O'Brien, Hollie

Project M

NASA INSPIRE

Johnson Space Center

Dr. Timothy P. Crain

6/13/10— 8/6/10

GN&C Autonomous Flight Systems Branch, EG6

Abstract Body:

The basis of the project was creating a scale model representation of the Apollo 17 lunar landing site. Vital components included surface slope characteristics, crater sizes and locations, prominent rocks, and lighting conditions. The model was made for Project M support when evaluating approach and terminal descent as well as when planning surface operations with respect to the terrain.

The project had five main milestones during the length of the project. The first was examining the best method to use to re-create the Apollo17 landing site and then reviewing research findings with Dr. Tim Crain and EG staff which occurred on June 25, 2010 at a meeting. The second step was formulating a construction plan, budget, and schedule and then presenting the plan for authority to proceed which occurred on July 6, 2010. The third part was building a prototype to test materials and building processes which were completed by July 13, 2010. Next was assembling the landing site model and presenting a mid-term construction status report on July 29, 2010. The fifth and final milestone was demonstrating the model and presenting an exit pitch which happened on August 4, 2010.

The project was very technical: it needed a lot of research about moon topography, lighting conditions and angles of the sun on the moon, Apollo 17, and Autonomous Landing and Hazard Avoidance Technology (ALHAT), before starting the actual building process. This required using Spreadsheets, searching internet sources and conducting personal meetings with project representatives. This information assisted the interns in deciding the scale of the model with respect to cracks, craters and rocks and their relative sizes as the objects mentioned could interfere with any of the Lunar Landers: Apollo, Project M and future Landers.

The project concluded with the completion of a three dimensional scale model of the Apollo 17 Lunar landing site. This model assists Project M members because they can now visualize approach phase, terminal descent phase, and surface phase operations on the physical model. The project had an additional requirement that was also satisfied: the granite table the model was placed on must be returnable to its original condition if needed in the future.

The contributing parties for the project were Dr. Timothy Crain, Mr. Richard Mrozinski, Mr. Chet Lund, Ms. Linda Smith, Mr. Dean Eppler, Ms. Alissa Keil, Mr. Jake Sullivan, Mr. Chad Hanak, Ms. Sara Scarritt, Mr. James Maida, Ms. Narcrisha Norman, Ms. Angie Zavala and Ms. Jeanette Fanelli.

Residential Internship

Johnson Space Center

Project M: Scale Model of Lunar Landing Site of Apollo 17

O'Brien, Hollie

August 3, 2010

Reviewed By:

Dr. Timothy P. Crain

GN&C Autonomous Flight Systems Branch, EG6

Project M: Scale Model of the Lunar Landing Site of Apollo 17

Hollie O'Brien

Abstract

The basis of the project was creating a scale model representation of the Apollo 17 lunar landing site. Vital components included surface slope characteristics, crater sizes and locations, prominent rocks, and lighting conditions. The model was made for Project M support when evaluating approach and terminal descent as well as when planning surface operations with respect to the terrain.

The project had five main milestones during the length of the project. The first was examining the best method to use to re-create the Apollo17 landing site and then reviewing research findings with Dr. Tim Crain and EG staff which occurred on June 25, 2010 at a meeting. The second step was formulating a construction plan, budget, and schedule and then presenting the plan for authority to proceed which occurred on July 6, 2010. The third part was building a prototype to test materials and building processes which was completed by July 13, 2010. Next was assembling the landing site model and presenting a mid-term construction status report on July 29, 2010. The fifth and final milestone was demonstrating the model and presenting an exit pitch which happened on August 4, 2010.

The project was very technical: it needed a lot of research about moon topography, lighting conditions and angles of the sun on the moon, Apollo 17, and Autonomous Landing and Hazard Avoidance Technology (ALHAT), before starting the actual building process. This required using Spreadsheets, searching internet sources and conducting personal meetings with project representatives. This information assisted the interns in deciding the scale of the model with respect to cracks, craters and

rocks and their relative sizes as the objects mentioned could interfere with any of the Lunar Landers: Apollo, Project M and future Landers.

The project concluded with the completion of a three dimensional scale model of the Apollo 17 Lunar landing site. This model assists Project M members because they can now visualize approach phase, terminal descent phase, and surface phase operations on the physical model. The project had an additional requirement that was also satisfied: the granite table the model was placed on must be returnable to its original condition if needed in the future.

Introduction

On October 4, 1957, the world's first artificial satellite, Sputnik 1, was launched into orbit by the Soviet space program. In response to this, President Dwight Eisenhower signed the National Aeronautics and Space Act on July 29, 1958, establishing the National Aeronautics and Space Administration (NASA). The organization includes large-scale development, management, and operations to tackle concerns of strategic and technological importance to America. Since being created, NASA has directed space exploration for America.

NASA's achievements illustrated the United States' capacity to organize the resources necessary to make the greatest engineering achievements the world has seen in the last century. However, times have changed as many nations and companies are competing with NASA for dominance of space. The motivation is that more are realizing the importance of the technology spin-offs and the power of inspiring young people. The United States is a technical society that is severely falling behind in graduating engineers and scientists. To keep its top spot and keep drawing in the new generations to work for them, NASA needs to do something big. It needs a task that includes inspiring the next generation, simplifying agency procedures, creating innovative partnerships, building a workforce and demonstrating technologies. All of these working together will let NASA continue human exploration beyond low Earth orbit. NASA is being proactive as they have found a solution: Project M.

It sounds like a tale out of a science fiction novel: land a robot on the moon in 1000 days. However, this plan is actually the basis for Project M: land a humanoid robot on the moon in 1000 days. The "M" in Project M does not mean moon, rather it comes from the Roman numeral meaning 1000. It is symbolic and stands for the people that work on the project. They take on what tasks they are capable of and then complete the tasks in the allotted 1000 days. The Lunar Lander will transport the humanoid robot to the moon using new propellant technology: liquid methane and liquid oxygen. Armed with autonomous landing equipment, the Lander will demonstrate avoidance of hazards or obstacles while descending to the surface. When the Lander touches down, the robot can get to work doing the engineering tasks for which it was designed. Some examples include maintenance and construction; science of opportunity (using existing sensors on the robot); and simple student experiments. NASA is leading the project which means in-housing much of the work. NASA is also incorporating innovative processes. This means that they work hard to form new partnerships and find ways to get things done. A prime example of this is when they think of what they can do and complete it in a set time. Also, the project inspires students in Science, Technology, Engineering and Math (STEM).

The Engineering Directorate (EA) proposed Project M as a way to test out new technology being developed and to get engineers involved with hardcore engineering again. The technologies being integrated are LOX/LCH4 propulsion, the Autonomous Landing and Hazard Avoidance Technology Project (ALHAT) and Robonaut 2 (R2). The EA leadership thinks that by combining these technologies, they can maximize their benefits. The core technologies of ALHAT, R2 and propulsion were already funded and Project M just put them together to unite them toward a single goal. The project also utilizes many different teams of people joining together to work toward a single goal. This paper focuses on the landing part of the large project. Project M consists of a fast-track concept that demonstrates precision landing and hazard avoidance technology (developed in the ALHAT project) in a lunar landing flight. A scale model of the nominal landing site will aid in visualization of approach phase, terminal descent phase, and surface phase operations.

Research

The project was very technical: requiring research about moon topography, lighting conditions and angles of the sun on the moon, Apollo 17, and Autonomous Landing and Hazard Avoidance Technology (ALHAT), before starting the actual building process. This required using Spreadsheets, searching internet sources and conducting personal meetings with project representatives. This information assisted the interns with the scale of the model in respect to cracks, craters and rocks and their relative sizes as the objects mentioned could interfere with any of the Lunar Landers: Apollo, Project M and future Landers.

Moon Topography

The topography of the Moon is measured using laser altimetry and stereo image analyses. The most recent data about topography was obtained during the Clementine mission. The biggest visual facet features the giant far side South Pole called the Aitken basin. It stretches 2,240 kilometers in diameter which makes it the largest known crater in the Solar System. Other large impact basins include Imbrium, Serenitatis, Crisium, Smythii and Orientale. They all have low elevations and elevated rims in common. The highest elevations are found just to the north-east of the Aitken basin. Geologists have said the elevation could be due to thick ejecta deposits that occurred during an impact event. The elevations are about 1.9 kilometers higher on average on the far side than the near side.

Surface Slope and Craters

The first concern for landing takes in account the surface slope. When designing a Lunar Lander, the surface slope needs to be considered with regard to the center of gravity so it does not tip over. Unfortunately, all Lunar Landers to date have kept a relatively high center of gravity which makes them highly unstable and dangerous to land as the moon slope angles varies. Other concerns include the crater sizes and locations and prominent rocks. Most times, large objects can be recognized with pre-flight planning. However, some cannot. An example of this was when Apollo 15's *Falcon* (Figure 1) landed on a crater which resulted in it tilting nearly 10 degrees to its back left, just 5° below the maximum acceptable angle. It set down on the rim of a crater and damaged its engine bell. After examining the leg, the crew reported that it was the proximity of the lunar surface rather than the contact that was causing the damage due to the buildup of pressure inside the nozzle. The engine bell buckled uniform throughout. The lunar module was oriented 6.9 degrees pitch up and 8.6 degrees roll to the left which resulted in a tilt of 11 degrees. This required the Lunar Module Pilot to pull the deployment cable to seat the Lander.

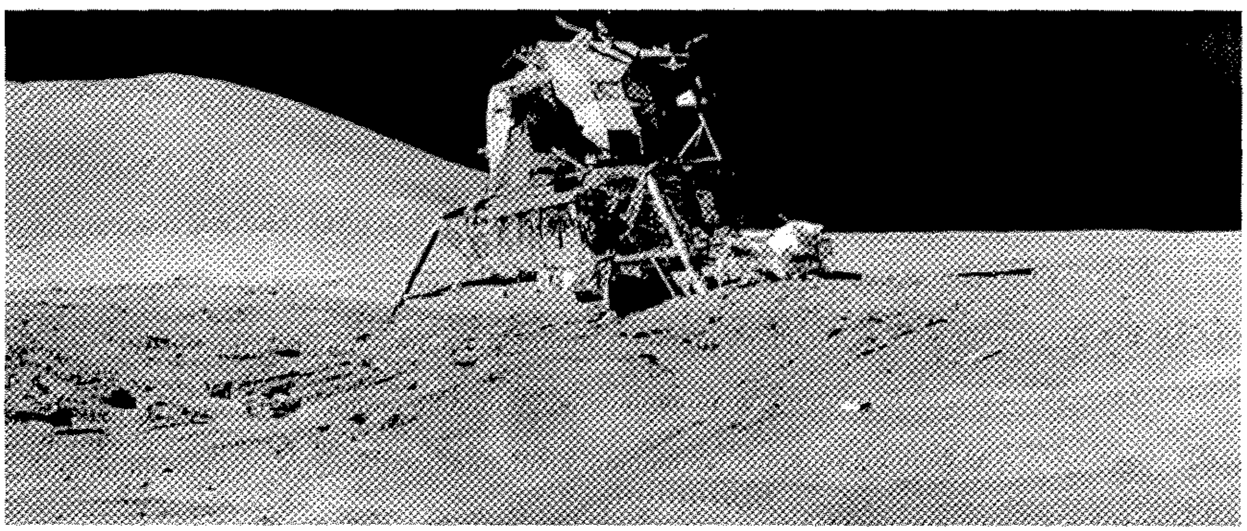


Figure 1. This picture shows the tilt of the *Falcon*.

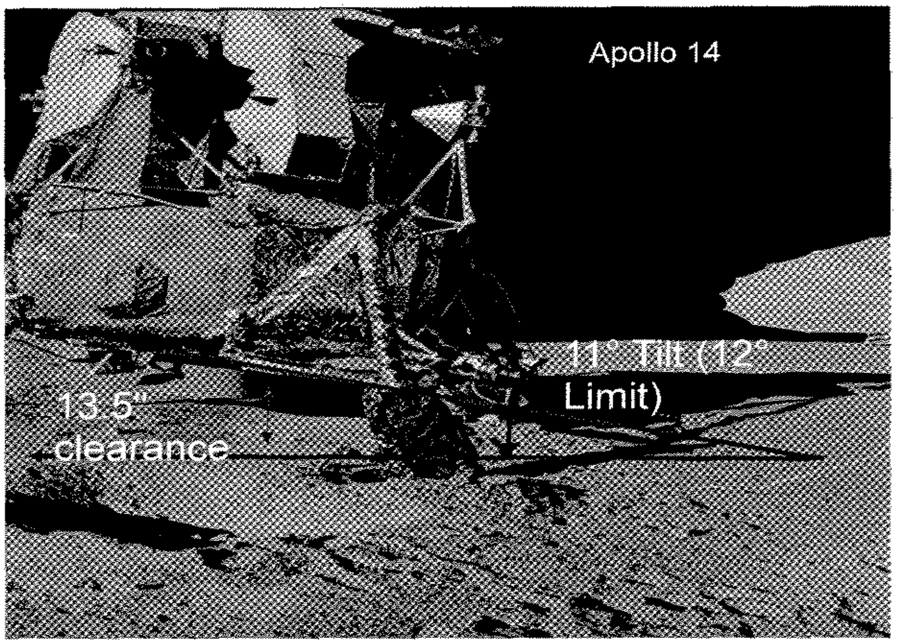


Figure 2. This shows the tilt of Apollo 14.

On the other hand, Apollo 14 was also tilted 11 degrees but had more clearance. The consequences that resulted from the tilt of the Lander were manageable because they were noticed primarily only during the sleep periods. However, the tilt interfered with the crew's sense of balance due to the fact that they felt that the Lander was going to topple over.

In general, the Lunar Module (LM) cabin worked as expected despite the cramped quarters and 11-degree tilt. However, the crew wrote in their report that if the LM had landed on terrain inclined more than about 12 to 15 degrees, difficulty would be experienced moving about the cabin.

Taurus-Littrow Valley

The Apollo 17 landing site is located in the Valley of Taurus-Littrow on the southeastern edge of the Sea of Serenity (Mare Serenitatis). About 3.8 billion years ago, a giant comet must have hit the moon at the Sea of Serenity as there is a blasted out 700 kilometer wide basin. Mountains and valleys were formed due this impact including the Taurus-Littrow valley. After these features formed, lava seeped from below the surface and filled the low places which give the surface its dark color. The variety of geology in the Taurus-Littrow contributed to it being chosen for the landing site. The crew could sample dark soil, lavas, and crustal material. A volcanic vent was also thought to have been there. Geologists also thought that the Sculptured Hills could be ejecta from the more recent Imbrium impact.

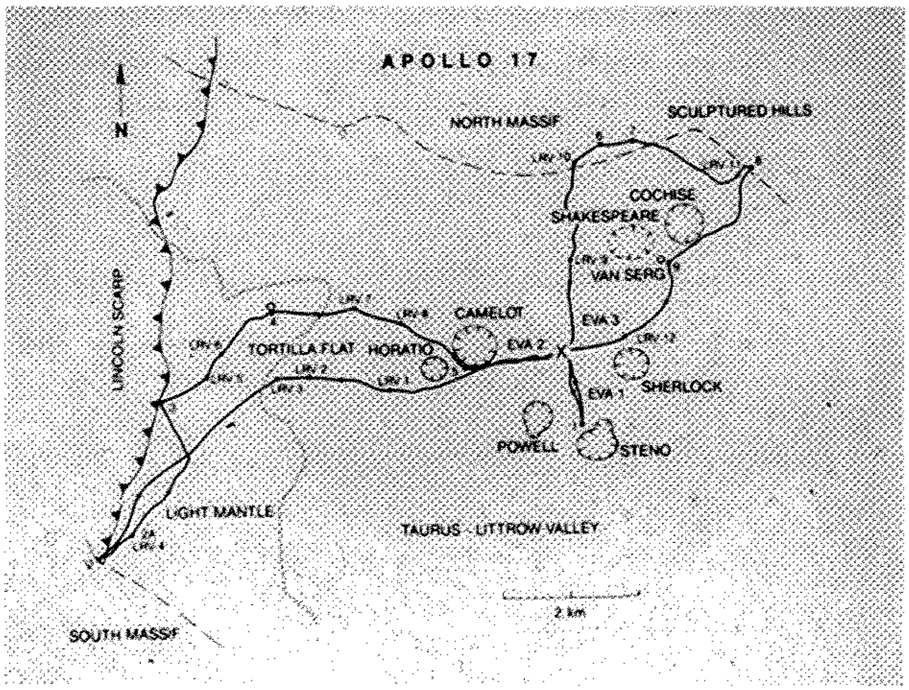


Figure 3. This is a map of the Apollo 17 landing site.

Taurus-Littrow points northwest towards the Mere Serenitatis. The East Massif is positioned at the valley's southeastern end. A narrow outlet is toward the south. The South Massif (Figure 3) is on the west side. Across the outlet to the north of the East Massif is the Sculptured Hills. The North Massif lies west of the Sculptured Hills. The gap between the South and North Massif stretches 7 kilometers wide but is blocked by a hill called Family Mountain and by a fault scarp that extends over 80 meters high in some places. Taurus-Littrow is not a large valley but still contained the landing ellipse safely.

Lighting Conditions

During the Apollo Program, limitations were implemented on lunar surface operations due to the sun. The astronauts could only "safely" be on the moon between early and late lunar morning. That meant only having from 24 to 96 hours after landing to complete their mission. No Apollo missions were planned or performed that would have extended beyond the lunar morning. No atmosphere covers the moon which means extreme temperature differences exist. It can drop down to -153°C during the night and rise to 107°C during the day. At the time of Apollo, the technology did not exist to have such resilient materials to be able to handle the differences for mid to low latitudes.

Albedo

One lunar day on the moon equals about 30 days. This means 327.5 hours equal a lunar day. 327.5 hours of sun hitting the surface with no clouds to cover the soil to keep it from baking in the heat means that heating is an issue but here it has no relevance. Right now, the Project is concerned with the rate at which the sun moves across the sky and how it affects shadows. The moon's surface is covered for the most part with the same color of soil uniformly. This becomes problematic when the sun is positioned over head and there are no shadows to distinguish between features. Besides that, the moon's surface is characterized by an albedo of .07 which means it reflects about 7% of all light that hits it. Albedo is defined as a measure of how strongly an object reflects light from light sources (i.e. the sun). Basically it means the same thing as reflectivity as it is the ratio of total-reflected to incident electromagnetic radiation. The array of possible outputs ranges from 0 (dark) to 1 (bright). The Earth is characterized at an albedo of 40%. While this is significantly higher, the important thing is that the Earth has vastly different colors, textures and soil components.

Apollo Requirements

During the Apollo Program, mission rules stated that all lunar landings had to happen when the Sun was placed between 5° and 20° above the horizon and behind the lunar module when it made its final approach to the landing site.

These conditions provided the maximum terrain information in the form of long shadows extending down-Sun from any significant terrain feature. It also ensured that the sunlight would not be in the astronauts' eyes during the final maneuvering for landing. It is assumed that similar mission rules will be in effect for future manned landings at unprepared landing sites. Looking at panoramic photographs from Apollo 15, Apollo 16 and Apollo 17 proves that as an observer gets closer to looking directly down-Sun, the view of local topography diminishes to virtually zero. In particular, the problem appears to become critical within 20° of directly down-Sun. This suggests that when the Sun is within 20° of the zenith, spacewalk activities may have to be curtailed due to a loss of shadows and connected poor surface definition. A loss of slope information also occurs due to poor color contrast in the bright sunlight. The conditions near sunset mimic the ones at noon because everything is in shadow.

Project M Lighting Conditions

In order to find the lighting conditions, resources besides the internet were needed. A spreadsheet (Figure 4) borrowed from a colleague was rendered necessary when it was realized it had all of the information needed to figure out the angle of the sun during each month, day and hour that the Project required to know. It included the coordinates (elevation and azimuth) of how to find the sun in the sky. (Figure 5) The horizontal angle measured clockwise from a north base line is called the azimuth. Elevation is described as the angle of altitude above the horizon.

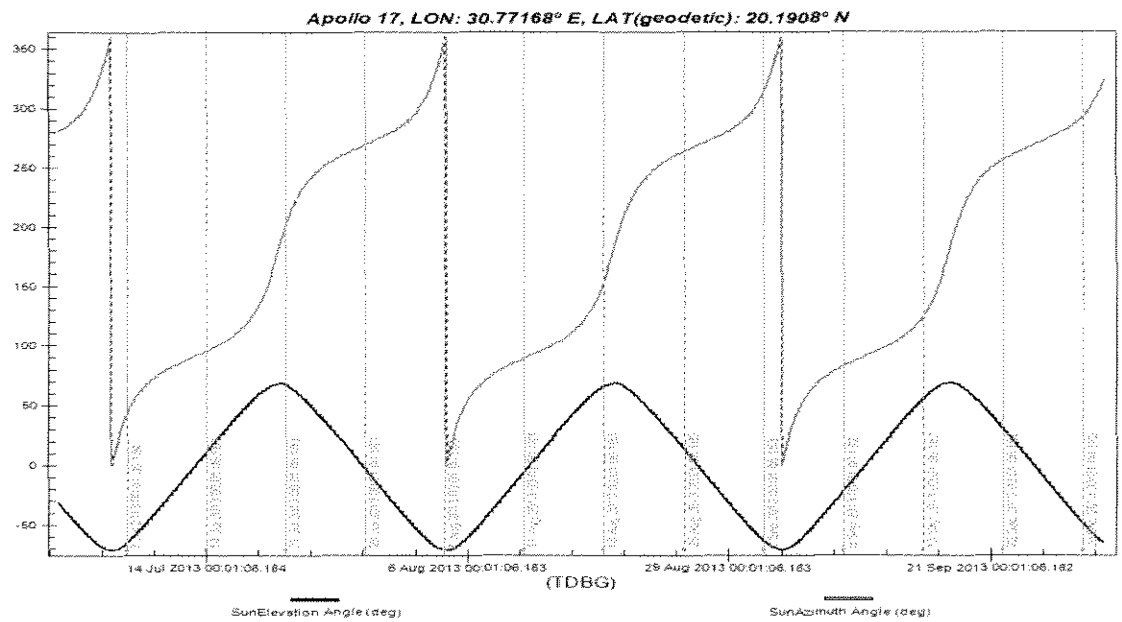


Figure 4. This graph summarizes 132,000 lighting and sun position data points into two functions: sine and tangent. They show that the moon is both: revolving around the sun and is rotating on its axis.

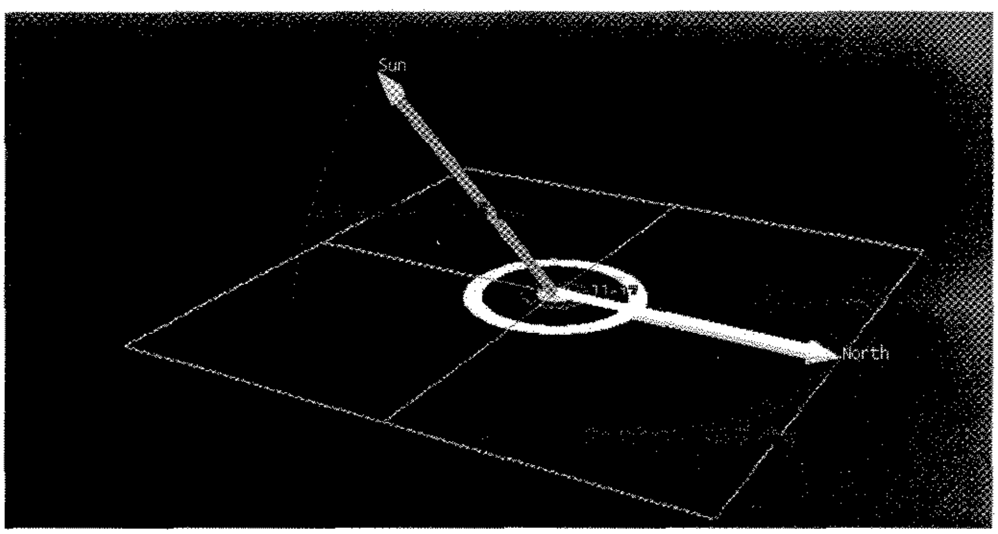


Figure 5. Shown is the placement of the sun on September 13th, 2013 at 11 AM. Due North is the Apollo 17 site.

Project M Considerations

Project M includes lighting in this scale mock-up for three reasons. The first is optical navigation. To land or navigate, shadows are needed to distinguish between land formations as this is difficult to do due to the likeness of surface color. Another is power and thermal. Most power on the Lander will come from solar radiation. This requires turning the panels toward the sun. Since Project M wants to inspire the next generation, the sun is also needed in order for the photography of the robot.

Apollo 17

Since Project M's lunar landing site is located where Apollo 17 landed, it was necessary to gain background knowledge on the mission. Apollo 17 landed in the Taurus-Littrow Valley to do many geological samplings. Many experiments were packed on board to help scientist learn about how the moon originated. Apollo 17 holds many titles: the most recent human moon landing, the most recent human flight beyond low Earth orbit, the longest human lunar landing flight, the longest total lunar surface extravehicular activities, the largest lunar sample return and the longest time in lunar orbit.

ALHAT

The Autonomous Landing and Hazard Avoidance Technology (ALHAT) Project is developing a software and hardware system capable of precision landing and hazard avoidance. It can be applied at any destination and is similar to autonomous rendezvous and docking. (Figure 6) To accomplish its task, it uses a laser altimeter and a flash Light Detection and Ranging sensor (LIDAR) to perform Terrain Relative Navigation (TRN) and Hazard Relative Navigation (HRN). This means it uses its full capacity to figure out if there are hazards, where the hazards are and where to go to avoid them. The first part is about recognizing hazards. The LIDAR uses remote sensing to create a three-dimensional digital elevation map that can be used to determine hazards to the landing vehicle. Software algorithms take this information and find the safest spot to land with minimal damage. The next step to ALHAT is arming it with a Doppler LIDAR velocimeter, an Inertial Measurement Unit (IMU) and updated software so that dust will not affect attaining the inputs for attitude, altitude, and velocity.

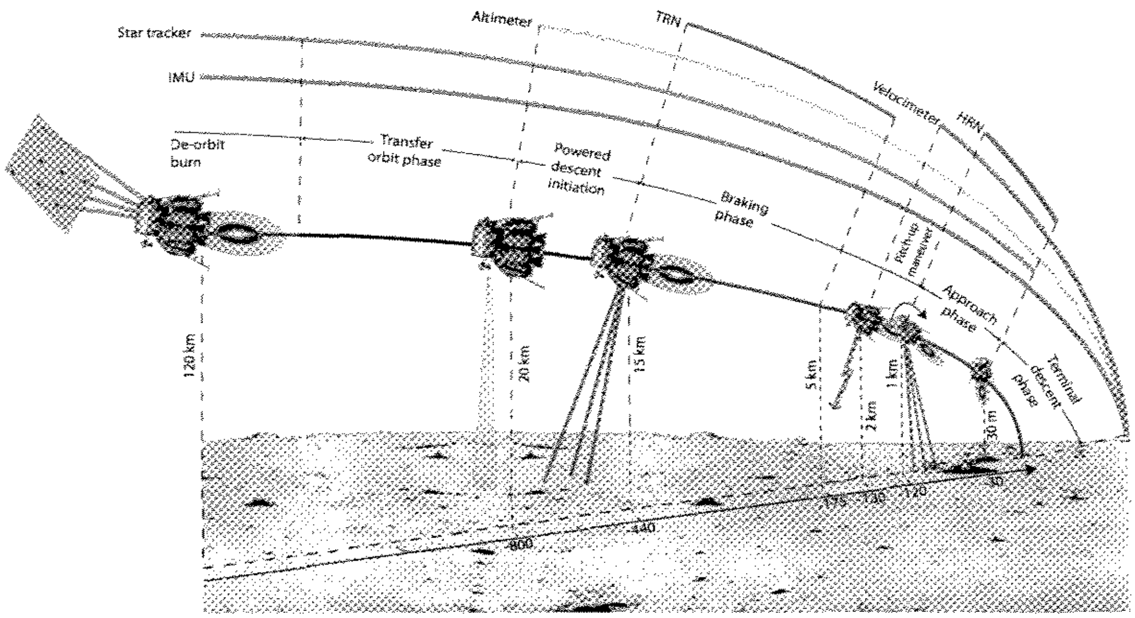


Figure 6. This shows the different ALHAT sensors used at different stages.

While Lunar Landers were successful during Apollo, there were certain risks taken with Apollo that NASA wants to minimize, regardless of whether the missions are planned to be crewed or un-crewed as safety is always the top concern for NASA. This explains why NASA is pushing ALHAT: it allows safe landing at any desired surface location under any lighting conditions. When Project M succeeds and lands safely on the moon, ALHAT will be better trusted and can move on to be used for future human or robotic vehicles at any destination.

Design

When making a model, one of the first things learned is starting from the ground up. The research showed that the model needed to be very accurate as Project M is looking for details on the surface. After concluding the research phase, it was decided to use plywood for the base. A meeting with Project M representatives showed the priorities of the project (i.e. how much detail to go down to and which craters needed to be shown).

Original Idea (Figure 7)

At first, the model would be built consisting of wire mesh on top of vertical pieces of contoured foam board. It included a plastic sheet covering the bottom to prevent messes. It also is comprised with "lunar soil" that consisted of baby powder, cement and charcoal. An advantage to this building design is the relative cheap cost and the weight being less than a solid clay model.

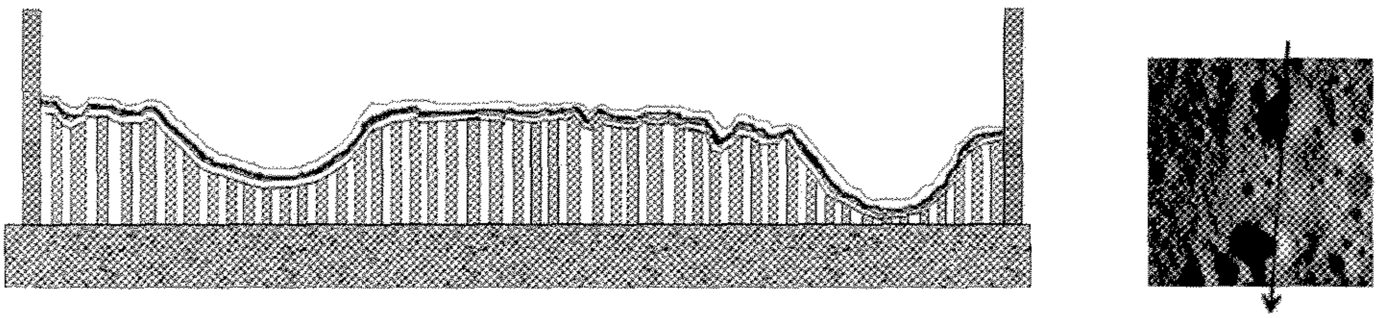


Figure 7. Here is a cut-away of the Apollo 17 Lunar Landing site using the projected plan. The cut-away includes the granite table, plywood sides, vertical contoured foam board, wire mesh, clay, and "Lunar Soil."

Scale

The scale of the mock-up changed numerous times during the design process. This was caused by the ongoing research process. At first, a 10 kilometer by 8 kilometer size was suggested. However, this was realized to be extremely too large. Then, a 3 kilometer by a 3.5 kilometer picture was suggested for design. This also was too big to fit Project M's purposes as the mock-up deals with the last two phases: Approach and Terminal Descent Phases (Figure 8). That phase will last between 1.5 to 3 minutes. The mock-up needed to show not only the landing site, but also the whole landing ellipse.

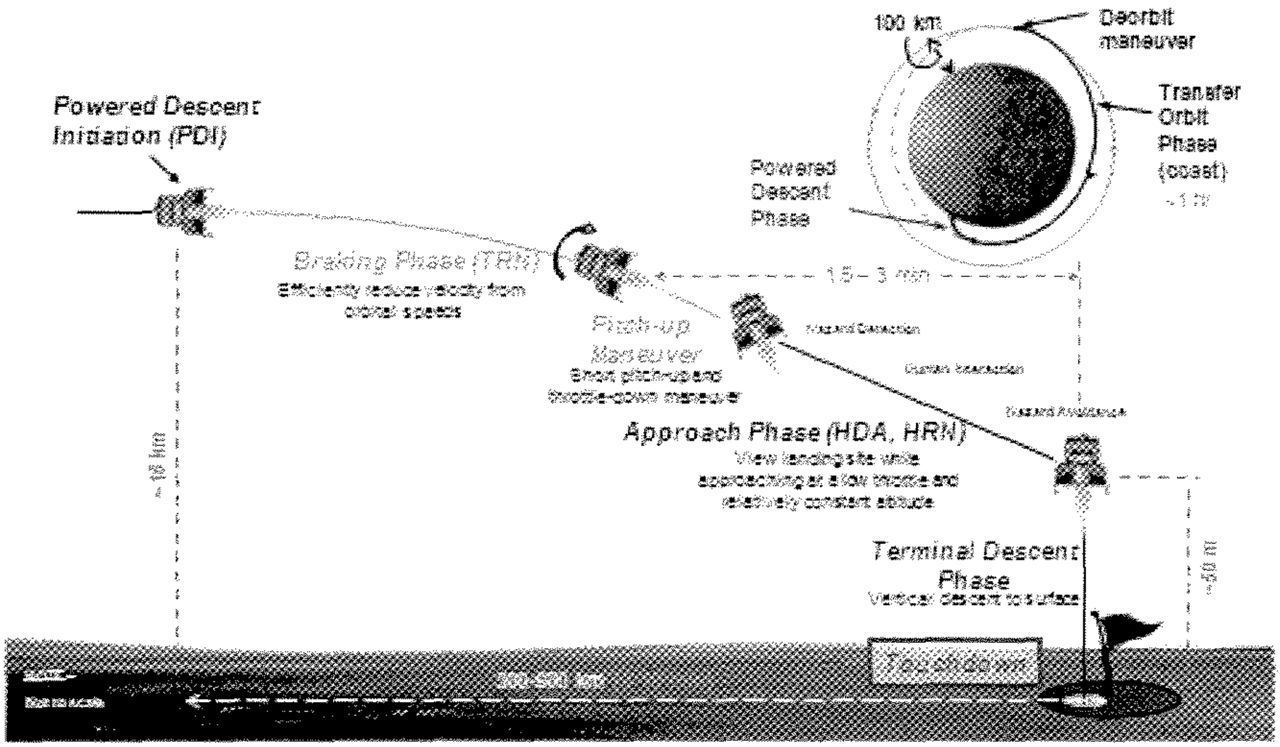


Figure 8. There are many parts of an ALAHAT lunar landing. The project focuses on the last 2: Approach and Terminal Descent Phases.

A concern about the landing size was voiced when deciding the scale. The Lunar Lander is defined as a precision Lander (Figure 9) and wants to land in the first yellow circle (precision diameter). However, because of tracking hazards, it could land in the 2nd yellow circle (total diameter). The small green circle is the size of the Lander. The scale is based off this after seeing the diameter of landing: a mere 200 meters. Project M is interested in accuracy due to the hazards the mock-up is trying capture.

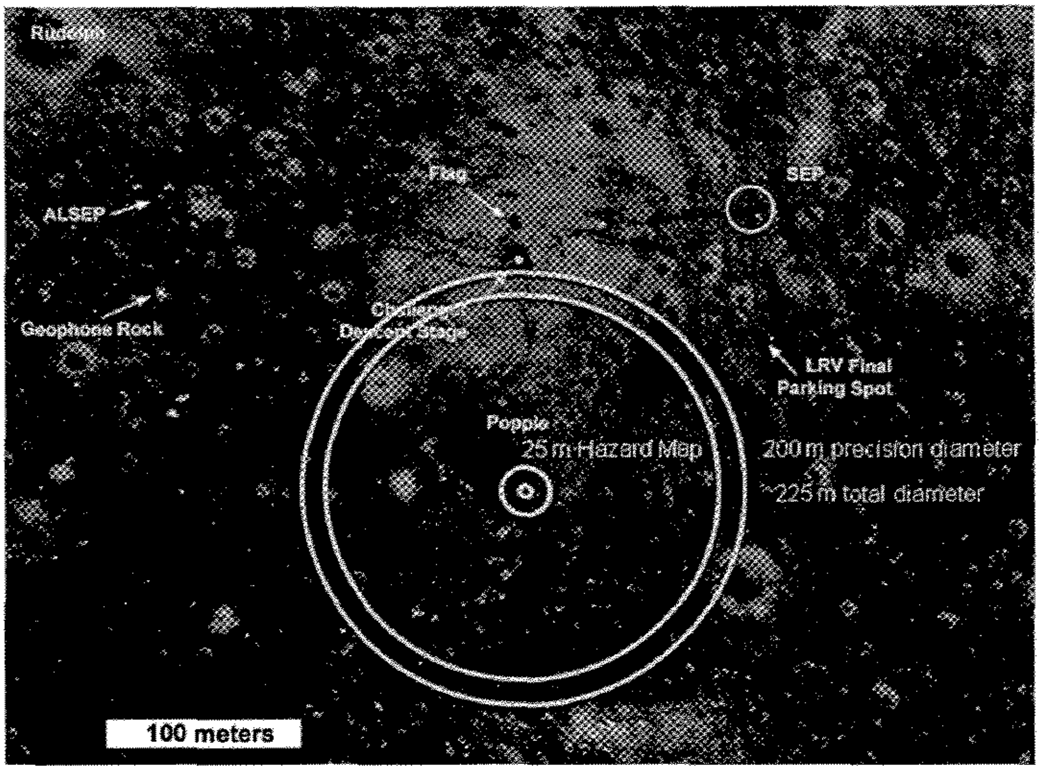


Figure 9. The precision landing site the scale of the model is based off.

Materials

Plywood was decided for the structure pieces. This was decided for many reasons. Plywood is characterized by being strong and flexible. The mock-up needed something to stabilize it but yet not hold it back if it needs to change. A solid clay layer was thought about and experimented with but was decided against due to the extreme weight. A solid clay layer is sufficient for small models but not for the large mock-up as calculations of how much was needed reached over 2 tons. After that, the choice pointed to plywood with some foam board for structural support.

After it was decided that foam board was to be used to help make the topography, a process of how to cut it was needed. Only one answer was found: drawing the contours on by hand using many different resources. One resource aiding in the contouring was a grid system of the landing site. This allowed the whole process to be very organized. The page was measured and marked to ensure correct spacing.

After using the grid (Figure 10), a topographical map from a birds-eye view was used to find the elevations of the cross-sections. The third resource consisted of a detailed elevation view of the 3 major craters at the site. This helped to make the model accurate.

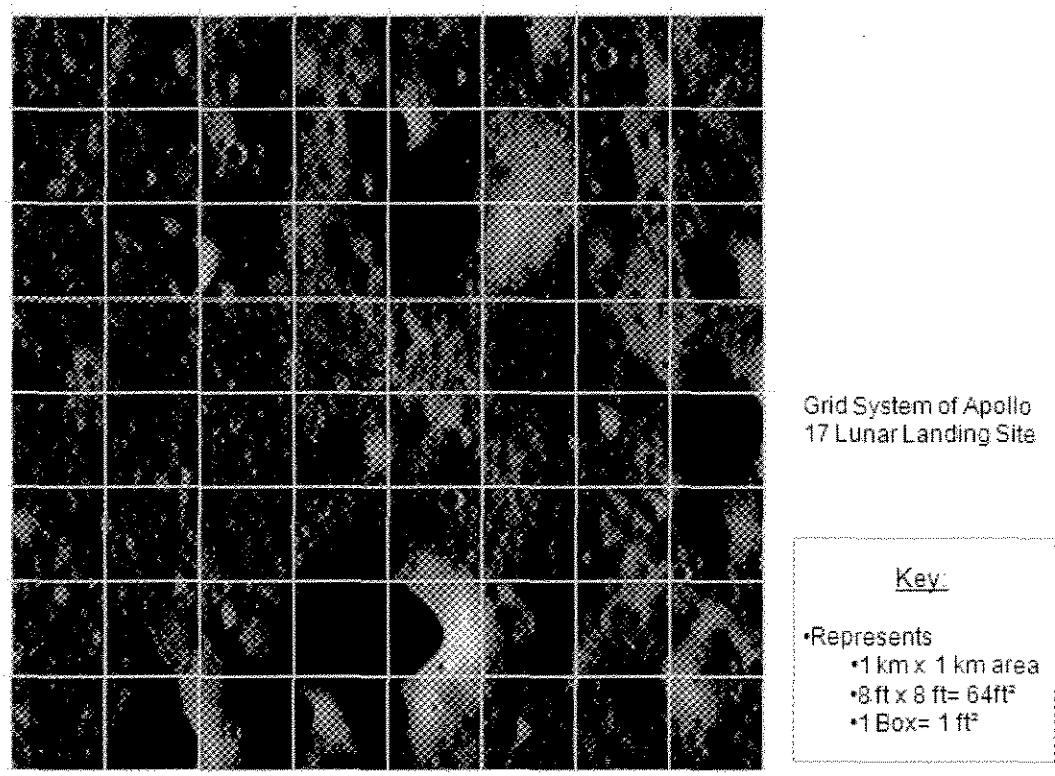


Figure 10. A Grid System of the Apollo 17 Lunar Landing Site.

On top of the foam board, wire mesh was attached. "Lunar Soil" was sprinkled on top of the wire mesh. The soil consisted of Portland cement, baby powder and charcoal powder.

Project Build Presentation

In order to start building, the idea had to be approved by the project mentor and supervisor. This was one of the most challenging parts of the whole project because the original idea morphed into a new but better one in the span of minutes. The only other concerns to address were safety. These were solved by making a Safety Plan of Action (SPA) and getting the Material Safety Data Sheets (MSDS) lined up.

Some concerns dealt with crawling on the table. However, this problem was fixed by building the model on the floor. To lift it on the table, the project utilized multiple people lifting it on the table with proper lifting techniques. All of the safety concerns were dealt with and safe practices were used to build the model. After re-designing the model and filling out the necessary paperwork, a prototype was built.

Prototype

Building

The Prototype tested materials and build techniques. The prototype was constructed in full scale but was only 2' by 2' (Figure 11). It used the building procedure explained before except with one exception: it added a plywood bottom to ensure it would not topple over. One extra addition to the build part included the corner section. Many different ways of connecting the plywood pieces were tried. The one that was used was a system of a one foot vertical 2" by 2" nailed into each wall in the corner: two sides and the floor board.

Figure 11. The Finished Prototype is pictured.

Results

Many lessons were learned as a direct result of building the mock-up. One included how exactly to cut foam board as it could split very easily. Another result determined that a structure support system between each foam board helps align them horizontally and vertically. At first, a V shaped cut in a square was tried but it failed as it was not stable enough to use in the model. The decided answer was the square struts. That was a good decision to choose because it made the model very solid and structurally stable. While attaching the wire mesh, it was discovered that it was more resilient than first planned. Staples were tried but they failed. Out of frustration, a nail was stuck through the mesh into the foam board. Surprisingly, it worked. That method of attachment was carried on to the next part of the project.

Full Scale Mock-up

Building

Once the plan was approved, another round of material pricing began. This included looking up prices for every material needed, planning out the phases of construction and printing out all the topographical maps needed to contour. The first materials acquired were the foam boards. Cutting all of them into usable sizes took a large amount of time due to the precision needed. As it turns out, one inch on the model equals 10.42 meters on the moon. Getting off, even a half inch, meant changing the landscape by 5 meters. This is significant because of the level of accuracy is due to the hazards and changing the landscape would affect the Lander and its tilt. After cutting the boards into 192 2' by 10" sections, they were contoured. This required not only precision cutting but also very detailed drawing. Every inch on the board required a data point. After drawing over 20 data points on each board, lines were added to connect them realistically. Following this, 4 boards were connected to create a long contoured foam board that was 8' long. (Figure 12)

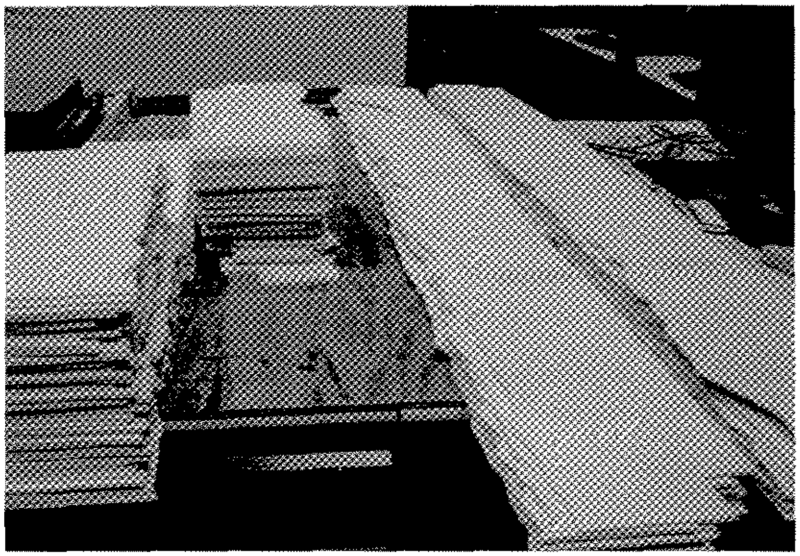


Figure 12. This shows the foam board struts after contouring.

After they dried, struts were connected every 4 inches to ensure strength and stability for the foam board. Wire mesh was then connected. (Figure 13)

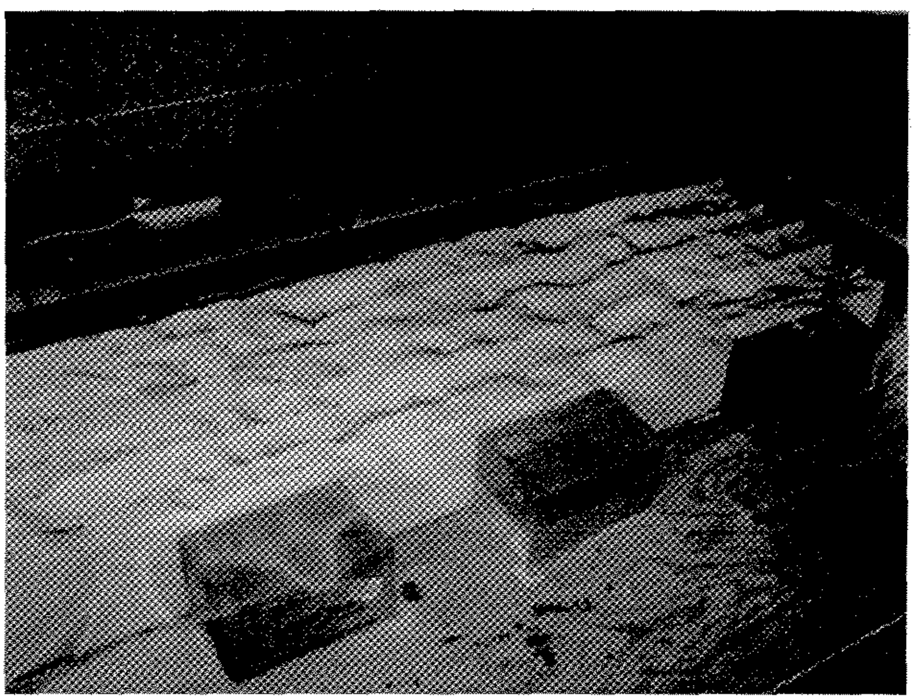


Figure 13. Here is a picture showing the method of building in phases.

Clay was applied but dried and curled at the end. This would not do well for the model so plaster cloth was swapped instead of the clay. After this, the "Lunar Soil" was dropped on top and the model was moved to the table. (Figure 14)

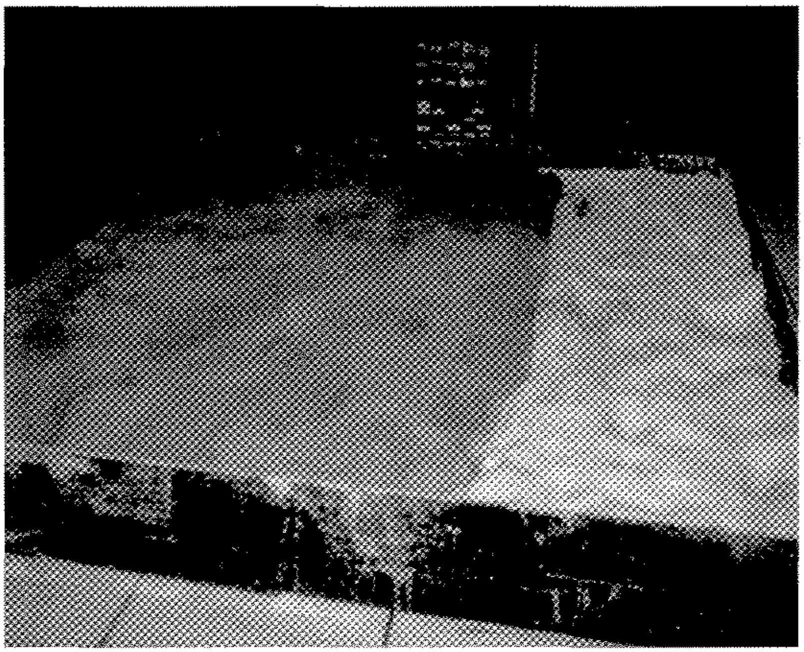


Figure 14. This shows the model right before moving to the table.

Problems

One of the problems that occurred was with the clay. Oil-based clay was required to ensure that the model did not crack or lose its shape. However, because of time restraints, the clay needed to be bought locally. The only clay found locally in the bulk required was clay that required baking. While the clay was tried on the model, it did not work. So, another source was found: plaster cloth. It was decided to go with a design of vertical contoured foam board with wire mesh nailed on top. After this, plaster cloth was soaked in water and overlaid.

Results and Conclusion

The model got completed to the greatest sense of accuracy that was capable in the eight week time span. The albedo ended at 19% which was close to its goal of 7-12%. The model meets all requirements and expectations that were explained before building it. The design worked well.

However, in future models of this sort, more time would be recommended to ensure that delays are accounted for. Another thing to do in the future is to make sure the plaster dries completely before putting on the "Lunar Soil".

Acknowledgements

The contributing parties for the project were Dr. Timothy Crain, Mr. Richard Mrozinski, Mr. Chet Lund, Ms. Linda Smith, Mr. Dean Eppler, Ms. Alissa Keil, Mr. Jake Sullivan, Mr. Chad Hanak, Ms. Sara Scarritt, Mr. James Maida, Ms. Narcrisha Norman, Ms. Angie Zavala and Ms. Jeanette Fanelli.

Project M: Scale Model of Lunar Landing Site of Apollo 17

Hollie O’Brien

INSPIRE Tier 2B Intern

Exit Presentation

Mentor- Dr. Timothy Crain

Overview

- INSPIRE
- About Me
- Project
- Challenges
- Activities
- Lessons Learned
- Future Plans
- Acknowledgements
- Questions

INSPIRE

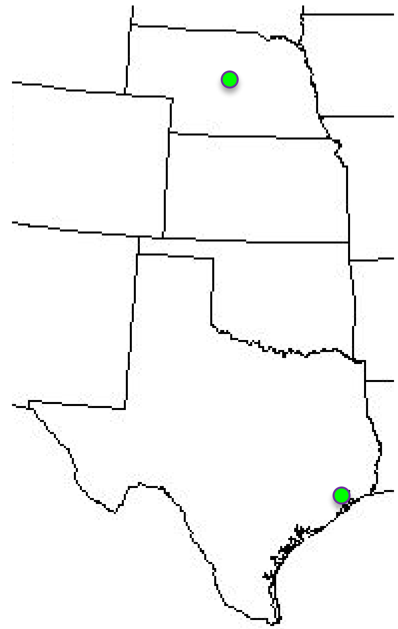
What is it?

– **I**nterdisciplinary **N**ational **S**cience **P**roject **I**ncorporating **R**esearch and **E**ducation
  - Online Learning Community
  - Multi-tiered year-round program
  - 9^{th}-12^{th} grade Students Interested in STEM
    - Science
    - Technology
    - Engineering
    - Math

Residential Internship Students

About Me

- Born and Raised
  - Ord, Nebraska
- Attend
  - Arcadia High School
    - Rising Senior
  - Involved
    - Volleyball, Basketball & Track
    - Quiz Bowl & Science Olympiad
    - FCA, Youth Congress & NHS



Hollie M. O'Brien

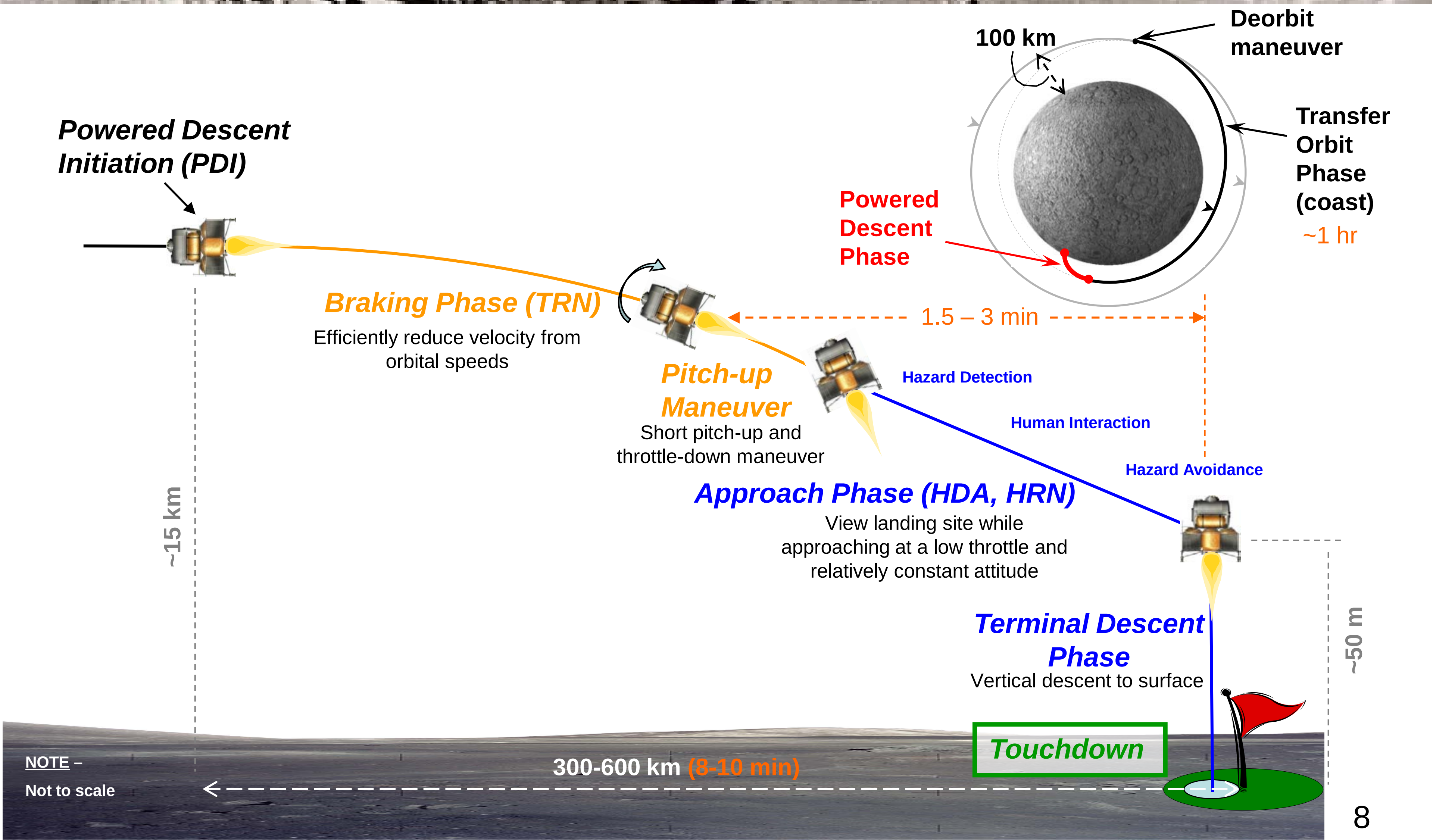
EG6: Guidance, Navigation & Control

- Engineering Directorate
  - EG Aeroscience and Flight Mechanics Division
    - EG6 - GN&C Autonomous Flight Systems Branch
      - Project M
    - NSTL (Navigation Systems and Technology Lab)

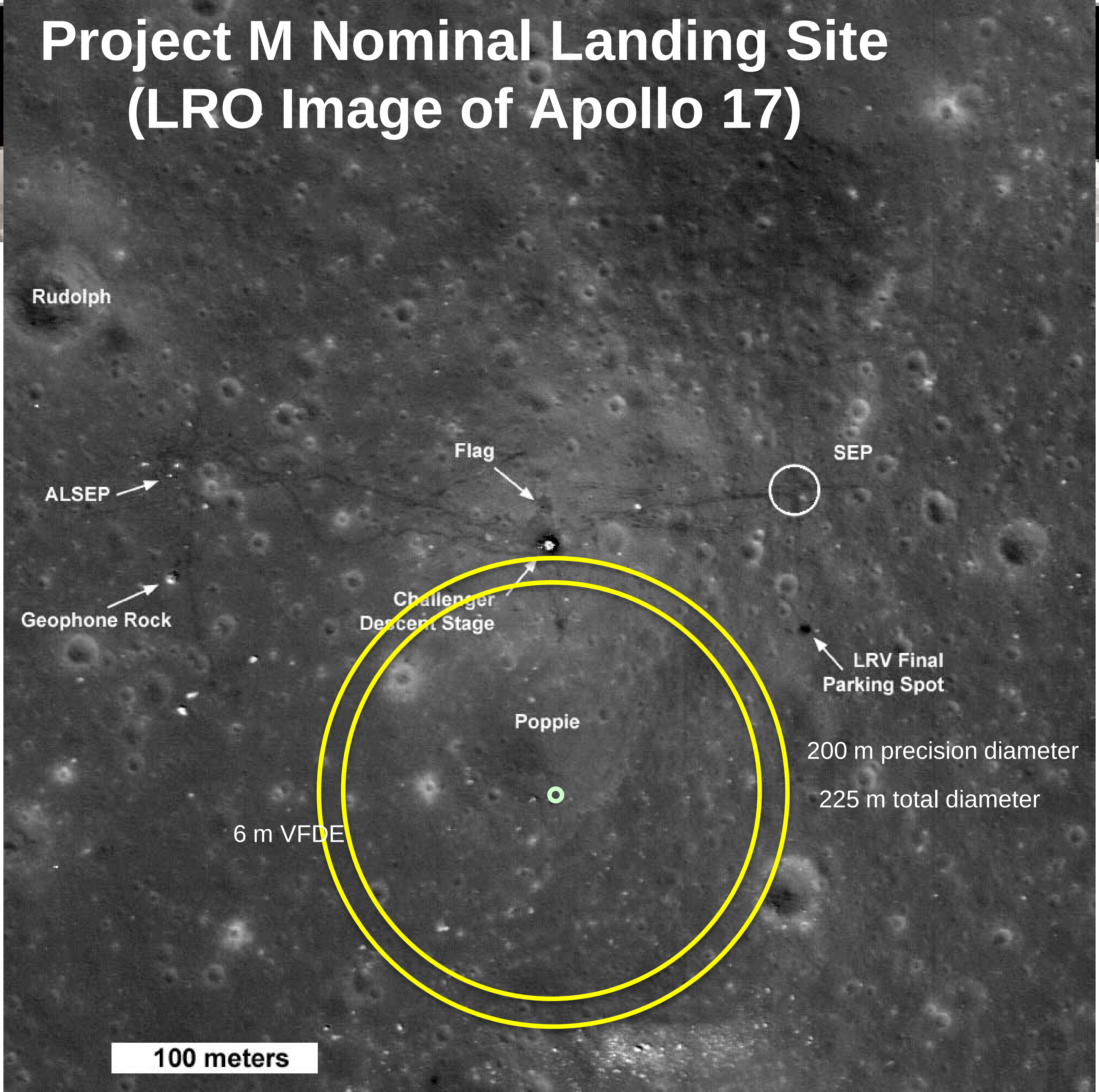
Project M

- Land a Lunar Lander on the Moon With Robonaut 2 Within 1000 Days
- Project Specifics
  - NASA Led
  - Innovative Approaches
  - Inspires Students in STEM

DESCENT & LANDING PHASES



Project M Nominal Landing Site (LRO Image of Apollo 17)



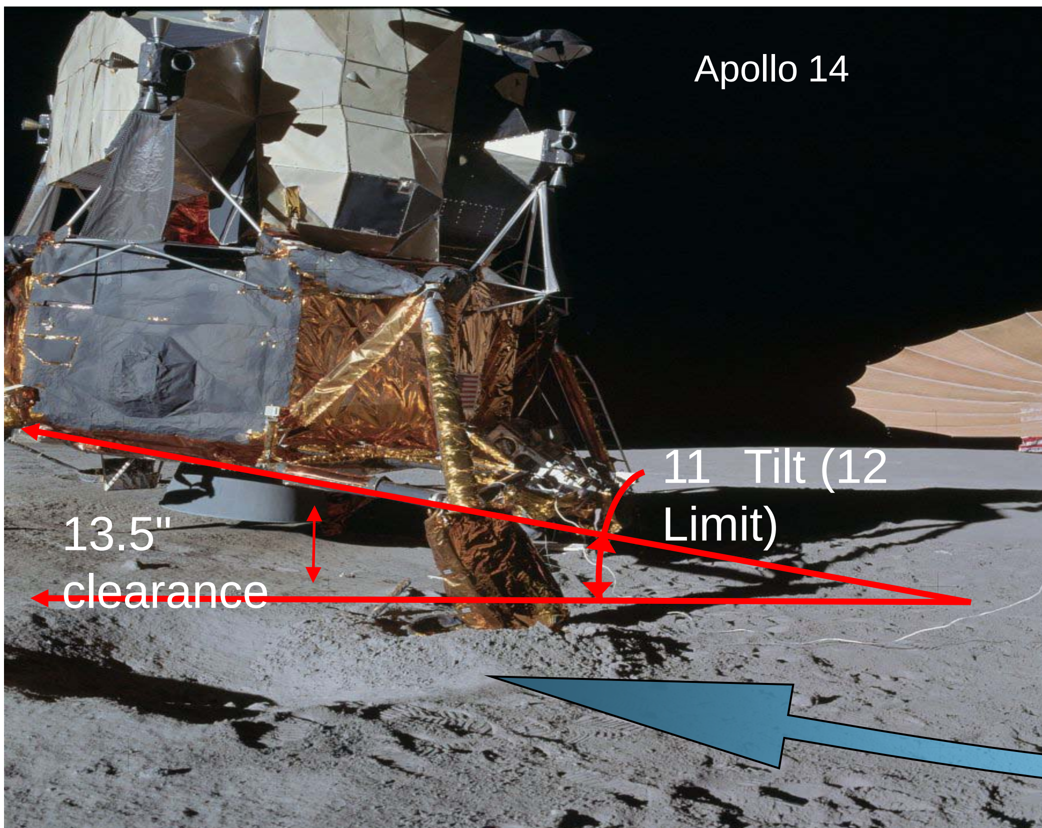
My Project

Overview:

- Build a Scale Model Of Apollo 17 Landing Site in XL Days
  - Helps Project M Visualize The Landing Site
  - Key Elements In This Model
    - Surface Slope Characteristics
    - Crater Sizes and Locations
    - Prominent Rocks
    - Lighting Conditions

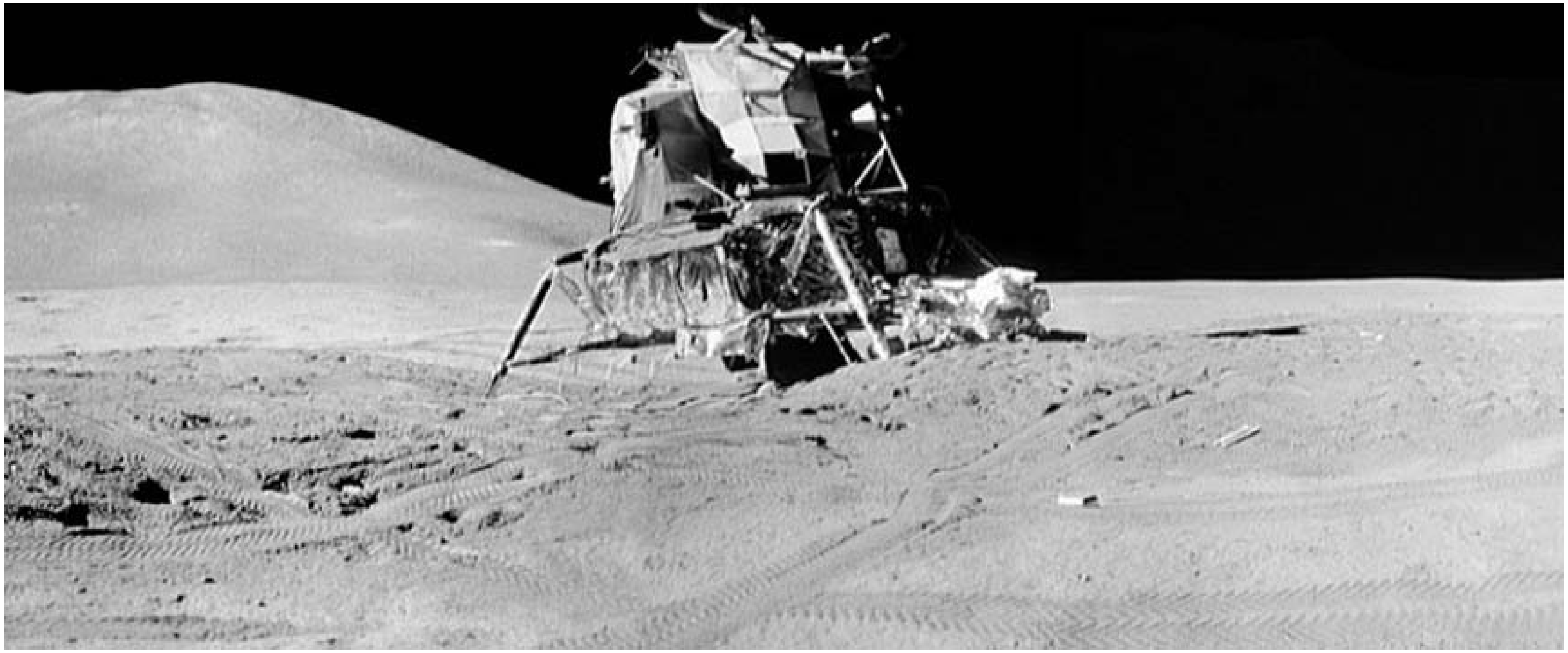
Key Hazards

Some hazards are recognizable during pre-flight planning.



However,
Some are not.

Key Hazards

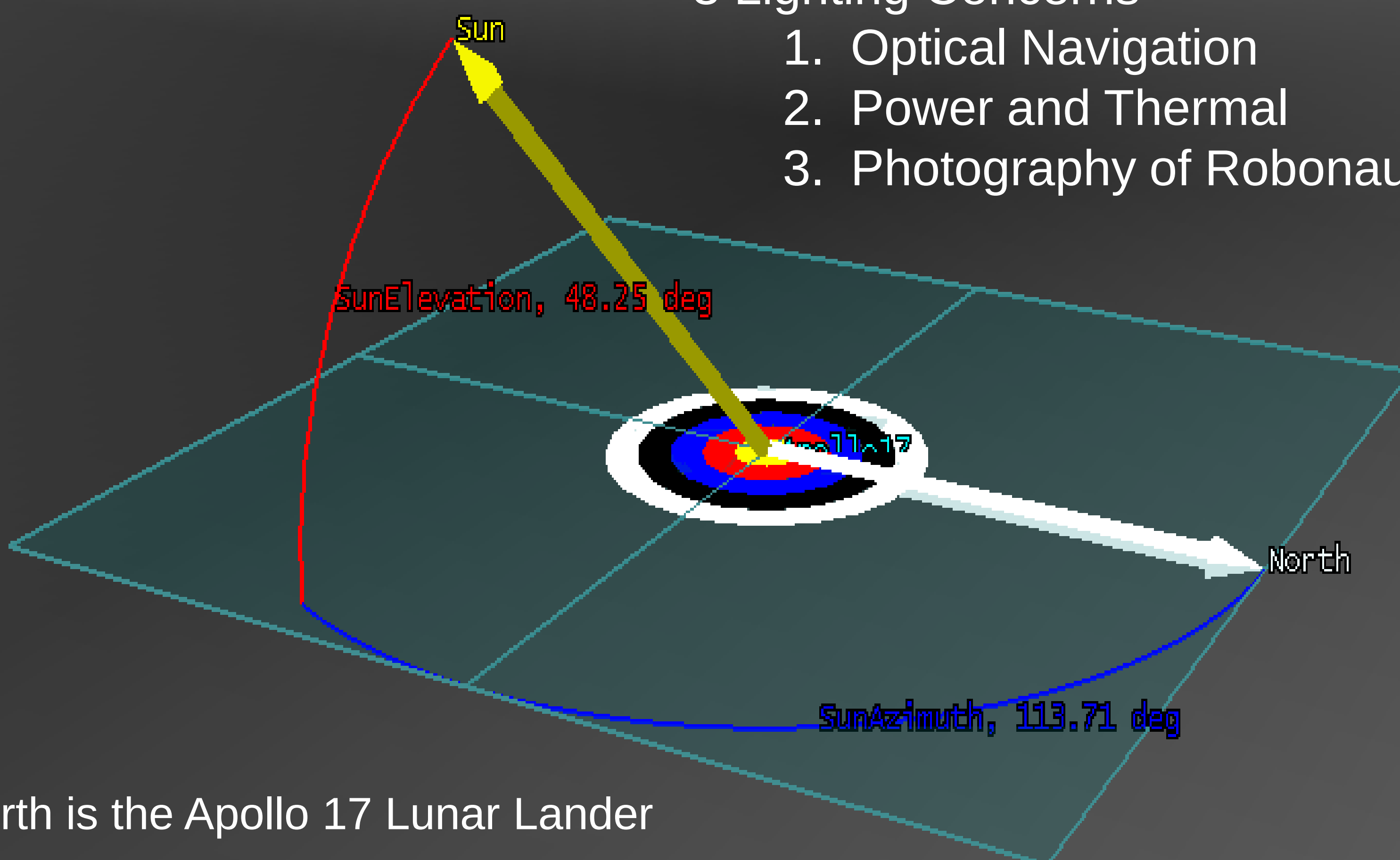


- Set down on rim of small crater
    - Damaged the engine bell and tilted at 10º
- Engine bell was crumpled and supported Lander

Project Lighting

3 Lighting Concerns

1. Optical Navigation
2. Power and Thermal
3. Photography of Robonaut 2



Due North is the Apollo 17 Lunar Lander

Major Milestones

1
- Review research findings
- On June 25, 2010

2
- Review of construction plan
- On July 6, 2010

3
- Construct miniature model
- On July 15, 2010

4
- Construction status report
- On July 21, 2010

5
- Model demonstration and exit presentation
- On August 4, 2010

Research

Preliminary Research

- Moon Pictures
- Topography Maps
- Material Ideas

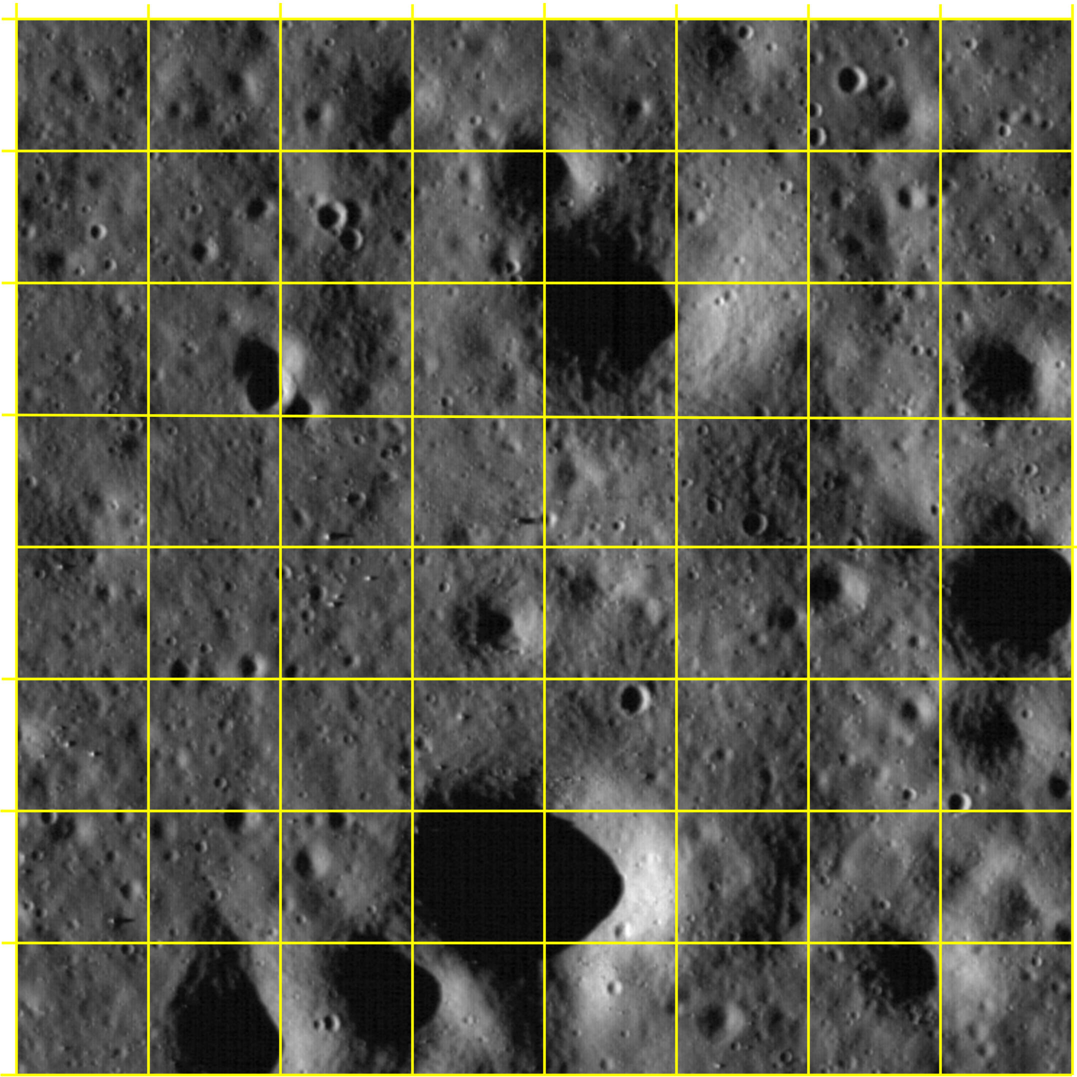
Personal Meetings

- Mr. Dean Eppler
- Mr. Chad Hanak
- Mr. Chet Lund

Project M Presentations

- Scale
- Technical Information
- Graphics

Grid Determination



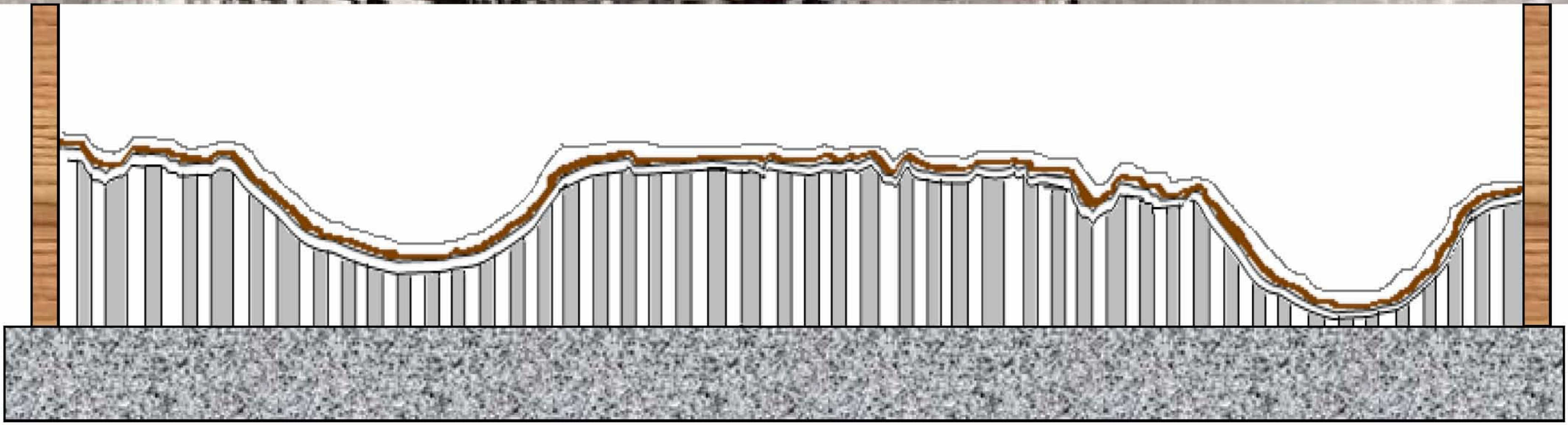
Developed Grid System of Apollo 17 Lunar Landing Site For Scale

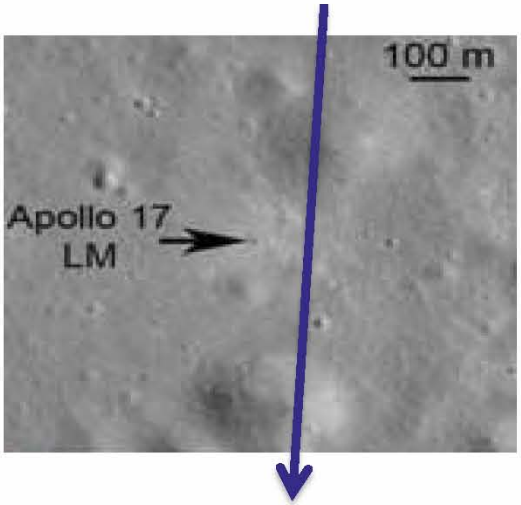
Key:

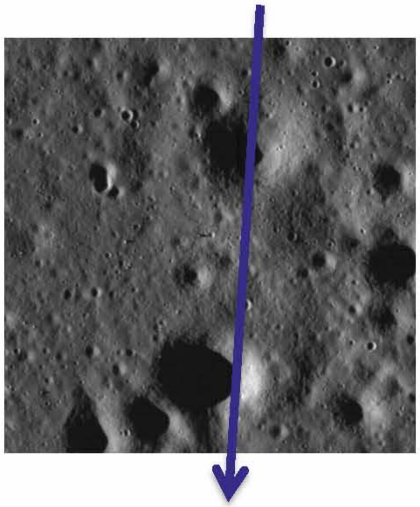
1 in = 10.42 m

- Represents
  - 1 km x 1 km area
  - 8 ft x 8 ft = 64ft²
  - 1 Box = 1 ft²

Project: Cross- Section







Project: Building Supplies

- Plastic Sheet
- Plywood
- Foam Board
- Wire Mesh
- Clay
- "Lunar Soil"
  - Cement
  - Charcoal
  - Baby Powder
- Hair Spray

Build Plan

Plywood Foundation

Foam board

Wire Mesh

Plaster Cloth

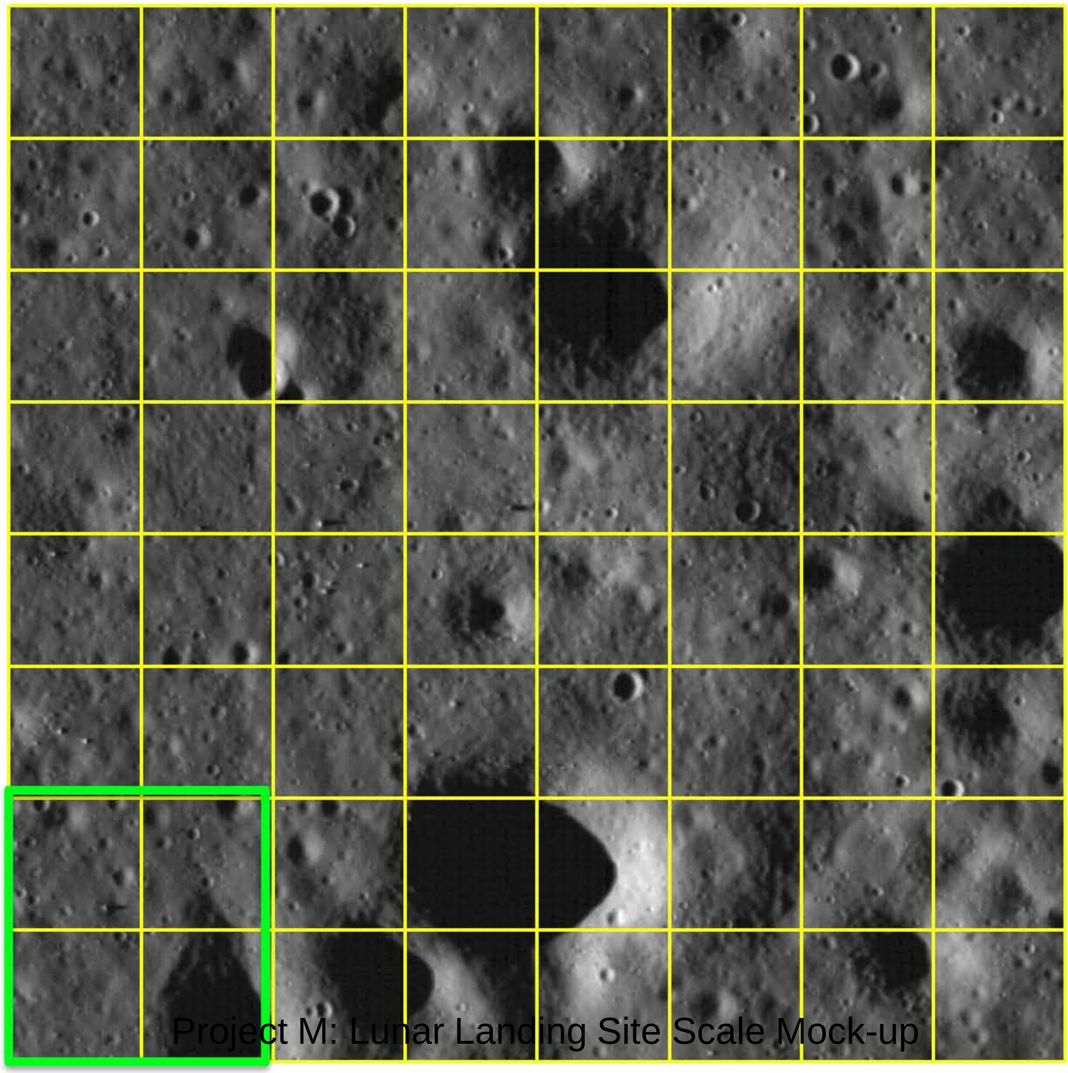
“Lunar Soil”

Lighting Conditions

Bottom — Top

My Project

Area of Prototype



My Project

- Prototype of Mock-up
  - 2’ by 2’
  - Trial Run-Through
  - Building Techniques
    - Foam board
      - Procedures
    - Structure
      - V or Rectangle
    - Wire Mesh
      - Holding Shape

My Project

- Things to Change
  - Clay
    - Oil not Air Dry
  - “Lunar Soil”
    - Thickness
  - Plywood
    - Aesthetics

Project: Building Supplies

Plastic Sheet

Plywood

Foam Board

Wire Mesh

Plaster Cloth

"Lunar Soil"

- Cement
- Charcoal
- Baby Powder

Spray Adhesive

My Project

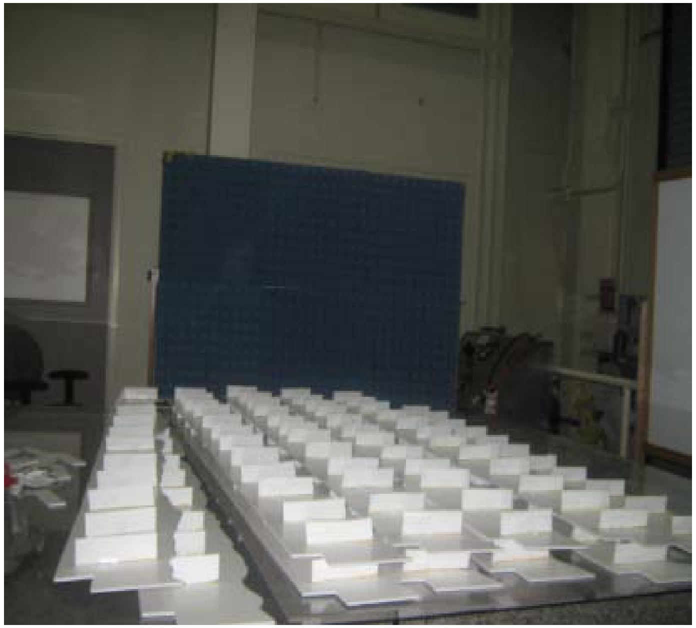
- Started by
  - Cutting & Contouring Form Board

My Project

- Then
  - Painting Boards and Attaching Them Together
  - Putting on Handles

My Project

- Next
  - Putting the Foam Board Together

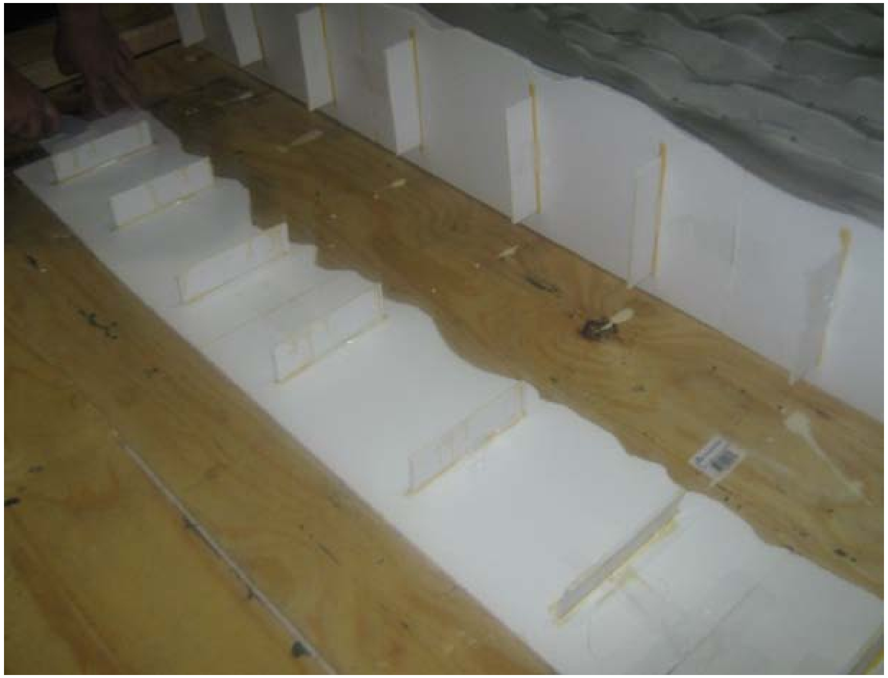


My Project

- Then
  - 4 Phases of 8’ by 2’ Sections
    - Foam Board
    - Wire Mesh
    - Plaster Cloth
    - “Lunar Soil”

My Project

These Pictures Illustrate the Phases.



My Project

- Final Phase Includes:
  - Lifting Model on Table
  - Determining Lighting Conditions on Floor

Challenges

- CLAY!
- Making Adjustments
- Getting in Touch with the Right People
- Finding Time in other Peoples' Schedules
- Things NEVER Go as Planned

Activities

- INSPIRE Meetings
- EG6 Students' Weekly Special Topic
- EG6 Branch overview
- Astronaut Talks
- Special Tours
- Key Speaker Lectures
- Storytelling Events

What I learned About NASA

- Variety of Engineering Jobs
- President is Ultimate Boss
  - Involves Politics
- Teamwork Without Competition
  - “We” Themed Thinking
- Endless Opportunities
- Project Complexities

Skills Learned

Skills

- Communication
- Professional Networking
- Professionalism
- Organization
- Time Management
- Problem-Solving
- Assertiveness

Future Plans

- **Intern/Co-op**
  - INSPIRE Intern Next Summer
  - Co-op Tour at JSC Starting in 2012
- **Further Education**
  - B.S. & M.S. at California Institute of Technology or Massachusetts Institute of Technology
  - Astronomy & Aerospace Engineering
  - PhD in Aerospace Engineering
- **Work**
  - NASA or CERN

Acknowledgements

- Mentor- Dr. Timothy Crain
- Supervisor- Mr. Richard Mrozinski
- Program Specialist - Ms. Linda Smith
- Education Specialist- Ms. Alissa A. Keil
- Administrative Officer- Ms. Angie Zavala
- Safety Resource - Mr. Chet Lund

Thank You to Everyone!

Any Questions?

Thank You For Attending!