Digital Preservation of CAD Artifacts

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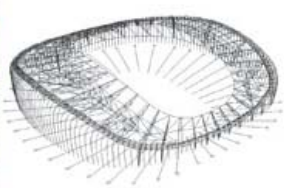
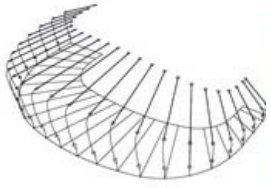
Computer-Aided Design & Manufacturing

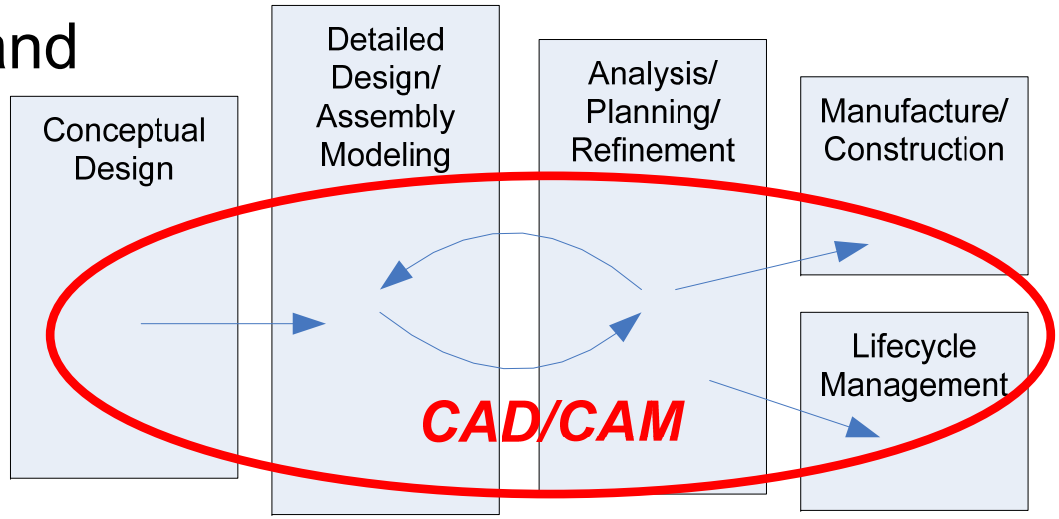
CAD/CAM data

- is ubiquitous
- supports a complete and unambiguous product
- documents several *trillion dollars* of institutional memory, intellectual property and trade secrets, etc
- is the critical for integrating design, manufacturing and product lifecycle activities
- captures behavior, performance, etc

Economist, Jun 5th 2008





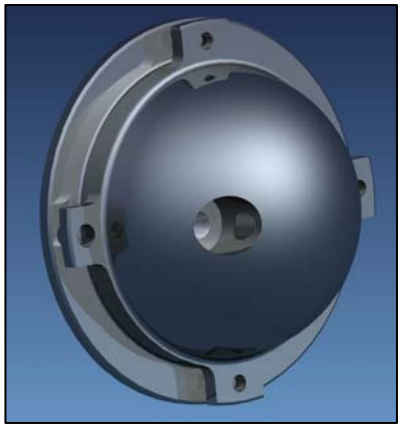


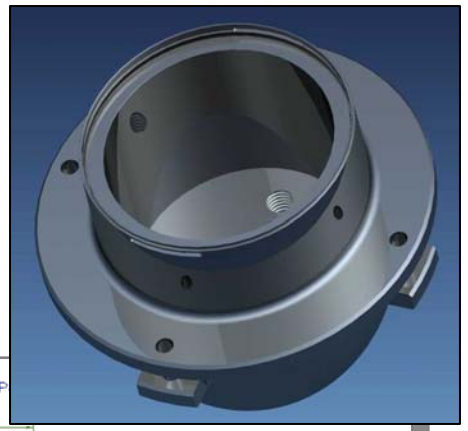
Why is Archiving CAD Challenging?

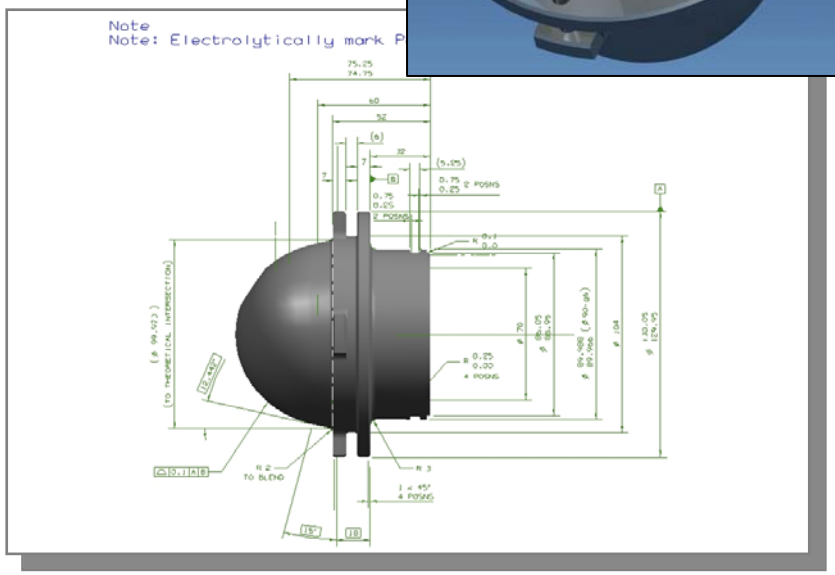
- Complexity & diversity of the data types
  - Metadata is complex, multi-disciplinary, and hard to formally represent
  - Semantics of data must be preserved (Design, modeling, simulation, etc)
  - Important formats are proprietary; 2D images do not suffice
  - Data elements can be huge! Integrity of data a vast problem.
- Temporal aspects
  - May need to preserve changes in an object over time
- Business process workflows within organizations
  - Data must be captured and integrated from different places within the organization
- Engineering information is both *descriptive* and *prescriptive*
  - What to make and how to make it
- Lack of a well-defined stakeholder
  - People do not want to do any additional work to preserve
- It is hard to envision the ultimate use for the preserved data
  - Archeology, forensics, history, etc.

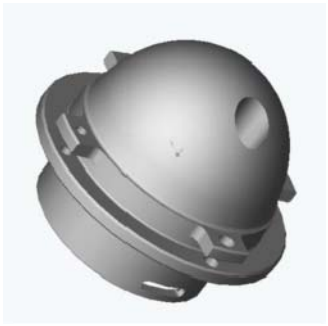
A Case Study in CAD Archiving: UK AWE Amber 2 Part

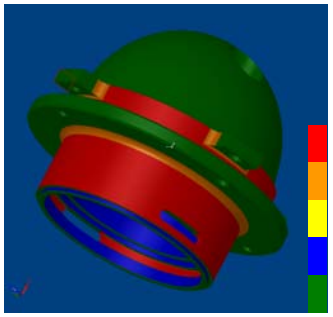
- Partner: **Kansas City Plant & UK AWE**
  - 50 year history
  - Primary manufacturing facility for the DoE & NNSA
  - Expertise in discrete parts, electronics, MEMS, …
- The Amber 2 part
  - High-precision machined part
  - Designed in the UK
  - Analysis at both UK AWE and KCP
  - Fabricated at KCP

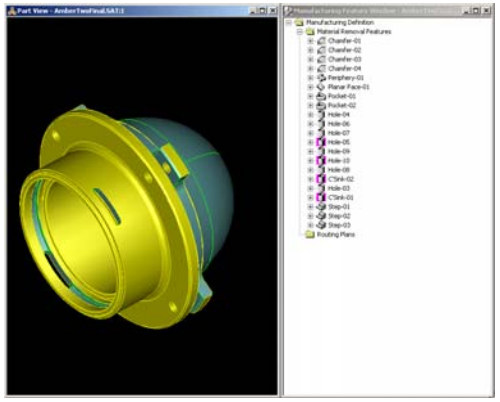


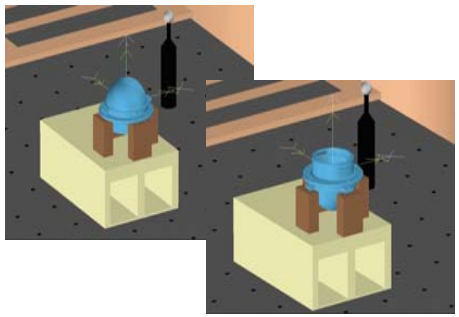












Tolerancing

Model Design

Process Planning

Inspection

Part Compare

Inspection

Model Exchange

Finite Element Analysis

Reverse Engineering

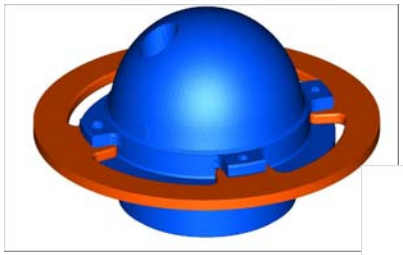
Reverse Engineer Model

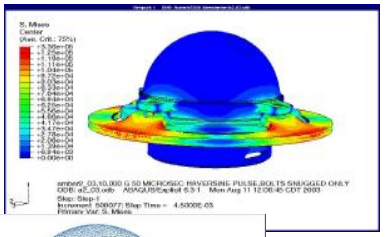
Machining

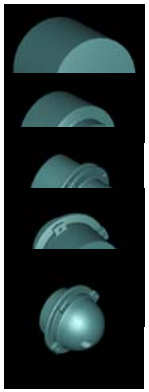
Machining

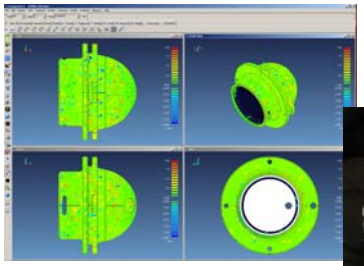
Baseline Model

Model Compare









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

1 Discrete Machined Part > 3.5GB data!

Some Current Challenges

- **Representations & Registries**
  - Existing standards, STEP (ISO 103033) are not enough!
    - Need engineering workflows, provenance, other data elements
    - One format, one file, will not be enough
- **Software Tools**
  - Use cases
    - Who are the consumers of engineering archives?
  - How to make preservation tangible? How to make ingest transparent? How to interrogate the data?
- **Open Testbeds**
  - If we aren't to have local, proprietary solutions, we need testbeds accessible to industry and academia

Representations & Registries

- Global Digital Format Registry (GDFR)
- UK National Archives PRONOM
- Library of Congress Digital Formats

Engineering-Specific Registries

- Our Approach:
  Semantic Wiki-based Format Registry
  - Identification and description
  - Example files
  - Format history and versioning
  - Sustainability factors
  - Quality and functionality factors
  - File type signifiers
  - Format Specifications
  - Useful links and references

ISO 10303

Name(s)	ISO 10303, Standard for the Exchange of Product model data, STEP, Industrial automation systems and integration - Product data representation and exchange
Version(s)	**Version** **Date Released** 1 1984
Original developer(s)	ISO
Current developer(s)	WG
Filename extensions	.step, .stp
Example(s)	airplane.step
Documenation	STEP Application Handbook ISO 10303 Version 3 (Source: SCRA)
File classification	Text

Tools for Archiving

- Challenges to building tools
  - What use cases are there for creation/use of engineering archives?
  - How to make “archiving” a first-order activity within organizations?
  - How to insert archiving activity seamlessly into existing workflows?
- Typical engineering projects involve many participants
  - Designers work within CAD environments; manufacturing engineers use CAM; data gets passed around to dozens of engineers
  - None has “archiving” as part of their job description

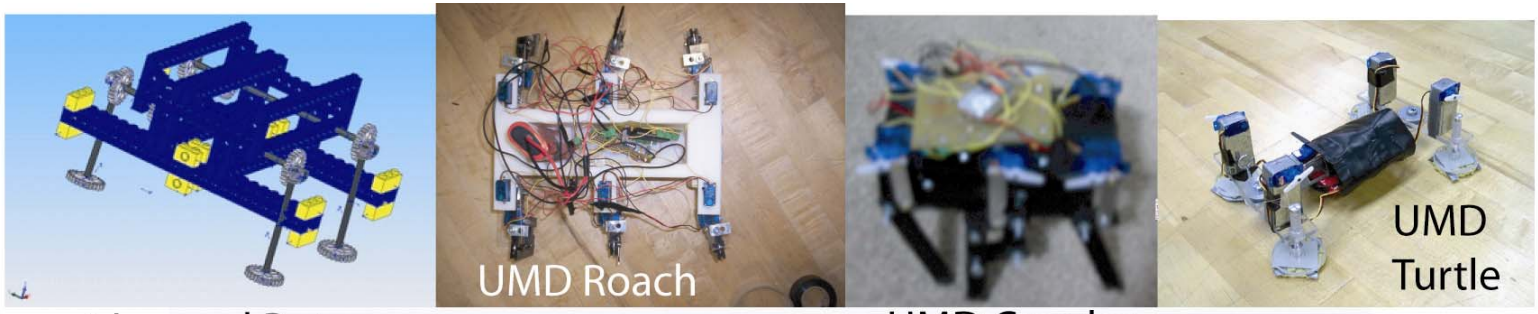
Example Tools needed for Engineering Archives

- Ingest
  - Drexel Archiving and Retrieval Tool (DART)
  - Key ideas: Ingest as design rationale capture, capture content during content creation and make it as easy as possible to integrate with workflows
- Data verification/repair
  - ITI Trancendata CADfix, translates and repairs the geometry/topology of CAD data
- Backend storage
  - SRB, Amazon S3, etc
- CAD Search
  - Drexel's 3D CAD search engines and others

CADfix®

Developing Testbeds

- National Design Repository
  - Originally sponsored by NIST, part model library for graphics, CAD/CAM, and manufacturing research
- NSF Cyber-Infrastructure Projects
  - Multi-Disciplinary Engineering Modeling
    - Create models/designs/analyses of bio-inspired robots
  - Engineering Repositories for Undergraduates (CIBER-U)
    - Use of design repositories to enhance instruction and learning in engineering undergraduate curricula at 9 institutions



Megan's Course Project

From GICLWiki

Final Paper

Contents

Documentation

This section includes a list of files that can be used to reconstruct

Bill of Materials

Media:ComponentList.jpg

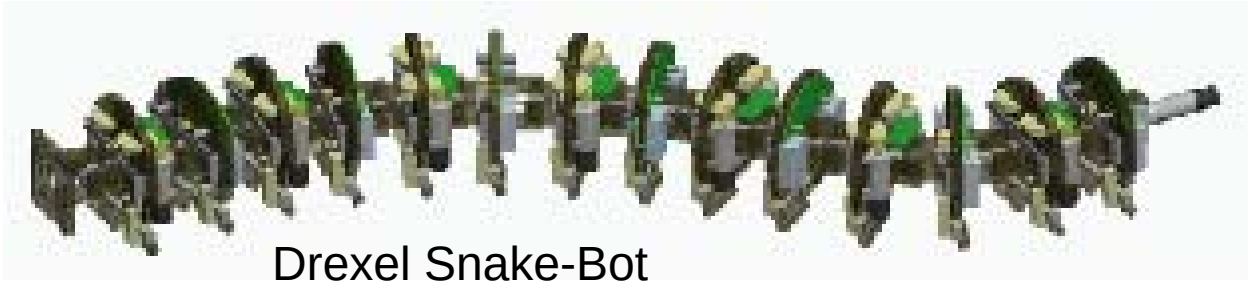
Final Videos

Physical
Media:Physcial.zip

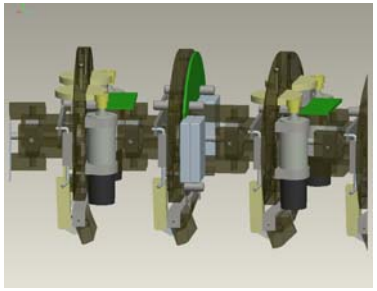
Virtual
Media:Simulation.avi

UMD-CP Bird Robot

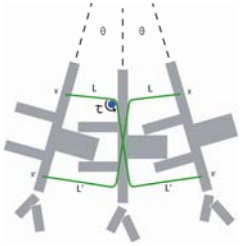
Engineering Models



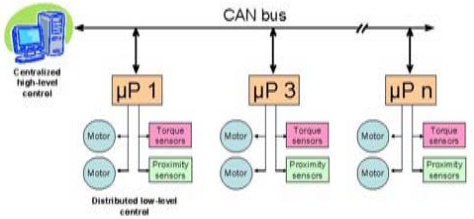
Drexel Snake-Bot



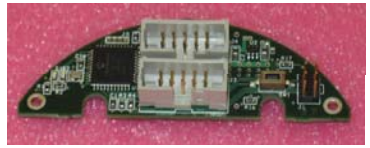
Mechanism Design



Kinematics



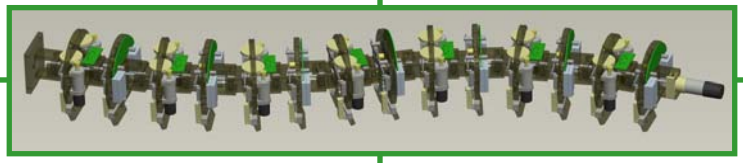
Communication System



Circuit Design

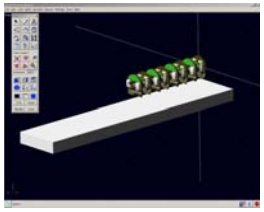
Mechanical

Simulation



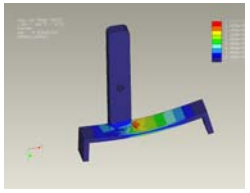
Electrical

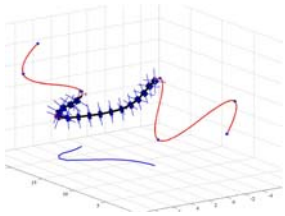
Controls



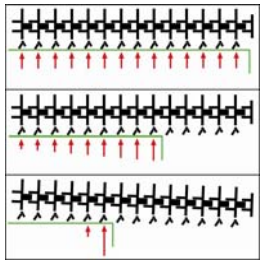
Dynamic Simulation

Finite Element Analysis



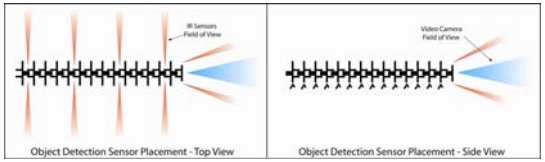


Kinematic Simulation



Stability Monitoring

Ground Hugging



Sensor Processing

CIBER-U: Example Product Dissection

Table 2: List of Models for Download

(Zipped ACIS, IGS, STL, STP, AD_PRT Files)

Part #	Part Name	Image	3D Models	2D Drawings
1	Ball		3D Package	2D Package
2	Bottom Cover		3D Package	2D Package
3	Bronze Controller		3D Package	2D Package
4	Brush		3D Package	2D Package
5	Cage for Motor		3D Package	2D Package
6	Claw Shaped Core for Motor		3D Package	2D Package
7	Controls		3D Package	2D Package
8	Fan		3D Package	2D Package

Files

3D Models

3D Models as Alibre AD_PRT Files
3D Models as ACIS Format
3D Models as IGS Format
3D Models as STL Format
3D Models as STP Format

2D Drawings

2D Drawings in Alibre AD_DRW format
2D Drawings in STP format
2D Drawings as tiff pictures

Mixer Assembly

AD_ASM, ACIS, STP, STL format
Back End Assembly
Claw and Shaft Assembly
Control Assembly
Full Mixer Assembly
Motor and Fan Assembly
Cover Assembly

Example CIBER-U Use Case: Hand-Held Mixer

- Students generated 24 separate part models, 6 assembly models, 3 disassembly animations and videos
- Engineering file formats are duplicated and translated prior to archiving
  - 3D models from Alibre are *saved as a vector of part files:* AD_PRT, ACIS, IGS, STL, and STP Formats
  - Same for 2D Drawings and Assembly files: AD_DRW, STP, AD_ASM, STP, ACIS, and STL Formats
- We are creating registries and workflows to:
  - Verify and validate these files upon Ingest
  - Provide information about the file types for search and indexing
  - Allow for digital preservation practices (transformations, metadata harvesting) to be performed on these files

Prospectus/Observations

- Available workshop reports on Engineering Archives
  - Atlantic Workshop on Long Term Knowledge Retention (LTKR)
    Department of Mechanical Engineering, University of Bath, UK, 12-13 February 2007
  - Long Term Sustainment Workshop Report, NIST, 26-MAR-08
  - Long Term Knowledge Retention Workshop Summary, NIST, 01-JAN-07
- Several obvious pieces of “low hanging” fruit
  - Format registries, ingest tools, data verification tools, development of “Best Practices”,
- Representation and capture of information is fundamental and difficult
  - Going beyond STEP, creating workflow & knowledge capture tools, testing them operationally
- Need for open testbeds

Q&A

For more information:

DART!: http://gicl.cs.drexel.edu/wiki/CIBER-U

CIBER-U: http://gicl.cs.drexel.edu/wiki/CIBER-U

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With input from….