CEBAF Performance Plan

Assets and Maintenance Management Workshop 2018

ALBA Synchrotron Barcelona, Spain

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Outline

I. CEBAF* Introduction and Overview
II. CEBAF Performance Plan (CPP) Introduction
III. CPP Categories and Methods
IV. Strategic Projections
V. Implementation and Execution
VI. Challenges
VII. Summary

**Continuous Electron Beam Accelerator Facility (CEBAF)*

CEBAF Introduction – Newport News, Virginia USA

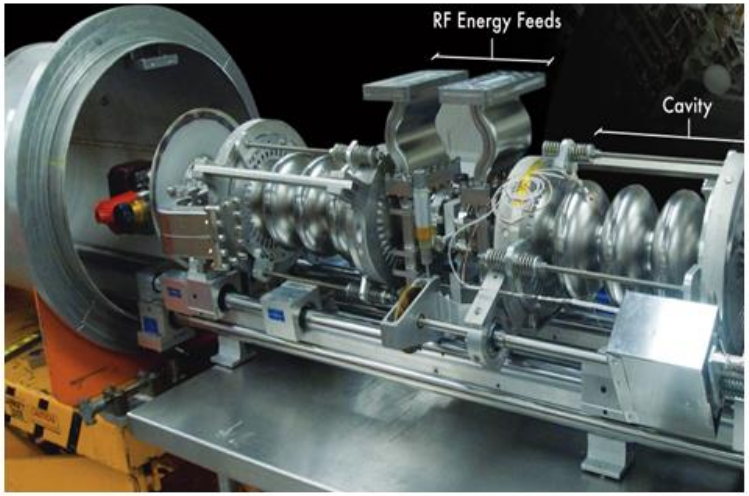
Operated for the US DOE Office of Science-Nuclear Physics

Jefferson Lab Research:

- Experimental, computational and theoretical nuclear physics
- Accelerator Science, SRF technologies and FEL
- Radiation detectors and medical imaging
- Cryogenic technology
- 1530 users from 236 institutions and 31 countries

CEBAF

SRF



Cryogenics

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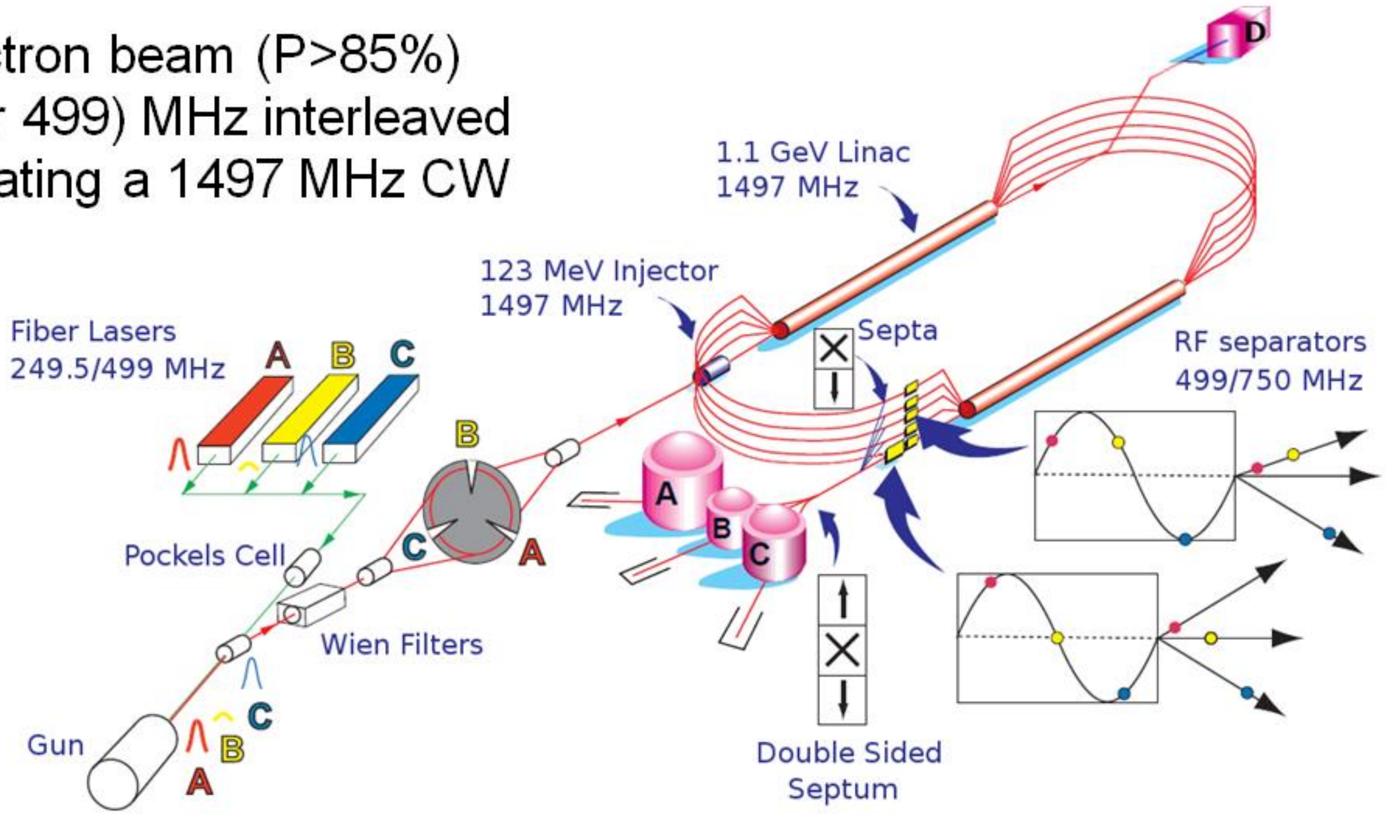
CEBAF Introduction - 12 GeV CEBAF Overview

- Polarized electron beam (P>85%)
- Four 249.5 (or 499) MHz interleaved beams, generating a 1497 MHz CW beam



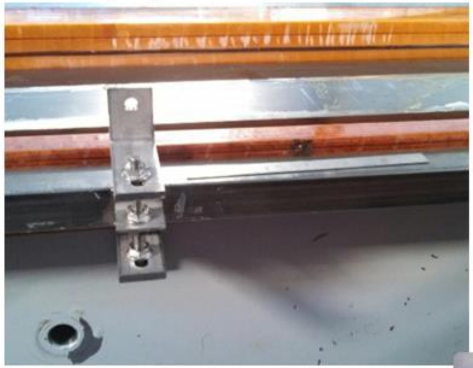
- CW SRF linacs
- Design energy 2.2 GeV/pass:
  - 5 passes, 11 GeV (Halls A,B & C)
  - 5.5 passes, 12 GeV (Hall-D)

- Flexible extraction options for ABC, 1st…5th pass
- Hall A & C 1 MW high power dumps

CPP Introduction - Major Failures

In many instances, new 12 GeV systems have been integrated into the original CEBAF infrastructure and systems. Reliability of these systems, old and new, have gained attention as CEBAF Operations and Engineering groups learn this "new" machine.

Spring 2014 – Spring 2017: CEBAF experiences 6 major equipment failures requiring program change/termination.



MZAAR03 damaged coil

ARC7 Magnet Power Supply melted choke

Cold Compressor 4 bearing failure

CPP Introduction - Purpose

Jefferson Lab FY18 PEMP* notable outcome:

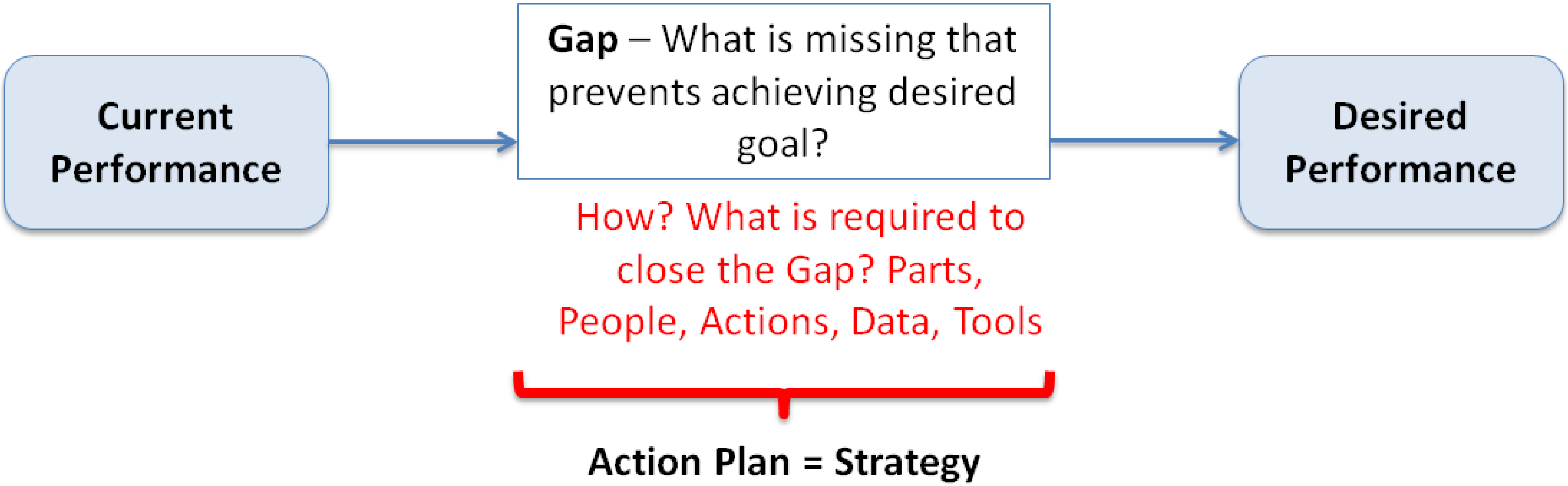
- Generate a robust and aggressive plan by January 15, 2018 that describes how the reliability of the CEBAF machine will be increased to at least 80% no later than FY 2021. This plan should be within available funding and clearly demonstrate that there is no greater priority at the laboratory than operating the CEBAF machine reliably and with increased beam availability for the nuclear physics community.

The <u>CEBAF Performance Plan (CPP)</u> is a 19 page strategy developed within Accelerator Operations at attempt to project the required actions and resources for the next 10-20 years of CEBAF Operation to achieve a higher level of performance.

**Performance Evaluation and Measurement Plan – US Dept Of Energy Lab Report Card*

CPP Categories and Methods – GAP Analysis

CPP was developed using **Gap Analysis** methods to formulate a strategy bridging technical requirements, goals, and resources to achieve the desired level of performance.

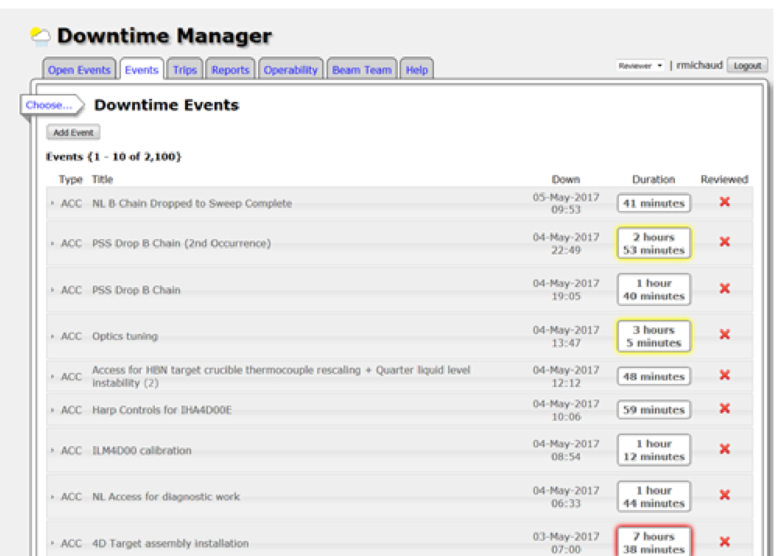


Each goal (system performance) was analyzed in this manner to understand what is needed to achieve the desired performance level.

CPP Categories and Methods – Data Supported Decisions

"Without data, you're just another person with an opinion." –Edward Demming

Operational downtime data proved instrumental in conducting the gap analysis, risk assessments, and strategy development.



Downtime Manager

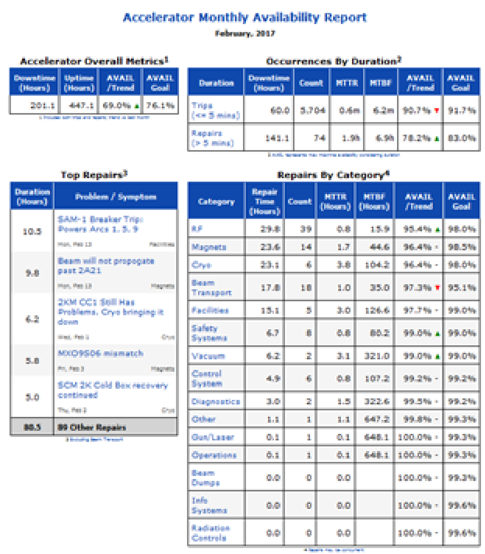
Open Events | Events | Trips | Reports | Operability | Beam Team | Help — Reviewer | rmichaud | Logout

Choose... **Downtime Events**

Add Event

Events {1 - 10 of 2,100}

Type	Title	Down	Duration	Reviewed
ACC	NL B Chain Dropped to Sweep Complete	05-May-2017 09:53	41 minutes	✗
ACC	PSS Drop B Chain (2nd Occurrence)	04-May-2017 22:49	2 hours 53 minutes	✗
ACC	PSS Drop B Chain	04-May-2017 19:05	1 hour 40 minutes	✗
ACC	Optics tuning	04-May-2017 13:47	3 hours 5 minutes	✗
ACC	Access for HBN target crucible thermocouple rescaling + Quarter liquid level instability (2)	04-May-2017 12:12	48 minutes	✗
ACC	Harp Controls for IHA4D00E	04-May-2017 10:06	59 minutes	✗
ACC	ILM4D00 calibration	04-May-2017 08:54	1 hour 12 minutes	✗
ACC	NL Access for diagnostic work	04-May-2017 06:33	1 hour 44 minutes	✗
ACC	4D Target assembly installation	03-May-2017 07:00	7 hours 38 minutes	✗



Accelerator Monthly Availability Report

February, 2017

Accelerator Overall Metrics[1]

Downtime (Hours)	Uptime (Hours)	AVAIL /Trend	AVAIL Goal
201.1	447.1	69.0% ▲	76.1%

Occurrences By Duration[2]

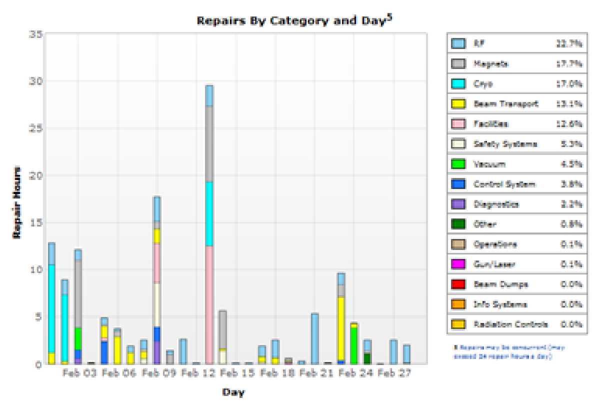
Duration	Downtime (Hours)	Count	MTTR	MTBF	AVAIL /Trend	AVAIL Goal
Trips (<= 5 mins)	60.0	3,704	0.6m	6.2m	90.7% ▼	91.7%
Repairs (> 5 mins)	141.1	74	1.9h	6.9h	78.2% ▲	83.0%

Top Repairs[3]

Duration (Hours)	Problem / Symptom
10.5	SAM-1 Breaker Trip: Powers Arcs 1, 5, 9 — Mon, Feb 13 — Facilities
9.8	Beam will not propogate past 2A21 — Mon, Feb 13 — Magnets
6.2	2KM CC1 Still Has Problems, Cryo bringing it down — Wed, Feb 1 — Cryo
5.8	MXO9S06 mismatch — Fri, Feb 3 — Magnets
5.0	SCM 2K Cold Box recovery continued — Thu, Feb 2 — Cryo
80.5	89 Other Repairs

Repairs By Category[4]

Category	Repair Time (Hours)	Count	MTTR (Hours)	MTBF (Hours)	AVAIL /Trend	AVAIL Goal
RF	29.8	39	0.8	15.9	95.4% ▲	98.0%
Magnets	23.6	14	1.7	44.6	96.4% -	98.5%
Cryo	23.1	6	3.8	104.2	96.4% -	98.0%
Beam Transport	17.8	18	1.0	35.0	97.3% ▼	95.1%
Facilities	15.1	5	3.0	126.6	97.7% -	99.0%
Safety Systems	6.7	8	0.8	80.2	99.0% ▲	99.0%
Vacuum	6.2	2	3.1	321.0	99.0% ▲	99.0%
Control System	4.9	6	0.8	107.2	99.2% -	99.2%
Diagnostics	3.0	2	1.5	322.6	99.5% -	99.2%
Other	1.1	1	1.1	647.2	99.8% -	99.3%
Gun/Laser	0.1	1	0.1	648.1	100.0% -	99.3%
Operations	0.1	1	0.1	648.1	100.0% -	99.3%
Beam Dumps	0.0	0	0.0		100.0% -	99.3%
Info Systems	0.0	0	0.0		100.0% -	99.6%
Radiation Controls	0.0	0	0.0		100.0% -	99.6%



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CPP Categories and Methods

Methods

- **GAP Analysis**
- Failure Modes Effects Analysis
- Risk Mitigation Scoring
- **Downtime Data Analysis**
- Cost-Benefit Analysis
- **System Expert Experience**

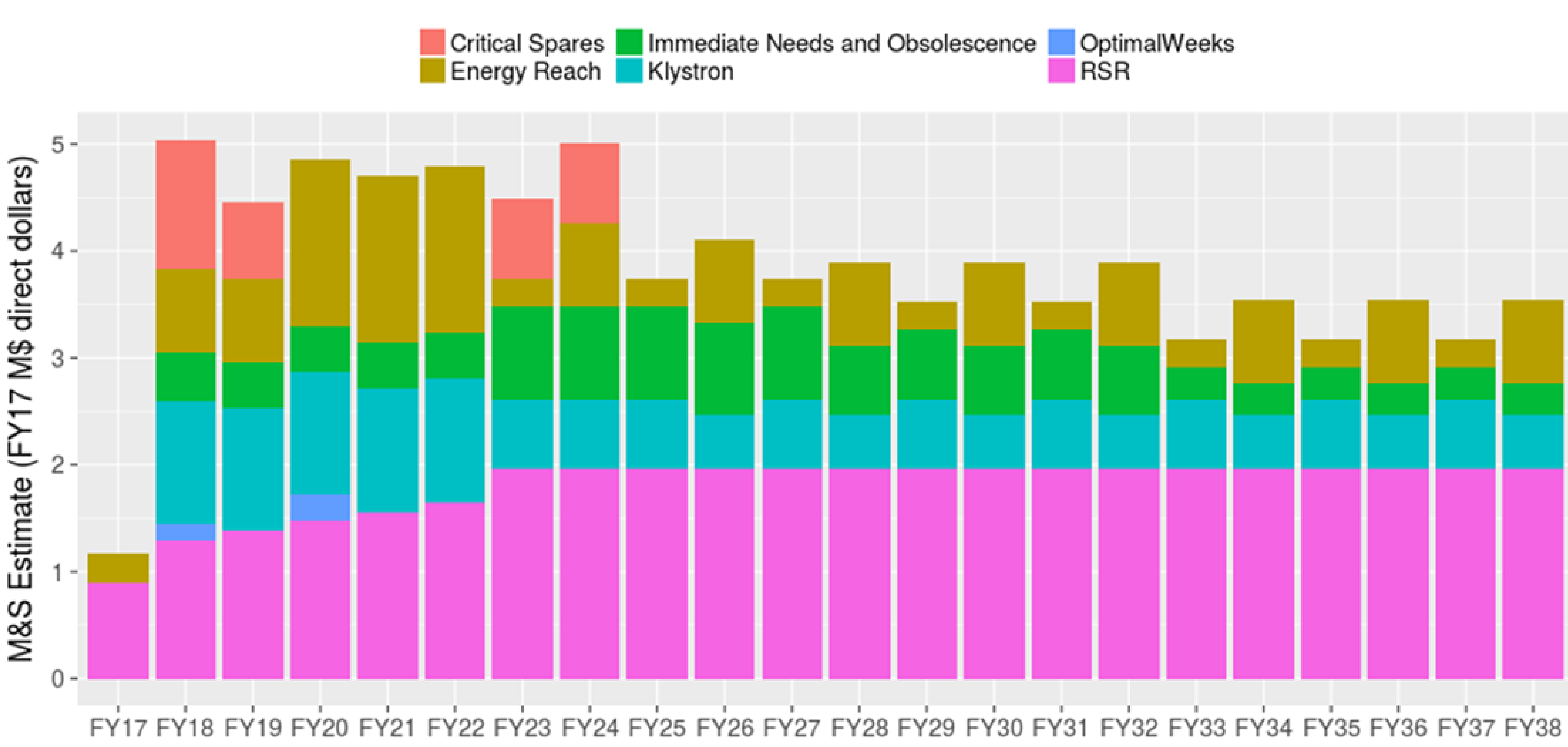
Categories

- Critical Spares
- RF Klystrons
- Energy Reach
- Immediate Needs and Obsolescence
- Optimal Weeks - Efficiency

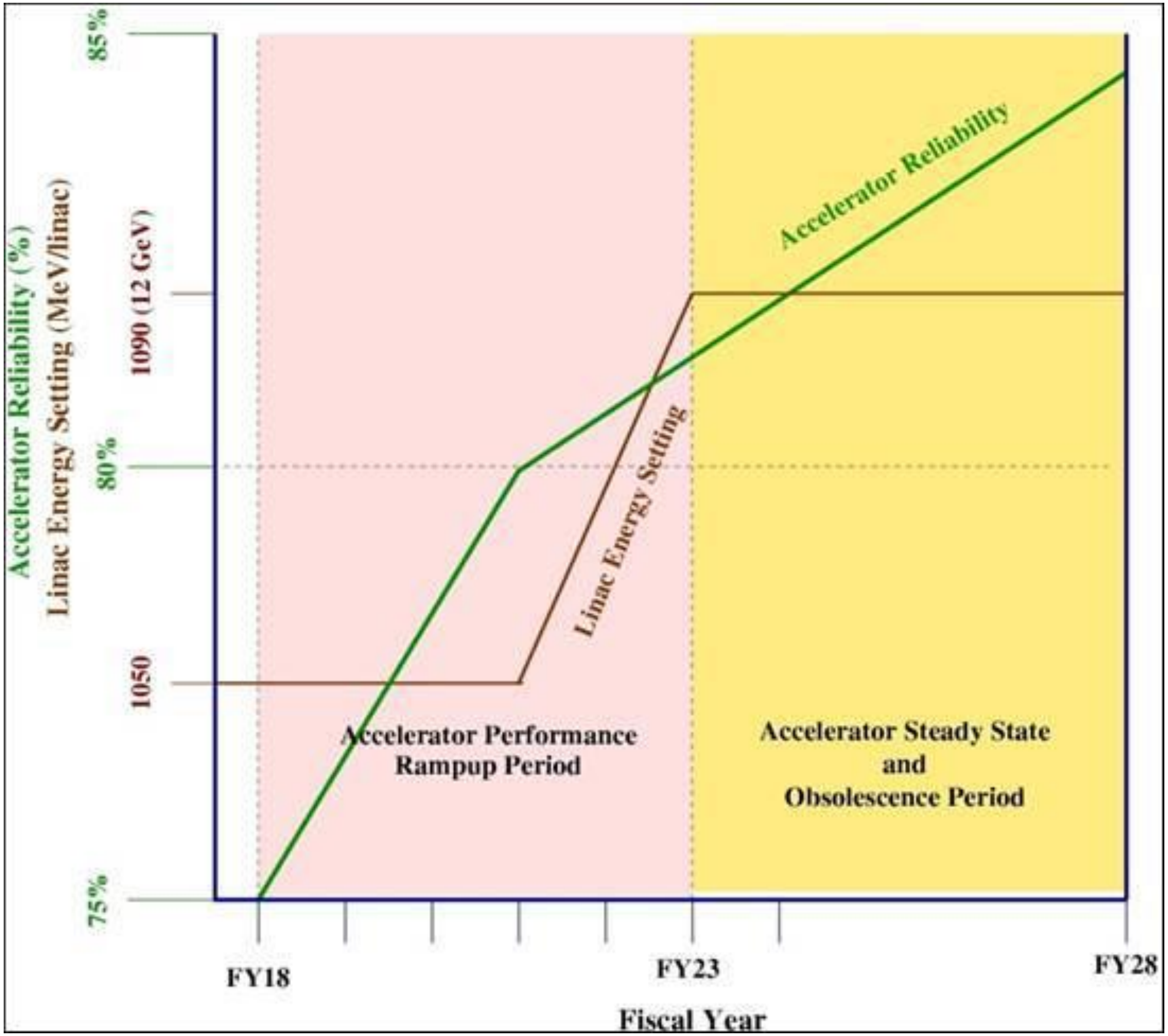
CPP Categories and Methods

- **Critical Spares:** Risk-based analysis of accelerator and cryogenic systems identified spare parts deemed critical for operation to address potential down-hard (months duration) failures.
- **Klystrons:** Klystron status is quite dire and if not corrected will lead to additional, gradient loss above that from the measured historical loss. CEBAF requires 418 klystrons to operate each of the SRF cavities. There are presently no new spare klystrons and over 50 klystrons in operation show signs of end-of-life.
- **Energy Reach:** The energy reach gap at the end of FY22, assuming no performance plan in place, will be -185 MeV/linac resulting in a maximum machine energy of 9.5 GeV (20% below design).
- **Obsolescence:** System owners reviewed the present capability to support the near term program, based on MTBF and MTTR and developed an obsolescence list. System designs were also reviewed and obsolete parts and unmaintainable systems were identified.
- **Optimal Weeks:** Investment activities identified to optimize maintenance periods allowing for shorter planned maintenance outages – longer weeks of accelerator operations.

Strategic Projections - Investment



Strategic Projection - Performance



Implementation and Execution

- Strategy was presented to Department of Energy Office of Science and JLab Management. (October 2017)
- Funds were committed for FY18 CPP Plans; FY18-21 funding profile laid out by management.
- CPP Project Director and Project Manager assigned within existing Operations Organization. Support groups (Facilities, Engineering, Business) assigned Area Managers matrixed to CPP.

	Critical Spares	Klystrons	Energy Reach	Obsole-scence	Optimal Weeks	Real Time Support and Repair RSR-CPP	Real Time Support and Repair RSR-OPS	Total (direct)	Total (loaded)
FY18	$910	$950	$800	$330	$150	$400	$890	$4,430	$4,730
FY19	$685	$1,150	$800	$425		$400	$890	$4,350	$4,625
FY20		$1,150	$1,600	$425		$185	$890	$4,250	$4,445
FY21		$1,150	$1,600	$425		$55	$890	$4,120	$4,305

*In thousands of US Dollars

Implementation and Execution - 2018 Progress

Utilizing the appropriated funding, 2018 CPP was able to be executed as planned.

- The top ‘at risk’ Critical Spares orders were placed – Magnet Box Supplies, Coils, Cryo Compressor Bodies, etc.
- 20 new Klystrons were ordered, negotiations in place for next 5 years.
- Obsolete/Immediate items focused on Safety Systems PLCs, upgrading system IOCs, and vacuum component inventory.
- Additional mobile “clean rooms” were built to support improved vacuum maintenance and increase capability during shutdowns.

- *Energy Reach has been delayed; new C75 cryomodule design reviewed, however vendor quality issues with cavities have limited production progress.*

Challenges

There are many challenges to face associated with developing and executing a long term strategy.

- How to show near term ‘return on investment’ to keep interest in funding and supporting the strategy – *what’s in it for me*.
- How to keep the long term vision of implementing the strategy when faced with short term problems – *fire fights*.
- How to maintain support and coordination across division organizational boundaries – *priorities change*.
- How to manage an internal project of such scope on a part time basis, as a collateral duty – *conflicting decisions and time management*.
- How to efficiently share resources with external, highly visible projects without integrated project plans – *competing for resources, external visibility*.

What have been some of your experiences? Challenges? Successes?

Randy Michaud

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Backup Slides

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- 12GeV Commissioning Runs
  - December 2013 – February 2014 *(~6 weeks)*
  - March 2014 – May 2014 *(~10 weeks)*
  - October 2014 – December 2014 *(~10 weeks)*
  - February 2015 – May 2015 *(~16 weeks)*
  - November 2015 – December 2015 *(~6 weeks)*
- Physics Runs
  - February 2016 – April 2016 *(~10 weeks)*
  - October 2016 – December 2016 *(~10 weeks)*
  - February 2017 – March 2017 *(~8 weeks)*

Achieved commissioning goals for 12 GeV upgrade project; limited run time to achieve hardened systems for highly reliable Physics running.

Major Failures

1. **Spring 2014**: ZA magnet coil and vacuum failure; **3 week interruption** to replace damaged coil and repair the vacuum chamber. This failure consumed the existing spare coil; **recovery from the next failure will take much longer**.
2. **Spring 2015**: Cold compressor 4 failure in 2 K cold-box, SC1; No spare at JLab, consumed the SNS cold compressor spare. **Program change required:** half design energy after 5 week down.
3. **Fall 2015:** YR coil on 3-pass extraction generated a spontaneous leak. No 3-pass program for FY16, repaired Summer 2016, consumed a YR coil spare. Required Hall-A DVCS experiment to re-arrange its run plan.
4. **Fall 2016**: Arc7 box supply failure, no spare. **Program change required:** to single hall operation until supply repaired.
5. **Fall 2016**: 5th pass separator vacuum leak. **Program change required**, could not support 5th pass beam to Hall-A simultaneously with 5.5 pass beam to Hall-D.
6. **Spring 2017**: Cold compressor 5 failure in 2 K cold-box, SC1; on-going root cause investigation, might be repairable. **Scheduled program terminated.**

Critical Spares

High Combined Risk, No Spares

	A	B	C	D	E	F	G
1	**Potential Down Hard Failures**	**Cost Estimate Of Spare**	**Likelihood**	**Schedule**	**Capability**	**Combined Risk**	**Impact**
2							
3							
4	BCOM Coil	$100,000	1	4	4	17	Down hard
5	ZA Coil	$100,000	2	4	3	14	No 4&5 extraction to ABC
6	Magnet Box Power Supply	$100,000	2	4	3	14	No 3rd pass or higher
7	Dogleg Coils	$50,000	1	4	3	13	Limited passes/pathlength control
8	Capture Window	$25,000	1	3	4	13	Down hard, only needed for 3 more years
9	MBL Chicane dipoles	$15,000	1	3	4	13	Down hard
10	RF Separator HV PS	$200,000	1	3	4	13	No RF separation
11	Master Oscillator: Both Fail	$250,000	1	2	4	11	Down hard: Should be L=0?
12	BCOM Vacuum Chamber	$15,000	1	2	4	11	Down hard
13	RF Sep. SS Amplifier	$70,000	3	2	3	10	Limited option on passes to ABC
14	Chopper Amplifier	$75,000	2	3	3	10	No low current running (B and D)
15	ZA Vacuum Chamber	$15,000	2	2	3	8	No 4&5 extraction to ABC
16	YR Vacuum chamber	$15,000	2	2	3	8	No 4&5 pass beam
17	YB Vacuum Chamber	$15,000	2	2	3	8	no 1st or 2nd pass extraction or beam to D
18	DogLeg Vacuum Chambers	$15,000	2	2	3	8	Limited passes/pathlength control
19	DogLeg Vacuum Bellows	$15,000	2	2	3	8	Limited passes/pathlength control

Immediate Needs and Obsolescence - example

Project	Procurements ($K)	Labor (weeks)	Consumable?	Comments/Status	Comments/Status	Immediate	Project Manager
PLC upgrade - Injector	$50	28	Obsolescence	some hardware has been obsolete for over 10 years	limited spares available	yes	Jerry Kowal
PLC upgrade - BSY	$40	28	Obsolescence	some hardware will be discontinued by 2018	limited spares available	yes	Jerry Kowal
PLC upgrade Hall A	$30		Obsolescence				Jerry Kowal
PLC upgrade Hall C	$10		Obsolescence				Jerry Kowal
PLC upgrade - Hall B	$40	28	Obsolescence	some hardware has been obsolete for over 10 years	limited spares available	yes	Jerry Kowal
PLC upgrade - S. Linac	$80	40	Obsolescence	some hardware has been obsolete for over 10 years	limited spares available	yes	Jerry Kowal
PLC upgrade - N. Linac	$100	40	Obsolescence	some hardware has been obsolete for over 10 years	limited spares available	yes	Jerry Kowal
PLC upgrade - LERF	$50	28	Obsolescence	some hardware has been obsolete for over 10 years	limited spares available	yes	Jerry Kowal
PLC upgrade - BELS	$50	28	Obsolescence	some hardware will be discontinued by 2018	limited spares available	yes	Jerry Kowal
Convert PLC programming software/hardware	$50	2	Obsolescence	programming software was discontinued in 2016	limited spares available	yes	Jerry Kowal
PA System upgrade - MCC	$1	3	Obsolescence	all hardware has been obsolete for over 10 years	limited spares available	yes	Jerry Kowal
Convert bar/bolt monitor to photoswitches	$8	6	reliability	some hardware has been obsolete for over 10 years	no spares	yes	Jerry Kowal
Lights/horns CEBAF (replace lighting contactor)	$15	10	reliability			yes	Jerry Kowal
Kicker redesign	$50	20	Obsolescence	some hardware has been obsolete for over 10 years	no spares	yes	Jerry Kowal
Beam Diffuser	$30	10	reliability	critical spare	no spares	yes	Jerry Kowal
Inline Dump	$60		reliability	critical spare - limited capability reconfig of machine state	no spares	yes	Jerry Kowal
iFix Driver and Server	$5	3	Obsolescence	subscription, drivers no longer available	not available	yes	Jerry Kowal
Repair damaged BLM HVPS cables	$5	4	reliability	limited spares available	limited spares available	yes	Jerry Kowal
Repair damaged FSD F. O. cables	$5	4	reliability	limited spares available	limited spares available	yes	Jerry Kowal
Explore individual Hall FSD shutdown	$10	10	reliability			yes	Jerry Kowal
BLM head rev 2 installation	$10	6	reliability	limited spares available	limited spares available	yes	Jerry Kowal
Modbus+	*$10*		*Obsolescence*				Jerry Kowal
PSS PLC network switch	*$30*		*Obsolescence*				Jerry Kowal
BLM signal cable system redesign/install	$5	6	reliability			yes	Jerry Kowal
Trim utility chassis PLC replacement	$48	5.1	Obsolescence	Replace obsolete PLC with new design.	10 Amp trims	yes	Sarin Philip
Buy and replace bulk supplies for 10 Amp trims	$825	6	Obsolescence	Replace all 160 bulk supplies that are >25 years old; FY17 12GeV contingency: $55K spent	10 Amp Trim	yes	Sarin Philip
u-Processor, digital section replacement 10 Amp				Engineer a "plug-in" solution for Trim Card u-processors			

Funded