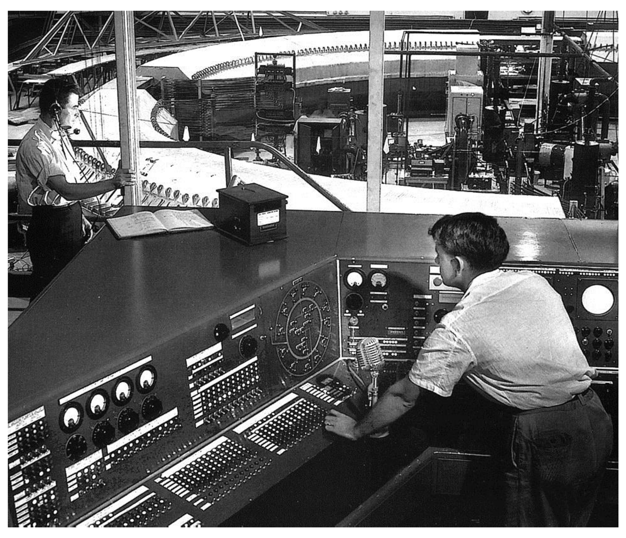
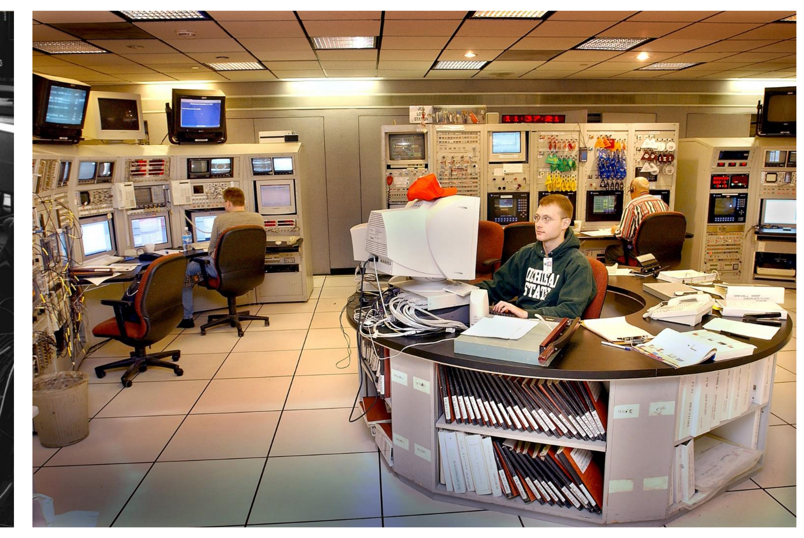


1953

1964

1989



2002

Today

BROOKHAVEN NATIONAL LABORATORY

70 YEARS OF DISCOVERY

A CENTURY OF SERVICE

Evolution of an Alarm System:

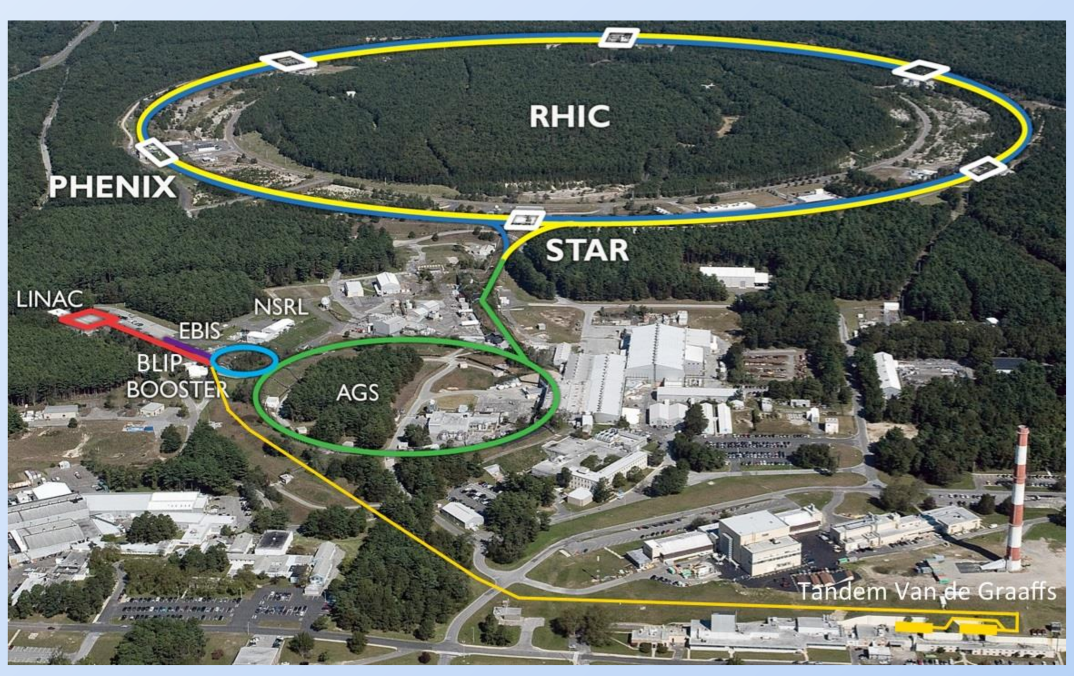
Merging Old Accelerators with New Installations

Gregory Marr, Collider-Accelerator Department, BNL, Upton, NY, 11973 U.S.A

Introduction

The Collider-Accelerator Department's (C-AD) Main Control Room (MCR) Operators at Brookhaven National Laboratory (BNL) have long used an alarm display as a first-line **diagnostic for failures** in our chain of accelerators, as well as a tool to **prevent or minimize downtime** thus **increasing reliability** overall. Our method of monitoring and tracking alarms has evolved as the accelerator complex has grown. With new systems being commissioned, the burden of sorting through relevant alarms has increased dramatically. Issues arise with integrating new installations, nuisance alarms, and high volumes of alarm data. Our strategies for alarm management continue to evolve to address these difficulties.

Scope



The C-AD controls system and MCR operators are responsible for controlling and monitoring:

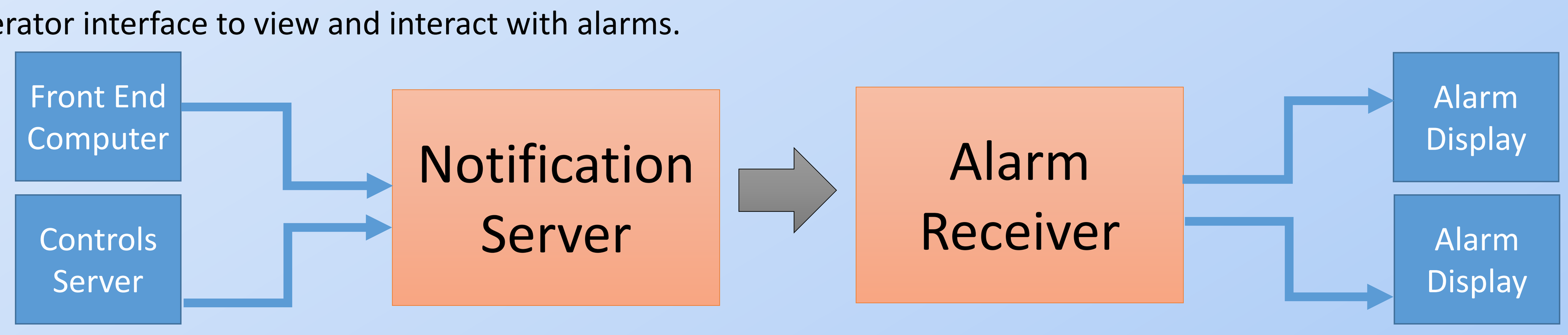
- Up to 7 ion sources, 4 electron guns
- 2 linear accelerators, 2 Tandem Van de Graaf accelerators
- 5 ion transfer lines
- 4 electron lines
- 2 injector rings, 2 collider rings
- Various research, development, and test facilities
- 3 independent & concurrent science programs

How **BIG** is the problem?

- Our accelerator controls contain over **1,936,203** parameters (compare to EPICS PVs).
- Of those 1.9 million, only **59,585** parameters are capable of creating alarms.
- However, just **27,112** parameters (45% of possible, less than 2% of total) created alarms in the previous run in 2016-2017, spanning 9 months of operations.
- But alarms came in from those parameters **3,766,735** times!
- Approximately 700 parameters alarmed more than 500 times during the run. They are responsible for 88% of the entries in the database. That still leaves **431,823** alarms.
- Control room operators took action on alarms **18,404** times during the run. Still, this is less than 5% of the remaining (non-repetitive) alarms in the database.

History

Much of our present alarm system architecture dates back even earlier than 1994, when a user interface was created for Unix, and later Linux, operating systems. Devices monitored on the Front End Computer, or higher level server software, produce alarms on the Alarm Receiver, via the Notification Server. Alarm Display applications are the operator interface to view and interact with alarms.



Severity levels are based on a standard employed by SLAC, and were defined in the "Specification for Revisions to Alarm Display Task" (P. Ingrassia, internal note, 1992). The levels range from 1 to 5, with 5 being the most severe. The levels are defined as follows:

Level 1 Warning, includes magnets going out of tolerance or tripping off.
Level 2 Interlock, indicates safe interruption due to the action of an interlock.
Level 3 Potential Equipment Damage, includes water leaks, vacuum problems, and high temperature alarms.
Level 4 Potential Environmental Impact (not immediately life threatening), includes radiation water leaks and high radiation fields.
Level 5 Potential Life Threatening, includes hydrogen target leaks and very high radiation fields.

Improvements: Alarm Design

Many alarms are generated because system and software engineers defined the alarm capabilities of their devices without operations oversight. Many of the 59,000+ alarms mentioned above are not necessary. To ensure meaningful alarm design we are implementing the following measures:

- Imposing increased oversight of alarms by Operations during design stage of new systems.
- Reducing multiple alarms into one summary alarm.
- Providing a subscription service -- apart from the alarm system -- to notify experts if selected devices exceed specified limits.
- Modifying software to allow Operations experts to revise alarm levels of older, established systems.
- Reprogramming nuisance devices that pollute the alarm logs, on a case-by-case basis.

Improvements: Alarm States

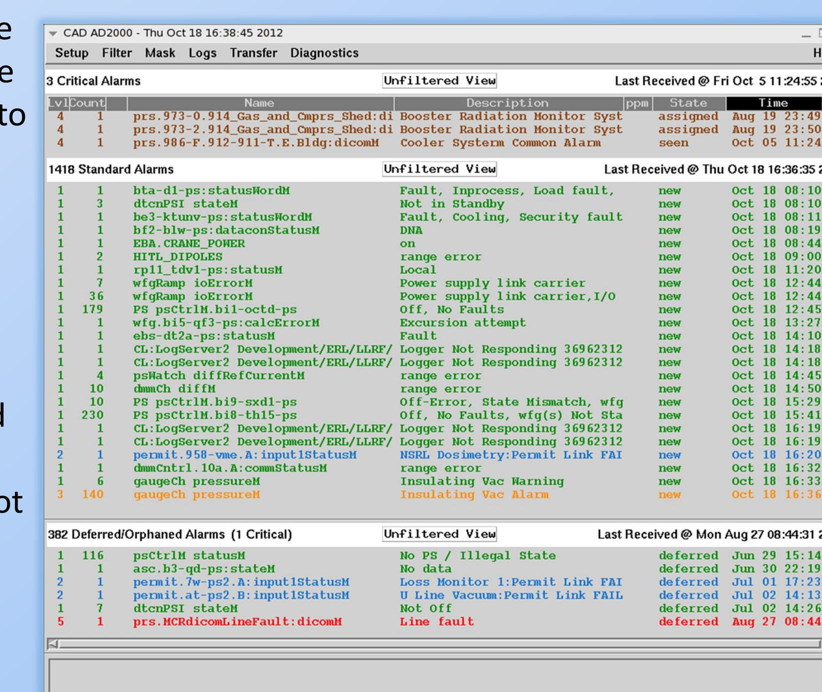
The alarm server originally recognized an alarm in 1 of 3 states:

- Clear – alarm disappears from screen
- Unacknowledged – new alarms
- Acknowledged – active alarm under investigation, repair, etc.

This arrangement was a problem because there was no useful way to track progress or ownership of the alarm investigation, and the alarm log database had no further information. Additionally, operators had different strategies for acknowledging alarms; as a result it was difficult to understand which alarms were actually under active investigation and/or repair, as opposed to being ignored. There was a way to "mask" alarms – suppress a device from generating any notification – but it was often overused, and resulted in genuine faults that never came to the operator's attention.

In 2011, our Controls Division completed an upgrade of the Alarm Display application and its associated database. One aspect of this changed the number of alarm states from 3 to 6, to clarify its disposition:

- Clear -- alarm is resolved.
- New -- alarm has arrived and has not been investigated by operator.
- Seen -- Operator has detected the alarm and assumes some responsibility to follow up.
- Assigned -- Operator can not resolve independently and has been forwarded to another group.
- Deferred -- investigation is complete but resolution is not immediately possible (access, other extensive work necessary).
- Orphaned -- alarm is expected to persist and no one is expected to do anything about it anytime soon.

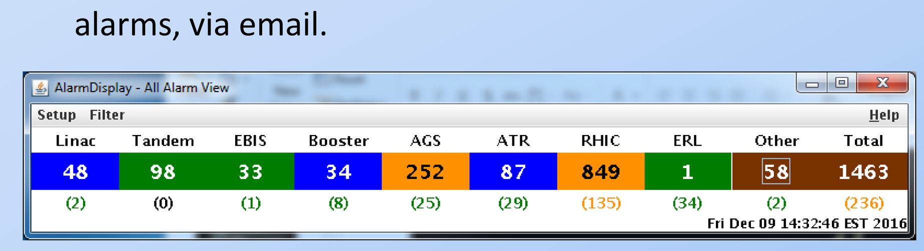


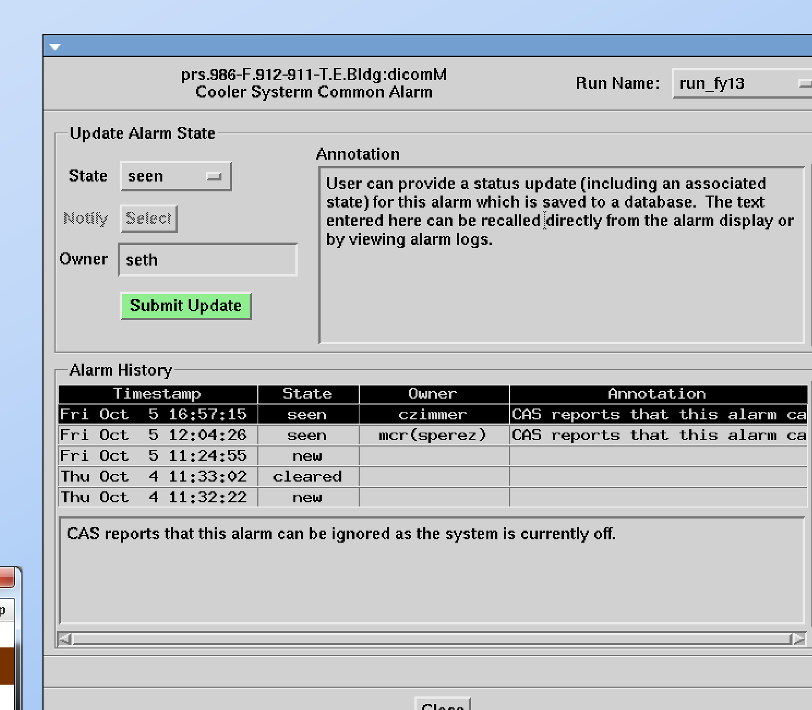
Masking an alarm is still possible but is only used sparingly in a few cases.

Improvements: Alarm Responsibility, History

The 2011 software upgrade also included enhancements to alarm tracking. In this way, an Operator takes personal responsibility for an alarm until it is resolved:

- Operator's name is associated to alarm as soon as it is "seen".
- Operators transfer ownership of unresolved alarms to oncoming personnel during shift change.
- GUI (see right) allows user to make multiple notes on an alarm, change alarm state, and view the history of the alarm.
- "Notify" allows Operator to remind experts of active alarms, via email.





Remaining Challenges

While previous improvements have been useful, our goal of a clear alarm screen remains elusive. Some reasons include:

- Repeated floods of alarms on the screen, as well as intermittent & repetitive alarms, deters Operators from managing or transferring alarms.
- Many established systems have alarm conditions that are erroneous, not urgent, or not useful; however, the sheer number makes remediation difficult on a case by case basis, especially without adequate software tools for reprogramming.
- New installations continue to add to the total volume of the alarm system.

Summary

The Main Control Room in the Collider-Accelerator Department has a vast amount of control points to monitor over a number of various systems in a number of accelerators. Effective management of alarms is hampered by this large amount of data, made worse by nuisance alarms that account for most of the alarm database entries. With upgrades to the user interface, we are more prepared to track alarms. Still, the large volume makes it difficult to keep the alarm screen clear. Our future efforts are geared toward reducing both nuisance alarms and overall alarm volume, in order to restore the alarm system to a state where it can once again be a useful preventative of failure, as well as first-line diagnostic in failure situations to minimize downtime.

ARW 2017 Accelerator Reliability Workshop