# Increasing Throughput and Accuracy in Mass Metrology Through Systematic Automation

**National Bureau of Standards, USA**
**Early 20th Century**

**NIST, USA**
**Early 21st Century**

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

**Metrology for Digital Transformation**
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**Patrick Abbott**
**NIST, USA**

# Outline

I. Introduction
II. Defining the Challenge
III. Planning a Solution
IV. Coding the Solution
V. Assessing Progress
VI. Planning the Future

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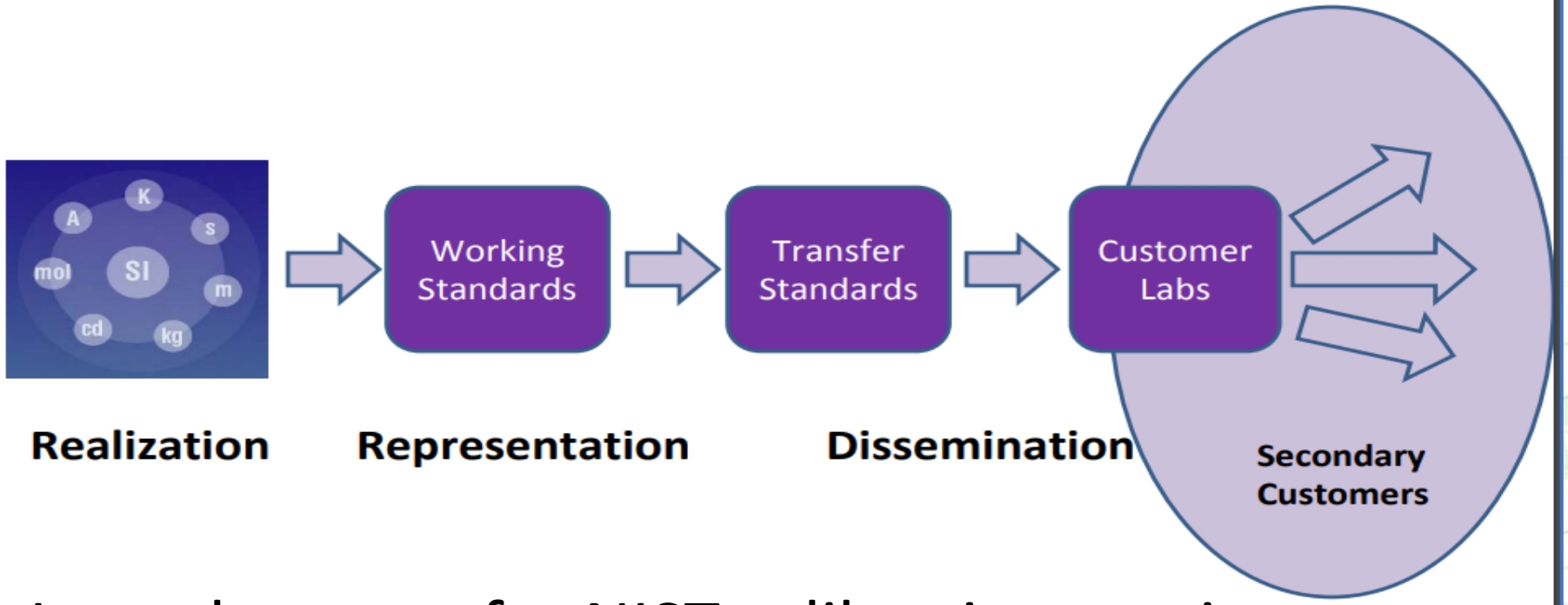
# Introduction: Goals of Automation

- Improve throughput of calibration items (1 mg to 50 kg)
- "Standardize" the software platform in use
- Eliminate human data editing (and mistakes)
- Make calibration systems remotely accessible
- Storage of all data in an electronic database
- Prepare for Digital Calibration Report generation

# Introduction: Traceability




Large leverage for NIST calibration services

Automation must not compromise quality!

# Introduction: Mass Metrology at NIST

- Calibration range: 1 mg to ~27,000 kg
- Serve secondary labs from States, Military, Pharma, Private Industry
- Income generated ~$150 k/year
- 11 Automatic Mass Comparators  from 1 mg to 64 kg
  - Six 4-position and Two 6-position carousels
  - Three ‘robotic’ comparators, 5 g, 100 g, 1000 g
    - 5 g: Magazine with 36 positions
    - 100 g: Magazine with 30 positions
    - 1000 g: Magazine with 18 positions

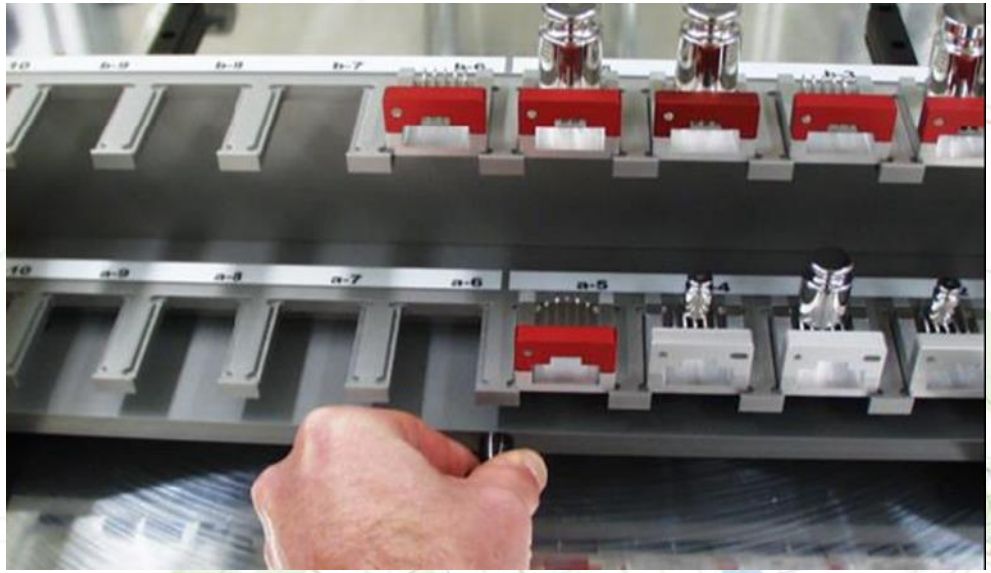


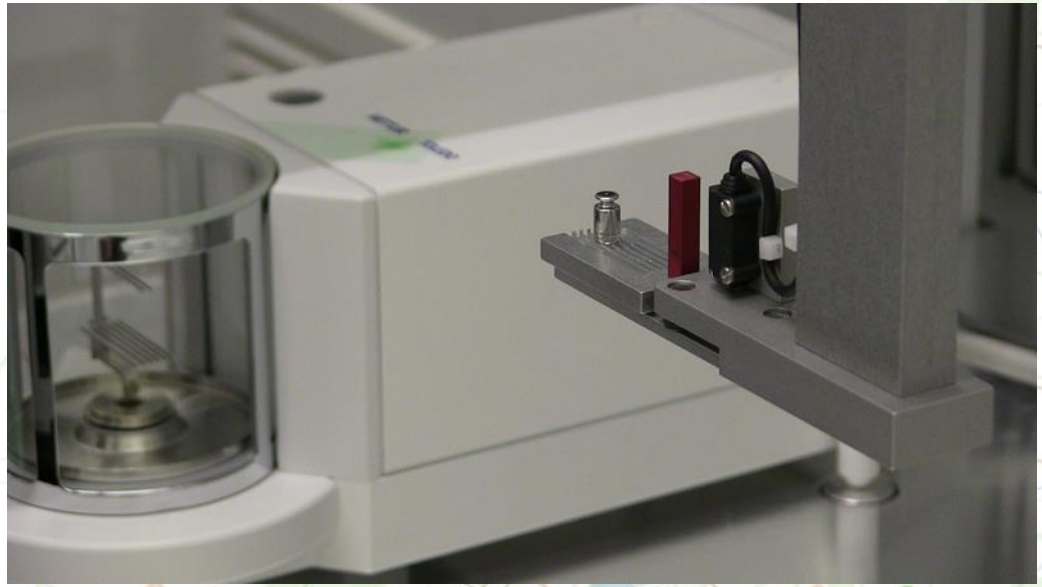


Photo Credit: Mettler-Toledo

# Introduction: Automated Mass Comparators

An instrument that can select single or multiple weights to be compared in a predefined sequence. The gathered data consist of mass differences between standard and test weights; the differences are used to determine the masses of the test weights. Temperature, air pressure, and relative humidity data are also collected.

4-Position Carousel



Robotic Comparator

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Photo Credit: Mettler-Toledo

# Introduction: Collecting Data

| Day | Time | Meas. ID | Weight Position | Raw Reading (mg) | Difference | Pressure (kPa) | Humidity (%) | Thermometer (ohms) |
|---|---|---|---|---|---|---|---|---|
| 26 | 18:34:41 | 010101A | a2 | 2000.025 | | 100.1171 | 41.25 | 4572.831 |
| 26 | 18:36:04 | 010101B | a11 | 2000 | | 100.1184 | 41.23 | 4573.639 |
| 26 | 18:37:26 | 010101B | a11 | 2000.001 | | 100.1224 | 41.18 | 4572.91 |
| 26 | 18:38:50 | 010101A | a2 | 2000.025 | -0.02464 | 100.1246 | 41.18 | 4572.72 |

- This is one A-B-B-A comparison!
- A simple weighing design requires SIX A-B-B-A comparisons using four weights
- A complicated comparison may have 8 or more weights with multiple weights used in each comparison!
- Each Mass Comparator has its own set of calibrated T, P, Rh sensors (and coefficients)
- Bottom Line: A large amount of data to collect, analyze, and control!

# Defining the Challenge

- Each comparator is a “stand-alone” instrument with a dedicated computer
- Difficult and time consuming for new staff to learn ☹
- No common software or platform for comparators
- Data files required extensive editing prior to analysis
- FORTRAN analysis program using DOS shell, one file at a time ☹
- Mass standards record keeping mostly in paper form or non-centralized spreadsheet
- Difficult to document in NIST Quality System ☹
- Human editing created LOTS of opportunities for mistakes in final report ☹

# Planning a Solution

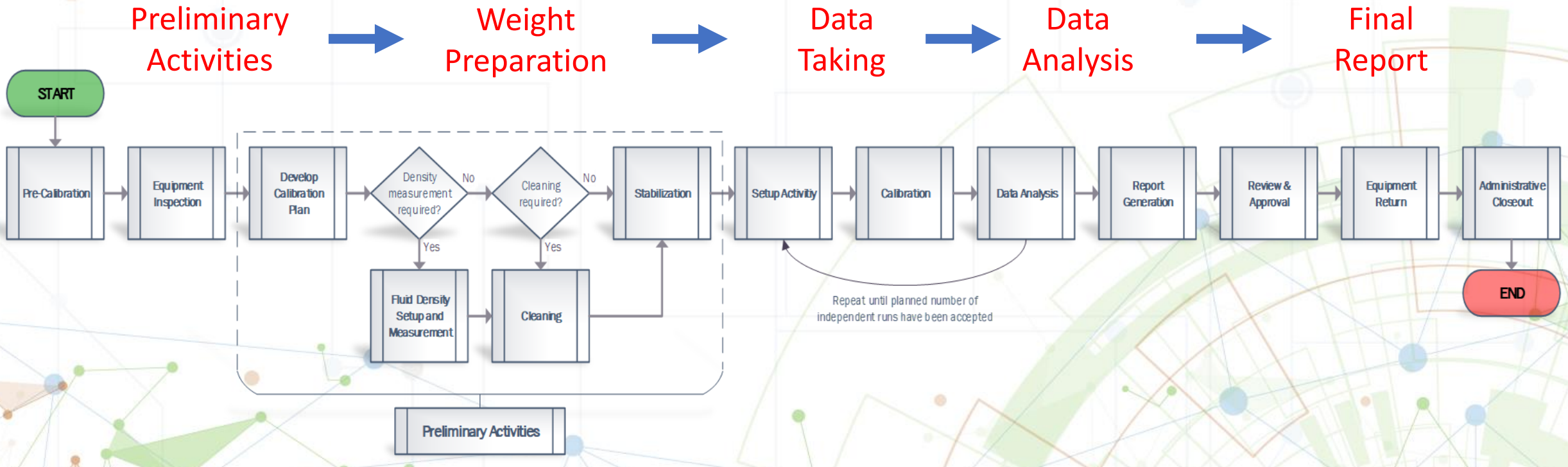
## Analyze entire measurement/analysis process from start to finish

- Identify steps that are common to all measurements
  (example: assigning weights to a weighing position)
- Identify processes that are unique to individual comparators
  (example: turntables vs. robots)
- Plan to give software a similar look and feel regardless of comparator
- Design a seamless route of information from set-up to presentation of results
- Minimize human interaction
- Design an electronic database that provides input parameters and stores results
- Provide ability to run any comparator from any on-site or remote computer
- KEEP IT SIMPLE!

# Planning a Solution

## Flowchart Showing Major Activities in Measurement Process

### Each Activity has its own detailed flowchart!

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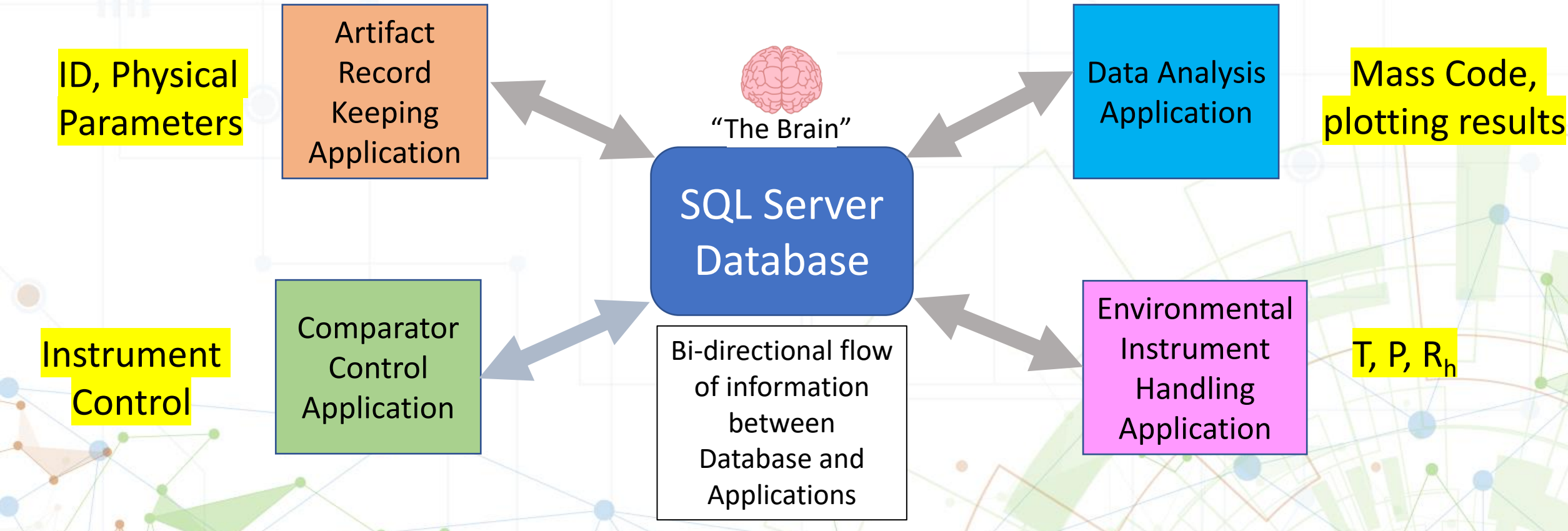
# Coding the Solution: Tools

- SQL Server Database
- LabVIEW Object-Oriented Programming
- NIST Professional Programmer & IT Specialist from Research Services Office
- Identical Workstations at each comparator
  - 64-bit Windows 10 platform
  - Laptop Computer, docking station, 61-cm display

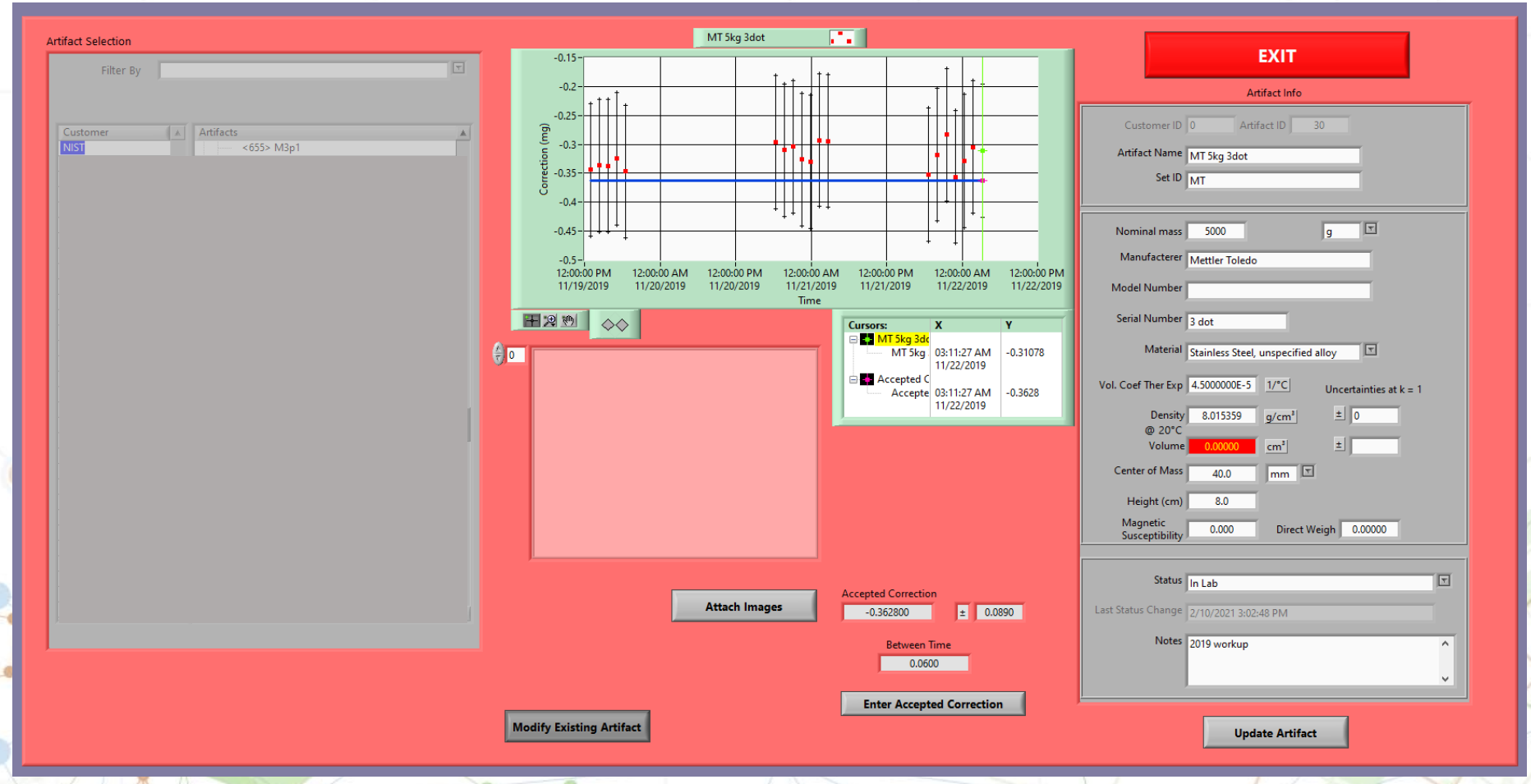


# Coding the Solution

## Custom Software Suite



# Coding the Solution: Artifact Database




## Database Contents

- NIST Standards
- Customer Artifacts
- History plots
- Artifact physical parameters
- Status
- Accepted Corrections

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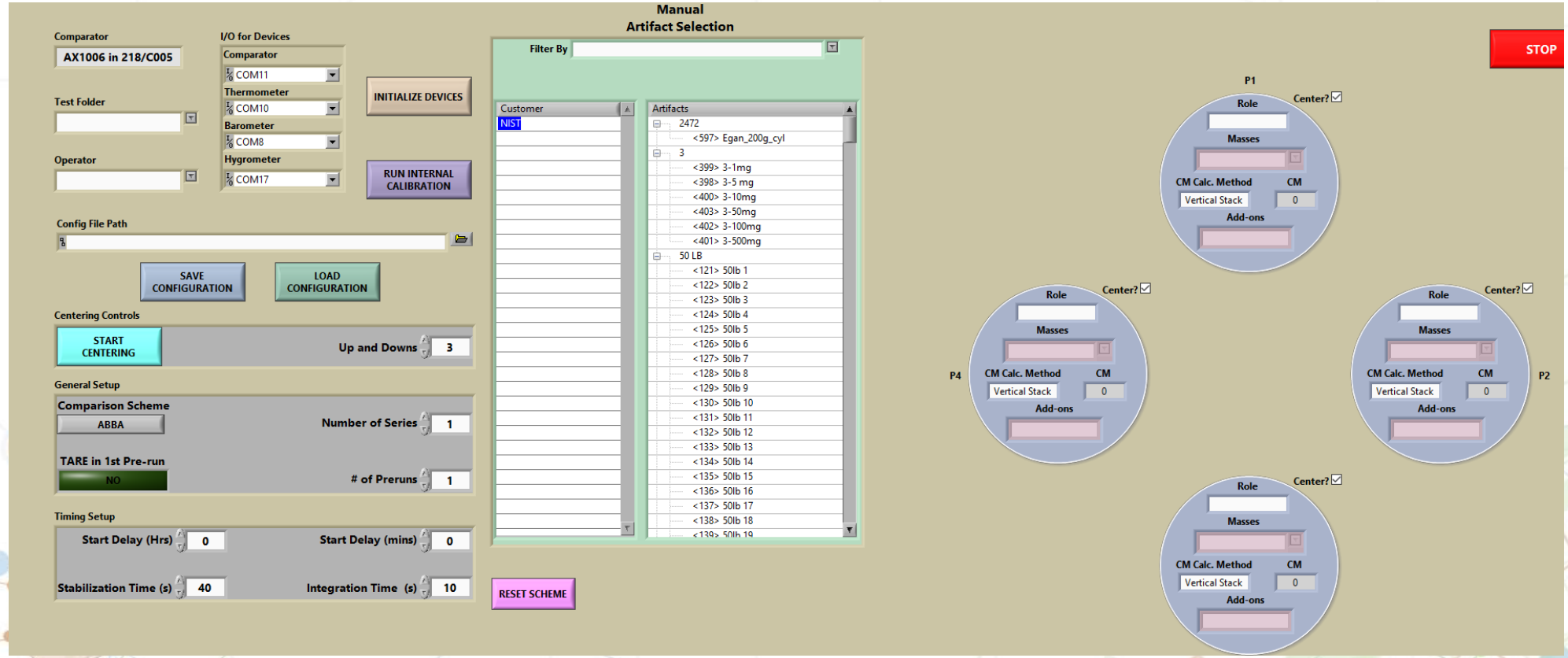
All information is shared within the Software Suite of Applications

# Coding the Solution

## Comparator Set-up

## Weight Selection

## Position Assignment




## Set-Up

- Comparator ID
- Test Folder ID
- Operator ID
- I/0 addresses
- Drag and Drop Positioning from Weight database
- All aspects of weight comparison
- Comparison Scheme
- Number of Series

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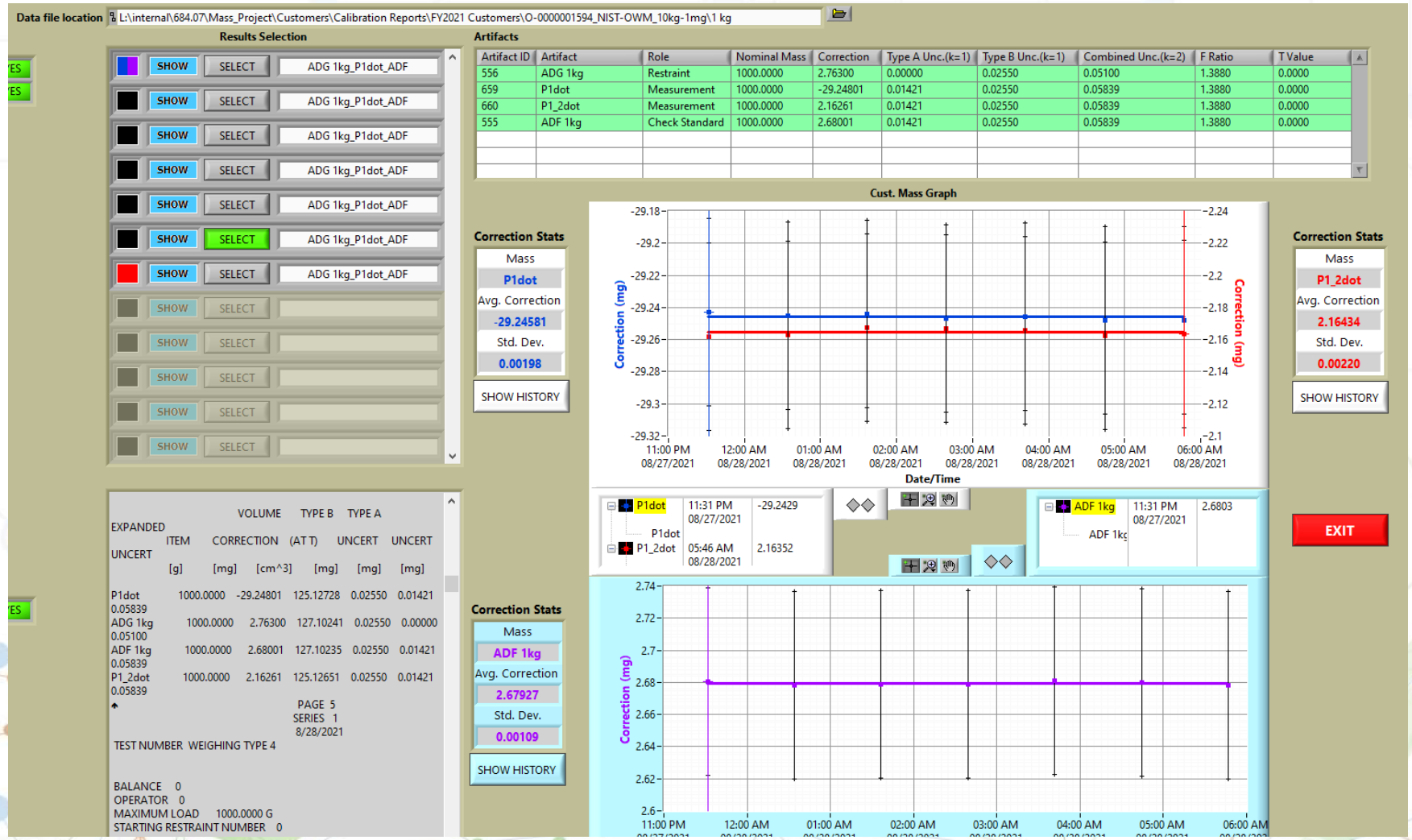
Selections are menu-driven
Weight positions are populated by “Drag and Drop”

# Coding the Solution




## Analysis Summary

- Mass code is called to run on all data files; very fast
- Calculated mass & uncertainty
- Statistics
- Unknown and Chk. Std. Plots
- Ability to remove data point

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# Assessing Progress

- Eight of Eleven Comparators running the new software suite (robotic comparators software currently being updated)
- Multiple comparators can operate and simultaneously interact with the SQL Database
- Email message sent to user when data taking is finished or if an error is encountered
- All NIST standard masses between 1 mg and 50 kg entered in SQL Server database
- Data on a given comparator can now be analyzed and plotted in less than two minutes. Previously took 1 – 2 hours!
- All datafiles timestamped and saved to individual calibration folders for quick review
- Documents (notes, photos) can be uploaded to database for particular folders
- Throughput and staff efficiency increased
- Errors due to manual data transfer eliminated

# Planning the Future

- Finish robotic comparator software
- Add report creation/routing to analysis application
- Long-term statistics on mass standards mined from SQL database
- Environmental instrument calibration reminders
- Inclusion of density measurements
- Ability to gather and enter data from non-automated comparators
- Digital Report handling capability (XML)?

Robotic Mass Comparator

Extensible Markup Language (XML) is a platform-independent subset of Standard Generalized Markup Language (SGML) that you can use to store and exchange information.

# Giving Thanks

Greg Cala
NIST Laboratory Automation Team Leader

John Quintavalle
NIST IT Specialist