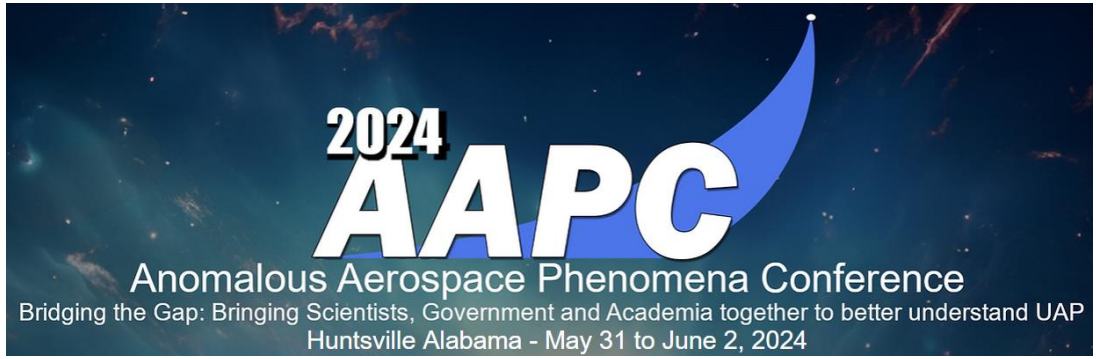


Aviation Safety and Steps Toward Eliminating Space-Object Caused UAP Reports:

Univ of Utah's Space Mission Engineering: Modeling Starlink Group 4-26

Doug Buettner, PhD, Richard Griffiths, PhD, Nick Snell, John Stilley

Presented by: Nick Snell

MUFON Case # 124190

- Since SOAP is only available to Aerospace employees and their government customers, Dr. Buettner wanted the modeling redone using publicly available tools
- He offered the following as a project to students in his Space Mission Engineering course at the University of Utah
  - Task 1: Model the SpaceX launch and Starlink locations using Ansys/AGI's System Toolkit (STK) after identifying other potential modeling tools
  - Task 2: Identify tools for (and do) physics-based visualization (rendering) to provide a photo-realistic cockpit view
    - OpenSpace, which is a professional rendering software for the space industry, was recommended but we chose not to use it due to its complexity

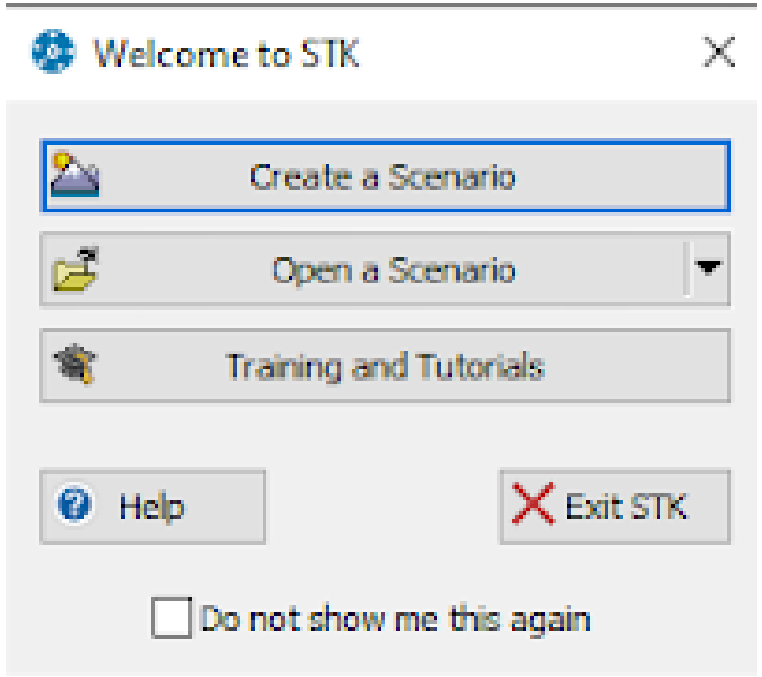
Task 1: Ansys STK Modeling

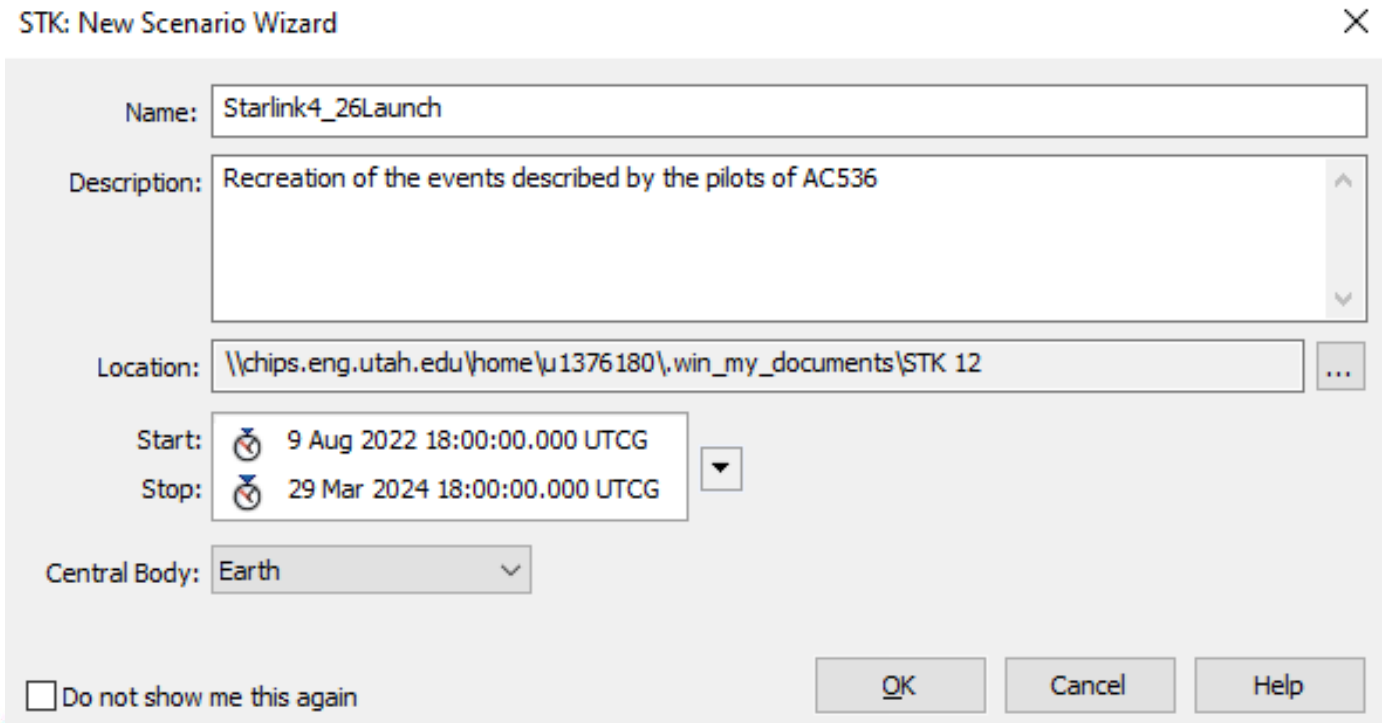
- Necessary modeling info can be obtained from:
  - AC536's Automatic Dependent Surveillance–Broadcast (ADS-B) flight data: FlightAware.com
  - SpaceX/Starlink launch information: Space Launch Now
  - SpaceX debris and Starlink satellite Two-Line Elements (TLEs): Celestrak®
  - Falcon 9 launch information (to add fidelity): SpaceX

Logos provided for informational purposes.

Task 1: Ansys STK Modeling

- STK's starting dialogue box →
  - Selecting Create a Scenario starts the New Scenario Wizard
- The required information is shown below

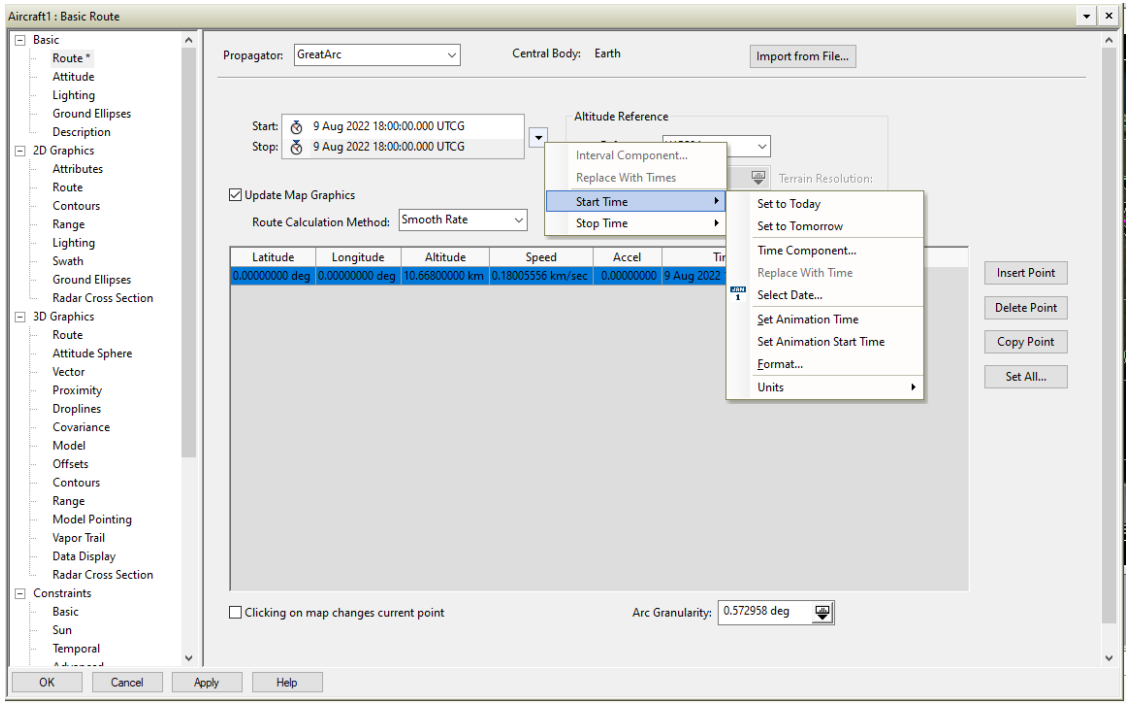




Logo provided for informational purposes.

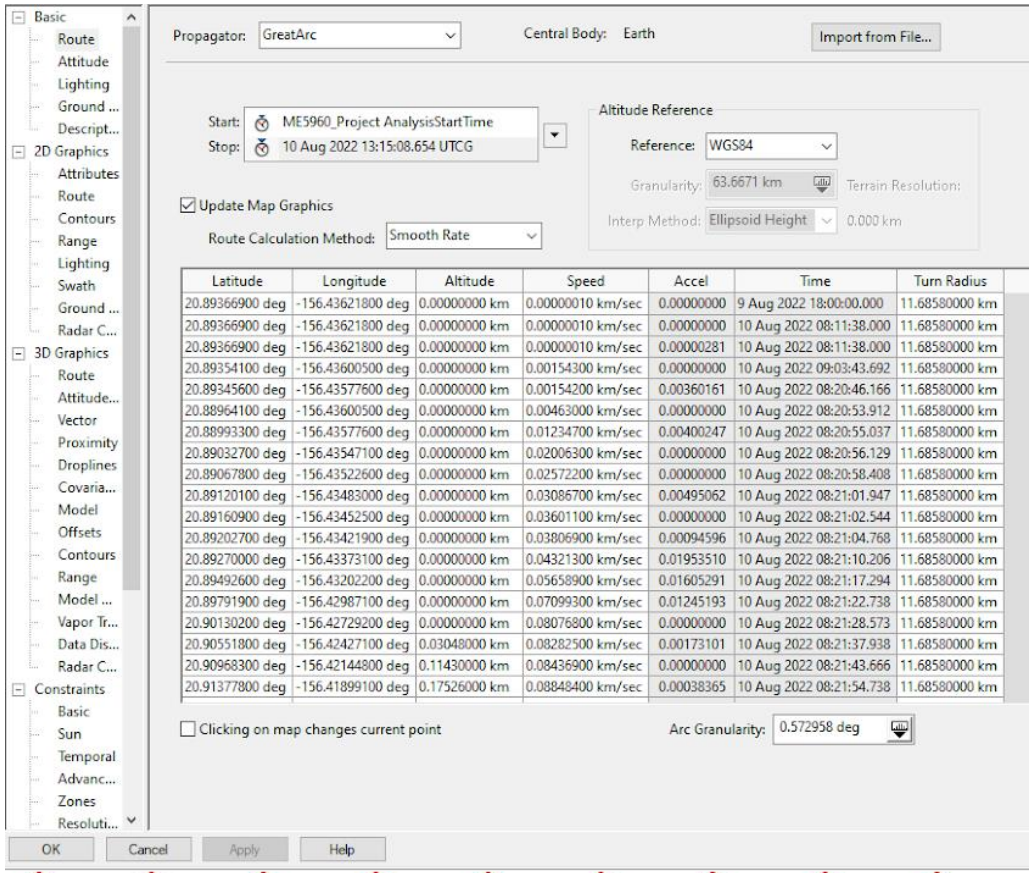
Task 1: STK Aircraft Flight Path Modeling

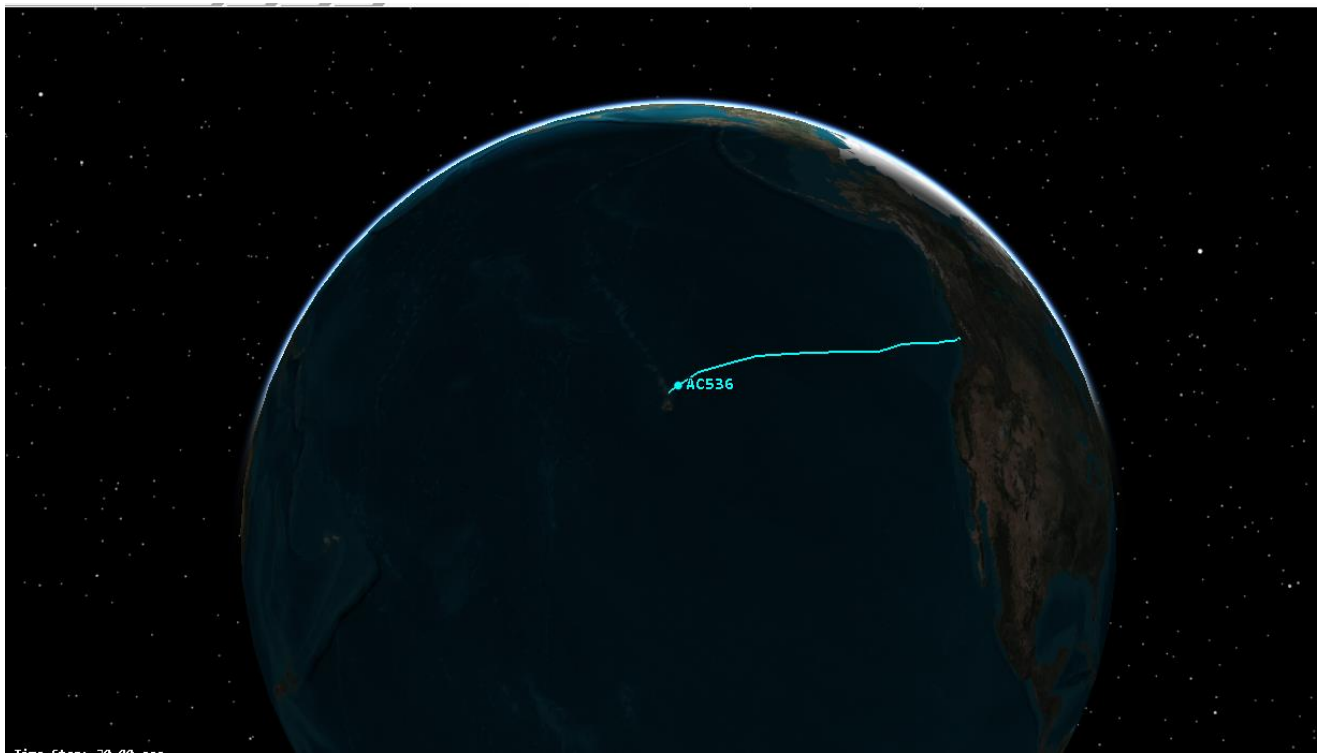
- To insert an aircraft, click insert and select “Aircraft” then “Define Properties”
  - A pop up will open and make sure propagator is set to “GreatArc”
  - From there, you need to change your “Start Time” to be the UTC time of the first ADS-B point available
  - Next you want to click insert a point and fill out the latitude, longitude, altitude, and speed columns.
    - Repeat until all ADS-B points have been entered



Task 1: STK Aircraft Flight Path Modeling

- If done correctly, your aircraft pop up window and 3D viewer should look like the following

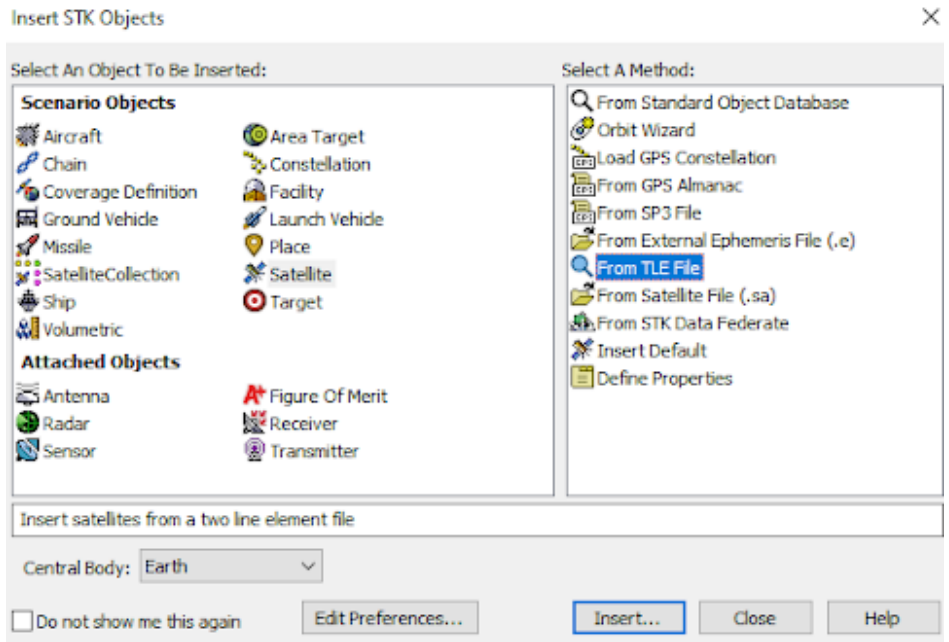


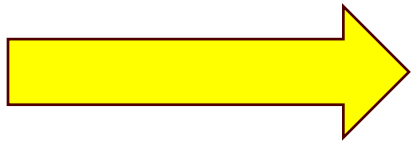


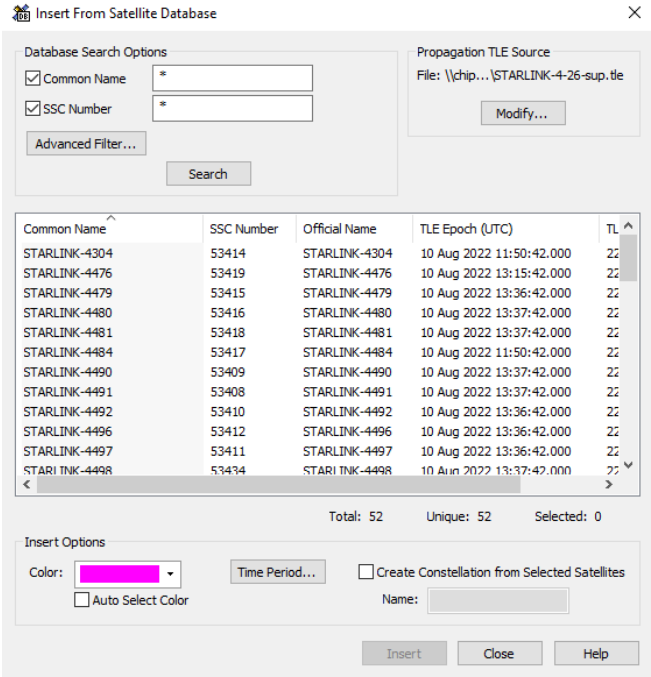
Flight path creation results from STK.

Task 1: Starlink Modeling

- Using the TLE's from Celestrak, to add them into the STK scenario
  - Select insert then select "Satellite" and "From TLE file"
  - After selecting "Insert", you will be prompted to select a TLE file
    - Another window will pop up prompting you to select the Satellite to add. For this scenario, you will select all of them

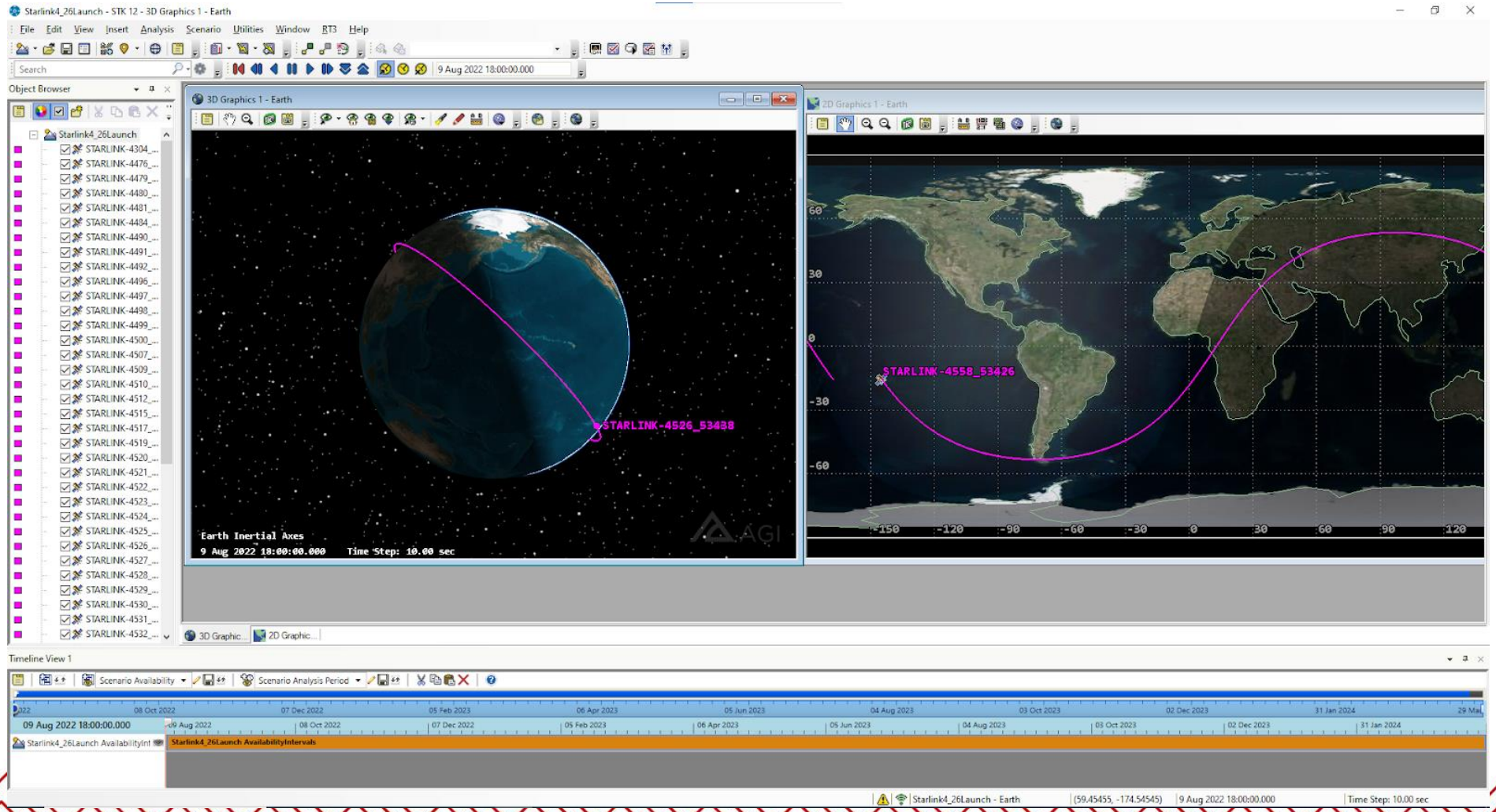






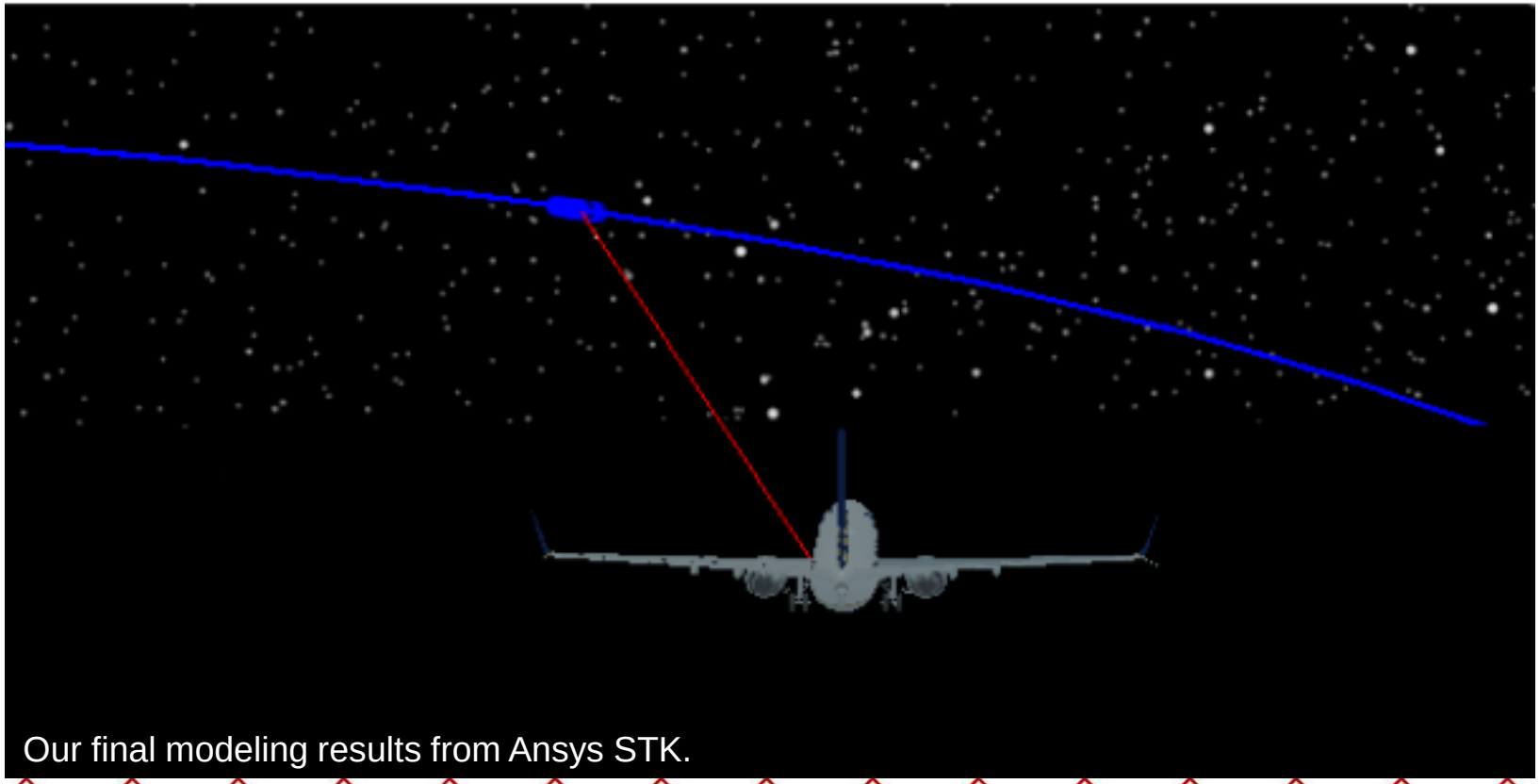
Task 1: Starlink Modeling

- Done correctly, your 3D and 2D windows will look like these ones



Task 1: Starlink Modeling Results

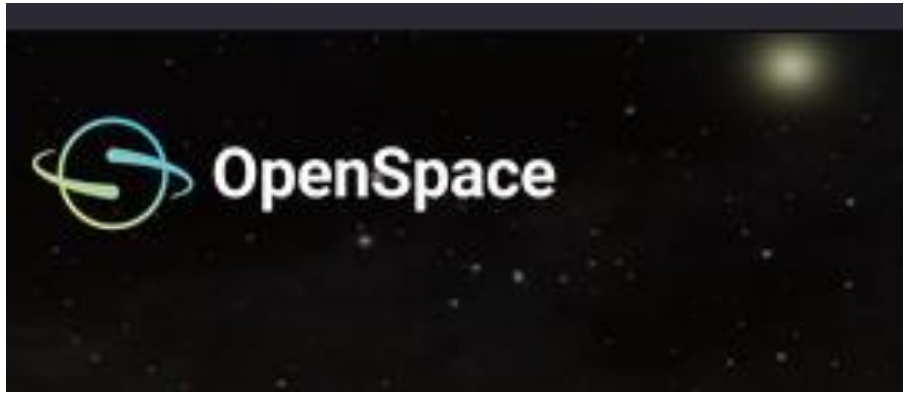
- Upon completion, the STK scenario is basically done
  - A “zoom to” the aircraft and you will see the Starlink train in basically the same part of the sky as seen in the case study photos

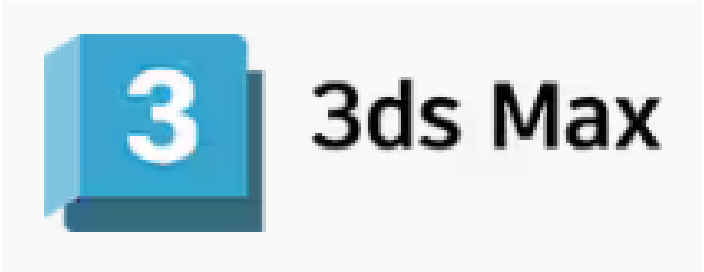


Our final modeling results from Ansys STK.

Task 2: Physics-Based Visualization

- Originally tasked to identify PROS & CONS of available rendering tools capable of physics-based modeling we reviewed OpenSpace, Autodesk 3ds Max, and Blender
  - Ultimately selecting Blender 4.0 due to its price (free) and the broad user community available online in addition to our original perception that physics-based modeling should be straightforward

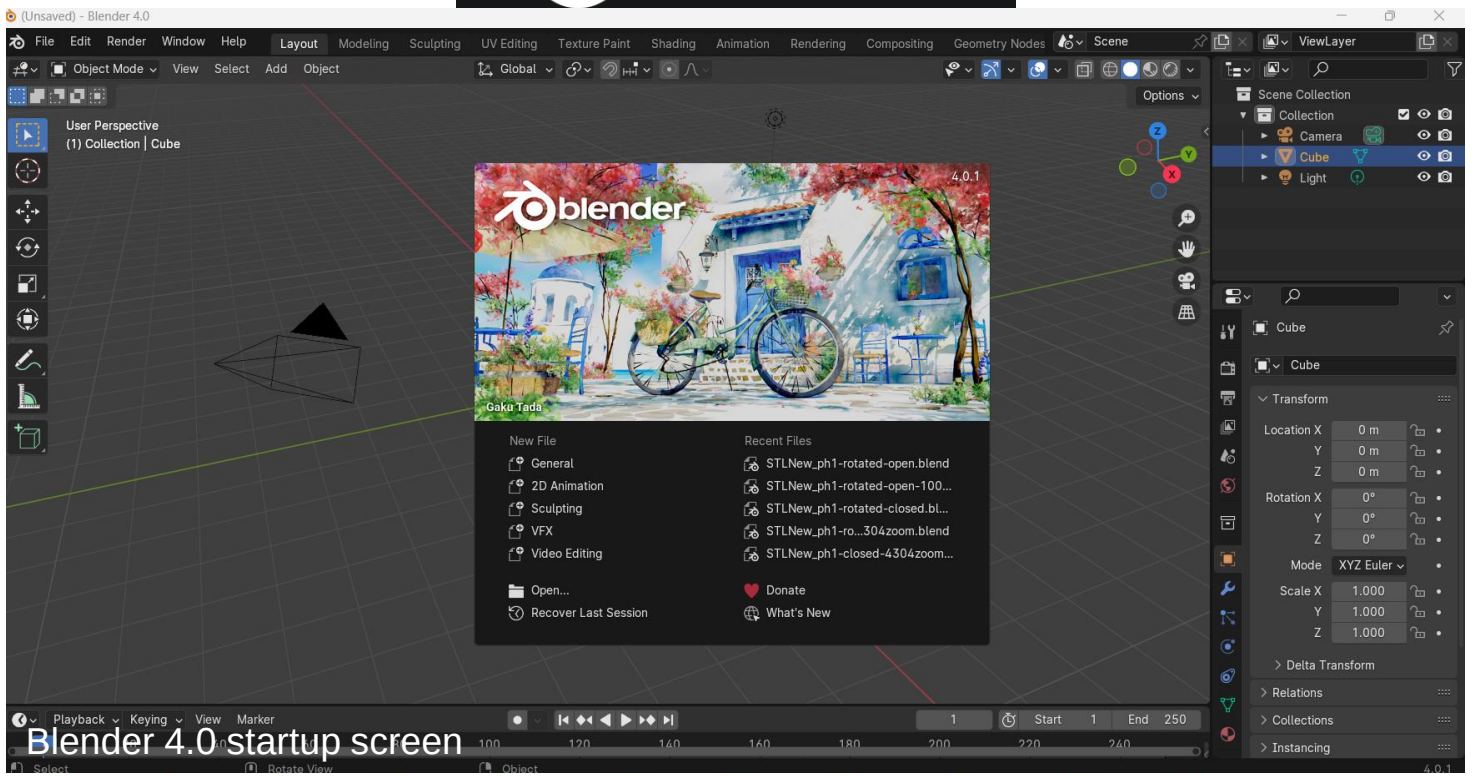




Logos provided for informational purposes.

Task 2: Blender Visualization Modeling

- The final step is to create a blender model to better visualize what the pilots saw
- The following steps are needed:
  - Add an aircraft model
  - Add the earth
  - Add lighting
  - Add Starlinks



Blender 4.0 startup screen

Logos provided for informational purposes.

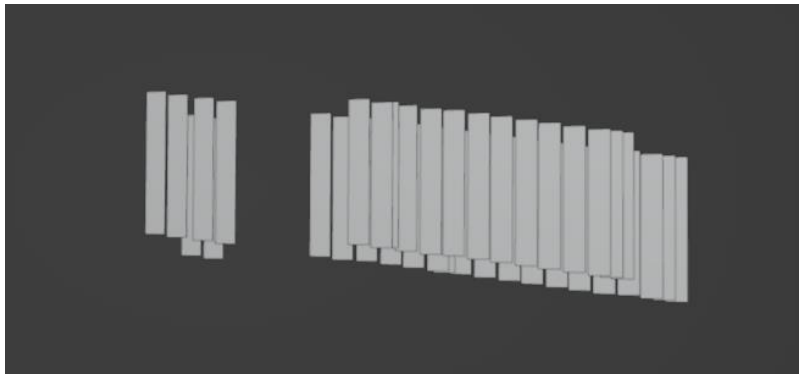
Task 2: Blender Visualization Modeling

- Use a free airplane model online (our paper documents which one)
  - Blender will not accept all CAD files, may need to convert the CAD file
- Import the plane model, this will be set at the center of the scene
  - This makes orientation and adding additional elements much simpler
- Scale the plane to the correct size.
  - All units will be in km, a Boeing 737 is 30 meters long.
- Add a spherical representation of the Earth using a “UV Sphere” *
  - In the Item tab, change the Dimensions to 12,742 m (diameter), and the z location to -6,371 m plus the airplane’s altitude
  - Right click the sphere and select shade smooth
- Add Earth satellite imagery
  - In shading, create a new node
  - Attach an image texture node with the satellite imagery of your choice
- Change the background color to black
- Rotate the Earth to approximately align with the position and heading of aircraft

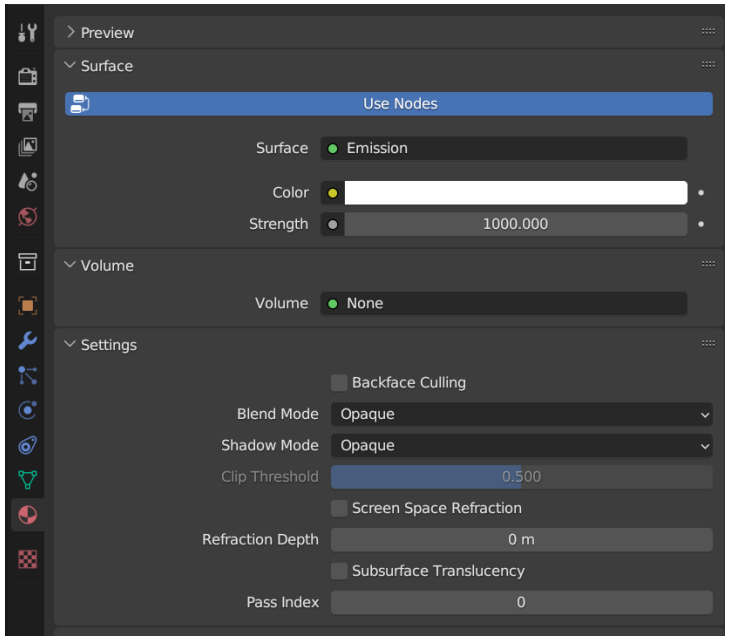
*Sphere is modeled with UV coordinates, which are blender Cartesian coordinates

Task 2: Initial Blender Modeling

- Add a Blender Cube (to simulate a Starlink satellite)
  - Modified the dimensions so it's as tall as the airplane is long, and as wide as it's fuselage. Exact scale was hard to achieve!
- Change the surface material properties of the cube
  - We used emission to simulate the rectangle reflecting light, surface was glass Bidirectional Scattering Distribution Function (BSDF)
- Change the location to a relative location using STK coordinates
  - Azimuth-Elevation-Range (AER) (initially obtained from STK) to XYZ coordinate conversion
  - If the reflection angle was calculated, that can also be added here
- Copy/paste new rectangles, change their relative location for each satellite



Starlink train modeled with STK data (not to scale)

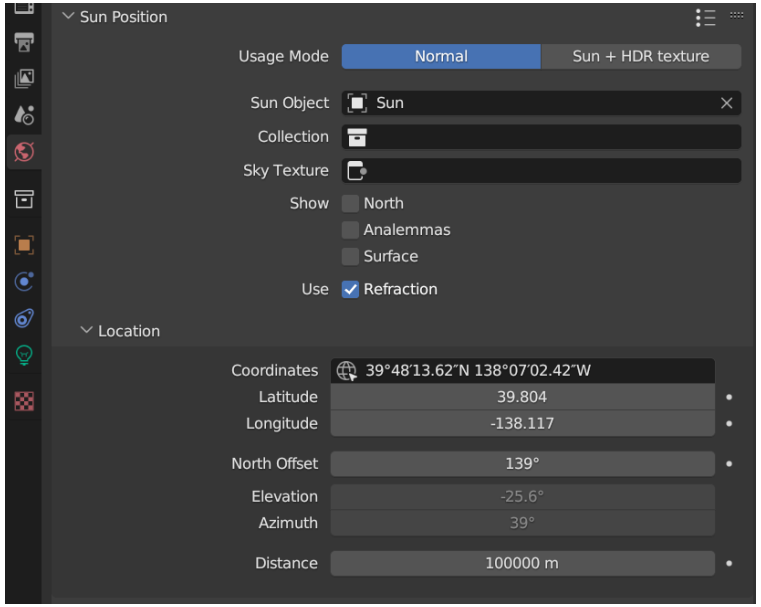


Material properties tab

Task 2: Initial Blender Modeling

- Add a sun object
  - Size didn't affect luminosity
- Position the sun accurately
  - Attach new sun object to "Sun Position" in "World Properties" (may need to enable "Sun Position" in "Preferences")
  - Adjust the date, time, and "North Offset" to the time of the photograph and the model airplane heading
  - Set the distance to a very far away value
- Set the "Strength" in "Data Properties"
- Added a small amount of light in the cockpit so the windows are visible

Shaded Earth Model

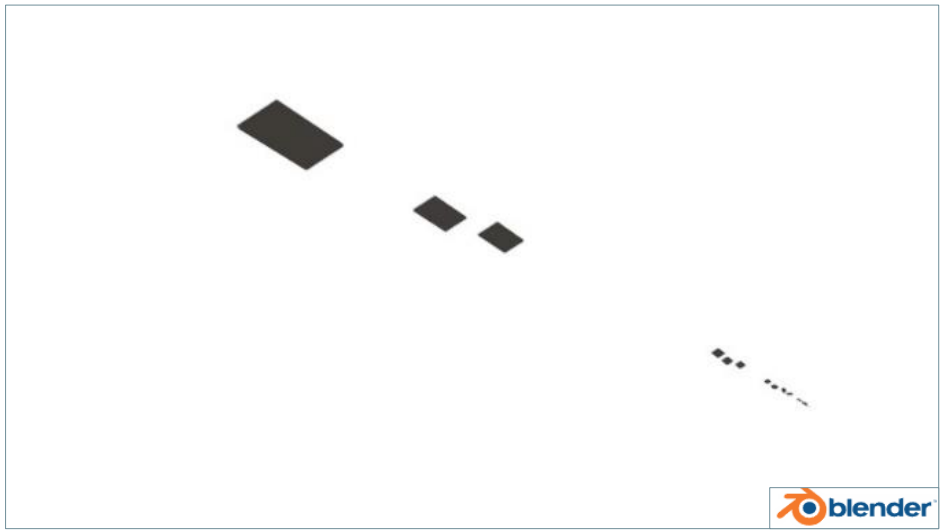


Material Properties Model

Task 2: Initial Blender Results

- Initially, we had to move the distance of the satellites much closer to the aircraft to ensure we could see them after rendering!
- After the term was over, Dr. Buettner modified our models to run visualization experiments
  - He moved the satellites out to their correct relative distances from AC536
  - And wanted to see if they were visible with and without the solar arrays being deployed

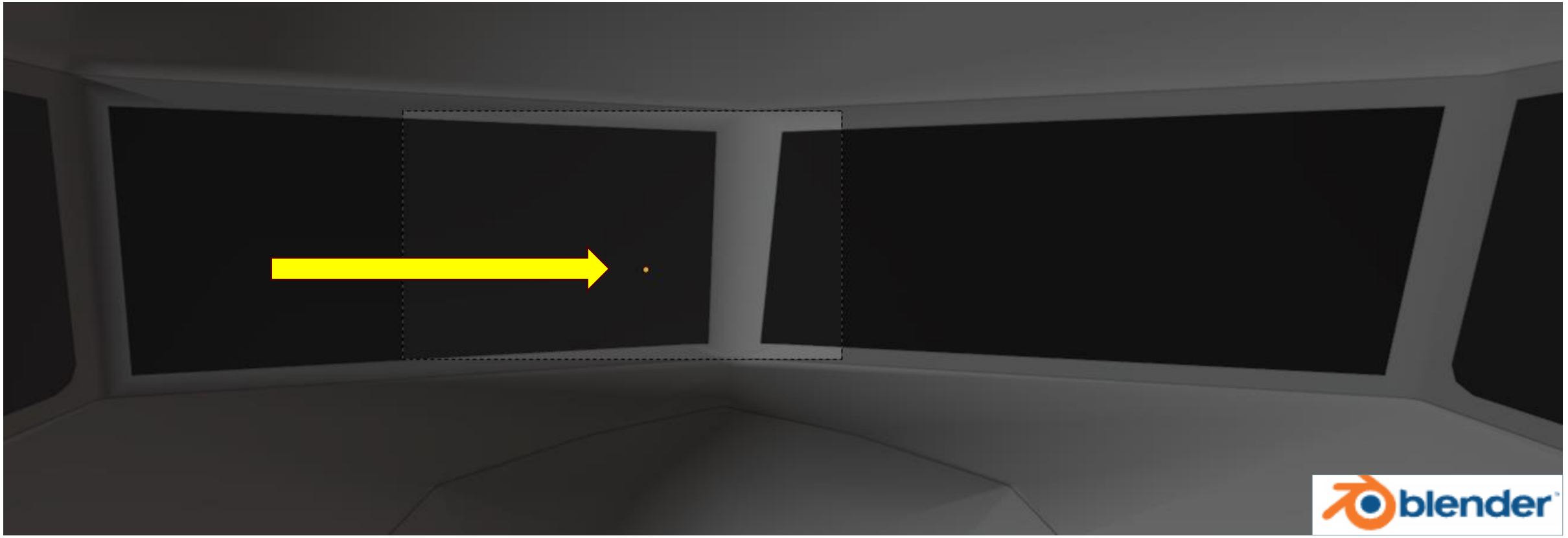
Solar arrays not deployed



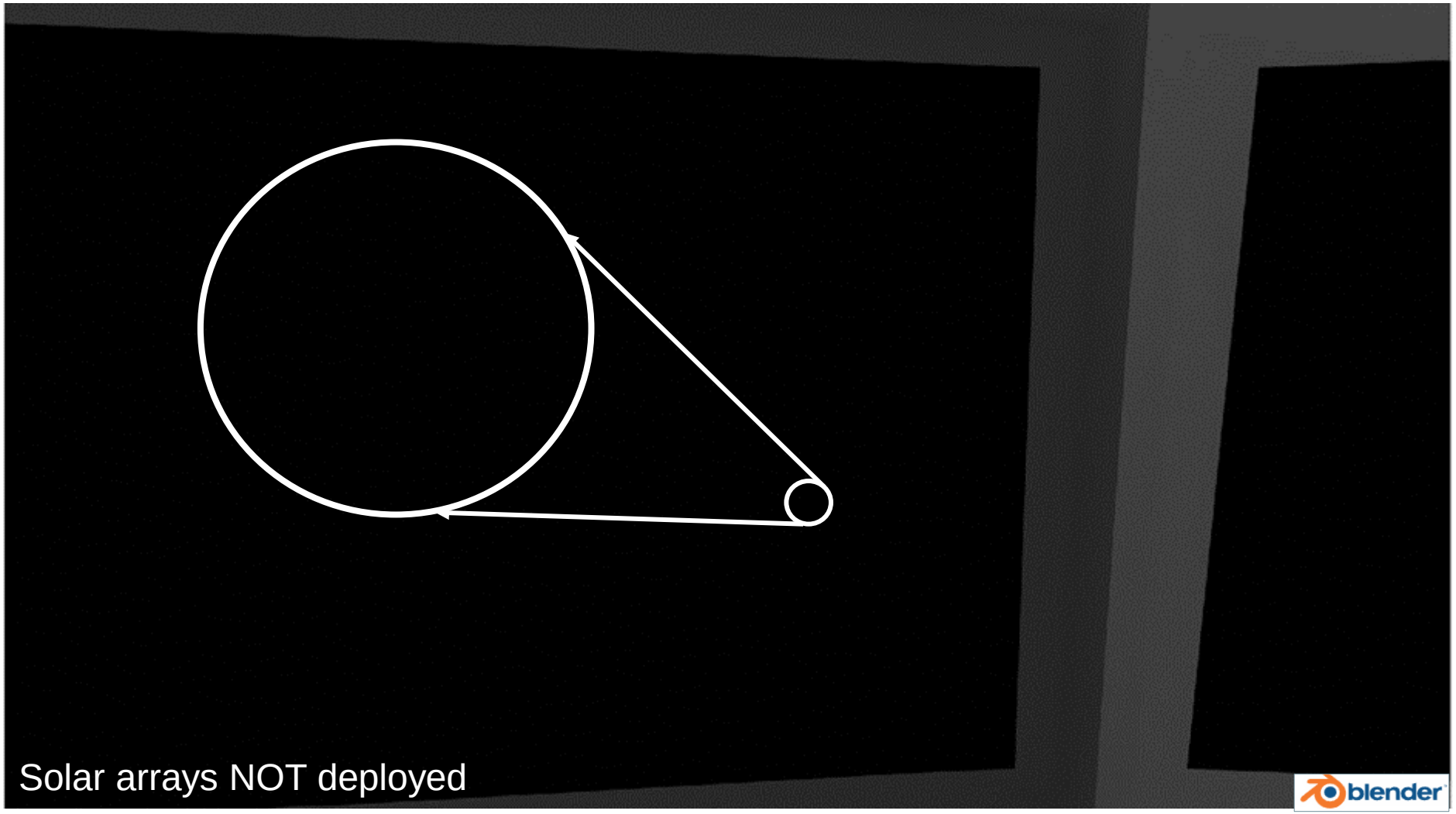
Solar arrays deployed

  - After running “lots” of rendering experiments some of results are provided on the next few pages

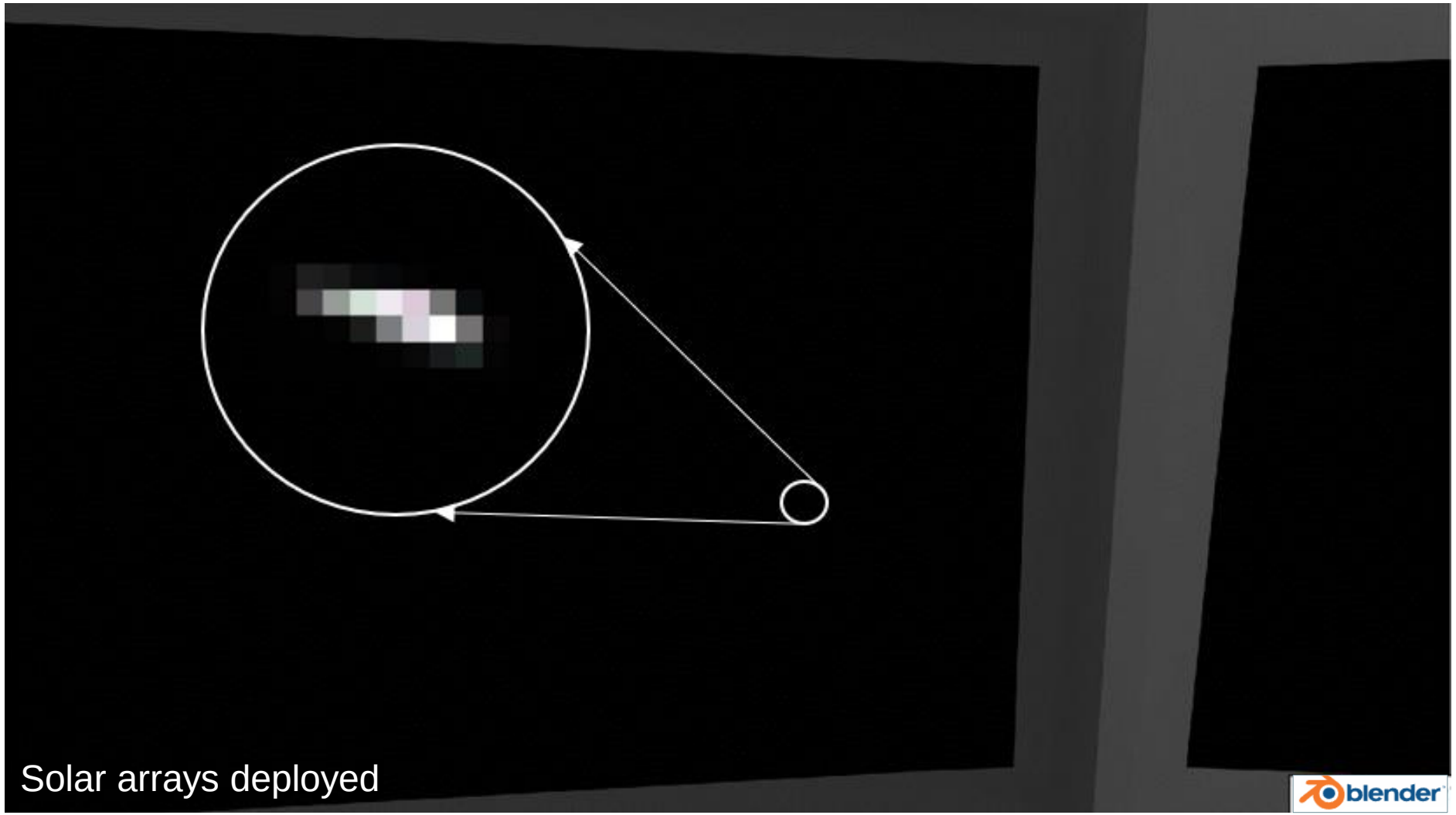
Task 2: Final Blender Results



Task 2: Final Blender Results



Task 2: Final Blender Results

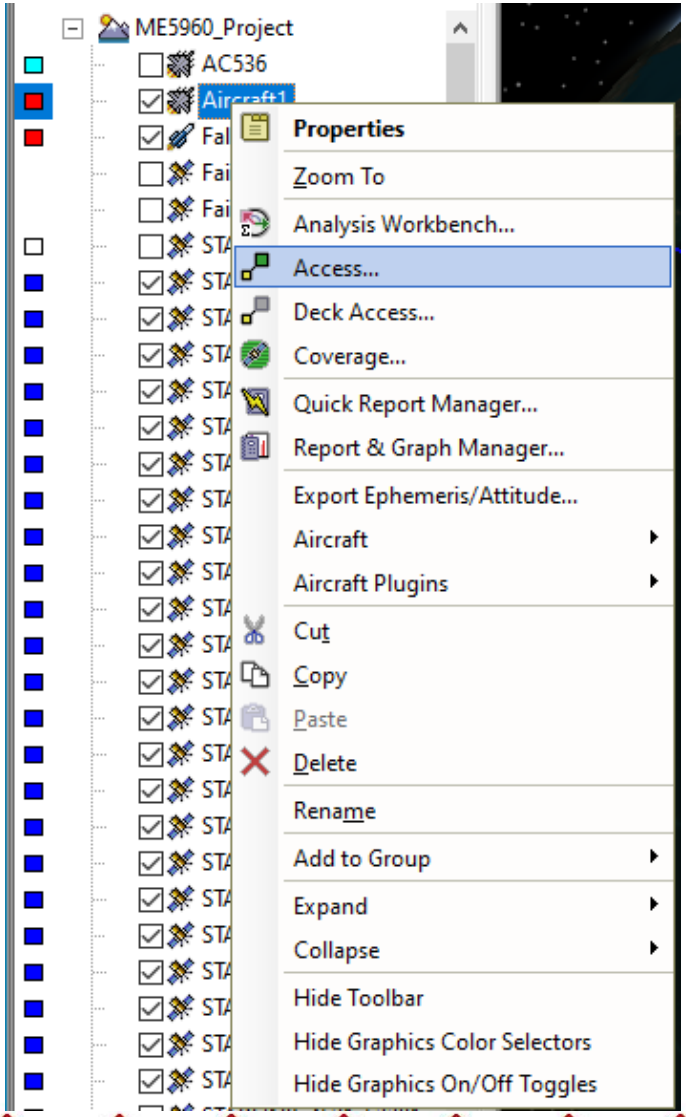


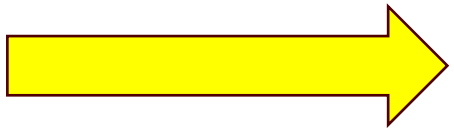
Task 1 & 2: Challenges

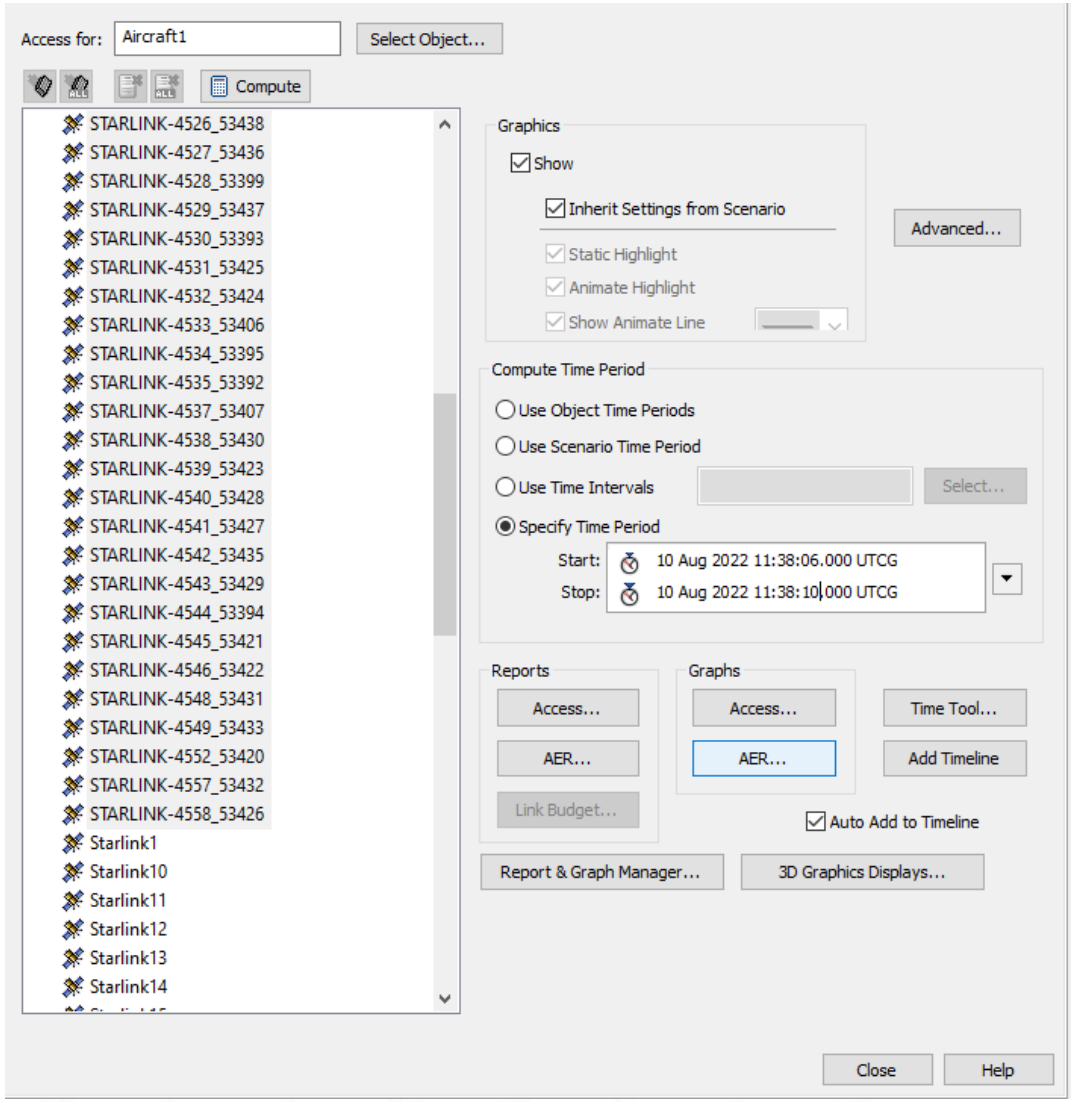
- We ran into a lot of challenges while creating these models
  - Inserting ADS-B data into STK was a quite difficult
  - STK was unable to model Starlink deployment from Falcon 9 upper stage (as near as we could tell)
  - Blender's fidelity with the satellites at the correct distance did not allow us to replicate the photos
  - No accurate Starlink CAD models to use
  - And many others
- SpaceX doesn't provide much information about Starlink deployment
  - How are satellites released from second stage? When do solar arrays deploy? When do ion engines fire? SpaceX transparency could be improved to facilitate modeling.

Backup Slides

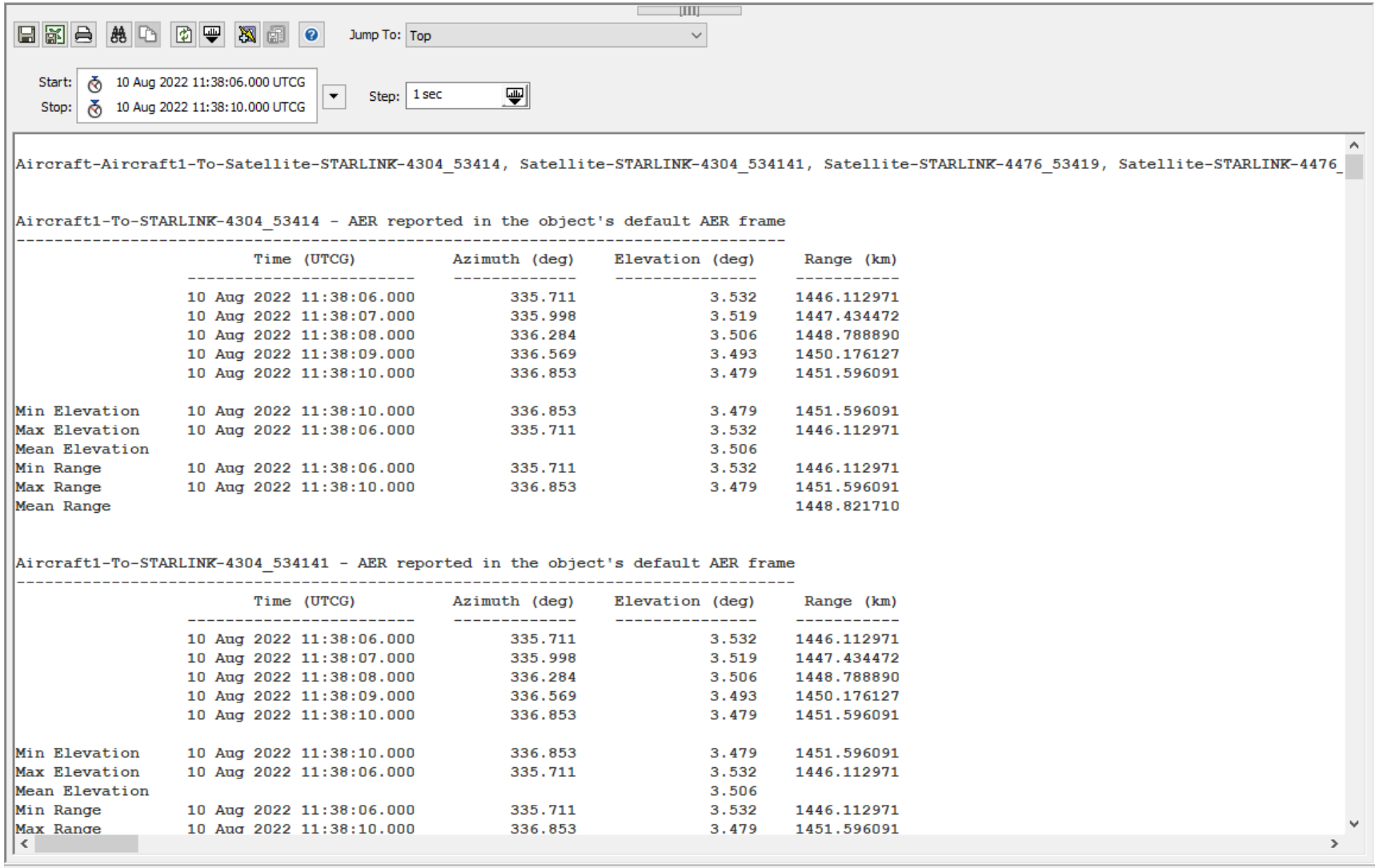
Obtaining AER Data From STK







Obtaining AER Data From STK



Jump To: Top

Start: 10 Aug 2022 11:38:06.000 UTCG
Stop: 10 Aug 2022 11:38:10.000 UTCG

Step: 1 sec

Aircraft-Aircraft1-To-Satellite-STARLINK-4304_53414, Satellite-STARLINK-4304_534141, Satellite-STARLINK-4476_53419, Satellite-STARLINK-4476_

Aircraft1-To-STARLINK-4304_53414 - AER reported in the object's default AER frame

	Time (UTCG)	Azimuth (deg)	Elevation (deg)	Range (km)
	10 Aug 2022 11:38:06.000	335.711	3.532	1446.112971
	10 Aug 2022 11:38:07.000	335.998	3.519	1447.434472
	10 Aug 2022 11:38:08.000	336.284	3.506	1448.788890
	10 Aug 2022 11:38:09.000	336.569	3.493	1450.176127
	10 Aug 2022 11:38:10.000	336.853	3.479	1451.596091
Min Elevation	10 Aug 2022 11:38:10.000	336.853	3.479	1451.596091
Max Elevation	10 Aug 2022 11:38:06.000	335.711	3.532	1446.112971
Mean Elevation			3.506	
Min Range	10 Aug 2022 11:38:06.000	335.711	3.532	1446.112971
Max Range	10 Aug 2022 11:38:10.000	336.853	3.479	1451.596091
Mean Range				1448.821710

Aircraft1-To-STARLINK-4304_534141 - AER reported in the object's default AER frame

	Time (UTCG)	Azimuth (deg)	Elevation (deg)	Range (km)
	10 Aug 2022 11:38:06.000	335.711	3.532	1446.112971
	10 Aug 2022 11:38:07.000	335.998	3.519	1447.434472
	10 Aug 2022 11:38:08.000	336.284	3.506	1448.788890
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Min Elevation	10 Aug 2022 11:38:10.000	336.853	3.479	1451.596091
Max Elevation	10 Aug 2022 11:38:06.000	335.711	3.532	1446.112971
Mean Elevation			3.506	
Min Range	10 Aug 2022 11:38:06.000	335.711	3.532	1446.112971
Max Range	10 Aug 2022 11:38:10.000	336.853	3.479	1451.596091