PROCEEDINGS

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
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for the Proceedings of the
Open Architecture in Metrology Automation Workshop
May 2 & 3, 2000 in Gaithersburg, MD

Sponsored by

Metrology Automation Association

National Institute of Standards and Technology

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.

Disclaimer

Glossary of Acronyms

ACIS	Spatial Technologies .SAT CAD files
A-M	Automated Metrology
ANSI	American National Standards Institute
API	Application Program Interface, also Automated Precision, Inc.
APT	Automated Programming Tool
BCAG	Boeing Commercial Airplane Group
B&S	Brown and Sharpe, Inc.
C3P	CAD/CAM/CAI Product information management (SDRC's Ideas software used at Ford)
CAD	Computer-Aided Design
CAI	Computer-Aided Inspection
CAM	Computer-Aided Manufacturing
CAM-I	Consortium for Advanced Manufacturing-International
CBO	Common Business Objects
CCAPI	Control center to Control center API
CCM	CORBA CoMponents
CMM	Coordinate Measuring Machine
CMMOS	Coordinate Measuring Machine Operating System
CMM R&R	CMM Repeatability and Reliability
CNC	Computer Numerically Controlled
COM	Component Object Model
CORBA	Common Object Request Broker Architecture
CW 170	a particular Ford car line designation
CWM	Common Warehouse Metadata
DA	Data Access
DAIS	Data Acquisition from Industrial Systems
DB	DataBase
DCC	Direct Computer Control
DCC	Direct Computer-Controlled
DCOM	Distributed COM
DCUI	Direct Command User Interface

DLL	Dynamic Link Library
DME	Dimensional Metrology Equipment
DMIS	Dimensional Measuring Interface Standard
DNSC	DMIS National Sub-Committee
DoC ATP	U.S. Department of Commerce Advanced Technology Program
DOT	DMIS Object Technology
DTF	Domain Task Force
EPRI	Electrical Power Research Institute
ERP	Enterprise Resource Planning
FCA	Factory Computing Architecture
FINS	Ford INspection Software
GD&T	Geometric Dimensioning and Tolerencing
GUI	Graphical User Interface
HMI	Human/Machine Interface
IC	Integrated Circuit
IEC	International Electrotechnical Commission
IEEE	Institute of Electrical and Electronics Engineers
IGES	Initial Graphical Exchange Specification
IIOP	Internet Inter-Orb Protocol
IMS	Industrial Measurement Systems (of Leica Geosystems)
ISA	Instrument Society of America
ISO	International Standards Organization
IT	Information Technology
KBE	Knowledge-Based Engineering
MAA	Metrology Automation Association
MC	Machine Control
MIDL	Microsoft Interface Definition Language
MOF	Meta Object Facility
M/T	Machine Tool
NC	Numerical Control
NCMS	National Center for Manufacturing Sciences
NCO	Numerical Control Orientation
NGIS	Next Generation Inspection System

NIST	National Institute of Standards and Technology
NMI	National Measurement Institute
OA	Open Architecture
OAC	Open Architecture Control
OAM	Open Architecture Metrology
OAMA	Open Architecture in Metrology Automation
OEM	Original Equipment Manufacturer
OI	Operator Interface or Open Interface
OLE	Object Linking and Embedding
OLP	On-Line Programming
OMAC	Open Modular Architecture Controls
OMG	Object Management Group
OMG MES/MC	OMG Manufacturing Execution Systems / Machine Control
OPC	OLE for Process Control
ORB	Object Request Broker
PC	Personal Computer
PCS	Process Control System
PDGS	Product Development Graphic System (CAD product)
PDM	Product Data Management
PDME	Product Data Management Enablers
PDQ&P	Product Quality and Productivity
PPD	Preferred Process Definition
PPE	Product and Process Engineering
PRT	Unigraphics CAD model file extension
RFI	Request For Information
RFP	Request For Proposals
ROI	Return On Investment
RT-OS	Real-Time Operating System
SIM	Sensor Interface Module
SPC	Statistical Process Control
STEP	Standard for the Exchange of Product model data
STEP AP219	STEP Application Protocol for Inspection Data
TCP/IP	Transmission Control Protocol/Internet Protocol

TEDS	Transducer Electronic Data Sheet
UG	Unigraphics
UML	Unified Modeling Language
VB	Visual Basic
VDA	certain European solid model CAD file extensions
VEC	Virtual Error Compensation
VMI	Virtual Measuring Interface
VPM	Virtual Product Model
XML	eXtensible Markup Language

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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MAA METROLOGY AUTOMATION ASSOCIATION

Open Architecture in Metrology Automation Workshop

MAA-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

NIST
National Institute of Standards and Technology
Technology Administration, U.S. Department of Commerce

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

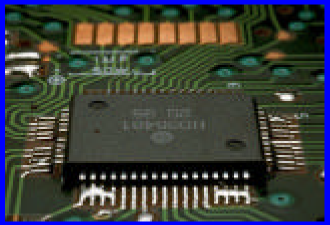
is being buffeted by an array of trends

that are driving metrology to a greater use

of automation and information technology

in which open-architecture systems play

an increasingly important role



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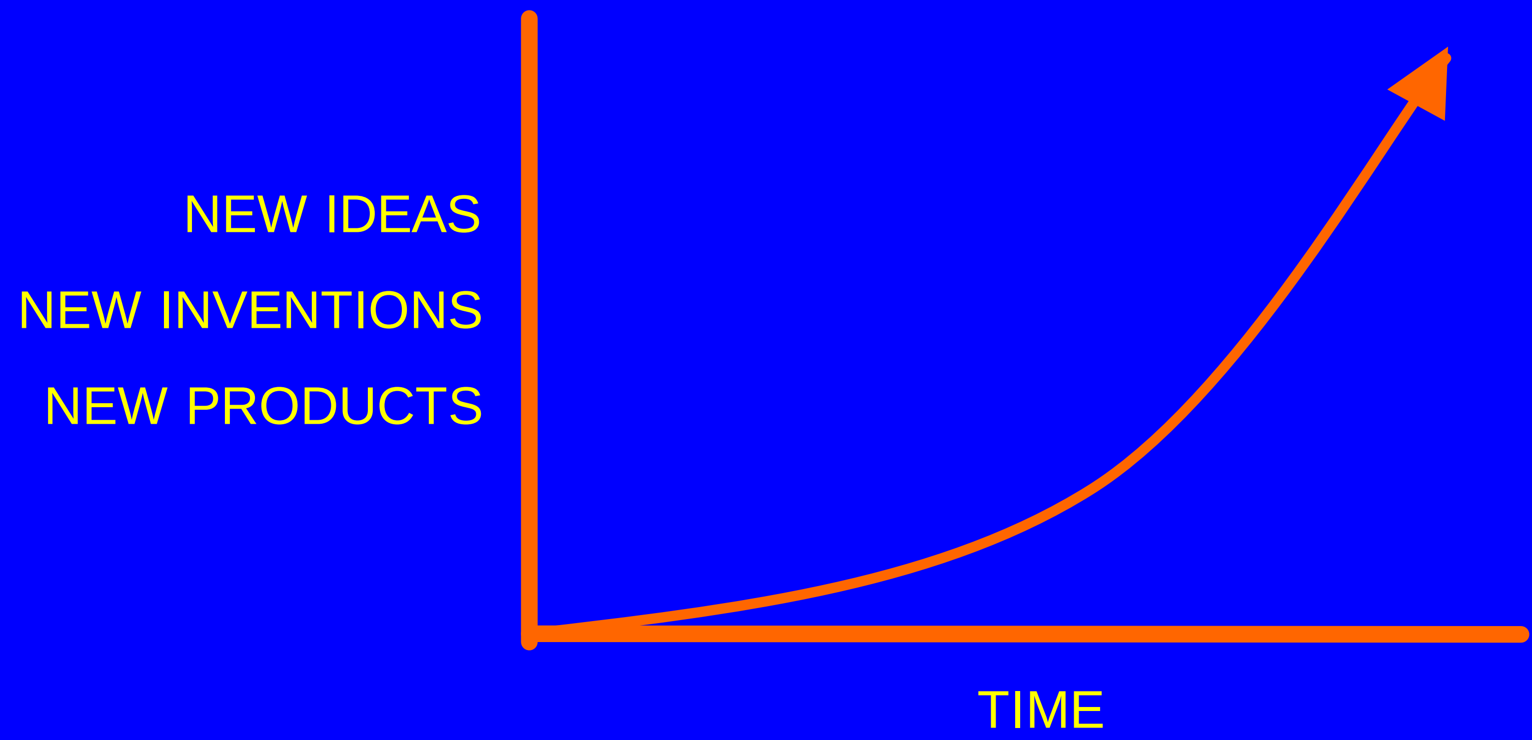
Market Trend 1
Continuing Globalization

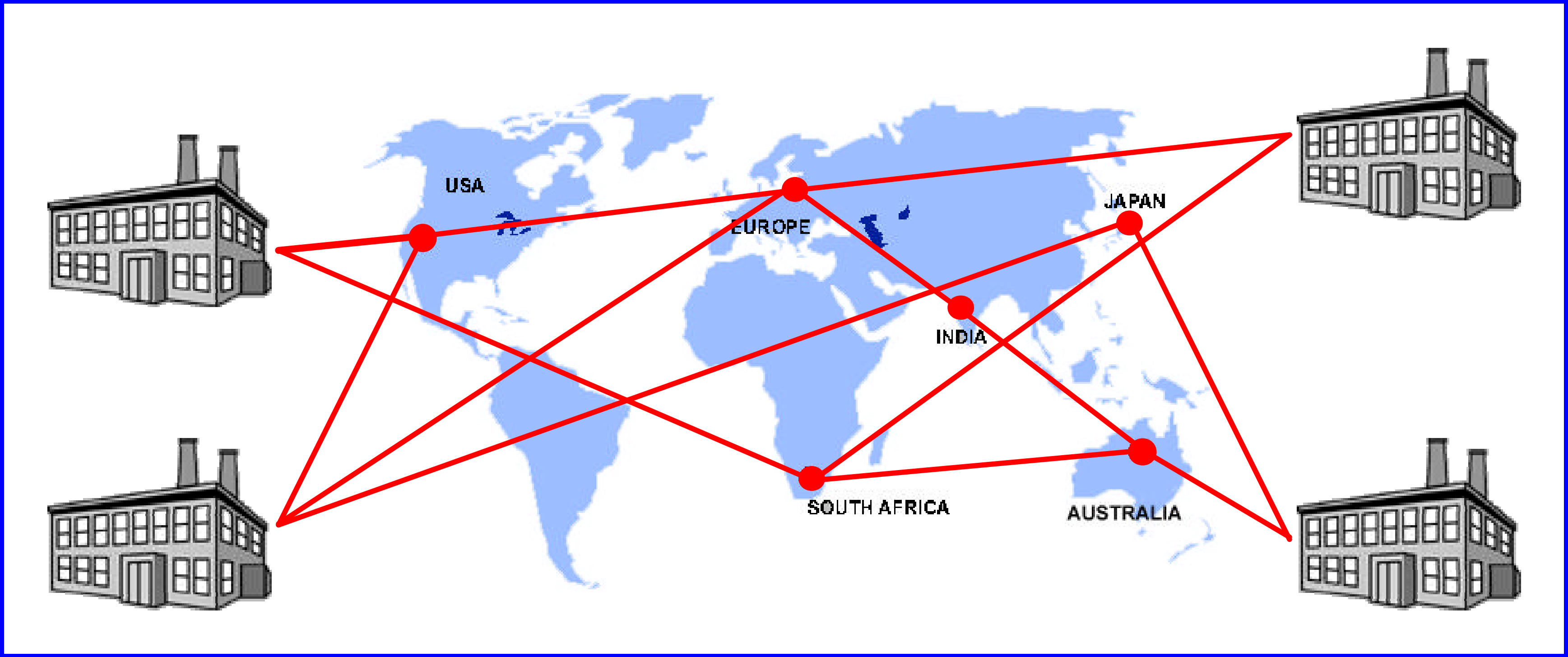
The Globalization Is of Markets, Enterprises, and Operations

Market Trend 2
The Pace of Change in Technology



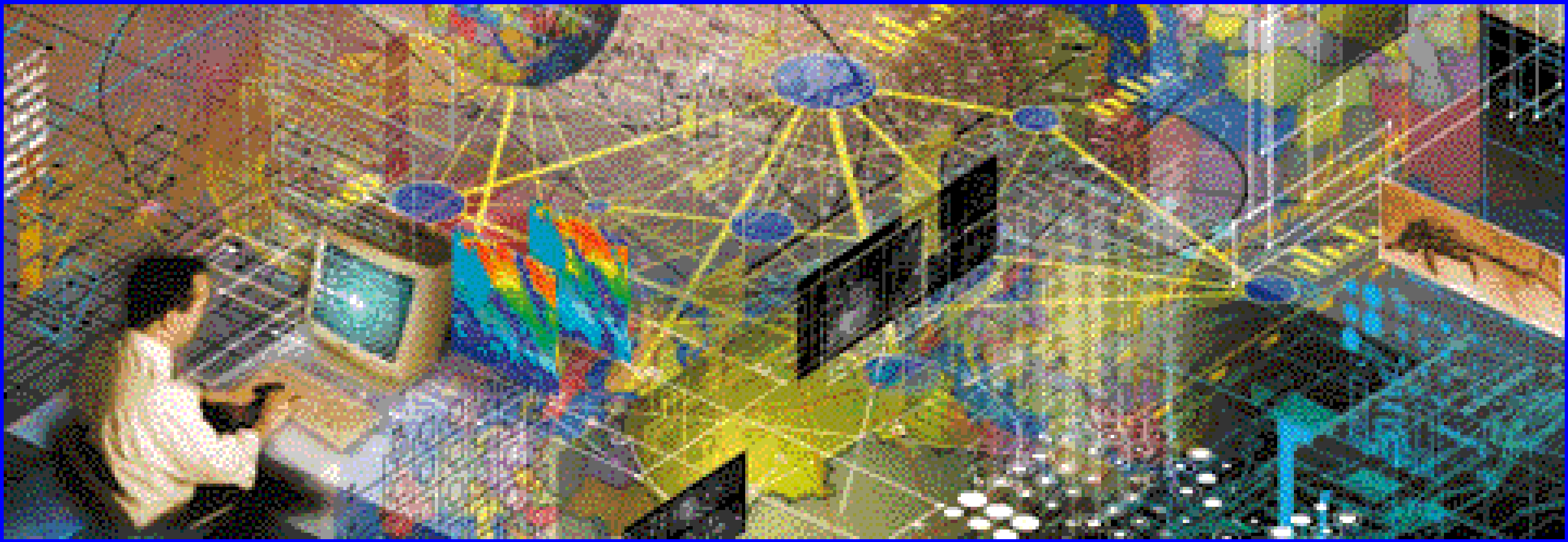
The Pace of Change of Technology, Including the Rate of Change, Is Continuing, If Not Accelerating

Market Trend 3
Rapidly Expanding Access to Technology



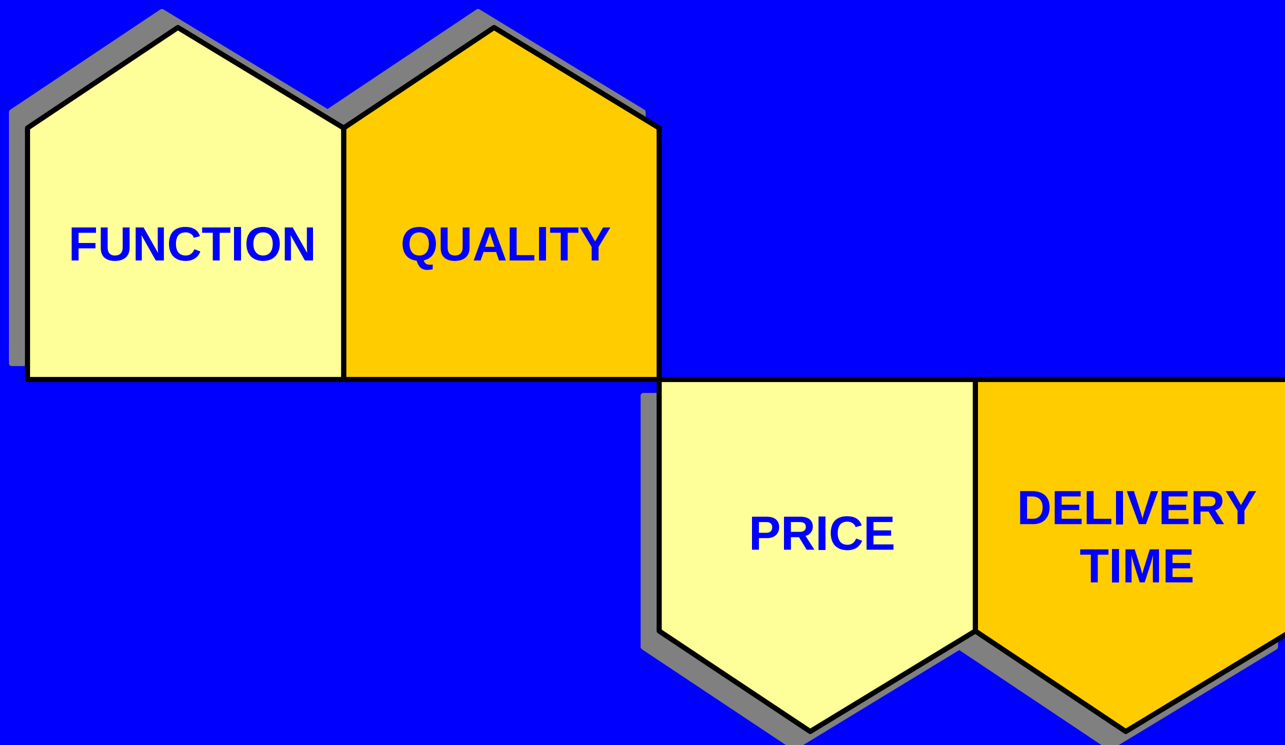
Competitive Advantage Is Not To Be Found
In Superior Technology Alone Since Virtually Anyone Can Get It

Market Trend 4
Ubiquitous Availability and Distribution of Information



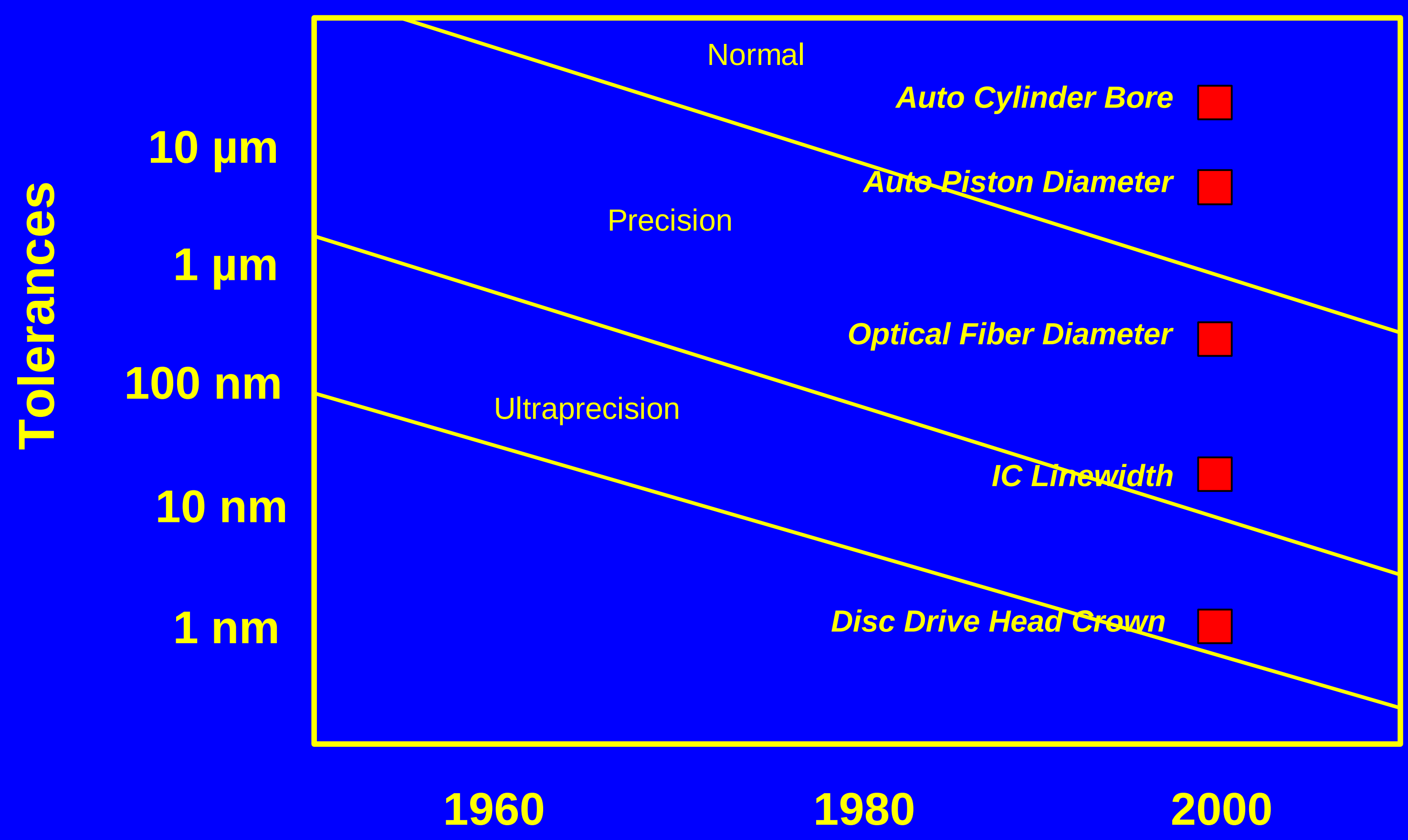
This Flood of Information Is A Major Challenge for Manufacturing Enterprises

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



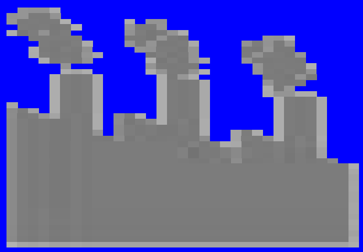
Tolerances Decrease In Size by Factor of 3 Every 10 years

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



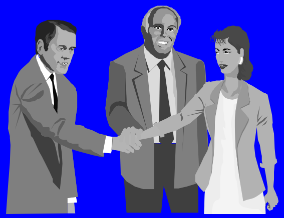
- **Real-time modeling and simulation of products, processes, and systems**
- **Use of multiple computer-interfaced sensors to extract dimension and process data**

- **Feeding-back of data to improve manufacturing processes in real time**

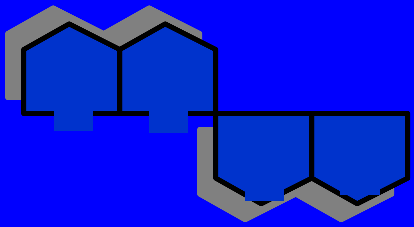
- **Development of IT standards for such operations, e.g. DMIS**
  Dimensional Measurement Interface Standard

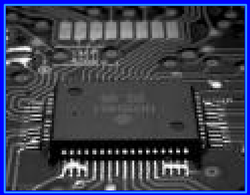
Manufacturing At the Confluence of These Market-Technology Trends

Manufacturers have customers to satisfy



These customers have expectations





There is a path for manufacturers to meet those expectations

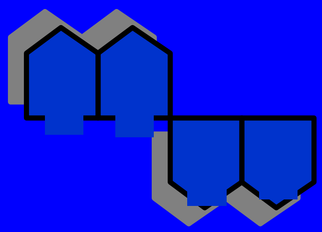
Path for Manufacturers to Meet Expectations

	Manufacturers' Products		
Expectations of Customer for Products	Higher Quality	Lower Cost	Faster Delivery
Needed of Mfg Process to Meet Expectations	Lower Variability	Higher Productivity	Greater Flexibility
Technology for Mfrs to Fulfill Requirements		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

Expectations of Mfrs as Users of A-M Products

Lower Variability

Higher Productivity

Greater Flexibility

A Requirement for A-M Products to Meet Expectations

Interoperability

Path for Producers of A-M Products to Fulfill Requirements

Open-Architecture

Machines

Controllers

Software

Conclusion

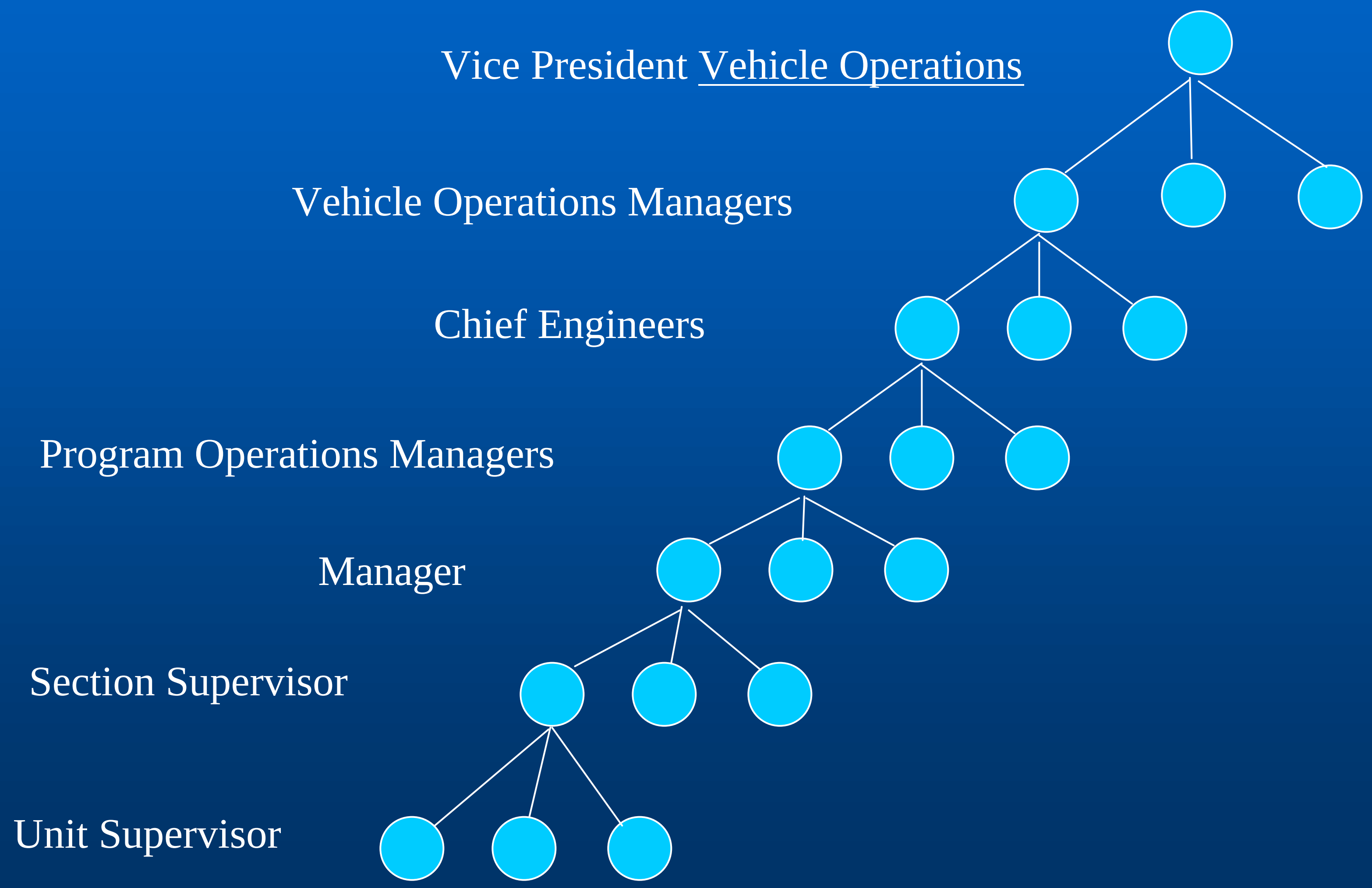
- **Manufacturing is buffeted by market and technology trends that must be dealt with effectively to achieve success**
- **IT-based automated metrology is a path for manufacturers to achieve such success with their customers**
- **Open architectures for IT-based automated metrology is a path for vendors 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

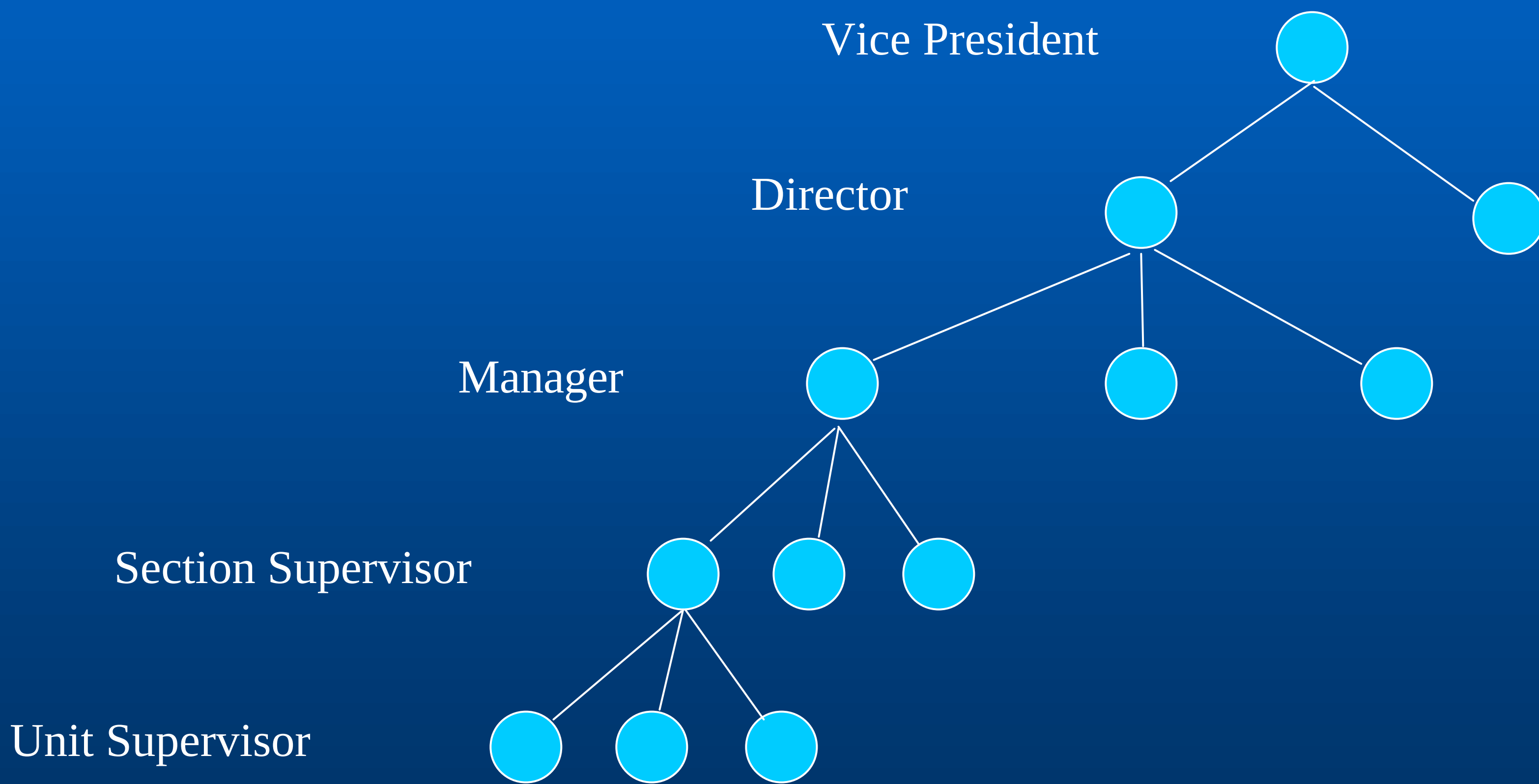
What brought on the need for change?

- CW 170
- Reorganization

Old Hierarchy



New Hierarchy (fewer people)



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

CAD/CAM	PDGS	C3P (Ideas)
Offline Programming	FINS	Silma
CMM	Avail	PC-DMIS
Reporting	DataPage	DataView
Operating Systems	Unix	Windows-NT
Editors	VI-Editor	MS-Editor

Europe and United Kingdom

CMM & Reporting	Zeiss	LK-DMIS/Cameo

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**
- **PC-DMIS – DMIS Dump → LK-DMIS – LK2000 Controller – PH9**

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

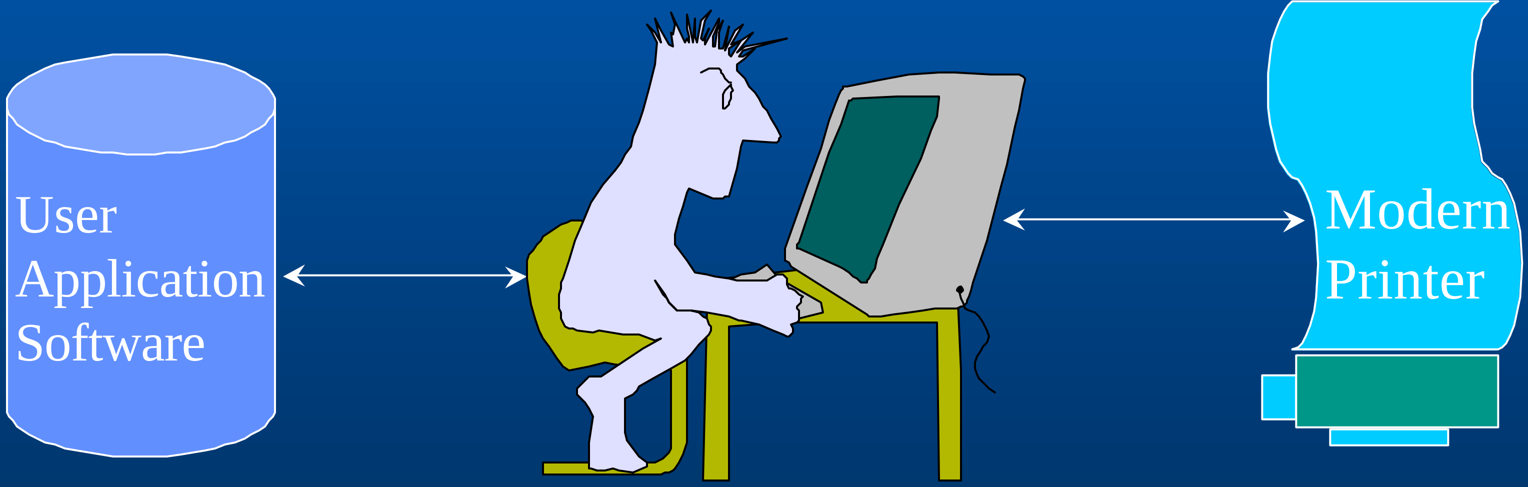
No communication with other equipment throughout the company

Customer’s Vision

Develop an open architecture that promotes Plug-N-Play

Analogy of Goal

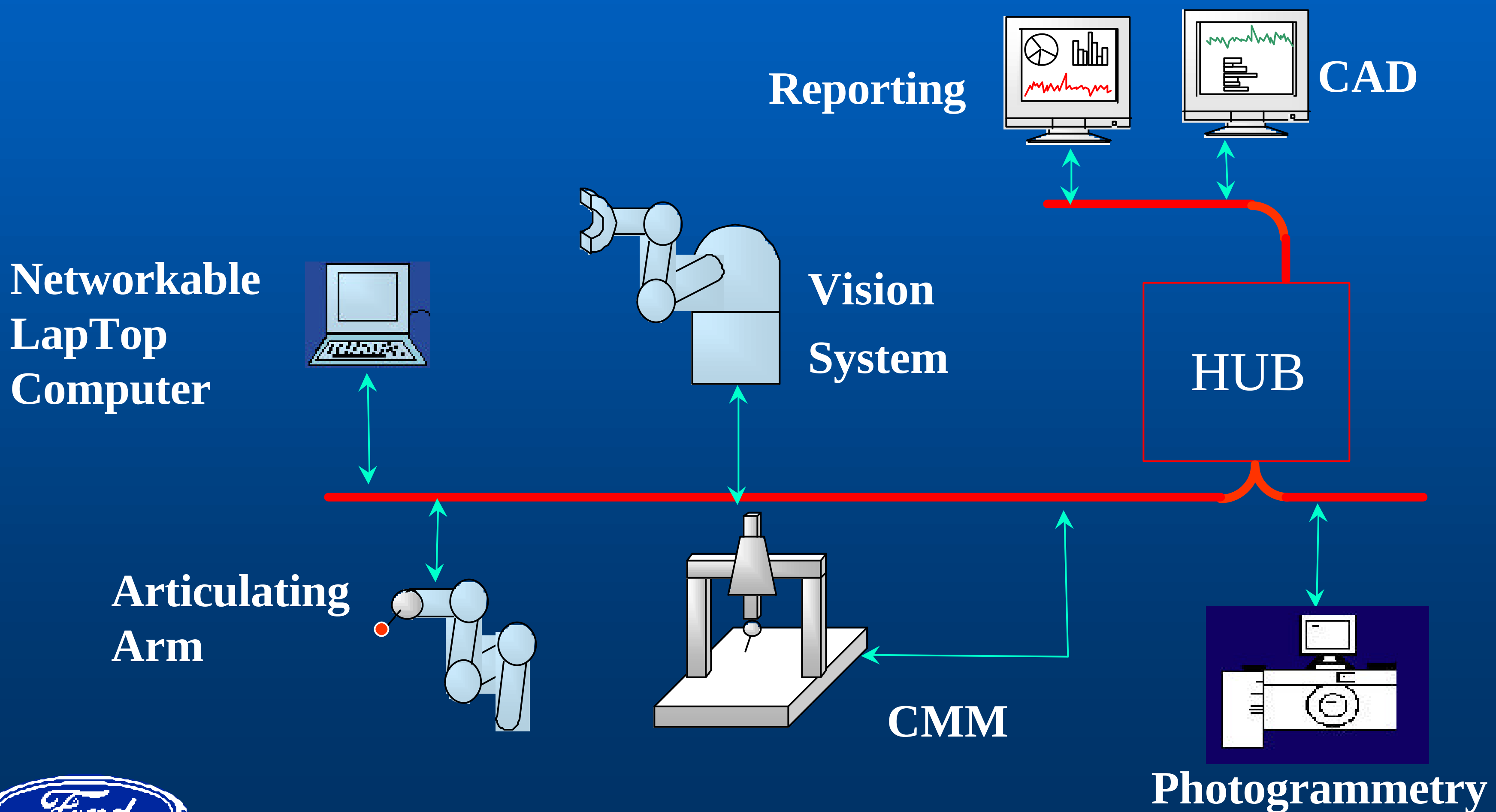
Today, anyone can purchase a modern printer, easily connect it to a wide variety of Windows based PC's, and successfully utilize a variety of hardware specific features from an assortment of application software's.



Multiple tool support

- CMM
- Photogrammetry
- Vision system
- Articulating arm
- Laser tracker
- Common Reporting

-- Overall Vision -
Connected Ass’y Plant



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

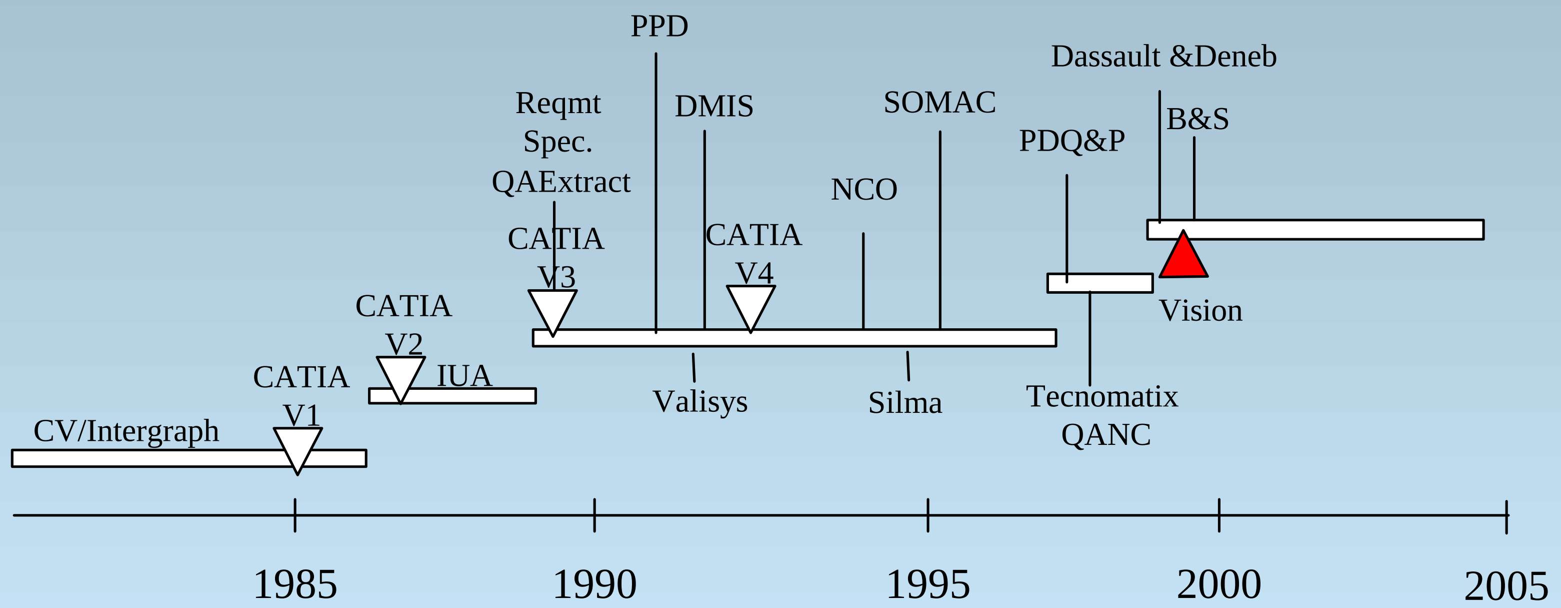
- Direction Statement
- Overview CAI Architecture
- CAI Prototype
- Conceptual CAI Architecture

❒ Summary

❒ What's Next

- Motivation-

Chronology of Measurement Requirements



(1991) PPD – QA Preferred Process Definition and Conceptual Design

(1992) DMIS Functional Test

(1997-'98) Product Definition Quality & Productivity QCNC project: team with Dassault and Brown&Sharpe

BOEING

- 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% 3rd Party
- **Operation Software:** (Control, UI, Results Computation/Analysis, Operator Tools)
  - 62% CMM Vendor System (VAX/VMS hosted)
  - 18% 3rd Party Proprietary Language
  - 20% 3rd Party DMIS

- Motivation -

CAI Dimensional Inspection Devices

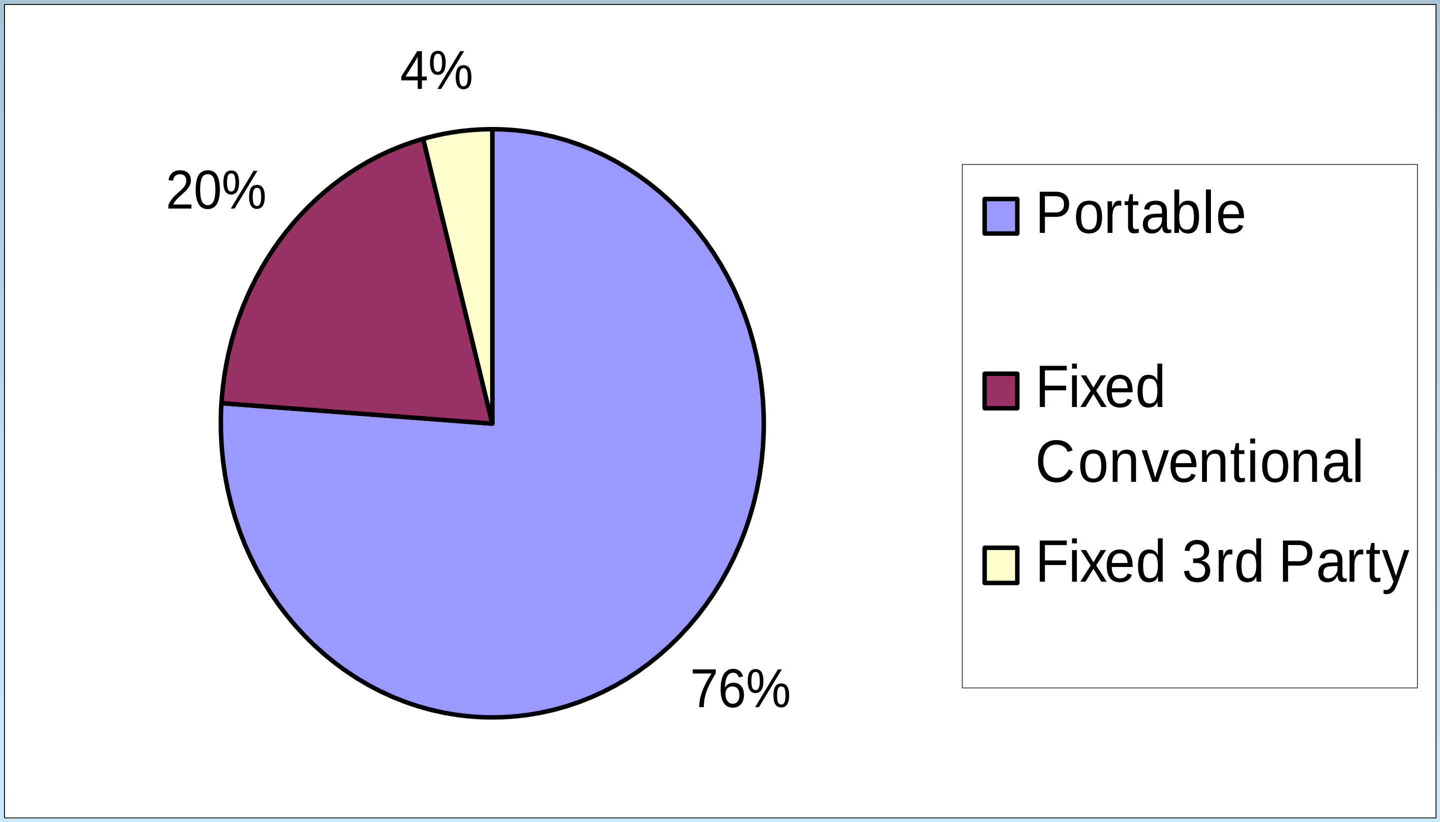
❒ 144+ Portable Inspection Devices (BCAG NW)

- **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-

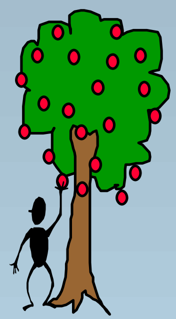
CAI Dimensional Inspection Devices

❒ **Fixed –vs- Portable**



- Motivation-
Business Strategies

❒ **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.

- Motivation-

What We Know!

- ❒ **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*

- VISION -

Direction Statement

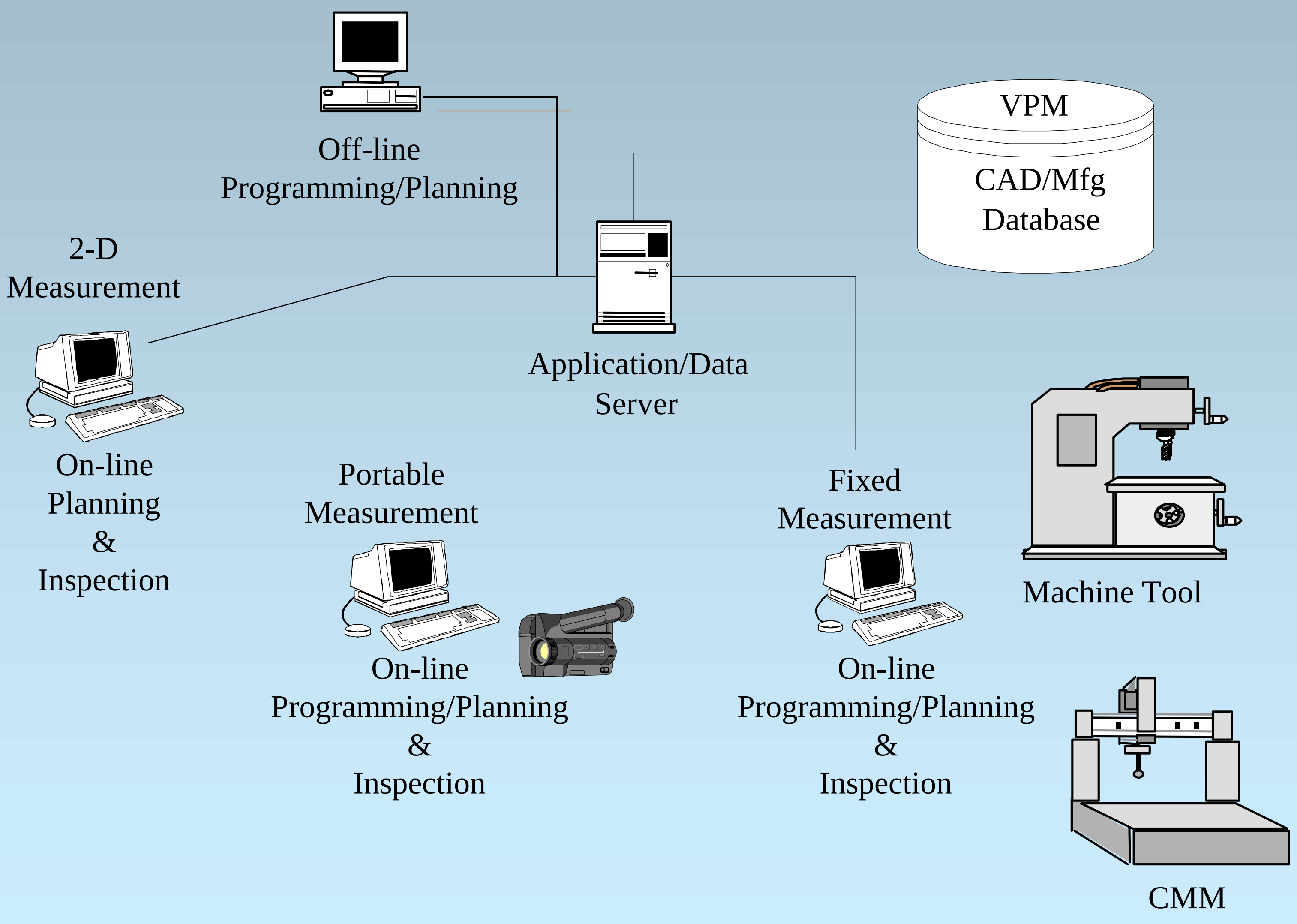
To Standardize on a **Single *Holistic* Measurement Solution.**

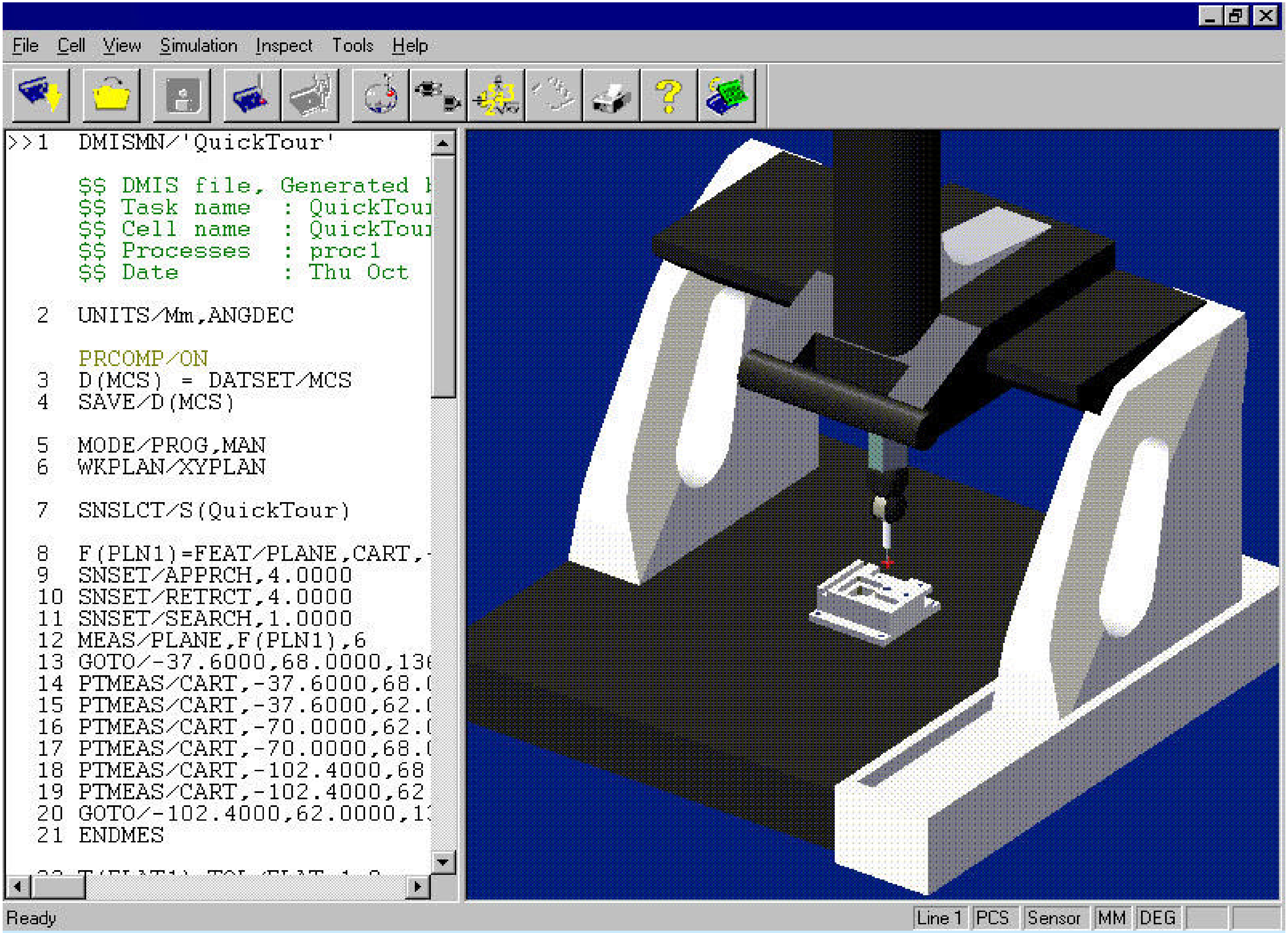
Holistic:

Emphasizing the importance of the whole and the interdependence of the parts.

- *VISION* -

Overview CAI Architecture

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5 MODE/PROG,MAN
6 WKPLAN/XYPLAN
7 SNSLCT/S(QuickTour)
8 F(PLN1)=FEAT/PLANE,CART,-
9 SNSET/APPRCH,4.0000
10 SNSET/RETRCT,4.0000
11 SNSET/SEARCH,1.0000
12 MEAS/PLANE,F(PLN1),6
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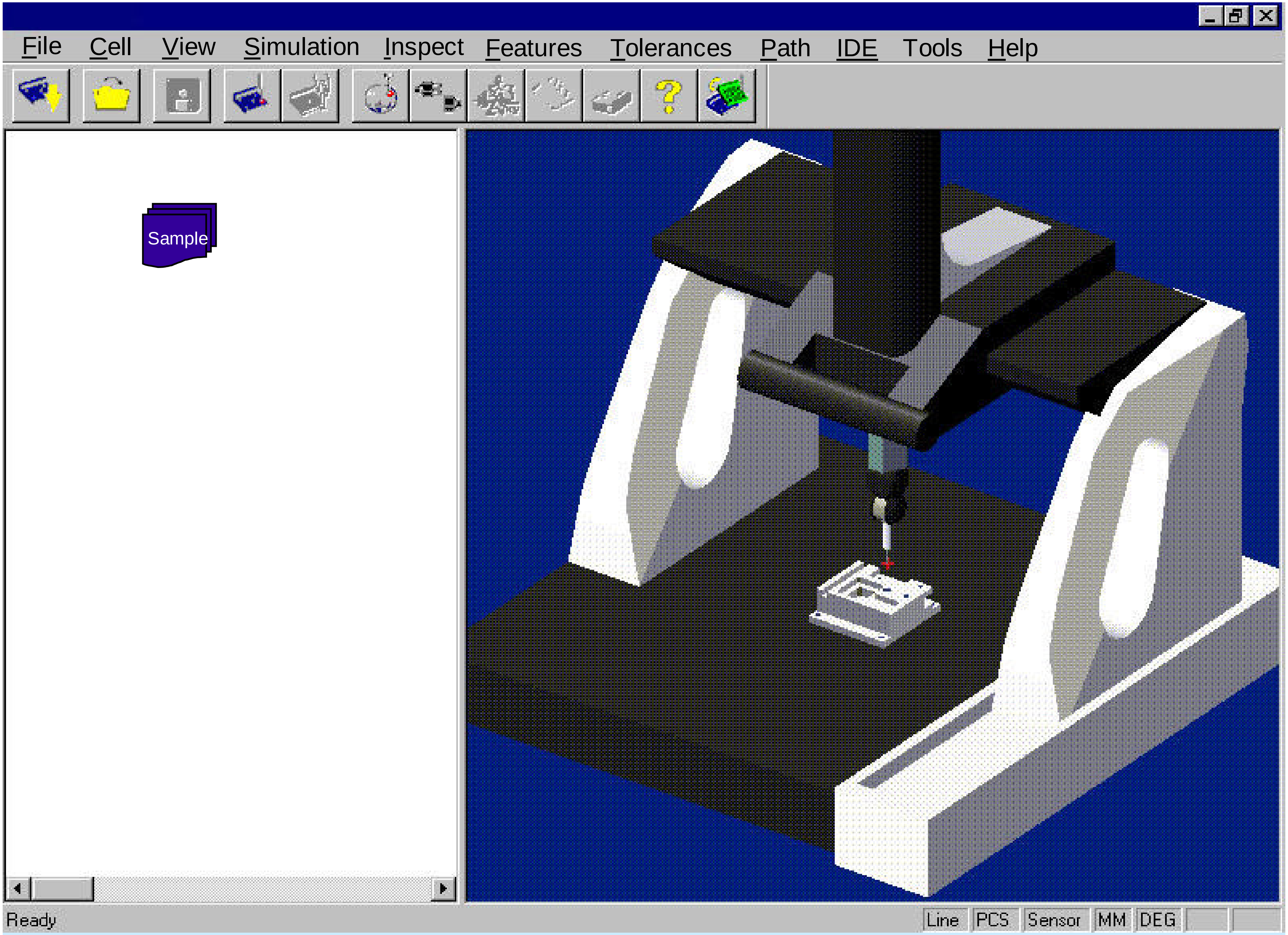
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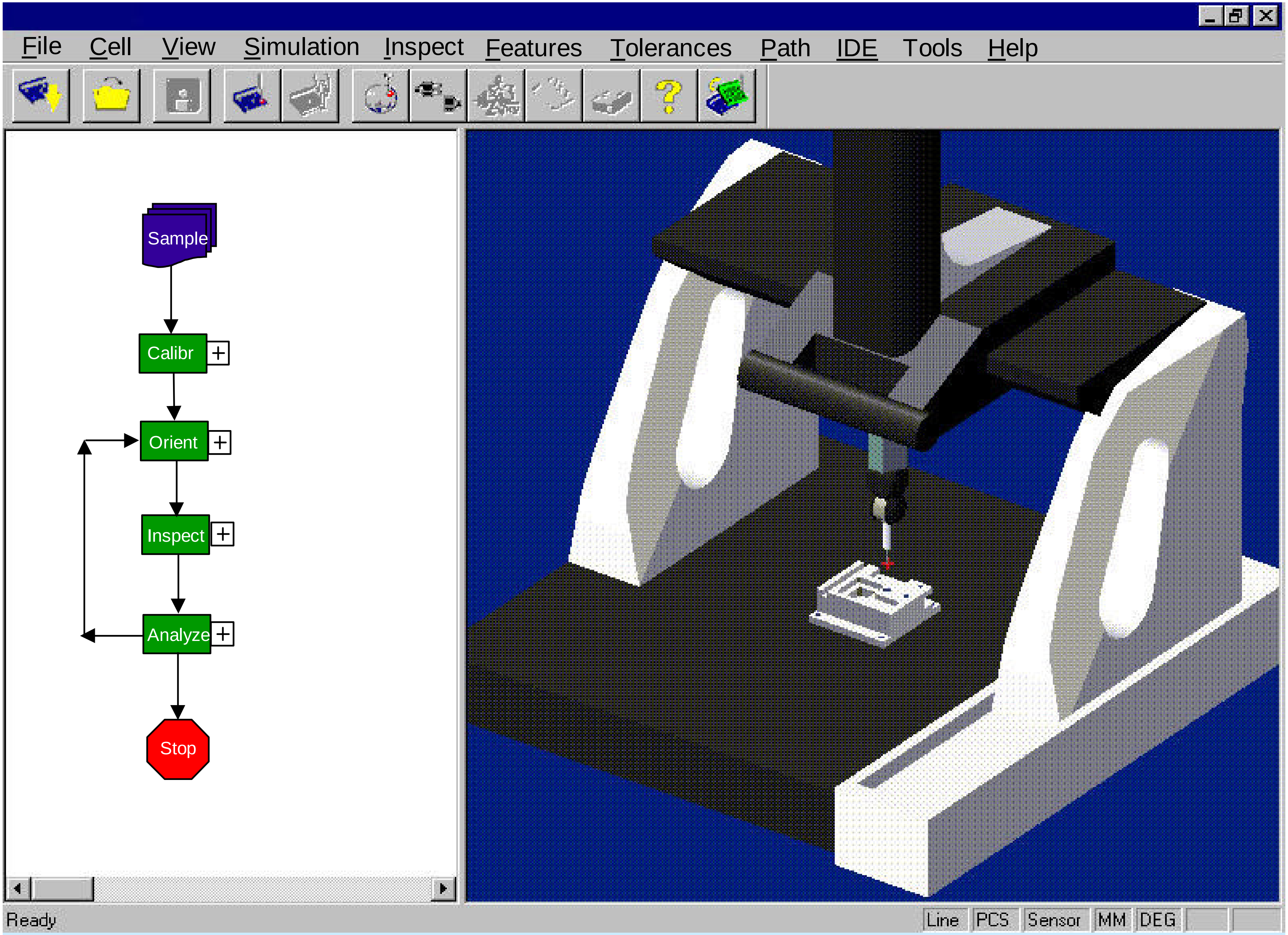
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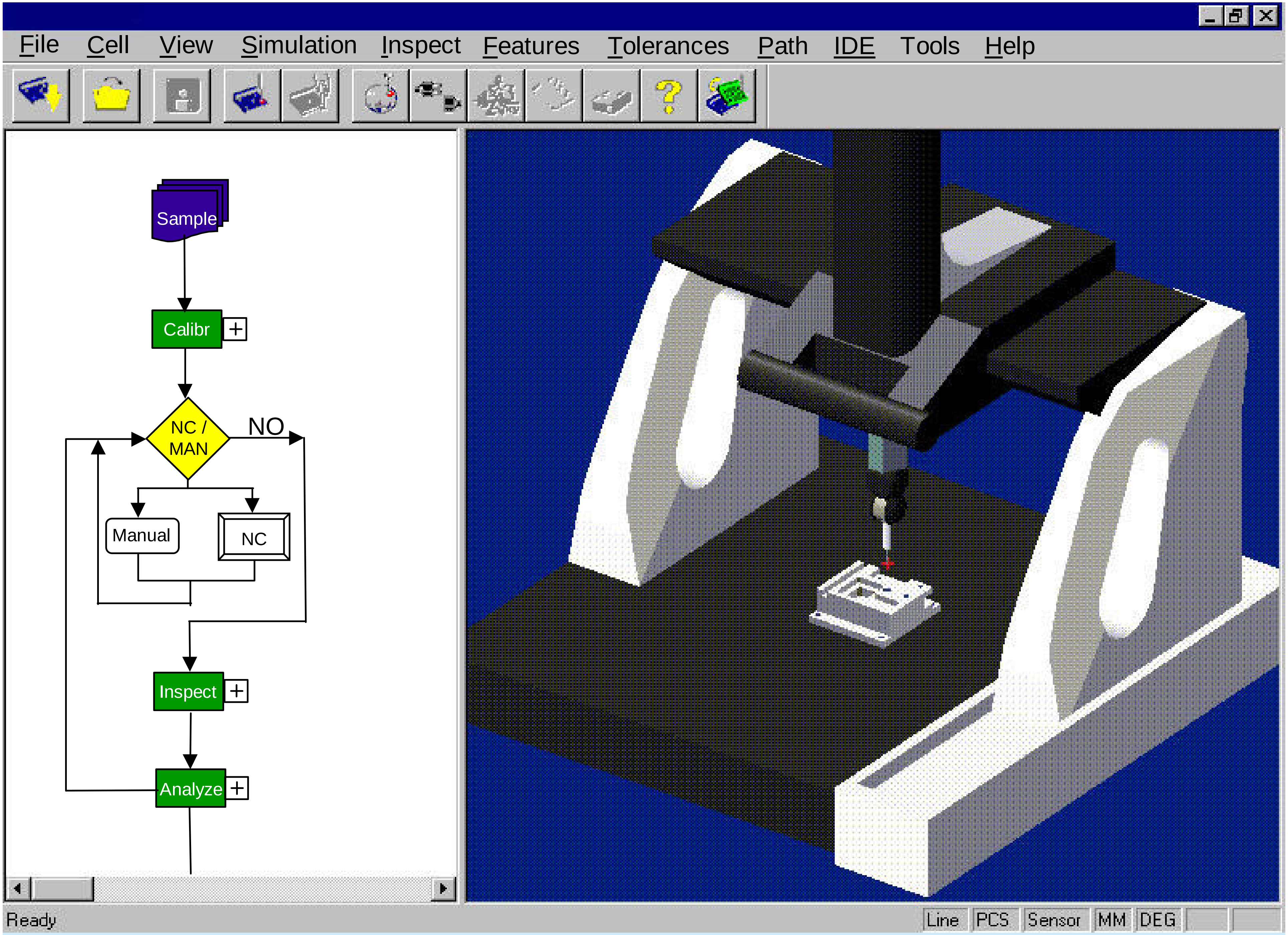
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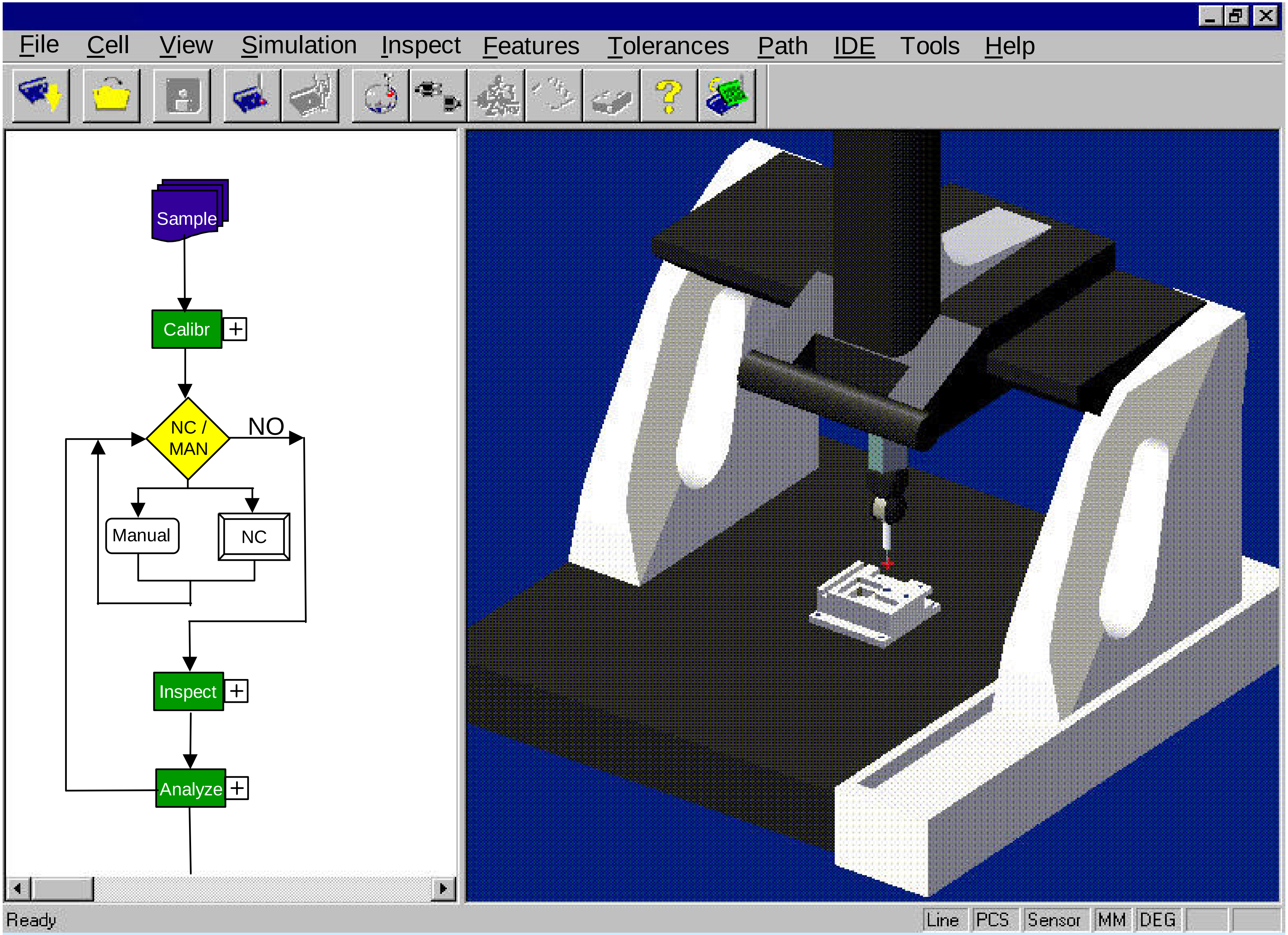
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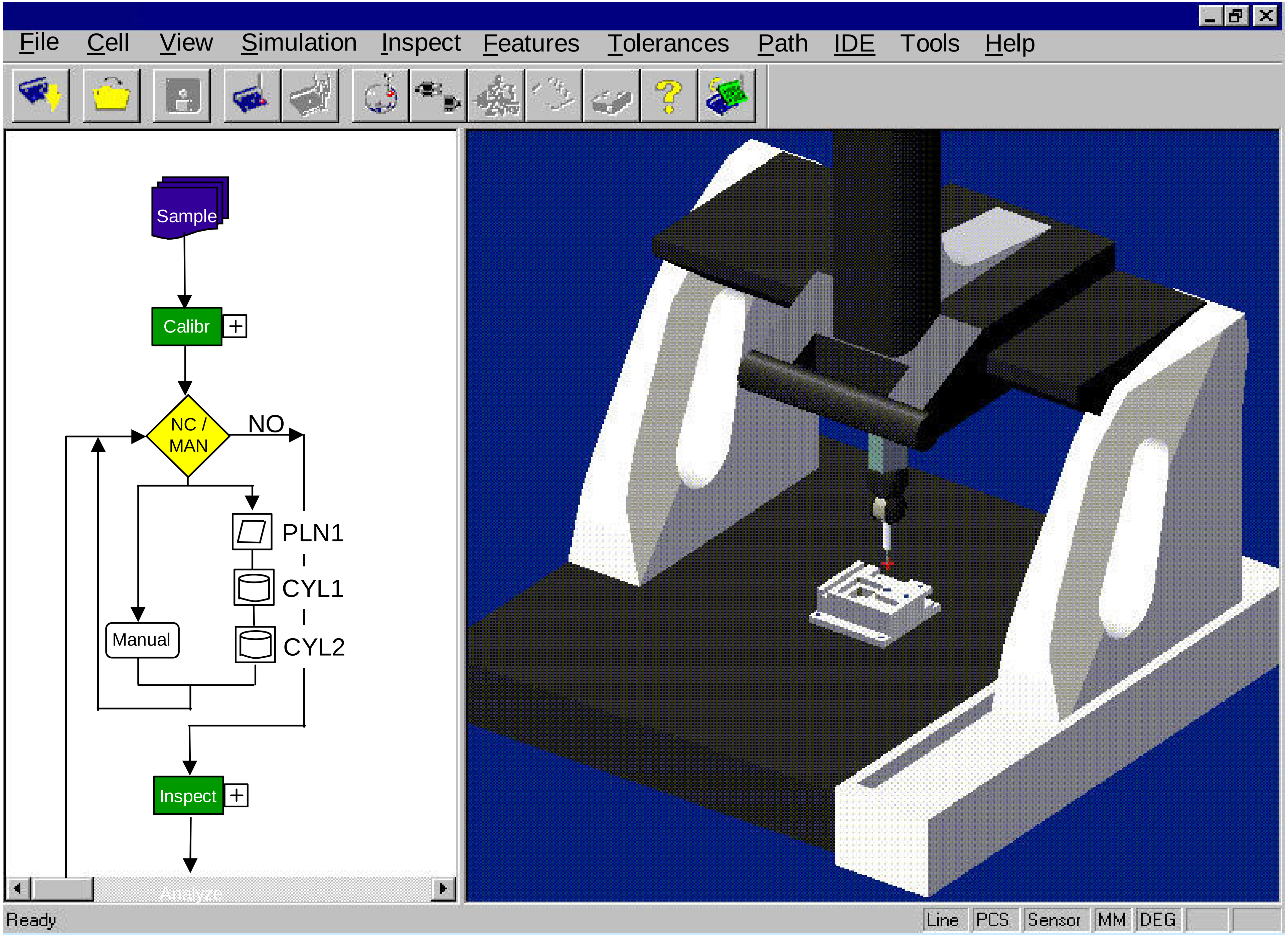
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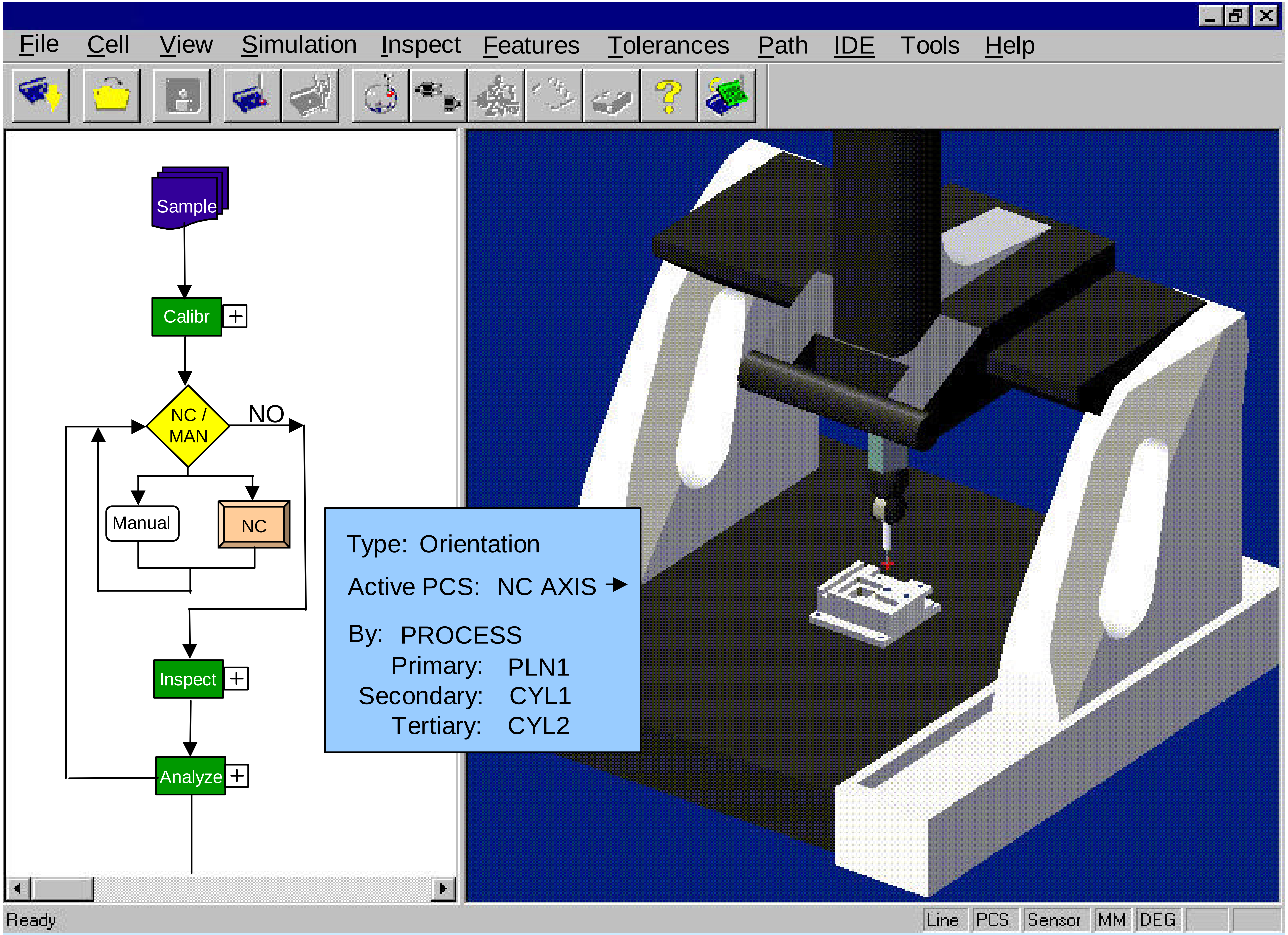
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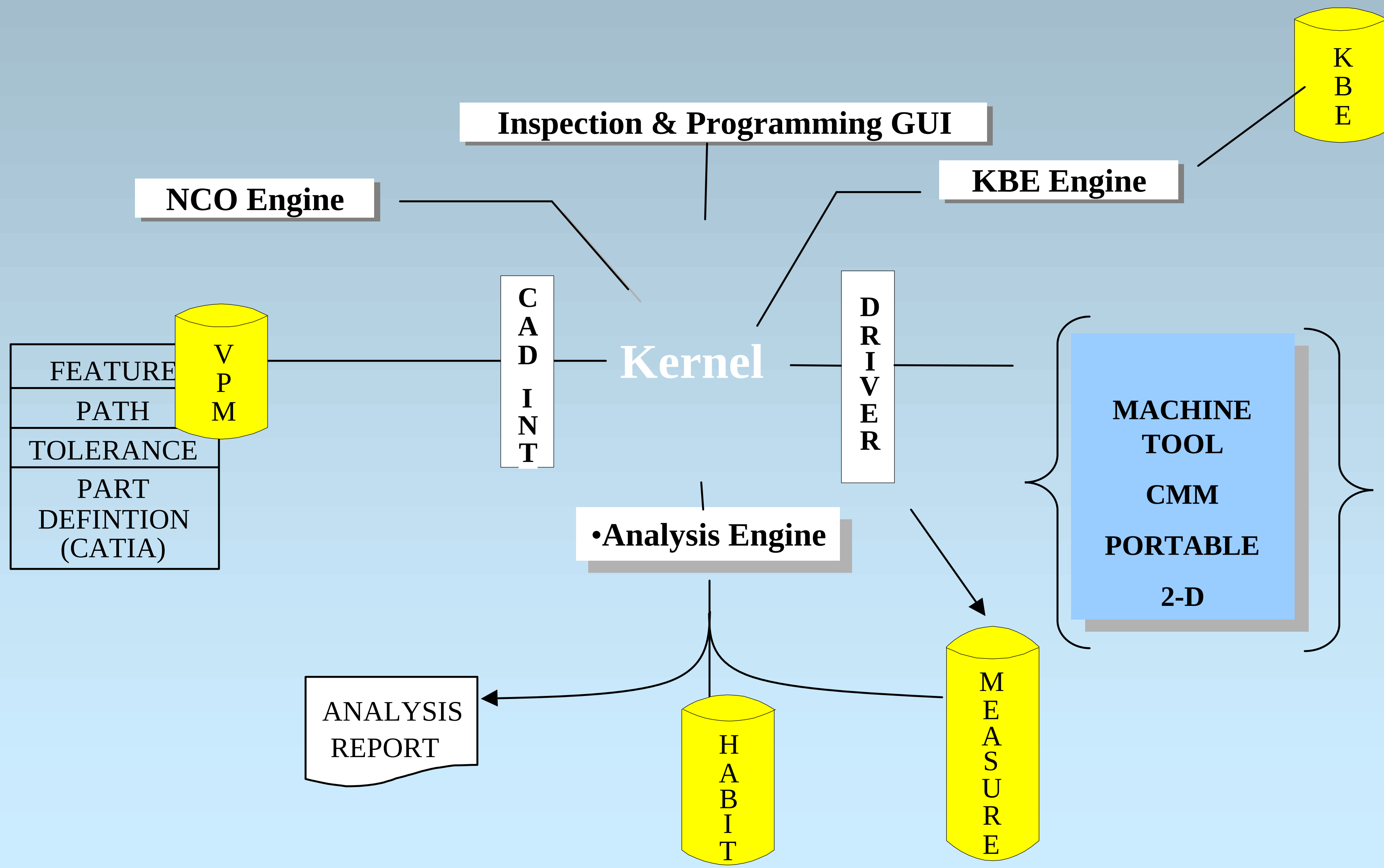
-VISION-

Conceptual CAI Architecture



- Summary-

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-

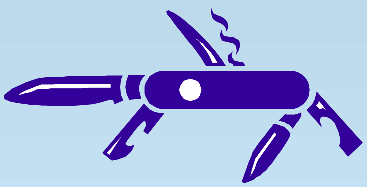
❒ **Supplier Awareness**

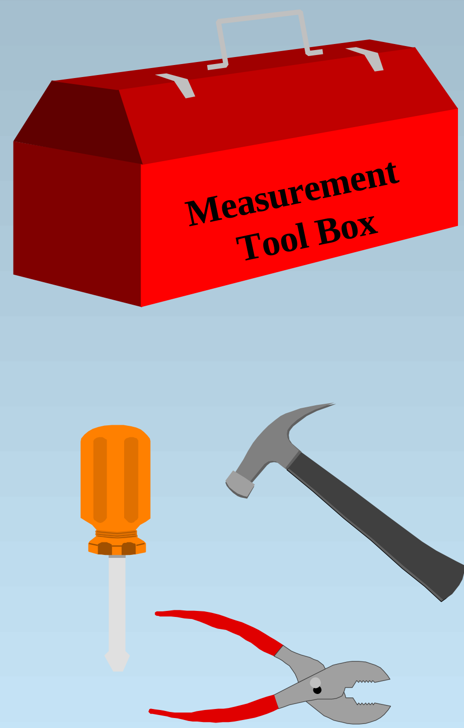
❒ **Continue to Participate in NIST STEP AP219 Development**

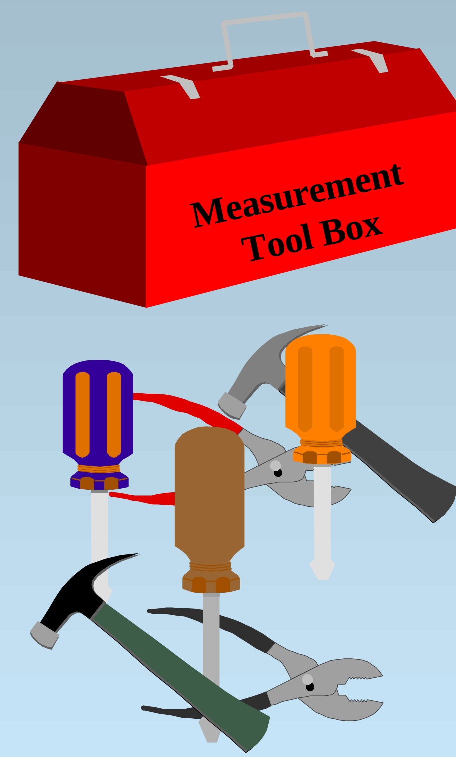
❒ **FCA defined Product Direction Statements for Metrology Systems**

- COMMON TOOLS -

CAI Tool Selection







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

Kam C. Lau, Ph.D.

President

Automated Precision, Inc.

Gaithersburg, MD

301-330-8100

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

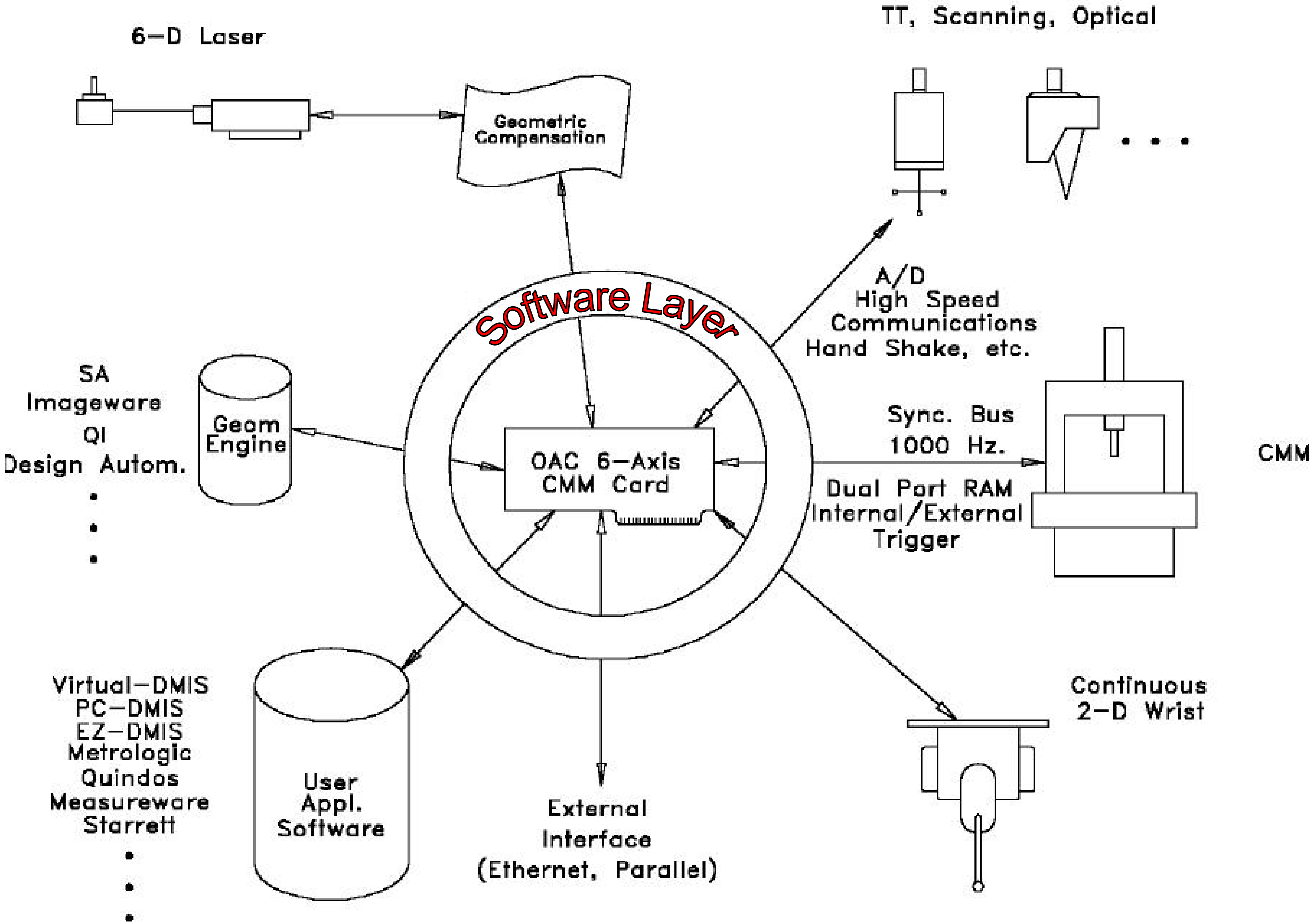
Tracker II (cont’d)

- 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

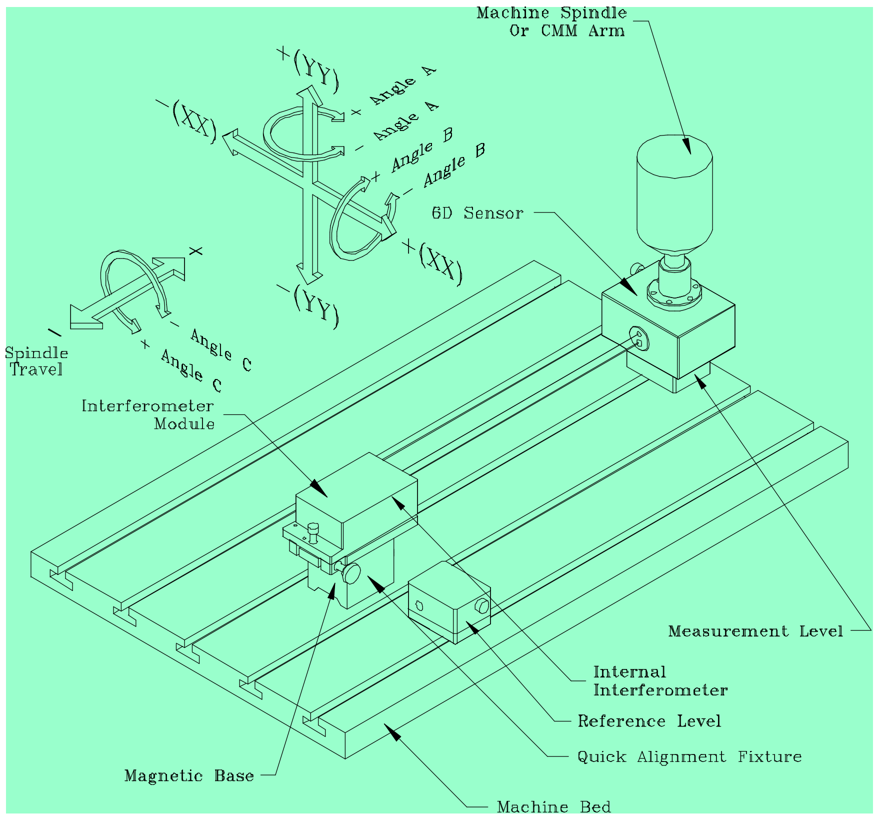
API Open Architecture CMM Controller



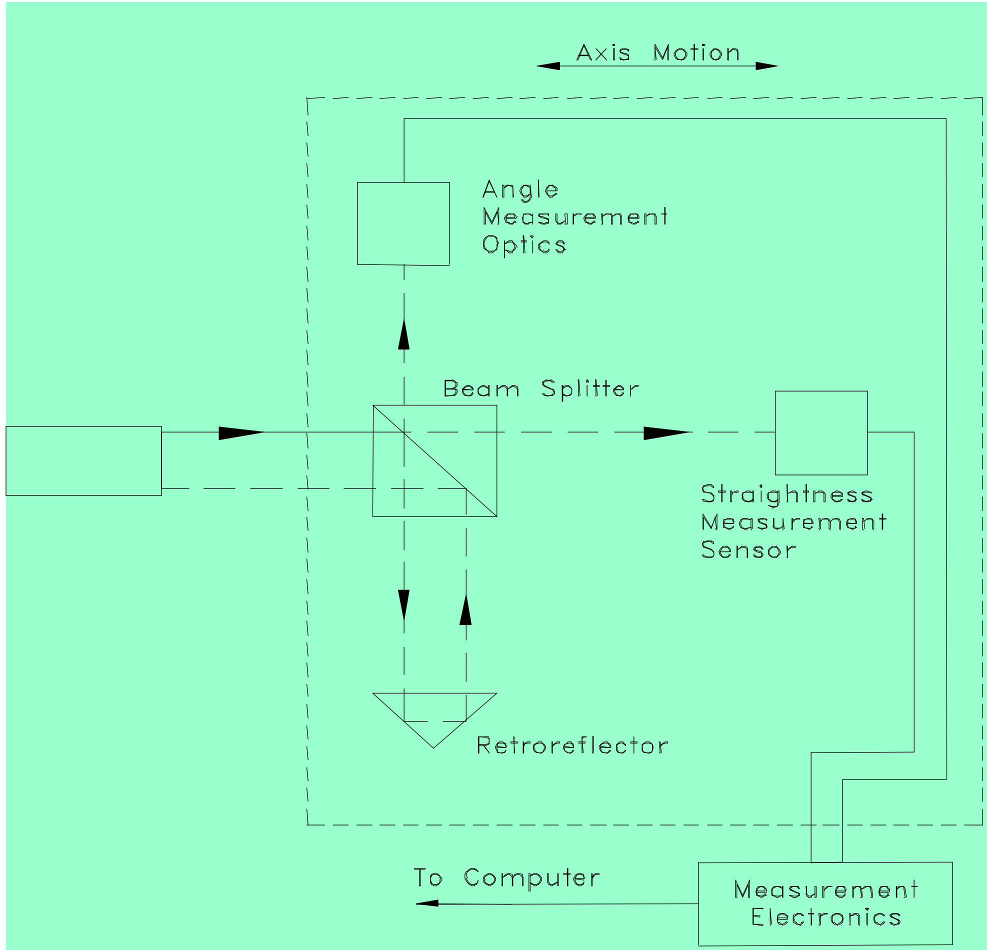
CMM Error Mapping and Compensation

- 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)

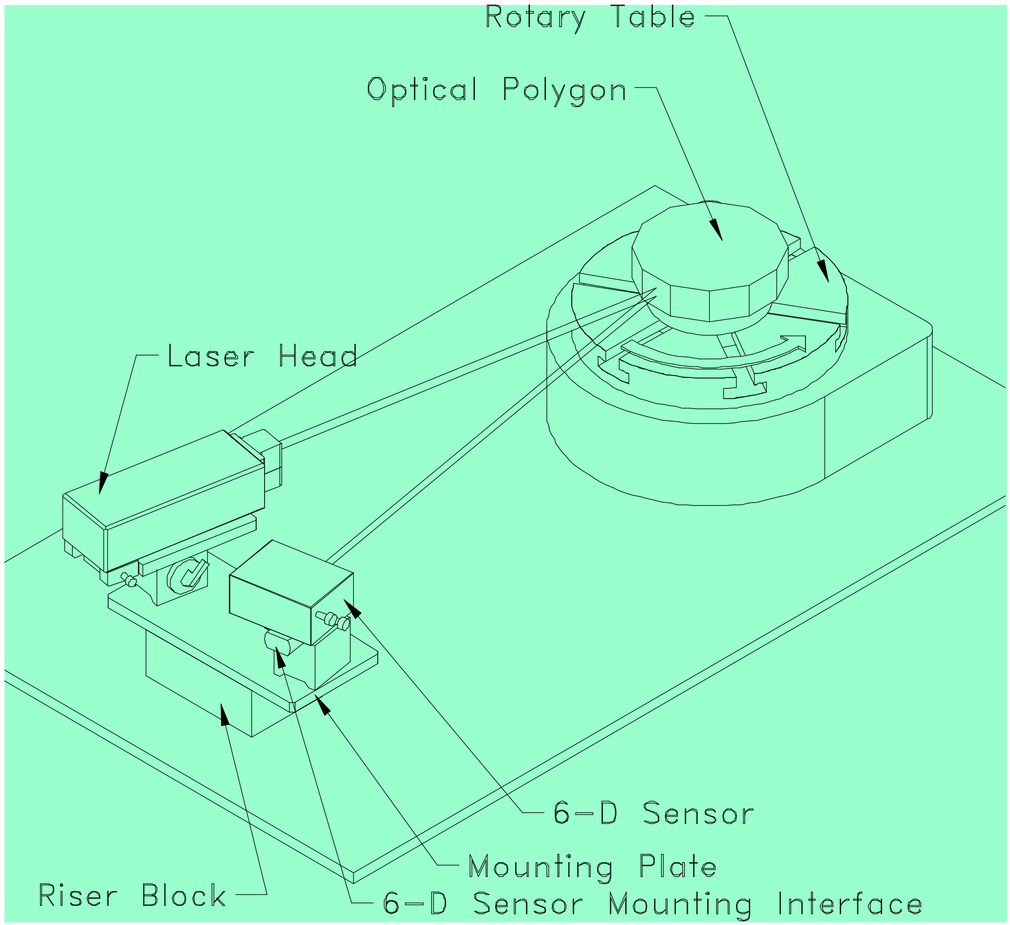
API 6-D Laser System for CMM Geometric Error Mapping and Compensation



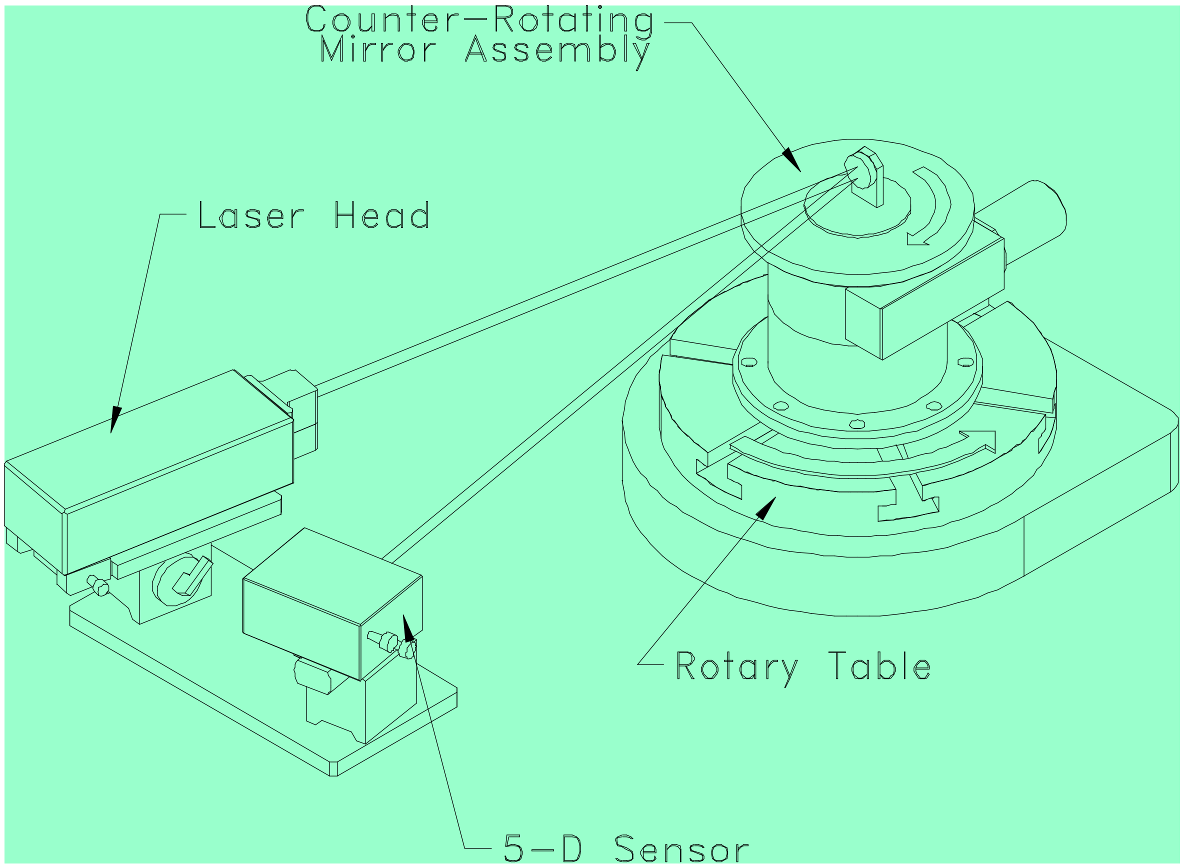
High-Precision 6-D Laser with Fiber-Guided Remote Laser Head



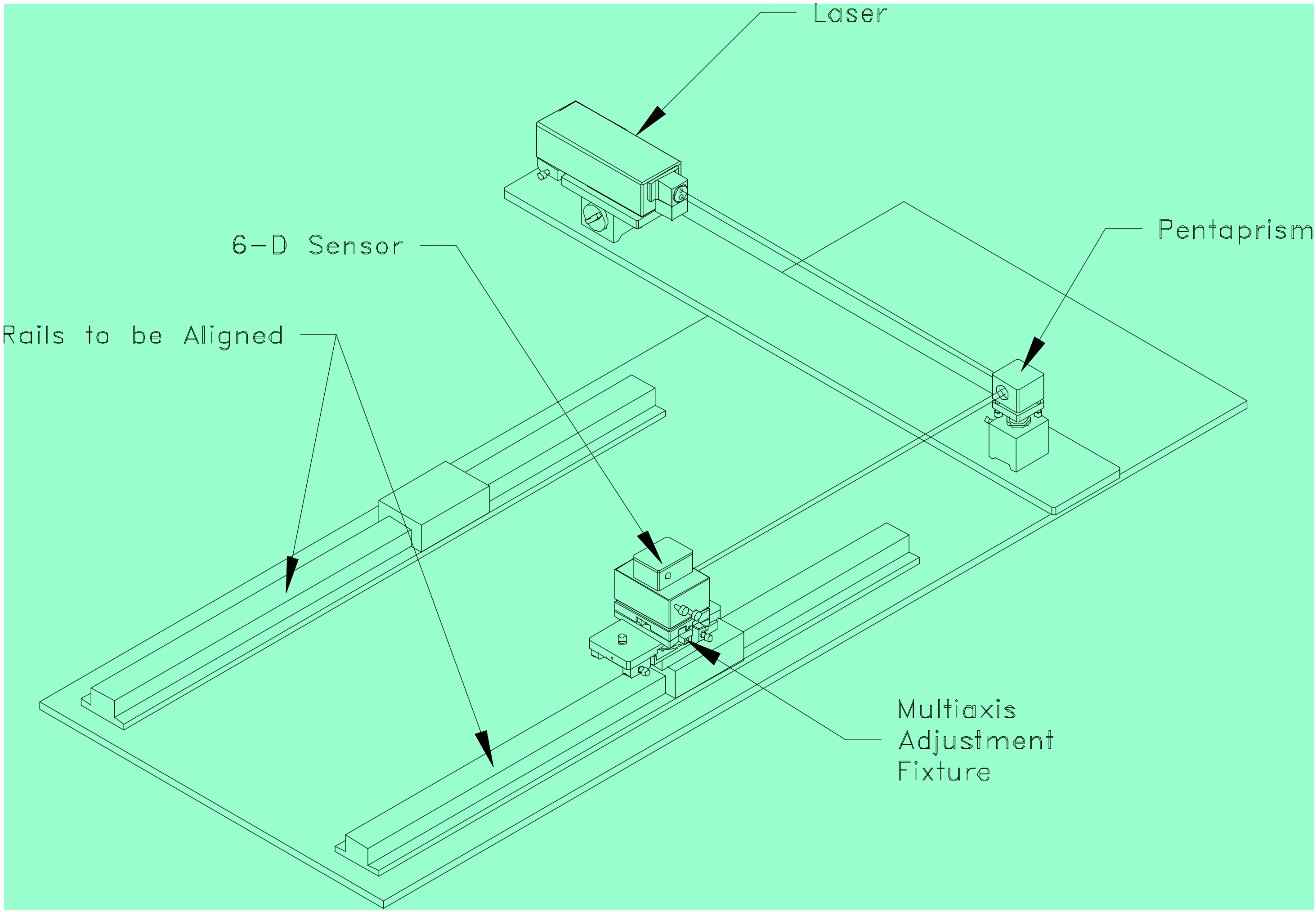
Principle of the API 5/6-D Laser Measuring System



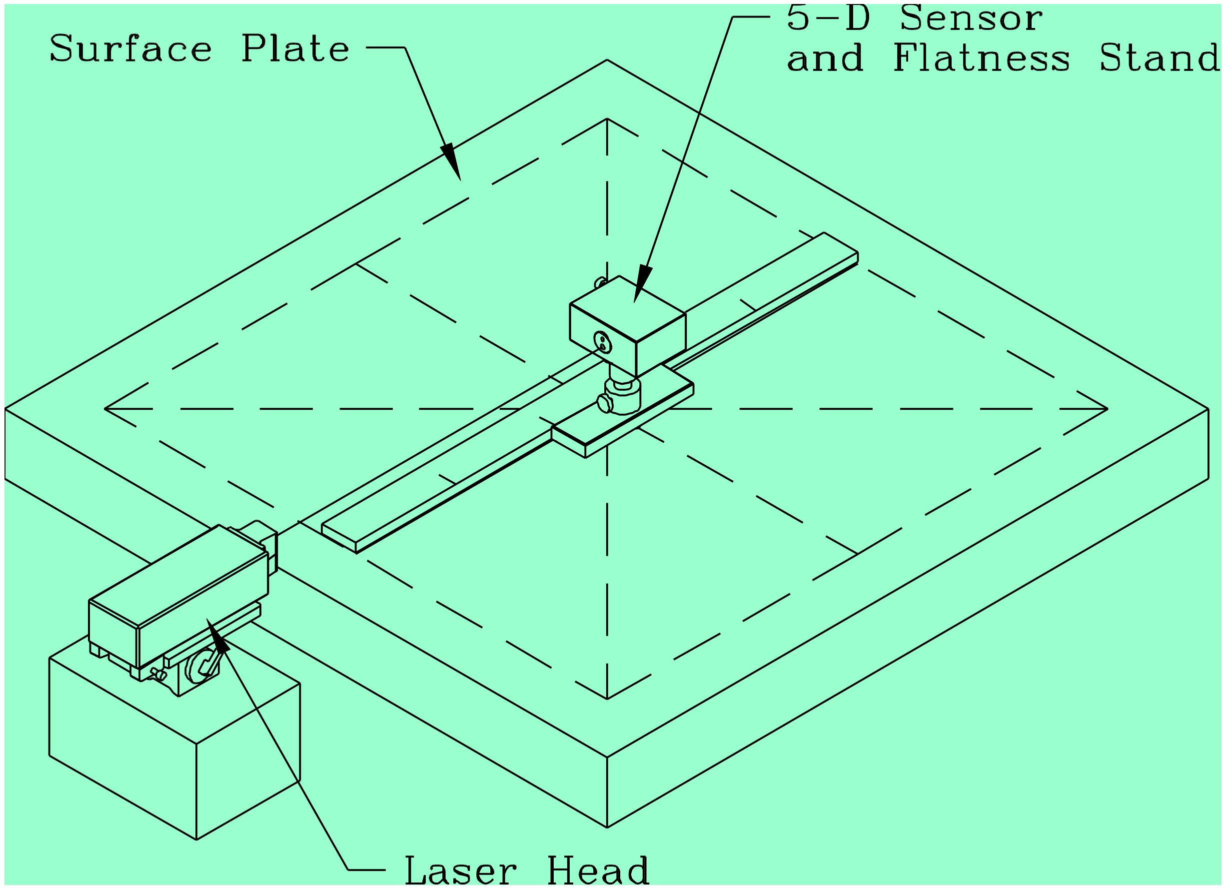
Rotary Table Measurement with 5/6-D Laser and Polygon



Rotary Table Measurement with 5/6-D Laser

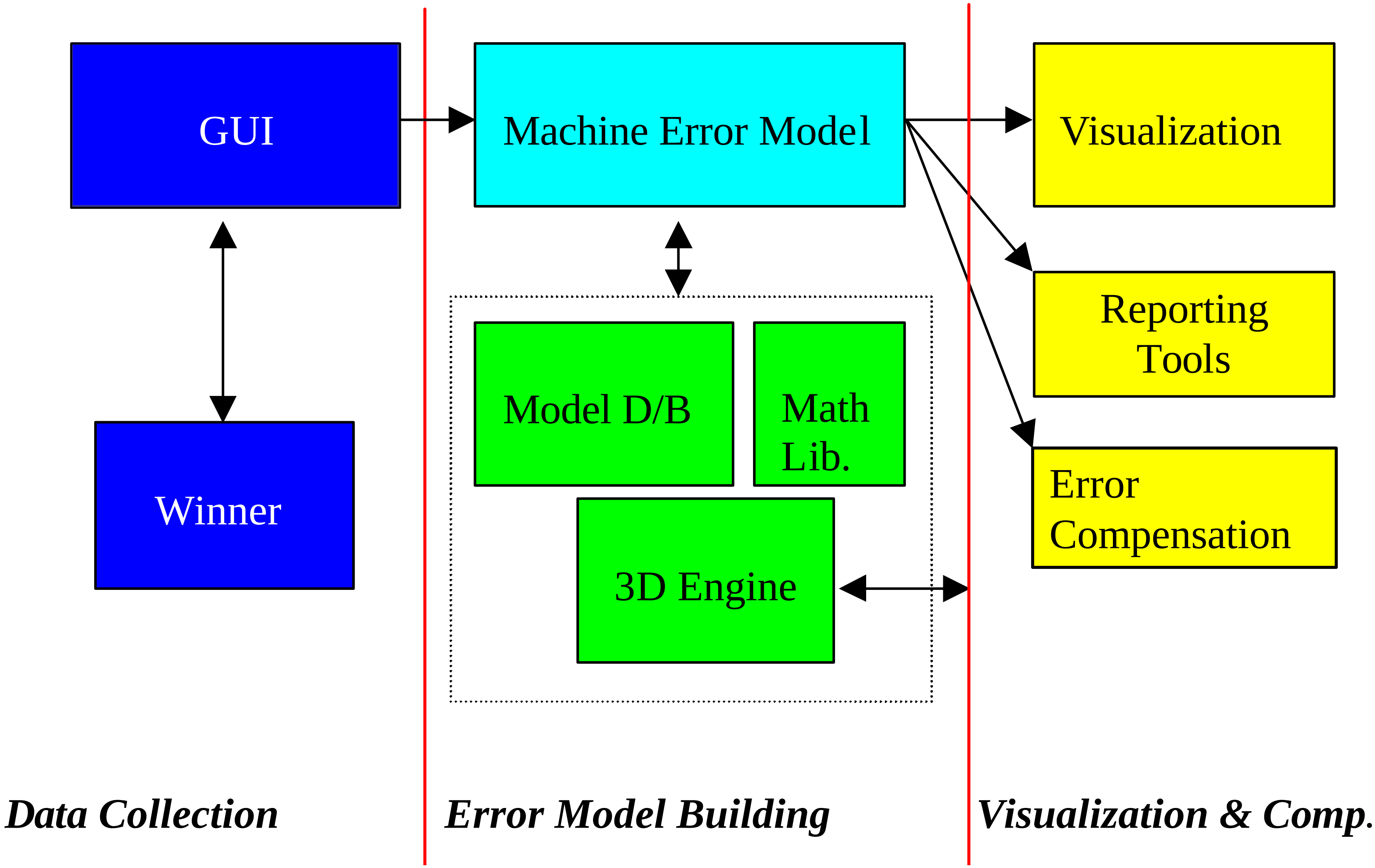


Parallelism Measurement with 6-D Laser



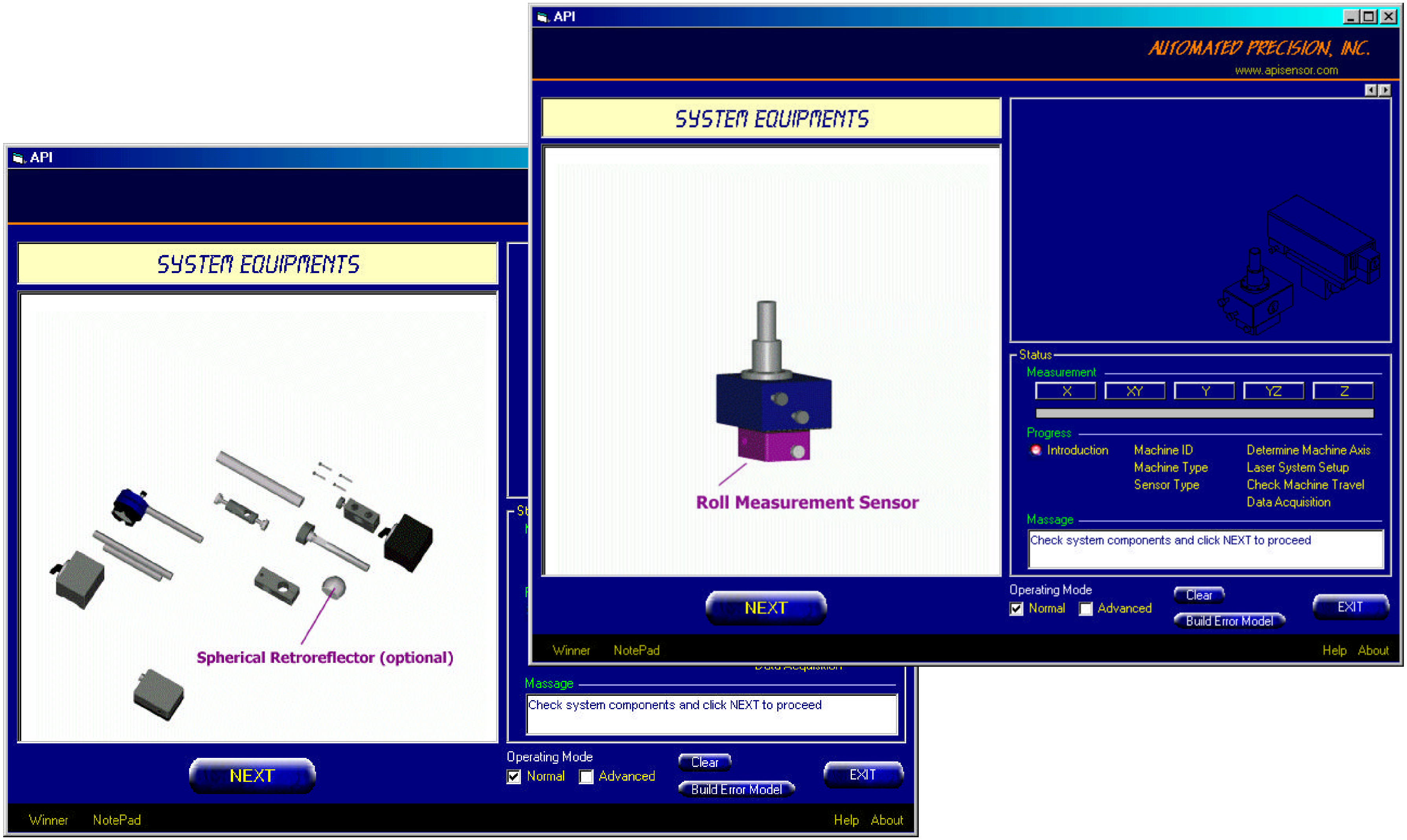
Flatness Measurement with 5/6-D Laser (Straightness)

API 5/6D Laser System for CMM Geometric Error Modeling



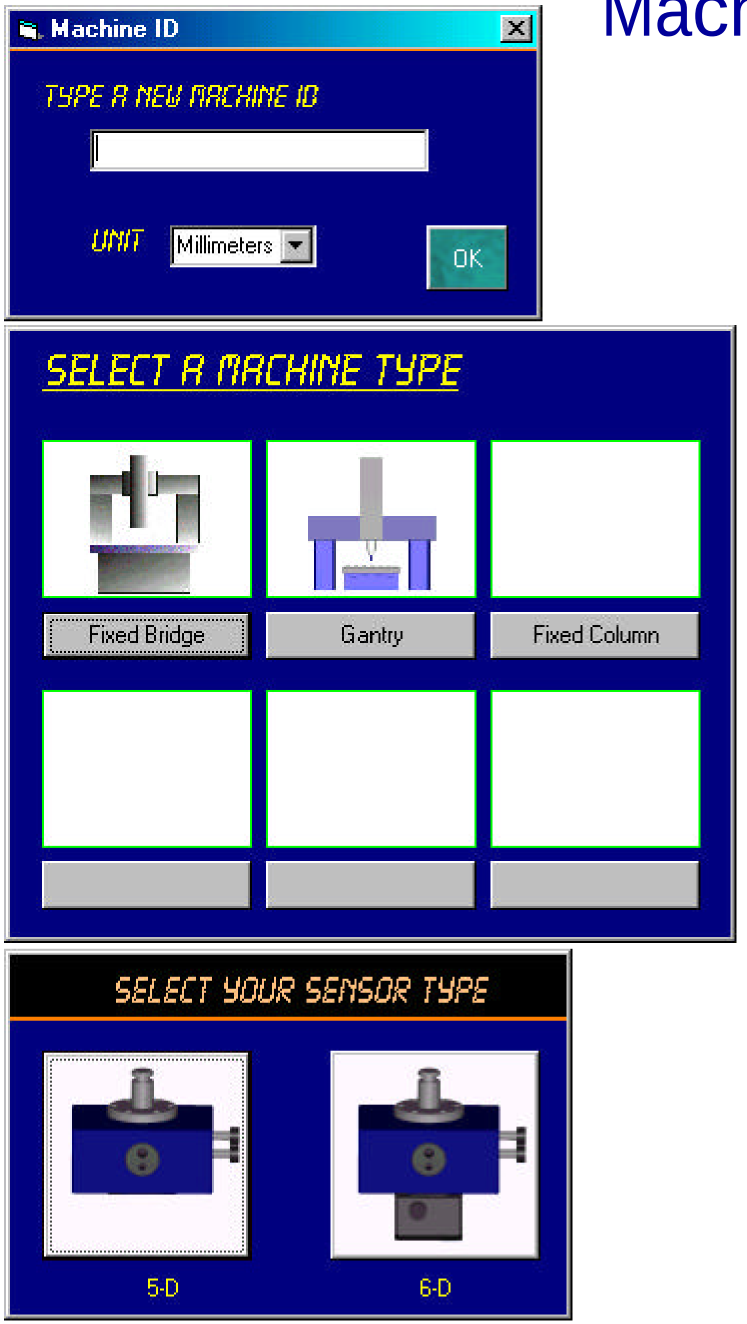
Machine Geometric Error Modeling

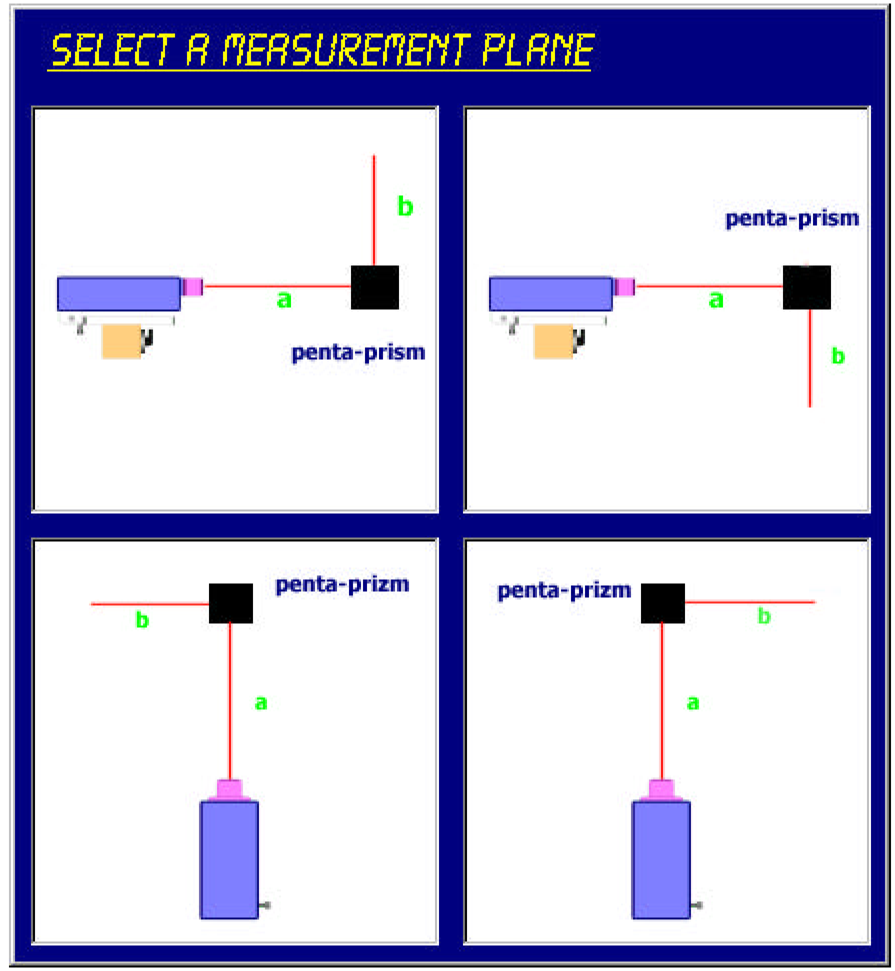
Data Collection (cont'd)



Machine Geometric Error Modeling

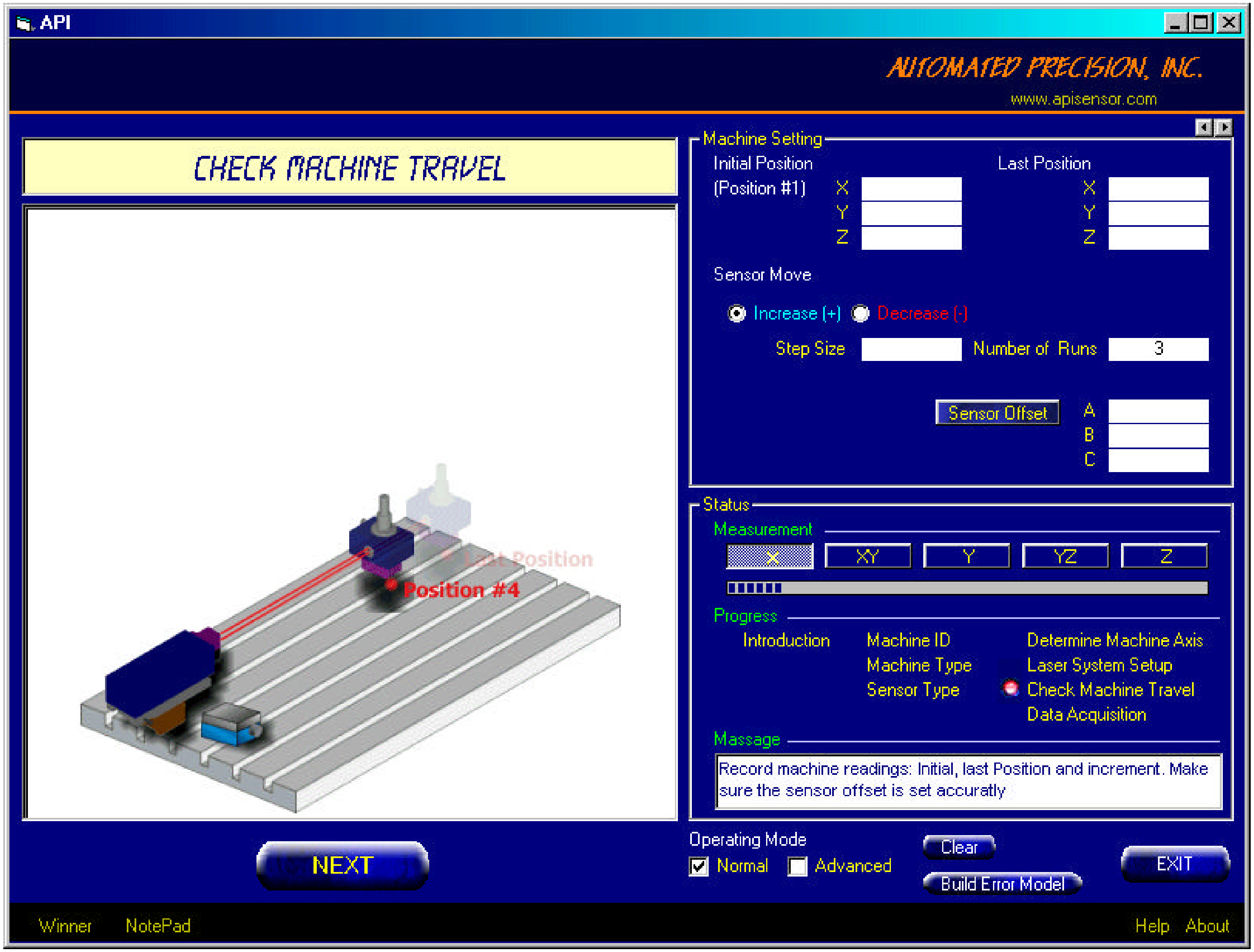
Data Collection (cont'd)

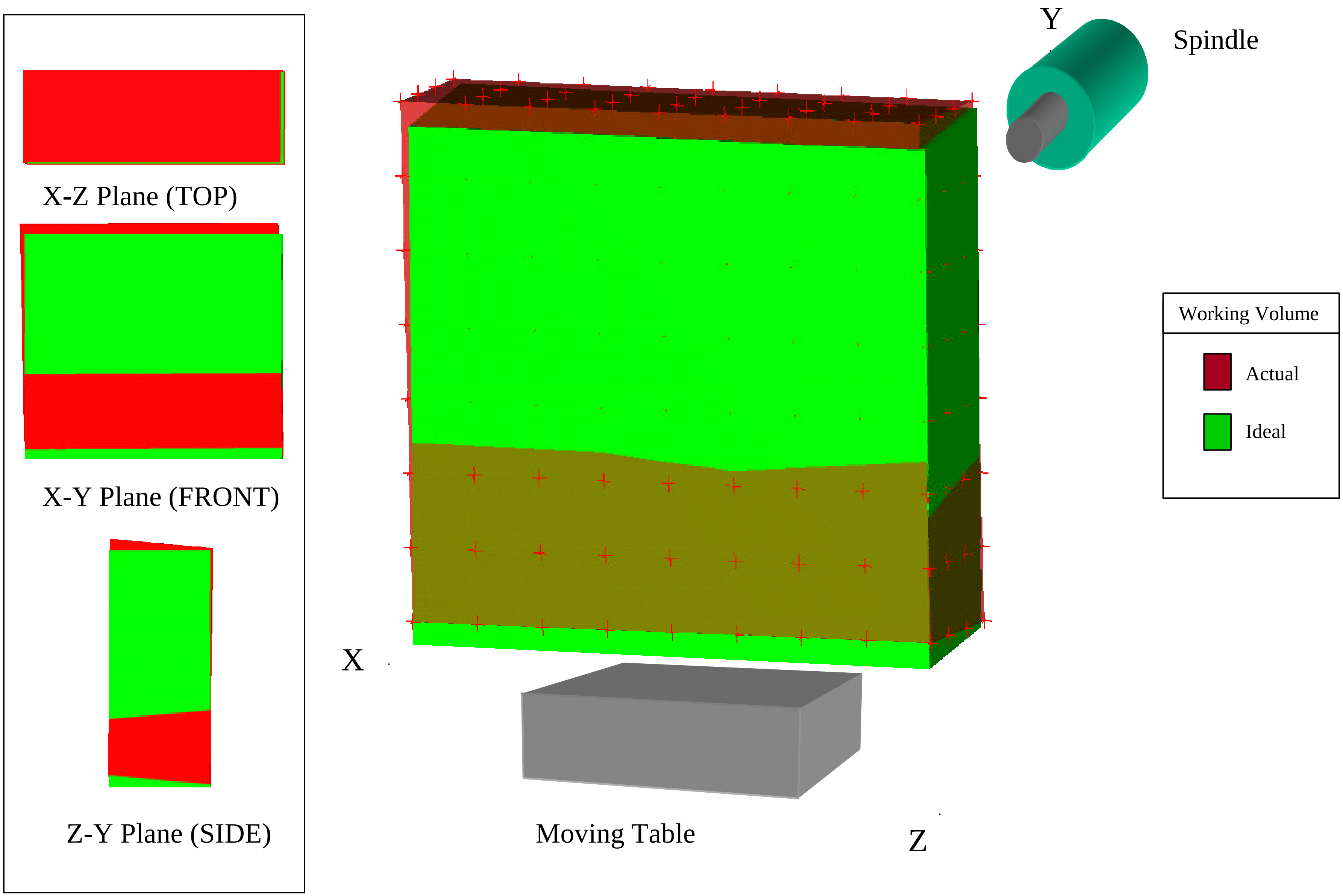




Machine Geometric Error Modeling

Data Collection (cont'd)



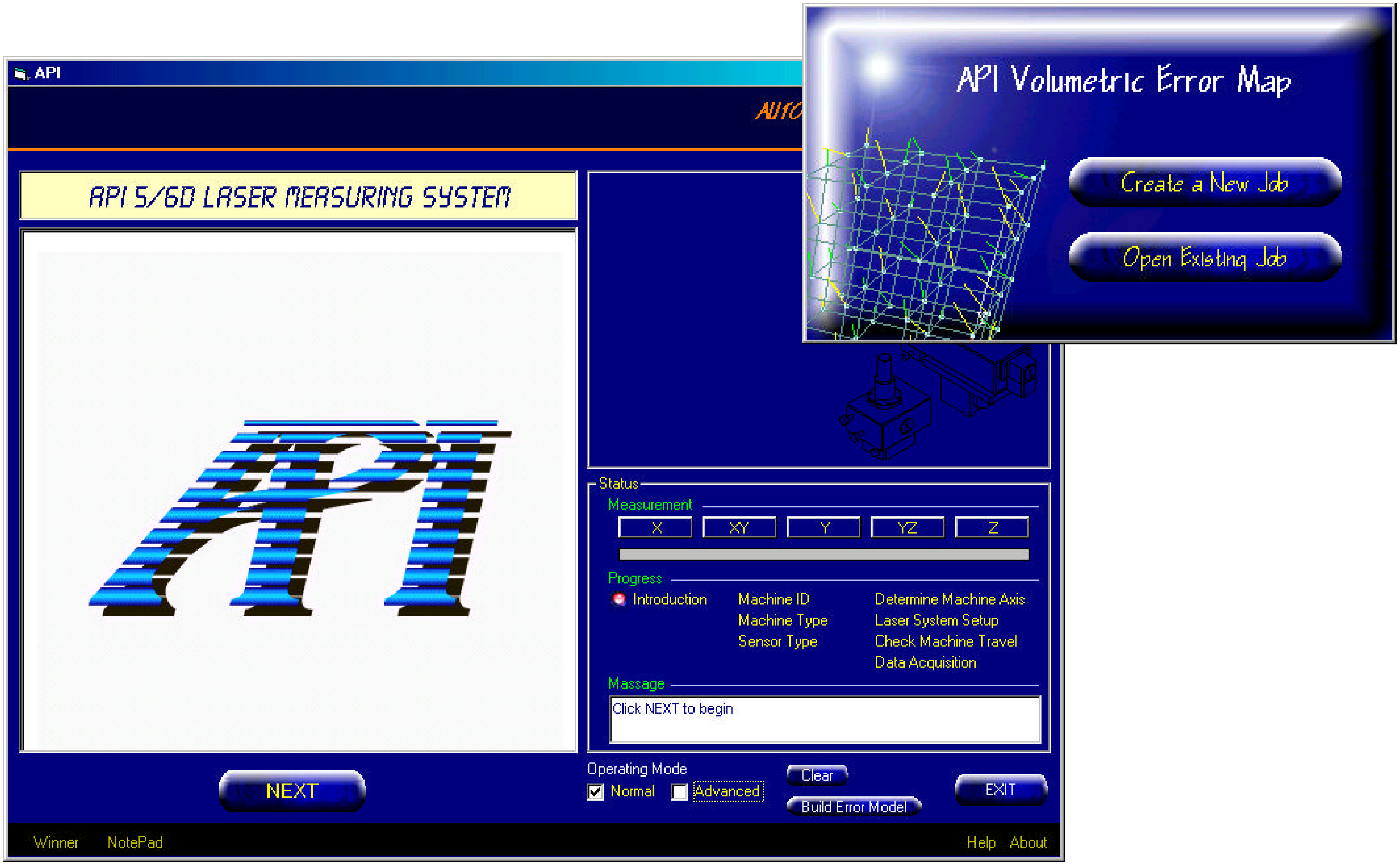


Note: Only geometric errors are shown in this figure, Errors are magnified by 100 times for the visual purpose.

RED: actual behavior of the machine, Green: a perfect working volume (assuming that the machine is perfect)

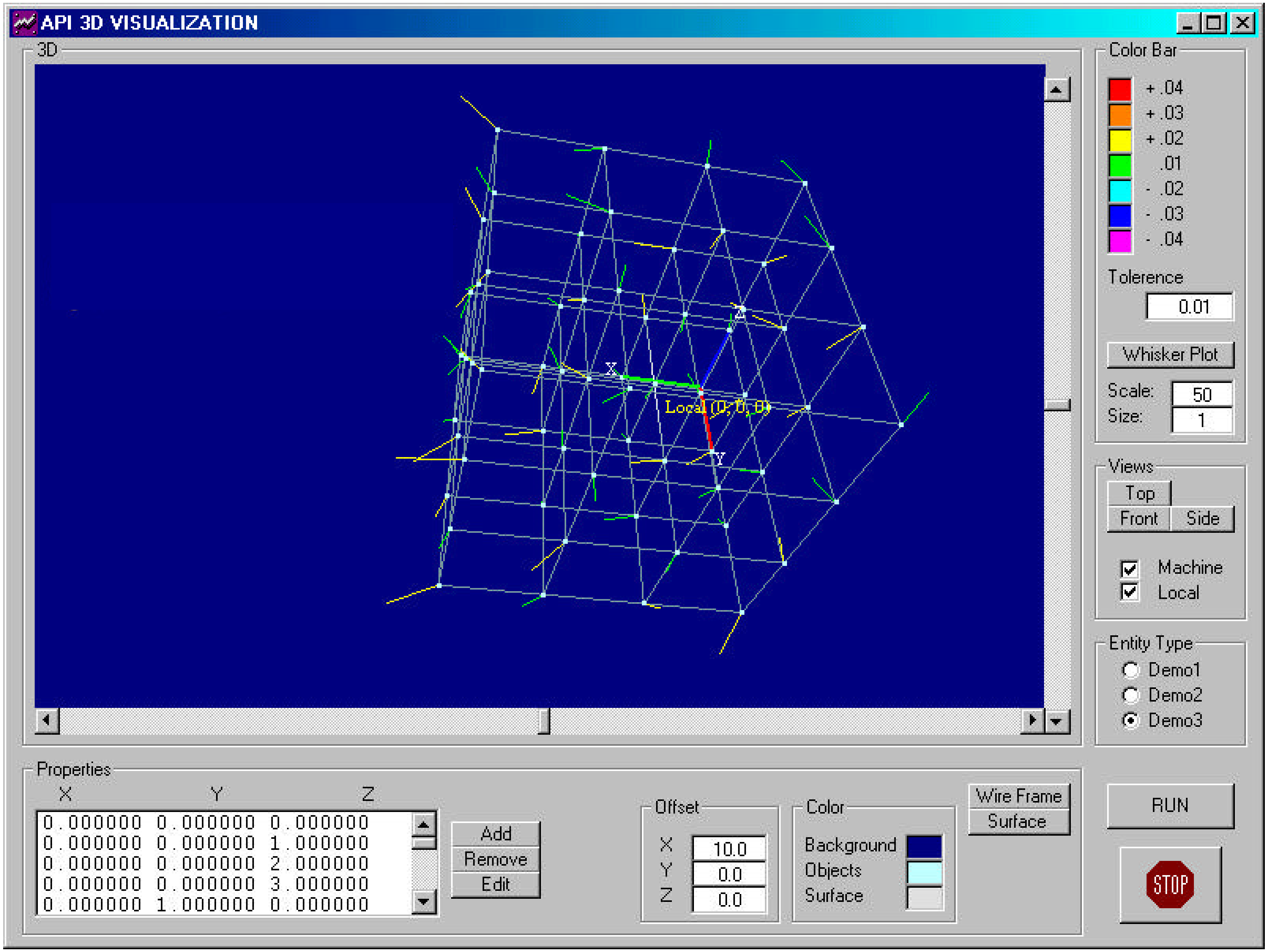
Machine Geometric Error Modeling

Data Collection



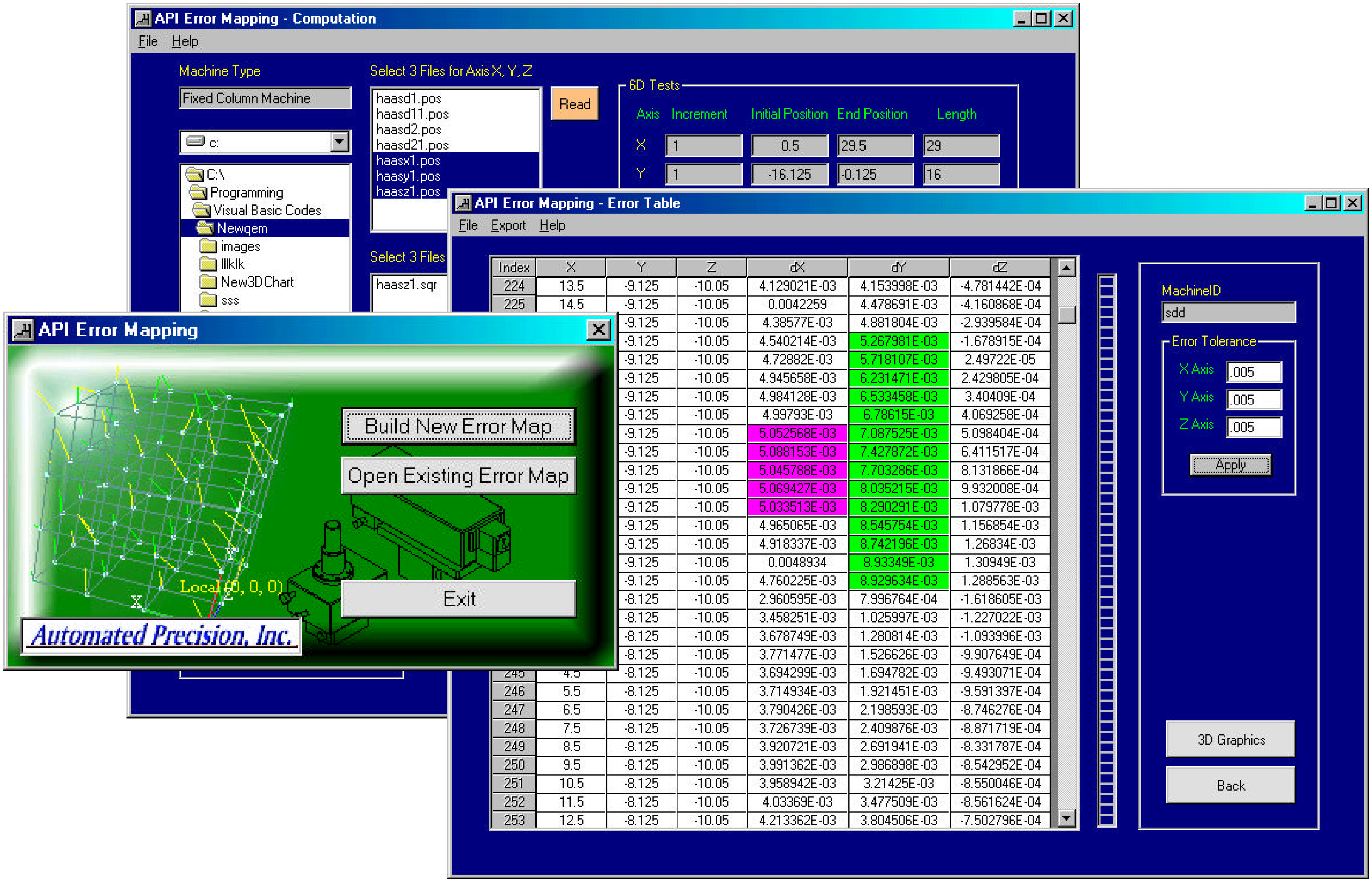
Machine Geometric Error Modeling

Visualization Interface

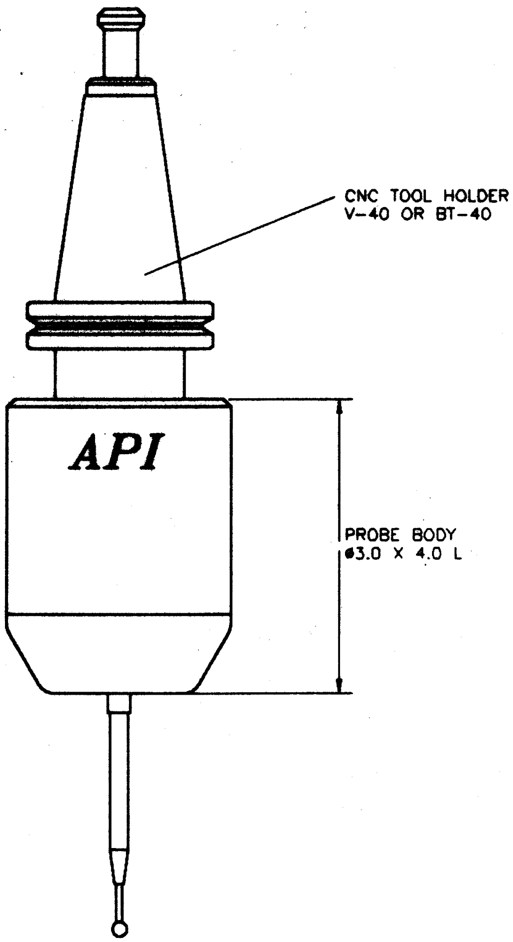


Machine Geometric Error Modeling

Error Model Building



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**

Leica

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)

Leica

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**

Leica

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

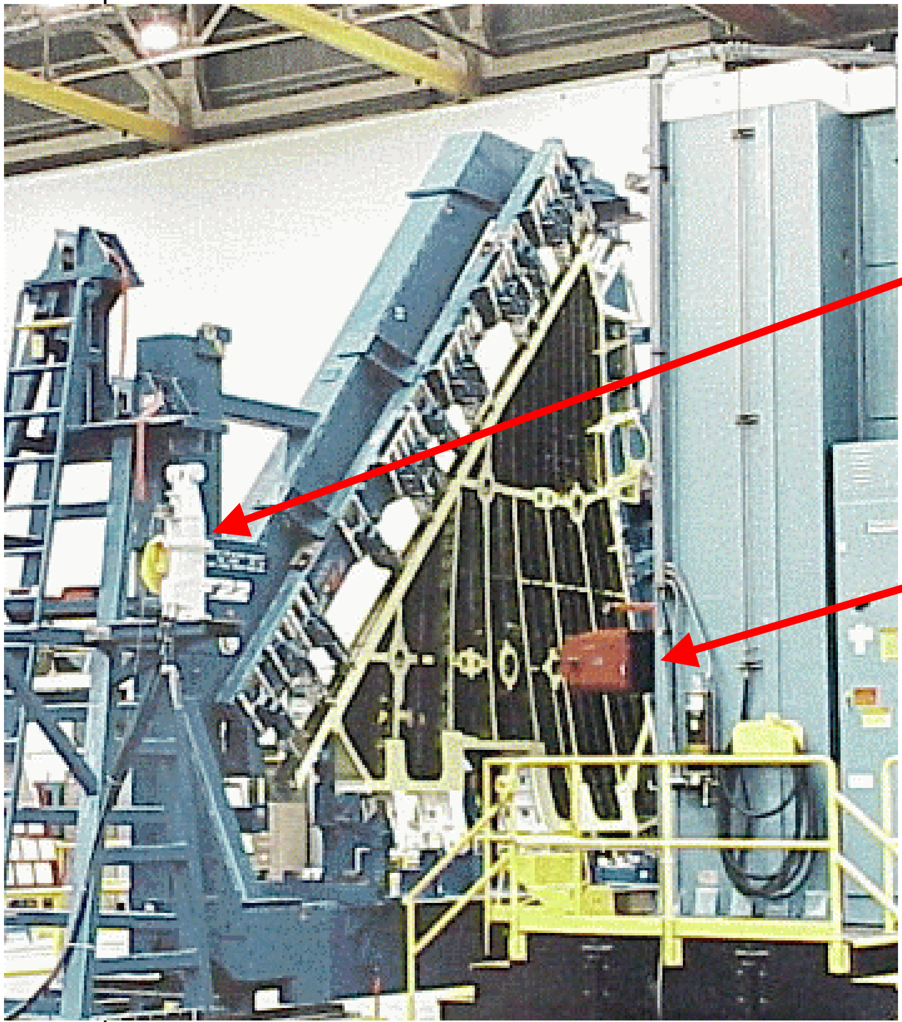
Leica

Existing Automation Applications

737 Wing To Body Assembly

- 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

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
Laser Trackers

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

SMX Laser Trackers

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

SMX Laser Trackers

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 Laser Trackers

SMX Hardware & 3rd Party Software

- 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

SMX
Laser Trackers

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

Open Architecture for Hardware

- 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

SMX Laser Trackers

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
Division of Adept Technology, Inc.

SILMA CimStation Inspection

- **Automate metrology planning**
- **Link between design and metrology**

Design (3D CAD) ⇔ **Planning** ⇔ **DME Execution**

SILMA CimStation Inspection

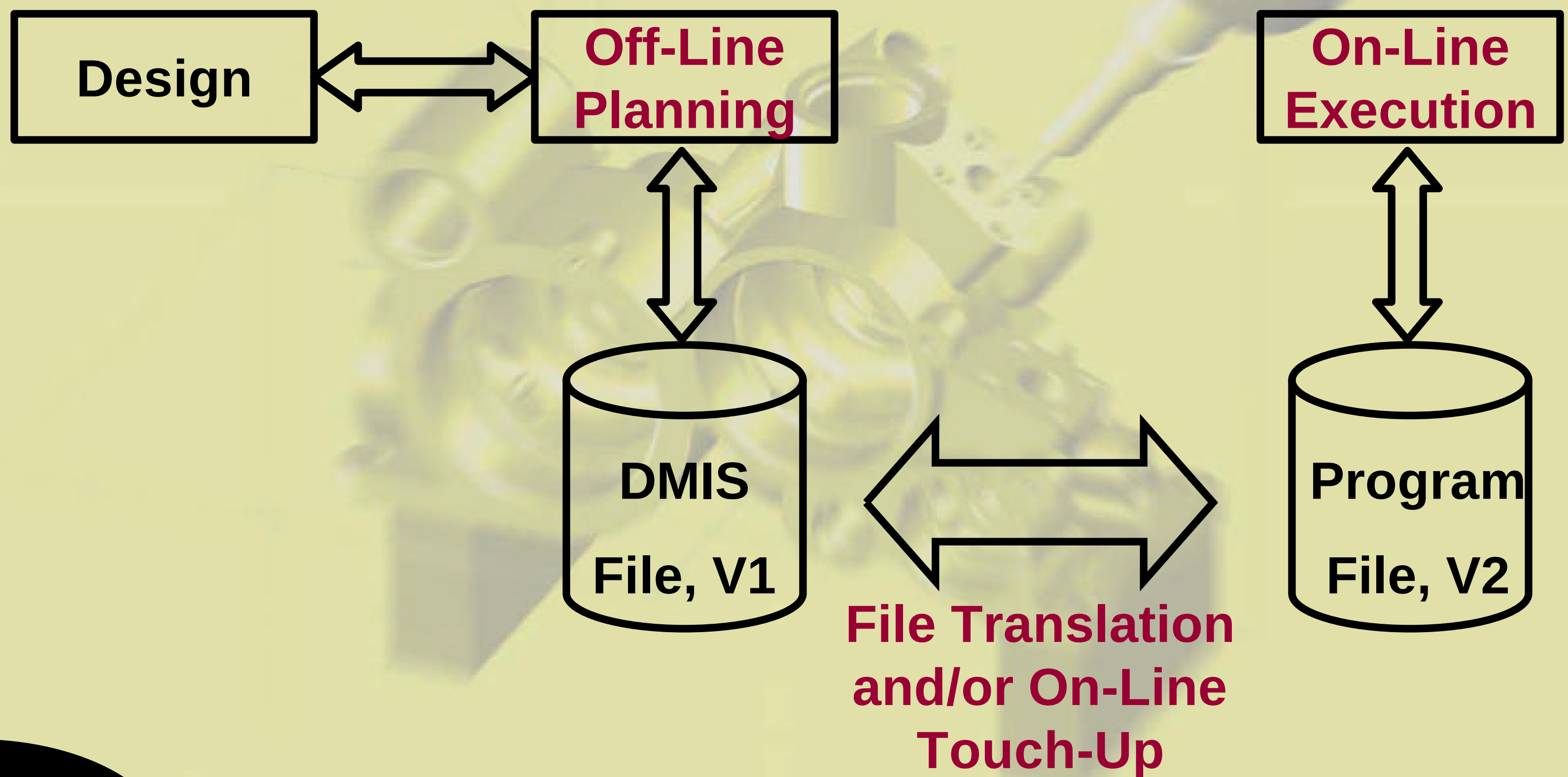
Benefits

- 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)

SILMA
Division of Adept Technology, Inc.

Problem Definition

Weakest link is between Planning and Execution



SILMA History

"We have seen it all"

Year	O/S	Neutral	Direct	Output
1988	Apollo,SGI,Sun	IGES	Anvil	DMIS
1989	Intergraph		CADDS	
1990	HP		Pro/E	
1992	IBM		CATIA	
1993		VDA-FS		FLB
1994		STEP		
1996	W/NT	ACIS	I-DEAS	UMESS UX, CMES
1997				UMESS 300
1998			UG	Quindos

SILMA
Division of Adept Technology, Inc.

Design-Side Integration

	Design	Effectiveness
Neutral	Geom	50%
(ie. IGES)	GD&T	25%
Direct	Geom	100%
(ie. Pro/E)	GD&T	100%
3rd Party	Geom	100%
(ie. ACIS)	GD&T	0%

SILMA.
Division of Adept Technology, Inc.

Execution-Side Integration

	Execution	Effectiveness
Neutral	DMIS	50%
Direct	SILMA Posts	80%
Other	?	?

Execution-Side Integration

	Execution	Effectiveness
Other	?	?

SILMA Vision

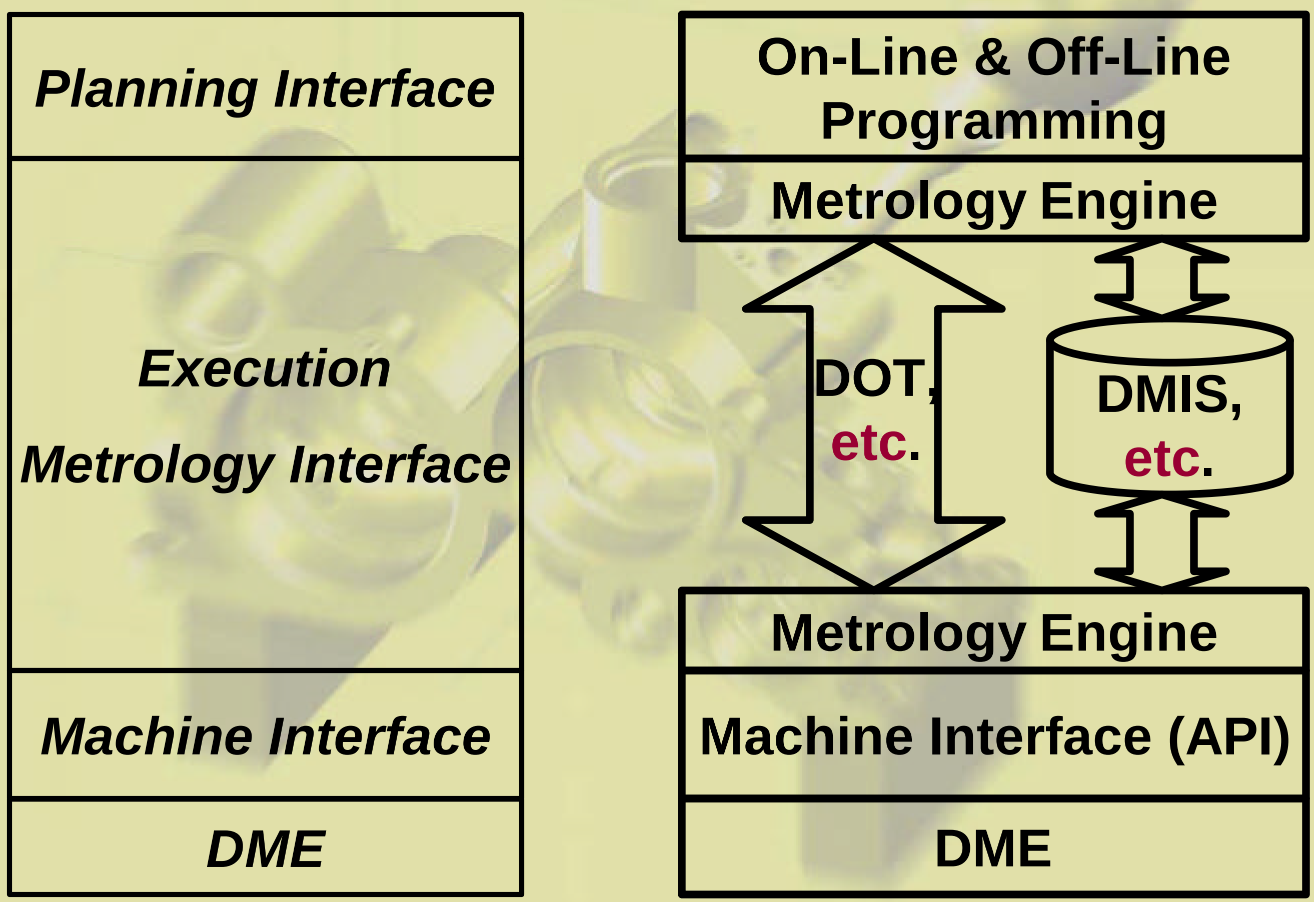
- CMM software-only retrofits
- Integrated on-line and off-line programming

Benefits

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

Potential Solution

CMM Software-Only Retrofit



Problem Solution

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

SILMA®
Division of Adept Technology, Inc.

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

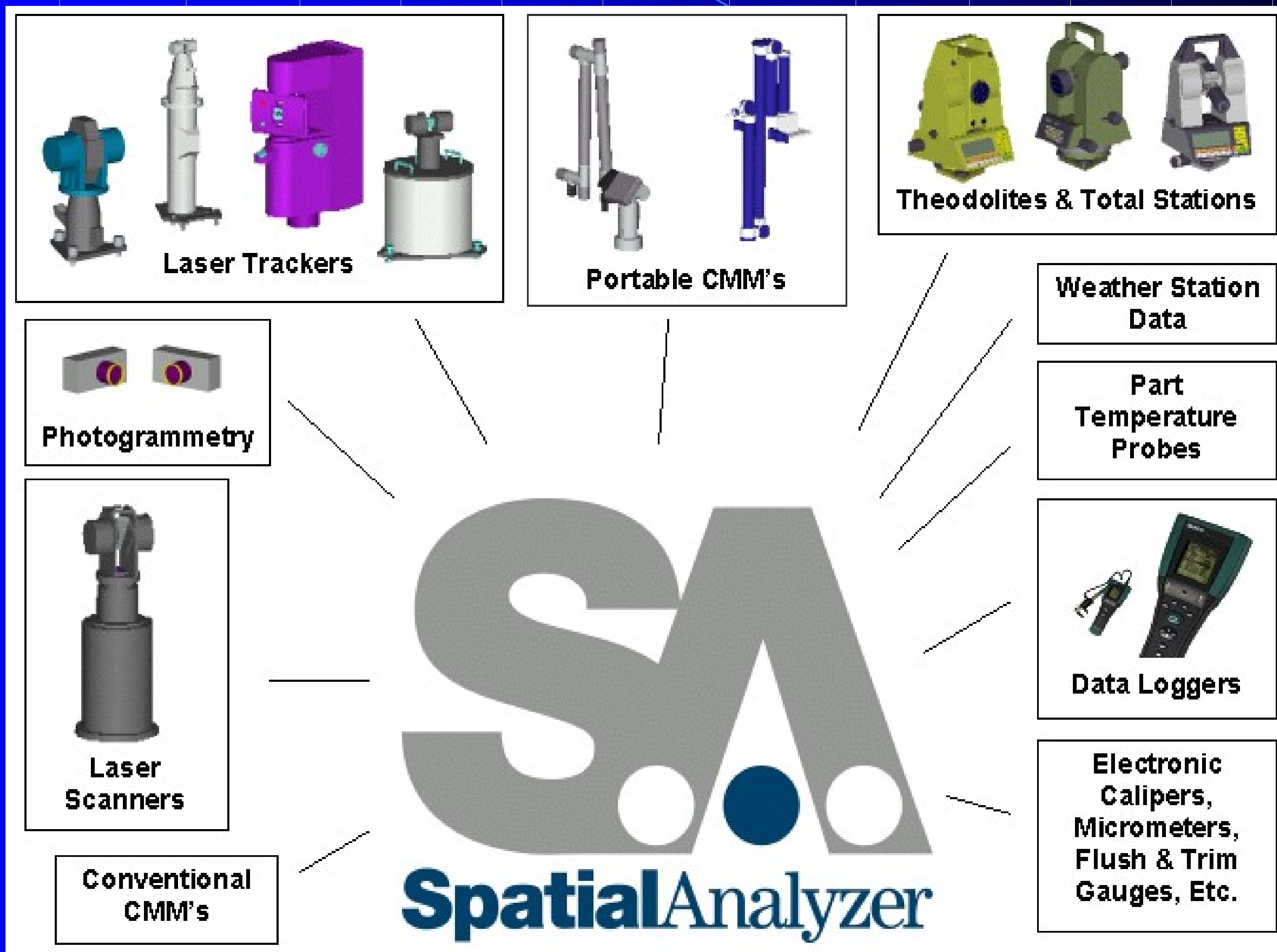
Applications:

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

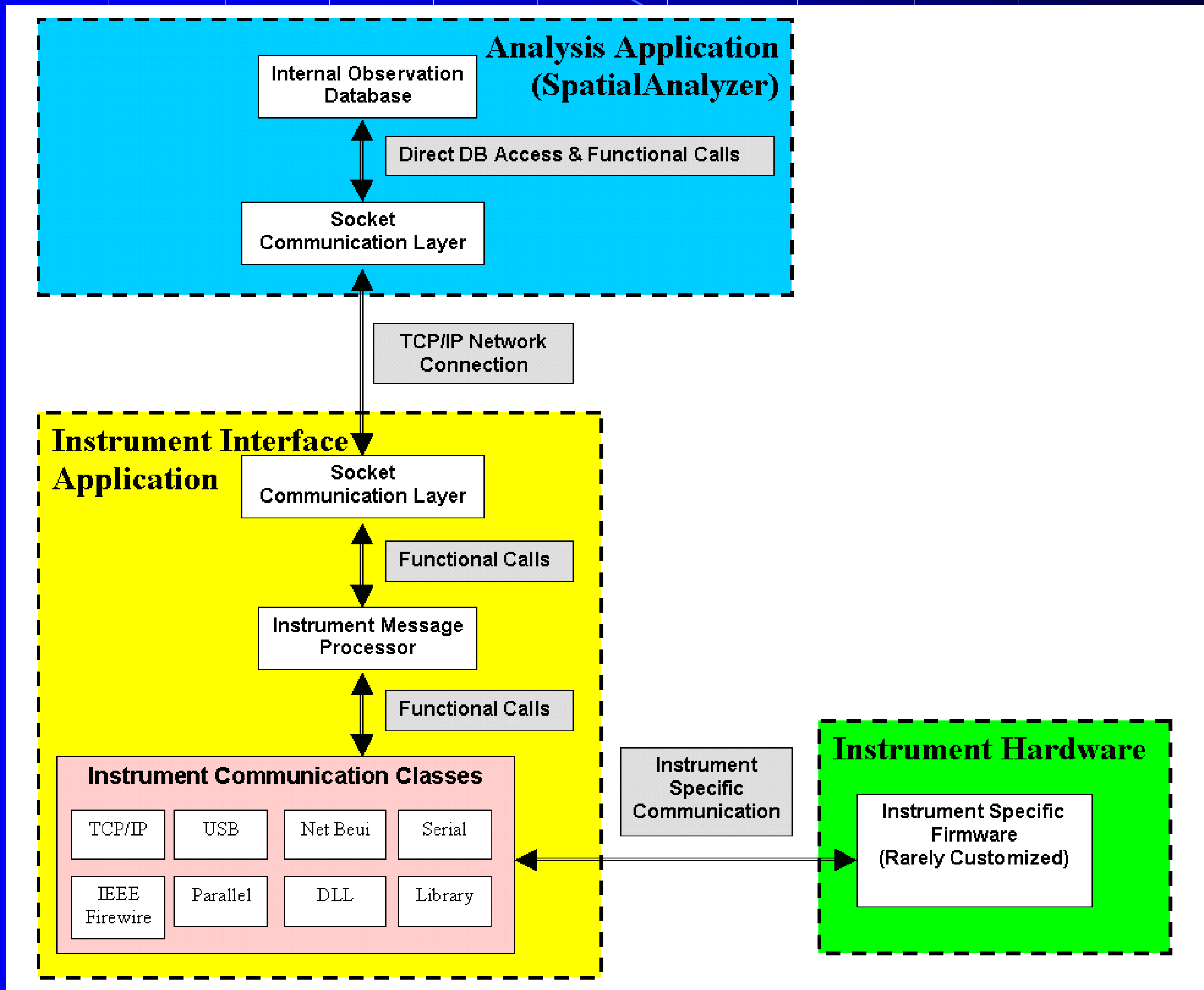
Customers:

- Aerospace
  - Airframe fabrication
  - Spacecraft
- Shipbuilding
- Nuclear / Industrial
- Precision civil / Plant layout

Metrology System Architecture



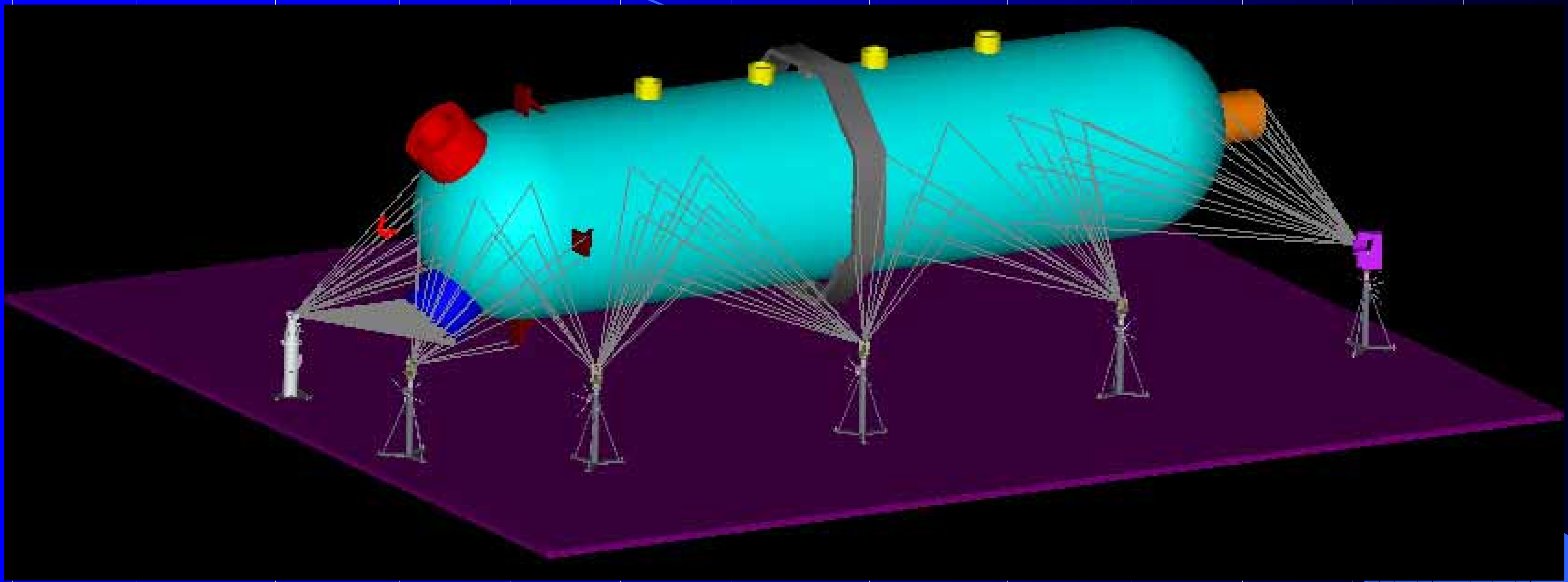
Metrology System Architecture



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



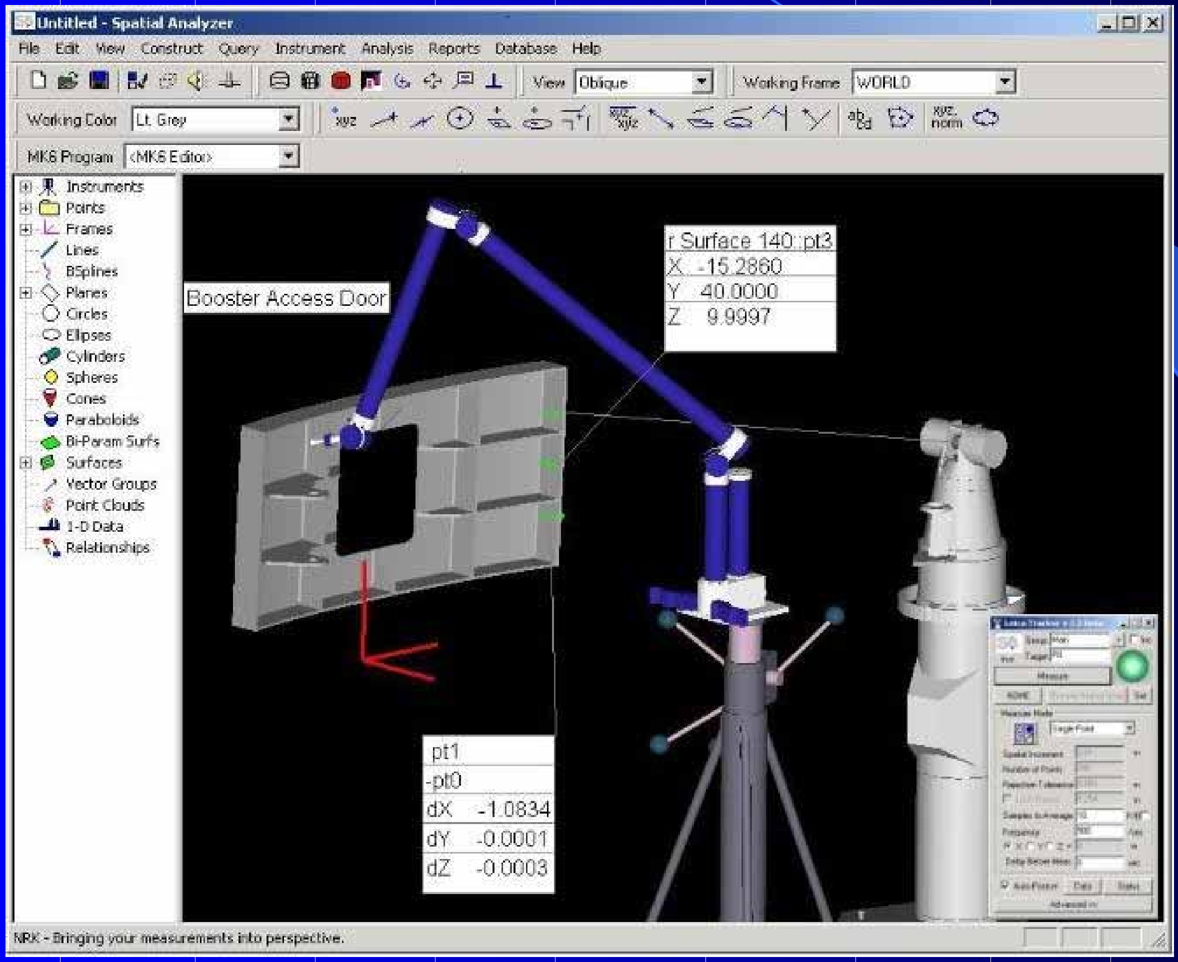
Uncertainty Components

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

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

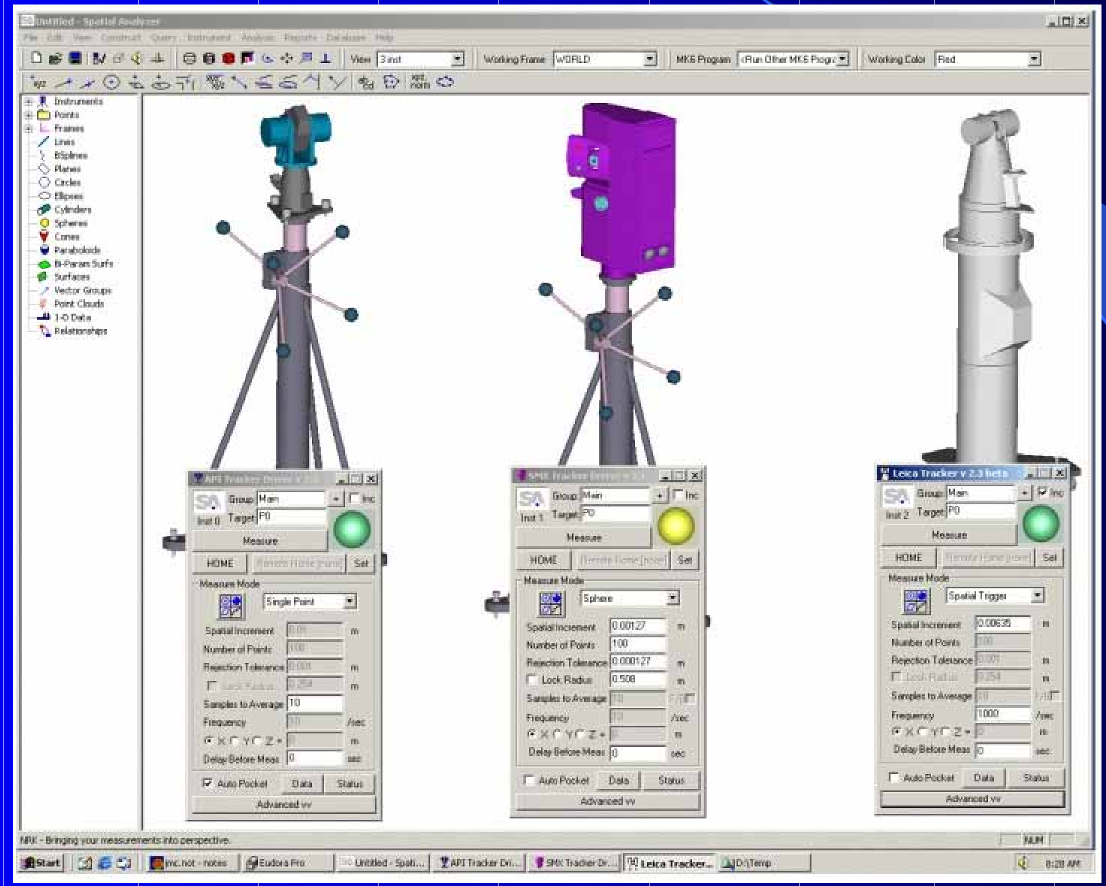
- A Practical Method for Evaluating Measurement System Uncertainty, Joe Calkins (NRK)
- The Shop Floor as NMI, Dr. Dennis Swyt (NIST)

Cooperative (Multi-Instrument) Measurement



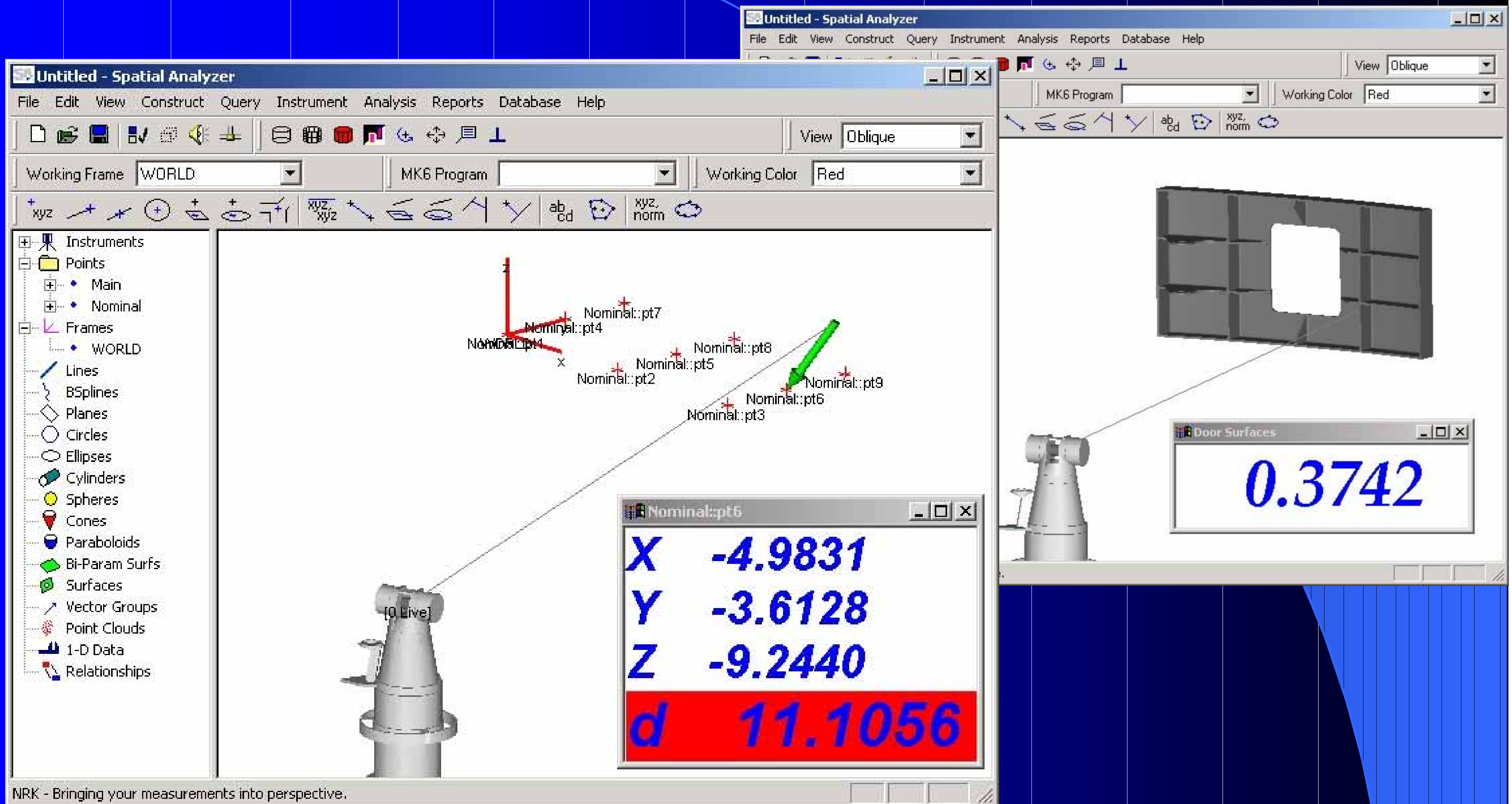
Hughes Space and Communication

Direct Common User Interface (DCUI) / Automation



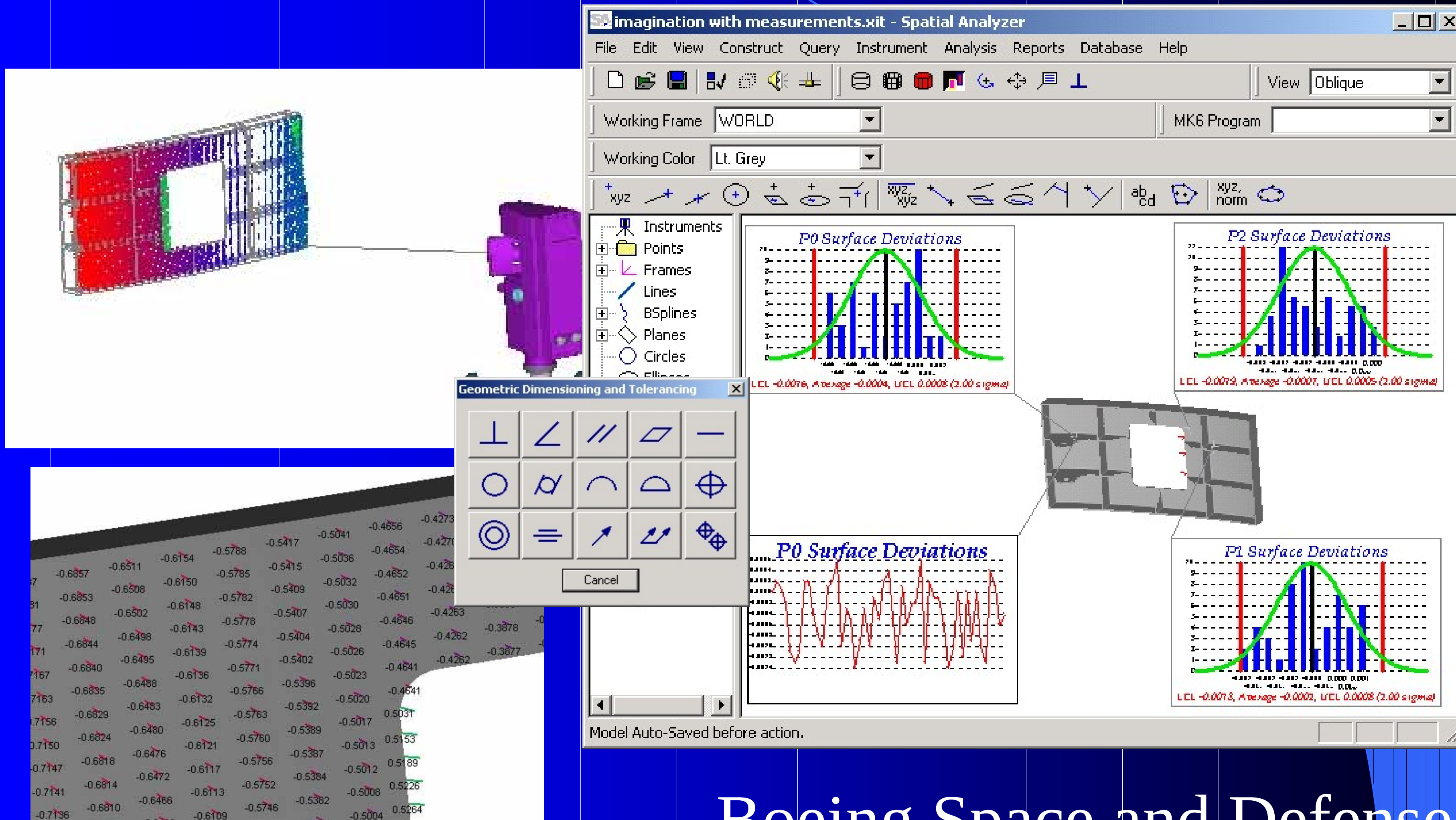
Boeing Commercial Airplane Group

Building Operations



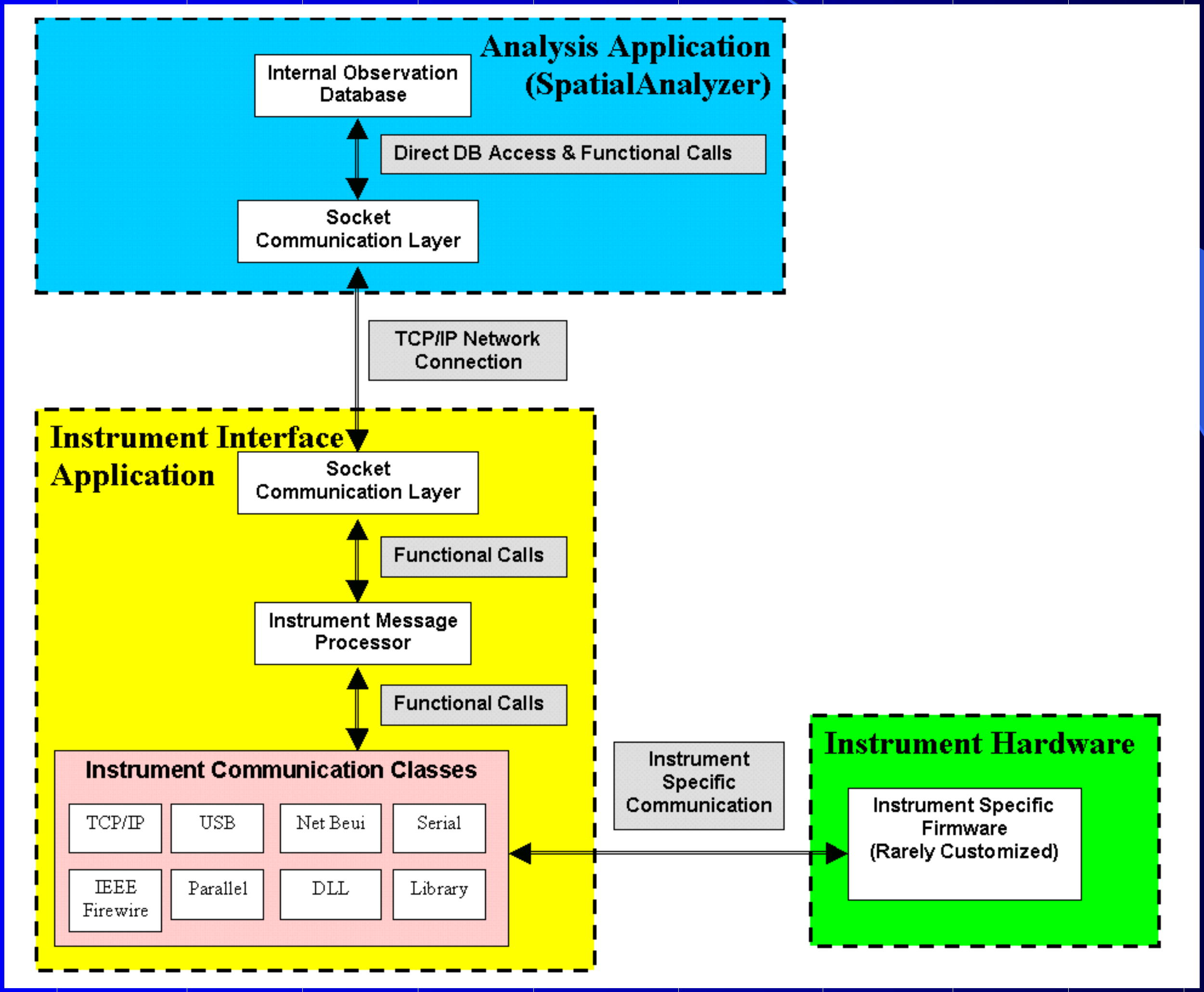
Goodyear Tire and Rubber Company

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

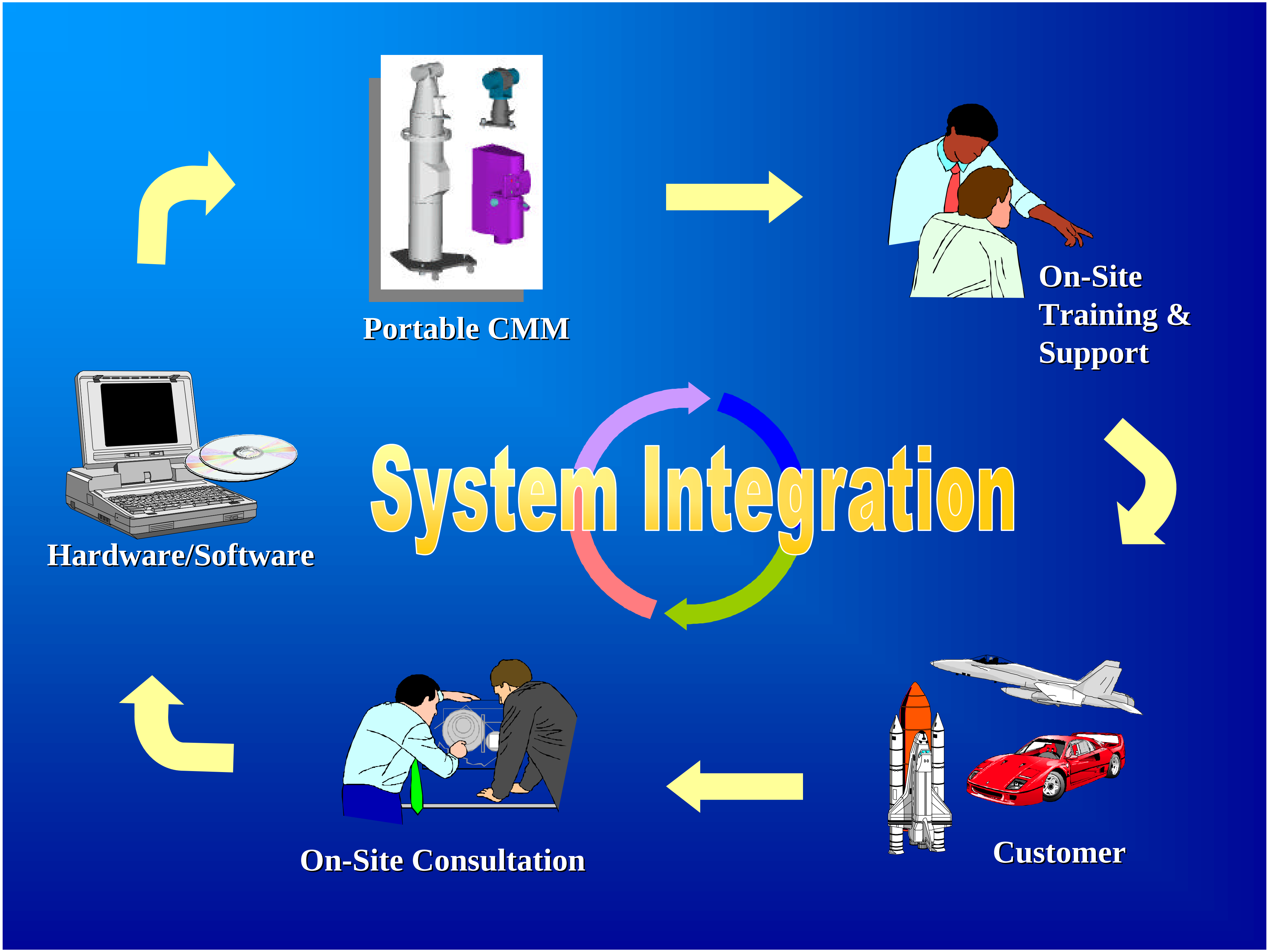
www.kinematics.com

(click on "Publications")

Integrator's Perspective on Open Architecture

Matt Settle

Brunson Instrument Company


Portable CMM
On-Site Training & Support
System Integration
Hardware/Software
On-Site Consultation
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

System Integration

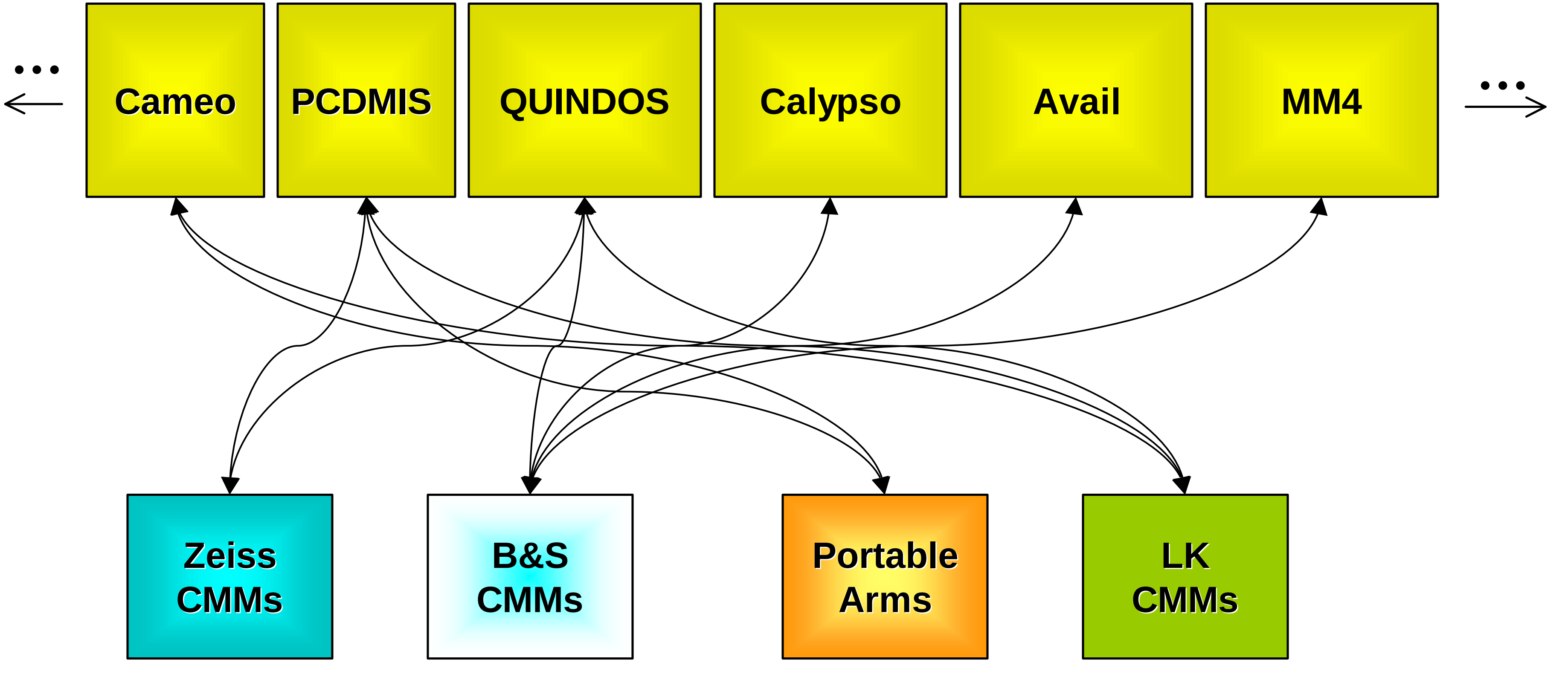
Instrument Needs

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

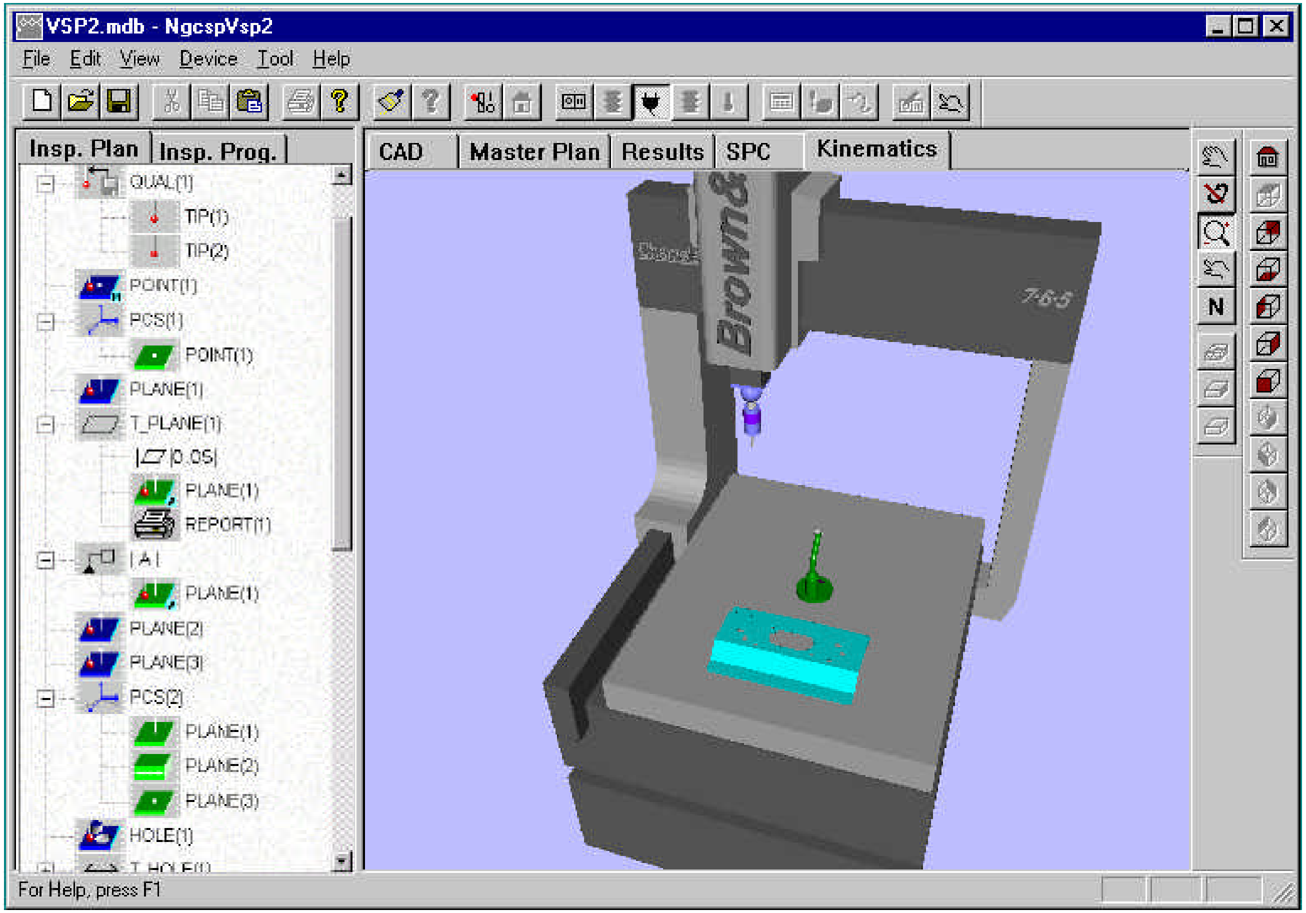
System Integration

B&S
Virtual Measuring Interface
(VMI)

Today's Situation



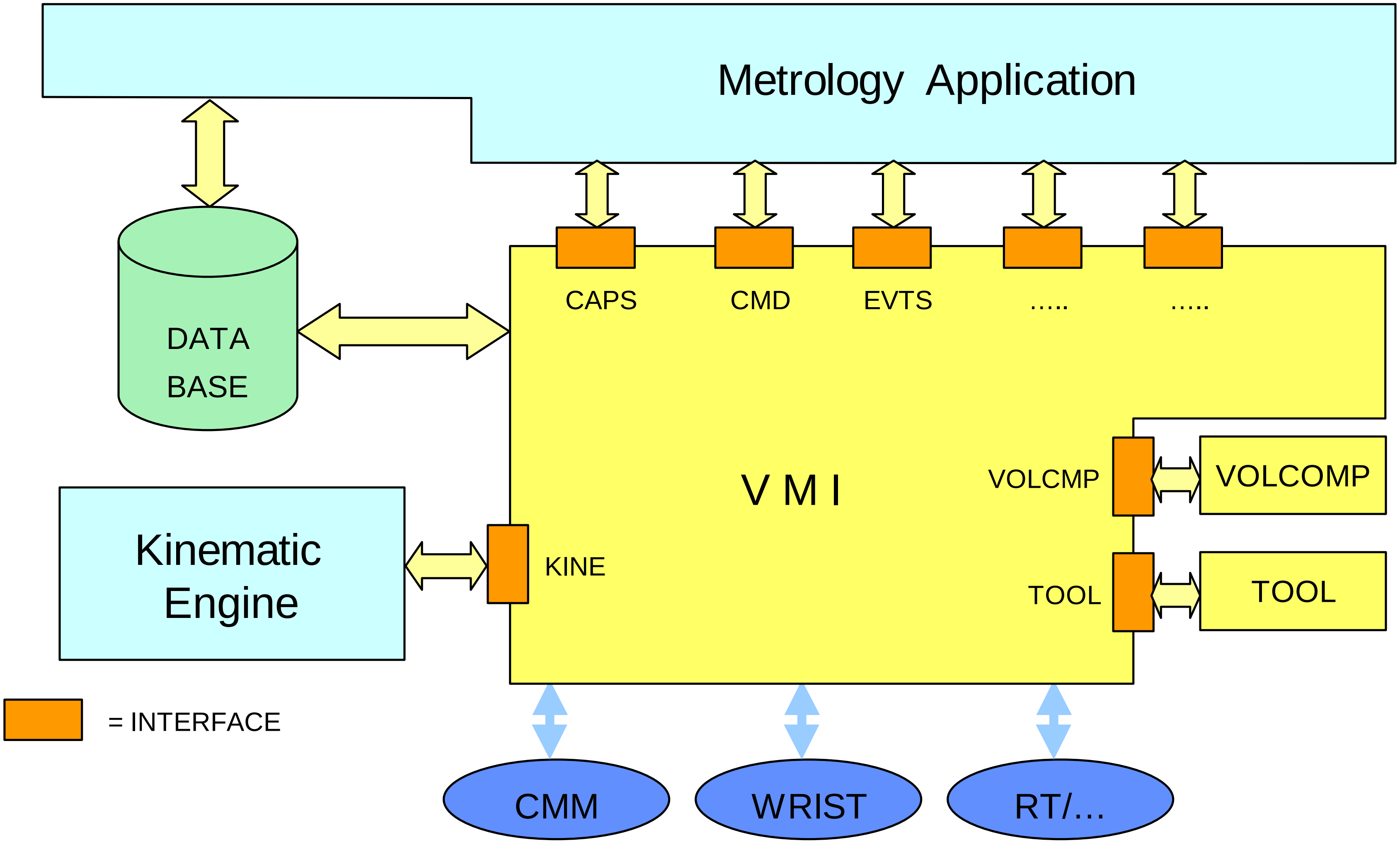
VMI Supports
Next Generation Metrology Applications



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



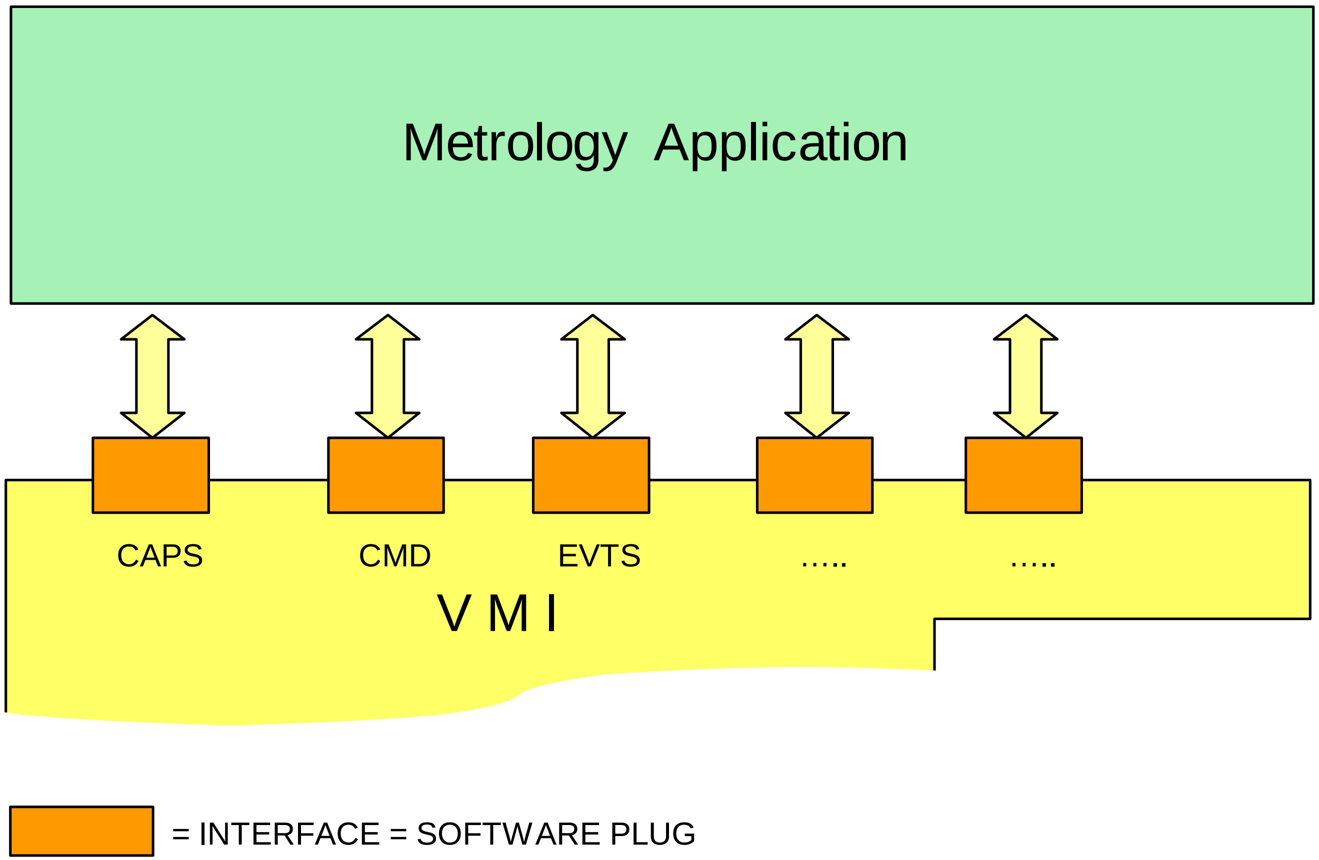
VMI : a set of COM Components

- 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

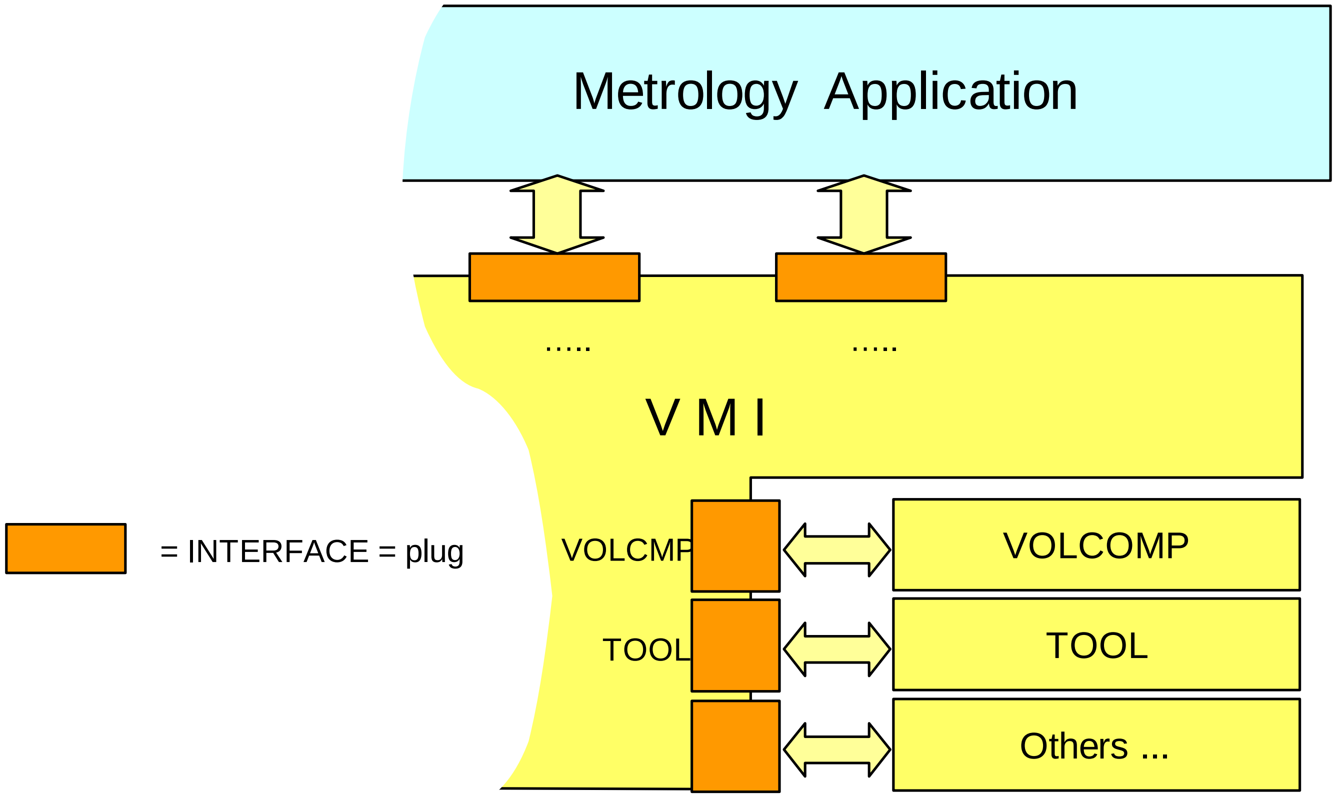
Interfaces


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

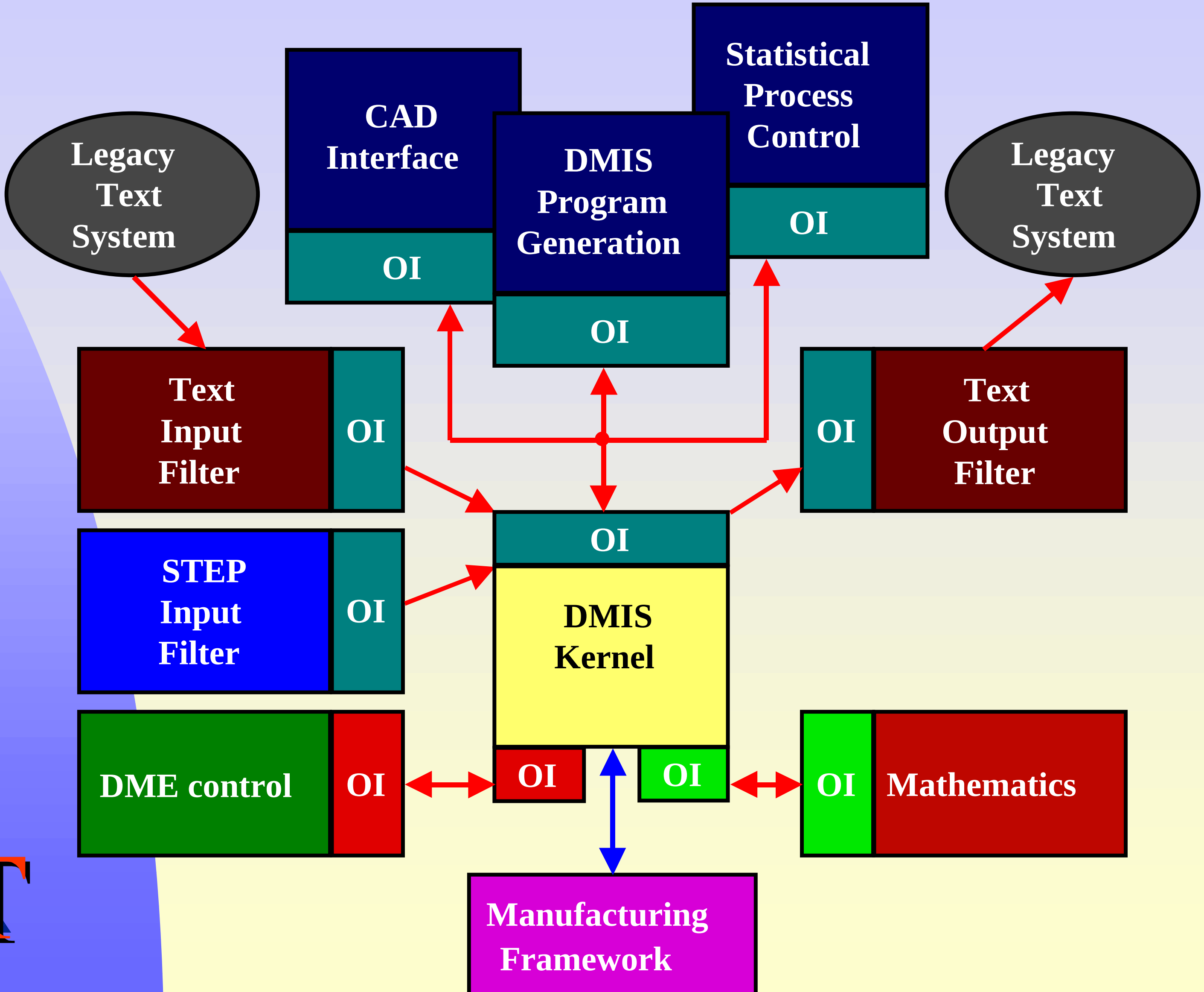
- Technology for plug-and-play inspection exists
  - intercommunication between metrology applications and devices
  - inter-operation between applications from different suppliers
- Object-oriented interface
  - powerful, flexible
  - inheritance, polymorphism
- Open Architecture software standards 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

DMIS

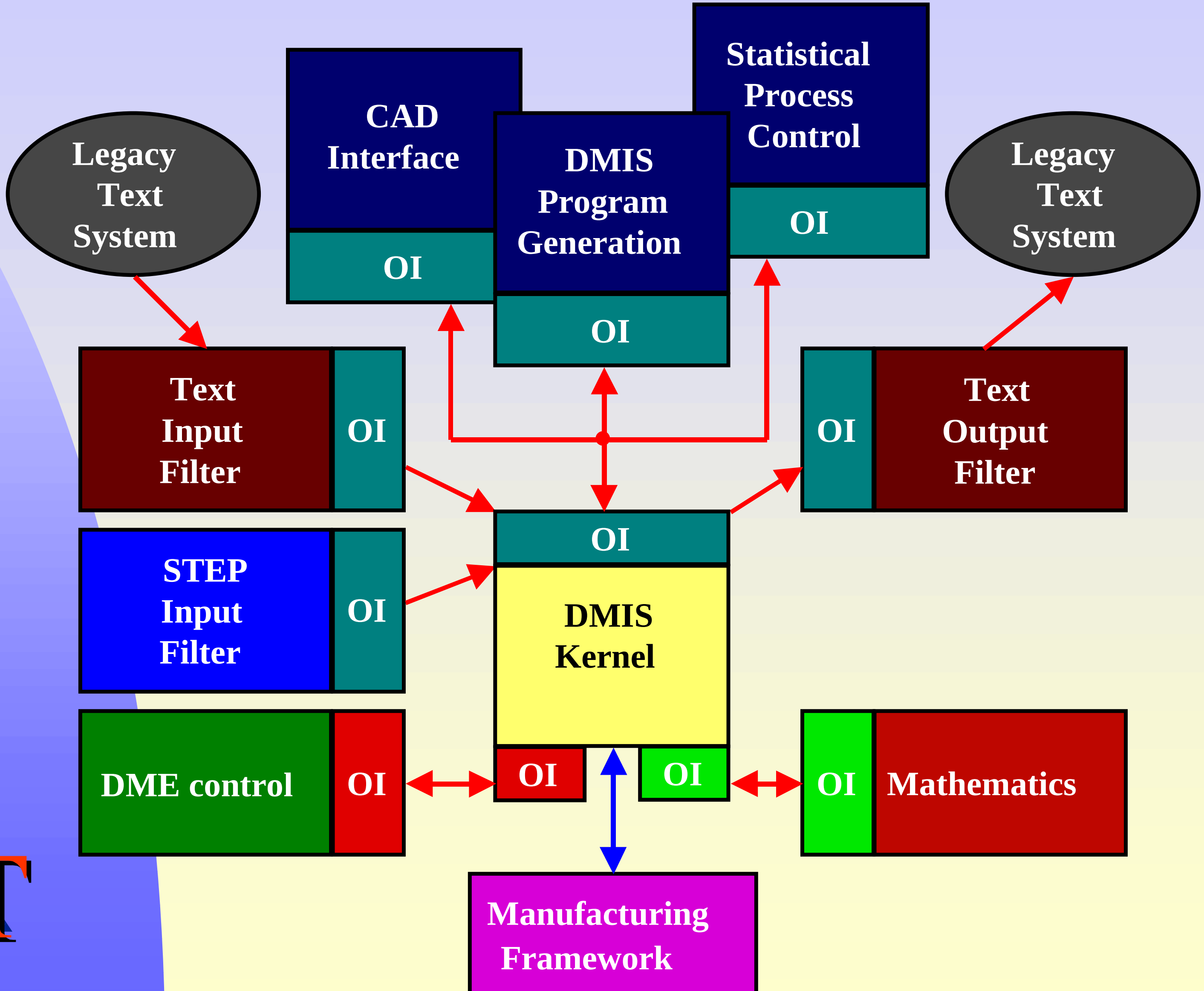
Interface Architecture



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

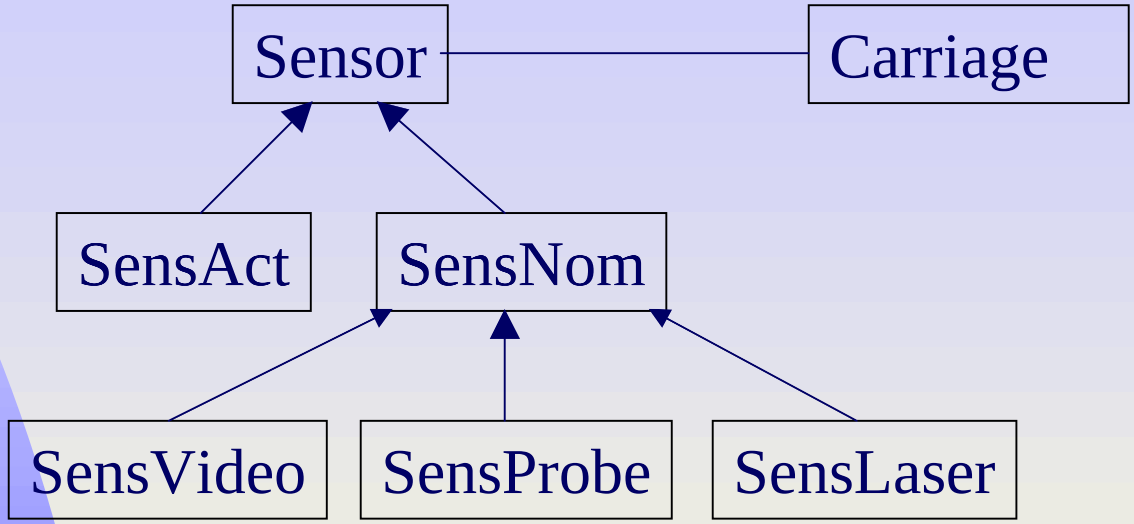
Interface Architecture



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

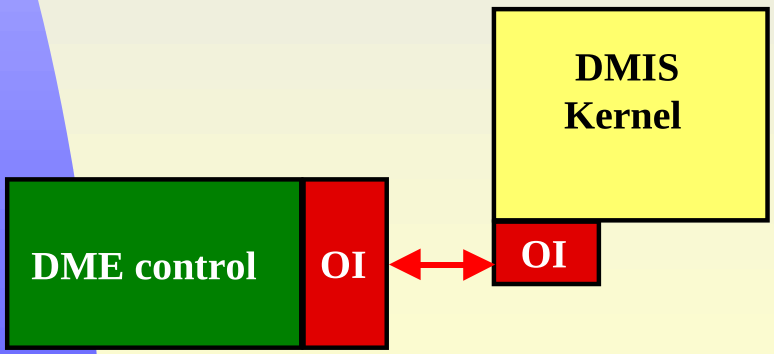
Object Definitions



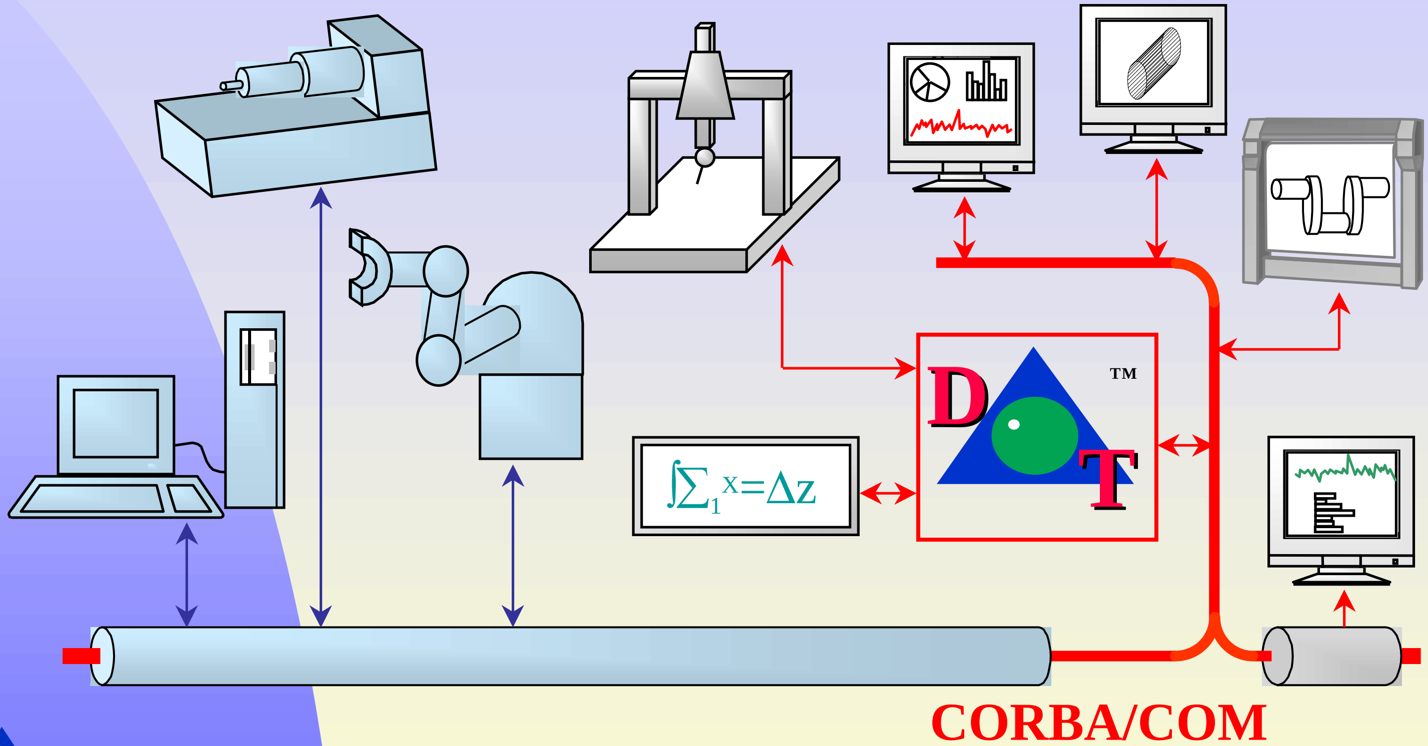

```
Carriage::select_sensor(Sensor)

SensNom::calibrate()

SensProbe::diam()
```

Machine Interface

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



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

Background

Open Modular Architecture Controls

OMAC USERS GROUP

- 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

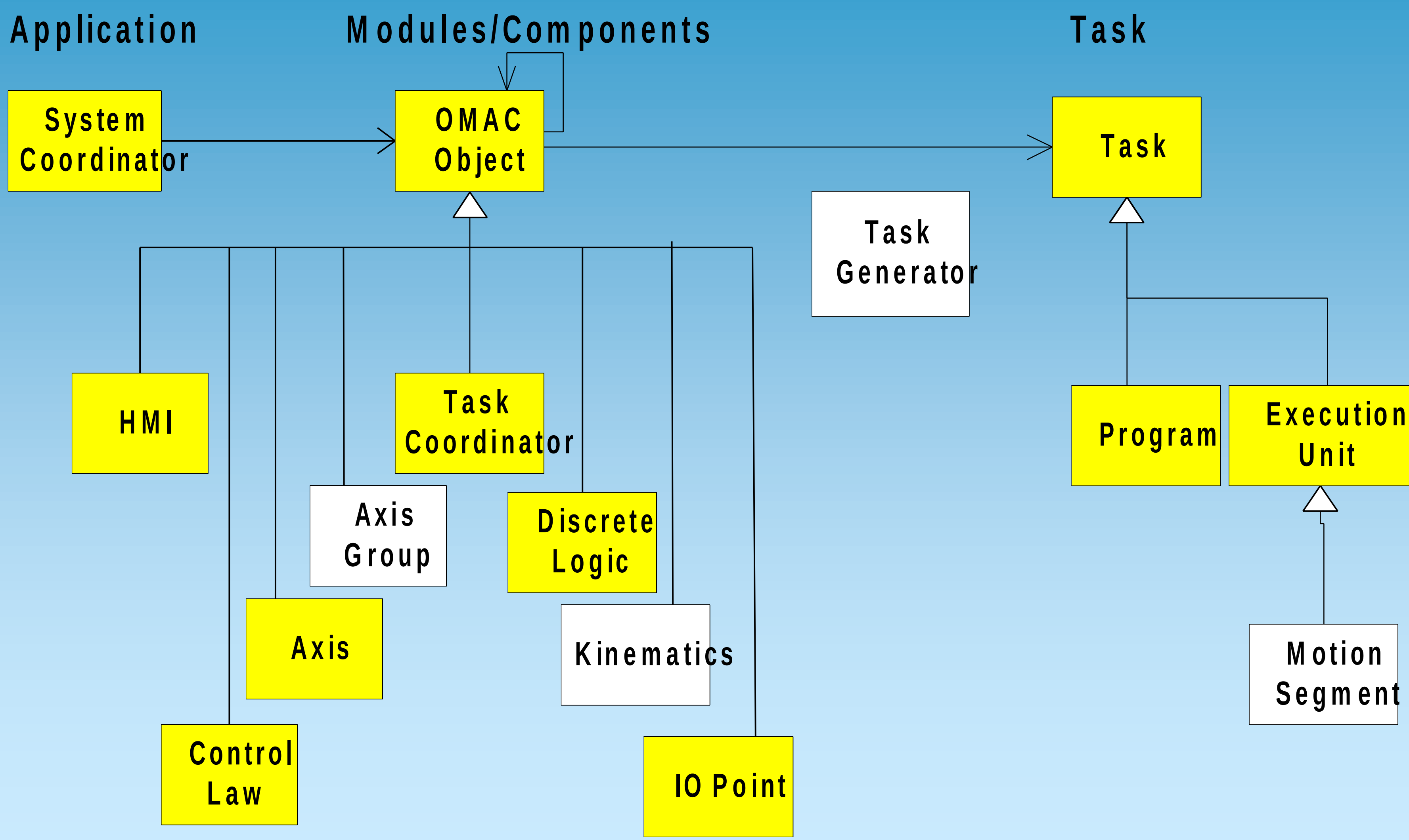
OMAC API Background

- 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 Specification



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

National Institute of Standards and Technology
Technology Administration, U.S. Department of Commerce

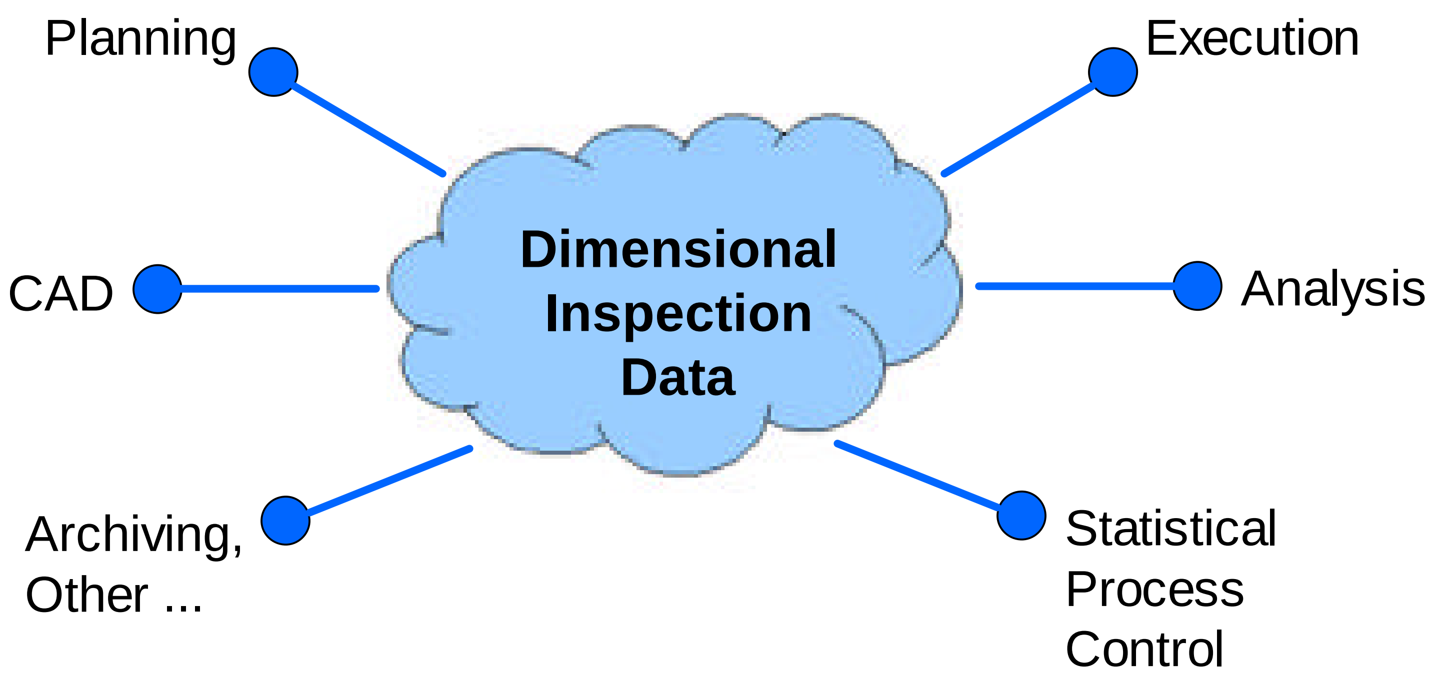
AP219: Dimensional Inspection Information Exchange

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 .

AP219: Dimensional Inspection Information Exchange

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

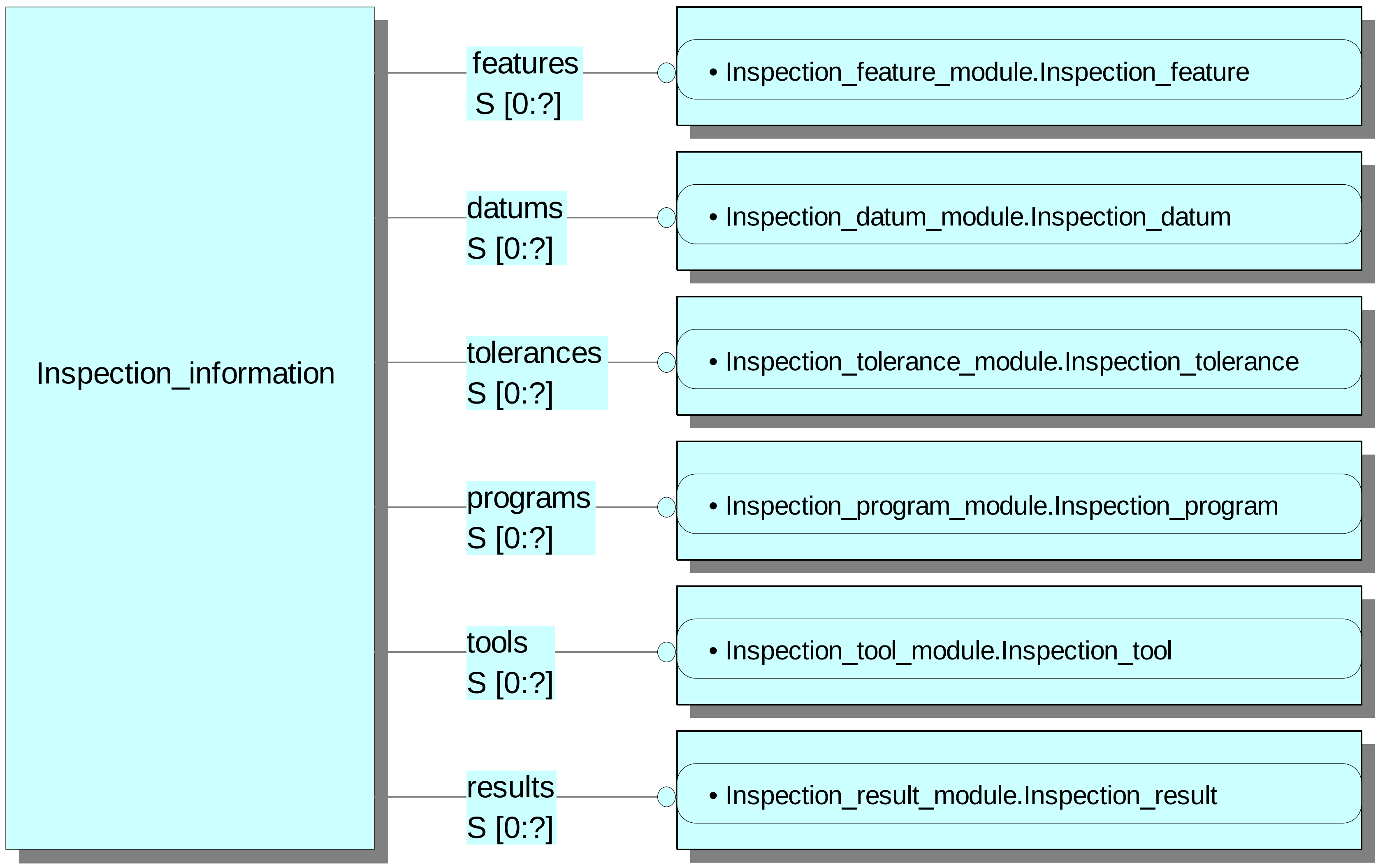
AP219 Application Reference Model (ARM) working draft

EXPRESS-G

Bill Danner

Seneca-IT.com

Inspection information module: *Content*



Application Reference Model (ARM)

Working Draft EXPRESS ARM AP219

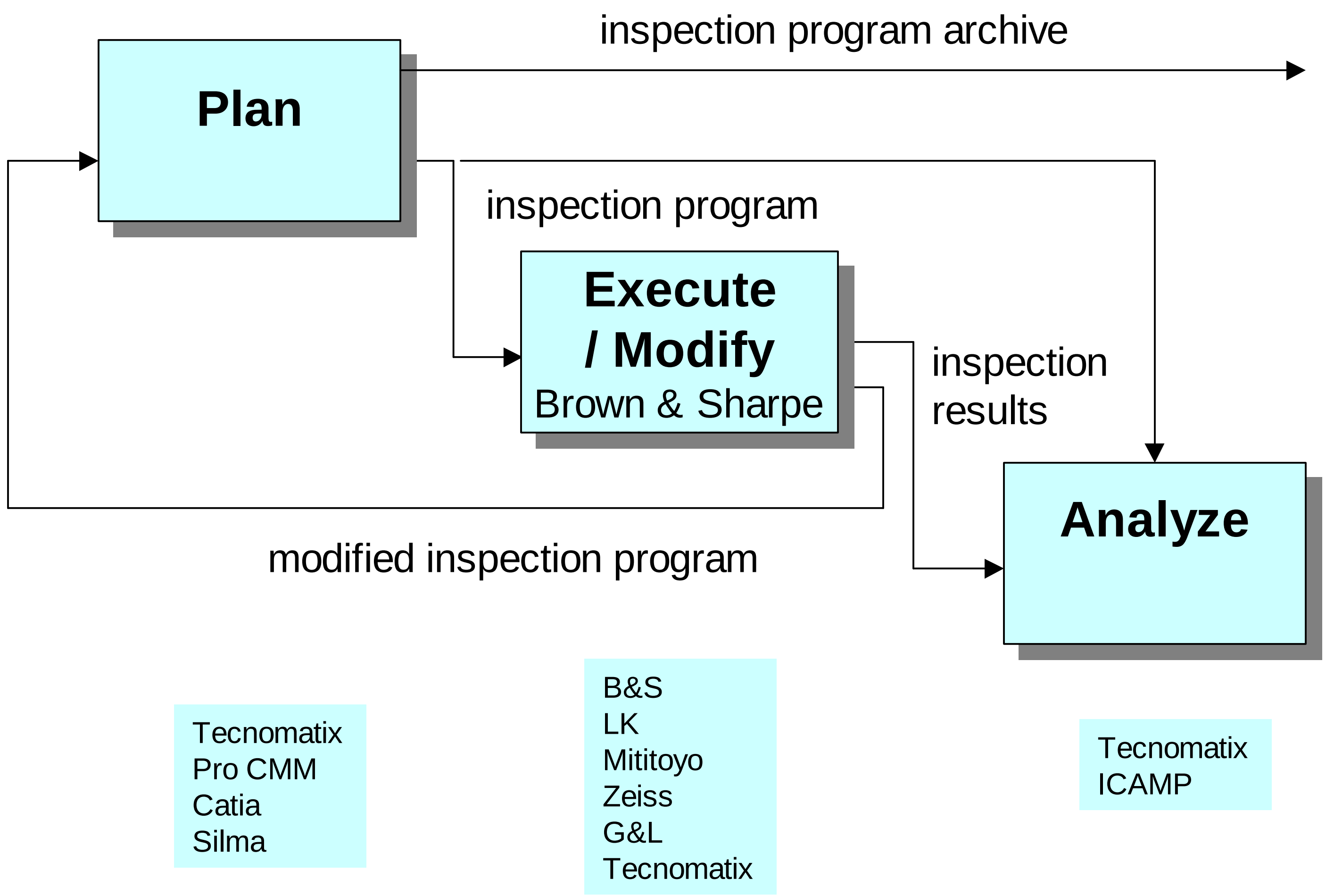
(Dimensional Inspection)

Version 0.1

```
SCHEMA AP219 ;

--
-- Base Stuff
--

-- all coordinates are returned in mm
-- all angles are returned in radians

```

```
TYPE CDIFeatType = ENUMERATION OF (
        POINT,
        LINE,
        PLANE,
        CIRCLE,
        CPARLN,
        SLOT,
        CYLINDER,
        CONE,
        SPHERE,
        GCURVE,
        GSURF,
        PATTERN,
        ELLIPSE,
        RECTANGLE,
        SURFACEOFREVOLUTION);
        END_TYPE;

TYPE CDITolZoneShape = ENUMERATION OF (
        CYL,
        SPHERICAL,
        PARPLANE,
        WEDGE,
        RADIAL);
END_TYPE;
```

Prototype Implementation Scenario



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.**

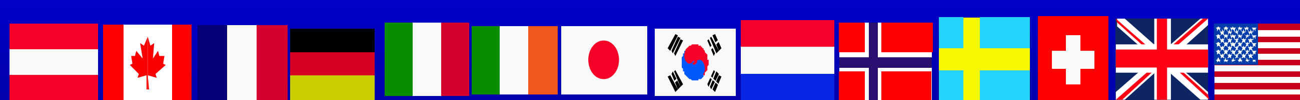
Consensus-based approach…..

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) ..

Member Organizations

3M
ABB Automation
Allied Signal/FM&T
AT&T
BaaN
British Telecom
Bankers Trust
Boeing
CoCreate
DaimlerChrysler
Deere & Co.mpany
Eurostep
EDS
Enovia
Ericsson
Ford Motor Co.
Fraunhofer
Foxboro
Fujitsu
Gensym
HP
Harris
Hitachi
IBM
Informix
Intel
IBM
Lucent
MatrixOne
Metaphase /SDRC
Microsoft
Motorola
Oracle
PSE/Siemens AG
POSC
PrismTech
ProSTEP
SAP AG
Schlumberger Tech.
Sun Microsystems
Thomson CSF
TRW
Unisys
Valtech
Yokogawa…….



Open Specifications

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..

Organization

OBJECT MANAGEMENT GROUP

Architecture Board

- *Policies & Procedures*
- *End-User Requirements*
- *Metrics*
- *Security*
- *Reference Model*
- *Domain Reference Model*

Domain Technology Committee

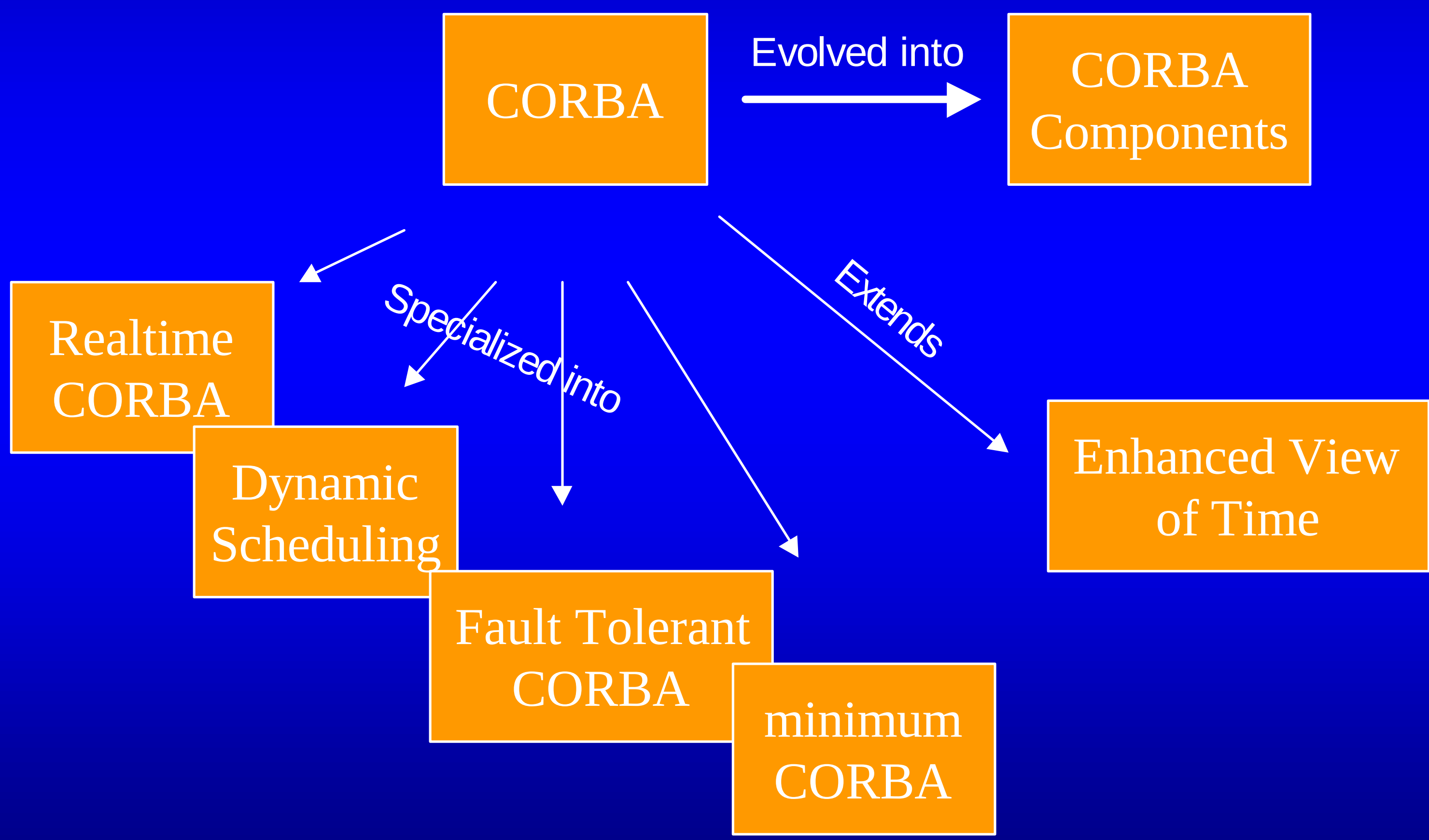
- *Finance*
- *Business Objects*
- *Healthcare*
- *Manufacturing*
- *Electronic Commerce*
- *Telecommunications*
- *Transportation*
- *Life Science Research*

Fast Growing...

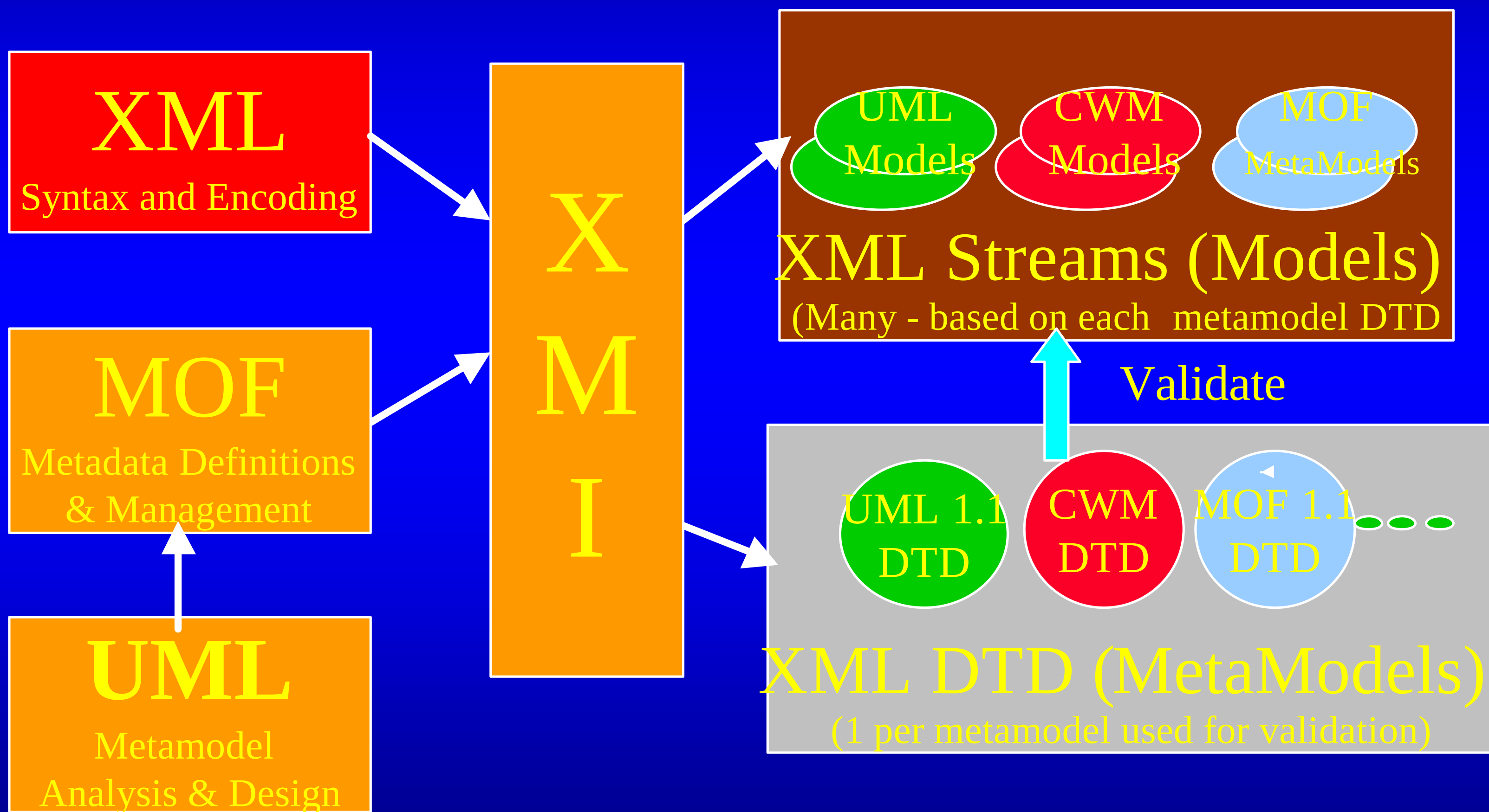
Platform Technology Committee

- *ORB & Object Services*
- *Common Facilities*
- *Analysis & Design*
- *Real-Time*

Platform Middleware Technologies



Platform Modelware Technologies



Domain Technologies

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)

DAIS RFP

"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

- OMG home page - http://www.omg.org
- Specifications: Adopted and In Process - http://www.omg.org/techprocess/meetings/schedule/adopt.html
- Manufacturing Domain Task Force (MfgDTF) - http://www.omg.org/homepages/mfg
- MES/MC working group - http://www.omg.org/homepages/mfg/mfgmesmc.htm
- DAIS RFP, schedule, status and submissions: http://www.omg.org/techprocess/meetings/schedule/Data_Acquisition_RFP.html
- LECIS RFP draft - http://www.omg.org/cgi-bin/doc?lifesci/2000-04-02

Steps

to a

Standard Machine Interface

for

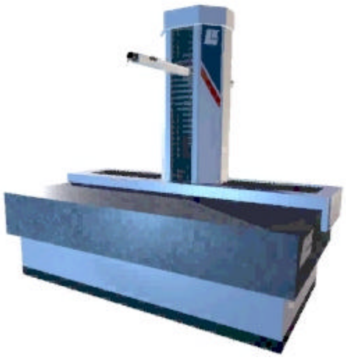
CMM Systems

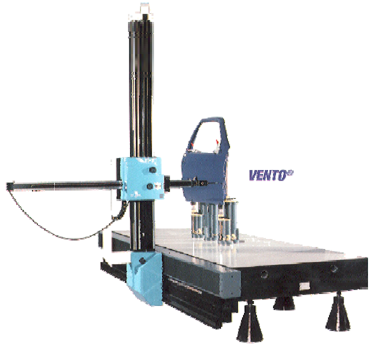
April 2000

Open Machine Interface for CMM Technology

Current situation

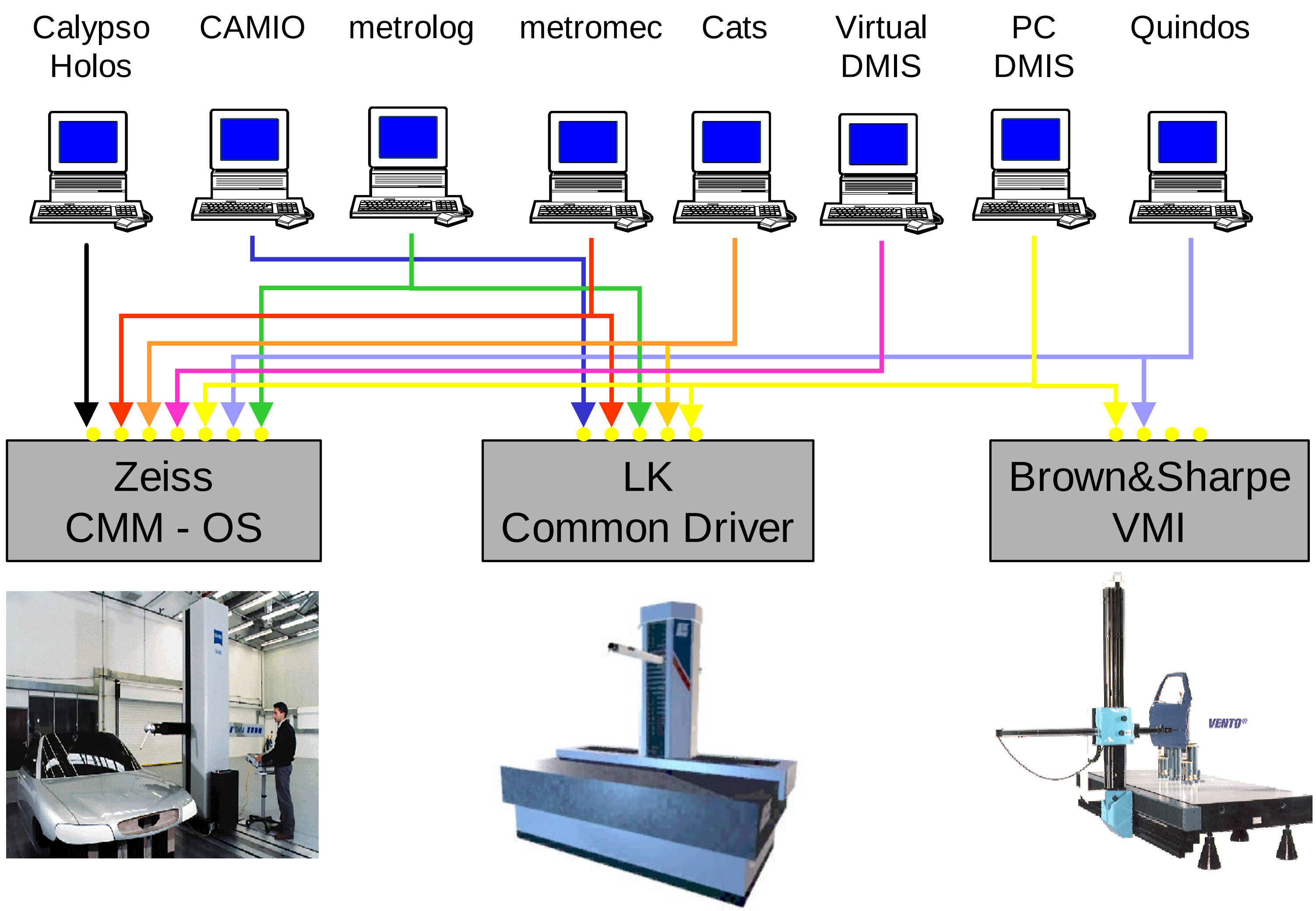
Zeiss Software	LK Software	B&S Software
Zeiss CMM - OS	LK Common Driver	Brown&Sharpe VMI





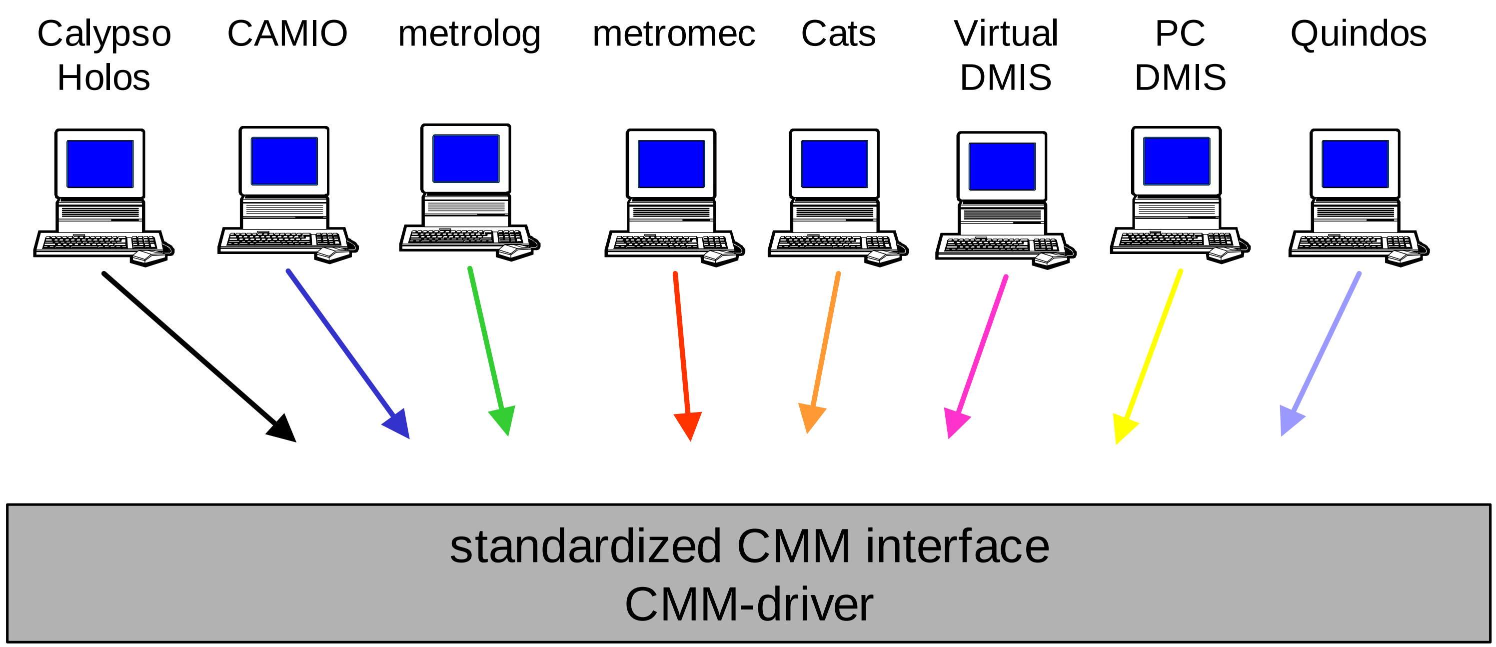
Open Machine Interface for CMM Technology

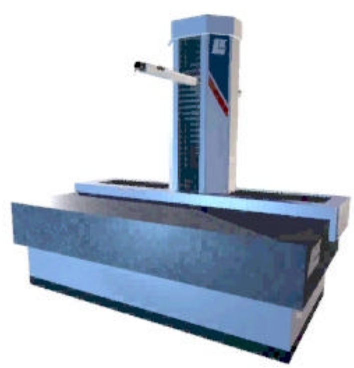
Situation April 2000

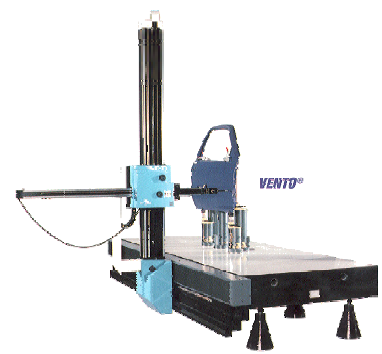


Open Machine Interface for CMM Technology

Desired situation







What

is

the

CMM-driver ?

What is the status today ?

- basic strategy defined
- basic commands defined
- basic error codes defined

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

Basic commands (part 2)

Toolchanger:

- query bay data
- return tool
- pick up tool

Transformations:

- set matrix for DRO
- set matrix for joystick

Position:

- get current position
- move to position
- move to home position

Miscellaneous:

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

Rotary head:

- rotate to angle
- query current angle

Hitpoint:

- CNC hitpoint
- MAN hitpoint

Basic commands (part 3)

Tooldata:

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

Alignments:

- save alignment
- list alignment
- read alignment

Basic errors

- Limit of travel reached
- Emergency stop
- no touch
- illegal touch
- not calibrated
- unsupported command
- incorrect parameters

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

Suggested strategy

The interface will

- use strings as commands
- use TCP/IP sockets for communication

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

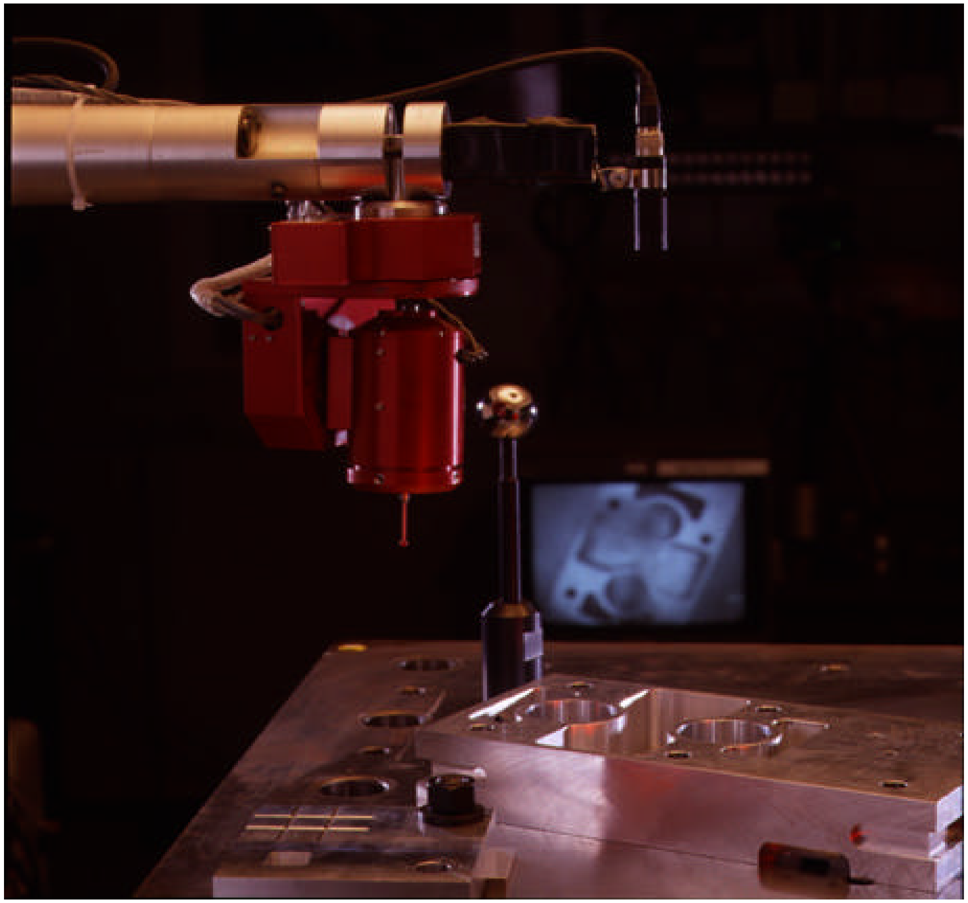
The NGIS Program

- 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 ->

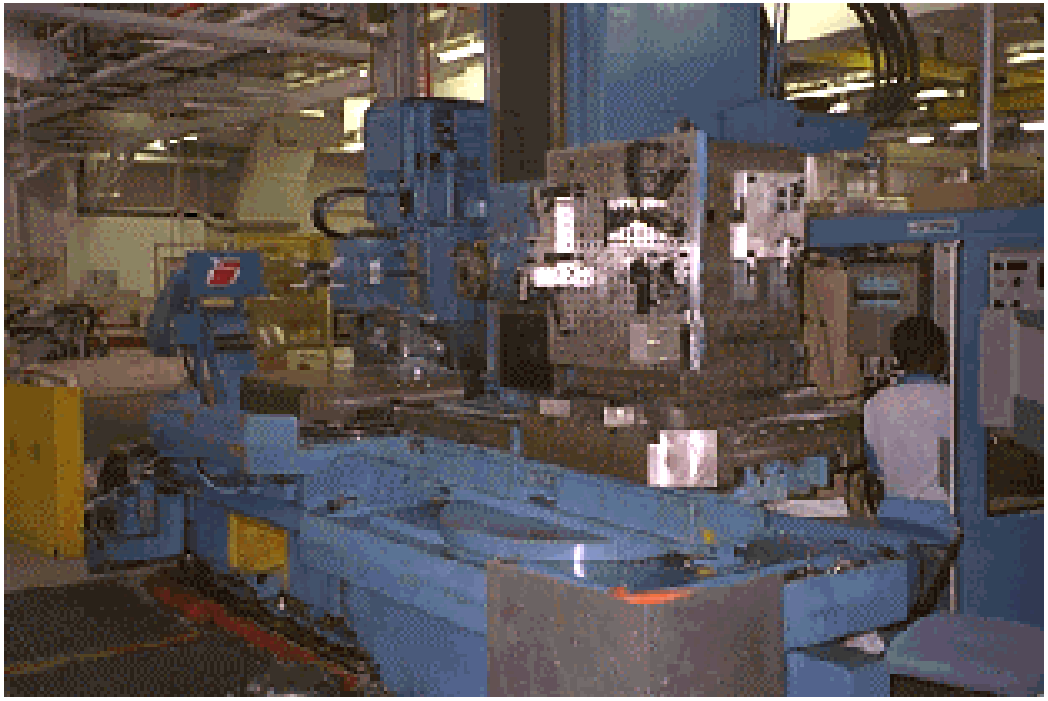
NGIS Program Members

- **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

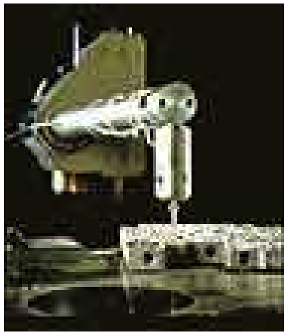
- 1996 - NGIS II, emphasis on demos at GM, Ford, testing at NIST
- 1997 - SIM Working group published 1st draft of SIM spec. Began rough draft of sync bus spec.
- 6/98 - "tapering" down of NGIS II.

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.

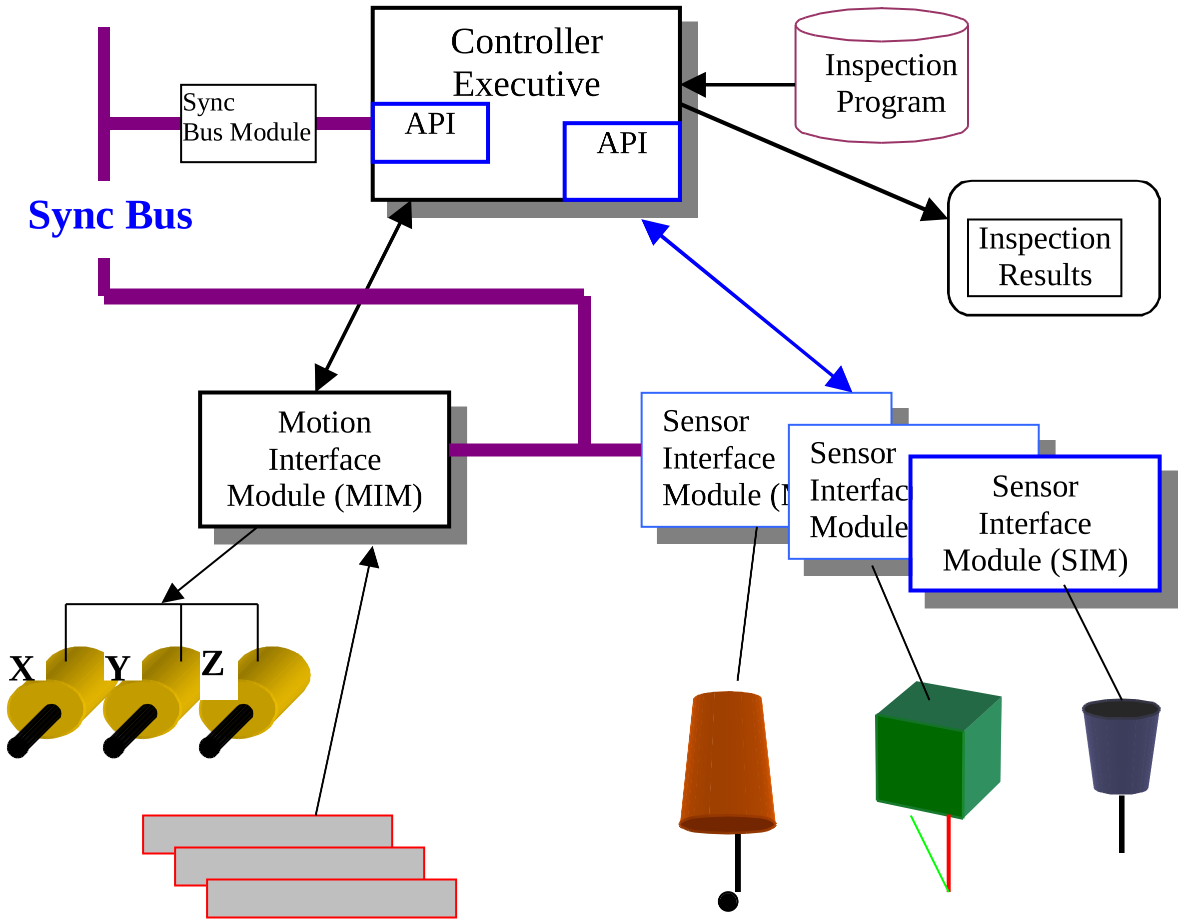
Ability to integrate a variety of probes.



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
  - http://www.isd.mel.nist.gov/projects/ngisAPI/
- 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 Specification", NISTIR 6116, January 1998.

- NGIS SIM website -

  http://www.isd.mel.nist.gov/projects/ngisAPI/.

NIST Capabilities

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

The End

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NIST

301-975-3417

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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 IEEE Instrumentation and Measurement Society's Technical Committee on Sensor Technology, TC-9.
  - 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 1451.2, Transducer to Microprocessor Communication Protocols and Transducer Electronic Data Sheet (TEDS) Formats - - - An officially approved standard.

- 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, Philadephia, 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

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

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	RESPONSES	NOTES:
Define "open architecture" for metrology in the context of the automated factory floor.	<u>**Possible Standardization Areas**</u> **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.)**	**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?		
How does the move towards in-process metrology affect the need for OA systems?	**In process metrology implies that you need RT meas.,Feedback and analysis – file transfer is not sufficient.**	
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?	**Captured by the chart.**	
What should the role of government laboratories and	**Leadership and laboratory testing. 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,

charge of this. Having NIST or MAA behind a standard gives it validity. – CLOUT

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?

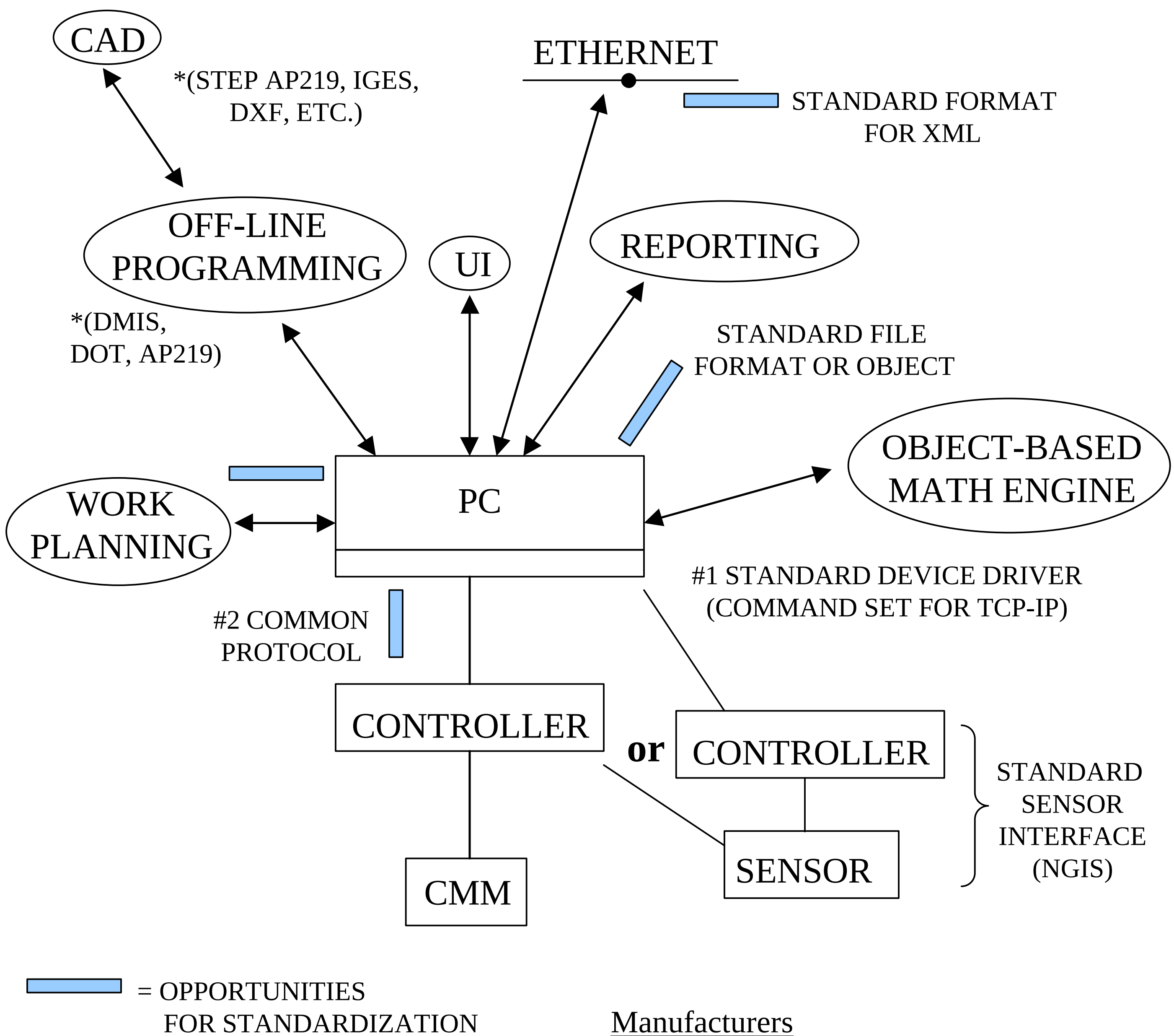
10) What are the research needs to achieve OA?

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

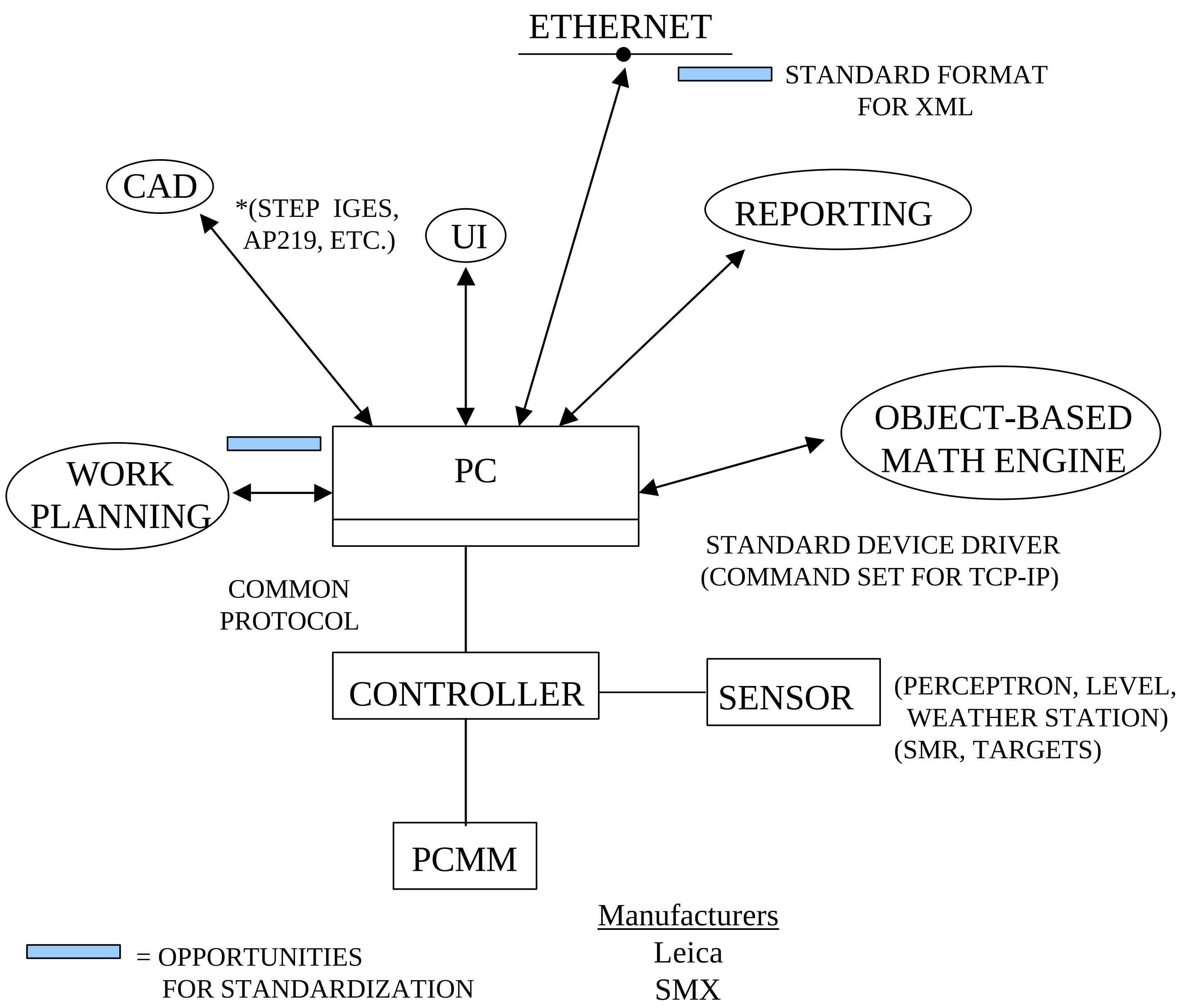


<u>Manufacturers</u>
B of S
LK
Zeiss
Starrett
Etc.

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



<u>Manufacturers</u>

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

BLUE GROUP
May 2, 2000
Bill Rippey, editor

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

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Define OA
- Must cover measurement technologies beyond CMMS
- Defined interfaces, <u>published</u> 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

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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

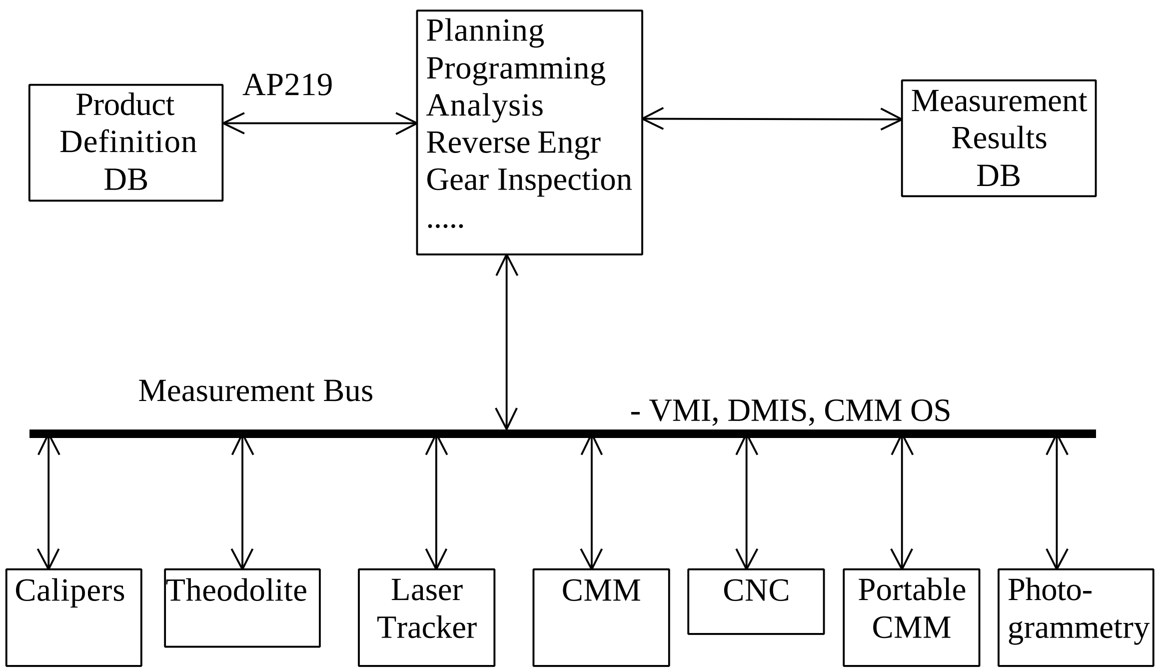
- Publish overview of efforts, directions, architectures, long and short term goals –
  - DMIS
  - DOT
  - AP219
  - VMI
  - ….

- 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



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	RESPONSES	ACTION ITEMS
Define "open architecture" for metrology in the context of the automated factory floor.	**A set of components and their relationships** - **Definition of the components and their interfaces** **SPC (Statistical process control) system – interface specifications** **Conformance to interface specifications**	
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 have to be flat, but may be hierarchical.	**See Green breakout group diagram**	draft scenarios of what would be happening in inspection
How important is openness to productivity and efficiency? Are there other technologies/issues of equal or higher importance?	**Very critical to productivity** **Issue of reliability impacts efficiency and productivity** **Openness with good implementation is important**	
What is the current state of openness in metrology systems?	**State of proprietary openness (And, this is just beginning)**	
What are the interface and interoperability problems you face?		

What is a business case for open architectures?	**Reduces integration costs** **Flexibility for the end user**	
How does the move towards in-process metrology affect the need for OA systems?	**SPC and other in-process needs will continue to be addressed and important** **Standards shouldn't stifle innovation**	
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?	**DOT, DMIS, AP219, etc. more work may need to be done to learn more about this**	**Understand relationships and direction of the various standards efforts – DOT and AP219 for example.** **"Informal discussions" (Zeiss, LK and Brown and Sharpe) effort – how may that help our effort** **(Is this effort to limited, it maybe should include others)**
What should the role of government laboratories and programs and standards bodies be to aid in the research, development, engineering, and standards development efforts?	**Neutral, catalyst to make this happen, facilitator, support role and provide information** **Participate in standards committees**	NIST try to help facilitate a model to give us a basis on working on this issue would it be helpful to start an e-mail list ?
What additional issues do we need to address?	**CAD folks needs to be involved in the standards process** **CAD architecture needs to be more open for addressing metrology issues**	**Representation within the MAA is important from this community**
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	**Web-enabled implementations ?** **Information availability maybe useful, but accessing and manipulating controller specifications, etc. would not be accessible** **Ethernet ?**	

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?

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

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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 permenant 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 similiarities 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 envolve

Discussion of drawing:

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

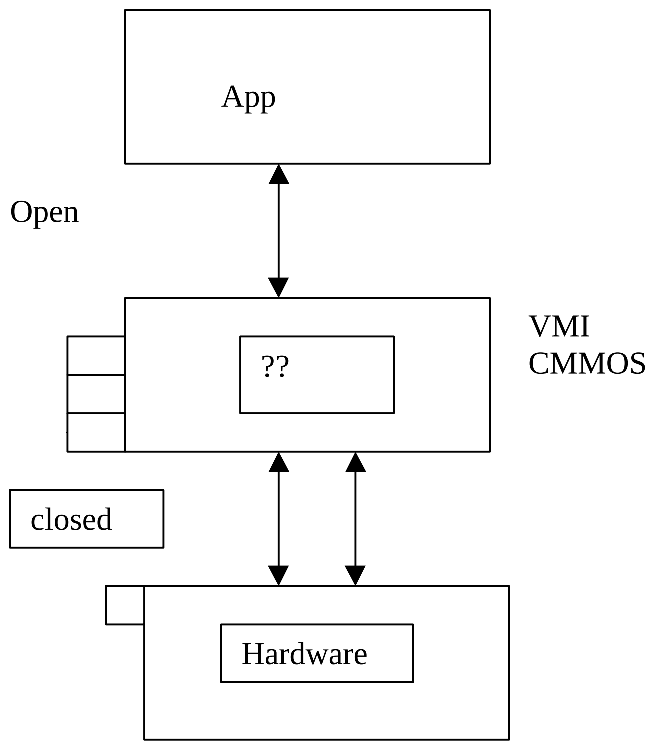
Metrology system would give you certain information, but ….

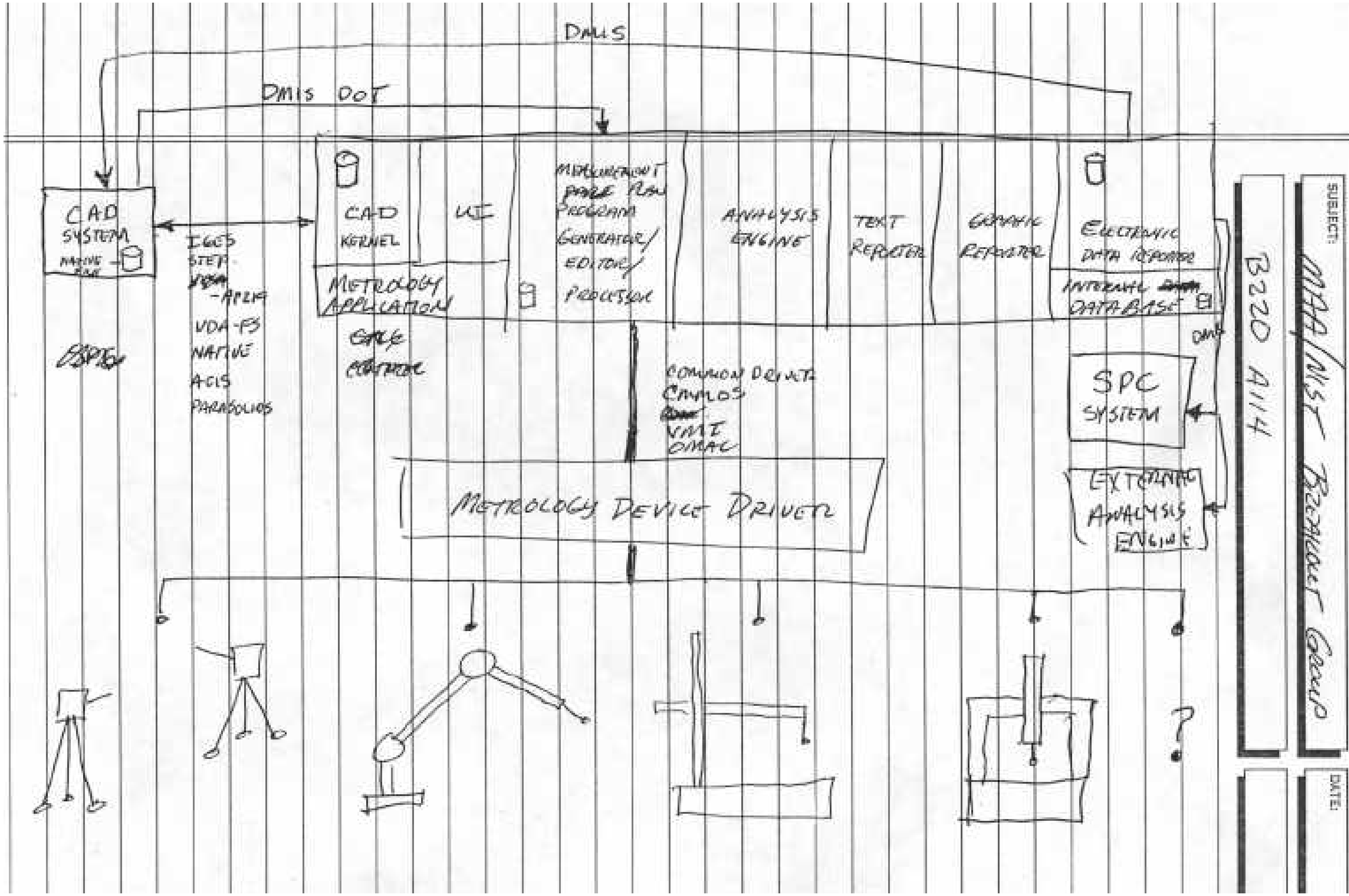
Start with high level meanings – Design, manufacture, inspect, etc…then break it down to smaller components to describe the activities that are taking place.

Defining "?" –

"App" is the communication app, not the actual app

Diagram is drawn.


App
Open
VMI
CMMOS
??
closed
Hardware


DMIS
DMIS OUT
CAD SYSTEM
NATIVE
IGES
STEP
-AP214
VDA-FS
NATIVE
ACIS
PARASOLIDS
CAD KERNEL
UI
METROLOGY APPLICATION
MEASUREMENT PLAN PROGRAM GENERATOR/ EDITOR/ PROCESSOR
ANALYSIS ENGINE
TEXT REPORTER
GRAPHIC REPORTER
ELECTRONIC DATA REPORTER
INTERNAL DATABASE
DMIS
SPC SYSTEM
COMMON DRIVER
CAMIOS
VMI
OMAC
METROLOGY DEVICE DRIVER
EXTERNAL ANALYSIS ENGINE
?
SUBJECT: NAA/NIST BREAKOUT GROUP
B220 A114
DATE:

Open Architecture for Metrology Automation Workshop

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 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 systems' robustness, accuracy, interfaceablity, 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.

  NIST 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, interfaceablity, graphical interface, and compatibility and integration.