Model-Based Systems Engineering (MBSE):

Topic Modeling of Academic Journals

Sunil

Table of contents

01

Introduction

Adoption of MBSE

Goal 1

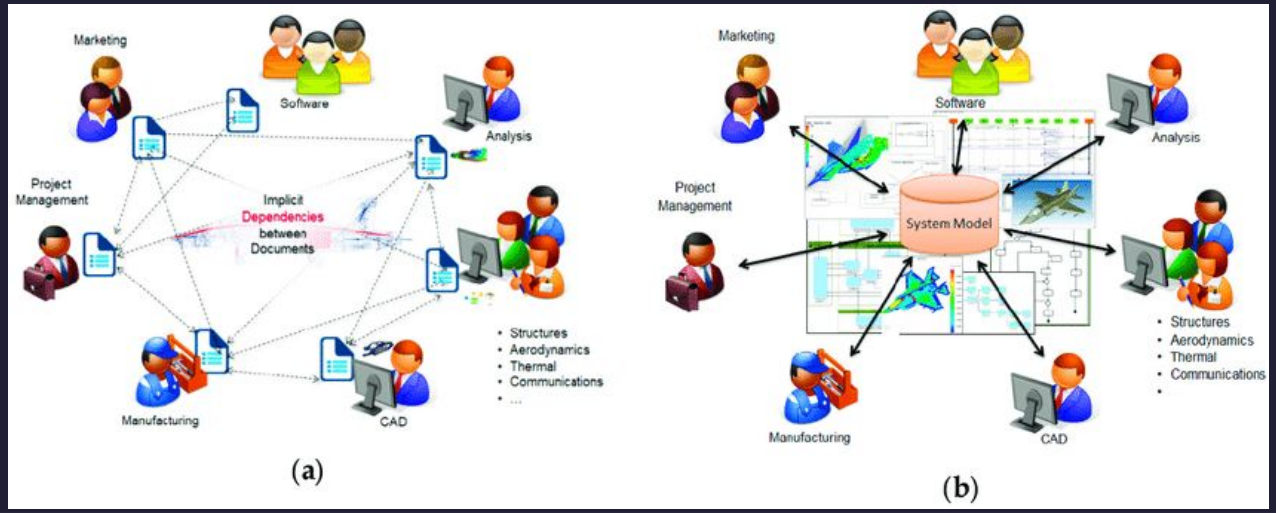
Manage Complexity

Goal 2

Improve Traceability

Goal 3

Enhance Communication



(a) Traditional Systems Engineering

(b) Model-Based Systems Engineering

Issues with Adoption of MBSE

Problem Statement

Systems engineering is a large established field. Due to the high start-up costs of adopting MBSE, large scope as well as inertia within the organization, it is difficult to:

- Identify organizational enterprise goals
- Focus R&D research efforts
- Identify latest trends

01

Org Enterprise Goals

- Where to scale up?
- Which stakeholder to engage?
- How to achieve economies of scale?

02

R&D Efforts

- Which aspect of the MBSE to implement first?

03

Latest Trends

- What is gaining traction in recent years?

Project Goals

- Explore the use of unsupervised models for topic modeling on academic journals
- Gain insight on topics/themes and their trends over the years
- Apply insight to guide organisational goals

02

Dataset

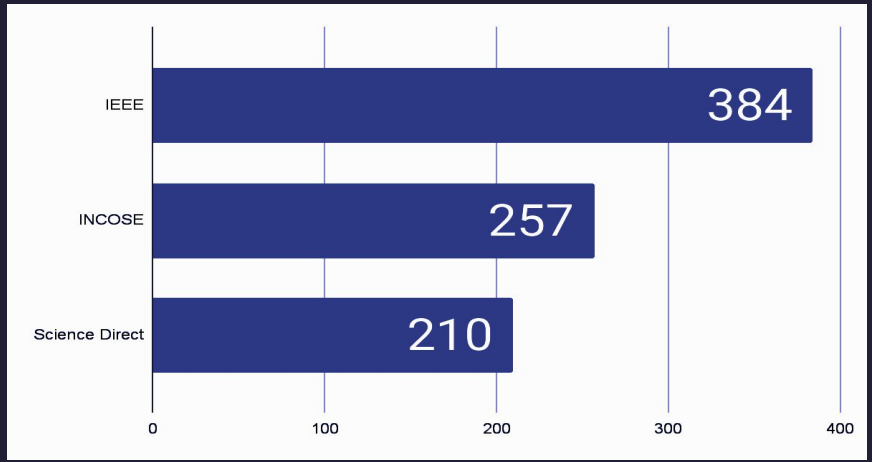
Dataset

851 Articles Collected

- Institute of Electrical & Electronics Engineers (IEEE)
- International Council on Systems Engineering (INCOSE)
- Science Direct

Article Format

- CSV Files
- Bibtex



Data Cleaning & Preprocessing

Remove apostrophes, URLs, numbers, etc

Clean the Text

Convert different words with the same meaning/intent into the same word

Lemmatize

Tokenize

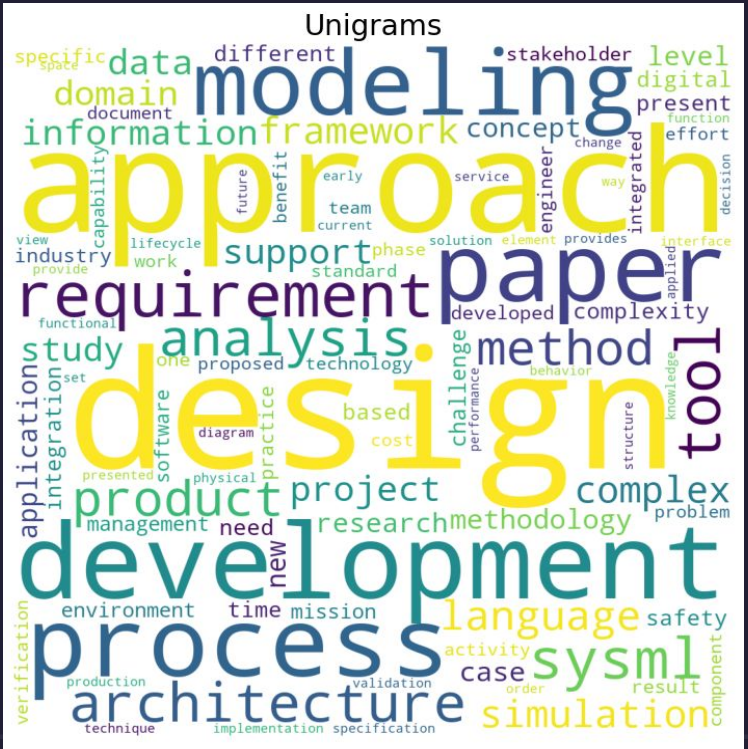
Convert sentences into individual texts

Remove Stop Words

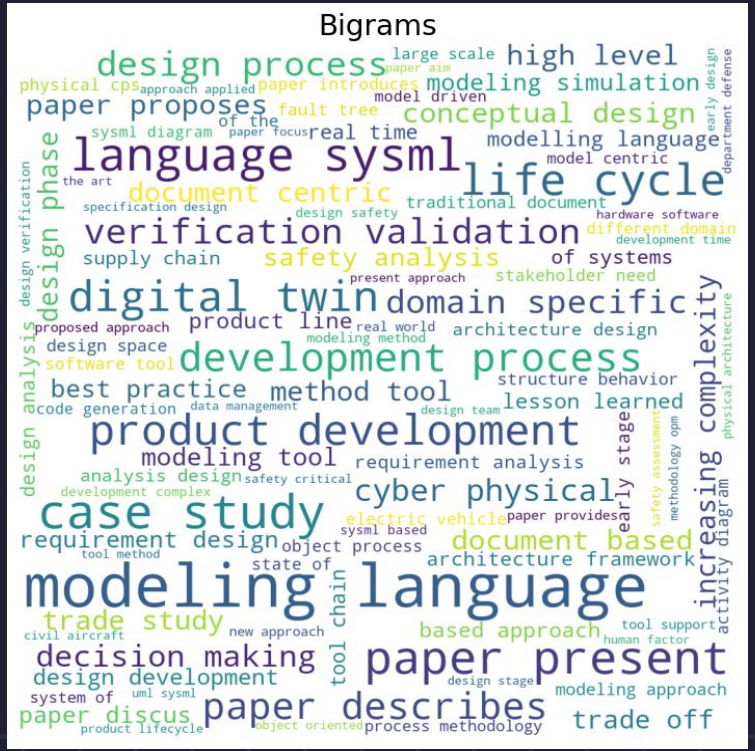
Filter words that provide no context or words common in every article

Data Exploration

Unigrams



Bigrams

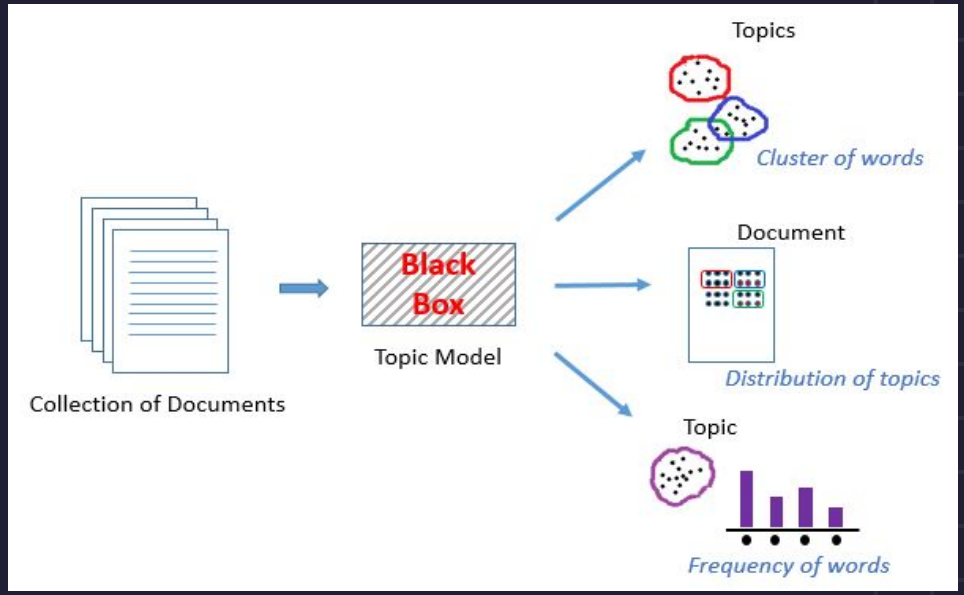


03

Modeling

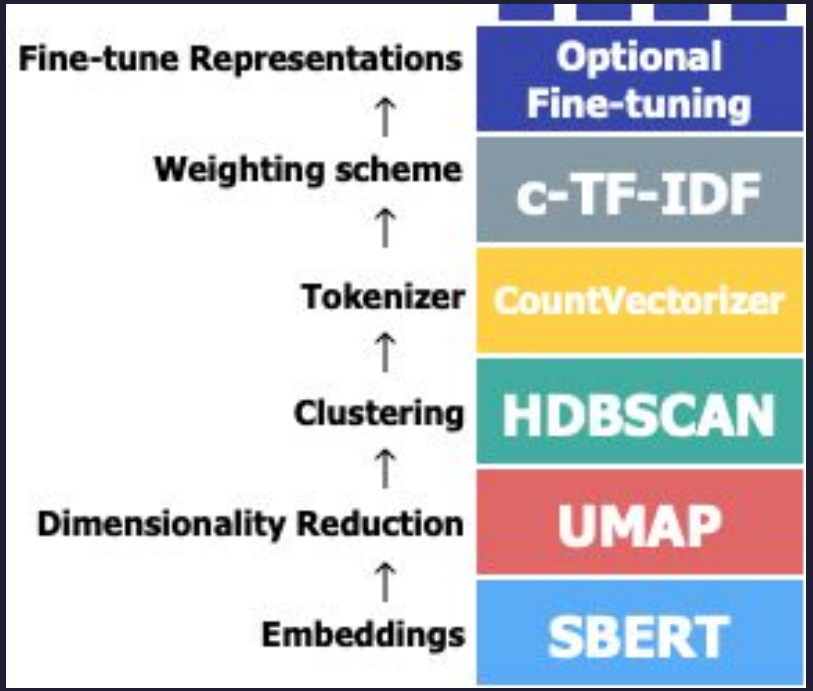
Topic Modeling

- Unsupervised machine learning
- Used to discover and extract topics or themes from a collection of documents
- Assign topics based on probability distribution of words
- E.g. Latent Dirichlet Allocation (LDA), Hierarchical Dirichlet Process (HDP), BERTopic



BERTopic

- Leverages on the BERT pre-trained language model
- Able to understand the contextual relationships between words
- Clusters documents together based on semantic similarity
- No need to define the number of clusters



BERTopic Modeling Process

17 topics identified (⅓ of dataset were outliers)

Initial Model

8 generalised topics were identified

Merge Similar Topics

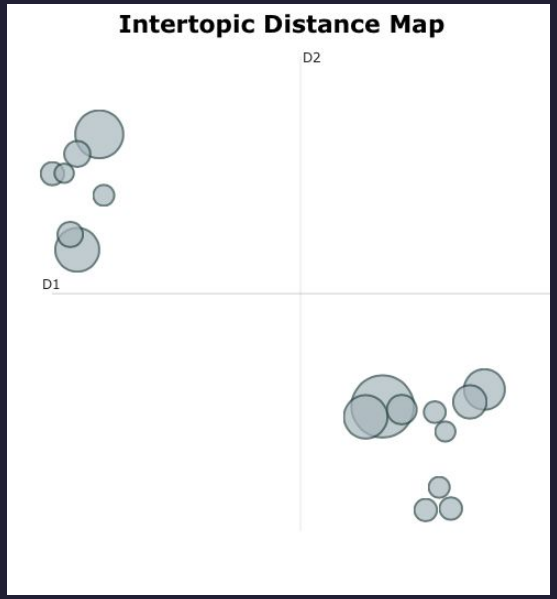
Summarise Topics

Summarise each topic and identify the similar ones using domain knowledge

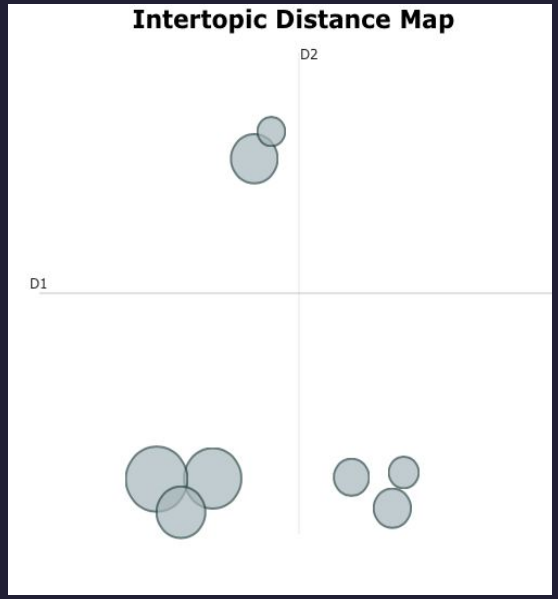
Reduce Outliers

Assign the outlier documents using the best matching c-TF-IDF representations

Intertopic Distance



Initial 17 Topics



Final 8 Topics

Identified Topics

Topic	Top 10 Key Words for Topic	Topic Label Using Domain Knowledge
0	cubesat, vehicle, spacecraft, satelite, requirement, nasa, modeling, submarine, payload, electric vehicle	Application of MBSE in Projects
1	sysml, modeling, simulation, modeling language, uml, language sysml, diagram, modeling language sysml, software, specification	Modeling language for MBSE
2	ontology, research, reuse, paper, industry, knowledge, semantic, tool, modeling, database	Adoption of MBSE and its Evaluation Metrics
3	development, product development, production, process, manufacturing, industrial, iot, product line, toolchain, development process	Product Development Process Using MBSE
4	reliability, safety analysis, fmea, fault tree, design safety, safety artifact, medical device, reliability analysis, failure mode, safety critical	Safety Assurance Using MBSE
5	mechatronic, inspection, inspection equipment, production scheduling, modeling, constraint, business rule, validation, property verification, mechatronic product	Validation & Verification Using MBSE
6	requirement, design, engineer, specification, hcd, wfrequirements, text-based requirement, cm process, property-based requirement, methodology	MBSE for Requirements Specification
7	digital twin, cyber, resilience, mbsecps, simplexity test-bed, security threat, vulnerability, twin technology, risk assessment, cpg	MBSE for Digital Twin and Cybersecurity

04

Insights & Recommendations

Reminder on Problem Statement

Problem Statement

Systems engineering is a large established field. Due to the high start-up costs of adopting MBSE, large scope as well as inertia within the organization, it is difficult to:

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Org Enterprise Goals

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Latest Trends

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Topic Insights

Topic 0

Application of MBSE in Projects

- Real-life examples of MBSE application
- Aerospace, NASA, ***Electric Vehicles***, Naval

Topic 1

Modeling Language for MBSE

- One of three pillars of MBSE
- Systems Modeling Language (***SysML***)

Topic 2

Adoption of MBSE and Evaluation Metrics

- Guide ***adoption*** process
- Evaluation metrics for ***ROI***

Topic Insights

Topic 3

Product Development Process using MBSE

- ***Product Development***
- Manufacturing

Topic 4

Safety Assurance

- ***Safety Analysis***
- ***Reliability***
- ***Failure Mode***

Topic 5

Validation & Verification using MBSE

- ***V&V*** of product
- Inspection of equipment

Topic Insights

Topic 6

MBSE for Requirements Specification

- ***Design Requirements*** Specification
- Change Management

Topic 7

MBSE for Digital Twin and Cybersecurity

- Digital Twin
- ***Cyber Resilience***
- Vulnerability Assessment
- Security

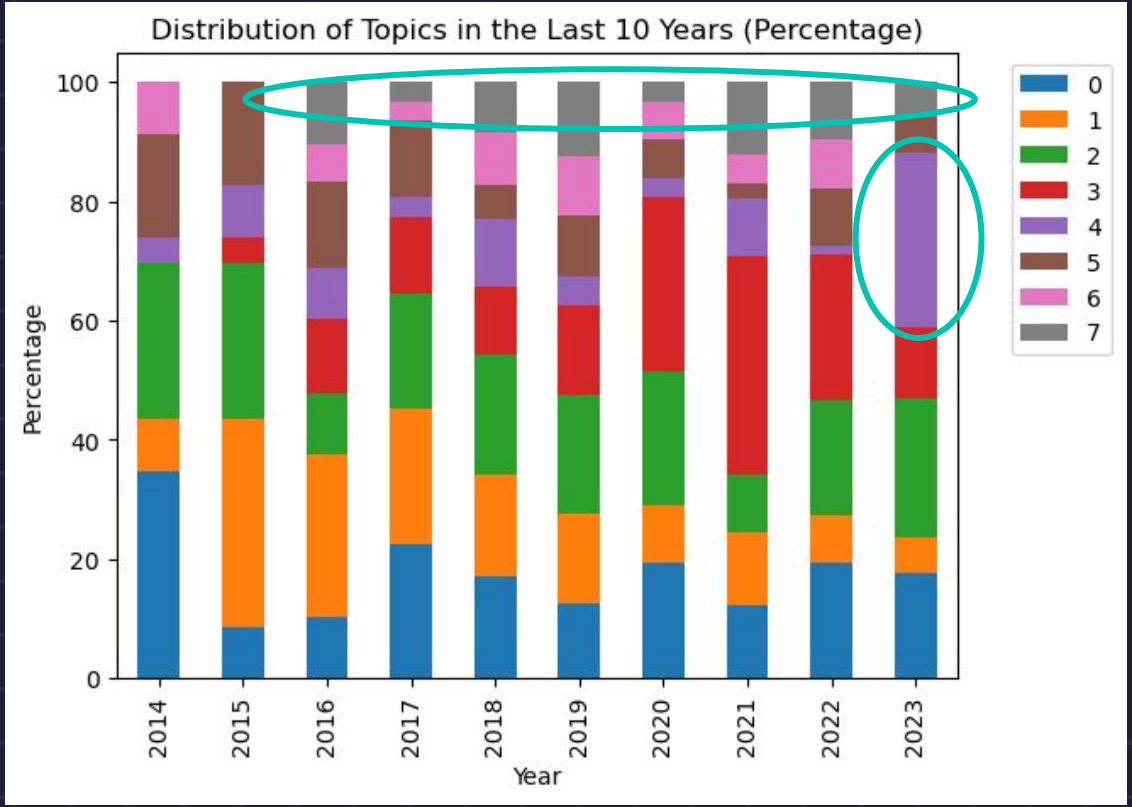
Identified Stakeholders

	Label	Stakeholder
Topic 0	Application of MBSE in Projects	***EV-Electric Charging Pte Ltd*** subsidiary recently set up
Topic 1	Modeling Language for MBSE	***All users***, to learn language and modeling best practices
Topic 2	Adoption of MBSE and Evaluation Metrics	***Core MBSE Team*** performing R&D to adopt MBSE in the Org
Topic 3	Product Development Process using MBSE	***Fare Systems Team*** performing in-house product development

Identified Stakeholders

	Label	Stakeholder
Topic 4	Safety Assurance using MBSE	***System Assurance Team*** performing and reviewing safety and reliability analysis for new projects
Topic 5	Validation & Verification using MBSE	***Project Teams*** in charge of ensuring project delivery
Topic 6	MBSE for Requirements Specification	***Engineering Teams*** in charge of specifying requirements for new projects
Topic 7	MBSE for Digital Twin and Cybersecurity	**Cybersecurity & Project Teams** delivering critical information infrastructure

Trends



- Application of MBSE in Projects
- Modeling Language for MBSE
- Adoption of MBSE and its Evaluation Metrics
- Product Development Process using MBSE
- Safety Assurance using MBSE
- Validation & Verification using MBSE
- MBSE for Requirements Specification
- MBSE for Digital Twin and Cybersecurity

Recommendations

Short Term

Engage Systems Assurance Team based on:

- Current trends
- Our teams have the same director (easier to overcome inertia to implement MBSE)
- Nature of systems assurance has significant impact given the important of our MRT lines

Long Term

Present to management for decision making:

- Identified capabilities of MBSE and relevant stakeholders
- Planning at organisational level for adoption of MBSE

05

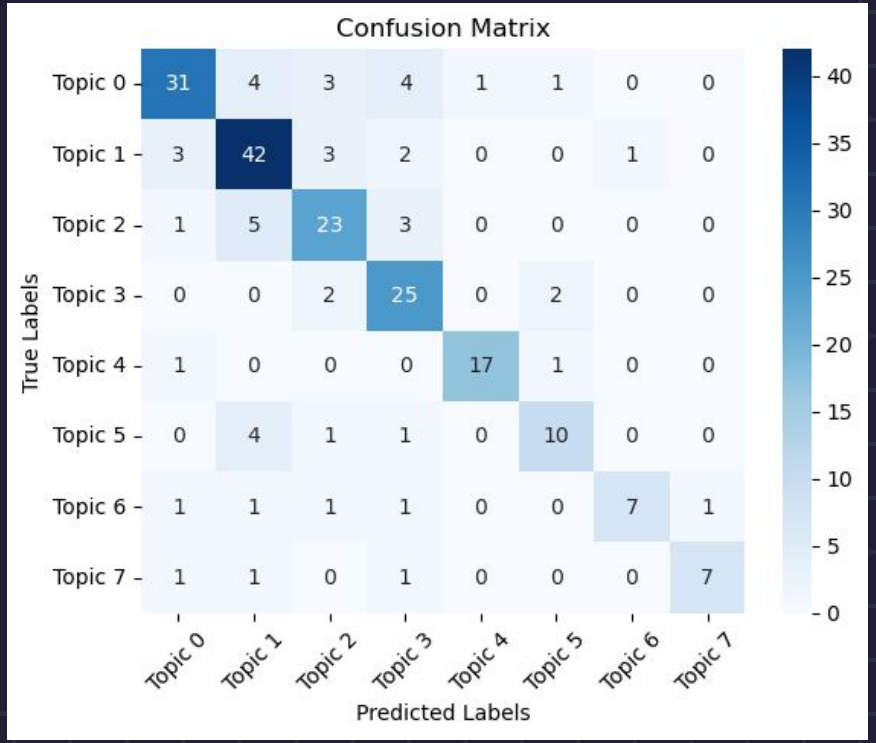
Support Tool

Classification Modeling

- New academic articles will continue to be published
- Naive Bayes classification model used to label new articles

76%

Macro Avg F1 Score / Accuracy



06

Future Works

Future Works

Break Down Topic 0

- Currently covers the application of MBSE for various fields
- Can be further broken down into aerospace, naval, electric vehicles etc
- Beneficial to stakeholders in specific fields

Create Front-End

- Need to process and label newly published articles
- Use front-end implementation to enable quick pre-processing and classification

Thanks!