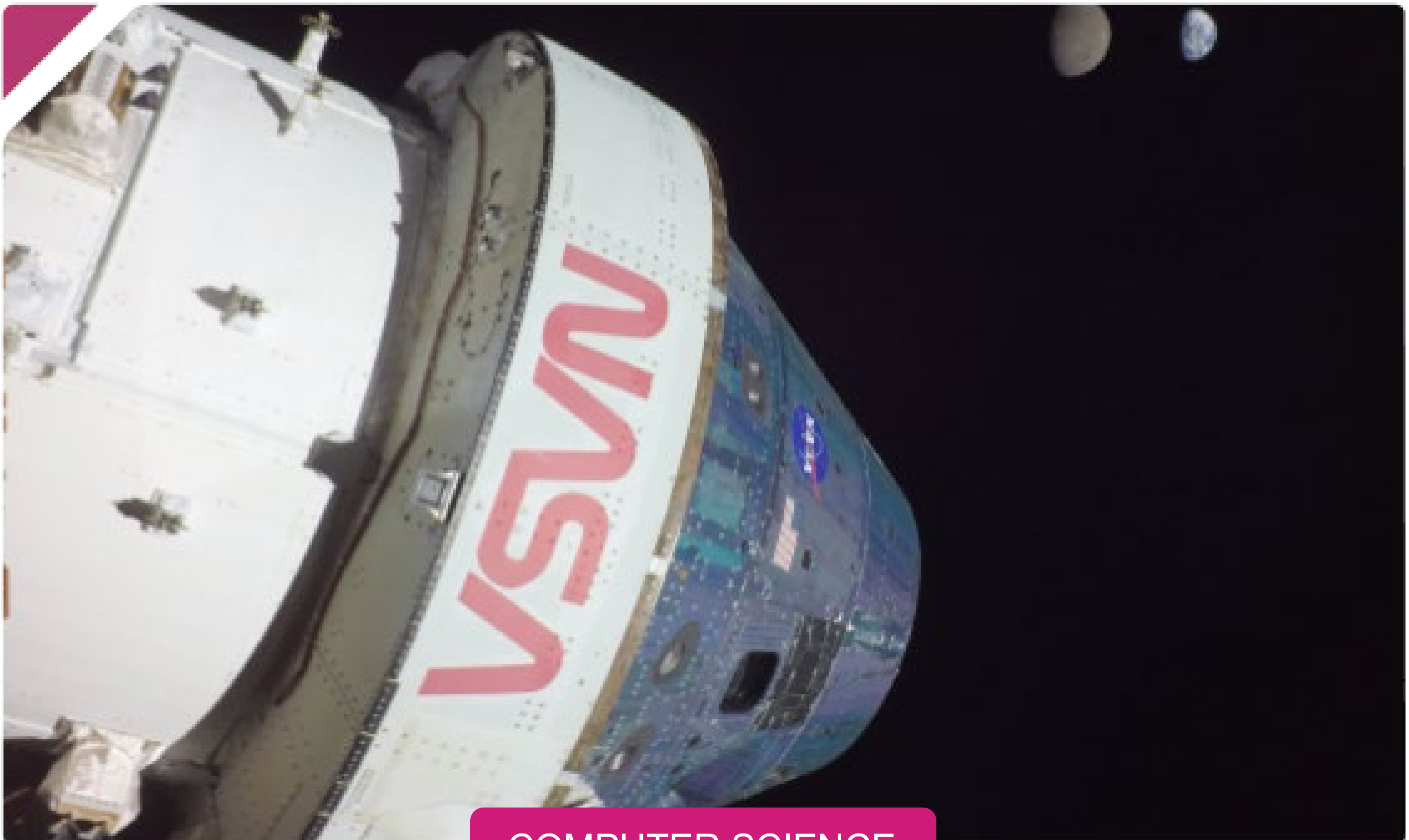
National Aeronautics and Space Administration

App Development Challenge

2025 Handbook



COMPUTER SCIENCE

Next Gen STEM

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Education Product	
Educators and Students	Grades 5-12

Contents

NASA App Development Challenge

Welcome middle and high school students and educators to the NASA App Development Challenge!

Are you someone who likes to code, create apps, or develop amazing visuals and graphics? Are you interested in coding or computer science, but just haven't had a chance to learn more? If so, then it's time to join the ADC!

About this Handbook

The App Development Challenge Handbook provides all relevant details for educators and students to develop a software application (app) in support of NASA's Space Communications and Navigation (SCaN) Team.

New to programming? [Check out NASA Computer Science Educational Resources](#).

Previous ADC Top Teams showcasing their applications to the public and NASA personnel at the culminating event.
Photo Credit: NASA

Artemis II

The Artemis II flight test will be NASA's first mission with crew under Artemis and will pave the way to land the first woman and first person of color on the Moon on Artemis III. With NASA's Artemis campaign, humans will return to the Moon for long-term exploration and scientific discovery, gaining the knowledge needed for future missions to worlds beyond, including Mars.

"The unique Artemis II mission profile will build upon the uncrewed Artemis I flight test by demonstrating a broad range of the Space Launch System and Orion capabilities needed on deep space missions," said Mike Sarafin, Artemis mission manager.

Leaving Earth

Artemis II will launch four astronauts from NASA's Kennedy Space Center in Florida on the Space Launch System (SLS) rocket. Orion will perform multiple maneuvers to raise its orbit around Earth and eventually place the crew on a lunar free return trajectory in which Earth's gravity will naturally pull Orion back home after flying by the Moon.

The initial launch will be similar to Artemis I as SLS lofts Orion into space. With crew aboard this mission, Orion and the upper stage, called the interim cryogenic propulsion stage (ICPS), will then orbit Earth twice to ensure Orion's systems are working as expected while still close to home.

Checking Critical Systems

They will remove the Orion Crew Survival System suit they wear for launch, until they don their suits again to prepare for reentry into Earth's atmosphere and recovery from the ocean.

While still close to Earth, the crew will assess the performance of the life support systems necessary to generate breathable air and remove the carbon dioxide and water vapor produced when the astronauts breathe, talk, or exercise. The long orbital period around Earth provides an opportunity to test the systems during exercise periods, where the crew's metabolic rate is the highest, and a sleep period, where the crew's metabolic rate is the lowest.

NASA astronauts (left to right) Christina Koch, Victor Glover, Reid Wiseman, Canadian Space Agency Astronaut Jeremy Hansen. Credit: NASA/Josh Valcarcel

Orion will also checkout the communication and navigation systems to confirm they are ready for the trip to the Moon. While still in the elliptical orbit around Earth, Orion will briefly fly beyond the range of GPS satellites and the Tracking and Data Relay Satellites of NASA's Space Network to allow an early checkout of agency's Deep Space Network communication and navigation capabilities. When Orion travels out to and around the Moon, mission control will depend on the Deep Space Network to communicate with the astronauts, send imagery to Earth, and command the spacecraft.

To the Moon and "Free" Ride Home

With a return trip of about four days, the Artemis II mission is expected to last about 10 days. Instead of requiring propulsion on the return, this fuel-efficient trajectory harnesses the Earth-Moon gravity field, ensuring that—after its trip around the far side of the Moon—Orion will be pulled back naturally by Earth's gravity for the free return portion of the mission.

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's 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 NASA space communications activities, enabling the success of more than 100 NASA and non-NASA missions. SCaN manages both the Near Space Network and the Deep Space Network and ensures the availability and allocation of the radio frequency spectrum for all NASA programs.

SCaN also supports the research and development of cutting-edge space communications technologies, such as optical and wideband communications. The program is responsible for developing an integrated space communications and navigation architecture to support current and future science and human exploration programs.

Challenge Overview

In this year's challenge, middle or high school teams have 10 weeks to create a video showcasing their application visualizing the flight path of Artemis II while indicating which of SCaN's antennas are available to communicate with Earth in real-time.

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. At the conclusion of the interviews, NASA will select the Top Teams for a culminating event.

Members of an ADC Top Team present their application to the NASA workforce during the culminating event. Credit: NASA

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

All student teams must:

- Use any programming language (Java, C#, C++, Scratch, etc.) to complete the 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 is accepted.
- Complete the program requirements as identified by the ADC team.

Middle school teams must:

- Create an application which:
    - Displays the path of Artemis II by processing and visualizing all provided position data for the mission.
    - Utilizes color to represent the different phases of the mission (e.g., orbiting Earth, traveling to the Moon, traveling to Earth) and number of available antennas.
    - Utilizes the SCaN antenna data to display a prioritized list of antennas which have line-of-sight access to Artemis II.

High school teams must:

- Create an application which:
    - Displays the path of Artemis II by processing and visualizing all provided position and velocity data for the mission.
    - Utilize color to represent the different phases of the mission (e.g., orbiting Earth, traveling to the Moon, traveling to Earth), number of available antennas, and resultant velocity vector.
    - Utilizes the Link budget formula and the SCaN antenna's data to display a prioritized list of antennas with line-of-sight access to Artemis II (e.g., least number of communication asset changes or highest link budget).

Review the Timeline

- September 25, 2024: STEM Gateway Registration Closes
- September 28, 2024: Lead Teacher Training (Lead Teacher chooses one to attend)
- September 30, 2024: Lead Teacher Training (Lead Teacher chooses one to attend)
- October 2, 2024: Live Virtual Kickoff Event
- October 16, 2024: Live Virtual Connection: Creating Visualizations of Trajectory Data
- November 6, 2024: Live Virtual Connection: Displaying Communication Information
- November 20, 2024: Live Virtual Connection: Planning a Mission
- December 11, 2024: ADC Video Submission Deadline
- January 15, 2025: Join the Artemis Generation Webinar

Review the Eligibility Requirements

- Formal or informal U.S. education organizations may participate.
- Signed letter of support from the principal or administrator of your organization must be uploaded to the Files section of your STEM Gateway application. See an example letter in Appendix E.
- 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 2024–2025 school year.
  - All members of a high school team must be in grades 9–12 during the 2024–2025 school year.
- Teams must be led by a sponsor or educator (i.e., Lead Teacher) from an informal or formal U.S. education organization.
- Lead Teacher must attend one of two virtual NASA CONNECTS events held on Oct. 24 or Nov. 11.
- The minimum team size is five students and one Lead Teacher. There is no maximum team size.
- If selected as a Top Team invited to the culminating event at NASA's Johnson Space Center in Houston, you must meet the following:
  - The Lead Teacher, five members of the team, and a chaperone will travel. The chaperone must be a part of the organization and be of opposite gender of the Lead Teacher if both genders are represented within the student team.
  - All participants who travel must be U.S. citizens.
  - Student members must be aged 13 or older during travel.
  - Organization chaperones are fully responsible for their students during the culminating event.
  - Traveling participants will use the provided housing and transportation. Participants are responsible for meal expenses and incidentals. 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 requirements above, each Lead Teacher must complete the steps below by **September 25, 2024**:

- 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: 2025 App Development Challenge Handbook.

Lead Teachers, by registering to participate, acknowledge the team, if selected, is confirming full participation through the end of the culminating event. Dates are subject to change.

Click to access the NASA STEM Gateway ADC 2025 opportunity and register your team.

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 2, 2024. Video submissions are due on Wednesday, December 11, 2024, by 2 p.m. CT. 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 (LVC) 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 25, 2024.

App Development Challenge Timeline*

Start Date	End Date	NASA ADC Activity*
10/2/2024	**12/11/2024**	**App Development Challenge (10 weeks)**
10/2/2024	10/2/2024	LVC† 1: Live Virtual Kickoff Event
10/16/2024	10/16/2024	LVC 2: Creating Visualization from Trajectory Data
10/24/2024	10/24/2024	NASA CONNECTS Event – Lead Teacher must attend 1 of the two events (10/24, 11/21)
11/6/2023	11/6/2024	LVC 3: Displaying Communication Information
11/20/2024	11/20/2024	LVC 4: Student Team Interviews, Planning a Mission
11/21/2024	11/21/2024	NASA CONNECTS Event – Lead Teacher must attend 1 of the two events (11/21)
12/11/2024	12/11/2024	Video Submission Deadline
1/15/2025	1/15/2025	ADC Special Virtual Event, "Join the Artemis Generation"
1/27/2025	2/3/2025	Selected Team Interviews with NASA SCaN Team
2/26/2024	2/26/2024	Announcement of Top Teams for Culminating Event
4/14/2025	**4/17/2025**	**NASA ADC Culminating Event**

**Timeline is subject to change.*

†LVC = Live Virtual Connection.

Middle School Challenge

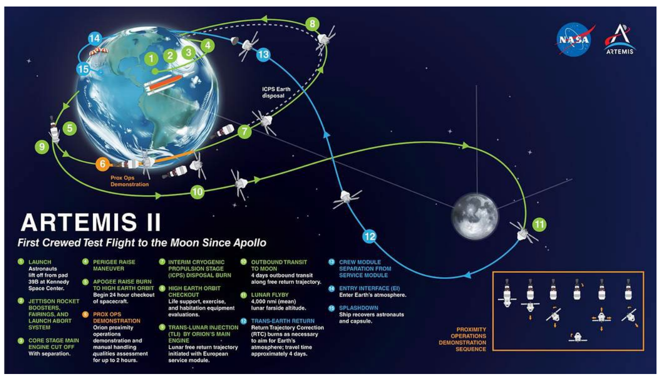
Initial Steps

1. Lead Teacher reads the challenge handbook and reviews information pertaining to the students' grade level.
2. Review the Middle School Scoring Rubric in Appendix A for detailed information on each challenge requirement.
    a. Download the middle school mission files (available at the ADC website on the day of the Live Virtual Kickoff) to create a visualization of the mission.
3. Organize your team and app design utilizing K-12 Computer Science Framework's 7 Core Practices and Storyboard located in Appendix B.

Visualization

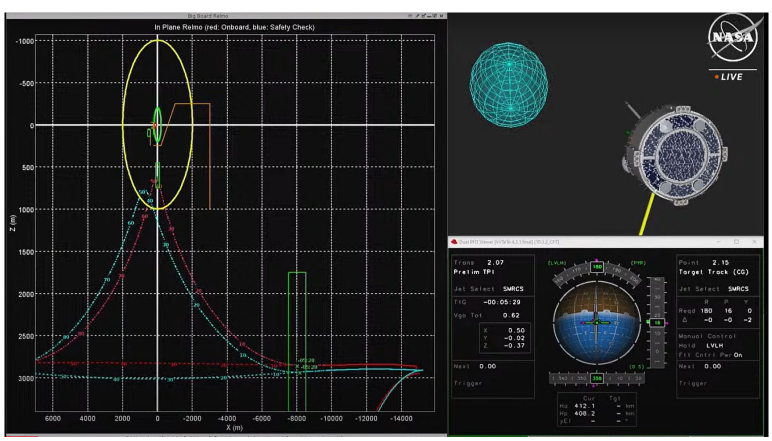
Create an application displaying critical information for the mission:

1. Mission Path — Utilize the mission path data file to create a real-time visualization of the mission.
    a. Change the color of the visualization and include a color key to convey information about:
        i. Mission Status (orbiting Earth, on the way to the Moon, returning to Earth, and Entry, Descent and Landing (EDL)).
        ii. Number of antennas available.



Artemis II mission map. Credit: NASA

2. Trajectory Information — Display the mission time and trajectory data of the mission during the visualization in some meaningful way beyond text.
3. Communication links — Utilize the antenna data to display a prioritized list of the available Deep Space Network antennas.



Mission Control Display of Boeing Starliner mission CFT1. Credit: NASA YouTube

App Development Challenge

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. They may include:

- Display total distance traveled during the mission.
- Create a mini map displaying the whole mission.
- Create a visual of the Orion capsule, service module, and second stage. Indicate when either the second stage or service module is firing.
- Utilize machine learning/neural networks in your solution.
- Overlay the sensor noise data (located in the MS Bonus File) to the mission data.
- Create a "smooth" path of the noise data utilizing filters and overlay the "smooth" path over the noise path.

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 Middle School Video Presentation Rubric (in Appendix A) will be used to assess and score the video. However, review the requirements using the 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 team's school or organization. *Note: team members can be seen in the video if in accordance with school guidelines.*
    - 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 according to the Middle School Rubric.
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 identified and used?
6. Describe community events held and plans for future events.

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

Mentors

Middle 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 the development of the app.

Middle school teams needing additional assistance in developing an app can reach out to the ADC team for guided practice and/or attend Technical Office Hours.

High School Challenge

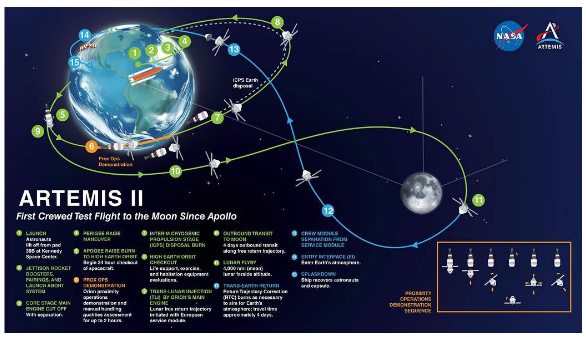
Initial Steps

1. Lead Teacher reads the challenge handbook and reviews information pertaining to the students' grade level.
2. Review the High School Scoring Rubric in Appendix A for detailed information on each challenge requirement.
3. Download the high school flight path file and communication file (available at the ADC website on the day of the Live Virtual Kickoff) to create a visualization of the mission.
4. 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

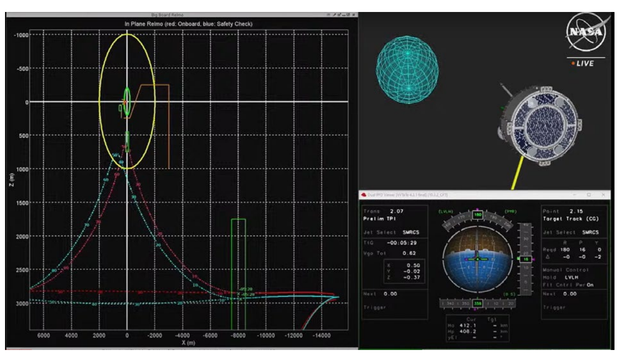
Create an application displaying critical information for the mission:

1. Mission Path — Utilize the flight path data file to create a real-time visualization of the mission.
    a. Change the color of the visualization and include a color key to convey information about:
        i. Mission Status (orbiting Earth, on the way to the Moon, returning to Earth, and Entry, Descent and Landing (EDL)).
        ii. Resultant Velocity Vector.
        iii. Number of antennas available.



Artemis II mission map. Credit: NASA

2. Trajectory Information — Display the mission time, velocity, and trajectory data of the mission through animation in some meaningful way beyond text.
3. Communication links — Utilize the link budget formula to display a prioritized list of the available antennas throughout the mission.



Mission Control Display of Boeing Starliner mission CFT1. Credit: NASA YouTube

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. Below are opportunities to gain extra points.

- Display total distance traveled during the mission.
- Create a mini map displaying the whole mission.
- Create a visual of the Orion capsule, service module, and second stage. Indicate when either the second stage or service module is firing.
- Utilize machine learning/neural networks in your solution.
- Plot the off-nominal mission path (located in the HS Bonus file) over the original mission path.
- Update the antenna availability and link budget for the off-nominal mission utilizing the location of the antennas, and rotation of the Earth.

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, review the requirements 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 team's school or organization. *Note: team members can be seen in the video if in accordance with school guidelines.*
    - Identify what coding language was utilized, 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 according to the High School Rubric.
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 plans for future events.

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 the 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

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 associated best practices. Live Virtual Connections provide student teams the opportunity to ask questions and seek clarification during the events. Teams may ask questions to NASA personnel at the end of the presentations.

Weekly Office Hours, held Wednesdays at 4 p.m. CST, provide student teams with the opportunity to ask questions to the ADC Technical Specialist and gain clarification about the Live Virtual Connections. The Office hours are optional and provide a place to obtain individualized team help on questions the team is struggling with. Students may attend only with a Lead Teacher present.

The ADC Team prefers student teams gather in one location to participate in LVCs or Office Hours and not use student names for logging into the event.

Plagiarism and Utilization of Artificial Intelligence

Teams must submit their own work, originating from the 10-week challenge. Additionally, teams shall not submit OpenAI generated solutions. AI code detection monitoring has been implemented. Teams found to be in violation of plagiarism or using AI code will be disqualified from the ADC.

Team Interview and Top Teams Selection

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

The interview will be 30 to 45 minutes long via video conference. Teams will answer questions posed by the ADC and SCaN teams, listen to technical suggestions to improve the application's functionality, and ask questions to both the SCaN and ADC teams.

Each team's written submission and live interview help determine the team(s) selected for the culminating event. The ADC team will rank the teams, 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. Top teams selected to participate in the culminating event will travel to a NASA field center, tour unique NASA facilities, and present their work to the community and NASA leadership. Additionally, top teams will be invited to a special virtual Artemis II launch event in September 2025 (schedule permitting).

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

Community Engagement

All teams are expected to share their work in space exploration through planned community engagement efforts. 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. **Lead Teachers and students should follow their school or organization's guidelines for these types of events.** As events are completed, Lead Teachers should email a short summary to the ADC team and include images and videos of outreach events. Teams should also include images and videos of outreach events in the team's video submission. Teams selected to participate in the culminating event will need to plan additional community engagement 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. The team's planned community engagement needs to include information on QIST, specifically World Quantum Day 2025 and QuanTime activities, lessons, and games for students and educators. Additional information and resources are located at NASA SCaN Quantum Communications.

Social Media

Social media allows teams the opportunity to share their unique NASA experience with the public and promote the challenge. Teams may create a web presence using platforms of their choice, including **#NextGenSTEM** and **#NASA_ADC** when posting, which allows the ADC team to follow along. Teams must follow their school or organization's guidelines related to social media.

Media Relations

As teams share their experiences with the public, opportunities to interact with the media may present themselves. 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 initial press releases to registered teams as well as a press release to the Top Teams selected to attend the culminating event.

Media Releases

The Lead Teacher, as well as all students of teams selected for an interview, must complete and submit a NASA Media Release. The media release covers challenge video submissions, team interviews, and any media covering participation in the culminating event.

Top Team(s) selected for the culminating event may need 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 simulations for use on various devices.
- Unreal Engine® (Epic Games, Inc.) — 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.
- GMAT — NASA's General Mission Analysis Tool (GMAT) an open-source software system (latest version R2022a) for space mission design, optimization, and navigation.

STEM Engagement Resources

- Code.org® — Nonprofit dedicated to expanding access to computer science.
- QuanTime — Activities designed to introduce middle and high school students to quantum information science.
- First Woman Graphic Novel — This set of hands-on activities accompanies NASA's "First Woman" graphic novel series, which tells the story of Callie Rodriguez, the first woman to explore the Moon.
- Artemis Rocket Build — Minecraft Education resource to introduce middle and high school students to the Artemis missions, and Newton's laws, through Minecraft.
- 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.
- 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.
- NetworKing — Allows players to become a network manager and build communications network to support scientific missions.

App Development Challenge

Research Links

Artemis Mission

- NASA Orion Spacecraft – NASA Orion website.
- Space Launch System – NASA Space Launch System (SLS) website.
- Artemis Missions – Artemis home page.
- Artemis I – Artemis I mission review.
- Artemis II – Artemis II overview and crew.
- Artemis II: Mission Overview – Video highlighting Artemis mission objectives.
- Success and Preparation – Video describing the success of Artemis I and the preparation for Artemis II.
- Artemis Mission Maps – Artemis I through Artemis V infographics.

Space Communications

- NASA's Space Communications and Navigation (SCaN) – SCaN home page.
- SCaN Space Networks – Links to description of the different communications networks associated with SCaN.
- SCaN Now – Real-time status display for NASA's ground stations.

Lunar Information

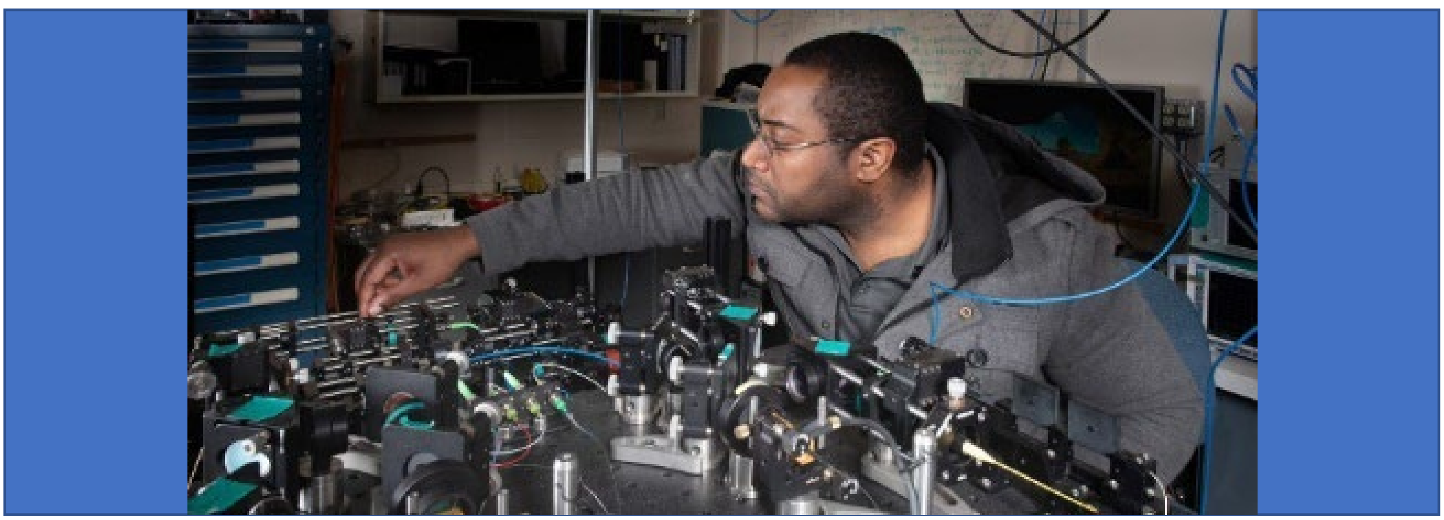
- Moon: NASA Science – Interactive Moon landing and geography map, news, and articles.
- NASA 3D Resources – NASA 3D models, images, and textures on GitHub®.

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 People – Articles and videos highlighting various NASA careers.
- NASA People (YouTube) – Videos of NASA employees highlighting their work across the Agency.



NASA Quantum Information Scientist Daniel Hart aligning optics for a setup that converts laser light from one wavelength to another. Wavelength conversion technique allows researchers to use a single laser for multiple laboratory applications. (NASA)

Appendix A – Rubrics

Middle School Rubric

Category	Best = 3 points	Better = 2 points	Good = 1 point	Missing = 0 points	Total Points
App Creation — Data Modeling	App visualizes the mission from the provided data and accurately displays it in real-time. Earth and Moon displayed accurately.	App visualizes the mission from the provided data and accurately displays it in real-time.	App visualizes the mission from the provided data and accurately displays it.	App fails to visualize the mission from the provided data.	Raw Score Multiplier x 3
App Creation — Color	App uses color to appropriately convey information about Mission Status and number of antennas available with corresponding color key.	App uses color to appropriately convey information about Mission Status OR number of antennas available with corresponding color key.	App uses color but does not appropriately convey information or is missing a color key.	App fails to use color to convey information.	Raw Score Multiplier x 2
App Creation — Prioritize Antennas	App provides a rationale supporting the prioritization list of available antennas by the least number of antenna changes. App provides a rationale supporting the prioritization list of available antennas by the link budget.	App provides a rationale supporting the prioritization list of available antennas by least number of antenna changes or link budget.	App identifies antennas available with no prioritization.	App fails to identify any antenna.	Raw Score Multiplier x 3
App Creation — User Interface	The User Interface shows the data modeling, color, and prioritization of antennas. Additionally, the User Interface has toggle switches for the color and the prioritization of antennas.	The User Interface shows 3 of the following: the data modeling, color, and prioritization of antennas, toggle switches for the color and the prioritization of antennas.	The User Interface shows 2 of the following: the data modeling, color, and prioritization of antennas, toggle switches for the color and the prioritization of antennas.	There is not a user interface or less than 2 of the following: the data modeling, color, prioritization of antennas, toggle switches for the color and the prioritization of antennas.	Raw Score Multiplier x 3
Video Commentary — App Creation	All App Creation components (above) 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 Creation component (above) 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 about how the team worked to complete it.	At least one App Creation component (above) is described, but its function, and how the team worked to complete it, is not fully described.	Identification of App Creation components (above) 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 or no action was taken to solve the challenges.	Narrative of challenges encountered is not included.	
Video Commentary — Student Acquired Skills	Key skills (hard and soft) 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 (hard and soft) 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 narrative on how they were acquired or incorporated into the development of the app.	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 is 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 two completed community engagement events including Quantum Day Information and QuanTime activities. Social media outreach, if allowed by school.	Evidence of one completed community engagement events including Quantum Day Information and QuanTime activities. Social media outreach, if allowed by school.	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. Below are opportunities to gain extra points. • Display total distance traveled during the mission. • Create a mini map displaying the whole mission. • Create a visual of the Orion capsule, service module, and second stage. Indicate when either the second stage or service module is firing.	• Utilize machine learning/neural networks in your solution. • Overlay the sensor noise data (located in the MS Bonus File) to the mission data. • Create a "smooth" path of the noise data utilizing filters and overlay the "smooth" path over the noise path.			
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 — Data Modeling	App visualizes the mission from the provided data and accurately displays it in real-time. Earth and Moon displayed accurately.	App visualizes the mission from the provided data and accurately displays it in real-time.	App visualizes the mission from the provided data and accurately displays it.	App fails to visualize the mission from the provided data.	Raw Score Multiplier x 3
App Creation — Color	App uses color to appropriately convey information about Mission Status, resultant velocity vector, and number of antennas available with corresponding color key.	App uses color to appropriately convey information about Mission Status, resultant velocity vector OR number of antennas available with corresponding color key.	App uses color but does not appropriately convey information or is missing a color key.	App fails to use color to convey information.	Raw Score Multiplier x 2
App Creation — Prioritize Antennas	App provides a rationale supporting the prioritization list of available antennas by the least number of antenna changes. App provides a rationale supporting the prioritization and accurately calculated link budgets.	App provides a rationale supporting the prioritization list of available antennas by least number of antenna changes and inaccurately calculated link budgets.	App provides a rationale supporting the prioritization list of available antennas by least number of antenna changes or link budget.	App fails to identify any antenna.	Raw Score Multiplier x 3
App Creation — User Interface	The User Interface shows the data modeling, color, and prioritization of antennas. Additionally, the User Interface has toggle switches for the color and the prioritization of antennas.	The User Interface shows 3 of the following: the data modeling, color, and prioritization of antennas, toggle switches for the color and the prioritization of antennas.	The User Interface shows 2 of the following: the data modeling, color, and prioritization of antennas, toggle switches for the color and the prioritization of antennas.	There is not a user interface or less than 2 of the following: the data modeling, color, prioritization of antennas, toggle switches for the color and the prioritization of antennas.	Raw Score Multiplier x 3
Video Commentary — App Creation	All App Creation components (above) 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 Creation component (above) 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 about how the team worked to complete it.	At least one App Creation component (above) is described, but its function, and how the team worked to complete it, is not fully described.	Identification of App Creation components (above) 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 or no action was taken to solve the challenges.	Narrative of challenges encountered is not included.	
Video Commentary — Student Acquired Skills	Key skills (hard and soft) 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 (hard and soft) 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 narrative on how they were acquired or incorporated into the development of the app.	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 is 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 two completed community engagement events including Quantum Day Information and QuanTime activities. Social media outreach, if allowed by school.	Evidence of one completed community engagement events including Quantum Day Information and QuanTime activities. Social media outreach, if allowed by school.	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. Examples include the following: • Display total distance traveled during the mission. • Create a mini map displaying the whole mission. • Create a visual of the Orion capsule, service module, and second stage. Indicate when either the second stage or service module is firing. • Utilize machine learning/neural networks in your solution. • Plot the off-nominal mission path (located in the HS Bonus file) over the original mission path. • Update the antenna availability and link budget for the off-nominal mission utilizing the location of the antennas, and rotation of the Earth.				
Team Name ______________________________			FINAL SCORE	(out of 48)	
			FINAL % SCORE		

Appendix B – Organizational Resources

K-12 Computer Science Framework's 7 Core Practices

The illustration below 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.

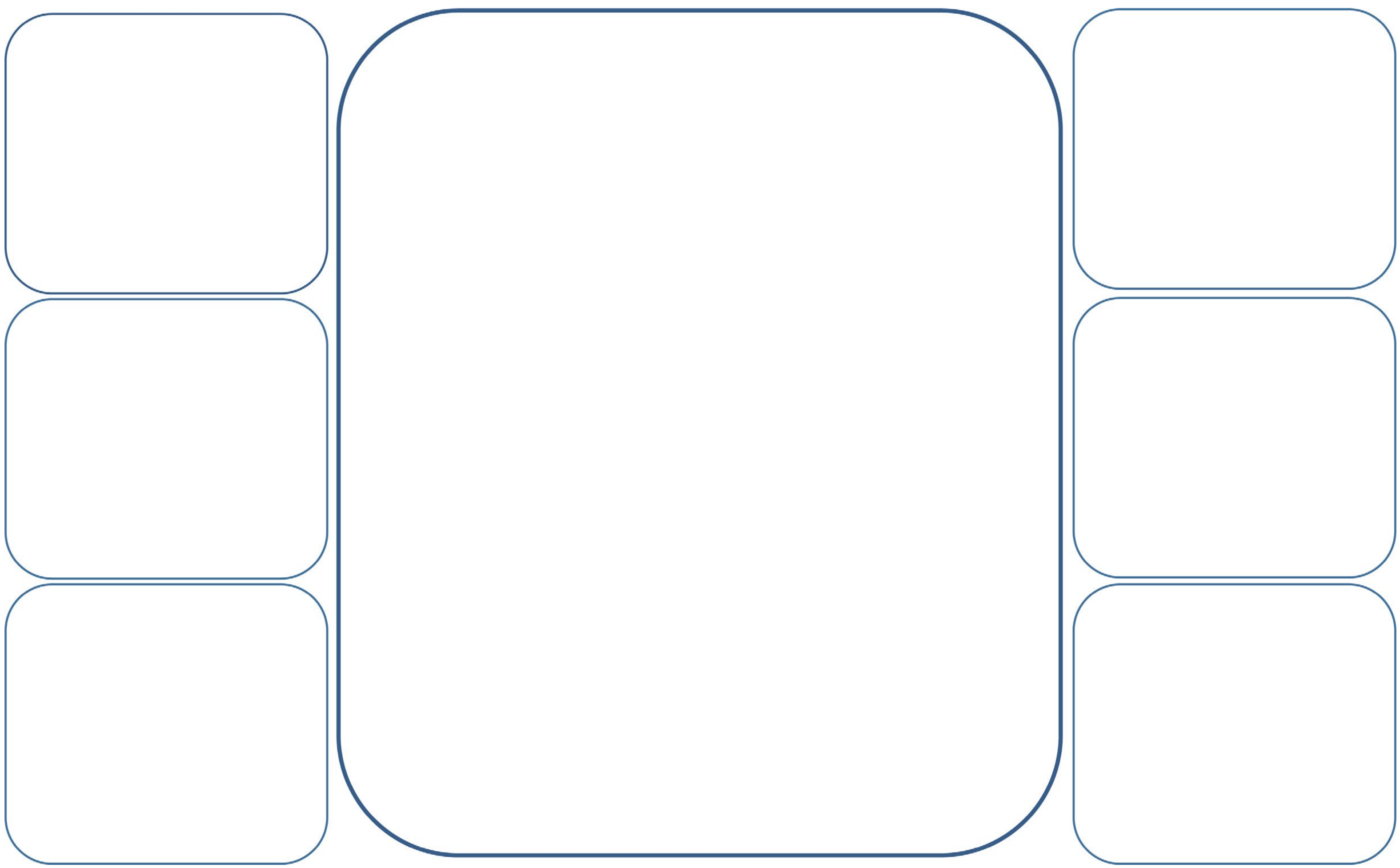
K–12 Computer Science Framework's 7 Core Practices.
(Adapted from K–12 Computer Science Framework, Creative Commons license CC BY-NC-SA 4.0)

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 trajectory data. • Code ways to communicate information via color. • Code ways to visualize available communication satellites. • 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 displaying the mission path in real-time. • 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.

App Development Challenge

Storyboard

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



Appendix C – Formula Chart

The following equations may be needed for the challenge.

Calculating Resultant Velocity (For HS challenge and MS extra credit)

- $velocity\ vector = \sqrt{{v_x}^2 + {v_y}^2 + {v_z}^2}$

Link Budget Equation (For HS challenge)

$$B_n = \frac{10^{\frac{1}{10}\left[P_t + G_t - Losses + 10\log_{10}\eta_R\left(\frac{\pi d_r}{\lambda}\right)^2 - 20\log_{10}\frac{4000\pi R}{\lambda} - k_b - 10\log_{10}T_s\right]}}{1000}$$

Constants for ADC25	Student Inputs	d_r = Ground Station Antenna Diameter (m)
P_t = Satellite Transmitter Power (in Decibel Watts, dBw) = 10 dBW	d_r = Ground Station Antenna Diameter (in meters, m)	DSS24 = 34m
G_t = Satellite Antenna Gain (in Decibel Isotopic, dBi) = 9 dBi	R = Slant Range (in kilometers, km);	DSS34 = 34m
Losses (in Decibels, db) = 19.43 db		DSS54 = 34m
η_R = Ground Station Antenna efficiency = 0.55		WPSA = 12m
λ = c/f = Speed of Light/Carrier Frequency (in meters, m) = 0.136363636 m		
k_b = Boltzmann Constant (in Decibel Watts per degree Kelvin per Hertz, dBW/K/Hz)= -228.6 dBW/K/Hz		
T_S = System Noise Temperature (in degrees Kelvin, K) = 222 K		

If the value of B_n that we calculate is greater than 10,000 kbps (10 Mbps), we must limit the rate at which Orion transmits data to 10 Mbps, if so B_n > 10 Mbps = 10 Mbps or 10,000 kbps.

Spherical to Cartesian Conversion (For HS extra credit to create new antenna availability)

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

Earth Radius = 6378.137 km   Radius = Earth Radius + Terrain Height

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

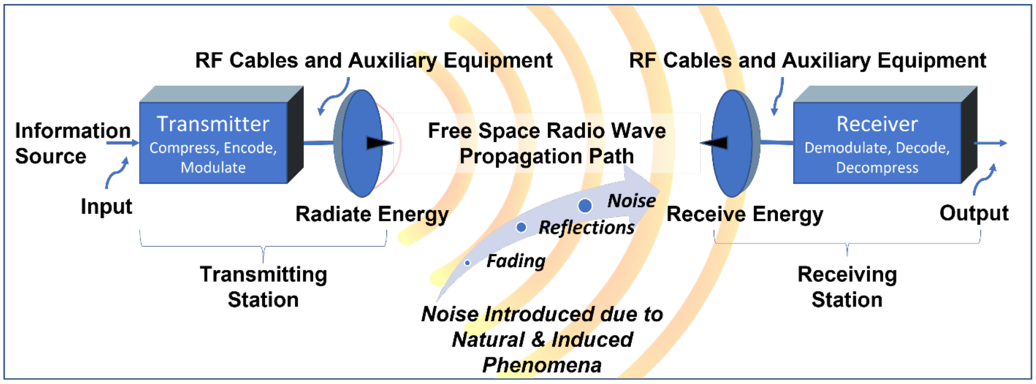
	Lat (deg)	Long (deg)	Terrain Height (km) (geodetic)
DSS 24	35.3399	-116.875	0.951499
DSS 34	-35.3985	148.982	0.69202
DSS 54	40.4256	-4.2541	0.837051
WPSA	37.9273	-75.475	-0.019736

- Launch Time: June 11, 2024, 3:25:47 PM UTC.

Earth and Moon Data

- Earth:
  - Mu (gravitational constant): 3.986e5 km^3/s^2
  - Mass: 5.974e24 kg
  - Radius: 6,378.137 km
- Moon:
  - Mu: 4.903e3 km^3/s^2
  - Mass: 7.3483e22 kg
  - Radius: 1737.4 km

Appendix D – Link Budget



A **link budget** is an equation accounting for all the gains and losses in power a communication signal experiences in transmitting over a communication medium, either wireless (e.g., radio waves) or wired (e.g., cable, waveguide, or optical fiber), to the receiver. In the figure above, the transmitter receives information from a source such as Orion's computer, transforms the information into the pattern used to transmit that information, radiates radio energy from an antenna that travels via the *medium*, receives a fraction of the energy, converts that signal back into the original information, and sends it over another link to its destination, such as the Mission Control Center. The "free space" path from Orion to the receiving ground station antenna occurs through the combined media that consists mostly of the vacuum of space, but also includes the Earth's atmosphere. The **space-Earth link** of interest, also known as the *downlink*, is transmission of data from a spacecraft to a ground station on Earth. We would design a separate link budget for the Earth-space link (or *uplink*) from the ground station to Orion.

The link budget lets us calculate the data rate we can achieve over a link based on the received power from the transmitted power after the attenuation of the transmitted signal (loss of signal strength) due to propagation through air and vacuum, as well as the **gains** due to amplifying the signal and **losses** due to imperfect design and noise, which comes from the naturally occurring background of the universe and interference induced by manmade sources. A link budget is calculated during the design of a communication system to determine how large the transmitting and receiving antennas must be, how much power is needed, and many other factors enable the data to be sent at the desired rate to ensure the information they receive is intelligible. For this year's App Development Challenge, the link budget is highly simplified, so it only depends on the range (distance) between Orion and the ground station antenna, as well as the size of the antenna. The antenna size is usually referred to in terms of the diameter of a circular dish, but the true measure of an antenna's gain is the transmitting or receiving *surface area* of the dish.

A simple link budget equation looks like this:

Received power = Transmitted power + Σ(gains) – Σ(losses)

To further simplify this for ADC25, the following equation uses these key components of a link budget, but translates from power directly into data rate using the following terms:

1. **Transmitted Power (P_t)**: This is the power of the signal sent from the satellite in Watts. Think of it as how loud the satellite is shouting.
2. **Antenna Gain (G_t and G_r)**: Antenna gains measure how well the Orion's transmitter antenna and ground station receiver antenna can focus the signal. Larger antennas can focus the signal better, just like a bigger ear can hear better.

3. **Slant Range (R)**: This is the distance between the satellite and the ground station and varies during the time the satellite and ground station are in contact (i.e., start range to stop range) due to the satellite's orbit and the Earth's rotation. The greater the distance, the weaker the signal gets, like how a friend's voice gets fainter as they move away.
4. **Noise (N)**: This includes all unwanted things that can interfere with the communication. Think of it as background noise that makes it harder to hear your friend's voice, like cars or other people talking.
5. **Losses**: There are many losses in a link budget, starting with the most critical one, the *free space path loss,* which is the signal lost as the signal travels from transmitter to receiver.
6. **Data Rate (B_n)**: This is how fast information can be sent. It's like how quickly you can talk without your friend missing any words. The more data you send, the more *electromagnetic spectrum* is needed to send it.
7. **Bandwidth constraint**: Since the whole world must share the electromagnetic spectrum of the universe, we impose limits on how much spectrum each system can use. For our example, we are transmitting on the downlink at 2200 million cycles per second, which is known as Mega Hertz (MHz). Our spectrum limit is 10 MHz[1] which equates to sending 10 million bits per second (Mbps).

Equation for data rate (B_n) in thousands of bps (kbps) without the bandwidth constraint:

$$B_n = \frac{10^{\frac{1}{10}\left[P_t + G_t - Losses + 10\log_{10}\eta_R\left(\frac{\pi d_r}{\lambda}\right)^2 - 20\log_{10}\frac{4000\pi R}{\lambda} - k_b - 10\log_{10}T_s\right]}}{1000}$$

Where:

Constants for ADC25	Student Inputs
P_t = Satellite Transmitter Power (in Decibel Watts, dBw) = 10 dBW	d_r = Ground Station Antenna Diameter (in meters, m)
G_t = Satellite Antenna Gain (in Decibel Isotopic, dBi) = 9 dBi	R = Slant Range (in kilometers, km);
Losses (in Decibels, db) = 19.43 db	
η_R = Ground Station Antenna Efficiency = 0.55	
λ = c/f = Speed of Light/carrier Frequency (in meters, m) = 0.136363636 m	
k_b = Boltzmann Constant (in Decibel Watts per degree Kelvin per Hertz, dBW/K/Hz)= -228.6 dBW/K/Hz	
T_S = System Noise Temperature (in degrees Kelvin, K) = 222 K	

If the value of B_n that we calculate is greater than 10,000 kbps (10 Mbps), we must limit the rate at which Orion transmits data to 10 Mbps, so if $B_n > 10$ Mbps = 10 Mbps or 10,000 kbps.

[1] This is actually determined by an agency of the United Nations called the International Telecommunications Union (ITU) which defines the world's Radio Regulations combined with coordination among the spacefaring nations that decide the single user limit within the 2200 MHz band so that many countries can share that frequency band.

Appendix E – Example Letter of Support

A letter, like the one shown below, should be uploaded to the Files section of you application in STEM Gateway. The letter must be on organization letterhead or in an email which includes the sender and subject line of the email.

Example:

> Dear ADC Team,
>
> I am the <Administrator Title> of <Organization Name>. <Teacher Name> has my full support to lead a student team in the 2025 App Development Challenge (ADC) through the entirety of the program. I understand the 2025 ADC runs from October 2–December 11, 2024, where <Teacher Name> will need to attend a two-hour teacher training (September 28th or 30th), a one-hour NASA CONNECT-ing Event (October 24th or November 21st), and four one and a half-hour Live Virtual Connections (October 2nd, October 16th, November 6th, and November 20th). I also understand if the student team does well enough, they may be invited to the Johnson Space Center in Houston on April 14–17, 2025.
>
> Sincerely,
>
> <Administrator Name>

Appendix F – General Mission Analysis Tool (GMAT)

The General Mission Analysis Tool is an optional piece of software students may use to get a visualization of the Artemis II mission. Students may research how to use the software and integrate it into the final solution for this year's App Development Challenge. The information below provides an overview of GMAT and a link to download the current 2022 version of the software.

> GMAT is an open-source, platform-independent, trajectory optimization and design system designed to model and optimize spacecraft trajectories in flight regimes ranging from low Earth orbit to lunar applications, interplanetary trajectories, and other deep space missions. The system supports constrained and unconstrained trajectory optimization, and built-in features, make defining cost and constraint functions trivial so analysts can determine how their inclusion or exclusion affects solutions.
>
> The system also contains initial value solvers (propagation) and boundary value solvers and efficiently propagates spacecraft, either singly or coupled. GMAT's propagators naturally synchronize the epochs of multiple vehicles and shorten run times by avoiding fixed-step integration or interpolation to synchronize epochs of spacecraft.
>
> A user can interact with GMAT using either a graphical user interface (GUI) or script language that has a syntax similar to the MathWorks' MATLAB® system. All of the system elements can be expressed through either interface, and users can configure elements in the GUI and then view the corresponding script or write a script and load it into GMAT.
>
> Analysts model space missions in GMAT by first creating resources such as spacecraft, propagators, and optimizers, to name a few. These resources can be configured to meet the needs of specific applications and missions. After the resources are configured, they are used in the mission sequence to model the motion of spacecraft and simulate events in a mission's time evolution. The mission sequence supports commands such as Nonlinear Constraint, Minimize, Propagate, Function Calls, Inline Math, and Script Events among others.
>
> The system can display trajectories in space, plot parameters against one another, and save parameters to files for later processing. The trajectory and plot capabilities are fully interactive, plotting data as a mission is run and allowing users to zoom into regions of interest. Trajectories and data can be viewed in any coordinate system defined in GMAT, and GMAT allows users to rotate the view and set the focus to any object in the display. The trajectory view can be animated, so users can watch the evolution of the trajectory over time.

- Download Link: GMAT version 2022a
- GMAT API documentation

Appendix G – Curriculum Standards

6^{th}-8^{th} Grade Standards

Science and Engineering (NGSS)
(https://www.nextgenscience.org/search-standards)

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 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

<table>
<tr><th colspan="2">Science and Engineering (NGSS)
(https://www.nextgenscience.org/search-standards)</th></tr>
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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)

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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).

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<tr><th colspan="2">Common Core State Standards Connections</th></tr>
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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)

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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)
- N-VM: Represent and model with vector quantities.
- G-MG3: Apply geometric methods to solve design problems.

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6th–8th Grade Computer Science Teachers Association (CSTA) Standards
(https://csteachers.org/k12standards/interactive/))

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://csteachers.org/k12standards/interactive/)

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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