Environmental, Safety, and Health (ES&H) Data Analytics and Machine Learning (DAMaL) Tools

U.S. Department of Energy
Office of Environment, Health, Safety and Security (EHSS)
Office of ES&H Reporting and Analysis (EHSS-23)
Last Updated: April 2024

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Office of Environment, Health, Safety and Security

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Introduction

The DOE/EHSS Environmental, Safety and Health (ES&H) Data Analytics and Machine Learning (DAMaL) tools are a collection of web-based tools that are being developed for the purposes of analyzing data and support decision making more effectively and efficiently by allowing users to leverage all the information in the EHSS's ES&H databases.

The tool capabilities include search and filtering of records, dynamic data visualization and plotting, text analytics (using natural language processing and clustering), and use of classification algorithms for classifying, visualizing, and analyzing out-of-sample data.

EHSS-23 Data Analytics Activities

EHSS Data Analytic and DAMaL Tools Development Activites

Data Sources

- DOE DBs (ORPS, CAIRS, Site-specific Data)
- Other (DNFSB, NRC, OSHA)

Coordination and Collaboration

- DOE PSO (AITO, SC, NNSA, EM)
- DOE Sites (SRS, INL, EM-LA, ANL, SNL, NA-LA, NREL, PNNL, and others)
- Other DOE Organizations (EFCOG and LOB)
- Federal Agencies (BLS, NRC, DNFSB, NITRD)

Structured or Unstructured Data

- Cluster Analysis
- Automatic Trend Calculation
- System Process Outcome Tool
- Task Automation
- Data Visualization and Dynamic charts
- Advanced Information Retrieval

Risk Modeling and Insights

- Topic Modelling
- Predictive Modelling
- Thematic Risk Modelling

- Development and Testing
- Upload site data

Data Analytics Tool Development Tasks → Deployable Tools

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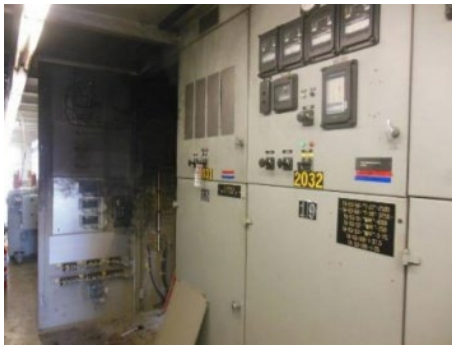
Data Sources

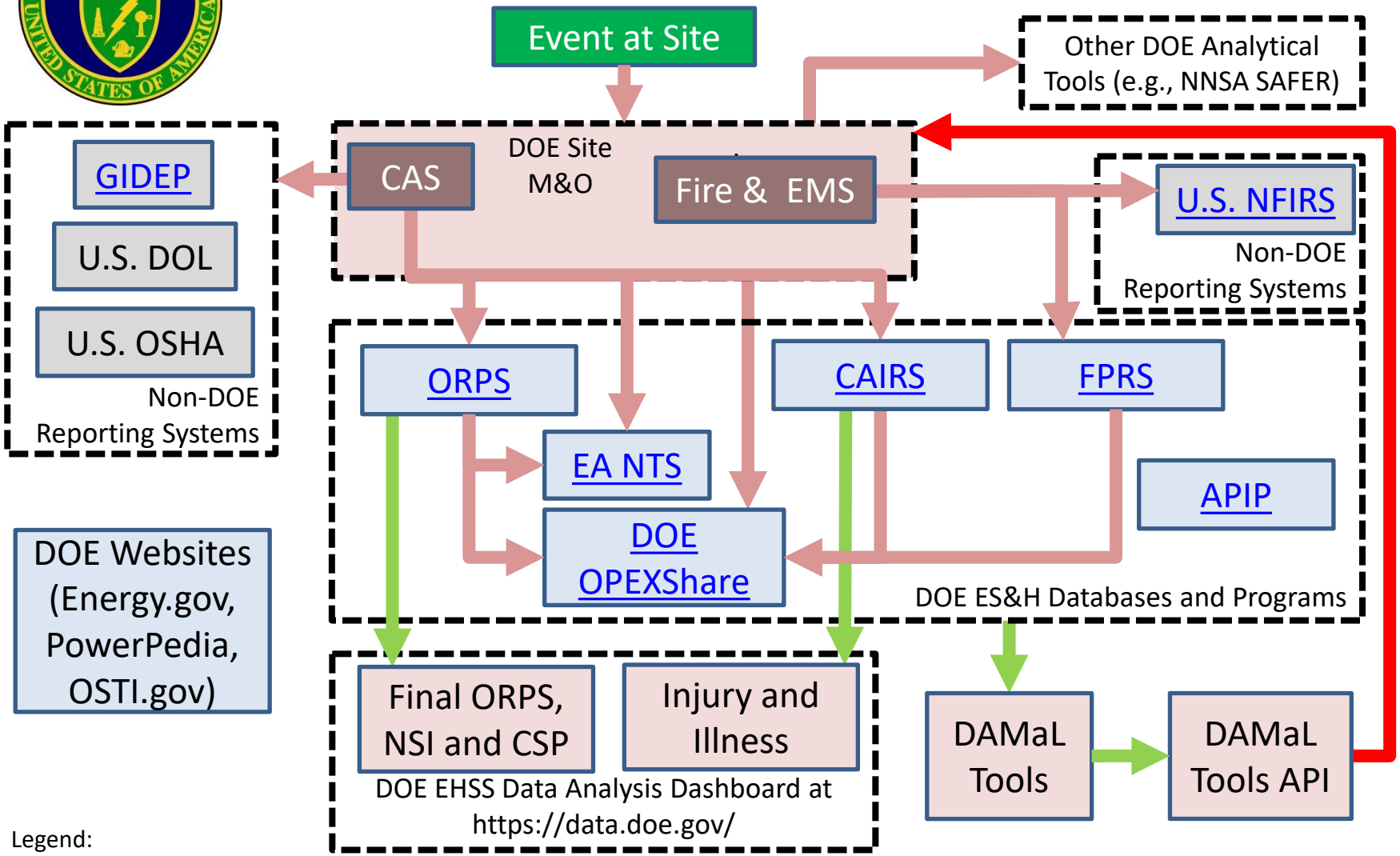


- Data warehouse for DOE/EHSS ES&H related datasets
  - ORPS
  - CAIRS
  - DOE OPEXShare
  - Fire Protection Database

- Non-EHSS ES&H related datasets
  - DNFSB
  - Site CAS level data
  - Other datasets

- Can be customized to work with any dataset

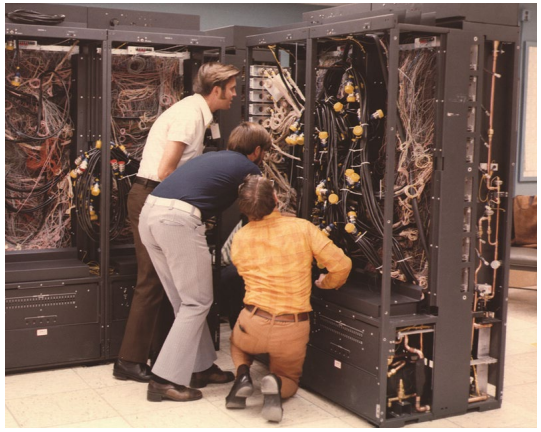
ESH Data Flows



Legend:

- Orange Arrows: Events that meet reporting criteria are submitted to the reporting system
- Green Arrows: Read only by a Data Analytics Dashboard

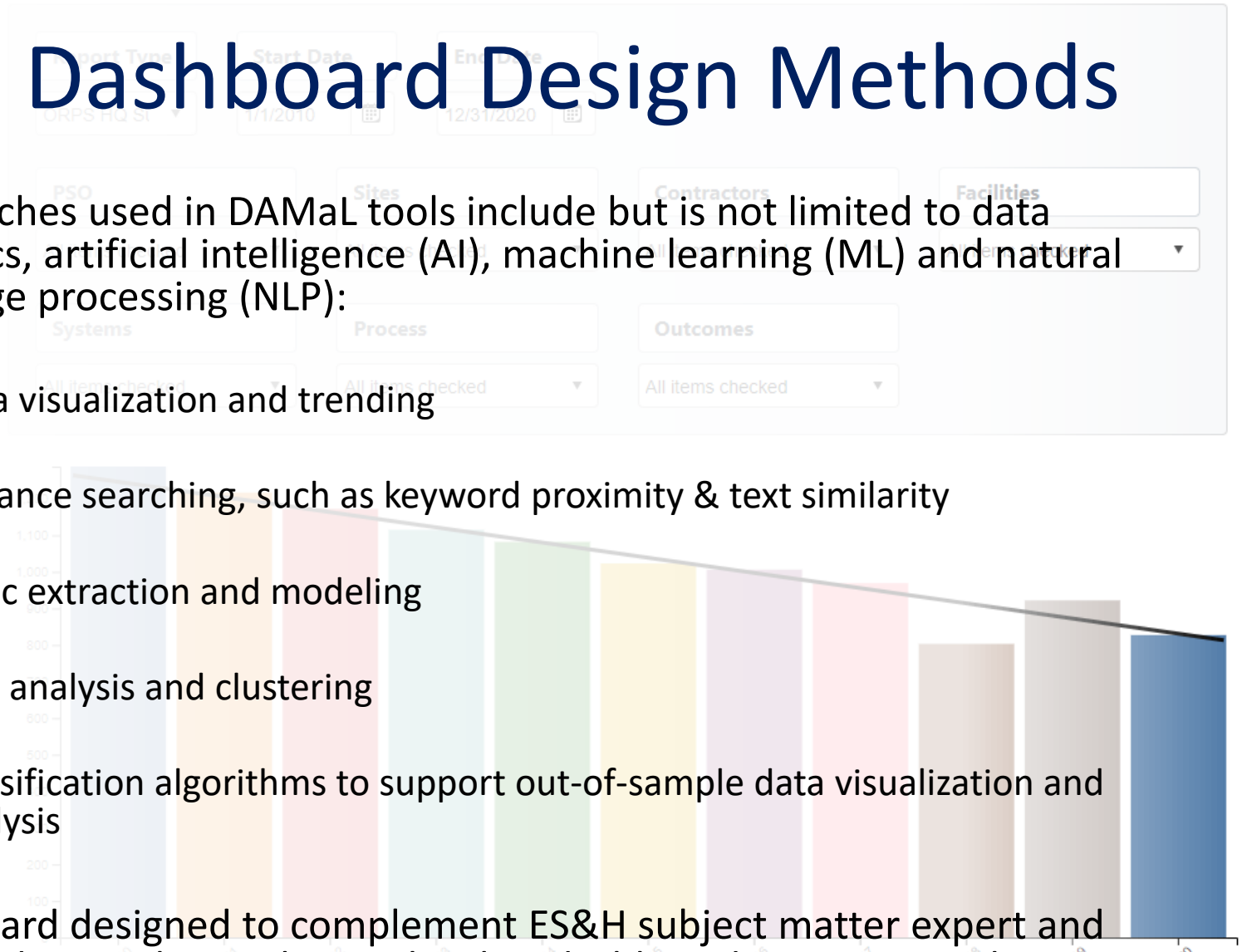
Main User Groups



- ES&H practitioners at DOE PSO's (e.g., HQ, FO):
  - Oversee site operations, trends and application of lessons learned (LL)
  - DAMaL tools serves as one of their main analytical tools
- ES&H practitioners from site staff (e.g., M&O)
  - Ensure operations are safe, analyze occurrences and report those that meet reportability criteria
  - Have access to internal M&O data and tools. May use DAMaL tools data via application programming interface
  - DAMaL tools serve as a support analytical tool and identify trends across the DOE complex that can be applicable to their site
- Non-ES&H DOE staff or External
  - Want to learn more about data science tools, how they work, capabilities, limitations and application development LL's
  - Limited access (e.g., Other agencies via MOU)
  - Temporary access (e.g., Other agencies conducting audits)

Dashboard Design Methods

- Approaches used in DAMaL tools include but is not limited to data analytics, artificial intelligence (AI), machine learning (ML) and natural language processing (NLP):
  - Data visualization and trending
  - Advance searching, such as keyword proximity & text similarity
  - Topic extraction and modeling
  - Text analysis and clustering
  - Classification algorithms to support out-of-sample data visualization and analysis
- Dashboard designed to complement ES&H subject matter expert and designed to work together with other dashboards to minimize limitations



Applications

- Use with DOE, PSO, and Site level dashboards
- Visualization tools help with identification of trends and patterns
- Advanced search tools improve effectiveness and efficiency to find relevant information to a topic or report of interest
- Text analysis tools help with report topic analysis, finding frequent topics, clustering/grouping reports by related topics, and identification of outlier topics
- Tools potentially predict topics and safety occurrences
- Improve resource utilization and efficiency of obtaining insights from ES&H indicators (leading and lagging)

Typical Data Analysis Process

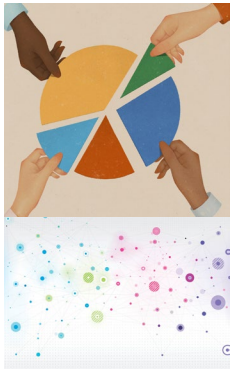
Define Problem and Collect data (e.g., data stored in SQL, CSV, other formats)

Prepare, filter, and aggregate data and perform calculation (i.e., via PivotTable)

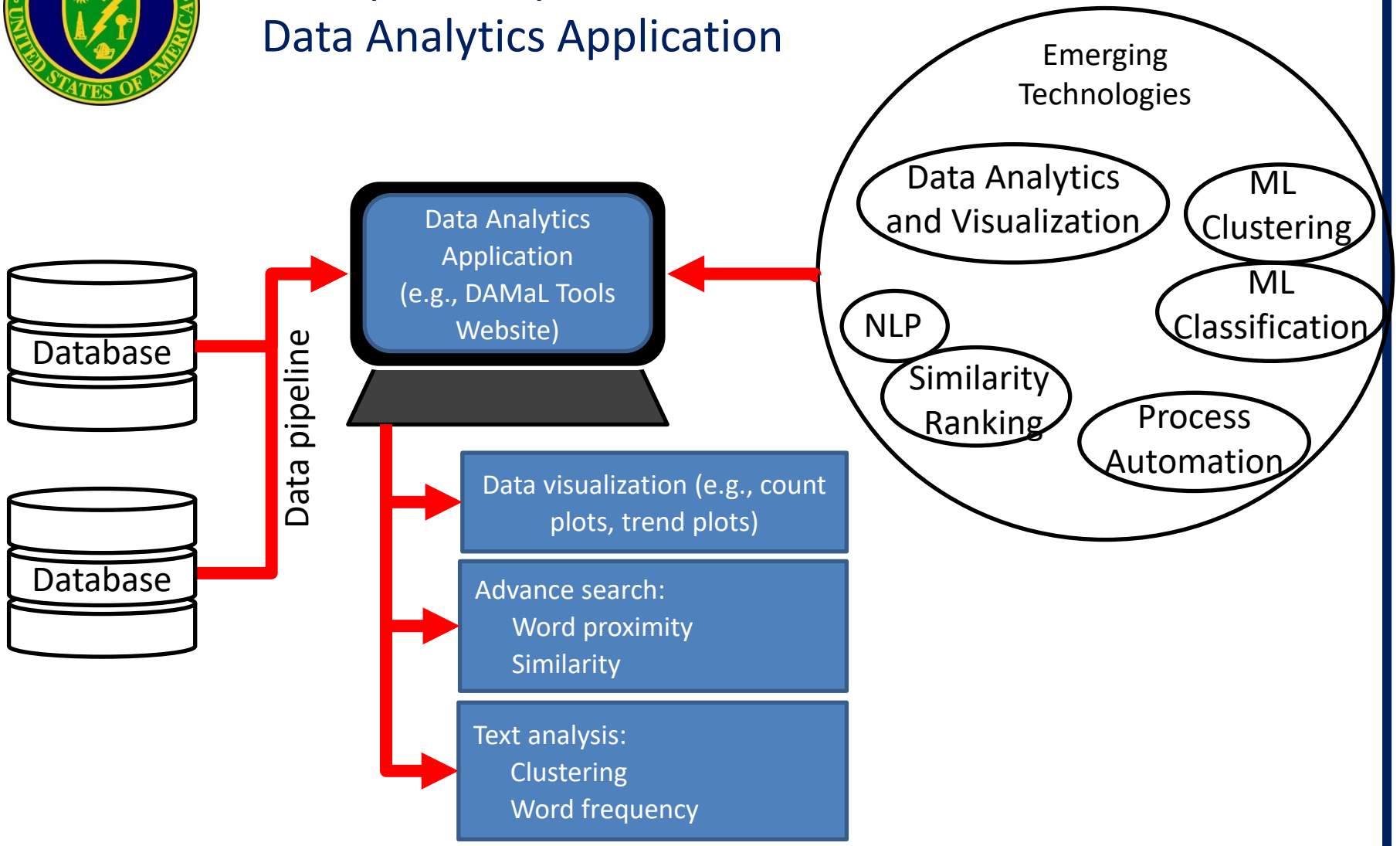
Analyze data (e.g., trends, patterns, change per time)

Interpret results, create visualizations, and conclusions

Document findings (e.g., report)



Example Components of a Data Analytics Application



Training, Demonstrations and References

- Trainings and webinars:
  - "All-user" training webinars conducted twice per year
  - Data science webinars (e.g., data analytics, artificial intelligence, machine learning, natural language processing, etc.) periodically scheduled
  - Custom training (per request)
- Users' guide available
- DAMaL tools and ES&H Analytics community of practice (CoP) and working group monthly meetings

Other Observations and Challenges

- Some potential analytic activities may be limited due to reporting systems design or information not available to EHSS
- Using DAMaL Tools as an ES&H data warehouse serves as a cybersecurity barrier to the system of record (e.g., ORPS, CAIRS, FPRS DOE OPEXShare)
- Semi-automated data processing due to lack of APIs in source databases
- Lack of real-time operational data will limit potential to perform predictive analytics
- Concerns for information sensitivity on non-sensitive datasets
- Time to resolve EHSS source database issues

Summary

- The goals of the tools is to increase the value of data and efficiency of analyses to inform strategy and aid decision making
- Provide high quality strategic tools and insights to decision makers
- Develop business intelligence, demographic, and trend analyses in support of increased understanding of drivers/factors that impact safety, performance and reliability
- Provide input to ES&H policy on opportunities to enhance protection for workers, public and environment from the hazards associated with DOE operations
- Driving business processes, not only by recommending the next best action but also by triggering those actions automatically

For questions and access contact

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Methods and Approaches Being Evaluated

Methods and Applications being Evaluated and Tested (1/2)

- Outlier/Anomaly detection (using density-based clustering algorithms, network analysis, and combination with similarity metrics)
- Use of importance weighting using ORPS reporting criteria, outcomes and other metrics
- Automatic identification of trend changes, predictive analytics and risk insights

Methods and Applications being Evaluated and Tested (2/2)

- Applications of network analysis, scatter text, deep learning

- Automation of data sharing using APIs
  - Similarity searching
  - Automating identification of relevant lessons learned for site's work packages
  - Combine site's internal data with DOE complex data

DAMaL Tools
Design and Capabilities

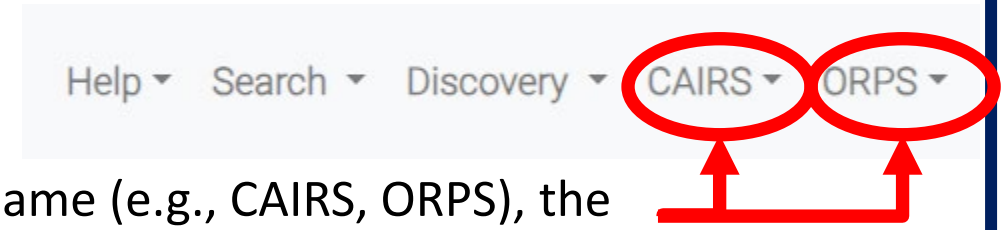
DAMaL Tools

- Different DAMaL tools' dashboards leverage different features of the data. Some may focus on the structured data while others focus on the unstructured data.

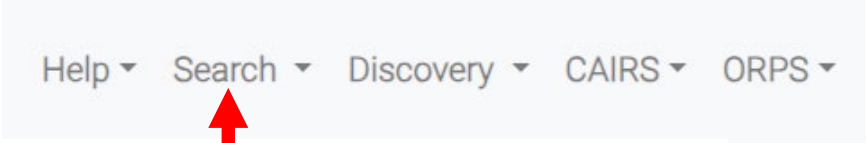
- Common Tasks:
  - Exploring the data (e.g., statistics, trends)
  - Finding important reports
  - Finding important lessons learned

- Example Topics of Interest:
  - Hazardous Energy Control – Lockout/Tagout
  - Positive Unreviewed Safety Questions
  - Telehandler Forklift Events

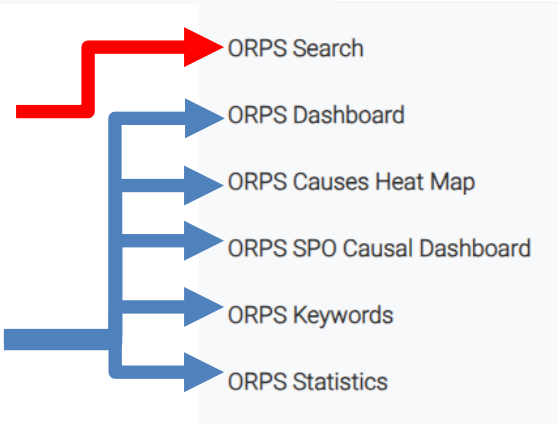
Tools Naming Convention



- Tabs
  - If it has an ES&H database name (e.g., CAIRS, ORPS), the dashboards under that tab only work with that ES&H data
  - Otherwise, it works with all datasets and the dataset can be specified in the report type filter



  - Search: focus on complicated data queries and exporting data. Improvements being implemented include buttons for showing statistics, data visualization and clustering
  - Other: focus on data visualization or statistics and metrics



DAMaL Tools Dashboards
Sample Print Screens

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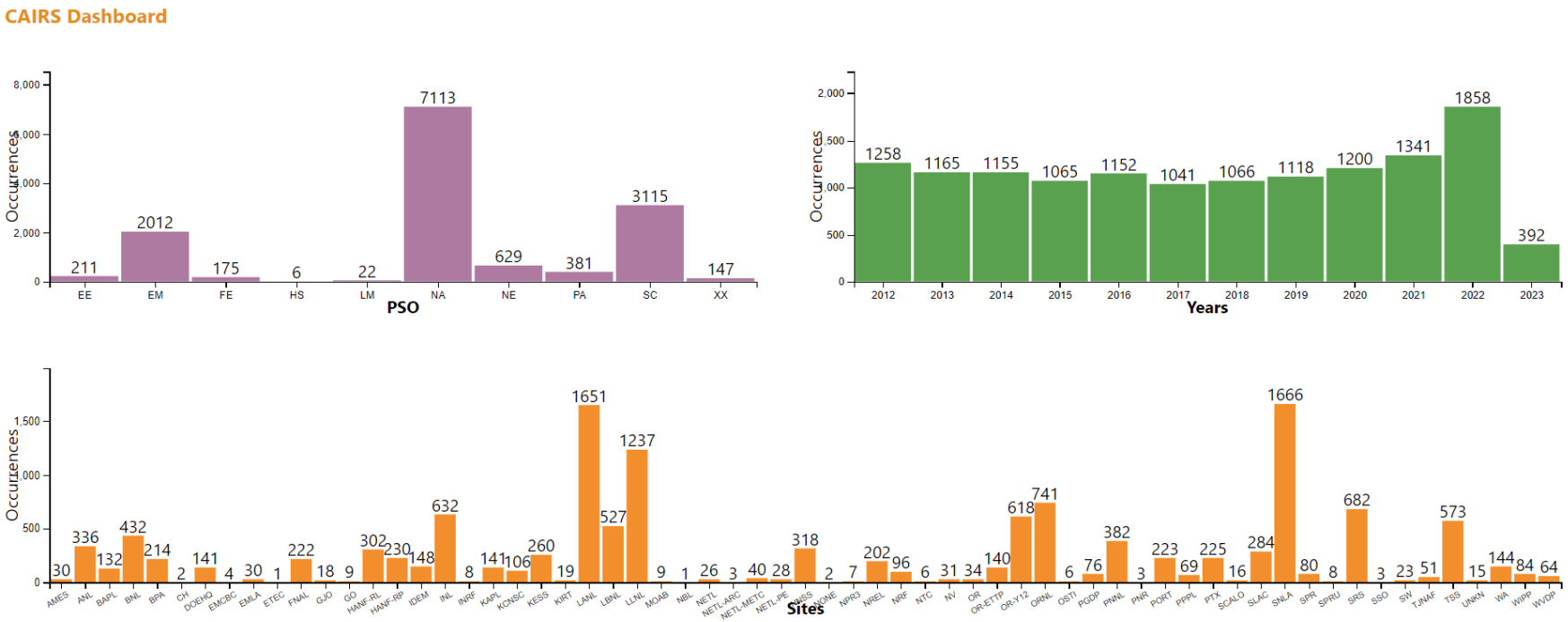
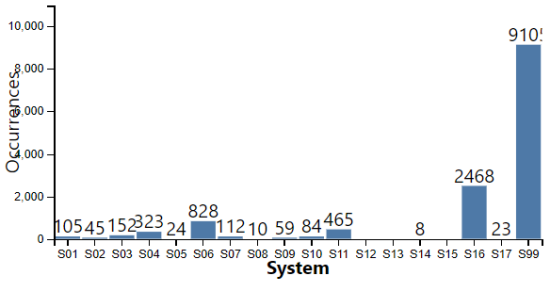
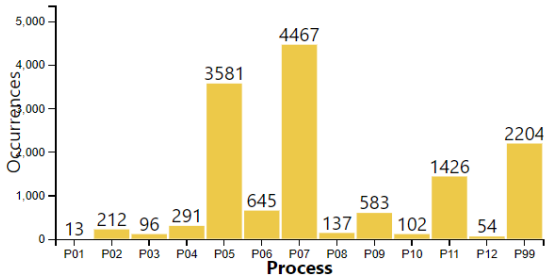
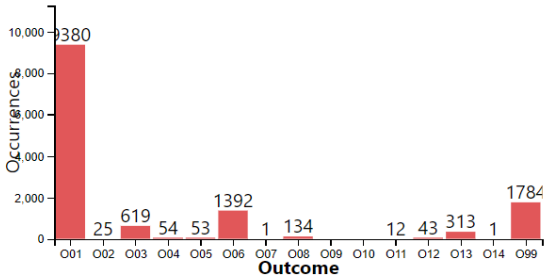
CAIRS Dashboard: Sample Print Screen (1/2)

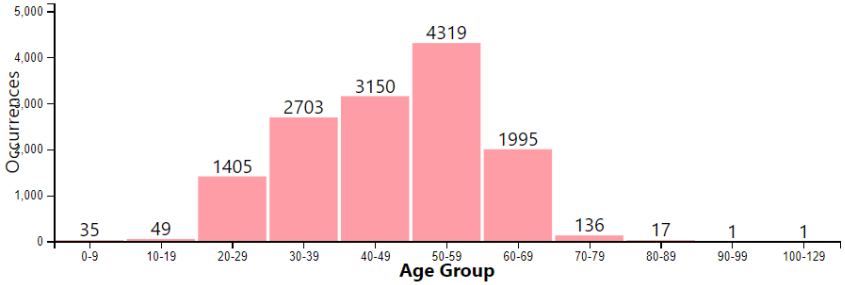


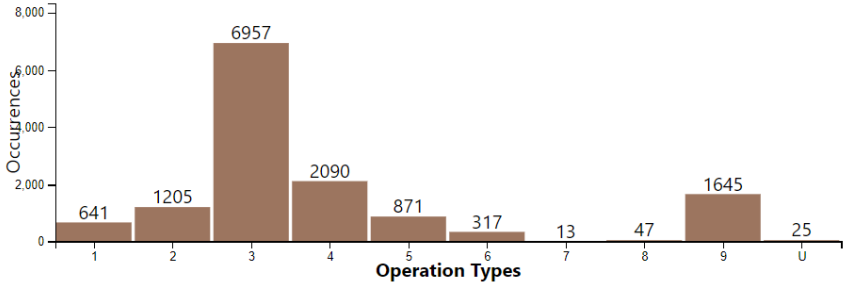
CAIRS Dashboard: Sample Print Screen (2/2)











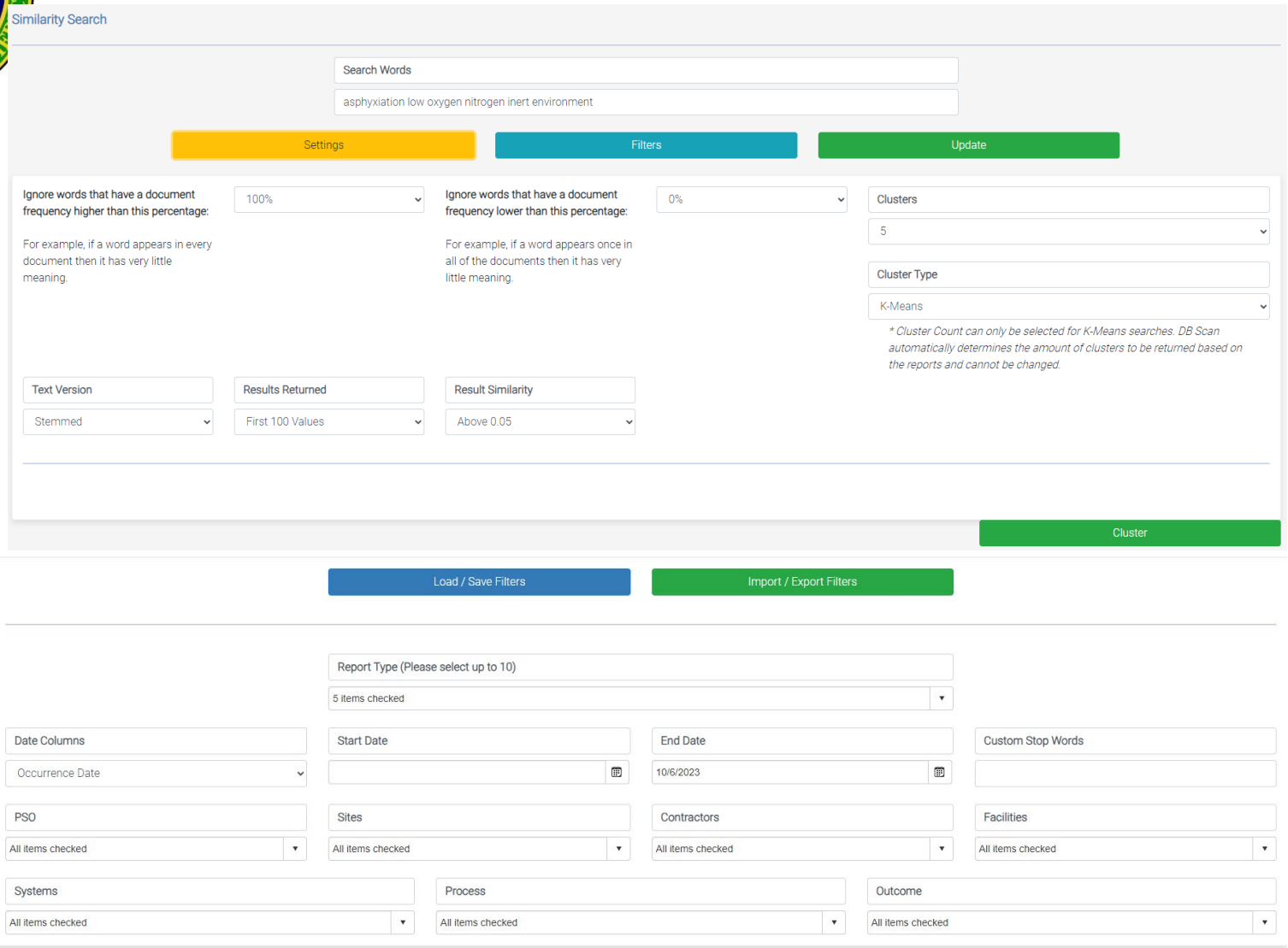
13,811 selected out of 13,811 records. Reset All

Excel Print

Search:

Event ID	Site	Report Name	System	Process	Outcome	Date
145844	SNLA	SCIENTIST experienced COVID-19 to his/her BODY SYSTEMS resulting in 0 Days away from work and 2 Days of job transfer or restriction.	S99	P99	O03	2023
145843	SNLA	ENGINEER experienced COVID-19 to his/her BODY SYSTEMS resulting in 0 Days away from work and 6 Days of job transfer or restriction.	S99	P99	O03	2023

Similarity Search: Print Screen (1/2)



Similarity Search: Print Screen (2/2)

Similarity Search Top Results

Report Type	Report Name	Rank
ORPS Corrective Actions	NA--NPO-CNS-Y12NSC-2015-0019 LCO Entry and Management Concern Due to High Oxygen Levels at Dust DumpStation	0.25
ORPS Corrective Actions	NA--YSO-BWXT-Y12NUCLEAR-2007-0025 Sparks were observed during a maintenance operation involving a machine dust collector.	0.20
ORPS HQ Summary	NA--LASO-LANL-NUCSAFGRDS-2019-0003 Near Miss: Worker Enters Room During Low Oxygen Alarm Activation	0.19
ORPS Corrective Actions	NA--LASO-LANL-PHYSCOMPLX-2017-0001 Near Miss: Worker Enters Room During Low Oxygen Alarm Activation	0.16
OPEXShare Lessons Learned	Confined Space Injury and Fatality	0.15
ORPS Corrective Actions	NA--LASO-LANL-TRITFACILS-2011-0013 Management Concern: Recommendation to Install Oxygen Monitors Not Implemented	0.15
ORPS HQ Summary	SC--ASO-ANLE-ANLENOD-2014-0002 Failure of the AGHCF Area 3 Oxygen Analyzer Sub-system	0.15
DNFSB	Oak Ridge Activity Report for Week Ending August 6, 2021	0.15
ORPS HQ Summary	NA--SS-SNL-5000-2004-0002 Evacuation of Building 890 Due to Nitrogen Leak	0.14
ORPS HQ Summary	NA--SRSO-SRNS-TRIT-2010-0002 Missed Glovebox Oxygen Alternate Monitoring Reading	0.14

« ‹ 1 2 3 4 5 6 7 8 9 10 › » Page size: 10 ▾ 100 items in 10 pages

Export Columns

All items checked ▾

Export

Text Clustering: Print Screen (1/2)

Cluster Dashboard

Settings | Filters | Update

Ignore words that have a document frequency higher than this percentage: 95%

For example, if a word appears in every document then it has very little meaning.

Ignore words that have a document frequency lower than this percentage: 5%

For example, if a word appears once in all of the documents then it has very little meaning.

Clusters: 5

Cluster Type: K-Means

** Cluster Count can only be selected for K-Means searches. DBSCAN automatically determines the amount of clusters to be returned based on the reports and cannot be changed.*

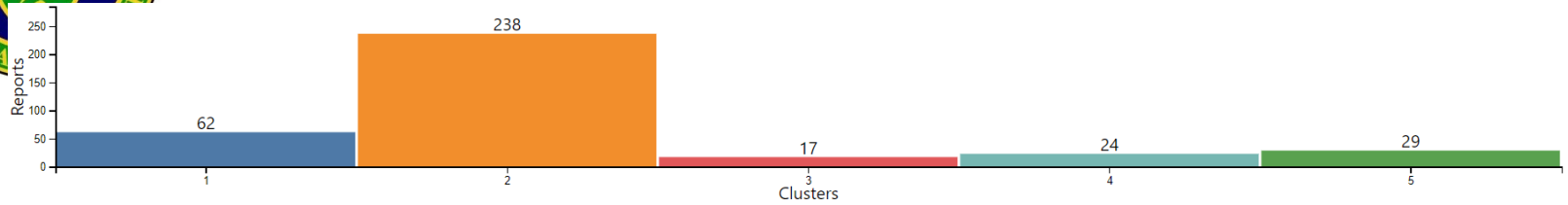
Date Type: Occurrence Date

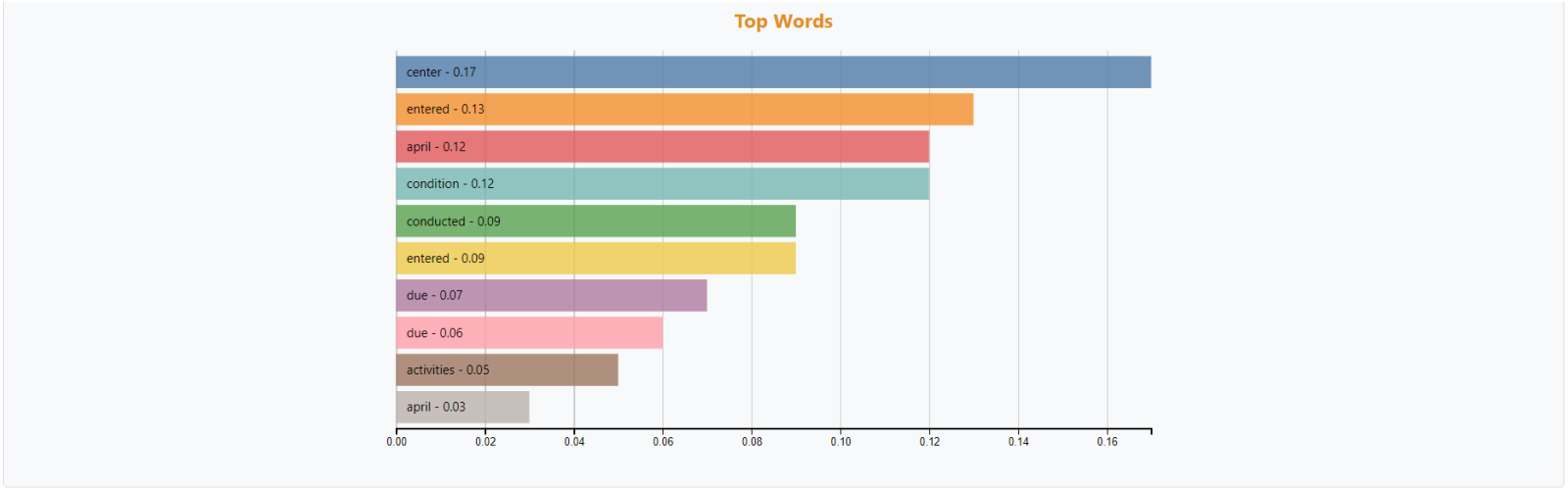
Report Type	Start Date	End Date	Custom Stop Words (comma separated)
All items checked	4/1/2023	5/1/2023	

PSO	Sites	Contractors	Facilities
All items checked	All items checked	All items checked	All items checked

Systems	Process	Outcomes
All items checked	All items checked	All items checked

Text Clustering: Print Screen (2/2)





Show Top Word Charts

Select cluster(s) to Re-Cluster:

**At least 5 Reports are needed to Re-Cluster*

Re-Cluster

79 selected out of 370 records. Reset All

Name	Cluster	Topics	Date
EM-SR--SRMC-SWPF-2023-0002 - Fire in Bus Duct between XFMR-103 & SWGR-203 resulting with a Loss ofProcess Vessel Vent System	3	('fire', '0.65'), ('system', '0.29'), ('center', '0.17'), ('lco', '0.12'), ('operation', '0.11'), ('reported', '0.10'), ('manager', '0.09'), ('entered', '0.09'), ('event', '0.08'), ('limiting', '0.07')	2023-04-20
EM-SR--SRMC-SWPF-2023-0002 - Fire in Bus Duct between XFMR-103 & SWGR-203 resulting with a Loss ofProcess Vessel Vent System	1	('safety', '0.24'), ('system', '0.15'), ('entered', '0.13'), ('management', '0.13'), ('april', '0.12'), ('condition', '0.12'), ('lco', '0.12'), ('operations', '0.10'), ('event', '0.09'), ('conducted', '0.09')	2023-04-20

DAMaL Tools Data Export

DAMaL Tools
Example Data Features

- Various DAMaL tools' dashboards allow exporting data.
  - High level data features include date range, PSO, Sites, Contractors, Facilities
  - Dataset specific features

- ORPS specific features include report title and number, reporting criteria, reporting level, cause codes, HQ Summary, etc.

ORPS and DOE OPEXShare Sample Data

ORPS

ID, Urls, and Titles
ORPS Number
Occurrence Id
ORPS Title
ORPS Link

Dates
OccurrenceDate
ReportingDate
FinalDate

Categorical Values
Cause Codes
Reporting Criteria
Keywords
Activity Category
Facility Function
Significance Category
Reporting Level

Entity and Organization
PSO
Site
Contractor
Facility

Text and Narratives
HQ Summary
Description Of Occurrence
Immediate Actions Taken
Description Of Cause
Evaluation By FM
Lessons Learned

SPO
System Tags
Process Tags
Outcome Tags

DOE OPEXShare

ID, Urls, and Titles
Report Name
Url

Dates
ReportDate
OccurrenceDate
ReportingDate
LastModifiedDate

Categorical Values
Report Type Name
Topics

Entity and Organization
PSOName
Department
Location
Company
Entity

Text and Narratives
ReportText

SPO
System Tag Name
Process Tag Name
Outcome Tag Name

System Process Outcome (SPO) Framework

DAMaL Tools
SPO Framework

- System Process and Outcome (SPO) framework was designed to provide another dimension to the data and increase its usefulness.

- Framework characteristics:
  - Organized in order of significance/importance
    - For example, System01 (e.g., S01) was determined to be more important than the S02, S02 more important than S03 and so on until S99.
  - SPO assignment based on ORPS keywords

- The ORPS SPO data is used as training data for SPO classification of non-ORPS data.

Sample ORPS Keywords (see Users Guide for the latest version)

Key Words

1. Work Planning and Control Deficiencies		2. Environmental	3. Fire Protection & Explosives Safety	4. Instrumentation/Controls	5. Mechanical/Structural
A. Inadequate Conduct of Ops (Retired) B. Loss of Configuration Management/Control C. Violation of AB Elements D. Missed/Late Surveillance E. Facility Operations Procedure Noncompliance F. Training Deficiency G. Inadequate Procedure H. Inadequate Safety Analysis/USQ/TSR I. Safety System Actuation/Evacuation J. Criticality Procedure Noncompliance	K. LOTO Noncompliance (Elect) L. LOTO Noncompliance (Other) M. Inadequate Job Planning (Electrical) N. Inadequate Job Planning (Other) O. Inadequate Maintenance P. Inadequate Oral Communication Q. Personnel Error R. Management Issues S. Incorrect/Inadequate Installation T. Willful Violation U. Unplanned Interruption of Operations	A. Radioactive Release B. Underground Storage Tank Release C. Compliance Notification (from regulator with a violation) D. Compliance Notification (to regulator without a violation) E. Hazardous Material Release F. Potable Water Release	A. Fire Protection Equip Degradation B. Fire Suppression Actuation C. Facility Fire D. Explosives Safety Issue E. National Fire Protection Association (NFPA) Code/Fire Protection Issue F. Explosion G. Wildland Fire	A. I & C Equipment B. Criticality Equipment C. Monitor/Analyzer D. Computer Software E. Computer Hardware	A. Freeze Protection Failure B. Seismic Qualification Deficiency C. Ventilation System/Fan D. Mechanical Equipment Failure/Damage E. Structural Deficiency/Failure F. Corrosion/Material Degradation/End of Life G. Glovebox Failure H. HEPA Filter I. Container/Package Failure

6. Radiological		7. Electrical Systems	8. OSHA Reportable/Industrial Hygiene		9. Safeguards/Security Issue
A. Clothing Contamination B. Facility/Equip/ Site Contamination C. Skin Contamination D. Airborne Radiological Release E. Radiological Control Procedure Noncompliance F. External Exposure G. Intake	H. Inadequate Radiological Control Job Planning I. Radiological Control Training Deficiency J. Inadequate Radiological Control Procedure K. Offsite Spread of Contamination	A. Emergency or Backup Generator Failure B. Electrical Distribution C. Power Outage D. Electrical Wiring E. Electrical Equipment Failure F. Arc Flash	A. Electrical Shock B. Indoor Air Contamination C. Industrial Hygiene Exposure D. Injury E. Fatality F. Industrial Operations Issues (Retired) G. Industrial Equipment H. Safety Noncompliance I. Safety Equipment Failure J. Near miss (Electrical)	K. Near miss (Other) L. Notice of Violation or Non-Compliance M. Chemical Safety N. Laser Safety O. Construction/Demolition Safety P. Hoisting/Rigging Incident Q. Forklift/Hand Truck Incident R. Excavations/Penetrations S. Landscaping/Mowing T. Beryllium Incident	A. Fitness for Duty Issue B. Material Accountability Issue C. Miscellaneous Security Issue D. Theft/ Sabotage

10. Transportation	11. Other	12. EH Categories (select only one)	13. Management Concerns	14. Quality Assurance
A. Shipping Regulation Noncompliance B. Vehicle Accident/Incident C. Industrial Equipment Movement Incident D. Transportation Notice of Violation or Non-Compliance from Local, State or Federal Agency E. Shipping Incidents/Accidents	A. Chemical Reaction/Pressurized Drum B. Emergency Management System Failure C. Nuclear Weapons Safety Issue D. Natural Phenomena E. Suspect/Counterfeit Items F. Inadequate Design G. Subcontractor H. Procurement Deficiency/Defective Items I. Visiting Scientist/Researcher or Student Employee J. Tenants on DOE Property K. Excessed Equipment/Material L. Supplier M. Outside Agency or Organization/ Site Visitor N. Nuclear Waste Handling Operations	A. Authorization Basis B. Conduct of Operations C. Electrical Safety D. Environmental Release/Compliance E. Equipment Degradation/Failure F. Fire Protection & Explosive Safety G. Industrial Operation H. Injuries Requiring Medical Treatment Other Than First Aid I. Lockout/Tagout (Electrical & Mechanical) J. OS/IH K. Near Miss (Electrical & Mechanical) L. Nuclear Criticality Safety Concerns M. Radiological Control N. Rad. Skin Contaminations/Uptakes/ Overexposures O. Safeguards & Security P. Shipping QA Q. Vehicular Accidents R. Suspect/Counterfeit Items – Defective Items Z. Other than Above	A. HQ Significant B. Accident Investigation - Type A (Retired) C. Accident Investigation - Type B (Retired) D. Accident Investigation – Other E. Facility Call Sheet F. Operating Experience Summary Article G. Suspect/Counterfeit Items - Defective Items Data Collection Sheet H. ARRA - American Recovery and Reinvestment Act (Retired)	A. Program Deficiency B. Training & Qualification Deficiency C. Quality Improvement Deficiency D. Documents & Records Deficiency E. Work Process Deficiency F. Design Deficiency G. Procurement Deficiency H. Inspection & Acceptance Testing Deficiency I. Management Assessment Deficiency J. Independent Assessment Deficiency K. Safety Software Deficiency L. No QA Deficiency

ORPS Reporting Training: https://orpspublic.doe.gov/, https://www.energy.gov/sites/prod/files/2017/08/f36/232_2A_ORPS_Training_Module_1.pdf

System, Process and Outcome Codes

*See the DAMaL users guide for full list and categorization.

Systems

S01 - Nuclear Weapon Operations
S02 - Nuclear Waste or Remediation Operations
S03 - Nuclear Safety Operations
S04 - Radiological Control Operations
S05 - Explosive Safety Operations
S06 - Electrical Safety/Systems
S07 - Fire Protection System
S08 - Emergency Management Ops
S09 - Shipping/Transportation Ops
S10 - Material Handling Ops
S11 - Security/Protective Forces Operations
S12 - Laboratory and Research Ops
S13 - Storage Tank Systems
S14 - Construction/Demolition Ops
S15 - Utilities (non-Electrical)
S16 – Industrial Operations
S17 - Balance of Plant (other)/Office Ops
S99 - Undefined or Unknown Operations

Process

P01 - Property/ Equipment/ Material Disposition Management LTA
P02 - Packaging and Containers LTA
P03 - Authorization Basis Compliance LTA
P04 - Supply Chain Management LTA
P05 - Design LTA
P06 - Configuration Management LTA
P07 - Job Planning LTA
P08 - Procedure Compliance LTA
P09 - Surveillance Maintenance LTA
P10 - Training LTA
P11 - Quality Control/Supervision LTA
P12 - Vehicle Movement LTA
P99 - Other Work Process Are or Unknown

Outcomes

O01 - Injury, Illness, Medical Treatment, or Fatalities
O02 - Personnel Radiation Exposure/ Uptake/ Contact
O03 - Hazardous Energy or Material Exposure (non-rad)
O04 - Environmental Release (Hazmat, Rad, Water, etc.)
O05 - Energy Release: Fire, explosion, Chemical Reaction, over-pressurization
O06 - Equipment, Structural, Property, Damage, Failure
O07 - Radiological Contamination (loss of primary confinement)
O08 - Near Miss
O09 - Safety System Outage/ Actuation/ Evacuation
O10 - LCO Entered/ Operational Interruption/ Facility Shutdown
O11 - Specification Non-compliance or defective part or Suspect or Counterfeit Part
O12 - Nuclear Safety/Safeguards Vulnerability
O13 - Operational Safety Vulnerability
O14 – Notice of Violation or Noncompliance
O99 – Other Impacts or Unknown

Outcome Definition Examples

Keyword Examples

Injury, Illness, Medical Treatment, Fatalities
- 08A - Electrical Shock
- 08E - Fatality
- 08D - Injury

Energy Release (fire, explosion, over-pressurization, etc.)
- 03 – Facility Fire
- 03F - Explosion
- 03G - Wildland Fire
- 11A - Chemical Reaction/Pressurized Drum

Near Miss
- 08J - Near Miss (electrical)
- 08K - Near Miss (other)

Nuclear Safety/Safeguards Vulnerability
- 01C - Violation of AB element
- 01H - Inadequate Safety Analysis
- 01J - Criticality Procedures Noncompliance
- 09B - Material Unaccountability
- 11C - Nuclear Weapons
- 11N - Nuclear Waste Handling Ops

Outcomes

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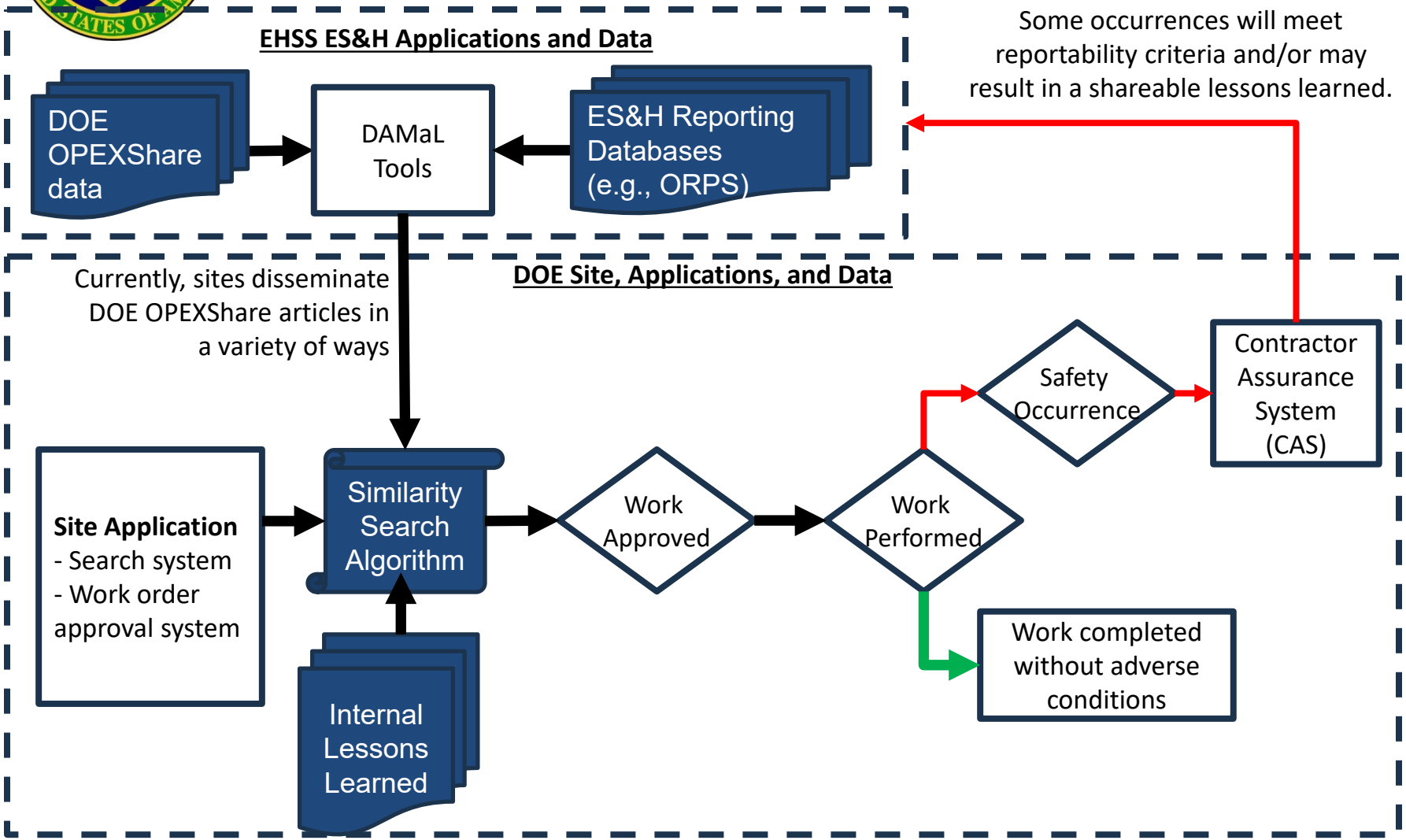
DAMaL tools Application Programming Interface (API) and DOE Site Use Cases

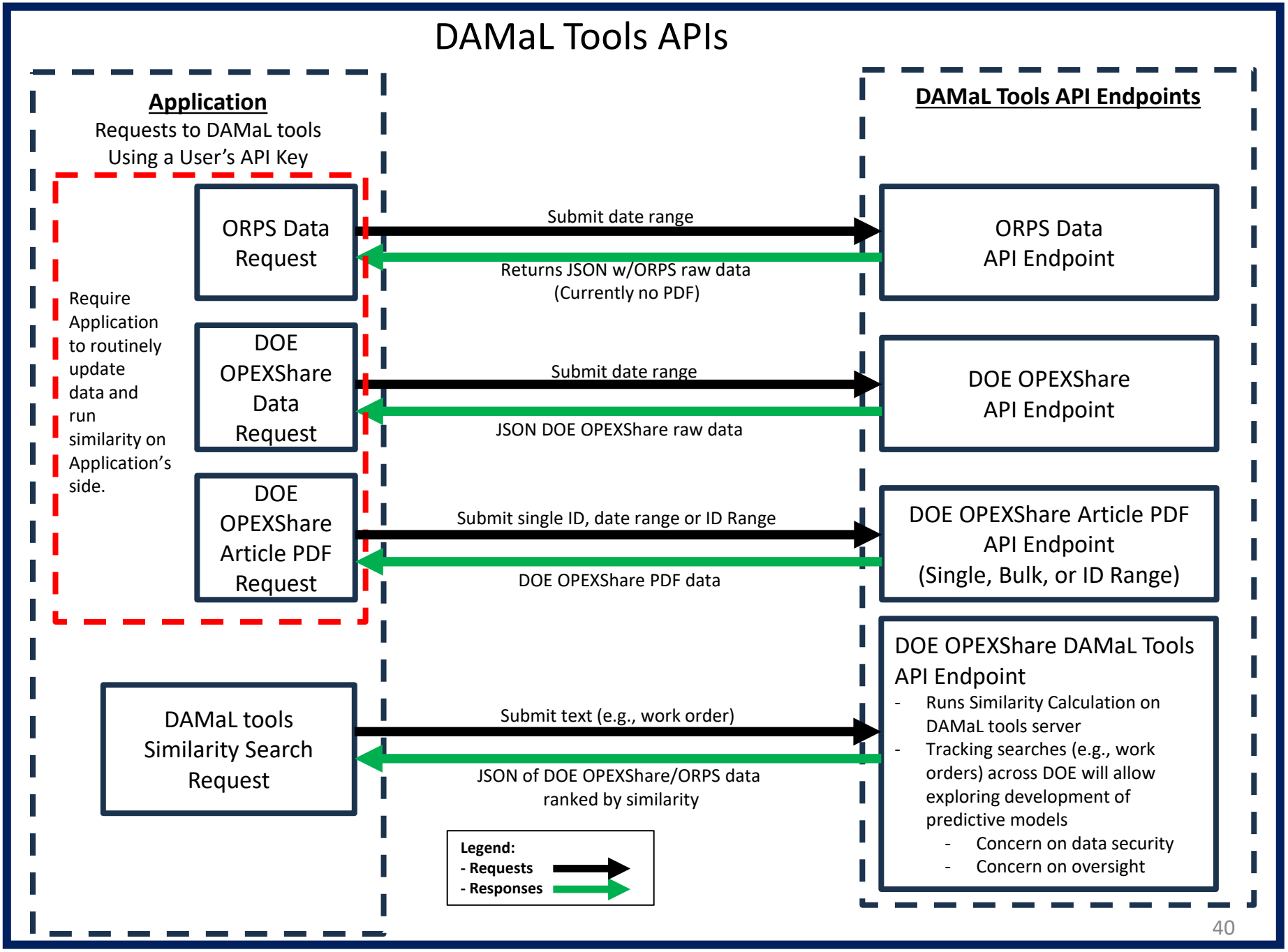
DAMaL Tools API

- Collaboration between Laboratory Operations Board (LOB), Idaho National Laboratory (INL), Argonne National Laboratory (ANL), and EHSS.
- Initial scope was to develop the capability to use AI algorithms to identify and share lessons learned within DOE ES&H data.
- DAMaL tools API allows data to be sent to an external system (e.g., at a site)
  - Combine DAMaL tools data with site internal data
  - Use the data with site search and analytical systems
- Limited to ORPS and DOE OPEXShare data found in the DAMaL Tools.

Use Case: Automating Similarity Searching of ES&H Lessons Learned



DAMaL Tools APIs



Resources and Next Steps

- DAMaL tools and API key:
  - Requires DAMaL tools account
  - API Key requires requesting organization to sign an interconnectivity security agreement
  - DAMaL tools API Python guide available
  - Example of open-source similarity search Python code also available upon request
  - DAMaL tools account and API key requests to project manager

- INL Similarity Search code:
  - Available via Docker Container
  - Requires requesting organization sign a code sharing agreement
  - Requires coordination with INL for obtaining similarity search code

- POC: Felix Gonzalez (Felix.Gonzalez@hq.doe.gov)

DAMaL Tools, Data Science and Emerging Technologies

DAMaL Tools, Data Science and Emerging Technologies

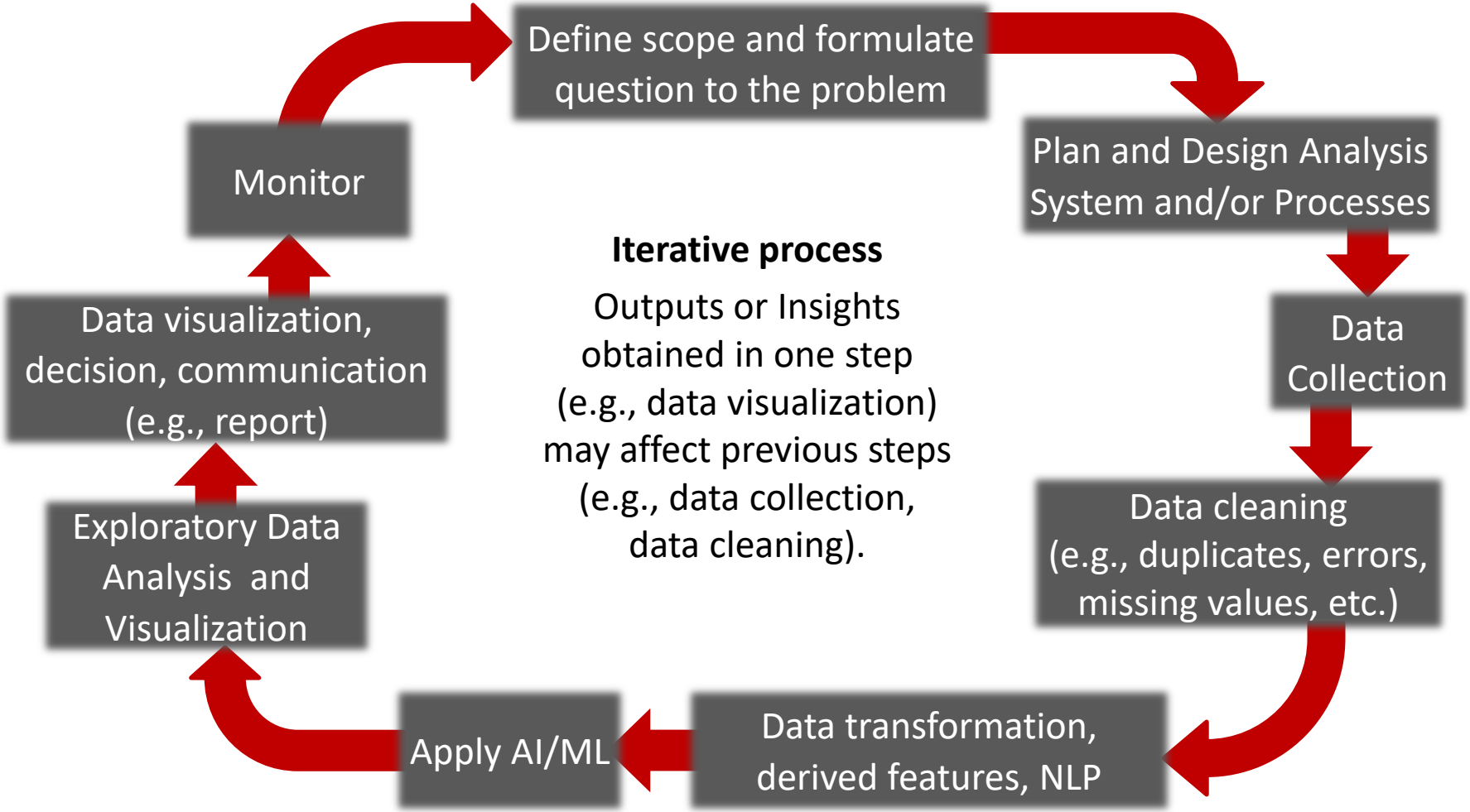
- **Data Science**: Unification of data analytics, AI, ML, NLP, big data and more to analyze and obtain insights from data.

- **Emerging Technologies** per S.1605 - National Defense Authorization Act for Fiscal Year 2022, 117th Congress (2021-2022), Public Law 81:

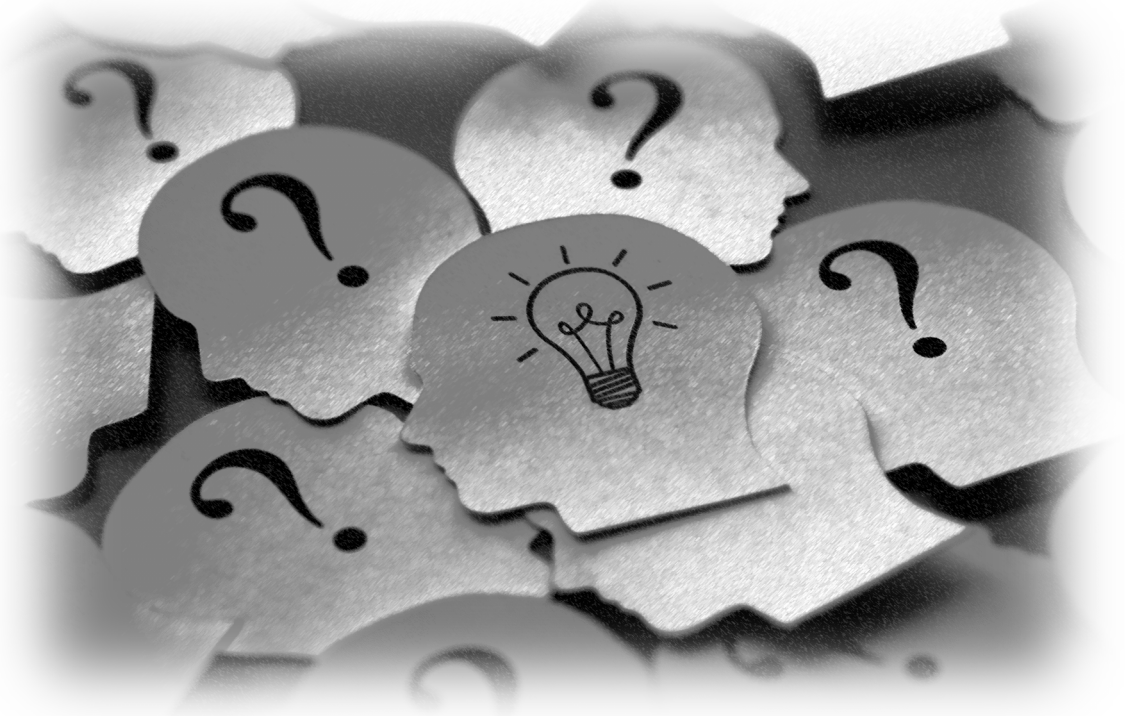
  > "The term **emerging technology** means technology jointly determined to **be in an emerging phase of development** by the Secretary of Defense and the Director of National Intelligence, including quantum information science and technology, **data analytics, artificial intelligence, autonomous technology**, advanced materials, **software, high performance computing, robotics,** directed energy, hypersonics, biotechnology, medical technologies, and such other technology as may be jointly identified by the Secretary and the Director."

- The DAMaL tools leverage approaches and algorithms that have been found to be useful and provide insights in ES&H data.

Overview of Typical Data Analysis and Data Science Problem Process



Q&A and Open Discussion



For questions and access contact

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Office of Environment, Health, Safety and Security

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