National Aeronautics and Space Administration

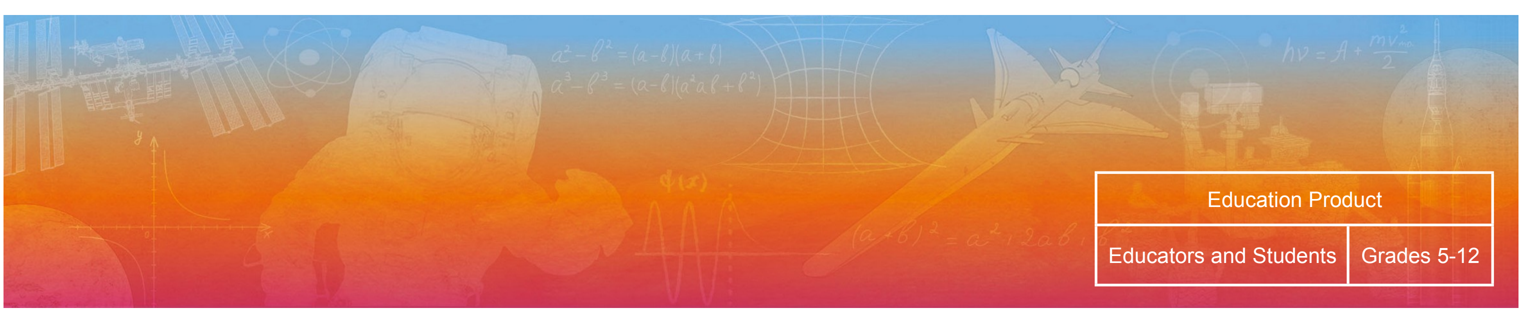
App Development Challenge

2024 Handbook

COMPUTER SCIENCE

Next Gen STEM-Moon

For more about Next Gen STEM visit www.nasa.gov/stem/nextgenstem/index.html



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NASA App Development Challenge

Introduction

The NASA App Development Challenge (ADC), a Next Gen STEM activity, is a coding challenge in which NASA presents technical problems to middle and high school students seeking student contributions to deep space exploration missions. The ADC, in cooperation with NASA's Space Communications and Navigation (SCaN) program, is one of NASA's Artemis Student Challenges, whose mission is to build foundational knowledge and introduce students to topics, techniques, and technologies critical to the success of the agency's Artemis program. By responding to the ADC, students take a part directly in the Artemis Generation endeavors to land American astronauts, including the first woman and first person of color, on the Moon.

SCaN serves as the program office for all of NASA's space communications activities, presently enabling the success of more than 100 NASA and non-NASA missions. SCaN manages the Near Space Network and the Deep Space Network and ensures the availability and allocation of the radiofrequency spectrum for all NASA programs. Additionally, SCaN supports the research and development of cutting-edge space communications technologies, such as optical and quantum communications, and is responsible for developing an integrated space communications and navigation architecture to support science and human exploration programs through 2040.

Challenge Overview

In this year's challenge, teams of middle school or high school teams have 10 weeks to code a visualization of the South Pole region of the Moon using lunar terrain data and display essential information for navigation and communication.

Teams will also use a wayfinding algorithm to plot the best path between a landing site and a destination site, as well as identifying communication link checkpoints for communication with Earth.

Teams ***must use coding originating during this year's ADC only*** to complete development of their app. Teams are encouraged to be creative and think outside the box.

Upon completion of the app, teams will create a video (use the Middle/High School Rubric in Appendix A). Teams with favorable submissions advance to present their app in an interview with NASA subject matter experts from the SCaN team. On conclusion of the interviews, NASA will select Top Teams for a culminating event.

NASA App Development Challenge - Summary

Prior to notifying NASA and registering your team for the ADC, please review the next two pages to ensure your team understands the challenge, the timeline, and eligibility requirements. If you have questions, please join us at one of the information sessions listed on the website or email us at JSC-ADC@mail.nasa.gov.

Review the Challenge

Student teams must

- Use any programming language (Java, C#, C++, Scratch, etc.) to complete development of an application
- Adhere to the policies of their school districts or organizations regarding participation in the challenge
- Submit a video of original student-led work about the completed app; no prior year work accepted
- Complete program requirements as identified by the ADC team

Middle school teams must

- Be able to process and read all provided position and slope data of the lunar South Pole region
- Display all position and slope data in some meaningful form beyond text
- Visualize a path accounting for mission planning goals and identify communication link check points

High school teams must

- Be able to process and read all provided position and slope data of the lunar South Pole region
- Identify and explain a selection for a landing and destination site, as well as areas of interest along the path
- Display height and slope data in some meaningful form beyond text
- Visualize a path accounting for mission planning goals and identify communication link check points
- Calculate and display elevation and azimuth angles

Review the Timeline

- September 27 ....STEM Gateway Registration Closes
- October 2 ....Lead Teacher Training
- October 4 ....Live Virtual Kickoff Event
- October 11 ....Live Virtual Connection: Creating a 3D Mesh
- November 8 ....Live Virtual Connection: Way Finding and Calculations
- November 29 ....Live Virtual Connection: Human Factors, Virtual Reality Applications, and Employee Profile
- December 13 ....ADC Video Submission Deadline

Review the Eligibility Requirements

- Formal or informal U.S. education organizations may participate
- Signed letter of support from principal or administrator of your organization must be submitted during registration to confirm participation
- Teams may be a middle school team or a high school team. Student participants must be on one team only.
  - All members of a middle school team must be in grades 5–8 during the 2023–2024 school year
  - All members of a high school team must be in grades 9–12 during the 2023–2024 school year
- Teams must be led by a sponsor or educator (i.e., Lead Teacher) from an informal or formal U.S. education organization
- The minimum team size is five students and one Lead Teacher. There is no maximum team size.
- If selected, a Top Team invited to the culminating event at NASA's Johnson Space Center in Houston must meet the following:
  - Only five student team members, the Lead Teacher, and one chaperone may travel. The chaperone must be a part of the organization and opposite gender of the Lead Teacher if both genders are represented within the student team.
  - All participants that travel must be U.S. citizens
  - Student members must be aged 13 or above during travel
  - Organization chaperones are fully responsible for their students during the culminating event
  - Traveling participants will use provided housing and transportation. Participants are responsible for meal expenses. Light snacks and drinks will be provided.
  - Participants will attend all scheduled events or planned activities during the culminating event
  - Teams will conduct a technical presentation for NASA personnel
  - Comingling of personal travel arrangements or travel arrangements for nonparticipants is not permitted
  - All team members must participate fully according to the challenge guidelines

Notify NASA and Register Your Team

After reviewing the above, each Lead Teacher must complete the below by September 27, 2023:

- Register their team in NASA STEM Gateway
- Include a signed letter of support from the principal or administrator of the team's school or organization
- Download and review the handbook: 2024 App Development Challenge Handbook

Click here to access the NASA STEM Gateway ADC 2024 opportunity and register your team

Lead Teachers: Note that by registering to participate, the team is confirming full participation, if selected, through the end of the culminating event. Dates are subject to change. **The Lunar Data Files and Lunar Surface Texture image will be available at the start of the challenge, October 4, 2023 on the ADC website.**

Email questions to NASA's ADC team at JSC-ADC@mail.nasa.gov

NASA App Development Challenge – Details

Challenge Timeline

The following timeline provides details on all major activities for the App Development Challenge (ADC).

The start date is Wednesday, October 4, 2023. Video submissions are due on Wednesday, December 13, by 2 p.m. Central Time. This will conclude teams' participation in the ADC unless selected to participate in interviews. Teams not selected for interviews will be notified by email.

Teams are encouraged to participate in all Live Virtual Connections (LVCs) to receive information about coding and app development. If there are any questions about this timeline, please contact the team at JSC-ADC@mail.nasa.gov. Reminder: Lead Teachers must register their team in NASA STEM Gateway before registration closes on September 27, 2023.

App Development Challenge Timeline*

Start Date	End Date	NASA ADC Activity*
10/4/2023	**12/13/2023**	**App Development Challenge (10 weeks)**
10/4/2023	10/4/2023	LVC† 1: LIVE VIRTUAL KICKOFF EVENT
10/11/2023	10/11/2023	LVC 2: Creating a 3D Mesh
11/8/2023	11/8/2023	LVC 3: Way finding and Calculations
11/29/2023	11/29/2023	LVC 4: Student Team Interviews, Virtual Reality Applications, and Employee Profile
1/24/2024	1/24/2024	ADC Special Virtual Event, "Join the Artemis Generation"
2/1/2024	2/15/2024	Selected Team Interviews With NASA SCaN Team
2/28/2024	2/28/2024	Announcement of Top Teams for Culminating Event
4/15/2024	**4/18/2024**	**NASA ADC Culminating Event**

*Timeline is subject to change.
†LVC = Live Virtual Connection.

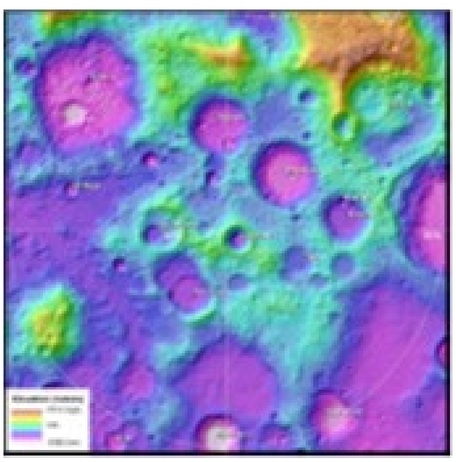
High School Challenge

Initial Steps

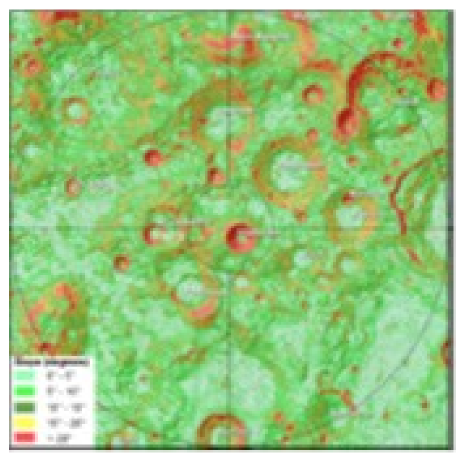
1. Lead Teacher reads the challenge handbook and reviews information pertaining to the student's grade level.
2. Review the High School Scoring Rubric in Appendix A for detailed information on each challenge requirement.
3. Students research which of the five Artemis III landing regions (Peak Near Shackleton, Connecting Ridged, Nobile Rim 1, Faustini Rim A, and Leibnitz Beta Plateau) they recommend NASA to choose.
4. **The Lunar Data Files and Lunar Surface Texture image will be available at the start of the challenge, October 4, 2023 on the ADC website.**
5. Download Lunar Data Files for the chosen landing region and Lunar Surface Texture Image (available at the ADC website on the day of the Live Virtual Kickoff, October 4th) to create a visualization.
6. Organize your team and app design using K-12 Computer Science Framework's 7 Core Practices and Storyboard located in Appendix B.

Visualization and Navigation

1. Use color to convey information (see examples below):
    a. Height in meters
    b. Slope in degrees
    c. Elevation angles from the astronaut's position to the horizon
    d. Azimuth angles from the astronaut's position to the Earth



Surface Height (Elevation)



Surface Slope

Different ways to color code the lunar South Pole. (Source: https://www.lpi.usra.edu/lunar/lunar-south-pole-atlas/)

2. Research within your selected landing region to choose a landing and destination site. Plot a path from the landing site to the destination site such that the slope does not exceed 15^{0}.
3. Identify 10 communication link checkpoints along the path.
    a. Identify azimuth and elevation angles from the astronaut's position to the Earth. The equations for calculating these angles can be found in Appendix C: Azimuth and Elevation Angle Equations.
    b. Earth cartesian position with respect to Lunar Fixed Frame at a single time instant is [X, Y, Z] = [361000, 0, –42100] km.

Extra Credit

Teams can receive up to five additional points for aspects that enhance the app in terms of displayed data, visualizations, functionality, ease of use, or accessibility for users needing special accommodations.

- Create and display an accurate mini map in a corner of the visualization to show progress or 2D perspective
- Compare potential route if slope constraint was relaxed to a maximum of 20 degrees (both routes appearing at the same time)
- Display the length (in meters) of the path
- Determine the smallest maximum number of degrees of slope allowed for any path
- Demonstrate a limitation of classical radio/laser communication and discuss how quantum communication might bypass that limitation

Video Requirements

Each team will submit a 5-to-7-minute video highlighting student-led work on the development of the team's app. The High School Video Presentation Rubric (in Appendix A) will be used to assess and score the video; however, use the material below as a check list.

1. Introductory statement:
   - This is team (team name) and we worked on NASA's App Development Challenge…."
   - Do not identify the name of any student, teacher, school, group, city, or region in the presentation. Videos should only include students 13 and older and must be in accordance with the media policies of the teams' school or organization.
   - Identify what coding language was used, what data points the app visualizes, and how successful the team was in creating a useful app
2. All app components are fully described with detailed information on the work required to complete each component, including
   - Visualizations of height, slope, elevation angle, azimuth angle using color to convey information to scale with a color key
   - Use of texture
   - App's algorithm for displaying a path
   - Placement of the communication links
   - Selection of Landing and Destination sites
   - Any extra features you were able to add
3. Description of obstacles and how they were overcome.
4. Key skills learned/acquired by participating in the ADC.
5. How were subject matter experts and local mentors used?
6. Describe community events held and events planned for the future.

Note: Teams are encouraged to use the rubric to self-score their video in advance of the final submission.

Mentors

High school teams should reach out to universities, local organizations, businesses, and subject matter experts to seek guidance on coding and app development. As part of their video presentation, teams must include a short narrative on the connections made and how these discussions helped in development of the app.

High school teams needing additional assistance in developing an app can request a mentor from the ADC team. Mentors are not guaranteed to be available and will be provided on a first-come, first-served basis.

Live Virtual Connections and Office Hours

Student teams will be supported during the challenge with Live Virtual Connections and Office Hours. We will hold a series of Live Virtual Connections (see timeline for dates and times) to provide guidance on key steps within the challenge and best practices. Teams may ask questions to the NASA personnel at the end of the presentations.

Additionally, we will hold Office Hours every week. Dates and times will be determined at the Kickoff event to accommodate team schedules. The Office Hours are optional and a place to get individualized team help on questions the team is struggling with. Students may attend only with a Lead Teacher present.

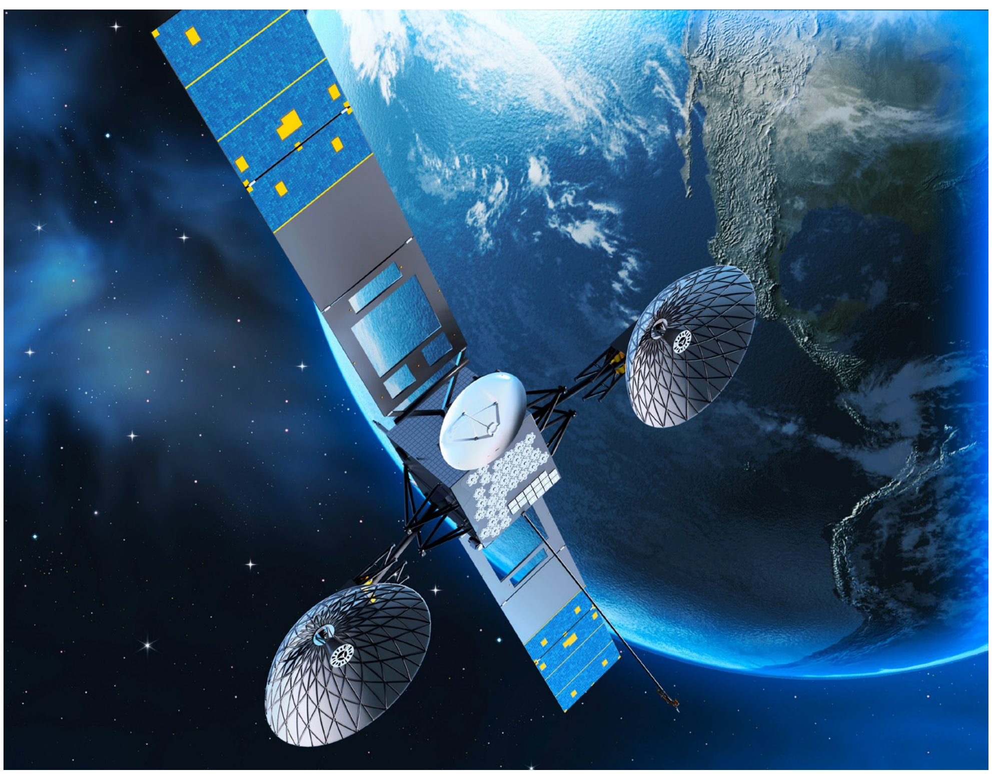
We prefer teams to gather in one location to participate in LVCs or Office Hours and to not use student names for logging into the event.

Team Interview and Top Teams Selection

Teams selected for the live virtual team interview will receive questions and comments from NASA's ADC and SCaN teams regarding their app and video presentation. Teams should complete written responses in preparation for the interview with NASA personnel and the ADC team. Lead Teachers must submit their written responses prior to their interview at a date and time set by the ADC team. Email answers to the questions to JSC-ADC@mail.nasa.gov.

Team interviews are facilitated through video conference. The date and time of the event will be emailed to the Lead Teacher by the ADC team. The interview will be 30 to 45 minutes long and will give teams the opportunity to speak to both the SCaN and ADC teams. Teams will provide answers to the questions and respond to additional comments. Technical suggestions to improve app functionality will be discussed.

Each team's written submission and live connection will be evaluated to help determine which team(s) will be selected for the culminating event. Teams must score 70% or higher to obtain eligibility as a Top Team. Eligibility does not guarantee Top Team status. Teams will be ranked by the ADC team, and **in case of a tie score, preference will be determined by the NASA technical team**. The Top Teams must work with ADC mentors and team members to adjust their application, based on technical suggestions by NASA, prior to attending the culminating event.



Artist concept of the Tracking and Data Relay System (TDRS), which relay signals between spacecraft, including the International Space Station, and ground control. Credits: NASA

Community Engagement

Teams are expected to share their work in space exploration with a wider audience. Community engagement efforts should be planned and implemented. Teams can share their efforts whether they are working in a formal or informal setting. A school-based team could share their app with a younger grade or as part of a virtual or in-person STEM day or science fair. A museum-based team might set up a display at the museum for a day to share their work with the public. An after-school program could host a virtual open house to highlight their work for parents along with other after-school activities. Each team has unique opportunities to share their work in space exploration with a wider audience. **Lead Teachers and students should follow their school or organization's guidelines for these types of events**. Be sure to include images and video of outreach events in the team's video submission. Teams selected to participate in the culminating event will need to plan additional events leading up to the culminating event.

Quantum Information Science and Technology (QIST)

Future ADCs will look to incorporate QIST elements as part of the coding challenge. Student teams are expected to share information on QIST, specifically Quantum Day 2024 and QuanTime resources, as part of community engagement efforts. Information regarding both items can be found on their respective websites: World Quantum Day 2024 is April 14, and QuanTime provides activities, lessons, and games for students and educators. Information regarding inclusion of QIST elements as part of the ADC can be found in the Resources section. Additional information and resources can be found at NASA SCaN World Quantum Day.

Social Media

Social media allows teams the opportunity to share their NASA unique experience with the public and promote the challenge. Teams are encouraged to create a web presence using platforms of their choice. Use **#NextGenSTEM** and **#NASA_ADC** when posting so the ADC team can follow your progress. Teams must follow their school or organization's guidelines related to social media.

Media Relations

As teams share their experiences with the public, they may have opportunities to interact with the media. The ADC team would like to know when a team is highlighted in the media. Each team should keep a list of these media interactions and share any links to newspaper postings, online stories, videos, live events, etc., with JSC-ADC@mail.nasa.gov.

Press Releases

The ADC team will provide press releases to registered teams to share with the media. An additional press release will be provided to the Top Teams selected to attend the culminating event.

Media Releases

NASA media releases will be required for all members (student and adult) of teams selected for an interview. The media release form will cover challenge video submissions, team interviews, and any media covering participation in the culminating event. Please check with your organization for any guidance on media releases.

Top Team(s) selected to the culminating event might be asked to complete additional documentation regarding their app submission and use by NASA.

Conclusion and Contact Information

The ADC team hopes participation in NASA's App Development Challenge is a beneficial and rewarding learning experience for each team. The ADC team will work to provide timely updates to Lead Teachers via email. Questions can be directed to JSC-ADC@mail.nasa.gov.

Resources

App Development and Design Resources

- Unity® (Unity Technologies) – A cross-platform game engine used to develop games and simulations for use on various devices
- Unreal Engine® – A suite of integrated tools for game developers to design and build games, simulations, and visualizations
- Blender® (Blender Foundation) – Free and open-source 3D creation suite
- Ursina – Game engine for Python

STEM Engagement Resources

- Code.org® – Nonprofit dedicated to expanding access to computer science
- QuanTime – Activities designed for K–12 to introduce middle and high school students to quantum information science
- Daily Moon Guide – A dynamic guide to viewing the Moon each day
- NASA's Next Gen STEM – Office of STEM Engagement initiative to provide STEM products and opportunities to engage students in NASA missions
- NASA Computer Science Educational Resources – Computer science resources for K–12 educators and students
- Join Artemis – Learn more about the Artemis missions and how to get involved
- NASA at Home – Activities, resources, books, apps, and much more for bringing NASA into your home
- SCaN Kids Zone – Activities, handouts, and resources for K–12 students
- STEM Classroom Activities – Lesson plans and educational resources for grades 5–8
- NASA eClips™ – Short educational videos
- NASA STEM Engagement Informal Education Resources – Home page for informal education institutions and organizations to explore NASA resources, activities, and programs
- NASA Museum and Informal Education Alliance – Alliance for informal education professionals providing free NASA educational resources and services
- SCaN Sponsored Outreach Programs and Exhibits – Projects or programs sponsored by SCaN for the public
- Quantum Code Crunchers Activity – Grade 3-6 activity to explain quantum communications
- Communication and the Lunar Outpost – Pre-Calculus activity to describe positioning of lunar communication towers

Research Links

Artemis Mission

- NASA Orion Spacecraft – NASA Orion website
- Space Launch System – NASA Space Launch System (SLS) website
- Artemis – Humanity's return to the Moon
- Artemis Missions – Artemis home page
- What is Artemis? – Article and video link answering questions about Artemis
- Artemis Fact Sheet (PDF) – Artemis handout with important facts
- Artemis I – Artemis I mission overview
- Artemis II – Artemis II overview and crew
- Artemis II: Mission Overview – Video highlighting the mission objectives
- Artemis Mission Maps – Artemis I through Artemis V infographics

Space Communications

- NASA's Space Communications and Navigation (SCaN) – SCaN home page
- SCaN Now – Real-time status display for NASA's ground stations
- Lunar Information
- Moon: NASA Science – Interactive Moon landing and geography map, news, and articles
- Moon Trek – Application to view imagery and perform analysis on Moon data
- NASA 3D Resources – NASA 3D models, images, and textures on GitHub®
- Computer-Generated Imagery (CGI) Moon Kit – Scientific Visualization Studio (SVS) – Color and elevation maps for 3D rendering software
- United States Geological Survey (USGS) Astrogeology Science Center – Resource website for lunar maps and data
- Lunar South Pole Atlas – Online atlas that consists of maps, images, and illustrations of the lunar South Pole region from the Lunar Planetary Institute, Houston
- Lunar Orbital Data Explorer – The data file provided to teams was collected using NASA's Planetary Data System Lunar Orbital Data Explorer
- NASA Lunar Reconnaissance Orbiter (LRO) – NASA LRO home page
- Lunar Reconnaissance Orbiter (LRO) Goddard – NASA LRO website from Goddard Space Flight Center (GSFC)
- Lunar Reconnaissance Orbiter Camera – Interactive map to explore the lunar surface
- NASA LOLA Data Node – Primary source for Lunar Orbiter Laser Altimeter (LOLA) data products
- Moon LRO LOLA Digital Elevation Model (DEM) – Specific DEM on the Moon

Additional Student Challenges

- Artemis Student Challenges – Selection of NASA student challenges engaging middle school through graduate school students as part of the Artemis generation
- NASA Space Apps Challenge – Annual international hackathon

Working at NASA

- NASA Internships – NASA home page for internships, fellowships, and Pathways opportunities
- NASA Careers – NASA home page for career information and links to job searches and recruitment events
- NASA Employee Profiles – Selection of individual NASA employee stories from across the Agency
- Exploring Careers @ NASA – Students – Resources for students interested in working at NASA including links to internship and fellowship opportunities
- NASA People – Articles and videos highlighting various NASA careers
- NASA People (YouTube) – Videos of NASA employees highlighting their work across the Agency

Appendix A - Rubrics

Middle School Rubric

Category	Best = 3 points	Better = 2 points	Good = 1 point	Missing = 0 points	Total Points
App Creation - Modeling	App visualizes both height and slope from the provided data and accurately displays it from a first-person perspective. Data is smoothed, looking like natural terrain.	App visualizes both height and slope from the provided data and displays it from a first-person perspective. 5-m data separation has not been smoothed or interpolated.	App visualizes both height and slope using some of the provided data and visualizes this data in some useful 2D form.	App fails to visualize data in some useful form beyond text.	Raw Score Multiplier x 3
App Creation - Color and Texture	App displays texture and uses color to convey information to scale with corresponding color key and allows user to toggle between different color coding.	App displays texture and uses color to convey either height (meters) or slope information with corresponding color key.	App displays either color or texture, but not both.	App fails to apply a texture or to use color to convey information.	Raw Score Multiplier x 2
App Creation -Wayfinding	App plots and clearly identifies complete path from the landing site to destination site that does not exceed 15 degrees of slope and has some sort of optimization, e.g., shortest distance or least amount of hill climbing.	App plots a path from the landing site to the destination site that does not exceed 15 degrees of slope, with no optimization.	App displays any path from the landing site to the destination site.	App fails to identify a path.	Raw Score Multiplier x 3
App Creation - Communication Link Checkpoints	App identifies and provides evidence supporting the selection of 10 locations for communication link checkpoints at a location of high elevation at regular intervals along the path.	App identifies and explains the selection of 10 locations for communication link checkpoints at some important location along the path, e.g., a place where you would turn.	App arbitrarily places 10 communication link checkpoints.	App fails to identify any place for communication checkpoints.	Raw Score Multiplier x 3
Video Commentary - App Creation	All app components are fully described, with detailed information on the work required to complete each component and how the team worked collaboratively to complete the app. Description includes mention of the 7 Core Practices of the K–12 Computer Science Framework.	More than one app component is described, but the components or how the team worked to complete the app are not completely identified, OR a single app component is described with detailed information and how the team worked to complete it.	At least one app component is described, but its function and how the team worked to complete it are not fully described.	Identification of app components and how the team worked to complete them is not included.	
Video Commentary -Trouble Shooting	Challenges encountered are clearly identified, with explanations of how the team solved or planned to solve each challenge and the results of these actions.	Challenges encountered are identified, with limited explanations of how the team solved or planned to solve each challenge and the results of these actions.	Challenges are implied or not fully stated. It is not identified whether any action was taken to solve the challenges.	Narrative of challenges encountered is not included or is incomplete.	
Video Commentary - Student Acquired Skills	Key skills learned and acquired through participation in the challenge are identified with detailed information and technical terms and are supported with visible app components.	Key skills learned are stated, but with limited details of how they were acquired or incorporated into the app development.	Key skills learned are stated, but no additional narrative on how they were acquired or incorporated into the development of the app is provided.	Narrative on student-acquired skills is not included or is incomplete.	
Video Commentary - Subject Matter Experts (SMEs) and Mentors	Interactions with scientists, engineers, or other relevant SMEs are fully described, including how their guidance and feedback are incorporated into the app design.	Interactions with scientists, engineers, or other relevant SMEs are described, and details are included on guidance they provided.	Interactions with scientists, engineers, or other relevant SMEs are acknowledged in general terms, but no specific details are included.	Interactions with scientists, engineers, or other relevant SMEs are not acknowledged.	
Video Commentary - Community Engagement	Evidence of completed events and social media outreach is included, with additional outreach planned. Evidence of shared Quantum Day information and activities provided to promote participant engagement. Social media outreach includes resources links. Evidence of completion of QuanTime activities.	Evidence of completed events and social media outreach is included. Inclusion of Quantum Day information and activities provided to participants or linked in social media outreach.	Evidence of only future planned events or social media is included.	No evidence of events or outreach is included.	
				SCORE (out of 48):	
Extras	Teams can receive up to 5 additional points for aspects that enhance the app in terms of displayed data, visualizations, functionality, ease of use, or accessibility for users needing special accommodations. 1. Create and display an accurate mini map in a corner of the visualization to show progress or 2D perspective. 2. Compare potential route if slope constraint was relaxed to a maximum of 20 degrees. (Both routes appearing at the same time) 3. Display the length (in meters) of the path. 4. Display real-time latitude and longitude. 5. Demonstrate a limitation of classical radio/laser communication and discuss how quantum communication might bypass that limitation.				
Team Name:			FINAL SCORE (out of 48):		
			FINAL % SCORE:		

High School Rubric

Category	Best = 3 points	Better = 2 points	Good = 1 point	Missing = 0 points	Total Points
App Creation - Modeling	App accurately visualizes the following from a first-person perspective: height, slope, elevation angle from astronaut to Earth, and azimuth angle from astronaut to Earth. Data is smoothed, looking like natural terrain.	App accurately visualizes height and slope from a first-person perspective, but not elevation angle from astronaut to Earth or azimuth angle from astronaut to Earth. 5-m data separation has not been smoothed or interpolated.	App visualizes the lunar surface in some useful 3D form.	App fails to visualize data in some useful form beyond text.	Raw Score Multiplier x 3
App Creation - Color and Texture	App displays texture and uses color to convey information to scale with corresponding color key and allows user to toggle between height, slope, elevation angle, and azimuth angle.	App displays texture and uses color to convey information to scale with corresponding color key and allows user to toggle between height and slope.	App displays texture and uses color to convey either height or slope information with corresponding color key	App fails to apply a texture or to use color to convey information.	Raw Score Multiplier x 2
App Creation -Wayfinding	App plots and clearly identifies a complete path from the landing site to the destination site that does not exceed 15 degrees of slope and allows user to toggle between different optimizations, e.g., shortest distance, least amount of hill climbing, or percentage of time Earth is visible.	App plots a complete path from the landing site to the destination site that does not exceed 15 degrees of slope and has some sort of optimization, e.g., shortest distance or least amount of hill climbing.	App plots a path from the landing site to the destination site that does not exceed 15 degrees of slope.	App fails to identify a path.	Raw Score Multiplier x 3
App Creation - Communication Link Checkpoints	App identifies 10 locations, along the path, for communication link checkpoints at a location where the elevation angle to Earth is greater than the elevation angle to the horizon at the same azimuth angle, with some sort of optimization, e.g., maximum distance between checkpoints.	App identifies 10 locations, along the path, for communication link checkpoints at a location where the elevation angle to Earth is greater than the elevation angle to the horizon at the same azimuth angle.	App identifies 10 locations, along the path, for communication link checkpoints at some important location, e.g., a place of high elevation.	App fails to identify any location for communication checkpoints.	Raw Score Multiplier x3
App Creation -Lunar Site Selection	Landing and destination sites as well as areas of interest along the path are identified with scientific evidence/data/rationale for site selection.	Landing and destination sites as well as areas of interest along the path are identified with conversational explanation of site selection.	Identification of landing and destination sites but no explanation.	No identification or explanation of site selections.	Raw Score Multiplier x2
Video Commentary - App Creation	All app components are fully described, with detailed information on the work required to complete each component and how the team worked collaboratively to complete the app. Description includes mention of the 7 Core Practices of the K–12 Computer Science Framework.	More than one app component is described, but the components or how the team worked to complete the app are not completely identified, OR a single app component is described with detailed information and how the team worked to complete it.	At least one app component is described, but its function and how the team worked to complete it are not fully described.	Identification of app components and how the team worked to complete them is not included.	
Video Commentary -Trouble Shooting	Challenges encountered are clearly identified, with explanations of how the team solved or planned to solve each challenge and the results of these actions.	Challenges encountered are identified, with limited explanations of how the team solved or planned to solve each challenge and the results of these actions.	Challenges are implied or not fully stated. It is not identified whether any action was taken to solve the challenges.	Narrative of challenges encountered is not included or is incomplete.	
Video Commentary - Student Acquired Skills	Key skills learned and acquired through participation in the challenge are identified with detailed information and technical terms and are supported with visible app components.	Key skills learned are stated, but with limited details of how they were acquired or incorporated into the app development.	Key skills learned are stated, but no additional narrative on how they were acquired or incorporated into the development of the app is provided.	Narrative on student acquired skills is not included or is incomplete.	
Video Commentary - Subject Matter Experts (SMEs) and Mentors	Interactions with scientists, engineers, or other relevant SMEs are fully described, including how their guidance and feedback are incorporated into the app design.	Interactions with scientists, engineers, or other relevant SMEs are described, and details are included on guidance they provided.	Interactions with scientists, engineers, or other relevant SMEs are acknowledged in general terms, but no specific details are included.	Interactions with scientists, engineers, or other relevant SMEs are not acknowledged.	
Video Commentary - Community Engagement	Evidence of completed events and social media outreach is included, with additional outreach planned. Evidence of shared Quantum Day information and activities provided to promote participant engagement. Social media outreach includes resources links. Evidence of completion of QuanTime activities.	Evidence of completed events and social media outreach is included. Evidence of shared Quantum Day information and activities provided to promote participant engagement. Social media outreach includes resources links. Evidence of completion of QuanTime activities.	Evidence of only future planned events or social media is included.	No evidence of events or outreach is included.	
				SCORE (out of 54):	
Extras	Teams can receive up to 5 additional points for aspects that enhance the app in terms of displayed data, visualizations, functionality, ease of use, or accessibility for users needing special accommodations. 1. Create and display an accurate mini map in a corner of the visualization to show progress or 2D perspective. 2. Compare potential route if slope constraint was relaxed to a maximum of 20 degrees. (Both routes appearing at the same time) 3. Display the length (in meters) of the path. 4. Display real-time latitude and longitude. 5. Demonstrate a limitation of classical radio/laser communication and discuss how quantum communication might bypass that limitation.				
Team Name:			FINAL SCORE (out of 54):		
			FINAL % SCORE:		

Appendix B - Organizational Resources

K-12 Computer Science Framework's 7 Core Practices

The following illustration depicts the K–12 Computer Science Framework's 7 Core Practices model. NASA's App Development Challenge (ADC) was designed to incorporate these core practices into the learning experience.

K–12 Computer Science Framework's 7 Core Practices.
(Adapted from K–12 Computer Science Framework, Creative Commons license CC BY-NC-SA 4.0)

The following descriptions show examples of what will be completed for each practice by students participating in the ADC:	
1. Fostering an inclusive computing culture − Identify a variety of people who can provide ideas, mentorship, and feedback − Identify a variety of people who might be end users for the product − Create functions to broaden accessibility and use 2. Collaborating around computing − Select the programming language, operating system environment, and development environment to be used based upon the team's skill set and experience − Identify roles and responsibilities for team members, as well as norms for ensuring everyone has a voice − Solicit and incorporate feedback from various stakeholders 3. Recognizing and defining computational problems − Explain the challenge − Break the challenge into smaller chunks − Develop storyboards for visualizing a final app 4. Developing and using abstractions − Identify and incorporate existing libraries, modules, images, and three-dimensional (3D) models that may provide useful features in visualizing an app − Code useful subroutines (e.g., recognizing keyboard and mouse input) that may be used multiple times in the final app	5. Creating computational artifacts − Develop some pseudocode to guide development of the app − Code ways to visualize the height and slope of the lunar South Pole − Code ways to communicate information via color − Code ways to visualize a path and identify communication link checkpoints − Code other useful features 6. Testing and refining computational artifacts − Run the app with the NASA-provided data − Run an entire mission visualizing the provided data and plotting a path from the start point to the destination point − Let other people beta test the app and provide feedback − Add useful functions for communicating information and ensure the app can handle these additions 7. Communicating about computing − Script and deliver a presentation on how the team's app works, what they learned making it, and what ideas they have for future improvements − Record a video of the team presentation and submit it to NASA − Share your experience with others in the community

Storyboard

The Storyboard Handout is for conceptualizing development of the app. A completed storyboard conveys what a team envisions as th
ADC, teams will encounter challenges that require them to define problems, brainstorm options, and choose the best possible solutio
design. As part of the video presentation, teams must include a narrative on the challenges they encountered and how the challenges
the Storyboard Handout to draw their main app in color, and then use the outer bubbles for additional details or descriptions of the ap
subject to change based on challenges encountered throughout the development process.

Return to Table

Appendix C - Azimuth and Elevation Angle Equations

The following equations are for the high school challenge.

Azimuth Angle from Location A to Location B

- $Azimuth_{AB} = \text{atan2}\left((\sin(Long_B - Long_A) * \cos(Lat_B)), ((\cos(Lat_A) * \sin(Lat_B)) - (\sin(Lat_A) * \cos(Lat_B) * \cos(Long_B - Long_A)))\right)$
- $\text{atan2}(y, x) = \begin{cases} \arctan\left(\frac{y}{x}\right), & x > 0 \\ \arctan\left(\frac{y}{x}\right) + \pi, & x < 0 \; and \; y \geq 0 \\ \arctan\left(\frac{y}{x}\right) - \pi, & x < 0 \; and \; y < 0 \\ +\frac{\pi}{2}, & x = 0 \; and \; y > 0 \\ -\frac{\pi}{2}, & x = 0 \; and \; y < 0 \\ undefined, & x = 0 \; and \; y = 0 \end{cases}$

Spherical to Cartesian Conversion

Changing latitude and longitude into [x, y, z] coordinates.

Lunar Radius = 1737.4 km

Radius = Lunar Radius + Terrain Height

- $x = Radius * (\cos(Lat)) * (\cos(Long))$
- $y = Radius * (\cos(Lat)) * (\sin(Long))$
- $z = Radius * (\sin(Lat))$

Elevation Angle from Reference Location A to Target Location B (Cartesian Conversion needed)

- $[x_{AB}, y_{AB}, z_{AB}] = [x_B, y_B, z_B] - [x_A, y_A, z_A]$
- $Range_{AB} = \sqrt{{x_{AB}}^2 + {y_{AB}}^2 + {z_{AB}}^2}$
- $rz = x_{AB} \cos(Lat_A) \cos(Long_A) + y_{AB} \cos(Lat_A) \sin(Long_A) + z_{AB} \sin(Lat_A)$
- $ElevationAngle_{AB} = \arcsin\left(\frac{rz}{Range_{AB}}\right)$

Appendix D - Haworth Mesh from Heightmap (Middle School Only)

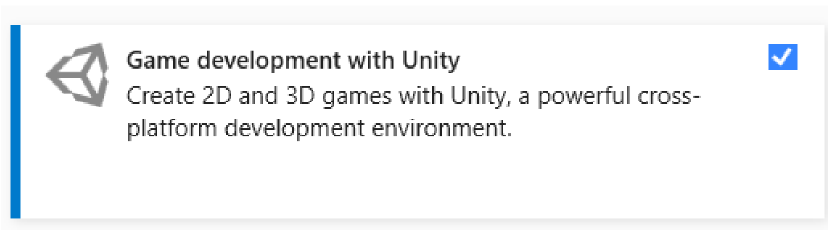
Lead Teacher: If you chose Option 2, follow the instructions below. Although Unity game engine is used for this option, teams may adapt the instructions to an alternate game engine of their choosing. *Note: heightmap will be available on the* ADC website *on October 4, 2023*

Install Unity gaming engine

1. Click here and select the **Download for Windows** button to download the latest version of Unity.
2. Open the file from downloads.
3. Select **Yes** if computer system prompts - **Do you want to allow app to make changes on your computer**.
4. Select **I Agree** to the terms of service.
5. Select **Install**. Do not change the program location suggested.
6. After completing the setup, select **Finish**.
7. A window will pop up. Click **2022.3.4f1**, then click **Install Editor**.

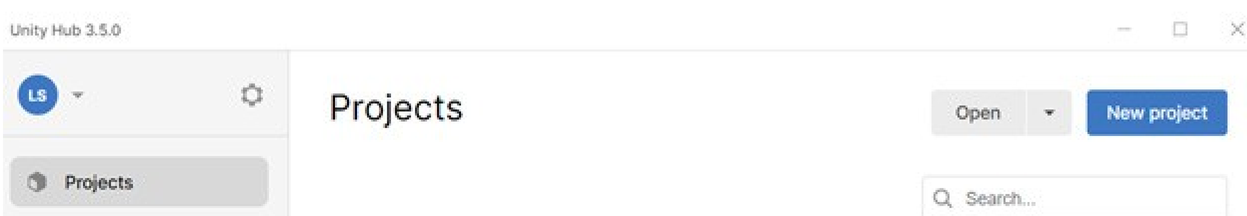
Install Visual Studio

1. You will need Visual Studio click here and select the Visual Studio - Community **Free Download** link
2. During installation you must select **Game development with Unity** option.

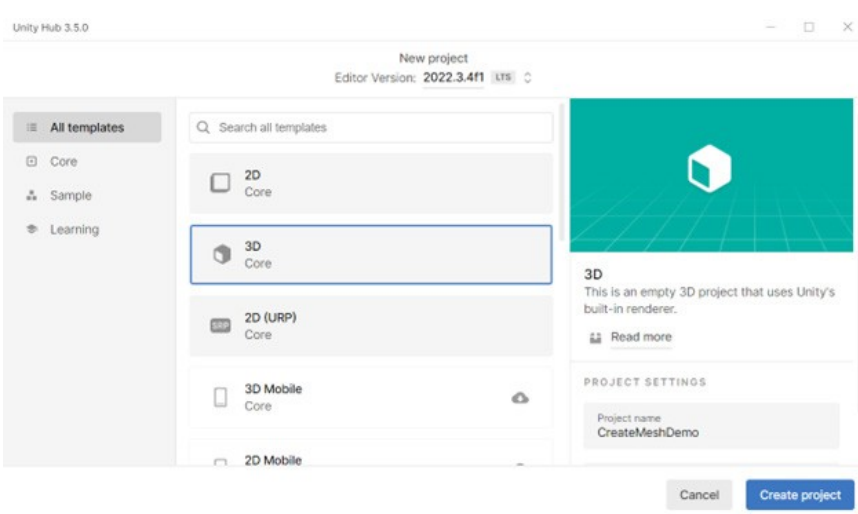


Configure Unity

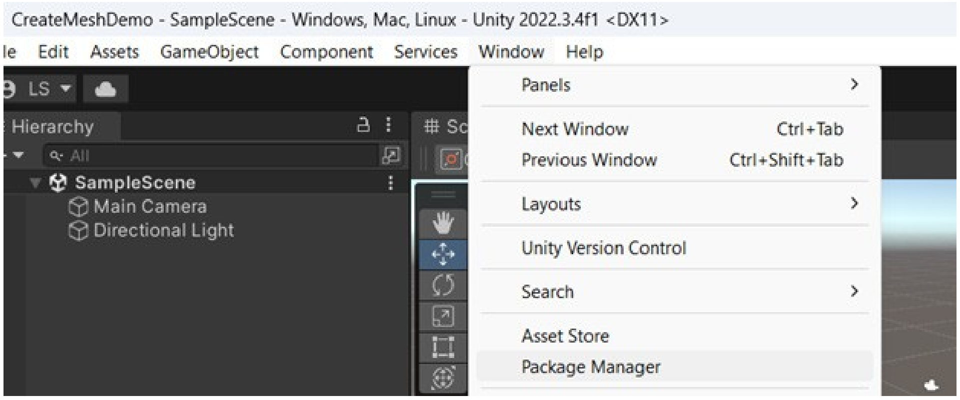
1. Open Unity and select **New project**.



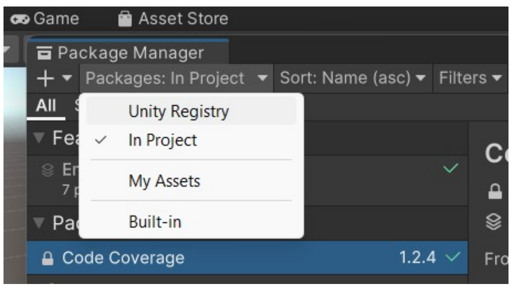
2. Select 3D and name the project, then select **Create project** button.



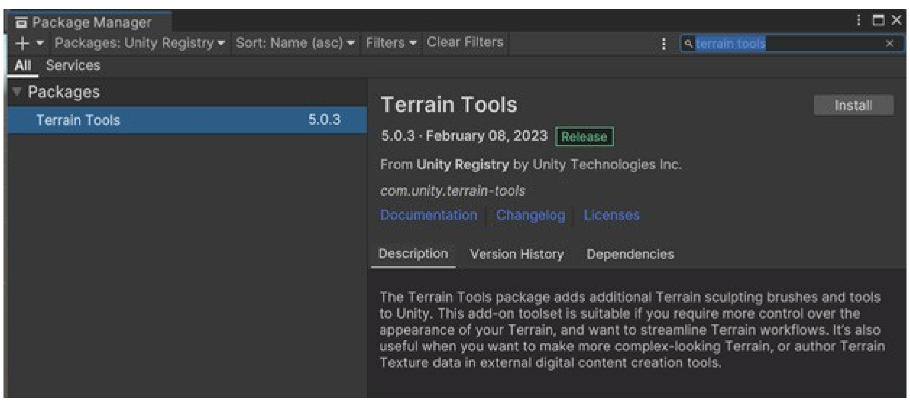
3. While in Unity, select Window>Package Manager.



4. Select **Packages**: In Project drop down, then select **Unity Registry.**



5. Enter terrain tools into the text box to have **Terrain Tools** display, then select **Install** and **X** out of the pop-up.

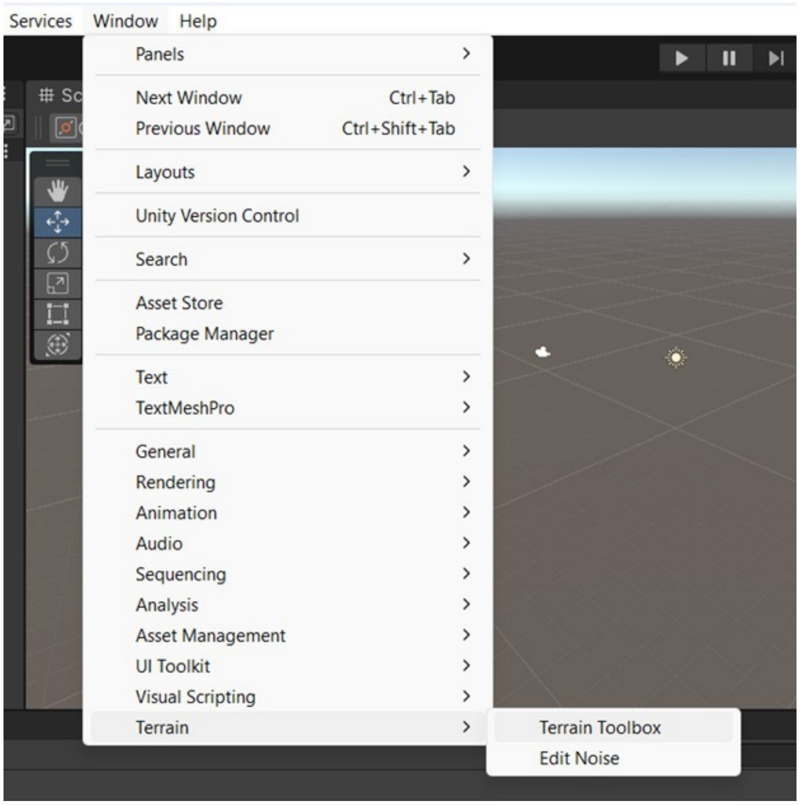


Obtain Heightmap

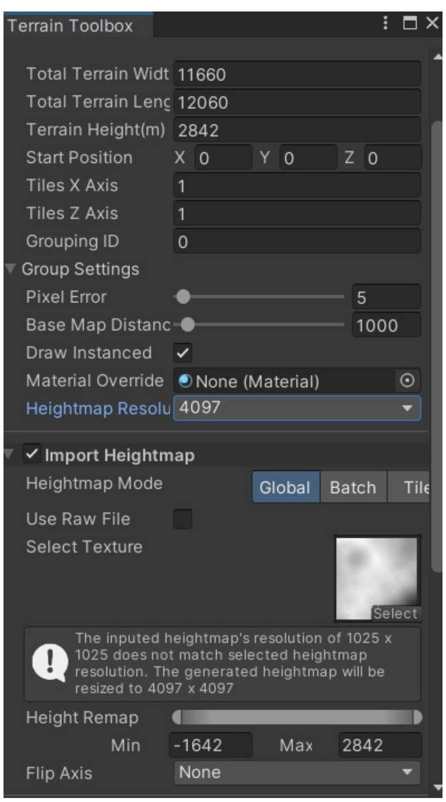
1. You are now ready to obtain the heightmap. **Go to the ADC website and look for these resources on the 2024 ADC Handbook page. Note: The resources will not be available until October 4, 2023**.

Import & Configure Heightmap

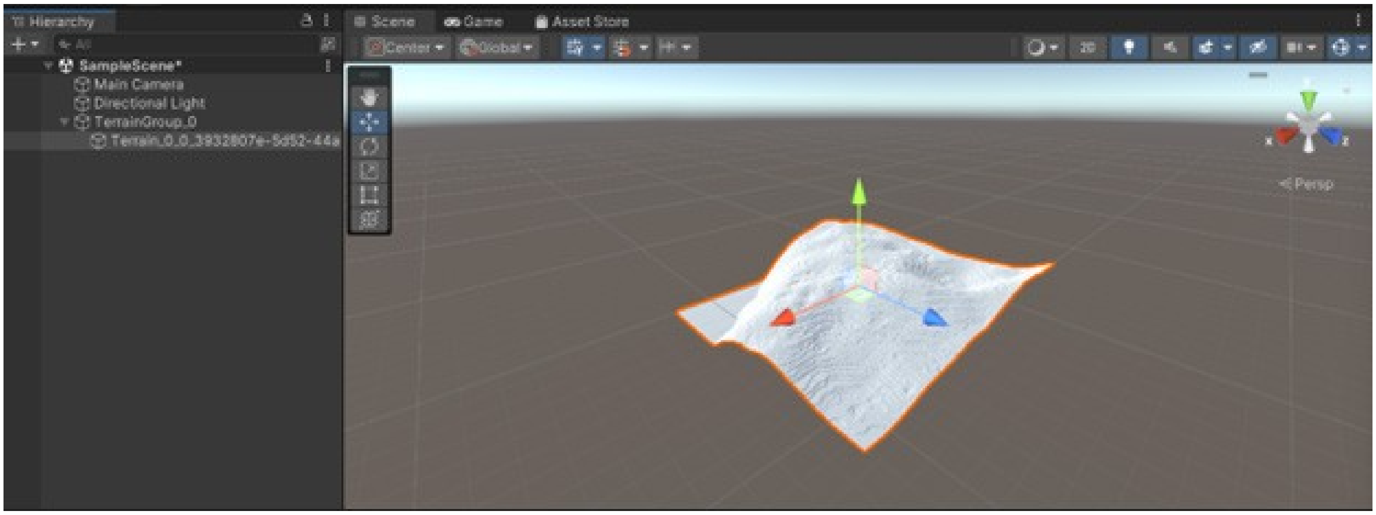
1. In Unity, right-click on **Assets**, then select **Import New Asset**. Next browse to the Haworth DEM file and select **Import**.
2. Select Window>Terrain>Terrain Toolbox.



3. Enter 11,660 for **Total Terrain Width**, 12,060 for T**otal Terrain Length**, 2842 for **Terrain Height**. Drag the Haworth DEM file to the **Select Texture** box or select the texture from the box. Enter 4097 for the **Heightmap Resolution**. Enter -1642 for the height **Min** and 2842 for the height **Max**.



4. Scroll down, then select the **Create** button to generate the mesh.
5. Double-click on the terrain mesh layer on the left-hand side to display the generated mesh.



Next Steps

Research the following topics to take the next steps in completing the challenge.

- Smoothing terrain
- Pathfinding NavMesh Surface walkable mesh/HeightMesh – AI Navigation
- HeightMesh color gradient/Shader graph gradient
- NavMeshVisualizer
- Waypoints
- Obtain terrain height using points from heightmap
- Bonus Topics
  - Augmented Reality – GPS location
  - GPS Encoder/Geolocation/Convert Unity x, y, z coordinates to GPS latitude/longitude by using 4 corners of Haworth DEM file coordinates:
    - Upper Left: 337.17387E, -86.59046; height 1874m
    - Lower Left: 334.27226E, -86.95283; height 1477m
    - Upper Right: 343.37578E, -86.72032; height 1250m
    - Lower Right: 341.12851E, -87.09890; height 265m

Appendix E - Curriculum Standards

6th-8th Grade Standards

(https://www.nextgenscience.org/search-standards)

Science and Engineering (NGSS)

Disciplinary Core Ideas

- MS-ETS1-1 Engineering Design: Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions.
  - ETS1.A: The more precisely a design task's criteria and constraints can be defined, the more likely it is that the designed solution will be successful. Specification of constraints includes consideration of scientific principles and other relevant knowledge that are likely to limit possible solutions.
- MS-ETS1-2 Engineering Design: Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem.
  - ETS1.B: There are systematic processes for evaluating solutions with respect to how well they meet the criteria and constraints of a problem.
- MS-ETS1-3 Engineering Design: Analyze data from tests to determine similarities and differences among several design solutions to identify the best characteristics of each that can be combined into a new solution to better meet the criteria for success.
  - ETS1.B: Sometimes parts of different solutions can be combined to create a solution that is better than any of its predecessors.
  - ETS1.C: Although one design may not perform the best across all tests, identifying the characteristics of the design that performed the best in each test can provide useful information for the redesign process—that is, some of those characteristics may be incorporated into the new design.
- MS-ETS1-4 Engineering Design: Develop a model to generate data for iterative testing and modification of a proposed object, tool, or process such that an optimal design can be achieved.
  - ETS1.B: A solution needs to be tested, and then modified on the basis of the test results, in order to improve it.
  - ETS1.B: Models of all kinds are important for testing solutions.
  - ETS1.C: The iterative process of testing the most promising solutions and modifying what is proposed on the basis of the test results leads to greater refinement and ultimately to an optimal solution.

Crosscutting Concepts

- Cause and Effect: Mechanisms and Prediction: Events have causes, sometimes simple, sometimes multifaceted. Deciphering causal relationships, and the mechanisms by which they are mediated, is a major activity of science and engineering.
- Systems and System Models: A system is an organized group of related objects or components; models can be used for understanding and predicting the behavior of systems.
- Influence of Science, Engineering, and Technology on Society and the Natural World: The uses of technologies and limitations on their use are driven by individual or societal needs, desires, and values; by the findings of scientific research; and by differences in such factors as climate, natural resources, and economic conditions. (MS-ETS1-1)

Science and Engineering Practices

- Asking Questions and Defining Problems: Define a design problem that can be solved through the development of an object, tool, process, or system and includes multiple criteria and constraints, including scientific knowledge that may limit possible solutions. (MS-ETS1-1)
- Developing and Using Models: Develop a model to generate data to test ideas about designed systems, including those representing inputs and outputs. (MS-ETS1-4)
- Planning and Carrying Out Investigations: Scientists and engineers plan and carry out investigations in the field or laboratory, working collaboratively as well as individually. Their investigations are systematic and require clarifying what counts as data and identifying variables or parameters.
- Analyzing and Interpreting Data: Analyze and interpret data to determine similarities and differences in findings. (MS-ETS1-3)
- Using Mathematics and Computational Thinking: Use digital tools (e.g., computers) to analyze very large data sets for patterns and trends.
- Constructing Explanations and Designing Solutions: Undertake a design project, engaging in the design cycle, to construct and/or implement a solution that meets specific design criteria and constraints.
- Engaging in Argument From Evidence: Evaluate competing design solutions based on jointly developed and agreed-upon design criteria. (MS-ETS1-2)
- Obtaining, Evaluating, and Communicating Information: Communicate scientific and/or technical information (e.g., about a proposed object, tool, process, system) in writing and/or through oral presentations.

Common Core State Standards Connections

English Language Arts/Literacy

- RST.6-8.7: Integrate quantitative or technical information expressed in words in a text with a version of that information expressed visually (e.g., in a flowchart, diagram, model, graph, or table). (MS-ETS1-3)
- RST.6-8.9: Compare and contrast the information gained from experiments, simulations, video, or multimedia sources with that gained from reading a text on the same topic. (MS-ETS1-2, MS-ETS1-3)
- WHST.6-8.7: Conduct short research projects to answer a question (including a self-generated question), drawing on several sources and generating additional related, focused questions that allow for multiple avenues of exploration. (MS-ETS1-2)
- WHST.6-8.9: Draw evidence from informational texts to support analysis, reflection, and research. (MS-ETS1-2)
- SL.8.5: Integrate multimedia and visual displays into presentations to clarify information, strengthen claims and evidence, and add interest. (MS-ETS1-4)

Mathematics

- MP.2: Reason abstractly and quantitatively. (MS-ETS1-1, MS-ETS1-2, MS-ETS1-3, MS-ETS1-4)
- 7.EE.3: Solve multistep real-life and mathematical problems posed with positive and negative rational numbers in any form (whole numbers, fractions, and decimals), using tools strategically. Apply properties of operations to calculate with numbers in any form, convert between forms as appropriate; and assess the reasonableness of answers using mental computation and estimation strategies. (MS-ETS1-1, MS-ETS1-2, MS-ETS1-3)

9th-12th Grade Standards

(https://www.nextgenscience.org/search-standards)

Science and Engineering (NGSS)

Disciplinary Core Ideas

- HS-ETS1-1: Analyze a major global challenge to specify qualitative and quantitative criteria and constraints for solutions that account for societal needs and wants.
  - ETS1.A: Criteria and constraints also include satisfying any requirements set by society, such as taking issues of risk mitigation into account, and they should be quantified to the extent possible and stated in such a way that one can tell if a given design meets them.
- HS-ETS1-2: Design a solution to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering.
  - ETS1.C: Criteria may need to be broken down into simpler ones that can be approached systematically, and decisions about the priority of certain criteria over others (tradeoffs) may be needed.
- HS-ETS1-3: Evaluate a solution to a complex real-world problem based on prioritized criteria and tradeoffs that account for a range of constraints, including cost, safety, reliability, and aesthetics, as well as possible social, cultural, and environmental impacts.
  - ETS1.B: When evaluating solutions, it is important to take into account a range of constraints, including cost, safety, reliability, and aesthetics, and to consider social, cultural, and environmental impacts.
- HS-ETS1-4: Use a computer simulation to model the impact of proposed solutions to a complex real-world problem with numerous criteria and constraints on interactions within and between systems relevant to the problem.
  - ETS1.B: Both physical models and computers can be used in various ways to aid in the engineering design process. Computers are useful for a variety of purposes, such as running simulations to test different ways of solving a problem or to see which one is most efficient or economical; and in making a persuasive presentation to a client about how a given design will meet his or her needs.

Crosscutting Concepts

- Systems and System Models: Models (e.g., physical, mathematical, computer models) can be used to simulate systems and interactions—including energy, matter, and information flows—within and between systems at different scales. (HS-ETS1-4)
- Influence of Science, Engineering, and Technology on Society and the Natural World: New technologies can have deep impacts on society and the environment, including some that were not anticipated. Analysis of costs and benefits is a critical aspect of decisions about technology. (HS-ETS1-1, HSETS1-3)

Science and Engineering Practices

- Asking Questions and Defining Problems: Analyze complex real-world problems by specifying criteria and constraints for successful solutions. (HS-ETS1-1)
- Developing and Using Models: A practice of both science and engineering is to use and construct models as helpful tools for representing ideas and explanations. These tools include diagrams, drawings, physical replicas, mathematical representations, analogies, and computer simulations.
- Planning and Carrying Out Investigations: Scientists and engineers plan and carry out investigations in the field or laboratory, working collaboratively as well as individually. Their investigations are systematic and require clarifying what counts as data and identifying variables or parameters.
- Analyzing and Interpreting Data: Scientific investigations produce data that must be analyzed in order to derive meaning. Because data patterns and trends are not always obvious, scientists use a range of tools—including tabulation, graphical interpretation, visualization, and statistical analysis—to identify the significant features and patterns in the data. Scientists identify sources of error in the investigations and calculate the degree of certainty in the results. Modern technology makes the collection of large data sets much easier, providing secondary sources for analysis.
- Using Mathematics and Computational Thinking: Use mathematical models and/or computer simulations to predict the effects of a design solution on systems and/or the interactions between systems. (HS-ETS1-4)
- Constructing Explanations and Designing Solutions: Design a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations. (HS-ETS1-2) Evaluate a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations. (HS-ETS1-3)
- Engage in Argument From Evidence: Evaluate competing design solutions to a real-world problem based on scientific ideas and principles, empirical evidence, and/or logical arguments regarding relevant factors (e.g., economic, societal, environmental, ethical considerations).
- Obtaining, Evaluating, and Communicating Information: Communicate scientific and/or technical information or ideas (e.g., about phenomena and/or the process of development and the design and performance of a proposed process or system) in multiple formats (including orally, graphically, textually, and mathematically).

Common Core State Standards Connections

English Language Arts/Literacy

- RST.11-12.7: Integrate and evaluate multiple sources of information presented in diverse formats and media (e.g., quantitative data, video, multimedia) in order to address a question or solve a problem. (HS-ETS1-1, HS-ETS1-3)
- RST.11-12.8: Evaluate the hypotheses, data, analysis, and conclusions in a science or technical text, verifying the data when possible and corroborating or challenging conclusions with other sources of information. (HS-ETS1-1, HS-ETS1-3)
- RST.11-12.9: Synthesize information from a range of sources (e.g., texts, experiments, simulations) into a coherent understanding of a process, phenomenon, or concept, resolving conflicting information when possible. (HS-ETS1-1, HS-ETS1-3)

Mathematics

- MP.2: Reason abstractly and quantitatively. (HS-ETS1-1, HS-ETS1-3, HS-ETS1-4)
- MP.4: Model with mathematics. (HS-ETS1-1, HS-ETS1-2, HS-ETS1-3, HS-ETS1-4)

6th–8th Grade Computer Science Teachers Association (CSTA) Standards

(https://www.csteachers.org/page/standards)

Computer Science Teachers Association (CSTA) K–12 Computer Science Standards	
• 2-CS-03: Systematically identify and fix problems with computing devices and their components. • 2-DA-07: Represent data using multiple encoding schemes. • 2-DA-08: Collect data using computational tools and transform the data to make it more useful and reliable. • 2-DA-09: Refine computational models based on the data they have generated. • 2-AP-10: Use flowcharts and/or pseudocode to address complex problems as algorithms. 2-AP-11: Create clearly named variables that represent different data types and perform operations on their values	• 2-AP-13: Decompose problems and subproblems into parts to facilitate the design, implementation, and review of programs. • 2-AP-14: Create procedures with parameters to organize code and make it easier to reuse. • 2-AP-15: Seek and incorporate feedback from team members and users to refine a solution that meets user needs. • 2-AP-16: Incorporate existing code, media, and libraries into original programs, and give attribution. • 2-AP-18: Distribute tasks and maintain a project timeline when collaboratively developing computational artifacts.

9th–12th Grade Computer Science Teachers Association (CSTA) Standards

(https://www.csteachers.org/page/standards)

Computer Science Teachers Association (CSTA) K–12 Computer Science Standards	
• 3A-CS-02: Compare levels of abstraction and interactions between application software, system software, and hardware layers. • 3A-CS-03: Develop guidelines that convey systematic troubleshooting strategies that others can use to identify and fix errors. • 3A-DA-11: Create interactive data visualizations using software tools to help others better understand real-world phenomena. • 3A-DA-12: Create computational models that represent the relationships among different elements of data collected from a phenomenon or process. • 3A-AP-17: Decompose problems into smaller components through systematic analysis, using constructs such as procedures, modules, and/or objects. • 3A-AP-18: Create artifacts by using procedures within a program, combinations of data and procedures, or independent but interrelated programs. • 3A-AP-21: Evaluate and refine computational artifacts to make them more usable and accessible. • 3A-AP-22: Design and develop computational artifacts working in team roles using collaborative tools.	• 3A-AP-23: Document design decisions using text, graphics, presentations, and/or demonstrations in the development of complex programs. • 3A-IC-24: Evaluate the ways computing impacts personal, ethical, social, economic, and cultural practices. • 3A-IC-27: Use tools and methods for collaboration on a project to increase connectivity of people in different cultures and career fields. • 3B-DA-06: Select data collection tools and techniques to generate data sets that support a claim or communicate information. • 3B-AP-14: Construct solutions to problems using student-created components, such as procedures, modules, and/or objects. • 3B-AP-20: Use version control systems, integrated development environments (IDEs), and collaborative tools and practices (code documentation) in a group software project. • 3B-AP-24: Compare multiple programming languages and discuss how their features make them suitable for solving different types of problems.

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