Fermilab | U.S. DEPARTMENT OF ENERGY | Office of Science

PIP-II Technical Discussion
Managing Technology Obsolescence

Victor Grzelak

PIP-II Technical Integration

July 25th 2022

A Partnership of:
- US/DOE
- India/DAE
- Italy/INFN
- UK/UKRI-STFC
- France/CEA, CNRS/IN2P3
- Poland/WUST

Agenda

Day 1

- 9:30-9:40 – Introduction – Victor Grzelak
- 9:40-10:25 – FNAL System design – Greg Vogel
- 10:25-10:50 – Operational Conditions at FNAL – Darren Crawford
- 1110-11:55 – FNAL software – John Diamond

Day 2

- 08:00 - 08:45 – RF Systems at FNAL – Victor Grzelak
- 08:45 - 09:20 – RF Systems – Gian Trento
- 08:45 - 09:20 – Ampleon's Approach to Obsolescence – Tom Dekker
- 10:30 - 12:00 – Round Table discussion

- Thank you to our speakers, and thanks to Tom D for thorough notes

- https://indico.fnal.gov/event/54738/

Overview Day 1

Day 1

- Greg Vogel – Modular upgradable and maintainable design
  - Obsolescence is inevitable, managing it is essential
  - Modular design is key
  - Perform End of Life redesign of a replacement (minor or major) i.e. individual component vs entire system/module
  - Replace aging hardware on a regular or planned basis
  - Discuss when to stockpile obsolete parts
    - Risk of aging equipment on the shelf
    - Functional spares

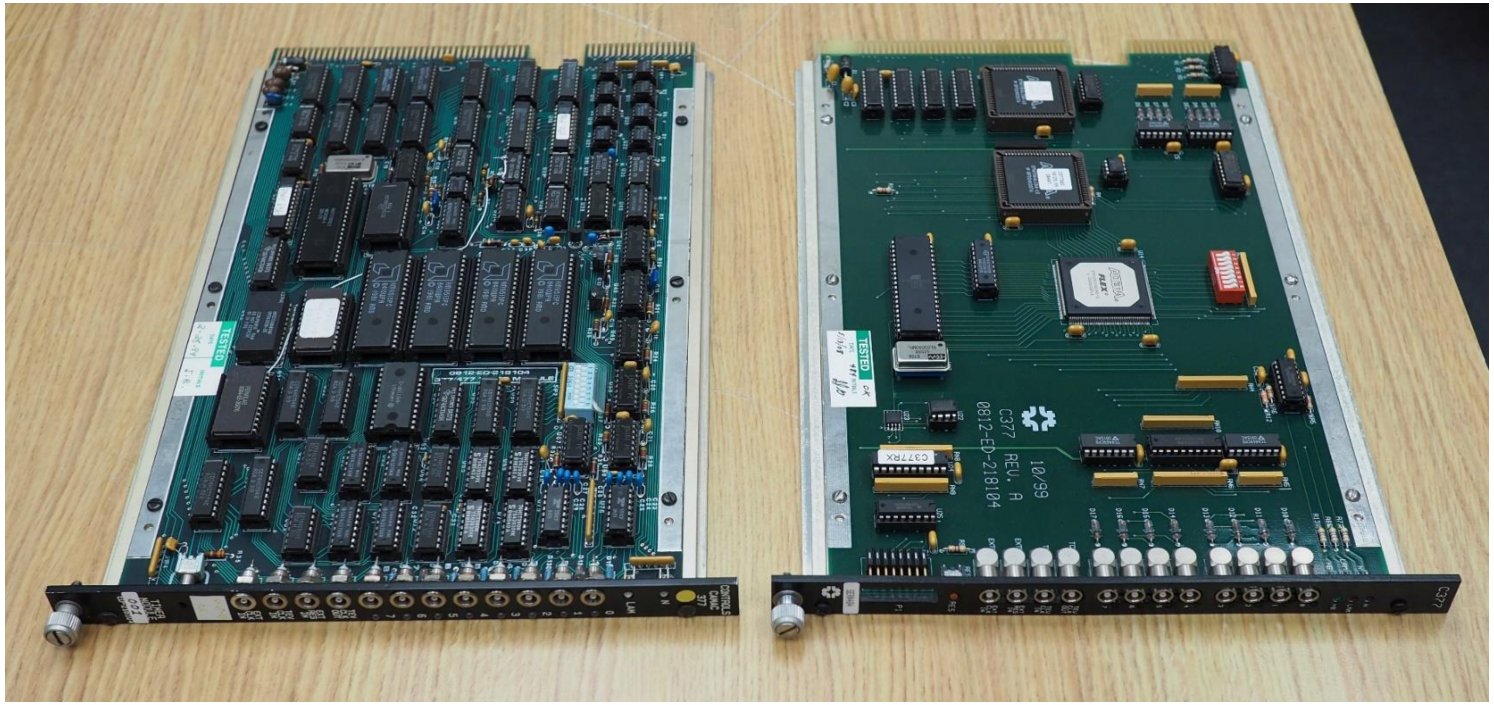
Overview Day 1

Day 1

- Greg Vogel – Modular upgradable and maintainable design

Simple End of Life redesign of replacement.

- – Replacement of existing system/module with functionally identical, interchangeable unit



Overview Day 1

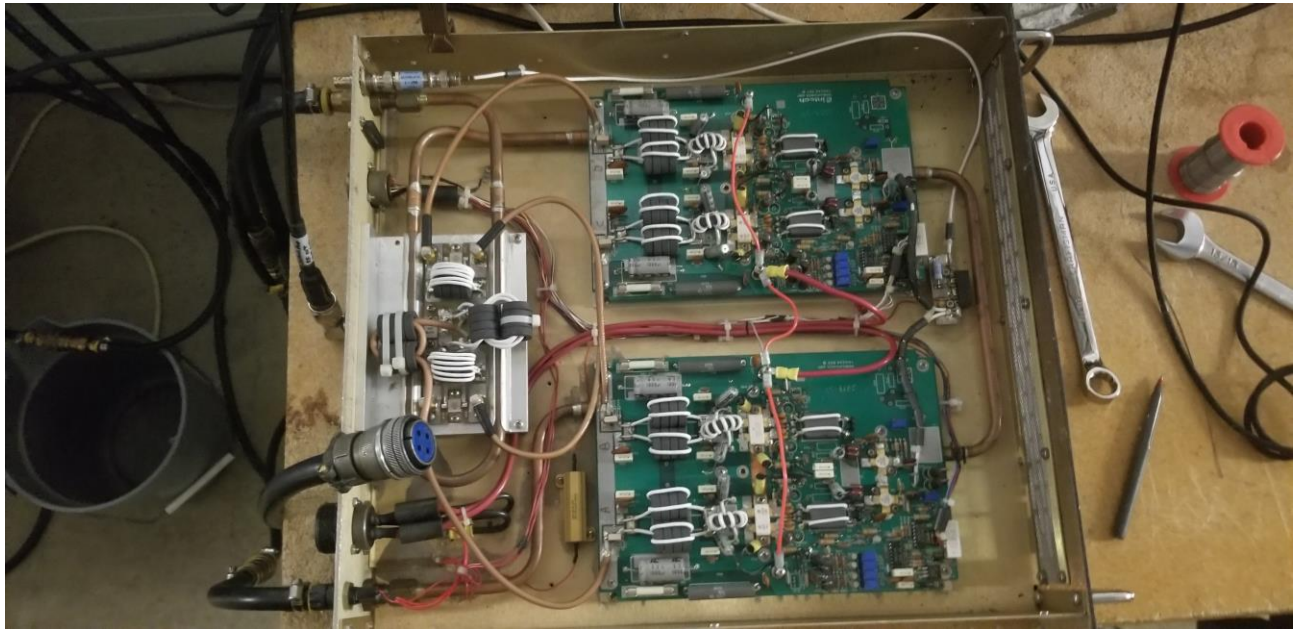
Day 1 - Darren Crawford- Operational conditions

- Plan on at least 85% Accelerator Complex uptime during operational period in PIP-II era
- Expect 8 week annual shutdowns for maintenance including 1 week Master Substation/KRSS power outage plus feeder maintenance
- Standardized equipment that can be easily swapped out reduces downtime

- Operators are the first line of investigation to equipment issues for all accelerators
- Rack Mount solutions are used throughout lab optimize operator maintenance

Overview Day 1

Day 1 - Darren Crawford- Operational conditions



- Fermilab standard for electronics racks is 19” rackmount hardware
- Operators can replace problematic equipment with available spares
  - Requires limited system knowledge
  - This reduces downtime!

Overview Day 1

Day 1 - John Diamond – Software obsolescence and Sustainability

- Tech Debt - Additional maintenance load that comes from a loss of context
  - The only way to eliminate tech debt is to delete code
- Legacy Software - Software that is in use, yet we fear to change it
  - can made to be maintainable
  - Automated testing helps lower the fear to making changes
- Obsolete Software - Software that is not used
  - The only way to eliminate tech debt is to delete code. We should deleting obsolete code
- Sustainable Software - Software that you don't fear changing
  - This is the goal of all new software

- Software stewardship
- Automated testing
- Code Reviews/Audits

Overview Day 1

Day 1 - John Diamond – Software obsolescence and Sustainability

How should we manage tech debt going forward?

The software we write today will need to be maintained for decades

From: Technical Debt First Steps, presented by Chelsea Troy (O'Reilly Media)

- Priorities:
  1. Remove obsolete features/software ← cheap & easy wins!
  2. Address documented "hot spots" that make implementing new features difficult ← big morale booster!
  3. Address "abandoned houses" *at the point change is needed*.
  4. Look for spots where code flexibility does not match the rate of change
  5. Don't get in the way of software developers maintaining the code – they know best!

Overview Day 2

Day 2 - Victor Grzelak– RF Systems at FNAL

1. Each system and subsystem is designed modularly
    1. Rack mountable designs – Serviceable, maintainable and upgradable
    2. Multiple source options for primary components – Prevent sole source issues
    3. Precise specifications on the component level
    4. Choose architecture with prospect of upgradability
2. Prototyping and advanced testing
    1. Implementing a new system into the machine is the best mechanism for proof of concept. “Beam is boss”
    2. Early design flaw detection, failure tracking database helps with this
3. Vendor communication an industry collaboration
    1. Communicate with industry and verify technology support
    2. Communicate with other labs to learn their design insights
    3. Prevent re-inventing the wheel when possible

Overview Day 2

Day 2 - Victor Grzelak– RF Systems at FNAL – Planning upgrades

1. Failure tracking
   - Serialize components
   - Log failures in database
   - Bi-annual review of largest issues
2. Annual technology obsolescence analysis
   - Review availability of parts list for each major system
   - Identify no-longer supported devices
   - As tubes become more obsolete, is moving to solid state an option?
3. Industry and lab communication
   - What is the availability of components needed?
   - Who else is driving the supply?
     - Fore example BNL, LANL, and FNAL used the 7835 Triode tube
   - Is there legacy technology involved?
     - Staggering procurements helpful?

Overview Day 2

Day 2 - Gian Trento – RF Systems at ANL

- RF Machines at APS have been in operation for about 30 years.
- RF switching system implemented for reliability and contributes to their amount of uptime
- Went to solid state to trigger the switch itself, haven't had a failure on this yet.
- Allen-Bradley PLC Controllers were replaced with Automation Direct Controllers
- Solid state systems used to replace some tube based components (Thytrons, Modulators)
- Solid State amplifiers being used to replace Klystrons

- Changes/upgrades made over the last 30 years:
  - They have gone to a "ScandiNova" system to help deal with obsolescence.
  - Thyratron (CX1863) has been giving them problems over time and has been going obsolete, it has been replaced with a Thyristor (S56-12), which is a solid state switch.
  - PFN Capacitors were replaced over time

Overview Day 2

Day 2 - Gian Trento – RF Systems at ANL

DESIGN CONSIDERATION

- ScandiNova modulator: Recommended and used at other national laboratories, many hospitals and industries purchasing smaller units, good presence in industry, good vendor communication, modular IGBT circuitry, turn-key system, provided a list of modules and components for spares.
- For SR, up to 10% of SSA system module failure and full output power is still possible.
- Allow ~20% power overhead.
- SS implementation will be qty. 12, 160kW CW systems, each driving one single-cell accelerating cavity.
- 200kW circulator between SSA and accelerating cavity to isolate / protect SSA.
- Plan to stock spare power amplifier assemblies and drain power supplies to allow for module-level repair of failed units.

Overview Day 2

Day 2 - Tom Dekker– Ampleon

- Ampleon has been designing and manufacturing RF Power products for over 50 years.
- Solid State continues to replace tube technology, but the value of tubes are hard to beat for certain applications.
- The market for Power FETs above 5W is 50% Telecom and 50% into various niche markets, including particle acceleration.
  - Telecom and Multimarket
    - In the telecom industry, life cycle of devices is typically 3 to 5 years,
    - In the multimarket market the life cycle is 15+ years.
- Longevity statement available through vendor
  - https://www.ampleon.com/dam/jcr:8eaee7e0-0645-4e88-9fa2-de5e50d0471c/Ampleon_Longevity_Overview.pdf
- Vendor communication in early stages helpful
  - Early communication can help tailor new series towards specific applications

Overview Day 2

AMPLEON **Longevity Overview**

Updated: 21/Jul/22

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Ampleon Longevity Statement

Ampleon offers **a dedicated longevity** for many of our products so as to provide supply reliability to our customers. Life cycles for participating Ampleon products begin with the launch of the product series and will be available for a minimum period of 10 years. The program is subject to Ampleon's standard end-of-life notification policy.

Ampleon manufactures through our own factories, qualified outside foundries and other manufacturing resources. In the event that transfer of a longevity product to another facility becomes necessary, Ampleon will re-qualify the participating product.

Ampleon offers the longevity products below under its general terms and conditions of commercial sale (https://www.ampleon.com/about/general-terms-and-conditions-of-sale.html) and reserves the right to provide longevity product substitution or successor version within a product series which do not adversely affect form, fit or function of the participating product.

Type Number	Launch Date	Longevity Date	Longevity Duration
BLF188XRS	2013/10/30	2023/10/30	10 years
BLF2425M9L30	2015/11/18	2030/11/18	15 years
BLF2425M9LS140	2016/08/30	2031/08/31	15 years
BLF2425M9LS30	2015/11/18	2030/11/18	15 years
BLF571	2009/02/10	2024/02/11	15 years
BLF574	2009/02/02	2024/02/03	15 years
BLF578	2009/11/30	2024/11/30	15 years
BLF642	2011/06/06	2026/06/06	15 years
BLF644P	2013/09/20	2023/09/20	10 years
BLF645	2009/12/21	2024/12/21	15 years
BLF647P	2012/12/19	2022/12/19	10 years
BLF647PS	2013/11/14	2023/11/14	10 years
BLF6G13L-250P	2011/08/05	2021/08/05	10 years
BLF6G13LS-250P	2011/08/05	2021/08/05	10 years
BLF6G13LS-250PG	2015/08/10	2025/08/10	10 years
BLF888D	2014/05/07	2024/05/07	10 years
BLF888DS	2014/05/07	2024/05/07	10 years
BLF888E	2016/08/30	2026/08/30	10 years
BLF888ES	2016/08/30	2026/08/30	10 years
BLF974P	2020/03/23	2035/03/24	15 years
BLF978P	2020/03/27	2035/03/28	15 years

Overview Day 2

Day 2 - Round Table

- Software
  - Pair programming – Helpful but difficult to implement
  - Code audits/reviews – Very valuable for code transfers
  - SQA – Should be reviewed, and potentially expanded for audits
  - Automated programming – Most time reliable solutions
  - ESS/Collaboration audit process – Laboratory should initiate (IE ESS, FNAL)
  - Knowledge transfer, lab to lab, and succession planning

- Hardware
  - Modularity – common to all designs
  - Test bench development – Component test facility useful for diagnostics, development
  - FPGA or PLC for interlocks – Discussed design philosphy
  - Component selection – Discussed Vendor communication

Lessons Learned

- By implementing modular design principles into both hardware and software development, obsolescence can be easier managed during operations by allowing for easier maintenance and upgrades.

- All design documents (i.e. drawings, schematics, board layouts, parts lists, specifications, functional descriptions, system block diagrams, etc.) should be available in easily accessible locations and should be of a format that is readable (i.e. PDF)

- Design to common 19” rack mountable hardware where possible in order to allow for easier replacement

- Obsolescence can be better managed/mitigated by conducting a technology obsolescence analysis on a set frequency

- Open lines of communication should be maintained with industry/vendors to understand component availability in order to manage obsolescence

Open issues

- Software code being developed as part of in-kind contributions should have a review/audit process defined and performed as part of the system acceptance review. This process is important to not only review/test the software being delivered, but to transfer knowledge/context to help with maintaining the software moving forward.

- A decision should be made about how much machine monitoring is necessary to support AI/Machine Learning Systems without overloading the bandwidth of the system

- It should be determined where PLC's will be used, and where FPGA's will be used in PIP-II. These devices should be standardized as well so that the same drivers, programming tools, etc. are used.

- It would be beneficial for Fermilab operations could connect an audit of the current rack designs (amplifiers, relay racks instrumentation controls) as designed

Thank you for your attention!