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

# Metrics

## Measuring Reliability (aka Accelerator Availability)

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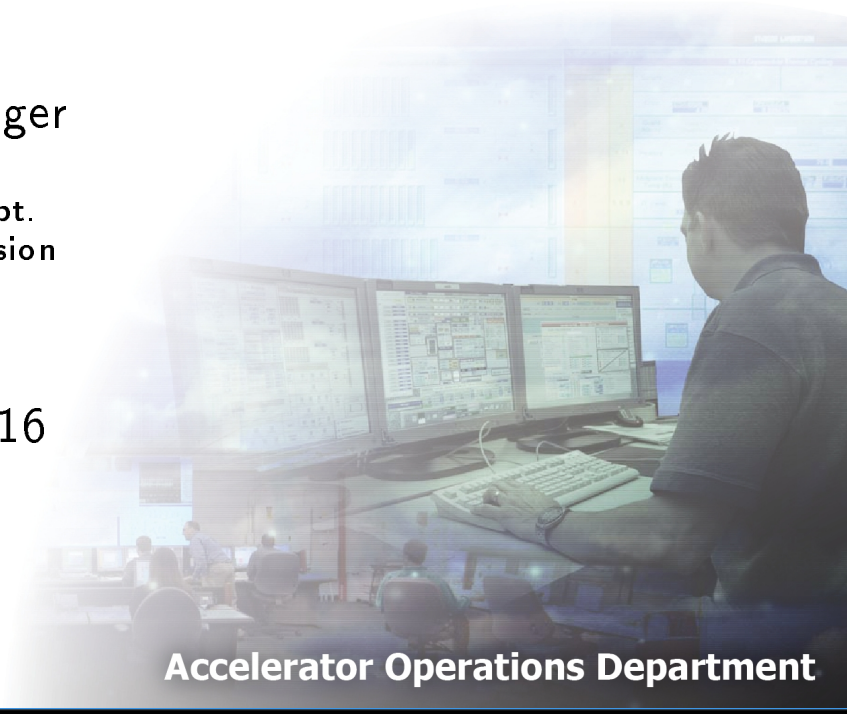


Accelerator Operations Department

# DOE Hours and the Annual Budget Review Process

- Nominally Jan/Feb series of meetings to prepare the Director's briefing to DOE on the future (5+y) budget.
  - The budgets under development are FY+2 and beyond.
  - FY+1 being set at the previous years briefing, unless there is a change in the budget.
- This budget briefing sets the weeks of operations for FY+2 and beyond.
- The weeks of operations are then used to generate the expected hours of operations for the Fiscal Year.
- Nominally there are 3 scenarios, Flat, Cost of Living (COL) and Proposed.
  1. **COL** scenario is the most probable scenario.
  2. **Flat** next probable senario, invoked when there is no budget agreement and Congress invokes a Continuing Resolution.
  3. **Proposed** Never happens, would be nice though.
- The degrees of freedom for budgeting purposes are:
  1. Weeks of Operations (major)
  2. Reliability (minor)
  3. Hall Multiplicity (minor)

# Weeks of Operations circa Feb. 2016: COL

| 2016BB: COL | | FY14 | FY15 | FY16 | FY17 | FY18 | FY19 | FY20 | FY21 | FY22 |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Actuals | Actuals | This Year | Next Year (set at last years BB) | FY + 2 | FY + 3 | FY + 4 | FY + 5 | FY + 6 |
| | | | | | | | | | | |
| Type | | | | | | | | | | |
| Research | | 0 | 0 | 0 | 21 | 21 | 21 | 21 | 21 | 21 |
| MD/Restore | | 10 | 15 | 16 | 2 | 2 | 2 | 2 | 2 | 2 |
| Support PreOPS | | 3 | 3 | | 0 | | | | | |
| 12GeV PreOPS | | 6 | 3 | | 3 | | | | | |
| | | | | | | | | | | |
| Total NP | | 13 | 18 | 16 | 23 | 23 | 23 | 23 | 23 | 23 |
| Total 12GeV | | 6 | 3 | | 3 | | | | | |
| | | | | | | | | | | |
| Total Weeks | | 19 | 21 | 16 | 26 | 23 | 23 | 23 | 23 | 23 |

# DOE Hours per Week circa Feb. 2016: COL

Hours for a Research Week:

| Type | Hour |
|---|---|
| Scheduled Research | 144 |
| Scheduled Beam Studies | 12 |
| Scheduled Tuning/Setup | 8 |
| Maintenance | 4 |
| | |
| Scheduled Hours per Week | 164 |
| Unscheduled Hours per Week | 4 |

Hours for a Restore or Machine Development Week (Nominally first week of each run-period, two restore weeks per year):

| Type | Hour |
|---|---|
| Scheduled Research | 0 |
| Scheduled Beam Studies | 72 |
| Scheduled Tuning/Setup | 72 |
| Maintenance | 24 |
| | |
| Scheduled Hours per Week | 144 |
| Unscheduled Hours per week | 24 |

# DOE Hours per FY circa Feb. 2016: COL

## First appearance of the word Reliability

| 2016BB: COL | | FY17 | FY18 | FY19 | FY20 | FY21 | FY22 |
|---|---|---|---|---|---|---|---|
| | | | | | | | |
| Scheduled Research | | 3,024 | 3,024 | 3,024 | 3,024 | 3,024 | 3,024 |
| Scheduled Beam Studies | | 396 | 396 | 396 | 396 | 396 | 396 |
| Scheduled Tuning/Setup | | 312 | 312 | 312 | 312 | 312 | 312 |
| 12GeV PreOPS | | 432 | | | | | |
| Total Scheduled Hours | | 4,164 | 3,732 | 3,732 | 3,732 | 3,732 | 3,732 |
| | | | | | | | |
| Delivered Research | | 2,117 | 2,238 | 2,359 | 2,480 | 2,570 | 2,631 |
| Delivered Beam Studies | | 277 | 293 | 309 | 325 | 337 | 345 |
| Delivered Tuning/Setup | | 218 | 231 | 243 | 256 | 265 | 271 |
| Delivered 12 preOPS | | 302 | 0 | 0 | 0 | 0 | 0 |
| Total Delivered Operating Hours | | 2,915 | 2,762 | 2,911 | 3,060 | 3,172 | 3,247 |
| Unscheduled Hours | | 1,249 | 970 | 821 | 672 | 560 | 485 |
| | | | | | | | |
| Total Scheduled Hours | | 4,164 | 3,732 | 3,732 | 3,732 | 3,732 | 3,732 |
| | | | | | | | |
| Reliability | | 70% | 74% | 78% | 82% | 85% | 87% |
| | | | | | | | |
| Weeks of Base Operations | | 23 | 23 | 23 | 23 | 23 | 23 |
| Weeks of 12GeV preOPS | | 3 | | | | | |
| Total Weeks of Operations | | 26 | 23 | 23 | 23 | 23 | 23 |

Reliability values in this table represent the target/goal. The numbers come from me and have not received that much attention since CEBAF was in the commissioning phase.

# DOE Reliability: This is really Availability

The most simple representation for **availability** is as a ratio of the expected value of the uptime of a system to the aggregate of the expected values of up and down time, or

$$A = \frac{E[\text{uptime}]}{E[\text{uptime}] + E[\text{downtime}]}$$

$$\mathcal{R} = \frac{\sum Delivered}{\sum Delivered + Unscheduled} = \frac{\sum Scheduled - Unscheduled}{\sum Scheduled}$$

- Either track delivered hours (hard) or track unscheduled hours (easy).

$$UnscheduledHours = Downtime - \text{Scheduled Downtime}$$

Scheduled Downtime 4h per Research Week (24h for Restore week) of operation is assigned to *maintenance* aka scheduled downtime.

Downtime is *scheduled* until it exceeds to allotted maintenance time.

appropriate way to treat such downtime as modern accelerators do not require routine maintenance and such interventions are only 'scheduled' when there is broken hardware that needs repair. However, for largely historical reasons, many of the numbers in the table

# Example: Last 18 days of Spring 2016

07:00 07-Apr-2016 → 07:00 25-Apr-2016

## Summary

| | |
|---|---|
| **Total Downtime (Hours):** | **27.0** |
| **MTTR (Hours):** | 0.8 |
| **Total Suspend (Hours):** | 22.8 |
| **Total Restore (Hours):** | 4.2 |
| **Period Duration (Hours):** | 422.0 |

Scheduled Maintenance: $\frac{422h}{168h} \times 4h = 10h$

Total Downtime $27h$

Unscheduled Downtime $27h - 10h = 17h$

Scheduled Hours $\frac{422h}{168h} \times 164h = 412h$

$$\mathcal{R} = 100. \times \frac{412h - 17h}{412h} = 96\%$$

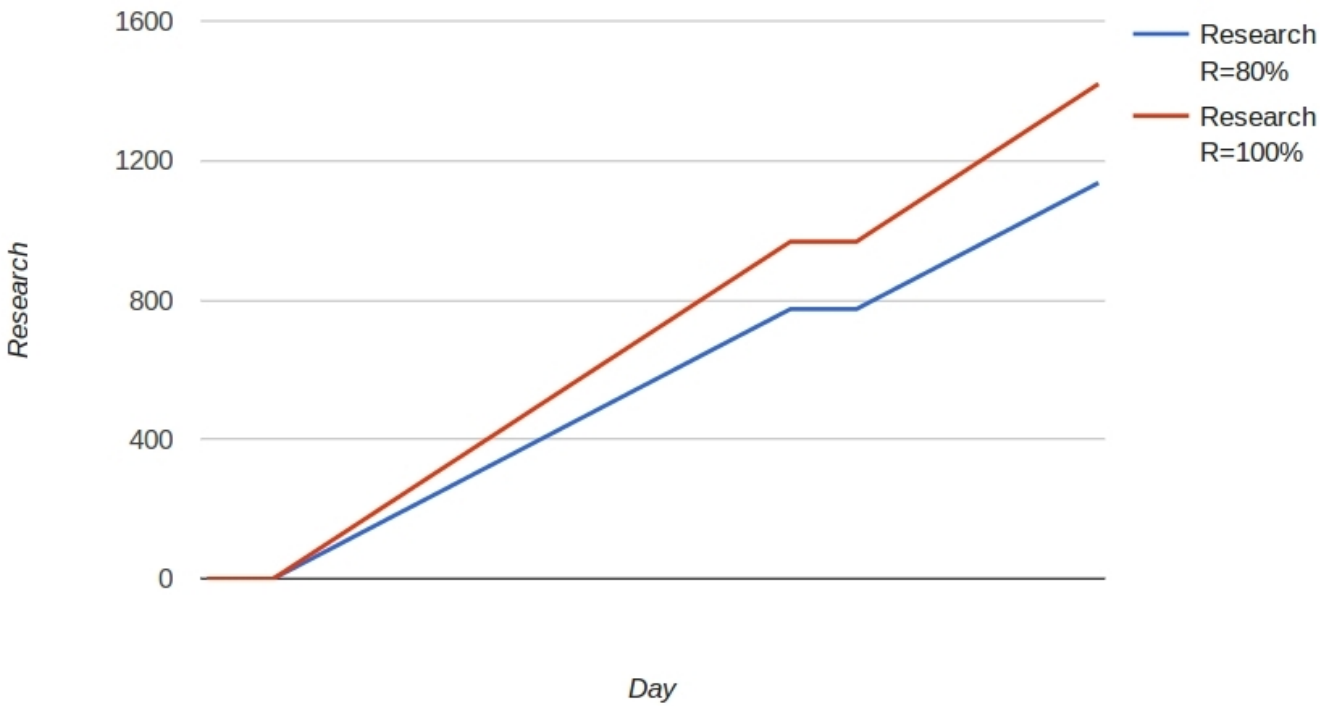
Note: FSD trips (downtimes less than 5 minutes) are not included in this calculation. **As long as FSD trip rate < 15 trips/h (RF related trip rate < 10 trips/h), this is the cost of doing business. CEBAF supports the program.**

# Consequences of using Downtime for Availability Metric

- ✔ Must use **event downtime** not system downtime to deal with parallel failures. DTM tool configured to deal with this. Thanks Ryan and Randy!
- ✗ Downtime is an administrative tool, its use must be consistent. Inconsistent use of DTM can lead to bad numbers.
- ✔ Removes the complexity of the CEBAF program, beam studies? tuning? research? Møller runs, special calibrations, .... CEBAF is either up or down.
- ✗ Still have to manually deal with schedule changes due to very long unscheduled downtimes that morph into scheduled accelerator downs (not maintenance): XXXX Unscheduled Crisis $\rightarrow$ Scheduled Accelerator Down.
- ✔ Use the same tool for system/sub-system performance metrics for internal purposed.
- ✗ Still need to track **at least two** of the following: Research, Beam Studies and Tuning hours for the DOE reports. And the sum must be equal to Scheduled-Downtime. That's the next problem.

# What we need to work toward

- Track Research, Beam Studies and Tuning hours on a daily basis.
  - Ideally only need to track Research Hours = Research Hours Scheduled - Downtime, in that period.
- Chart actuals and the expect sums assuming the target $\mathcal{R}$ and the optimum, $\mathcal{R} = 100\%$




- Create similar Chart for Beam Studies and Tuning.
- Charts should be available in **real time** but also presented at the Wednesday

# Reliability Scenarios

## My aspirations for CEBAF Reliability

| | % Gap Change/y | FY17 | FY18 | FY19 | FY20 | FY21 | FY22 |
|---|---|---|---|---|---|---|---|
| | (%/year) | | | | | | |
| **Reliability (FLAT)** | **-5** | 80% | 79% | 78% | 77% | 76% | 74% |
| **Reliability (COL)** | **10** | 80% | 82% | 84% | 85% | 87% | 88% |
| **Reliability (Proposed)** | **20** | 80% | 84% | 87% | 90% | 92% | 93% |

Set FY17 Reliability goal to the DOE SC minimum, 80%. Following years goal is set by:

$$R_{goal}(FY) = R_{actual}(FY-1) + \mathcal{G} * (100 - R_{actual}(FY-1))$$

and close the gap to 100% by $\mathcal{G}$% of the gap in subsequent years.

This only makes sense if additional funds in the proposed scenario is not 100% consumed by adding additional running weeks.

Note that FY17 Reliability of 80% is higher than that presented in Feb. 2016 (70%).

# Top down

The goal of 80% is a top down, somewhat arbitrary goal. Have no idea if the hardware can support it. Peak performance is in the mid 90s, but what is the sustained performance?

The energy knob will be invoked to keep the trip rate at an acceptable rate (<10/h). It is unknown if the energy knob is correlated with reliability, naively one would expect that it is.

It would be very useful to have a bottoms up determination and continual tracking of accelerator systems and sub-system availability.

- Aid in determining priorities, near and long term.
- Identification of end-of-life systems.
- Ability to estimate sub-system/system lifetime.

# Open Issues

1. Tracking of Scheduled Hours: Research, Beam Studies and Tuning.
2. Tracking of Delivered Hours: Research, Beam Studies and Tuning.
   - What is the simplest way to do this?
   - Can it be done without also binning Downtimes by the program(s) during the event downtime?
3. Do the above issues throw the whole simple approach out the window?

# CHAPTER 8

# Reliability, Availability, and Operability

## 8.1 CHARGE AND ORGANIZATION

When ICFA commissioned the second ILC-TRC report, two working groups were formed, the first on Technology, RF Power and Energy Performance and the second on Luminosity Performance. Part of the charge to the Technology group was to "determine whether the machines can reliably reach their operating energy, [and] be tunable." The Luminosity group was charged to "analyze all those factors which affect the ultimate performance (both peak and integrated), including . . . tunability, and reliability." Because the issues of technology and luminosity reliability are so intimately coupled, a third joint Working group was formed with members from each of the primary working groups.

### Working Group Members

Members from Technology Performance:
**R. Pasquinelli**, FNAL (Subgroup leader); C. Adolphsen, SLAC;
Y.H. Chin, KEK; H. Edwards, FNAL; K. Hübner, CERN; M. Ross, SLAC;
T. Shintake, KEK/Riken; N. Toge, KEK; H. Weise, DESY

Members from Luminosity Performance: **N. Phinney**, SLAC (Subgroup leader); R. Assmann, CERN; W. Kozanecki, CEA/Saclay;
D. Schulte, CERN; P. Tenenbaum, SLAC; N. Walker, DESY