Slide 1 –

Alex: Welcome, as you are coming in, please note you are not able to share your camera or use your mic as we want to conserve bandwidth for people. You may communicate with us via chat, to access the chat please click on the chat bubble at the top. Next, look at the questions in orange and answer one or more of them. We are especially interested in knowing any challenges you have encountered along the way so far. As a reminder, do not share personal information such as your school's name or the city you are from. We will record the event, but as I stated last time it is taking a while to process the video. We will get it out to you as soon as we can.

To ensure your questions are answered, please post them once to avoid a constant scroll of questions, we will answer as many as we can. I know we all feel our question is the most important one, but you do not need to let the rest of us know by emphasizing it. Additionally, please keep the cross talking to a minimum as you may miss some of the information being presented.

Slide 2 – Start Recording.

Welcome everyone to the second Live Virtual Connection for the App Development Challenge. I am Alex Gladney-Lemon, the Senior Project Coordinator of the ADC. Joining me tonight is the ADC's Technical Specialist, Beth Szijarto.

Slide 3 –

Alex: As a reminder, this event is being recorded. Please do not share any personal information in the chat. Additionally, participants are not allowed to record the event or take pictures of other participants.

Slide 4 –

Alex: To get us started, I was able to find an animation of select events in the Artemis II Mission. What you are seeing now is after almost one full orbit around the Earth. The Orion capsule is still attached to the European Space Agency service module and is separating from the cryogenic propulsion stage. Here the Orion Capsule with the service module performs a series of manual maneuvers. In future flights the Orion capsule will do similar maneuvers to take modules to Gateway or to take items to the Moon. After completing check outs of the Life support, exercise, and habitation equipment the service module initiates the trans-lunar injection burn to put Orion in a free return trajectory to the Moon. It will spend the next 4 days going to the moon. Where it will fly by the Moon at an altitude of 4,000 miles. It will spend the next 4 days coming back to Earth. The rest of this animation shows the flight path for Artemis II. You can find the full animation here:

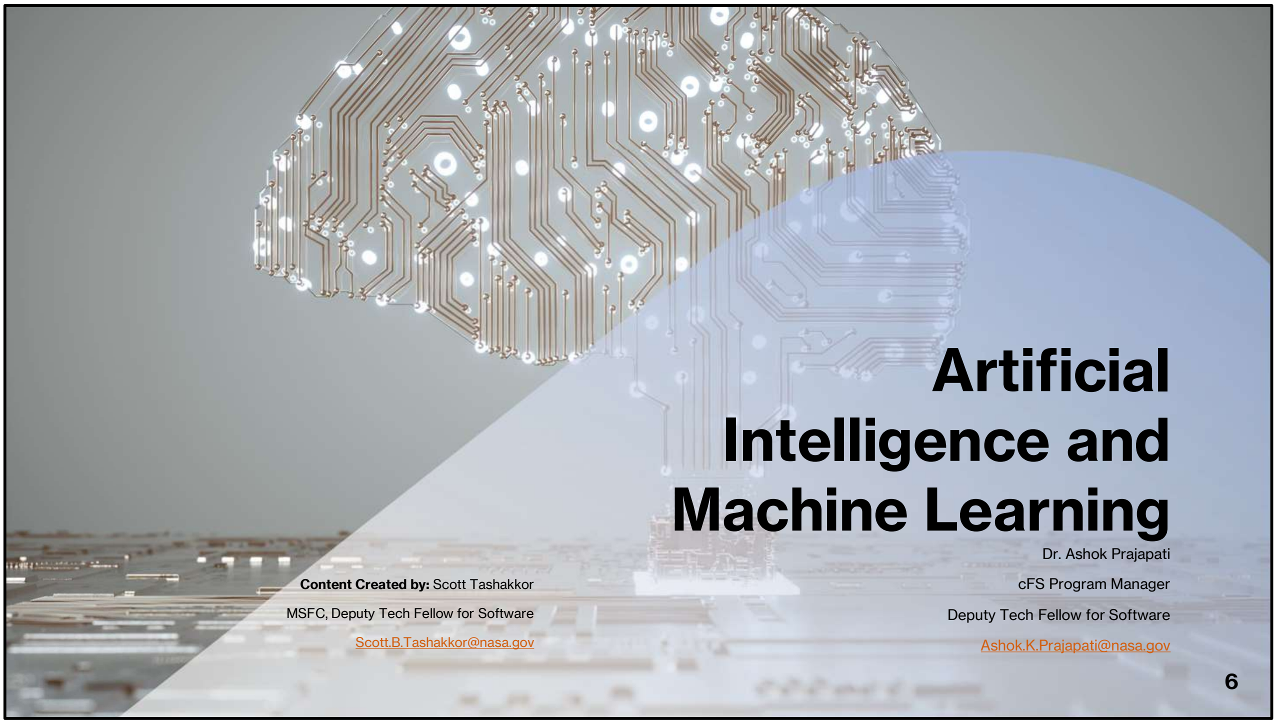
https://images.nasa.gov/details/NHQ_2023_0404_Artemis%20II%20Mission%20Animation%20Broll

The explanation of the different dots can be found here: https://www.nasa.gov/wp-content/uploads/2023/03/artemis_2_map_october_2021.jpg

Note: Your data does start at launch but jumps to minute 8 right after the core stage is separated.

Slide 5

Alex: With us tonight is Dr. Ashok Prajapati. He is the Program Manager for the Core Flight System stationed at NASA's Goddard Space Flight Center. He earned his Ph.D. in Computer Engineering with a focus on Artificial Intelligence and Machine Learning from Oakland University in 2011. He currently supports Software Architecture Reviews across the agency and creates software training course. Among his many highlights he has also worked with outside vendors to improve Autonomous Driving and Battery Management Software for vehicles. As you have questions, please type them into the chat and Dr. Prajapati will answer them at the end. Please welcome Dr. Prajapati.



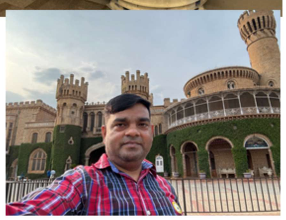
Presentation by Dr. Ashok Prajapati on Artificial Intelligence and Machine Learning.

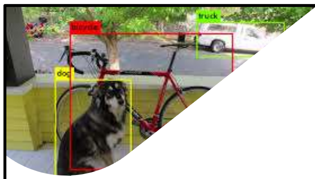
Agenda

- My Journey to NASA
- What is AI/ML?
- AI/ML vs Autonomy
- When to use AI/ML?
- AI/ML Ethics
- AI/ML Types
- Models of ML (Sample)
- AI/ML within NASA
- Other Applications/Examples
- Summary

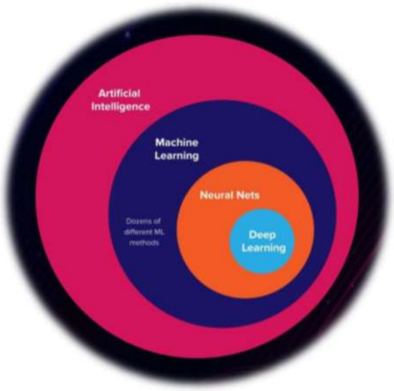
Dr. Ashok Prajapati

- B.S. Computer Engineering (KNIT. India)
- M.S. Computer Engineering (NITD/IITK India)
- Ph.D. Computer Engineering (OU, USA)
- Program Manager at NASA Goddard (Maryland)





What is AI/ML?



- Artificial Intelligence
  - Definition, no NASA Standard, varies internally and externally
  - Computers capability to emulate functions that are associated with thinking
    - We are not at the level in which systems are “thinking” (i.e. synthesizing concepts)
- Machine Learning
  - Data is presented to a computer program that the machine builds an algorithm without being explicitly programmed.

9

AI/ML vs Autonomy

- AI/ML is Autonomy, but not all Autonomy is AI/ML
- Both concepts have been around for decades

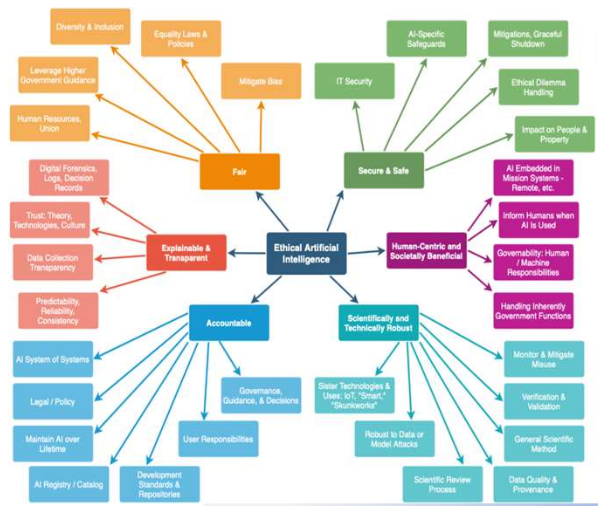
- What is the difference? (simplified)
  - Autonomy
    - System gathers inputs, analyzes, and outputs a response
    - Can be explicitly programmed responses (Expert system)
    - Does not have to be software
      - Thermostat
    - Examples (NASA has been doing this for a long time):
      - SLS launch vehicle (short time to effect)
      - Mars Landers (delayed Communications)
  - AI/ML
    - Uses algorithms to analyze data statistically to build model
    - Is implicitly programmed (i.e. weights are generated for outcomes)

When to Use AI/ML

- ML is **<u>NOT</u>** a solution for every type of problem
- If rules, computations, or predetermined steps can be explicitly programmed, *<u>do that</u>*
  - Simplifies Verification/Validation
  - More deterministic
  - Order of approximation can be determined
- If rules cannot be coded explicitly
  - Complex rules
  - Rules overlap/finely tuned
- Information cannot be scaled
  - While some data can be analyzed by people, large data sets are better for ML algorithms
- Large Data sets
  - Amount of data
  - Image analysis
  - Ability to sufficiently train and test the model dataset

AI/ML Ethics

- Fair
- Explainable and Transparent
- Accountable
- Secure and Safe
- Human-Centric and Societally Beneficial
- Scientifically and Technically Robust



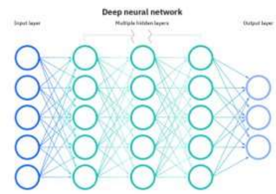
NASA/TM-20210012886 NASA Framework for the Ethical Use of Artificial Intelligence (AI)

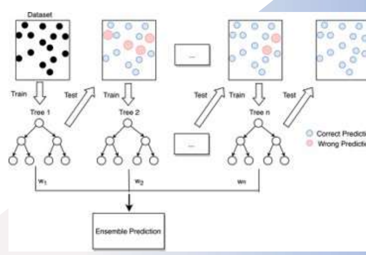
Types of ML

- Supervised Learning
  - Labeled data is presented to the system, the computer determines rules that maps inputs to outputs
- Unsupervised Learning
  - Unlabeled data is presented to the system, the computer determines the rules from the inputs only, correlations between the data only
- Reinforcement Learning
  - A reward function is created, and this is optimized to obtain the maximum reward
    - Game theory, control theory, genetic algorithms, statistics..
- Mixtures/Other

Models of ML (Sample)

- Artificial Neural Networks
  - Linked layers of weights
- Decision Trees
  - Binary decisions on classifications
- Regression Analysis
  - Linear Regression (statistics)
- Bayesian Networks
  - Probabilistic graphs
- Genetic Algorithms
  - Mutations with “better” methods surviving
- Ensemble
  - Multiple combined methods





AI/ML within NASA

- All centers doing some degree of AI/ML – GSFC, Ames, JPL leading -- being used as a useful tool where it best fits
- Early career employees gravitating toward use
- Agency CoP and center-level AI/ML CoP meetings held regularly and well attended
- Science (earth, space, aeronautics) and research applications readily utilizing
  - Big data, data science, data reduction, pattern recognition, image processing
  - Onboard data reduction in presence of limited comm bandwidth common
- No safety-critical AI/ML in spaceflight yet, but reliability curve may approach classical software failure levels
- Challenge in assurance and recognizing difference between probabilistic and deterministic software behavior
- General concern over high autonomy demand beyond LEO without necessary rad-hard computational hardware
- Over 400 AI projects of varying quality and usage documented (Still growing)

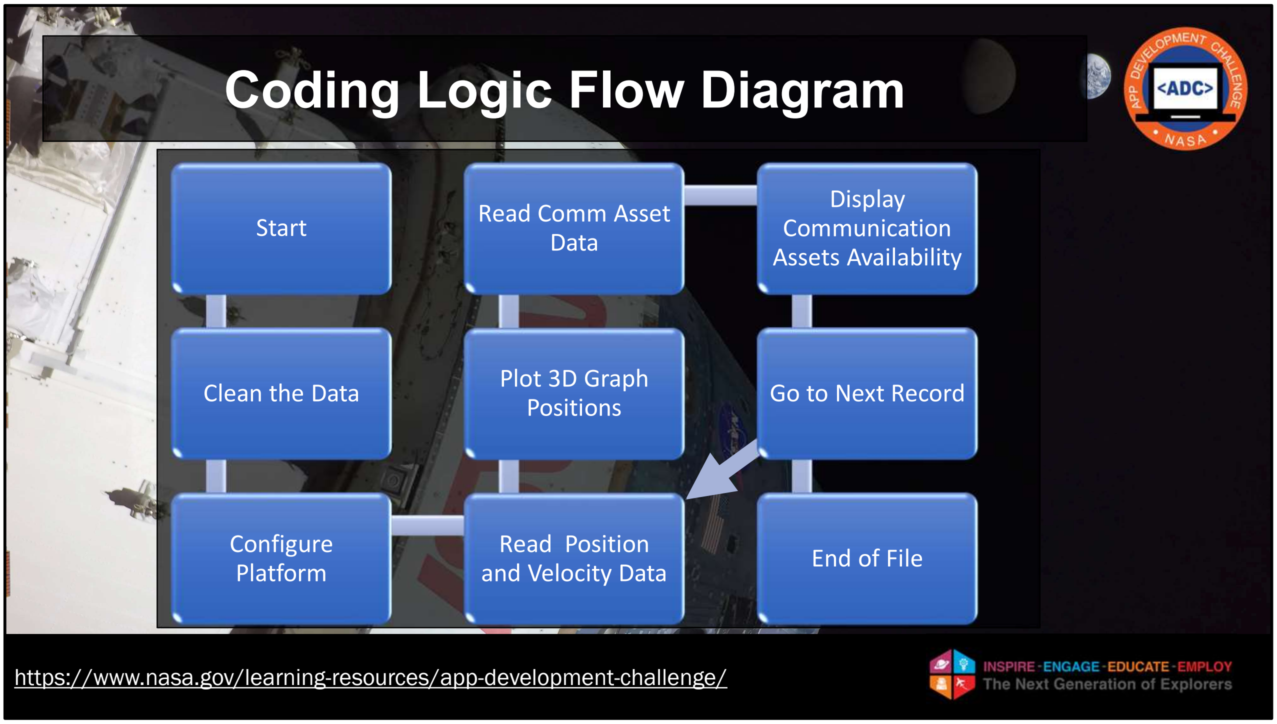
Summary

- Autonomy does not have to be AI/ML
  - Understand when to use the correct tool for the correct problem
- NASA policies are still required to be followed
  - The policies do not explicitly state AI/ML but the processes still apply
- Ethical uses of AI/ML can add complexity to the problem
- There are different types of AI/ML and each has strengths and weakness
- Implementation of AI/ML has multiple “knobs” that can be change
  - Data is the key

Slide 18 –

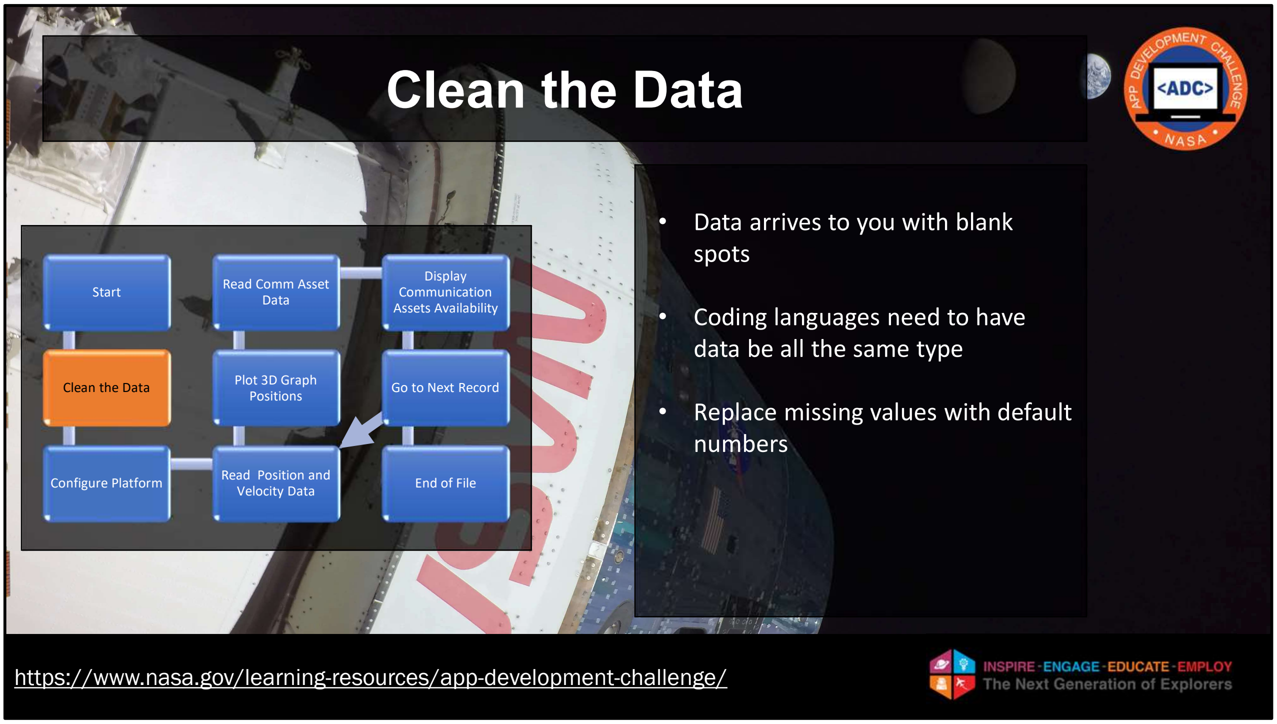
Thank you Dr. Prajapati. As a reminder, please type any questions into the chat. We will do our best to get through them all.

Thanks again Dr. Prajapati your insight into the world of AI and ML has been great, thank you for sharing what NASA is working on. Next up we have our very own Beth Szijarto, the ADC's Technical Specialist. As you may have seen by now there is a lot of data to process for this challenge and we wanted to help you through some of the thought process for dealing with it. Beth, take it away.



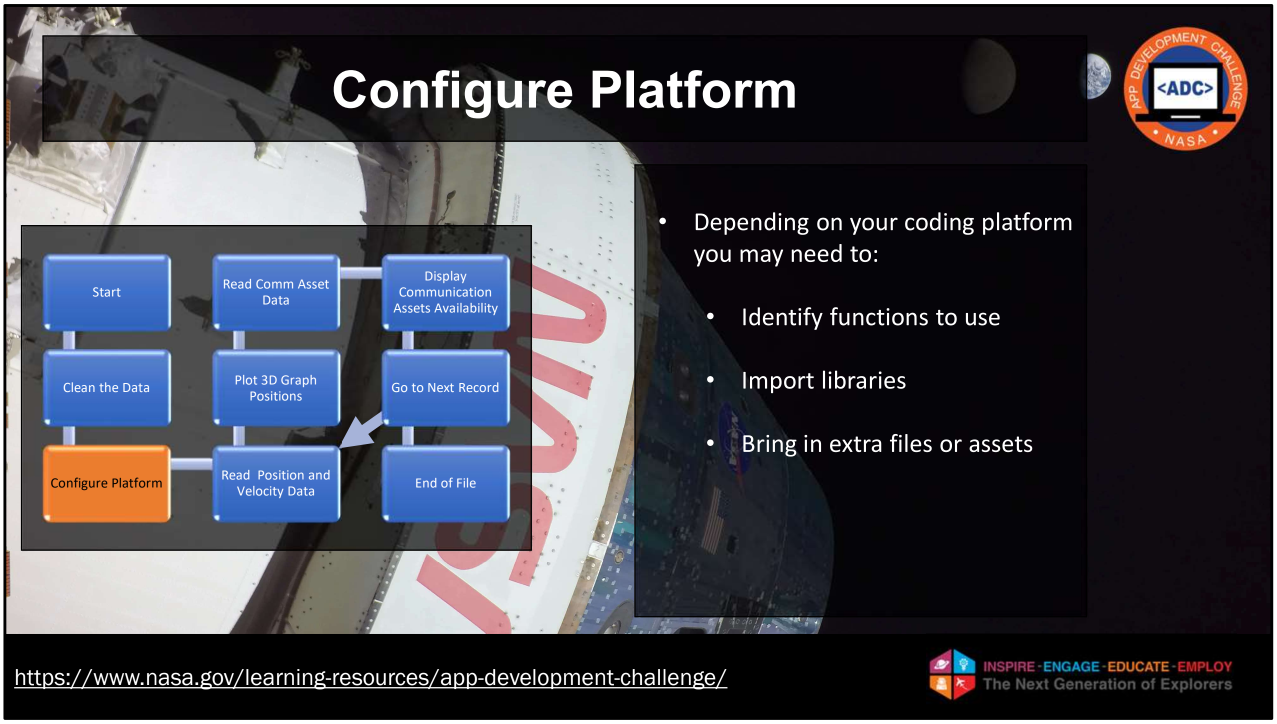
Slide 19

Beth: Today, we're going to learn about how to handle large sets of data, focusing on the Artemis II mission. This data includes important things like the spacecraft's path and the communication assets it uses to stay connected. We'll go step-by-step, using something called pseudocode—which is like writing a plan in plain language before we code it—to work through this data and understand how to manage it effectively.



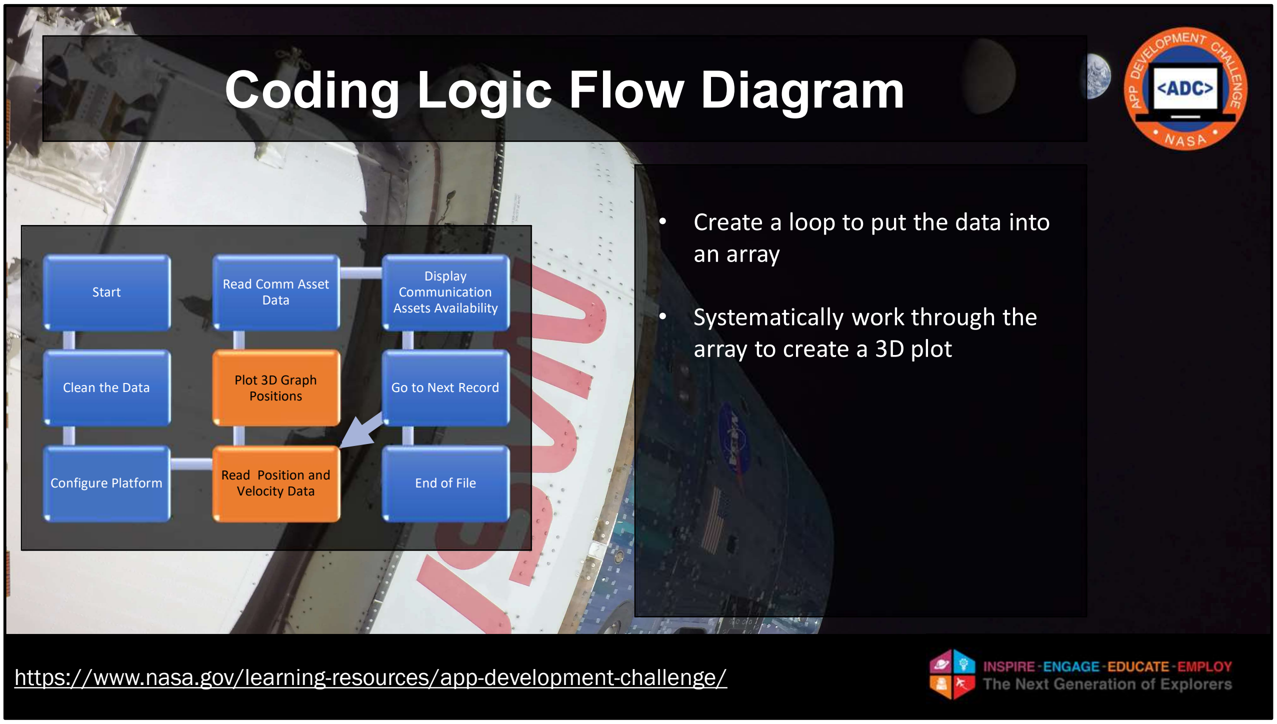
Slide 20

Beth: The first thing we always need to do with large datasets is to clean the data. What does that mean? Well, sometimes when you collect data, some of it can be missing or incomplete. In our dataset, when something is missing, we'll see 'NaN,' which stands for 'Not a Number.' We can't leave this missing data as is, because it could mess up our analysis later. So, we'll replace these missing values with default numbers or something appropriate to keep everything running smoothly.



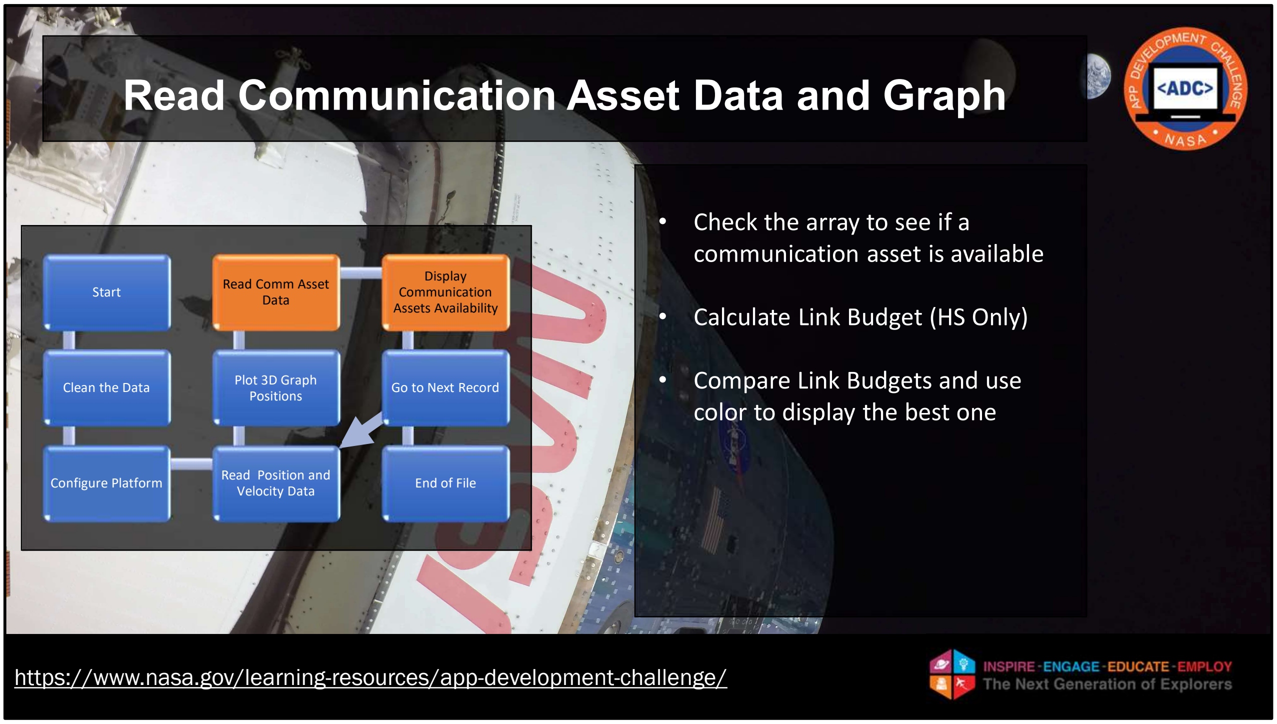
Slide 21

Beth: Once the data is cleaned, we need to set up our coding environment or platform. This means getting the right tools or libraries ready so we can handle and visualize the data. This typically includes libraries for data manipulation, numerical operations, plotting visualizations, artificial intelligence, simulations, and animations. Sometimes, we might also need to bring in extra files or assets that contain more information we need to process.



Slide 22

Beth: Now, we're ready to read the data and store it in something called an array. Think of an array as a container that holds a list of values. Each value in the array has a position, starting at 0 for the first item, then 1 for the second, and so on. To go through the values in this array, we use something called a loop, which allows us to start at 0 and work through each value in order. For example, if we have an array with 5 values, the loop will go from index 0 to 4, helping us access all the data efficiently. This step is important because it organizes the data in a way that makes it easy for us to manipulate and analyze. Once we have the data loaded into the array, we can start looking at the first row. This row represents the very beginning of the mission and contains information like the spacecraft's position and velocity. Using this data, we create a 3D plot that shows the spacecraft's path in space, using the Rx, Ry, and Rz coordinates.



Slide 23

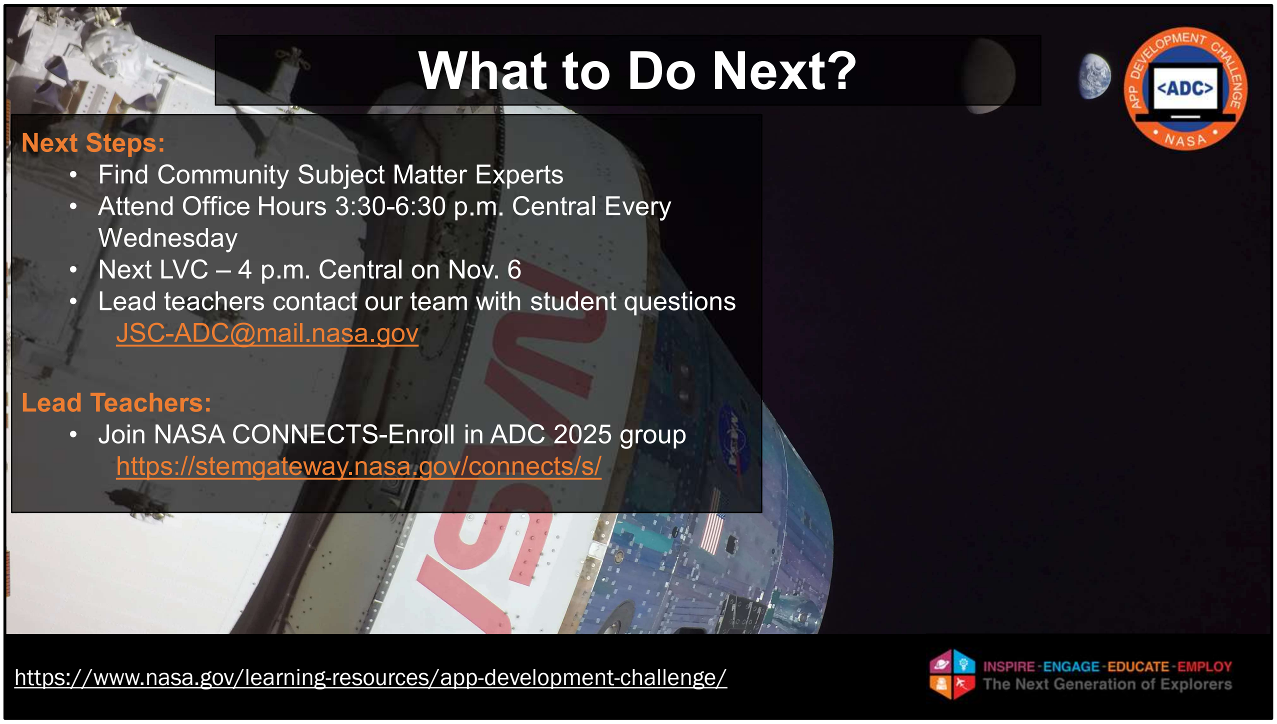
Beth: Next, we focus on the communication assets—these are the systems the spacecraft uses to send and receive signals. We'll check the data to see which communication assets are available and how strong their signals are. Based on this, we can prioritize which asset to use during the mission. We'll add this information to our 3D plot, color-coding the systems so it's easy to see which ones are available at any given time.
Now, we'll have a complete picture of the spacecraft's path and know which communication assets were working at each stage of the mission.

Slide 24

Beth: After we've finished processing the first record, we don't stop there! The dataset has a lot more information, so we'll use another loop to move on to the next record. We'll follow the same steps: read the data, plot the spacecraft's path, and check the communication assets, then display them. This process is repeated for each record, allowing us to get a full picture of how the spacecraft's position and communication assets change over time during the mission.

So, to sum it up, we've learned how to handle large datasets by cleaning the data, storing it in arrays, and using loops to process each record. We've also seen how to plot the spacecraft's path in 3D and track the communication assets it uses. This helps us understand the mission step-by-step and provides a detailed view of how everything is functioning.
Alex, do you have anything to add? Thank you.

Alex: Thank you, Beth. As someone who doesn't code very much this made a lot of sense to me. Students and teachers as we said earlier, we hope this makes the 13000+ lines of data less daunting when you can see a process for handling it.



Slide 25 –

Alex: As you are getting deeper into the challenge, seek out subject matter experts in your local area. You can have multiple as you encounter different problems.

Don't forget about our weekly technical office hours. Beth is there to answer your questions. In fact, she will be in the Technical Office Hours meeting room right after we get done and every Wednesday from 3:30-6:30 p.m. Central.

Students, you can also get your questions together and give them to your lead teacher to send into us.

JSC-ADC@mail.nasa.gov

Lead Teachers, again we invite you to join Connects and enroll in the ADC 2025 group.

https://stemgateway.nasa.gov/connects/s/

Slide 26 –

Alex: Thank you so much for joining us today. Please email us with your questions or better yet, jump over the technical office hours being held right after we get done here.