Digital Engineering Archives

NSF IIS-0456001

William C. Regli
Department of Computer Science
College of Engineering
Drexel University
Philadelphia, PA

Drexel UNIVERSITY

GICL

Digital Engineering Archives Team

- Co-Investigators
  - Ali Shokoufaneh — Drexel University
  - Wenfei Fan — University of Edinburgh, UK
  - Steve Brooks — Department of Energy & KCP/Honeywell FM&T
- Collaborators
  - Maurice Smith — Department of Energy & KCP/Honeywell FM&T
  - Steve Ray — National Institute of Standards and Technology
  - Tony Brown — AWE, Ministry of Defence, UK

An Engineering Archive Problem

3D CAD data

- is ubiquitous
- is a complete and unambiguous shape definition
- documents institutional memory, intellectual property and trade secrets
- is the critical for integrating design, manufacturing and product lifecycle activities
- captures device behavior and performance

However

- Formats are proprietary
- Complete content and meaning are not captured by 2D images or shape representations
- Engineering designs are "prescriptive"
  - We need to be able to make it and use it
- Related metadata is complex, multi-disciplinary, and hard to formally represent
- Engineering data is hard to index and search
  - Currently: BoMs or keywords

Current State of Engineering Archives in Industry

From PDES Inc/USPro studies in 1995 and 2002:

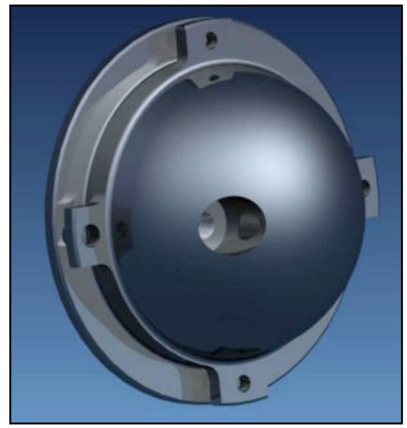
- Media are tape, microfilm, and paper
- Archived product data is generally in native CAD, proprietary, or paper formats.
- Conversion is necessary to make archives usable.
- Most keep old versions of application systems to make use of the archived product data.
- Top issues from industry:
  - Completeness of data
  - Usability of data
  - Platform independence

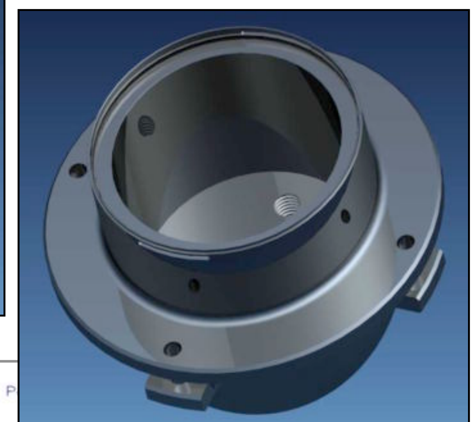
Case Study: Airbus (from PDES Inc/USPro)

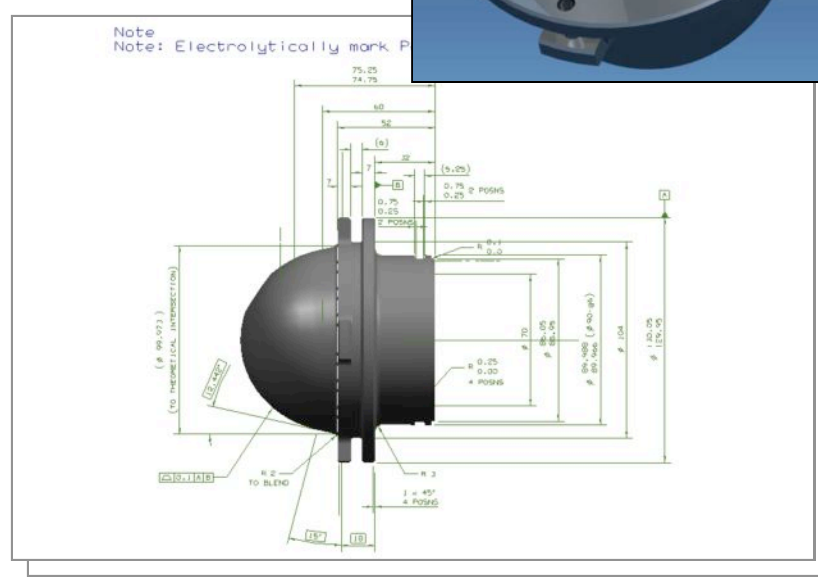
- Aerospace industry uses many 3D CAD systems
  - Full definition is based on 3D Digital Mock-up's (DMU)
  - The number of CAD and PDM Models has grown rapidly.
- AIRBUS has experience in digital long term archiving of "Drawing Sets" and other documents since 1986
  - As of 2002
    - 923,126 CAD-Drawings as tiff documents
    - 3,500,000 archived objects in total
- **Result:** Every airplane is 100% described by 2D-Drawings and other text documents in the archive
- **Why:** No long term archive for 3D-CAD data!
  - CAD models are managed in native formats in their native data bases (problems of periodic migrations)

Our Challenge Problem: <u>UK AWE Amber 2</u> Part

- Partner: **Kansas City Plant**
  - 50 year history
  - Primary manufacturing facility for the DoE & NNSA
  - Expertise in discrete parts, electronics, MEMS, …
- The <u>Amber 2</u> part
  - High-precision machined part
  - Designed in the UK
  - Analysis at both UK AWE and KCP
  - Fabricated at KCP



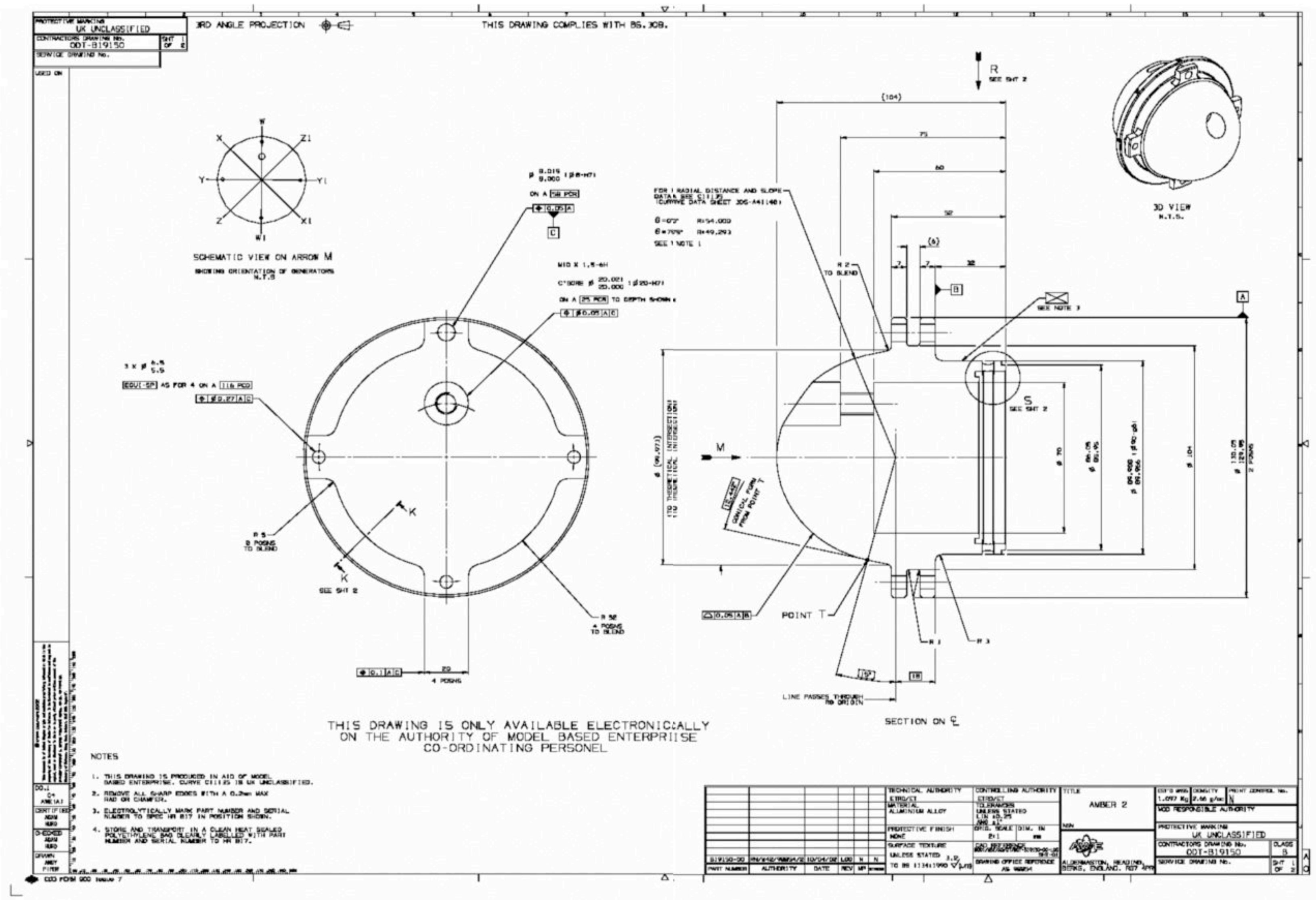




UK AWE Amber 2 Part Data

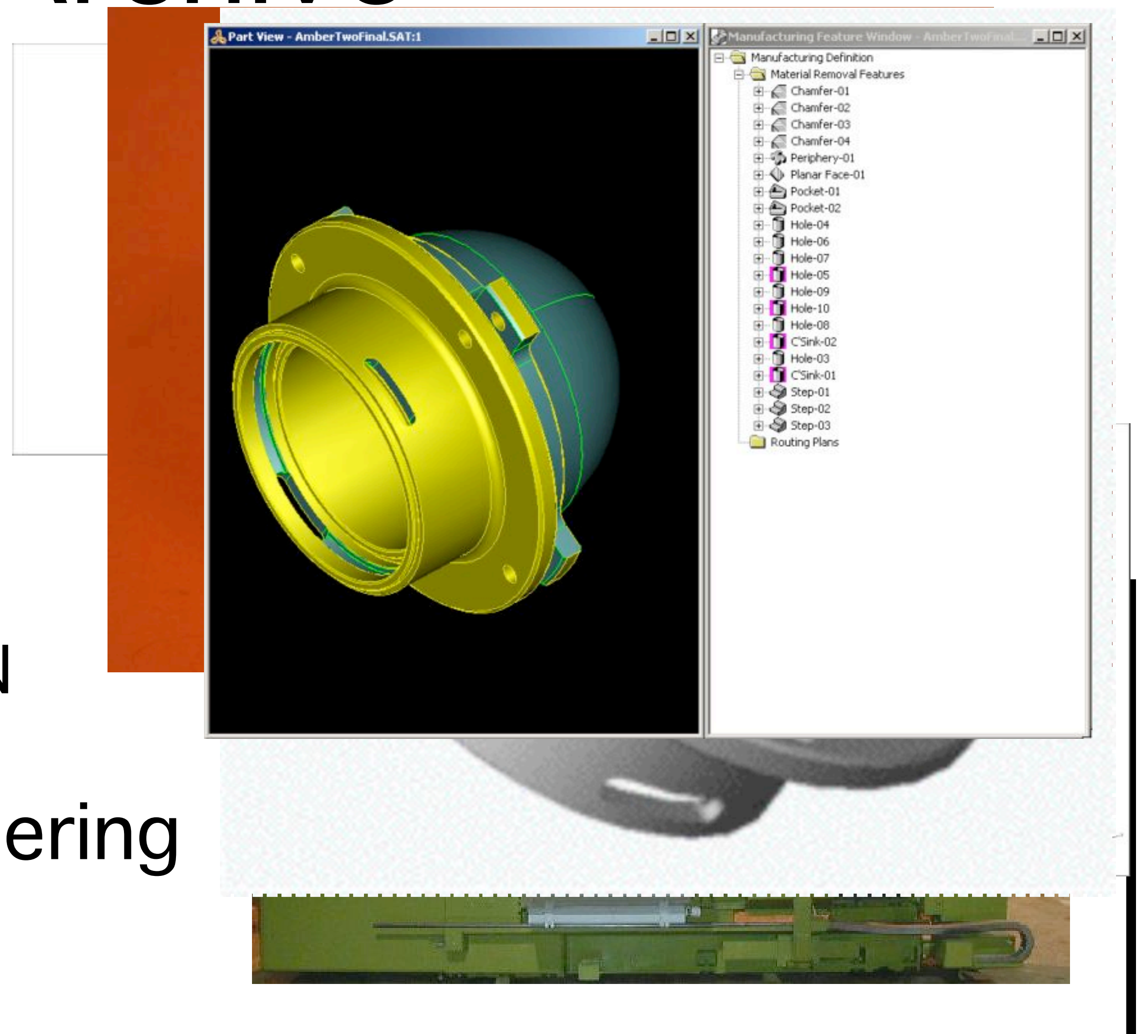
- 2D CAD Drawings
  - TIFF images
- 3D CAD data
  - Parasolid, Pro/E, STEP, ACIS, …
- Shape data
  - Mesh & point cloud
- Tolerance data
  - ASME Y14.5 tolerances and tolerance features
  - Tolerance analysis
- Analysis data
  - FEA parameters and output
- Manufacturing data
  - Features
  - Process plans
  - Manufacturing plan simulations
- Fabrication data
  - Tooling, cost, time
- Inspection data
  - Inspection plan, robotic simulation
- Documentation
  - MS Word files
  - AVIs, MPGs
  - Other files

Current Archive Format?



Information Missing from Archive

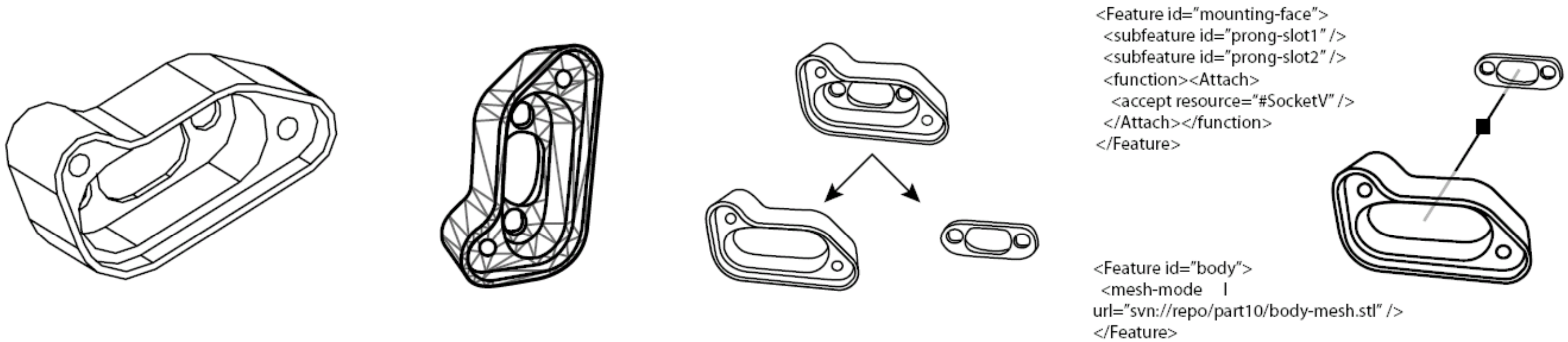
- Tolerances
- Manufacturing Planning
- Analysis
- Inspection
- Fabrication
  - Okuma LH35-N CNC lathe
- Reverse Engineering



Digital Engineering Archives Demonstration Objectives

- Archive Representations
  - Extend techniques from ISO, NIST, W3C
- Indexing & Search Techniques
  - Extract archive knowledge from semi-structured engineering data
  - Search and matching algorithms
- Deploy and Test
  - With DoE-NNSA & UK-AWE collaboration data
  - With Design Repository (http://www.designrepository.org)

Archive Representations



CAD

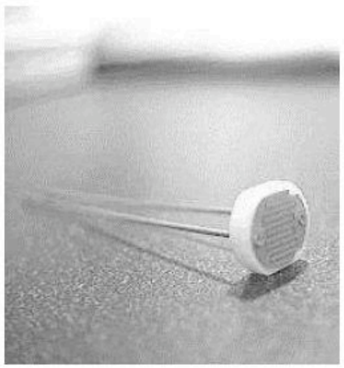
Shape Model

Extraction of semantic features---e.g. assembly points, mechanical joints

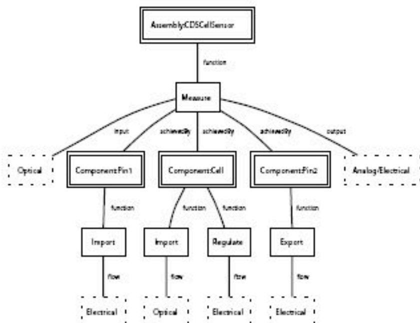
Annotation and linking of feature geometry

- Objective: Semantic transparency
- Approach:
  - Integrate shape models with ISO and W3C standards
  - Capture metadata by *extending* ISO/W3C representations
  - Link and cross-reference metadata to shape models
- Rationale:
  - ISO/W3C standards we propose (PSL, OWL) are based on formal logics
  - Shape data is easily preserved (points, triangles)

Example Representation



(a) Typical CDS Cell.



(b) Simplied function and flow structure.

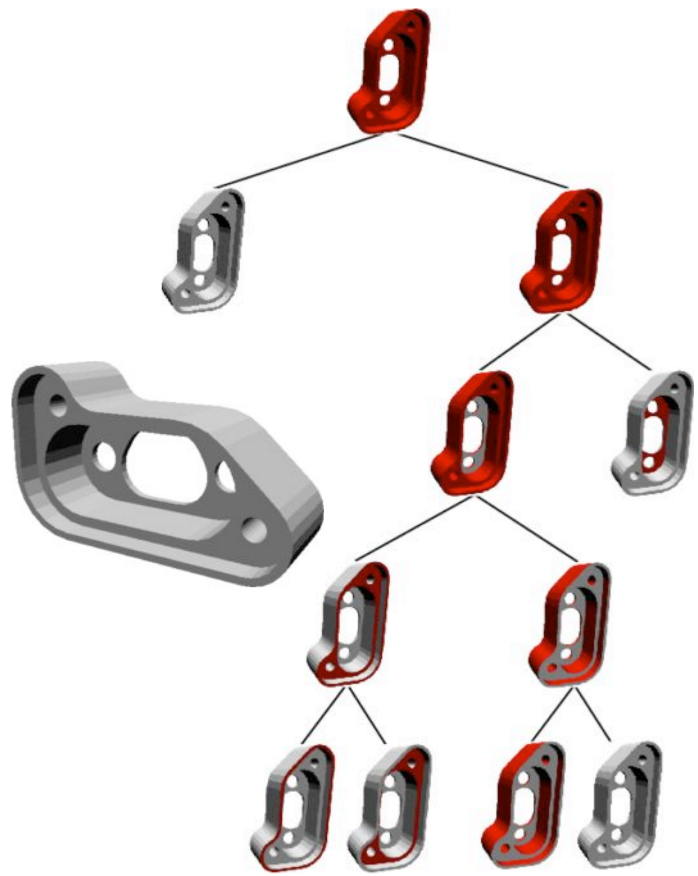
CDSCellSensor type Assembly	*Cell type Component*	*Pin2 type Component*
anonA5 type Measure	*anonA11 type Import*	*anonA16 type Export*
anonA6 type Optical	*anonA12 type Optical*	*anonA17 type Electrical*
anonA5 input anonA6	*anonA11 ow anonA12*	*anonA16 ow anonA17*
Pin1 type Component	*Cell function anonA11*	*Pin2 function anonA16*
anonA8 type Import	*anonA13 type Regulate*	*anonA5 achievedBy Pin2*
anonA9 type Electrical	*anonA14 type Electrical*	*anonA18 type Analog*
anonA8 ow anonA9	*anonA13 ow anonA14*	*anonA18 type Electrical*
Pin1 function anonA8	*Cell function anonA13*	*anonA5 output anonA18*
anonA5 achievedBy Pin1	*anonA5 achievedBy Cell*	*CDSCellSensor function anonA5*

(c) Description-logicmodel form.

- Previous work
  - Use of OWL and PSL to represent engineering function and behavior
  - Joseph Kopena, William C. Regli: Functional Modeling of Engineering Designs for the Semantic Web. IEEE Data Eng. Bull. 26(4): 55-61 (2003)
  - Joseph Kopena, William C. Regli: DAMLJessKB: A Tool for Reasoning with the Semantic Web. International Semantic Web Conference 2003: 628-643

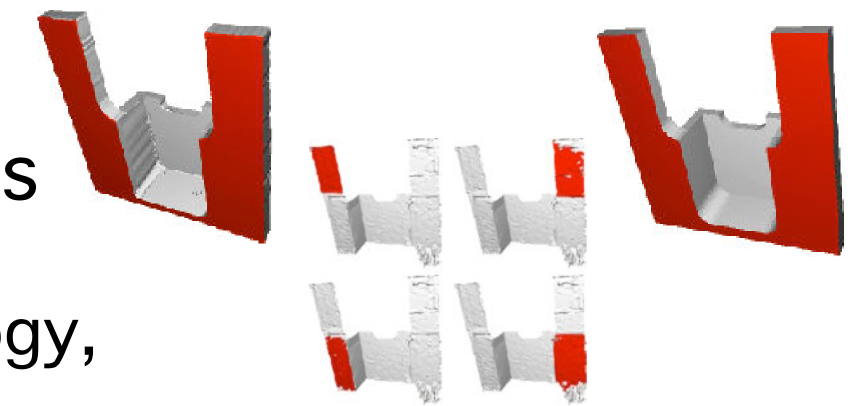
Indexing & Search Techniques

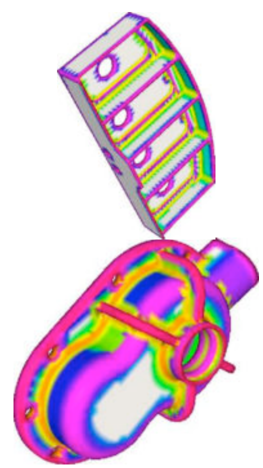
- Objective: populate archives and answer engineering questions
- Approach:
  - Extract knowledge from semi-structured documents
  - Semantically-driven segmentation and matching
- Rationale:
  - Algorithmic techniques will be in the open literature and preservable

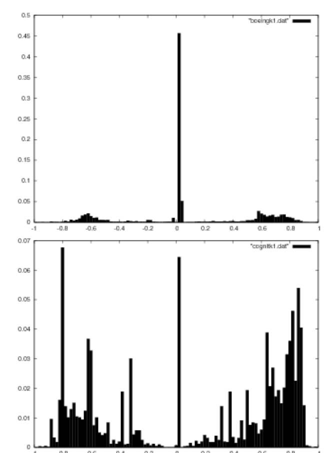


Our Previous Work

- Over 10 search & matching techniques
  - Feature-based, shape-based, topology, curvature
- Wide set of 3D data types
  - Point-based, facet, solids
- Current work
  - Learning classifications
  - Many-to-many matching

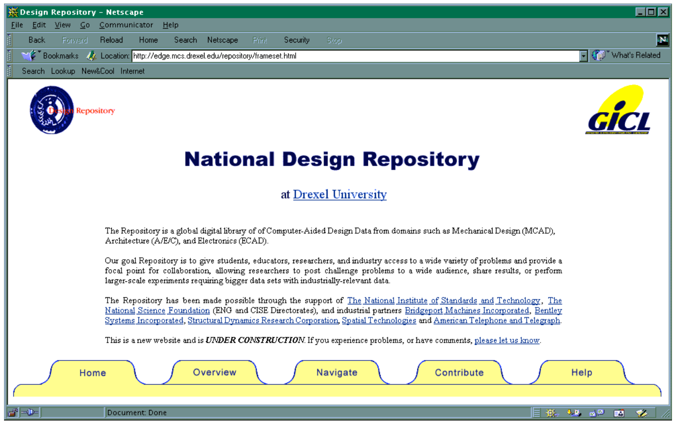


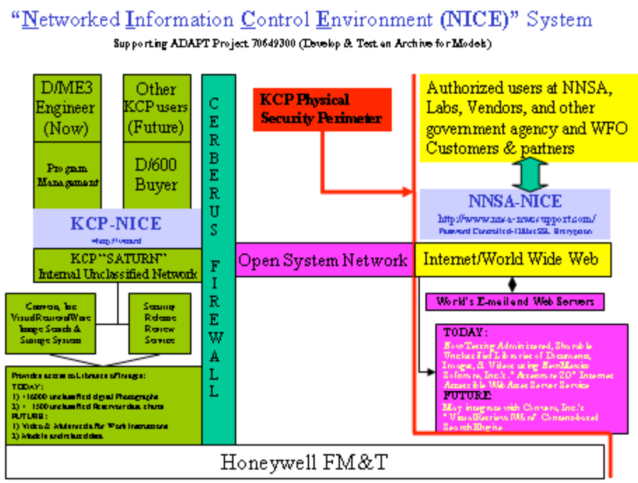




Deploy and Test

- Objective:
  - Validate across large and diverse dataset
  - Improve representations and algorithms based on data
- Approach:
  - National Design Repository
  - DoE NNSA KCP datasets
    - “NICE” System





Synergistic Activities

- At DoE/NNSA KCP and UK AWE
  - Model-Based Design Initiatives, Model Archive Standards Team
- At Drexel University
  - Indexing and Matching Relational Structures for Image Interpretation, Office of Naval Research
  - Representation and Design of Heterogeneous Structures, NSF ITR
  - Computer Aided Tissue Engineering, NSF ITR
  - Applied Communications and Information Networking (ACIN), US Army
- At Edinburgh
  - Digital Curation Centre (EPSRC)
  - Vectorised XML (EPSRC)
  - The Royal Society Wolfson Merit Award
- Collaboration with agencies and organizations
  - NIST, ISO, etc

Milestones

- Year 1
  - Focus on tolerance and manufacturing metadata
  - W3C/ISO-based tolerance representation
    - Extend OWL with NIST PSL
  - Enhanced shape representation
    - "In process" shapes
    - Links to tolerances
  - Representation of Amber 2 part and search demo on a part dataset
- Years 2-3
  - Expand representations to include other metadata
    - Analysis parameters
    - Assembly information
  - Extraction of metadata from semi-structured engineering documents
  - Semantics-based object segmentation and indexing
  - Digital Archive Toolkit for Engineering (DATE)
    - Within DoE/NNSA KCP
    - National Design Repository

Expected Impact

- New, semantically transparent, grounded representations for engineering metadata
  - Starting with tolerances and manufacturing processes
- Toolkit for populating and searching geometry-rich engineering archives
- Support stewardship, surveillance and de-manufacturing missions of the DoE/NNSA and UK AWE
- Transition tools into use by government and industry
  - NNSA's problem is also American industry's problem
- Work for positive changes in ongoing standards efforts at NIST, W3C and ISO

Q&A