An Open Material Database for Additive Manufacturing

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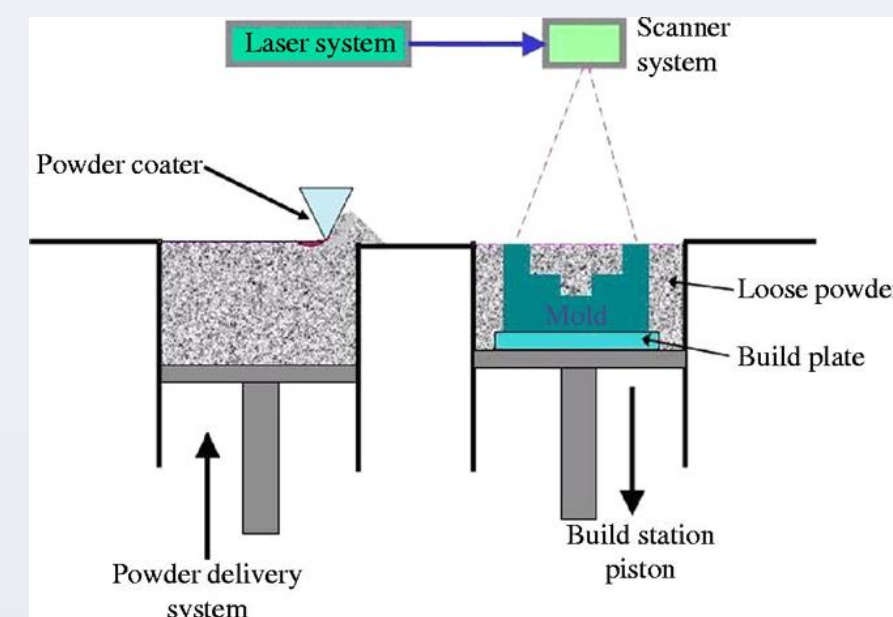Engineering Laboratory, National Institute of Standards and Technology (NIST)

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INTRODUCTION

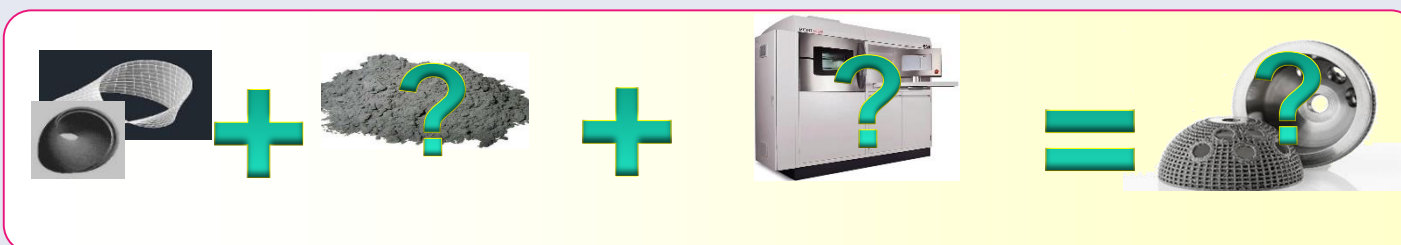### Additive Manufacturing

- ❑ Uses 3D design data to build up a component layer upon layer.
- ❑ AM fabrication process is complicated: e.g. rapid melting and solidification
- ❑ Quality depends on material, geometry, machine and process parameter

Direct Metal Laser Sintering

Hurdles preventing widespread adoption of AM technology in production

- ❑ Limited material choice
- ❑ Low repeatability and quality inconsistency associated with AM processes
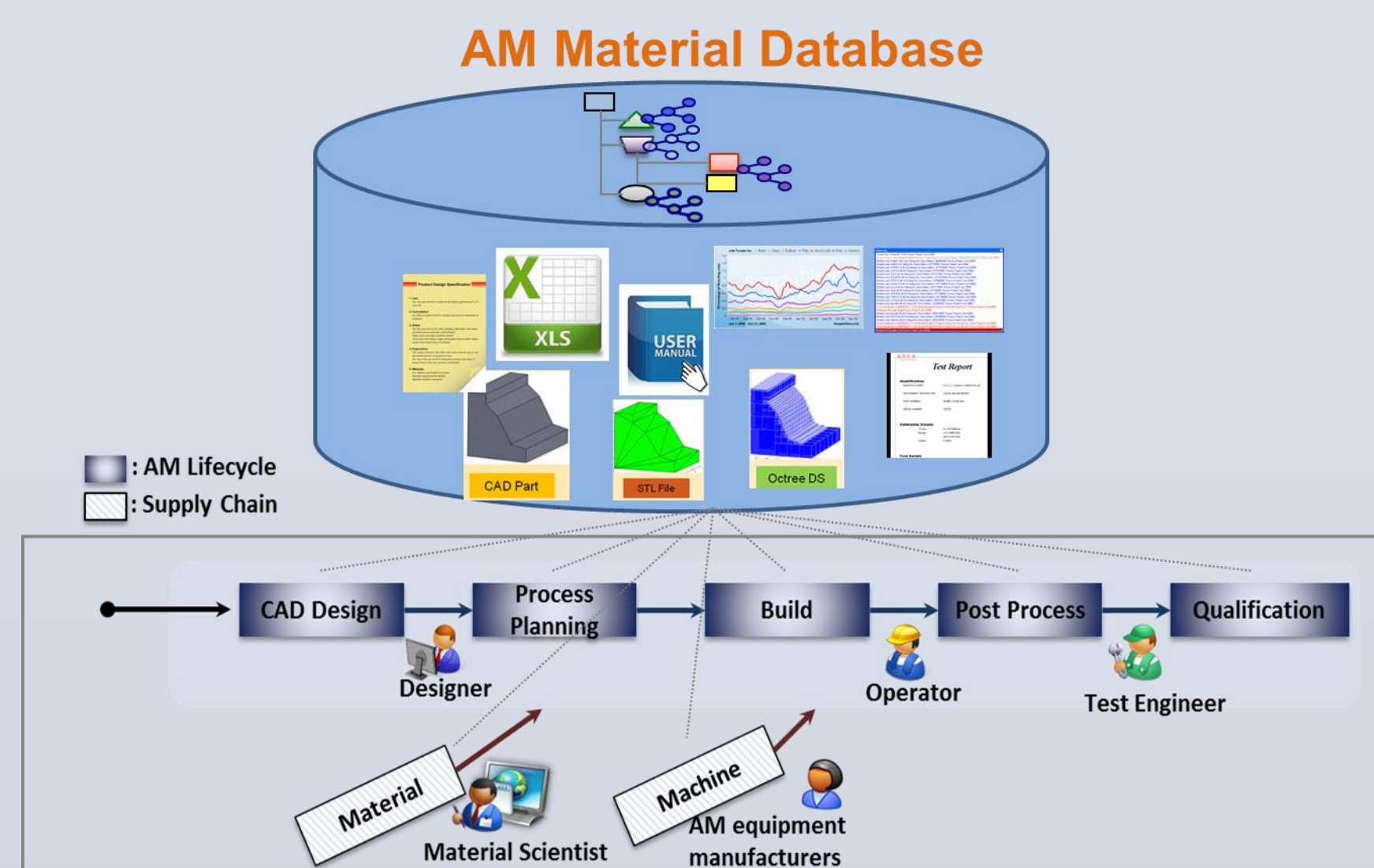- ❑ High cost and time in AM qualification

A key step in overcoming these hurdles is to understand geometry-material-process–structure-property relationships for any given AM process.
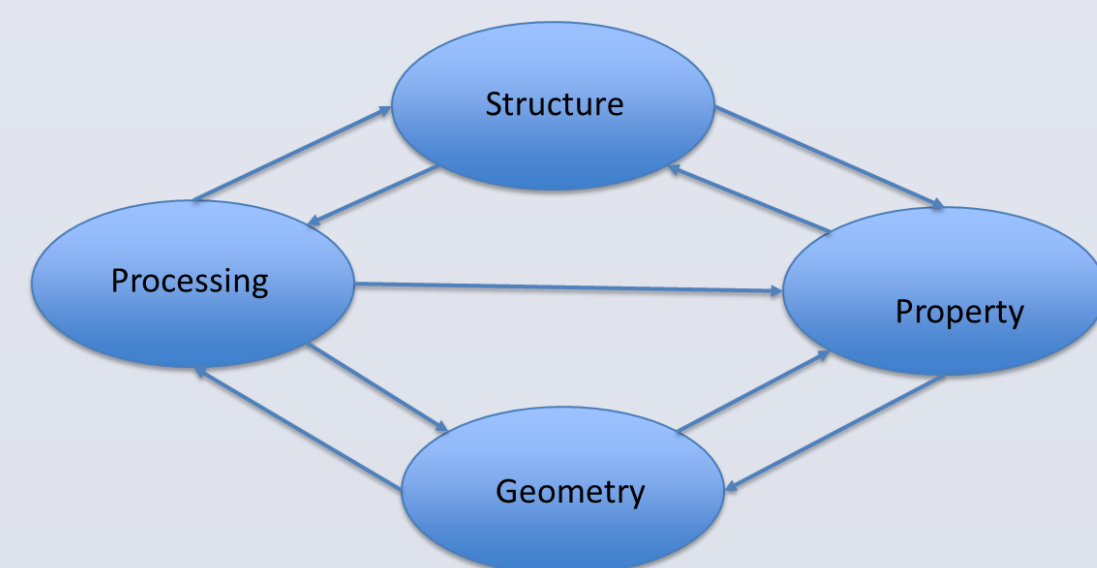
OBJECTIVES

To develop an open access additive manufacturing material database (AMMD) for the AM community to study AM material

AM Material Database

- ▪ AMMD shall capture the full process history through AM product cycle and supply chain data from material vendors and machine builders
- ▪ In addition AMMD supports:
  - ❑ Consensus schema development
  - ❑ Open data availability to all
  - ❑ Community generated/shared resource for varying data sets
  - ❑ Reference/ exemplary data for analytics

DATA SETS and MODELS

Vendor Provided Feedstock Material Data

Data properties	Description
Vendor Name	Feedstock material manufacturer's name
Material Type	Choose from nickel alloy, aluminum alloy, titanium alloy, cobalt alloy, copper alloy, stainless steel alloy and precious metal alloy.
Material Name	Name given by the vendor
Material ID	Unique ID given by the vendor; Vendor name + Material ID should identifies a specific feedstock material
Feedstock Material (powder) Properties	Provided material information includes powder density, powder size, powder chemical composition, spreadibility and flowability etc.
Feedstock Material (powder) processing information	Feedstock material processing information, e.g., is the powder inert gas atomized?
Feedstock Material Conformance Information	The conformance standards of the feedstock material, e.g., AMS 5666, ASTM B446 for Inconel 625

Feedstock Materials Testing Data

Test Information	Test name, ID; test organization, location, operator names, etc.
Test Type	Flowability/emissivity/emittivity/spreadibility etc.
Material Tested	Feedstock material information, including vendor name, material ID and lot/sublot numbers
Test equipment information	Test equipment model, identification
Test Standards	The conformance standards of the test.
Test Results	The results of a test

AM Machine Data

Vendor Name	AM machine manufacturer name
Process Type	One of the seven process types (defined by ASTM) the machine is capable of (currently only L-PBF is addressed)
Model Name	Machine model name given by the manufacturer
Owner Name	Machine owner's name
Machine ID	Unique ID given by the owner; Owner name + Machine ID should identifies an AM machine
Machine Location	Current machine location
Year of Made	When the machine was factory accepted
Calibration History	The calibration history of AM machine and its subsystems
Maintenance History	The maintenance history of AM machine and its subsystems

AM Part Design Data

| Part Geometry	Model or drawings defining a part geometry
GD&T and Support information	Geometry, dimensional, and tolerance information
Specimen location	Specimen location in the build volume
Specimen geometry	Specimen drawings
Specimen ID	Unique identification of a specimen in a build

AM Build Process Data

| Manufacturer Name	AM Service provider's name
Build ID	Unique build ID given by the manufacturer; Service provider's name + Build Id should uniquely identify a build
Build Duration	Start and stop times of the build
Operator Information	Operator's name, skill level (hours of operating an AM machine)
Material Used	Feedstock material information, including vendor name, material ID and lot/sublot numbers
Machine Used	machine ID of the machine used for this build, which will link to the complete information (in the previous table) about the machine
Material Handling	Pre-process of feedstock material, including recycling information
Machine Setup	Machine set up procedures
Process parameters	Process parameters configured for the build
In-situ Monitoring	Process monitoring information, including build logs, monitoring data and control data trended.
Post Process Information	Post process procedures and parameters
Other pedigree information	Process control/ approval information

AM Part Testing Data

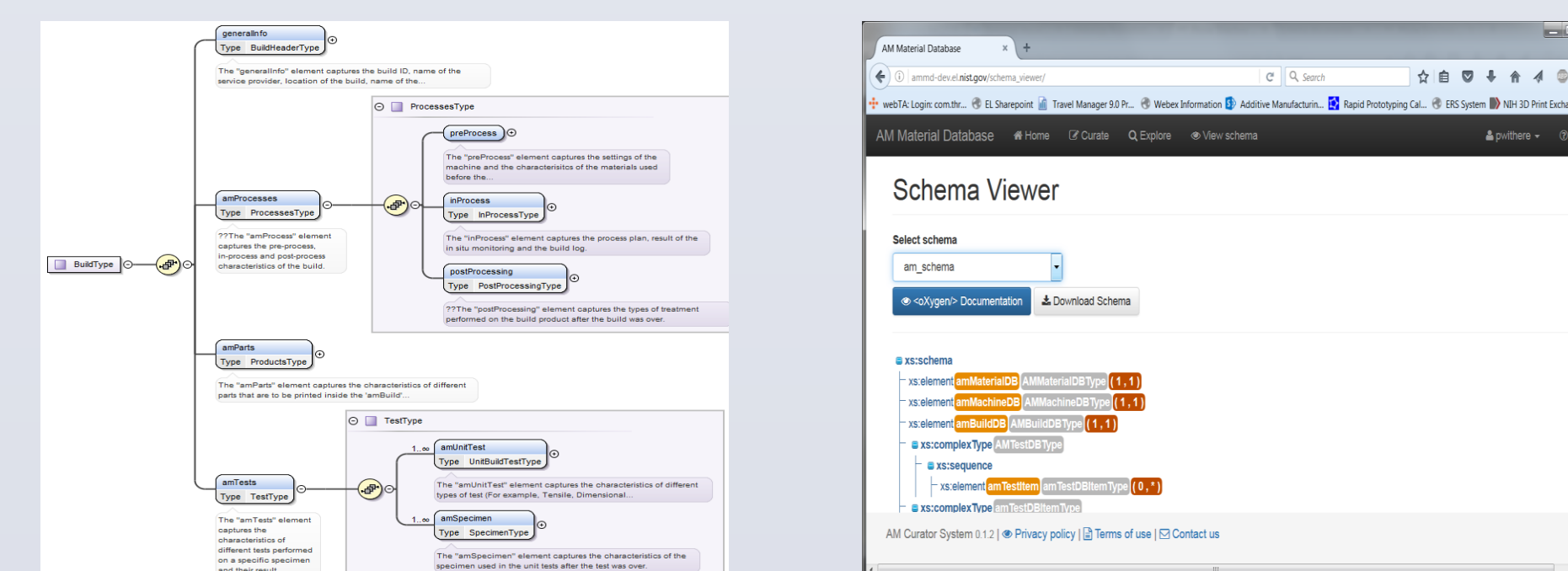| Tester Information	Test organization, location, operator names, and certifications etc.
Test Type	Mechanical/chemical/microstructure/dimensional/surface etc.
Specimen information	Build ID and Specimen ID
Test equipment information	Test equipment model, identification
Test Name/ID	Test names and IDs; Build ID + Test ID should uniquely identify a test
Test Standards	The conformance standards of the test.
Test Results	The results of a test

AMMD Data Structure
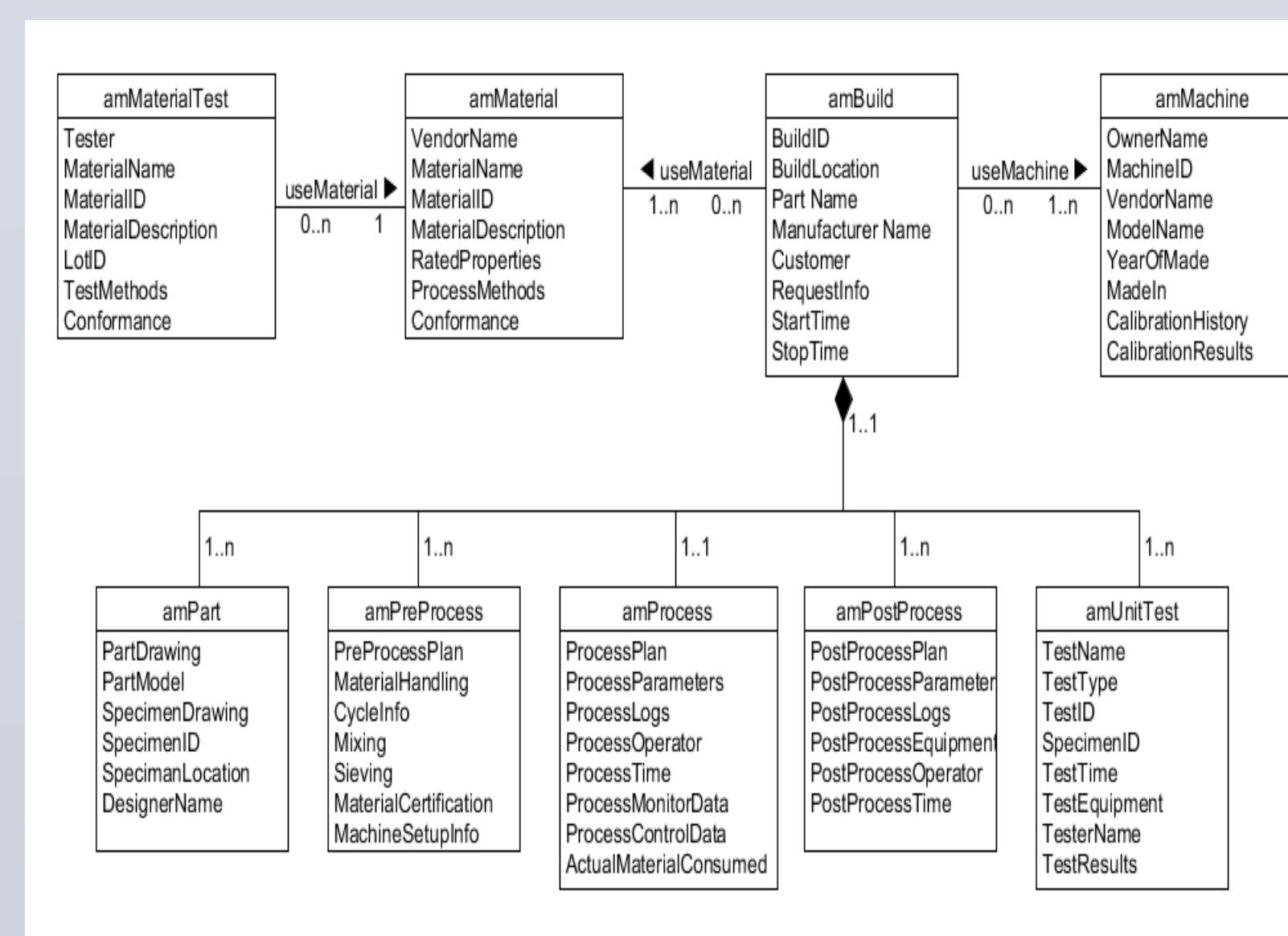
DATABASE SYSTEM

AMMD System Architecture
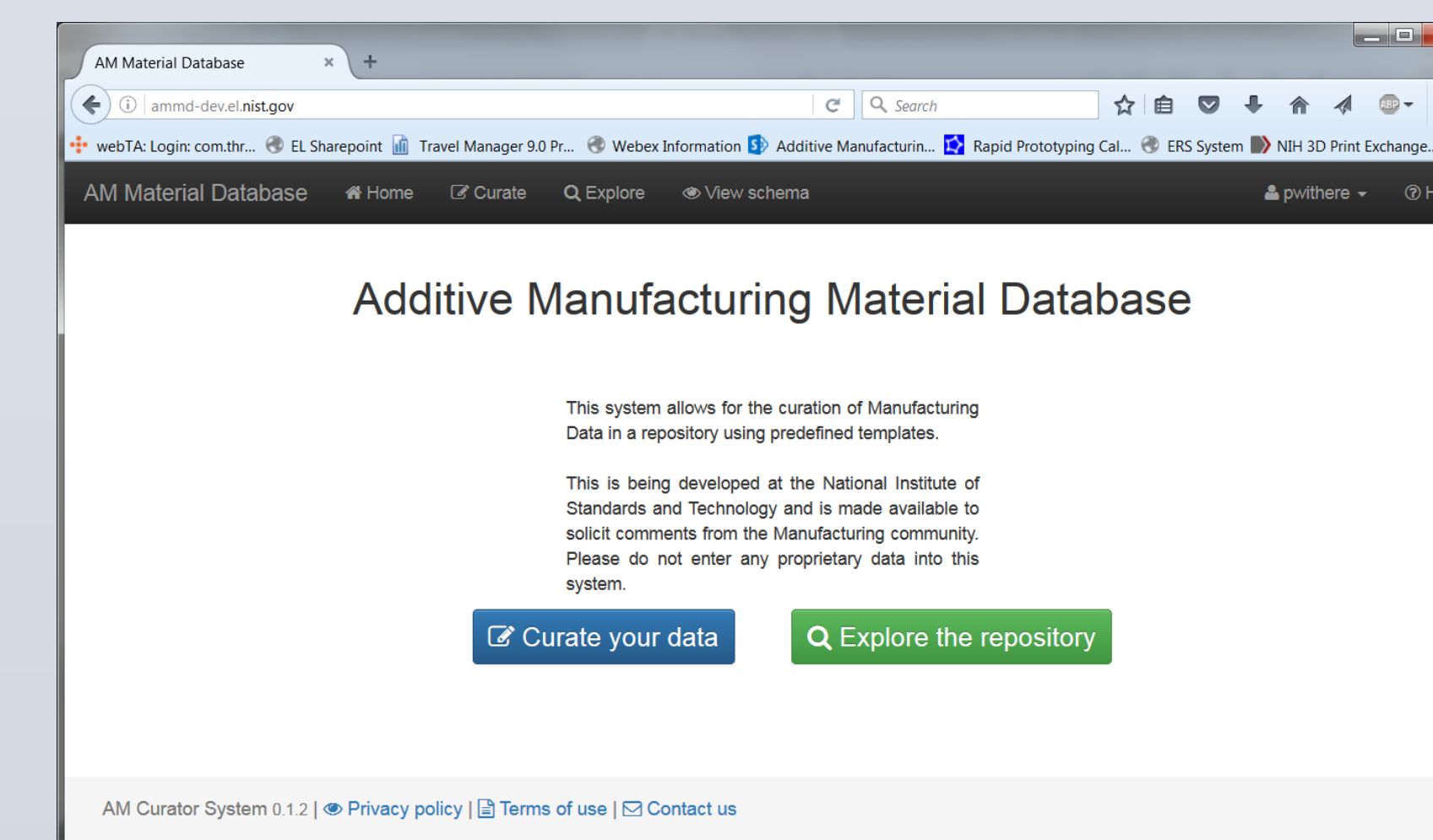
NIST AM Database Schema
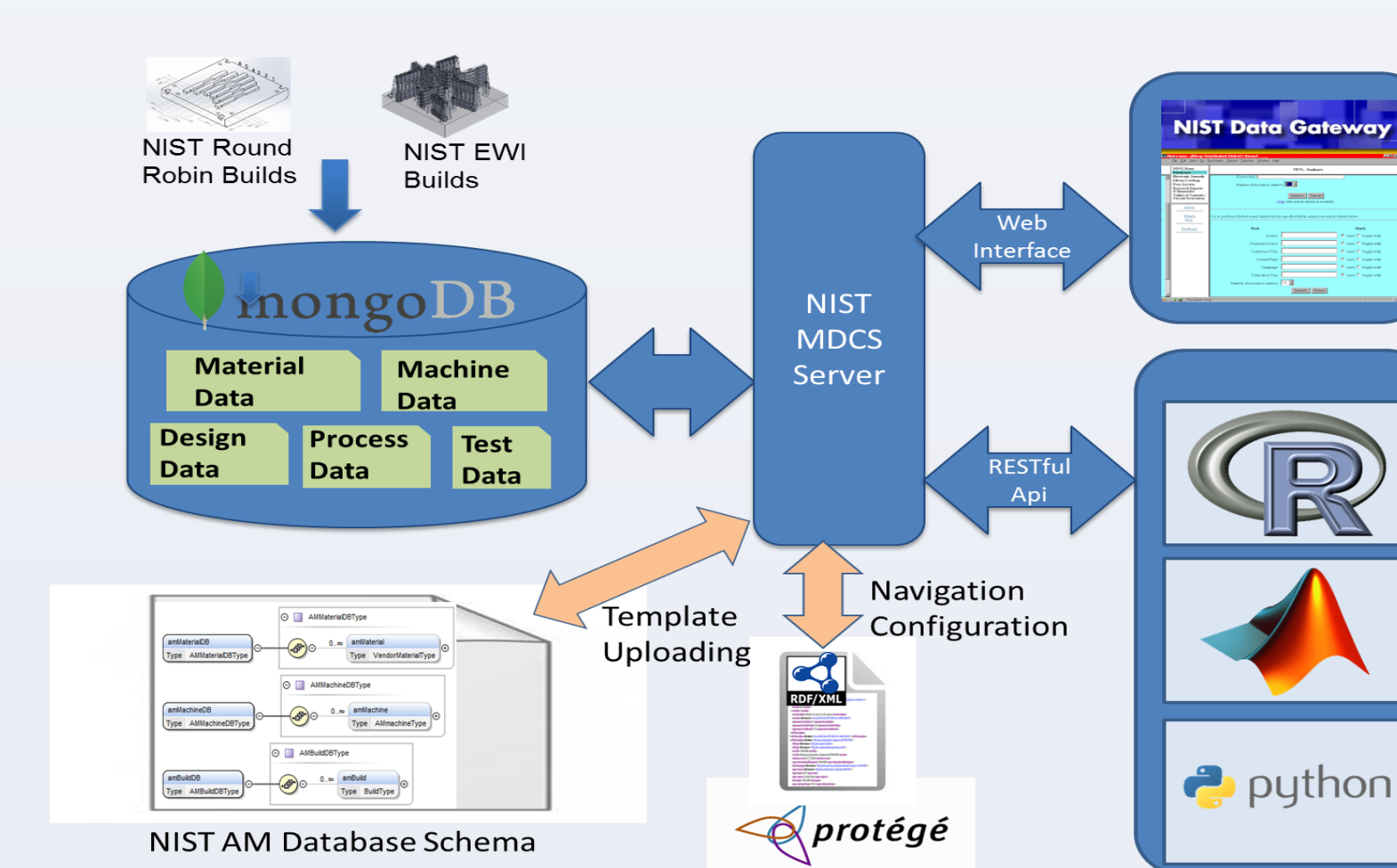
- ❑ *MongoDB database* – a document-based database allowing open structure and access for data population.
- ❑ *NIST MDCS (Material Data Curation System) server* developed under Material Genome Initiative (MGI) effort to wrap MongoDB by providing XML-based templates for data population and provide a REST API for application integration.
- ❑ *NIST AMMD database schema* – The xml schema is developed to model the data sets for AM material database.
- ❑ *A NIST-hosted web portal* – AM material data, AM machine data, build data and test data can be explored through a user friendly navigation schema.
- ❑ *Schema navigator* – A tool build on the navigation configurable through a Resource Description Framework (RDF)/XML file, built using an ontology editor such as Protégé.
- ❑ *AM Build, Material, and Testing Data* - Complete process history and test data AM builds generated from AM research community.
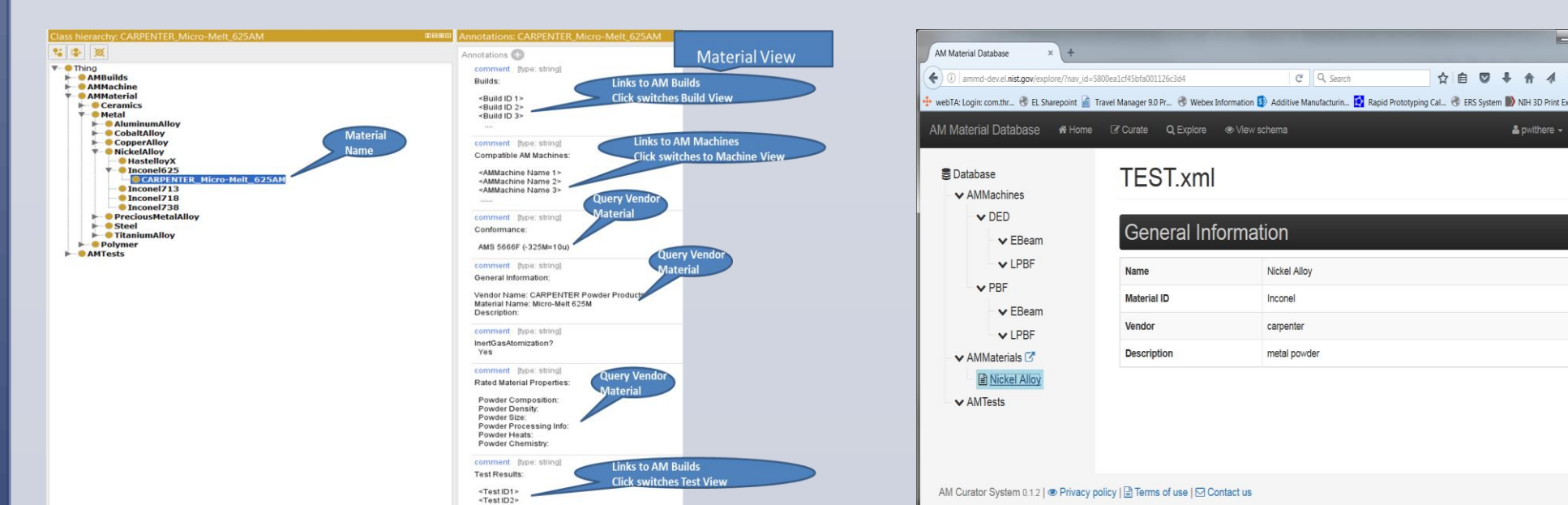
AMMD Data Schema and Viewer

Schema Viewer
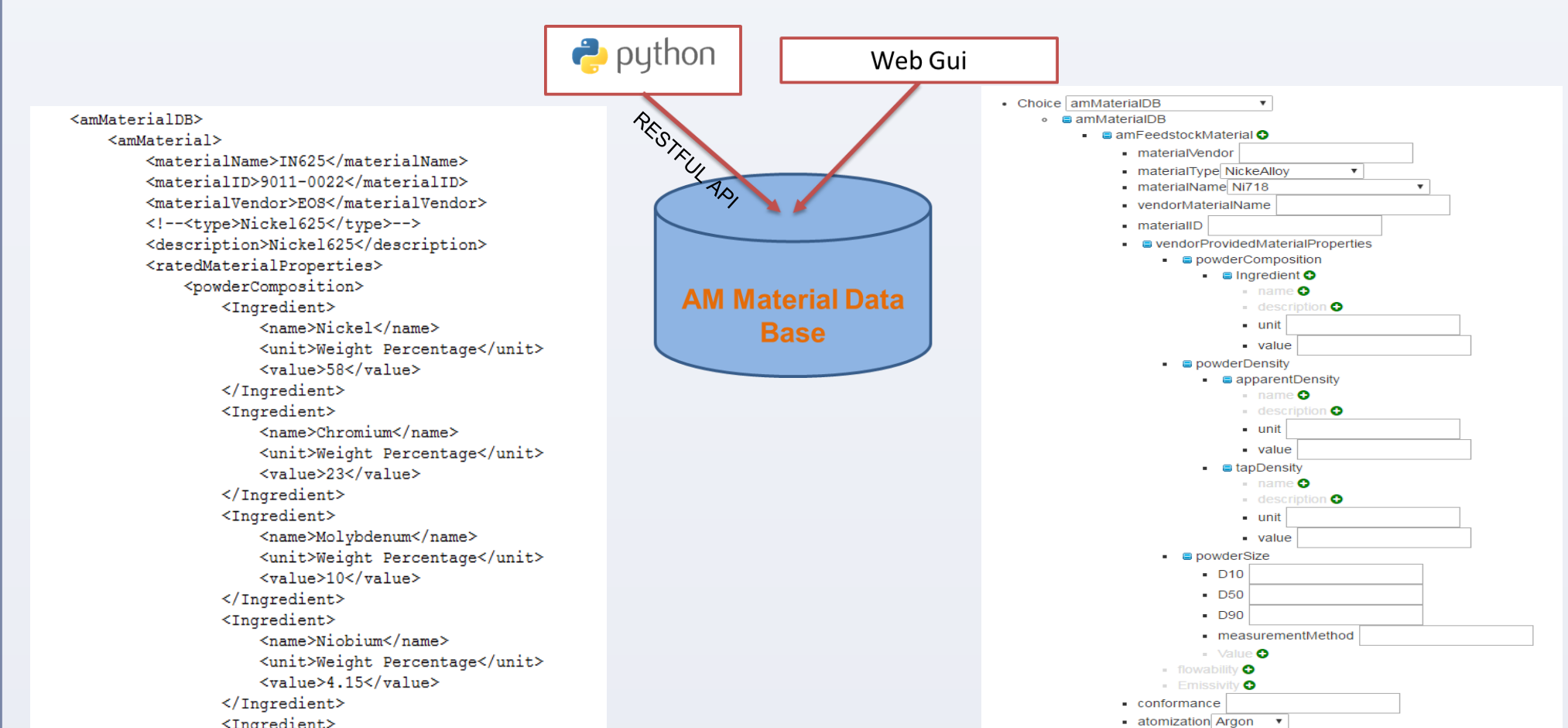
AMMD Web Portal

Additive Manufacturing Material Database

This system allows for the curation of Manufacturing Data in a repository using predefined templates.

This is being developed at the National Institute of Standards and Technology and is made available to solicit comments from the Manufacturing community. Please do not enter any proprietary data into this system.

Curate your data   Explore the repository
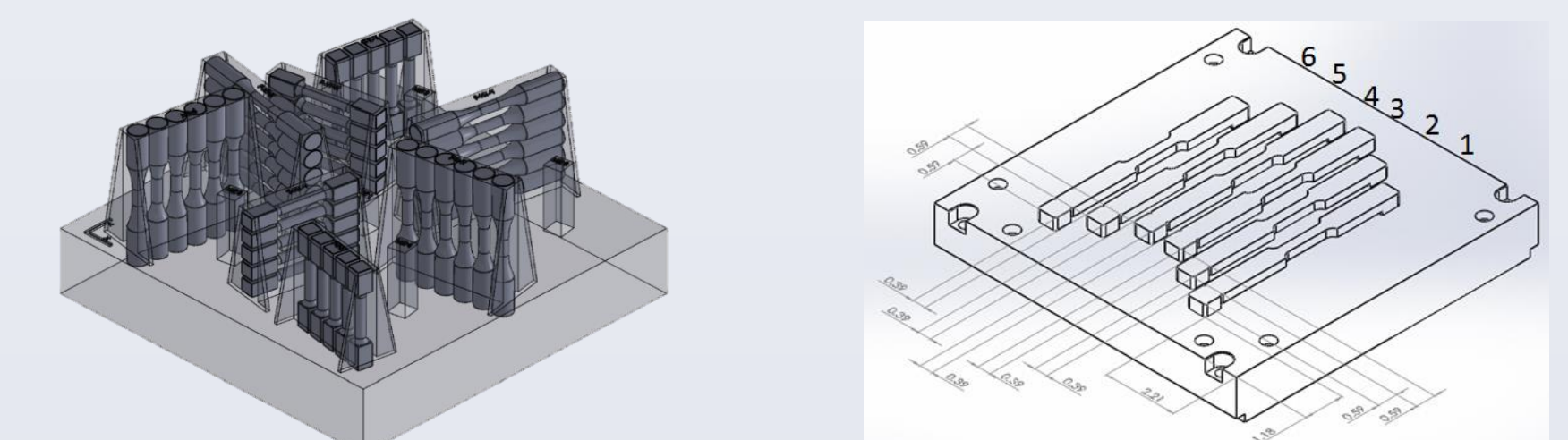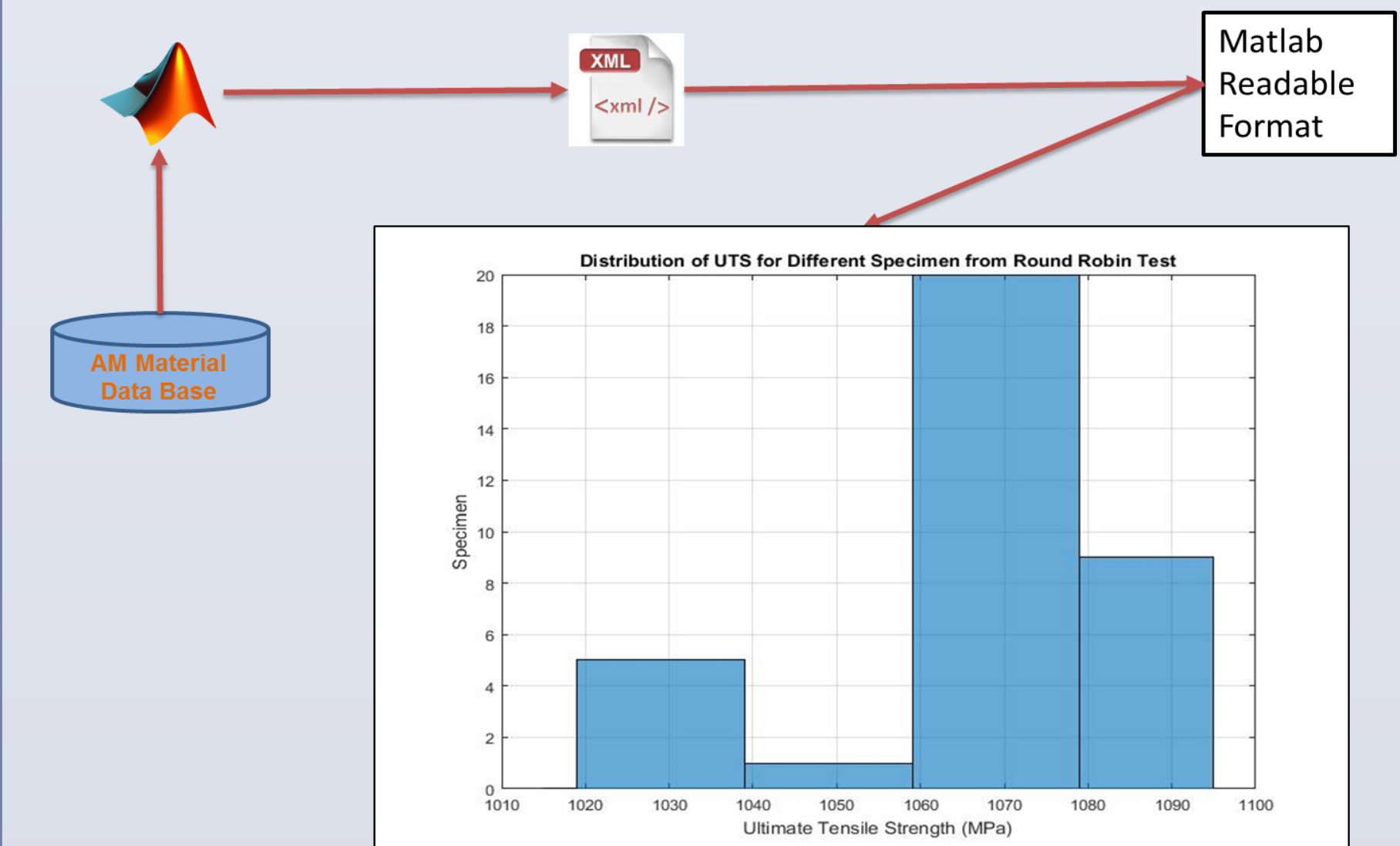
AMMD Customizable Data Exploration

AMMD DATA CURATION

Two Ways of Populating Data

First Batch of Data – NIST Round Robin Test Data, Nickel 625 on EOSINT M 270

DATA ANALYTICS

Matlab Readable Format

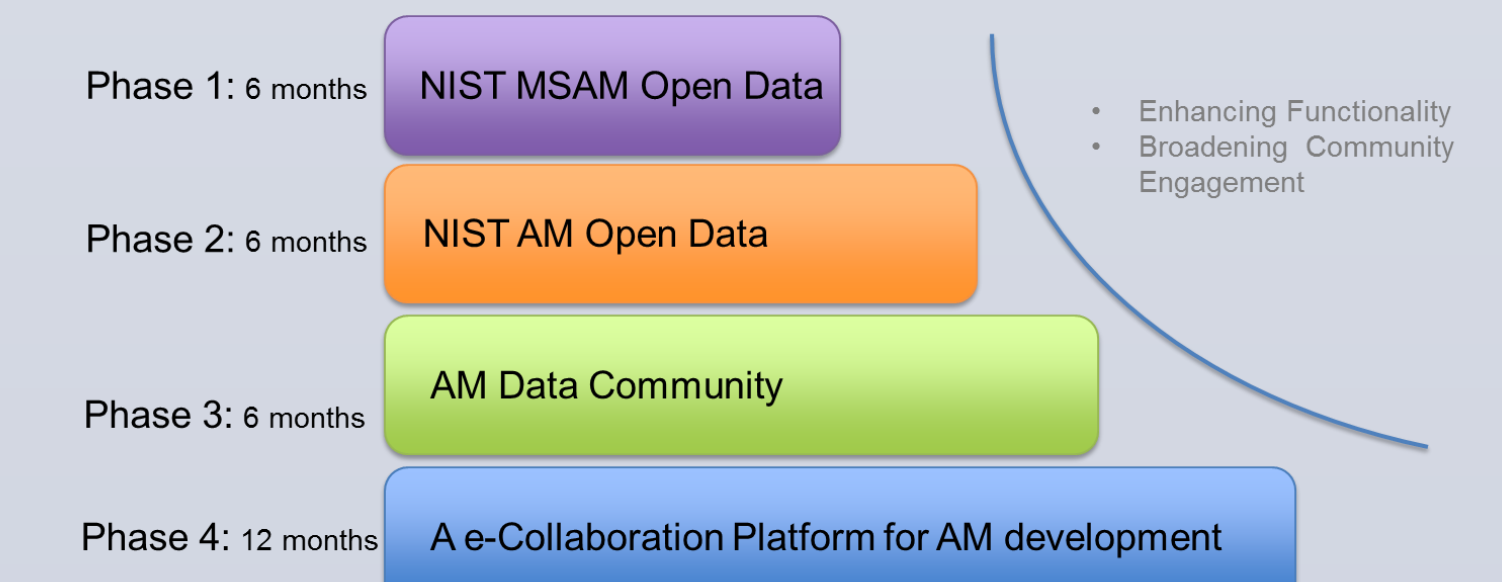Distribution of UTS for Different Specimen from Round Robin Test

CONCLUSION AND FUTURE WORK

- ❑ Releasing the database at the end of Nov, 2016
- ❑ Improving the enabling technologies
- ❑ Build an Open AM Collaborative Development Environment

Phase 1: 6 months   NIST MSAM Open Data
Phase 2: 6 months   NIST AM Open Data
Phase 3: 6 months   AM Data Community
Phase 4: 12 months   A e-Collaboration Platform for AM development

- Enhancing Functionality
- Broadening Community Engagement

REFERENCES

National Science and Technology Council, *Materials Genome Initiative for Global Competitiveness,* Office of Science and Technology Policy, Washington DC; 2011