FUELS KNOWLEDGE GRAPH PROJECT

Chief Data Officer Council Sponsored

April – October 2021

U.S. Forest Service and Larimer County CO prescribed burn to reduce hazardous fuels.

Acknowledgments

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- US Department of the Interior
- US Department of Agriculture
- National Park Service
- California Department of Forestry and Fire Protection (CalFire)

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Executive Summary

The Fuels Knowledge Graph Project (FKGP), funded through the Federal Chief Data Officers (CDO) Council, explored the use of knowledge graphs to achieve more consistent and reliable fuel management performance measures. The team hypothesized that better performance measures and an interoperable semantic framework could enhance the ability to understand wildfires and, ultimately, improve outcomes. To develop a more systematic and robust characterization of program outcomes, the FKGP team compiled, reviewed, and analyzed multiple agency glossaries and data sources. The team examined the relationships between them, while documenting the data management necessary for a successful fuels management program.

The strategic management of burnable vegetation (fuels) before a wildfire occurs is a cost-effective approach to reduce the negative effects of wildfires on highly valued resources and assets. Department of the Interior (DOI) and United States Department of Agriculture Forest Service (USDA FS) carry out fuels management projects in collaboration with multiple partners, including other federal agencies, tribes, states, counties, local organizations, and private landowners.

Figure 1: Example Glossaries Collected

- WF-FKG APA WUI Planning
- WF-FKG Australia Bushfront Fire Glossary
- WF-FKG CA-SF Openspace Org WFRP Glossary
- WF-FKG CALFIRE Glossaries
- WF-FKG Canada Ontario Forest Fire Glossary
- WF-FKG DOI-FS Forests and Rangelands Fire Terms
- WF-FKG Data Governance
- WF-FKG FEIS Fire Effects Info System Glossary
- WF-FKG IFTDSS Glossary
- WF-FKG NFPA
- WF-FKG NFPORS Glossary
- WF-FKG NPS-PWR-SEKI Fire Terms

Fuels management is coordinated across natural resource management agencies and stakeholders to mitigate wildfire risks and ensure projects are l regulatory compliant. Agency specialists plan, implement, and monitor fuels management projects to reduce wildfire risk and achieve priority land management objectives. Specialists use a variety of active management practices, including prescribed fire, mechanical or other methods to achieve specific landscape goals. The interagency wildland fire community supports implementing fuels management work to support the Cohesive Strategy Goals: fire-adapted communities, resilient landscapes, and safe and effective wildfire response.

The ability to reliably monitor, understand, and communicate the effectiveness of fuels treatment projects in terms of wildfire outcomes is critical to the interagency wildland fuels management program. The FKGP supports efforts to consistently identify fuels management effectiveness across agencies and jurisdictions for planning, analysis, and reporting. A critical component of this effort is to clearly define and interpret technical and business terms, allowing stakeholders to communicate effectively.

Federal laws and guidelines require agencies' data to be transparent, accessible, and sufficient for policymaking and informing the public. This project combined fuels treatment effectiveness with data governance by developing a semantic framework for fuels management data based on the World Wide Web Consortium's (W3C) Standards for graph data.

Knowledge graphs capture the meaning or semantics of data, their relationship to other concepts, business rules, and data quality controls. The approach delivers shareable and reusable data with accessible semantics, business rules, and executable code, which humans and machines can understand. This data-centric approach significantly increases interoperability across the interagency wildland fire community. The governed use of these data elements enables the implementation of a well-orchestrated interagency data framework. In turn, this supports many applications across the interagency community, while providing metadata to overcome the challenge of aggregating data from multiple agencies.

Data management and governance in the complex, interagency wildland fire community requires precise terminology, documentation of agreements and concepts, and the ability to adjudicate related conflicts between agencies or business areas. A data governance overlay of established data stewards, roles, processes, polices, standards and metrics is necessary to achieve the real value of data catalogs, models, and knowledge graphs. The application of a semantic-based approach provided the ability to document, visualize, and manage data to support interagency activities.

To establish data interoperability and increase machine usability, the FKGP applied best practices to deconstruct the elements of the wildland fire datasets, map those elements to well-defined and clearly understood concepts and define how those concepts relate to each other in the real world. In knowledge graph terms, the team reviewed the datasets and mapped them to extensible ontologies and taxonomies within a semantic framework. A taxonomy is a grouping of items usually in a hierarchy that allows users and machines to search for things more broadly or narrowly. The team defined the hierarchical, structural, and semantic relationships between the program concepts and the representative data by peeling back layers of assumptions and ambiguity found across agency applications. As a result, the team's knowledge is captured for reuse through the graph.

This project demonstrates the operational value of implementing Federal Data Strategy principles and practices. It constructs an effective platform for managing and extracting value from interagency wildland fire data assets. The opportunities identified through this project will be incorporated in the Wildland Fire Information and Technology (WFIT) enterprise strategy to enable highly efficient operations and machine readability. The lessons learned will also be incorporated in the National Wildfire Coordinating Group Data Strategy to provide highly reliable data and improved mission insight.

Thomas Gruber, co-founder and Chief Technical Officer of Intraspect Software said, “Every ontology is a treaty—a social agreement—among people with some common motive in sharing.” Within the wildland fire community, one of the most powerful aspects of applying a knowledge graph is that it provides an intuitive model to engage the business in defining and documenting their own data. The knowledge graph is essentially a bridge between the business and IT which will result in better outcomes across the mission area.

Summary of Next Steps

- **Continue to improve outcomes and performance measures.** Restructuring existing data and improved data sharing capabilities will allow the national fuels programs to better represent outcomes, performance, and business value. This will assist The U.S. Department of Interior (DOI) with improved performance fuels metrics as it updates the Department's strategic plan and associated annual performance goals.

- **Redesign the National Fire Plan Operations and Reporting System (NFPORS).** A team of data management and technical subject matter experts are using newly compiled business requirements to design the data architecture and recommended technical capabilities for a data centric refresh of NFPORS Fuels, Community Assistance, and Burned Area Rehabilitation planning and reporting. Reference data sets identified and or developed on the FKGP will be further validated and matured for production in 2022.

- **Create consolidated organizational reference data set.** Utilize the organizational data models and reference data to consolidate two redundant databases into a single governed reference data set for wildland fire.

- **Collaborate with federal and state entities.** Collaborate with the National Association of State Foresters to share data on planned and completed fuels treatments. This collaboration facilitates the implementation of landscape-scale treatments, which improves protection for communities.

- **Build an incident position training assessment tool.** This assessment determines the type of training needed for a position to ensure safe incident operations. The assessment tool will take advantage of linked data and potentially enable automatic changes in linked products and data sets.

- **Facilitate automated data use**. Establish API connections for interoperability within the knowledge graph framework. This will facilitate more efficient application development as projects link to controlled vocabularies.

- **Expand knowledge.** Apply the lessons learned in this focus on the Fuels Business Subject Area to other areas in the wildland fire enterprise like Incident, Resources, Fire Weather, and Geospatial data.

- **Work with the CDO Council to identify opportunities for improving the format and accessibility of foundational data, such as federal agency organizational names, codes, and locations.**
    - For example, General Services Administration (GSA), Office of Personnel Management (OPM), Office of Management and Budget (OMB), USDA, DOI, United States Geological Survey (USGS), and the Census Bureau have organizational data. However, this data can be inconsistent and not easily accessible via a service in a machine-understandable format.

These tangible outcomes of the Fuels Knowledge Graph Project will provide value far into the future.

1. Project Overview

The Federal CDO Council funded the Fuels Knowledge Graph Project (FKGP). The vision of the CDO Council is to improve government mission achievement and increase the benefits to the Nation through improvement in the management, use, protection, dissemination, and generation of data in government decision-making and operations. The CDO Council provided a unique opportunity in this limited scale, but big picture project for a small group of staff and subject matter experts to work closely with experienced contractors, explore business and data concepts, and rapidly map out a case for implementing a well-governed knowledge graph framework.

This pilot project was funded to explore the general use of knowledge graph technology and its use in data governance. The use case for the pilot focused on wildland fire fuels management, involving the Department of the Interior and the Department of Agriculture Forest Service, in partnership with other state and federal land management agencies. A knowledge graph was developed, according to W3C standards, that encompasses the organizational and mission framework within which fuels management activities occur. An aspirational goal was to see if applying a knowledge graph could help refine or develop new performance measures.

The process of developing a knowledge graph resulted in new insights about wildland fire data. The Wildland Fire Information and Technology (WFIT) strategy talks about a “data-driven” program, but project teams lacked clarity on implementing the concept. Developing the knowledge graph provided a clear path for transitioning to managing data first, then building applications that use curated reference data and data services, highlighting the possibility of greater interoperability across the wildland fire interagency community.

The team spent many hours with subject matter experts from the wildland fire community to gather background information on the historical, organizational, and legal environment in which wildland fire fuels reduction and management programs operate. Building the organizational and legal structure models which relate to and provide a foundation to link to other areas of the data model also took considerable effort. Clear, consistent organizational information is critical in a multi-agency environment. Organizations act in various roles, from jurisdiction for land, to providing funding and resources, to reporting outputs and outcomes. Each federal, state, and tribal agency has its own office codes, and the wildland fire community assigns a National Wildfire Coordinating Group (NWCG) Unit ID as an interagency organization code. Without a master list of organizations, individual applications created their own list, including abbreviations or acronyms. This plethora of organizations and codes make it difficult for

Figure 2: NWCG Unit ID Database Collection

Data Asset	type
CONTENTS (UNITID.TEMP_EXPO...	Database Column
COST (UNITID.HTMLDB_PLAN_T...	Database Column
COUNTRY_ID (UNITID.UI_PENDI...	Database Column
COUNTRY_ID (UNITID.UI_UNIT)	Database Column
COUNTRY_ID (UNITID.UN_UNIT_...	Database Column

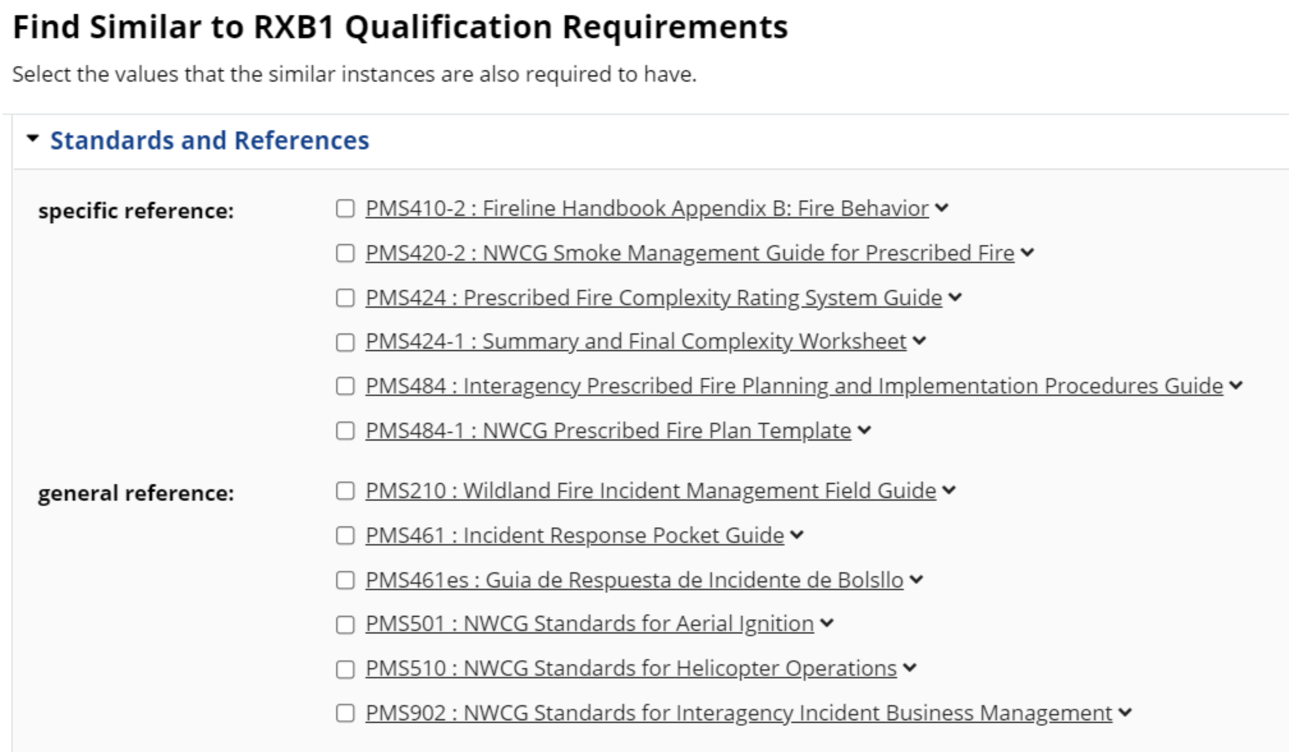
anyone but the closest insiders to understand who is involved and what their roles are. Documenting this type of complexity is an area where knowledge graphs shine.

As the project progressed, best practices were developed, key data sources were identified, APIs were tested, and data issues were brought to light. The products developed represent a solid start on the linked open data model with a noteworthy list of lessons learned and recommended next steps. The project demonstrated, through proof of concept, the use of the Top Quadrant Enterprise Data Governance (EDG) tool as a data governance-driven authoritative data set for national fuels management information. The project also explored querying the knowledge graph via HTTP link from a geospatial tool.

The power of clearly defined business terms and unambiguous controlled vocabularies became apparent as collections developed. Collections is the term used in EDG to represent a data group with similar functions or relationships. Out of the box collections include: Glossaries, Taxonomies, Data, or Technical Assets. The linked data model of prioritizing data reusability requires clearly defining and drilling down to the elemental level of terms and concepts and understanding the hierarchical and semantic relationships between them. This process required the business SMEs to step back and ask fundamental questions about what, how, and why the program does what it does. This can be uncomfortable when a clear answer isn't readily available, and each individual has to question their understanding of "commonly known" concepts. Because knowledge graphs were a new concept for many of the SMEs, it provided an opportunity for people to be curious and explore business concepts in a new way. The flexibility of a knowledge graph allows concepts to be linked with a clear, representative relationship such as "exact match" or "related." This ability to relate very similar concepts instead of imposing agreement on a single description provides space that makes it much easier for federal and state agencies to describe what their data means to them. It is much easier to share data when agencies are confident that their data is understood and will be used appropriately through documented rules.

Data management and governance in the complex, interagency wildland fire community requires clear terminology, documentation of agreements and concepts, and the ability to adjudicate conflicts when definitions or understandings of concepts don't align between agencies or business areas. Data catalogs, models, and knowledge graphs must be combined with a governance overlay of established stewards, roles, processes, policies, standards, and metrics for effective implementation. Governance models built into the fully extensible RDF standard EDG collection framework provide an ideal base model for government staff to collaborate, extend and implement governance solutions over their highly interdependent datasets, without inherent costs, limitations, or opacity associated with proprietary solutions. This approach aligns perfectly with the Open Data Act, and based on the project team's experience, the value of this approach cannot be overstated.

Figure 3: Linking standards to Prescribed Fire position



The wildland fire community was a great environment to explore new tools to support data governance because governance structures already exist within the National Wildfire Coordinating Group (NWCG). They establish interagency standards for wildland fire operations, qualifications, and training. This means the culture already values standards and has a general framework for data and information. Implementing data governance is often more about cultural change than technology. However, one opportunity that arises from mapping out the inter-relationships between systems and concepts in a governed knowledge graph, is that the diagrammatic vision is available for everyone to see and share and to identify where the gaps in our understanding are. All stakeholders have the concept plan as a map for reference, making the pieces of the puzzle visible to all parties. The business and data stewards within wildland fire have had very positive reactions to viewing their "universe" in a graph and immediately understand how it can help them navigate complex relationships across the program. There is tremendous power in the aligned conceptual vision a knowledge graph provides.

For years, the fire community has tried to integrate data through data exchange services and various warehouse efforts. Today, it is clear that for data interoperability, semantic correctness far outweighs physical proximity. In other words, it is far more important that integrated data elements are aligned semantically and unambiguously than it is for the disparate data to be co-located. Rather than aligning one dataset to the next and so on, our recommended approach is to semantically align all interoperable datasets to core extensible ontologies. Offering a service as a connection to other applications by exposing an application programming interface (API) of metadata models and controlled vocabularies is a powerful opportunity revealed by this pilot.

This project was an extensive learning opportunity and generated healthy seeds that will be instrumental in growing the operational value of implementing Federal Data Strategy principles and practices. The opportunities identified through this project will be incorporated in the Wildland Fire Information and Technology (WFIT) enterprise strategy to enable highly efficient operations and machine readability. The NWCG Data Strategy will provide highly reliable data and improved mission insight.

The proposed next steps involve maturing interagency data governance and processes to implement the data framework designed here. There are four significant efforts that will directly benefit from the FKGP.

- For the DOI Office of Wildland Fire, the lessons learned on this project will significantly impact the complete redesign and development of a new fuels treatment planning and reporting application. This redesign will incorporate the use of governed metadata models and controlled vocabularies via an application programming interface (API).

- The DOI, USDA FS, and National Association of State Foresters are collaborating to develop a Shared Wildfire Risk Mitigation (SWRM) visualization tool to facilitate open planning and sharing of completed treatment data. The SWRM project team is coordinating with the WF Data Management Program team to ensure they use the same glossaries, reference data and controlled vocabularies. The outputs of SWRM will also be cataloged in the WF Enterprise Data Governance tool.

- The Data Graph Module used to explore a graph version of the National Fire Plan Operations and Reporting System (NFPORS) is being applied to wildland fire incident position training assessments. This assessment is currently calculated in a massive excel spreadsheet. The use of a Data Graph will create a linked data application that applies reusable vocabularies and taxonomies and calculates an assessment score. The assessment uses data that exists in operational and incident position standards already in a knowledge graph.

- Currently, there are two national databases dedicated to wildland fire organizational data. The NWCG Data Management Committee will use the organizational taxonomies developed on the FKGP to consolidate the data into a single reference data set. This will provide a single source of organizational data for all interagency wildland fire applications and ensure interagency wildfire and fuels data clearly represents all partners' organizations and roles.

These tangible outcomes of the Fuels Knowledge Graph Project will continue to provide value far into the future. Developing a knowledge graph resulted in new insights about wildland fire data. The Wildland Fire Information and Technology (WFIT) strategy references data-driven approaches; however, project teams did not know how to implement the concept. Developing the knowledge graph provided a clear path for transitioning to a data-centric approach, where data is managed and understood first, and then applications get built using curated reference data and data services. This data-centric approach will lower technology costs, improve consistency of information, and enable new mission insights through greater interoperability across the wildland fire interagency community.

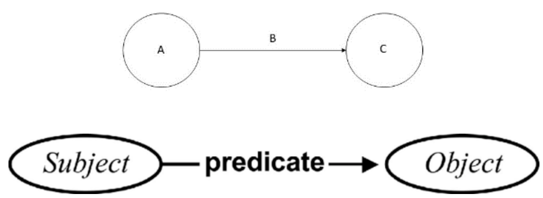
2. Technical Appendix
2.1 Knowledge Graphs

A simplified view of a graph approach decomposes database tables into their unique values for each data element (domains), then independently connects those elements to each other via relationship properties.

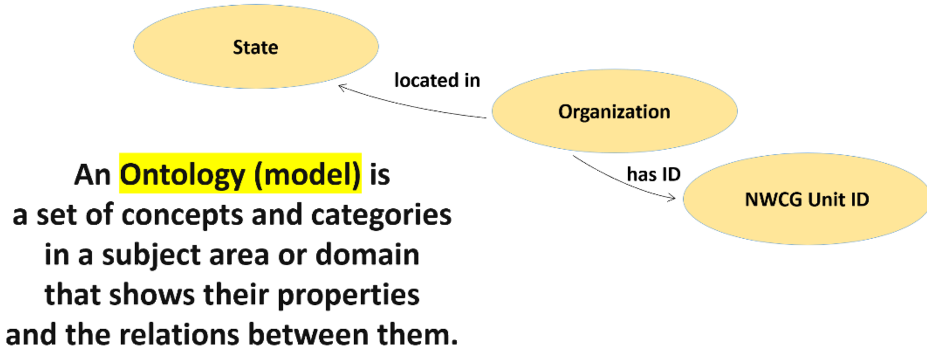
Each subject-predicate-object relationship forms a triple. See Figure 4 below.

Figure 4: Subject-Predicate-Object Information Chart

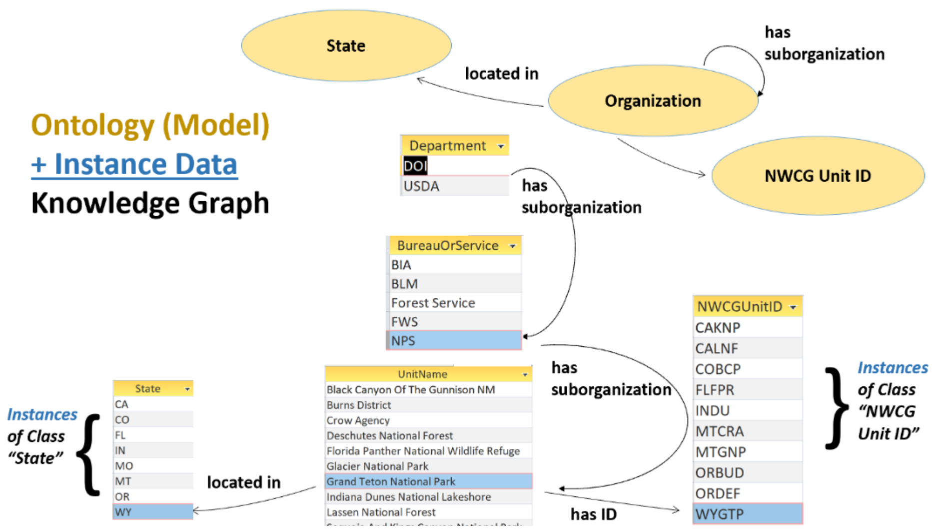
Subject	***Predicate***	**Object**
Organization	***has code***	**NWCG UnitID**
Department	***has suborganization***	**Bureau or Service**
Organization	***is located in***	**State**



NFPORSID	Department	BureauOrService	UnitName	UnitCode	Category	NWCGUnitID	TreatmentType	State	Acres
6285793	DOI	NPS	Indiana Dunes National Lakeshore	YOSE	Fire	INDU	Broadcast Burn	IN	180
6332123	DOI	NPS	Black Canyon Of The Gunnison NM	BLCA	Mechanical	COBCP	Thinning	CO	4
6276004	DOI	NPS	Grand Teton National Park	GRTE	Mechanical	WYGTP	Biomass Removal	WY	36
6314226	DOI	NPS	Sequoia And Kings Canyon National Park	SEKI	Fire	CAKNP	Broadcast Burn	CA	216
3318438	DOI	FWS	Florida Panther National Wildlife Refuge	41545	Mechanical	FLFPR	Mastication/Mowing	FL	0
3213671	DOI	BLM	Burns District	OR02000	Mechanical	ORBUD	Thinning	OR	12
3144886	DOI	BIA	Crow Agency	C52	Fire	MTCRA	Broadcast Burn	MO	382
3035828010602	USDA	Forest Service	Lassen National Forest	6	Fire	CALNF	Broadcast Burn	CA	150
5543783010602	USDA	Forest Service	Deschutes National Forest	1	Mechanical	ORDEF	Crushing	OR	210
6276016	DOI	NPS	Glacier National Park	GLAC	Mechanical	MTGNP	Lop and Scatter	MT	10
6263451010602	USDA	Forest Service	Lassen National Forest	6	Mechanical	CALNF	Thinning	CA	76
3314611	DOI	NPS	Grand Teton National Park	GRTE	Other	WYGTP	Chemical	WY	476



An Ontology is the model for a Graph Data Structure. Concepts and categories in a subject area or domain are "Classes" in the Graph model.



"Classes" have "properties" including labels, identifiers, definitions, and specific relationships to other classes.

Figure 5: Properties and Glossary Terms

"Broadcast Burn" is an instance of Class "TreatmentType" which has a relationship property "glossary term definition" which links to an instance of class "Glossary Term" in another graph.

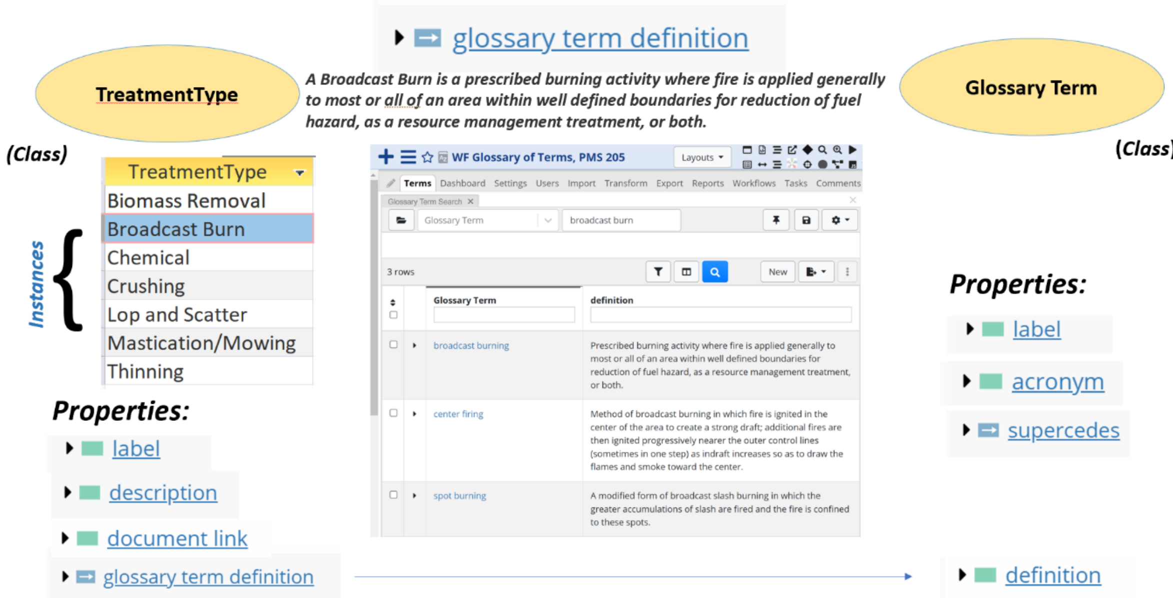
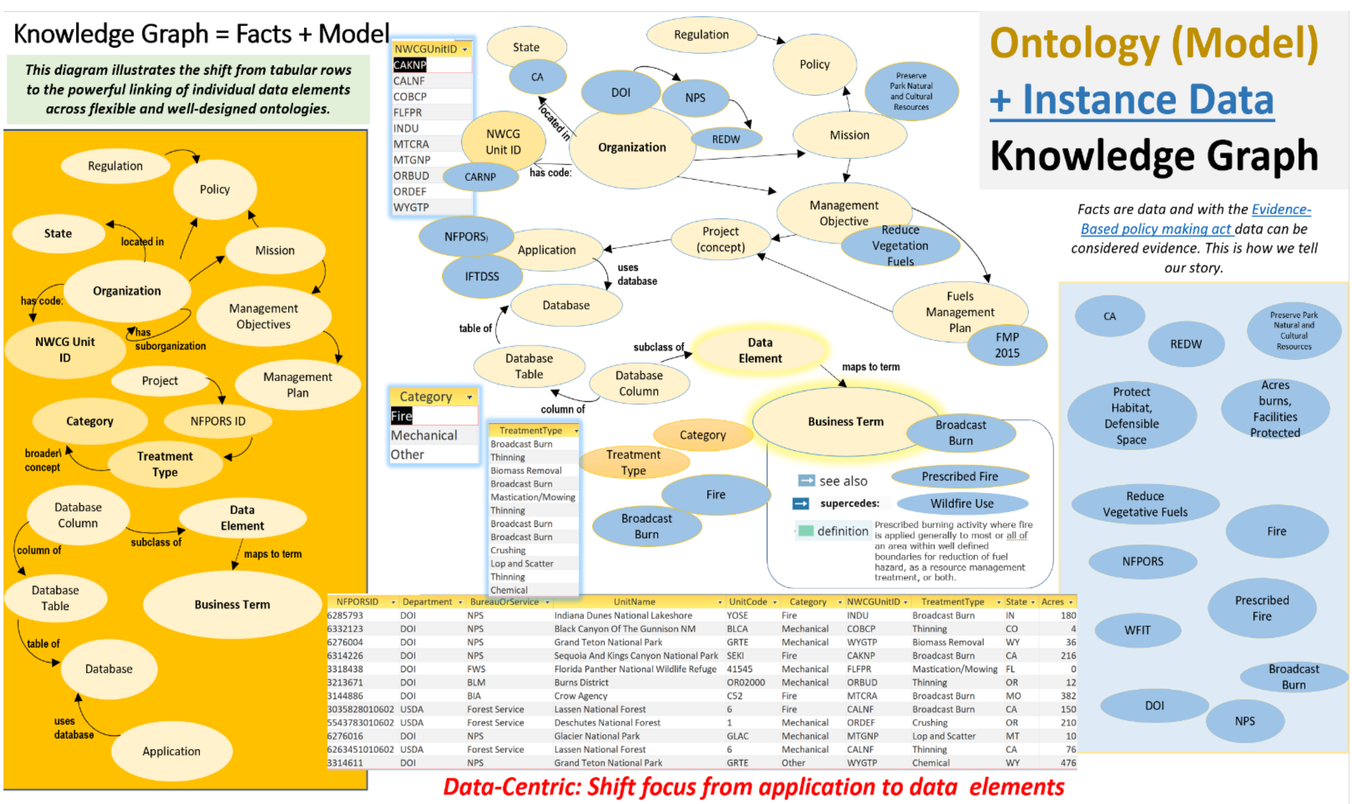


Figure 6: Knowledge Graph = Facts (Instances) + Model (Ontology)



These are the steps needed to govern, connect, and reuse semantically rich data:

- Identify reference data, how it is used by different system(s), and associated properties required by various systems.
- Establish governance over-controlled vocabularies (taxonomies, reference datasets, enumerations, glossaries) as graphs.
- Link these controlled vocabularies within an extensible knowledge graph framework.
- Share and deliver external system access to the semantic services via flexible and scalable APIs.
- Work with stakeholders and extend the governed Federal knowledge graph framework.

2.2 A Data-Centric Approach

Federal Data Strategy principles and practices support the view of data as a strategic asset and a paradigm shift from an *application-centric* towards a governed interagency *data-centric* approach to Federal systems.

Figure 7: Data-Centric vs Application-Centric

Application-Centric	Data-Centric
Business rules and semantics are hard coded in the application.	Data can be "active" ***(accessible without modification or reconstruction)*** with accessible semantics, business rules, and executable code.
Focus and intelligence are built into the application which is of primary importance.	Applications are "model-driven".
Data is of secondary importance, with data sharing between applications requiring subsequent effort.	Data is the main asset, inherently shareable.
Data models can't be understood without the application's logic.	Data is self-describing as it includes the metadata needed to interpret the data stream.
Often an application steward involvement is often required for data consumer to find, access, and understand the data.	Data consumers can find, access, and understand the data (without the presence of the data owner or system admin).
Rigid data models.	Flexible and evolvable data models.

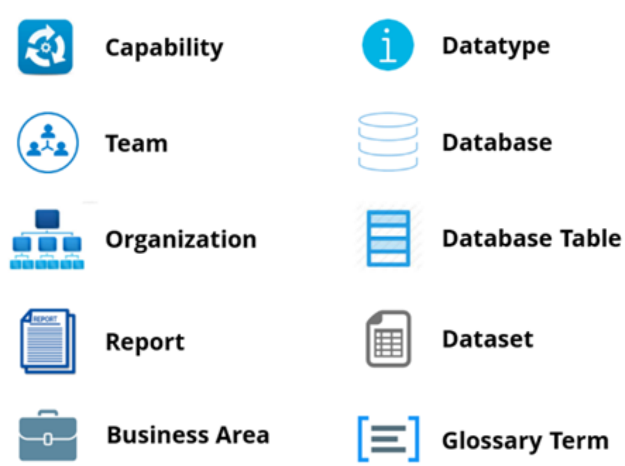
Changes to a data model requires changes to the tightly coupled application code and is therefore expensive.	Inexpensive data model changes without requiring application changes.
Information and Data as a "second class citizen".	Information and Data as a "first class citizen".
A machine can often not automatically find and use the data (not machine actionable).	A machine may be able to automatically find and use the data (machine actionable).
Each application has one data model.	Parts of data models can be shared and reused, extended as needed.

2.3 Enterprise Data Governance (EDG) Assets and Graphs

An **asset in EDG** is **a technical, business, or operational resource** governed by an organization, such as a database, reference data, vocabulary term, business application. Assets are organized into **collections** (or meaningful domains), which are technically stored as named **graphs**. You can think of collections as datasets. Collections can include each other by reference. Each asset collection has exactly one type (which determines the kind of assets/metadata and functionality of collection). Each collection has one manager and any number of users with edit and view privileges. Most asset collections are based on some ontology that defines a schema for the data (assets) they hold.

Data assets in EDG are stored as named graphs or meaningful organized ‘collections.

Figure 8: Select Assets in EDG



Common EDG Asset Collections *are “Controlled Vocabularies” including* Glossaries, Taxonomies, Reference Datasets, and Enumerations*.*

Glossaries are used for collections of defined business terms, which can be linked to data elements and applications (data and technical EDG asset collections).

Taxonomies are based on the Simple Knowledge Organization System (SKOS) w3c standard with important hierarchical ("has broader," "has narrower") and other relationship properties.

Reference Datasets are generally collections of defined codes, which are found in many back and front-end enterprise applications.

Enumerations are small, controlled, sometimes ordered, lists of values used across all asset collections.

Figure 9: EDG Assets and Collections

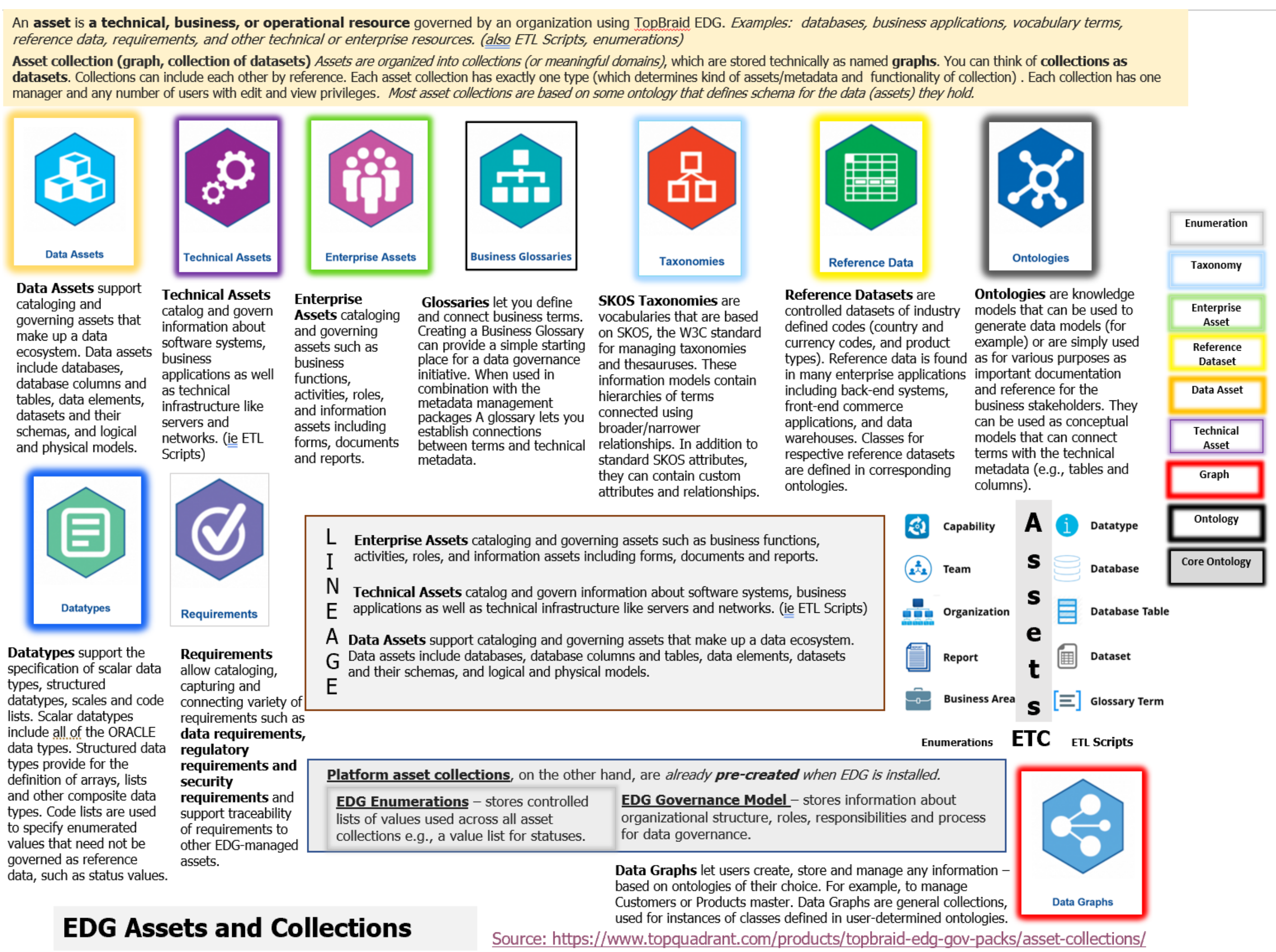


Figure 10: Fuels-Related and Core Collections Graphs

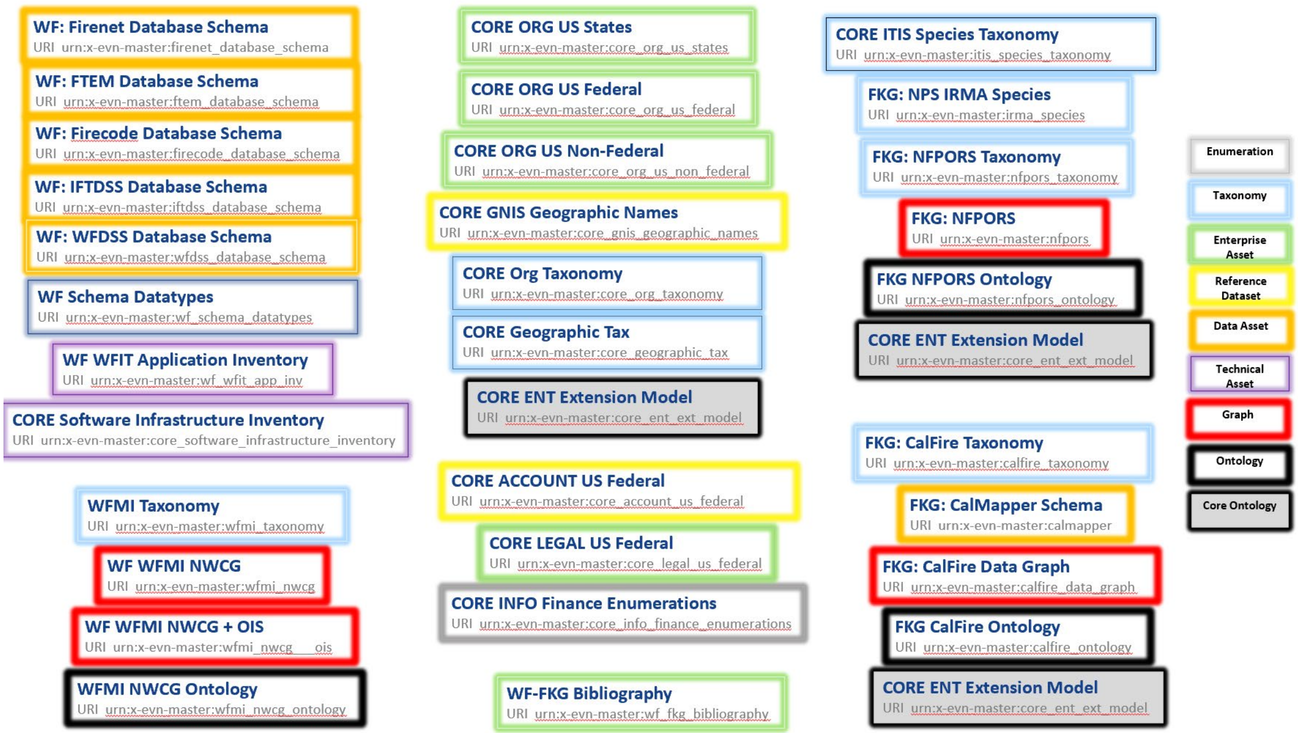


Figure 11: Example Glossaries Collected

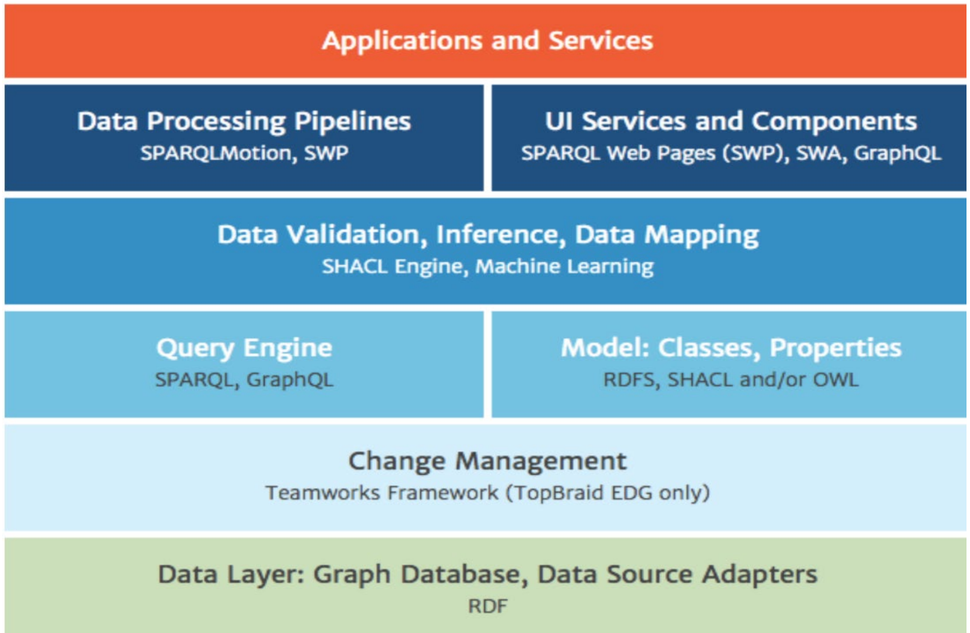
Examples of the numerous fuels-related business glossaries collected.
WF-FKG APA WUI Planning
WF-FKG Australia Bushfront Fire Glossary
WF-FKG CA-SF Openspace Org WFRP Glossary
WF-FKG CALFIRE Glossaries
WF-FKG Canada Ontario Forest Fire Glossary
WF-FKG DOI-FS Forests and Rangelands Fire Terms
WF-FKG Data Governance
WF-FKG FEIS Fire Effects Info System Glossary
WF-FKG IFTDSS Glossary
WF-FKG NFPA
WF-FKG NFPORS Glossary
WF-FKG NPS-PWR-SEKI Fire Terms

The team developed the knowledge graphs using TopQuadrant's Enterprise Data Governance (EDG) platform, built on the Resource Description Framework (RDF) w3c semantic web foundation, incorporating standards of SPARQL, SHACL, and GraphQL. SPARQL and GraphQL are query languages that allow users to ask the knowledge graph for specific resources based on a particular set of constraints. Every resource in the knowledge graph can be reliably referred to and accessed from any application as each resource has a globally unique dereferenced web identifier – a URI. The Linked Data representation allows users and applications to retrieve specific resources based on their URI. In turn, if these resources point to other resources, these can be retrieved as well, in the 'follow your nose' principle of browsing linked data.

EDG has inherent flexibility and extensibility of standards-based model development for connected knowledge-informed enterprise data governance. Developed data source adapters, powerful capabilities for specifying business rules, describing user interfaces, and providing web services using SPARQL and GraphQL. The EDG core API includes JavaScript objects working with RDF-based data, which can be entered and executed from the user interface. It can also be used to access and modify data stored in the collections, communicate with external data sources and web services, automate tasks, and customize interface extensions. Additionally, Active Data Shapes (ADS) technology is incorporated with domain-specific JavaScript APIs based on the SHACL shape definitions stored in the ontologies.

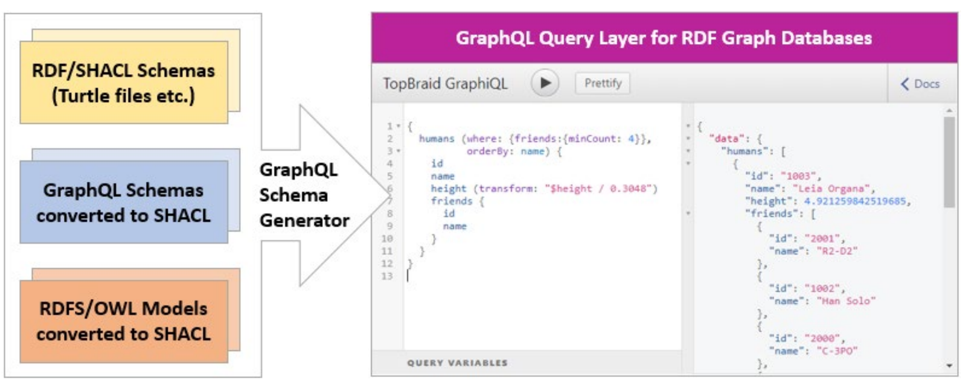
The broader community of data stakeholders can search, explore, and export the enterprise knowledge graph by accessing published collections. The enterprise knowledge graph, curated in individual asset collections by TopBraid EDG, is published from EDG to TopBraid Explorer. All stakeholders can search, query, and view the published information via Google-like access to connected information about all data, its meaning, and context. This information includes search and visual exploration of graph connections, data lineage, and impact. External applications can access the rich semantic services delivered through flexible and scalable APIs. Multiple formats will include full export capabilities of collections or queries.

Figure 12: EDG Semantic Web Layers



The Resource Description Framework (RDF) is used to store and organize knowledge graph data, and SPARQL is the query language for RDF. These RDF knowledge graphs are available to JSON and browsers via GraphQL, a JSON-centric query language for APIs. There is also support for SPARQL expressions from GraphQL queries. The Shapes Constraint Language (SHACL) is the EDG ontology and schema language to define classes and constraints on their properties. Users can define multiple views for the same data as SHACL shapes are the starting point to initiate GraphQL (with alternative use of SHACL converters to start with OWL or RD Schema). SHACL shapes are used to validate data mutations to create, update, or delete objects with reports of violations or suggested fixes.

Figure 13: SHACL Shape Definitions Used to Generate GraphQL Schemas In EDG



Every ontology is a treaty among people with a common motive in sharing. Similarly, an API is a contract or a shared understanding of a digital interface's capabilities, allowing applications to be programmed based on these terms. An API explicitly defines how it is expected to be used and what a user can expect when using it. Continuing the treaty analogy, HTTP or Hypertext Transfer (or Transport) Protocol is yet another, albeit lower level, contract-like communication protocol. A SPARQL Endpoint is a point of presence on an HTTP network capable of receiving and processing SPARQL protocol requests. It is identified by a SPARQL Endpoint URL. SPARQL is the query language of RDF, and comes with a protocol to talk against SPARQL Endpoints allowing these queries to be posted from anywhere on the web.

The Linked Data representation allows users and applications to retrieve specific resources based on their URI. In turn, if these resources point to other resources these can be retrieved as well. This is the 'follow your nose' principle of browsing linked data. SPARQL and GraphQL are query languages that allow users to ask the knowledge graph for specific resources based on certain constraints.

GraphQL is a programming language that can be used to specify exact data needed from an API through queries with declarative data fetching. Through the endpoint, it will specify how data will be retrieved, and it can be mutated or changed as the programming allows.

Figure 14: GraphQL Language Used to Specify Data Needed from API

- W3C Standards (RDF Schema, SHACL and OWL) or, as a starting point,
- **RDF**, the standards-based graph data model
- **SPARQL**, the query language for RDF
- **SHACL**, the semantic data modeling language that supports data validation and reasoning
- **GraphQL**, the query language for APIs and data selection

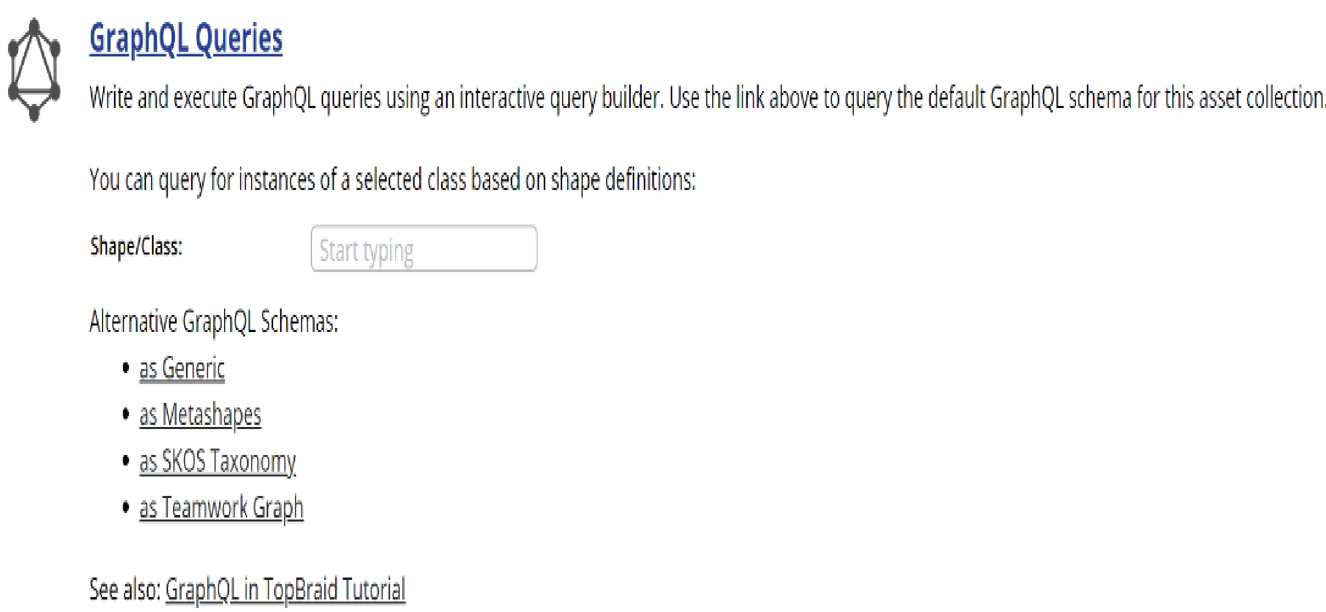
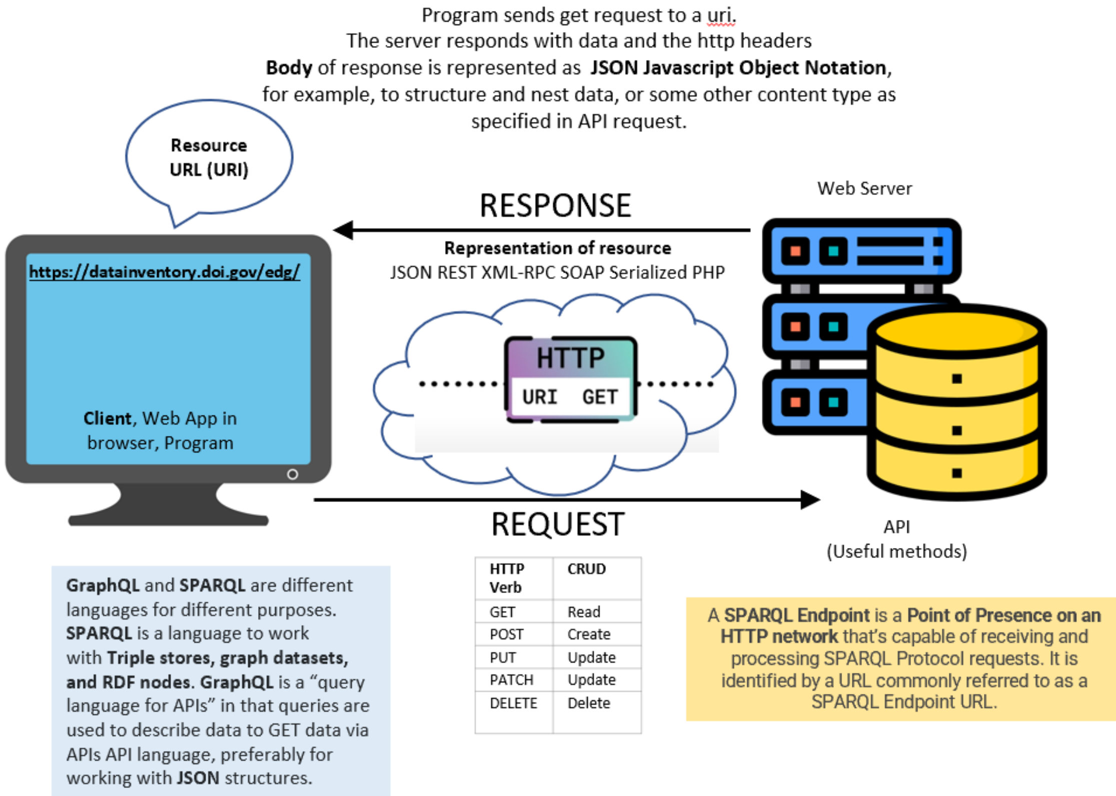


Figure 15: Application Programming Interface (API)



HTTP Verb	CRUD
GET	Read
POST	Create
PUT	Update
PATCH	Update
DELETE	Delete

2.4 Acronyms and Abbreviations

ADS	Active Data Shapes	**API**	Application Programming Interface
BIA	Bureau of Indian Affairs	**BLM**	Bureau of Land Management
BOR	Bureau of Reclamation	**CDOC**	Chief Data Officer Council
CDO	Chief Data Officer	**CORS**	Cross-Origin Resource Sharing
CEGIS	Center of Excellence for Geospatial Information Science (USGS)	**DCAT**	Data Catalog Vocabulary
CPM	Core Person Model	**EDG**	Enterprise Data Governance
DOI	Department of the Interior	**EPA**	Environmental Protection Agency
eERDMS	Email Enterprise Records and Document Management System	**FACTS**	Forest Service Activity Tracking System
ERA	National Archives Electronic Records Archives	**FAIR**	Findable Accessible Interoperable Reusable
ETIC	Electronic Technical Information Center	**FBMS**	Federal Business Management System
FASTBOO	Federal Account Symbols and Titles	**FEMA**	Federal Emergency Management Agency
FEIS	Fire Effects Information System	**FKGP**	Fuels Knowledge Graph Project
FMB	Fire Management Board	**FPPS**	Federal Personnel and Payroll System
FOUO	Federal Hierarchy “For Official Use Only”	**FS**	Forest Service (also USDA-FS)
FTEM	Fuels Treatment Effectiveness Model	**GLC**	Geographic Locator Code
FWS	Fish and Wildlife Service	**GNS**	GeoNet Names Server
GNIS	Geographic Names Information System	**GRAPHQL**	Graph Query Language
GUI	Graphical User Interface	**HTTP**	Hypertext Transfer (or Transport) Protocol
GSA	U.S. General Services Administration	**IFTDSS**	Interagency Fuels Treatment Decision Support System
HTML	Hypertext Mark-up Language (technology for presentation of data)	**ITIS**	Integrated Taxonomic Information System (itis.gov)

IRMA	Integrated Resource Management Applications	**ISO**	International Organization for Standardization
IQCS	Incident Qualifications and Certification System	**JSON-LD**	JavaScript Object Notation Linked Data
ISO	International Organization for Standardization	**NFPORS**	National Fire Plan Operations and Reporting System
NARA	National Archives and Records Administration	**NIEM**	National Information Exchange Model
NGA	National Geospatial-Intelligence Agency	**NWCG**	National Wildfire Coordinating Group
NPS	National Park Service	**OIS**	Organization Information System
OGC	Open Geospatial Consortium	**OMB**	Office of Management and Budget
OPM	Office of Personnel Management	**OWL**	Web Ontology Language
OWF	Office of Wildland Fire	**REST**	Representational State Transfer
RDF	Resource Description Framework (technology for encoding the meaning of data)	**SHACL**	Shapes Constraint Language
SKOS	Simple Knowledge Organization System	**SPARQL**	SPARQL Protocol and RDF Query Language
SME	Subject matter expert	**UI**	User Interface
SRA	CA State Responsibility Area	**URL**	Uniform Resource Locator (web page address)
URI	Uniform Resource Identifier (superset term of URL, real things)	**USDA**	United States Department of Agriculture
USA	United States Army	**USGS**	United States Geological Survey
USDA-FS	United States Department of Agriculture – Forest Service	**WFDSS**	Wildland Fire Decision Support System
WFIT	Wildland Fire Information Technology	**XSD**	XML Schema Definition
WFLC	Wildland Fire Leadership Council		