Centre of Excellence in Modelling and Simulation for Next Generation Ports
Industrial Systems Engineering and Management
College of Design and Engineering

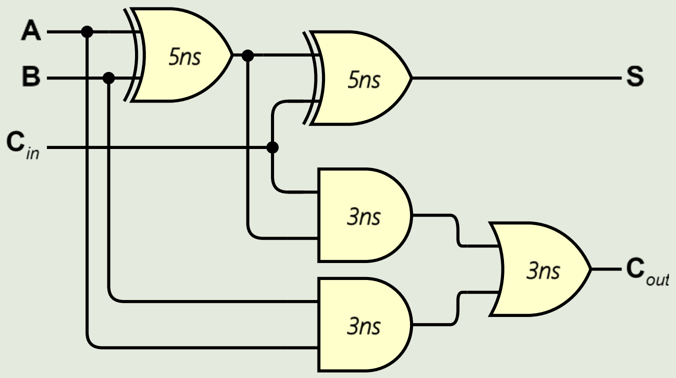
# Maritime Port Infrastructure using AI for Digital Twin with Parallel O2DES

*Riza Marhaban (@rizamarhaban)*
*Senior Associate Director (Senior IT Architect)*

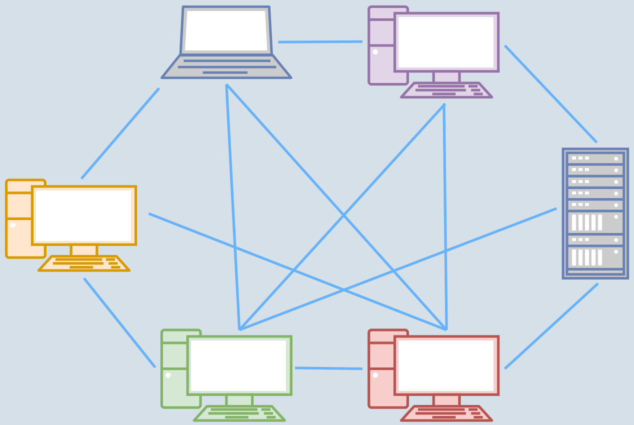
# MODELING AND DISCRETE EVENT SIMULATION

Discrete Event Simulation (DES) is a widely use scientific method for study and analysis of complex processes or systems and used in many domains from digital logic design, communication network, epidemiology and others.

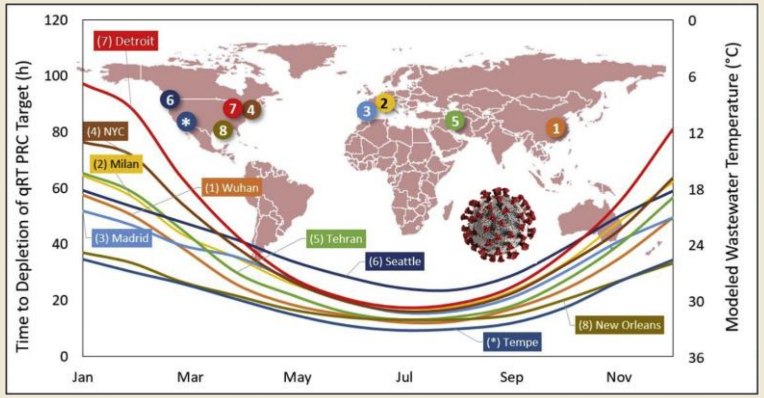
### Digital Logic Design
(CPUs, GPUs, etc.)




### Communication Network
(Protocols, QoS, etc.)



### Computational Epidemiology
(Disease control, vaccination, etc.)



# MODELING AND DISCRETE EVENT SIMULATION

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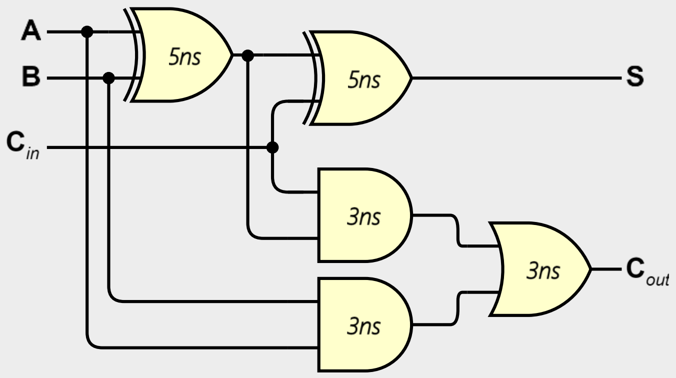
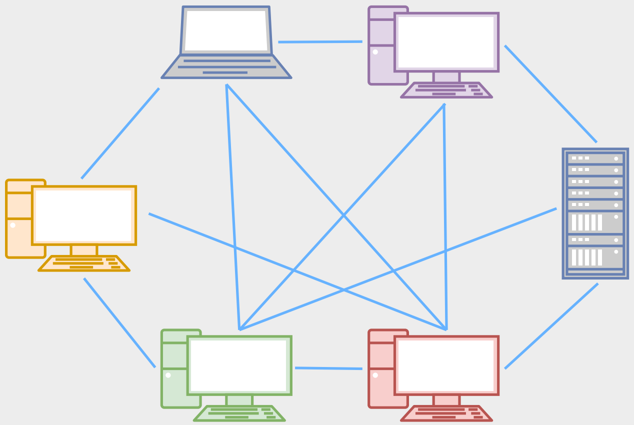



**Communication Network**
(Protocols, QoS, etc.)



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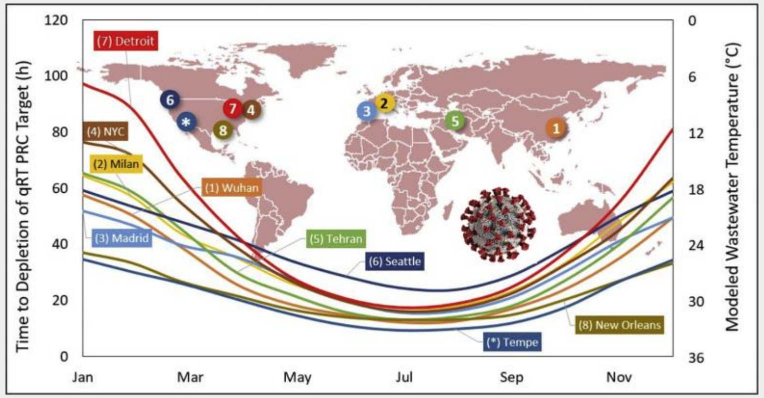
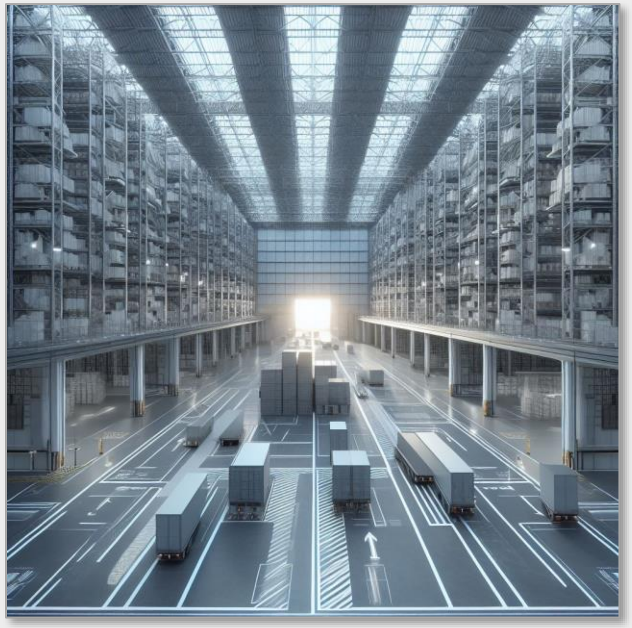
(Disease control, vaccination, etc.)



# DISCRETE EVENT SIMULATION IN DIGITAL TWIN

Modeling and discrete event simulation has also been incorporated as part of a digital twin system since decade ago such as for container terminal ports, general cargo ports and in logistic warehouses.



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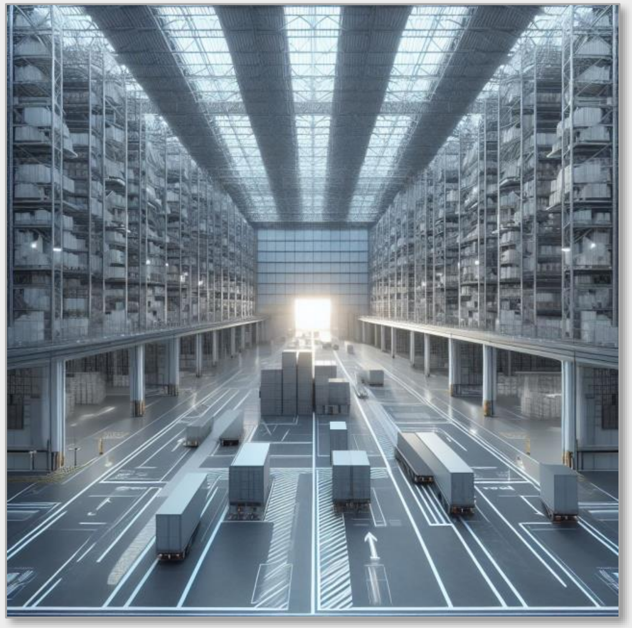
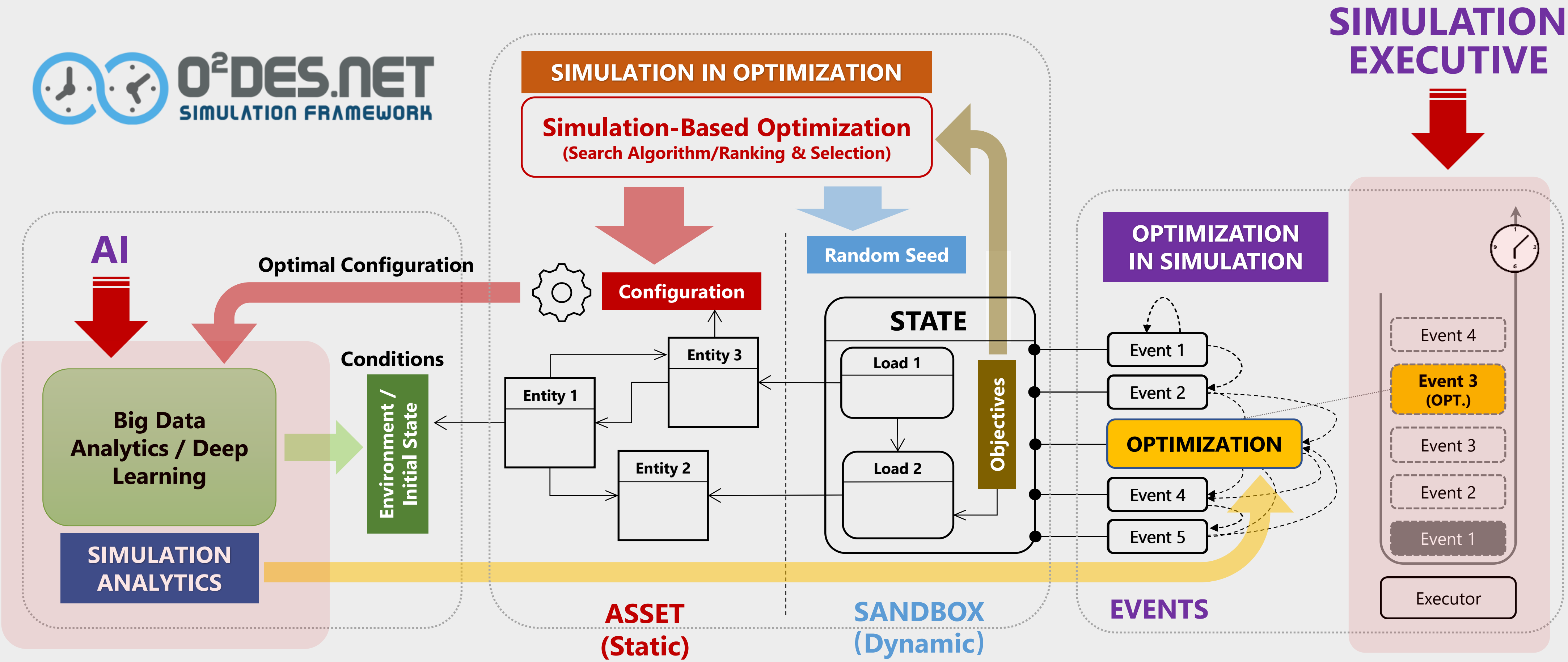
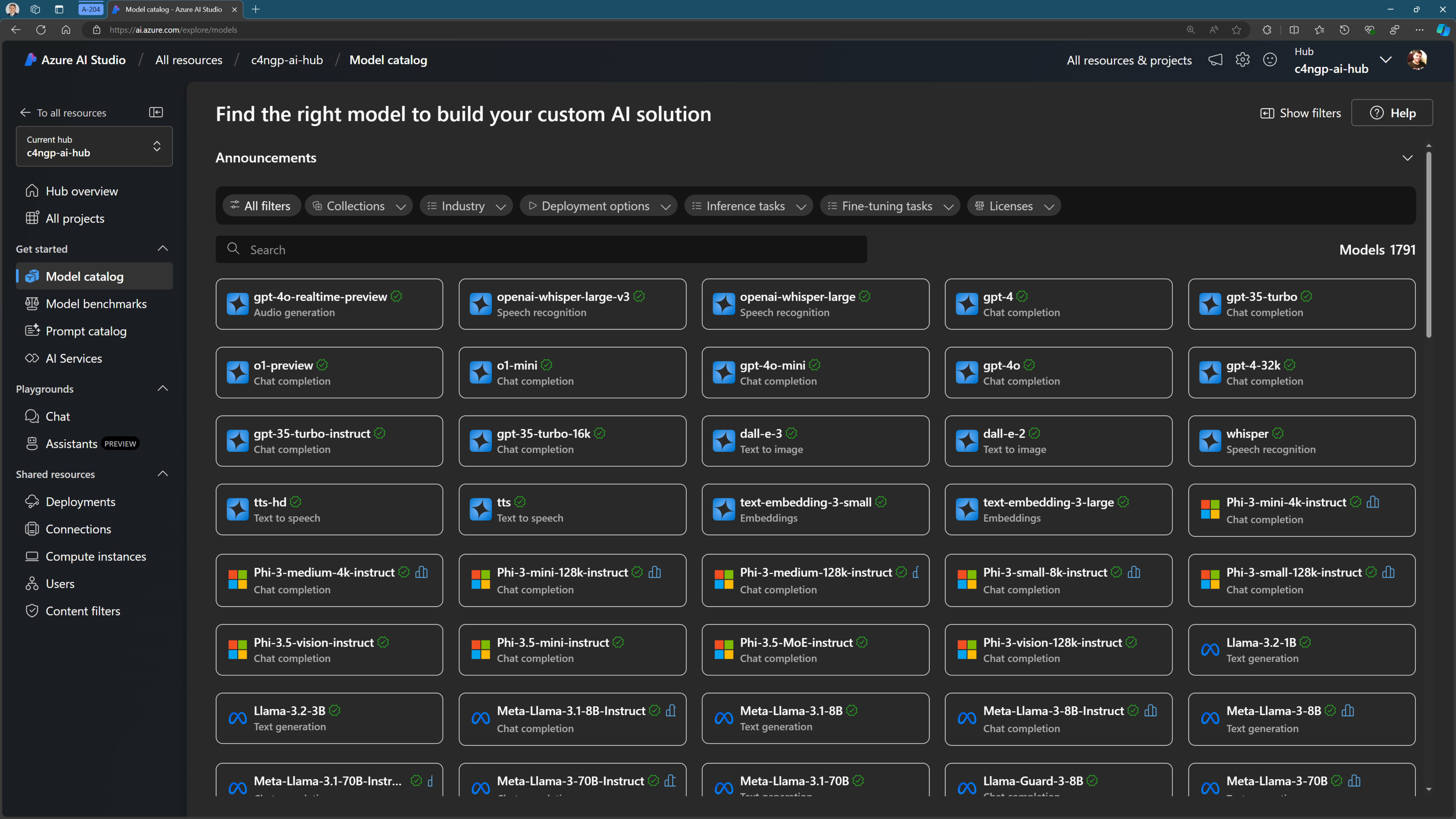


# O2DES Library (Latest Using .NET 9.x/C# 13)





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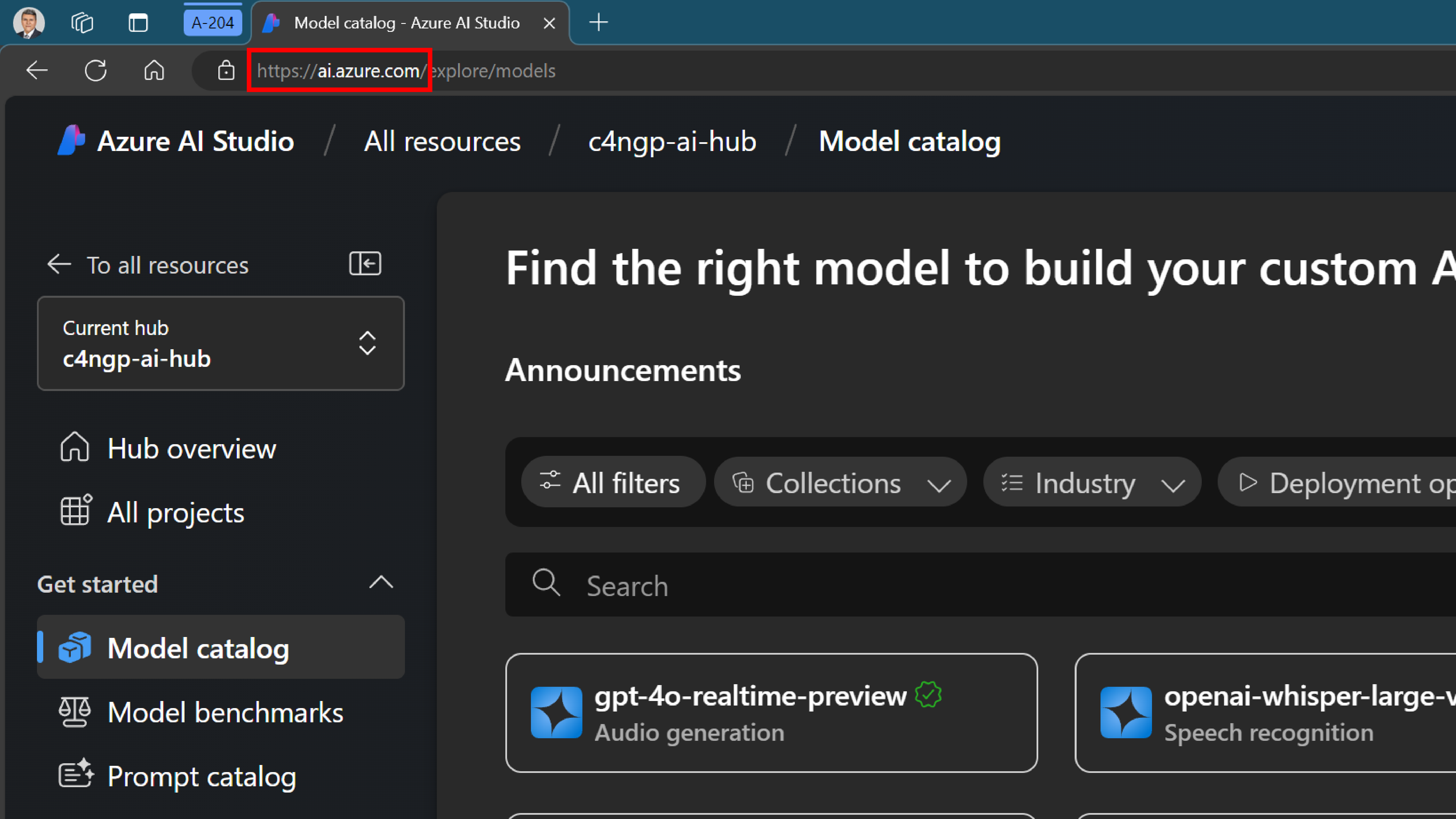
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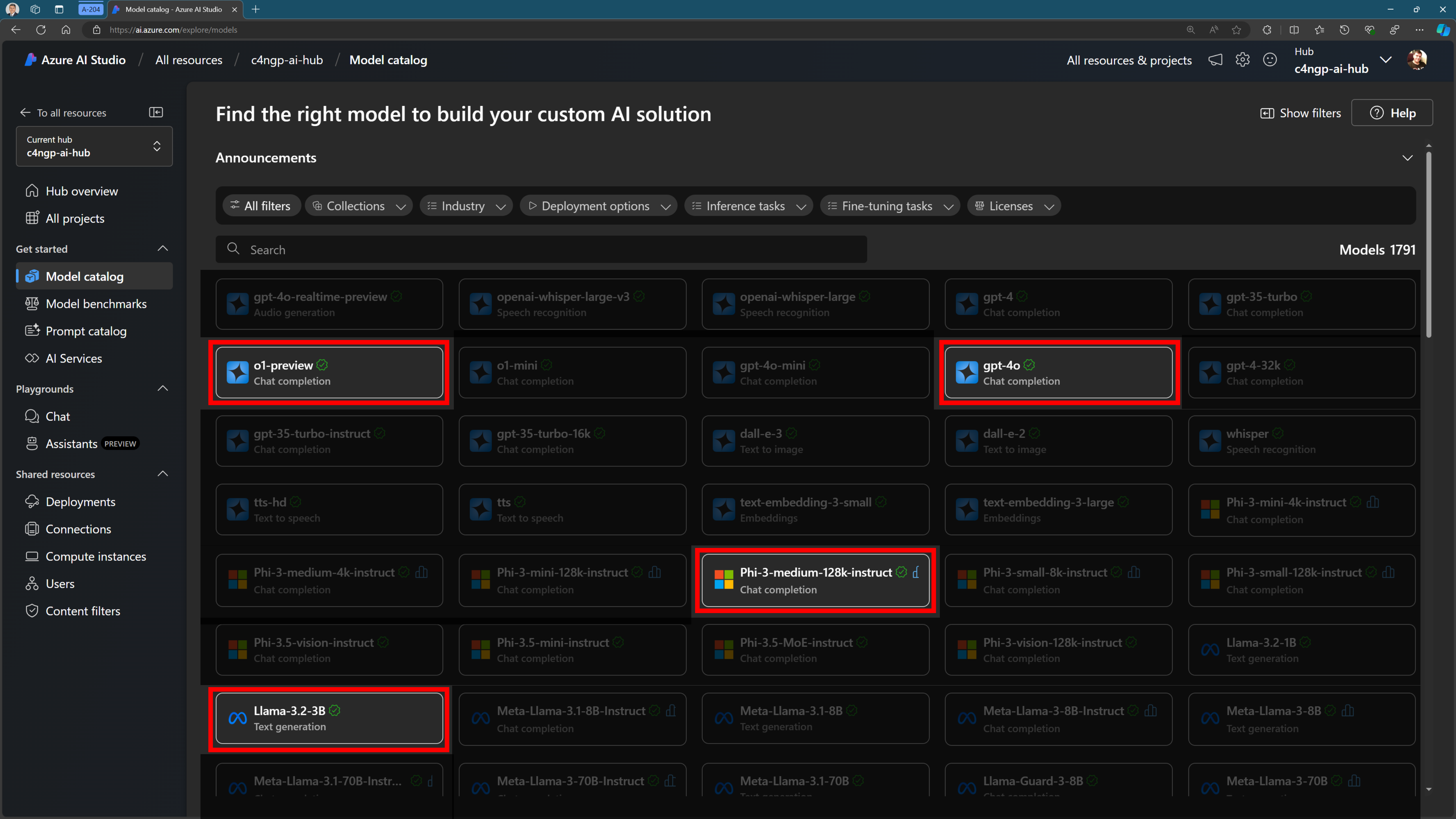
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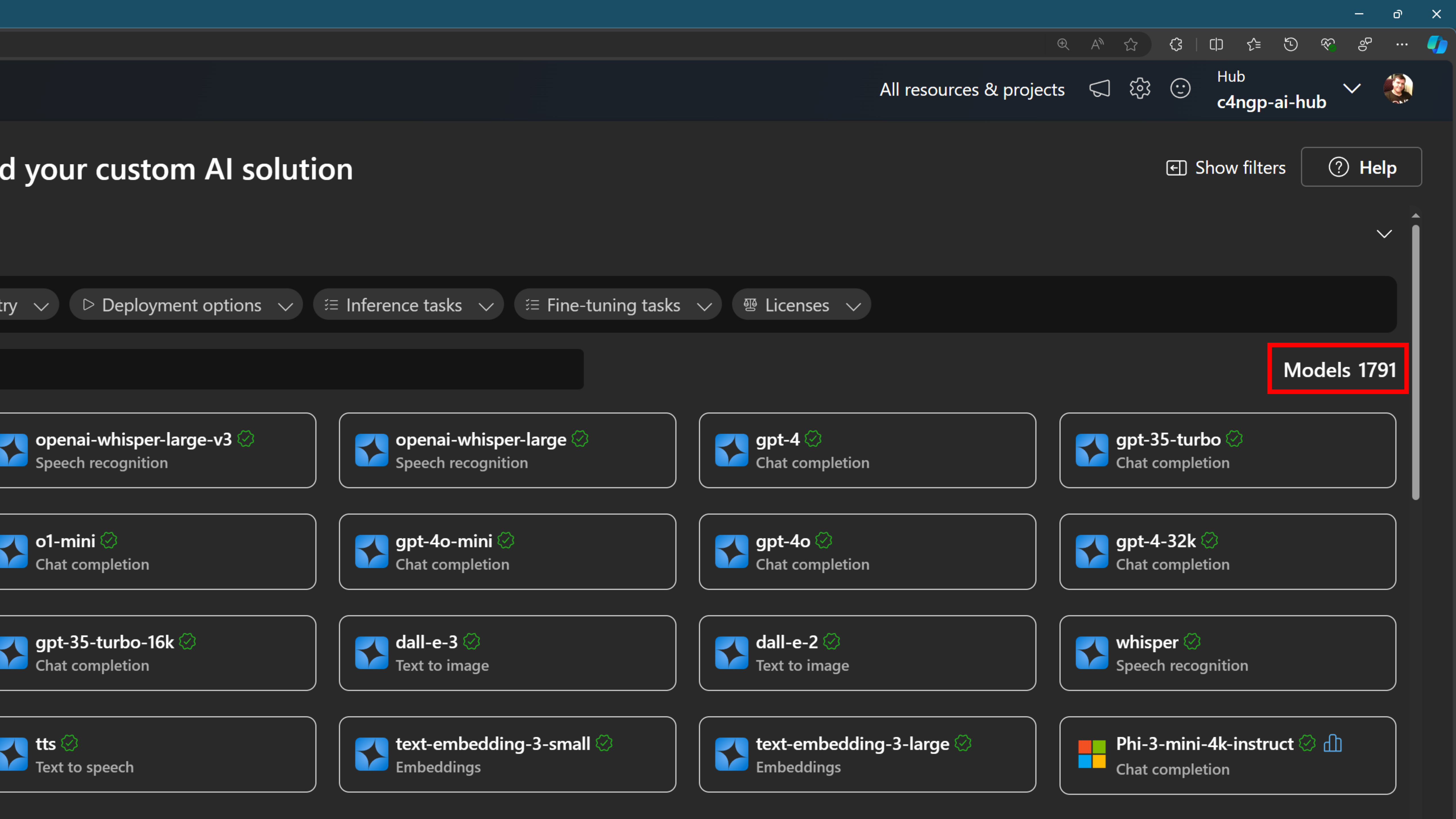
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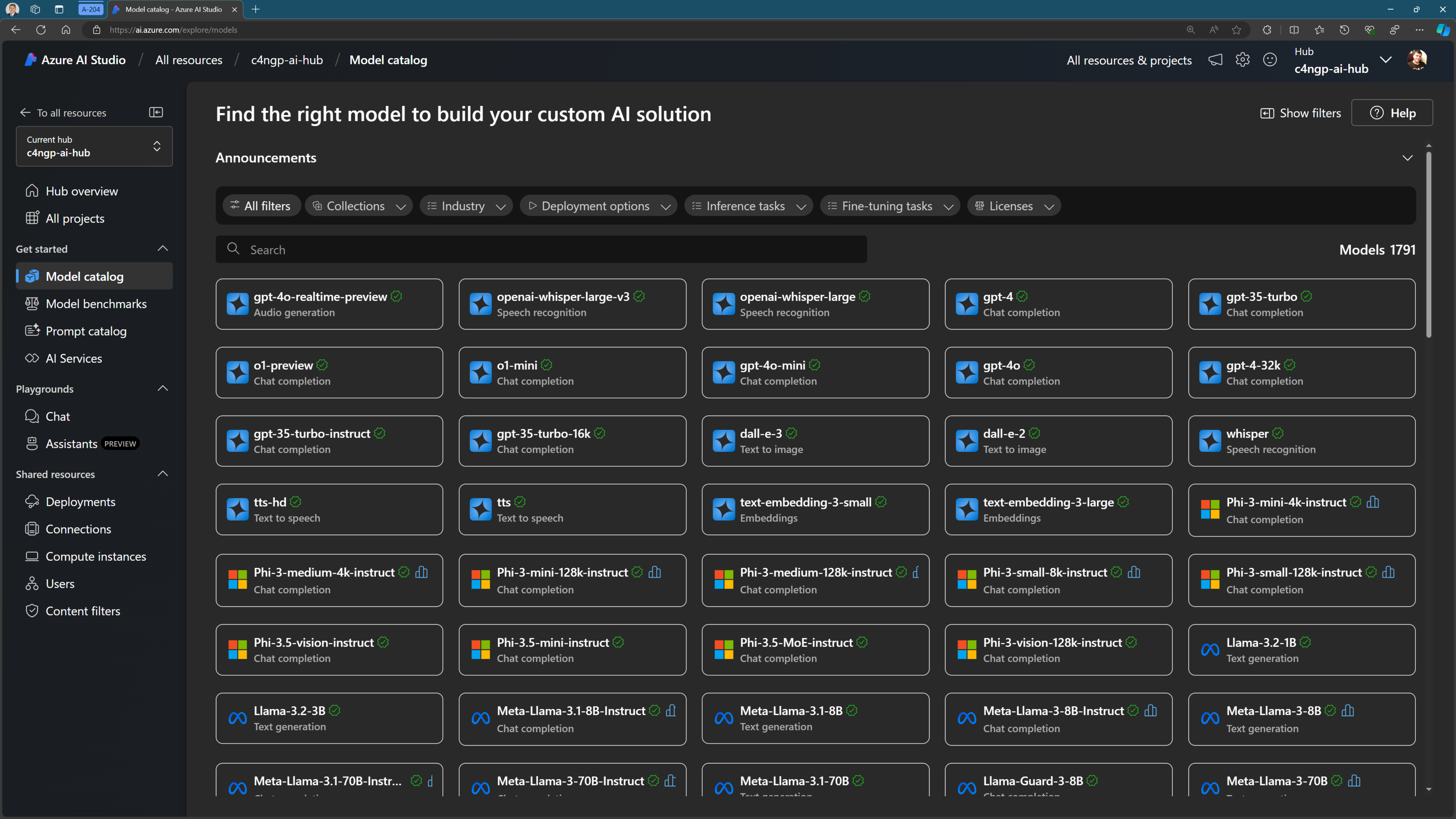
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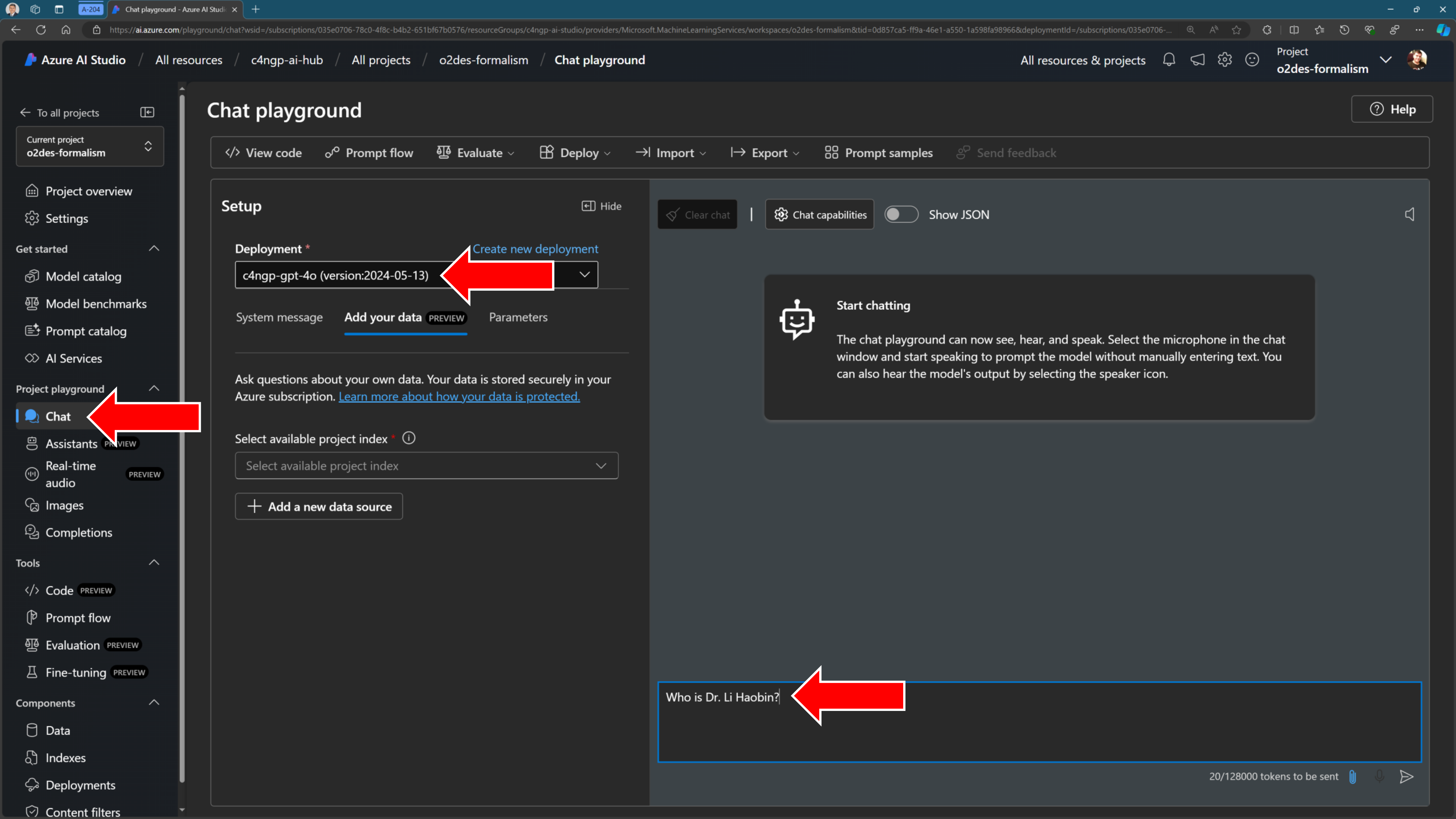
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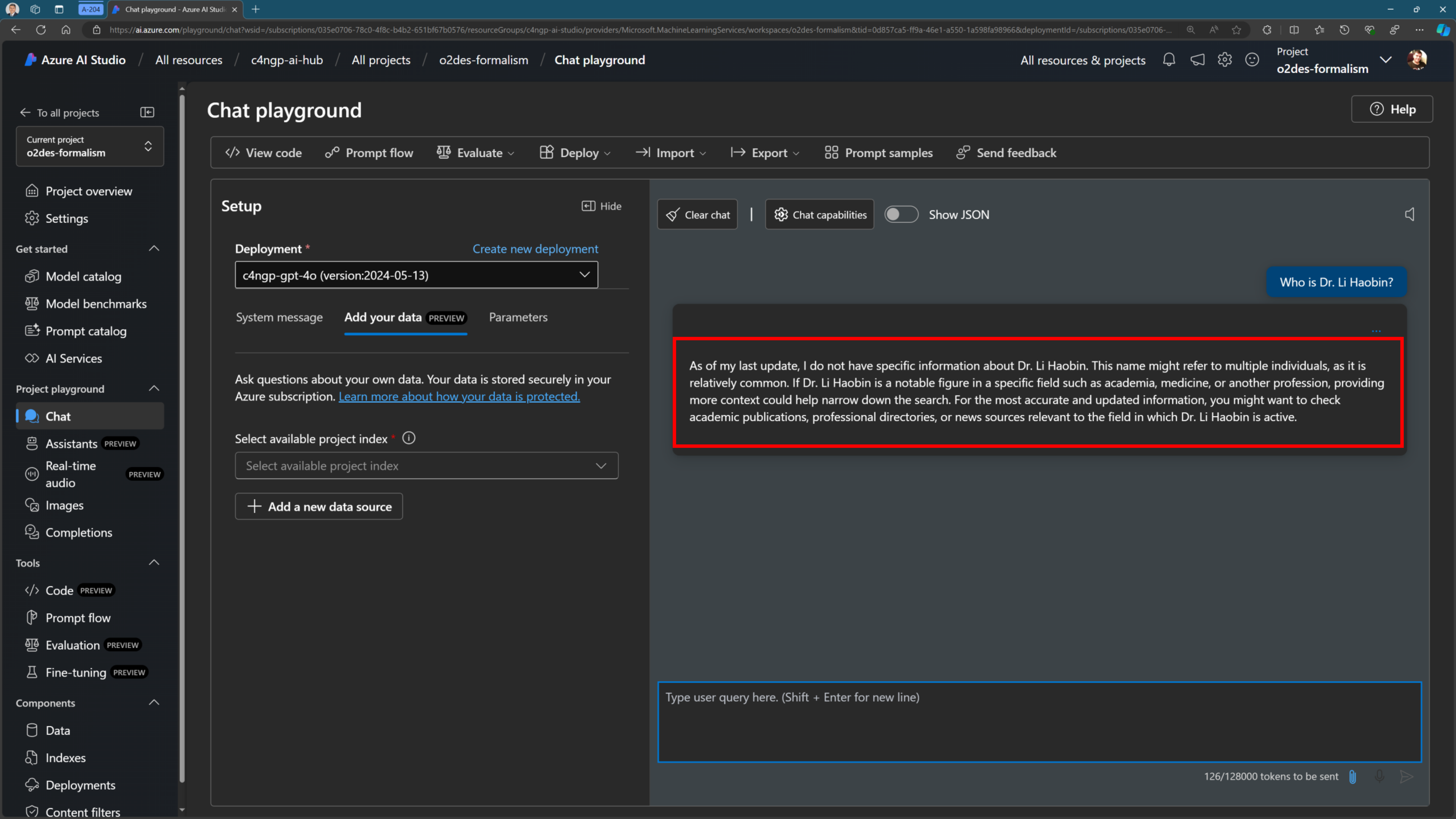
Deployment *
Create new deployment
c4ngp-gpt-4o (version:2024-05-13)
System message
Add your data PREVIEW
Parameters
Ask questions about your own data. Your data is stored securely in your Azure subscription. Learn more about how your data is protected.
Select available project index *
Select available project index
Add a new data source
Clear chat
Chat capabilities
Show JSON
Start chatting
The chat playground can now see, hear, and speak. Select the microphone in the chat window and start speaking to prompt the model without manually entering text. You can also hear the model's output by selecting the speaker icon.
Who is Dr. Li Haobin?
20/128000 tokens to be sent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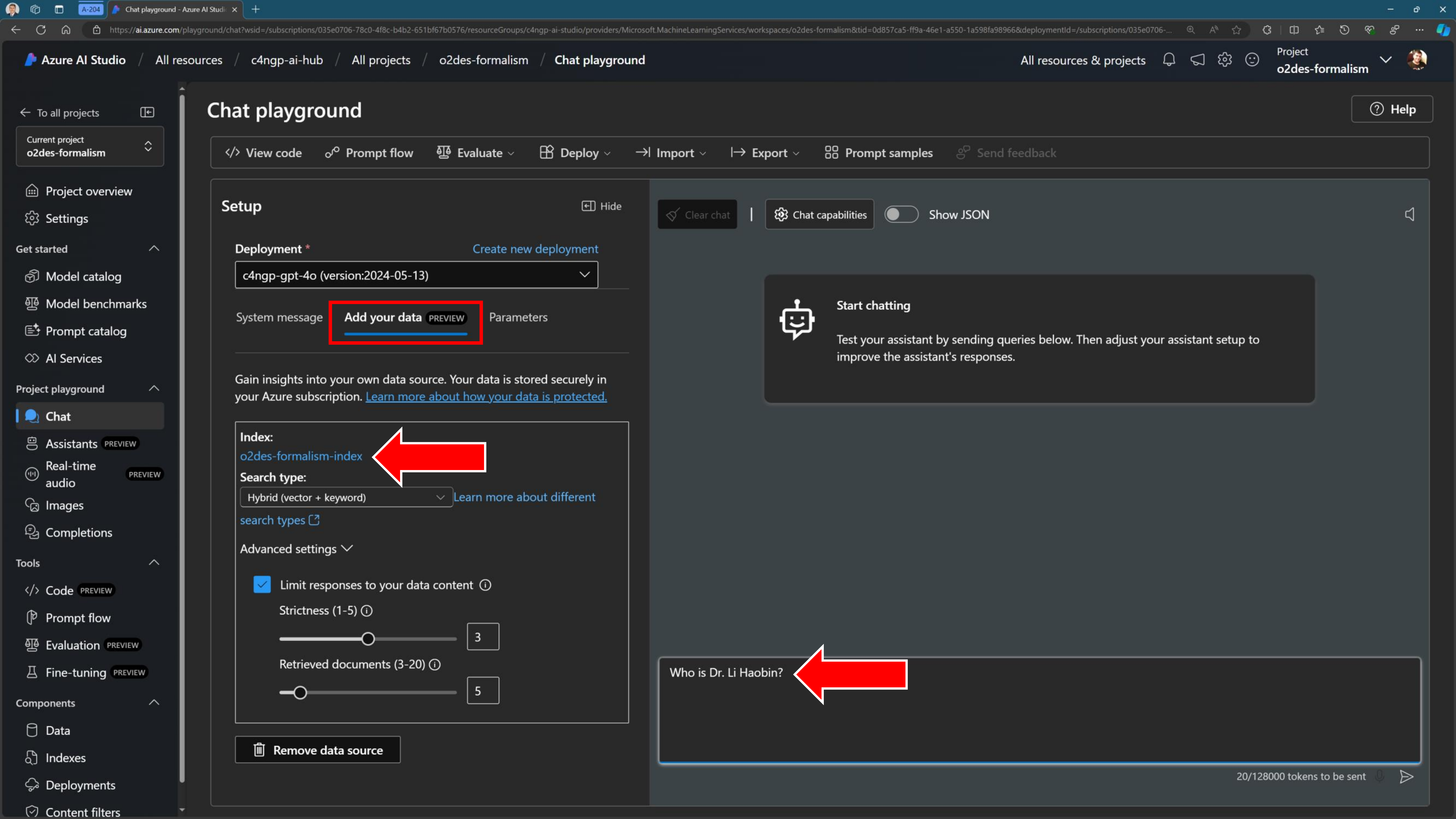
Deployment *
Create new deployment
c4ngp-gpt-4o (version:2024-05-13)
System message
Add your data PREVIEW
Parameters
Ask questions about your own data. Your data is stored securely in your Azure subscription. Learn more about how your data is protected.
Select available project index *
Select available project index
Add a new data source
Clear chat
Chat capabilities
Show JSON
Who is Dr. Li Haobin?
As of my last update, I do not have specific information about Dr. Li Haobin. This name might refer to multiple individuals, as it is relatively common. If Dr. Li Haobin is a notable figure in a specific field such as academia, medicine, or another profession, providing more context could help narrow down the search. For the most accurate and updated information, you might want to check academic publications, professional directories, or news sources relevant to the field in which Dr. Li Haobin is active.
Type user query here. (Shift + Enter for new line)
126/128000 tokens to be sent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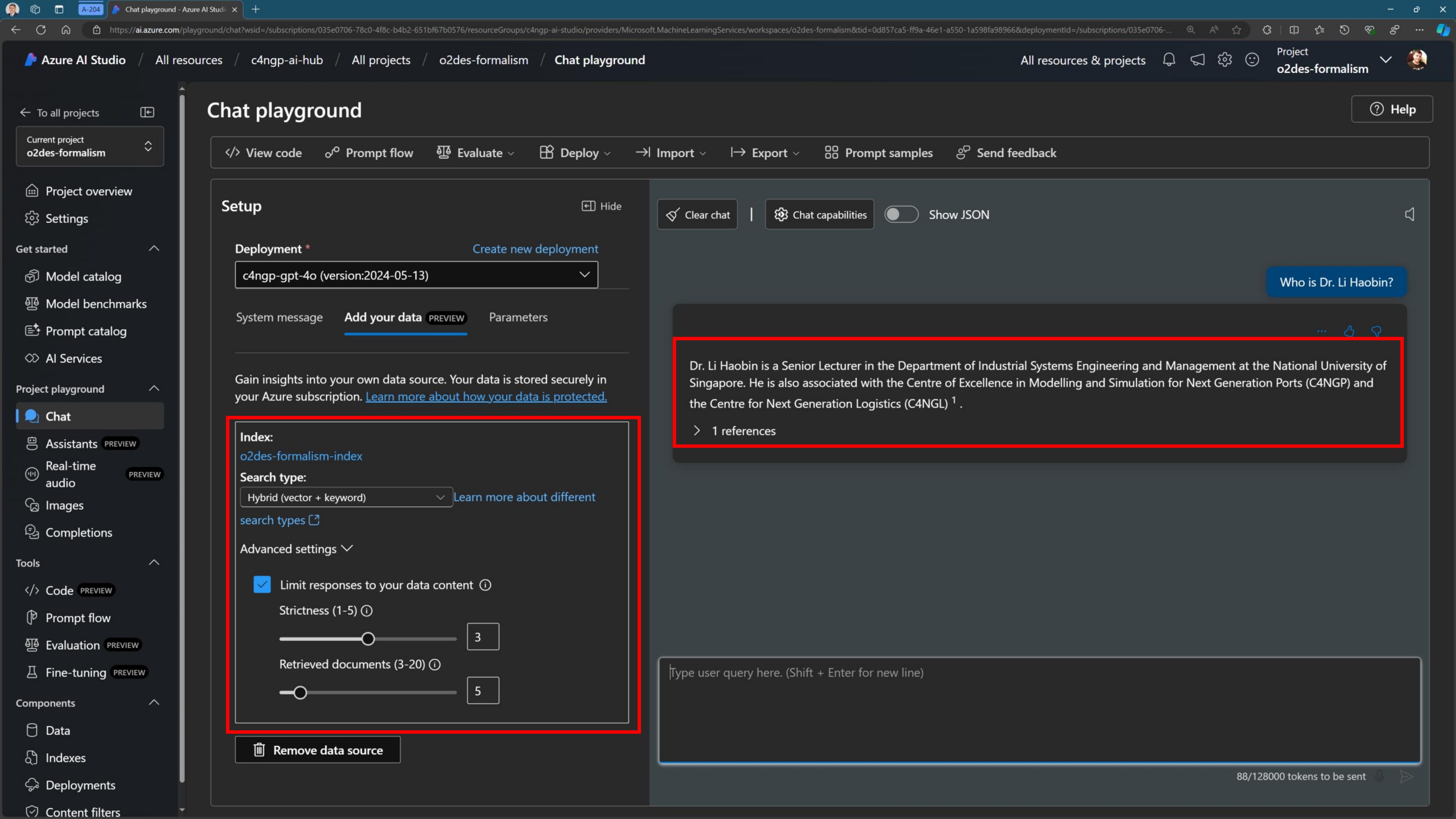
Deployment *
Create new deployment
c4ngp-gpt-4o (version:2024-05-13)
System message
Add your data PREVIEW
Parameters
Gain insights into your own data source. Your data is stored securely in your Azure subscription. Learn more about how your data is protected.
Index:
o2des-formalism-index
Search type:
Hybrid (vector + keyword)
Learn more about different search types
Advanced settings
Limit responses to your data content
Strictness (1-5)
3
Retrieved documents (3-20)
5
Remove data source
Clear chat
Chat capabilities
Show JSON
Start chatting
Test your assistant by sending queries below. Then adjust your assistant setup to improve the assistant's responses.
Who is Dr. Li Haobin?
20/128000 tokens to be sent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Learn more about different search types
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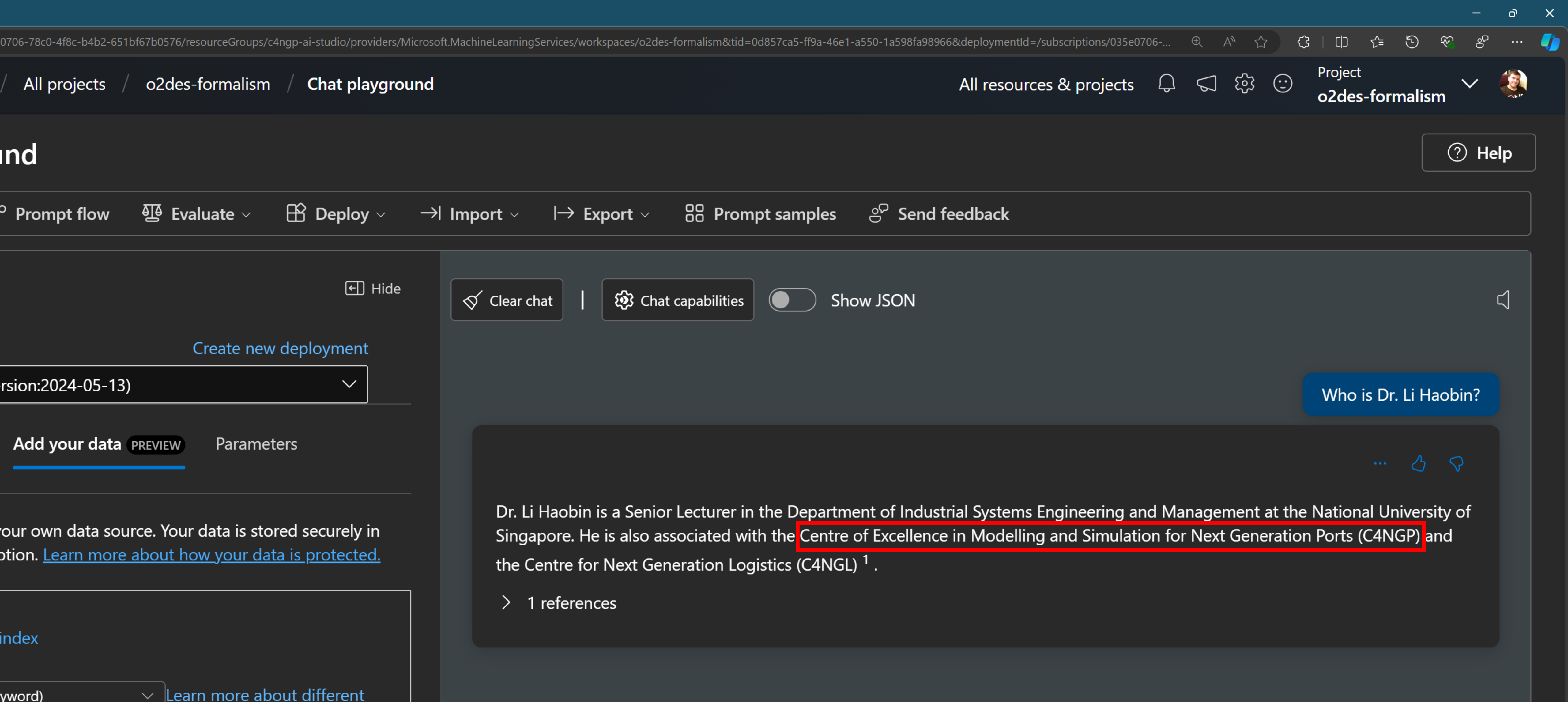
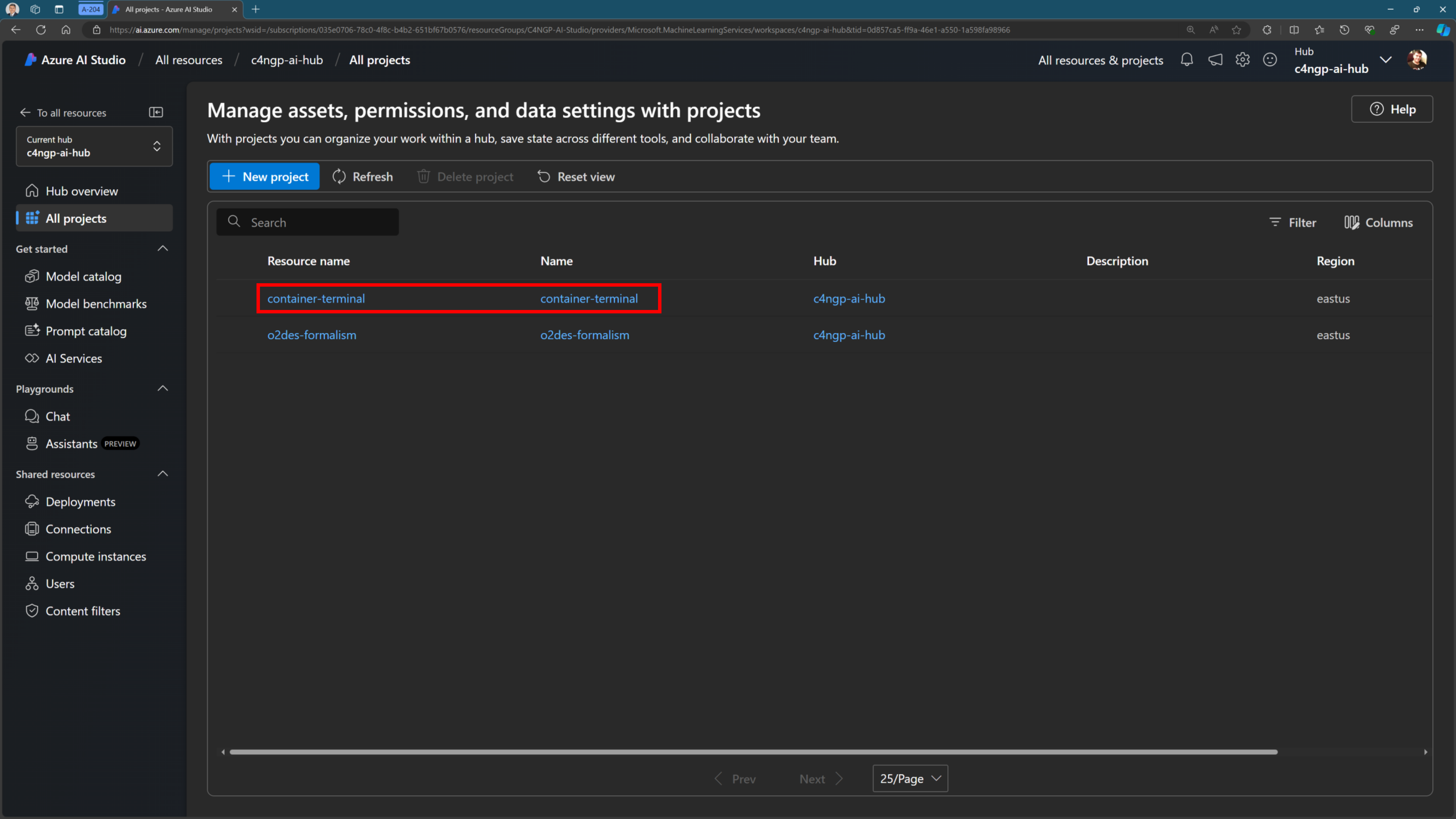
Remove data source
Clear chat
Chat capabilities
Show JSON
Who is Dr. Li Haobin?
Dr. Li Haobin is a Senior Lecturer in the Department of Industrial Systems Engineering and Management at the National University of Singapore. He is also associated with the Centre of Excellence in Modelling and Simulation for Next Generation Ports (C4NGP) and the Centre for Next Generation Logistics (C4NGL) 1 .
1 references
Type user query here. (Shift + Enter for new line)
88/128000 tokens to be sent




# RAG (Retrieval Augmented Generation)

Part of Generative AI using LLM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Manage assets, permissions, and data settings with projects
With projects you can organize your work within a hub, save state across different tools, and collaborate with your team.
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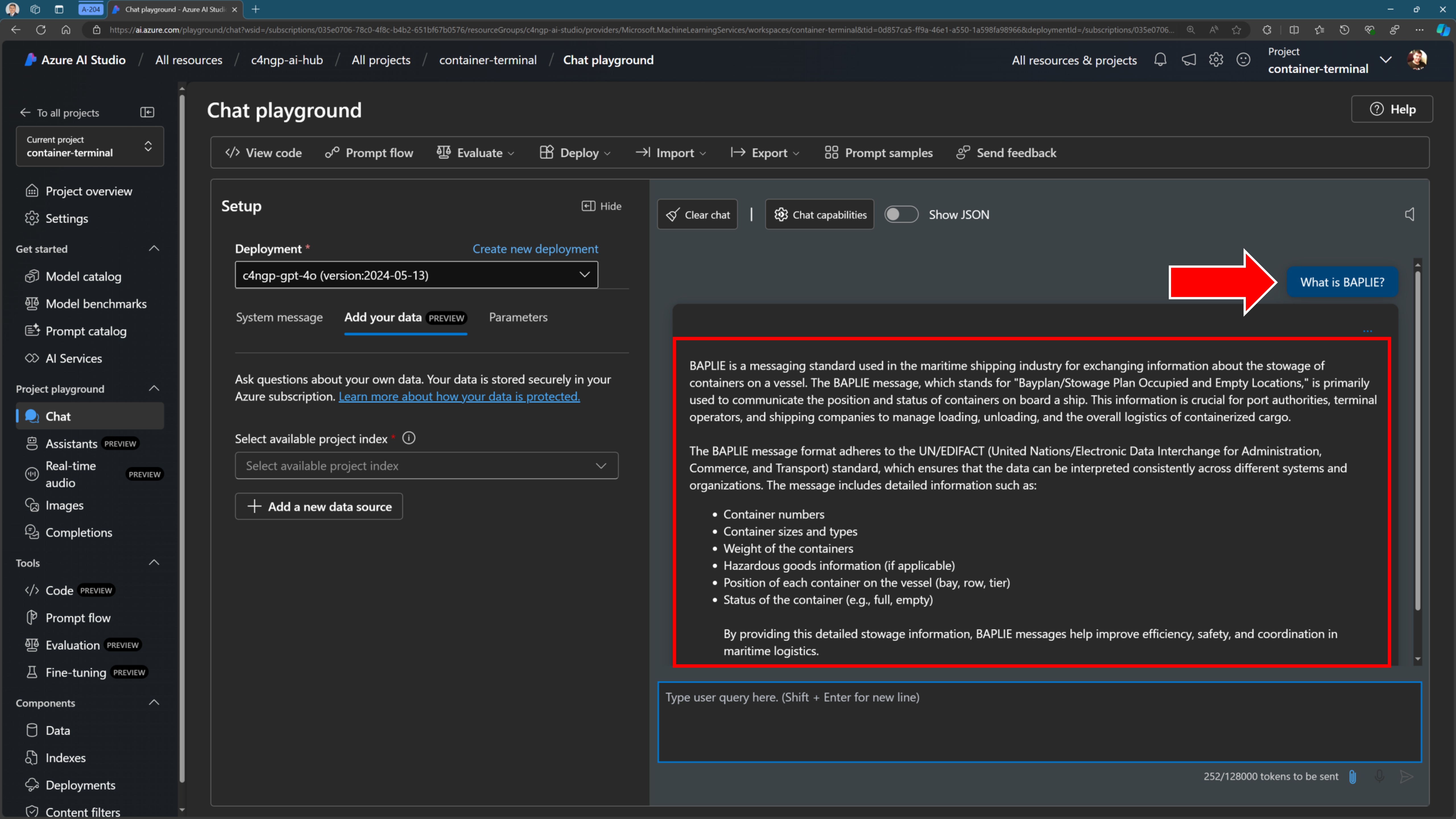
Chat playground - Azure AI Studio
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Chat
Assistants PREVIEW
Real-time audio PREVIEW
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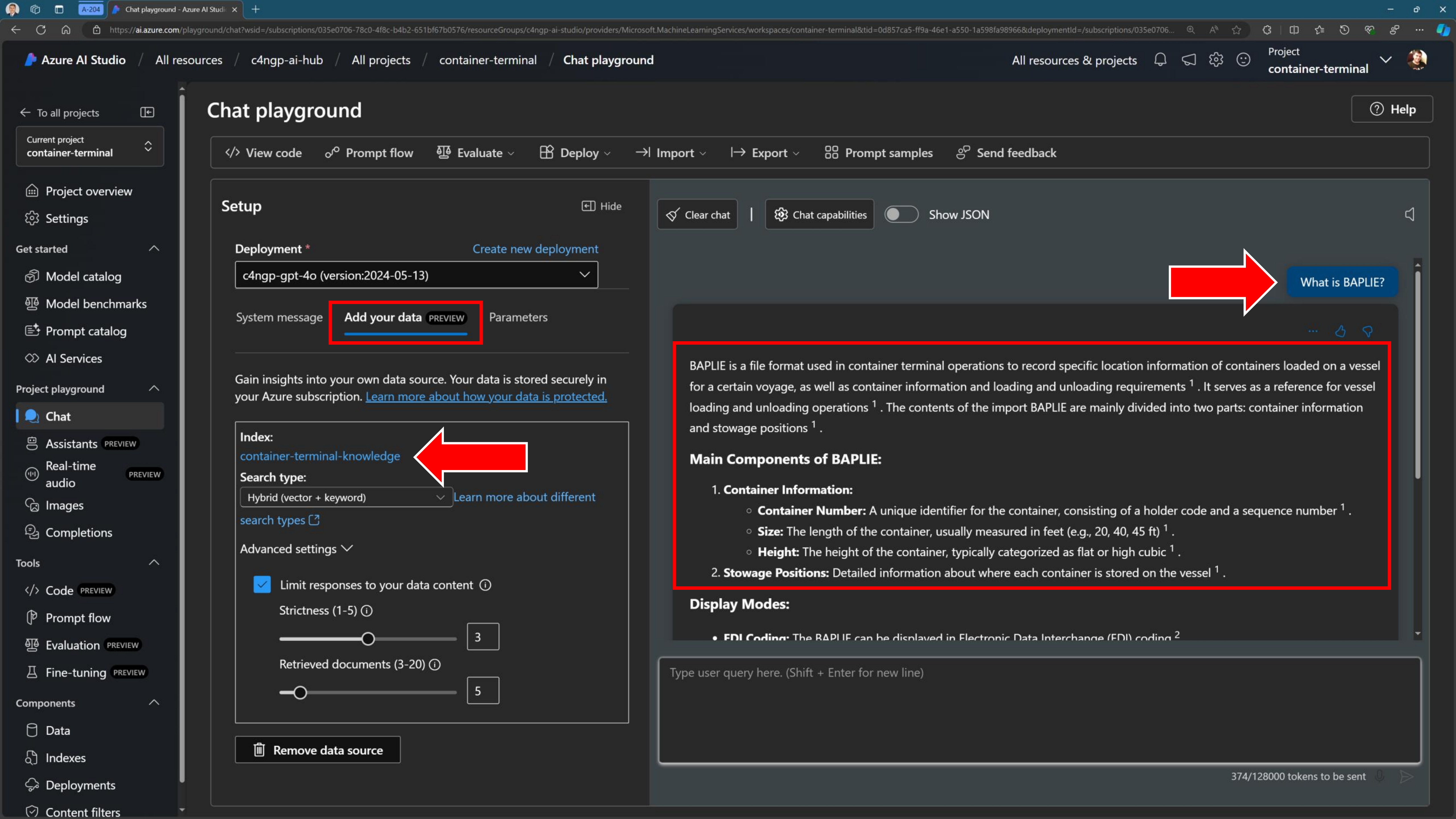
Prompt samples
Send feedback
Setup
Hide
Deployment *
Create new deployment
c4ngp-gpt-4o (version:2024-05-13)
System message
Add your data PREVIEW
Parameters
Ask questions about your own data. Your data is stored securely in your Azure subscription. Learn more about how your data is protected.
Select available project index *
Select available project index
Add a new data source
Clear chat
Chat capabilities
Show JSON
What is BAPLIE?
BAPLIE is a messaging standard used in the maritime shipping industry for exchanging information about the stowage of containers on a vessel. The BAPLIE message, which stands for "Bayplan/Stowage Plan Occupied and Empty Locations," is primarily used to communicate the position and status of containers on board a ship. This information is crucial for port authorities, terminal operators, and shipping companies to manage loading, unloading, and the overall logistics of containerized cargo.
The BAPLIE message format adheres to the UN/EDIFACT (United Nations/Electronic Data Interchange for Administration, Commerce, and Transport) standard, which ensures that the data can be interpreted consistently across different systems and organizations. The message includes detailed information such as:
Container numbers
Container sizes and types
Weight of the containers
Hazardous goods information (if applicable)
Position of each container on the vessel (bay, row, tier)
Status of the container (e.g., full, empty)
By providing this detailed stowage information, BAPLIE messages help improve efficiency, safety, and coordination in maritime logistics.
Type user query here. (Shift + Enter for new line)
252/128000 tokens to be sent


Chat playground - Azure AI Studio
Azure AI Studio / All resources / c4ngp-ai-hub / All projects / container-terminal / Chat playground
All resources & projects
Project
container-terminal
To all projects
Current project
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System message
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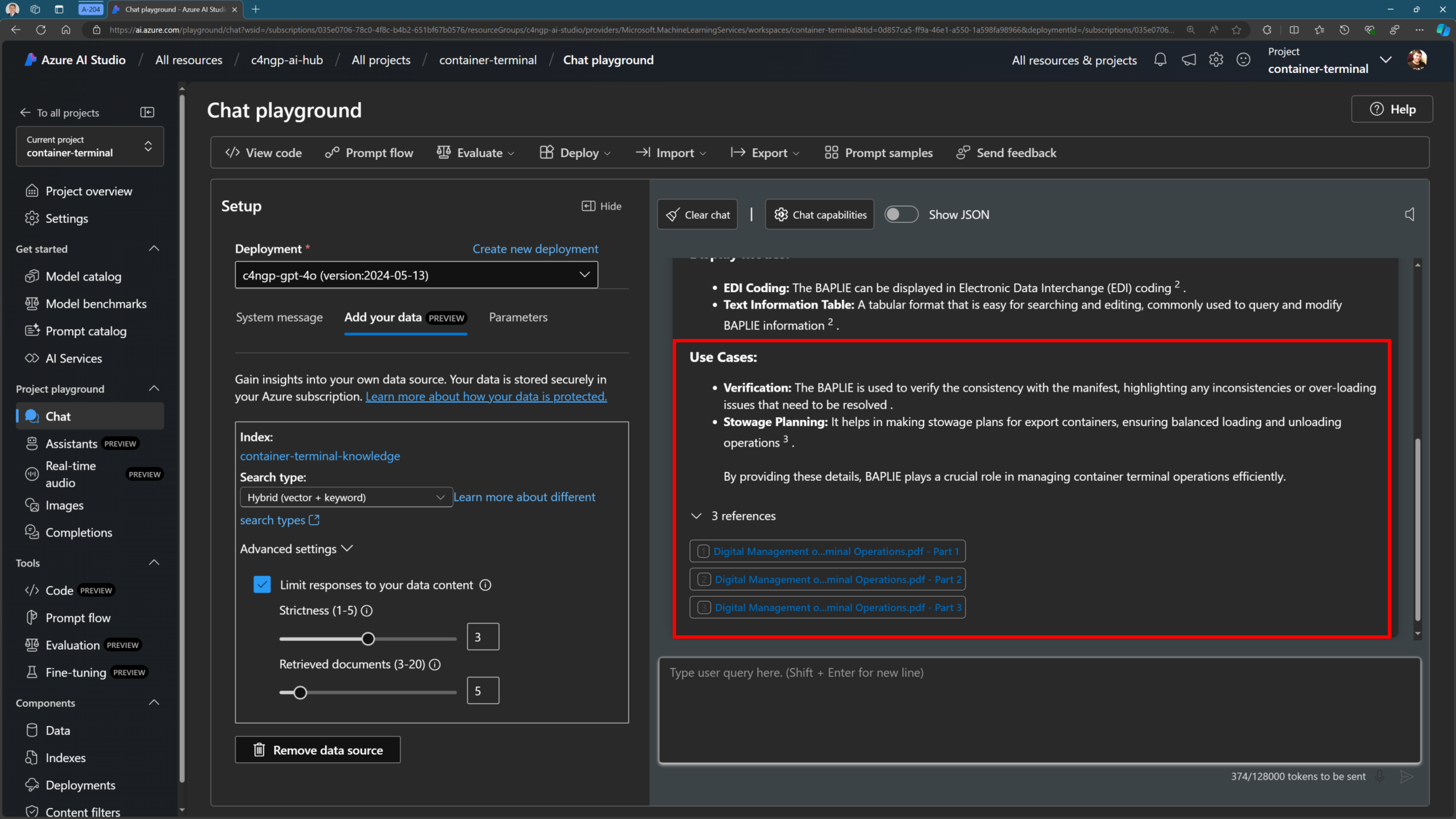
Gain insights into your own data source. Your data is stored securely in your Azure subscription. Learn more about how your data is protected.
Index:
container-terminal-knowledge
Search type:
Hybrid (vector + keyword)
Learn more about different search types
Advanced settings
Limit responses to your data content
Strictness (1-5)
3
Retrieved documents (3-20)
5
Remove data source
Clear chat
Chat capabilities
Show JSON
What is BAPLIE?
BAPLIE is a file format used in container terminal operations to record specific location information of containers loaded on a vessel for a certain voyage, as well as container information and loading and unloading requirements 1. It serves as a reference for vessel loading and unloading operations 1. The contents of the import BAPLIE are mainly divided into two parts: container information and stowage positions 1.
Main Components of BAPLIE:
1. Container Information:
Container Number: A unique identifier for the container, consisting of a holder code and a sequence number 1.
Size: The length of the container, usually measured in feet (e.g., 20, 40, 45 ft) 1.
Height: The height of the container, typically categorized as flat or high cubic 1.
2. Stowage Positions: Detailed information about where each container is stored on the vessel 1.
Display Modes:
Type user query here. (Shift + Enter for new line)
374/128000 tokens to be sent



Chat playground - Azure AI Studio
https://ai.azure.com/playground/chat?wsid=/subscriptions/035e0706-78c0-4f8c-b4b2-651bf67b0576/resourceGroups/c4ngp-ai-studio/providers/Microsoft.MachineLearningServices/workspaces/container-terminal&tid=0d857ca5-ff9a-46e1-a550-1a598fa98966&deploymentId=/subscriptions/035e0706...
Azure AI Studio / All resources / c4ngp-ai-hub / All projects / container-terminal / Chat playground
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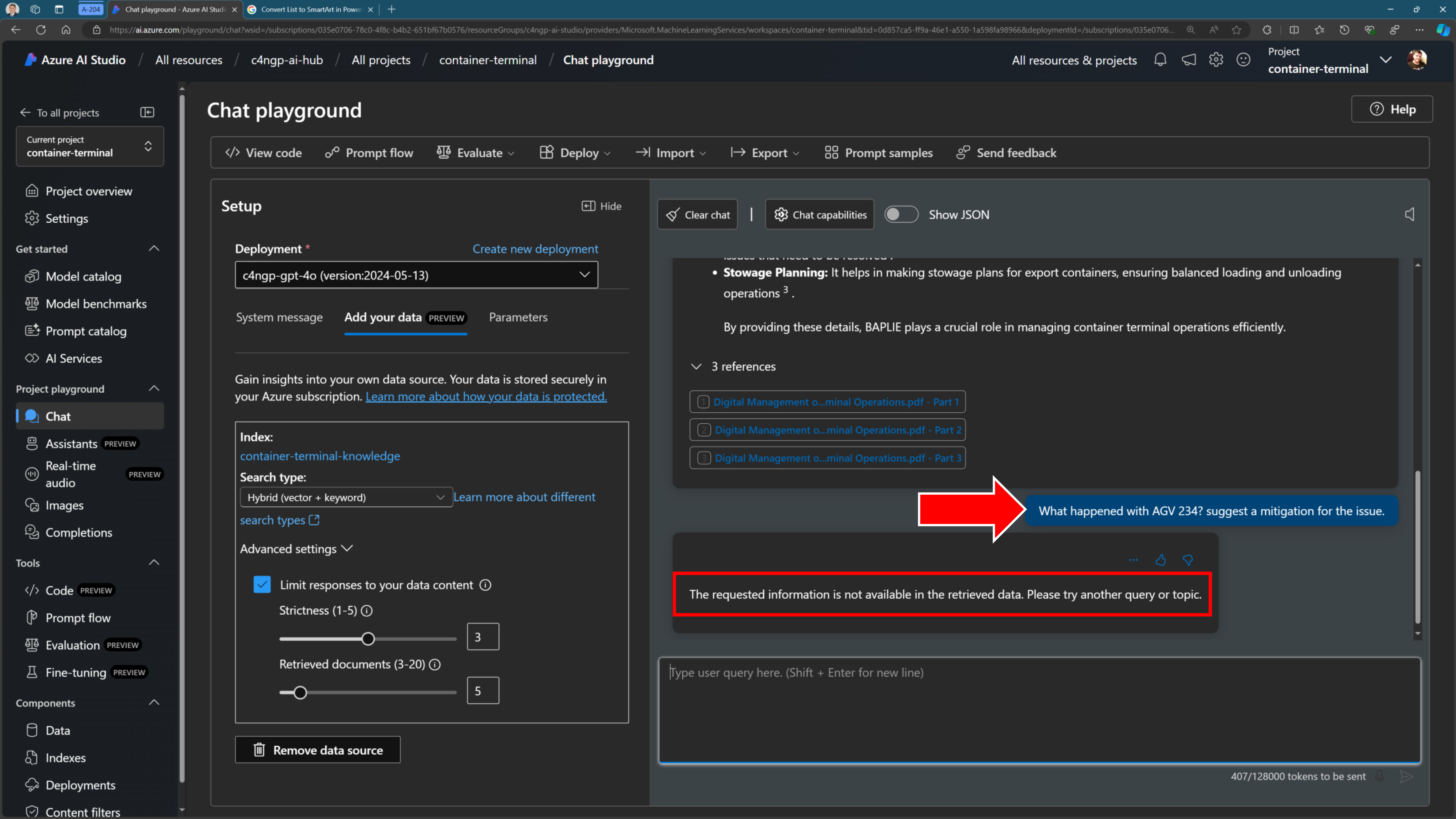
EDI Coding: The BAPLIE can be displayed in Electronic Data Interchange (EDI) coding 2 .
Text Information Table: A tabular format that is easy for searching and editing, commonly used to query and modify BAPLIE information 2 .
Use Cases:
Verification: The BAPLIE is used to verify the consistency with the manifest, highlighting any inconsistencies or over-loading issues that need to be resolved .
Stowage Planning: It helps in making stowage plans for export containers, ensuring balanced loading and unloading operations 3 .
By providing these details, BAPLIE plays a crucial role in managing container terminal operations efficiently.
3 references
1 Digital Management o...minal Operations.pdf - Part 1
2 Digital Management o...minal Operations.pdf - Part 2
3 Digital Management o...minal Operations.pdf - Part 3
Type user query here. (Shift + Enter for new line)
374/128000 tokens to be sent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Digital Management o...minal Operations.pdf - Part 1
Digital Management o...minal Operations.pdf - Part 2
Digital Management o...minal Operations.pdf - Part 3
What happened with AGV 234? suggest a mitigation for the issue.
The requested information is not available in the retrieved data. Please try another query or topic.
Type user query here. (Shift + Enter for new line)
407/128000 tokens to be sent

# Speaking on Data for AI Training

Now/Current Time

## Historical Data

- Data has existed.
- Data collected from historical logging.
- It might be solving for some/overall issue.
- Maybe not optimized but it works.
- It is use for learning from experience.
- **AI can use this for learning/training process.**
- You get what you get when dealing with problem solving issue.
- Use AI to predict by existing solutions.
- Most commercial Digital Twins use for monitoring.

Time Barrier

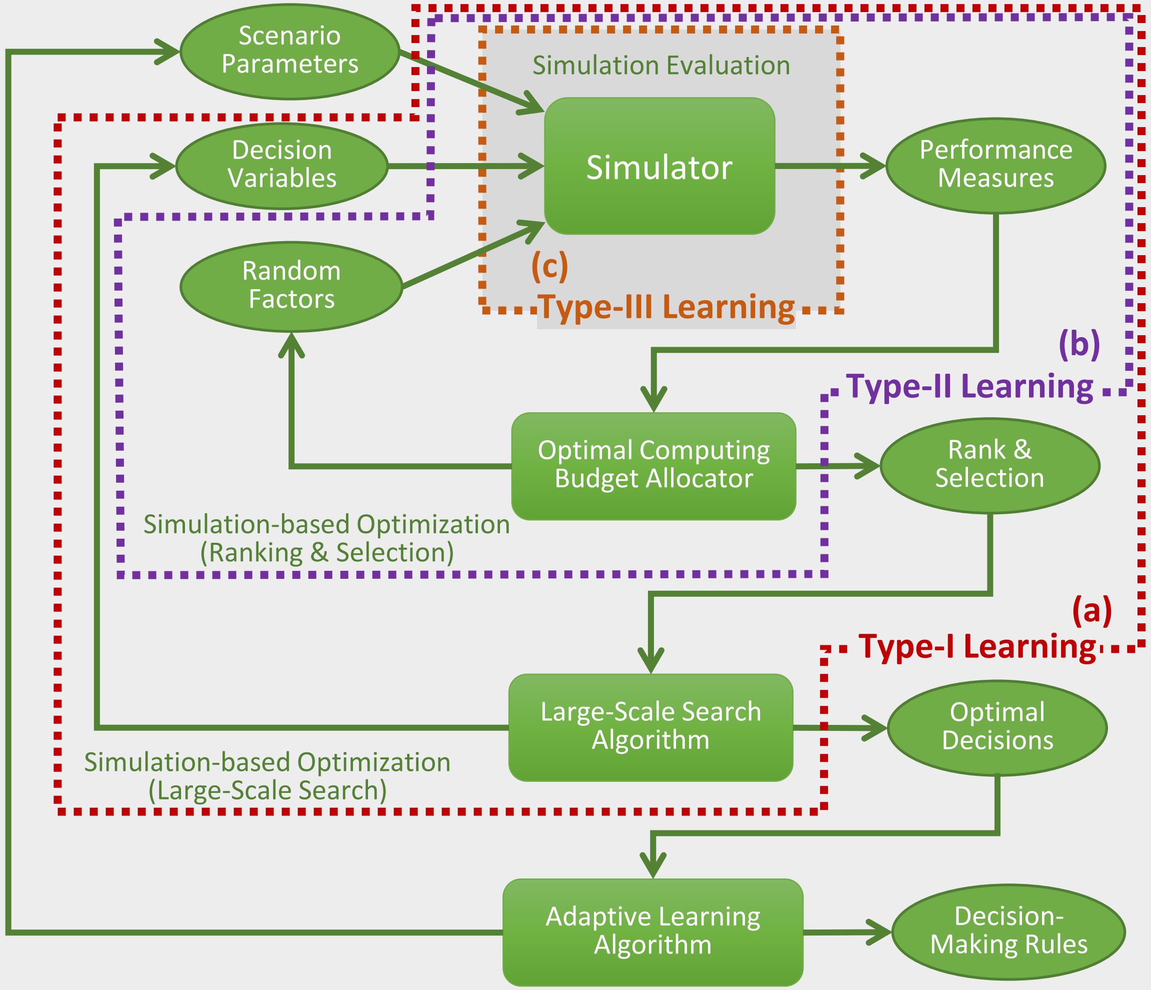
## Future/Unknown Data

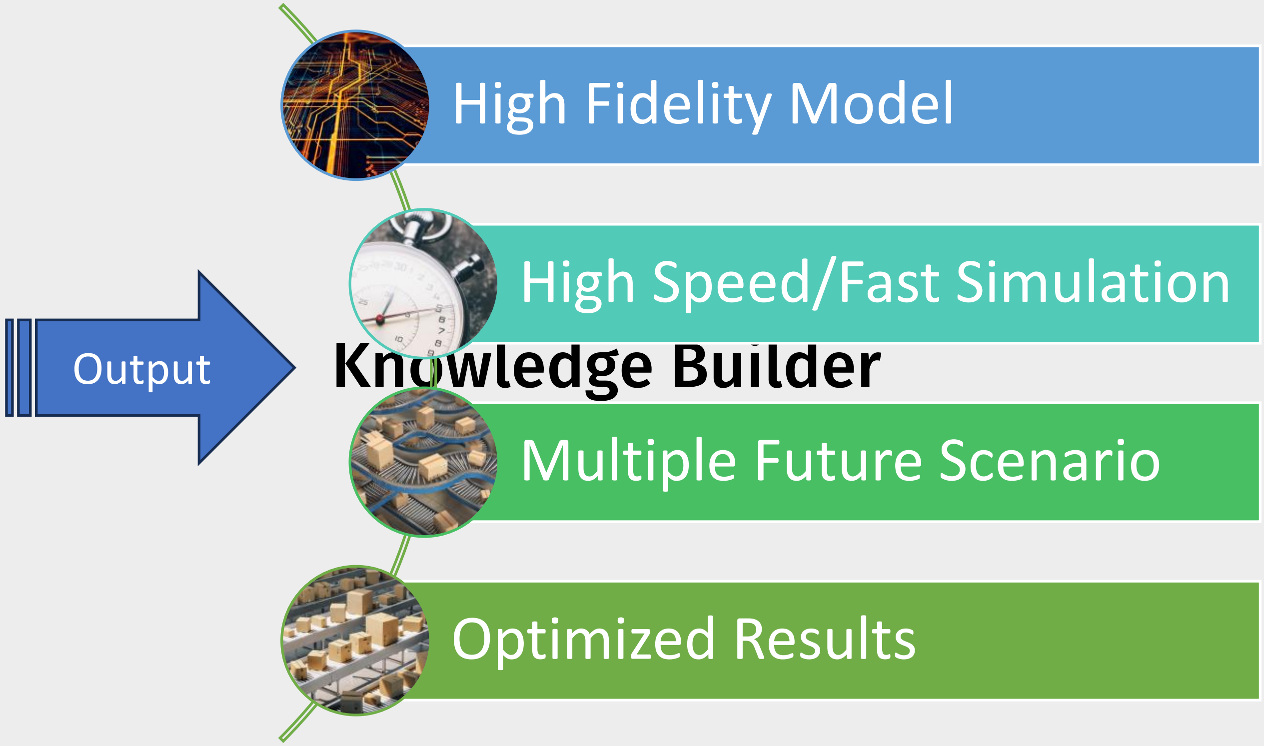
Time

- Data does not exist yet.
- Data maybe collected by running simulations.
- Can generate for better optimized results.
- It is use for learning future problem.
- Different parameters for every scenario.
- **AI can use this for learning/training process.**
- You get what you configure when dealing with problem for solving issue.
- Use AI to predict by generating solutions.
- Digital Twin 2.0 (uses historical + future data)

# Using Simulation Analytics to Train AI in Digital Twin

## Learning with Simulation



# Requirement: Fast Simulation

- High Fidelity Model
- High Speed/Fast Simulation
- Multiple Future Scenario
- Optimized Results

Require High Speed
Discrete Event Simulation

# What is Parallel Discrete Event Simulation?

Parallel Discrete Event Simulation (PDES) is a technique for speeding up a single simulation of systems where events occur at specific times by running different parts of the simulation simultaneously on multiple processors or computers.

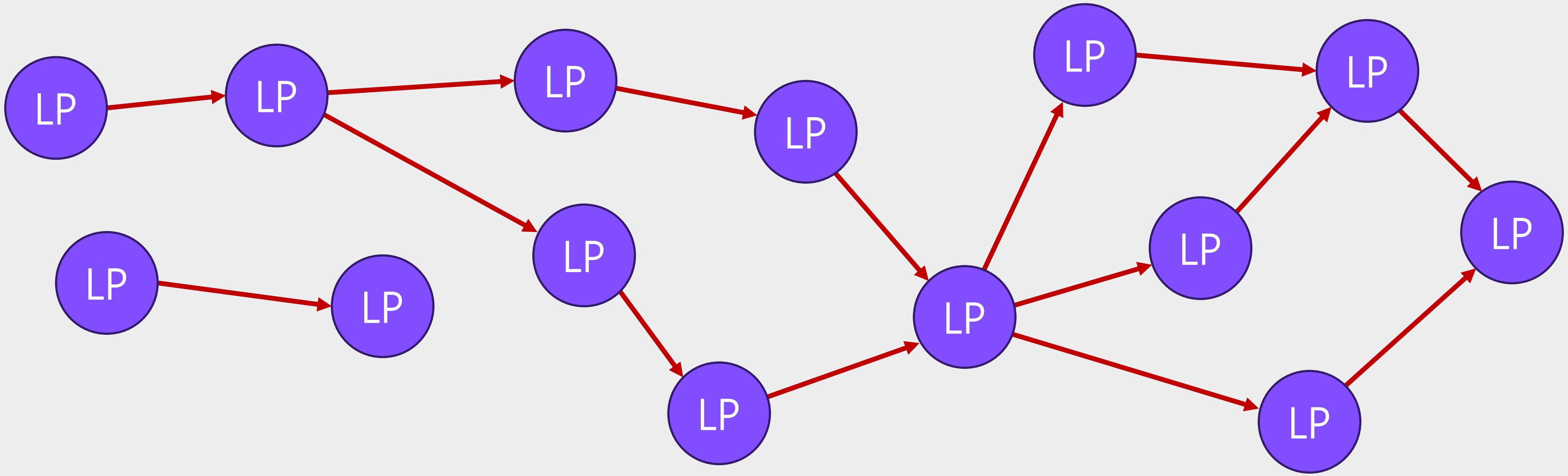
# What is NOT Parallel Discrete Event Simulation?

**Running multiple traditional DES in many computers with different parameters is NOT PDES.**

Example: If a single traditional DES runs simulation and finish in 2 days, with 100 different parameters in 100 different computers will still run for 2 days. Still slow but will get 100 different results.

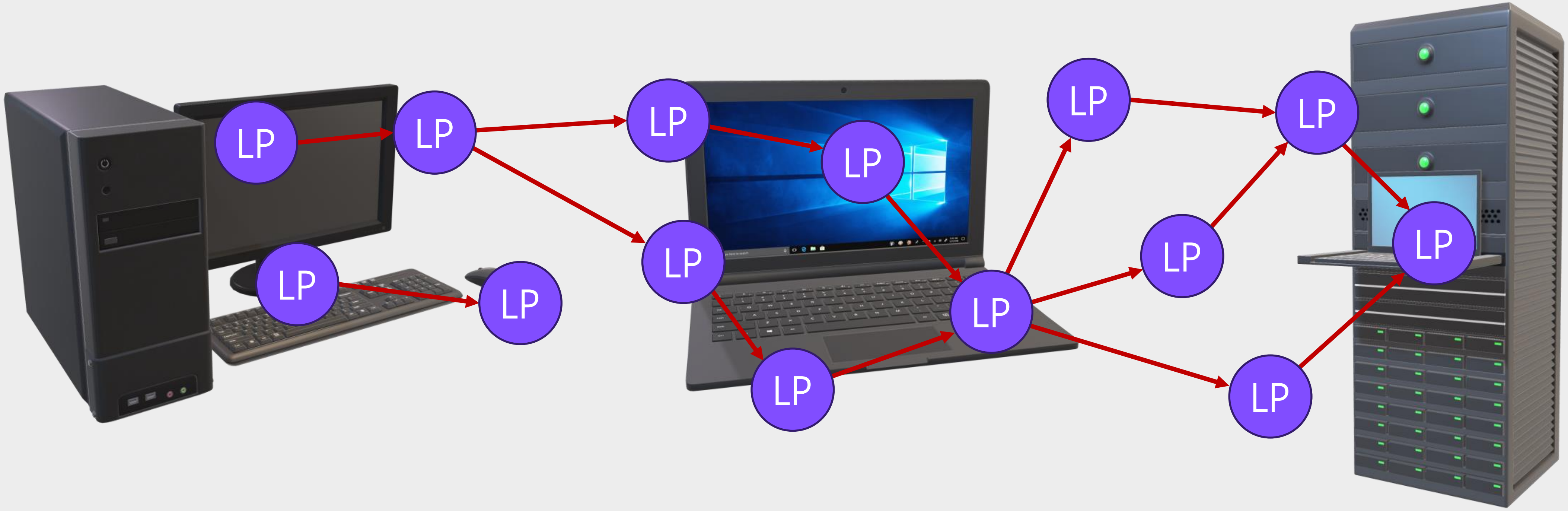
# Problem with Sequential Simulation

In discrete event simulation, event processing consumes CPU time, ranging from microseconds to hours depending on the processor and model complexity. For large models with numerous logical processes (LPs) exchanging millions of events, the simulation can take an extended period, sometimes lasting hours or even days to run.



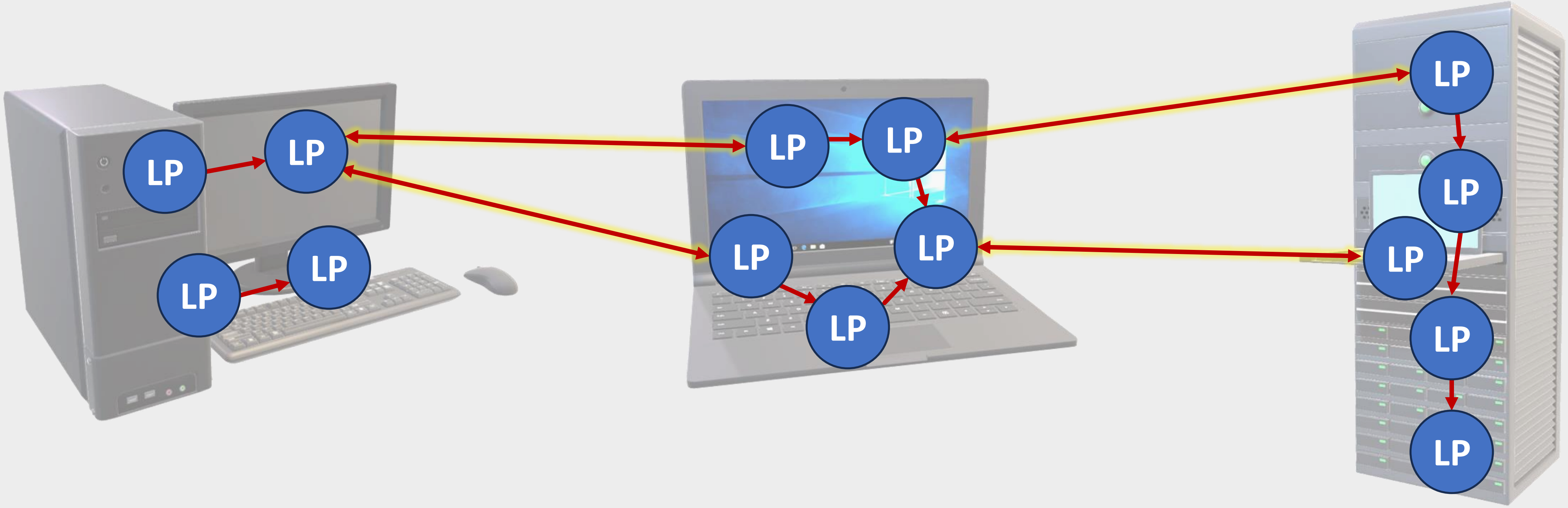
# Parallel Discrete Event Simulation (PDES)

The solution is to parallelize the simulation process. The idea is to immediately process events from any incoming messages received by the LP, eliminating waiting times. This allows us to distribute the LP across separate tasks, threads, processors, or even different computers.



# Parallel Discrete Event Simulation (PDES) cont.

The LPs are partitioned to run on multiple threads, processors, and machines. This can include desktops, laptops with multicore processors, on-premise servers, HPC data centers, or cloud platforms. Event messages are exchanged between machines over a high-speed network or the internet.

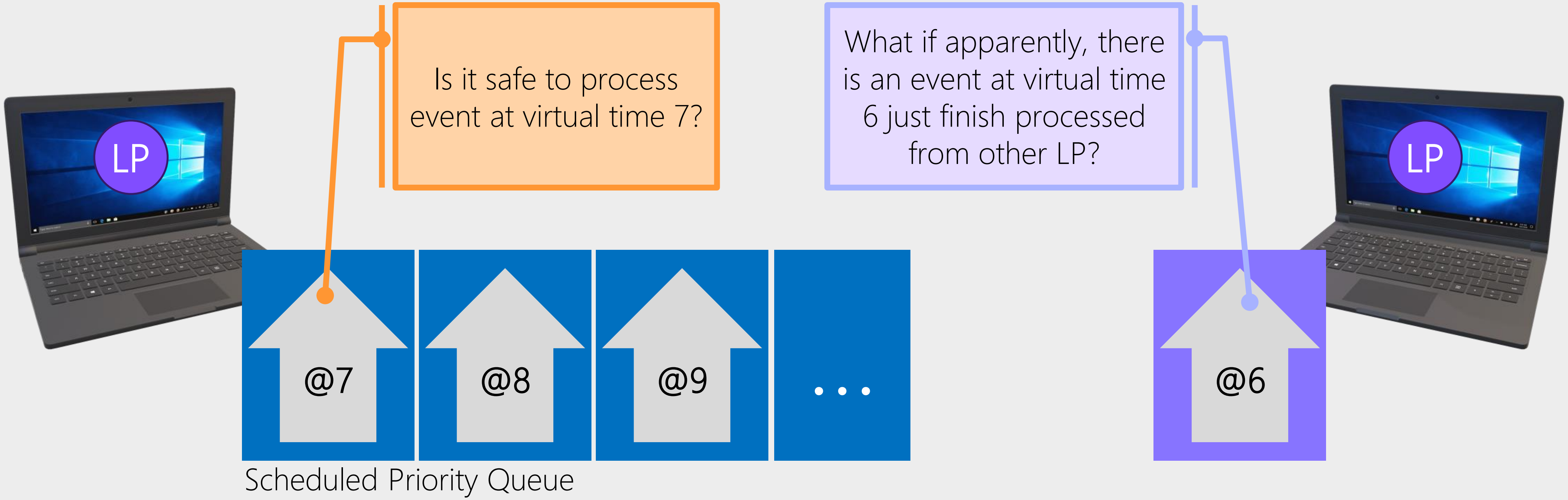


# One BIG problem...

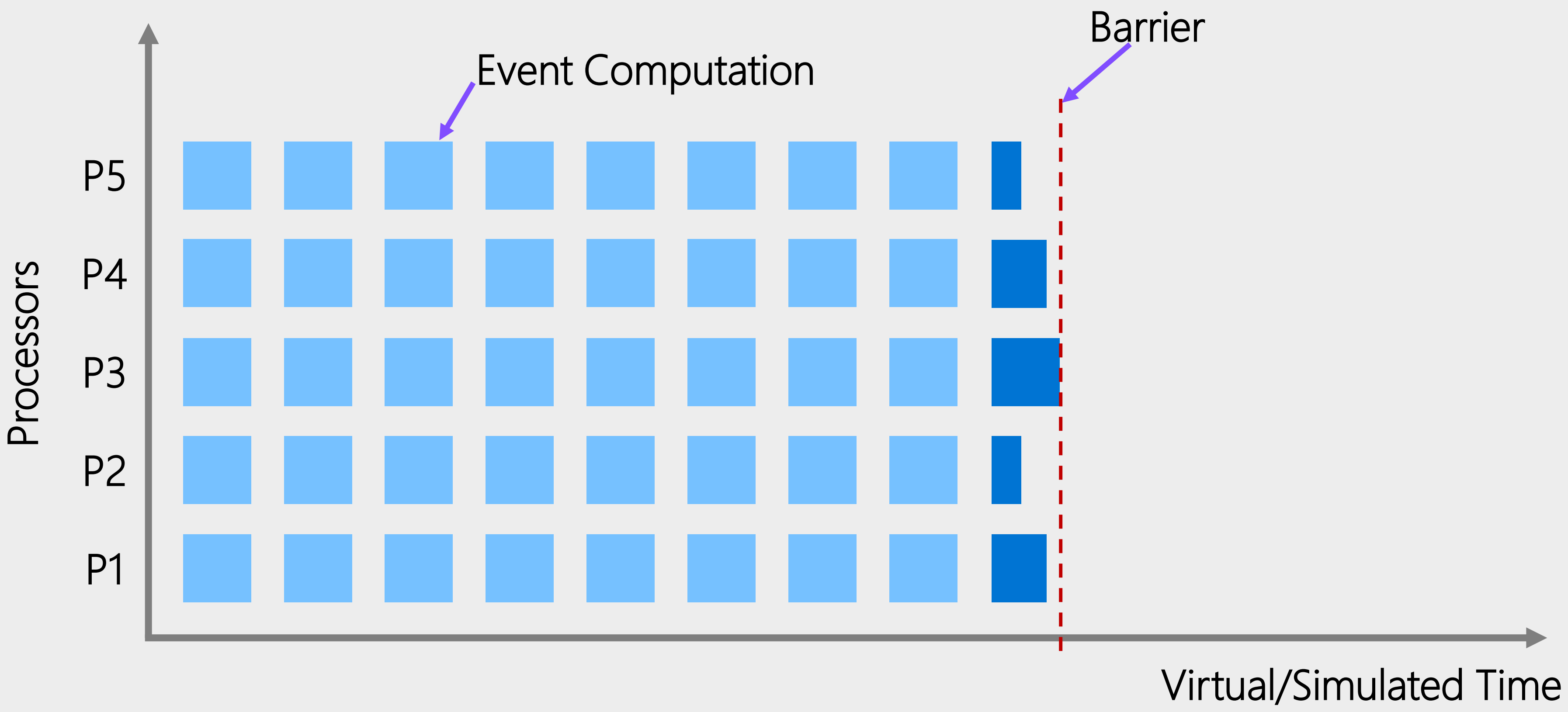
# Synchronization

# Synchronization Challenges

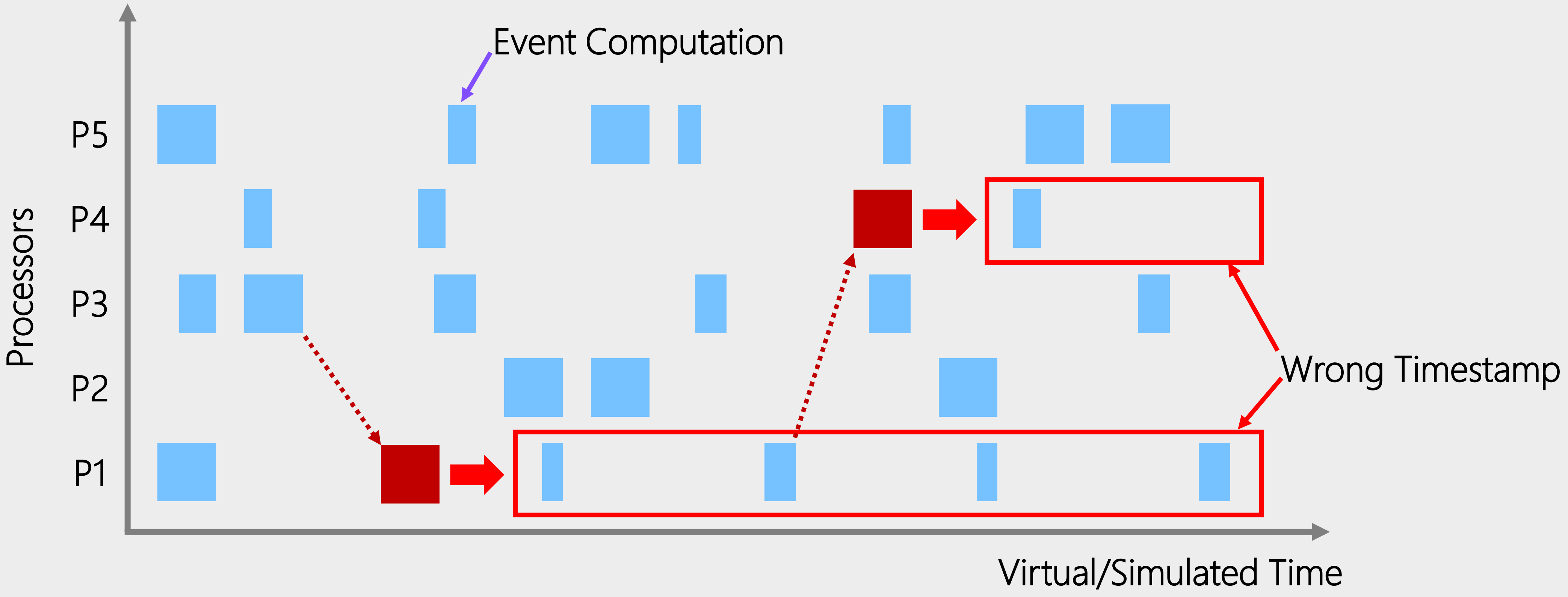
- The challenge is how to know if it is safe to process an event from a scheduled message.
- The simulation must maintain causality constraints where an event for each LP must be processed in order of timestamps and cannot be violated.



# Parallel Processing Expectation



# Parallel Processing Reality



# Maintain Causality Approaches

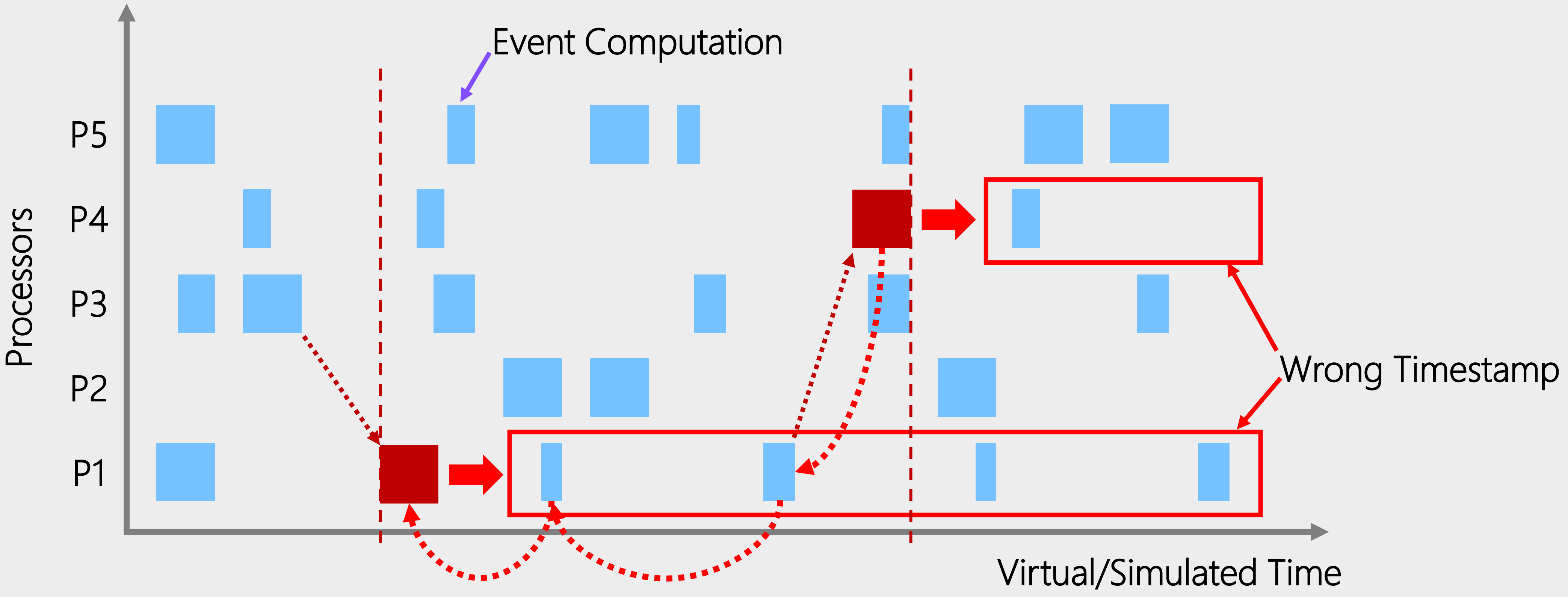
## Conservative Approach

- Conservative/Sequential Synchronization
  - Process events only when it is **safe** to do so.
  - Heavy CPU usage due to thread sleeping or force waiting.
- Different approaches to preserve causality
  - Exchange ***null*** messages between compute nodes.
  - May need deadlock detection & recovery.
  - Heavy load on the networking and messaging.

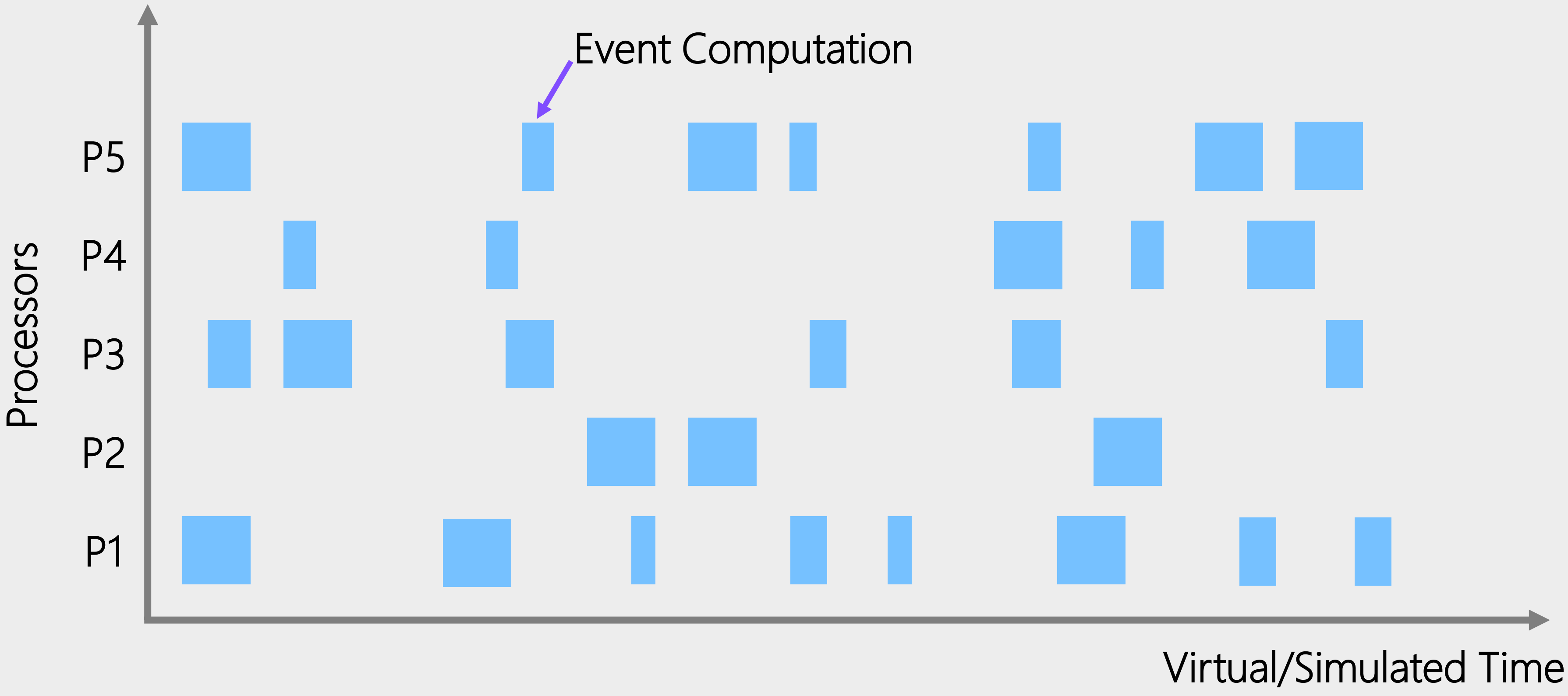
## Optimistic Approach

- Optimistic/Parallel Synchronization
  - Process events as is or when available.
  - Temporary causal violations can occur.
  - If an event is received with lower timestamp (a ***straggler*** event), use some approach to recover from causal violation.
- Time Warp
  - Rollbacks handling mechanism.
  - Sending Anti-Messages to other process.
  - Global Virtual Time garbage collection.

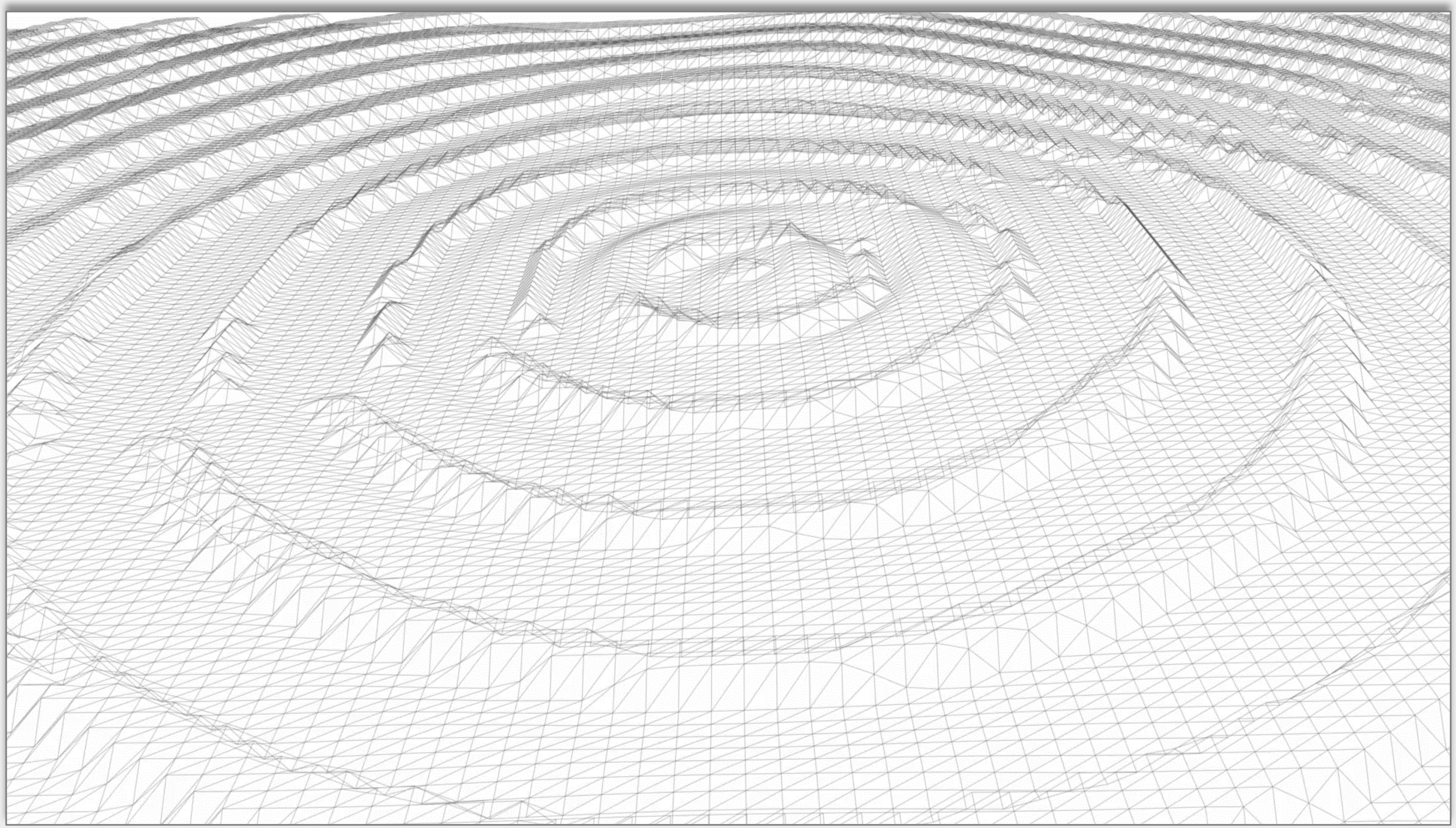
# Time Warp Rollback



# Synchronization Resolved

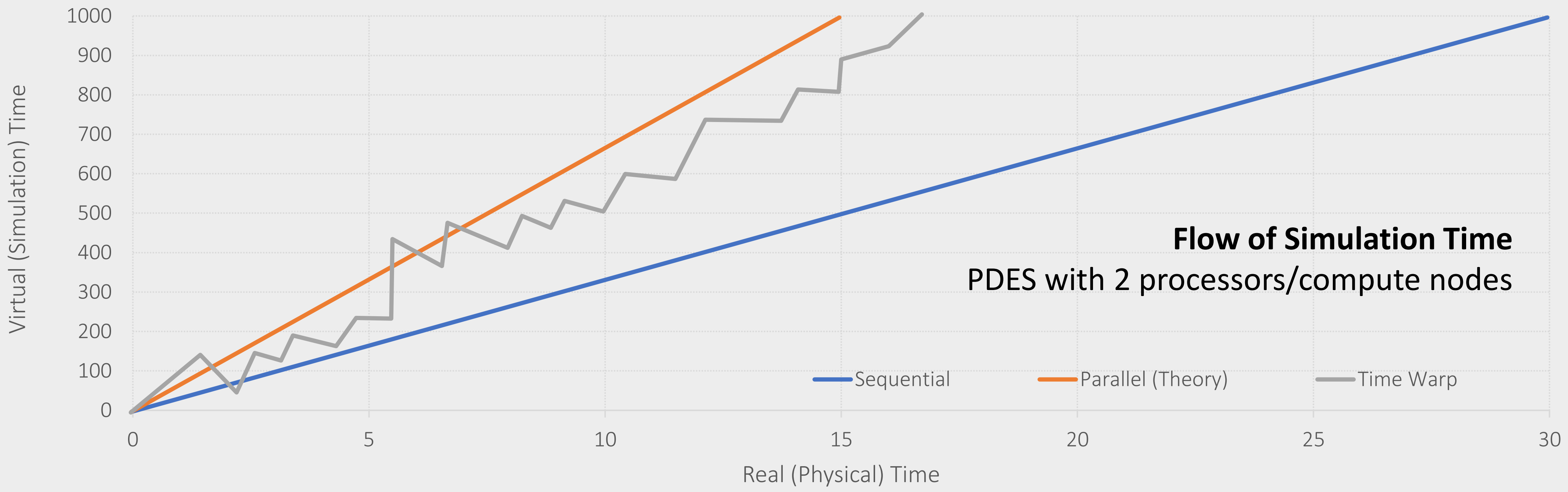


# Time Warp Rollback Ripple Effect Restoring Causality



# Time Warp Rollback Characteristics

- Optimistic Synchronization in PDES allows temporary causal violations.
  - Rollbacks ripple through the PDES restoring causality.
- Progress of virtual time is non-linier due to rollbacks to restore causality violations.



# Summary

## Simulation Modeling and Digital Twin

- Digital Twin with high fidelity model require fast simulation to be able generating future scenario in an optimized and accurate twin.
- Using historical data for training AI may need to pair with the future data.

## Parallel Discrete Event Simulation

- Time Warp is an optimistic synchronization method for PDES.
- Events are processed as soon as possible while may cause a temporary causal violations.
- State saving, rollbacks and anti-messages are used to correct causal violations.

## Advantages & Drawbacks

- Effectively utilizes parallelism inherent in a model.
- Very scalable & efficient – Has been run on 2 million cores!
- Difficult and very hard to understand the relativity of Time Warp mechanism.
- State saving & rollbacks can be significant overheads.

# Thank You!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*Senior Associate Director (Senior IT Architect)*