



Enhancing Risk-Informed Decision Making Through LLM-Based Concern Analysis in the Human Landing System Program

Nipa Phojanamongkolkij (NASA Langley Research Center),
Rebekah Whitten (NASA Marshall Space Flight Center),
Lien Moore (NASA Marshall Space Flight Center)

September 2026



Introduction – NASA Human Landing System (HLS) Program



- HLS is a central component of the Artemis campaign, enabling crewed lunar surface missions and supporting long-term exploration objectives.
- As part of NASA's public–private development strategy, the program integrates Commercial Providers' lander designs with NASA's insight and oversight responsibilities to ensure crew safety, mission performance, and sustainable lunar operations.



Artemis I

Launched in 2022, Artemis I was the first in a series of increasingly complex missions that will enable human exploration at the Moon and future missions to Mars.



Artemis II

The first crewed Artemis flight marks a key step toward long-term return to the Moon and future missions to Mars.



Artemis III

Scheduled for 2027, this new demonstration mission in low Earth orbit will test one or both commercial landers from SpaceX and Blue Origin, respectively.



Artemis IV

NASA continues to target early 2028 for the first Artemis lunar landing, a date that has remained unchanged since mid-2025. After reaching lunar orbit, the crew will transfer from Orion to a commercial lunar lander for their descent to the Moon's surface.



Artemis V

Using the standard SLS (Space Launch System) rocket configuration, NASA expects to launch this lunar surface mission by late 2028, with subsequent missions planned roughly once per year.

Source: [Moon to Mars](#) | [NASA's Artemis Program - NASA](#)



Introduction – HLS Risk Management Process



NPR 8000.4C -- TOC

Page 1 of 48

- The HLS Program employs an Agency-defined Risk Management framework built on Risk-Informed Decision Making (RIDM) and Continuous Risk Management (CRM).
- A key element of this RM process is the identification and maturation of **Office Concerns**, which serve as early indicators of potential risks requiring additional definition before formal assessment.
- However, recognizing **thematic similarity across numerous Concerns remains challenging** due to variations in technical perspective and overlapping subject matter.



NASA Procedural Requirements

COMPLIANCE IS MANDATORY FOR NASA EMPLOYEES

NPR 8000.4C

Effective Date: April 19, 2022

Expiration Date: April 19, 2027

Agency Risk Management Procedural Requirements

Responsible Office: Office of Safety and Mission Assurance



National Aeronautics and
Space Administration

HLS-PLAN-006

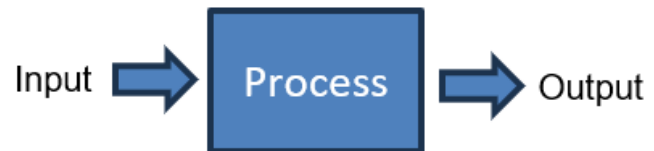
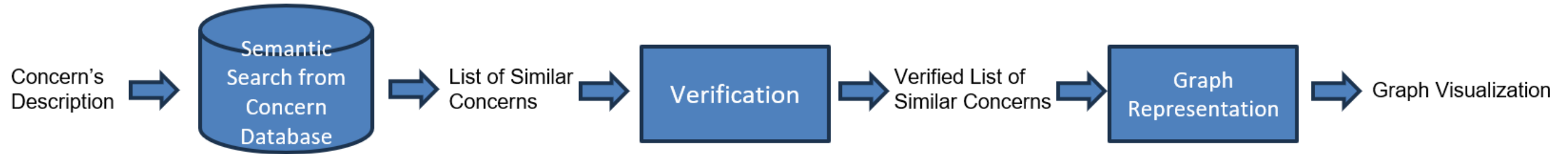
REVISION B

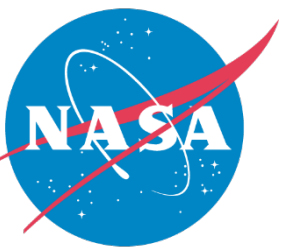
RELEASE DATE: MAY 22, 2024

HUMAN LANDING SYSTEM (HLS) PROGRAM
RISK MANAGEMENT PLAN

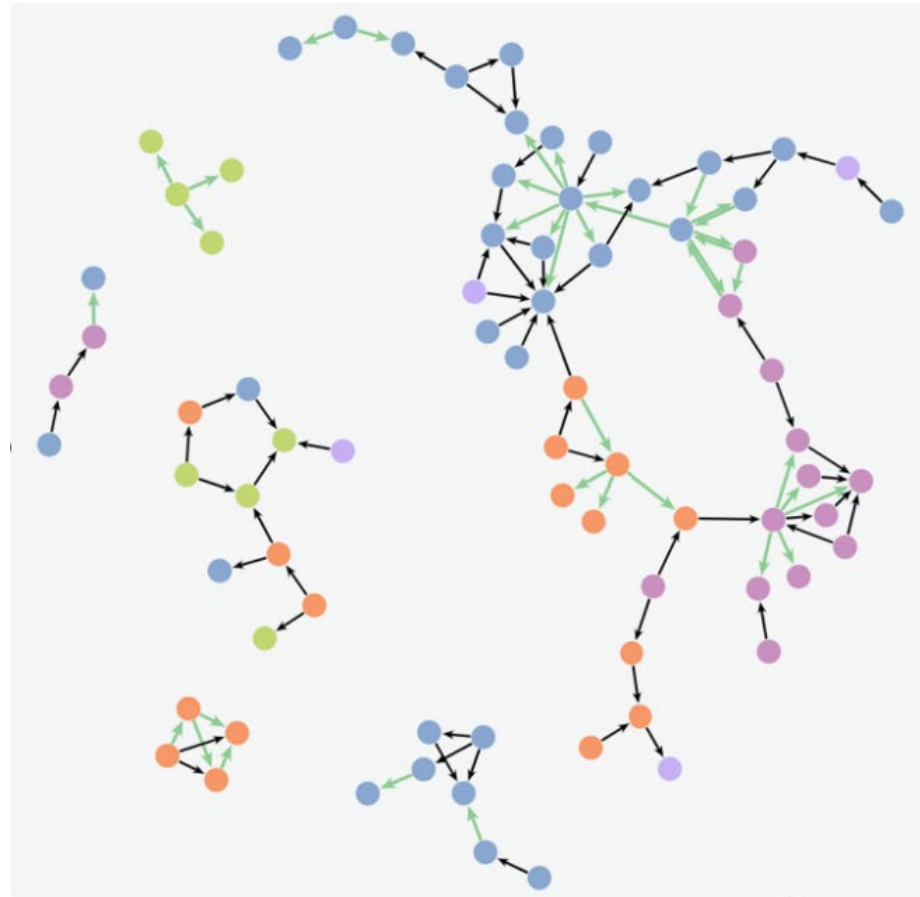
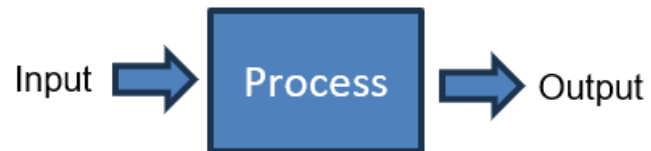
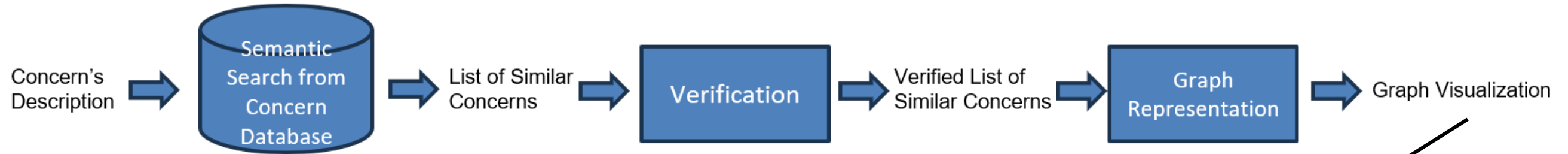


LLM with Graph Approach – 1 of 2





LLM with Graph Approach – 2 of 2



Results overview

Nodes (76)

* (76) Week1scram (15) Week2scram (33)

Week3scram (16) Week4scram (8)

Relationships (96)

* (96) affects (2) impacts (4)

isParentOf (21) isSimilarTo (1)

llmRelateTo (58) relatesTo (10)



LLM with Graph Result



Ranked Themes using LLM + Graph

1. *Propellant Aggregation & Operational Cadence*
2. *Program Integration, Governance & Contracting*
3. *Navigation, Landing & Hazard Avoidance*
4. *Mass Properties & Margins Maturity*
5. *Mission Availability & Windows*
6. *Rendezvous, Proximity Operations, and Docking*
7. *Lunar dust mitigation*
8. *Safety, Fire, Avionics*
9. *Docking mechanism, seal-on-seal configuration*
10. *Crew constraint*



Microsoft CoPilot Approach



- Microsoft CoPilot was used for this use case with several trial-and-error prompts.
 - Each trials, CoPilot provided different themes posing a repeatability challenge.
- Hybrid approach



1st Prompt: “Please create structured table summarizing all concerns in this file into themes. The columns are Theme and Core Summary.”

2nd Prompt: “Please use the following list as the themes to create structured table summarizing all concerns in the file into these themes. Please suggest additional themes beyond this list if necessary, when creating the structured table.”



LLM with Graph vs. Microsoft CoPilot - Results



Ranked Themes using LLM + Graph	Ranked Themes using CoPilot (Hybrid Prompt)
<i>1. Propellant Aggregation & Operational Cadence</i>	<i>1. Navigation, Landing & Hazard Avoidance</i>
<i>2. Program Integration, Governance & Contracting</i>	<i>2. Propellant Aggregation & Operational Cadence</i>
<i>3. Navigation, Landing & Hazard Avoidance</i>	<i>3. Program Integration, Governance & Contracting</i>
<i>4. Mass Properties & Margins Maturity</i>	<i>4. Mission Availability & Windows</i>
<i>5. Mission Availability & Windows</i>	<i>5. Safety, Fire, Avionics & Atmosphere</i>
<i>6. Rendezvous, Proximity Operations, and Docking</i>	<i>6. Interfaces & Payload/Utilization Integration</i>
<i>7. Lunar dust mitigation</i>	<i>7. Communications & Link Geometry (Orion/HLS/Surface)</i>
<i>8. Safety, Fire, Avionics</i>	<i>8. Mass Properties & Margins Maturity</i>
<i>9. Docking mechanism, seal-on-seal configuration</i>	<i>9. Modeling, Test & “Test-Like-You-Fly” Readiness</i>
<i>10. Crew constraint</i>	

Note: Leading themes identified by two methods; duplicated sets are in *italics*.



LLM with Graph vs. Microsoft CoPilot - Comparison



Aspects	LLM + Graph Visualization	Microsoft CoPilot
Analysis method	Starting from grouping concerns into cluster visually and then determining themes from clusters.	Starting from determining themes from all concerns and then assigning concerns into those themes.
Pros	Themes are repeatable.	Faster, can provide refresh quickly (once per month), could capture new emerging theme if data changes rapidly.
Cons	Labor intensive, frequent refresh is not possible (once per quarter is do-able)	Themes are not repeatable even with the exact dataset.



Future Works



- The methodology is adaptable for use with all HLS Program Risks, and Cross-Program Risks (including other Artemis Programs, such as Orion).
- Exploring the use of LLM technology to aid in identifying supporting documentation for NASA's HLS Program Mission Certification of Flight Readiness (CoFR).