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Flexible & Maintainable Control Systems with a Small Team

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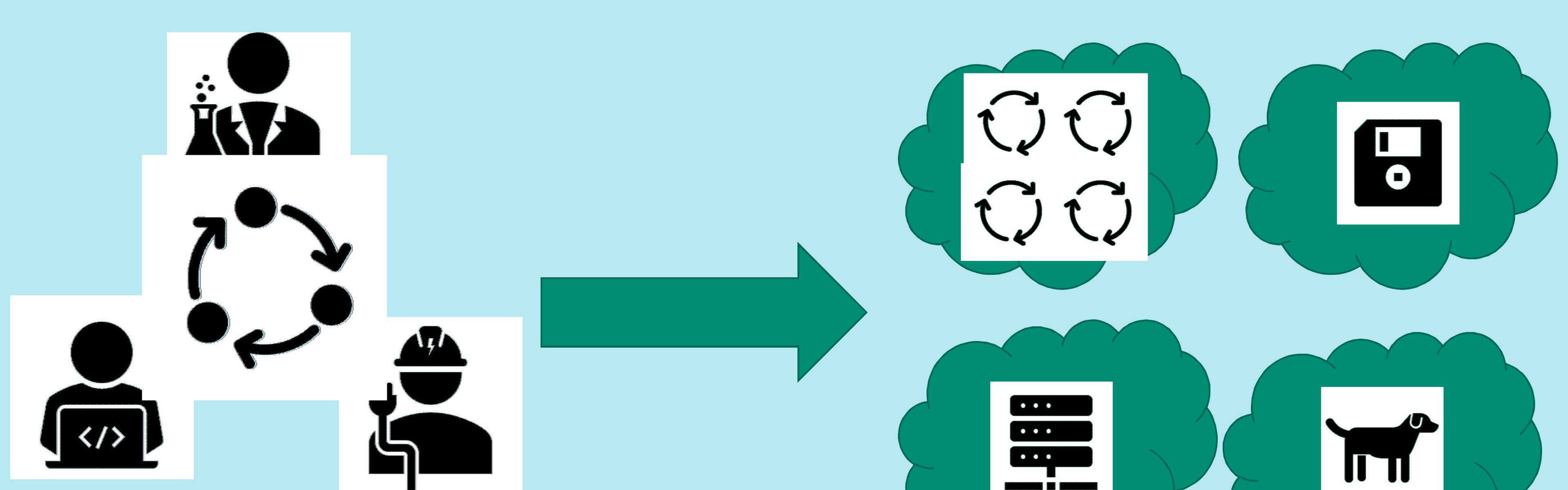
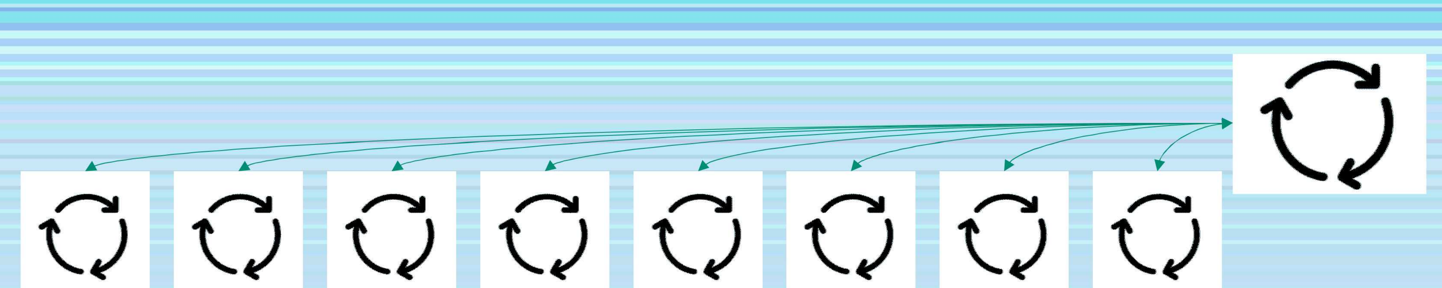
Introduction

Large research facilities contain a variety of distributed systems that need to be coordinated properly to successfully perform experiments. In most facilities, this coordination requires a large team of programmers and engineers to build, maintain, and expand the interconnected control systems. Using a combination of **flexible tools** and **adaptive strategies**, we have managed to reverse-engineer, rebuild, maintain, and even expand our facility's control systems to include **four pulsed power machines** that can be fired in various combinations with each other. This was managed with a **small controls team** (three programmer/electrical engineers and a mechanical engineer) that were also supporting other projects at other facilities.



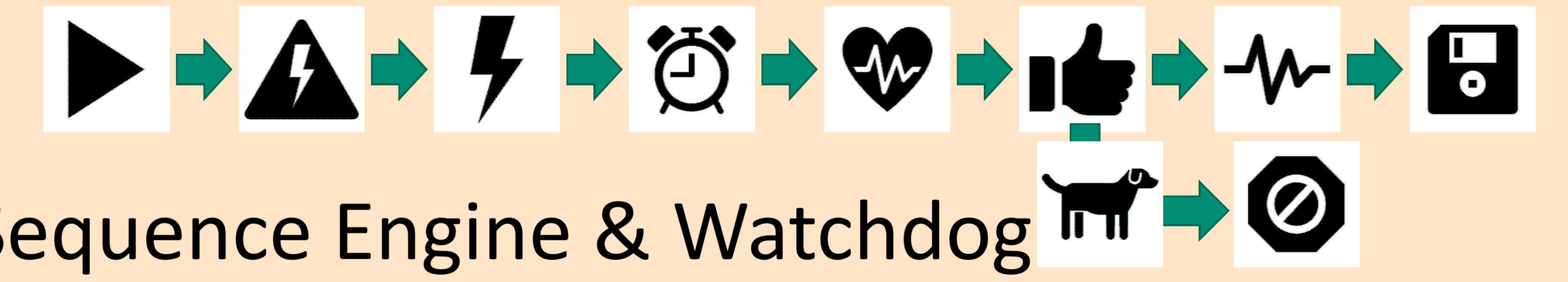
Communication

Fostering an **open dialog** between the controls team and the operations team is crucial to making efficient use of resources. When **operators understand the system**, they can **fix problems on their own** if provided the **proper interfaces**. Programming tasks that normally take weeks can be replaced with tasks that can take days but require operations to understand more of the system.



Independent, Parallel Subsystems

Large lasers consists of **many different subsystems** covering things such as high voltage, timing/triggering, environmental monitoring, vacuum, data collection, access control, and more. By running each of these systems independently and in parallel, they can be **independently maintained and tested** with **minimal interference** to shot operations. Additional **subsystems can be added** into the same architecture without affecting existing systems. Failures of unnecessary subsystems won't interfere with experiments.



Sequence Engine & Watchdog

The sequence engine uses the **selected sequence** to determine what will happen, in what order, and what conditions must be met before continuing. The watchdog's job is to track the **"online" status** of each subsystem. If a required subsystem **becomes unresponsive** before or during a sequence, the **watchdog will abort** the sequence along with an easy to understand error message. The watchdog will also **monitor all of the subsystems** so that the operators can see which systems have problems **before they start operations**.

Master Sequence

Event	System	Argument	Abort?	Category
Send Command	Subsystem 1	RESET	TRUE	BASELINE
Check Ready	Subsystem 1	TRUE	TRUE	BASELINE
Send Command	Subsystem 2	CHARGE	TRUE	TYPE 1
Send Command	Subsystem 3	ARM	TRUE	TYPE 2
Send Command	Subsystem 1	SAVEDATA	TRUE	BASELINE
Check Ready	Subsystem 2	TRUE	FALSE	TYPE 1
Check Ready	Subsystem 3	TRUE	TRUE	TYPE 2

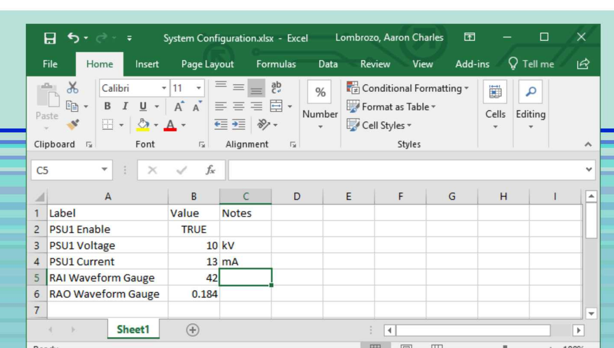
BASELINE & TYPE 2 →

Selected Sequence

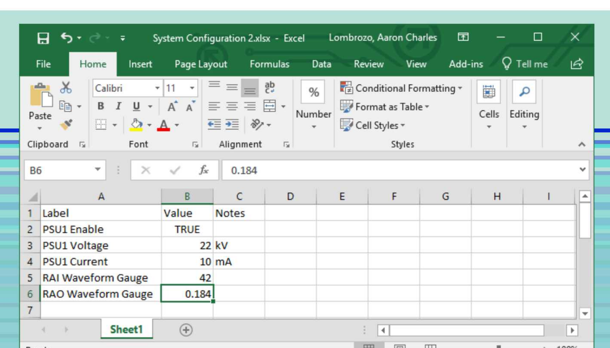
Event	System	Argument	Abort?	Category
Send Command	Subsystem 1	RESET	TRUE	BASELINE
Check Ready	Subsystem 1	TRUE	TRUE	BASELINE
Send Command	Subsystem 3	ARM	TRUE	TYPE 2
Send Command	Subsystem 1	SAVEDATA	TRUE	BASELINE
Check Ready	Subsystem 3	TRUE	TRUE	TYPE 2

Master Sequence

A Master Sequence File **defines the allowable events** that could occur in the **automation engine**, as well as defining **groupings of events** that are used together to accomplish tasks. A pre-defined recipe is used to select **sets of these groupings** to quickly generate & re-generate Sequence Files that operators select to **execute pre-defined shot sequences**. New subsystems and events can be added to existing sequences without affecting unrelated sequences.



OR

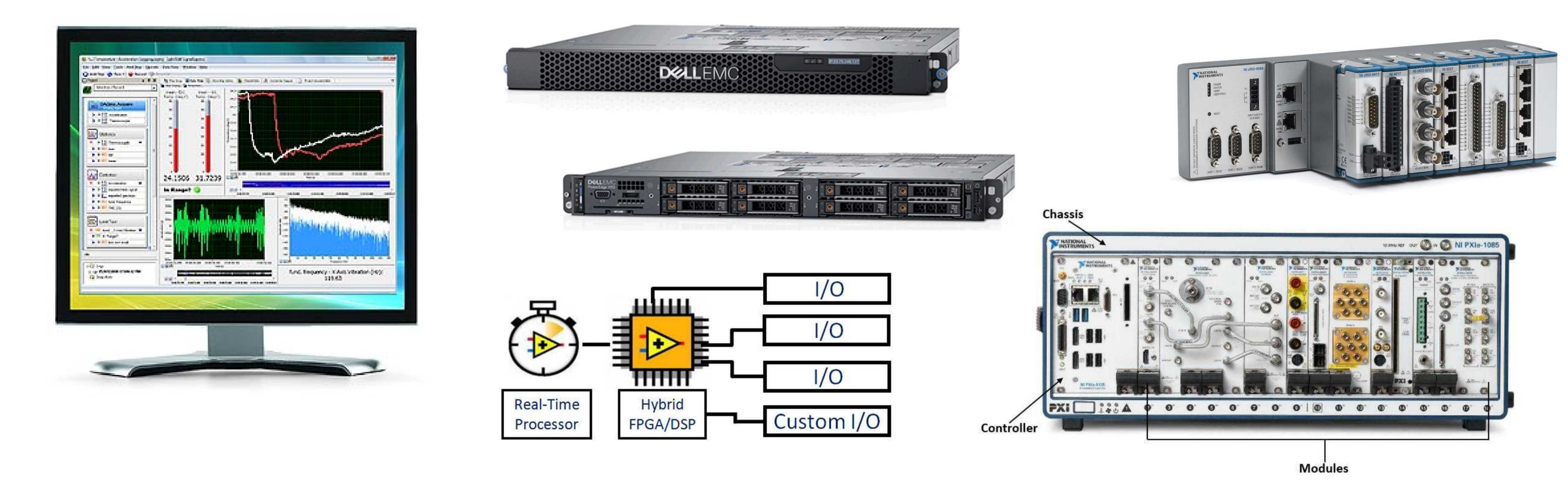


System Configurations

We use CSV files that **list all of the settings** which define how subsystems perform requested tasks. The configuration files are **saved along with shot data** for every shot. Operators use these files to quickly return the system to previously used configurations. This allows **quick changes to large sets** of configuration settings.

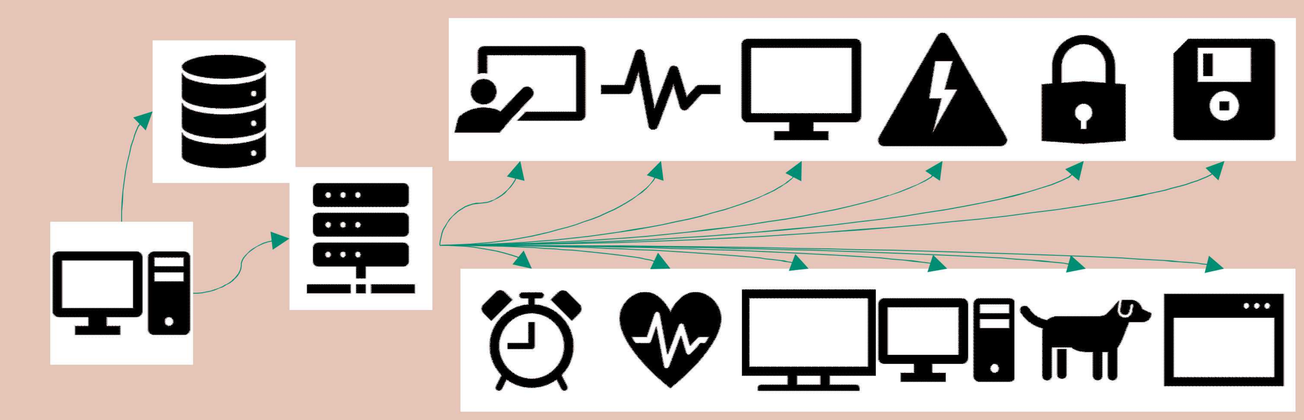
Event Logging

All events that occur are **centrally logged and saved** along with shot data to enable **easier troubleshooting** after the problem has occurred. Each of the distributed subsystems sends status messages back to the central automation/watchdog/logging server along with local backups in case of network failure.



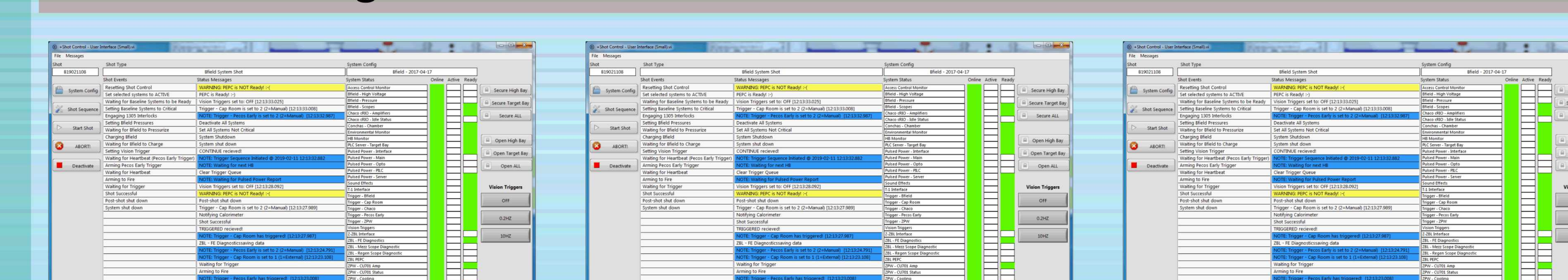
Single Language (UI, Server, Realtime, FPGA)

Control system teams typically consist of a variety of programmers that can target different platforms along with the various engineers, technicians, and other subject matter experts. By using **LabVIEW**, each programmer can target Windows PCs, embedded controllers (real-time systems), and FPGAs. **LabVIEW's ease of learning** leads to it often being picked up by engineers and technicians to supplement their existing skillsets.



Version Control

All code is checked into **source code control**. Executables are **timestamped** when deployed, launchers run the **latest versions** available, and the operator can **easily revert to previous versions** when issues occur. A **launcher system** is used to manage which programs run on which systems. This strategy **accelerates iterative testing** as part of typical development and troubleshooting tasks.



Multi-User Interfaces

Shared resources are **easier to manage** when visibility is increased. In our case, many **subsystems are shared** between different pulsed power machines. The **multi-user interface** allows operators in different buildings to easily **observe the status** of subsystems and shot events without interfering with their own shot preparations. Since only one sequence can be executed at a time, the other operators are able to **watch the sequences** proceed and finish before being allowed to start their own.

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