Model-Based Systems Engineering (MBSE) Approach to Develop an Artificial Intelligence Bill of Material (AIBOM) for AI System Compliance Verification

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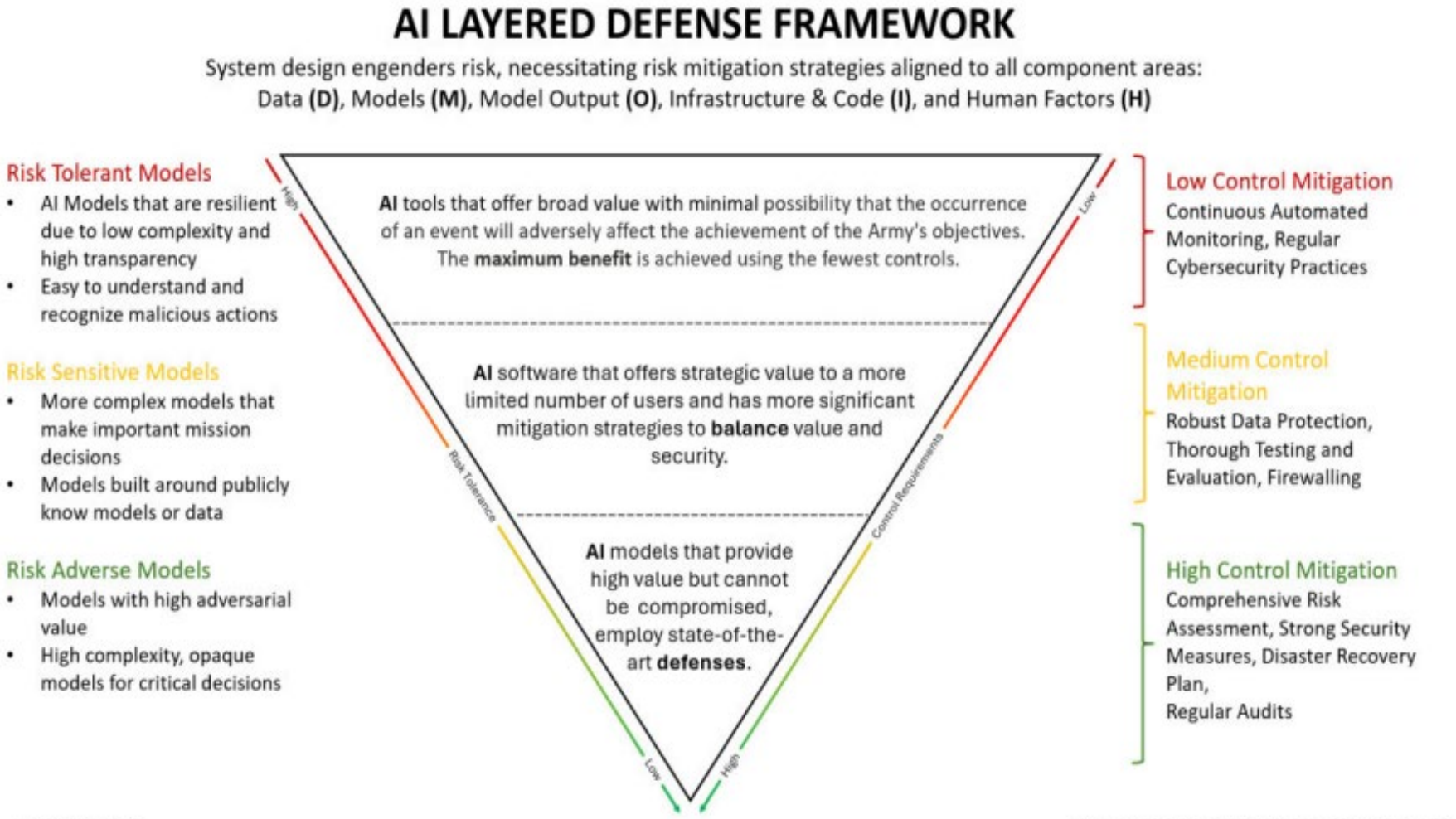
The AI BOOM vs Lack of Adoption

- Why haven't we seen AI implemented in more places across the Army/DoD?
  - Lack of explainability
  - Data privacy and security
  - Risk of errors and bias
- Can we trust AI / ML to make decisions for us?
  - Model stealing
  - Data poisoning
  - AI supply chain integrity

AI Layered Defense Framework (AI-LDF)

- A comprehensive library of AI-related risks and mitigations to inform and guide the development and implementation of AI models and software



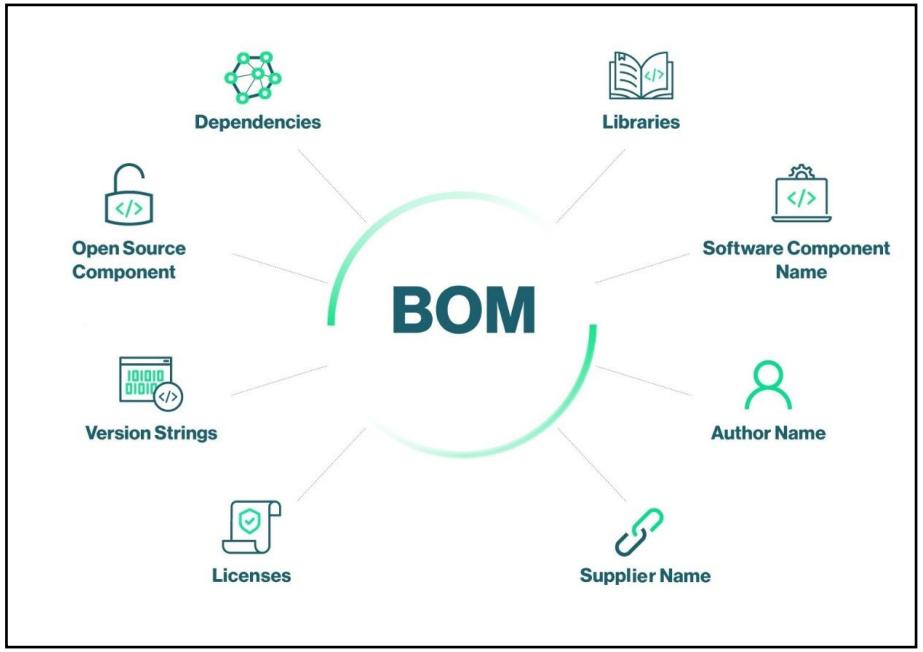
AI-LDF: AI Risks and Mitigations

AI Layered Defense Risk Matrix

Component	Risk	Implement Basic AI User Training	Implement Basic MLOps Practices / Standards	Establish Access Controls for Data and Model	Document Data Sources and Use	Ensure Basic Input Validation and Control	Outline and Document ML Supply Chain	Create Detailed MLOps and Security Guides	Maintain Vetted and Monitored Model Libraries	Identify and Address Vulnerabilities	Implement Sophisticated Network Security
	Note: Numbers in cells show correspondence between Risk, Mitigation and Layer (1, 2, 3). Color coding is for visual alignment to AI-LDF Figure 1.	Layer 1 Mitigation			Layer 2 Mitigation						Layer 3 Mitigation
Data	Loss of System, Model or Data Controls										
Data	Trojan Attacks										
Data	Data Poisoning										
Data	Corruption or Drift of Data										
Infrastructure	Model Asset Leak or Reverse Engineering										
Infrastructure	Malicious Libraries / Code										
Infrastructure	Byzantine Attacks										
Infrastructure	Insufficient Input Resource Control										
Infrastructure	Unsecured and Vulnerable Systems										
Infrastructure	Label Flipping Attacks										
Infrastructure	Test and Evaluation Data Poisoning										

Artificial Intelligence Bill of Material (AIBOM)

- Response to the growing need for managing AI supply chain risk
- Motivated by software bill of materials (SBOM), which is a nested inventory, a list of ingredients that make up software components
  - Key building block in software security and software supply chain risk
  - Builds stakeholder confidence in software systems through enhancing transparency, security, and compliance
- AIBOM can help organizations understand and manage the components that are part of their AI systems and reduce various risks by:
  - Managing vulnerabilities
  - Tracking compliance
  - Ensuring the integrity and security of components from the AI supply chain



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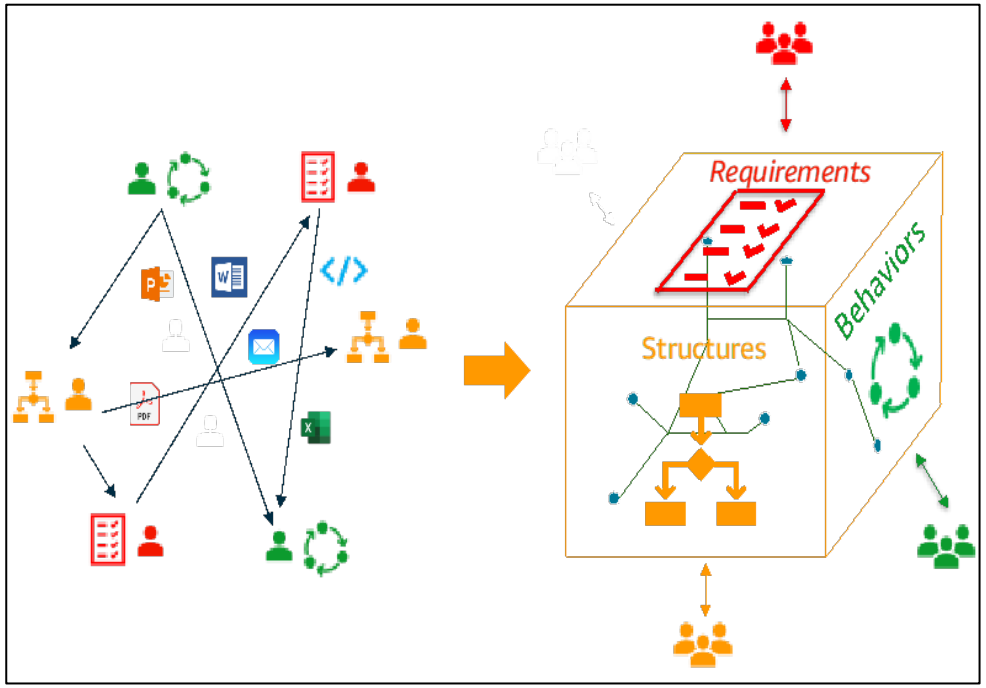
AIBOM Application

- Malicious packages can be distributed through various means, including official channels
  - i.e. PyPI package manager
  - Some packages may have similar names to prominent Python packages, making it possible to install them by accident
- Once installed, bad actors could potentially steal sensitive information, disrupt processes, or gain control of other connected systems
- For organizations with complex software systems, code bases, and AI/ML applications, AIBOM can provide a compliance framework that enumerates and catalogs all components used in AI systems
- Automate checking against vulnerability reports (CVE's)

Created by Author using ChatGPT 4o

Model-Based Systems Engineering (MBSE)

- A systems engineering methodology that focuses on creating and exploiting domain models as the primary means of information exchange between engineers rather than on document-based information exchange.
- More recently, the focus has also started to cover aspects related to model execution in computer simulation experiments, further overcoming the gap between the system model specification and the respective simulation software.
- As a reflection of this evolution, the term 'modeling and simulation-based systems engineering (M&SBSE)' has also come into use alongside 'MBSE ', underscoring the expanded scope and capabilities of the methodology.



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What is the Unified Architecture Framework?

- The Unified Architecture Framework® (UAF®) is a generic and commercially orientated architecture framework based on work in the defense domain by the Object Management Group (OMG)
- UAF defines ways of representing an enterprise architecture that enables stakeholders to focus on specific areas of interest in the enterprise while retaining sight of the big picture.
- UAF meets the specific business, operational, and systems-of-systems integration needs of commercial and industrial enterprises as well as the U.S. Department of Defense (DoD), the UK Ministry of Defense (MOD), the North Atlantic Treaty Organization (NATO), and other defense organizations.

UAF	Motivation Mv	Taxonomy Tx	Structure Sr	Connectivity Cn	Processes Pr	States St	Sequences Sq	Information[c] If	Parameters[d] Pm	Constraints Ct	Roadmap Rm	Traceability Tr
Architecture Management[a] Am	Architecture Principles Am-Mv	Architecture Extensions Am-Tx[e]	Architecture Views Am-Sr	Architecture References Am-Cn	Architecture Development Method Am-Pr	Architecture Status Am-St		Dictionary Am-If	Architecture Parameters Am-Pm	Architecture Constraints Am-Ct	Architecture Roadmap Am-Rm	Architecture Traceability Am-Tr
Summary & Overview Sm-Ov												
Strategic St	Strategic Motivation St-Mv	Strategic Taxonomy St-Tx	Strategic Structure St-Sr	Strategic Connectivity St-Cn	Strategic Processes St-Pr	Strategic States St-St		Strategic Information St-If	Environment En-Pm and Measurements Me-Pm and Risks Rk-Pm	Strategic Constraints St-Ct	Strategic Deployment, St-Rm-D Strategic Phasing St-Rm-P	Strategic Traceability St-Tr
Operational 0p	Requirements Rq-Mv	Operational Taxonomy Op-Tx	Operational Structure Op-Sr	Operational Connectivity Op-Cn	Operational Processes Op-Pr	Operational States Op-St	Operational Sequences Op-Sq	Operational Information Op-If		Operational Constraints Op-Ct		Operational Traceability Op-Tr
Services Sv		Services Taxonomy Sv-Tx	Services Structure Sv-Sr	Services Connectivity Sv-Cn	Services Processes Sv-Pr	Services States Sv-St	Services Sequences Sv-Sq			Services Constraints Sv-Ct	Services Roadmap Sv-Rm	Services Traceability Sv-Tr
Personnel Ps		Personnel Taxonomy Ps-Tx	Personnel Structure Ps-Sr	Personnel Connectivity Ps-Cn	Personnel Processes Ps-Pr	Personnel States Ps-St	Personnel Sequences Ps-Sq	Resources Information Rs-If		Competence, Drivers, Performance Ps-Ct	Personnel Availability Ps-Rm-A Personnel Evolution PS-Rm-E Personnel Forecast Ps-Rm-F	Personnel Traceability Ps-Tr
Resources Rs		Resources Taxonomy Rs-Tx	Resources Structure Rs-Sr	Resources Connectivity Rs-Cn	Resources Processes Rs-Pr	Resources States Rs-St	Resources Sequences Rs-Sq			Resources Constraints Rs-Ct	Resources evolution, Resources forecast Rs-Rm	Resources Traceability Rs-Tr
Security Sc	Security Controls Sc-Mv	Security Taxonomy Sc-Tx	Security Structure Sc-Sr	Security Connectivity Sc-Cn	Security Processes Sc-Pr					Security Constraints Sc-Ct		Security Traceability Sc-Tr
Projects Pj		Project Taxonomy Pj-Tx	Project Structure Pj-Sr	Project Connectivity Pj-Cn	Project Processes Pj-Pr						Project Roadmap Pj-Rm	Project Traceability Pj-Tr
Standards Sd		Standards Taxonomy Sd-Tx	Standards Structure Sd-Sr								Standards Roadmap Sd-Rm	Standards Traceability Sd-Tr
Actual Resources Ar			Actual Resources Structure, Ar-Sr	Actual Resources Connectivity, Ar-Cn	Simulation[b]					Parametric Execution/ Evaluation[b]		

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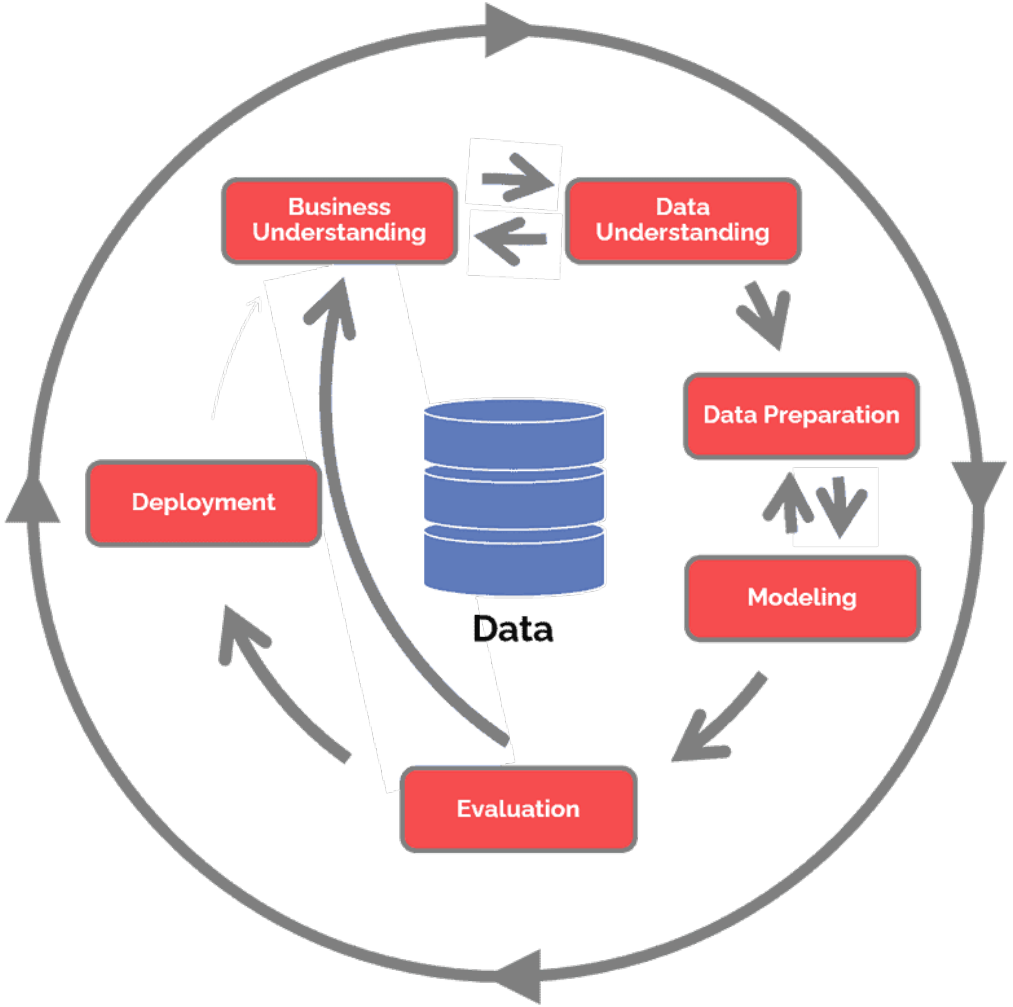
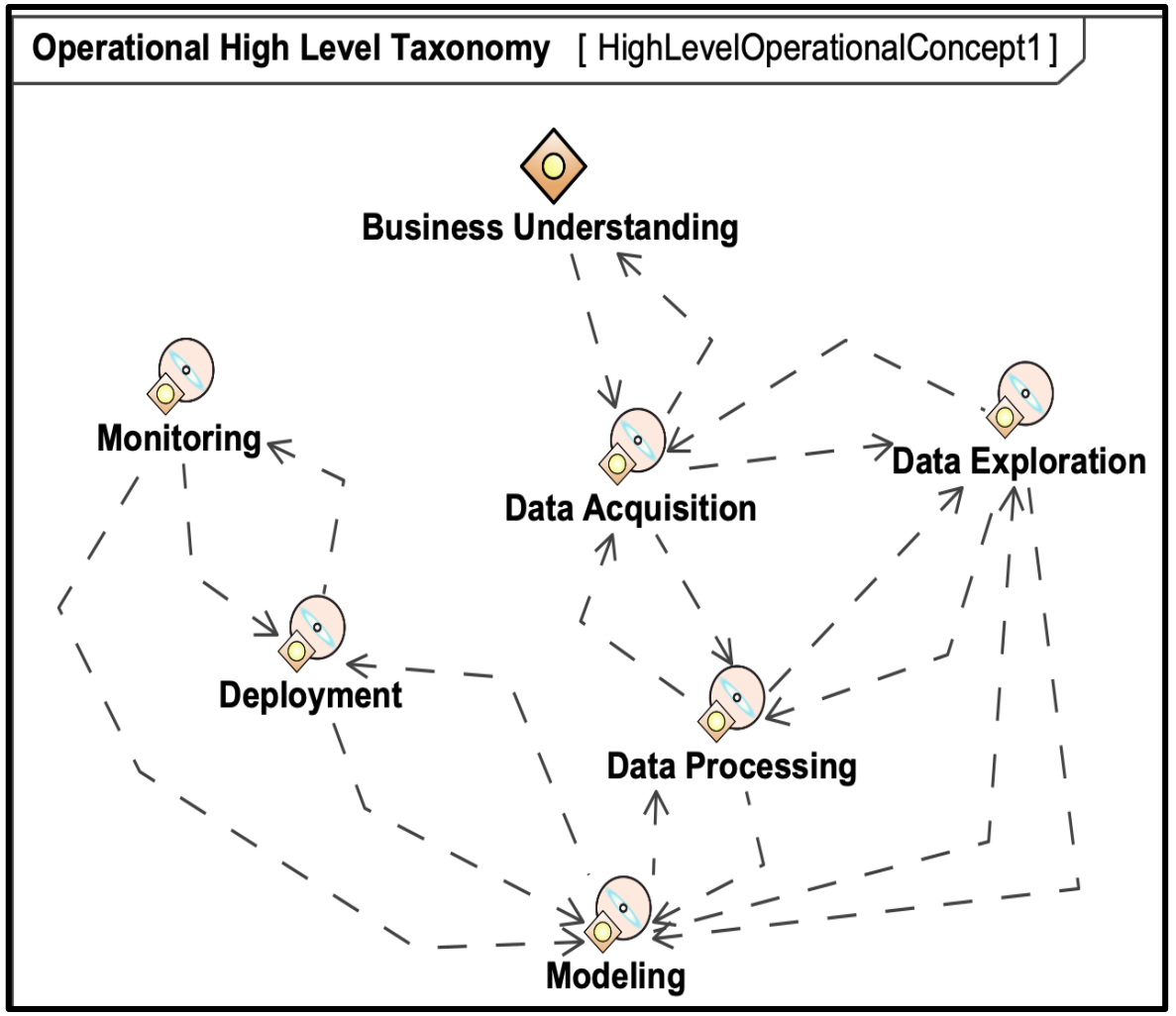
UAF for AIBOM

- Model overall system architecture, including relationships and dependencies between software components and other parts of the system
- Provides traceability features, allowing organizations to trace requirements through the system to components
  - Can help understand the impact of vulnerabilities as they are discovered
- Assist in managing changes to system components to maintain up-to-date AIBOM

High-level Taxonomy of System

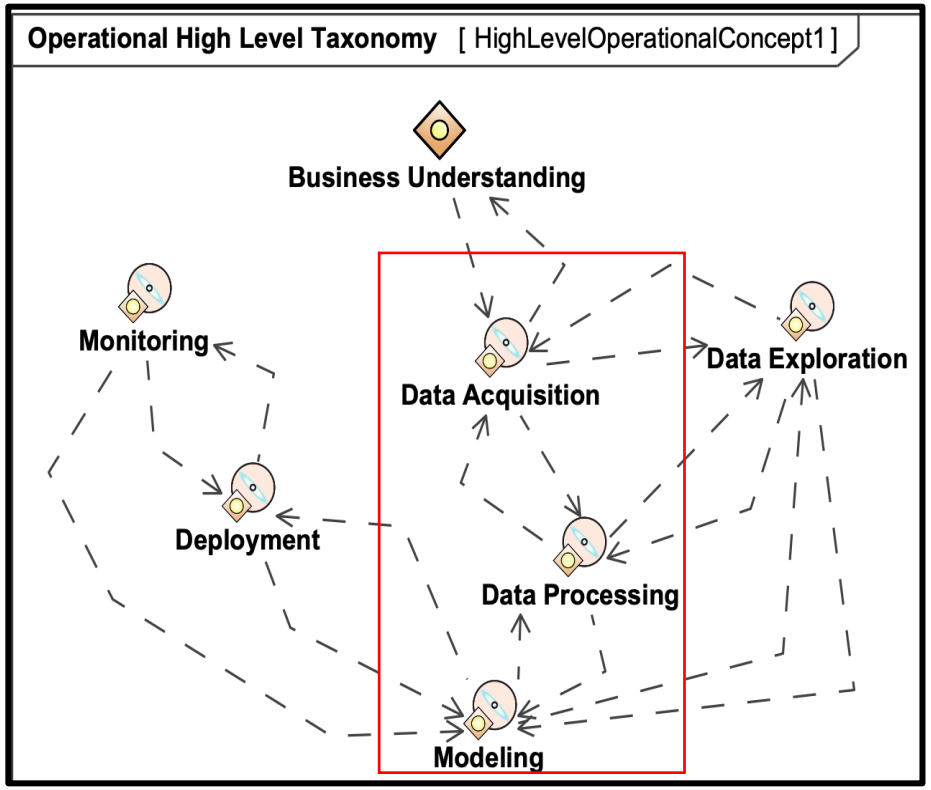


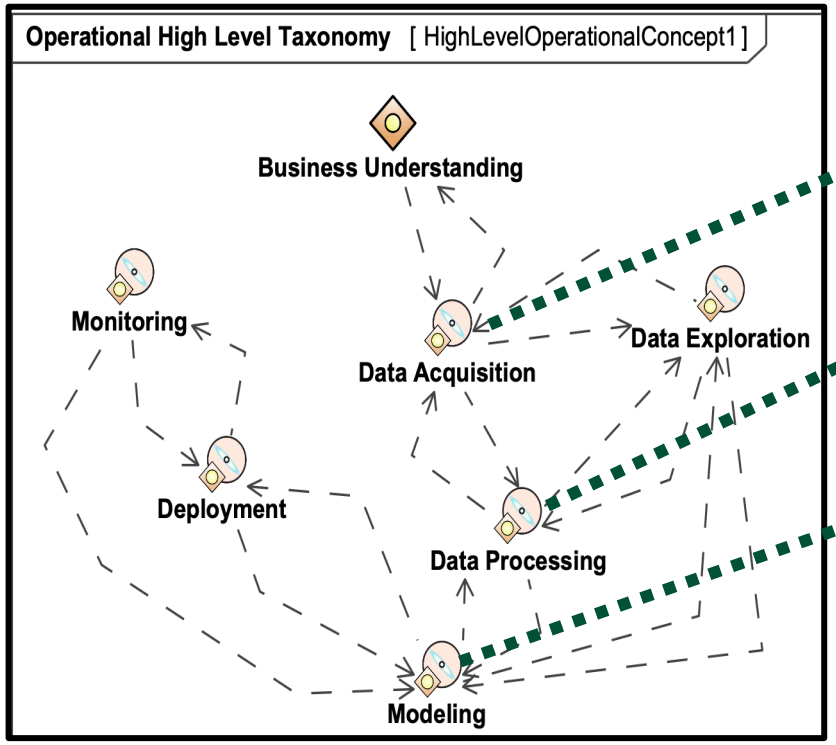
AI/ML Model Development Life Cycle

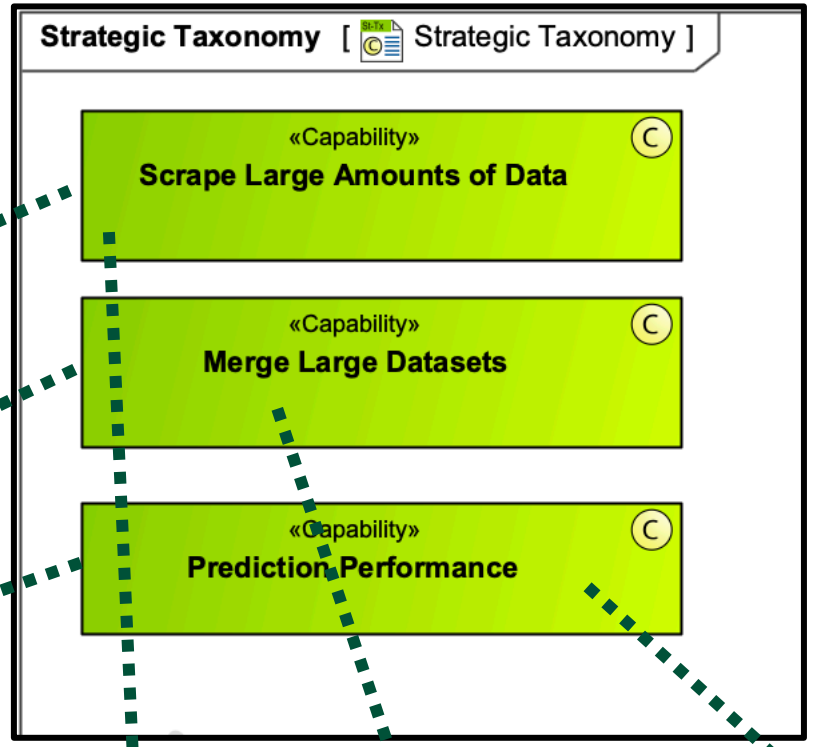


Example: AI Model Development

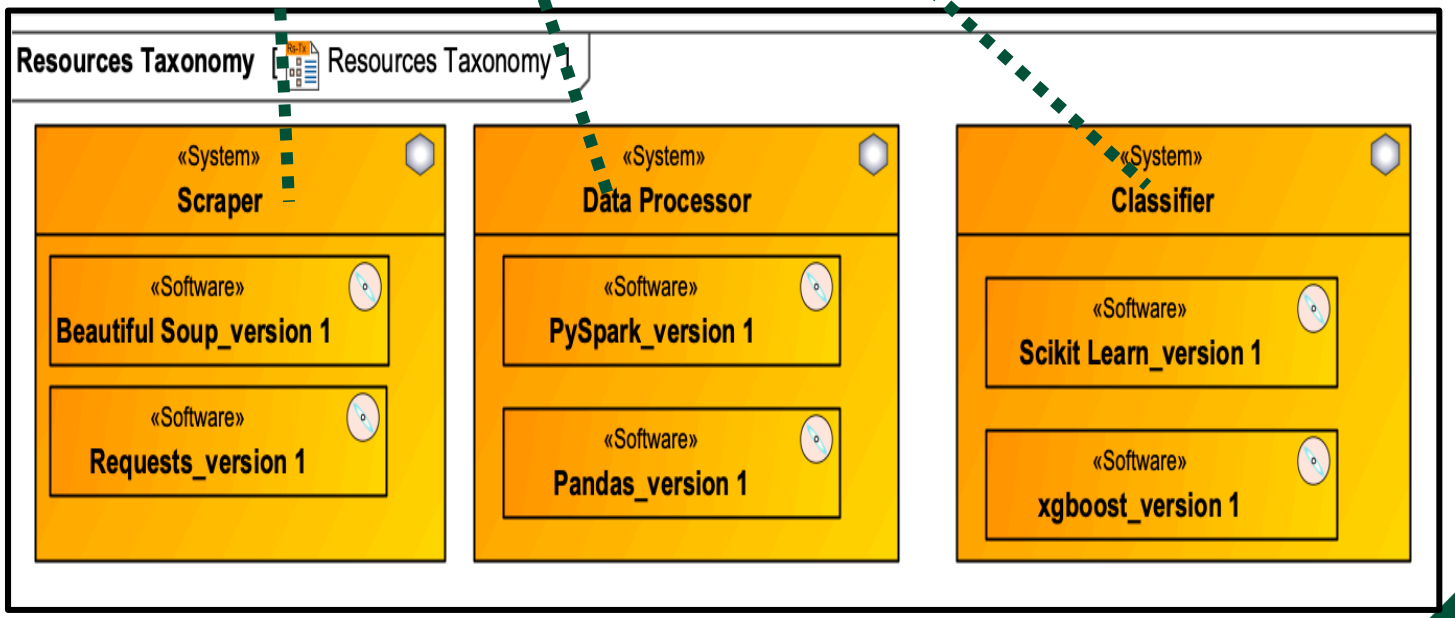
- Objective: build an AI model to predict the speed of sale on cover photo used on client facing real estate websites (i.e. redfin.com)
- Step1: scrape the website for cover photo and days on market value and store in database **DATA ACQUISITION**
  - Packages: beautiful soup, requests
- Step2: generate embeddings (numerical representation) of the images and create binary based on days on market (sold in less than a week of posting) **DATA PROCESSING**
  - Packages: pyspark, pandas
- Step3: partition the data and train an xgboost model for classification **MODELING**
  - Packages: scikit learn, xgboost







Vulnerability Database



Benefits of UAF for AIBOM

- Help systematically define and organize the components of the AIBOM, ensuring that all relevant elements are covered and properly documented.
- Emphasizes detailed documentation of architectural elements. For AIBOM, this means having a clear and comprehensive record of AI components, dependencies, and interactions, which is essential for managing complex AI systems.
- Benefit from a common language and set of concepts. This facilitates better communication among different teams involved in the development and maintenance of the AIBOM
- Helps in identifying potential risks and vulnerabilities using the AIBOM. This can aid in proactive risk management and ensure that the AI system is robust and resilient.

References

[1] “Software Bill of Materials (SBOM) | CISA.” Accessed: Jun. 14, 2024. [Online]. Available: https://www.cisa.gov/sbom

[2] J. Petersen, “Army Issues RFI for Project Linchpin AI Bill of Materials.” Accessed: Jun. 14, 2024. [Online]. Available: https://executivegov.com/2023/11/army-issues-rfi-for-project-linchpin-ai-bill-of-materials/

[3] “PyPI · The Python Package Index,” PyPI. Accessed: Jun. 14, 2024. [Online]. Available: https://pypi.org/

[4] “CVE - CVE.” Accessed: Jun. 14, 2024. [Online]. Available: https://cve.mitre.org/

[5] J. J. López García and D. P. Pereira, “Analyzing System Security Architecture in Concept Phase Using UAF Domains,” *INSIGHT*, vol. 25, no. 2, pp. 56–60, Jun. 2022, doi: 10.1002/inst.12388.

[6] M. Torkjazi, A. J. Davila-Andino, A. Alghamdi, and A. K. Zaidi, “UAF Strategic Planning for Enterprises,” *IEEE Access*, pp. 1–1, 2022, doi: 10.1109/ACCESS.2022.3224456.

[7] A. Alghamdi, M. Torkjazi, A. J. Davila-Andino, and A. K. Zaidi, “Employing UAF Inter-Domain Traceability for Performance and Effectiveness Evaluation,” in *2023 IEEE International Systems Conference(SysCon)*, Vancouver, BC, Canada: IEEE, Apr. 2023, pp. 1–8. doi:10.1109/SysCon53073.2023.10131056.

[8] D. Mor-Ofek, “It’s Time to Talk About AI/ML BOM (Artificial Intelligence Bill of Materials) And Vulnerability Management,” C2A Security - The Only Risk-Driven DevSecOps Platform. Accessed: Sep. 17, 2024. [Online]. Available: https://c2a-sec.com/its-time-to-talk-about-ai-ml-bom-artificial-intelligence-bill-of-materials-and-vulnerability-management/

[9] Dr. Burak Gozluklu, “What is MBSE and why do industries start to use? - Model Based Systems Engineering (MBSE) on AWS: From Migration to Innovation.” Accessed: Sep. 17, 2024. [Online]. Available: https://docs.aws.amazon.com/whitepapers/latest/model-based-systems-engineering/what-is-mbse-and-why-do-industries-start-to-use.html

[10] 3DS CATiA NoMagic, “UAF 1.2 - UAF 1.2 Plugin 2021x Refresh2 - No Magic Documentation.” Accessed: Sep. 17, 2024. [Online]. Available: https://docs.nomagic.com/display/UAF12P2021xR2/UAF+1.2

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Questions