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

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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.
Old Timing System

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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
New Timing Distribution System
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?”
Observation 1: You can’t replace the whole system at once.

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Legend:
- Yellow: Turn on
- Red: Outage
- Green: Run Cycle
- Light Green: Warm Stand by
- Dark Red: Outage w/ IPF production
Observation 1: You can’t replace the whole system at once.
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Negotiating the schedule is like driving over the mountains.
The Maintenance Periods

STARTING DOWN HILL! DISCONNECT THE TRANSMISSION!
The Operational Periods
The Startup Periods
Observation 2: Some compatibility must be maintained between the old and new systems.
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Question: Can one accelerator be governed by two timing systems?
Observation 2: Some compatibility must be maintained between the old and new systems.

Can one accelerator be governed by two timing systems?

Final answer: **NO!**

Jitter between the two AC zero crossing detectors prevents running in parallel.
Observation 2: Some compatibility must be maintained between the old and new systems.

Can one accelerator be governed by two timing systems?

Solution:
Observation 2: Some compatibility must be maintained between the old and new systems.

Can one accelerator be governed by two timing systems?

• Disconnect old system from its distribution.

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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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Can one accelerator be governed by two timing systems?

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.
- Connect LGR to old distribution system.
Observation 2: Some compatibility must be maintained between the old and new systems.

Can one accelerator be governed by two timing systems?

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.
- Connect LGR to old distribution system.
- Old distribution now “slaved” to new timing system.
Recommendation 1: Always have a way to fall back.

ARGH! MY ENGINE'S MISSING!

DON'T PANIC. I HAVE A SPARE IN MY TRUNK.
Recommendation 1: Always have a way to fall back.

- 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.
Recommendation 1: Always have a way to fall back.

**Timing System Fall-Back Plan:**
- *Old system is disconnected but still in place.*
Recommendation 1: Always have a way to fall back.

Timing System Fall-Back Plan:
• Old system is disconnected but still in place.
• Disconnect Legacy Gate Replicator and re-connect old system.
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**Timing System Fall-Back Plan:**
- *Old system is disconnected but still in place.*
- *Disconnect Legacy Gate Replicator and re-connect old system.*
  - Involves moving four ribbon cables.
Recommendation 1: Always have a way to fall back.

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.
Observation 3: You will be surprised.
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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.
Observation 3:
You will be surprised.

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).
Observation 3: You will be surprised.

- LLRF needs features of the new timing system – use new distribution.
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– LLRF needs features of the new timing system – use new distribution.
– Machine protection does not need new features – keep old distribution.
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Observation 3: You will be surprised.

The machine protection system also gets inputs from various monitoring devices.
Observation 3: You will be surprised.

Including a signal from the Low-Level RF System

Old Distribution

Legacy Gate Replicator

New System

New Distribution

AP

XM

LM

RM

Machine Protection

Low-Level RF
Observation 3: You will be surprised.

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

Resulting in solid machine protection faults!
Observation 3: You will be surprised.

Reconfigure:
Supply machine protection system with gates from the new distribution.
Recommendation 2: Sympathy for the operations staff.
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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!