Attachment 1
Reliable Experimental and Accelerator Operations Performance Metrics

Introduction

While the body of Appendix B contains general definitions for the five metrics used to assess Reliable Experimental and Accelerator Operations performance, this Attachment provides the precise definitions in terms of formulae used to compute the metrics.

For convenience all of the parameters used in the formulae are defined in Table A1.1.

Table A1.1 Definitions

Quantity	Definition
$A_{accel\text{-}goal}$	The goal for three-hall accelerator availability—percent of scheduled time during which the beam meets all experimental specifications (see Table A1.2)—nominally 80% at a multiplicity of 2.0 and modified (according to the formula) whenever a significant new capability is being commissioned
E_i	The experimental equipment availability for experiments in Hall i as determined by the criteria defined below*
$E_{i\text{-}goal}$	The experimental equipment availability goal for experiments in Hall i; nominally 80%, but may be modified in the contract whenever a significant new capability is being commissioned
M_{goal}	The goal for multiplicity—the number of halls running simultaneously—nominally 2.0, but may be changed in the contract whenever unusual major hall installations are expected to impact the achievable multiplicity
M_{sched}	The scheduled multiplicity—the average number of halls scheduled to run simultaneously during the year
$N_{cap\text{-}upgrade}$	The number of major accelerator capability upgrades performed during the year
S_{ad}	The total number of hours of accelerator development activities scheduled for the accelerator
$S_{ad\text{-}actual}$	The number of hours the accelerator is actually able to support scheduled accelerator development activities
S_{beam}	The total number of hours in the published schedule that the accelerator is to provide beam for physics experiments
$S_{beam\text{-}actual}$	The number of hours that the accelerator actually provides beam for scheduled physics experiments in at least 1 hall
S_i	The total number of hours assigned in the published schedule for experiments in Hall i
$S_{i\text{-}actual}$	The actual number of hours when both the beam and experimental equipment are available and being used to carry out the planned scientific program in Hall i
S_j	The total number of hours assigned to the j^{th} experiment in the published schedule
t_{bs}	The date on which a firm beam schedule is released
t_{sa}	The actual date on which an experiment begins taking data
t_{ss}	The date on which an experiment is scheduled to begin taking data as published in the firm beam schedule

*E_i, the availability of the experimental equipment for Hall i (where i = A, B, or C), is defined as the ratio of the time the equipment for that hall is operational at its design specifications in a particular configuration to the time it is scheduled for use in that configuration. The metric will initially consider only the "base" equipment as defined by the Jefferson Lab construction project. As new equipment is added to the base equipment (or as major new experimental apparatus is developed) it shall be treated separately following the availability goals established for the base equipment during its first two years of operation, and treated as part of the base equipment thereafter.

Table A1.2 defines the nominal beam parameters referenced in the metrics.

Table A1.2 Beam Requirements - General Characteristics

Parameter	**Nominal Value and Range**	**Stability (during 8 hours)** *(note 1)*	**Helicity Correlated Unbalance Averaged Over 1 Hour**
rms spot size at the target	A: $\sigma_{x \text{ and } y}$ = 50 to 200μm; B: 50 < $\sigma_{x \text{ and } y}$ < 250μm; C: $\sigma_{x \text{ and } y}$= 100 to 500μm A & C may request specific sizes *(note 2)*	A & C: 25% of requested value; B: any value within nominal range	A & C: 100% of nominal size; B: 60μm
Angular divergence at the target	$\sigma_{x'}$, $\sigma_{y'}$ < 100 μr	50% of value	100% of beam divergence tolerance
Beam position	any value requested by experiment within 3 mm of optics axis	Drifts A: < 50% of spot size; B: < 120 μm; C: < 250 μm; transients A, B, C: < 1mm	A & C < 10μm; B < 60 μm
Beam direction	any value requested by experiment within 1mr of optics axis to dump center	< 50μ r (1/2 beam divergence tolerance)	100% of beam divergence tolerance
Energy (average)	multipass operation: 0.63 to 5.75 GeV; 1 pass 1 hall dedicated operation: 0.33 GeV to 0.63 GeV	A or C: ΔE/E < 1E-4 B: ΔE/E < 5E-4 and ΔE/E < 1E-3 over days for all	100% of energy spread tolerance
Energy Spread (1σ)	A & C: σ_E/E < 5E-5 for E>1GeV B: σ_E/E < 4E-4	A & C: σ_E/E < 5E-5 for E>1GeV B: σ_E/E < 4E-4	X
Background (Beam halo) close to the target	A, B, C: < 1 E-4 outside of a 5 mm radius *(note 3)*	any value within the nominal range	100% of nominal halo tolerance
CW average current *(notes: 4 & 5)*	1 μA < A < 120 μA 1ηA < B < 1 μA 1μA < C < 120μA A+C < 180μA ; A + C < 800 KW A or C < 180 μA (single hall)	Within +/- 5% of nominal value (includes high frequency fluctuations)	A < 200 ppm; B & C< 1000 ppm 3 Halls: excursions of 5 second samples up to 5 times the nominal value are acceptable.
Polarization (current range to be determined between Physics and Accelerator Divisions)	> 70% all halls with currents up to 100μA in A or C	Polarization > 70%	X
Effective duty factor DF	loss (1-DF) including trips: < 5% @ 0.33 to 5 GeV (5 + (E-5)*20) % @ 5 to 6 GeV	X	X

Note 1) With continuous monitoring the beam is good when within tolerances. With invasive diagnostics, one does not know the beam quality between measurements. The user accepts the uncertainty except if he can provide a continuous non-invasive diagnostic.

Note 2) Some beam size requests in the range will preclude the Moller optics to be the same as the beam-delivery-on-target optics

Note 3) After the halo monitors for halls A and C are operational.

Note 4) Lower currents can be delivered with relaxed tolerances

Note 5) Proper impingement on beam dump has to be checked with accelerator operation (centering on dump face, current density on dump face, visibility on dump viewer, amount of radiation in the hall, on the site, etc.)

Development of Goals and Scoring of Performance Metrics

Each of the five metrics is scored relative to a performance goal (PG) set each year during contract negotiations. The percent of points assigned is determined from Table A1.3 where the Performance Level is the percent of the performance goal actually achieved.

Table A1.3 Points Assigned per Performance Level[1]

Performance Level	Adjectival Rating	% of Assigned Points
≥100% of PG	Outstanding	= 100
90% to 100% of PG	Outstanding	= (% of PG achieved)
80% to < 90% of PG	Excellent	
70% to < 80% of PG	Good	
60% to < 70% of PG	Marginal	
50% to < 60% of PG	Unsatisfactory (Poor)	
25% to < 50% of PG	Unsatisfactory (Failing)	= 2 * (% of PG achieved - 25%)
0% to < 25% of PG	Unsatisfactory (Failing)	= 0

The discussion of each metric includes the formulae used in calculating the Performance Goal and the Actual Performance.

PM 1.11: Delivered Physics Research Operations, $S_{physics\ research}$, is determined by the number of hours the accelerator beam and experimental equipment are simultaneously available. [100 points]

Performance Goal: $S_{physics\ research\text{-}goal} = S_{beam}A_{sim\text{-}goal}M_{goal}$ (hours), the scheduled hours times the goal for simultaneous availability of the accelerator beam and experimental equipment times the multiplicity goal.

S_{beam} is obtained from the published schedule.

$A_{sim\text{-}goal} = A_{accel\text{-}goal}E_{t\text{-}goal}$, the product of the Three Hall Accelerator Availability goal and the weighted average of the equipment availability in the halls. Three Hall Accelerator Availability is defined as the percent of scheduled beam time that the beam meets all experimental specifications; it is nominally 80% for a multiplicity of 2.0. Represented as $A_{accel\text{-}goal}$, it is calculated assuming an 80% availability goal for two hall operation, increasing the availability goal by 5% when only one hall is operated and decreasing the availability goal by 5% when three halls are operated simultaneously. In addition, the goal is adjusted for commissioning of major new accelerator capabilities ($N_{cap\text{-}upgrade}$) and other significant demands (*e.g.*, energies near 6 GeV) that may negatively impact accelerator availability. Each such upgrade is expected to reduce accelerator availability by 10% for one quarter, corresponding to 2.5% for the year. Thus $A_{accel\text{-}goal} = 90\% - (M_{sched} * 5\%) - (N_{cap\text{-}upgrade} * 2.5\%)$. The average availability of experimental equipment is given by $E_{t\text{-}goal} = \Sigma E_{i\text{-}goal}S_i/\Sigma S_i$, the average of the hall goals for experimental equipment weighted by the scheduled hours in the halls. $E_{i\text{-}goal}$ is nominally 80%, but may be reduced by agreement in the contract for a hall in which new equipment is to be installed or commissioned.

[1] The table is altered for PM 1.12. Points are awarded based on [1-PG].

The multiplicity, M_{goal}, is the average number of halls that are running any time the accelerator beam is available for physics. This is nominally 2.0, but may be reduced by agreement in the contract when extended hall downs make it appropriate.

Note: Because the PG depends on details of the published beam schedule, which is not finalized until after the start of the year, a numerical value for the PG is not included in the contract.

Actual Performance: $S_{physics\ research} = \Sigma S_{i\text{-}actual}$, the sum of the actual hours of physics research operations in the halls.

PM 1.12: Total Accelerator Downtime, D_t, is the percent of time the accelerator is not able either to support the scheduled research program of at least one hall or to carry out scheduled machine development studies. [40 points]

Performance Goal: The goal for Total Accelerator Downtime is < 15% but may be adjusted by agreement in the contract when atypical demands on the accelerator (*e.g.*, energies near 6 GeV) will negatively impact accelerator performance.

Actual Performance: $D_t = 100\% \text{ X } [(S_{beam} - S_{beam\text{-}actual}) + (S_{ad} - S_{ad\text{-}actual})]/(S_{beam} + S_{ad})$, the percent of time beam is actually unavailable either to support the scheduled research program of at least one hall or to carry out the scheduled accelerator development work compared to the time scheduled for those activities.

PM 1.13: Total availability of the base experimental equipment, E_t is the weighted average over all halls of the availability of experimental equipment. [20 points]

Performance Goal: $E_{t\text{-}goal} = \Sigma E_{i\text{-}goal} S_i / \Sigma S_i$, where $E_{t\text{-}goal}$ is nominally 80% for each hall but may be reduced by agreement in the contract when the learning curve associated with new equipment in the hall impacts the availability of the equipment.

Note: Because the Performance Goal depends on details of the published beam schedule, which is not finalized until after the start of the year, a numerical value for the Performance Goal is not included in the contract.

Actual Performance: $E_t = \Sigma E_i S_i / \Sigma S_i$, where E_i is the actual availability of experimental equipment in the hall.

PM 1.14: Effectiveness of the scheduling process, ε_{sched} is the average performance with respect to scheduled experimental start times weighted by the length of the experiment.
[20 points]

Performance Goal: $\varepsilon_{sched\text{-}goal} = 1$, corresponding to all experiments starting on time.

Actual Performance: $\varepsilon_{sched} = \Sigma S_j R_j / \Sigma S_j$, where S_j is the scheduled length of the j^{th} experiment and $R_j = (t_{ss} - t_{bs})/(t_{sa} - t_{bs})$, the ratio (for the j^{th} experiment) of the number of days between the scheduled start and the publication of the schedule to the number of days between the actual start and the publication of the schedule. If the experiment starts on time, the ratio is 1; if the experiment starts late, the ratio is less than 1 and grows smaller the longer the delay.

PM 1.15: Overall operations effectiveness, ε_{ops} is defined as the ratio of total time the accelerator is operated for physics to the total time for accelerator operations that was identified as the joint expectation for the year during negotiations of the Laboratory's operation budget. [20 points]

Performance Goal: 100%

Actual Performance: ε_{ops} = 100% X (actual weeks of accelerator operations for physics/weeks of accelerator operations for physics in contract).