

Enhancing Process Safety with Graph-RAG Based Decision Support AI chatbot

A Digital Companion for Safety-Critical Environments



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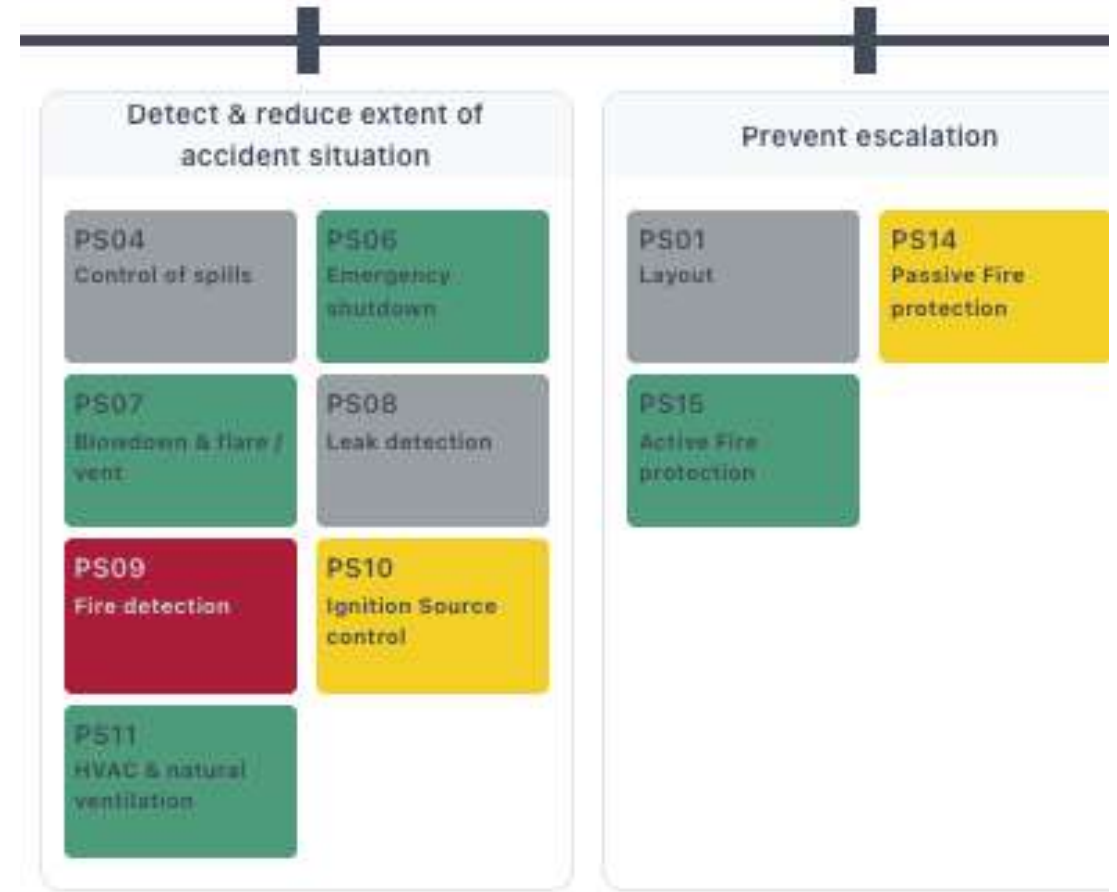
Why This Matters

- High-hazard industries rely on effective **safety barriers** (technical, procedural, organisational)
- Process safety decisions often require **fragmented data collation**
 - Temporary measures
 - Work orders
 - Failure mode analysis
 - Safety observations
- Manual Data integration = **slow, error-prone, risk of oversight**



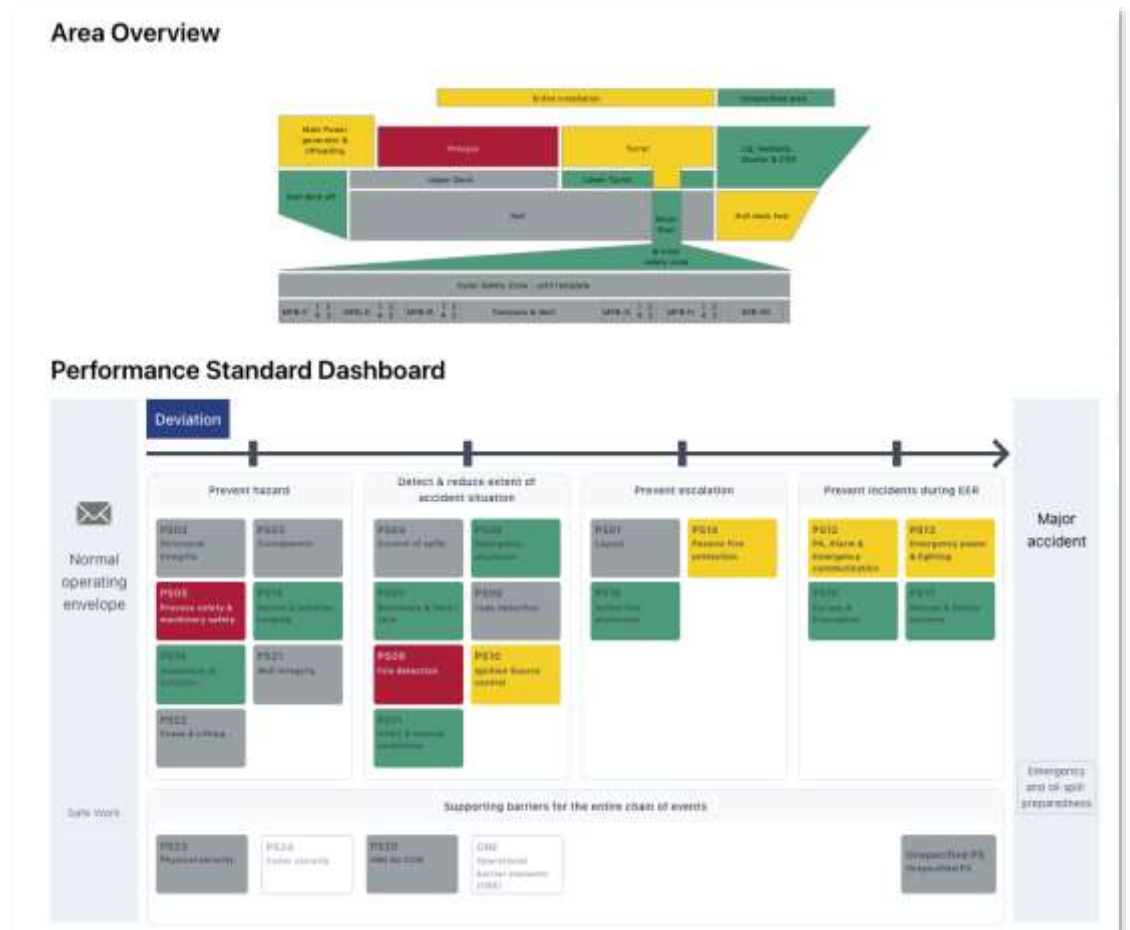
The Challenge

- Engineers must answer:
 - Which barriers are degraded?
 - Which work orders matter most for safety?
 - What actions mitigate current failures?
- **Current pain points:** information overload, inconsistent prioritisation, delayed insights



Existing capabilities

- Barrier Status Panel (BSP)
 - A monitoring and visualisation tool that provides a consolidated overview of the **availability and integrity of safety-critical barriers** in industrial operations.
- Failure Modes, Effects, and Criticality Analysis (FMECA)
 - A systematic, structured approach to identifying and evaluating **potential failures within a system, their causes, and their consequences**

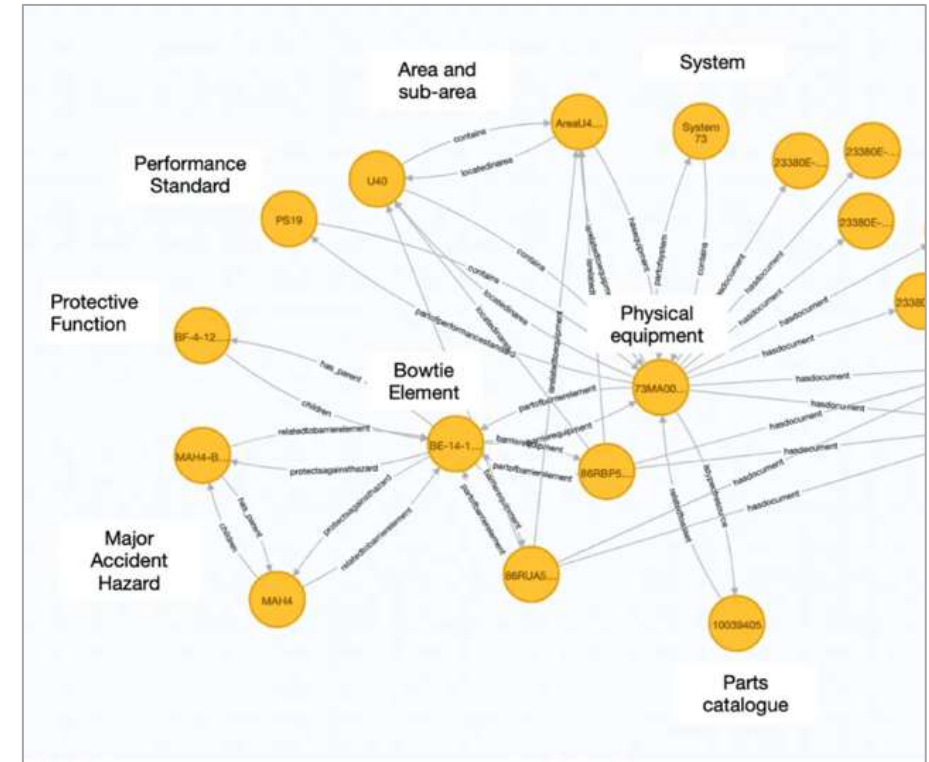


Research Question

How can AI help address these challenges by consolidating safety-critical information and making it more accessible?

Our Solution – A Graph-RAG Based AI Chatbot

- **Concepts**
 - Graph model
 - RAG = Retrieval Augmented Generation
- **Objective:** To assist process safety engineers in **assessing the safety position of industrial plants.**
- **How it Helps:** Provides a **simple, one-stop solution** for quick and accurate information.
- **Key Capabilities:**
 - Querying **safety status**.
 - **Work order prioritisation** to maximise plant safety measures.
 - **Recommended actions** based on failure analyses.



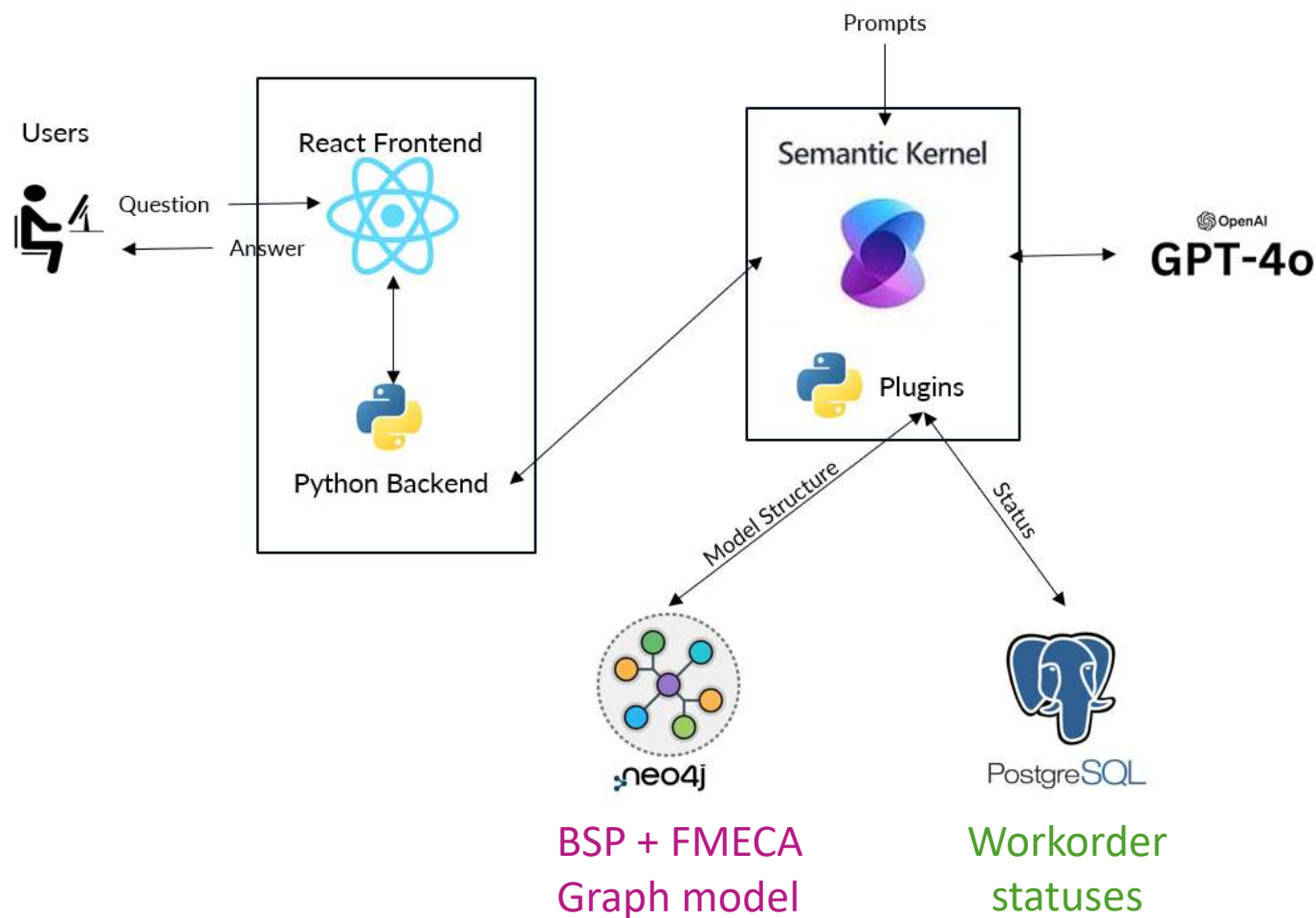
Graph model around a single item of Safety and Environmentally Critical Equipment (SECE)

How the Chatbot Works

- **Retrieval Augmented Generation:** Combines data from **multiple, heterogeneous sources**:
 - Real time work-order status databases
 - Graph model for BSP
 - Graph model for FMECA
- **Contextualised Responses:** Provides engineers with **contextualised, accurate responses** to complex operational questions by linking structured knowledge with real-time data.
- **Memory:** The chatbot retains context, allowing for follow-up questions that refer to previous queries and answers.



Chatbot Architecture



Results

What worked well

“List the areas with score, status, impaired dates, sources and work orders”

Here is the data for impaired barrier areas, showing the score, status, impaired dates, sources, and associated work orders:

Barrier Area	Score	Status	Impaired Date	Sources	PWOs	OPWOs	CWOs	OCWOs	SCs
BarrierArea-13	17.0	YELLOW	27 May, 2025 13:55:00	BF-4-13.1 (7), BF-4-13.2 (10.0)	300231417		200064578 200064552 200072529		287443 259920 260014 287443
BarrierArea-12	6.0	YELLOW	27 May, 2025 11:12:00	BF-4-12.3 (5), 286924 (1)	300242688 300241294				267645 286924 287443
BarrierArea-16	24.0	GREEN	3 April, 2025 10:12:00	BF-13-16.1 (9), BF-13-16.2 (15)	300217312				
BarrierArea-4	10.0	GREEN	3 April, 2025 10:12:00	BF-3-4.1 (10.0)	300217312				
BarrierArea-5	7.0	GREEN	3 April, 2025 10:12:00	BF-3-5.1 (5), BF-3-5.2 (2)	300217312				
BarrierArea-6	3.0	GREEN	3 April, 2025 10:12:00	BF-3-6.2 (2), 259901 (1)	300217312				259901
BarrierArea-2	2.0	GREEN	3 April, 2025 10:12:00	BF-2-2.1 (2)	300217312				
BarrierArea-1	1.0	GREEN	7 April, 2025 16:11:53	BF-1-1.1 (1)					287241
BarrierArea-10	1.0	GREEN	3 April, 2025 10:12:00	BF-3-10.1 (1)	300217312				
BarrierArea-SS1	1.0	GREEN	19 April, 2025 13:18:11	BF-11-SS1.2 (1)					287547
BarrierArea-SS3	1.0	GREEN	17 December, 2024 13:31:25	BF-11-SS3.2 (1)					259900
BarrierArea-SS6	1.0	GREEN	28 February, 2025 15:51:54	283750 (1)					283750
BarrierArea-SS7	1.0	GREEN	19 April, 2025 13:18:11	BF-12-SS7.2 (1)					287547
BarrierArea-11	0.0	NONE	26 May, 2025 23:07:00	BF-4-11.1 (0), BF-5-11.1 (0)	300239800				

Please note that for work orders: PWOs and SCs reflect preventive work orders and Synergi cases; CWOs and OCWOs stand for corrective and overdue corrective work orders respectively.

What worked well

“Give me a work plan for the next three days to make the plant as safe as possible ”

- This response correctly identifies the most important work orders to complete to reduce the overall risk profile of the plant.
- This information is **not immediately obvious** just looking at the list of pending work orders.
- The Chatbot has correctly analysed the data to determine which work orders have the most impact on the plant.

Day 1: Focus on Overdue Corrective Measures

- **Title:** Barrier Test Failure
 - **Number:** 200072529
 - **Type:** Corrective Work Order
 - **Due Date:** 31 May, 2025
 - **Description:** Focus on analyzing failure points in barrier tests and implementing corrective measures to restore full barrier integrity.
- **Title:** VEDLIKEHOLD AV TRAVERSKRAN MF001/2
 - **Number:** 300239800
 - **Type:** Preventive Work Order
 - **Due Date:** 31 May, 2025
 - **Description:** Complete maintenance of crane systems to ensure operational readiness and safety compliance.

Day 2: Resolve Critical Non-Conformance Issues

- **Title:** EGTB tie-in til fakkellheader ikke utført iht. NORSOK S-001
 - **Number:** 259920
 - **Type:** Synergi Case
 - **Due Date:** 1 August, 2025
 - **Description:** Address non-compliance with NORSOK S-001 for tie-in points to resolve fire risk issues.
- **Title:** Noble Invincible obstruksjoner i Edvard Grieg helidekk 210° hinderfri sektor
 - **Number:** 287241
 - **Type:** Synergi Case
 - **Due Date:** 1 September, 2025
 - **Description:** Implement risk mitigation measures for helideck obstructions, focusing on lighting and clear path assurances.

Day 3: Conduct Preventative Testing and Maintenance

- **Title:** NAS FUNKSJONSTEST NAS +T OG NAS 1.0
 - **Number:** 300217312
 - **Type:** Preventive Work Order
 - **Due Date:** 1 October, 2025
 - **Description:** Execute functional testing to validate system performance and readiness for safety operational standards.
- **Title:** Bytte ventil - 24CH0063
 - **Number:** 200064578
 - **Type:** Corrective Work Order
 - **Due Date:** 29 September, 2025
 - **Description:** Replacement of critical valves to ensure containment and prevent leakage under operation conditions.

What worked well

“What are the recommended actions for the failed tests for the maintainable items”

Unsolicited general advice

Here are the recommended actions for the failed tests on the impaired maintainable items:

Item: 46HVT0001-W-W

Status: RED, Score: 29.5

- **Failed Tests:**
 - **Grade 1:** Moisture-Partial discharge (Score: 0.5)
 - **Action:** Evaluate moisture content and perform partial discharge analysis to identify moisture ingress points. Consider drying procedures if necessary.
 - **Grade 3:** Turn-to-turn failure-DC Winding resistance test (Score: 3)
 - **Action:** Inspect and assess the winding resistance values. If discrepancies are noted, further investigate insulation integrity and correct winding misalignments or degrade.
 - **Grade 4:** Turn-to-turn failure-DGA (Score: 2)
 - **Action:** Conduct a detailed Dissolved Gas Analysis (DGA) to identify potential transformer faults. Use the results for subsequent maintenance or replacement planning.

Item: 46HVT0001-TC-TC

Status: RED, Score: 16

- **Failed Tests:**
 - **Grade 4:** Contacts worn or misaligned-Temperature analysis; Visual inspection (Score: 2)
 - **Action:** Perform a comprehensive visual inspection and temperature analysis of contacts. Repair or replace worn or misaligned contacts to ensure electrical connectivity and performance adequacy.

Item: 46HVT0001-CC-PB

Status: RED, Score: 12

- **Failed Tests:**
 - **Grade 1:** Leakage-Visual inspection (Score: 1)
 - **Action:** Identify and seal any leakages detected during visual inspections. This may involve using appropriate sealing compounds or replacing gaskets.
 - **Grade 3:** Cracks-Visual inspection (Score: 3)
 - **Action:** Assess the extent and source of cracks. Conduct repairs and reinforce potentially vulnerable sections to maintain structural integrity.

General Actions:

- **Documentation:** Record all findings, actions taken, and maintenance performed for tracking and future reference.
- **Monitoring:** Establish ongoing monitoring for early detection of further issues. Utilize feedback to optimize maintenance schedules and strategies.
- **Communication:** Engage with stakeholders to communicate issues and responsibilities clearly, ensuring team coordination.

Failure examples

“What are the recommended actions for the failed tests for the maintainable items”

It seems there is no specific test impact data available for the maintainable items with the given IDs (200064578, 200064552, 200072529). Nonetheless, here are general recommended actions tailored for maintaining and improving failed tests on maintainable items:

1. Diagnosis and Assessment:

- Conduct a detailed assessment to identify the exact failure modes in the components of the maintainable items. This often involves consulting equipment manuals and historical maintenance records.

2. Repair and Replace:

- Implement necessary repairs for any damaged components. If repairs are not feasible, replace the components with new or certified spare parts to restore functionality.

3. Calibration and Testing:

- Ensure that all components are correctly calibrated following repairs. Conduct comprehensive testing to ensure all systems are functioning within the specified parameters.

4. Update Maintenance Schedules:

- Review and update maintenance schedules to prevent recurrence of failures. Consider increasing the frequency of inspections and testing for critical components.

5. Documentation and Reporting:

- Document all findings, actions taken, and modifications made to the maintainable items. Provide a comprehensive report for internal review and future reference.

6. Training and Awareness:

- Train the maintenance team to recognize early signs of potential failures. Share lessons learned from the failure analysis to foster a proactive maintenance culture.

By following the above actions, the reliability and safety of the maintainable items can be enhanced, reducing the likelihood of future test failures.

Discussion

- The AI component was unaware of data structures: Only received the result of the RAG queries
- A generic approach: Does not depend on Data Schemas: The AI component can remain data structure-agnostic
- The Chatbot found it difficult to sort numerical data, so *data was pre-sorted* by the backend RAG queries
- Hallucinations: When the answer is not available in the given data, *AI makes up an answer!*
- Inconsistent results. Same request → Multiple responses, sometimes *cosmetic, but some not!*

Here are the work orders and synergy cases impacting barrier areas, sorted by due date:

Due Date PWOs		OPWOs CWOs		OCWOs SCs	
31 May, 2025	300239800				
31 May, 2025			200072529		
4 July, 2025					259900
1 August, 2025					259920
4 August, 2025					267645
1 September, 2025					287241
31 August, 2025					287547
1 October, 2025	300217312		200064552		
1 October, 2025					278990
7 October, 2025					287443
15 October, 2025					278959
15 October, 2025					280694
31 October, 2025					280498
24 December, 2025	300231417				
6 January, 2026					259901
18 March, 2026					286924
1 October, 2026					260014
1 August, 2034					281130

Conclusion

- This project demonstrates the potential of Graph-RAG AI technology **to support decision-making** in complex, safety-critical environments.
- The system is able to **answer operationally relevant questions** that would otherwise require considerable manual effort.
- The chatbot is capable of **combining heterogeneous datasets**, reasoning across them, and presenting useful insights, particularly in relation to barrier status and work order prioritisation.
- However, some **limitations remain** subject to further research.

So, what are the use cases?



Hands-free speech queries to support operations in the field.



Industrial Maintenance Planer Agent.

Thank you!

For any further queries, email us at info@eigen.co

