Engineering Research Center for

Reconfigurable Manufacturing Systems

Improving Factory Operation Through Automated Event-Based Control

Technical Advisory Committee Meeting

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January 14th, 2009

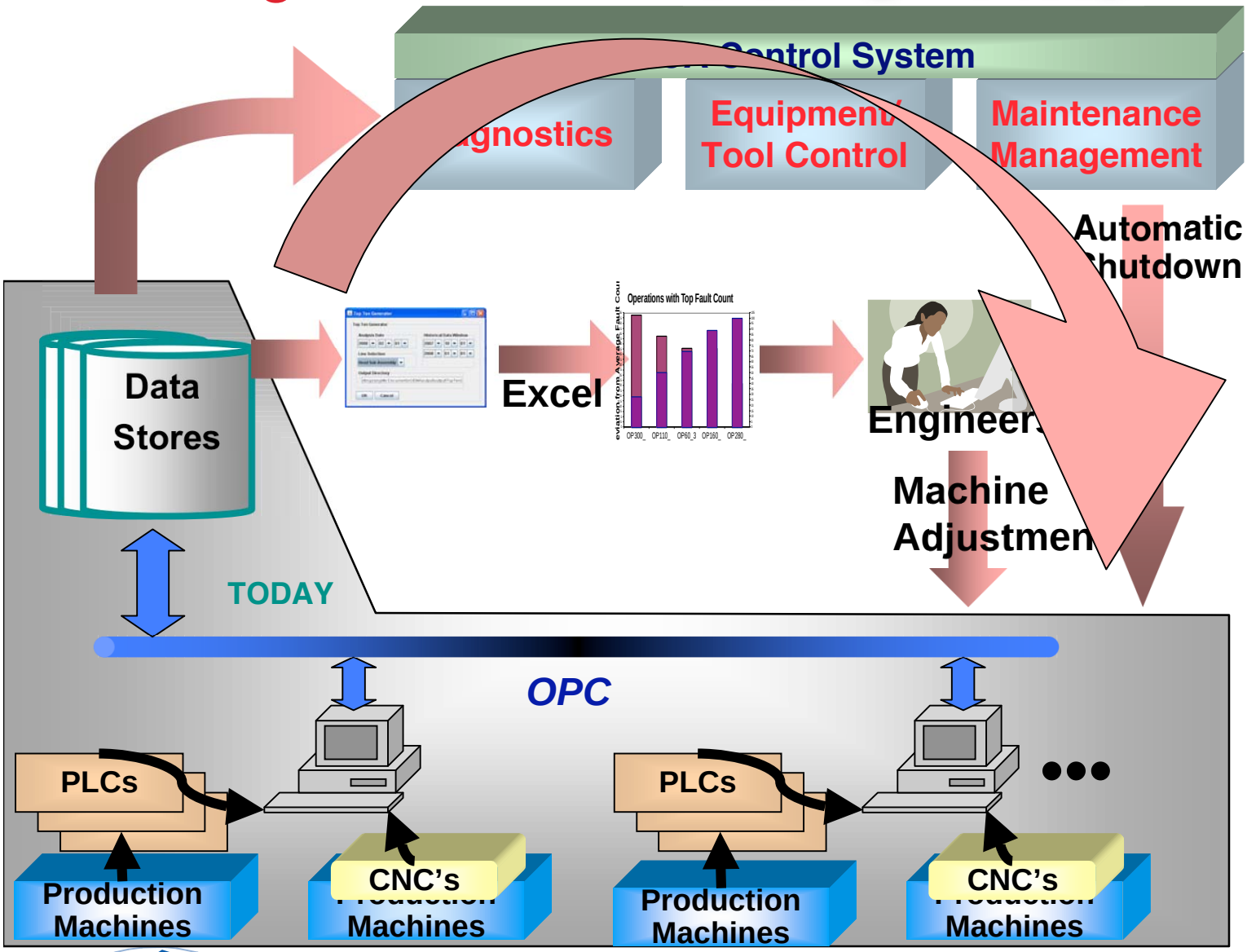
New Result Since March 2008

Objectives

- **Overall Project Objective:** Deliver a **predictive and preventive maintenance** capability through ECA (Event Condition Action) rule based control
- **Intermediate Objectives:** Predict and reduce unscheduled downtime
  - Provide solutions for auto correlation of data sets including test stand and fault data.
  - Identify gaps in plant-floor systems with regards to maintenance and quality issues.
  - **Improve data quality of plant floor systems**
  - **Explore pattern recognition methods for improvement of maintenance scheduling.**
- **Continuous:** Provide and help implement **best practices in plant-floor data management for improvement in maintenance management and downtime prediction.**

The Big Picture

Closing the Loop



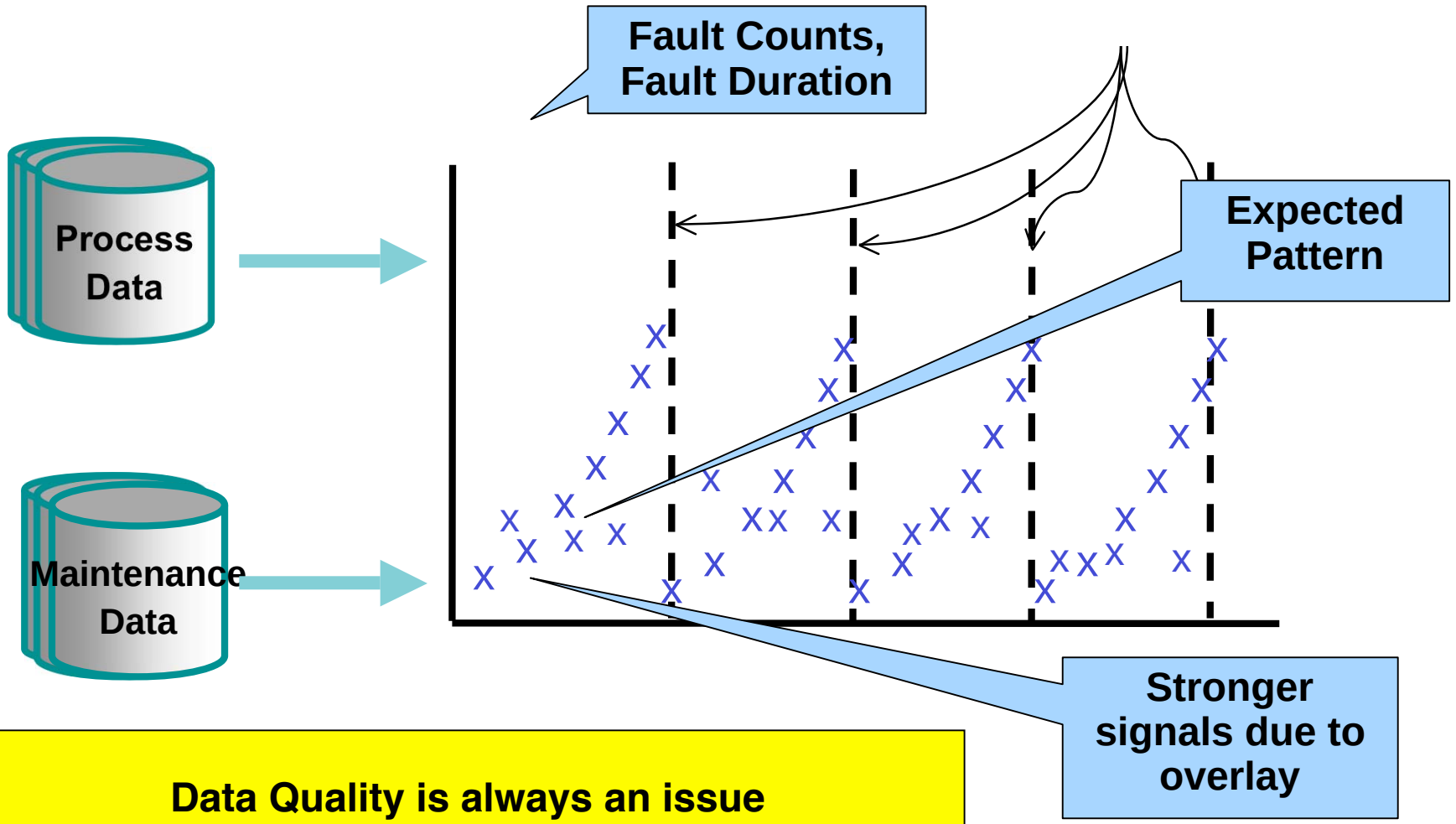
BENEFITS

- **Reduced Unscheduled Downtime**
- **Reduced Scrap**
- **Reduced MTTR**
- **Improved Productivity**

Deliverables Completed

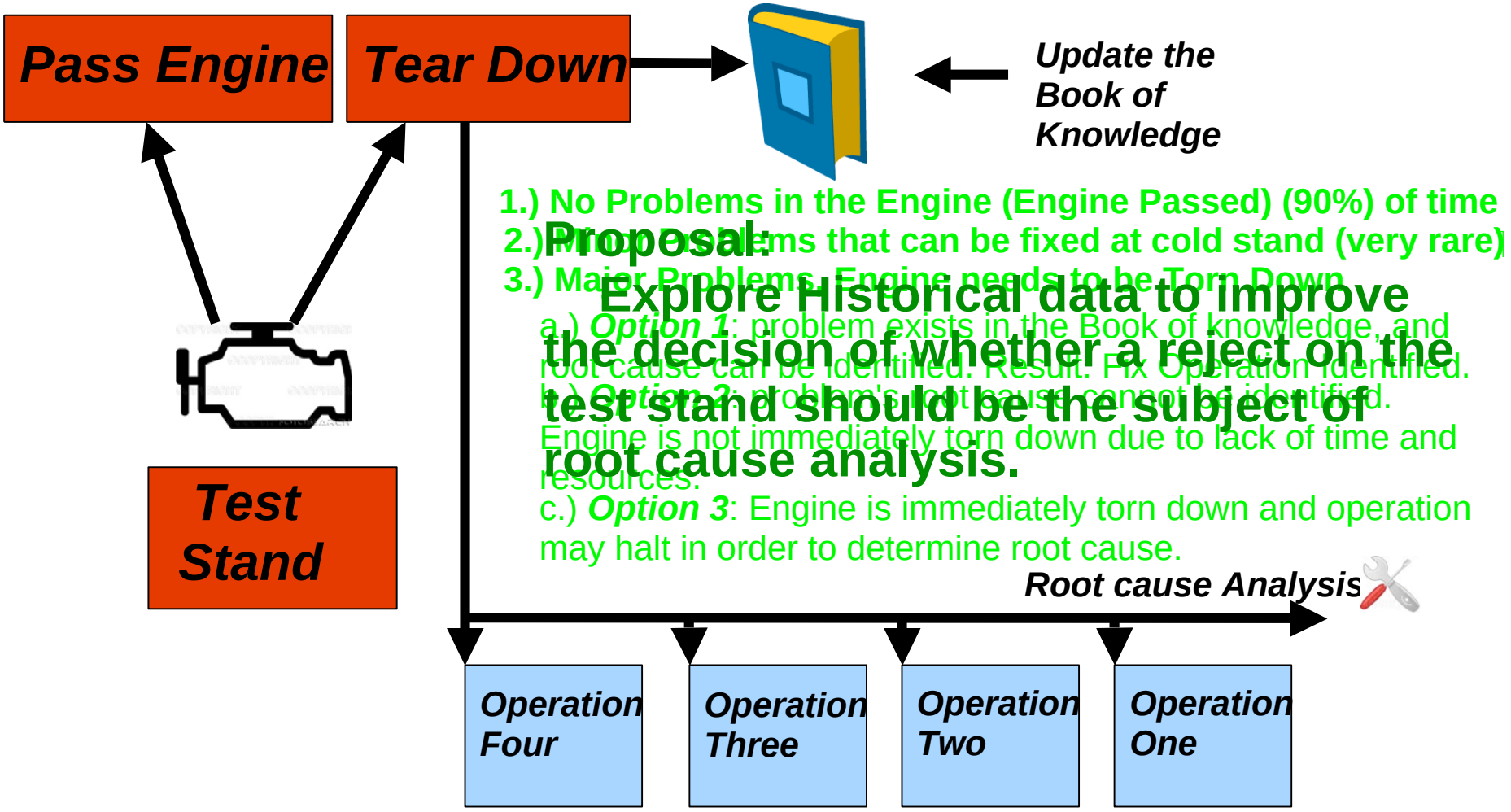
- **Top Ten anomalies software** Identifies "interesting" events / anomalies in process data
- **MATLAB analysis module** for maintenance event correlation
  1. Installed at GEMA, validated and available for use
  2. Provides for automated drill-down tool for maintenance investigation
  3. C++ code auto-generated from MATLAB source ➔ no MATLAB license required
- **Methodologies** to standardize data collection
- **Audited** machine automation, maintenance and repair, quality and tool change data management systems
  - Outline of Day in the Life of Test Stand.
  - Developed a UML Outline and Recommended Data Layout
  - Iteration with GEMA as part of a continuous improvement process
- **Best practices** for improving maintenance mgmt. & data quality
  - Closing codes, Maintenance pooling, etc.
  - Comparing maintenance practices to documented maintenance requirements
  - Iteration with GEMA as part of a continuous improvement process

Using Event Data to Predict Downtime



Data Quality is always an issue
Need multiple techniques to improve

Cold Test Stand Analysis

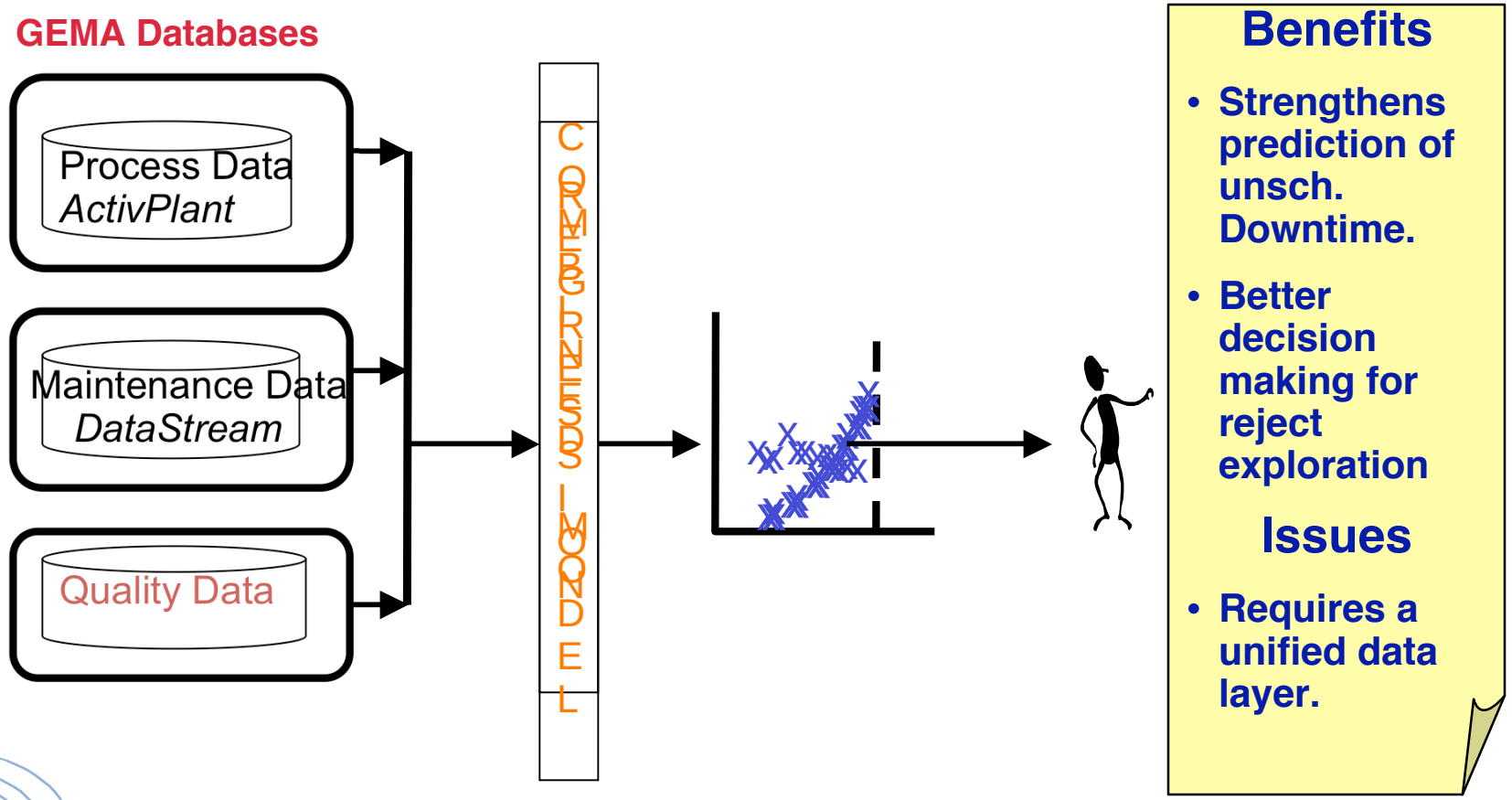


Proposal:

Explore Historical data to improve the decision of whether a reject on the test stand should be the subject of root cause analysis.

Test Stand Data and Downtime Reduction

Another application of reject data can be to increase the accuracy of regression analysis done to predict downtimes. The continuous data from the test stand can strengthen predictions for unscheduled downtimes. This requires a unified data layer that can track a part through the system.



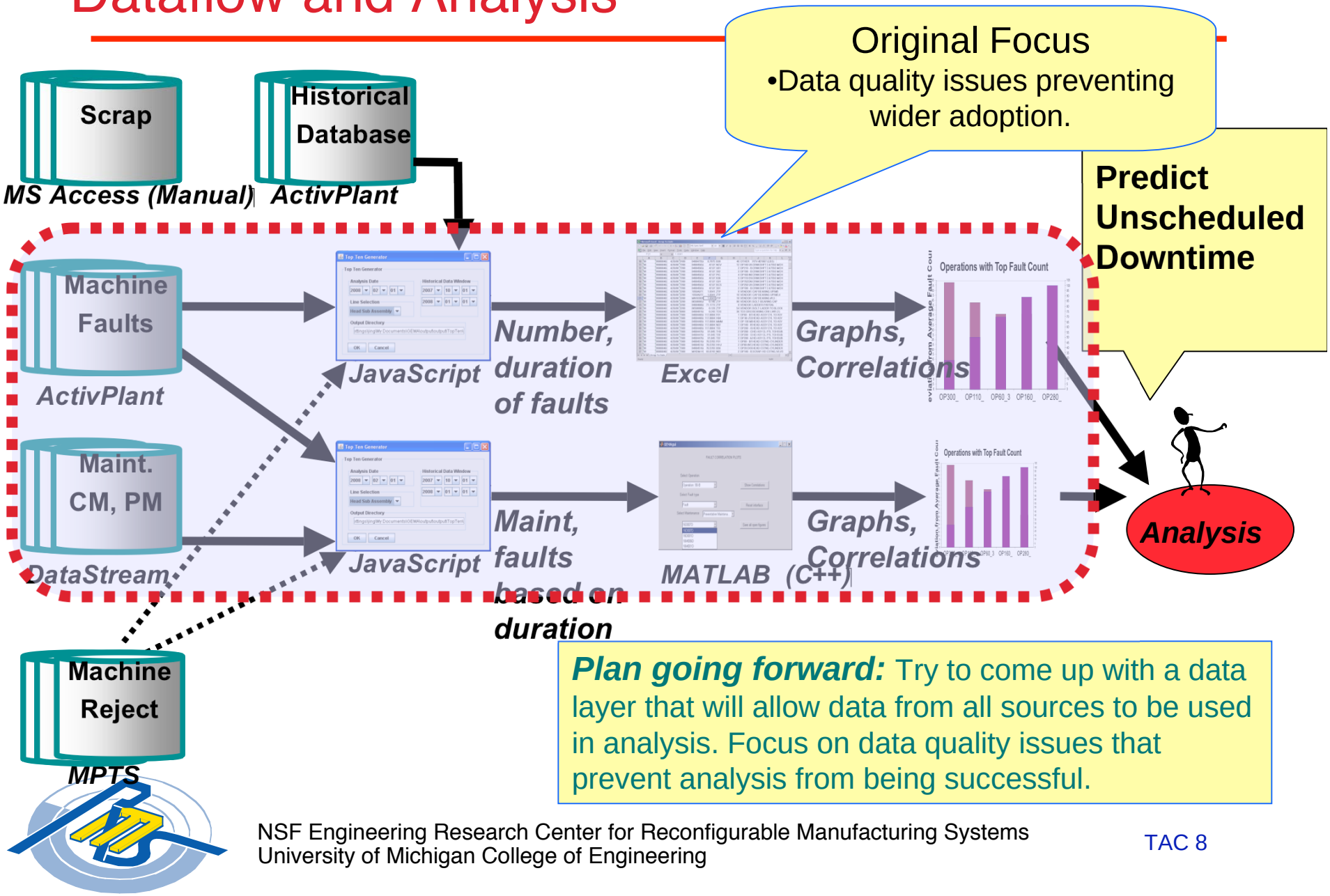
Benefits

- Strengthens prediction of unsch. Downtime.
- Better decision making for reject exploration

Issues

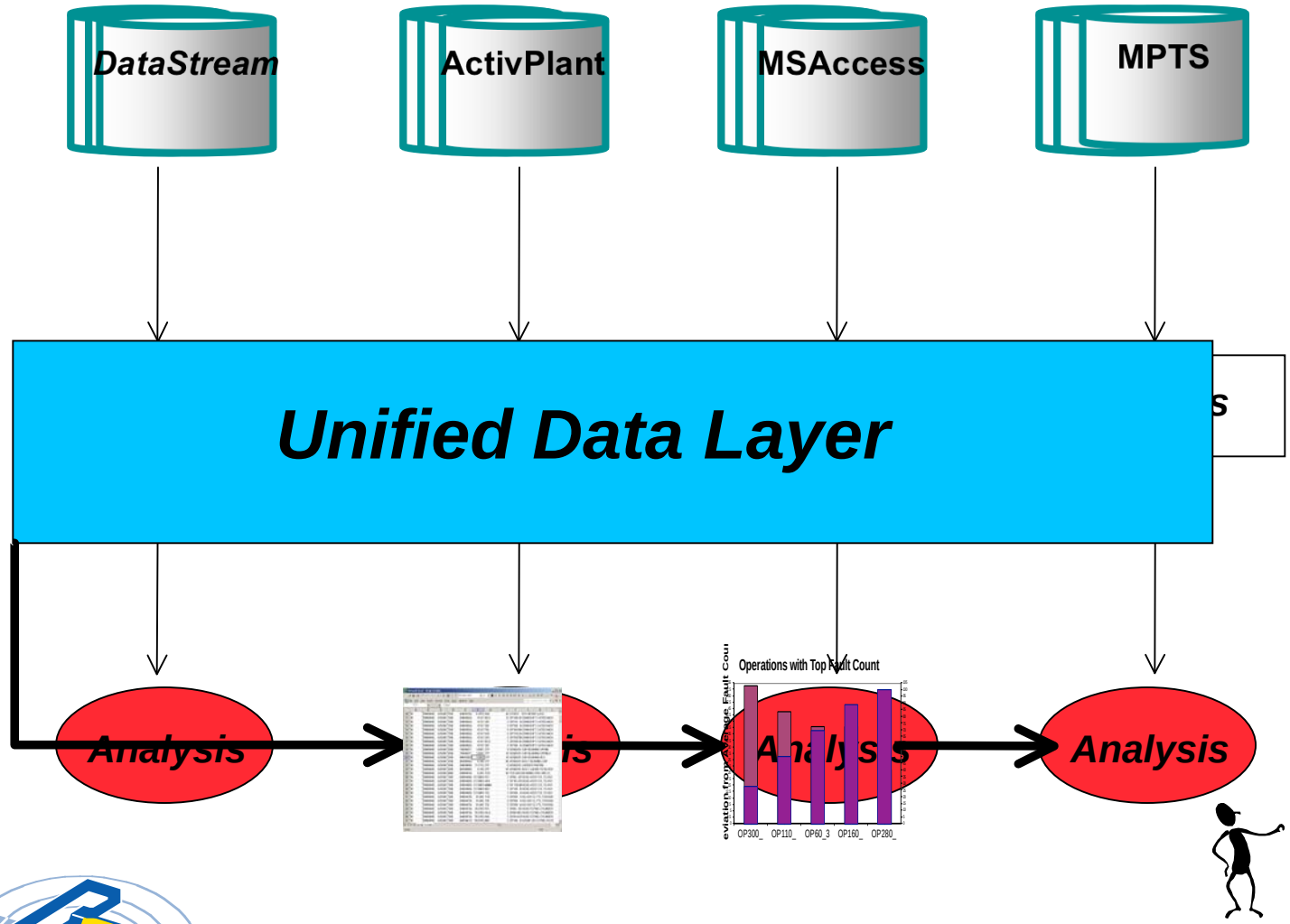
- Requires a unified data layer.

Dataflow and Analysis



Plan going forward: Try to come up with a data layer that will allow data from all sources to be used in analysis. Focus on data quality issues that prevent analysis from being successful.

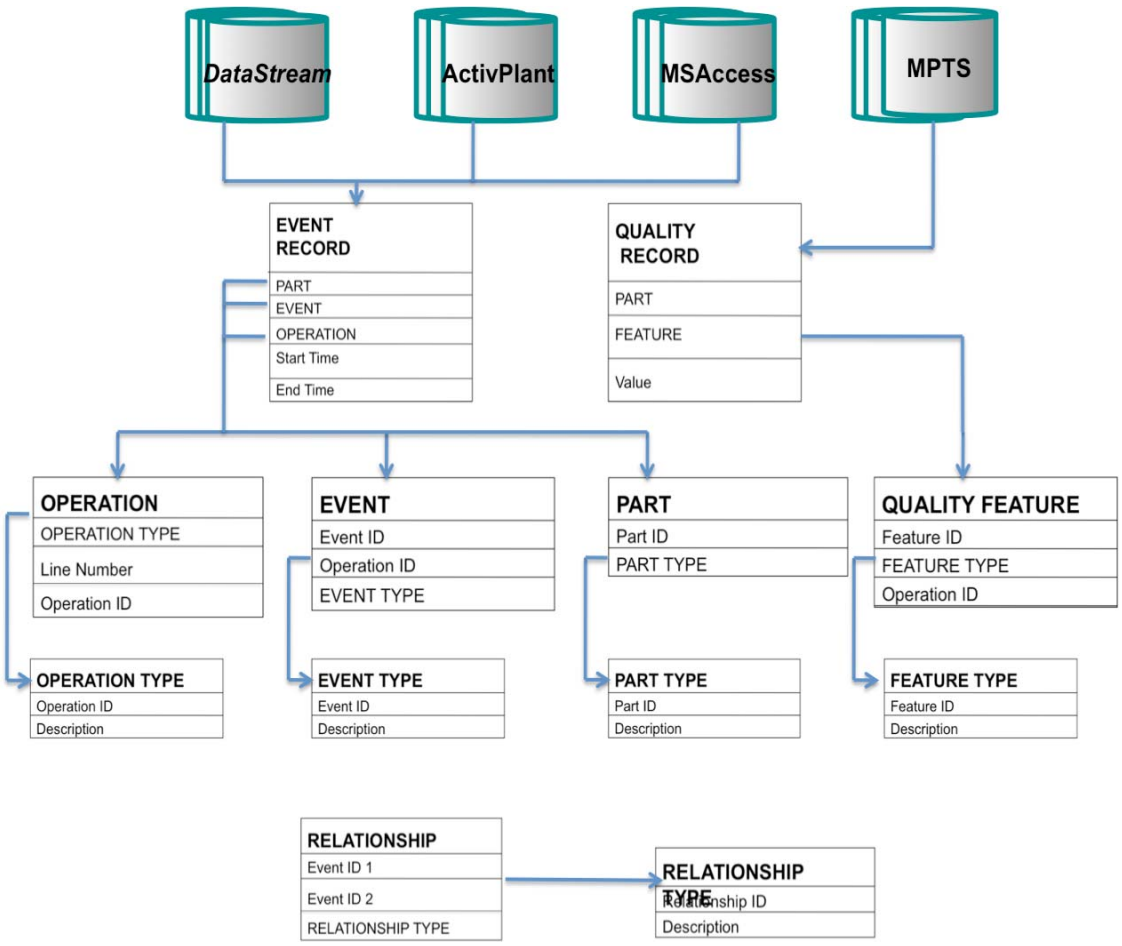
Data Consolidation



Unified Model

- Data can be accessed universally
- Data quality improved
- Data errors easy to address.

UML DATA LAYER (Proposed)



BENEFITS

- **Allows for a more comprehensive visualisation and understanding of factory data.**
- **Facilitates correlation analysis across many variables**
- **Allows "islands of automation" to be focused on the same factory objectives**

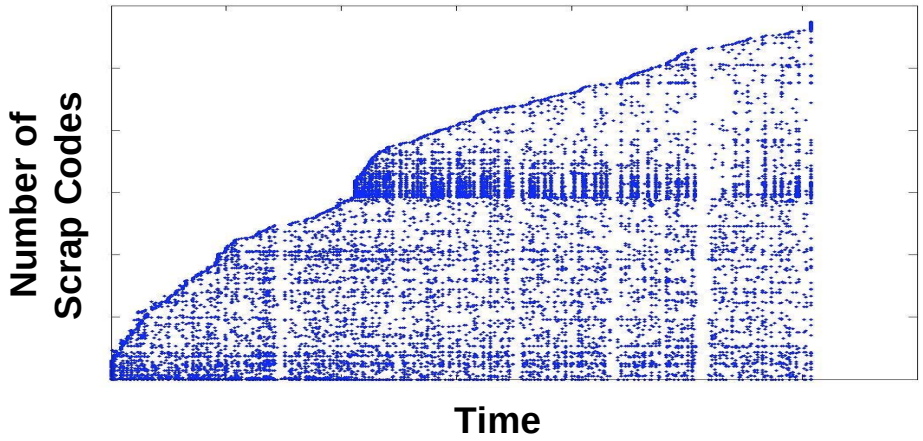
ISSUE

- **The large issues with data quality is a major obstacle to unification.**

Examples of Data Quality Issues Encountered

- System collects only a subset of the data generated from the PLCs. There is often not enough information to identify strong correlations to support control.
- Historical Data is limited, making larger trends and behaviour difficult to identify.
- Maintenance records have missing data.
- Insufficient standardisation of data, manually entered data unsuitable for computerised analysis.
- Scrap code definition process results in unbounded growth of codes ➔ nearly useless for correlation analysis

Ad-hoc scrap code creation



Samples of Recommendations for Improving Data Quality

- **Modular and Hierarchical "Reason Code" Scheme**
  - Incorporate an ID system for maintenance to help record keeping and reduce redundancy
  - E.g., Maintenance and scrap databases
- **System Wide Data Unification**
  - Create a factory meta-data layer for access, analysis and drill-down
  - Create a unified labelling system so that a part can be tracked through the system.
- **Extended Access to Historical Data**
  - Build in a mechanism for access to large vectors of archived data.
- **"Deep" Analysis Of Key Operations**
  - Select a single operation within the system and analyse its behaviour over a long historical period to understand fault alarms and downtime behaviour
  - Use this process to better identify underlying data quality issues

Sample of Project Issues and Approaches

Issue	Approaches
Overly conservative maintenance practices	➢ Observe relationships between fault system data and unsch. Downtime. ➢ Work to implement system to allow managers to schedule maintenance with respect to factory conditions. ➢ Address data quality issues that prevent downtime prediction
Data quality issues	➢ Design unified data layer to increase the data sources available for analysis. ➢ Propose modularized identification of maintenance events ➢ Obtain and analyze historical data sources to strengthen analysis. ➢Introduce modular data entry as a way of controlling scrap codes. ➢Try to eliminate data filtering at a low level in order to maximize data quality.
Creating the Unified Data Layer	➢ Look for “Low Hanging Fruit”: e.g. low cost ways of improving modularity ➢ Interface with GEMA regarding implementation.
Root Cause Decision Analysis	➢ Collect historical data to analyze likely re-occurrence of undocumented rejects. ➢ Use data regarding cost of root causing vs. cost of reject to create an optimized rule for root determining benefit of examining root cause of reject. ➢Implement system to allow engineers to view history

Research Directions and Opportunities

- **Creation of Data Meta-Layer**
  - Data quality improvement, creation of behavioral models
- **Modeling Unscheduled Downtimes**
  - Simulated fault and downtime data to show that if correlations exist between fault and downtime, regression analysis can be used to predict unscheduled downtime
- **Data quality metrics, analysis and improvement techniques**
- **Data analysis and prediction techniques**
  - Principal component analysis, partial least squares across multiple factory metrics
  - Providing analysis and prediction in the face of low data quality
- **Developing Best practices**
  - Develop practices for increasing data accuracy and collection of factory information

Summary and Acknowledgements

- **Milestones**
  - **Ongoing contributions to best practices for maintenance management data collection and management**
  - **Mechanisms for identifying and addressing data quality issues**
  - **Correlation analysis of fault and downtime signals**
  - **Software and technology transfer to GEMA**

- Acknowledgements
  - We would like to thank the team at Global Engine for access to their facilities and the help they provided.
  - Special thanks to Jeffrey Dobski, Gary Majhail for their help in accessing and understanding the plant data

Milestones and Future Plans