Systematic Approach of Experimental Analysis Provides a Collaborative Research Environment Pathway

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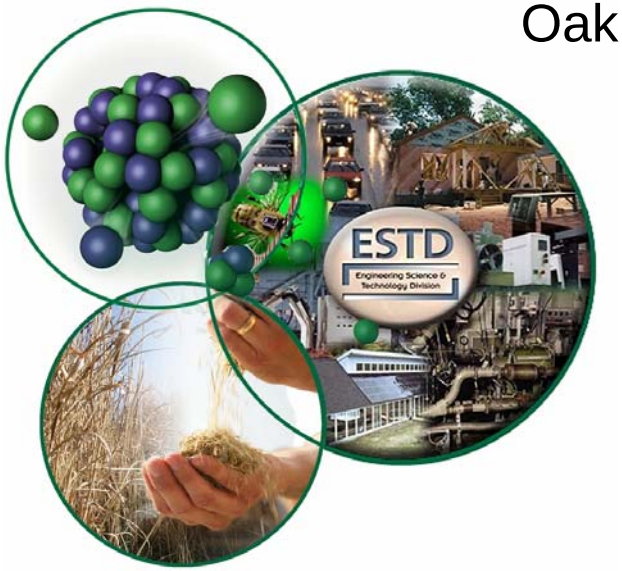
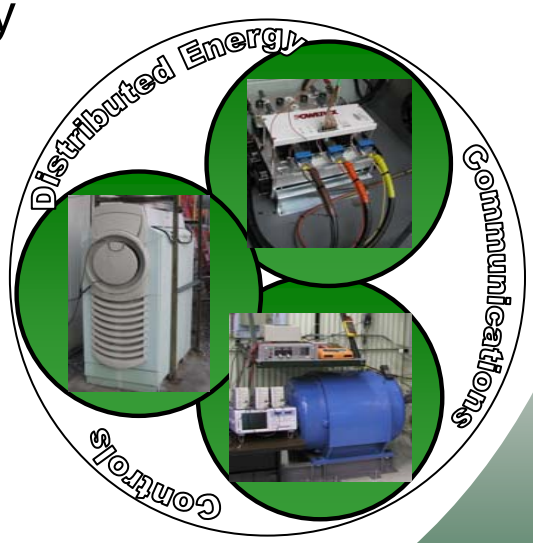




Outline

- **Overview of Analysis & Display Development**
- **Automation of Lab Controls**
- **Applicability to the Field Environment**
- **Conclusions**

First, Lets Talk About Some Background Information

- **We have instrumented most of the dynamic test equipment with potential transformers and current transducers (PTs & CTs)**
  - **Synchronous condenser**
  - **Inverter**
  - **Micro-turbine**
  - **Induction Motor**
  - **Load banks**
- **Our measured data consists of:**
  - **PWM switching waveform**
  - **Instantaneous and DC currents & voltages**
  - **Inverter temperatures**
  - **RMS voltages via model**

DECC Testing Produces A Large Amount Of High Resolution Data

- **Data acquired using MATLAB/Simulink in conjunction with a dSPACE front-end subsystem**
- **Each file typically contains:**
  - **35 data channels**
  - **Sample period of 70 to 90 uS**
  - **Duration of 10 to 30s**
- **Use a structured array (arrays and variable fields within) format with information on what is in each file**
- **Data channels (in terms of order and number) can vary from test file to test file**
  - **Ordering of channels and channels present or not present changes as the model evolves**
  - **Need flexibility in opening each test file to see what channels have been acquired**
  - **Some earlier test files were acquired with down-sampling (such as every other sample rather than every sample)**

As of September 24, 2007 We Have Acquired Approximately 15 GB of DECC Test Data

- **Data files and quantity acquired recently:**

Testing Date	Number of Files	Total Space (MB)
July 17, 2007	9	320
July 18, 2007	4	193
August 21, 2007	2	51
August 27, 2007	15	340
August 28, 2007	22	760
August 29, 2007	5	135
August 30, 2007	6	244
August 31, 2007	9	351
	72	2,394

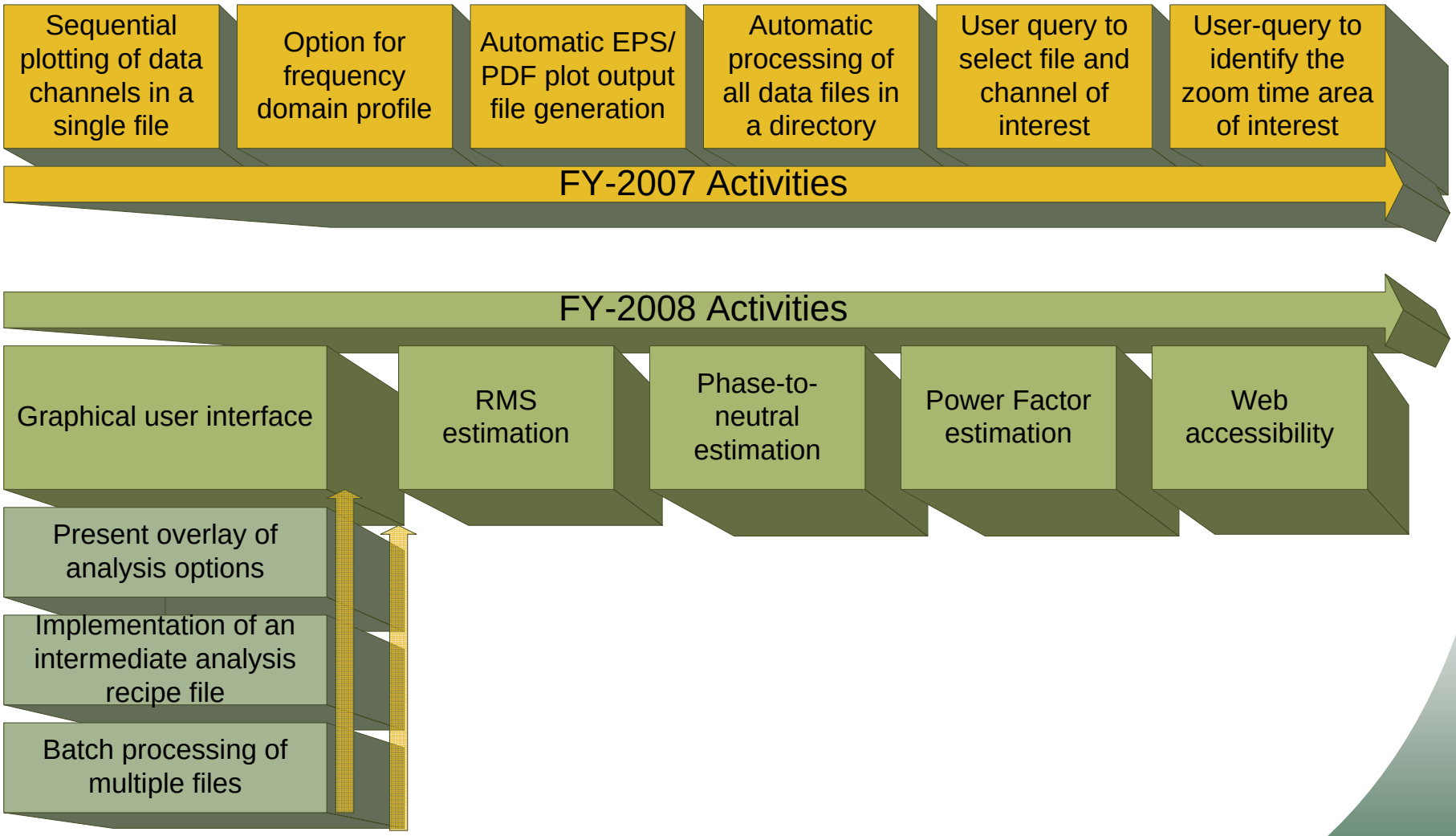
It Is Desirable To Have A Standard & Flexible Interactive Tool For Analysis Of The Data Files

- **Provide consistent analysis and reporting capability**
- **Reduce user's burden in developing custom code to load data file and channels**
- **Allow rapid quick-look assessment of test results**
  - **Quickly determine if data was properly acquired**
  - **Quickly determine outcome (positive/negative) of test**
  - **Identify specific areas of interest**
  - **Identify test anomalies**

Two Analysis Tools Are Envisioned

- **Quick-Look Analysis Tool**
  - **Flexible for loading any test file that is acquired**
  - **“On-the-fly” tool to quickly display test data**
  - **Provide simple displays (such as time series), analyses and statistics (max, min, avg)**
  - **Quickly determine outcome of tests for possible follow-up testing**
  - **Development is on-going**
- **Detailed Analysis Tool**
  - **Tool for detailed analysis and calculations**
  - **To generate more complex and final plots and results for reports**
  - **Development is planned in FY08**

Development Of The Quick-Look Analysis Tool Has Been Evolutionary



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The Quick-Look Analysis Tool Is Currently Command-Line Oriented

Starting processing now.

There are 9 data files in this directory.

1, Ambient_Everything_off.mat

2, Ambient_OnlyMTG_on.mat

3, MTG_Shutdown.mat

4, SC(KP40,KI5)_INV(KP300,KI30)_MTG(20kW).mat

5, SC(KP40,KI5)_INV(KP300,KI30)_MTG(30kW).mat

6, SC_INV(KP300,KI30)_MTG_unbalanced_motor_start.mat

7, SC_Regulating_MTG_No_Inverter.mat

8, SC_Shutdown_MTG(30kW)_Inv(off).mat

9, SC_Startup_MTG.mat

Please enter the number of the desired data file to analyze.6

The Quick-Look Analysis Tool Is Currently Command-Line Oriented (Cont'd)

There are 35 data sets in this file.

1, "Model Root"/"Demux_PWM"/"Out1"

2, "Model Root"/"Demux_PWM"/"Out2"

3, "Model Root"/"Demux_PWM"/"Out3"

…

34, "Model Root"/"gain_vll_sc"/"Out1[1,2]"

35, "Model Root"/"gain_vll_sc"/"Out1[1,3]"

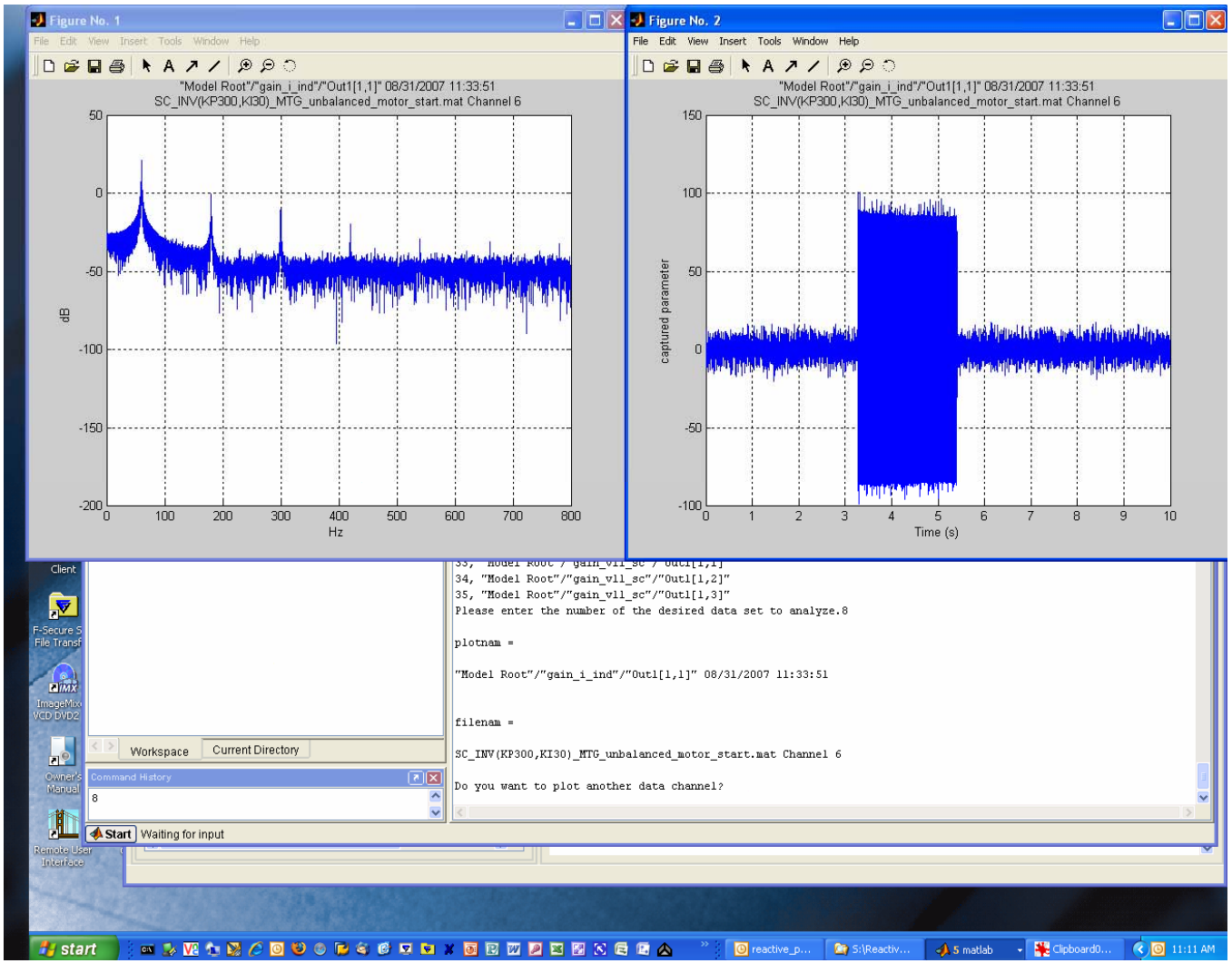
Please enter the number of the desired data set to analyze.8

plotnam ="Model Root"/"gain_i_ind"/"Out1[1,1]" 08/31/2007 11:33:51

filenam =SC_INV(KP300,KI30)_MTG_unbalanced_motor_start.mat Channel 6

Do you want to plot another data channel?

The Quick-Look Analysis Tool Is Currently Command-Line Oriented (Cont'd)



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Recent Attention Has Been Toward A GUI-Based Approach For The Tools

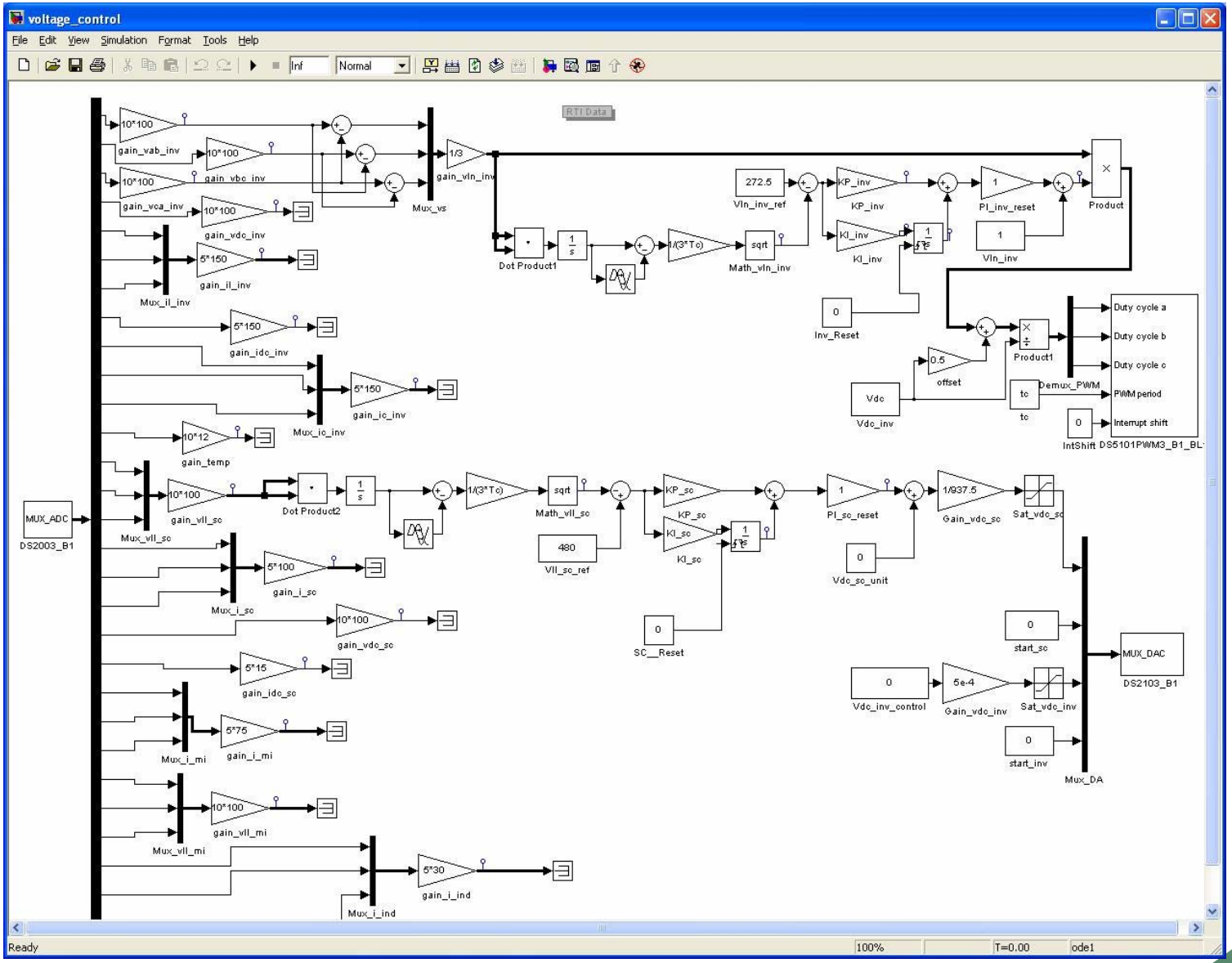
- **Offers**
  - **More friendly interface for the user**
  - **More professional looking user interface**
  - **User overlay of analysis options**
- **Allows creation of an intermediate analysis recipe file**
  - **Useful for subsequent re-analysis of data (i.e., you start where you left off last time or repeat a previous sequence for a new dataset)**
  - **Sequence can be used for batch analysis of multiple files**
- **Can easily evolve into a web-based system - our vision of the future**
  - **Web-based tool could provide for selection of post-processed plots and results tables**
  - **Web-based would eliminate need for shared users to require Matlab/Simulink program and scripts**
- **Still in the early stages of any development**

Automation of Lab Controls

Some Background

- **The DECC currently uses an interactive Simulink model tied to dSpace to**
  - **Set startup levels for our DECC devices, such as DC levels**
  - **Monitor instrumentation parameters**
  - **Calculate parameters, such as RMS**
  - **Set power supply levels and PI control gains**
  - **Implement dynamic controls, such as local voltage regulation with the DECC devices**
- **Control algorithm gain settings are set using virtual instruments, such as knobs, radio buttons, etc.**
  - **Hard to replicate previous test conditions**
  - **More prone to user entry error**
  - **Researcher presently writes down the gains for historical record**
  - **Very much like working with instrumentation on a lab bench**

Modeling and Control Implementation Is Currently Done in Simulink



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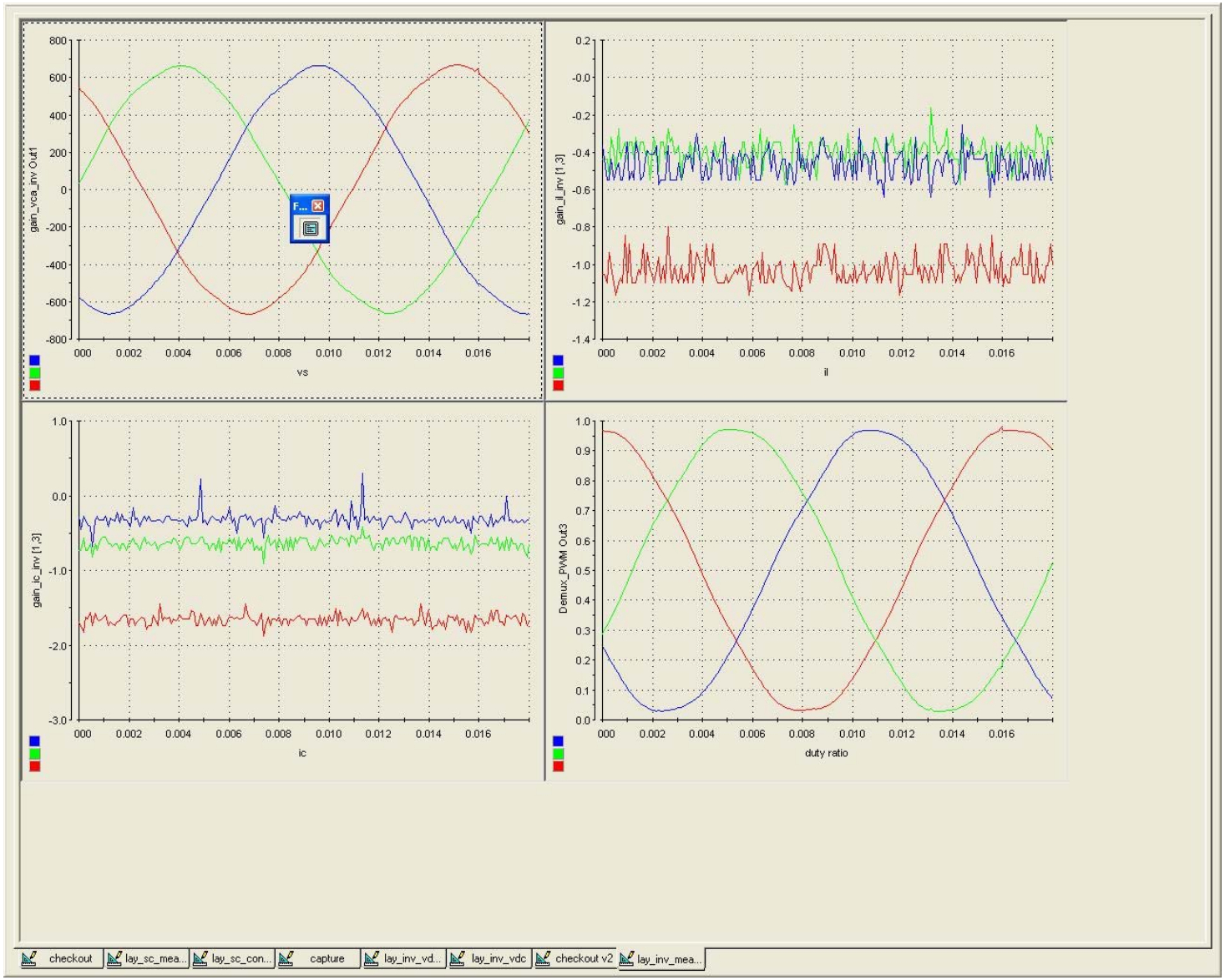
Example of Inverter dSpace Monitoring Screen



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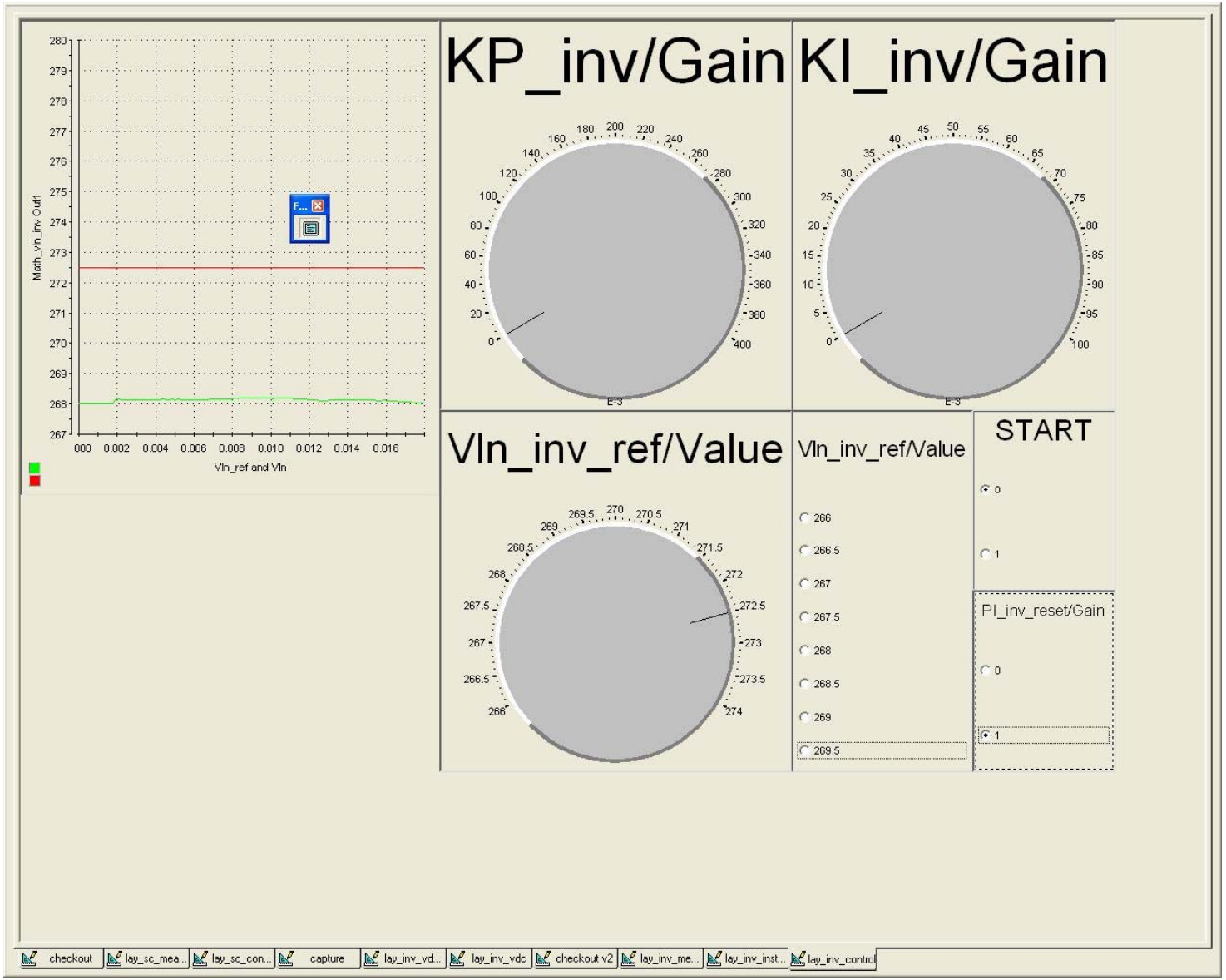
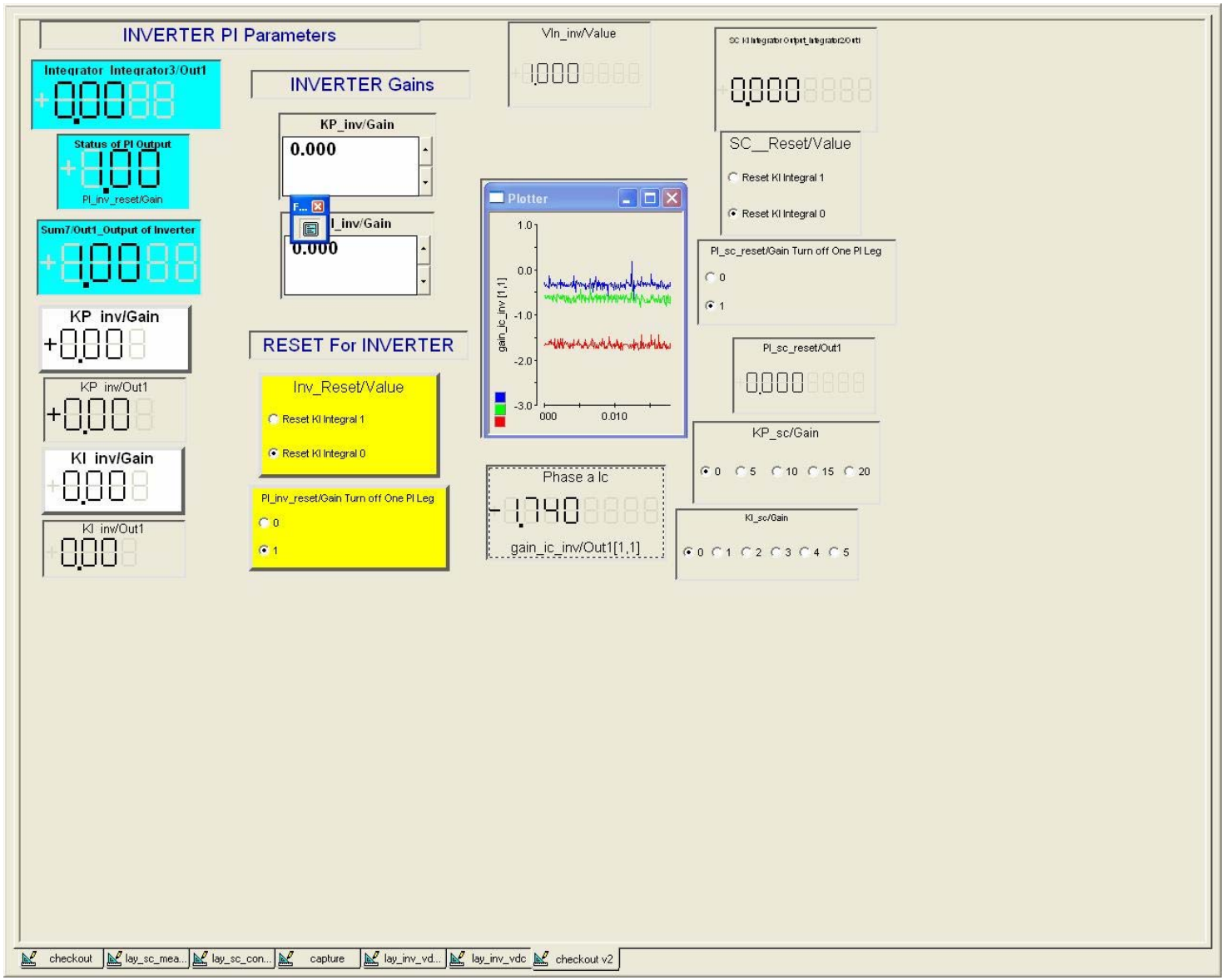
Example Of A Screen for Setting Controller Gains and Setpoints



This Is An Example Of A General Purpose Checkout Screen



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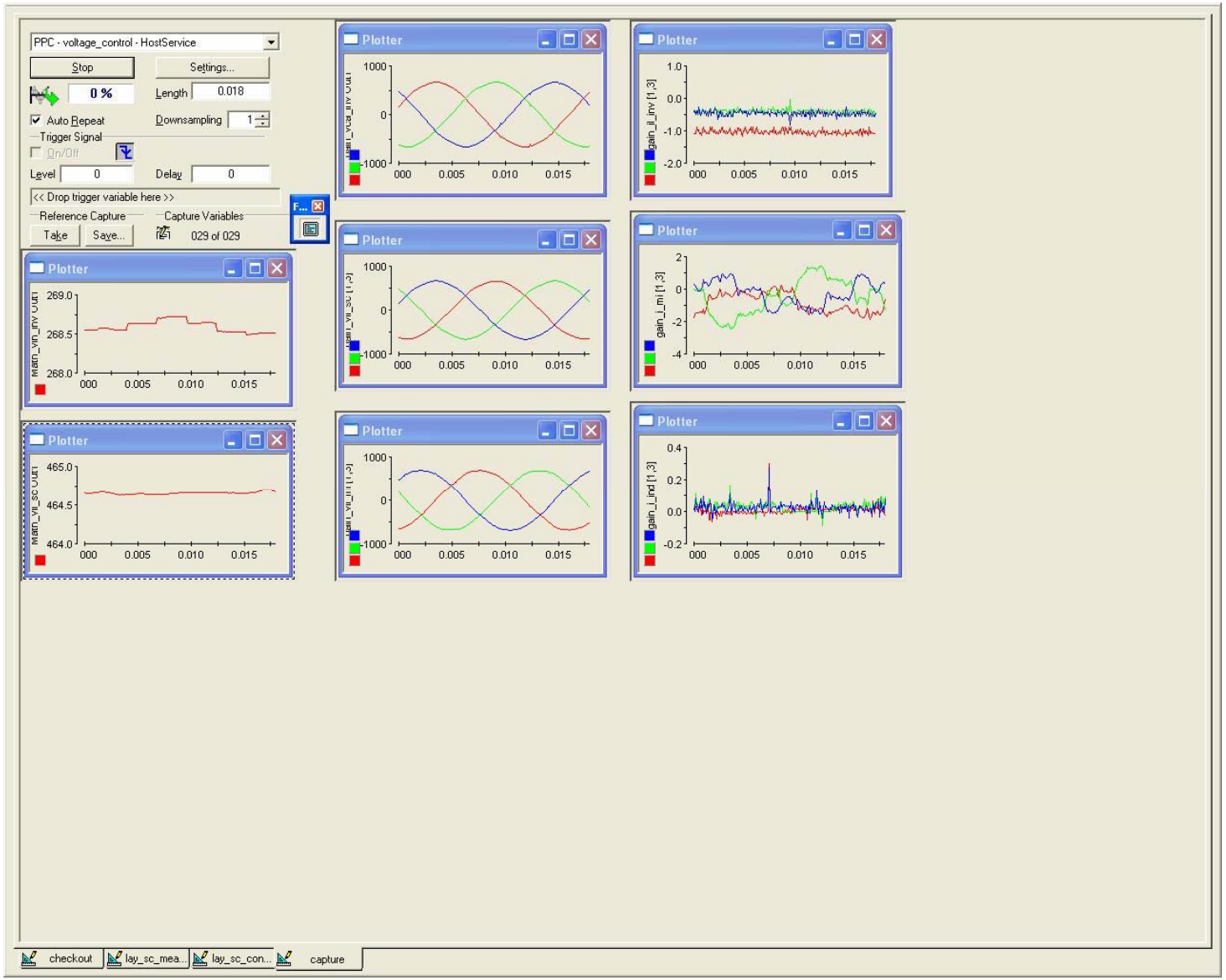
This Is An Example Of A Data Acquisition Control Screen



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Successful Implementation Of DE Controls Require More Rigorous Exploration Of Our Control Methods

- **A manufacturer will want substantial proof and methodology qualification before "mortgaging the farm" on an approach**
  - **Need ability to more effectively conduct testing to cover a wide range of test conditions**
  - **Need repeatable conditions to confirm performance results**
    - **Thus need ability to easily replicate test conditions**
  - **Our present implementation has too many degrees of freedom**

- **Need to understand the tradeoffs in overall DE system performance with respect to measured, calculated and controlled quantities**
  - **Need to understand the performance gains/losses with more or less data, resolution, control, etc.**
  - **Overall cost to benefit of implementation will be an important metric for success**

<u>Automation of lab controls is the solution</u>

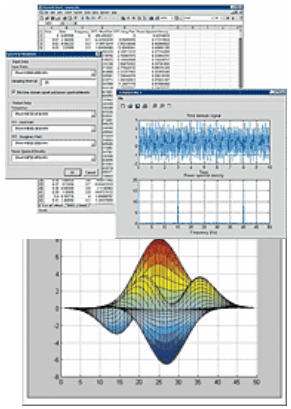
Automated Framework Would Benefit The Development Of Deployable Control Strategies

- **Our present implementation can be adapted to accomplish automated lab controls**
  - **Need to interface manually operated equipment with computer controls**
  - **Configure Simulink model to adjust parameters based on input file**
- **Modify so everything runs from a recipe file**
  - **Automatically store all crucial parameters and test setup conditions**
  - **Less degrees of freedom in the execution of tests**
  - **Tests become easily repeatable**
- **Should reduce test configuration and setup times**
  - **We can make more tests to cover more ground faster!**
  - **Less time spent setting up each time.**
- **View Display layouts**
  - **Implement some simplification to present layouts**
  - **Capture any setting changes that are in the input file**
  - **Cache all settings and parameters to file that the layout pulls from**

Potential For Partnering With Outside Collaborators Introduces New Challenges

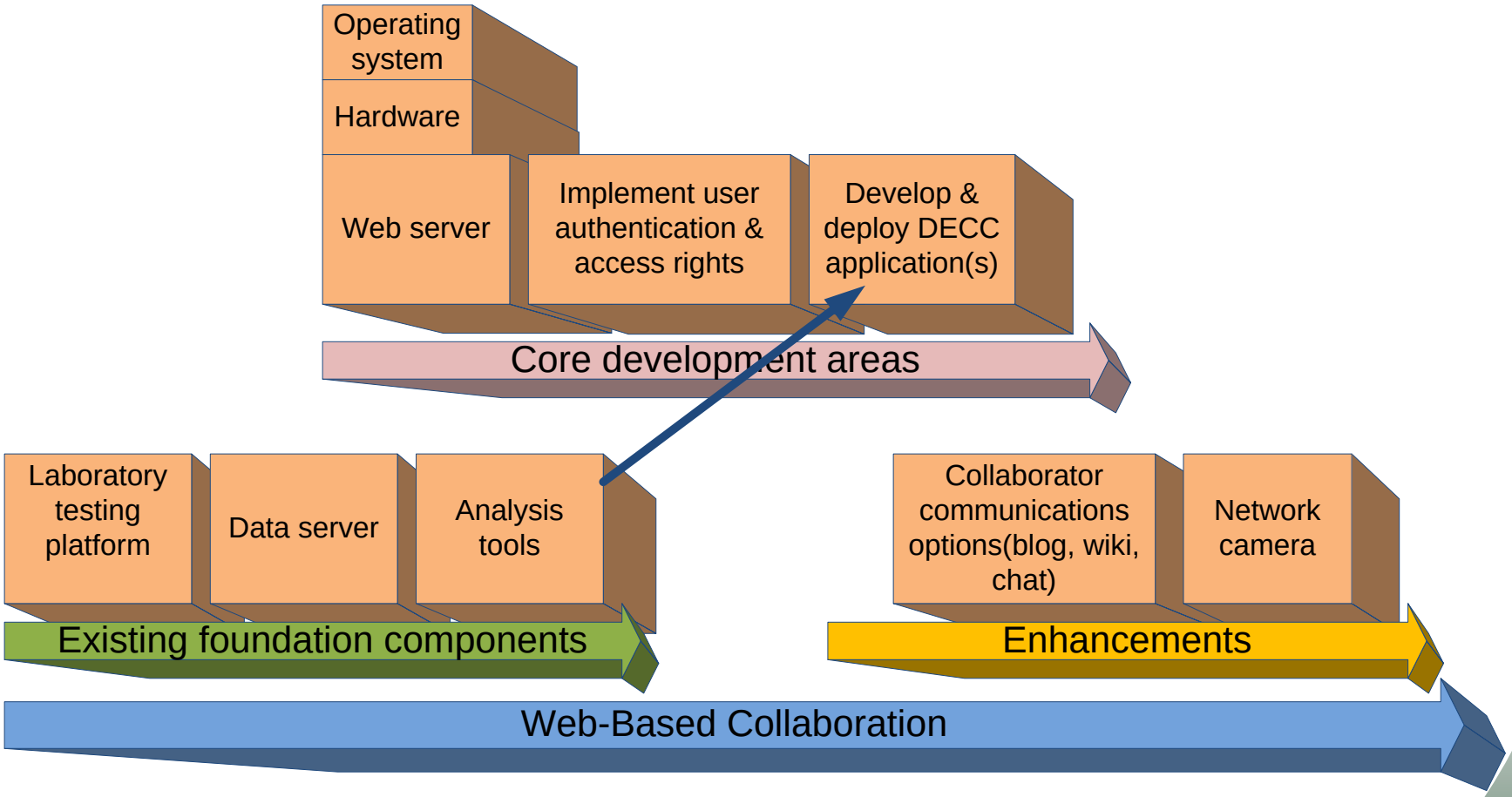
- **Data and Analysis Challenges include:**
  - **Sensitivity of the data – we have to have proper controls to limit access**
  - **Size of data files – may be too large for routine export to remote sites**
  - **Analysis software (we have MATLAB) – may not be available at the remote site**
  - **Collaborators could benefit from our analysis toolset and we need to determine how to provide access**
  - **If collaborator is a partner or a sponsor – we would want a professional solution**
- **In some cases it would be beneficial to allow almost immediate access and interaction with test results**
  - **Example : optimization of a DE control approach for an inverter when working in cooperation with the manufacturer**
  - **Manufacturer could provide immediate feedback on changes to follow-on tests**

Web-Based Analysis Offers A Solution



- **Matlab has capabilities for supporting web-based implementation of user packages**
  - **MATLAB® Builder for Java™ 2.0**
  - **MATLAB® Builder for .NET 2.2.1**
- **We could compile our tools and then deploy them on a web-server that is accessible internally and externally**
- **Controls via user name and password would limit access to only those users with access privilege**
- **Users would be able to interact with the data**
  - **Produce analysis results on their own PCs**
  - **But not require direct access to the large data files**
- **We could combine with an interactive blog or instant messenger (i.e., chat) communications tool**
  - **Provide almost real-time interactive environment to outside collaborators.**
  - **Experimental procedures could be a wiki (medium that can be edited by anyone with access, Wikipedia is an example)**

Roadmap For Implementation Of Web-enabled Collaborative Environment



Applicability To The Field Environment

- **These developments can enable effective end-user participation in DECC testing**
  - **Implementation of automated testing**
  - **Web-based analysis tools**
  - **Collaborator interfaces**
- **Increases participation in the testing without introducing risk to the experimental area**
  - **No need for participants to have safety training if not actually in the laboratory during the tests**
  - **Don't have to be present at the lab to observe test results and can still provide feedback even that day**
- **Builds on what we already have in our laboratory**

Conclusions

- **We are in the process of implementing a more systematic approach to DECC data analysis**
  - **Quick-Look Analysis tool (now)**
  - **Detailed Analysis Tool (FY08)**
- **Our analysis tools will give us analysis consistency and allow us to more easily share results with our sponsors and partners**
- **Automating our lab controls will allow us to more effectively conduct testing, cover more ground and ensure repeatable results**
- **Also, the automation techniques and "lessons learned" can help transfer laboratory results into field-able solutions**
- **Implementation of a web-based collaborative environment will capitalize on all available resources for DECC R&D**