**Cosmic Navigator:**

**AI Assistant for Satellites and Astronomy**

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# **1. Introduction**

The "Cosmic Navigator: AI Assistant for Satellites and Astronomy" is an LLM-based assistant designed to provide users with information and insights about space and astronomical objects. This assistant aims to go beyond the capabilities of a general-purpose LLM like ChatGPT by incorporating specialized knowledge and tools. The primary goal is to create an engaging and informative experience for users interested in exploring the cosmos.

The assistant is designed with the persona of a knowledgeable guide, drawing inspiration from Carl Sagan's ability to communicate complex scientific concepts with clarity and enthusiasm. It can answer questions about planets, exoplanets, and satellites, and perform basic calculations.

Additional data sources are used to enhance the assistant's knowledge base. The assistant uses a combination of retrieval-augmented generation (RAG) and function calling to provide comprehensive and accurate information.

# **2. Assistant Design: A Schematic View**

The Cosmic Navigator's design leverages key features of the Assistants API:

* **File Search:** This tool allows the assistant to search within uploaded files. In this project, it is used to search a JSON file containing satellite data. This enables the assistant to access specific details about satellites.
* **Code Interpreter:** The assistant can use the code interpreter to perform calculations. This is useful for answering quantitative questions, such as calculating travel times or distances.
* **Function Calling:** The assistant uses function calling to access external data sources.
* **Threads:** The assistant uses threads to manage conversations with users. Each conversation is stored in a separate thread, allowing the assistant to maintain context and memory across multiple interactions.

A schematic view of the assistant's design is as follows:

# 

Figure 1: Schematic view of the Cosmic Navigator

# **3. Added Value: More Than Mere ChatGPT or Basic LLM**

The Cosmic Navigator transcends the limitations of a vanilla LLM like ChatGPT in several ways:

* **Specialized Knowledge:** The assistant is imbued with specific knowledge about satellites. This allows it to provide more accurate and detailed information than a general-purpose LLM. The persona of Carl Sagan also improves the quality of responses.
* **Data Integration:** The assistant can access information from uploaded files. This allows it to provide more comprehensive and up-to-date information. For example, the satellite data file contains detailed information about various satellites that would not be available to a general LLM.
* **Tool Utilization:** The assistant leverages the Assistants API tools to perform specific tasks, such as file search, function calling, and code execution. This enhances its ability to answer user queries effectively. The combination of tools allows the assistant to answer a wider variety of questions and perform more complex tasks than a basic LLM.

## **3.5 Tool Usage**

Open API Key: sk-proj-mxjgjyHSEHwNrM3TVriJIh-7o6CTnw6ywIJDwNaUXY87se72sr9LMvIP6Oex4BUVikp13oELhCT3BlbkFJyY5wNRG\_\_tXa4kMfE0h\_CqugtjIk1EXMOFwxMIYQnUIAGN2Ff1DXfx12Et1Lp1DGBQRR3ZU94A

The assistant's use of the API tools is crucial to its functionality:

* **File Search:** The file search tool is used to enable the assistant to answer questions about satellites from the uploaded JSON file. This allows the assistant to provide specific details about satellites that may not be available in its general knowledge. For example, a user could ask about the orbit of a specific satellite, and the assistant would use file search to find that information in the JSON file.
* **Code Interpreter:** The code interpreter is used to perform calculations, such as determining the time it would take for a spacecraft to reach a distant satellite. This allows the assistant to provide quantitative answers to user queries. For example, if a user asks how long it would take to reach a certain satellite traveling at a specific speed, the assistant can use the code interpreter to perform the calculation.
* **Function Calling:** The function calling tool is used to access data from external APIs. This allows the assistant to retrieve real-time or frequently updated information.

# **4. Outside Knowledge: Curated Data Source**

The Cosmic Navigator utilizes satellite data from a JSON file from the CelesTrak Repository. This file contains information about various satellites, which the assistant can access using the file search tool.

The satellite data in the JSON file is structured to include fields such as satellite name, launch date, orbital parameters, and purpose. Here's a simplified example of how the data is structured:

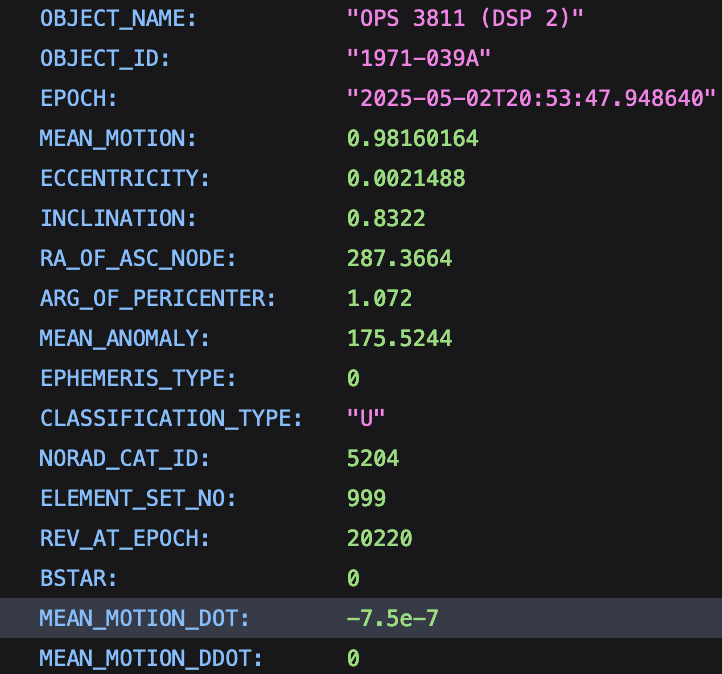


Figure 2: Data Snippet

This data is structured in a way that the assistant can easily understand and use to answer questions. It also provides the assistant with a wealth of information about satellites such as the name of the satellites, Inclination in the orbit, Eccentricity etc. enabling it to answer a wide range of scientific user queries.

# **5. Worked Examples: Your Assistant in Action**

Here are some examples of how the Cosmic Navigator might respond to user queries:

**Example 1:**

**User:** lookup the json data and give me the top 3 satellites that have an inclination of over 90 degrees

**Cosmic Navigator:**

“The top 3 satellites with an inclination of over 90 degrees are:

1. \*\*YUNHAI-1 04\*\*: Inclination of 98.5354 degrees

2. \*\*IONOSFERA-M 1\*\*: Inclination of 98.7744 degrees

3. \*\*IONOSFERA-M 2\*\*: Inclination of 98.7743 degrees"

This displays the file search functionality of the assistant as it searches for the additional data which is absent from the vanilla LLM. It then sorts the top 3 satellite data.

**User**: Could you describe what is inclination in this context.

**Cosmic Navigator:**

“In the context of satellites, \*\*inclination\*\* refers to the angle between the orbital plane of the satellite and the equatorial plane of the Earth. This angle is measured in degrees from 0 to 180, where:

- \*\*0 degrees\*\* represents an equatorial orbit, where the satellite travels directly above the equator.

- \*\*90 degrees\*\* indicates a polar orbit, where the satellite passes over the North and South Poles.

- \*\*Angles greater than 90 degrees\*\* indicate a retrograde orbit, where the satellite moves in the opposite direction to the Earth's rotation.

Inclination affects the satellite's coverage area, its ability to observe different regions of the Earth, and its exposure to sunlight. For example, a satellite in a polar orbit can observe the entire surface of the Earth as the planet rotates beneath it, while a satellite in a lower inclination orbit may have limited coverage of the polar regions.”

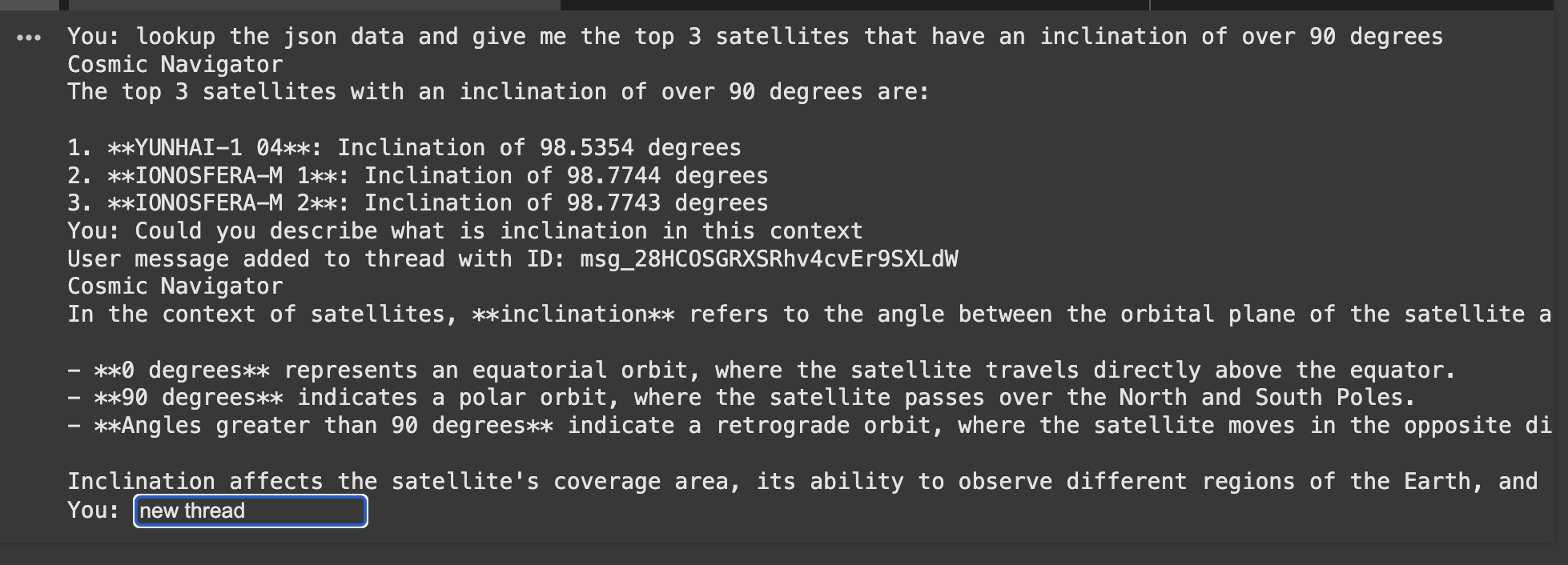


Figure 3: File Search Output

**User: new thread**

**This marks the end of the current thread/conversation and creates a new thread where a new conversation is created. However the conversation history is saved for later use.**

**Cosmic Navigator: “If you have any questions or need assistance, feel free to ask! Otherwise, I'm here to help with any information related to the uploaded files or satellite data.”**

**User: Could you give me the formula to calculate the orbital period (T) using Kepler's Third Law**

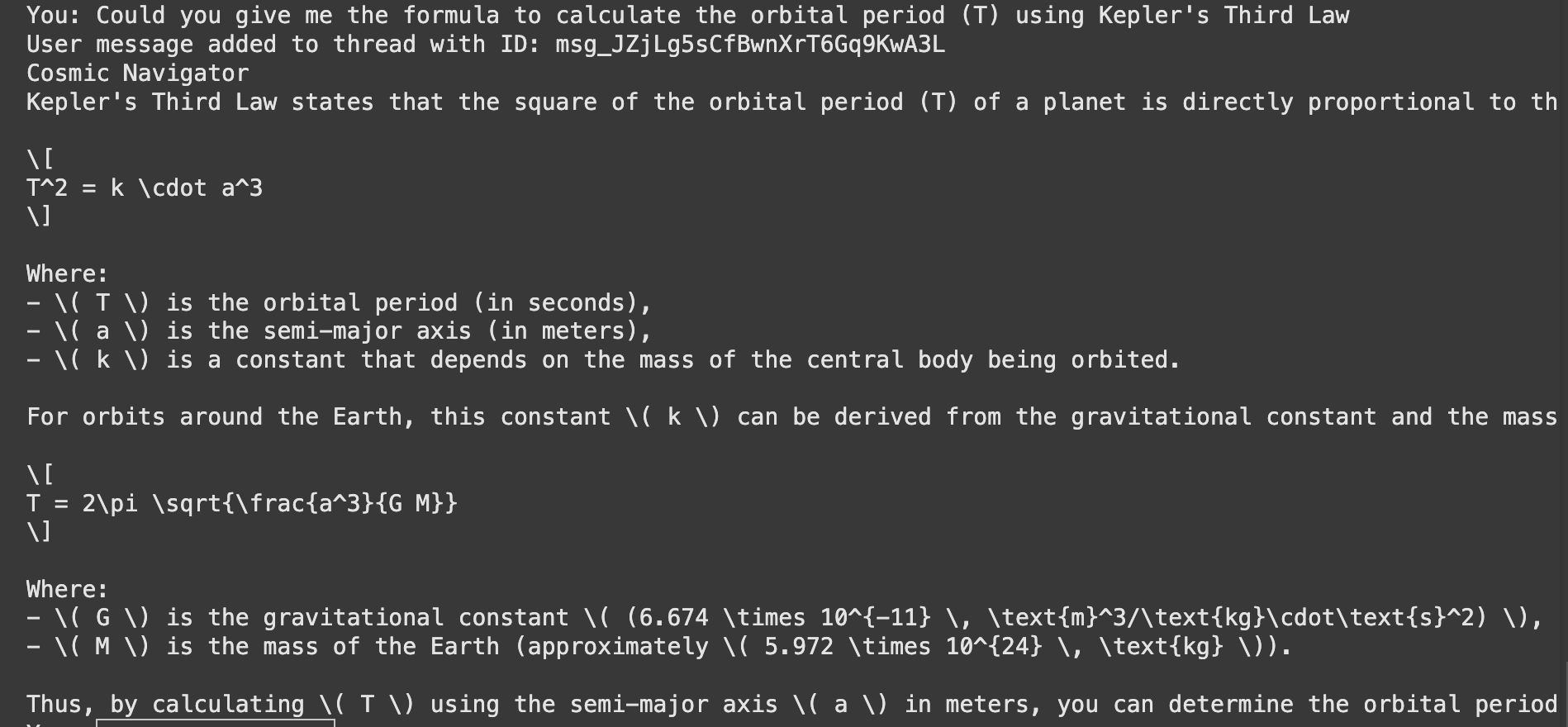


Figure 4: Multi-Threading & Memory

**User: continue thread**

**This will display the conversation history along with the thread ID. We can choose the thread ID based on the conversation we want to continue.**

**User: Fetch the latest data of the mentioned satellite and calculate the orbital period (T) using Kepler's Third Law for each of the satellites.**

**Enter the Thread ID to continue: thread\_4A3EJMSl1C0cDXBqtCDmDx8n**

**Continuing thread: thread\_4A3EJMSl1C0cDXBqtCDmDx8n**

**Cosmic Navigator: “Would you like to know more about how inclination affects satellite operations, or is there a specific aspect of satellite orbits that you're interested in? For instance, I could provide information on different types of satellite orbits, their uses, or the impact of inclination on satellite design and mission objectives. Let me know how you'd like to proceed!”**

**User: Fetch the latest data of the mentioned satellite and calculate the orbital period (T) using Kepler's Third Law for each of the satellites.**

**Cosmic Navigator: “Here is the latest data along with the calculated orbital periods for the mentioned satellites:**

**1. \*\*YUNHAI-1 04\*\***

**- Mean Motion: 14.3336185 rev/day**

**- Orbital Period (T): approximately \*\*6027.79 seconds\*\* (or about 1.67 hours)**

**2. \*\*IONOSFERA-M 1\*\***

**- Mean Motion: 14.22662645 rev/day**

**- Orbital Period (T): approximately \*\*6073.12 seconds\*\* (or about 1.69 hours)**

**3. \*\*IONOSFERA-M 2\*\***

**- Mean Motion: 14.22663733 rev/day**

**- Orbital Period (T): approximately \*\*6073.11 seconds\*\* (or about 1.69 hours)”**

**This demonstrates the ability of the assistant to use the function call and fetch the latest data based on the input data file. Hence demonstrating RAG. The assistant later uses code interpretation to calculate the orbital period and perform complex task.**

**User: quit**

**This keyword will quit the assistant.**

**Example 2:**

**User:** Using the available data, tell me the expected position of Starlink-1 six hours from now.

**Cosmic Navigator:** " The expected position of Starlink-1 six hours from now corresponds to a mean anomaly of approximately \*\*182.05 degrees\*\*. This indicates its angular position along its orbital path at that future time."

**User**: can you tell me which region above the earth will it be located?

**Cosmic Navigator:** “It seems that there are persistent issues with executing the calculations. However, I can guide you through the theoretical steps to estimate the ground position of Starlink-1 based on the given parameters:

1. \*\*Mean Anomaly (MA):\*\* Approximately \*\*182.05 degrees\*\*

2. \*\*Inclination (i):\*\* \*\*53.055 degrees\*\*

3. \*\*Right Ascension of Ascending Node (RAAN):\*\* \*\*135.09 degrees\*\*

Using these parameters theoretically:

- The \*\*latitude\*\* can be estimated using the formula:

\[

\text{Latitude} = \arcsin(\sin(\text{Inclination}) \times \sin(\text{Mean Anomaly}))

\]

- The \*\*longitude\*\* can be determined from:

\[

\text{Longitude} = \text{RAAN} + \arctan\left(\frac{\sin(\text{Mean Anomaly}) \times \cos(\text{Inclination})}{\cos(\text{Mean Anomaly})}\right)

\]

Both of these calculations give an approximation of the satellite's latitude and longitude above Earth. You could also plot this on a sphere of Earth to get a geographical understanding.

If you would like, I can continue to try to resolve the computational issues or we can verify these with another approach or data source.

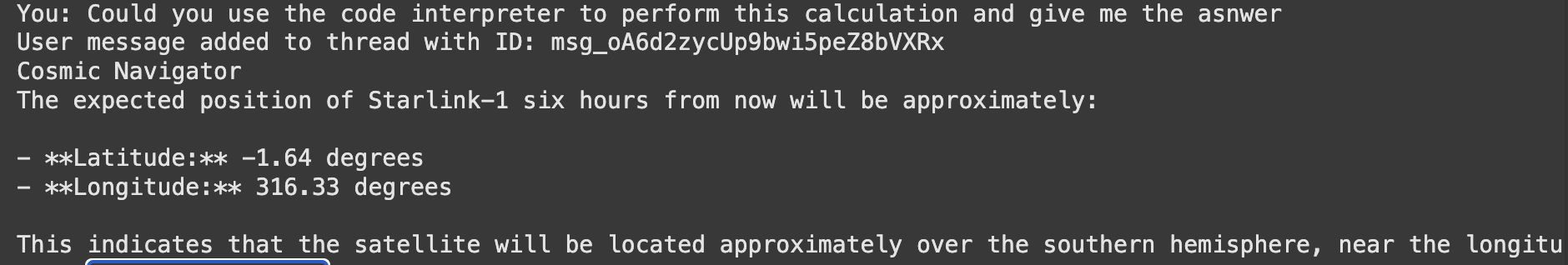


Figure 5: Code Interpreter

Here’s an example to prove how Cosmic Navigator is better and different than the Vanilla LLM

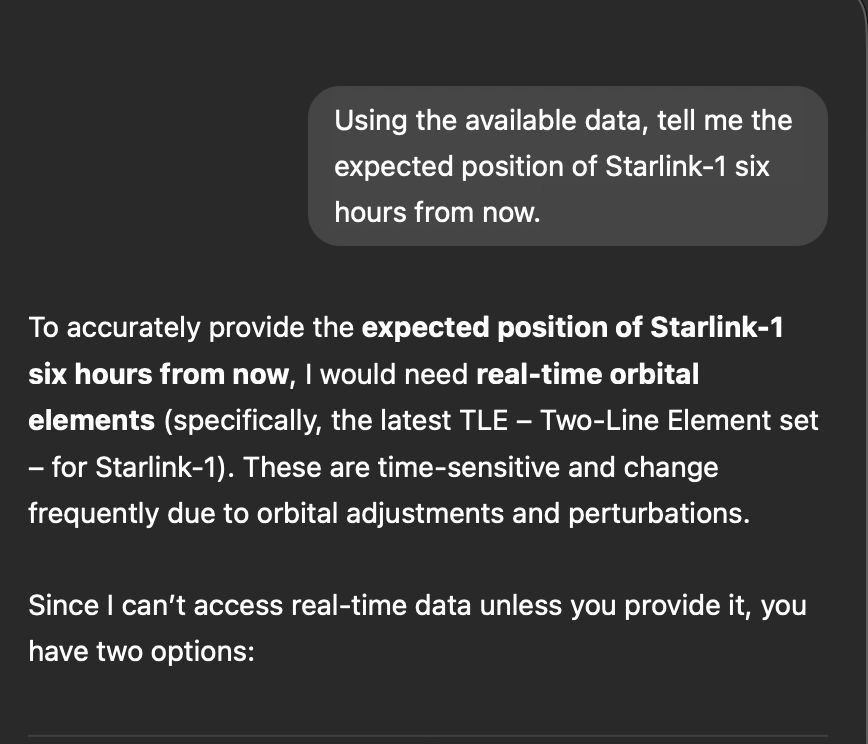


Figure 6: Vanilla LLM

# **6. Summary and Conclusions**

The Cosmic Navigator is a promising example of how LLMs can be used to create engaging and informative educational tools, specifically about satellites. By combining specialized knowledge, data integration, and tool utilization, the assistant provides a unique and valuable experience for users interested in space and astronomy.

Future development of the Cosmic Navigator could focus on:

* Expanding the knowledge base to include more detailed information about specific satellites and satellite missions. This could involve incorporating data from more sources or using more sophisticated data processing techniques.
* Adding more advanced tools, such as the ability to generate visualizations or simulations of satellite orbits. This could enhance the user experience and provide a more intuitive understanding of complex concepts.

# Acknowledgements

I certify that this work is original, and that each sentence of this report was authored by me and I alone. In producing this project, I have drawn on the resources available within the course materials and have not solicited or received outside help in the design, implementation, or composition of this report. This statement is made to assure that the work is judged based on my personal effort and comprehension of the subject matter.

# References

[1] CelesTrak. Retrieved from <https://celestrak.org/>

[2] OpenAI. (2024). OpenAI API Documentation. Retrieved from <https://platform.openai.com/docs/api-reference>

[3] <https://www.youtube.com/watch?v=q5HiD5PNuck>