate with public and educating them about various scientific issues, there will be a section of people who will be difficult to convince about the importance of scientific understanding and religion-based values and beliefs will prevail in those sections (Nisbet, 2005). Literature

also suggests that positively framed messages are more persuasive to the public if the public involvement in those issues are low and therefore they do not scrutinize the messages in detail. However, negatively framed messages become more persuasive to the public if public involvement in those issues are high and then those messages are scrutinized in much more detail (Maheswaran & Meyers-Levy, 1990) (Cox & Cox, 2001).

3.7 Framing Space Exploration During Cold War (1960s)

Competition with Russia and New Frontiers were the two most powerful frames used in 1960s to appeal to the public senses and they proved to be quite popular (Neal, 2007). Space exploration was framed as a necessary step to defeat Russia and regain American leadership in the world as a pioneering nation. Launch of Sputnik and other firsts in the space-race added salt to the wound. Even though the surveys reveal that public was not seething with impatience to defeat Russia, these frames were still able to appeal to the "national identity" value of the American citizens (Neal, 2007).

3.8 Frames Describing Human Spaceflight in the Shuttle Era

Five main frames have characterized the Space Shuttle Era. They are: (1) A new era of routine space transportation (2) Business (3) Scientific Research (4) Heroism (5) Exploration (Neal, 2007). NASA, print media (newspapers, editorials, op-ed pieces), cartoons, brochures, press releases, US Presidents, scientific community, and the public opinions influenced the creation, extension, transformation, dissemination, and sometimes rejection of these frames in America (Neal, 2007). In the following paragraphs, I discuss how each of these frames described human spaceflight in the shuttle

era. The purpose of using these frames was to provide a rationale for continued exploration of space through human spaceflight for public and political support. The main reason for doing so was the change in political circumstances during that time. It became increasingly difficult to convey the purpose and justification for pursuing a risky and expensive human exploration of space in the absence of a Cold-War like situation to the public. There were no wars or competitions to win. Without an appealing rationale for the human spaceflight, it would have been extremely challenging to garner public and political support for a sustained human exploration of space program.

Neal (2007) in her landmark article "Framing the meaning of spaceflights in the shuttle era" provided a detailed analysis of the events that transpired a change in frames for space exploration. She also discussed different frames proposed by NASA, media, and the politicians to appeal to the public for their support. Following is a brief overview of the five main frames that were used to justify space exploration during the Shuttle era.

A New Era of Routine Space Transportation: Introduced in 1972 after the decision to develop the Space Shuttle, this frame emphasized two key concepts: (i) Newness implied innovation in space exploration i.e. using space shuttles to fly like an aircraft carrying satellites, placing space science observatories, and defense devices and equipment from earth to the lower earth orbit (ii) Making space transportation a "common" or a "routine" affair, something that was no longer an "exploration" or "adventure". This frame of reference when combined with the public respect for innovation in American transportation, made it popular and resonant with their existing

values. Human spaceflight was framed in such a way that it would bring practical benefits for the country in the areas of commerce, science, and defense.

Business frame: This frame was an extension of the routine space transportation frame. Inspired by the American airline business industry, NASA framed space shuttle in such a way that the frequent spaceflights between earth and lower earth orbit would bring down the costs of shuttle manufacture and make spaceflights affordable. This frame was in response to the critics of human spaceflight because they believed the endeavor was not needed and was extremely costly. As an extension of the routine transportation, business frame was familiar to the public and it implied doing "useful work" in space.

Scientific Research: NASA used the scientific research frame to describe and justify the establishment of international space station in such a way that it would improve scientific understanding in various fields of research. Studying motion sickness in space, how humans adapt to weightlessness, understanding microgravity, and conducting materials science research formed some of the main science objectives for the missions in the late 1990s.

Heroism: Heroism became a frame in response to the tragic incident of the Space Shuttle Challenger explosion, resulting in the death of seven crew members, minutes after the launch. Public, critics, journalists, and other important stakeholders of the endeavor realized that the routine space transportation was not as routine as it was framed. One thing became clear from this catastrophe– Financial benefit was no longer the parameter for evaluating the Space Shuttle program. The loss of human lives mattered more to the nation. The accident shattered public values such as "national pride", trust in technology,

and “safety” of human lives in the spaceflight. There was a dire need to provide a greater meaning to this tragedy that would symbolize the risks taken by astronauts and their deaths, which led to the frames of “courage”, “sacrifice”, and heroism.

Exploration: Exploration became a frame of reference to excite and promote optimism among the different stakeholders of the spaceflight program after the Challenger incident. Exploration and making humans a multi-planet species within our solar system were the main themes during this time. This era was characterized as having improved space infrastructure and spacecraft, a base on the moon and Mars, and an International Space Station. Exploration was framed in such a way that the human spaceflight endeavor will lead to setting up a home outside planet earth. Exploration frame was placed within the already familiar themes of “transportation” and “new frontiers” (Neal, 2007).

3.9 Frames Describing Mars Exploration

Even though the robotic Mars exploration had started in 1960s, the idea of human exploration of Mars was not promoted among the public until the Challenger tragedy in January,1986. The accident mandated a strict revision of space goals in America. One of the ideas suggested in this light by a New York Times article was a human exploration of Mars as the future goal of spaceflight program to “satisfy humanity’s sense of adventure” [2]. After the Challenger disaster, it was clear that humans should be sent to space only when it was extremely necessary and for accomplishing goals that could not be achieved by robots. Human exploration of Mars was one the ways to justify sending humans in space once again.

Other frames that have been used to initiate and promote human exploration of Mars include “excitement” and “optimism” by National Commission on Space to explore space by enhancing space infrastructures (Neal, 2007). It included establishing a residence on Mars, a proposal by the internal agency planning group at NASA which mentioned a crewed mission to Mars. A newspaper article published by space scientist Carl Sagan emphasized exploring Mars as “the next step” after robotic and Mars Sample Return programs [3]. However, he focused on the “scientific knowledge”, “inspiration”, “prestige”, and “excitement” frames to justify this effort (Neal, 2007). Timothy Ferris, another New York Times journalist emphasized “putting a colony” on Mars [4]. Robots on Mars performing useful scientific work for societal benefits were the frames associated with the new era of space exploration after the Challenger catastrophe.

Finn (2013) in her study on the coverage of Curiosity Rover in print media and on JPL website articles found ten frames describing the mission. They are: Action movie, awesome science, scientific risk, the expectation game, in your neighborhood, engaging the public, anthropomorphism, implications, total victory, and an American win. Dittmer (2007) found that the coverage of Mars Pathfinder Mission in major US newspapers, cable television and radio news shows contained three main frames: (1) Scientific advance and search for life (2) Naming of various places for experiments on Mars (3) Similarities between earth and Mars. He also found that the mission and rover technology was framed in such a way that it represented Mars as a venue for future human colonization. In UK, a study on the coverage of Beagle 2 spacecraft for Mars exploration

revealed frames of pride and scientific knowledge dominating the press coverage (Jergovic & Miller, 2008).

3.10 Mars in Popular Culture

No other planet in our solar system except Mars has been a serious topic of interest, discussion, mystery, curiosity, and inspiration. Long before we landed on Mars, astronomers, philosophers, writers, filmmakers, media, and public have been fascinated with the red planet. We can see the evidence of this fact in the history of popular culture associated with Mars.

Progress in scientific knowledge on Mars seems to have impacted popular culture on this topic and popular culture in turn has also influenced great advancement in science. For instance, one of the most popular science fiction books named "The War of the Worlds" by H.G. Wells was released in 1898, just a few years after an American astronomer Percival Lowell proposed his theory about the presence of canals on the Martian surface created by intelligent beings (Hogan, 2009). Although his theories were rejected by other astronomers, they fueled the imaginations of people about the presence of extraterrestrial beings on Mars like never before (Hogan, 2009). In the future, the book became a source of inspiration for renowned scientist Robert H. Goddard's work on planet discovery, creation of liquid fueled rocket and multistage rocket which proved to be highly useful in the Apollo Mission in 1969. The book was later adapted in a radio show in 1938 by Orson Wells where the telling of the story was so vivid that millions of Americans actually believed that Martians had invaded New Jersey!

Other books such as “A Princess of Mars” published in 1917 by Edgar Rice Burroughs, “Red Planet” published in 1949 by Robert Heinlein, “The Martian Chronicles” published in 1950 by Ray Bradbury, and “Double Star” by Robert Heinlein in 1956 have significantly shaped the popular culture surrounding Mars (Hogan, 2009). NASA has actually named the landing site for Curiosity in the Gale Crater after the famous author Ray Bradbury as a tribute to his stories on the possibilities of life on Mars. “Double Star” became one of the most critically acclaimed science fiction novels based on Mars and the then civil rights movement in United States. The science fiction also won a Hugo award for the best novel in 1956.

In addition to books and novels, movies are another great way to shape public opinion on a given topic. They are a powerful medium for sharing stories, imaginations, history, creativity, science, reality, and fantasy with the public. Movies have played a big role in communicating the vision of life on Mars and a scope for eventual human settlement on the planet (Launius, 2003a). Although the collaboration between NASA and Hollywood began in 1990s, movies based on Mars were released long ago. Some of the movies that have created a huge social impact are: A Trip to Mars (1918), Flash Gordon’s Trip to Mars (1938), Flight to Mars (1951), Robinson Crusoe on Mars (1964), Total Recall (1990), We are One (2012), John Carter (2012), and The Martian (2015). While some movies have framed Mars as having a peaceful and advanced civilization (A Trip to Mars), some have shown that the civilization on Mars is evil and is destroying earth and its atmosphere (Flash Gordon’s Trip to Mars). Some movies have portrayed Martians to look like humans (A Flight to Mars) and share qualities like sympathy,

empathy, and helpfulness as humans do, some have incorporated the canals, polar ice-caps, thin atmosphere, redness of the planet found in scientific investigations of Mars to show how the planet might look like (Robinson Crusoe on Mars), some have focused on how an astronaut learns to grow food on Mars in order to survive when he is accidently left alone on the planet during a mission (The Martian). Many of these movies have framed Mars as having potential for supporting human life, making it easier for public to believe that living on Mars can be the future of humanity. Apart from that, frames of adventure, excitement, an advanced civilization on Mars, Martians invading earth, Martians being kind and helpful, and hardships in growing food on Mars were found in the movies.

3.11 Framing Space Exploration in the Media

The news media has played a key role in communicating the meaning and justifications of various space exploration events and phases of spaceflight in the US history. While sometimes media coverage has been positive and supportive of the frames introduced by NASA to support exploration, there have been various instances where media coverage has been critical of NASA and their frames. In those situations, the media attempted to reshape public opinions by questioning existing frames, suggesting new frames, arguing the merits and demerits of a program, and salvaging a given situation by introducing new frames. Media has been a voice of reason when it comes to space exploration.

For instance, Media coverage in response to NASA's new era of space transportation frame was very positive with the New York Times director, John Wilford

Noble echoing support for this frame with articles titled “Another Small Step for Man: Shuttling into Space” and “Commuting Age Dawns in Space” positively portraying the meaning of spaceflight as a new and different way of working in space by using the Space Shuttle and transforming space travel [3][4]. These frames were promoted among the public before the actual Space Shuttle missions were operational. The goal of these frames was to provide a meaning to the new Space Shuttle era, which it did. However, once the Space Shuttles were operational and flown a few times, business stakeholders became aware that the endeavor was not as profitable as it was portrayed earlier. The cost of manufacturing and operating the Shuttle was much more than the benefits gained from the work done by astronauts (Neal, 2007). Space Shuttle had also suffered various technical issues, delays, and became expensive over the course of 4 years. Business frame was no longer resonant among the various stakeholders of the spaceflight enterprise (Neal, 2007). Media also conveyed its doubts, uncertainty, and caution in response to this situation by sharing news stories about the technical problems, weather issues, and delays associated with the Space Shuttle operation, creating a realistic image of the status of spaceflight for the public (Neal, 2007).

Spaceflight missions between 1984 and 1985 were framed a little differently. A new theme of “humans to the rescue” was introduced from NASA and the media to describe astronauts in their spacesuits flying away from the Space Shuttle to repair satellites that were not working properly (Neal, 2007). The sophisticated tools and instruments carried by astronauts were also highlighted in the media and by NASA.

Using the frames of orbital freight, emphasis on tools, and humans to the rescue, media tried to salvage the situation of technical issues faced by the Shuttle (Neal, 2007). Frames of skepticism in response to Space Shuttle operation became apparent with article titled "Is the Shuttle Worth Rooting For?" [5] in the New York Times editorial. Although the editors appreciated the advancement in technology, they still believed that Space Shuttle needed to accomplish much more (Neal, 2007). NASA was also criticized for not using the Space Shuttle efficiently (Neal, 2007). With the constant news of delays, failures, and "Space Shuttle could do better" articles, there was a growing need for a new frame of reference that would provide a new meaning to spaceflight. The frames of orbital freight, and routine space transportation were not enough. Media then suggested a new frame of reference "robotic discovery" in the solar system as a replacement of the previous frames describing spaceflight. A New York Times article by John Noble Wilford focused on how robotic spaceflights had the power to stimulate the nation once again to support space exploration as they did during the Apollo era [6].

With several criticisms of the Space Shuttle program from the news media, NASA introduced a new frame of reference called "scientific knowledge" to construct a new meaning of spaceflight (Neal, 2007). In addition to Space Shuttle, proposal for building a space station was also introduced. NASA promoted this development with a new frame called "permanent presence" in space [7]. Media was not convinced of this new frame of reference and disagreed with the "scientific potential" of putting a space station in orbit (Neal, 2007). A New York Times article objected to this new frame and requested its cancellation (Neal, 2007). The main reasons for doing so were the increased

costs and purpose for creating a space station. Many scientists believed that robots and satellites were enough to collect important scientific data and creating a space station was of no significant use. Media in this scenario tried to provide a new meaning of spaceflight by portraying space station as a huge failure (Neal, 2007).

While Voyager 2 spacecraft was a great success, providing useful information about the physical features of Saturn in the form of images, Space Shuttle and Space Station were not proving to be as helpful as expected. Especially after the Space Shuttle Challenger tragedy, there was a greater need for a new frame to make sense of the spaceflight enterprise. Media in this case provided frames of sacrifice, courage, and heroism to the public [8]. Frame of exploration was introduced by the media after the 2003 Columbia accident to provide public with a new hope and meaning for the continued exploration of space.

CHAPTER 4
METHODS

4.1 Introduction

The goals of this dissertation are (1) To explore the frames in the science videos posted by NASA on YouTube to raise public awareness of space exploration (2) To examine public reaction to those videos in terms of tone and themes that have appeared in their interaction.

To achieve these goals frame analysis has been used to identify the frames that have appeared in the video transcripts and qualitative content analysis has been used to examine the comments posted by YouTube users in response to those videos.

4.2 Justifications

My decision to choose framing theory to identify various frames in the space exploration videos is inspired by a significant amount of research in climate change. Many climate change researchers have used frame-analysis to identify diverse frames in climate research communication to help raise awareness about the issue (T. A. Morton, Rabinovich, Marshall, & Bretschneider, 2011; Nisbet, 2012). These studies have helped climate science communicators to understand which frames and ideas are useful in educating people about the reality and relevance of climate change for the society. In addition, framing theory has also been used to explore different frames in understanding media coverage of space exploration. However, there are very few studies which have explored space exploration through frame-analysis on social media platforms (especially YouTube) to examine how science is framed for the public. Therefore, I have chosen

frame-analysis to explore the topic of space exploration on social media. Results from this study will be useful in identifying various frames used by science agencies to raise public awareness of space exploration on social media.

Qualitative content analysis has been used to examine YouTube user comments because it is a widely-used research method to investigate user reactions on social media platforms in information science, politics, journalism, and health research. Results from these studies have revealed trends in user-reaction to information posted on social media platforms, how users interact with each other on these platforms, difference in public reactions depending upon the platform and content, and recommendations for creating better videos to enhance public outreach of social issues. Therefore, I have employed qualitative content analysis to examine public reactions to space exploration videos posted by NASA. Results from this study will be useful in understanding how the public reacts to space exploration information on social media and how they interact with each other on the platform. It will also help science agencies such as NASA to assess the effect of their videos on public on YouTube. Qualitative content analysis is defined as "a research method for subjective interpretation of the content of text data through the systematic classification process of coding and identifying themes or patterns"(Hsieh & Shannon, 2005). Patton (2002) defines qualitative content analysis as "any qualitative data reduction and sense making effort that takes a volume of qualitative material and attempts to identify core consistencies and meanings".

I have chosen to explore YouTube in my dissertation because it is one of the most popular social media platforms and the second largest website in the world. It is also the

most viewed video platform with 400 hours of video uploaded to it each minute and one billion hours of videos watched every day as of July, 2017. YouTube allows users to create an account, post videos and comments, watch videos, create channel and playlists, like, dislike, share, and subscribe to the various channels present on the website. Most services on YouTube are available for free which adds to its popularity. It has over a billion users and is one of the most popular social media platforms used by space exploration agencies such as NASA. The NASA channel on YouTube has over a million subscribers and the channel hosts over 4000 videos on various space exploration events. The NASA/JPL channel on YouTube has over 200,000 subscribers and it hosts over 700 videos capturing several space exploration events. Some of the most viewed videos on NASA/JPL YouTube channel on the MSL mission are: Curiosity has landed with 1,036,990 views; Seven minutes of terror- The Challenges of getting to Mars with 2, 589,131 views; First Rover Report on 10th August, 2012 with 297, 059 views; and Curiosity's Descent with 3, 893, 084 views. These views indicate popularity of the mission as well as public interest in watching videos that depict the rover in action. Another reason to choose YouTube in my dissertation was the lack of studies exploring public reaction to Mars Rover mission on social media platforms.

I have chosen to explore NASA in my dissertation because it is the world leader in space research and exploration. Established in 1958, NASA is the hub of cutting edge space research. It holds the record for world's most space exploration efforts. Some of its major manned missions are: Project Mercury; Project Gemini; Project Apollo; Skylab; Space Shuttle Program; and International Space Station. Some of its notable unmanned

missions are: Voyager Program; Mars Science Laboratory; Cassini Huygens Mission; and New Horizons. NASA's future space goals include: Project Orion (2020s-2030s) – Manned missions to an asteroid and Mars; James Webb Telescope (2018) – To study the history of universe; and Titan Saturn System Mission (2018) -Exploration of Saturn's Moons Titan and Enceladus. The Mars Science Laboratory (MSL) mission was launched by NASA to investigate the habitability of the Red planet. Known for its engaging social media presence, NASA has set an example for federal agencies all over the country to utilize the power of social media for public outreach. Its dynamic presence on several social media platforms such as Twitter, Facebook, YouTube, Tumblr, Instagram, and Reddit has enhanced its popularity among public. NASA's first tweet after Curiosity Landing – I am safely on the surface of Mars. GALE CRATER I AM IN YOU!!! #MSL was retweeted 70,000 times. NASA has also won two consecutive Shorty Awards in 2012 and 2013 for its outstanding contribution towards sharing scientific information with the public (Best Government Use of Social Media).

I was particularly interested in exploring public reactions to space exploration mission because advances in space technology create a lot of excitement among the masses. Especially an effort such as Mars Exploration which is extremely fascinating as well as challenging to accomplish draws a lot of media and public attention. Although the literature on space exploration suggests that public knowledge and support of space exploration is low (especially when it comes to funding), the popularity of Curiosity Rover mission on social media told a different story. According to a CNN news report

(Mendoza & CNN, 2012), Curiosity landing inspired a sense of "awe" and "wonder" among people. Following are some of the social media statistics from the news report: The total number of followers for the Curiosity Twitter account called @MarsCuriosity by NASA/JPL increased from 150,000 followers prior to the landing to 818,000 followers after the landing. The Twitter account kept receiving 1000 new followers every hour during the next few weeks after landing. The subscribers on Facebook increased from 30,000 to 200,000 members. Hyperlinks, tweets and images containing "Mars" were searched over 700,000 times on the Internet. CNN's article on Curiosity landing was shared 26,000 times on social media with over 4,900 user comments. A few scientists associated with the mission became "Internet Sensation" with some of them receiving thousands of followers on Twitter. A mashup video called "Call me maybe" featuring the launch and testing of the rover at JPL, animations of the entry, descent, and landing of the rover received over 85,000 views on YouTube. The video was a parody of the original song "Call me maybe" by a Canadian singer Carley Rae Jepsen symbolizing how challenging it was for the rover to successfully land on Mars and that NASA scientists were eagerly waiting for the rover to call back on earth to resume communications and begin experiments. Curiosity Rover mission has been a scientific marvel and an extremely popular social media phenomenon. I chose to explore public reactions to this mission in order to understand the role of social media in raising awareness about space exploration among public.

4.3 Phase 1: Frame Analysis

Video transcripts were downloaded from NASA/JPL's YouTube channel to begin frame analysis. The analysis of frames in YouTube video transcripts occurred in various steps. The first step was identification of key terms and concepts that indicated a frame (Hertog & Mcleod, 2001). They furthermore stated that a frame can be identified by the presence of "master narrative", individuals in a story and focus on specific topics. The second level of analysis involved a closer inspection of video transcripts for key phrases, tones, and representation of information in the form of images or video. The repetition of specific "adjectives, adverbs, verb tenses, and nouns" indicate a frame (Hertog & Mcleod, 2001). Narrative, tone, and representation of information combined provides a perspective, frame, or lens through which public views an issue. A co-coder and I have used these criteria to identify and describe the frames used in the representation of Mars rover mission on YouTube. The video transcripts were analyzed using a codebook which included details about the videos such as date of publication, introduction of scientists, their designation, type of information shared (images, slides, texts, animations, charts), main topic discussed in the video as well as secondary topics. Most frequent frames were identified using the open coding method (Creswell, 2013). Each transcript was read once to identify the broad topics discussed in the videos and later a constant comparison technique (Creswell, 2013) was used to perform closer inspection to gather similar topics in one category which led to "themes" or "frames". After coding each transcript, all the themes were compared once again to identify similarities and deviations. Similar topics were once again grouped in an overarching frame. A co-coder coded 10% of the

transcripts to ensure validity and consensus between primary coder and co-coder was reached. Holsti's simple agreement ranged between 94% and 100% between each variable: date of publication (100%), introduction of scientists (100%), designation (100%); type of information shared (98%), main topic discussed in the video (94%), frames (95.6%), and tone (96%). Scott's pi ranged from 0.95 and 1 for each variable: date of publication (1.0), introduction of scientists (1.0), designation (1.0), type of information shared (0.97), main topic discussed in the video (0.96), frame (0.95), tone (0.96).

4.4 Phase 2: Comment Analysis

4.4.1 Selection of Videos

The initial search on YouTube with keywords "Curiosity Rover" returned 622,000 results which included videos created and posted by several users of YouTube who are not NASA officials. However, since the goals of this study are to explore public opinion about science information shared by national science agency, only videos posted by JPL were used in this study. Jet Propulsion Laboratory (JPL) is a federally funded organization associated with NASA and is responsible for the creation and operation of robotic spacecraft and space missions including Mars Science Laboratory (Curiosity rover). I have chosen the videos posted by JPL because they are actively involved with the Mars Rover project and have posted the most number of videos (621) on their YouTube channel called NASA Jet Propulsion Laboratory. Out of 621 videos, a total of 86 videos were found on the topic of Curiosity Rover which involved topics such as building Curiosity, Curiosity on Demand, Mars Science Laboratory, and Curiosity Rover Reports. The search for videos was further refined to include videos which focused solely

on Curiosity Rover Updates provided by JPL scientists which resulted in 43 videos between 10th August 2012 and 15 December 2015. All the videos are downloaded and stored for future reference. A list of videos and their respective links is added in the Appendix section.

4.4.2 Selection of Comments

All the comments associated with each of the 43 videos were downloaded and stored in a Microsoft Excel file. The total number of comments were 5393 out of which 138 comments were removed due to factors such as comments in a different language other than English, comments that only included an emoticon, comments that only included numbers or a single digit, and comments that were spam. Example:This resulted in a total of 5255 comments.

4.4.3 Comment Sample

A systematic sampling procedure was used to derive a comment sample out of the total number of comments (5255) for analysis. Yamane's (1967) formula for sample size computation was used to determine the number of comments to be used for analysis. According to the formula,

$$n = N/\ 1+ N\ (e)^2$$

where n = sample size, N = total number of comments and e = level of precision (in this case 95% confidence interval was assumed). After putting the values of N and e in the equation, the result was $n = 371.7 \approx 372$. (Minimum number of comments to be sampled out of total N =5255)

$$n = 5255/1+ 5255\ (0.05)^2 = 371.70$$

Since there were 43 videos in the video sample and at least 372 comments were required to build the sample dataset, a minimum of 9 comments were collected from each video, which resulted in a total sample of n=387 comments i.e. (43 * 9 = 387). Systematic sampling procedure involves selection of elements from a larger dataset at regular intervals with a random starting point. The interval is calculated by dividing total population by sample size. Therefore, in this case, the interval I is calculated by dividing total number of comments by sample size i.e. I = N/n = 5255/387 = 13.57≈ 14. As a result, each comment was chosen at a fixed interval of 14. An online random number generator program was used to calculate the random starting point of comments associated with each video. A list of comment sample is attached in the Appendix section. All the comments are stored in a Microsoft Excel file for future reference. NViVo 11 was used to analyze all the comments in this study. Each comment was categorized into Individual, Parent, or Child Comment category. Individual comments were messages posted directly in response to videos. Parent comments attracted additional comments from other commenters and child comments were the additional comments. Each of these categories were further divided into type of comments (statements, words or phrases, statements and questions, questions), tone of comments (positive, negative, neutral, sarcastic, humorous, debate), topics discussed (Mars, Mars Exploration, NASA, NASA Scientists, Other) and so on. Each of the comment was read once and categorized into its suitable theme. A co-coder coded 10% of the comments to ensure validity. Holsti's simple agreement ranged between 93% and 100% between each variable: Individual, Parent or Child Comment (98%), topic discussed (93%), tone (94%);

relation with the video (93%). Scott's pi ranged from 0.93 and 1 for each variable: Individual, Parent, Child Comment (1.0), topic discussed (0.96), tone (1.0), relation with the video (0.93).

CHAPTER 5
ANALYSIS AND RESULTS

The goals of this study are to identify how space exploration is framed on social media and to examine public reaction to such videos.

5.1 Research Question 1

What frames appear on YouTube in NASA's coverage of Curiosity Rover Mission?

This study examined 43 YouTube video transcripts on Mars Science Laboratory Misison published by NASA/JPL from 10th August, 2012 through 15th December, 2015. All video transcripts were coded and none was discarded. There were 860 references from 43 videos in total. Frame-analysis revealed 7 major frames in the YouTube coverage of the Curiosity Rover Reports. They are: "Science Experiments (33.72%)"; "Curiosity Rover (21.62%)"; "Findings (15.58%)"; "Mars (8.83%)"; "Science Team (6.62%)"; "Success (6.04%)"; and "Communication and Engagement with Public (2.79%)". Although these frames did not appear in a particular order in the data, the percentages here denote their frequency of appearance in the video transcripts. Each frame served a different purpose and highlighted various aspects of the mission. Some frames focused on rover activities, some focused on the science team who was constantly working throughout the mission, and some focused on humanizing the experience of the mission for public. In the following paragraphs, I provide the meaning and a detailed analysis of each frame's appearance in the video transcripts.

5.1.1 Science Experiments

This frame emphasized the scientific investigation aspect of the mission. It was characterized by informing public about the hypothesis, detailed explanation of science experiments, reasons and clarifications for performing those experiments, discussion of future experiments, critical aspects of the mission, maintaining safety of the sample, process of analyzing the results, testing, exploration, use of scientific terminologies/names of instruments and how they function as well as the challenges, dangers, and failures experienced during the mission. "Scientific Experiments" was the most frequent frame with major emphasis on describing the ongoing, already accomplished, and future experiments of the mission.

The focus of this frame was science and exploration. This emphasis was created by using specific science terminologies, words, phrases, and description of scientific processes to collect data, perform experiments, analyze results, test, and explore Mars. For instance, "*our hypothesis is*", "*we are trying to discover*"; "*engineers performed mobility tests*"; "*we then scooped up the soil and analyzed it if our X-ray diffraction instrument that can identify minerals in the soil based on their unique crystal structure*"; "*we use MAHLI, our hand lens imager to take close up views of the soil to look at different particle sizes, shapes, and colors, and how they change with depth*"; *Curiosity has been continuing the analysis of the John Klein area where it drilled into rock and acquired its first sample of rock powder*"; "*In preparation for drilling we did some testing here in the Mars yard to understand how changing some of our drill parameters could help us be more effective at drilling softer and more breakable rocks like the ones*

we see at the Pahrump Hills". Statements and phrases such as these indicated the scientific procedure followed by scientists to arrive at conclusions based on experiments, analysis, and interpretations of data. It indicated what scientists were trying to investigate and how they were doing so using several tools on the rover.

While some of the experiments and sites were pre-planned by NASA scientists, a significant number of experiments and locations were decided once the rover was on Mars and was able to perform some preliminary tests of the rock, soil and atmospheric samples. This contributed to the exploration aspect of the mission where scientists planned a series of new experiments and locations based on the rover data. Therefore, many references in the videos indicate how scientists were exploring Martian surface. For example: *"Exploring the foothills of Mount Sharp is like turning a history book page by page as we look at each layer we want to know what formed and deposited these layers and how are they related to each other. We also want to understand the potential for organic preservation in each of these layers"; "We began the Rocknest campaign by searching for suitable drift of sandy soil using our MastCam color cameras. We used our ChemCham laser and our APXS chemical sensor to do an initial technical analysis of the soil, determining whether it was similar to soils that we understand from Spirit and Opportunity and therefore safe for scooping and sending to our laboratories."*

There was a heavy use of technical and scientific terminologies to describe science instruments, maneuvers, and experiments performed by the rover. For instance, "*Wheel Scuff Maneuver*"; *"Internal Sandblasting"; "Foreign Object Debris" (FOD); "Tunable Laser Spectrometer"; "Autonomous Navigation"; "X-ray diffraction";*

"Radiation Assessment Detector" (RAD) and many more. Despite the rover containing highly sophisticated scientific tools, many images, maps, simulations, animations, and in-person demonstrations were used in the videos to make the content easy to understand for the lay public.

The greatest number of references in the "Scientific Experiments" frame referred to the ongoing, already accomplished, and future tasks to be performed by the rover. The science team performed a series of health check-ups to ensure that the rover was ready to work after its successful landing. When the rover was ready, it was directed to perform a series of simple tasks such as taking pictures of itself "selfie" and of the Martian surface. It was scheduled to perform much more complex experiments later in the mission. Some of the future experiments depended on the results of the ongoing tasks. Some examples of the already accomplished, ongoing and future experiments are as follows: *"We first deployed the high gain antenna to facilitate communications back to earth so that we can communicate with Curiosity much more efficiently"; "We are giving rover the capability to do sampling portion of the mission as well as being able to drive more efficiently to different targets on the surface"; "So coming up, we're going to give the rover a brain transplant. We are wiping away all of the cruise and entry, descent and landing software and making room for the software needed to perform the exciting portions of the surface mission ahead".* All the references presented here are from the first video published on YouTube to update public about the work of the rover on 10th Aug, 2012. By describing the various tasks that were already completed, ongoing and plans about the future, the

videos indicated that the rover was ready for Mars exploration soon after it landed on the Red planet.

While a majority of the references in this frame belonged to description of scientific experiments being performed on Mars, a significant number were dedicated to explain the reasons and clarifications behind conducting those experiments. These clarifications and explanations along with simulations and images were important to understand the processing of samples, sophistication of tools, and learning outcomes of the experiments. Some of the examples in this frame are: "*We did some internal sandblasting by vibrating the sample at different orientations on the turret in order to remove any internal contamination"; "ChemCam is actually two instruments in one. It includes a camera with telephoto lens and it also has a laser that vaporizes a very small amount of rock so we can tell what its chemical composition is"; "This helps geologists understand how the rock formed and how it's related to other rocks we've studied so far on Mars"*.

In addition to explaining the reasons and clarifications behind the experiments, scientists also took time to highlight some of the interesting, important, and critical events during the mission.

For instance, some of the quotes in this category were: "*A few sols ago we completed an interesting campaign where we actually acquired images of the Martian moons, Phobos and Deimos, transiting across the sun";* "*The Morse Code spells out 'J-P-L', but in reality, it's a very important way for us to measure how far we are driving each day*"; *"Earlier this week we had a major success when we deployed the arm for the*

first time on Mars. This is critical to ensuring that we can get sample into our instruments and use the arm for its scientific purposes".

The team and the rover also faced a few challenges and problems during the mission. The videos highlighted the issues encountered by the rover and how scientists were trying to discern the issue and find solutions to the problem. For instance, some of the quotes that discussed the problems rover and the team were facing are: *"Sharp embedded rocks on the surface of Mars are really giving trouble to our wheels"; "We noticed that the wheels are taking much more damage than we had expected"; "This is where the sun positions itself between the Earth and Mars, and it's going to interrupt our ability to communicate with Curiosity for upwards of two weeks*". Quotes that explained how scientists dealt with the technical issues are: "*One of the other things we've done here at the Mars yard to understand the wheel wear issue is we built a half of a rover that we're driving over the simulated terrain so we can watch how wheels really wear. We think we have got new techniques to be able to drive the rover safely and identify some safe paths*".

5.1.2 Curiosity Rover

This frame focused on several aspects of the rover during the mission. It was characterized by informing the public about the movement of the rover through various locations on the Martian surface, its extraordinary capabilities of performing several complicated science experiments, its character as a "robotic avatar" sent from earth to the surface of Mars for exploration. "Curiosity Rover" was the second most frequent frame which emerged from the dataset with major emphasis on describing the rover's potential

of performing complex experiments such as drilling Martian rocks, soil sample analysis, and taking pictures of the Martian surface as well as analysis of the samples collected during the mission.

The video transcripts reveal a huge emphasis on discussing rover capabilities by describing the function of each scientific instrument on the rover and how it was used to explore various geological features, rock, soil, and air samples and provide results of those analysis. For instance, "*The CheMin instrument uses X-rays in order to image the sample and determine what minerals make it up"; "ChemCam is actually two instruments in one. It includes a camera with telephoto lens and it also has a laser that vaporizes a very small amount of rock so we can tell what its chemic composition is"; One the way to Mars, Curiosity's Radiation Assessment Detector or (RAD) measured the high-energy radiation from within the capsule that enclosed the rover".* The focus on various instruments of the rover indicated the variety of tasks Curiosity was designed to perform. One of the highlights of the rover was its ability to take panoramic pictures of the Martian surface as well as create a "self-portrait" or "selfie". Images sent back from the rover were extremely useful for the science team at NASA to plan future locations of experiments, calculation of the safest path for Curiosity to follow in order to reach those sites, and it also provided an idea about what to expect ahead in the journey in terms of geological features. The ability of Curiosity to date a rock meant that the astronauts no longer had to bring back Mars sample to Earth for analysis, which indicates a major advancement in rover technology and cost effectiveness because it eliminates the need for Mars sample return missions.

YouTube portrayal of MSL mission paints “Curiosity” as the hero, “robotic avatar”, “robotic photographer” on Mars set to explore the planet with its powerful tools. Words used to describe Curiosity, its movement and accomplishments were “fantastic”; “exciting”; “wonderful”; “amazing”; “exhilarating”; “momentous”; “busily exploring”; “versatile”, “trailblazing”. These words were used to characterize its personality and indicate its remarkable activities and potential. The journey with Curiosity to explore Mars was framed as an “adventure”. Curiosity was sometimes framed as a human to explain the meaning of its activities and to make it relatable for the public. For instance, words, phrases, and descriptions such as “*belly*”; “*Curiosity’s health”; “this is Curiosity’s version of kicking up dirt with your hiking boots*”; *“Curiosity is our robotic avatar on Mars, and as such she uses her instruments in much the same way we would use our eyes and our hands during a walkabout*” were used to show that it was just like a human being with a body, whose health was an important concern, and who sometimes behaved just like humans do. On other occasions, it was framed as a robot with its exceptional tools ready to take on the challenges of exploration. For instance, “*Once the New Year approached, Curiosity was ready to spin her wheels and stretch her arms*”; “*But now that we have a fantastic rover, a great set of tools and fully functional scientific payload. So, let’s get on exploring*”.

A significant amount of attention was given to Curiosity’s movement across the Martian surface. This was achieved by mentioning its whereabouts, its movement through various locations on Mars, distance covered to reach destinations, and how Curiosity analyzed its path based on images taken by its cameras and calculated safe

routes to arrive at the required sites. For example: "*Curiosity is now roving through the Bagnold dune field on lower Mount Sharp"; "In our first Martian year, we have driven almost eight kilometers of total distance with the rover"; "The drive lasted about 10 meters and you can see in the animation that she turned her camera this way and that to look at what's ahead of her. And you can also see, she didn't go in a straight line. She actually curved a little bit to the right to avoid some of the small rocks that were directly in front of her*".

5.1.3 Findings

As the name suggests, this frame focused on proving information about the findings of science experiments being performed on Mars by the rover. It was characterized by the presence of goals of the mission, information regarding signs of habitable environment, organic carbon, signs of ancient rivers and lakes, composition of the Martian soil and atmosphere and similarities with earth. Findings were shared using various representations of data such as charts, figures, and diagrams. This was the third most frequent frame that emerged from the data which heavily focused on core findings related to Martian surface and atmosphere during the mission.

The goal of Curiosity Rover mission was to explore Mars for signs of habitable environment. The video updates contained an extensive amount of information regarding the results of experiments performed on Mars in search of those signs. Scientists at NASA took time to share these findings, explain the meaning and implications of those findings using images, charts, simulations, and animations, provide interpretation of data gathered by the rover, and specified interesting, unusual, and unexpected results.

5.1.3.1 General Findings

"With our QMS, SAM is able to detect the most dominant gas in the Martian atmosphere, carbon dioxide"

****

"The images returned by Curiosity show a diverse collection of interesting features, including sedimentary rocks, pebbles, cracks, nodules, and veins. The vein features are seen as a bright white material, and we see them just about everywhere we look in Yellow Knife Bay. The ChemCam instrument has found that these veins contain elevated levels of Calcium Sulfate, likely in the form of Bassanite or Gypsum"

5.1.3.2 Unusual, Interesting, Cool, and Exciting Findings

"*As we climbed the hill, Curiosity's ChemCam laser spectrometer noticed unusually high amount of silica in nearby rocks"*

****

"The surprising thing is that when we looked at the pebbles closely, we discovered that many of them were quite well-rounded"

****

"*We also received these color beautiful high resolution images. They show clearly the back shell, the site where the descent stage crashed, and also very cool, you can clearly see the rover tracks in these images"*

****

"So, this is really exciting news for the science team because this is the first time we are seeing gravel transported by water on the surface of Mars"

5.1.3.3 Similarities and Differences with Earth

"The CheMin data provide us with distinctive signatures of the minerals: plagioclase feldspar, pyroxenes and olivine. Peridot is a variety of olivine; just keep in mind that the olivine in the soil sample is much smaller than these crystals. Roughly half of the soil consists of poorly crystalline material, such as volcanic glass. Thus, this Martian soil appears very similar to some weathered basaltic soils that we see on Earth, in places like the flanks of Mauna Kea, Hawaii."

****

"Gypsum veins are also seen here on Earth and associated with water percolating through cracks and fractured rocks"

****

"SAM found that the mix of Argon at Mars today is heavier than in the Earth's atmosphere, the sun, and in Jupiter. These measurements are evidence that Mars once had a thicker atmosphere, and much of it was lost long ago. That would help explain the evidence for rivers and lakes in the past, in spite of the cold and dry conditions today"

5.1.3.4 Signs of Habitable Environment

"As we learned how to explore with Curiosity, we discovered that the rocks that we have drilled are actually part of much thicker packages, much longer-lived intervals of geologic time.

And so, we have a long-lived habitable environment that's actually younger than what we may have expected when we first came to Gale Crater. And this means that other similar places on Mars, that are also relatively young, that have such clay bearing rocks, could've also been habitable".

****

"We found a lake bed on Mars that we drilled into and found the ingredients and conditions that could've supported microbial life, if life ever was on Mars"

****

The first year was spent traversing through ancient stream beds and exploring Yellowknife Bay, the site of an ancient lake. That's where Curiosity drilled samples from the lake floor to reveal mineral evidence of long-lived, fresh water. So if life ever were present on Mars, a site like Yellowknife Bay could sustain it"

****

"When we combine what we've learned from our remote sensing and contact science instruments with the data that's coming in from CheMin and SAM, we get a picture of an ancient watery environment, which would have been habitable had life been present in it"

5.1.3.5 Image Data Interpretation

Images, simulations, and animations played a vital role in conveying information about Mars exploration to the public. Some of the activities for which images and simulations were used are:

Assessment of success in the scooping and sample processing activities, creation of a three-dimensional model of the target areas, x-ray diffraction results for mineral composition of the rocks, to determine presence of dust devils on the Martian surface, to take pictures of the rover (selfie), panoramic images of the exploration sites, to visually identify how much sample has been collected, to understand and view the drilled samples and their corresponding results, to view the beauty of the Martian surface, to identify geology of the surrounding areas, to identify safe routes to reach interesting locations for exploration, to view the process and location of Curiosity landing, to view the transition of two Martian moons, Phobos and Deimos, and to view pictures of locations which have never been seen before on Mars. "*The diffraction signals appear on the detector as rings that represent the fingerprint of the individual minerals. The rings tell us not only what minerals are present in the soil but also how abundant they are."*

5.1.4 Mars

The "Mars" frame highlighted the Red planet from various perspectives such as its atmosphere, beauty, its surface, description of various geologic features on Mars such as its sand dunes, trails, valleys, rivers, lakes, and mountains, its exploration history and most importantly by naming various Martian target points for experiments and exploration. The rover moved to various locations on Mars based on what scientists

believed were the most promising and interesting points for exploration. Each location was therefore named and mapped so that Curiosity can drive from one site to the next and conduct experiments. Figure 3 below represents the first X-ray view of Martian soil.

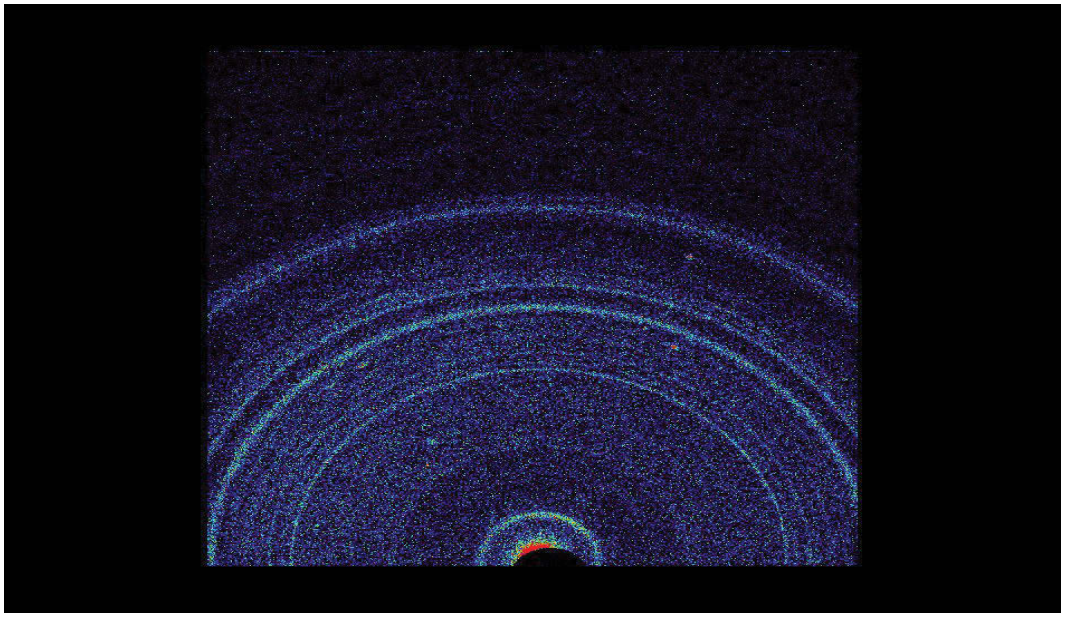

Figure 3: First X-ray View of Martian Soil. Courtesy: NASA/JPL

Mars atmosphere was framed as "dusty" and "windy" and its surface as "beautiful", "amazing", "pretty", "never seen before", "rocky", "challenging" and as a place for future human exploration. Mars was framed as an ancient planet with rich history, an ideal place for exploration and potential human colonization. Exploration on Mars was framed as "turning a history book page by page". Scientists also shared Martian exploration history by NASA to provide a background and educate public about

how each mission has contributed to more knowledge and understanding about the planet. For instance:

"Fifty years ago, Mariner 4 became the first spacecraft to take close-up pictures of Mars. Thirty-nine years ago, Viking 1 Lander became the first spacecraft to successfully land on the Red planet. And now Curiosity celebrates 3 years on Mars – operating well over a thousand Martian days."

The most important aspect in framing Mars was mapping of various sites and their names. These locations were called target areas where Curiosity was programmed to visit. Each location was named after a renowned scientist, author, places and geological features on earth, most likely to create a sense of familiarity among public. Some of the sites were also named to commemorate NASA scientists who had worked on the Curiosity Rover project but passed away soon after it's landing. The naming of locations helped scientists track Curiosity's movement and understand how much distance it had covered. Some of the names of target areas are: Mount Sharp, John Klein, Jake Matijevic, Yellow Knife Bay, Snake River, Rocknest, Grandma's House, Bell Island, Gale Crater, Glenelg, Bagnold Dune, Marias Pass, Logan Pass, Pahrump Hills, Lewis and Clark Trail, Kimberley, Moonlight Valley, and so on. According to Dittmer (2007), "the power to map and name is key to colonization". He argued that the act of "naming and mapping" Martian locations is an act of exerting political power by NASA. In addition, the images gathered during the mission also helped NASA and media to frame Mars as "a stage of human action". Figure 4 below represents the path traversed by Curiosity.

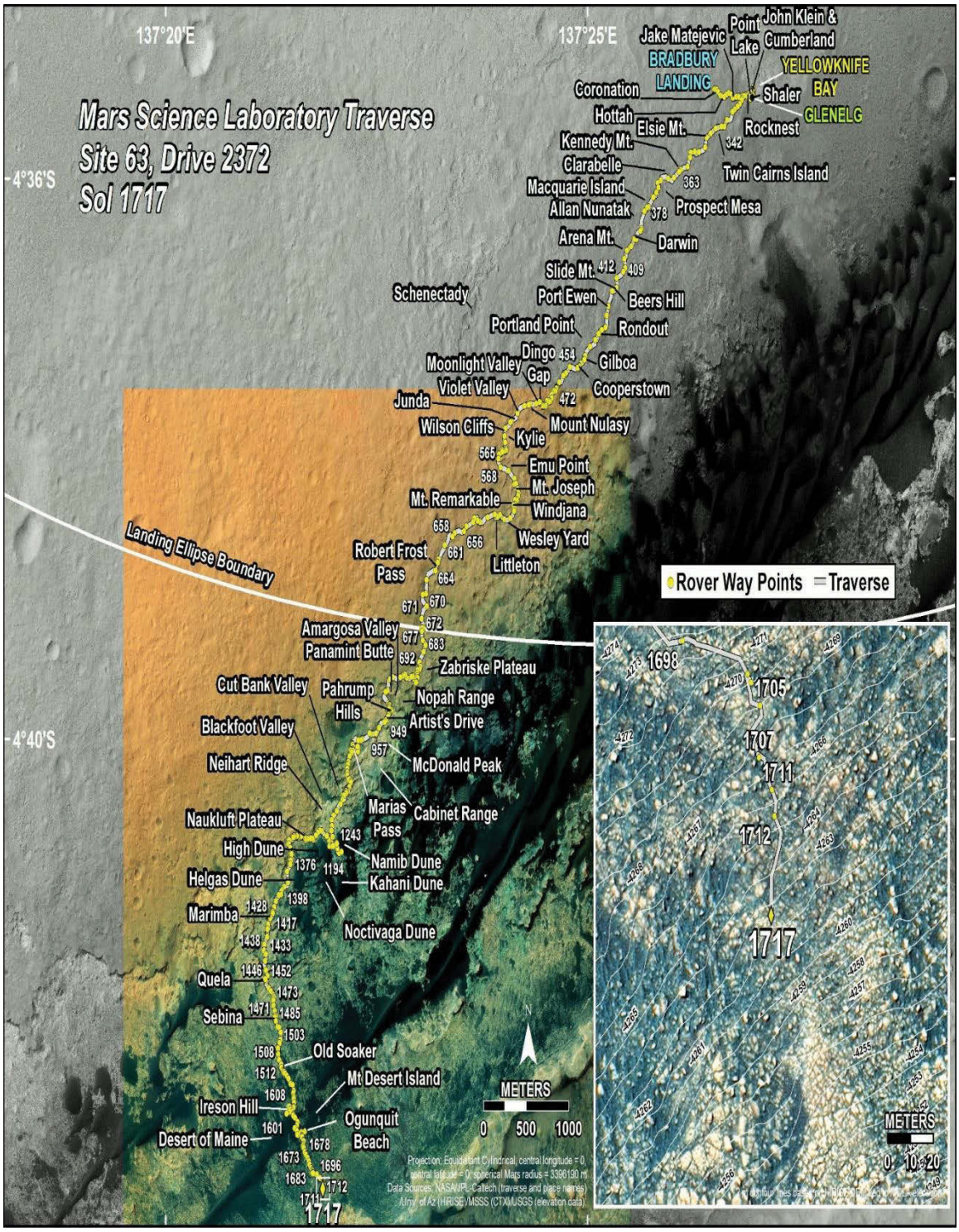

Figure 4: Path Traversed by Curiosity. Courtesy: NASA/JPL

5.1.5 Science Team

This frame featured "science team" as one of the most indispensable aspects of the mission. It was characterized by members of the MSL team themselves presenting the rover updates on YouTube, providing information about their role during the mission, discussing how scientists were making observations based on data provided by the rover, their speculations, guesses, expectations, goals, what they were exploring, what they will learn from the experiments, what they considered were important and critical events and findings, how they were using different instruments on the rover, how they handled safety of samples and rover, and appreciating work done by other members of the team during the mission.

Neal (2007) mentioned that space shuttle missions allowed scientists on the ground to collaborate with astronauts in space on various science research areas. She furthermore states that this step was extremely popular among scientists as it reduced the gap between scientists and astronauts and it also "opened" space to many researchers. Similarly, it has become much easier to interact with the scientists on a one-on-one basis with the advent of social media platforms such as Twitter, Facebook, YouTube, and various Science Blogs. NASA leveraged this situation by making the mission more relatable, engaging, and personal by letting MSL scientists present the updates of the mission on YouTube. In each update, scientists introduced themselves stating their name and designation at NASA, and how they were involved in the MSL project. This step allowed NASA to put a human face to the mission and bridge the gap between public and scientists. Out of 43 videos, 42 had NASA scientists as speakers except one which was a

silent video with images. More men (18) than women (14) were speakers in the video updates.

Scientists shared their fascination, excitement, expectations, goals, important findings, and use of rover instruments in the video updates. This was achieved by statements such as: "*The science team has been fascinated by all the signs of ancient water at Mount Sharp. It's likely that Gale Crater once hosted many rivers and lakes, carrying sediment to the crater floor that now forms the bottom layer of Mount Sharp"; "Scientists are going through the data at this point and I'm very excited because since Viking mission, we haven't had any instruments on Mars that can tell what is the composition of the Martian atmosphere".* The word "we" and phrases such as "the team" and "science team" have been used frequently to show how the group of NASA scientists were engaged in the process of Curiosity rover exploration and that it was a collective effort. Although most of the updates were focused on how scientists used the rover to conduct several experiments, they also shared what they were trying to understand through those experiments. For instance, "*We want to understand how sands of different grain sizes may have different mineralogy and chemistries"; "we also want to understand the potential for organic preservation in each of these layers".* Scientists talked about their expectations about results from exploration. For instance, "*We were able to estimate that we collected about 14 cubic centimeters of sample, or about a tablespoon, and this matched our expectations of what we would see in the scoop when we got to this point."*

Scientists expressed their enthusiasm and happiness towards exploration of Mars with statements such as: "*we'll look forward to some exciting first time drilling activities"; we're happy to report that Curiosity is healthy and clicking off all the activities that we asked her to perform for the first few days on the surface."* They also shared their speculations, observations, and guesses based on evidence with the audience. For instance: "*Looking carefully at images, the team noticed a bright object lying on the ground just in front of the rover. We typically call something like this FOD, Foreign Object Debris. The ChemCam remote micro-imager captured a high-resolution image of the object showing that it's most likely a benign piece of plastic or shrink tube left over from a terminated wire. This could've possibly come from the rover or from the descent stage separation event during landing"; "Our best guess at what's going on is that Curiosity is seeing dust devils go right over it. So, what we think is happening is that the same sorts of vortexes, driven by convection are occurring on Mars at Curiosity's site but just not picking up dust".* Most importantly, scientists appreciated each other's work and mentioned that the mission would have been impossible without the dedicated efforts of all their colleagues. "*None of this would be possible without the dedicated team of rover engineers here at JPL".* Congratulatory messages were also shared on YouTube by scientists towards their team highlighting the great feat of Curiosity rover exploration. For instance: "*So congratulations to the team and happy anniversary to Curiosity. Let's keep on going!"*

5.1.6 Success

This frame highlighted the numerous accomplishments, milestones, significant discoveries, and many first-time activities that were conducted on the surface of Mars. This can be considered as an extension of the "Findings" frame which also discussed the results obtained from the experiments performed on Mars. However, since Curiosity was a much heavier, sophisticated, and expensive rover than the previous ones, and given the history of Mars exploration where two-thirds of the spacecraft have been unsuccessful, it was a huge achievement for the science team that Curiosity was "healthy" after its landing and could perform all the experiments it was designed to do successfully.

Major emphasis was provided to the several first time activities being performed on Mars. This was accomplished by using phrases such as "*we will make our first attempt"; "we'll be looking for our first rock to drill"; or "this week ChemCam did its very first depth profile".* Many other activities such as the first X-ray diffraction results from soil sample analysis, first scientific use of all the instruments in the rover, first analysis of sample in CheMin and SAM instruments, first movement of Curiosity's wheels on Mars, first atmospheric experiment, first audio file played from Mars by NASA administrator Charlie Bolden congratulating the team and first pop song titled "Reach for the stars" by will.i.am beamed from Mars to inspire kids, were mentioned during the video updates. The video updates suggested that Curiosity with its powerful tools provided scientists an ability to conduct various kinds of experiments that were not possible with previous rovers on the planet.

NASA scientists also shared information about their successful experiments by using words and phrases such as “significant milestone”, “major milestone”, “success”, “incredible success”. For instance, “*After several weeks of being stationary at the Rocknest site we began driving again on Sol 100. This marked a significant milestone on the mission as we reached about a half a kilometer of total driving distance on the surface of Mars”; “All in all, these few tablespoons of powder from a Martian rock have provided the Curiosity science team with an exciting new data set that tells us that Gale Crater, and perhaps all of Mars, contained habitable environments. This is an incredible success for the Curiosity mission to Gale, and the science team is looking forward to digging deeper into Mars' ancient watery past in the weeks, months, and years ahead”.* Other activities which were successful involved Curiosity reaching 5 Kilometers mark, first soil sample and rock powder analysis, and first successful deployment of robotic arm.

5.1.7 Communication and Engagement with Public

This frame emphasized on connecting with the audiences emotionally, engaging them and communicating with them directly through the videos. It was characterized by members of the science team answering some of the most frequently asked questions by public, using humor during the presentation, sharing pictures and videos of their family, showing video clips of kids visiting NASA to learn about Curiosity and its experiments, playing music from Mars, sharing personal stories and setting the public expectation about the mission.

YouTube provided a great platform for scientists to not only share the technical details of the mission but also to engage with the public at a personal level. One video update was entirely dedicated to answering some of the most frequently asked questions on Curiosity rover cameras by the public. For instance, how many cameras are on the rover, why some cameras take black and white images and some take color pictures, resolution of the cameras, whether Curiosity can make videos, how does Curiosity take pictures of Martian surface, and how does Curiosity click a "selfie". A scientist from the engineering camera team provided an in-depth information to all the questions mentioned above. The responses were technical in nature focusing more on explaining the science behind Curiosity's cameras. Humor was also used during presentation to connect with the public and to silence any misconceptions about aliens on Mars. For instance, "*The ChemCam unit or chemistry and camera instrument fired the laser for the first time on Mars using the beam from the science instrument to interrogate a fist-sized rock called Coronation. We promised no Martians were injured in this experiment".* Scientists also shared pictures of their family members visiting NASA and going out in Los Angeles to take some well-deserved time off from the mission. The emphasis was to show how scientists and public are not that different and that they also live regular lives just as public. Video clips of children visiting NASA and the beaming of pop song "Reach for the stars" was meant to inspire kids about the "awesomeness" of NASA and science. One scientist also became famous because of his Mohawk hairstyle. He garnered thousands of Twitter followers overnight because of his hairstyle and became an Internet sensation, indicating that scientists can also be "cool". Most importantly, NASA scientists took time

to set the public expectation about Mars exploration as realistic as possible. They offered no specific promises, guarantees, or raise unrealistic hopes among public without evidence. The information shared by scientists was "accurate" yet the language and tone of the statements conveyed some uncertainty about the findings of the exploration. It was implied that science exploration comes with no guarantees and requires a lot of time.

For instance, *"Finally, it's worth remembering that the big questions in science whether Copernicus finding that the Earth goes around the sun or Darwin showing that natural selection drives biological evolution, were answered only after many measurements were taken compared against one another and hypotheses were proposed and tested against the data. Only then can the big picture emerge and the theory get accepted. It'll be no different for Curiosity in its mission to understand the habitability of ancient Mars at Gale Crater. There won't be any single image or measurement that'll answer everything. We're in it for the long haul".* In this context, the mission was also portrayed from the exploration perspective with scientists emphasizing that the mission was more about studying, figuring out, and exploring Mars. For instance, "*A lot of what this mission is about is figuring out the possibility that ancient Mars was a habitable environment. But we're also studying the present environment"; "One of the big things that Curiosity is trying to do is explore and find organic carbon on Mars".*

The following Figure 5 presents a word cloud of 100 most frequently occurring terms in the video transcripts in the Mars Mission Videos by NASA.

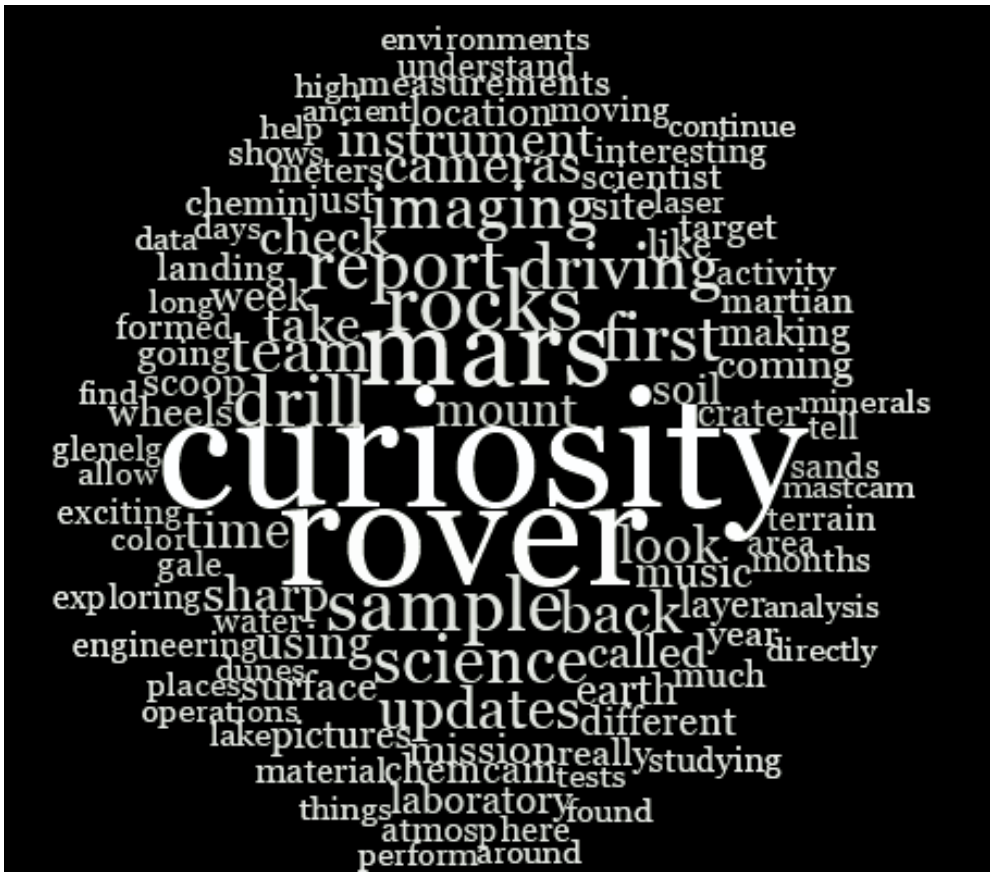

Figure 5: Word Cloud of 100 Most Frequently Occurring Words in NASA's Video Transcripts

5.1.8 Tone of Curiosity Rover Mission Coverage

The video transcripts reveal an overall positive and enthusiastic coverage of Curiosity on Mars by NASA. This was achieved by using words such as "exciting"; "really exciting"; "momentous"; "incredibly exciting" to describe important events and findings related to the mission. For instance, "*One of the things that's so exciting about the Curiosity mission is that the rover takes so many pictures"; "What the Curiosity team has found is incredibly exciting. The SAM instrument is telling us that these rocks contained all of the*

ingredients necessary for a habitable environment. We found carbon, sulfur and oxygen, all present and a number of other elements in states that life could have taken advantage of. All in all, these few tablespoons of powder from a Martian rock have provided the Curiosity science team with an exciting new data set that tells us that Gale Crater, and perhaps all of Mars, contained habitable environments". The only times when the tone implied nervousness and concern were to describe Curiosity landing by using the word "nail-biting" and when scientists found out that Curiosity's wheels were being damaged more than they had anticipated. Overall, scientists seemed passionate, happy, and ready to embark on the exploration of Mars with Curiosity.

5.2 Research Question 2

What are the different tones and perceptions of YouTube users in response to the Curiosity Rover Mission videos posted by NASA?

This study conducted a content analysis of YouTube comments posted in response to Curiosity Rover Reports published between 10th August 2012 and 15th December, 2015. The videos are posted by NASA/JPL. Total number of videos involved in this study are 43. As mentioned in the method section, a minimum of 9 comments from each video were analyzed, i.e. N= 43 * 9 = 387. However, data collection of 387 comments revealed that some of these comments incurred reaction from other viewers in the form of additional comments. These additional comments are also taken into consideration for analysis in this study to examine how public reacts to comments from each other on social media in response to space exploration videos. Therefore, 4 categories of

comments emerged from the data: 1. Individual Comments 2. Parent Comments 3. Child Comments 4. Original Comments Not Found.

5.2.1 Individual Comments – Comments that are directly in response to the video which did not incur any reaction from other viewers in the form of additional comments.

5.2.2 Parent Comments – Comments that provoked reaction from other viewers in the form of additional comments.

5.2.3 Child Comments – Comments that were responses to parent comments.

5.2.4 Original Comments Not Found – Comments that seemed like responses to parent comments but in this case, parent comments were missing either because the YouTube account associated with them were deleted, or the user themselves deleted their comments. These comments were not included for analysis in this study.

Therefore, total number of comments collected in this study are N = 765 where Individual Comments = 207, Parent Comments = 120, Child Comments = 403, and Original Comment Not Found = 35. Since the last category of comments were not included in this study, the revised N is equal to 765-35= 730. So, N = 730.

The following Figure 6 indicates the frequency of comments in each category namely: Individual, Parent, and Child. As we can see, individual comments that did not incur any reaction were considerably more than the parent comments. Also, the number of child comments were almost double the amount of individual comments. This is understandable because the number of people reacting to parent comments were much larger than the person who posted the one parent comment. The ratio of parent to child

comments in this study is about 3.35 which indicates that each parent comment on an average incurred a minimum of 3 comments/responses from other viewers.

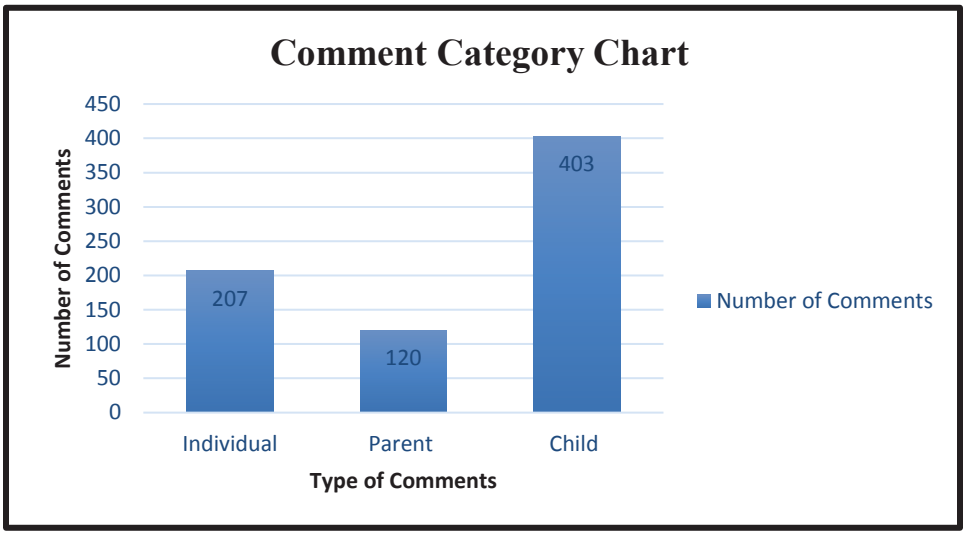

Figure 6: Comment Category Chart

Responses in this case indicate that the YouTube user who read the comment felt the urge to respond to the parent comment so that others can see and read his or her reply. Having a low response ratio indicates that parent comments did not exert a great influence on other commenters. It is critical to note that number of people who read the comments are much larger than those who choose to respond the comments. Replying to a comment indicates a person's desire to share his or her views with others. The following paragraphs provide a detailed analysis of each category of comments.

5.2.5 Individual Comments Analysis

The analysis of individual comments indicates a variety of tones. The coding of comments was not mutually exclusive i.e. one comment was coded into multiple themes if it indicated different tones, and/or themes. A majority of the individual comments were positive in nature indicating a liking and/or appreciation towards the updates, Curiosity rover, science, education, and "thank you" messages addressed to NASA/JPL. Most of the individual comments were in the form of statements, words, or phrases and were directly related to the content presented in the video. The dominant theme of discussion in this comment category was praise towards Curiosity, NASA, JPL, Science, Education, and messages of appreciation towards the video updates. The second most frequent tone was negative where users commented on a variety of topics such as black and white images, song chosen to be beamed back from Mars, physical appearance of the NASA scientists presenting the video updates, conspiracy theories, technology, and the video updates. The third most frequent tone was neutral in nature wherein users mostly asked questions related to the mission or made some observations based on the content of the video. The following Figure 7 outlines the various tones found in this category.

Analysis of individual comments reveals a variety of tones in the responses posted by YouTube users. Although 14 different tones were identified in the comments, 7 of them were dominant. They are: (1) Positive (2) Negative (3) Neutral (4) Humorous (5) Demands (6) Sarcastic (7) Sadness.

5.2.5.1 Positive Comments

Positive tone here refers to comments indicating praise, hope, admiration, pride, and thankfulness towards Curiosity, NASA, JPL, Science, Education, and Mars Video Updates. Positive tone was expressed in a variety of manner. For instance, use of words and phrases such as “outstanding”; “excellent”; “this is truly amazing”; “great work”; “love these reports”; “nice” indicated public favoring/liking the updates and work performed by NASA.

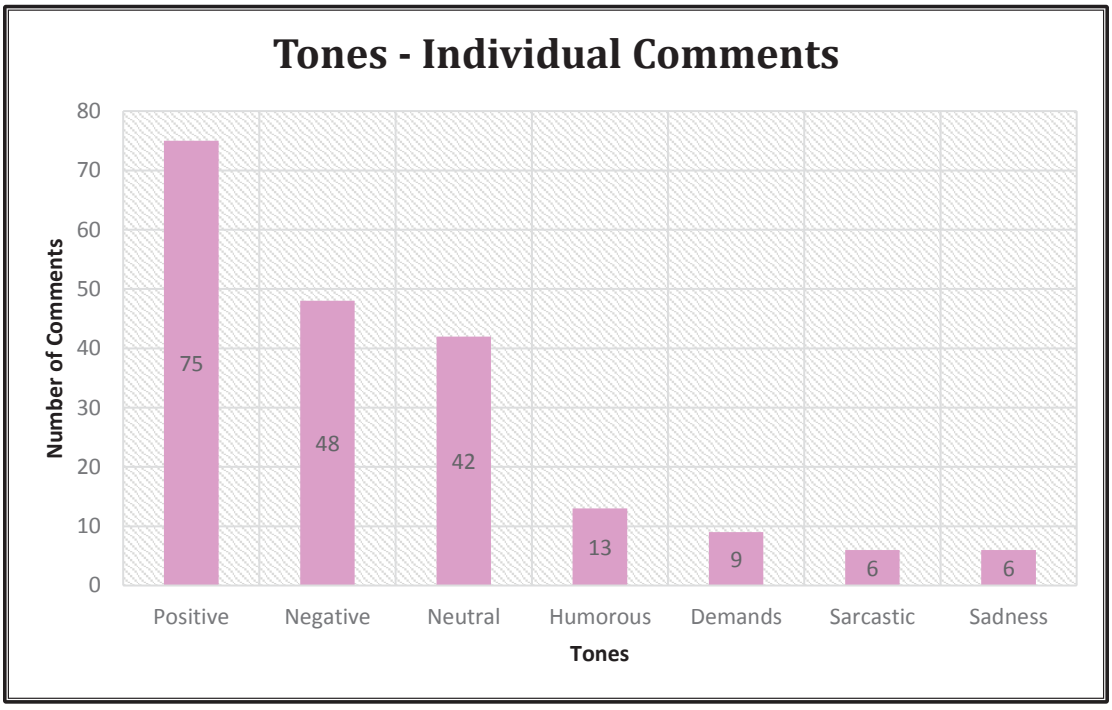

Figure 7: Tones – Individual Comments

A lot of comments also explicitly expressed thankfulness for the video updates with phrases such as “great report, wonderfully spoken”; “thanks for the update,

Sanjeev"; "thank you for the latest :-)"; "thank you, NASA/JPL…for sharing these updates on YouTube! Love it to watch this kind of news, great work guys!" Public applauded scientists who worked on the mission and presented the updates. They also shared condolences for the ones who passed away during the mission. For instance, "Good work, Dr. Bish!"; "Great video Scott! Really cool to see how far science has come, drilling on Mars who would have ever thought!"; "thank you Jake for helping us go to Mars, I hope that one day when people are living on the red planet they will remember that you were one of the many who go them their. R.I.P. and God bless you". *(The incorrect spellings are part of the original comment).* While male scientists were applauded for their work and presentation of information, female scientists attracted comments based on their appearance, only few of which were tasteful. For instance, "Nina's too damn cute, I couldn't pay attention!"; "pretty girls in science". There was only one instance where a female scientist was thanked for her presentation. For example, "Thanks, Aileen! Very neat. Public liked the fact that the updates were presented by MSL team members. For instance, "Fantastic! Absolutely love the continuing news that you are providing. It's completely fascinating! Also, I am thrilled to see news reports coming from real team members. Thank you". Some praised and congratulated Curiosity as well as the rover team. For instance, *"Happy Holiday JPL team &Curiosity*"; "*Congratulations! Three years and counting*"; "*I honestly forgot that Curiosity had a drill. This rover is too cool*", *"she is so ingenious, curiosity"; "the rover got the most smartest computer ever*!!!!!!". Some commenters seemed amused by rover's capability of taking self-portraits and posted comments such as "*Even robots are taking selfies now";*

"Best rover update yet! I had always wondered how that great self-image was done".

Some of the more elaborate praise messages were as follows:

"This is truly amazing. I love all the science behind it. And knowing what's going on. It's incredible work. It's also an incredible view. It looks so much like earth it's awesome".

****

"This is all still just the coolest thing. I'm sitting here watching a video of a 1-ton roving geochemical robot that got sent to MARS ... using a worldwide communications network that has completely obviated traditional media. I'm sorry, but that's cool -- and it's about time that the future finally got as cool as they said it would be when I was a kid. :-)

NASA: TAKE MORE OF MY MONEY!"

****

Some found the mission interesting and a step towards colonization:

"It seems things are about to get very interesting on the nutty ol' red planet. That's one of the reassuring things about technology - there's always room for progress. I mean, we live in age age where Honda has just built a 130 mph lawn mower - that shoot flames! Jules Verne could not have imagined something like that . . . but we did!"

****

"paving the way for earth's first extraterrestrial colony :D"

5.2.5.2 Negative Comments

Negative tone refers to comments indicating insults towards Curiosity, NASA, and NASA scientists, use of abusive language, suspicion, allegations, doubts and conspiracy theory-laden messages. Like positive comments, negativity was also

expressed in many ways. While some used abusive languages to convey their message, some insulted NASA and NASA scientists, some commented on other commenters, some raised suspicion and doubts over images used by NASA, some shared their conspiracy theories, and some just outright believed that NASA was withholding relevant information from the public.

The following instances reveal examples of each kind of negative messages. A classic example of a comment that falls under the category of conspiracy, suspicion, allegation is:

"Interesting that you really don't show anything but rocks and the wheels and some instruments on the rover. Even more interesting is the fact that so far you Haven't Released Any High Resolution Pictures of the area, although you claim those artificially smudged pictures are truly HR. Although you try treat the general public as if they're all a bunch of ignorant kids, who you can fool with a candy bar, an increasing number of them turn to Mars TV Channel for the truth about Mars!"

Other examples in this category are:

"Thats right nasa, put that screen door censoring effect over your so called Martian images from Curiosity...can't have your bad photo editing discovered"

****

"All 3d graphic or imaginary pictures.!!!"

****

"Its like the space station...they feign giving you data but in truth its much of a smoke screen. ...and they do it very well I might add".

Usually, when people posted comments about conspiracy, they revolved around the issue of images or data or both. Some were annoyed by the quality of images, especially if the images were black and white even though it was explained in the videos that some of the cameras on Curiosity were intentionally black and white because scientists did not need color photographs for every analysis. For instance:

Please tell me why are the photos in black and white, Its got damn 2013 and we still cant get colored photos??? I mean your freaking N.A.S.A and still giving the public black and white photos.....”

****

“Where are all the images from sol 760????? and only 4 from sol 761???? And the images are getting worse as your censoring programs are getting better.....Honestly, the image quality from Curiosity is no better than a $1.98 drug store camera...”

****

Some insulted scientists especially women based on their appearances. For example:

“I was quite sure she was a dude before watching the video judging from the video thumbnails. I was like: "Why do I see some guy on a rover report video?”

****

Hey lady could you please try and look a little more smug? You're not nearly smug enough about your job for me to take you seriously.

****

“hi Jess, you're hot”

Male scientists were also targeted based on their appearances a few times but not as much as women. For instance:

"bla bla look at my hair bla. COME ON MAN. LIVEN UP. YOU@RE ON FUCKIN MARS MAN!"

****

"All that buzz about him having a mohawk was kinda stupid. The real news was that we landed a fucking SUV sized robot on Mars. Not some guys hairstyle".

****

Some commenters seemed extremely annoyed about the selection of song to be beamed from Mars for the first time and they expressed their views quite harshly.

"Why the hell did they pick Will I Am.... ? He sucks.."

****

"Out of all of the wonderful music you could have chosen you chose the insignificant mediocrity that is will i am (or however he spells his stupid, pretentious name)? Very disappointing".

****

"Of all the songs in the world? WHY NASA WHYYY??? Will I Am.. Are you serious? Fuck the kids, this annoys me! You've just deficated in a whole bunch of history books."

****

Some believed that NASA was withholding relevant information from the public and wanted NASA to be more active about that.

"Don't want to sound too murky, but it's as usual: we've done something today, it was

exciting, but we will not provide you with any actual data. I'm perfectly aware it takes time to analyse the data, but all you provided us so far is one chart with light spectra, about 2 weeks ago. Too bad you see all this data as your personal property and won't share".

"they don't want us to see the aliens"

****

"No data no stats, no info, pick up your game .."

Some comments were a mixture of positive and negative tones. I have classified them under negative tone category as the comments expressed more negative undertones. For instance:

"It's wonderful to get these reports, but if only you did not have to gabble as if each second was costing a million dollars. PLEASE take your time - make like you are interested in the fabulous news you have for us. It IS clever to speak so quickly about advanced technology - but does not impress those with the intelligence to take in the news."

"These videos are great, but they need to be longer. We paid way too much for this mission for a 2 minute video once a week".

****

"I not trying to sound rude, but could you like give more tech information.. its not the 80s anymore, the average person watching these video are interested in science not blurb or quick fixes."

5.2.5.3 *Neutral Comments*

Neutral tone refers to lack of any extreme emotion (positive or negative) represented in the comments. Comments in this category often involved questions and observations by viewers about the mission, rover, results of experiments, as well as video updates. Some of the examples of comments in this category are:

Wait so, what were the results of the SAM?

****

How many years ago did this river exist ? Was this at a time where the martian weather was similar to earths ?

****

Question JPL: How does the scoop clean itself so that subsequent samples aren't contaminated from soil of earlier scoops?

****

"*So what minerals were actually in the acquired samples?"*

"Will it take months to come up with a conclusions about the past of mars after the results come through?"

Some of the comments that were observations based on the videos are as follows:

"based on the photos, drilled rock looks like a limestone- very fine talcum like ground portion".

****

"well from the pictures, it seems that the martian desert resembles a terrestrial desert".

****

"So the Rover moves on average almost 12 meters per day. Its gonna take a while to climb Mount Sharp!"

5.2.5.4 Humorous Comments

Humorous tone here refers to comments that are funny or witty in nature addressed towards Curiosity, Mars, NASA scientists, and a few jokes or silly comments. For instance*, "Chuck Norris has already been to Mars..that's why there are no signs of life there"; "*7 days???!!!?! *Man you guys must have tons of patience over at nasa. I would want to just throw it into full speed :p"; "Last week's spokeswoman was way Hottah. Get it? ;-)"; "No we got RickRolled. Dead Planet. No martians"; "Dust removal tool! Son... thats a brush.."*

5.2.5.5 Demands

Demands refers to public comments insisting NASA for specific information, audio, videos, or images. These comments were mostly polite requests, wishes, and suggestions. For instance,

"Do another video with Mohawk Guy! PLEASE???"

****

"Can you do another video with Mohawk Guy?"

****

"Maybe NASA should add a flyable drone to their next rover. It could detach from the rover and fly ahead and assess the terrain."

****

"That rover must be equipped with 4 k pictures cause I would want clear image from my first mars mission."

****

"Send that dang rover to Cydonia."

5.2.5.6 Sarcastic Comments

Sarcastic tone refers to comments that indicated sarcasm towards video updates, public, other commenters, and NASA. For example:

"this is a movie?"

****

"And that's, like, the main point of the video?"

****

"Where are the contradicting conspiracy clowns? The Clowns who post videos that no one can comment on & present supposed NASA photos as evidence, but omit a source reference for comparison & omit a scale of size.You know... the "Hoax clowns" claiming curiosity is in a desert & show blurry linear topography as roads VS "Martian artifact" clowns who show blurry teapot shaped rocks. When Curiosity to gets to the top of Mt. Sharp a clown will post a blurry Martian yeti pic. Send in the Clowns!"

****

"It's not long 'till the surface of mars is littered with McDonald's wrappers."

5.2.5.7 Sadness Comments

Sadness tone refers to comments that expressed sorrow. These comments were reactions to lack of views on YouTube videos regarding Curiosity space exploration,

missing their favorite scientist who presented the updates, and lack of attention to this great accomplishment. For instance,

"it just breaks my heart to see only a couple of thousand views on these vids..".

****

"I miss Sanjeev Gupta!!!!!!!!!"

****

"I am amazed at how far science has come, and by Curiosity's endurance and continual discovery. It can be easy to assume this can be taken for granted, and its a shame each new discovery or even new territory traversed by Curiosity isnt given as much attention as it should. Even a simple short video like this, summarising what must be an enormous amount of scientific work it is mind blowing when you think about how far space exploration has come - from Apollo, to Mariner, to Pathfinder, and now this. Well done to eveyrone involved with Curiosity and long may it continue to explore."

The following Figure 8 indicates the variety of topics in the individual comments.

5.2.6 Parent Comments Analysis

The results of parent comments analysis were not very surprising. It is important to note that parent comments are the comments that influence other users to respond to them either to share their views that may or may not support the original commenter's perspectives. The results of analysis reveal that most parent comments that provoked others to comment on them were negative in nature. The second most dominant category of comments that attracted attention was neutral in nature followed by positive ones.

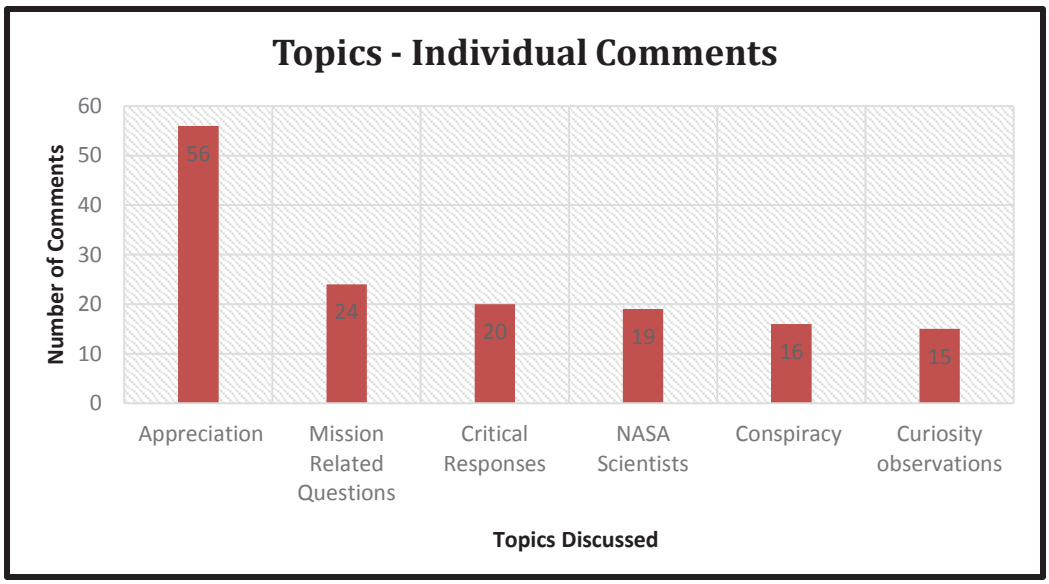

Figure 8: Topics – Individual Comments

This is in line with the previous findings in literature where negative comments have been known to encourage YouTube commenters to comment on them. Regardless, the coding of comments in this category was once again not mutually exclusive. A few comments were coded in multiple nodes. Most parent comments were only somewhat related to the content posted in the videos. This means that negative comments comprised of topics that were not directly related to the video content. The details of such comments are discussed in the following paragraphs. Three different types of comments were identified in this category: (1) Statements (2) Statements and Questions (3) Questions. Most parent comments were in the form of statements, followed by statements and questions, and questions respectively. The following figure 9 indicates the frequency of comments in this category.

5.2.6.1 Negative Comments

Most comments under this category focused on conspiracy theories about NASA using Photoshop to alter Mars images. That they airbrushed those images and are disseminating them to the public. Commenters came up with their own theories about strange objects found in Mars and NASA withholding that information from the public. Some also called Curiosity and MSL mission "fake". Some questioned by the pictures were not in color implying that despite having advanced technology, NASA was choosing to show black and white pictures to public.

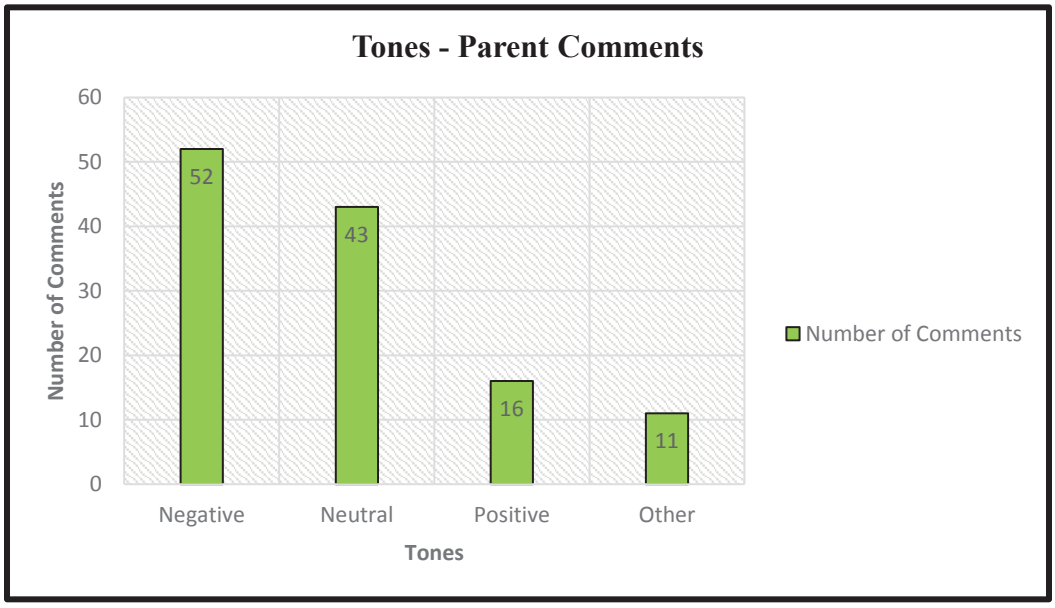

Figure 9: Tones – Parent Comments

After going through each comment in this section, there were hints that some commenters intentionally "trolled" most NASA videos analyzed in this study to provoke

reactions from other commenters. Some came up with their own version of religious stories about Mars and some commented on the bad quality of rover cameras. The second most frequent theme under negative comments category was insulting NASA and NASA scientists and third most frequent theme was negative reaction towards video updates and/or Curiosity. Examples of each of these categories are as follows:

(a) Image/Video related Negative Comments and Conspiracy Theories

"So that "unimpressed" photoshop is being sent everywhere now and they're still talking about you guys on Reddit. ;)"

****

"They can't show the images one minute after they receive them,first they need to airbrush the detailes we are not alowed to see :)"

****

"This is fake, Curiosity is totally FAKE."

****

"Iam wondering why the video or photos are not given to us in true colour, instead of the usuall red tint! All that tech as well:("

****

"Where's the critical thinking people??? are you unable to recognize tampered/ retouched/ obfuscated/ faken data??? NASA and JPL are lying to you about Mars and mostly about everything, they are misleading you to their own story half of the truth, no science here, only lies"

****

"By the way, when are you going to provide video from Mars??? i mean real video FPS, i know you can't do that, if you do all you little fake circus would go to an end, that is why there's no video of Mars surface, that is why you are providing shitty 2MB pixel quality images. guys. really, next time send an iphone to show real good quality pictures, stinky, plus i wonder why you never ask those kind of comments back....."

****

"Mars was inhabited and had many waters, but his people were wicked and idolatrous, so God sent a prophet possibly called Eon, saying it would destroy Mars by desertification, and continued not believe in evil. Meanwhile here on Earth at the same time, God sent the prophet Noah saying it would destroy the earth by flood (flood) because of the wickedness of the people did not repent; past the deadline, as none of the planets repented, God came orbits".

(b) Insults towards NASA and NASA Scientists

"yea, the right idea by hiring people who look like they have no idea what they are talking about and are just reading a script"

****

"You know, this is awesome, I love to learn more about the Curiosity Rover and Mars, but NASA, frankly, you guys really need to grow some balls! It's time to friggin send humans to Mars! Now is the time! Go for it! The public is ready and they want something to be able to believe in, such as this. It is time".

****

"They are not interested in Mars,, it is the Gold on Phobus that they are after...Our tax dollars to make the rich richer."

****

"A mic weigh less than an ounce. Really? They couldn't put a mic on it? The game is to get us interested. I watch, but this is pure stupidity on their part. Oh ok I will wait for the next Mission.... Fuckin retards, They could monetize thes vids and make some cash for the space program. But NO they have to continue to be stupid."

"Damn Katie! Scientist and hot. Dreamy..."

****

"Nasa is a disgrace for mankind. The End."

"Dear JPL... Why doesn't anyone from your organization ever respond to questions from the tax payers who pay your salaries? There are hundreds if not thousands of Curiosity photos that range anywhere from the ridiculous to the blatantly absurd. NASA/JPL has nothing but contempt for the average U.S. citizen and your silence proves it. (Roger In Kansas City) p.s. thanks for all the video material"

(c) Negative Reaction Towards Video Updates and Curiosity

"By the way, when are you going to provide video from Mars??? i mean real video FPS, i know you can't do that, if you do all you little fake circus would go to an end, that is why there's no video of Mars surface, that is why you are providing shitty 2MB pixel quality images. guys. really, next time send an iphone to show real good quality pictures, stinky, plus i wonder why you never ask those kind of comments back....."

"Amazing hoax!"

"i think the 3 year summary could have given more detail ?"

****

"Why every time NASA play a video about Curiosity those videos are just animation and not the real one? Why Don't they play the actual video?"

5.2.6.2 Neutral Comments

Neutral comments that attracted additional comments from other users were mostly questions related to Mars, Mars exploration, MSL mission, Curiosity, Science and Technology. The questions raised by commenters indicate significant interest and curiosity towards understanding the content or space science. Some of these comments are responses to various individual comments that were commenting on the lack of videos. Well informed commenters took time to share the reasons behind the scarcity of videos from NASA. Comments in this category also indicate that people were curious about the results of experiments and were interested in Mars missions. Some applauded the technological marvel of Curiosity, some were concerned about its wheels, some wondered about aliens on Mars and some wondered about astronaut's living conditions on Mars. The examples are as follows:

"Are sounds able to be heard from Mars via the rover? Can audio from earth be played from the rover? It would be interesting to hear sounds from the rover while it is driving or digging. Thanks"

****

"For the folks asking about color HD video cameras: the cameras themselves aren't very heavy and shouldn't present a problem. But the power to send that video back to earth is

a problem. Curiosity's high-gain X band radio is 15 watts and 32 kbit/s direct to Earth, and works for half the Martian day. The UHF radio is 9 watts and 2 megabit/s, but only when one of the two orbiters is overhead (8 minutes/day). You'd need 15 megabit/s for HDTV. Needed: 3 relay satellites in high Mars orbit."

****

"Viking probably found microbial life on Mars in 1976, but they didn't analyze the tests properly. Re-analysis has shown that the tests confirmed the presence of organic life. Google it. How long will it take for NASA to re-confirm this with Curiosity?"

"Wow That 3D Model of Curiosity looks damn nice. Is that a fully 3D Production model made out of the Part Drawings in Corel Draw or something like that?"

****

"What's the difference in Sunlight strength on Mars than it is on Earth ? ... it should be dimmer ... right"

****

"what if there is a completely different civilisation already existing on Mars which survives on different conditions? even on earth, we know plants need CO2 while humans need O2 so why can there not be species surviving on , say methane ? what if they are observing us now? mmm.. interesting to know what they think of us?"

****

"Aluminum (or aluminium) wheels... I wonder how they're affected by extreme cold (and hot-cold cycle). Do they become more susceptible to damage? Such cold can't easily be simulated for the Earth-bound twin. How is this taken into account?"

"Could astronauts on Mars live underground? Would sleeping under a couple feet of rock protect them from the Sun's radiation and save weight in lead shielding?"

****

"so what was the cause of the wheel damage? chemical-physical-hot/cold?"

5.2.6.3 Positive Comments

Positive comments attracted least number of additional comments from other viewers. However, this is not a surprising finding. Nevertheless, comments under this category expressed liking towards NASA scientists, rover, rover pictures, and samples, some wanted to spend more money towards space exploration and reduce money spent in the military, some wanted to see a similar mission to Titan, some wanted longer videos, some were thankful to NASA for creating such videos for public outreach, and some thought that the science was "cool". Examples of such comments are as follows:

"By golly she's a fine looking geek! Ahem and yes that whole Mars lander Curiosity rover science robotic arm pictures and samples thing is pretty cool too also.."

****

"Everyone who works there is so likeable!"

****

"I'm so grateful that you guys take the time to make these public outreach videos. It's awesome to see science and engineering in action."

****

"Too awesome. Am I being greedy if I really want to see a similar mission on Titan?"

****

"Hey, curious people at nasa. This is a LOT of fun but not enough fun. Please, please, please, minutes are not enough. How about a regular Curiosity hour report. You have time. I know you do. The reason I know is because it's my money (partly). More information please."

"Amazing reports as always! I love these."

****

"We have a nuclear powered robot firing a laser on Mars. Tell me that's not cool"

5.2.6.4 Others

The comments in this category were fewer in number and indicated a variety of tones such as surprise, sarcastic, ridicule, jealousy, impatience, humor, and dislike towards conspiracy theorists. For example:

"Can't wrap my mind around why you would have "Ratings disabled"???"

****

"5K? Yeah, NASA is going metric!!! Yessss! Now you only need to add an "m" to the "K". Let's hope you don't need another 200 years more to do that".

****

"So that "unimpressed" photoshop is being sent everywhere now and they're still talking about you guys on Reddit. ;)"

****

"Dang I'm getting old. When I first saw the representative from JPL my first reaction was "What's a kid like that doing saying he is a scientist!" I guess I am just jealous".

****

"Just get people up there"

"Give me $100 million, a camera, and a shovel, and I'll go to Mars. I'm obviously cheaper, and I dig a lot faster too".

****

"I seriously can't stand all the conspiracy theorists. Come on guys, just enjoy science for sciences' sake. We have an automated mobile laboratory on another freaking planet. IS THAT NOT AWESOME ENOUGH FOR YOU?!"

5.2.7 Child Comment Analysis

The results of child comment analysis were interesting. Six dominant tones emerged upon analysis of child comments. They are: (1) Neutral (2) Debate (3) Negative (4) Humorous (5) Positive (6) Sarcastic. According to the results, most responses to parent comments were neutral in tone. Majority of the comments under this category were responses to questions posted by parent commenter. These questions were somewhat related to the content posted in the videos. However, the new category "debate" indicates that many users confronted the original commenter about their comment/perspective on YouTube, especially the ones who posted insulting comments about NASA, Curiosity, Mars exploration, and conspiracy theories. Specific examples of such instances are presented in the following paragraphs. The third most frequent tone was negative wherein commenters posted conspiracy theories and insults towards NASA. The number of humorous, positive, and sarcastic comments were low. Figure 10 outlines the total number of comments in each category.

5.2.7.1 Neutral Comments

Most comments under this category were responses to questions posted by parent commenters. These questions were only somewhat related to the content posted in the videos and mostly revolved around general space science inquiries among YouTube commenters. More specifically the questions were on topics such as possibility of water on Mars, living on Mars, Mars exploration, going and coming back from Mars, internet communication between Earth and Mars, Viking Experiments, Curiosity Rover, images, satellites, and a few responses to people who posted conspiracy stories about NASA.

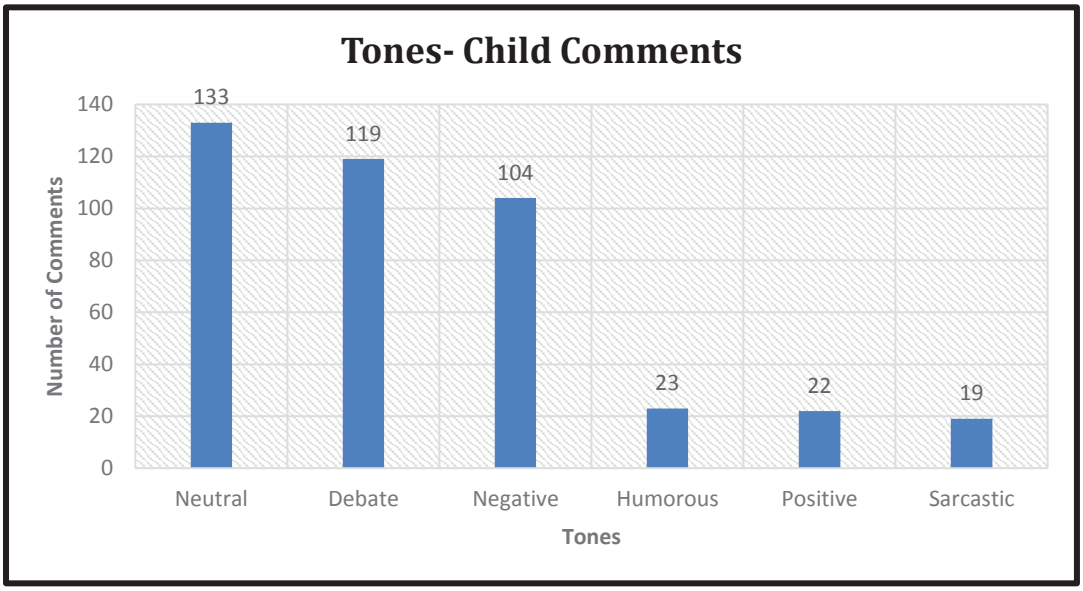

Figure 10: Tones – Child Comments

Most comments were in the form of statements and phrases and were informational in nature wherein one commenter answered and/or discussed questions posted by the parent commenter. For instance,

Parent Comment: *Are sounds able to be heard from Mars via the rover? Can audio from earth be played from the rover? It would be interesting to hear sounds from the rover while it is driving or digging. Thanks*

Child Comment: *Since Mars has an extreamely thin atmosphere, there aren't much sounds. Maybe some grains of sands blowing across the desert when the wind is strong enough. A micriphone would need some kind of amplifier and also a bit of the narrow bandwidth for it's signal. Everything weighs and is it important for the scientifical studies?*

Parent Comment: *Viking probably found microbial life on Mars in 1976, but they didn't analyze the tests properly. Re-analysis has shown that the tests confirmed the presence of organic life. Google it. How long will it take for NASA to re-confirm this with Curiosity?*

Child Comment*: Actually the data from the Viking biological experiments was entirely inconclusive even after re-analysis.*

****

Parent Comment: *Wow That 3D Model of Curiosity looks damn nice. Is that a fully 3D Production model made out of the Part Drawings in Corel Draw or something like that?*

Child Comment: *NASA actually built 2 of them; the one stays on earth so they can have an exact model to fine tune the position movements with to the other on mars. This leaves the guess work out of this part of the mission. This info is on another NASA vid of this mission.*

5.2.7.2 Debate

Comments in this category reveal that people did not hold back when parent commenters insulted NASA, NASA scientists, shared conspiracy theories, or shared any false information related to the mission. Many commenters confronted such parent commenters and sometimes also made fun of them. Analysis also indicated that many child commenters were aware of the presence of "trolls" who intentionally post stimulating statements which would attract attention from others. Overall, this category of comments revealed that public were genuinely interested in knowing and understanding more about space exploration, Curiosity, and Mars and they engaged with other users by asking questions and sharing their perspectives. Some of the examples in this category are:

Parent Comment: *They can't show the images one minute after they receive them, first they need to airbrush the detailes we are not alowed to see :)*

Child Comment: *Are you trolling or just stupid?*

Parent Comment: *None of this, but i wonder how you dare to insult people whithout any reson?*

Child Comment: *I was sincerely asking. If you were joking, by imitating conspiracy nutjobs' arguments, then good, everyone likes a trolling from time to time. But if you seriously believe they airbrush stuff out, then... boy...*

****

Parent Comment: *No, i'm not trolling, actually i have studied the pictures posted by JPL on their website ,go there and see yourself ,i'm not the kind of person who believe in*

conspiracies, but if you are really interested ,pm. me and i will show you a clear building on mars they forgot to brush out(it looks like a dome) :)

***Child Comment**: They don't darken some areas, those are just areas where no photo has been taken. Jesus, do your homework before making yourself look dumb.*

****

***Parent Comment:** Give me $100 million, a camera, and a shovel, and I'll go to Mars. I'm obviously cheaper, and I dig a lot faster too.*

***Child Comment, User 1**: Haha, Before you talk you should look out the facts that the images what has taken by 'Curiosity' is all faked and done in photoshop. There's facts everywhere you dumb brainwashed fag.*

***Child Comment, User 2**: That's a rather heavy claim to make, and to simply state something as being a fact does not make it so. Perhaps you could elaborate with a level head without insult?*

5.2.7.3 Negative Comments

Comments in this category indicated conspiracy theories posted by users about images of Mars, insults from public who realized they were interacting with "trolls", insults towards NASA and NASA scientists and allegations that NASA is not sharing relevant information with the public. Negative comments were mostly targeted towards other commenters and it took the form of undermining and disrespecting other commenters, disagreement from the commenters, or correcting the parent commenters. For instance:

"They should of post videos or pictures about mars. I don't think the people from Nasa would let us see the video like if they find life on mars or aliens. Why? because they don't

want to scare people or want you guys to know that there's life somewhere else out there. That's just my opinion just saying. But great video."

"Ignorance at its finest, eh? Okay. So be it, I'm ignorant. But I can tell you what I am not: I'm not a coward. The reason NASA has not sent humans to Mars is not because it is beyond the realm of human knowledge and technological prowess. It is because they lack a backbone. They don't want the public spotlight if the mission fails and humans die en route, or on the red planet. What they do not understand is that the educated layman knows the dangers, and wants this anyway."

****

"Gullible Americans that believe what there told without researching the subject are idiots or "Sheeple"... Don't like that term ? well, that's too too bad. Are you a rational person ?.. The bottom line is I will continue to use this term as many others do. You need a "reality" check before telling ANYBODY what to do or say. Your opinions are flawed, especially if buy in to NASA lies and their continued bullshit.."

5.2.7.4 Humorous Comments

Comments in this category revealed YouTube users responding in a silly, witty, or funny manner to the parent comments posted in response to videos. Some made fun of serious questions such as what happened to all the water on the surface of Mars, some mentioned aliens are not letting NASA scientists to reveal that there's life on Mars, and some made silly jokes about Curiosity. Examples are as follows:

Parent Comment: *Life on Mars still exist supported by molecular nuclear fusion deep beneath a plant surface: Google 'molecular nuclear fusion'to read about my greatest*

science insight ever! This process goes on in the deep on earth

Child Comment: *Life on Mars "may" still exist. Don't get to sensational without evidence. But I agree that there is a high chance for microbial life on suitable depths (at least around the water rich poles) of the planet.*

Child Comment: *The more interesting question I have is 'given that there is evidence for water to have existed in liquid form on the surface of Mars, what happened to the environment there to make it disappear?'*

Child Comment: *The martians drank it all ? And when there was nothing left they settled over to earth :P*

****

Parent Comment: *Why don't they just come out and admit that there is other life out there already.*

Child Comment*: The aliens would not let them obviously.*

****

Parent Comment*: I wanna be dropped off on an uninhabited life dwelling planet with tha girl i love*

Child Comment: *lol you can get ur chance sign up*

****

Parent Comment: *Since when was Curiosity a "girl"?*

Child Comment: *I'd say it was since Curiosity killed the cat :o)*

Child Comment: *Since she became cold and distant and started to take over half an hour to respond to our signals. Sure, that was sexist and beneath me but, admit it, it was*

awfully clever.

5.2.7.5 Positive Comments

Comments in this category revealed how positive parent comments attracted positive child comments. Although the number of parent positive comments that attracted positive child comments were much lower than negative and neutral comments. Some of the examples of positive parent and child comments are as follows:

Parent Comment: *By golly she's a fine looking geek! Ahem and yes that whole Mars lander Curiosity rover science robotic arm pictures and samples thing is pretty cool too also..*

Child Comment: *AND she's a freakin rocket scientist!!*

****

Parent Comment: *Imagine if whole humanity could stop wasting money on religions and military gear, and concentrated on space-exploration. We could achieve so much amazing things,and learn so much in just couple of decades. There would be 20 Hubbles taking pictures on every direction, these Rovers would be crawling on every planetary body we can reach.We would have massive international space stations, and the space-elevator project properly on the way. I want to live in THAT world, not on this crap we have now*

Child Comment: *I couldnt agree more! we waste so much money on stuff that doesnt really benefit us, if we pumped more money into space programs and exploration just think of what us humans could acheive! i personally think we need to start giving more money to space research and less to military and religous cause, hell we could discover*

FTL travel and have colonies on planets in other systems of the galaxy!....we may even discover new life and learn from them! More money to space research!!!!!!

****

Parent Comment: *Everyone who works there is so likeable!*

Child Comment: *Yes, it is wonderful to see the results presented from all those people who work with Curiosity!*

5.2.7.6 Sarcastic Comments

Comments in this category revealed how some parent comments attracted sarcastic responses from YouTube users. Some examples of such comments are as follows:

Parent Comment: *ok let say there is a water and life in mars and a way humans can live there - and we figure out all what there is in mars, what then ? who will want to live in this hell called Mars?! and we don't have the technology to send people to live there and make mars suitable for people - what benefit is it gonna give us at all to live there?! you can say there is resources in mars that we can exploit, i know places in Earth that have a great of resources and they not profits at all*

Child Comment: *"Who will want to live in this hell called Mars?" I would, and A LOT other people would eagerly sign up. "we don't have the technology to send people to live there" Yeah we do, just no country willing to do it, the first trip would be a international venture "what benefit is it gonna give us at all to live there?!" You really can't see the enormous importance of making life multi-planetary?*

Child Comment: *for the last Question: no - for now this is just another land for peploe to fight for yes - for the next 500-1000 years to come maybe*

****

Parent Comment: *there are intelligent beings, lakes and dams full of water on mars and nasa keep the secrets to itself, nasa and american government will never admit it because it's against their interest*

Child Comment: *You know this before we even try it? Good. Lets cancel all exploration of the universe and then you can tell the scientists whats out there. Much cheaper.*

****

Parent Comment: *This is fake, Curiosity is totally FAKE.*

Child Comment: *go troll somewhere else*

Child Comment: *Curiosity a Fake? ...BUT I BET YOU BELIEVE, 911 was an inside job, the world is going to end in December, chemtrails are not condensation, the illuminati is in control of all governments, cancer is created by whatever industry you don't like this month, the cure for cancer is drugs you frequently use, the moon landing was faked, aliens landed in Roswell....ect. Am I right Troll?*

****

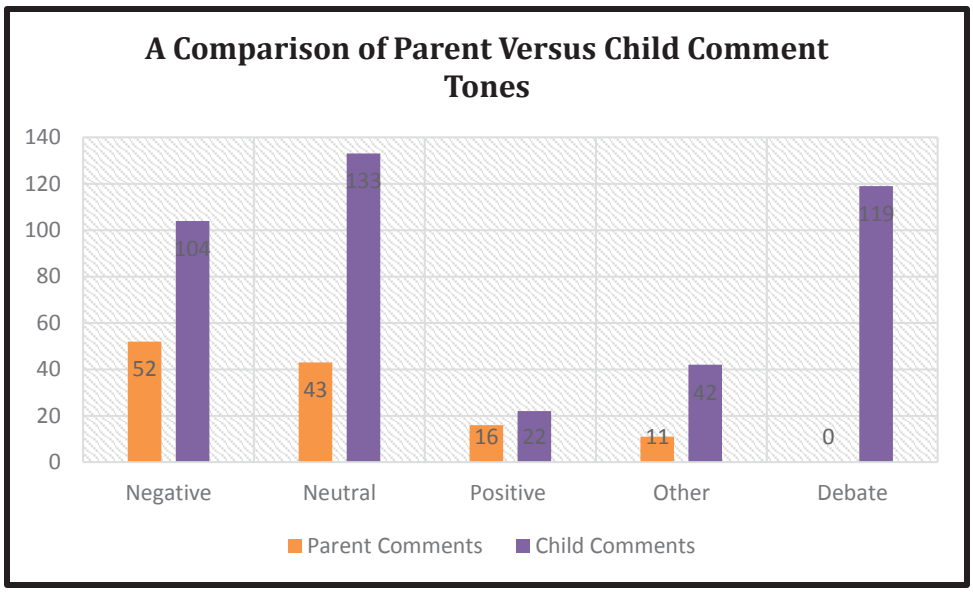

Figure 11: A Comparison of Parent Versus Child Comment Tones

A comparison of parent versus child comment tones in Figure 11 indicates that the ratio of negative comments is 1:2 = 0.5. This means that negative child comments were twice the number of negative parent comments. Similarly, the ratio of parent-child neutral comments is 43:133 = 0.32, parent-child positive comments is 16:22 = 0.72, parent-child other comments is 11:42 =0.26. Although the ratio of parent-child positive comments is highest in the above chart, the number of positive parent and child comments were considerably low. The second highest ratio is of negative parent-child comments and it indicates that negative child comments were twice the number of negative parent comments. The third highest ratio is of parent-child neutral comments where the number of parent-child neutral comments is highest (43+133 = 176).

CHAPTER 6
DISCUSSION

One of the goals of this dissertation was to identify the frames present in the YouTube videos published by NASA on Mars Science Laboratory (MSL) mission. Videos published between 10th August, 2012 (First Rover Report after its landing) and 15th December, 2015 were analyzed to determine the most prevalent frames utilized in the coverage of the mission. Framing is the "packaging" of information which resonates with public values and beliefs. The aim of this dissertation was to analyze Curiosity Rover video transcripts to determine which frames emerged from NASA's characterization of the MSL mission. Seven frames emerged from NASA's coverage of Curiosity rover on YouTube. Some frames appeared far more frequently than others which indicated the dominant angle with which the mission was portrayed by NASA.

The first and most frequent frame was "Science Experiments". This frame portrayed the mission from the perspective of scientific experiments and exploration on Mars. It provided audience an insight into how scientists are working on the Mars exploration project, how they are using and controlling Curiosity from Earth to explore the planet, the specifics of how each instrument on the rover works, what it analyzes, purpose and reasons for performing each experiment, dangers of being on Mars, and critical aspects of the mission. This frame clearly indicated that NASA focused on educating public about the specifics of the mission (i.e. scientific literacy) instead of just providing them a generalized overview of the mission. Studies on public perception on space exploration suggest that people are not aware of the scientific details of the space

program, which leads to misunderstanding about the relevance of such endeavors and in turn influences public support for funding the space exploration programs. Therefore, the videos posted by NASA indicate a strong focus on providing public information about the "science" and "exploration" aspects of the mission. MSL scientists in the video take viewers on an interplanetary journey and explain the specifics of their hypothesis, which experiments they are going to perform and why, what are the different instruments on the rover and how do they work, what they are testing, what will be the learning outcome of the experiments, and implications associated with the results. By using such narrative, the frame had the potential to inform public about the value and complexities of such an endeavor. This frame might also influence public perception of the mission. The focus on providing a scientific perspective of the mission could have influenced public understanding and awareness of the importance of space exploration. By placing science at the core of the mission, these videos also had the power to inspire young children to pursue careers in STEM (Science Technology Engineering and Medicine). This representation could also bridge the information gap and trust between public and scientists as public could witness how science is conducted and how their tax money is being utilized.

The way information is packaged and presented or how it's framed can influence people's receptivity. Different people are receptive to different kinds of packaging of information. In the past, media has framed space exploration with an emotional framing such as appealing to the national pride value of American citizens, nostalgia of the cold war era, or frames of science, business, and heroism. Based on my research, seven frames

have been identified in NASA's coverage of space exploration (Curiosity Mission) today. They are: Science Experiments, Curiosity Rover, Findings, Mars, Science Team Characterization, Success, and Communication and Engagement with the Public. This begs the question as to which frames are most effective and successful in garnering public interest and support for space exploration. To do so, I propose a study where a large random sample of people are requested to fill a survey rating their knowledge and support of space exploration on a scale of -5 through 5 where -5 indicates strong disapproval of space exploration, 0 indicates no opinion and/or ambivalence, and 5 indicates high knowledge, and high approval. After filling the survey, people are shown videos on Curiosity Mission and comments associated with them. The researcher can then ask questions about how individuals feel about space exploration after watching the video and reading comments to investigate which frames are more successful in garnering support and which are not.

The comments analysis revealed a complicated picture of the interaction between public, social media, science agencies, and science. ***Based on my data I found that there were 3 major interactions going on in this scenario. 1. Videos influencing individual opinion when a user watches video content and gets impressed or unimpressed in any manner. 2 Commenters influencing individual opinion when people who only read comments and do not comment themselves. In this scenario, new information may come into light and their perception may change. 3. Commenters influencing each other's opinion by sharing their views on a specific topic.***

The average number of views on the NASA videos examined in this study are 106101. The average number comments posted in response to these videos are 104. Therefore, the percentage of people who comment on those videos are a very small percentage of the ones who view these videos (in this case 0.09%). Most of the people who are impacted by the video don't comment on the videos. Exploration of frames presented by NASA/JPL and analysis of comments posted by YouTube users play a significant role in shaping individual opinion. A person with little opinion either in favor of or against NASA could be compelled by video content to support NASA's efforts. For Example:

"Fantastic! Absolutely love the continuing news that you are providing. It's completely fascinating. Also, I'm thrilled to see news reports coming from real team members. Thank you."

Alternatively, a person with an inherently negative view on the cost of space exploration might have their perspective challenged after reading information in the comment section comparing the relatively small size of NASA's budget compared to the bloated defense budget. For instance,

"its seems like they are just demonstrating their toy "curiosity" ,nothing more .. 2.5 billion nice toy"

"Yep, lets keep testing sand with those billions of dollars, I dont think there are other things we can use that money in a useful manner, like cancer research or any other useless stuff like that"

"Why not? We spent 5 trillion dollars defending a pile of rocks in the middle east."

"Interesting that you really don't show anything but rocks and the wheels and some instruments on the rover. Even more interesting is the fact that so far you Haven't Released Any High Resolution Pictures of the area, although you claim those artificially smudged pictures are truly HR. Although you try treat the general public as if they're all a bunch of ignorant kids, who you can fool with a candy bar, an increasing number of them turn to Mars TV Channel for the truth about Mars!"

By following the trends of these individuals, we can begin to model how public opinion might be swayed by social media.

This research also revealed that there are many asinine comments that do not deal with discussing science on YouTube in response to space exploration videos. For instance, comments such as "Hi Jess! You're hot!" What bearing do comments such as these (Personal insults, silly, derogatory) have on swaying individual opinions, if any? Do people tend to ignore them? Do they find them distracting? Do they cease to read comments further after reading a comment like that? Do they ignore them? These questions are worth exploring in the future studies.

In my study, there is just one instance when NASA responded to a public comment about enabling the comment ratings.

Parent Comment, User 1*: Can't wrap my mind around why you would have "Ratings disabled"???*

Child Comment, User 2*: That is simple. Some will use the ratings to serve their own purposes. If a Science video happens to get some negative votes, They will interpret that as if it is a public vote to defund more and more government funded Science programs.*

Child Comment, NASA/JPL: *Ratings should have been enabled on this video as we do for all our videos. It's fixed now.*

Child Comment, User 1: *Thanks, now I can give it a thumbs up :)*

Most of the times, NASA does not respond to public comments (positive or negative). However, in the recent past, NASA did make an official statement to debunk a conspiracy theory where NASA was blamed for sending children to Mars to become sex slaves (Collins, 2017). In this case, when a story became a national controversy, NASA took the initiative to debunk the myth.

Does enabling comments in an open discussion platform like YouTube have a positive or negative effect on public opinion of space exploration? A future study could take a large sample of individuals and survey them to determine their initial support for or against NASA on a scale of 1 to 10 where 1 is not very supportive and 10 is very supportive. By random selection half of the individuals would watch a video and read comments and then take the survey again to determine any shift in opinion. The other half would do the same without reading the comments.

This concern of how public opinion might be swayed by social media is not limited to space exploration. There are many cases of government programs presenting evidence based research to the public for which people nevertheless have polarized opinions; Infrastructure development, Climate change, Wild life resource management, GMO crops, Healthcare, Anti-Vaxxers. Understanding how people view space exploration in this dissertation could be mirrored into these other cases. In my research, most parent comments that sparked discussion had the premise of the images presented

being part of an elaborate government supported “hoax” (For example, one of the comments in the study explicitly called the images and work by NASA an “Amazing hoax”). Given the current political environment, one might easily imagine seeing such patterns mirrored in comment sections of videos concerning climate change (Jacobson, 2016).

There are several themes that emerged from Parent-Child comment interaction. First of all people came to YouTube to watch videos. The comments reveal that they also came to the platform for interaction. They asked questions about science, related to science, or Mar/Space exploration. There were instances when a person implied conspiracy in their comment and others either supported them, ridiculed them, criticized them, or were neutral towards them. Many commenters were aware that they are interacting with trolls. Majority of the parent comments that were related to conspiracy theory were refuted and challenged by the commenters.

A: *They can't show the images one minute after they receive them,first they need to airbrush the detailes we are not alowed to see :)*

B: *Are you trolling or just stupid?*

A: *None of this,but i wonder how you dare to insult people whithout any reson?*

B: *I was sincerely asking. If you were joking, by imitating conspiracy nutjobs' arguments, then good, everyone likes a trolling from time to time. But if you seriously believe they airbrush stuff out, then... boy...*

A: *No,i'm not trolling,actually i have studied the pictures posted by JPL on their website,go there and see yourself ,i'm not the kind of person who believe in*

conspiracies,but if you are really interested,pm. me and i will show you a clear building on mars they forgot to brush out(it looks like a dome) :)

B: *They don't darken some areas, those are just areas where no photo has been taken. Jesus, do your homework before making yourself look dumb.*

Most parent-child comments were public asking questions and/or providing answers related to science.

Finally, there is a lack of studies exploring the role of social media especially YouTube in space exploration research. Public perception of space exploration has been described as a complicated issue where people are supportive of the endeavor "in principle" but are unaware of the specific details of the programs by space agencies, unaware of the importance and value of space exploration research and are also averse to funding for space research. This has resulted in the lack of federal funding for space exploration. This is an important issue because space exploration is crucial for the advancement of a nation in terms of scientific knowledge, technology, business, health, agriculture, climate monitoring, economy, and future of humanity. Literature suggests that lack of public interest in space exploration, lack of science education, and tendency to make important policy decisions based on political affiliation, ideology, and religious values have exacerbated the problem. It is important to address this issue of lack of public interest in science because policy decisions related to space affects one and all. The larger the goal, the greater funding is required to accomplish it. A significant amount of this money comes from tax-payer's share and with expensive space goals, future generations of people will be responsible to pay for this effort. It is critical that they understand the

importance and relevance of space exploration. It is important that they are not just curious in space-related events but also develop a greater passion and long-term interest in sciences. Future space goals will require accomplished scientists, doctors, engineers, programmers and many scientifically skilled individuals. Therefore, it is important to examine the current perceptions of public towards space exploration.

Traditionally, the news media has played a key role in framing and educating public about space exploration. Current trends suggest that public uses social media to access news. Science agencies are reaching out to public to educate them and inform them about their programs, encourage and inspire them to pursue science careers via social media platforms. In this scenario, science agencies are framing and portraying science in a different manner than traditional media. Literature on the coverage of Mars Mission by newspapers and science agencies indicate that although there are some similar frames in representing information to public, scientists approach public outreach and sharing of information in a different way than newspapers do. The information in newspapers are more sensational than information shared by scientists on websites, seminars, blogs, social media, and articles. This is also because of the underlying interests of the two professions. Sensational news is more popular, attracts more readers and creates more revenue than science-focused articles. There is a need to change this mindset and interest in sensational news because it stops people from understanding and supporting science which affects how public views science and scientists. Another problem in science communication is the presence of two opposing groups of scientists framing controversial science topics in such a way that public has no idea who to believe,

which group is right, who to support. This leads to growing distrust in science and scientists. There is a need for scientists to communicate with public in such a way that they address their concerns, build the trust, engage the public, and educate them about important science issues that require attention and support.

Social media provides such opportunity. It provides a platform for scientists to engage with public directly. It provides an opportunity for scientists to frame science like science, to explain to public how machines are developed, how they function, and the scientific process. Social media provides an opportunity to blur the distance between public and scientists and encourage communication. Websites like YouTube, Facebook, Twitter offer the capability to share information in the form of videos, images, and texts and make topics engaging. The ability to get rapid feedback and broadcast live events also adds to the popularity of social media platforms. Most importantly, it offers public a stage to voice their opinion and be heard. Therefore, I decided to explore social media for this study.

CHAPTER 7
CONCLUSIONS, LIMITATIONS AND FUTURE RECOMMENDATIONS

7.1 Conclusions

This dissertation investigated YouTube, one of the most popular video-sharing social media platforms and examined how space exploration is framed in YouTube videos. It also examined user comments in response to those videos to understand public perceptions towards space exploration and the role of social media in it. Transcripts from videos published by NASA/JPL on YouTube were analyzed to identify frames that appeared in the portrayal of space exploration (Curiosity Rover Mission). Public comments in reaction to those videos were analyzed to understand their perceptions of space exploration and the role of videos in it. Framing theory was used to analyze the video transcripts and content analysis was used to analyze the user comments.

Results of this study indicate that most individual comments were positive in nature signifying liking and appreciation towards the science updates, rover, advancement in science, education, and thankfulness towards NASA/JPL. Even though the second most dominant tone of comments was negative, the topics discussed in those comments were not about a science topic or procedure. Most of the negative comments were either related to the song chosen by NASA to beam back to earth, conspiracy-related to Mars images, and physical appearance of scientists with very few comments on video content, science, or the rover itself. This indicates an inherent downside of YouTube in which it attracts all kinds of comments including inappropriate comments. In

some cases, it does not matter the type of content being shared. Even space exploration videos received fair share of negative comments and conspiracy theories. Both male and female scientists were insulted based on their appearances, although more women than men received such crude comments.

The results of parent comments analysis were not very surprising. The results of analysis reveal that most parent comments that provoked others to comment on them were negative in nature. The second most dominant category of comments that attracted attention was neutral in nature followed by positive ones. This is in line with the previous findings in literature where negative comments have been known to encourage YouTube commenters to comment on them. Most parent comments were only somewhat related to the content posted in the videos. This means that negative comments comprised of topics that were not directly related to the video content. Neutral parent comments were focused on asking questions about science and space exploration.

The results of child comment analysis were interesting. Six dominant tones emerged upon analysis of child comments. They are: (1) Neutral (2) Debate (3) Negative (4) Humorous (5) Positive (6) Sarcastic. According to the results, most responses to parent comments were neutral in tone. Majority of the comments under this category were responses to questions posted by parent commenter. These questions were somewhat related to the content posted in the videos. However, the new category "debate" indicates that many users confronted the original commenter about their comment/perspective on YouTube, especially the ones who posted insulting comments about NASA, Curiosity, Mars exploration, and conspiracy theories. Specific examples of

such instances are presented in the following paragraphs. The third most frequent tone was negative wherein commenters posted conspiracy theories and insults towards NASA. The number of humorous, positive, and sarcastic comments were low. YouTube videos and comments seem to play a significant role in encouraging interaction between public and science. Public do not always trust negative commenters who share conspiracy theories. Many commenters are aware of "trolls" and call them out during interactions. Seven frames have emerged after analyzing YouTube video transcripts: They are: Science Experiments, Curiosity Rover, Findings, Mars, Science Team Characterization, Success, and Communication and Engagement with the public. NASA's coverage of Curiosity mission has been found to focus more on the scientific and technical aspects of the mission rather than appealing to the emotions of the public unlike newspaper coverage of the mission which was found to sensationalize the mission and present more dramatic narrative to appeal to the public. It would be interesting to explore which of these frames are more persuasive in engaging and raising awareness of space exploration among public.

7.2 Limitations

The results of this study are based on the comments posted by YouTube users who watched the NASA videos on Curiosity Rover Mission and/or who wanted to communicate with NASA and/or other commenters on YouTube. As reported earlier, the number of views on each of these videos far outnumber the comments. Therefore, the results only indicate the perceptions of YouTube users who chose to comment on the videos and the sample size of that population is very small in comparison to the people

who watched these videos. A larger sample size of social media users need to be considered to generalize the findings of this study.

According to revised YouTube settings, video content shown to a user are altered based on his/her geographic location. For example, a YouTube user in the US will be able to see the videos trending in the US based on his IP address. In this case, his content location on YouTube is set to United States by default. Whereas by default a user in India will be able to see the videos trending in India based on his IP address. In this scenario, content location on his YouTube account will be set to India. This means that not all YouTube users around the world will be watching the trending NASA videos published on YouTube in the US. It also means that there is more likelihood of YouTube users from English speaking countries and/or users who have explicitly set the default content location of their YouTube content to US are more likely to watch and comment on NASA videos. Although the content posted by NASA on YouTube is visible worldwide, people from other countries must explicitly seek NASA videos on YouTube to watch and comment on them. This means that results of my study are reflective of perceptions from YouTube users mainly from English speaking countries than others. Although there is no way to determine the location of each user who has watched and commented on NASA videos, a NASA/JPL statistics report generated by a social video intelligence and analytics platform called BrandMaxima indicate that the top 5 subscriber locations of NASA/JPL YouTube channel are: United States, Brazil, United Kingdom, Canada, and Spain.

It is difficult to gauge the intent of the commenter on these videos through texts. Some comments are easier to categorize and understand than others. For example, positive comments are easier to distinguish with keywords such as “outstanding”; “great work”; “excellent”; and “love these reports”. However, there were many comments that had both positive and negative tones, and some comments that could be categorized as sarcastic as well as negative based on researcher’s understanding, bias, and cultural sensitivity. The rubric developed to categorize comments in this study reflects researcher’s understanding of the intent of the commenters.

7.3 Future Recommendations

There are myriad future directions of this research. My research explores how science information (in this case, space exploration) is framed by a national science agency, NASA on social media. In doing so, I have found specific patterns and trends in how NASA communicates with the public on YouTube. The understanding of these patterns and trends can be helpful in improving science communication in other government funded research areas as well as controversial social issues that require better public awareness such as climate change, infrastructure development, wild life resource management, genetically modified crops, healthcare, sex education, LGBT rights, evolution versus creationism education, and gun control to name a few. Although my research is based on how an American space agency (NASA) frames space exploration for the public, most of the issues mentioned above are global. The public all over the world is using social media to comment, learn, communicate, and share information with each other and with the government agencies. In this scenario, it becomes extremely

essential to understand their perceptions on government funded research programs because public perception is a key factor in policy formation in many countries around the world. Some of the questions I would like to address in the future are: How does the interplay between government framed information and public posted comments on social media (YouTube) influence people who chose to watch videos but did not comment, or who did not watch videos and only read the comments to form an opinion about an issue? How is government and news media framing science information on social media about climate change, healthcare, education, and other socially relevant issues? What are the most effective platforms in communicating science information to the public? Does public favor one social media platform over other for gathering science information on various issues and why?

Another important part of my research dealt with public comments in response to NASA videos on Mars Mission. The results uncovered that majority of the negative comments were conspiracy theories about NASA and its representation of information on YouTube, mostly about the pictures shared by NASA being untrue, black and white, and lack of videos. This reflects the current media landscape where the public is regularly fed conspiracy theories by popular "news" sources given a veneer of reputability by the current 2017 political administration; e.g. Alex Jones, Breitbart News, and one could argue Fox News. Some commenters even insulted women who presented news updates on YouTube based on their physical appearances. Although there were some insulting and disrespectful comments for male scientists, they were infrequent. Certain commenters (trolls) intentionally posted inflammatory comments to get more attention,

stir more discussion, malign NASA and their work. Previous research on the usefulness of comments have indicated that even a small fraction of "uncivil" comments have a great impact on readers in changing their perception about an issue. Although my research indicated that public who chose to respond to trolls did not believe the insults posted against NASA, this scenario raises a lot of questions: How is the public opinion swayed by factors such as conspiracy theories, negative comments, gender of the news presenters, and political affiliation of the viewers. Timing of an event is another crucial factor in influencing the public perception of an important issue, i.e. the public care more about an issue in the wake of an important event. For instance, the topic of climate change gets more attention in the wake of a hurricane (Harvey, Irma, Maria, 2017), the topic of space exploration gets more attention in the wake of an important space event (Cassini Crash 2017, Solar Eclipse, 2017, Launch of 104 satellites by one rocket by Indian Space Research Organization, 2017), the topic of gun control gets more attention in the wake of a mass shooting (Las Vegas Mass Shooting, 2017). It is crucial for government agencies to take advantage of such grand events to educate and encourage public about the relevance of scientific and social issues. Investigation of the above factors will help researchers understand some bigger questions such as: Is it even beneficial to enable comments section on important science videos posted by government agencies, do people who do not comment on videos and comments from social media users believe negative comments/fake information/conspiracy theories posted by trolls, how should government agencies deal with the problem of negative comments that have the power to influence public on a larger scale? In my dataset, there was only one

example where NASA directly responded to a public comment about enabling its like/dislike section. In this case, NASA chimed in to acknowledge that they have rectified the issue brought up by the commenter. In my dataset, NASA did not respond to any comments/questions/allegations on YouTube. It would be interesting to examine whether and when NASA and other government agencies would or should intervene to dispel large scale conspiracy theories, fake news, and misleading facts about them.

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APPENDICES

Appendix A: Glossary of Terms

Frames - Packaging of information to appeal to public values.

NASA – National Aeronautics Space Administration

Science Communication – Practice of communicating science information to educate public about scientific research, process, and findings. It includes science exhibitions, science journalism, or raising awareness about science via social media. Science communication also includes communication between scientists.

Social Media – Web-based applications that allow users to create, edit, and share information.

YouTube – A social media platform that allows users to create, upload, and share videos. It also allows user interaction in the form of comments, likes, dislikes, and sharing of videos.

Tone – Tone is a literary device used to convey the "attitude" of an author towards a topic to the audience. It is often conveyed through the choice of words by the author. Tone is a powerful tool to convey the sentiment of an author.

Appendix B: List of YouTube Videos

	Title	Link
1.	Mars Curiosity Rover Report (Aug.10, 2012)	https://www.youtube.com/watch?v=yKDBojlncss&index=43&list=PLE8C83FF0367EEF8C
2.	Curiosity Rover Report (Aug. 17, 2012)	https://www.youtube.com/watch?v=mz2eVthmNn4&index=42&list=PLE8C83FF0367EEF8C
3.	Curiosity Rover Report (Aug. 24, 2012)	https://www.youtube.com/watch?v=JhhueOO0iqU&index=41&list=PLE8C83FF0367EEF8C
4.	Curiosity Rover Report (Aug. 31, 2012)	https://www.youtube.com/watch?v=qj86ZqkxNpQ&list=PLE8C83FF0367EEF8C&index=40
5.	Curiosity Rover Report (Sept. 6, 2012)	https://www.youtube.com/watch?v=uRod4vTyzkg&list=PLE8C83FF0367EEF8C&index=39
6.	Curiosity Rover Report (Sept. 13, 2012)	https://www.youtube.com/watch?v=JQiB2Nkj6ng&index=38&list=PLE8C83FF0367EEF8C
7.	Curiosity Rover Report (Sept. 20, 2012): Tribute to Jake	https://www.youtube.com/watch?v=slOaSwcO1NE&list=PLE8C83FF0367EEF8C&index=37
8.	Curiosity Rover Report (Sept. 28, 2012) Mars Streambed	https://www.youtube.com/watch?v=HYHc2alzdUk&list=PLE8C83FF0367EEF8C&index=36
9.	Curiosity Report (Oct. 4, 2012): Rover Gets Set to Scoop	https://www.youtube.com/watch?v=I5b6KSTst-o&index=35&list=PLE8C83FF0367EEF8C
10.	Curiosity Rover Report (Oct. 12, 2012) Here's the Scoop!	https://www.youtube.com/watch?v=rLmHedIEbus&index=34&list=PLE8C83FF0367EEF8C
11.	Curiosity Rover Report (Oct. 19, 2012) Mars Soil Sample Delivered	https://www.youtube.com/watch?v=neUJ5y4hrkE&list=PLE8C83FF0367EEF8C&index=33

12.	Curiosity Rover Report (Oct. 26, 2012): Working with Curiosity's ChemCam Laser	https://www.youtube.com/watch?v=iDgv14Qtl1c&list=PLE8C83FF0367EEF8C&index=32
13.	Curiosity Rover Report (Nov. 1, 2012): First CheMin Results	https://www.youtube.com/watch?v=L70uKS_4wGM&index=31&list=PLE8C83FF0367EEF8C
14.	Curiosity Rover Report (Nov. 9, 2012): SAM Sniffs Mars' Atmosphere	https://www.youtube.com/watch?v=e6uWUrxuuok&index=30&list=PLE8C83FF0367EEF8C
15.	Curiosity Rover Report (Nov. 15, 2012): Wind and Radiation on Mars	https://www.youtube.com/watch?v=_0596IF-8s4&index=29&list=PLE8C83FF0367EEF8C
16.	Curiosity Rover Report (Nov. 29, 2012): Curiosity Roves Again	https://www.youtube.com/watch?v=QApb9l2JAbQ&index=28&list=PLE8C83FF0367EEF8C
17.	Curiosity Rover Report (Dec. 7, 2012): Rover Results at Rocknest	https://www.youtube.com/watch?v=dvrw486cFsI&index=27&list=PLE8C83FF0367EEF8C
18.	Curiosity Rover Report (Dec. 21, 2012): Curiosity's Martian Holiday	https://www.youtube.com/watch?v=tpeK_V5JLCk&index=26&list=PLE8C83FF0367EEF8C
19.	Curiosity Rover Report (Jan. 10, 2013): Giving Mars the Brush-off	https://www.youtube.com/watch?v=MVE1LaV5iMI&index=25&list=PLE8C83FF0367EEF8C
20.	Curiosity Rover Report (Jan. 18, 2013): Curiosity Finds Calcium-Rich Deposits	https://www.youtube.com/watch?v=U5pnfpRiwi8&list=PLE8C83FF0367EEF8C&index=24
21.	Curiosity Rover Report (February 15, 2013): Curiosity Drills on Mars	https://www.youtube.com/watch?v=YoGGdEpso84&index=23&list=PLE8C83FF0367EEF8C

22.	Curiosity Rover Report (Feb. 21, 2013): Curiosity Collects First Rock Sample on Mars	https://www.youtube.com/watch?v=yFfRhXxEeGk&list=PLE8C83FF0367EEF8C&index=22
23.	Curiosity Rover Report (Mar. 15, 2013): Rover Hits Paydirt	https://www.youtube.com/watch?v=UUVmyI9yjyU&list=PLE8C83FF0367EEF8C&index=21
24.	Curiosity Rover Report (April 12, 2013): Mars' Bygone Atmosphere	https://www.youtube.com/watch?v=B8OUL9QYNpI&list=PLE8C83FF0367EEF8C&index=20
25.	Curiosity Rover Report (May 9, 2013): 'Spring Break' Over: Commanding Resumes	https://www.youtube.com/watch?v=ft5gJbqdzfY&list=PLE8C83FF0367EEF8C&index=19
26.	Curiosity Rover Report (May 16, 2013): Rover Readies for Second Drilling	https://www.youtube.com/watch?v=YVwuOByJ5zw&list=PLE8C83FF0367EEF8C&index=18
27.	Curiosity Rover Report (June 7, 2013): Rover Ready to Switch Gears	https://www.youtube.com/watch?v=GH56wMh3FZg&list=PLE8C83FF0367EEF8C&index=17
28.	Curiosity Rover Report (June 13, 2013): Curiosity's Cameras	https://www.youtube.com/watch?v=b2rwWECbEHg&index=16&list=PLE8C83FF0367EEF8C
29.	Curiosity Rover Report (July 11, 2013): Trek to Mount Sharp Begins	https://www.youtube.com/watch?v=vluaivJqo9w&list=PLE8C83FF0367EEF8C&index=15
30.	Curiosity Rover Report (Aug. 23, 2013): The Odometer Keeps Turning	https://www.youtube.com/watch?v=ryZatqbdnDw&index=14&list=PLE8C83FF0367EEF8C

31.	Curiosity Rover Report (Sept. 19, 2013): Leave the Driving to Autonav	https://www.youtube.com/watch?v=kpqdCBiK1w8&list=PLE8C83FF0367EEF8C&index=13
32.	Curiosity Rover Report (Dec. 9, 2013): Dating Younger Rocks	https://www.youtube.com/watch?v=X-iqwAt2Qmk&list=PLE8C83FF0367EEF8C&index=12
33.	Curiosity Rover Report (Feb. 14, 2014): Rover's 5K Run	https://www.youtube.com/watch?v=PiBbFC4Isr0&list=PLE8C83FF0367EEF8C&index=11
34.	Curiosity Rover Report (6/24/2014): Curiosity Completes Its First Martian Year	https://www.youtube.com/watch?v=SSf1HenQhWs&list=PLE8C83FF0367EEF8C&index=10
35.	Flash from Curiosity Rover's Laser Hitting a Martian Rock	https://www.youtube.com/watch?v=r0cauXpMniw&index=9&list=PLE8C83FF0367EEF8C
36.	Curiosity Rover Report (Aug. 5, 2014): A Softer Trek to Mount Sharp	https://www.youtube.com/watch?v=g7wX-feyWac&list=PLE8C83FF0367EEF8C&index=8
37.	Curiosity Rover Report: We made it! Curiosity reaches Mount Sharp (Sept 11, 2014)	https://www.youtube.com/watch?v=7szg3JrNT-4&list=PLE8C83FF0367EEF8C&index=7
38.	Curiosity Rover Report: A Taste of Mount Sharp (Sept. 25, 2014)	https://www.youtube.com/watch?v=QWaUCFccvPk&index=6&list=PLE8C83FF0367EEF8C
39.	Curiosity Rover Report: The Making of Mount Sharp (Dec. 8, 2014)	https://www.youtube.com/watch?v=oS99yR1cooE&index=5&list=PLE8C83FF0367EEF8C

40.	Curiosity Rover Report (Feb. 12, 2015): Rover Walkabout	https://www.youtube.com/watch?v=IXSIZcj8WgA&index=4&list=PLE8C83FF0367EEF8C
41.	Curiosity Rover Report (May 8, 2015): Rover Road Trip	https://www.youtube.com/watch?v=MLFwOBnyvio&index=3&list=PLE8C83FF0367EEF8C
42.	Curiosity Rover Report (August 2015): Three Years on Mars!	https://www.youtube.com/watch?v=Txti0XLxOzI&index=2&list=PLE8C83FF0367EEF8C
43.	Curiosity Rover Report (Dec. 15, 2015): First Visit to Martian Dunes	https://www.youtube.com/watch?v=ur_TeOs3S64&list=PLE8C83FF0367EEF8C&index=1

Appendix C: Codebook for Frames

SL. No.	Codes	Explanation
1	Date of Publication of Video	Date when the video was published on YouTube by NASA/JPL.
2.	Introduction of Scientists	NASA Scientists sharing their name and which department they are associated with
3.	Designation	Designation of NASA Scientists
4.	Main Topic of the Video	Main concept discussed in the video
5.	Type of Information Shared and their description	Information Representation Types in the video (Text, graphics, animations, charts, diagrams, slides)
6.	Frames and their description	Key concepts discussed in the video
7.	Tone	Positive, Negative, Neutral Tones

SL. No	Frames	Sub Frames
1.	Science Experiments	Technical Words, Hypothesis, Tasks (Ongoing, Already Accomplished, Future), Goals, Reasons for Performing Experiments, Critical Information, Analysis, Testing, Exploration, Failures and Challenges.
2.	Curiosity Rover	What is Curiosity Exploring, Rover's Movement, Rover's Capabilities, Rover's Personality
3.	Findings	What are scientists looking at, What are they hoping to find, What they have found, Goal of the Mission, Similarities with Earth
4.	Mars	Mystery, Weather Conditions, Mars Target Points, Martian Beauty, Mars Surface Description, Mars Exploration History, Mars Atmosphere
5.	Success	First Time Activities, Successful activities
6.	Science Team Characterization	Name, Designation, Department, Scientists Role, What will scientists learn
7.	Communication and Engagement with Public	Humor, Connecting with the audience emotionally, Personal Stories, Inspiring Kids, Answering Public Questions, Setting Public Expectations
8.	Tone	Positive, Negative, Neutral Portrayal of Information

Appendix D: Codebook for Comments

SL. No	Comments	Codes
1.	Type of Comment	Individual, Parent, Child
2.	Topic Discussed	Topic discussed
3.	Tones	Positive, Negative, Neutral, Humorous, Sarcastic
4.	Relation with the video	Directly Related, Somewhat Related, Not Related
5.	Form of Comments	Statements, Words and Phrases, Statements and Questions, Questions

SL. No	Comment Tone	Explanation
1.	Positive	Comments showing appreciation, thankfulness, praise, love, pride, admiration.
2.	Negative	Comments showing hate, anger, use of abusive words, slangs, insults, conspiracy theories, arrogance, disrespect, undermining others, annoyance.
3.	Neutral	Lack of any strong positive or negative attitude/emotion.
4.	Sarcastic	Use of irony to mock and contempt others
5.	Humorous	Funny comments, jokes.

VITA

Priyanki Sinha was born in Kolkata, India. She came to University of Tennessee, Knoxville in 2010 to attend the PhD program in Communication and Information. Priyanki's major professor is Dr. Carol Tenopir, and her committee members are Dr. Suzie Allard, Dr. Devendra Potnis, and Dr. Harry Dahms. Her doctoral dissertation focuses on how science is framed on social media by science agencies to raise awareness of space exploration among public and how public reacts to such information by responding to the videos posted by NASA and comments posted by YouTube users. Her research focuses on how social media plays a vital role in creating awareness among masses about relevant science issues and how such platforms and strategies of presenting science information influences the public.