

AM Data Modeling Efforts

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Key Data Modeler Contributors

- Kareem Aggour: GE Aviation Research
- Joy Gockel: Colorado School of Mines
- Alex Kitt: EWI
- Yan Lu: NIST
- Afina Lupulescu: ASM
- Luke Mohr: EWI
- Hunter MacDonald: Hexagon
- Mike McNair: SAE
- Shengyen Li: NIST
- Mike Vasquez: 3 Degrees
- ...

Agenda

- Problem Statement
- Effort to Date
- Help Needed

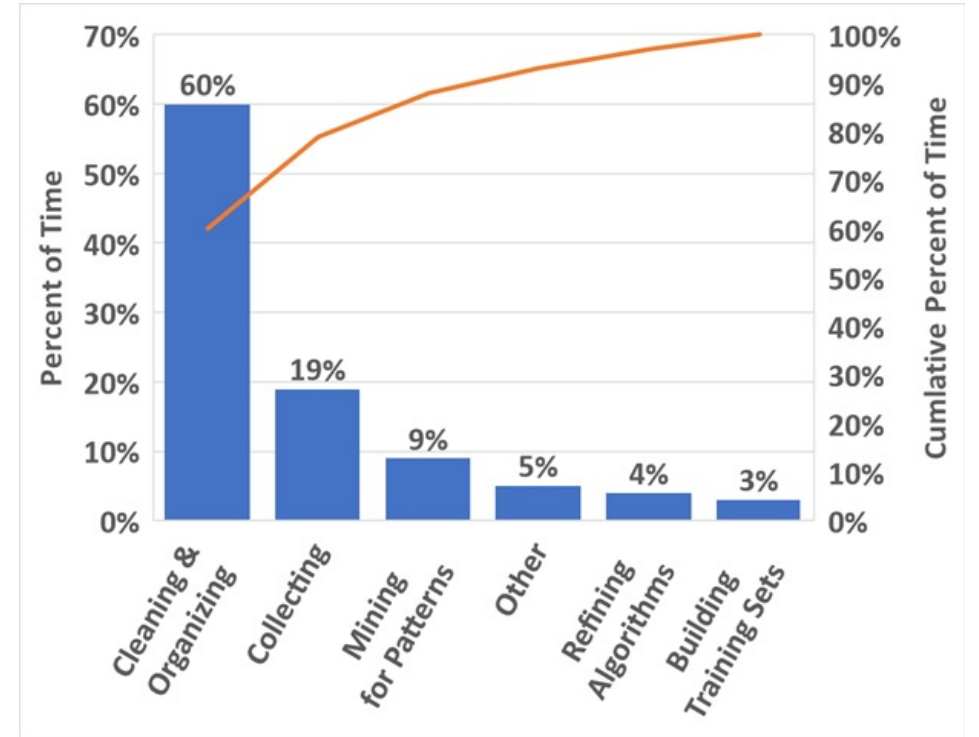


Problem Statement

General Problem Statement: Value of FAIR Data

EU study on general research community cost of not following FAIR practices:

- **≥ €10.2 B/yr.** Cost of not having FAIR data
- **≥ €16.9 B/yr.** Cost to innovation
- **80%** of the duplicative funded work could be eliminated.
- **72%** of the research data generated could be made open.
- **28%** must remain closed due to security and privacy reasons.



People who work primarily with data
80% of their time
Finding, filtering, reformatting, and integrating data

AM Specific Problems: Value of FAIR Data

Redundancy: Design allowable data sets

- Cost \$3-5M to generate per process specification (specific to material, AM process type, AM equipment type, heat treat, etc.)
- An aerospace company recently estimated that the community had spent >\$250M generating redundant design allowable datasets for the same material
- The material referenced is an industry standard material not associated with having a competitive advantage

Process Understanding: Process qualification

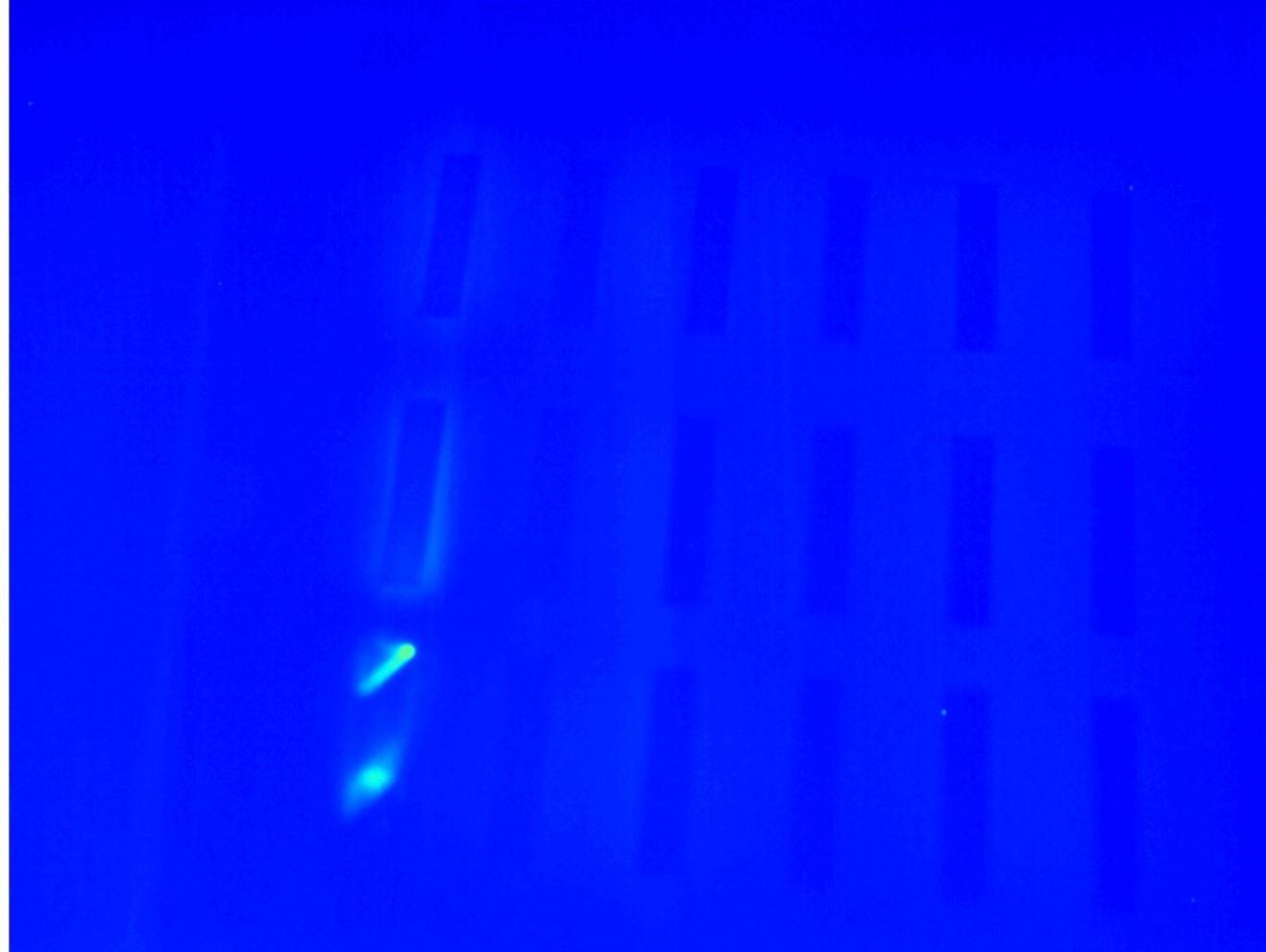
- Scaling an AM process to a second, identically configured system costs >6 months, >\$1.5M

AM Challenges

- Many islands of unstructured & uncoordinated work
- No established means to convergence on a consensus solution
- AM equipment are often “black boxes” which limit data accessibility
- Data viewed as IP. Data models viewed as IP by extension
- Data generators are not the ones who benefit from data



AM Datasets can be HUGE



Effort to Date



Workshops

- Empowering Small and Medium Size Enterprises Through Effective Additive Manufacturing Data Management [2023]
- Data Enabled Accelerated AM Process Qualification [2022]
- Additive Manufacturing Data Management and Schema Workshop [2020]
- Additive Manufacturing for Maintenance and Overhaul [2020]
- Additive Manufacturing for Maintenance and Overhaul [2019]
- ...

ASTM F42.08 – AM Data

Scope: The development of AM standards that relate to AM data interoperability, AM data analytics, and AM data management (including but not limited to data security) (not including design data).

ASTM F42.08 – AM Data

Approved:

- **ASTM F3490-2021 (Data Pedigree):** Approved, ad-hoc group developing AM common data model which may be included in first revision of F3490
- **ASTM F3560-22 (CDEF for PSD):** Approved(Based on ASTM CoE R&D)
- **ASTM F3605-23 (File Structure for In-Process Monitoring):** Approved(Based on ASTM CoE R&D)

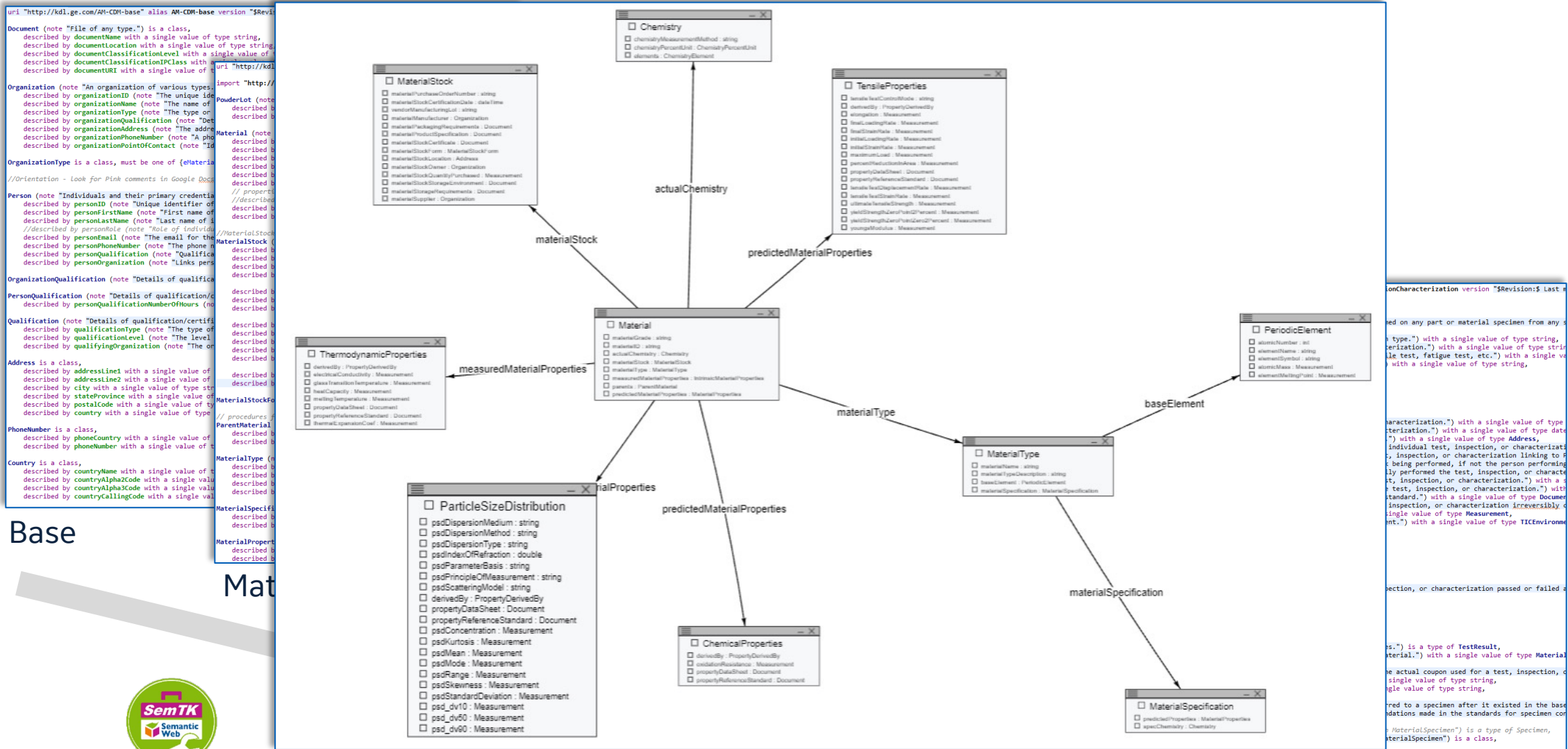
Joint Standards in Development:

- **ISO/ASTM PWI 52953 (Data Registration):** Addressing one negative from F42 committee ballot

Early Stage:

- **WK76970* (Guidelines for Technical and Intellectual Property Authentication and Protection)**
- **WK78322* (Guidelines for AM Security)**

Material-centric view (visualized in SemTK)



```

uri "http://kd1.ge.com/AM-CDM-base" alias AM-CDM-base version "REV1"

Document (note "File of any type.") is a class,
  described by documentName with a single value of type string,
  described by documentLocation with a single value of type string,
  described by documentClassificationLevel with a single value of
  described by documentClassificationPClass with a single value of
  described by documentURI with a single value of type string

import "http://kd1.ge.com/AM-CDM-base" as AM-CDM-base

Organization (note "An organization of various types") is a class,
  described by organizationID (note "The unique identifier of the organization")
  described by organizationName (note "The name of the organization")
  described by organizationType (note "The type of organization")
  described by organizationQualification (note "Details of qualification")
  described by organizationAddress (note "The address of the organization")
  described by organizationPhoneNumber (note "A phone number")
  described by organizationPointOfContact (note "The contact person")

OrganizationType is a class, must be one of {MaterialStock,
//Orientation - Look for Pink comments in Google Docs

Person (note "Individuals and their primary credentials") is a class,
  described by personID (note "Unique identifier of the person")
  described by personFirstName (note "First name of the person")
  described by personLastName (note "Last name of the person")
  described by personRole (note "Role of individual")
  described by personEmail (note "The email for the person")
  described by personPhoneNumber (note "The phone number")
  described by personQualification (note "Qualification of the person")
  described by personOrganization (note "Links person to organization")

OrganizationQualification (note "Details of qualification") is a class,
  described by personQualificationNumber (note "Number of qualification")
  described by personQualificationNumberHours (note "Hours of qualification")

Qualification (note "Details of qualification/certificate") is a class,
  described by qualificationType (note "The type of qualification")
  described by qualificationLevel (note "The level of qualification")
  described by qualifyingOrganization (note "The organization")

Address is a class,
  described by addressLine1 with a single value of type string,
  described by addressLine2 with a single value of type string,
  described by city with a single value of type string,
  described by stateProvince with a single value of type string,
  described by postalCode with a single value of type string,
  described by country with a single value of type string

PhoneNumber is a class,
  described by phoneCountry with a single value of type string,
  described by phoneNumber with a single value of type string

Country is a class,
  described by countryName with a single value of type string,
  described by countryAlphaCode with a single value of type string,
  described by countryAlphaCode with a single value of type string,
  described by countryCallingCode with a single value of type string

MaterialStock (note "Material stock") is a class,
  described by materialPurchaseOrderNumber : string
  described by materialStockCertificateIssueDate : DateTime
  described by materialManufacturingLot : string
  described by materialManufacturer : Organization
  described by materialPackagingRequirements : Document
  described by materialStockCertificate : Document
  described by materialStockForm : MaterialStockForm
  described by materialStockLocation : Address
  described by materialStockOwner : Organization
  described by materialStockQuantityPurchased : Measurement
  described by materialStockStorageEnvironment : Document
  described by materialStorageRequirements : Document
  described by materialSupplier : Organization

MaterialType (note "Material type") is a class,
  described by materialGrade : string
  described by materialID : string
  described by actualChemistry : Chemistry
  described by materialStock : MaterialStock
  described by materialType : MaterialType
  described by measuredMaterialProperties : ThermodynamicProperties
  described by predictedMaterialProperties : ParticleSizeDistribution
  described by predictedMaterialProperties : ChemicalProperties
  described by predictedMaterialProperties : TensileProperties

MaterialSpecification (note "Material specification") is a class,
  described by materialName : string
  described by materialTypeDescription : string
  described by baseElement : PeriodicElement
  described by materialSpecification : MaterialSpecification
  
```



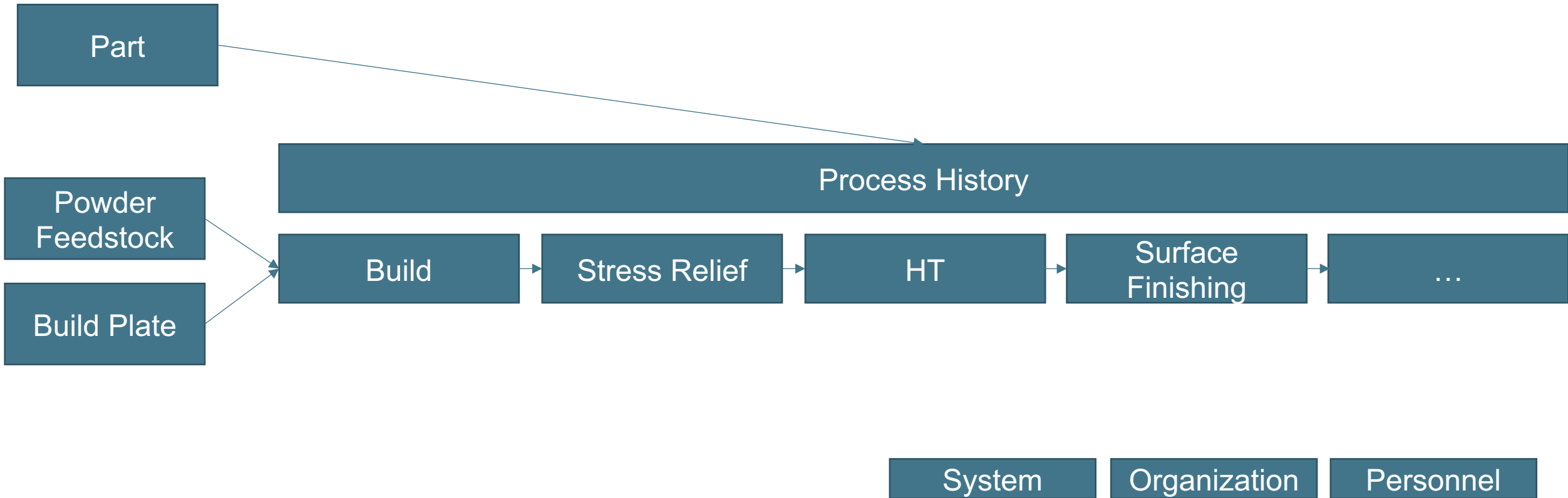
Semantics Toolkit (SemTK) - <https://github.com/ge-semtk/semtk>

```

described by parentPart with a single value of type Part,
described by specimenCoordinate (note "The location that the specimen was extracted from the original part.") with values of type
described by specimenTestLocation (note "Location of the test, inspection, or characterization relative to the specimen.") with a
// Future work: more robust definitions of orientations with respect to each other
  
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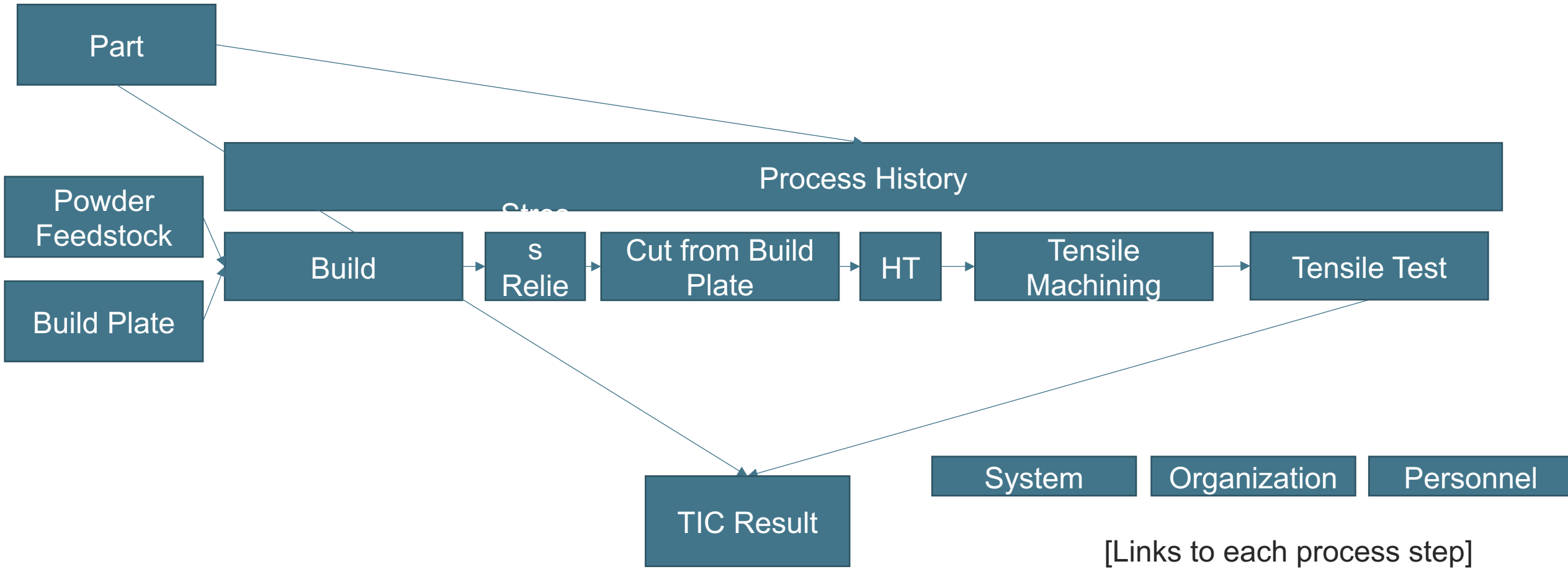
Test-Inspection-Characterization

AM Common Data Model: Example View

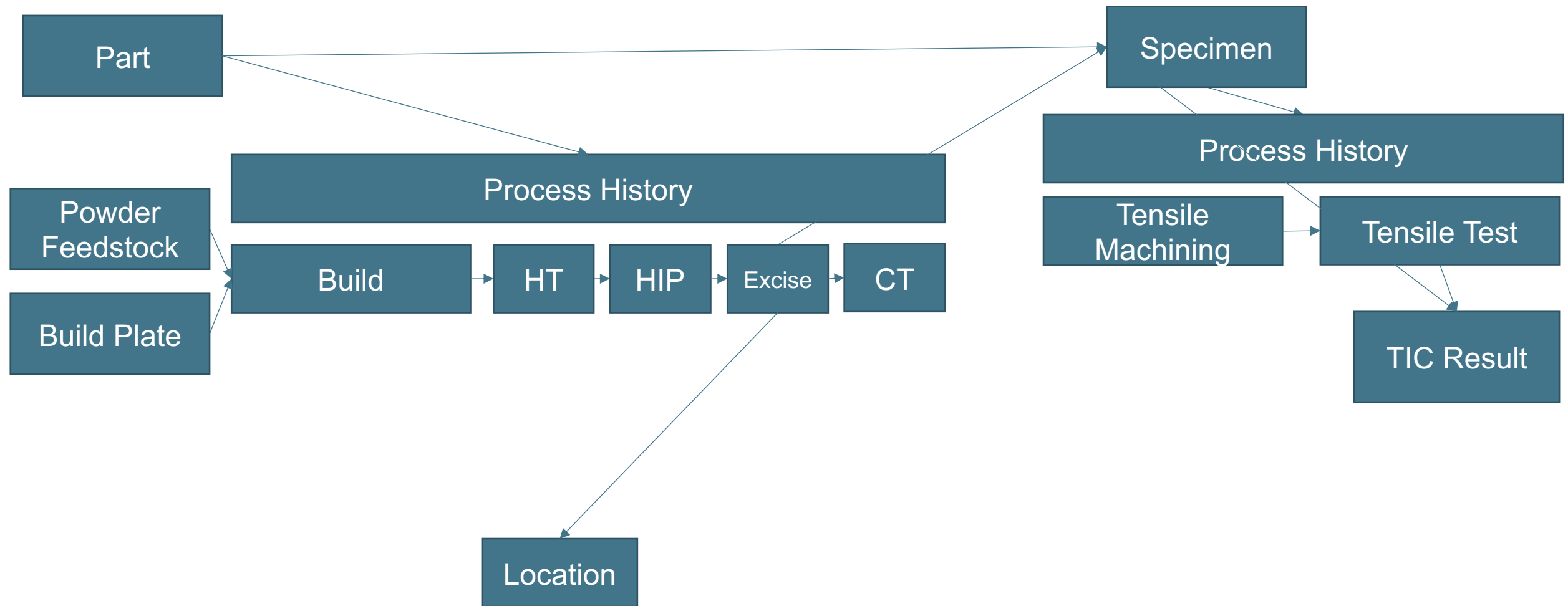


[Links to each process step and TIC]

AM Common Data Model: Example View



AM Common Data Model: Example View





Help Needed

AM is not all New

(Usual) AM Process Steps:

- Powder Manufacturing
- Powder Characterization
- AM Build
- Thermal Post Processing
- Machining
- Nondestructive Testing
- Destructive Testing

Legend:

- Legacy Process with Data Standardization
- Legacy Process with Standard Test Methods
- Other Legacy Process

Questions

- Will Adopting IOF Accelerate our Efforts?
- How Does IOF Help Define:
 - Data Structures/Schemas/Models?
 - Common Data Exchange Formats?
 - IIoT Communications
- Will Adopting IOF Help with PEST Challenge?

Thank you for your time.

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