17th International Magnetic Measurement Workshop

Toward the Next Generation Magnetic Measurement System

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Barcelona, September 2011

Genesis

With Fermilab's conventional magnet measurement system approaching the end of its lifecycle, there arose a need to develop its replacement, a next generation measurement system.

Vision

In the concept of the next generation measurement system, the emphasis is on the **completeness** of the solution. It should capture the full lifecycle of the measurement, starting from entering test subject information, through configuring a required measurement, conducting the measurement, saving the results and raw data, and, finally, reviewing and analyzing these results. The system will be **extensible**, allowing for new measurements or analyses to be added, as well as new DAQ instruments and subsystems. The **automation** of measurements will be accomplished by scripting that will provide the necessary flexibility in changing measurement sequences.

Basic Functional Requirement

The system has to support the full lifecycle of testing.

Configure -> Measure -> Assess -> Publish Results -> Analyze Off-line

The use of the measurement system is typically a sequence of the following activities:

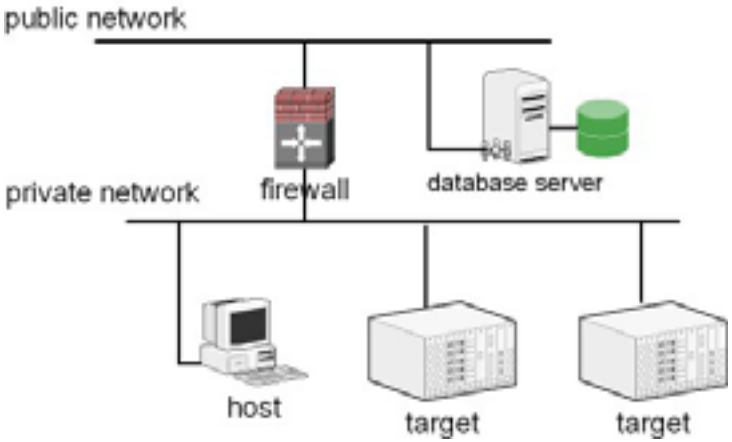
- Configuring the system and the subject
- Measuring/testing the subject and on-line analysis
- Registering the successful test and publishing the data
- Off-line analysis of results.

In addition, the system will include software to aid in debugging and maintaining DAQ hardware.

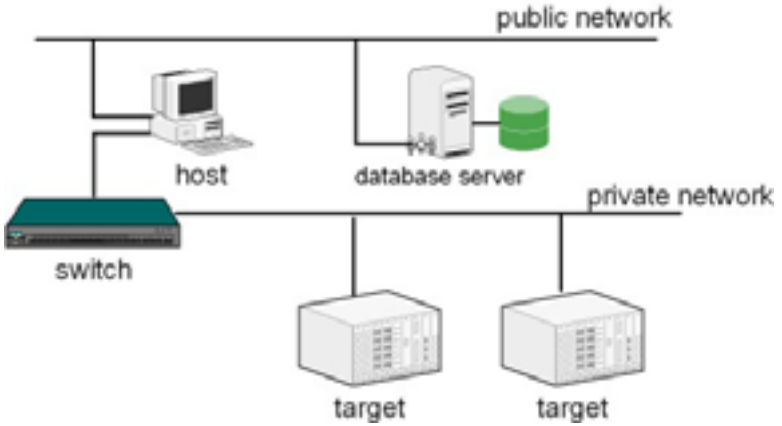
Hardware Architecture Requirements

- The system should work standalone (not connected to the network).
- The system should be operational when:
  - Connected to a public network
  - Connected to a private (isolated) network
- The system should support the following instrumentation interfaces:
  - PXI
  - NI CompactRIO
  - GPIB
  - LXI

Hardware Architecture

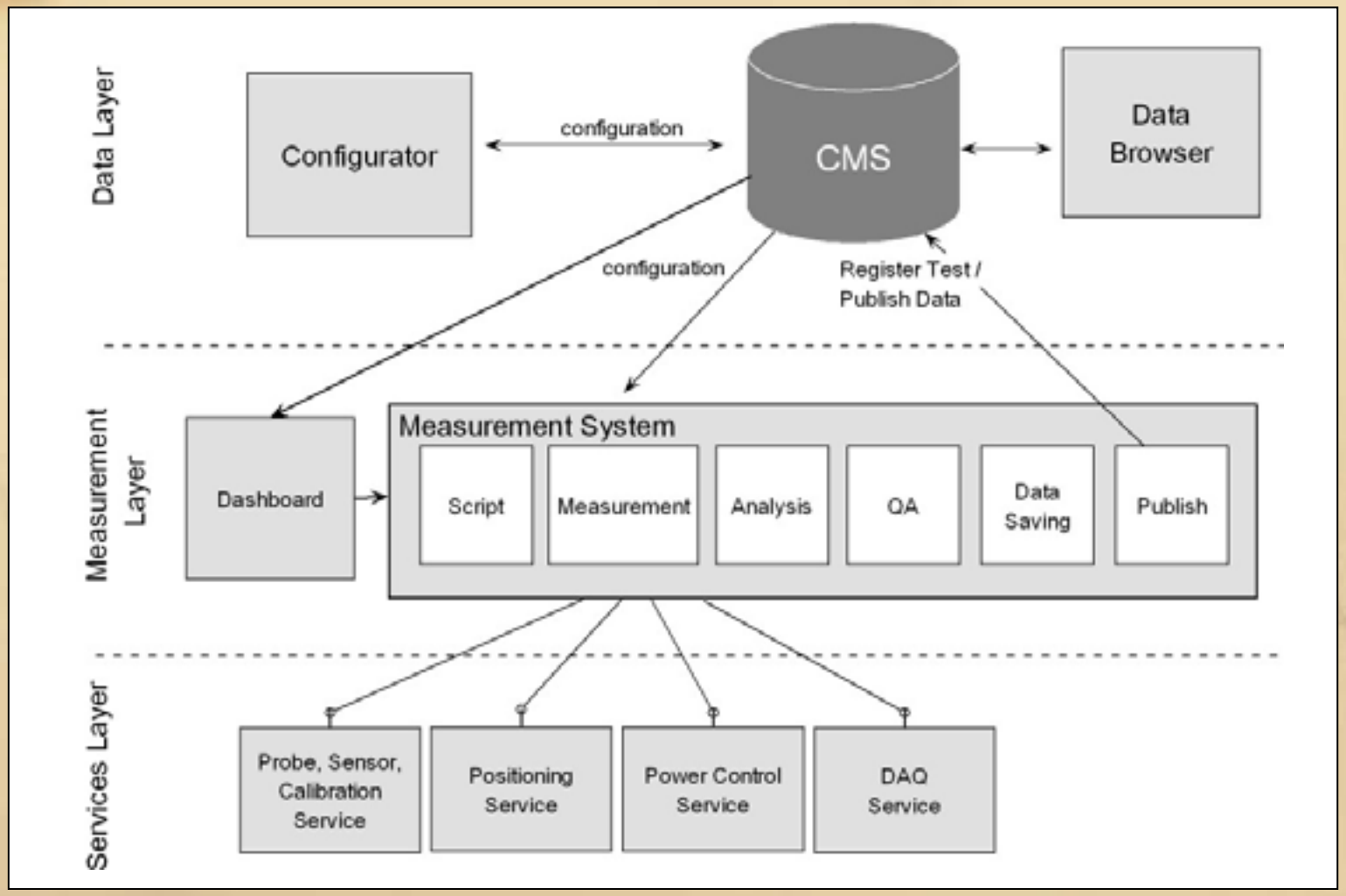


A configuration where host and targets are in the same protected subnet accessed via a firewall.



A configuration where host has two NICs and accesses its instrumentation on a private LAN.

Software Architecture



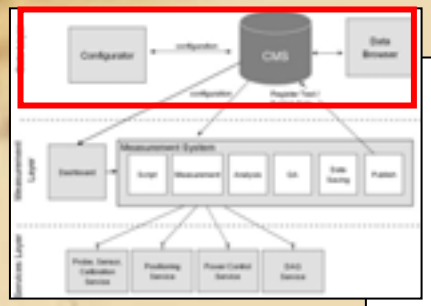
Major Architectural Components

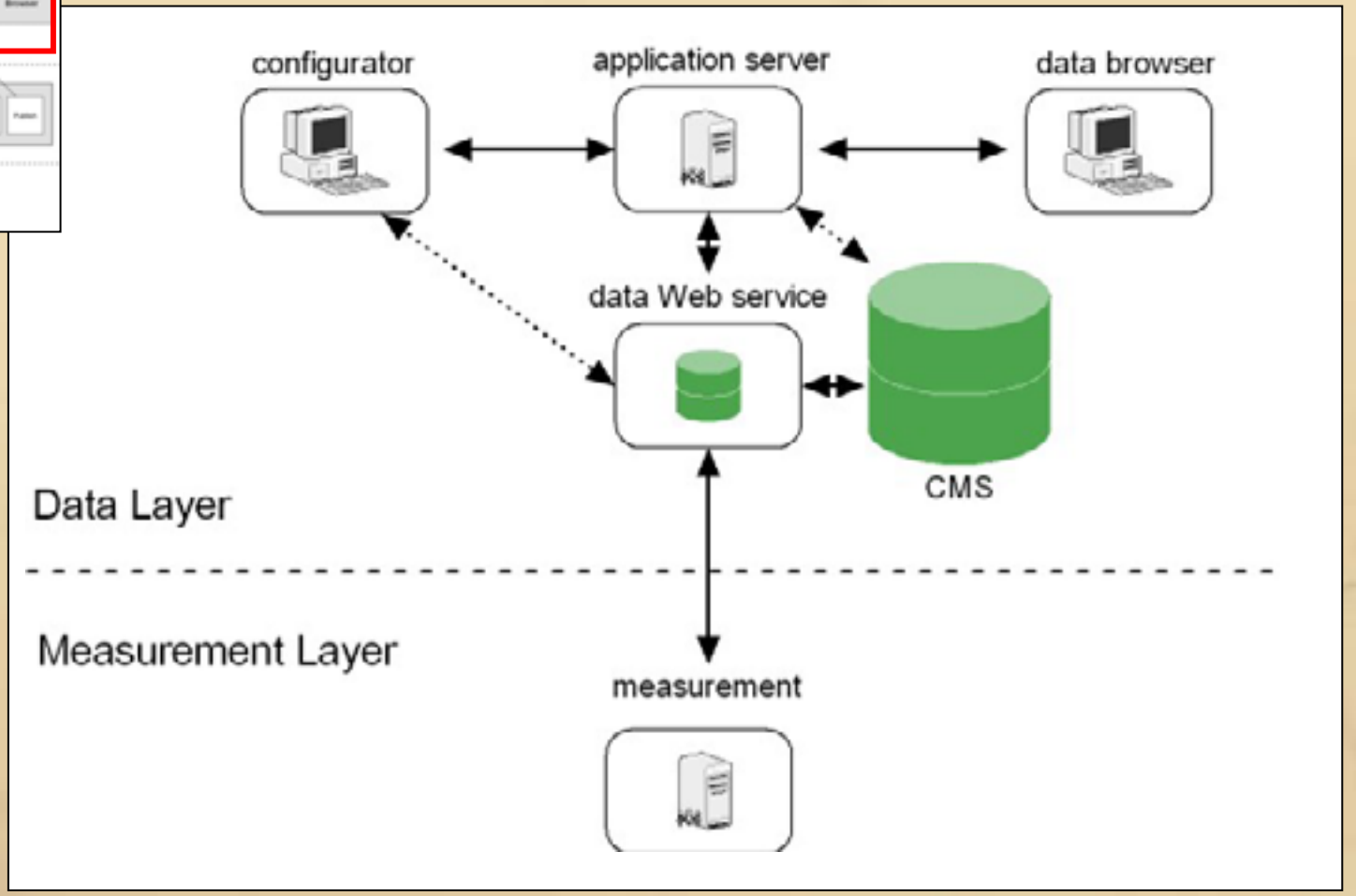
- **CMS** - a content management system, based on a relational database, which serves as a central repository for configuration, measurement results, and related documents.
- **Data Browser** – a Web application to be used by analysts and test coordinators to examine the progress of testing, peruse results, submit documents and comments, and obtain raw data for re-analysis.
- **Configurator** – a Web application to be used by test coordinators and operations personnel to prepare measurements, maintain hardware configuration information and create test configurations.
- **Dashboard** – software module to be used to run a selected script with a selected configuration.
- **Measurement System** – software implementing measurement algorithm, on-line analysis, QA, data saving and publishing.
- **Services** - separate sub-systems accessible via well-defined and standardized interfaces, including probe and sensor database sub-system, the power control sub-system and the probe positioning system.

Architecture Characteristics

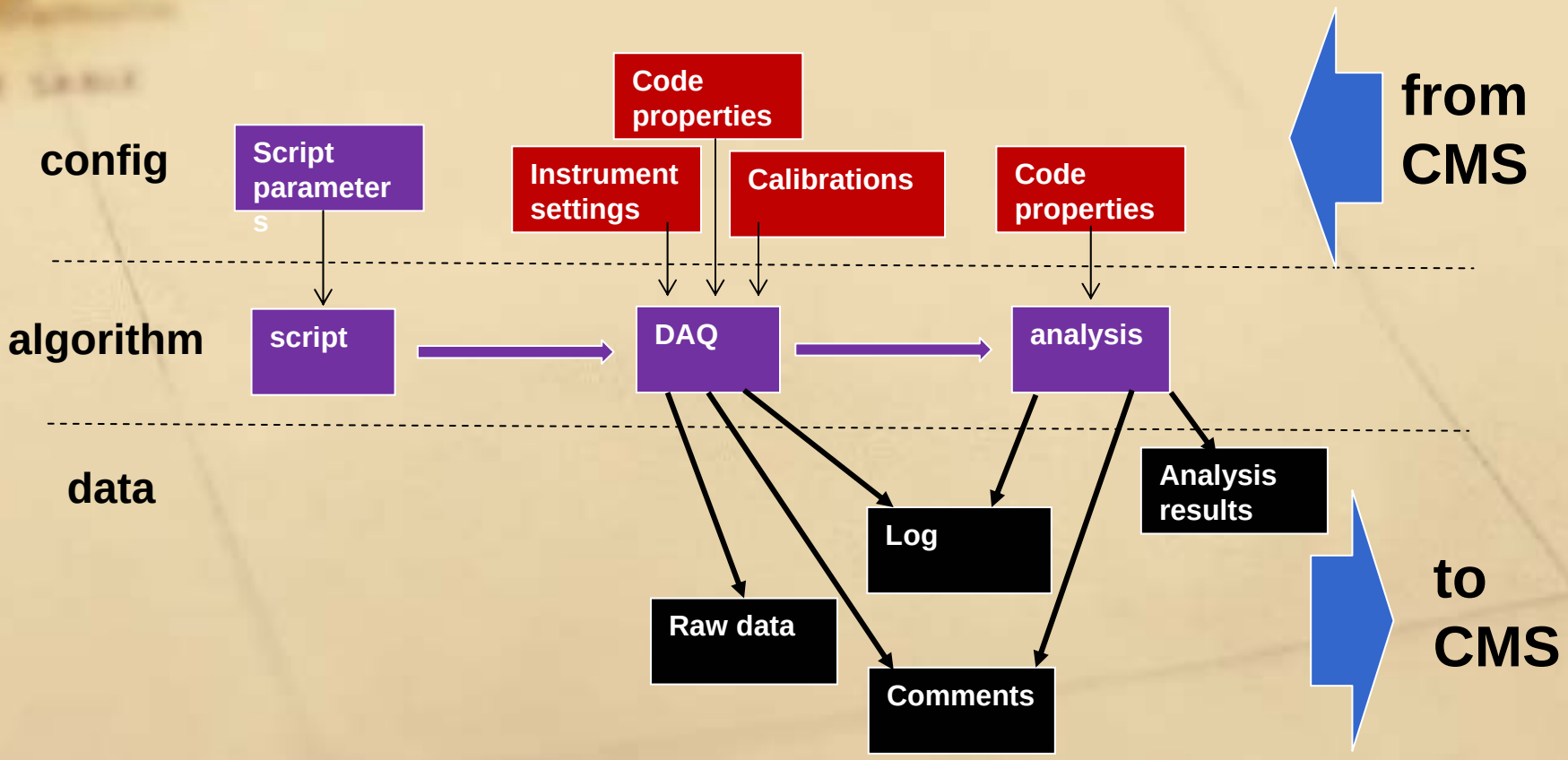
- The design is based on layers, which can be freely modified due to loose coupling between layers.
- The architecture includes data management and places the CMS, a central repository for configurations, measurement results and measurement-related documents, at the center of the design.

Data Layer




configurator
application server
data browser
data Web service
CMS
Data Layer
Measurement Layer
measurement

Measurement Data Flow

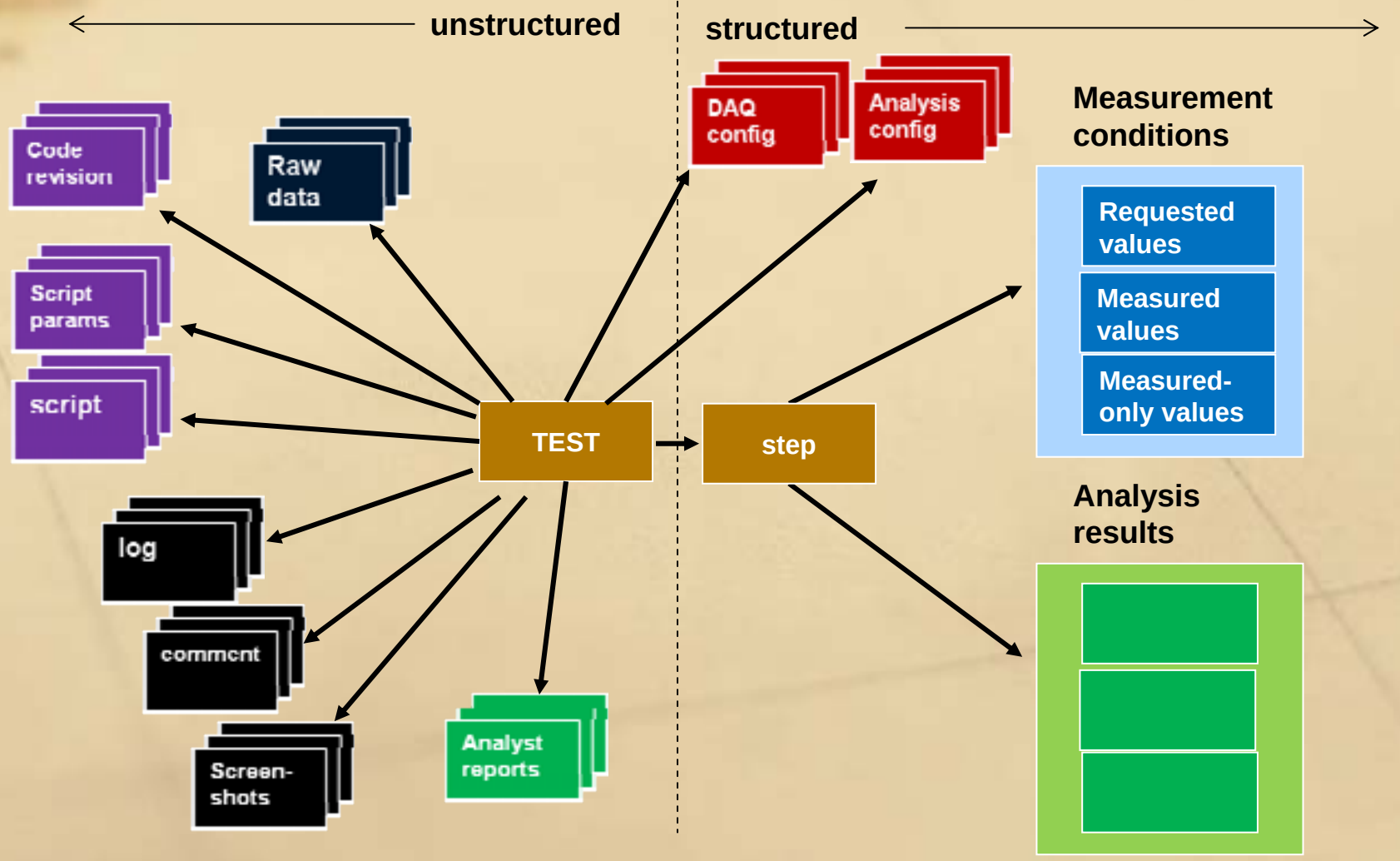


Structured and Unstructured Data

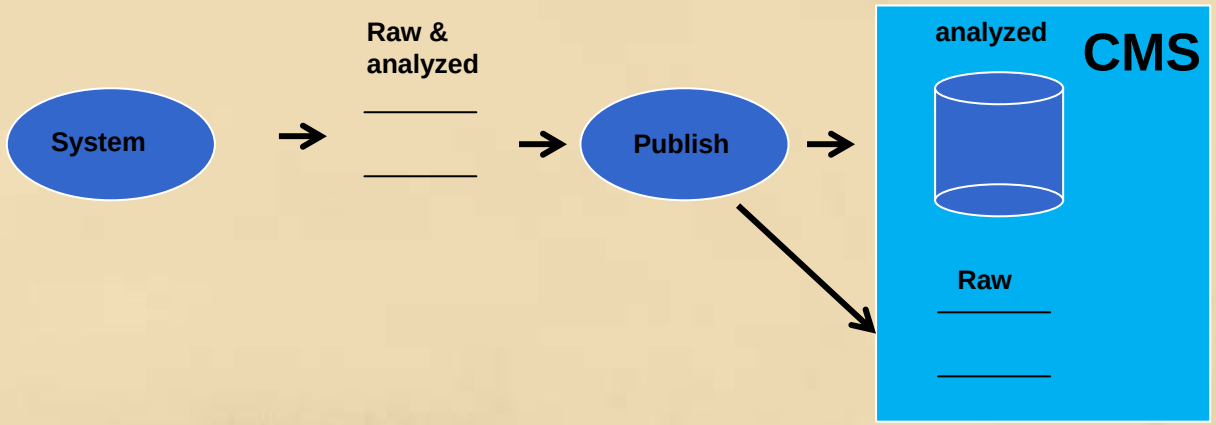
- Ideally, to keep data well organized one would like to deal only with structured data.
- In practice, information ranges from well-structured, homogeneous, and stable (well-suited for DBMS) to unstructured collections of data or documents (well-suited for CMS).
- All measurement data and documents should be related and organized. Therefore, the solution will include both structured (relational) and unstructured data.

A specialized CMS is built based on a RDB, where the RDB will relate the documents and files with the data that has been stored in tables.

Structured and Unstructured Data



Two-phase Data Archiving



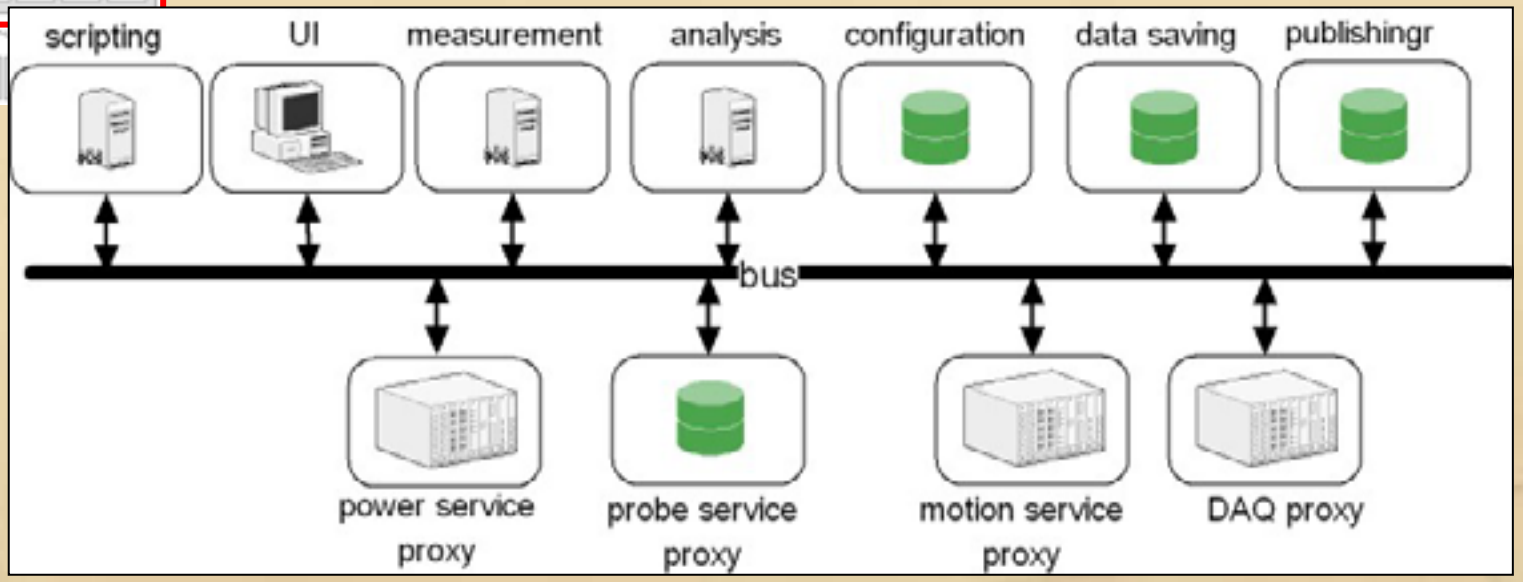
- The CMS is loosely coupled with the measurement system.
- Archiving can be done in two phases:
  - saving data in a local file system
  - publishing data (writes analyzed data to DB and registers raw data files)
- Two-phase data archiving allows for standalone systems to “re-synchronize” with the CMS when reconnected to the network.

Data Layer Characteristics

- The center of the design is the CMS, a central repository for configurations, measurement results and measurement-related documents.
- Access to data in the CMS is language independent (Web service).
- Both the configurator and the Data Browser will be implemented as Web applications to allow for easy, platform independent access.

Measurement Layer

Data Service



Hardware Services

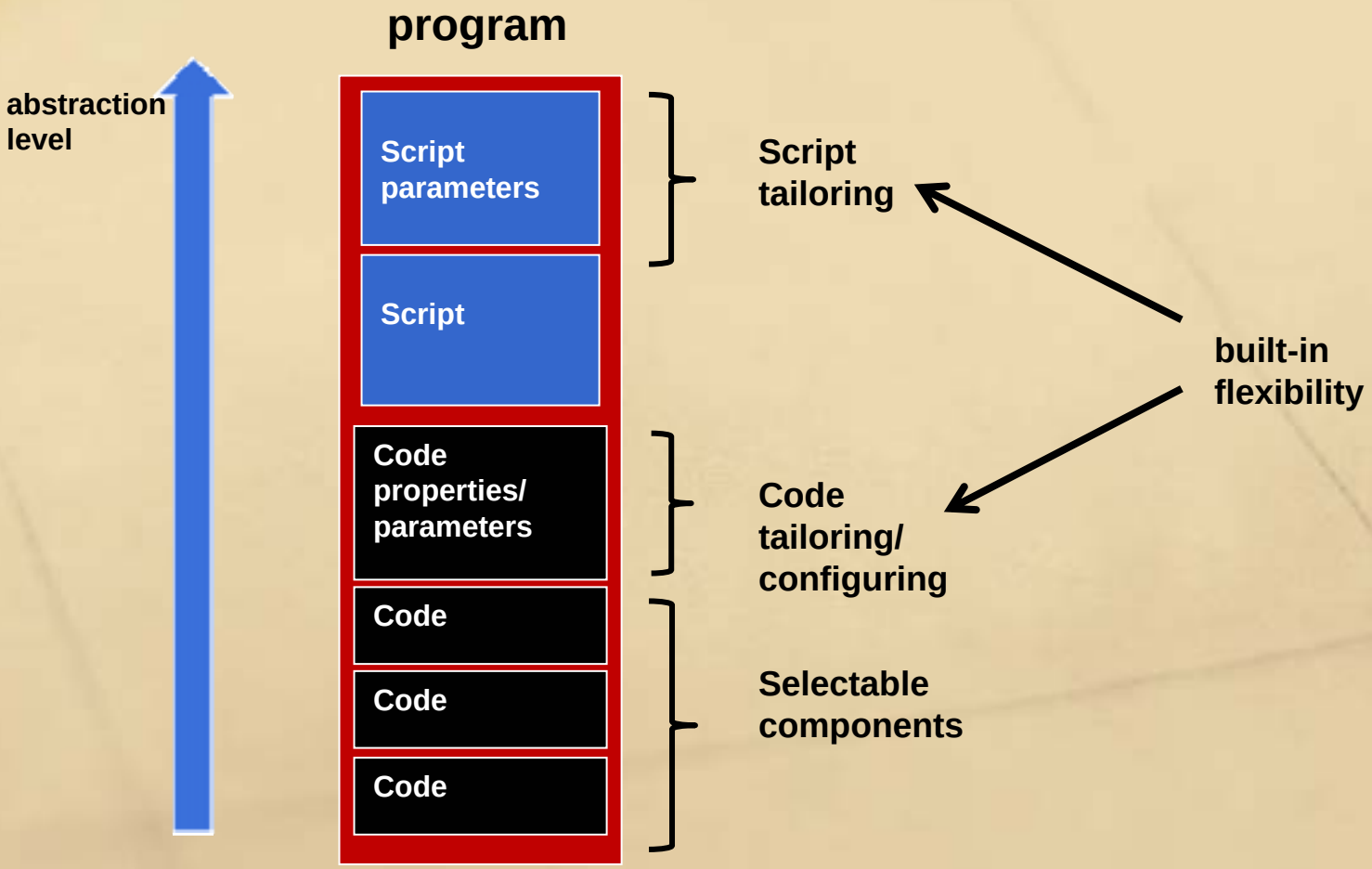
Software Bus Implementation

- The software bus implements the publish/subscribe messaging pattern.
- In the publish/subscribe pattern, components subscribe to specific topics (types of data messages exchanged on the bus) and publish messages with defined topics. When a message with a given topic is published on the bus, all the components that have subscribed to that topic are notified.
- A publish/subscribe bus is similar in its features to its hardware equivalent and allows for installing, configuring, and uninstalling of components and, also for inter-component communication.

Software Bus Implementation (cont.)

- Topic translators allow for flexibility when changing system topologies, by duplicating a message of one topic type and publishing it as a message with another topic type.
- Each component runs in a separate thread.
- Local components communicate with the bus via queues.
- Remote components communicate with the bus via sockets (TCP/IP).

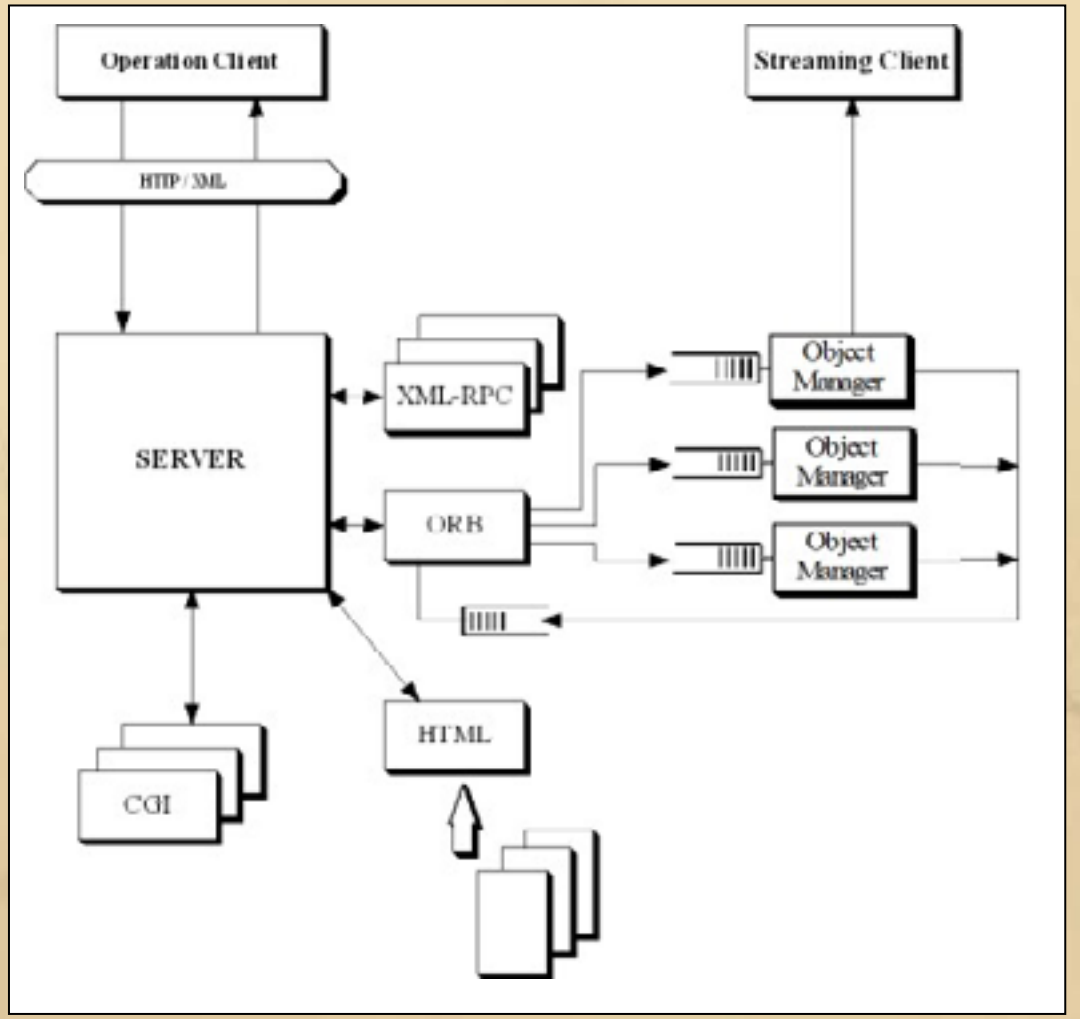
Flexibility



Measurement Layer Characteristics

- The Measurement Layer implements the logic of the measurement with help of data and hardware access services.
- Overall functionality is partitioned into a set of well-defined components, each focusing on a distinct function.
- Components are loosely coupled with publishers not aware of the existence of subscribers. Since the main focus is on topics (delivered data), the topology of the system (sequence of processing) can be modified without impacting the individual components.
- The design allows to easily exchange a component with one that implements similar functionality (e.g., to support a different hardware module), without changing any of the components providing it's input data or the components using its output data.

Service Layer Architecture



Service Layer Architecture

- The Service Layer interacts with the instruments and DAQ boards with an exception of the probe, sensor and calibration service, which provides data about calibrated items.
- Services can run on one or more dedicated DAQ computers (targets) connected with the main measurement computer (host) via a LAN (e.g., PXI, CompactRIO, servers).
- Options for accessing the service:
  - XML-RPC: invoking a remote method
  - ORB: creating, destroying or invoking a method on an object
  - CGI: invoking a CGI program
  - HTML: requesting an HTML page or image.
- The server can be easily extended to also recognize RESTful requests.
- The services may be implemented differently for different test stands.

Service Layer Characteristics

- A platform neutral interface (XML/HTTP) allows for developing client modules in different languages/platforms than the DAQ server languages/platforms.
- Multiple clients, both local and remote, may concurrently work with the DAQ subsystem.
- Separate connections for streaming data allow for achieving high data transfer rates while keeping control of the stream source in the same platform-neutral paradigm.

Service Layer Characteristics (cont.)

- The solution incorporates remote invocation of procedures as well as remote invocation of methods on objects, therefore allowing for the use of both procedural and object-oriented paradigms.
- The solution is highly extensible and adding a new RPC requires only dropping the VI implementing this RPC in the appropriate server folder, and adding a new class requires only putting it in the appropriate server folder.
- The design allows for creating and controlling multiple objects of any given class (e.g., multiple stepping motors).

Summary

- The next generation measurement system will be a comprehensive solution supporting the full lifecycle of the measurement.
- The system will leverage the relative strengths of tools and languages (Java and Flex for Web applications, LabVIEW for DAQ, Matlab for analysis).
- The system will use a CMS to ensure completeness of all data and documents pertaining to the test.
- The system will be extensible (new measurements, analyses, DAQs).
- Measurements will be automated via parameterized scripts.
- The system is distributed and is based on the services model (hardware access and data access services).
- The measurement layer will be built from components integrated via a software bus.