Open Architecture in Metrology Automation

May 2 & 3, 2000
The National Institute of Standards and Technology
Gaithersburg, Maryland

A Workshop Sponsored by

Metrology Automation Association
900 Victors Way, P.O. Box 3724
Ann Arbor, MI 48106

National Institute of Standards and Technology
100 Bureau Drive, Stop 8230
Gaithersburg, MD 20899-8230
www.isd.mel.nist.gov
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for the Proceedings of the  
Open Architecture in Metrology Automation Workshop  
May 2 & 3, 2000 in Gaithersburg, MD  

Sponsored by  

![MAA Logo](image1)  
Metrology Automation Association  

![NIST Logo](image2)  
National Institute of Standards and Technology  

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The ordering of the talks in these Proceedings follows the same ordering found in the agenda for the workshop.
Executive Summary

The Metrology Automation Association (MAA) and the National Institute of Standards and Technology (NIST) co-sponsored the Open Architecture in Metrology Automation (OAMA) workshop on May 2-3, 2000 in response to a perceived need for increasing metrology system component interoperability. Approximately 50 persons representing metrology systems users, vendors, third party OEMs, systems integrators, and government attended. Their purpose was to identify issues and problems relating to system component plug-and-play and to identify specific actions towards the solution to these problems.

Presentations from key users, vendors, third party OEMs, and system integrators laid the foundation for the need for interoperability, as well as defining the issues and impediments to openness. Related efforts, including standard languages (DMIS Object Technology, DOT), standard information modeling (STEP AP219), standard interface APIs (VMI and CMMOS), communications infrastructure (OMG), and related open-architecture efforts (OMAC), were presented to the attendees. Several demonstrations of open architecture related work within NIST were given to the attendees including a demonstration of feature-based open architecture CMM control.

The workshop participants defined the metrology system in the context of all supporting components, such as CAD, controllers, analysis software, and human operators. Interfaces between these components were identified and discussion ensued as to the importance and current status of these interfaces. It was reported that Zeiss, Brown & Sharpe, and LK Metrology have already begun discussions towards the development of a common application programmer interface (API) definition, which will standardize the interface between the inspection plan software and the metrology system.

The critical action items were threefold.

1. MAA and NIST should collect and analyze all the standards efforts (including documentary standards, de facto standards, and specifications) relating to the metrology systems interfaces identified at the workshop and report on gaps and redundancies.

2. MAA and NIST should create or identify an “umbrella” organization to play a leadership role in bringing standards to completion and in resolving conflicts between different standards and standards organizations.

3. NIST should partner with industry and perhaps other government agencies to create a national metrology systems testbed for development of standards validation methods, interface testing, and system/component performance measures.

It was also decided that in three weeks all attendees would receive the workshop proceedings on a compact disk, which would also be available on the web soon thereafter. In four weeks, a draft action plan for these action items will be distributed to all attendees. In five weeks, a net meeting will be held by all attendees to discuss and amend the draft plan. The action plan is intended to be complete prior to the Quality Show to be held in Novi, Michigan on June 14 and 15, 2000.
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Certain commercial equipment, instruments, and/or software identified in these proceedings are to describe the subject matter and to specify the pertinent experimental procedure adequately. Such identification is not intended to imply recommendation or endorsement by the National Institute of Standards and Technology, nor is it intended to imply that the equipment, instruments, or software identified are necessarily the best available for the purpose.
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<td>Spatial Technologies .SAT CAD files</td>
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<tr>
<td>A-M</td>
<td>Automated Metrology</td>
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<tr>
<td>ANSI</td>
<td>American National Standards Institute</td>
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<tr>
<td>API</td>
<td>Application Program Interface, also Automated Precision, Inc.</td>
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<td>APT</td>
<td>Automated Programming Tool</td>
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<tr>
<td>BCAG</td>
<td>Boeing Commercial Airplane Group</td>
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<tr>
<td>B&amp;S</td>
<td>Brown and Sharpe, Inc.</td>
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<tr>
<td>C3P</td>
<td>CAD/CAM/CAI Product information management (SDRC's Ideas software used at Ford)</td>
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<tr>
<td>CAD</td>
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<td>CAI</td>
<td>Computer-Aided Inspection</td>
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<td>CAM</td>
<td>Computer-Aided Manufacturing</td>
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<td>CAM-I</td>
<td>Consortium for Advanced Manufacturing-International</td>
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<td>CBO</td>
<td>Common Business Objects</td>
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<td>CCAPI</td>
<td>Control center to Control center API</td>
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<td>CCM</td>
<td>CORBA CoMponents</td>
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<tr>
<td>CMM</td>
<td>Coordinate Measuring Machine</td>
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<tr>
<td>CMMOS</td>
<td>Coordinate Measuring Machine Operating System</td>
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<tr>
<td>CMM R&amp;R</td>
<td>CMM Repeatability and Reliability</td>
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<tr>
<td>CNC</td>
<td>Computer Numerically Controlled</td>
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<tr>
<td>COM</td>
<td>Component Object Model</td>
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<td>CORBA</td>
<td>Common Object Request Broker Architecture</td>
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<td>CW 170</td>
<td>a particular Ford car line designation</td>
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<td>CWM</td>
<td>Common Warehouse Metadata</td>
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<td>Data Access</td>
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<td>Data Acquisition from Industrial Systems</td>
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<td>DCOM</td>
<td>Distributed COM</td>
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<td>DCUI</td>
<td>Direct Command User Interface</td>
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<td>Abbreviation</td>
<td>Full Form</td>
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<tr>
<td>DLL</td>
<td>Dynamic Link Library</td>
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<td>DME</td>
<td>Dimensional Metrology Equipment</td>
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<td>DMIS</td>
<td>Dimensional Measuring Interface Standard</td>
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<td>DNSC</td>
<td>DMIS National Sub-Committee</td>
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<td>DoC ATP</td>
<td>U.S. Department of Commerce Advanced Technology Program</td>
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<td>DOT</td>
<td>DMIS Object Technology</td>
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<td>DTF</td>
<td>Domain Task Force</td>
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<td>EPRI</td>
<td>Electrical Power Research Institute</td>
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<td>ERP</td>
<td>Enterprise Resource Planning</td>
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<td>FCA</td>
<td>Factory Computing Architecture</td>
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<td>FINS</td>
<td>Ford INspection Software</td>
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<td>GD&amp;T</td>
<td>Geometric Dimensioning and Tolerencing</td>
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<td>GUI</td>
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<td>HMI</td>
<td>Human/Machine Interface</td>
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<td>IC</td>
<td>Integrated Circuit</td>
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<td>IEC</td>
<td>International Electrotechnical Commission</td>
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<td>IEEE</td>
<td>Institute of Electrical and Electronics Engineers</td>
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<tr>
<td>IGES</td>
<td>Initial Graphical Exchange Specification</td>
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<td>IIOP</td>
<td>Internet Inter-Orb Protocol</td>
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<td>IMS</td>
<td>Industrial Measurement Systems (of Leica Geosystems)</td>
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<td>ISA</td>
<td>Instrument Society of America</td>
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<td>ISO</td>
<td>International Standards Organization</td>
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<td>IT</td>
<td>Information Technology</td>
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<td>KBE</td>
<td>Knowledge-Based Engineering</td>
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<td>MC</td>
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<td>Microsoft Interface Definition Language</td>
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<td>Meta Object Facility</td>
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<td>M/T</td>
<td>Machine Tool</td>
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<td>National Center for Manufacturing Sciences</td>
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<td>NCO</td>
<td>Numerical Control Orientation</td>
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<td>NGIS</td>
<td>Next Generation Inspection System</td>
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<td>NIST</td>
<td>National Institute of Standards and Technology</td>
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<td>NMI</td>
<td>National Measurement Institute</td>
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<tr>
<td>OA</td>
<td>Open Architecture</td>
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<td>OAC</td>
<td>Open Architecture Control</td>
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<td>OAM</td>
<td>Open Architecture Metrology</td>
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<td>OAMA</td>
<td>Open Architecture in Metrology Automation</td>
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<tr>
<td>OEM</td>
<td>Original Equipment Manufacturer</td>
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<tr>
<td>OI</td>
<td>Operator Interface or Open Interface</td>
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<tr>
<td>OLE</td>
<td>Object Linking and Embedding</td>
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<td>OLP</td>
<td>On-Line Programming</td>
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<td>OMAC</td>
<td>Open Modular Architecture Controls</td>
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<td>OMG</td>
<td>Object Management Group</td>
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<td>OMG MES/MC</td>
<td>OMG Manufacturing Execution Systems / Machine Control</td>
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<tr>
<td>OPC</td>
<td>OLE for Process Control</td>
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<td>ORB</td>
<td>Object Request Broker</td>
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<td>PC</td>
<td>Personal Computer</td>
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<td>PCS</td>
<td>Process Control System</td>
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<td>PDGS</td>
<td>Product Development Graphic System (CAD product)</td>
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<td>PDQ&amp;P</td>
<td>Product Quality and Productivity</td>
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<td>PPD</td>
<td>Preferred Process Definition</td>
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<td>RFP</td>
<td>Request For Proposals</td>
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<td>ROI</td>
<td>Return On Investment</td>
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<td>RT-OS</td>
<td>Real-Time Operating System</td>
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<td>SIM</td>
<td>Sensor Interface Module</td>
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<td>Statistical Process Control</td>
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<td>STEP</td>
<td>Standard for the Exchange of Product model data</td>
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<td>STEP AP219</td>
<td>STEP Application Protocol for Inspection Data</td>
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<td>TCP/IP</td>
<td>Transmission Control Protocol/Internet Protocol</td>
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<td>TEDS</td>
<td>Transducer Electronic Data Sheet</td>
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<td>UG</td>
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<td>Unified Modeling Language</td>
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<td>VB</td>
<td>Visual Basic</td>
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<td>VDA</td>
<td>certain European solid model CAD file extensions</td>
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<td>Virtual Error Compensation</td>
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<td>VMI</td>
<td>Virtual Measuring Interface</td>
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<td>VPM</td>
<td>Virtual Product Model</td>
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<tr>
<td>XML</td>
<td>eXtensible Markup Language</td>
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Agenda for Open Architecture for Metrology Systems Workshop
Co-sponsored by the Metrology Automation Association (MAA) and the National Institute of Standards and Technology (NIST)

May 2-3, 2000
Gaithersburg, MD
See www.nist.gov/public_affairs/maps/nistmaps.html for maps and directions to NIST buildings

Tentative agenda:

Schedule, Tuesday May 2
7:30 AM
Registration and Continental Breakfast
Location: Shops conference room in the Building #304 (Shops)
8:30 AM
Welcome and Introduction
Location: Shops conference room in the Building #304 (Shops)
Don Vincent, MAA
Dennis Swyt, NIST
John Evans, NIST
9:00 AM
User Perspectives
Location: Shops conference room in the Building #304 (Shops)
Automotive user, Ford: Plonka, et al
Aerospace user, Boeing: Vinson
Electronics user, Motorola: Ronjon Chatterjee
10:00 AM
Networking Break
Location: Shops conference room in the Building #304 (Shops)
10:15 AM
Vendor Perspectives
Location: Shops conference room in the Building #304 (Shops)
LK Metrology Systems, Inc.
Automated Precision, Inc.
Leica Geosystems, Inc., Dennis Warren
SMX Corporation
11:15 AM
Third Party Perspectives
Location: Shops conference room in the Building #304 (Shops)
Silma
New River Kinematics, Robert Salerno
Brunson Industrial Measurement, Matt Settle
12:00 PM
Related Efforts I
Location: Shops conference room in the Building #304 (Shops)
VMI (Virtual Machine Interface) – Brown & Sharpe
DOT (DMIS Object-oriented Technology) – CAM-I, Dietmar May
12:30 PM
Lunch
1:30 PM
Related Efforts II
Location: Shops conference room in the Building #304 (Shops)
OMAC
STEP AP 219 NIST – Ted Vorburger
OMG (CORBA) NIST - Evan Wallace
CMMOS – Zeiss
NGIS III - NCMS

2:30 PM – 5:00 PM
- Breakout group sessions
  - Location: Various rooms on NIST campus
  - Elect scribe and spokesperson
  - Address challenges and breakout group tasks
  - Develop issues and action items

5:00 PM – 6:00 PM
- NIST laboratory demonstrations
  - Open Architecture for Machining demo (Proctor/Shackleford)
    - Location: Shop floor of the Building #304 (Shops)
  - Open Architecture for Metrology demo (Scott/Messina/Horst/Kramer/Huang)
    - Location: Shop floor of the Building #304 (Shops)

6:00 PM
- Day #1 Adjournment

Schedule, Wednesday May 3

8:00 AM
- Continental Breakfast
  - Location: Shops conference room in the Building #304 (Shops)

8:30 AM – 10:00 AM
- Breakout group sessions (continued)
  - Address challenges and breakout group tasks
  - Develop issues and action items

10:00 AM – 10:30 AM
- Scribes file merging time and, for others, networking break

10:30 AM – 12:30 AM
- Plenary group meeting
  - Location: Shops conference room in the Building #304 (Shops)
    - Summarize, discuss, aggregate, and prioritize action items
    - Decide future directions and ownership of action items

12:30 PM
- Workshop Adjournment
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Open Architecture in Metrology Automation Workshop
M-AA-NIST Workshop on
Open-Architecture Controllers for Metrology Automation
May 2-3, 2000

Metrology, IT, and Automation
at the Start of the 21st Century:
A View from NIST

Dennis A. Swyt
NIST Manufacturing Engineering Laboratory
The View from NIST in a Nutshell

At this the opening of the 21st century
all of manufacturing
from aircraft and automobiles
to electronics and disc drives
is being buffeted by an array of trends
that are driving metrology to a greater use
of automation and information technology
in which open-architecture systems play
an increasingly important role
Contents

• Five Macroscopic Market Trends
• Three Microscopic Technology Trends
• Manufacturing at the Confluence of the Trends
• Vendors Supplying Those Manufacturers
• Conclusion
Market Trend 1
Continuing Globalization

The Globalization Is of Markets, Enterprises, and Operations
Market Trend 2
The Pace of Change in Technology

The Pace of Change of Technology, Including the Rate of Change, Is Continuing, If Not Accelerating
Market Trend 3
Rapidly Expanding Access to Technology

Competitive Advantage Is Not To Be Found
In Superior Technology Alone Since Virtually Anyone Can Get It
Market Trend 4
Ubiquitous Availability and Distribution of Information

This Flood of Information Is A Major Challenge for Manufacturing Enterprises
Market Trend 5
Rising Customer Expectations

One Means for Manufacturers to Better Deliver Products That Meet Customer Expectations Is For Manufacturers to Work More Closely with Their Suppliers
Technology Trend 1
Tightening Tolerances

Tolerances Decrease In Size by Factor of 3 Every 10 years
Measurement Uncertainty Needs to Decrease Similarly
Technology Trend 2
Rise of International Standards

With global industries seeking “one world standard” and with Europe seeking to use standards for a trade advantage, international standards are becoming more and more important.
Technology Trend 3
Increased Use of Information Technology in Mfg

- Real-time modeling and simulation of products, processes, and systems
- Use of multiple computer-interfaced sensors to extract dimension and process data
- Feeding-back of data to improve manufacturing processes in real time

- Development of IT standards for such operations, e.g. DMIS
  Dimensional Measurement Interface Standard
Manufacturing At the Confluence of These Market-Technology Trends

Manufacturers have customers to satisfy

These customers have expectations

There is a path for manufacturers to meet those expectations
Path for Manufacturers to Meet Expectations

Expectations of Customer for Products

Needed of Mfg Process to Meet Expectations

Technology for Mfrs to Fulfill Requirements

Manufacturers’ Products

- Higher Quality
- Lower Cost
- Faster Delivery

- Lower Variability
- Higher Productivity
- Greater Flexibility

IT-Based Automated Metrology
At the Confluence of Market-Technology Trends — Manufacturers are Customers Too

Manufacturers are customers of the vendors of IT-based automated metrology

As customers, manufacturers have expectations

There is a path for vendors to meet those expectations
Path for Vendors to Meet Manufacturers’ Expectations

IT-Based Automated Metrology

Lower Variability

Higher Productivity

Greater Flexibility

Interoperability

Open-Architecture

Machines

Controllers

Software

Expectations of Mfrs as Users of A-M Products

A Requirement for A-M Products to Meet Expectations

Path for Producers of A-M Products to Fulfill Requirements
Open-Architecture Controllers for Metrology Automation

Conclusion

- Manufacturing is buffeted by market and technology trends that must be dealt with effectively to achieve success

- IT-based automated metrology is a path for manufacturers to achieve such success with their customers

- Open architectures for IT-based automated metrology is a path for vendors to succeed with manufacturers

- This workshop aims to support development of open-architecture controllers for metrology automation

- **We at NIST appreciate your participation in it — and we wish you success in the effort**
Global Dimensional Control Inspection Strategy
What brought on the need for change?

- CW 170
- Reorganization
Old Hierarchy

Vice President Vehicle Operations

Vehicle Operations Managers

Chief Engineers

Program Operations Managers

Manager

Section Supervisor

Unit Supervisor
New Hierarchy (fewer people)

- Vice President
- Director
- Manager
- Section Supervisor
- Unit Supervisor
Utilize Resources Efficiently

**Brown & Sharpe**
- North America
  - Truck,
    - Large & Medium
  - Car Vehicle Center

**LK**
- Great Britain
  - Luxury Car Vehicle Center

**Zeiss**
- Europe
  - Small Car Vehicle Center
### CMM Inspection Software Complexity

<table>
<thead>
<tr>
<th>CAD/CAM</th>
<th>PDGS</th>
<th>C3P (Ideas)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Offline Programming</td>
<td>FINS</td>
<td>Silma</td>
</tr>
<tr>
<td>CMM</td>
<td>Avail</td>
<td>PC-DMIS</td>
</tr>
<tr>
<td>Reporting</td>
<td>DataPage</td>
<td>DataView</td>
</tr>
<tr>
<td>Operating Systems</td>
<td>Unix</td>
<td>Windows-NT</td>
</tr>
<tr>
<td>Editors</td>
<td>VI-Editor</td>
<td>MS-Editor</td>
</tr>
</tbody>
</table>

### Europe and United Kingdom

<table>
<thead>
<tr>
<th>CMM &amp; Reporting</th>
<th>Zeiss</th>
<th>LK-DMIS/Cameo</th>
</tr>
</thead>
</table>
What steps have we taken thus far?
CMM Compatibility

Projects

Completed:

- Silma → LK-DMIS – LK2000 Controller – PH9
- LK-DMIS → Silma
- LK-DMIS – DMIS Dump → PC-DMIS – Sharpe 32Z Controller – PHS
- Silma → PC-DMIS – Common Driver LK2000 Controller – PH9
- PC-DMIS → Silma

Demonstrated, but needs refining:

- PC-DMIS operating Zeiss through CMM-OS
Metrology Automation Association (MAA)

- OEM/Customer Information Source
- Collectively Develop Standards
- Better Communication throughout Metrology Community
Consortium

- General Motors
- Daimler-Chrysler
- Ford Motor
- Boeing
- Others

- Better Direction to OEM’s
- Better Products to Customer
- Customer Driven Market
What would we like to see happen?
Customer’s Concern
No communication with other equipment throughout the company

Customer’s Vision
Develop an open architecture that promotes Plug-N-Play
Today, anyone can purchase a modern printer, easily connect it to a wide variety of Windows based PC’s, and successfully utilize a variety of hardware specific features from an assortment of application software’s.
Multiple tool support

- CMM
- Photogrammetry
- Vision system
- Articulating arm
- Laser tracker
- Common Reporting
The Boeing Commercial Airplane’s Metrology Vision

Mark Vinson
Precision Machining & Inspection
Boeing Commercial Airplane Information Systems

1-March-2000
AGENDA

- Motivation
  - Chronology of Metrology Requirements
  - Current Baseline of Computer Aided Inspection (CAI) 3D Tools
  - Corporate Initiative to Standardize Tools and Processes

- Vision
  - Direction Statement
  - Overview CAI Architecture
  - CAI Prototype
  - Conceptual CAI Architecture

- Summary

- What’s Next
(1992) DMIS Functional Test
(1997-’98) Product Definition Quality & Productivity QCNC project: team with Dassault and Brown&Sharpe
- Motivation -

CAI Dimensional Inspection Devices

45+ DCC (Direct Computer Control) Coordinate Measuring Machines (BCAG NW)

- **Use:** Detail Part, Minor Assembly and Tool Inspection

- **Programming Software:** (Percentage of machines programmed with)
  - 60% CATIA NC Mill + APT + Machine Specific Post Processors
  - 15% CATIA NC Mill + APT + DMIS (Dimensional Measurement Interface Std) Post Processor
  - 25% 3\textsuperscript{rd} Party

- **Operation Software:** (Control, UI, Results Computation/Analysis, Operator Tools)
  - 62% CMM Vendor System (VAX/VMS hosted)
  - 18% 3\textsuperscript{rd} Party Proprietary Language
  - 20% 3\textsuperscript{rd} Party DMIS
☐ 144+ Portable Inspection Devices (BCAG NW)

• **Use:** Major Assemblies and Tool Inspection

• **Brands:**
  - 61% Laser Trackers
  - 21% Computer Aided Theodolite
  - 13% Portable CMMs
  - 5% Video-Based Photogrammetric System

• **Operation Software:** (Control, UI, Results Computation/Analysis, Operator Tools)
  - 100% Vendor System
- Motivation -

CAI Dimensional Inspection Devices

Fixed –vs- Portable

- 76%
- 20%
- 4%

- Portable
- Fixed
- Conventional
- Fixed 3rd Party
- Motivation -

Business Strategies

_square boxes

Single Solution

• **BOEING DIMENSIONAL MEASUREMENT STANDARD**
  A process that establishes the requirements for effective/efficient and consistent measurement processes in our factories and at our suppliers.

• **QUALITY ASSURANCE CAD/CAM PROCESS MANAGEMENT BOARD {MPMB}**
  A Boeing Commercial Committee unifying Quality Assurance CAD/CAM/CAI operations, leading continuous improvement, and standardization of common practices and processes.

• **FACTORY COMPUTING ARCHITECTURE Measurement Domain Direction**
  1. Use measurement devices and sensors to *adjust/correct* automated *manufacturing in process*.
  2. Establish and *implement* a logical computing *architecture for measurement* that promotes *common yet flexible solutions*.
  3. Move aggressively towards *direct interaction* with *digital product definition* for measurement processes.
  4. Establish and promote company-wide *object oriented*, software measurement tools and standards that are compliant with emergent industry standards.
Boeing has performed poorly in articulating requirements.
Multiple suppliers competing for a market share.
Portable and 2-D devices virtually untouched.
Boeing has defined a strategy.

The solution is *The Vision*
To Standardize on a **Single Holistic Measurement Solution.**

*Holistic:*

Emphasizing the importance of the whole and the interdependence of the parts.
- VISION -
Overview CAI Architecture

2-D Measurement
On-line Planning & Inspection

On-line Programming/Planning
Portable Measurement

On-line Programming/Planning & Inspection

Off-line Programming/Planning
Application/Data Server

Fixed Measurement
On-line Programming/Planning & Inspection

Machine Tool
CMM

VPM
CAD/Mfg Database
DMIS file, Generated 1
Task name : QuickTour
Cell name : QuickTour
Processes : proc1
Date : Thu Oct

UNITS/Mm, ANGDEC
PRCOMP/ON
D(MCS) = DATASET/MCS
SAVE/D(MCS)
MODE/PROG, MAN
WKPLAN/XYPLAN
SNSLCT/S(QuickTour)
F(PLN1)=FEAT/PLANE,CART,
SNSET/APPRCH, 4.0000
SNSET/RETRET, 4.0000
SNSET/SEARCH, 1.0000
MEAS/PLANE,F(PLN1), 6
GOTO/-37.6000, 68.0000, 138.0000
PTMEAS/CART,-37.6000, 68.0000, 138.0000
PTMEAS/CART,-37.6000, 62.0000, 138.0000
PTMEAS/CART,-70.0000, 62.0000, 138.0000
PTMEAS/CART,-70.0000, 68.0000, 138.0000
PTMEAS/CART,-102.4000, 68.0000
PTMEAS/CART,-102.4000, 62.0000, 138.0000
GOTO/-102.4000, 62.0000, 138.0000
ENDMES
T(FLAT1)-TOL/FLAT-1.0
Type: Orientation
Active PCS: NC AXIS
By: PROCESS
  Primary: PLN1
  Secondary: CYL1
  Tertiary: CYL2
-VISION-
Conceptual CAI Architecture

NCO Engine

KBE Engine

Inspection & Programming GUI

Kernel

- Analysis Engine

MACHINE TOOL
CMM
PORTABLE
2-D

FEATURE
PATH
TOLERANCE
PART DEFINITION (CATIA)

FEATURE

PATH

TOLERANCE

PART DEFINITION (CATIA)

ANALYSIS REPORT

HABIT

MEASURE
Summary:

Measurement System must be based on Object Oriented Technology and embraces the philosophy of an open architecture;

User manipulation and operation on objects should occur in a natural way through a GUI without knowledge of a procedural language such as DMIS.

Creation and manipulation of manufacturing and design attributes (e.g., features, tolerances, paths, etc.) must occur directly against the digital definition in its native environment.
- What’s Next -

- Supplier Awareness

- Continue to Participate in NIST STEP AP219 Development

- FCA defined Product Direction Statements for Metrology Systems
One All-Purpose Tool?

A Few Select Tools that Compliment One Another?

A Proliferation of many Tools (many redundant)
CMM Interoperability

• Component Data Source
• Programming Language
• Communication
• Machine Nomenclature
• Result Data
Component Data Source

• Drawings
  – ANSI

• CAD Models
  – IGES
  – STEP
  – Native

• Feature Definition
Programming Language

- DMIS
  - Syntax
  - Application
Communication

• Application to Hardware Communication
• Sensor Technology
Machine Nomenclature

- Machine axis - Single - Multiple
- +/- Volumes
- Probe Axis
- Rotary Table
- Etc
Result Data Archive

- Data Format
- Data Source Attachment
Advanced 6-D Laser System for Quick CMM Error Mapping and Compensation

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President
Automated Precision, Inc.
Gaithersburg, MD

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e-mail: Kam.Lau@apisensor.com
Background of API

• Found 1987
• R&D and manufacturing of advanced metrology instruments and control systems
• 40 employees, 1/4 advanced degrees supporting R&D
• Inventor of
  – modern laser tracker technology
  – 5/6-D laser measuring system for M/T & CMM
  – machine geometric/thermal modeling and compensation system
• Awards
  – IR100, Circle of Excellence, Advanced Productivity Technology
Major Products and Technologies

• Large Dimensional Metrology
  – 1st & 2nd Generation Laser Tracker

• Machine Tool Metrology
  – Complete suite of metrology instruments, control and software technologies-- 6-D laser, spindle analyzer, VEC, error modeling, etc.

• CMM Technology (developed in NGIS II)
  – OAC, 3-D scanning probe, 2-D articulating wrist, 6-D laser, wireless communication, and sensor interface standardization
NGIS III

- Continuation of NGIS II (sponsored by NCMS) Member
  - Technology Providers
    - API (control, sensor and machine performance enhancement)
    - MRI (CNC machine builder)
    - NIST (test site)
  - Technology Users
    - U.S. Army Depot at Cherry Point
    - Solar Turbine
- Main Focus on On-Machine Metrology
API 2nd Generation Laser Tracker System-- Tracker II
Second Generation Laser Tracking System-- Tracker II

• Advanced optics, motor and control technologies
• Compact and light weight design 1/4 size and weight of previous models
• Direct interferometer-based beam output without complicated optical path
• Low maintenance with concealed optics and bearing systems
• Low cost, easy to setup, one carrying case
• High performance with complete field diagnostics and calibration capabilities
Tracker II (cont’d)

- Readily integrated to in-process control, assembly and inspection with open-architecture design and high-speed communication
- Two or more trackers simultaneous operation for absolution ranging and/or multi-axis feedback control
- Optional dual-axis electronic level available
- Optional wireless trigger control and/or remote control console available
Concept of API-CMM OAC

- Idea introduced to the NGIS II in 1995
- Common interface standards for sensors (current and advanced) and CMMs
- Sensor interface standard protocols developed along with NGIS II members and NIST
- API’s first commercial OAC introduced in 1997
- Users included major and small CMM manufacturers and software developers
CMM Error Mapping and Compensation

- CMM requires error mapping and compensation to be accurate
- Current techniques with conventional lasers taking too much time, are tedious and costly
- Complete error mapping and compensation are usually done in factory, not on-site
- No standards on procedures, model and format
- End users generally do not have access or ability to modify the model (unlike CNCs)
API 6-D Laser System for CMM

Geometric Error Mapping and Compensation
High-Precision 6-D Laser with Fiber-Guided Remote Laser Head
Principle of the API 5/6-D Laser Measuring System
Rotary Table Measurement with 5/6-D Laser and Polygon
Rotary Table Measurement with 5/6-D Laser
Parallelism Measurement with 6-D Laser
Flatness Measurement with 5/6-D Laser (Straightness)
API 5/6D Laser System for CMM Geometric Error Modeling

Data Collection | Error Model Building | Visualization & Comp.

GUI | Machine Error Model | Visualization

Winner | Model D/B | Math Lib.

| 3D Engine | Reporting Tools | Error Compensation
Machine Geometric Error Modeling
Data Collection (cont’d)
Machine Geometric Error Modeling
Data Collection (cont’d)
Machine Geometric Error Modeling
Data Collection (cont’d)
Note: Only geometric errors are shown in this figure. Errors are magnified by 100 times for the visual purpose.

Red: actual behavior of the machine, Green: a perfect working volume (assuming that the machine is perfect)
Machine Geometric Error Modeling
Data Collection

API Volumetric Error Map
Create a New Job
Open Existing Job

API 5/60 LASER MEASURING SYSTEM

Status
Measurement: X, XY, Y, YZ, Z

Progress
- Introduction
- Machine ID
- Machine Type
- Sensor Type
- Determine Machine Axis
- Laser System Setup
- Check Machine Travel
- Data Acquisition

Message:
Click NEXT to begin

Operating Mode
- Normal
- Advanced

Clear
EXIT

Help
About
Machine Geometric Error Modeling
Visualization Interface
API 3-D CNC Scanning Probe
Benefits of 6-D Laser System for Error Mapping

- Simultaneous measurements of all 6-degree of freedom, squareness measurements require no additional setup
- High precision exceeding traditional laser interferometer
- Typical mapping time for a CMM is 3-4 hours w/ proper fixtures
- Flexible compensation formats-- B-spline, parametric or grid-type (up to 80x80x80)
- Algorithms embedded on software interface layer of SIM card or other CMM controller requirements
- Well-suited for routine CMM calibration, certification and compensation
- Reduce CMM downtime, cost, and increased user confidence
Leica Geosystems

Industrial Measurement Systems
Metrology Automation Association
Gaithersburg, MD
May 2, 2000


**Introduction**

- Steve Albrecht
  - Key Account Manager – IMS Group
  - Responsibilities: Sales, Support, & Market Development

- Dennis Warren
  - Special Products Manager
  - Responsibilities: Software Development, & System Integration
Presentation / Overview

- History & Milestones
- Current Situation
- Industries
- Products & Applications
- Automation Perspective
- Conclusion
History of the IMS Group

- Started in 1984
- Licensed Software from Boeing
- Developed WildCAT Theodolite System
  - 2 T-2000 Instruments & HP Basic
- 5 People
- Office in Norcross, GA
Milestones

- 1984 IMS Founded with WildCAT
- 1986 TomCAT System – Six Instrument
- 1988 Wild & Kern Merger
- 1989 ManCAT System – DOS Based
- 1989 Licensed Tracker Technology
  - NIST & API, Inc.
Milestones Continued

- 1991 Smart 310 System - 1st Trackers
- 1995 Axyz Modular Software – Windows Based
- 1996 LT / LTD 500 Laser Trackers
- 1997 Marketing Agreement with GSI
- 1998 TPS 5000 Theodolites
- 2000 Axyz 1.4 with PAM (Process Automation Module)
IMS Group Today - America

- Five Technology Centers
  - Atlanta, Detroit, Los Angeles, Seattle, & Wichita

- 26 Sales / Support Personnel
  - Covering North, South, & Central America
  - Direct Sales Force in USA, Canada, & Mexico
IMS Group Today - World-Wide

- World-Wide Coverage
- R & D – Unterentfelden, Switzerland
- Production – Heerbrugg, Switzerland
- 19 IMS Offices
- Over 90 Sales / Support Personnel
- FY99 – Over 40 Million Dollars in Sales
IMS Industries

- Aerospace
- Automotive
- Truck & Bus
- Heavy Industry
- Shipbuilding
- Antenna
- Nuclear Power Plants
- Linear Accelerator
IMS Services

- Sales & Marketing
- Training
- Equipment Rental
- Service Work
- Consulting
- Customized Software
IMS Products

- Single Head Theodolite Systems
- GSI Videogrammetry Systems
- Multi-Head Theodolite Systems
- Laser Tracking Systems
- Axyz Software
Existing Automation Applications
The wing will be moved to the correct position before final attachment.

The Laser Tracker is positioned below the aircraft.

Position feedback by automated serial connection to controlling computer.
F-22 Wing Automated Drilling

- Laser tracker provides additional positioning accuracy.
- Automated drilling head

Leica
Other Automation Tasks

- Long term Monitoring
  - Measure fixed points every 4 hours
  - System operation 24 hours / 7 days
  - Store and chart deviations

- Tool Repeatability Tests
  - Measure fixed points
  - Remove and replace part
  - Repeat cycle 30 times
  - Report results
Other Automation Tasks (Cont.)

- Tool Inspection
  - Transform to tool coordinates
  - Automatic measurement of fixed points
  - Measure details
    - Point to detail for identification
    - Set laser and measure detail
  - Go / no go on tolerance
    - Correct any deficiencies (build mode display)
    - Re-measure detail as required
  - Report results
Leica’s View of MAA Objectives

- Metrologists can use Measurement Equipment Interchangeably
- Open Architecture can Adjust for Equipment or Sensors Individuality
- Reduction in Training and Equipment Costs
Leica’s Concerns

- Directing Person vs Machine
  - Machines follow a precise path
  - A person can adjust to changes

- Analysis of measurements may be delayed
  - Machines can complete a measurement set
  - Laser trackers and Theodolites need a line of sight (station moves)
Leica’s Concerns (Cont)

- Many Software Programs for CMMs are not Structured to use Laser Trackers and Theodolites and vise versa
  - Software must direct people to perform measurements
  - Multiple stations may be required
  - Some measurements may be delayed for a station move
  - Theodolites require additional calculations for XYZ
  - Probing from a point along a vector requires special routines to perform
Conclusion

- Interchangeability of measurement equipment will be a benefit for all
- Software to effectively use all equipment must be structured properly
- MAA could prove to be the organization able to achieve these goals
Thank You!
SMX Perspective
Open Architecture in Metrology Automation

NIST/MAA Workshop
02-May-00
Jim West
SMX Software & 3rd Party Hardware

- SMXInsight® was written specifically to support its Laser Tracker 4000 & 4500
- SMXInsight® has been enhanced to support:
  - Kern Theodolite: E1, E2, etc.
  - Wild/Leica Theodolite: T2000 family
  - Zeiss Theodolite: ETH family
Challenge of 3rd Party Hardware

- Each theodolite interface required custom development
- Each theodolite interface supported the requirements of a specific customer
- Requests have been made to support additional and other types of instruments
- ROI for these efforts is questionable
SMX Software & CAD Formats

- SMXInsight® currently imports/exports data from/to:
  - IGES
  - CATIA
Challenge of CAD Formats

- Each CAD format required custom development plus 3rd party licensing.
- Each CAD format supported the requirements of a specific customer.
- Requests have been made to support PRT, VDA and ACIS formats.
- ROI for these efforts is questionable.
SMX’s Laser Tracker 4000 is currently supported by:

- Brown & Sharpe’s PC-DMIS
- Imageware’s Surfacer
- Metrologic’s Metrolog II
- New River Kinematics’ Spatial Analyzer
- Verisurf’s Verisurf
Challenge of 3rd Party Software

- SMX provides only the driver to 3rd party developers and then supports as needed.
- Some 3rd parties have required substantial support.
- Often, the resulting implementation still requires SMXInsight® for certain tracker-specific functions.
- No implementation fully exploits unique tracker functionality.
The Open Architecture must provide an abstract framework for the manufacturer’s to develop:

- A device interface (driver)
- Complete set of machine-specific functions
- Machine-specific compensation routines
- Machine-specific operation & diagnostic checks
Challenge to Open Architecture support for Hardware

- Framework must accommodate peculiarities of Portable CMMs:
  - Bundling from multiple stations
  - Material expansion/contraction

- Framework must carry overhead required to abstract many different devices:
  - Measurement methods
  - Error propagation models
  - Targeting
  - Ability to run in an automated scenario
Summary

- Open Architecture efforts should:
  - Separate Hardware issues from CAD Format issues
  - Keep exchanged data low level, i.e. angles and/or distances - below the feature level
  - Ensure that these efforts are not competing with other standards efforts
  - Efforts must be truly international
MAA/NIST Workshop
Open Architecture in Metrology Automation
May 2, 2000

Third Party Perspective - SILMA
Eric Jacobs - Director of Marketing
SILMA CimStation Inspection

- Automate metrology planning
- Link between design and metrology
SILMA CimStation Inspection

Benefits

• Higher quality DME programs
  • Exact nominal points and normals
  • Higher point density
• Error free programming
  • Proper syntax generated automatically
  • Collision free
  • Verified off-line
• Create DME programs up to 10x faster
• Free DME for production (measurement)
• No waiting for physical parts (concurrent engineering)
Problem Definition

Weakest link is between Planning and Execution

- Design
- Off-Line Planning
- On-Line Execution
- DMIS File, V1
- Program File, V2
- File Translation and/or On-Line Touch-Up
**SILMA History**

"We have seen it all"

<table>
<thead>
<tr>
<th>Year</th>
<th>O/S</th>
<th>Neutral</th>
<th>Direct</th>
<th>Output</th>
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<tr>
<td>1988</td>
<td>Apollo, SGI, Sun</td>
<td>IGES</td>
<td>Anvil</td>
<td>DMIS</td>
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<td>ACIS</td>
<td>I-DEAS</td>
<td>UMESS UX, CMES</td>
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## Design-Side Integration

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<td>Neutral (ie. IGES) Geom</td>
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<td>Direct (ie. Pro/E) Geom</td>
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<tr>
<td>3rd Party (ie. ACIS) Geom</td>
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<tr>
<td>3rd Party (ie. ACIS) GD&amp;T</td>
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## Execution-Side Integration

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<td>SILMA Posts 80%</td>
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<td>? ?</td>
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Execution-Side Integration

<table>
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<th>Effectiveness</th>
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<tbody>
<tr>
<td>Other</td>
<td>?</td>
</tr>
</tbody>
</table>

SILMA Vision

- CMM software-only retrofits
- Integrated on-line and off-line programming

Benefits

- End-user flexibility and portability
- Lower cost to upgrade and maintain CMM software
Potential Solution

CMM Software-Only Retrofit

Planning Interface
Execution
Metrology Interface
Machine Interface
DME

On-Line & Off-Line Programming
Metrology Engine
DOT, etc.
DMIS, etc.

Metrology Engine
Machine Interface (API)
DME
Qualities of a good interface (API)

- Right level of abstraction
  - Minimum command set
  - Easy to implement = likely to be adopted

- Technology is less important
  - CORBA, COM, DLL
  - Vendor specific
Open Architecture for Portable Metrology Equipment

Robert J. Salerno, Ph.D.
Joseph M. Calkins

New River Kinematics

www.kinematics.com
(click on “Publications”)
Our Scope

Environment:
- Portable devices
- Large scale
- Unstructured environment

Applications:
- Large 6-D object tracking
- ISO uncertainty analysis
- Inspection AND building
- Cooperative (multi-instrument) measurement
- Process automation

Customers:
- Aerospace
  - Airframe fabrication
  - Spacecraft
- Shipbuilding
- Nuclear / Industrial
- Precision civil / Plant layout
Critical Standardization Issues

- Combined measurement uncertainty analysis
- Cooperative (multi-instrument) measurement
- Direct common user interface (DCUI) / automation
- Building operations
- Real-time analysis
- Inter-process communication (protocol & transport)
Combined Measurement Uncertainty Analysis

Presented at the 2000 Boeing Large Scale Metrology Conference, Long Beach, CA

- A Practical Method for Evaluating Measurement System Uncertainty, Joe Calkins (NRK)
- The Shop Floor as NMI, Dr. Dennis Swyt (NIST)

Uncertainty Components
- Instrument Values (angles, distances)
- Coordinate Uncertainty-XYZ (for a given geometry)
- Combined Uncertainty (considering chaining and looping effects)
Cooperative (Multi-Instrument) Measurement

Hughes Space and Communication
Direct Common User Interface (DCUI) / Automation

Boeing Commercial Airplane Group
Building Operations

Goodyear Tire and Rubber Company
Real-Time Analysis

Boeing Space and Defense
Inter-process Communication
(Protocol & Transport)
Open Architecture for Portable Metrology Equipment

Critical Standardization Issues:
- Combined Measurement Uncertainty Analysis
- Cooperative (Multi-Instrument) Measurement
- Direct Common User Interface (DCUI) / Automation
- Building Operations
- Real-Time Analysis
- Inter-process Communication (Protocol & Transport)

Robert J. Salerno, Ph.D
Joseph M. Calkins
www.kinematics.com
(click on “Publications”)
Integrator’s Perspective on Open Architecture

Matt Settle
Brunson Instrument Company
System Integration

Portable CMM

Hardware/Software

On-Site Consultation

On-Site Training & Support

Customer
Software Needs

1. Robust modern software
2. Develop on the latest and best operating systems
3. Field access to developers when required
4. Up to date "on line help" and documentation
Instrument Needs

1. The communication method reflects instrument capabilities
2. Native software should use same comm method provided to third party vendors
3. Support staff should be knowledgeable about the communication method and lower level instrument control
4. Instrument compensation routines
5. Instrument diagnostics at the controller level
6. Sales force should be exposed to third party software
B&S
Virtual Measuring Interface
(VMI)
Today’s Situation

Cameo
PCDMIS
QUINDOS
Calypso
Avail
MM4

Zeiss CMMs
B&S CMMs
Portable Arms
LK CMMs
VMI Supports
Next Generation Metrology Applications
VMI :

- Is a collaborating set of COM components
- Defines a neutral interface between a Metrology Application and a Measuring Instrument
- Provides Services to Metrology Application
- Is designed for flexible configuration
VMI / CMM / APP relations

Metrology Application

DATA BASE

Kinematic Engine

V M I

CAMS CMD EVTS ..... ..... VOLCMP VOLCOMP TOOL TOOL

CMM WRIST RT/…

= INTERFACE

Brown & Sharpe Confidentiel
VMI : a set of COM Components

- Component Object Model = Proven technology
  - used extensively in Windows 95/98/NT and any up-to-date Microsoft application
  - used by OLE, ActiveX (i.e. Browser plug-ins).

- Build-in flexibility

- Plug in architecture.

- Standard mechanisms like:
  - storage (persistence)
  - user interface (property sheets)

- Ease of update / extension
VMI Defines Neutral Interfaces

• Interfaces: Relations between Metrology Application and VMI through a set of “plugs”
• “Plugs” group logical functions together.
• Neutral: Measuring Instrument Protocol Independent Commands
• COM based: Programming Language neutral
  – C++ / DELPHI / …..
• But Visual Basic/VBA Friendly too: Automation
Interfaces

Metrology Application

CAPS  CMD  EVTS  .....  .....  V M I

= INTERFACE = SOFTWARE PLUG
VMI : Many Services to Metrology Applications

- Plug-in Volumetric Compensations (component)
- Plug-in Tool Calibration (component)
- Plug-in Tool Qualification (component)
- Temperature compensation
- Supports Kinematic Model Simulation (virtual machine with Collision Detection)
- Machine connection sharing for legacy & maintenance / support utilities
Plug-in Tool(s) / Volcomp
Maintenance / Support Access to Machine & Calibrations

- CMM VMI can use legacy Compensations via Component plug-in mechanism.
- One “plug” offers transparent access to CMM to allow re-use of support / maintenance utilities.
- VMI Components are VB friendly: Custom utilities are easier to build.
Designed for Flexible Configuration

• Metrology Application sees a standard “panel of plugs”.
• “Cabling” of those plugs depends on the measuring instrument capabilities.
• Various VMI “cabling” for:
  – Hand Tools
  – Manual or DCC Coordinate Measuring Machines
  – Optical / Non contact measurements
• A new VMI is easy to install.
VMI Summary

• Developed to Support growth of B&S Next Generation Metrology Applications (PCDMIS, XactQuindos...).

• Developed to support integration of B&S Legacy Products (Quindos, Chorus, MM4, Tutor…)

• Open-set of COM Interfaces allows any Metrology Application (PCDMIS, CAMEO, Calypso…) to control any Metrology Device (B&S, Zeiss, LK) accurately and confidentially.
Open Standards: DOT

DMIS Object Technology and Open Architecture Standardization for Metrology

Dietmar May
Object Workshops
State of the Industry

- Wide variety of machines
  - different measurement capabilities
  - different controllers
  - different inspection tasks
- Proprietary software
- Isolated pockets of inspection
  - inspection tools relegated to corner of factory
  - tremendous loss of capability
State of the Art

- Technology for plug-and-play inspection exists
  - intercommunication between metrology applications and devices
  - inter-operation between applications from different suppliers

- Object-oriented interface
  - powerful, flexible
  - inheritance, polymorphism

- Open Architecture software standards needed
Standardization

- New standards should build on existing standards, where possible
  - proven body of knowledge
  - availability of tools
- Need to support a broad range of implementation platforms
  - Windows, Unix, Linux, RT-OS
- Applicable standards
  - DMIS
  - CORBA, proprietary COM
Highly Modularized

- Plug-n-play application interface for third-party inspection tools
  - CAD, Analysis, SPC, Programming
- Plug-in equipment
  - Portability layer for differing controller architectures, interfaces
- Plug-in mathematics
  - Common algorithms across machines
  - Custom feature / tolerancing
- User-replaceable report formatting
Based on DMIS

- Leverages work on DMIS standard
  - large existing body of knowledge
  - man-years of industry expertise
  - proven concepts and definitions
- DMIS as objects and methods
  - Object operations create DMIS
    - ideal archive format for learn mode
    - DMIS input and output formats
  - DMIS statements create objects
    - immediate support for large body of existing programs
  - seamlessly bridges text and object
Object Definitions

Sensor

SensAct

SensNom

SensVideo

SensProbe

SensLaser

Carriage

Carriage::select_sensor(Sensor)

SensNom::calibrate()

SensProbe::diam()
Machine Interface

- High-level abstracted interface
  - Minimized command set
  - Raw and formatted sample data
  - Compensation hidden within equipment plug-in

[Diagram showing DME control, OI, and DMIS Kernel]
Total Integration

- Plug-n-play Inspection Applications
- Process Monitoring
- Factory Integration
Standardization Status

- Interface Specification nearly complete
  - Copyright owned by CAM-I
  - Progressed by DNSC sub-committee
    - anticipated as DMIS Part II
    - initial target - ANSI
    - ultimate submission to ISO
- Reference implementation in Beta
  - Concepts and interfaces validated
Standards Bodies

- Standards-making organizations play vital role in coordinating standards activities
  - MAA
  - NIST
  - CAM-I - - - DMIS, DOT
  - others
- Participation by developers
  - valuable input for different application, technology needs
- Support by users crucial
Open Modular Architecture Controllers
- OMAC -
Overview

John Michaloski
Intelligent Systems Division
Manufacturing Engineering Laboratory
National Institute of Standards and Technology

May 2, 2000
OMAC is an Industry Users Group - *NOT* a Standards Body

OMAC chartered to facilitate open technologies:

- Genesis: Chrysler, Ford and GM paper on Open Architecture Requirements Document
- Now scores of control automation users, OEMs, and vendors
- Establish Guidelines for development of future control products

URL- http://www.arcweb.com/omac/
OMAC Working Groups

- Business Justification for Open Systems
- General Motion Control for Packaging Machinery
- Microsoft Manufacturers User Group - (MSUG)
- CNC HMI-API
- PC Application Integration
- Architecture
- OMAC API
- New CNC Programming Languages and Extensions
OMAC API Background

- Lack of a standard open architecture specification hinders the controller plug-and-play evolution.

- Domain and Requirements
  - Simple Control - “60% of GM controllers are one-axis”
  - Motion Control - Computer Numerically Controlled (CNC) Machine Tools, Robotics, Conveying
  - Process Control - motion/sensor integration is highly desirable
  - Applications - Cutting, Manipulation, Inspecting, Forming, Grinding, Deburring, etc.

- Natural Overlap leading to common API and Component-based specification

- URL: http://isd.mel.nist.gov/info/omacapi
OMAC API Methodology

- Vision: enable control vendors to supply standard components that machine suppliers configure into machine control systems. The integrated control system and machine are then delivered to the end-user.

- Adopt component/framework Architecture
  - MIDL/COM for initial component specification, UML and XML in future

- Use Finite State Machine for control and data flow

- Use proxy agents to hide distributed communication
  - Implying need for DCOM or CORBA

- Emphasize on embedding information into components

- Focus on component life cycle
  - Vision: IDE builder tool can query an OMAC component for the references it publishes, the types of OMAC interfaces it requires as references, and the events-in it requires and the events-out it generates. The designer can then connect the “wires” among the various OMAC components. Synergy with IEC 61499.
OMAC API Conclusion

- Agreement to basic model
  - Component-based technology
  - UML as API specification, FSM as behavior specification
  - COM as first Reference API

- Work with Relative Standard Bodies, for example,
  - IEC 61499, OPC XML, DA 3.0, etc.

- Note: The OMAC Users Group does not endorse any Vendor products and has not authorized any products to be 'OMAC-Compliant' or to meet 'OMAC-Specifications'.
Questions?
AP219:
Dimensional Inspection Information Exchange
under STEP (Standard for the Exchange of Product Model Data)

Ted Vorburger, Simon Frechette, Larry Welsch (NIST)
Bill Danner (Seneca-IT.com)

Workshop on Open Architecture in Metrology Automation
May 2-3, 2000
AP219: Dimensional Inspection Information Exchange

Contents:

• Motivation
• Structure of the TC184
• Scope
• Activity Model
• Requirements Model – Modules, EXPRESS, EXPRESS-G
• Implementation
• Participants
• Contact Information
AP 219 Motivation:

Need for a Common Data Model and Format for Automated Dimensional Inspection Systems

Otherwise: A proliferation of direction translations between systems
Information Modeling is carried out by:

ISO TC184 - Industrial Automation Systems and Integration,

SC4 - Industrial Data - responsible for STEP, Standard for the Exchange of Product model data

A key activity under STEP is the development of Application Protocols (APs) for various industrial fields

An AP for a particular field is largely a specification of all data entities (constants & variables), including their
- names
- definitions
- data types (real, string, etc.),
- classification hierarchies,
- attributes,
- constraints,
- other relationships.
Scope and Functional Requirements:

This Application Protocol (AP) will specify information requirements to manage dimensional inspection of solid parts or assemblies, which includes administering, planning, and executing dimensional inspection as well as analyzing and archiving the results. Dimensional inspection can occur at any stage of the life cycle of a product where checking for conformance with a design specification is required.
AP219 Application Reference Model (ARM) working draft

EXPRESS-G

Bill Danner
Seneca-IT.com
Inspection information module: **Content**

- **features**
  - Inspection_feature_module.Inspection_feature

- **datums**
  - Inspection_datum_module.Inspection_datum

- **tolerances**
  - Inspection_tolerance_module.Inspection_tolerance

- **programs**
  - Inspection_program_module.Inspection_program

- **tools**
  - Inspection_tool_module.Inspection_tool

- **results**
  - Inspection_result_module.Inspection_result
Application Reference Model (ARM)

1 Working Draft EXPRESS ARM AP219
2 (Dimensional Inspection)
3 Version 0.1
4 SCHEMA AP219 ;
5
6 --
7 -- Base Stuff
8 --
9
10 -- all coordinates are returned in mm
11 -- all angles are returned in radians
12
58  TYPE CDIFeatType = Enumeration of ( 
59       POINT, 
60       LINE, 
61       PLANE, 
62       CIRCLE, 
63       CPARLN, 
64       SLOT, 
65       CYLINDER, 
66       CONE, 
67       SPHERE, 
68       GCURVE, 
69       GSURF, 
70       PATTERN, 
71       ELLIPSE, 
72       RECTANGLE, 
73       SURFACEOFREVOLUTION); 
74  END_TYPE; 
75 
76  TYPE CDITolZoneShape = Enumeration of ( 
77       CYL, 
78       SPHERICAL, 
79       PARPLANE, 
80       WEDGE, 
81       RADIAL); 
82  END_TYPE;
Prototype Implementation Scenario

Plan

inspection program

Execute / Modify
Brown & Sharpe

modified inspection program

inspection results

Analyze

inspección program archive

Tecnomatix
Pro CMM
Catia
Silma

B&S
LK
Mititoyo
Zeiss
G&L
Tecnomatix

Tecnomatix
ICAMP
Participants include:

Ray Bagley - Engineering Animation
Randy Bowman & Steve Scigliano - Tecnomatix
Larry Parker - GM
Hari Sannareddy - Caterpillar
Clay Tornquist - Brown & Sharpe
John Wootton - LK Limited
Bill Danner - Seneca-IT.com
Alan Jones - Boeing
Ted Vorburger, Larry Welsch, Howard Harary, Simon Frechette - NIST
More Participants Invited:
• To Help Review the Requirements Model
• To Participate in the Prototype Implementation

Point of Contact:
Ted Vorburger, 301-975-3493, tvtv@nist.gov

For access to Email exploder: step-inspect@nist.gov
Website: http://step-inspect.nist.gov

Acknowledgment:
This project has been supported at NIST by the National Advanced Manufacturing Testbed Framework Project and the Systems Integration for Manufacturing Applications Program.
Object Management Group: 
* A Forum for Open Interface Specification

Evan K. Wallace
ewallace@nist.gov

*chair - OMG MES/MC working group*
The Technical Goal

Foster interoperability and portability for application integration through cooperative creation and promulgation of object-oriented standards based on *commercially available* software:

- Single terminology for object-orientation.
- Common abstract framework.
- Common reference model.
- Common interfaces & protocols

*Consensus-based approach*.....
Background

- Not-for-profit company based in United States, with representation in Italy, United Kingdom, Germany, Japan, Australia & India.
- Founded April 1989.
- Small staff (35 full time); no internal development.
- Almost all technical work done by engineers in member companies.
- Over 800 members (4/00)
<table>
<thead>
<tr>
<th>Member Organizations</th>
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<tbody>
<tr>
<td>3M</td>
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<tr>
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<tr>
<td>BaaN</td>
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<td>British Telecom</td>
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<tr>
<td>Unisys</td>
</tr>
<tr>
<td>Valtech</td>
</tr>
<tr>
<td>Yokogawa………</td>
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</table>
Innovative approach to adoption of standard interfaces:

1. OMG adopts & publishes interfaces.

2. Interface Implementations must be available commercially from OMG Corporate member.

3. Interface specifications freely available via the Web to members and non-members alike.

4. Interfaces chosen from existing products in competitive selection process.
Adoption Process

- RFI (Request for Information) to establish range of commercially available software.
- RFP (Request for Proposals) to gather explicit descriptions of available software; Architecture Board approves.
- Letters of Intent to establish corporate direction.
- Task Force evaluation & recommendation; simultaneous evaluation by Business Committee.
- Architecture Board consideration for consistency.
- Board decision based on recommendations from the appropriate Technology Committee & Business Committee.
- Fast Track Process..
Platform Middleware Technologies

CORBA

- Evolved into CORBA Components
- Specialized into Realtime CORBA and Dynamic Scheduling
- Extends Fault Tolerant CORBA and minimum CORBA

Enhanced View of Time

Dynamic Scheduling

Fault Tolerant CORBA

minimum CORBA
Platform Modelware Technologies

XML
Syntax and Encoding

MOF
Metadata Definitions & Management

UML
Metamodel Analysis & Design

XML Streams (Models)
(Many - based on each metamodel DTD)

XML DTD (MetaModels)
(1 per metamodel used for validation)

UML 1.1 DTD

CWM DTD

MOF 1.1 DTD

Validate

UML Models
CWM Models
MOF MetaModels
Adopted:
• Product Data Management (PDM) Enablers V1
• Workflow Management Facility
• Utility Management System Data Access Facility

In Process:
• PDMEv2 (RFP issued)
• CAD services (target issue date: June 16, 2000)
• Data Acquisition from Industrial Systems (DAIS) (initial submissions received, proposals in revision)
“Data Acquisition from Industrial Systems” (dtc/99-01-02)

Scope: To provide interfaces for collecting data from industrial systems and devices: on demand, according to a schedule or driven by events

Major Requirements:
- Data Access Retrieval
- Event Notification of Availability of MC Data
- Event Driven Data Upload
Domain Technologies (continued)

- Laboratory Equipment Control Interface Specification (RFP draft)
- Workflow Resource Assignment Interfaces (RFP Issued)
- Workflow Process Definition (RFP draft)
- Organizational Structure (initial submissions received, proposals in revision)
OMG Subgroups Related to Automation Integration

• Realtime Platform Special Interest Group (RTSIG)
• Utilities Domain Task Force (UDTF)
• Life Sciences Research Domain Task Force (LSR)
• Business Objects Domain Task Force (BODTF or BOM)
• Manufacturing Domain Task Force (MfgDTF)
Manufacturing DTF

Has several working groups focused on different aspects of manufacturing:

- **Product & Process Engineering:** design & analysis (PPE)
- Enterprise Resource Planning (ERP)
- **Manufacturing Execution System/Machine Control:** production (MES / MC)
- Manufacturing Common Business Objects (CBO)
Why OMG for Interface Specification?

• OMG understands heterogeneous interoperability & technology evolution
  – CORBA, CCM, IIOP, UML, XMI, PDME…
  – OMG is not just about CORBA anymore!

• Open standards process that works
  – Strong architectural foundation in CORBA, MOF, and UML
  – XMI happened from inception to adoption in about a year

• The place where technology integration via an open process is happening rapidly
Upcoming Meetings

• OMG Technical Committee meeting in Oslo, Norway - June 12-16, 2000
• CAD Services submissions meeting at the Ford Training and Development Center (FTDC), Dearborn MI - May 25, 2000
• Joint OMG Utilities DTF/EPRI CCAPI Task Force meeting to discuss DAIS submissions in Southern California (location TBD) - July 11-12, 2000
• OMG Technical Committee meeting in Burlingame, CA - September 11-15, 2000
Some Related Links

- DAIS RFP, schedule, status and submissions: http://www.omg.org/techprocess/meetings/schedule/Data_Acquisition_RFP.html
Open Machine Interface for CMM Technology

Steps to a Standard Machine Interface for CMM Systems

April 2000
Open Machine Interface for CMM Technology

Current situation

Zeiss  
Software
 Zeiss  
CMM - OS  

LK  
Software
 LK  
Common Driver

B&S  
Software
 Brown&Sharpe  
VMI
Open Machine Interface for CMM Technology

Situation April 2000

Calypso Holos
CAMIO
metrolog
metromec
Cats
Virtual DMIS
PC DMIS
Quindos

Zeiss CMM - OS
LK Common Driver
Brown & Sharpe VMI

April 2000
Open Machine Interface for CMM Technology

**Desired situation**

Calypso
Holos

CAMIO

metrolog

metromec

Cats

Virtual
DMIS

PC
DMIS

Quindos

standardized CMM interface
CMM-driver

April 2000
Open Machine Interface for CMM Technology

What is the CMM-driver?
Open Machine Interface for CMM Technology

What is the status today?

- basic strategy defined
- basic commands defined
- basic error codes defined
Open Machine Interface for CMM Technology

Basic commands (part 1)

44 commands and their parameters were defined

- Setting CMM parameters:
  - speed (probing, measure)
  - accelerations
  - probing parameters (approach, retract, search, force)

- Query CMM parameters:
  - speed (probing, measure)
  - accelerations
  - probing parameters (approach, retract, search, force)

- Probe head and tips:
  - changing angles
  - query angles
  - activate tip
  - disable data transfer
Open Machine Interface for CMM Technology

Basic commands (part 2)

Toolchanger:
- query bay data
- return tool
- pick up tool

Position:
- get current position
- move to position
- move to home position

Rotary head:
- rotate to angle
- query current angle

Transformations:
- set matrix for DRO
- set matrix for joystick

Miscellaneous:
- initialize CMM
- get configuration data
- change mode (man/cnc)
- abort current operation

Hitpoint:
- CNC hitpoint
- MAN hitpoint
Open Machine Interface for CMM Technology

Basic commands (part 3)

Tooldata:
- get name of active tool
- query active tool
- query active tip

Alignments:
- save alignment
- list alignment
- read alignment
Open Machine Interface for CMM Technology

Basic errors

- Limit of travel reached
- Emergency stop
- no touch
- illegal touch
- not calibrated
- unsupported command
- incorrect parameters
Open Machine Interface for CMM Technology

Demands on the interface

The interface must be

- very reliable
- able to work with old and new controllers
- easy to implement for vendors
- easy to debug and trace
- a driver level solution
- flexible for extensions
- able to work with old and new software
Open Machine Interface for CMM Technology

Suggested strategy

The interface will
• use strings as commands
• use TCP/IP sockets for communication
Open Machine Interface for CMM Technology

And now?

Next steps:

• get everyone involved
• discuss draft
• finalize the proposal
• start implementing
The NGIS II Project

Bill Rippey
National Institute of Standards and Technology
May 2-3, 2000
MAA Workshop

301-975-3417
william.rippey@nist.gov
Motivation

• Inform you of past NGIS project technical activities, who was involved, goals, and what was done.

• Allow you to decide:
  – How to use past efforts
  – Who may be interested in NGIS III and could contribute
Capsule

• NCMS/NGIS II developed a specification for integrating inspection probes with machine controllers (CMM and NC), the SIM concept.

• It was tested on CMM and NC sites, implemented by two sensor developers.

• We were soliciting opinions of CMM users, sensor vendors, and CMM vendors about feasibility, features, possible formalization.

• Preliminary work was done on wireless link.
Outline

• NCMS/NGIS II Project
  – Goals
  – Members
  – Progress

• NGIS II Technical Work
  – Sensor Interface Module (SIM) Specification
  – Sync Bus Specification
  – Wireless Link

• Summary
Alphabet Soup

- **NCMS** - National Center for Manufacturing Sciences
- **NGIS** - Next Generation Inspection System
- **SIM** - Sensor Interface Module
- **NIST** - National Institute of Standards and Technology
The NGIS Program

• Begun 1991.

• Sponsored by NCMS and its members.

• **Goal**: Improvement of inspection on CMMs and NCs, especially throughput, using analog probes.

• NGIS 2 begun 1996, emphasis on demonstration.

• Members ->
NGIS Program Members

- **Users** - Ford Motor Co., General Motors
- **Controls** - Advanced Technology and Research Corp., Automated Precision Inc., Raytheon Consulting Group
- **Sensors** - Automated Precision Inc., ExtrudeHone, Sensor Applied Machines Inc.
NIST Inspection Testbed
GM Powertrain CNC Testbed
NGIS II Progress

- 1996 - NGIS II, emphasis on demos at GM, Ford, testing at NIST


- 6/98 - “tapering” down of NGIS II.
The Sensor Interface Specification

- **Purpose** - define interface between commercial probes and commercial controllers.

- **Commercial Scenario**
  - controller and sensor vendors build to it.
  - products can be purchased and integrated, under the control of users.
Ability to integrate a variety of probes.
Technical Aspects

- Controller architecture
- Sensor Interface Module
  - Hardware
  - Software (API)
- Sync Bus
  - Sync bus module (SBM)
  - Software (API)
Controller Architecture
SIM Components

• **SIM Hardware**
  – ISA card
  – interface to Sync Bus

• **api (software)**
  – standard interface to all probes
  – operating system compatible
  – communications technology (e.g. dll, COM)
Scenarios of SIM Use

• Installation, configuration

• Touch trigger probing

• Scanning probing
SIM API Functionality

- Configure - e.g. hardware address
- Program trigger events - e.g. touch-trigger emulation
- Program response to trigger events, build arrays of synchronous data
- Get asynchronous data
Benefits of the SIM Specification

• Users and/or integrators will be able to use a wider array of probes.
• Users have better inspection capabilities.
• Ability of control users and builders to easily upgrade sensors.
• Sensor suppliers will have the selling point of interoperability through known compatibility.
Challenges

• achieve fast response in a distributed system -> accuracy.
• develop scanning control algorithms.
• develop scanning inspection strategies.
• develop compatible products.
NIST Role in SIM Spec

• Member of working group

• Editor of SIM document

• Sponsor of web site

• Tester of the specification on our testbed
NGIS Next Steps

• Refine, test, publish Sync Bus Specification.

• Compare the SIM Spec to IEEE 1451.
  – http://129.6.36.211/Home/P1451/IeeeSite/P1451.htm

• Formalize the spec?
Acknowledgements

• ATR - Daron Underwood
• API - Herbert Lau, Eun Soo Lee
• ExtrudeHone - John Rose
• Raytheon - Bill DeWys
• RDC - Nat Frampton
• NIST - Martin Herman, John Michaloski, Bill Rippey, Sandor Szabo
Wireless Link to Probes

- API did preliminary study and experiments on wireless link

- Required for mounting inspection probes in spindle of machine tools
Summary

• NCMS/NGIS developed a specification for integrating inspection probes with machine controllers (CMM and NC).

• It was tested on three CMM and NC sites. Sync spec is untested.

• Preliminary study in wireless link was done.

• We want opinions of CMM users, sensor vendors, and CMM vendors about feasibility, features, possible formalization.
References


• NGIS SIM website -
NIST Capabilities

- CMM-based testbed
- Real-time controls expertise
- System integration via “RCS” architecture concepts and tools
- “Educated user” viewpoint
- Meeting facilities
The End

Bill Rippey
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What is IEEE 1451?

• In September, 1993, NIST and IEEE Technical Committee on Sensor Technology of the Instrumentation and Measurement Society co-sponsored the first meeting.

• This standard will make it easier for transducer manufacturers to develop smart devices and to interface those devices to networks, systems, and instruments by incorporating existing and emerging sensor-networking technologies.
Why is IEEE P1451 needed?

• Proliferation of sensor/control networks
  – allow sensors to be connected to control networks for distributed measurement and control applications.

• Benefits:
  – save wiring cost,
  – allow plug and play installation, lower diagnostic and maintenance cost, more flexible than point-to-point systems.

• Problem:
  – too costly to support multiple networks - example buses or networks: ARCNET, ASI, CAN, DeviceNet, FIP, HART, ISP SP50, Interbus S, LonWorks, Profibus, SDS, SERIPLEX, WorldFIP, etc.
Needs cont’d

• Emergence of smart transducers in market
  – electronic data sheet
  – self-compensation
  – built-in signal conversion or processing
  – digital data output

• Benefits: reduced overall size, enhanced functionality, and increased reliability.

• Problem: No standard interface between transducers and microprocessor to enable self-describing sensors.
The Goals of IEEE 1451

- Define an open, network-independent, common communication interface for sensors/actuators.

- IEEE Draft Standards for a Smart Transducer Interface for Sensors and Actuators.

- Sponsored by:
  - The National Institute of Standards and Technology (NIST)

- With participation and support from sensor, measurement and control, and control networking providers as well as users.
What is IEEE 1451?

- A set of standards for smart transducer interface.

- Simplify the connectivity of transducers (sensors or actuators) to control systems or networks.

- Allow the “plug and play” of 1451-compatible sensors and actuators with different control networks at the device level.

- Allow sensor manufacturers/users to support multiple control networks.
What standards are being developed?

- IEEE P1451.1, Network Capable Application Processor (NCAP) Information Model


- IEEE P1451.3, Digital Communication and Transducer Electronic Data Sheet (TEDS) Formats for Distributed Multidrop Systems

- IEEE P1451.4, Mixed-mode Communication Protocols and Transducer Electronic Data Sheet (TEDS) Formats
Expected Benefits from the IEEE P1451 Standard

• With a common transducer interface
  – interoperability and interchangeability of sensors/actuators across different sensor/actuator buses are possible.

• A common transducer interface will
  – speed up the development of smarter sensors/actuators
  – cost less to design to a single standard
  – lower overall expenses to interface

• Having TEDS will
  – enable self-describing sensors and actuators
  – provide long term self-documentation
  – reduce human errors
  – ease field installation and maintenance by simply “plug and play” devices to control systems or networks
Expected Benefits -cont.

• Transducer Manufacturers
  – can support multiple control networks.
  – can focus effort on added-values to transducers.

• Control Network Providers
  – increased utilization of control networks due to the availability of
    large pool of standards compliance sensors/actuators.

• System Integrators
  – significant reduction in implementation effort, pick sensors and
    control networks for their merits.

• End Users
  – reduced sensor system life-cycle costs.
Industry/Government Collaboration

Determined industry needs through workshops

Five workshops
   NIST, Cleveland, Boston, Chicago, NIST
Public demonstrations
   SENSORS Expos in Boston, Philadelphia, and Detroit
   ISA Tech/97

Control network providers supported demo
   DeviceNet by Allen-Bradley
   LonWorks by Echelon
   Smart Distributed System (SDS) by Honeywell Microswitch
## Industry /Government Collaboration -cont’d

Sensor and network manufacturers, system integrators, & users

<table>
<thead>
<tr>
<th>Company</th>
<th>Industry/Technology</th>
</tr>
</thead>
<tbody>
<tr>
<td>AB Networks</td>
<td>-- Lucas Control Systems Products</td>
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<tr>
<td>Aeptec Microsystems</td>
<td>-- Lucas NovaSensors</td>
</tr>
<tr>
<td>Allen-Bradley</td>
<td>-- Lucas Control Systems Products</td>
</tr>
<tr>
<td>Analog Devices</td>
<td>-- Intelligent MicroSensor Technology</td>
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<td>Echelon</td>
<td>-- MCNC</td>
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<td>EDC</td>
<td>-- Veir-Jones</td>
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<td>Endevco</td>
<td>-- Moore Products</td>
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<td>Eurotherm Controls</td>
<td>-- Motorola</td>
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<tr>
<td>Delta Tau</td>
<td>-- NIST</td>
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<tr>
<td>Hewlett-Packard</td>
<td>-- Texas Instruments</td>
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<tr>
<td>Holjeron Corporation</td>
<td>-- Sandia National Laboratories</td>
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<td>Honeywell Microswitch</td>
<td>-- SSI Controls Technologies</td>
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<tr>
<td>Huron Net Works</td>
<td>-- Weed Instrument Company</td>
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<tr>
<td>Grayhill</td>
<td>-- Boeing Commercial Airplane Group</td>
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<tr>
<td>Optek Technologies</td>
<td>-- Oak Ridge National Lab</td>
</tr>
</tbody>
</table>
1451 Information

• http://www.ic.ornl.gov/p1451/
• http://129.6.36.211/Home/P1451/IeeeSite/P1451.htm
• 129.6.36.211/Home/P1451/IeeeSite/sensdemo.htm
Open Architecture in Metrology Automation Workshop Breakout Session Tasks

Toward the goal of defining the issues, the following “tasks” that should provide a springboard for discussion and consensus building.

**TASKS**

Define “open architecture” for metrology in the context of the automated factory floor.

**RESPONSES**

**Possible Standardization Areas**

- Component-based architecture (NGIS II)
- Common protocols (VMI, DOT, CMM-OS, DMIS)
- Transferable object-based measurement plan (AP219)
- Common definitions of measurement objects? (STEP AP219)
- Standard user interface, including procedures
- Object-based plug-in math engines? (DOT)
- Standard output technology (XML, etc.)

**NOTES:**

- What do we want to produce?
- What problem do we want to solve?
- Whose problem do we want to solve: users’ (hide the technology), DME vendors’, intra-vendor issues (plug-in)?
- Should we focus on fixed CMMs only to simplify the task?
- What should we do with the overlap between DOT & AP219?
- Can CMM folks learn from the tracker folks?
- Is a standard protocol required, or just multiple available protocols?
- Zeiss, LK & Brown & Sharpe will merge into a (de facto) standard device drivers that is std command set.

Agree on a graphic that **coarsely** defines the modules (components and systems) and interfaces that constitute most metrology systems in the context of the automated manufacturing process. Include downstream and upstream systems and activities that affect and are affected by the metrology system. The graphic doesn’t

**Note:** But more complicated to deal with device drivers from portables because they are unstructured. Therefore, need two(?) common drivers.

Common protocols is the second issue: TCP/IP is preferred as the standard device driver protocol.
have to be flat, but may be hierarchical.

Need to deal with both portable devices and traditional CMMs within a single environment. Prefer to deal with the biggest need first

Question: In terms of open arch. Where is the best place to plug sensor in?

How important is openness to productivity and efficiency? Are there other technologies/issues of equal or higher importance?

What is the current state of openness in metrology systems?

What are the interface and interoperability problems you face?

Standard user interface is undesirable both from the vendor and user point of view – reduces flexibility and creativity

What is a business case for open architectures?

In process metrology implies that you need RT meas., feedback and analysis – file transfer is not sufficient.

Captured by the chart.

What does the move towards in-process metrology affect the need for OA systems?

What are the existing programs (e.g., proprietary standards efforts, industry-wide standards efforts, consortia, government programs) with whom we should cooperate and, if so, how?

What should the role of government laboratories and leadership and laboratory testing be? Need them to take
programs and standards bodies be to aid in the research, development, engineering, and standards development efforts?

What additional issues do we need to address?

If time allows, consider the following questions:

1) How do current technology trends affect interoperability, such as the software and hardware standards of the PC, component-based software, the Internet, etc.

2) What are the differences and commonalties among the metrology systems in the various sectors represented (automotive, aerospace, and electronics) in regard to interoperability, modularity, and openness?

3) What would an OA or a collection of interface specifications look like that is a win-win technology for all, including the customer?

4) Should we work towards standards that are de facto (from market pressures) or de jure (from standards committees) or a combination of both?

5) What are the development and engineering needs to achieve OA?

6) What are the cultural impediments to OA and how can they be overcome?

7) Assuming that OA systems will be achieved in stages,
what might those stages be?

8) How will future directions in metrology (more speed, more measurement data, tighter integration with CAD) affect the need for OA?

9) How can we implement open architectures in a way that does not impede innovation?

10) What are the research needs to achieve OA?

11) Identify long and short term goals for achieving OA?

Note: Workshop
White Team Vision of Efforts and Needs for Open Architecture in Metrology

Traditional Measuring Machine

- CAD *(STEP AP219, IGES, DXF, ETC.)*
- OFF-LINE PROGRAMMING *(DMIS, DOT, AP219)*
- ETHERNET STANDARD FORMAT FOR XML
- UI STANDARD FILE FORMAT OR OBJECT
- REPORTING STANDARD SENSOR INTERFACE (NGIS)
- PC #1 STANDARD DEVICE DRIVER (COMMAND SET FOR TCP-IP)
- WORK PLANNING #2 COMMON PROTOCOL
- CONTROLLER
- CONTROLLER or SENSOR

Manufacturers
- B of S
- LK
- Zeiss
- Starrett
- Etc.

J. West et al.
MAA/NIST Workshop
May 3, 2000
*edited by T. Vorburger,*
05/24/00
White Team Vision of Efforts and Needs for Open Architecture in Metrology (cont)

Portable Measuring Machine

- Ethernet
  - Standard Format for XML
- CAD *(STEP IGES, AP219, ETC.)*
- UI
- Reporting
  - Object-Based Math Engine
  - Standard Device Driver (Command Set for TCP-IP)
- Work Planning
- Common Protocol
- Controller
- Sensor
  - (Perceptron, Level, Weather Station)
  - (SMR, Targets)
- PC
  - Opportunities for Standardization

Manufacturers
- Leica
- SMX
- API
- Faro
- Romer
- GSI Photogrammetry
- Metronor
- Etc.

J. West et al.
MAA/NIST Workshop
May 3, 2000
edited by T. Vorburger,
05/24/00
Business case for OA

- Ford has $1B in CMMs, fixtures, they are diverse!
- Reduce training costs
- Manage software management
- Ability to level production loads, e.g., between CMMs and operators
- More competitiveness (among suppliers?)
- Commodity technology
- Flexibility (in case of breakdowns, changes to new products)
- Globalization
- OA enables common business processes w/ flexibility
- End user vs. supplier viewpoint
- OA enables use of new technology
- Encourages metrology vendors to concentrate on core competencies

Define OA

- Must cover measurement technologies beyond CMMS
- Defined interfaces, published in public domain
- Modular
- Object based (is this required?)
- Allows hardware and software interchangeability (within equipment capabilities)
- Easy/consistent exchange of information, up and down

Issue: Automation

- Could be reporting and analysis only (with manual data gathering)
- OA is still needed/useful for manual operations (full automation is not needed for OA to be beneficial)

Parking Lot

- Is there a lack of expressed needs and goals by users?
- Is there a need for more non-mechanical inspection tools?
- Wait for de facto standards to emerge or push for formal standards?

Scope

- CMMs, micrometers, laser trackers, theodolites, cameras

Need – better knowledge and understanding of current OA, standards, efforts

What is the overlap, in common, different aspects of say CAM-I and MAA?
Existing efforts
• VMI –
• LK DMIS
• CMM OS
• OMG
• OMAC
• AP219
• NGIS 2, 3
• IEEE 1451
• DOT

Issue: avoid duplication and overlap of efforts

Other Technology Issues (needs)
• Need to maintain compatibility of OA with new, emerging technology
• Need to keep up with new computer technology, e.g. COM
• Need ways to certify/determine uncertainty of analysis software, GD&T, SPC (similar to NIST feature algorithm certification)
• Determine linearity for any gage for ISO 9000, i.e. “CMM R&R”
• More/better optical technology – need certification of photogrammetry systems
• Common calibration artifacts for CMMS (for touch probe, laser, vision) to compare results between different probe technologies
• How does the move towards in-process metrology affect Open Architecture or vice versa?
  • Metrology <-> Manufacturing Systems
  • How high a priority is this?

What should the role of the government be?
• DoD/DoE drive some efforts (Mantech, dual use, …)
• Money is available for other government agencies, such as NIST, manufacturers, vendors
  • DoC ATP
  • DoD

NIST Actions
• Develop techniques to certify optical metrology
  • Photogrammetry
  • Structured light
  • B89?
  • Business case: reluctance to use because of lack of cert.
• Users: Ford, DaimerChrysler, Boeing

• Publish overview of efforts, directions, architectures, long and short term goals –
  • DMIS
  • DOT
  • AP219
  • VMI
  • ….

• ATP funding perhaps

---

How to speed up Open Architecture efforts?

• Users have to pull
• Vendors have to participate in efforts as well
• MAA can coordinate? NCMS?, CAM-I?
• How to more directly get to the technology without a middle layer of management?
• Need
  • Facilities to test compatibility & interoperability of systems & products
  • Measures of openness
  • Common interface specifications that vendors can build to
Notes from Blue Group at OAM workshop, May 2-3, 2000
Editor, Bill Rippey, NIST

Product
Definition
DB

Planning
Programming
Analysis
Reverse Engr
Gear Inspection
.....

Measurement
Results
DB

AP219

Measurement Bus

- VMI, DMIS, CMM OS

Calipers
Theodolite
Laser
Tracker
CMM
CNC
Portable
CMM

Photo-
grammetry
Open Architecture in Metrology Automation Workshop Breakout Session Tasks

Toward the goal of defining the issues, the following “tasks” that should provide a springboard for discussion and consensus building.

<table>
<thead>
<tr>
<th>TASKS</th>
<th>RESPONSES</th>
<th>ACTION ITEMS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Define “open architecture” for metrology in the context of the automated factory floor.</td>
<td>A set of components and their relationships</td>
<td>draft scenarios of what would be happening in inspection</td>
</tr>
<tr>
<td></td>
<td>- Definition of the components and their interfaces</td>
<td></td>
</tr>
<tr>
<td></td>
<td>SPC (Statistical process control) system – interface specifications</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Conformance to interface specifications</td>
<td></td>
</tr>
<tr>
<td></td>
<td>See Green breakout group diagram</td>
<td></td>
</tr>
<tr>
<td>Agree on a graphic that <em>coarsely</em> defines the modules (components and systems) and interfaces that constitute most metrology systems in the context of the automated manufacturing process. Include downstream and upstream systems and activities that affect and are affected by the metrology system. The graphic doesn’t have to be flat, but may be hierarchical.</td>
<td>Very critical to productivity</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Issue of reliability impacts efficiency and productivity</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Openness with good implementation is important</td>
<td></td>
</tr>
<tr>
<td></td>
<td>State of proprietary openness (And, this is just beginning)</td>
<td></td>
</tr>
<tr>
<td>How important is openness to productivity and efficiency? Are there other technologies/issues of equal or higher importance?</td>
<td></td>
<td></td>
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<td>What is the current state of openness in metrology systems?</td>
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<td>What are the interface and interoperability problems you face?</td>
<td></td>
<td></td>
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<tr>
<td>Question</td>
<td>Answer</td>
<td></td>
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<tr>
<td>---------------------------------------------------------------------------------------------------------</td>
<td>--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
<td></td>
</tr>
<tr>
<td>What is a business case for open architectures?</td>
<td>Reduces integration costs</td>
<td></td>
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<tr>
<td></td>
<td>Flexibility for the end user</td>
<td></td>
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<tr>
<td></td>
<td>SPC and other in-process needs will continue to be addressed and important</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Standards shouldn’t stifle innovation</td>
<td></td>
</tr>
<tr>
<td>How does the move towards in-process metrology affect the need for OA systems?</td>
<td>DOT, DMIS, AP219, etc. more work may need to be done to learn more about this</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Understand relationships and direction of the various standards efforts – DOT and AP219 for example.</td>
<td></td>
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<tr>
<td></td>
<td>“Informal discussions” (Zeiss, LK and Brown and Sharpe) effort – how may that help our effort</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(Is this effort to limited, it maybe should include others)</td>
<td></td>
</tr>
<tr>
<td>What are the existing programs (e.g., proprietary standards efforts, industry-wide standards efforts, consortia, government programs) with whom we should cooperate and, if so, how?</td>
<td>Neutral, catalyst to make this happen, facilitator, support role and provide information</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Participate in standards committees</td>
<td></td>
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<tr>
<td></td>
<td>NIST try to help facilitate a model to give us a basis on working on this issue</td>
<td></td>
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<tr>
<td></td>
<td>would it be helpful to start an e-mail list?</td>
<td></td>
</tr>
<tr>
<td>What should the role of government laboratories and programs and standards bodies be to aid in the research, development, engineering, and standards development efforts?</td>
<td>CAD folks needs to be involved in the standards process</td>
<td></td>
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<tr>
<td></td>
<td>CAD architecture needs to be more open for addressing metrology issues</td>
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<tr>
<td></td>
<td>Web-enabled implementations ?</td>
<td></td>
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<td>Information availability may be useful, but accessing and manipulating controller specifications, etc. would not be accessible</td>
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<td>Ethernet ?</td>
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<td>What additional issues do we need to address?</td>
<td>Representation within the MAA is important from this community</td>
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<td>If time allows, consider the following questions:</td>
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<td>1) How do current technology trends affect interoperability, such as the software and hardware standards of the PC, component-based software, the Internet, etc.</td>
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<td>2) What are the differences</td>
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and commonalities among the metrology systems in the various sectors represented (automotive, aerospace, and electronics) in regard to interoperability, modularity, and openness?

3) What would an OA or a collection of interface specifications look like that is a win-win technology for all, including the customer?

4) Should we work towards standards that are de facto (from market pressures) or de jure (from standards committees) or a combination of both?

5) What are the development and engineering needs to achieve OA?

6) What are the cultural impediments to OA and how can they be overcome?

7) Assuming that OA systems will be achieved in stages, what might those stages be?

8) How will future directions in metrology (more speed, more measurement data, tighter integration with CAD) affect the need for OA?

9) How can we implement open architectures in a way that does not impede innovation?

10) What are the research needs to achieve OA?

11) Identify long and short term goals for achieving OA?

At the application level – already have interoperability and make use of existing standards
Other discussion:

MODEL DISCUSSION--

Fred – John E.’s example of Robotic Controller Model………

Model — what component is the most urgent…..

Kernel – CMM frame or physical metrology system

- framework to put software application within or working with – specification – skin around the kernel – wrapper around the CMM to allow software interface.

- Ideal – controller and components very interoperable and compatible – sensors, hardware components, different controllers, etc. If a part or component goes down it would be easy to replace and exchange.

- Something to augment the machine controller – the GUI and all of the attachments…simplify the GUI for operators

Other activities related to this effort--

Comment that there is already discussion outside of this group is already on-going – example of Chris Garcia working on VMI, working with Zeiss and LK, etc… do we really need to do anything, are the manufacturers already going to work towards a solution? Short term or is this a long term solution - ? It will only deal with three vendors.

At what level of involvement should we have?

We don’t want another “throw away”. We need involvement from others like the third party vendors, etc. There is a difference between getting something out that just works vs. a more permanent solution.

We need to start at defining the concept of a measurement. Fixed CMMs, theodolites, etc. Maybe have a broad measurement architecture, and build or move from there. No quick solution. Would be nice to handle technologies which haven’t even been developed yet.

Are hardware systems so different?

Manual vs. automatic

Different points with different orientation and reference frame. Then, you need to bring the data together into meaningful results.

Measurement vs. a coordinate, understand the difference.

Application layer

Data formats

Manual systems – two way communications required

Different levels of how data is handled

We may need minimum amount parameterization…

We will assume that the controller will be attached to the hardware and would remain closed.
Existing standards:
XML
DMIS
Etc…

Need to agree on the standards in the “open” section in our drawing.
Vendors, users, etc. need to agree

------------------------------------------------------------------------------------------------------------------

CAD and DMIS discussion--

DMIS shortcomings:
- how does DMIS relate to the CAD world – it was designed and originated to work with the CAD world?
- 4.0 effort help tie down some of the issues

other users in the world using different legacy systems

CAD design needs to define tolerancing, etc…but it doesn’t go through DMIS…the tolerancing needs to become part of the model definition so the designers information is more than a mark on a drawing.

AP219 – DOT discussion….

Sequencing or ordering of features …is this part of the standard? It holds the process information, construction of features information, etc.

How does DOT fit into representing this information – “motion” sequencing

Suggestion – agree upfront on the domains that you will discuss and the area will you standardize

Have a common map or “world model” – address interface standards and data issues. NIST could come up with a draft activity model

Draft a scenario of the “perfect day” in the inspection shop – get feedback from the users and manufacturers – with this info it will help draft a mapping of what is desired.

ACTION - AP219 has all ready defined a reference model for inspection – Ted or Howard may know.

Scenarios would be helpful if you could send them to NIST

ACTION – draft scenarios of what would be happening in inspection

ACTION – NIST try to help facilitate a model to give us a basis on working on this issue

ACTION – would it be helpful to start an e-mail list ?

From a manufacturing viewpoint, CAD part – this a complete part – now go make it….etc.
Critical info in tolerancing, inspection plan, tooling info needs to be maintained and passed on for inspection and what to inspect at the different stages also – rough through finished part.

Need a nice diagram to understand the scenario and how to address the issues

Near term objects?

Customer needs and miscellaneous observations --

Customers would like to integrate the different software components, hardware, etc. Modernization issues and costs are justified. This is such an issue because hardware is adequate, but there is a need of openness with various software packages.

Observation – more portable applications than fixed seems to be the case. Important to include other manufacturers as well in the standards development. There is a need for a broad standardization.

Need to understand the similarities and differences between fixed and portable systems. Do we strive for “a” metrology/interface standard or have more than one.

Machine centric view – maybe we need to evolve

Discussion of drawing:

Breakout of the components of the application box – DNC, spc, Analysis, etc…which would then go to the metrology system

Metrology system would give you certain information, but ….

Start with high level meanings – Design, manufacture, inspect, etc…then break it down to smaller components to describe the activities that are taking place.

Defining “?” –

“App” is the communication app, not the actual app

Diagram is drawn.
Report of the Gold Team

John Plonka
Ford Motor Company
Brain-Stormed Aspects of Open Architecture

- Able to utilize a variety of different companies’ software & hardware products
- Standard framework into which you can insert functional modules
- List of standard interfaces for Inputs and Outputs.
- Definition of standard interfaces.
- Limit the first item to software.
- The controllers are equally important to the software.
- A common set of standards
Working Definition of “Open Architecture for Metrology”

A common set of interface standards for metrology systems that will allow one to use a variety of different companies’ software and hardware products as components, where the hardware and software are not themselves standardized.
Brain-Stormed Components of A Metrology System

- Controller
- Computer
- Probe
- Sensor
- Tool Changer
- Motor
- Rotary Table
- Data Acquisition Device
- Communication Network
- Camera
- Scales
- Targeting
Generic Components of Metrology System

Sensor       Probe or Camera
Carriage     The mechanical element that holds and possibly moves the sensor or part relative to sensor
Computer     As Sensor Data Processor
Communication Network
Proposed Testbed for Open-Architecture Metrology System

A physical assembly line to simulate real world applications including a variety of different types of metrology systems to allow for the testing of each system’s robustness, accuracy, interfaceability, graphical interface, and compatibility and integration.
Current State OAM:

- Reverse of our working definition, i.e. you are unable to use a variety of hardware and software from different vendors as components of a metrology system.

- The rate of progress by vendors to OAM is less than customers say they need.

- Vendors have a substantial investment in the current state of the art,

- and to reengineer the existing product would require a substantial additional investment.
Issues:

- How to introduce new OAM technology that allows use of legacy hardware systems.

- No one is spearheading the effort from the big picture view of all-manufacturing, not just automotive, aerospace, etc.

- No central location for manufactures to work on concern collectively, e.g. test bed.
Actions to Address Issues:

- Vendors develop new adapters that allow new OAM technology hardware to use legacy hardware.

Someone develops OAM standards that are in place by a mutually agreed upon date, as soon as possible, while still giving vendors time to accommodate.

NIST should proactively lead a concerted effort to develop the standards to interface between the hardware and software products.

Brown & Sharpe, LK, and Carl Zeiss should continue their work on a common CMM interface as a defacto standard for DCC and manual machines.
Actions to Address Issues:

- Create a roadmap for development of the required set of interface standards referred to in the working definition of the OAM.

NI ST should lead the development of a physical assembly line to simulate real world applications including a variety of different types of metrology systems, to allow for the testing of each system's robustness, accuracy, interfaceability, graphical interface, and compatibility and integration.