



Establishing ASOTs

***Matthew Daskilewicz
Alanna Carnevale***

The Aerospace Corporation

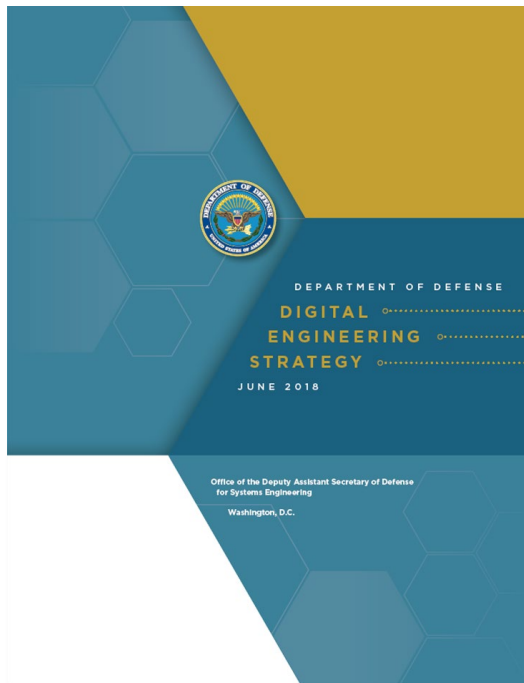
***Systems Engineering Forum
Digital Engineering Standards
16 Aug 2022***

Approved for public release. OTR 2022-00905.

DE Strategy Push for ASOTs



“Digital Engineering is an integrated digital approach that uses authoritative sources of system data and models as a continuum across disciplines to support lifecycle activities from concept through disposal.”



Digital Engineering (DE) Vision: Modernizes how the Department conceives, builds, tests, fields, and sustains our national defense systems.						
GOALS	1 Formalize the development, integration, and use of models to inform enterprise and program decision making	2 Provide an enduring, authoritative source of truth	3 Incorporate technological innovation to improve the engineering practice	4 Establish a supporting infrastructure and environments to perform activities, collaborate, and communicate across stakeholders	5 Transform the culture and workforce to adopt and support digital engineering across the lifecycle	GOALS
FOCUS AREAS	Formalize the planning for models to support engineering activities and decision making across the lifecycle	Plan and develop the authoritative source of truth	Establish an end-to-end digital engineering enterprise	Develop, mature, and use digital engineering IT infrastructures	Improve the digital engineering knowledge base	FOCUS AREAS
	Formally develop, integrate, and curate models	Govern the authoritative source of truth	Use technological innovations to improve the digital engineering practice	Develop, mature, and use digital engineering methodologies	Lead and support digital engineering transformation efforts	
	Use models to support engineering activities and decision making across the lifecycle	Use the authoritative source of truth across the lifecycle		Secure IT infrastructure and protect intellectual property	Build and prepare the workforce	
MEANS	METHODS, PROCESSES, TOOLS, TECHNOLOGY, DATA, PEOPLE					MEANS

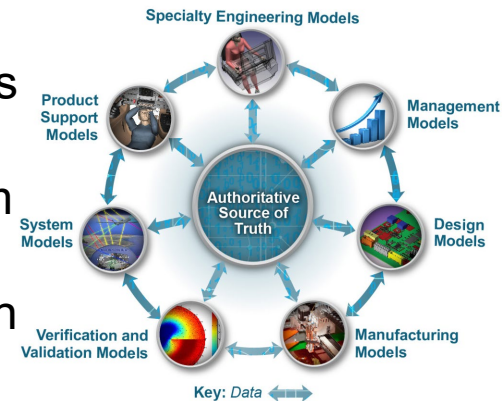
Department of Defense Digital Engineering Strategy
Office of the Deputy Asst Sec. Def. for Systems Engineering, 2018

What is an ASOT?

Different organizations have proposed different definitions

- Department of Defense Digital Engineering Strategy
 - “The authoritative source of truth captures the current state and the history of the technical baseline. It serves as the central reference point for models and data across the lifecycle”
 - “The primary means of communication moves away from static and disconnected artifacts and shifts the paradigm to models and data ... providing an integrated information exchange throughout the lifecycle”

Department of Defense Digital Engineering Strategy
Office of the Deputy Asst Sec. Def. for Systems Engineering, 2018



- U.S. Space Force Vision for a Digital Service
 - “The single, definitive source of a given piece of information that all consumers of that information should reference to mitigate the risk of relying on outdated, inconsistent, or inaccurate information.”

U.S. Space Force Vision for a Digital Service
SF/CTIO, 2021

[https://media.defense.gov/2021/May/06/2002635623/-1/-1/1/USSF%20VISION%20FOR%20A%20DIGITAL%20SERVICE%202021%20\(2\).PDF](https://media.defense.gov/2021/May/06/2002635623/-1/-1/1/USSF%20VISION%20FOR%20A%20DIGITAL%20SERVICE%202021%20(2).PDF)



What is an ASOT?



- OMG Definition:
 - *“An authoritative source of truth is an entity such as a person, governing body, or system that applies expert judgement and rules to proclaim a digital artifact is valid and originates from a legitimate source.”*
 - *“... majority of experts accepts the credibility, accuracy, and trustworthiness...”*
 - *“... preponderance of evidence upholds the validity of...”*

https://www.omgwiki.org/MBSE/doku.php?id=mbse:authoritative_source_of_truth

<https://www.linkedin.com/pulse/difference-between-system-record-source-truth-santosh-kudva/>



What is an ASOT?

- Adventium Labs “ASOT Study”
 - *“An authoritative source of truth is a capability that gives definitive answers to queries about a collection of systems”*
 - *“Queries are questions about the past, present, or future state of the design or implementation of a collection of systems.”*
 - *“Definitive answers are answers governed by organizational processes.”*

Final Report (2019-09-01 to 2020-12-31) Authoritative Source of Truth Study (ASoT Study)

Adventium Enterprises, LLC, 2021

https://www.adventiumlabs.com/sites/default/files/documents/2021-03_AuthoritativeSourceOfTruthStudy_DEWG.pdf

What is an ASOT?



An entity such as a person, governing body, or system that applies expert judgement and rules to proclaim a digital artifact is valid and originates from a legitimate source. - OMGWiki

An authoritative source of truth is a capability that gives definitive answers to queries about a collection of systems. – Adventium Labs

[The ASOT] serves as the central reference point for models and data across the lifecycle...The goal is to enable delivery of the right data to the right person for the right use at the right time – DE Strategy

- Similar terms might cause confusion
 - *Single Source of Truth: Indicates all data is coming from one place*
 - *Single Version of Truth: One view of the data that is agreed upon as true*
 - *System of Record (SOR): Authoritative source for one given data element or piece of information*
 - *Authoritative Source of Data: Derives from the question “what is truth?” and addresses future/to-be state of data*
- Reviewing these terms and definitions suggests that an ASOT:
 - *Must be “digital”, i.e., a model or data set that provides APIs to access information*
 - *Must be “accepted” or “agreed upon” as the appropriate source for a particular application*
 - *Should be quickly updated when the underlying facts change*
 - *Should address the whole picture of the data (the whole lifecycle)*
 - *Could be the primary source or could originate from other sources*

ASOTs enable greater sharing of information and baselines to accelerate learning, facilitate knowledge management and sharing, and improve the accuracy, validity, and responsiveness of analyses.



The role of ASOTs in Digital Engineering

What capabilities does the ASOT provide?

- Controls access to the information it contains
- Keeps everyone on the same page. Reduce errors
- Enable automated analysis workflows: “CI/CD” style analysis
- Enable recreating analyses done months/years ago
 - Version control *everything*
- *Digital engineering is a big dream. Getting there will be slow and incremental, with mistakes made along the way.*
- *Don't refuse to make progress because things aren't “authoritative” enough. ASOT is a goal, not a requirement*
- *Digital Engineering: “How do we make different models talk to each other?”*



McDermott, T.; Collopy, P.; Nadolski, M. & Paredis, C.
The Future Exchange of Digital Engineering Data and

8

Two Sides of “Establishing ASOTs”



Governance

- What models/data are should be elevated to “ASOT”?
- What standards are ASOTs held to?
- What are the responsibilities of ASOT owners?
- Fostering a digital engineering culture

Utility

- How do ASOTs help us work more efficiently?
- How do we make information contained in ASOTs available?
- How do we develop an ecosystem of tools that are ready to make use of ASOTs?

Governance: What should be considered an ASOT?



An ASOT is more than just “the best model we have”.

An ASOT must include the supporting hardware, software, people, and processes to make the information content available to new audiences throughout the organization.

Establishing and maintaining an ASOT is a lot of work. Before you begin, consider:

- Is this model ready for “prime time”? Is it correct? Complete? Documented? Usable?
- How much demand is there for the information it contains?
- Do the support systems needed to extract information already exist? If not, how hard will it be to build them?
- Are the model owners willing to take on the new responsibilities of being an ASOT?

Governance: What standards are ASOTS held to?



- The “ASOT” label is partly a promise to uphold some standards of quality, security, usability, etc.
- Establish an “ASOT Governance Board” to determine what these standards will be for your organization, and to certify when a digital artifact meets them and earns the “ASOT” label.
- See sample questionnaire in the appendix, and use cases collected in Adventium Labs ASOT report for ideas

- “The ASoT supports all stakeholders by enforcing constraints”
- “The ASoT supports the government approval authority by linking analytical results to the artifacts that produced those results”
- “The ASoT supports all stakeholders by providing a capability to define which ASoT in a set of ASoTs is the authoritative source at a given point in time”
- “The ASoT supports the government approving authority by providing a central repository for artifact generation, action notification, and artifact routing”
- “The ASoT supports the supplier by providing evolving design details necessary for requirements, design, and integration”
-

Final Report (2019-09-01 to 2020-12-31) Authoritative Source of Truth Study (ASoT Study)

Adventium Enterprises, LLC, 2021

https://www.adventiumlabs.com/sites/default/files/documents/2021-03_AuthoritativeSourceOfTruthStudy_DEWG.pdf

Governance: Responsibilities of ASOT Owners



- Set expectations for potential ASOT owners to help them understand the new responsibilities that come with the “ASOT” label
- Develop self assessment for potential ASOT owners to help them understand what is required for ASOT owners, and how well positioned they are to become one. *(See example questions in Appendix of this presentation)*
- Provide compelling reasons for people to want to get on board. Develop querying and other data access capabilities

Utility: How do ASOTs help us work more efficiently?



There is no point in establishing an ASOT if it doesn't help someone do their job better

Think of all the ways your ASOT could add value. How can you ensure that...

- It supports the work of people of different technical backgrounds and skill levels
- It is easy to perform “what if” analyses using the ASOT as a baseline without fear of breaking the ASOT or confusing “what if” data with authoritative data
- It is easy to retrieve any past versions of the information it contains
- A system is in place to alert users when the ASOT is updated
- It is impossible to accidentally break the ASOT

Utility Requires Standardization



- DE is fundamentally about *information exchange involving ASOTs*
- Deriving utility from ASOTs is fundamentally about making the information they contain accessible and integrable in a way that doesn't require day to day humans in the loop.
- If we're talking about ASOTs, then presumably we're in a situation where we want to pass information from one source/format/tool to another one.
- How hard will this be? It depends...

Utility: Making Information in ASOTs Accessible



Just publishing an MBSE model in a shared folder is not enough

- Becoming an ASOT probably means making your information available to a much wider user base than you've historically worked with
- In an organization with thousands of people with different technical backgrounds and skill levels, how to you make information available as widely as possible?
- The ASOT and the interface that people use to extract information from the ASOT may be wildly different.



Utility: Building an ecosystem of ASOT-base tools

Lessons learned from the Semantic Web

- The “Semantic Web” is an idea for making data on the internet machine readable to make it easier for information on the internet to be accessed
- Key ideas related to the semantic web include:

Knowledge Graphs: The idea that information can be described with “objects” (things) and “predicates” (relationships) in a directed graph structure

Ontologies: Models that describe the allowable “objects” and their attributes, and what “predicates” can connect what “objects” in a knowledge graph

Using URLs as a unique identifier for a piece of information

Using RDF as a standard format for communicating the content of a knowledge graph

Semantic Web and Knowledge Graphs



- Take away the *differences* of the various tools/formats/domains we are about, and what's left?
- A **knowledge graph** consists of objects connected by links.
- Links are “predicates”, defining how the “subject” relates to the “object”.
- Each object, and each link, can have associated properties that define the data content of the knowledge graph, and associated metadata, which is “non-knowledge” data.
- Knowledge graphs are most useful when they have: small nodes and many links

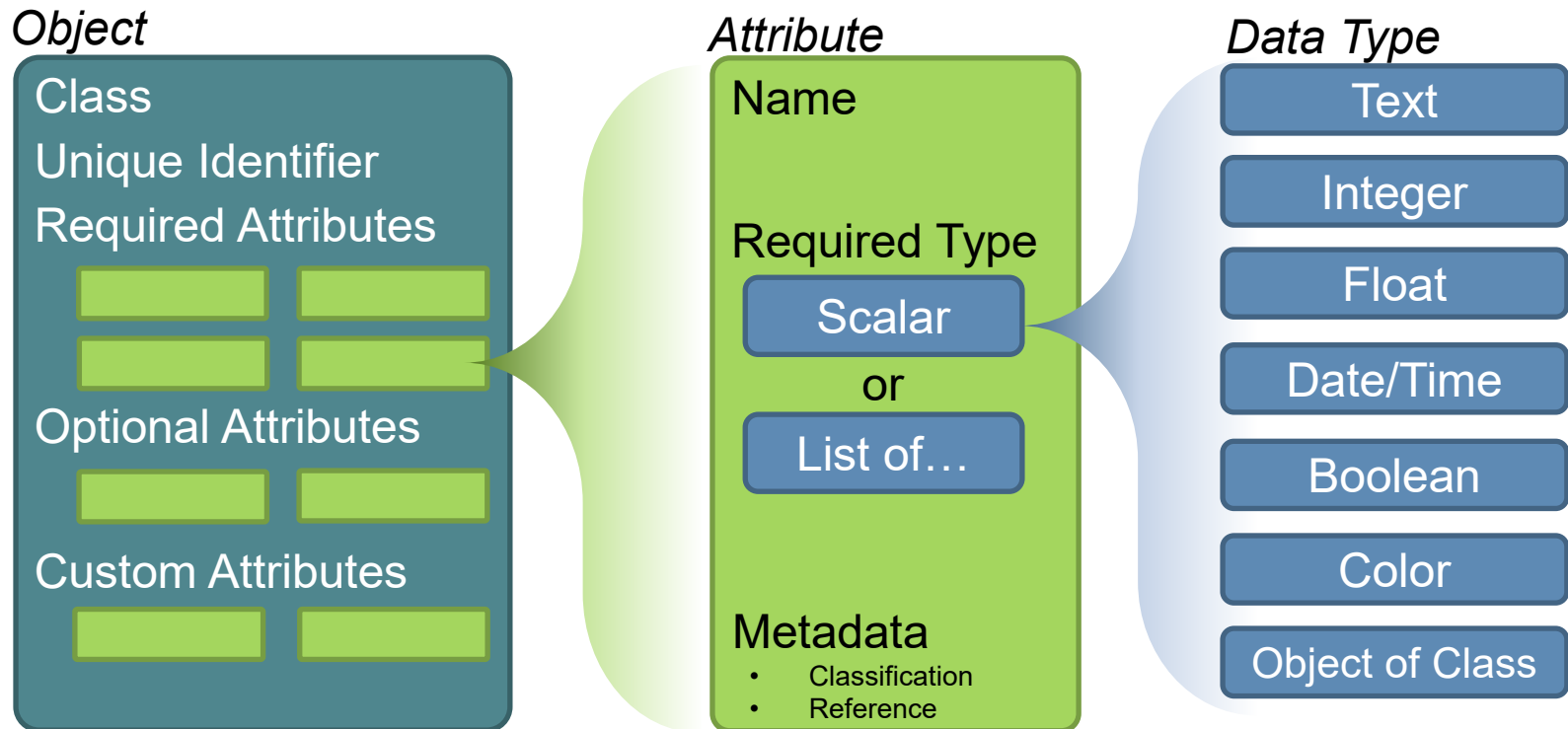
Postulate: Any model can be represented as a knowledge graph



Utility: Building an ecosystem of ASOT-based tools

A flexible data model for communicating between ASOTs

- If we want to have a user interface that explains data changes, it helps to have a simple, flexible data model that can be applied to many domains



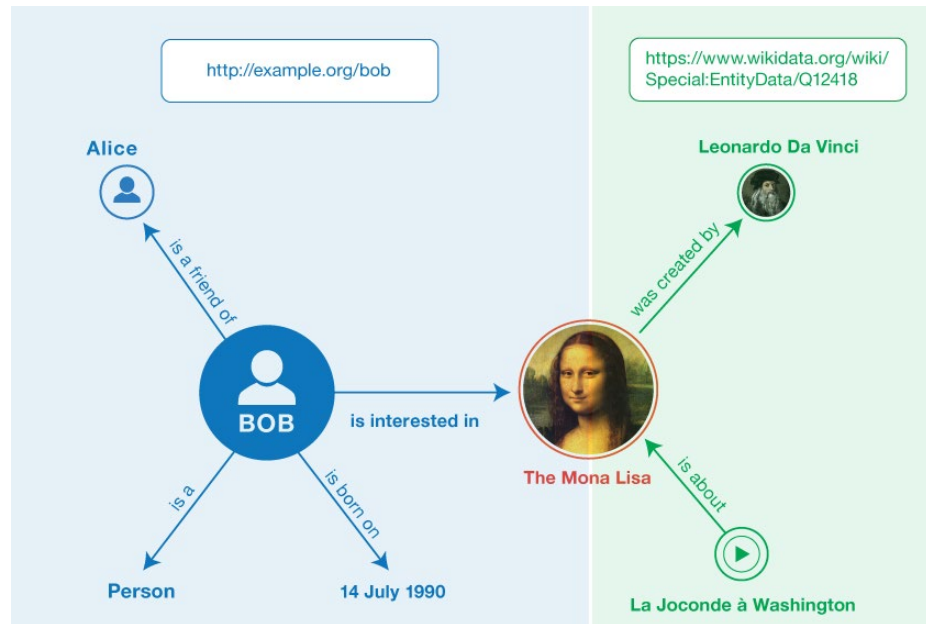
Any piece of data can be uniquely identified by:

Artifact Name + Object Unique Identifier + Attribute Name

Utility: Building an ecosystem of ASOT-base tools

Ontologies

- The data model on the previous slides works much better if we can all agree on *what classes* and *what attributes* and *what relationships* and *what units*
- Ontologies make it easier to build digital engineering toolchains by establishing a common vocabulary for all these things
- Helps ensure that different tools can talk to each other as long as they agree on certain boundary conditions



<https://www.w3.org/TR/rdf11-primer/>

Utility: Building an ecosystem of ASOT-base tools

Ontologies

Ontologies describe the allowable structure of the knowledge graph:

- What types of objects can exist (these are called classes), and what properties each one can/must have
- What types of relationships (predicates) can exist between each class, and what properties the relationships can/must have

If two data sources use the same ontologies, they can live in the same knowledge graph. If they use different ontologies, they must live in different knowledge graphs, and we need *something* (code? Another ontology?) that describes how they relate to each other.

This is one reason having a relatively small number of standards is important! Each time two tools used different standards we need some manual fix to get them to communicate

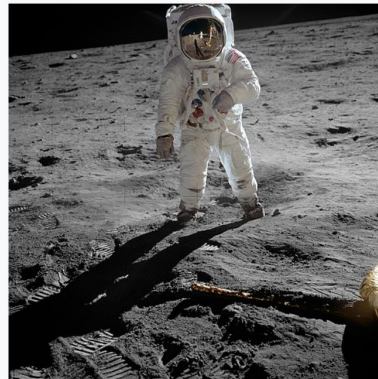
Knowledge graphs and ontologies in action



Wikipedia (Human Readable)	Wikidata (Machine Readable)
https://en.wikipedia.org/wiki/Apollo_11	https://www.wikidata.org/wiki/Q43653
https://en.wikipedia.org/wiki/Sun	https://www.wikidata.org/wiki/Q525
https://en.wikipedia.org/wiki/USA-293	https://www.wikidata.org/wiki/Q106405833

Apollo 11 (July 16–24, 1969) was the American [spaceflight](#) that first [landed](#) humans on the [Moon](#). Commander [Neil Armstrong](#) and lunar module pilot [Buzz Aldrin](#) landed the [Apollo Lunar Module Eagle](#) on July 20, 1969, at 20:17 UTC, and Armstrong became the first person to step onto the Moon's surface six hours and 39 minutes later, on July 21 at 02:56 UTC. Aldrin joined him 19 minutes later, and they spent about two and a quarter hours together exploring the site they had named [Tranquility Base](#) upon landing. Armstrong and Aldrin collected 47.5 pounds (21.5 kg) of lunar material to bring back to Earth as pilot [Michael Collins](#) flew the [Command Module Columbia](#) in [lunar orbit](#), and were on the Moon's surface for 21 hours, 38 minutes before lifting

Apollo 11



[Buzz Aldrin](#) on the Moon as photographed by [Neil Armstrong](#) (Armstrong seen in the visor reflection along with Earth,^[1] the [Lunar Module Eagle](#), and the U.S. flag)

Mission type Crewed lunar landing (G)
Operator [NASA](#)

instance of

 [human spaceflight](#)

▼ 0 references



[Moon landing](#)

[start time](#)

20 July 1969

[end time](#)

21 July 1969

▼ 0 references

part of

 [Apollo space program](#)

▼ 0 references



Recommendations for getting started with ASOTs



Establishing a “Starter ASOT”

Start with a small model or data set you already work with

1. Store information in documented, well-structured formats that don't often change
2. Give objects permanent, (globally) unique identifiers whenever possible, as soon as possible
3. Use widely agreed upon standards, ontologies, schemas, and units of measurement as much as possible
4. Track data changes using discrete "numbered" versions
5. Include a change log with each version explaining *why* the changes occurred
6. Separate authoritative data from non-authoritative data as much as possible
7. Establish authoritative “component models” before trying a “composite model”
8. Don't insist on getting everything right the first time
9. Start as soon as possible, you'll learn a lot as you go



Next, think about making it “Archival”

1. Allow any past version of the ASOT to be retrieved
2. Provide an API for accessing data with automated scripts
3. Allow different access permissions to be assigned to each user
4. Track important metadata associated with each version
5. Allow “work in progress” to be managed separately from “release” versions
6. Support merging changes from multiple users and conflict resolution
7. Allow users to authenticate the state of the database
8. Perform regular backups



Recommendations for Communicating Changes

1. Produce reports at different levels of abstraction
2. Communicate using language that is meaningful to the end user
3. Produce reports that communicate *changes* to the ASOT from one version to the next



Appendix: Questionnaire for Potential ASOTs

So, you want to be an ASOT?



The following slides present a series of questions for potential ASOT owners and ASOT governance boards to use to assess whether a particular model or data set should be considered an ASOT.

The questions cover a wide variety of topics to address concerns such as suitability, feasibility, and value.

The questions refer to the potential ASOT as a “model” but could also be used for a data set or other digital artifact.



So, you want to be an ASOT?

What is it?

- Name of model?
- Describe the information contained in this model in language that someone who is not already familiar with it would understand?
- Point(s) of contact:
 - Who creates or obtains the model?
 - Who curates and manages the model?
 - Representative users of the model?
- Department responsible for managing this model?
- Describe the format of the model briefly, but specifically
 - E.g. "Excel workbook with multiple sheets, including a mix of source data sheets and pivot tables"
- Describe, in terms relevant to the information content, the approximate scope or size of this model
 - E.g. for a catalog of satellites, how many satellites are included? For geospatial data, what is the area of coverage and at what resolution?



So, you want to be an ASOT?

What is it? (continued)

- What is the “native format” of this model?
 - E.g. “UAF Model”, “Relational Database”, “Excel workbook”
- Is the model is built in/for a particular software tool? If so, which one(s)?
- Is the model based on any standards, ontologies, or reference? If so, which one(s)?



So, you want to be an ASOT?

Where does it come from?

- Briefly describe the source(s) of the information contained in/used to build this model.
- Were there SMEs involved in data collection and preprocessing? If so, who?
- Are any other ASOTs inputs to this one? If so, briefly describe each one
- What challenges or unmet needs do you perceive related to the source data?
 - E.g.: Is its quality sufficient?
 - Is it accessible/delivered in a timely manner?
 - Is it in a format that is easy to work with?



So, you want to be an ASOT?

How is it used?

- Describe some actual and potential uses for this model. I.e. what business or technical problems does this model help solve?
- What groups (departments, program offices, customers?) are currently using this data set? What kind of applications are they using it for?
- Are there any other groups (internal or external) involved in generating, managing, or using this data set? If so, who, and how are they involved?



So, you want to be an ASOT?

Scope and Completeness

- Describe the intended "fidelity level" of this model. I.e. how "detailed" is this model?
 - Does the model currently meet this goal?
- Describe the "level of abstraction" of this model.
 - E.g. enterprise level, system of systems level, system level, subsystem level...
- From 0-5, How would you rate the overall **quality** of this model?
 - 0 = unable to find good source data; this data set contains many assumptions or guesses.
 - 5 = we have good source information, and it is accurately translated into this model. You won't find better information than this.
- How would you rate the overall **completeness** of scope of this model?
 - 0 = very limited scope; it represents only a small piece of the overall system of interest
 - 5 = has complete coverage of its intended scope
- How would you rate the overall **maturity** of this model?
 - 0 = we're just getting started; still learning and frequently changing the scope and/or structure of the model;
 - 5 = long history with established users. We do not anticipate major changes to format or scope



So, you want to be an ASOT?

Accessing the information

- Does the model, or the software used to access it, provide APIs for interacting with the model from software/tools other than the one the model is built in?
- Does the model, or the software used to access it, provide the ability to export in plain text or other "generic" formats (such as JSON, XML, CSV, etc.)?
- Does the model, or the software used to access it, provide robust query capabilities for finding and extracting specific pieces of information from the model?
- Is the information contained in the model accessible by people without expertise in the modeling tool?
- Is the information contained in the model accessible without each user needing a software license for the modeling tool?
- What, if any, graphical user interfaces are available for accessing or visualizing this data?



So, you want to be an ASOT?

Related Models

- Is this model typically or frequently used in conjunction with other models? If so, briefly describe them and how they relate to each other.
- Does this model substantially overlap with the contents of another model? If so, describe:
 - Which other models
 - What information is duplicated
 - How the duplication occurs (e.g. manually copied vs. synched automatically with a script vs. both based on a 3rd source)
 - Which model is considered more authoritative.
- Does this model cover the same scope but at a different fidelity level or with different assumptions than another model?
 - If so, briefly describe which other models and how they differ.



So, you want to be an ASOT?

Management and Governance

- Who is responsible for data ingestion and updates?
- How long has this model existed? Are older versions archived?
- How often is this model updated?
- How are versions tracked? (E.g. version numbers, release dates)
- Are specific data elements within the model versioned, or only the model as a whole?
- What processes do you have for ensuring quality/correctness is maintained when updating this data set?
- What processes are in place to control who is allowed to read/write and/or create new versions of the data?



So, you want to be an ASOT?

Management and Governance (continued)

- Are there any dependencies with other models (or other digital artifacts) that require coordination of updates/versions between this model and the others?
- Is there a repository that serves as the "archival" source of this model? If so, what form does it take? (E.g. "A shared network folder")
- For all processes below, consider whether the existing processes are sufficient, efficient, scalable, secure, and user friendly:
 - What processes do you have for determining who is allowed to access the model and what permissions they should be granted?
 - How do you normally go about distributing this model when someone requests access to it? (E.g. "We send them an email with a link to the share folder where the files are hosted")
 - What processes do you have for archiving older versions of this model?
 - What processes do you have for recording and communicating what has changed between versions (e.g. release notes)?
 - What processes do you have for recording and communicating when the model is no longer relevant or should otherwise no longer be used?



So, you want to be an ASOT?

Documentation

- Is there documentation that describes the format of this model? (Possibly from an external source if the format is based on established standards)
- Is there documentation that describes the scope/completeness of this model?
- Is there documentation that describes assumptions or omissions that users should be aware of when interpreting the model?
- Are there any publications associated with the model?



So, you want to be an ASOT?

Access Control

- Does this model contain classified data?
- Are there any NDAs or other access restrictions involved?
- Can the model be subdivided into usable portions that classified at a lower level? E.g. can the unclassified information be extracted into a separate stand-alone model?
- How are access controls currently implemented?



So, you want to be an ASOT?

Food for Thought

- Do you think this model should be your organization's go-to resource for the information it contains?
- Do you think more people would use this model if they knew it existed?
- Do you have the resources to handle a potential influx of new users and use cases for this model?

Can a document be an ASOT?

Not really.

- The purpose of digital engineering is to enable more robust and efficient systems engineering processes by the integration of authoritative sources of data and models into an "end-to-end" digital representation of the system of interest.
- An enabling change is the transition from "documents" to "models" as the authoritative sources of information
 - A document is human-readable
 - A model is machine-readable
- Machine readable means "data in a format that can be easily processed by a computer without human intervention while ensuring no semantic meaning is lost." <https://stratml.us/references/HR4174.htm#machine-readable>
- Machine-readable data can be processed without the need for human interpretation.

