Replacing the Engine In Your Car While You Are Still Driving It

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LA-UR-27876

Lessons Learned From A Very Ambitious Upgrade Program

Complete With:
3 Observations &
2 Recommendations
For Anyone Contemplating A Similarly Ambitious Upgrade

The Scope Of The Project

- ✓ Install New Network Backbone
- ✓ Replace 201 MHz RF Tubes
- ✓ Replace Low-Level RF System
- ✓ Replace Timing System
- ✓ Replace Industrial I/O System
- ✓ Replace Beam Synchronous Data Acquisition System
- ✓ Replace Fast Protect Reporting System
- ✓ New Wire Scanner Hardware
- ✓ New Beam Position/Phase Monitor Hardware

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✓ Continue Delivering Beam To Our Customers

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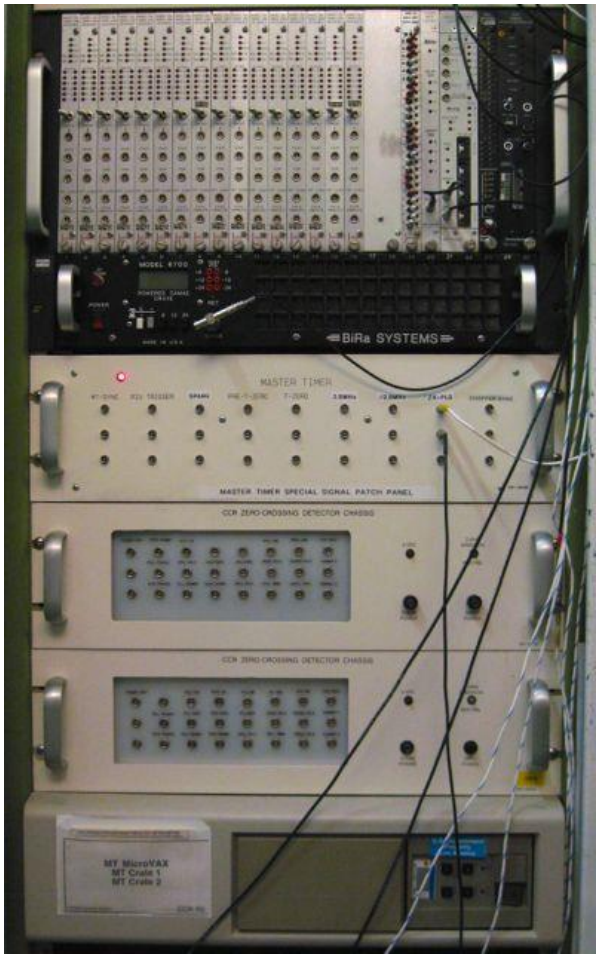
Old Timing System

- 96 discrete timing gates (maximum).
- Each gate individually distributed via dedicated coax cables.
- ~ 1 uSec resolution.



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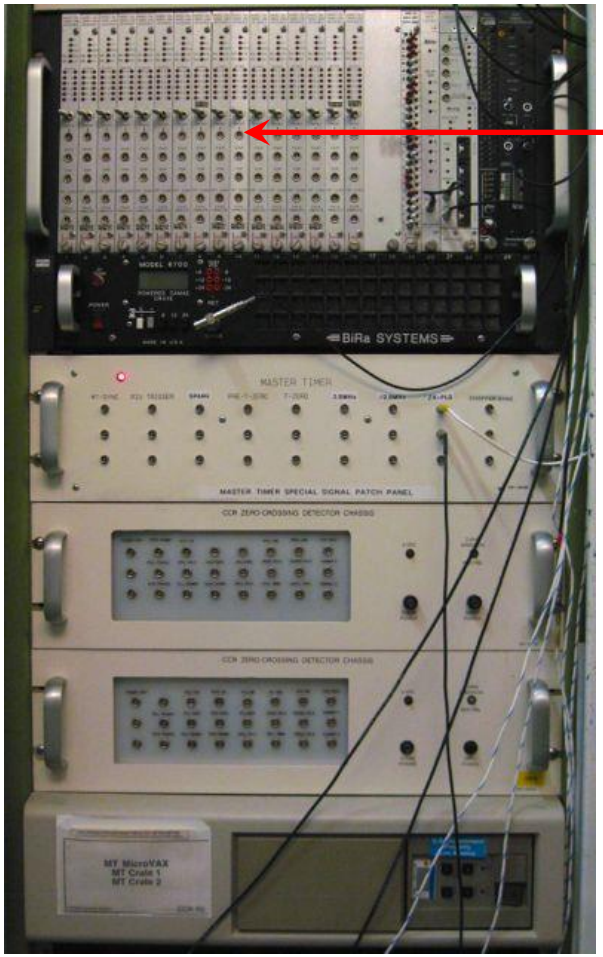

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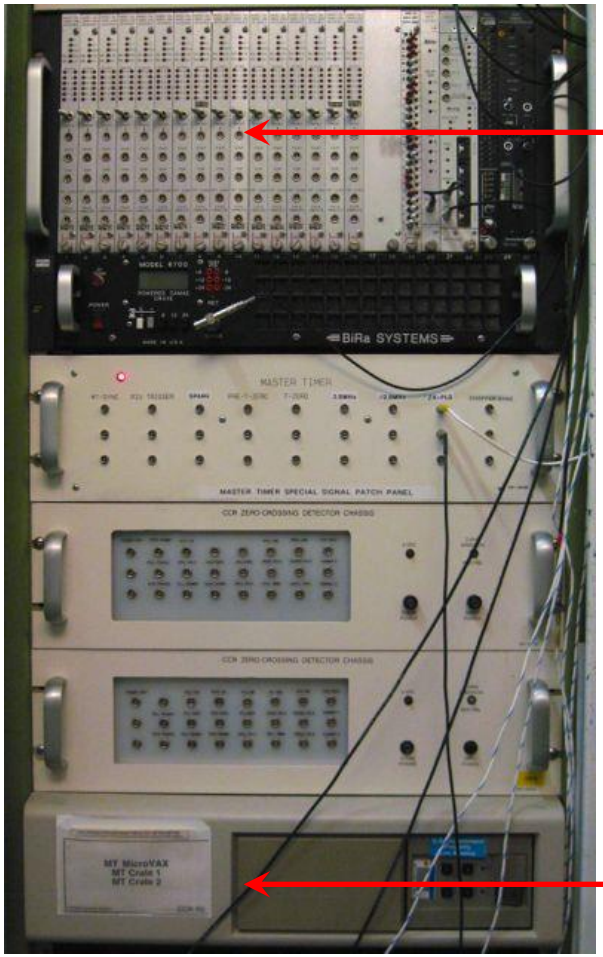
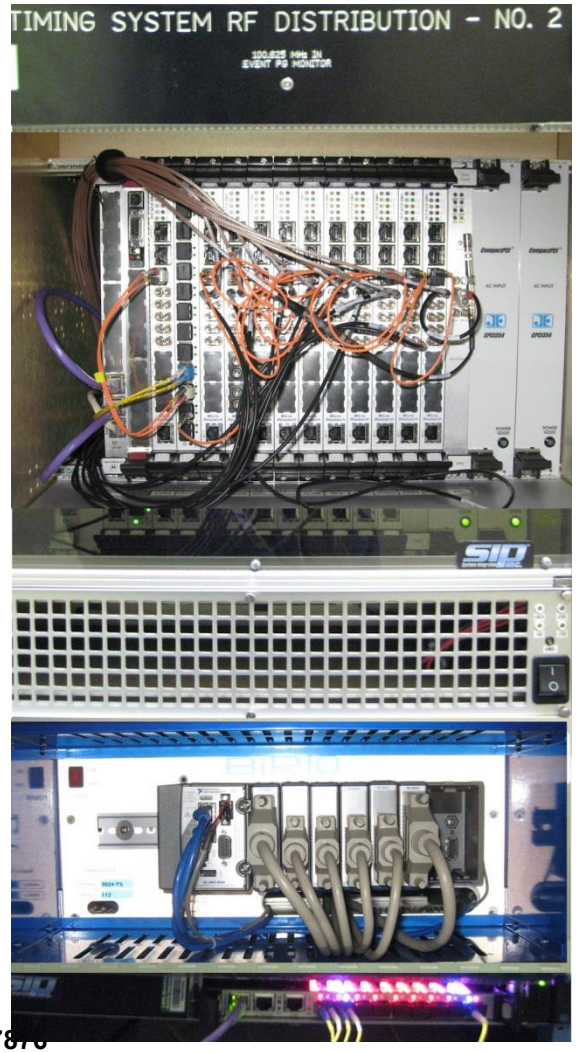
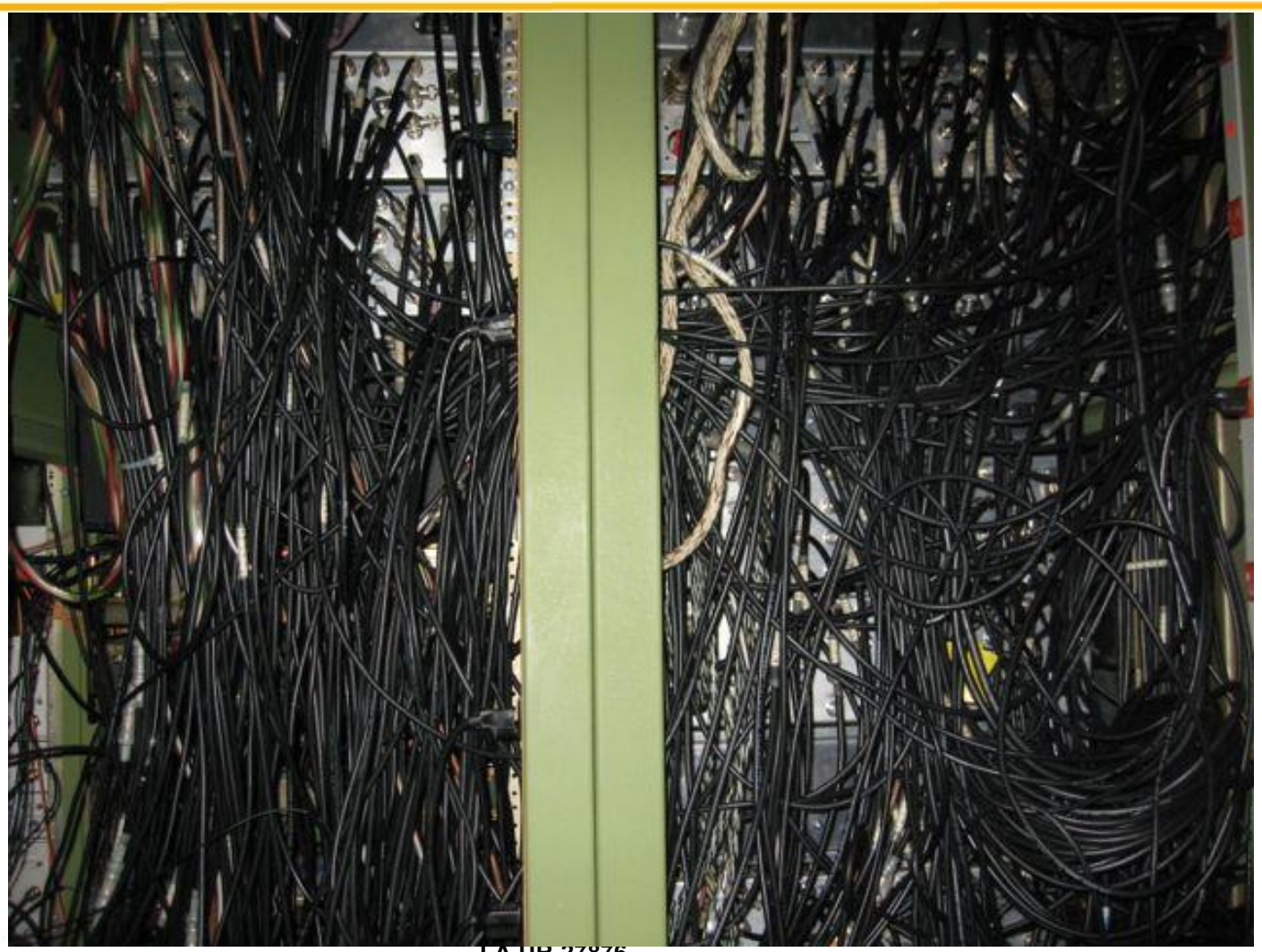


New Timing System

- Commercial event system from Micro Research Finland.
- VME, Compact PCI, Compact RIO.
- 255 events.
  - Potentially as many gates as you want.
- Event link distributed over 2.5 GHz fiber optic cables.
- 10 nSec resolution.



Old Timing Distribution System



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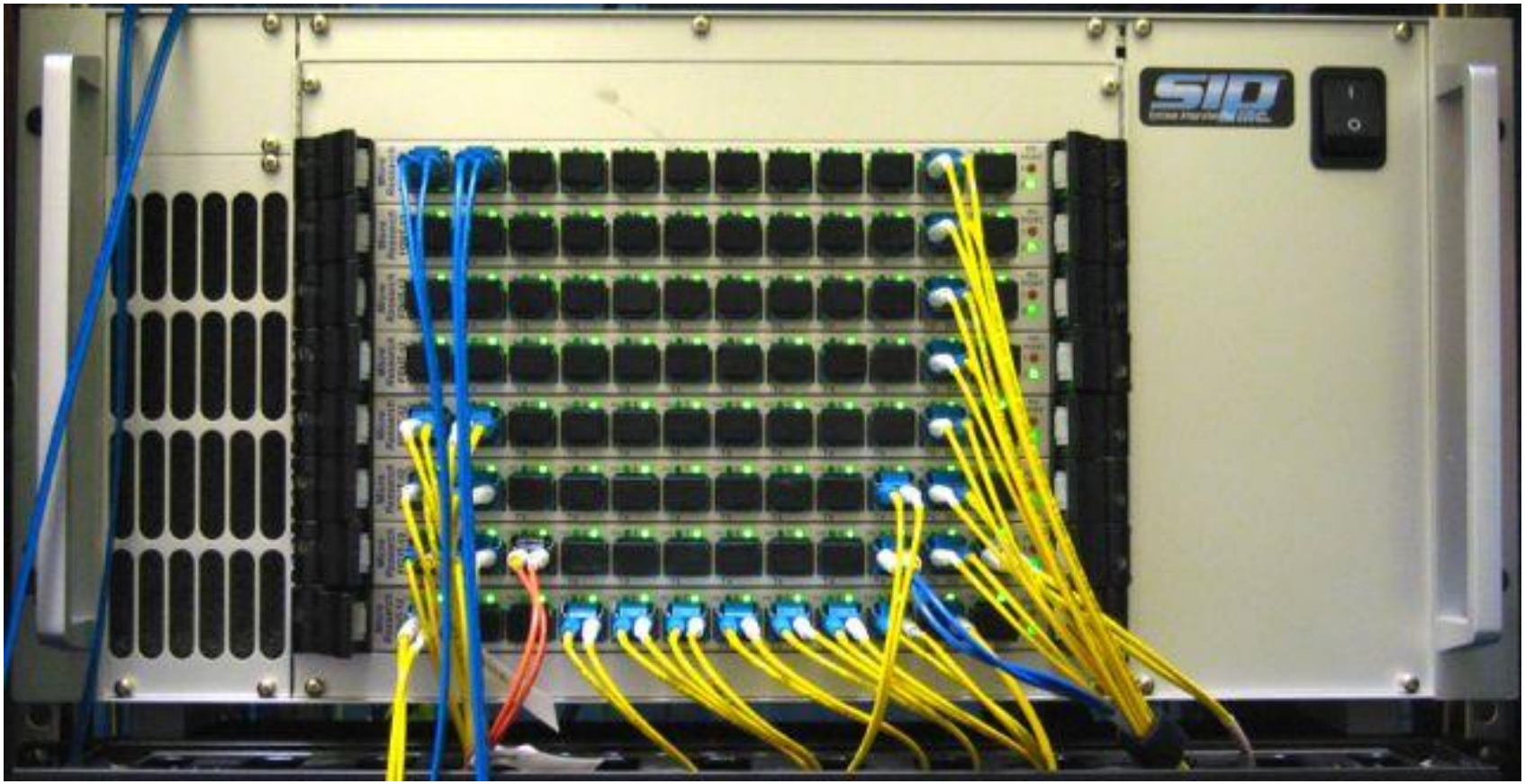

Observation 1: You can't replace the whole system at once.

"If you don't have a schedule, how will you know what you're deviating from?"

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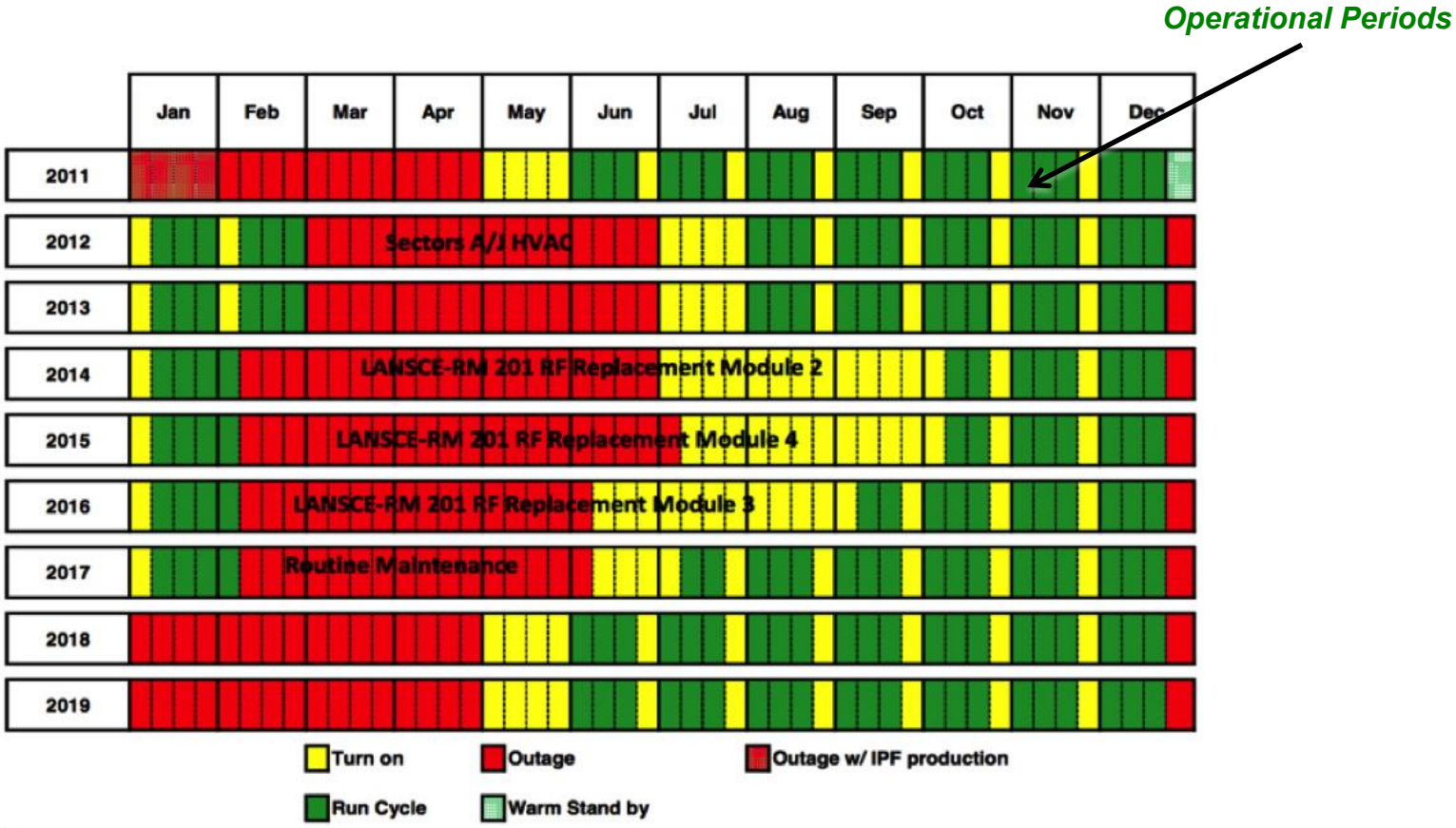

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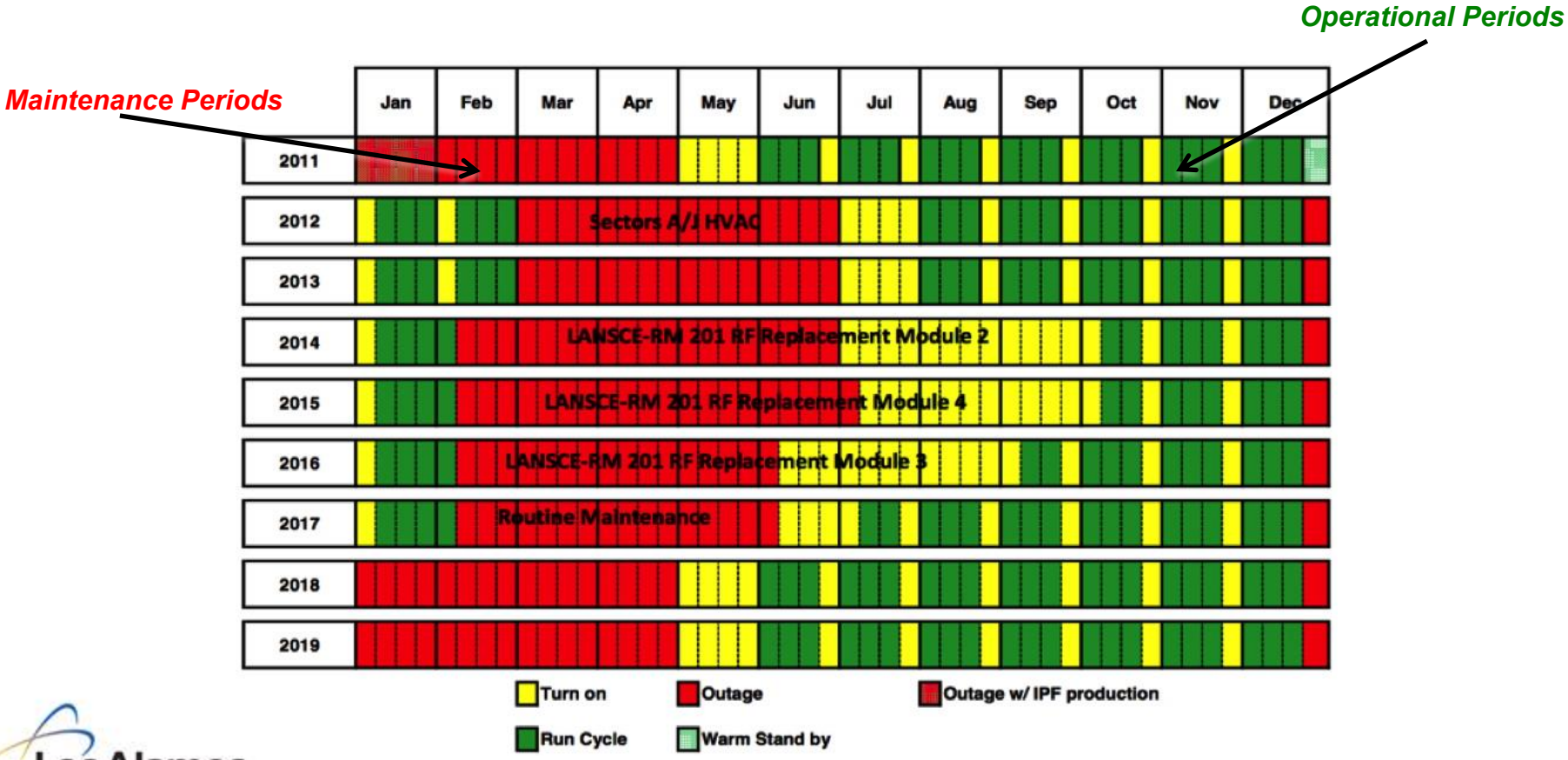

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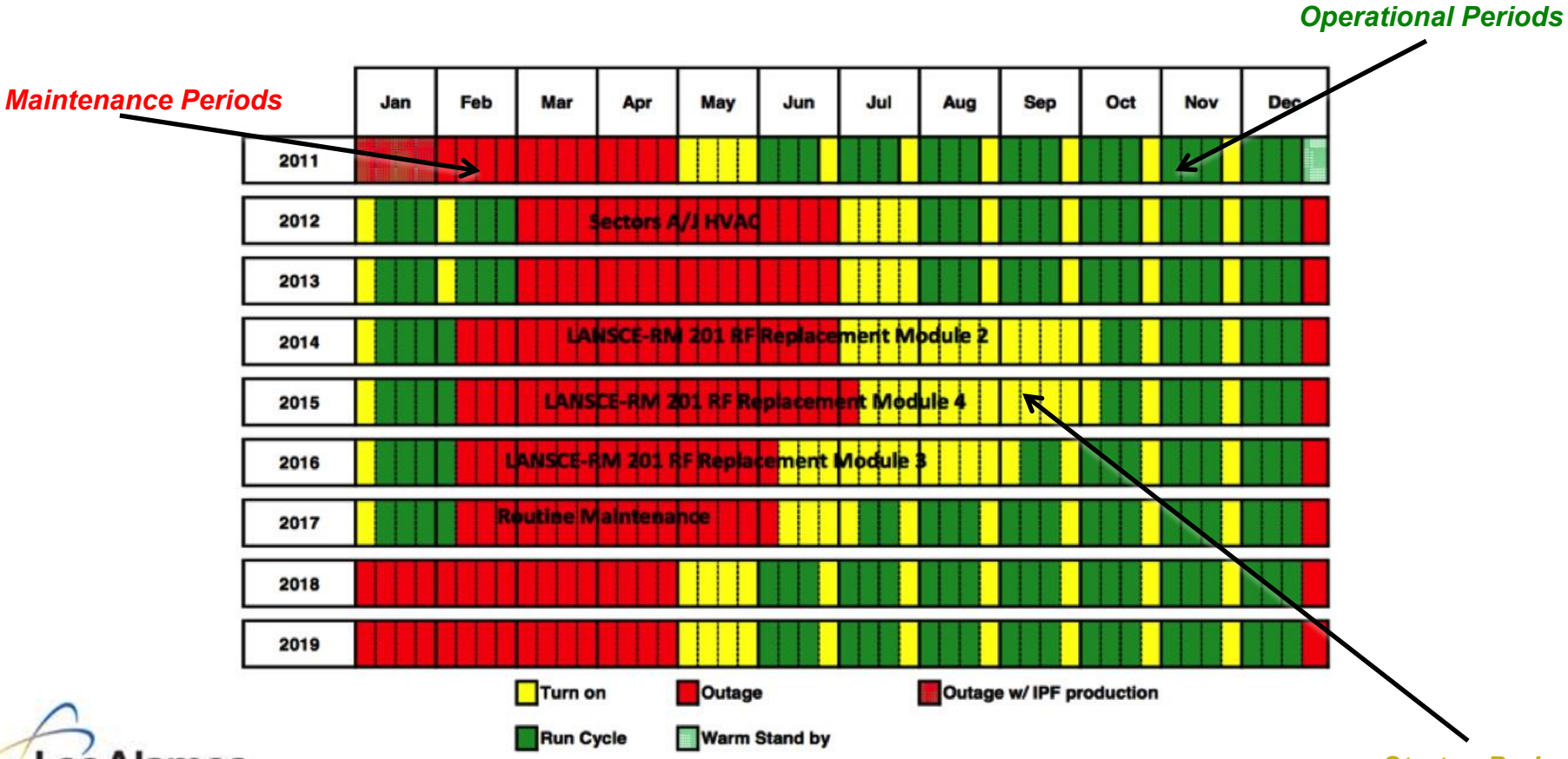
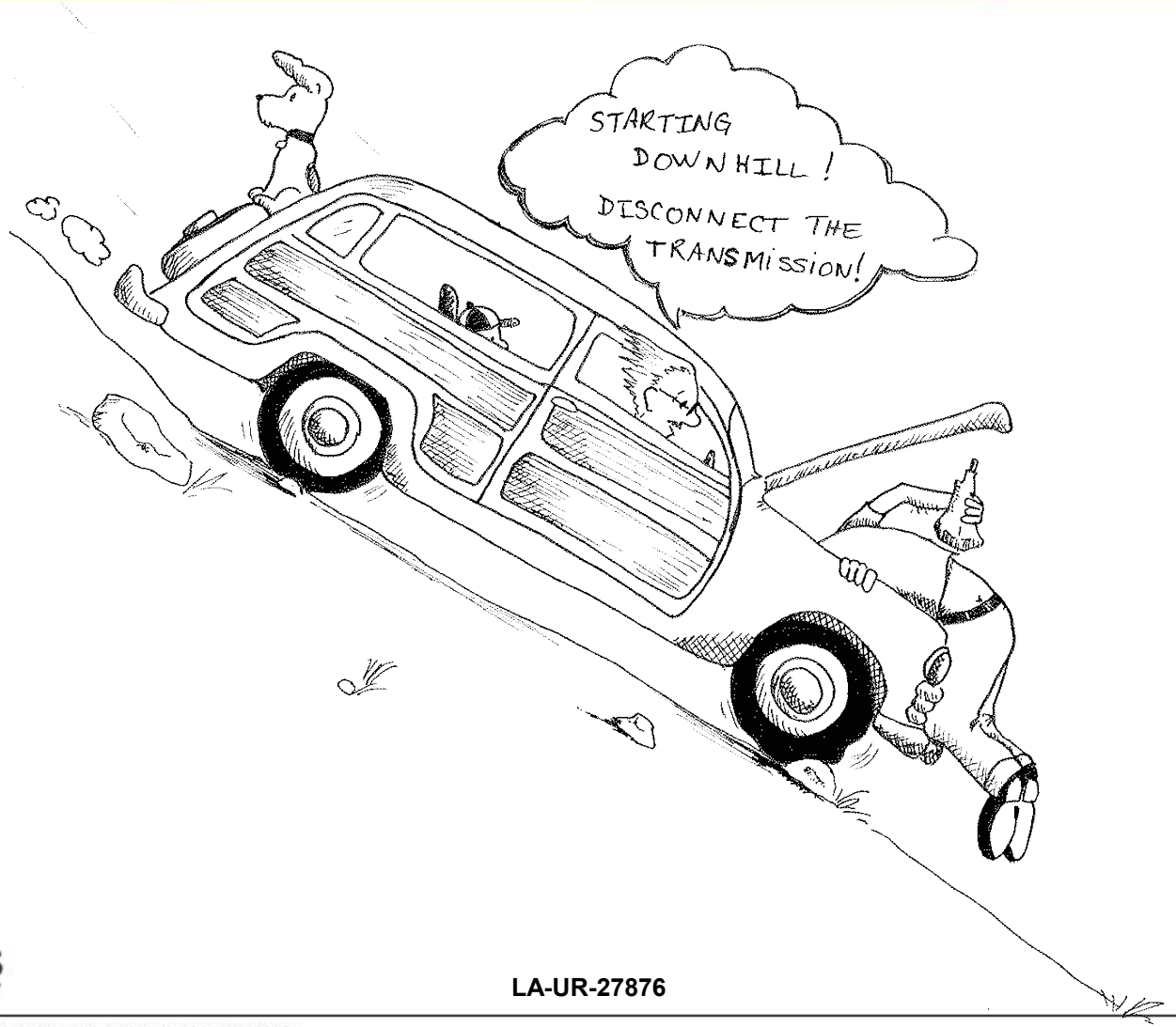
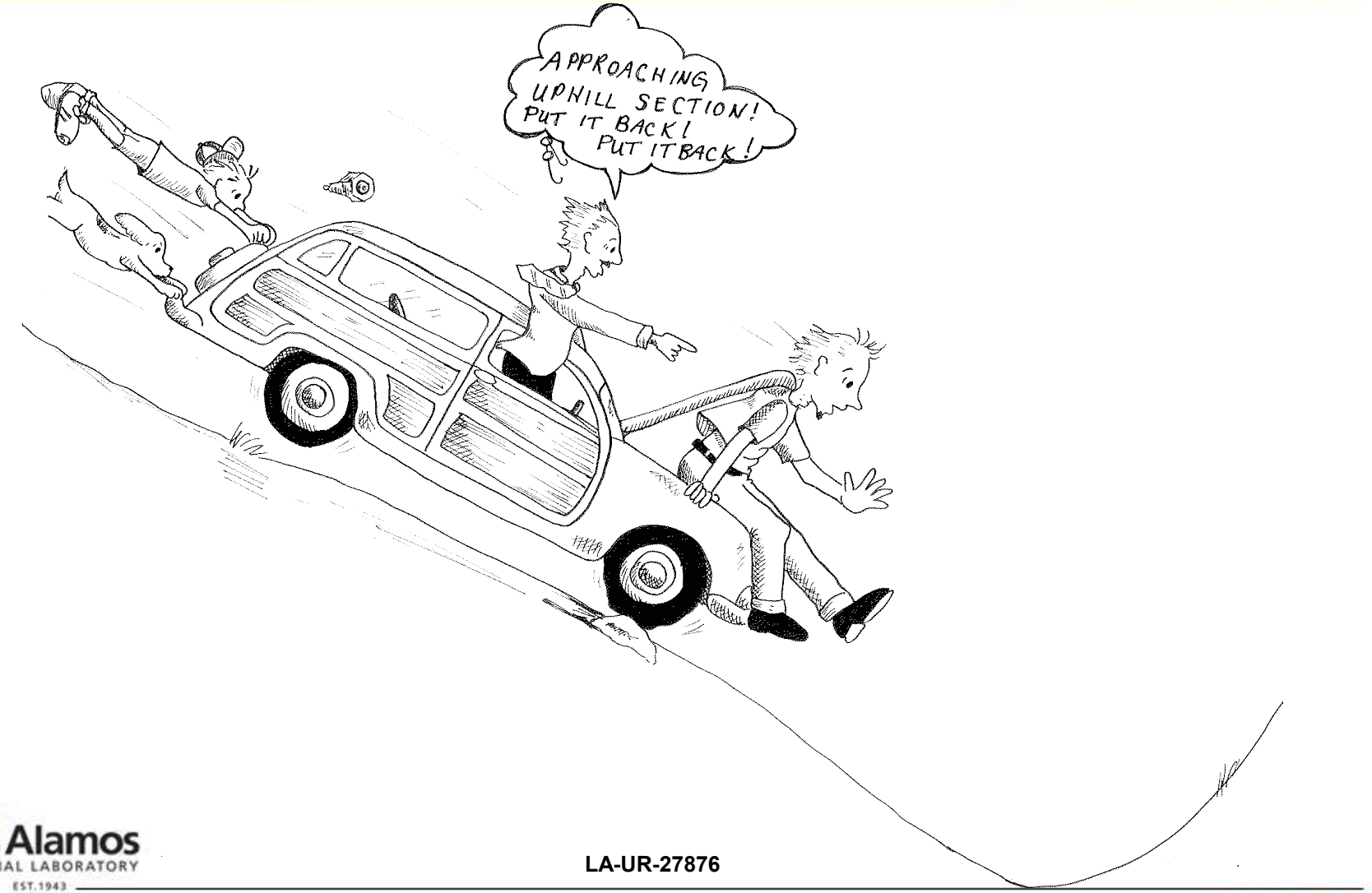


Negotiating the schedule is like driving over the mountains.

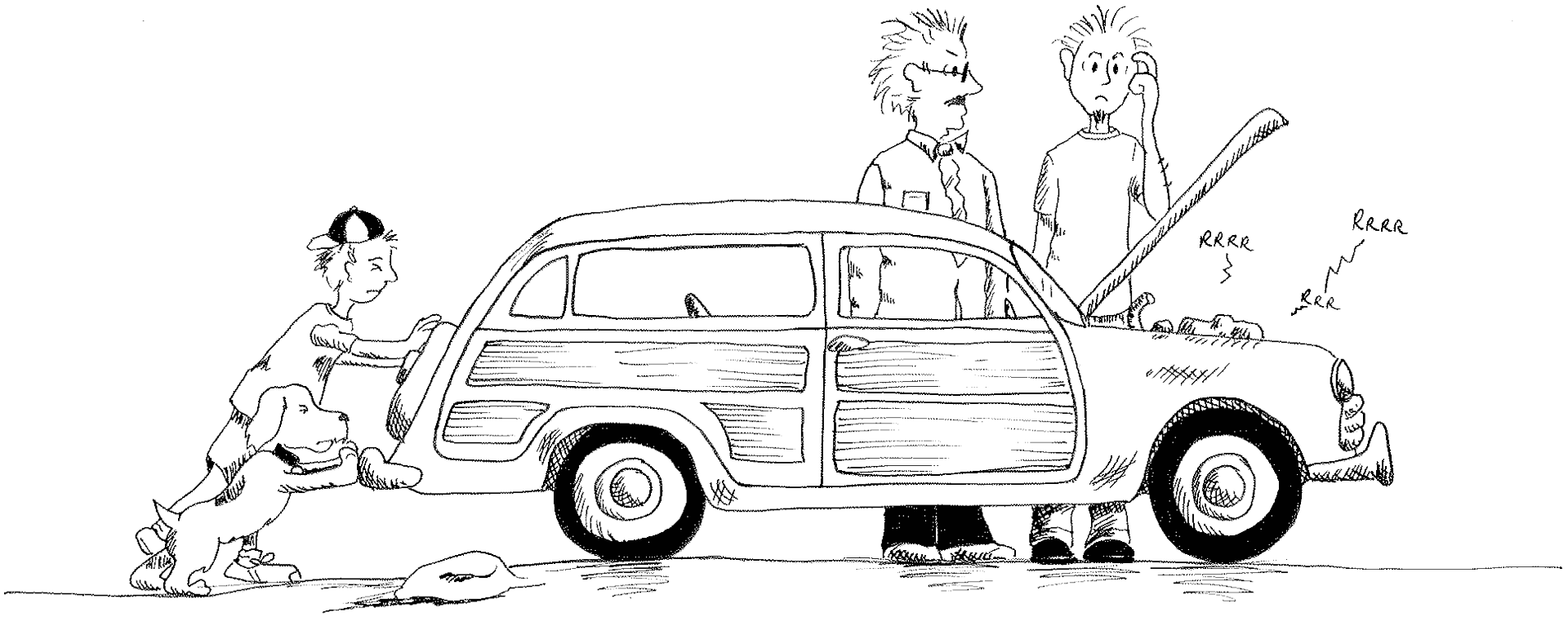
The Maintenance Periods



The Operational Periods



The Startup Periods



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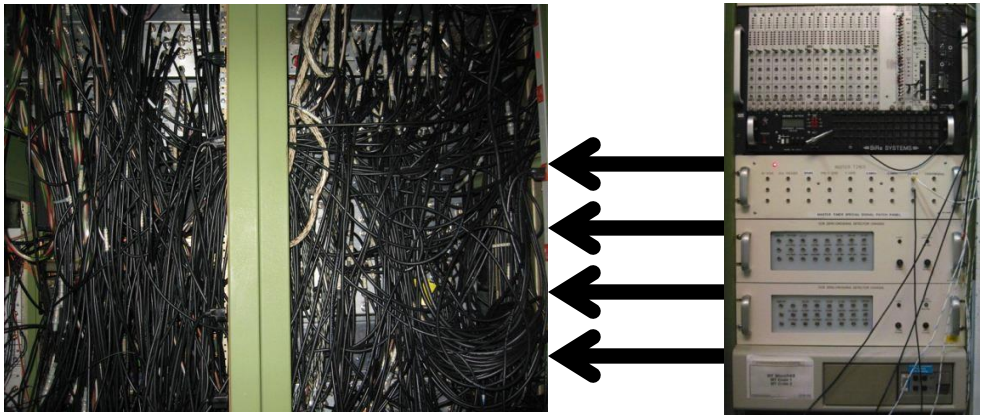
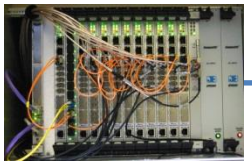
Question: Can one accelerator be governed by two timing systems?



Old Distribution

Old System

?



New System

New Distribution

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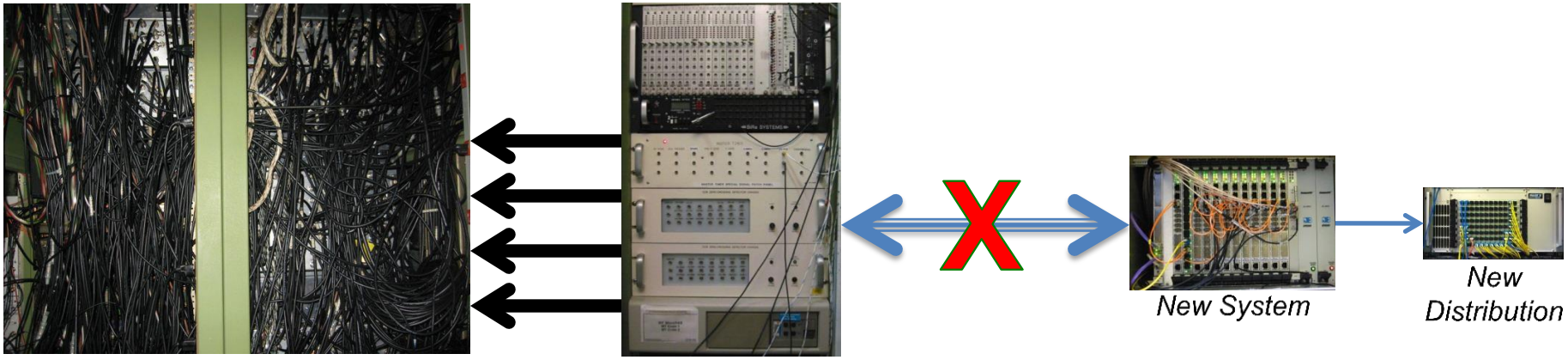
Can one accelerator be governed by two timing systems?
Final answer: **NO!**

Jitter between the two AC zero crossing detectors prevents running in parallel.



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Can one accelerator be governed by two timing systems?

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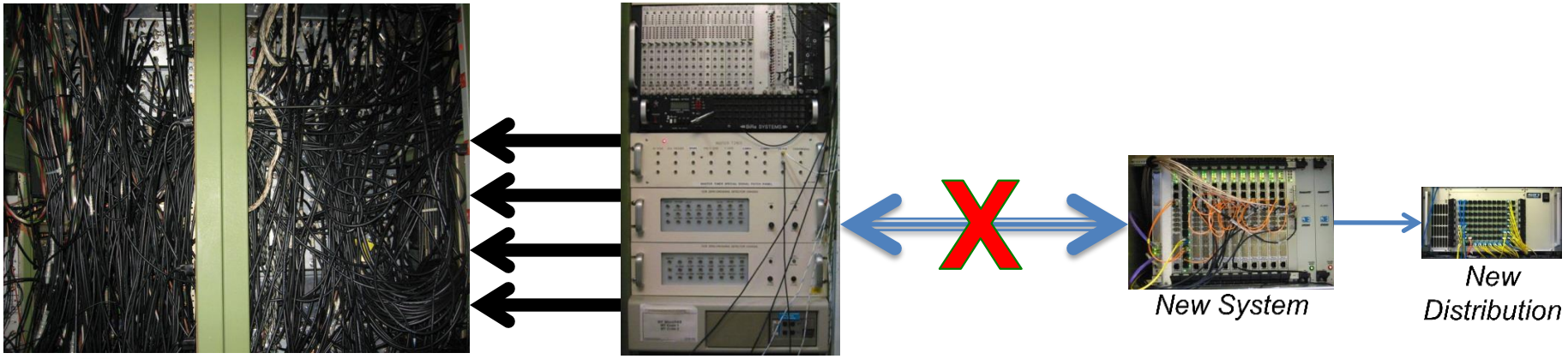

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Can one accelerator be governed by two timing systems?

- *Disconnect old system from its distribution.*

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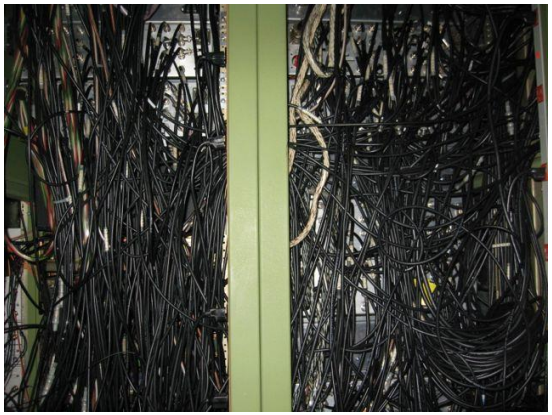

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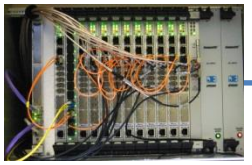

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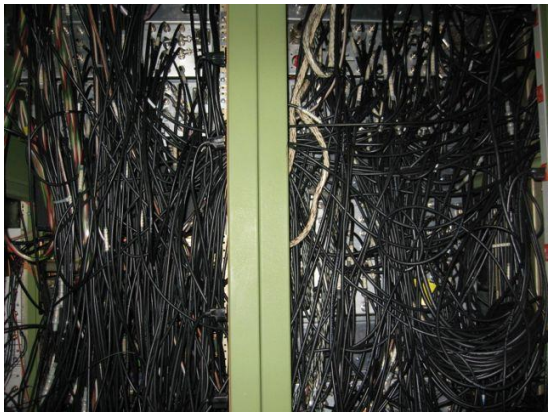
Solution:

- *Disconnect old system from its distribution.*
- *"Legacy Gate Replicator" – 10 event receivers (160 gates total) programmed to duplicate the gates generated by the old system.*



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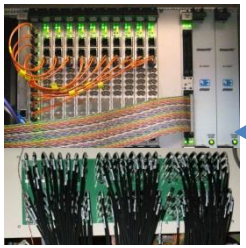
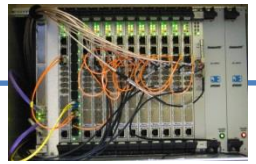


Legacy Gate Replicator



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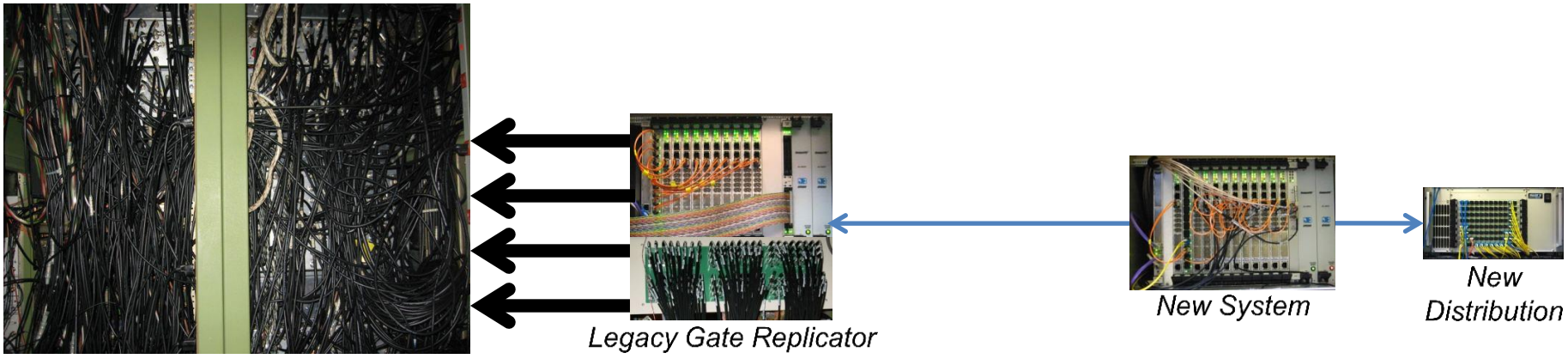

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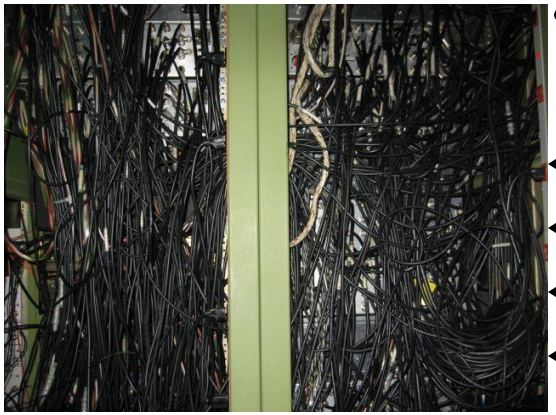
- *Old distribution now "slaved" to new timing system.*



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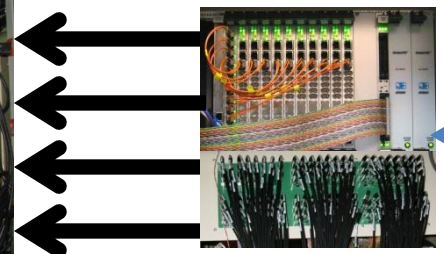

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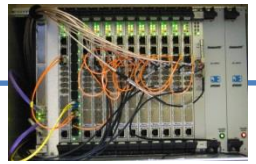

New System

New Distribution

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- Keep old systems available for at least a year.
- May need to quickly revert to old system for operational period.
  - Even if the new system is working perfectly.

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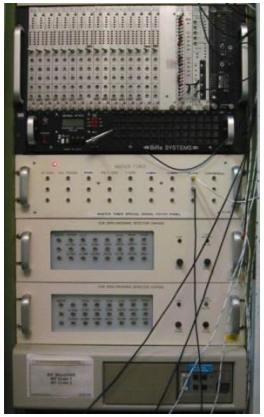
Timing System Fall-Back Plan:

- *Old system is disconnected but still in place.*



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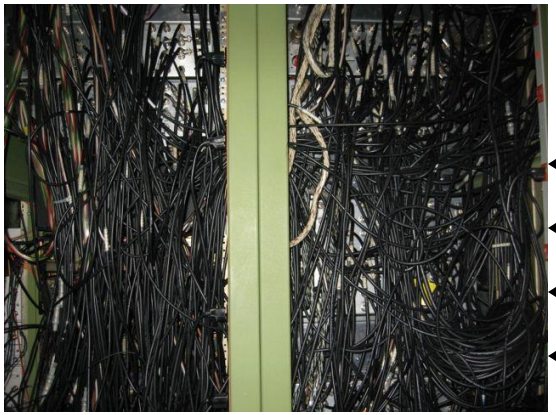

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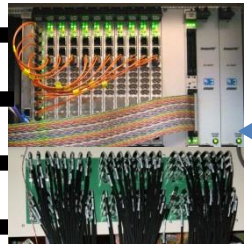

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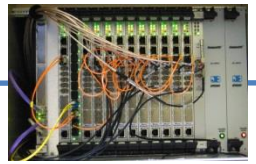

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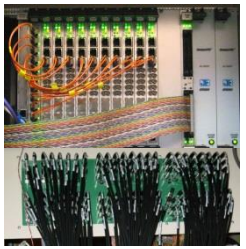

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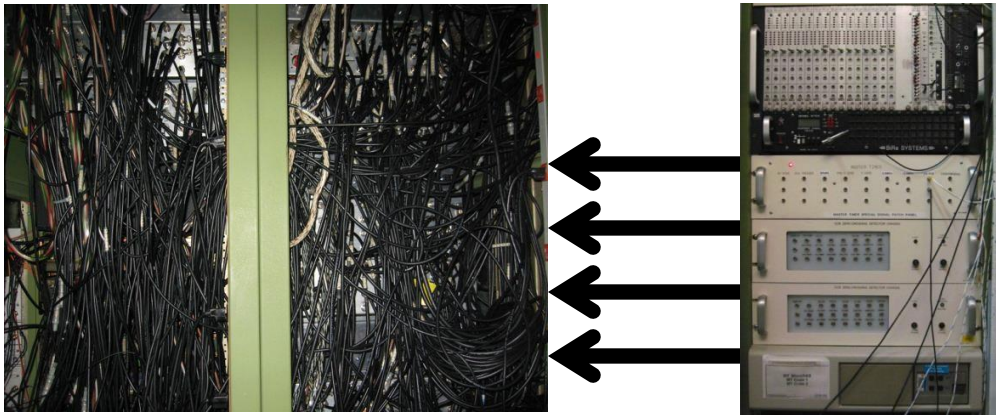

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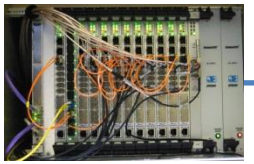

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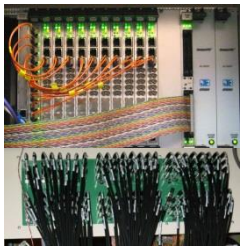
  - *Involves moving four ribbon cables.*



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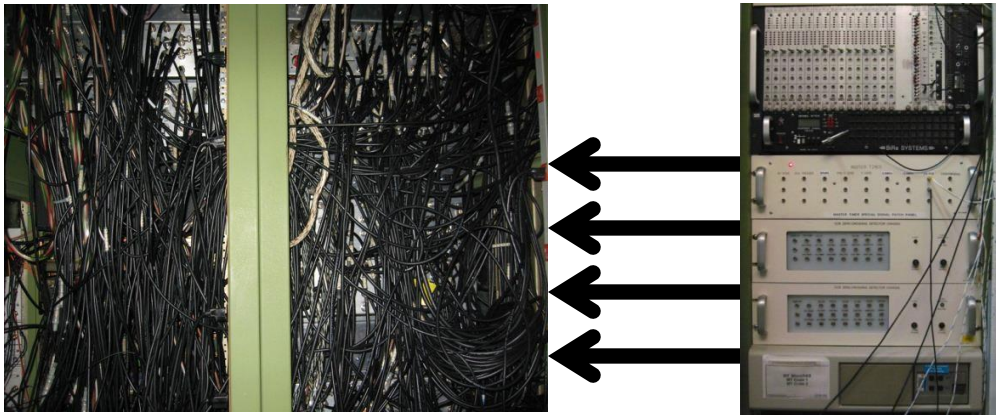

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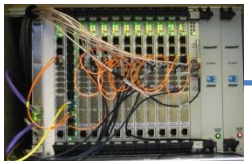

New System

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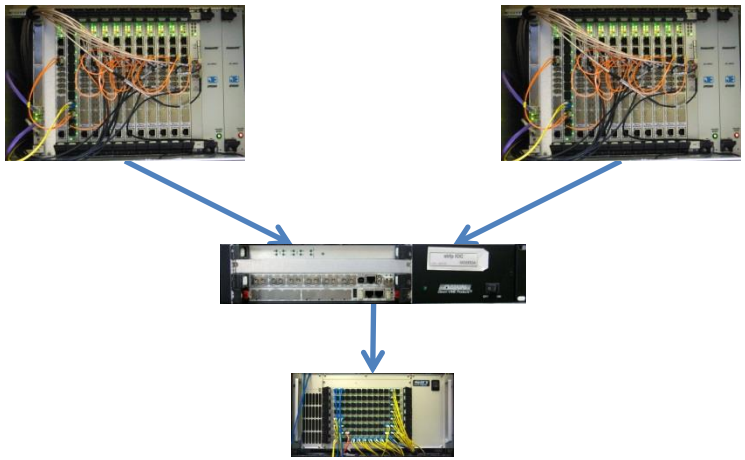
Redundancy: "falling back" to the new system

- *Originally planned on redundant systems for reliability.*
- *Also turned out to be a good way to fix problems while still providing timing gates.*



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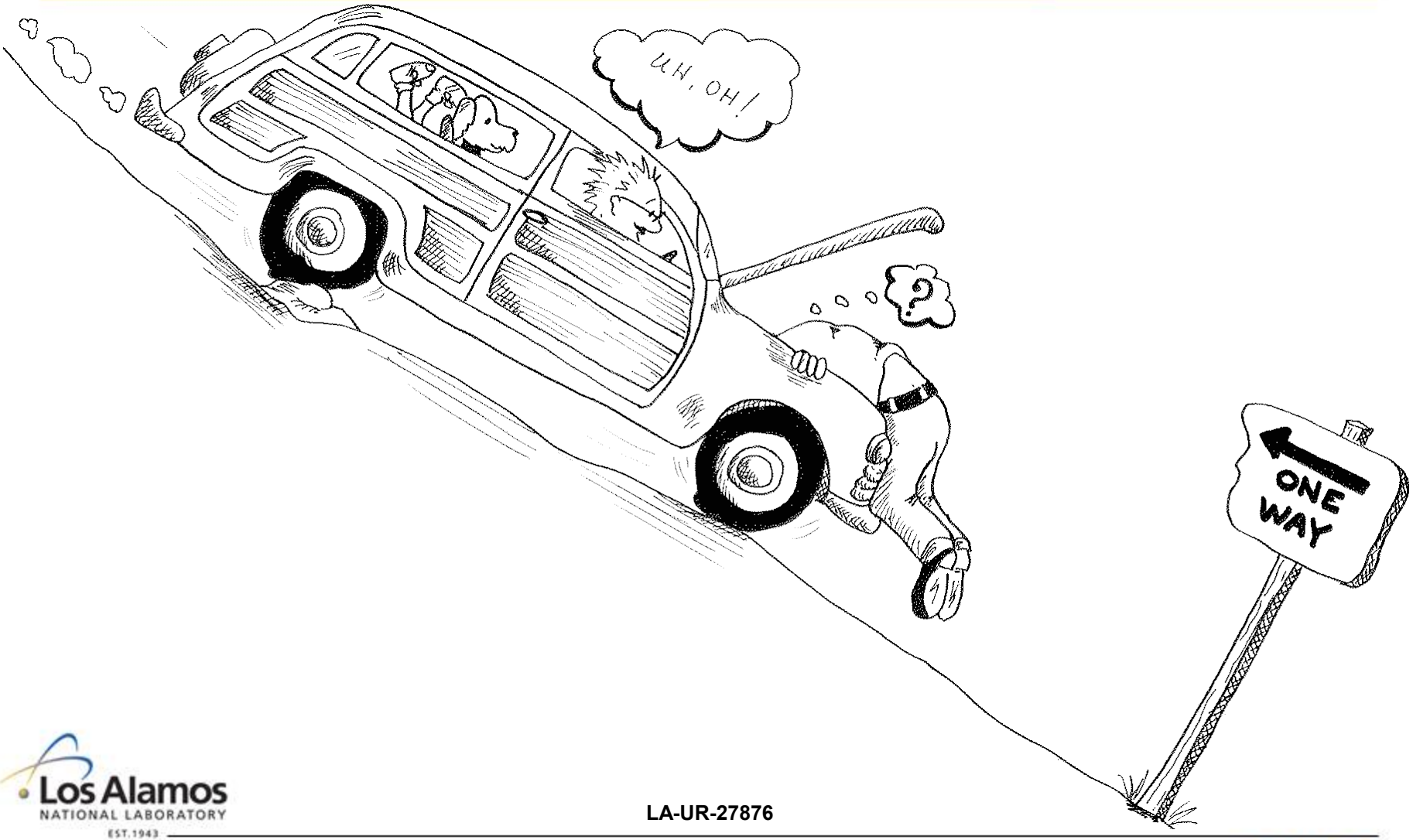

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- You will be surprised at how long old equipment can keep running!
  - Long after designers have retired.
  - Long after spares are available.
- You will be surprised to discover what you didn't know!
  - Hidden design "Features".
  - Undocumented inter-system dependencies.

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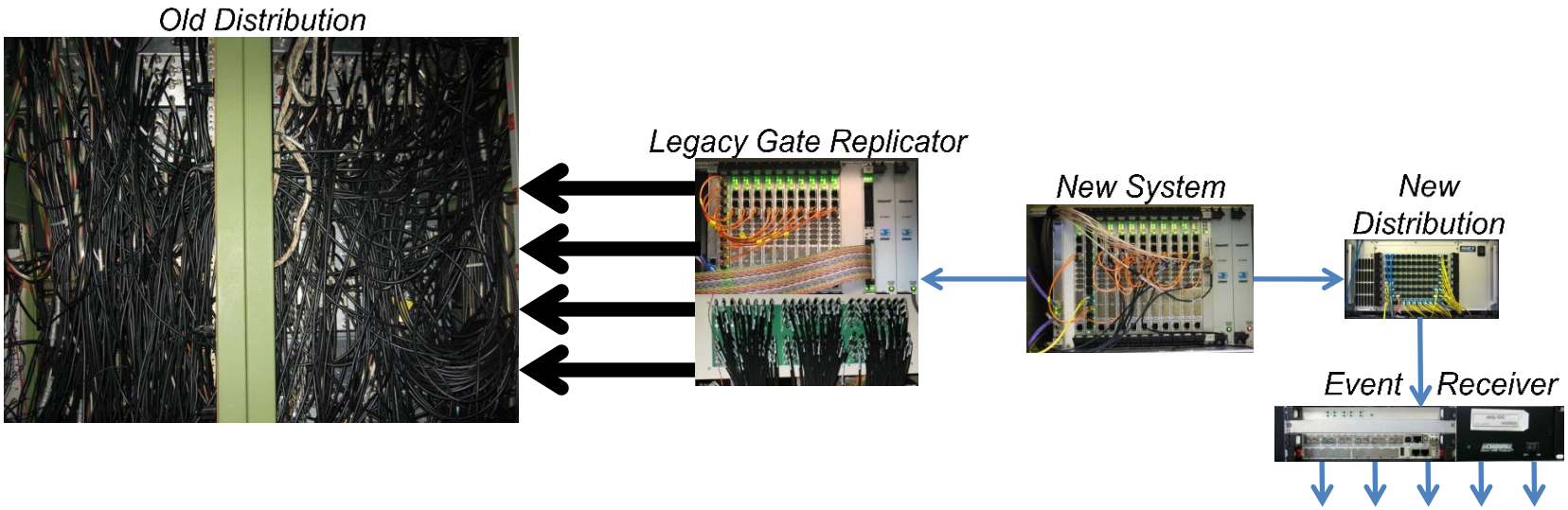
Example: We knew there would be a skew between signals generated from the event link (new distribution) and the LGR (old distribution).



So make sure all the signals to a piece of equipment come from the same source (old or new distributions).

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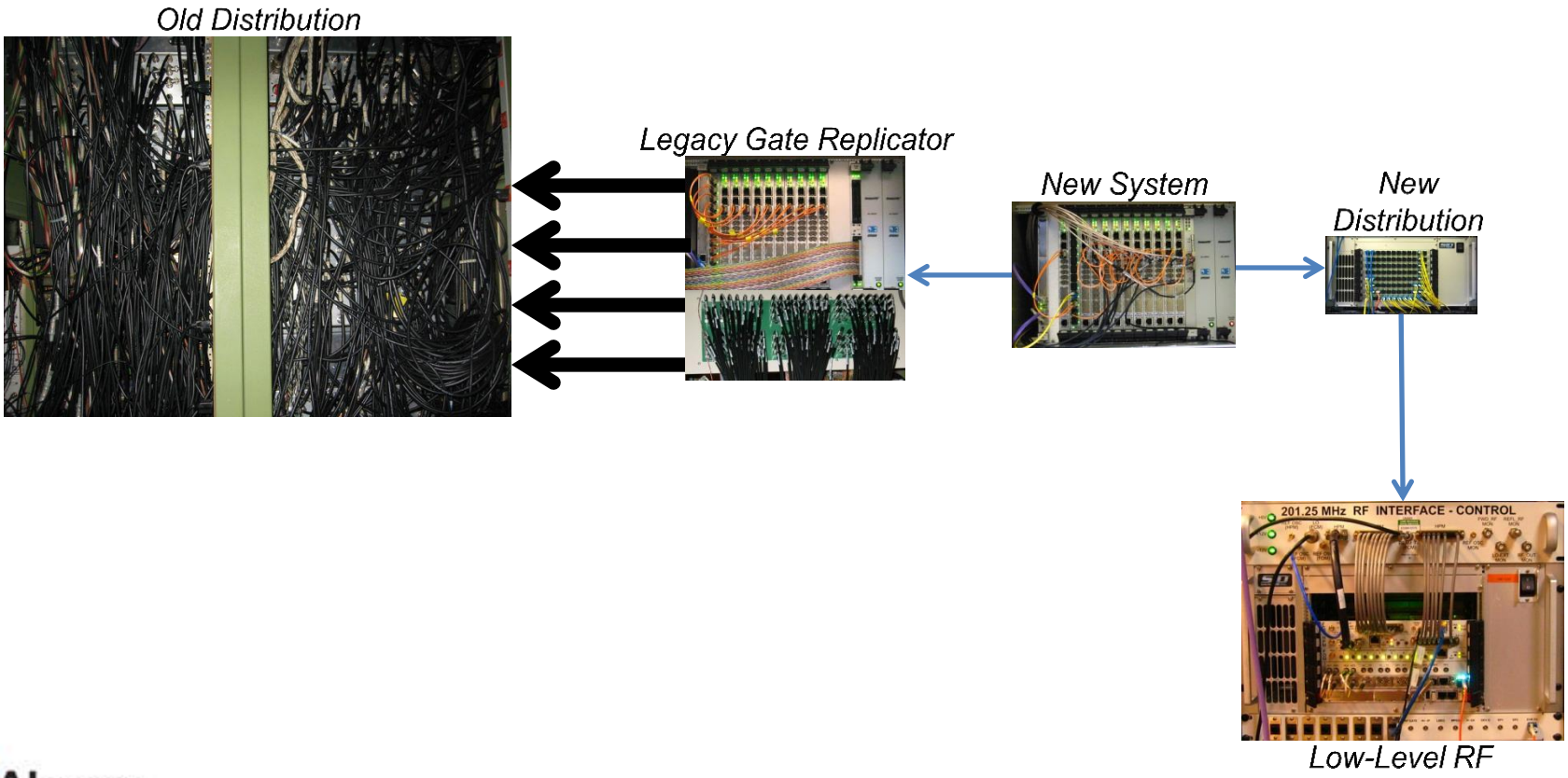
– LLRF needs features of the new timing system – use new distribution.



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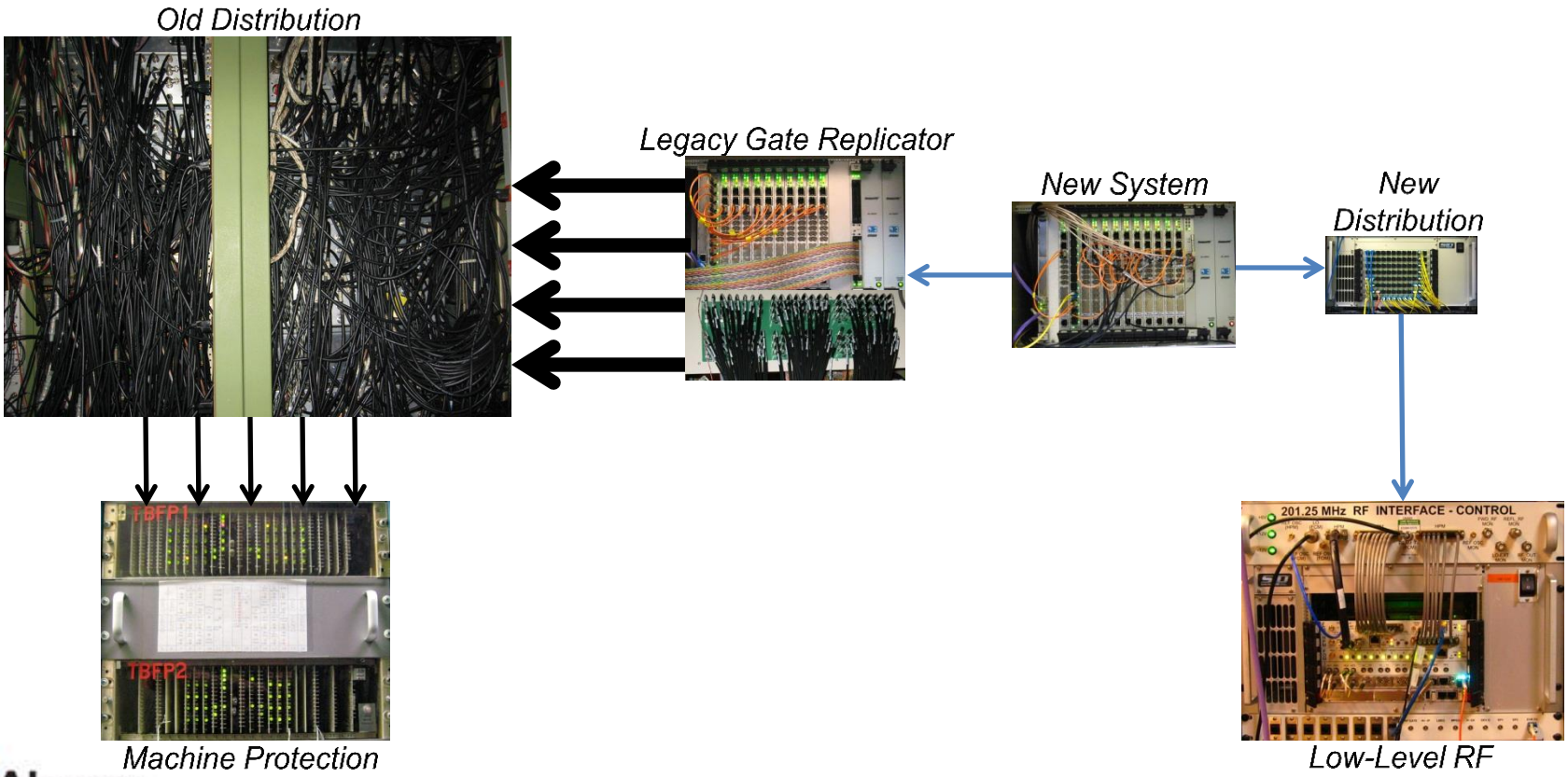
– *Machine protection does not need new features – keep old distribution.*



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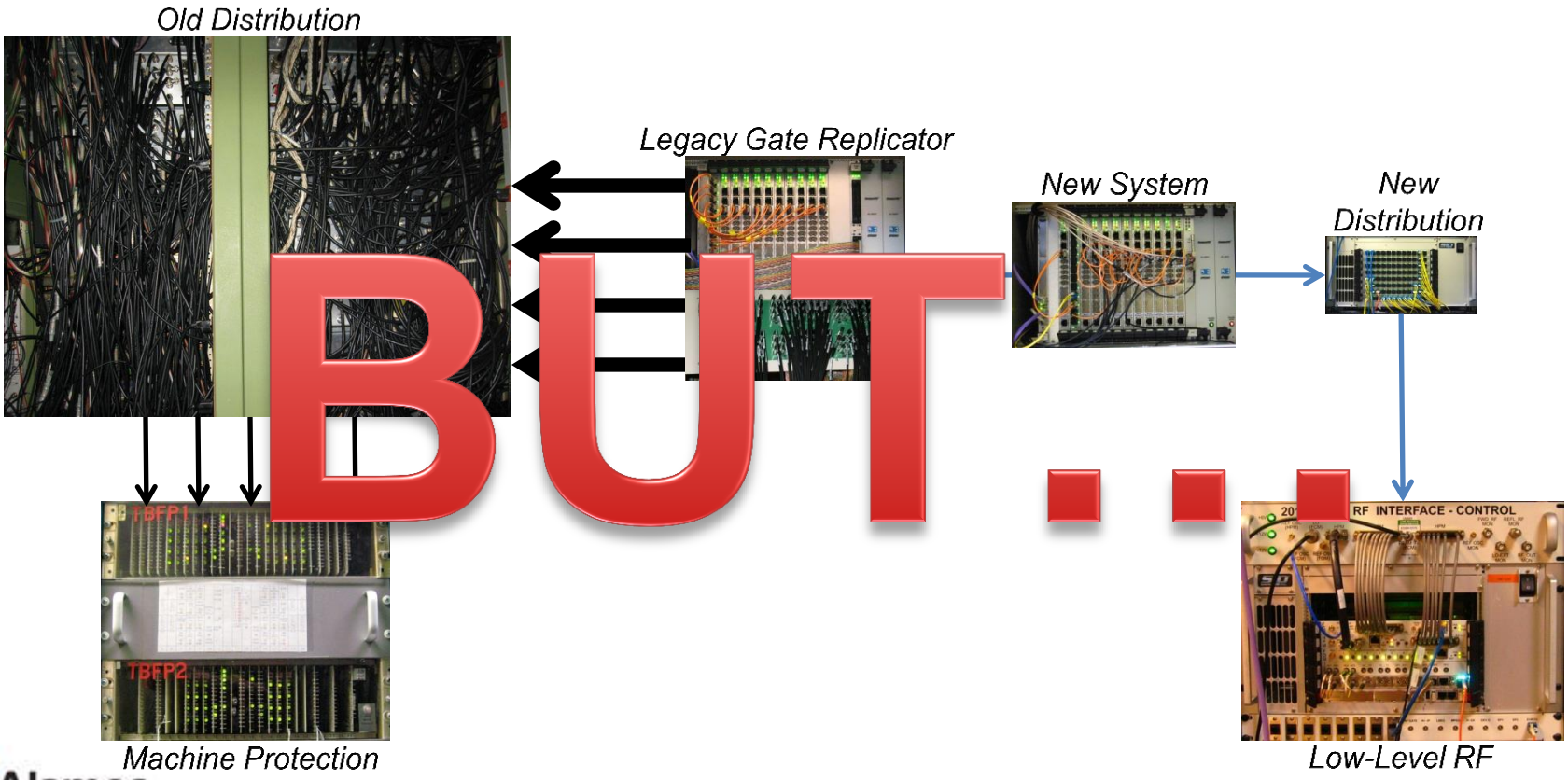

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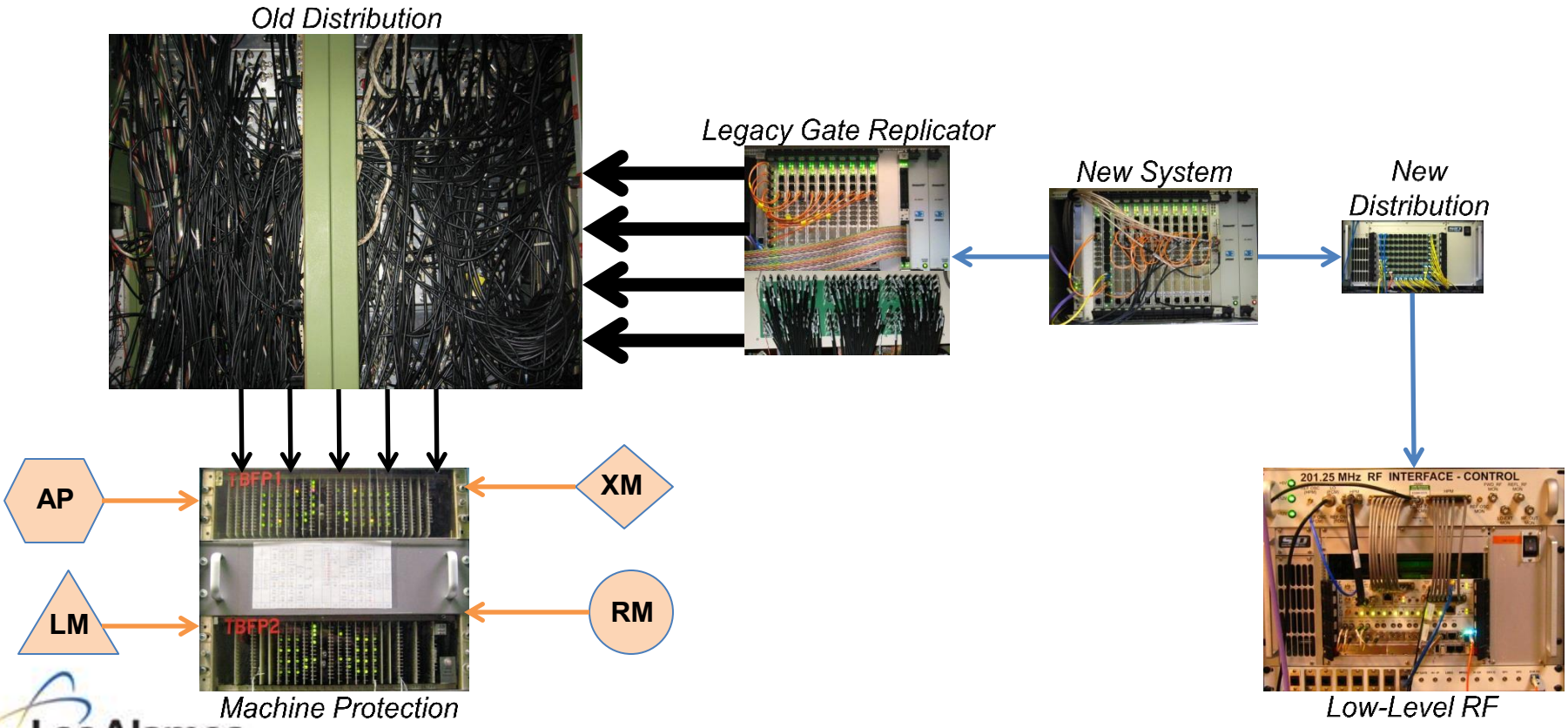
The machine protection system also gets inputs from various monitoring devices.



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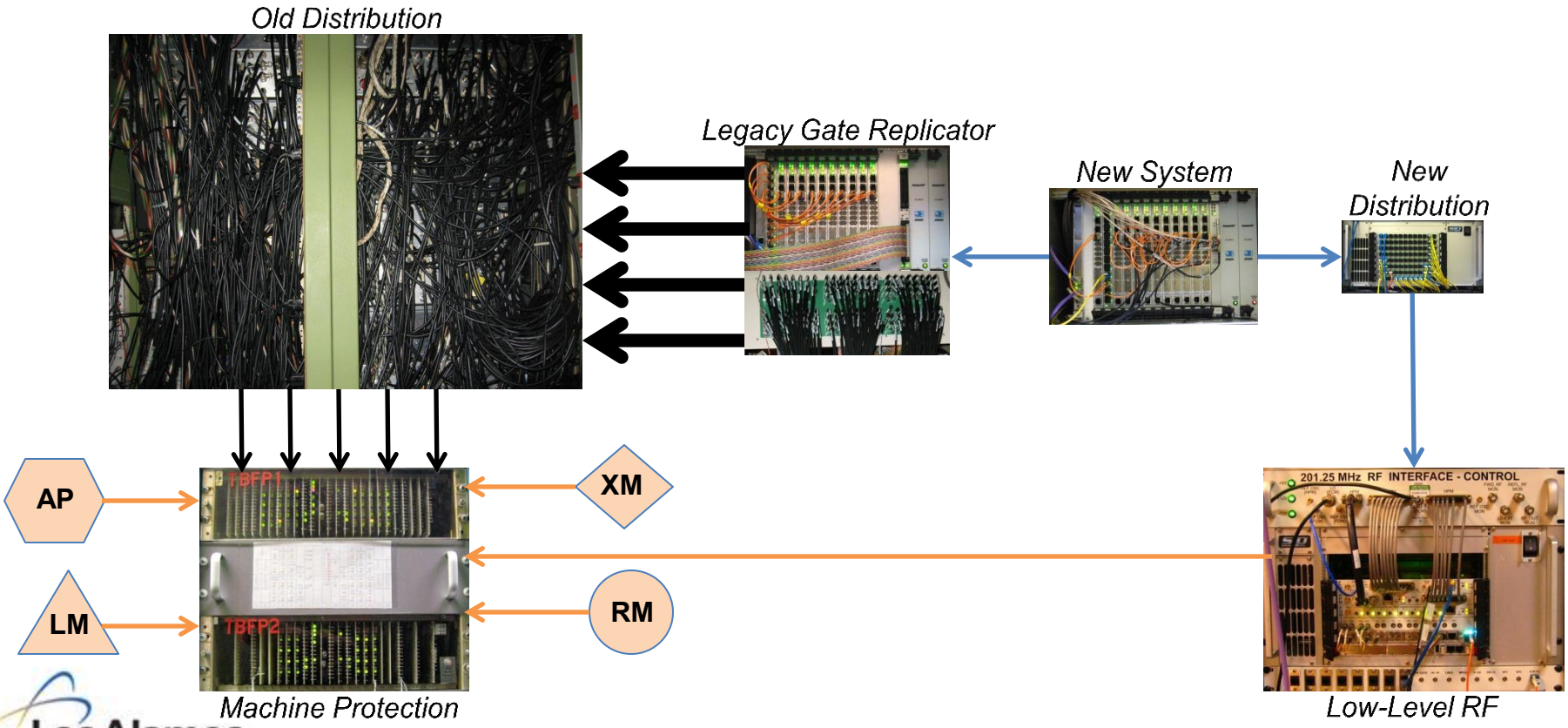
Including a signal from the Low-Level RF System



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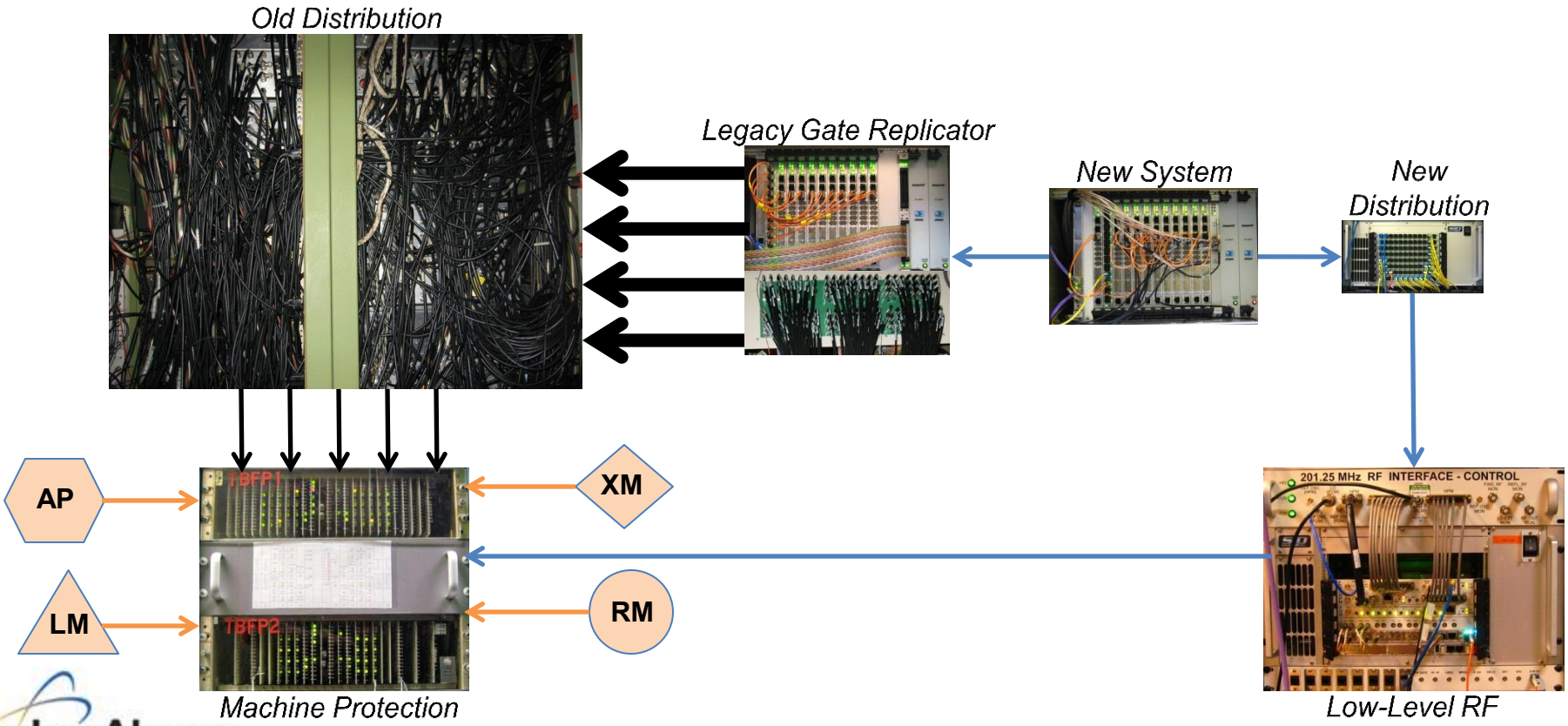
Including a signal from the Low-Level RF System
…which is derived from new timing system signals.



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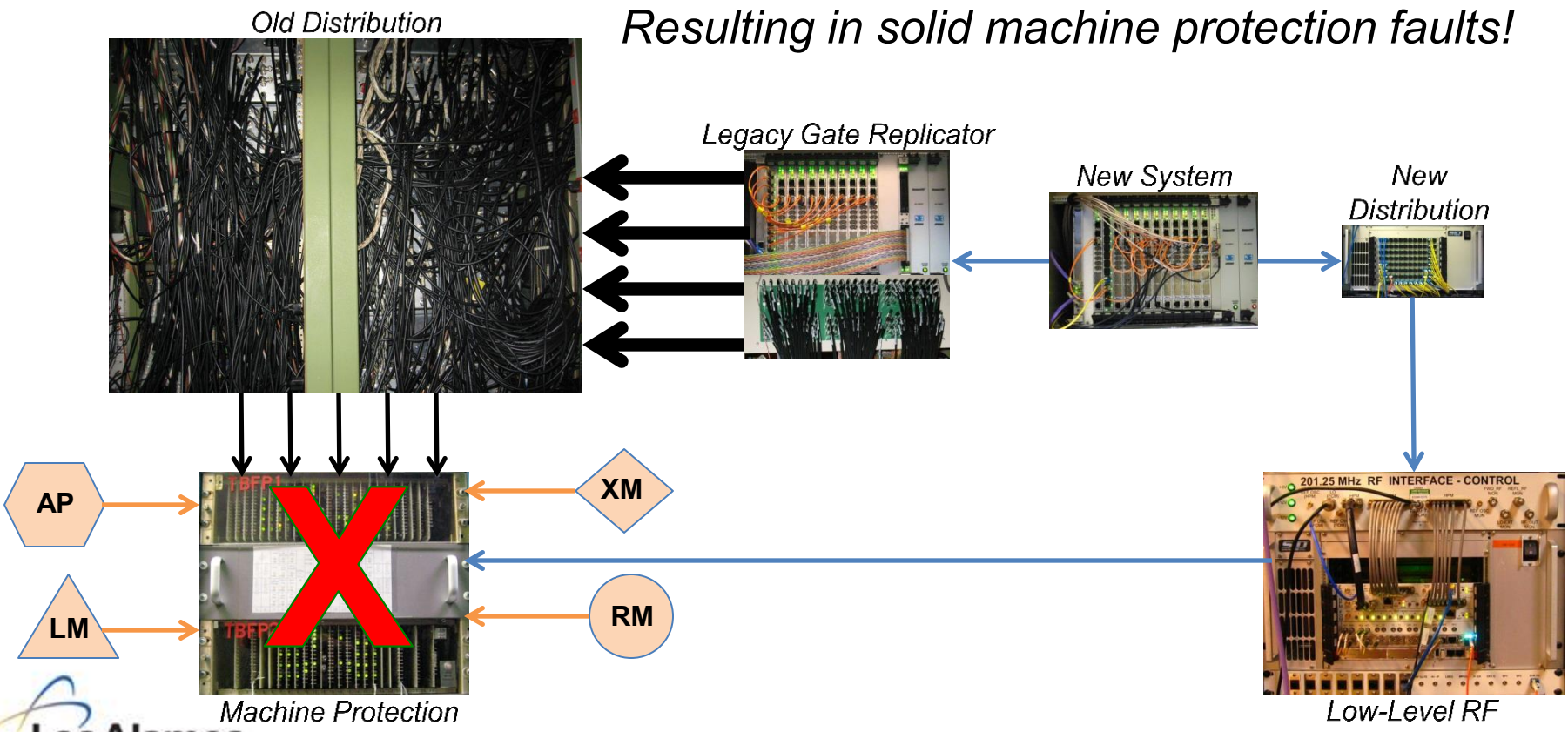
Resulting in solid machine protection faults!



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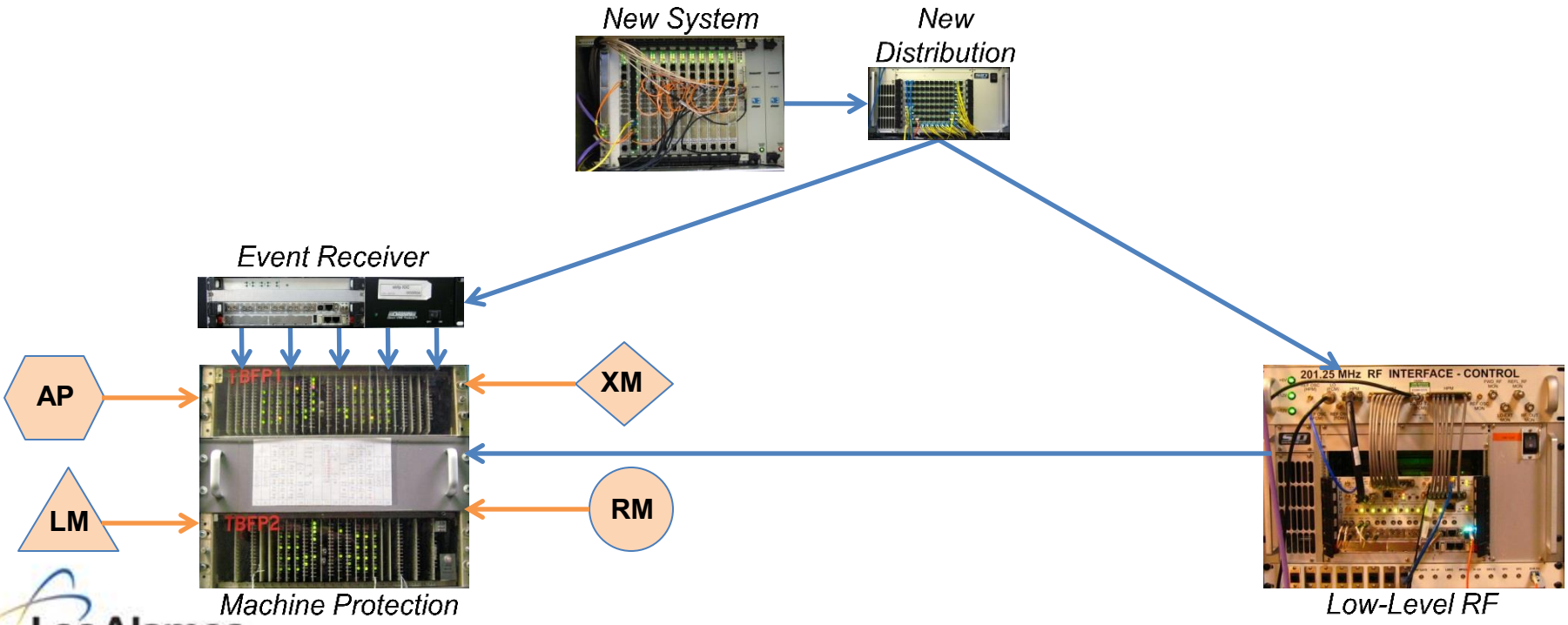
Reconfigure:
Supply machine protection system with gates from the new distribution.



Recommendation 2:
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HOW MANY LABORATORY EMPLOYEES DOES IT TAKE TO CHANGE A LIGHT BULB?

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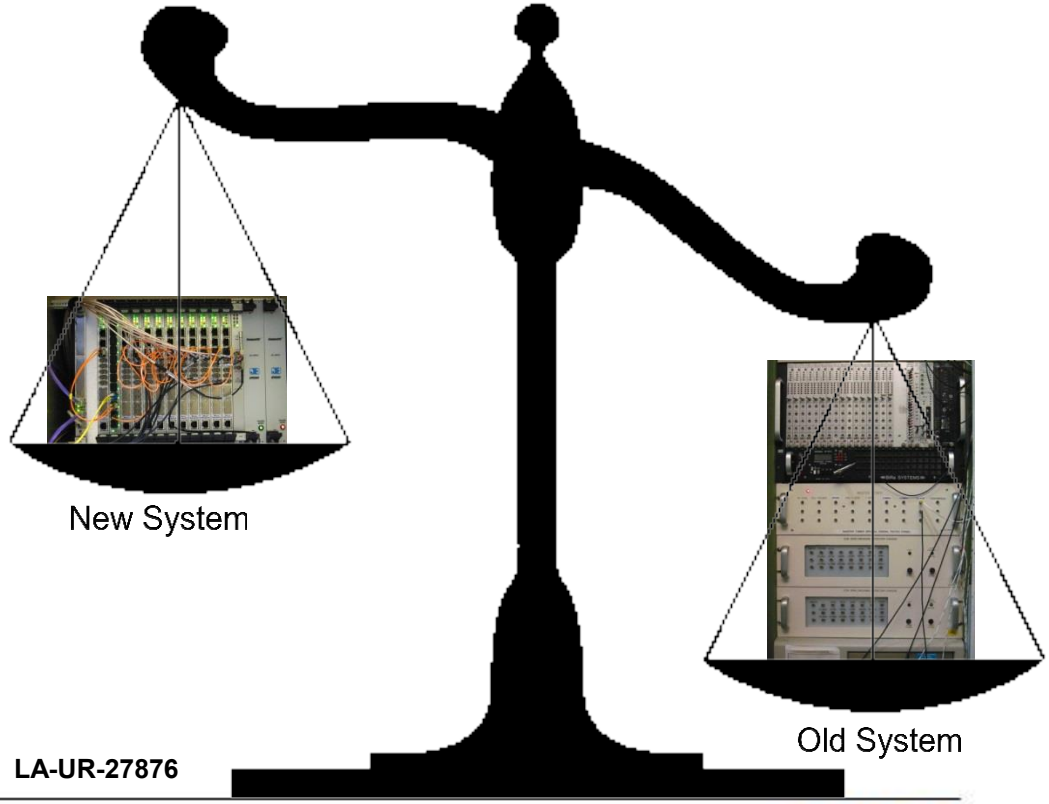
Change is Hard:

- It is even harder if the change is a surprise.
- Even a “good” change is still a change.
- What is gained from the new is often eclipsed by what is lost from the old.
- Bottom Line: The machine does not work the same way anymore.
  - New timing system altered the way an entire section of the accelerator behaved because of a change in how the beam was chopped.



Recommendation 2:
Sympathy for the operations staff.

Keeping Operations In The Loop:

- Training sessions
- Involve operations personnel in design reviews
- Involve operations personnel in installation activities
  - Operations global perspective vs system engineer's local perspective.

Thanks…

Special Thanks To Kristi Carr

(the Carr-Toonist)

Thanks…

And Thank You For Your Attention!