

Requirement Discovery Using Embedded Knowledge Graph with ChatGPT

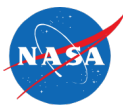
An aerial night view of a city with glowing flight paths and drones. The image shows a cityscape at night with lights from buildings and streets. Several drones and aircraft are flying in the sky, connected by glowing white lines that represent flight paths or data connections. The overall scene is futuristic and technological.

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Outline

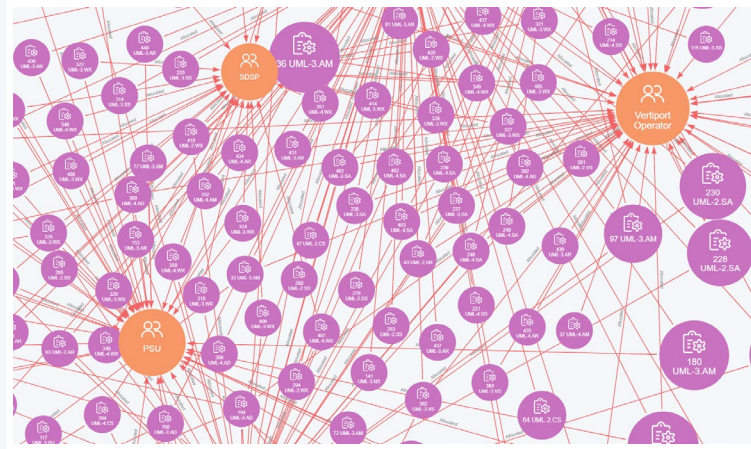
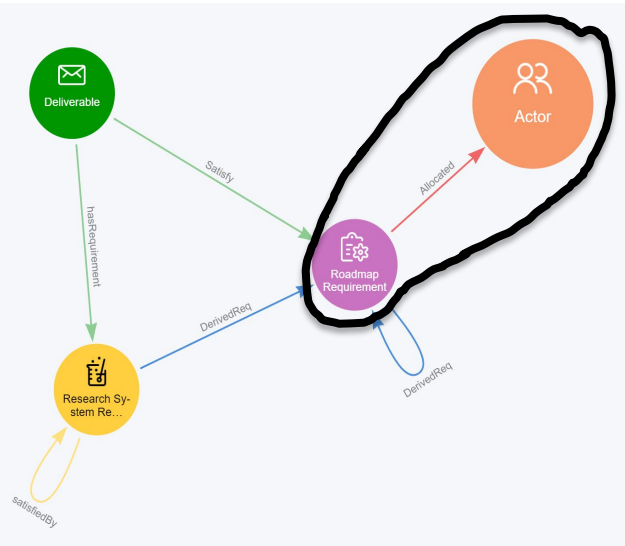
- Introduction
 - Project description
 - Knowledge graph
- Exploratory Approaches
- Comparison, Lessons Learned, and Next Steps



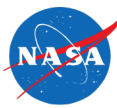
Introduction

- NASA's Air Traffic Management-Exploration (ATM-X) Urban Air Mobility (UAM) Subproject is conducting research that **evolves UAM airspace** towards a highly automated and operationally flexible system of the future.
 - See <https://www.nasa.gov/uam-overview/> for more information
- The complexity of UAM airspace evolution requires a **plan** to effectively organize, integrate, and communicate NASA's research and development.
 - This planning tool is called **the UAM airspace research roadmap**.
 - Implemented through Model-Based Systems Engineering (**MBSE**) methodology
 - Leveraging machine learning natural language processing (ML NLP, or just **NLP**), Knowledge Graph data science, and Large Language Model (i.e., ChatGPT)

Knowledge Graph for Roadmap Development



- Schema (left) showing graph structure between nodes.
 - Node represents the type of objects (e.g., Actor, Roadmap Requirement, etc.)
 - Link represents the relationship types.
- Due to the CUI nature of data, only focus on **Roadmap Requirement and Actor** for this study.
- Knowledge graph (middle and right) displays **complexity** beyond human user's ability to perform Roadmap's requirement discovery and analysis to identify potential missing requirements.



Requirement Discovery Using Embedded Knowledge Graph with ChatGPT

Challenges:

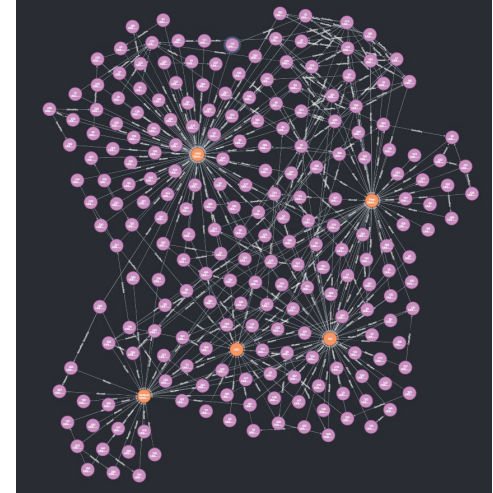
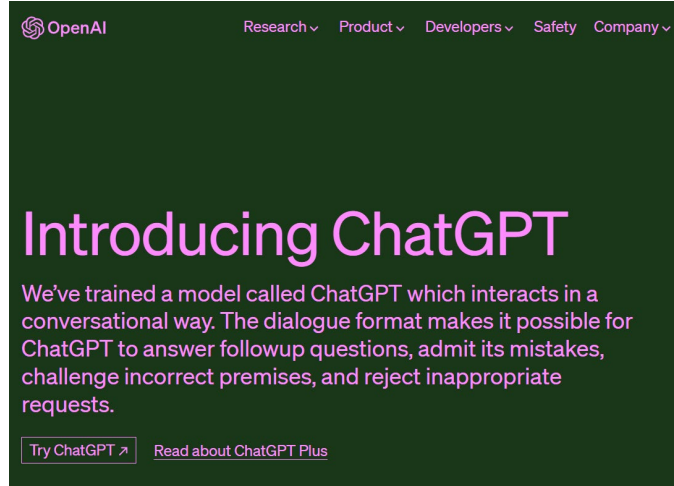
- SE is worried that we might **miss** some requirements in the roadmap.
- SE has a limited bandwidth to perform requirement analysis.

Solution:

- Using Knowledge Graph structure with ChatGPT capability

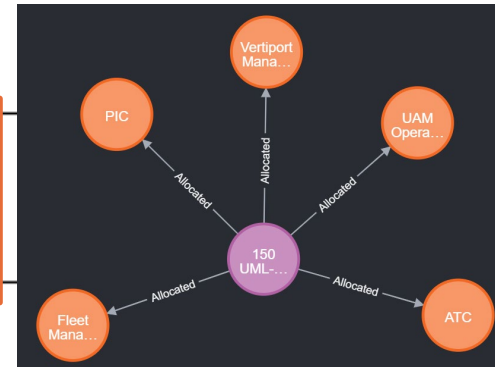
Expected Impact:

- Revolutionize the way SE works



Off Nominal Procedures For operations in controlled airspace, the FAA will approve off-nominal procedures that accommodate the appropriate aircraft performance characteristics. (268 UML-2.AD)

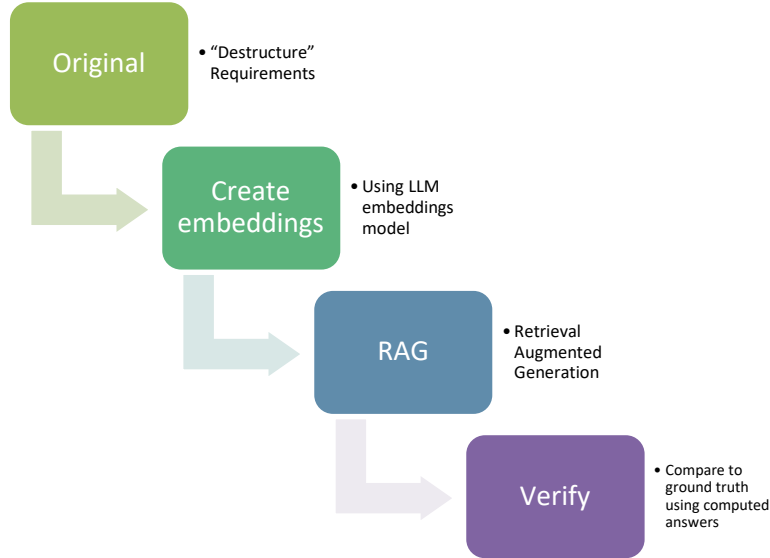
The UAM Operator shall establish a plan to resolve off-nominal conditions with the PIC, Fleet Manager, or Vertipoint Manager, without ATC involvement. (150 UML-3.AD)



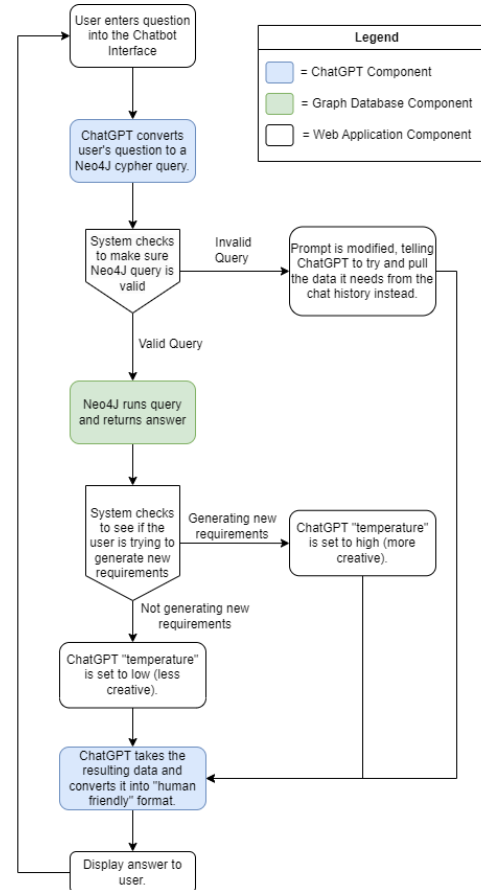


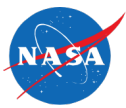
Approaches

- ChatGPT (Large Language Model (LLM) Approach)



Graph Database + ChatGPT





ChatGPT (Azure OpenAI GPT 3.5)

Applied Stereotype	ReqID	Actor	Requirement Text
Allocate [Abstraction]	19 UML-2.AM	ATC	When ATC is the designated separator; The Fleet Manager and PIC will receive services from ATC.

Requirement number "19 UML-2.AM" states "When ATC is the designated separator; The Fleet Manager and PIC will receive services from ATC." and has an Allocate relationship to the actor "ATC".

Query submitted to LLM after retrieval of relevant requirements information

How many unique requirements do we have for the System?

How many unique system actors do we have?

Please list the unique system actors

Give me 5 requirements with multiple actors. List them using a Python list of Requirement Numbers

List all existing requirements for UAM Aircraft

Predict five requirements for Urban Air Mobility systems that I may have missed

Create ten new requirements based on these predictions.



Graph Database (neo4j) + ChatGPT (Azure OpenAI GPT 4.0)

UAM Chatbot

FOR PUBLIC DATA ONLY, DO NOT SEND ANY SENSITIVE NASA DATA THROUGH THIS SEARCH ENGINE

Selected Model: gpt-4-32k

UAM Chatbot

Hello! You can ask me questions regarding UAM requirements and their relationships. If you would like additional information about this dataset or have questions about using this tool, visit the help page by [clicking here](#). Here are some examples of questions I can answer:

1. Provide the schema of the graph database.
2. Please provide a list of all system actors.
3. What are the top 5 Actors based on allocated requirements?
4. Display the roadmap requirements associated with the actor node `U1`.
5. Predict 10 nodes that might be related to roadmap requirement `REQ_001_4_01`.
6. Generate 5 new requirements for the Actor `U1` based off predicted Roadmap Requirements.

What would you like to ask me?

Clear Chat History

Ask a question here!

Ask Away!



Graph Database + ChatGPT

User:

List 3 existing requirements for the [ATC](#).

ChatGPT generates an appropriate cypher query

```
MATCH r = (a:Actor {name:'ATC'})-[:Allocated]-('Roadmap Requirement') RETURN r LIMIT 3
```

Database runs the query and returns the result

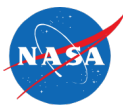
UAM Chatbot:

Based on the information provided, here are three existing requirements for the Air Traffic Control ([ATC](#)):

1. Requirement [89 UML-4.SS](#): The [FAA](#) will approve flight rules that allow [ATC](#) to delegate separation responsibility to the [PIC](#), [Fleet Manager](#), or [Vertiport Manager](#), or [PSU](#) under appropriate conditions. This requirement is part of the '07_SS. Separation Services and Standards' component and is expected to be implemented in FY22.
2. Requirement [297 UML-3.AD](#): The [FAA](#) will establish emergency procedures that include how to alert [ATC](#) and how to execute clearing procedures or other appropriate actions. This requirement falls under the '02_AD. Airspace and Procedure Design' component and is slated for FY23.
3. Requirement [333 UML-4.AM](#): The [PSU](#) shall coordinate airspace configuration actions with [ATC](#) when necessary. This requirement is part of the '01_AM. Airspace Management Systems and Services' component and is expected to be implemented in FY22 and FY23.

ChatGPT converts the response to something "human readable"

```
[[<Node element_id='215' labels=frozenset({'Roadmap Requirement'}) properties={'owner': 'UAM Airspace RAC Details', 'pageRank': 0.6946460391326209, 'community': 350, 'rml': 2.0, 'combined_index': 2.2, 'actors': ['PIC', 'ATC', 'Fleet Manager', 'FAA', 'PSU', 'Vertiport Manager'], 'component': '07_SS.C04. Roles and Responsibilities', 'fy': 'FY22', 'uml': 'UML-4 [NamedElement]', 'children': ['Initial UAM Airspace Structure Concept_DASC2022', 'InitialAirspaceStructureConcept-4 ATC separation services', 'Fleet Operator'], 'name': '89 UML-4.SS', 'tr_min': '', 'text': 'The FAA will approve flight rules that allow ATC to delegate separation responsibility to the PIC, Fleet Manager, or Vertiport Manager, or PSU under appropriate conditions.', 'id': 89, 'element': '07_SS. Separation Services and Standards'}>], [<Node element_id='199' labels=frozenset({'Roadmap Requirement'}) properties={'owner': 'UAM Airspace RAC Details', 'pageRank': 0.3978375937584387, 'community': 347, 'rml': 2.0, 'combined_...
```



Graph Database + ChatGPT

- The system predicts requirements using Adamic-Adar link prediction provided by the Neo4J Graph Data Science Library.

User:

predict 3 requirements that may be related to the [ATC](#)

UAM Chatbot:

Based on the information provided, here are the three predicted requirements that may be related to the Air Traffic Control ([ATC](#)):

1. Requirement '[327 UML-3.WX](#)': The [SDSP](#) (System Data Service Provider) should use numerical weather prediction models that meet performance standards for estimating weather parameters. This requirement is relevant to the [ATC](#) as it relies on accurate weather predictions for managing air traffic.
2. Requirement '[411 UML-3.WX](#)': The [SDSP](#) should publish forecasts that meet performance standards for weather parameters to all subscribers. This requirement is also pertinent to the [ATC](#) as it uses these forecasts to ensure the safe and efficient flow of air traffic.
3. Requirement '[20 UML-2.CS](#)': The Pilot in Command ([PIC](#)) and [ATC](#) should have the ability to communicate by voice in all classes of airspace as required by regulation. This requirement is directly related to the [ATC](#) as it emphasizes the importance of clear communication between the [ATC](#) and pilots for maintaining air traffic safety.



Graph Database + ChatGPT

- The UAM Chatbot combines the information from the ATC and the predicted requirements to generate a whole new set of requirements catered towards the ATC.

User:

Using these predicted requirements, generate 3 new requirements for the [ATC](#)

UAM Chatbot:

Based on the predicted requirements, here are three new requirements for the Air Traffic Control ([ATC](#)):

1. New requirement based on '[411 UML-3.WX](#)': The [ATC](#) shall utilize the weather forecasts published by the [SDSP](#) to manage the safe, orderly, and expeditious flow of air traffic.
2. New requirement based on '[327 UML-3.WX](#)': The [ATC](#) shall rely on the numerical weather prediction models used by the [SDSP](#), which meet performance standards for estimating weather parameters, to aid in air traffic control decisions.
3. New requirement based on '[20 UML-2.CS](#)': The [ATC](#) shall maintain the ability to communicate by voice with the Pilot in Command ([PIC](#)) in all classes of airspace as required by regulation, ensuring effective coordination for air traffic safety.



Preliminary Comparison Results

Aspects	ChatGPT (Azure OpenAI GPT 3.5)	Graph Database / Data Science + ChatGPT (Azure OpenAI GPT 4.0)
Implementation	Moderate: Retrieval-augmented generation pattern using LLM and vector store	Difficult and more expensive
Cost for cloud server and developer	OpenAI subscription	<ul style="list-style-type: none">• Open AI subscription• Server for graph database• Server for web-application• Application / system administrator
Quality of solutions	Varies based on type of query and structure of embedding vector store: better on general open queries, worse on numerical counting	Using the graph database provides a ground truth, chances of hallucination are much lower (almost 0 but not quite).
Lessons Learned	<ul style="list-style-type: none">• CUI content not permitted	<ul style="list-style-type: none">• CUI content not permitted• Difficult to get consistent, complex, cypher queries from GPT.• Capacity issues during peak hours.



Next Steps

ChatGPT

- Continue testing through better prompt engineering

Graph Database + ChatGPT

- Optimize performance of ChatGPT interface, currently some responses can take 30+ seconds to come back to the user.
- Improve requirement prediction algorithm, utilize a combination of community detection and link prediction.