LC availability Simulation done for the LC comparison task force

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Committee Members

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Contents

* Our approach to estimating an accelerator's availability
* The simulation
* The state of the input data
* Very preliminary results
* Plans

Overall plan of Attack

- Write a simulation that given the MTBFs, MTTRs, numbers and redundancies of components, and access requirements for repair can calculate average availability and the integrated luminosity per year. Luminosity will mostly be either design or zero in this simulation.
- Collect data on MTBFs and MTBRs of components in existing machines to guide our budgeting process
- Make up a reasonable set of MTBFs that give a reasonable overall availability.
- Iterate as many times as we have time for (probably once during this task force) to minimize the overall cost of the LC while maintaining the goal availability

Why a simulation?

- We chose to go with a simulation instead of a spreadsheet calculation for the following reasons:
 - Including tuning and recovery times in a spreadsheet calculation is difficult.
 - Fixing many things at once (during an access) is also difficult to put in a simple spreadsheet formula.
 - If later, one wants to more carefully model luminosity degradation on recovery from downtimes a simulation is simpler
 - A disadvantage of a simulation is its use of random numbers so one needs high enough statistics go get a meaningful answer. This is particularly a concern if one wants to compare two slightly different cases. Random number seeds will be handled in a way to allow meaningful comparisons of similar cases.

Simulation overview

- * About 1100 lines of Matlab code
- Reads an Excel spreadsheet with data that describes the accelerator
- * Lets things break according to their MTBFs
- Evaluates how the accelerator performance degrades
- Schedules repairs when performance is too poor
- Does crude accounting of retuning time after a repair. Accrues opportunistic machine development time.
- Outputs a comma delimited file for import to Excel that has the downtime caused by each device.

Accelerator parameters

* The simulation keeps track of various accelerator parameters which degrade as components break. Examples:

e- linac energy overhead

- + damping ring extraction kicker strength
- e- damping ring RF voltage
- Luminosity

If a parameter gets below its minimum allowed value, the LC is declared broken and repairs are scheduled.

Actual parameter input sheet

name	design	minimum
luminosity	1.00E+34	5.00E+33
e- energy overhead	5000	0
e+ energy overhead	5000	0
e- DR RF HV	54	49.49955
e+ DR RF HV	54	49.49955
e- DR inj kick	0.63003	0.6
e- DR ext kick	0.63003	0.6
e+ DR inj kick	0.63003	0.6
e+ DR ext kick	0.63003	0.6
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2% energy overhead 11 of 12 RF cavities 20 of 21 working inj and extraction kickers

Few lines of Actual Component Input Sheet

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9 Water pumps	beamline	e- linac	broken	3	luminosity	mult	0.00	1.20E+05	4		1	2	
0 Water	beamline	e- linac	broken	3	luminosity	mult	0.00	3.00E+04	2		1	2	
1 Flow Switch	beamline	e- linac	broken	6	luminosity	mult	0.00	2.30E+05	1		1	2	34
1 Cavities	cavity	e- linac	degrade	7152	e- energy o	\add	-12.00	1.00E+08	336		1	2	35
1 Cavities	cavity	e- linac	broken	7152	e- energy o	add	-36.33	1.00E+08	336		1	4	36
2 Cavity tuner	cavity	e- linac	broken	7152	e- energy o	\add	-36.33	5.00E+05	336		1	4	37
3 Cavity piezo tuner	cavity	e- linac	broken	7152	e- energy o	add	-12.00	5.00E+05	2	power c	1	4	38
4 LLRF	cavity	e- linac	broken	7152	e- energy o	add	-36.33	1.00E+05	1		0	1	39
1 power coupler	coupler	e- linac	degrade	7152	e- energy o	add	-288.00	1.00E+07	2	power c	1	2	40
1 power coupler	coupler	e- linac	broken	7152	e- energy o	\add	-871.92	1.00E+07	2	power c	1	2	41
1 power coupler disc	coupler	e- linac	disc	7152	e- energy o	add	-36.33	1.00E+50	336	2023	1	4	42
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5 pulse transformers	klystron	e- linac	broken	293	e- energy o	\add	-871.92	1.00E+05	4		-1	2	222
2 Modulators	klystron	e- linac	broken	293	e- energy o	add	-871.92	2.00E+04	2		0	2	64
5 pulse cables	klystron	e- linac	broken	293	e- energy o	add	-871.92	1.00E+06	4		0	2	65
2 Quads	beamline	e- DR	broken	849	luminosity	mult	0.00	4.90E+06	8		1	2	77
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Component Sheet Columns Defined

- Rank in subsys:
- Component name
- Subsys/segment:
- Region:
- Problem name:
- **Quantity:**
- Parameter effected:
- Add/mult:
- Degradation:
- MTBF:
- MTTR: Mean Time To Repair (hours) not including time to access & recover
- Still broken after repair: Component name of what is still broken after a kludged repair is complete. E.g. corrector supply still needs to be fixed after temporary fix of steering around it. (Not implemented yet)
- Access needed:
- =1 means access to the accelerator tunnel is needed for a repair
 =0 means no access is needed, but accelerator is down during repair
- =-1 means component is hot swappable e.g. a klystron in 2 tunnel case.

n repair people:

뽂

number of people needed to repair a component (specialties are ignored)

Not used by simulation. Helps sheet organization

Not used by simulation. Helps sheet organization

Part of the accelerator, e.g. e- linac or e+ source

Allows for problems with different consequences

Affect on the parameter is additive or multiplicative

Amount the parameter is degraded for each broken device

e.g. klystron or modulator or bend magnet

Total number of this device in this region

e.g. e- energy overhead or luminosity

Mean Time Between Failures (hours)

Rand seed: Allows use of same random numbers even when a new component line is added

Tom Himel

122		e+ linac broken 379 luminosity mult		0.5 0	0 1 124	10.2 8	8.8 1.8 1.		10.2 10.6 1.8	
122 123 124 125 126 127		e+ linac broken 3 luminosity mult e+ linac broken 253 luminosity mult		1 0 2 0	0 1 224 0 1 125	0 0 9 6.7	0 0 9.5 9 9.	0 0 0 5 16.8 5.8	0 0 0 9 7.1 10.6	
125		e+ linac broken 379 luminosity mult e+ linac broken 6 luminosity mult		0.5 0	0 1 126	4 2.2 0 0	2.4 2.7 3.	8 2.7 3.3 0 40.1 0	4 4.4 4	
120	7 VacP beamline	e+ linac broken 596 luminosity mult		2 0	1 2 128	0 0	0 0	0 0 0	0 0 0	
128 129 130 131 132 133	9 Water pumps beamline	e+ linac broken 4 luminosity mult e+ linac broken 3 luminosity mult	0 200000	2 0 4 0	1 2 129 1 2 130	5.6 0 0 0	0 12.1 11. 0 0		5.6 4.7 14 0 0 0	
130	10 Water 11 Flow Switch beamline	e+ linac broken 3 luminosity mult e+ linac broken 6 luminosity mult	9 30000 230000	At the	1 2 131	to the			11.2 8.2 16.8 5.6 3 16.8	ot
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137	1 power coupler coupler	e+ linac degrade 7152 e+ energy cadd	-288 10000000	2 power o	1 2 138	0.9 5.6	0 0	0 7.5 0.6	5.6 0.9 0.7	
138		e+ linac broken 7152 e+ energy cadd e+ linac disc 7152 e+ energy cadd	-871.92 10000000 -36.33 1E+50	2 power c 336 0	1 2 139 1 4 140	12.6 5.6 0 0		0 0 0	7 3.9 0.7 0 0 0	
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146 147 148 149 150 151 152		e+ linac broken 0 luminosity mult e+ linac broken 1 luminosity mult		2 0 8 0	1 2 150	0 0	0 0	0 0 0 0 0 0	0 0 0	and the second
150		e+ linac broken 5 luminosity mult e+ linac broken 5 luminosity mult	0 40000 0 20000	8 0	-1 2 151	0 0	7 0	87. 0	0 0 0	
152	2 Modulators first klystron	e+ linac broken 5 luminosity mult	0 20000	2 0	0 2 225 0 152 0 2 63 0 154		7 6 1		3 5 6	get
153		e+ linac broken 5 luminosity mult e+ linac broken 5 luminosity mult		4 0 1 0						ZUU
155		e+ linac broken 5 luminosity mult e+ linac broken 5 luminosity mult		1 0	0 1 155	1.6 10.3	13 10.3 1	3 0 0.7 0 26.1 0	1.6 1 1.6	
153 154 155 155 157 159 169 169 169 161 162 163 164 166 166 166 166 166 167 177 172 173 174 177 177 177 177 178	6 Water pumps first klystron	e+ linac broken 2 luminosity mult	0 120000	4 0	0 2 7	5. 11.2	11.2 11.2 11.	2 0 2.1	5.6 3.5 5.6	
158		e+ linac broken 2 luminosity mult e+ linac broken 6 luminosity mult		2 0 1 0			5.6 5.6 7. 7.5 0 7.		0.9 0.9 2.3 0.9 0.9 1.1	
160		e+ linac broken 2 luminosity mult e+ linac broken 293 e+ energy cadd	0 360000	4 0 8 0	0 2 0			0 0 0	0 0 0	
162	1.5 pulse transformers klystron	e+ linac broken 293 e+ energy cadd	-871.92 100000	4 0	-1 2 226	4.4 55.9	7 37.3 30.	8 3.7 13.2	25.1 20.2 14.7	
163		e+ linac broken 293 e+ energy cadd e+ linac broken 293 e+ energy cadd	-871.92 20000 -871.92 1000000	2 0 4 0	0 2 162 0 2 163	65.6 35.3 1.4 1.4	15.4 65.2 47. 0 11.2		68.2 50.2 41.8 1.4 0.9 2.8	
165	3 klys pre-amp klystron	e+ linac broken 293 e+ energy cadd	-871.92 100000 -871.92 100000	1 0	0 1 164 0 1 165	9.8 61.6 4.5 22.3	29.8 61.2 32.	6 34.9 6.9	10.2 9.3 8.6	
167	5 VacP klystron	e+ linac broken 293 e+ energy (add	-871.92 100000	1 0	0 2 166	4.5 22.3 7.2 47.4	22.4 68.6 35.	2 207 55	6.5 4.4 1.4 7.9 8 3.5	
168		e+ linac broken 146 e+ energy cadd e+ linac broken 146 e+ energy cadd	-1743.84 120000 -1743.84 30000	4	0 2 167	58.1 97.6 55.3 199.1	36.4 144.7 69.	8 60.6 26.6	67.2 39 32.8	
170	8 Flow Switch klystron	e+ linac broken 438 e+ energy cadd e+ linac broken 146 e+ energy cadd	-871.92 230000 -1743.84 360000	1		5.3 1.3 1.6 5.7	30.4 144.7 05. 31.4 250.7 124. 35.4 250.7 124. 35.4 29. 36.5 07.		6 5 4	at it
172	1 controls backbone sector	e+ linac broken 298 luminosity mult	0 100000	1		JT.7	421.9 36.3 57.	3 54.0 31.5	2.0 52.2 30.4 3.4	
173		e+ linac broken 305 luminosity mult e+ linac broken 305 luminosity mult		1 0	0 1 172	39.1 239.6 73.4 237	277.2 44.8 55. 283.6 41.5 46	9 28 26.8 4 39.2 51.5	39.5 35.5 8.5 72.5 64.5 11.1	
175	1 Bends beamline	e+ DR broken 216 luminosity mult e+ DR broken 849 luminosity mult	0 4900000	8 0	1 2 174			7 3.9	0 7 (
176	3 Sextupoles beamline	e+ DR broken 312 luminosity mult	0 4900000	8 0	1 976			$\begin{bmatrix} 7 & 3.9 \\ 9.4 \\ 2.4 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ $		
178		e+ DR broken 629 luminosity mult e+ DR broken 90 luminosity mult	0 1E+08 0 490000	0.5 quad or 8 0	0 2 77	0 0				
180	6 Kickers - injection beamline	e+ DR broken 21 e+ DR inj k add e+ DR broken 21 e+ DR ext i add	-0.03 100000 -0.03 100000	8 0	1 2 179 1 2 180	0 0 11.2 11.2	0 0 0 30.	0 0 0 8 0 11.7	0 0 0	
181	8 Power supplies strings beamline	e+ DR broken 36 luminosity mult	0 40000	2 0	0 2 181	29.7 20.3	24.8 0	0 3.5 17.7	29.7 29.2 (
183		e+ DR broken 629 luminosity mult e+ DR broken 36 luminosity mult		0.5 quad or 1 0	0 1 183	104.4 78.8 1.3 1.2	86.6 9.3 9. 1.2 0	6 11.7 68.8 1 0 0 0.7	05.9 114.9 12.3 1.3 1.2 0.7	
185		e+ DR broken 629 luminosity mult e+ DR broken 4 luminosity mult	0 500000	0.5 quad or	0 1 186	9.3 129.1	161.3 24.9 37.	3 27 5.5	9.3 10.2 1.8	
187	13 VacP beamline	e+ DR broken 2048 luminosity mult	1 100000	2	1 2 188				in and	7 7 1 1 1 1 1 1 1 1
188		e+ DR broken 125 luminosity mult e+ DR broken 6 luminosity mult		2 4	1 18 1 19	5 28.9 0	6/3 1.2 B5. 0 1.2 11	$\begin{bmatrix} 27 & 5.5 \\ 16.9 & 3.9 \\ 28 & 0.9 \\ 8 & 20.5 & 4.6 \end{bmatrix}$	8.5 2.1 5 5.6 4	
183 184 185 186 187 189 180 190 191 192 193 194 195 196 201 202 203 204 205 206 206 206 206 206 207	16 Water beamline	e+ DR broken 6 luminosity mult e+ DR broken 12 luminosity mult		2 0	0 191	7.1 16.3	18.4 22.6 3 7.5 0 8	20.5 4.6 4 5.6 2.1	7.7 8.2 9.0	
192	1 Cavities cavity	e+ DR broken 12 e+ DR RF I add	-4.5 1E+08	336 0	1 2 193	0 0	0 0	0 0 0	0 0 0	
193 194	3 power coupler coupler	e+ DR broken 12 e+ DR RF I add e+ DR broken 12 e+ DR RF I add	-4.5 100000 -18 1000000	1 0 336 0	0 1 194			S in the second		
195	4 coupler interlocks coupler	e+ DR broken 12 e+ DR RF I add e+ DR broken 24 e+ DR RF I add	-18 1000000 -18 1000000	1 0	1 1 10	0	0 0	S O O		
197	6 insulating vacuumP cryo module	e+ DR leak 4 e+ DR RF ładd	-18 100000	8 0	1 2 100			11.2 0.2		The state of the s
198		e+ DR broken 1251 luminosity mult	-18 100000 0.99 500000	8 0 1 0	0 1 200	14.9 11.2	0 0	7 22.4 4.6 0 0 0	0 0 0	
200	2 laser wires diagnostic	e+ DR broken 2 luminosity mult e+ DR broken 0 luminosity mult	0.95 100000	2 0	0 1 201	0	0	0 0 0 • •	0	
202	3 wires diagnostic	e+ DR broken 0 luminosity mult	0.95 100000	2 0	0 203	ngi				e off
203		e+ DR broken 0 luminosity mult e+ DR broken 3 e+ DR RF ladd	0.95 7000 -18 40000	8 0 4 0	1 2 204 0 2 205		17.7 11.2 23.	u v ul	20.2 17.5	
205		e+ DR broken 3 e+ DR RF ladd e+ DR broken 3 e+ DR RF ladd	-18 20000 -18 100000	2 0	0 2 206	3.5 3.5	3.7 3.5 5.	2 5.6 3.3	3.5 4.7 6.6	
200	4 VacG/Ctrl klystron	e+ DR broken 3 e+ DR RF ladd	-18 100000	1 0	0 1 2	0.6	0.6 0.6	0.6 0.3	0.7 0.6	
208		e+ DR broken 6 e+ DR RF ladd e+ DR broken 3 e+ DR RF ladd	-18 100000 -18 120000	1 0 4 0		6 5				TO
210	7 Water klystron	e+ DR broken 3 e+ DR RF ł add e+ DR broken 6 e+ DR RF ł add	-18 30000 -18 230000	2 0	0 2	UC	.2 3.7 1.		2.3	
211	9 Electrical - >0.5 klystron	e+ DR broken 3 e+ DR RF ladd	-18 360000	4 0	0 2 213	0 0	0	0 0 0	0 0 0	
213	2 timing sector	e+ DR broken 3 luminosity mult e+ DR broken 3 luminosity mult	0 100000 0 100000	1 0 1 0	0 1 214 0 1 215	0 0 0.6 7.5	0 0 7.5 0	0 5.6 0 0 0 0.3	0 0 0 0.6 0 0	Contraction and the second
215	1 Electrical05<<0.5 Utility power		0 100000	2 0	0 1 216 0 0 217	1.2 0	0 0 5. 3955.1 3694.9 267	6 0 0.7	1.2 1.2 1.2	total down
210		e+ DR dummy 0 luminosity mult e+ DR dummy 0 luminosity mult	1 1.00E+50 1 1.00E+50	1	0 0 217 0 0 218	2526.3 4542 2.871 14.07	12.1 10.06 6.			#access per month

Tom Himel

Lumped Availability Budgets

- Due to time constraints, only linacs and DRs were modeled in detail.
- Here are downtime budgets we assigned to other systems.
- Actually unavailabilities will be roughly double these numbers due to recovery times.
- Total unavail goal is
 25%. 10% contingency is unbudgeted, leaving 15% to budget.

	warm	cold
	nominal %	nominal %
region	downtime	downtime
e- injector	0.48	0.36
e- compressor	0.48	0.36
e- BDS	0.48	0.36
e+ source	0.48	0.36
e+ PDR	0.48	1.00E-40
e+ compressor	0.48	0.36
e+ BDS	0.48	0.36
IP	0.48	0.36
cryo plant	1.00E-40	1
site power	0.5	0.5
Sum	4.34	4.02
2*Sum	8.68	8.04

Modeling breakdowns

- * At initialization calculate the next time each component will break.
 - Average time is MTBF/(number of the component)
 - Throw a random number with an exponential distribution with the above average.
- * When that time comes, degrade the corresponding parameter and calculate the next time one will break.
- If that parameter is too far degraded, then immediately plan and start repairs.
- All the downtime and recovery time from the repairs is accounted to the component which put us over the edge even though other components will also be repaired.
- * To keep things simple, if something breaks when we are in the middle of repairs, it is just ignored. In real life, sometimes it would be noticed and fixed, and other times it would contribute to the recovery time.

Downtime planning

- * This is without doubt the most complicated part of the simulation.
- Anyone who has participated in a downtime scheduling meeting will understand why.
- And computers don't get a gestalt of the situation like humans can.
- It's hopefully good enough

Downtime planning

- 1. Check each component to see if by itself it "breaks" the accelerator. If there is then fix all of those components. For example if 2 DR kickers are broken then they would both be scheduled for repair.
- 2. Next we handle the case where multiple components together break the accelerator. For example, broken klystrons and cavity tuners both reduce the energy, but only together do they reduce it enough to run out of energy headroom.
 - Loop through the components in order of increasing "bang for the buck" (improvement per repair hour)
 - Accumulate parameter degradation (e.g. linac energy overhead)
 - Repair all components after the degradation gets too big
 - * This gets the accelerator fixed in the minimum possible time.

Downtime planning

- 3. The above repairs are scheduled taking into account the available number of repair people (set to 25 in the accelerator tunnel and 100 outside it) and the access times for the regions. These repairs are enough to make the accelerator work again. Note that the fact that repair people have specialties has been ignored to keep things simple.
- 4. Now schedule extra repairs .
 - In this case, we plan repairs which give the most "bang for the buck" first.
 - Keep scheduling things until it would extend the downtime by too much (set to 50% if no access is being done and a factor of two if there is an access)
 - Note there is no logic to decide which degraded parameter should be addressed first. Hence the simulation could choose to repair e- linac klystrons before e+ linac klystrons even though there happens to be less headroom in the e+ linac.

Regions and PPS zones

name	ppszone	upstream	accesshours	recoverhours	tunetimefraction	start of beamline'
none	none	none	0	0	0	0
e- injector	e- injector	none	2	1	0.1	1
e- DR	e- linac	e- injector	3	1	0.2	0
e- compressor	e- linac	e- DR	3	1	0.1	0
e- linac	e- linac	e- compressor	3	1	0.1	0
e- BDS	e-BDS	e- linac	3	1	0.1	0
e+ source	e+ source	e- linac	2	1	0.1	1
e+ DR	e+ linac	e+ source	3	1	0.2	0
e+ compressor	e+ linac	e+ DR	3	1	0.1	0
e+ linac	e+ linac	e+ compressor	3	1	0.1	0
e+ BDS	e+ BDS	e+ linac	3	1	0.1	0
IP	IP	e+ BDS	1	1	0.2	0

- * Two regions are in the same PPS zone if access to one of them means there can be no beam in the other. E.g. with the DR and linac in the same tunnel, they are in the same PPS zone.
- * "Upstream" indicates the order the beam goes through the regions.
- * "tunetimefraction" is used for the crude way we simulate recovery from a downtime. The time with no beam in a region times the tunetimefraction gives the time it takes to get good beam to the end of that region. At that time tuning can begin in the next downstream region.

Machine Development time Budget

- We budget % of time needed for MD in each region.
- Note conventional e+ source allows simultaneous MD in e.g. both DRs.
- Some MD will get done opportunistically while other parts of accel are down.
- Rest must be scheduled.

	%MD time	%MD
name	warm	time cold
e- injector	1	1
e- DR	2	2
e- compressor	1	1
e- linac	1	1
e- BDS	1	1
e+ source	1	1
e+ PDR	1	0
e+ DR	2	2
e+ compressor	1	1
e+ linac	1	1
e+ BDS	1	1
IP	1	1
total conv e+ source	8	7
total wiggler e+ source	13	12

Modeling recovery

- It is assumed that everything goes exactly according to schedule and the exact MTTRs are used as repair times (no random numbers thrown for this).
- Hence the time work will be done in each region and PPS zone is easily determined.
- * Working our way downstream from each injector, we see how long the region has been without beam, use tunetimefraction to calculate when beam will be at the end of the region and then go on to the next region.
- If the next region is still undergoing repairs that will continue for more than 2 hours, we assume opportunistic machine development will be done in the part of the accelerator with beam. This reduces the amount of scheduled MD time which must be done.

Modeling Long shutdowns

* This is very simple.

Every 9 months (an input parameter) all devices which take more than 300 hours to repair are instantaneously repaired.

✷ That's it.

- Other devices are not repaired as some probably break during the long shutdown anyway.
- Recovery from a long shutdown is not modeled. This should be done by hand when estimating annual integrated luminosity. For a 3 month shutdown, assuming 1.5 months with no luminosity would do a good job of mimicking the probably 3 month slow recovery of luminosity.

Misc Parameter sheet

variable name	value	Maximum number of people allowed in the accelerator tunnel to make								
maxaccess	25	repairs. We assume this limitted to minimize control room chaos controlling access via the PPS system								
maxpeopleoutside	100	Maximum number of people making repairs outside the accelerator								
maxmaintpeople	20	tunnel when the accelerator is down Maximum number of people making routine repairs								
simhours	32850	Number of hours to run the simulation for that can be done while the accelerator is running								
runhours	6570	(e.g. replacing klystrons in a 2 tunnel LC) Length (in hours) of a "run". A "run" is the time between long (e.g. 3 month) down times. In the								
randseed	5	simulation, items which take more than 999 hours to repair are all magically repaired every this often.								
extrarepairtimefactor1	arepairtimefactor1 1.5 Overall random number seed used in the simulation. Note that if you leave this the sa									
extrarepairtimefactor2	2	imes of a component will not change from one run to the next even if other components are added.								
allowaccesshours	8	to fix some extra things								
minMDhours	2	Factor by which we are willing to extend a down period which DID require and access in order to fix some extra things								
traceprtlevel	3	If the total time to repair something that did not require an access is greater than this, then								
tracefilename	trace.da									
resultsfilename	availres	ults 3. If the downstream part of the LC is down for more than this number of hours, then assume								
runname	2 tunnel	2% euseful Machine Development (MD) can be done in the upstream portion during that time								
Service and the service of the										
filename whe results will be										
Should have a	an	and a state of the								
extension of make import										
easy.		real and the second statement of								
STOP TO STOP	Inclusion	<u> 이상이는 것 같은 것 같은 것 않는 것 같은 것 같</u>								

State of input data

Only DRs and linacs are modeled in detail

- Have reasonably good parts counts
 - Some components could still be missing (definitely pulsed cables and 3 stub tuners)
 - Need to make clearer definitions of each component: e.g. are transducers considered part of the power supply, the controller, or as a separate part.
- MTTRs may be good to a factor of 2.
- Just learning the consequences when a part breaks was far more difficult then expected and still needs more work.
- Tuning model assumes there is a tune-up dump at the end of each region.

State of input data

MTBFs are the big problem

- In many cases, don't have data from present accelerators to get a good starting value
- Often just used 100,000 hours for no good reason.
- Ideally we would know MTBF vs. cost for each component and minimize total cost subject to the constraint on overall availability – We knew upfront this wasn't possible.
- For a few which are real availability drivers we will look in detail. Others will just be guesses.
- Even calculating the MTBF of a power supply with redundant regulators is difficult as common mode failures (e.g. water leak) must be considered.
- Remember: GIGO

All Results are Preliminary

 Many MTBFs are just defaulted to 100k hours
 Haven't budgeted enough of the unavailability to the non-DR, linac regions

Almost NO optimization of the MTBFs has been done

 Just took initial set of MTBFs, used the simulation to see which components made major contributions to the downtime and then increased their MTBFs.

Haven't checked many sensitivities e.g. to the number of repair people.

Results can be useful anyway

They highlight the components whose MTBFs must be increased.

- * The general magnitude (and sign) of availability changes with major design changes should be reasonable.
 - At present have done too few runs to judge how sensitive these changes are too other inputs.
 - There are so many inputs, hopefully their errors average out.

Very Preliminary Results

Ŧ

% access # energy

time per tun- over- MTBF

down month nels head fudge special conditions

				<u> </u>	
25.3	2.9	2	2%	1	
45.4	14.1	1	2%	1	
39.6	12.1	1	4%	1	
36.9	10.1	1	2%	10	
26.8	6.4	1	4%	10	
27.0	6.1	1	4%	10	
13.6	3.4	2	2%	1	
24.7	2.9	2	2%	1	
19.8	3.3	2	2%	1<	
15.6	2.3	2	4%	10	

DR magnet MTBF = 10*SLACs = 4.9e6 hours DR vacuum valve MTBF = 6e5 instead of nominal 1e5

MTBFs of magnet power supplies, timing, controls backbone, and electrical distribution increased by a factor of 10.

A different random number seed to see how precise the results are. The total downtime changes very little. The components vary by around 0.25%.

reduces the tuning time by a factor of 10 to give and idea of how important that tuning time is.

DR is separate tunnel. A surprisingly small effect

Conventional e+ source: Just assumed e+ could be produced with no beam in e- linac. No changes were made to the reliability of parts in the e+ source itself. This illustrates the penalty of not being able to tune up (or keep tuned) the positrons when something in the electron system is down

Warm MTBF budgets

	% time down	% time fully up integrati	% time		% time actual	% time	MTBF impro			
run	incl	ng lum				usele			1202.44	
numb er	forced MD	or sched MD	ting lum	ed MD	unistic MD	SS	nt	MTBF before	MTBF	devices
warm1	31.8	68.2			4.3		Tactor	beiore	now	initial run with nominal MTBFs
waiiii	51.0	00.2	59.5	0.7	4.5	21.5	1.1.1.1.1.		000000	
							10	1 00E+06	1 00F+07	all water cooled magnets
										DR Q movers
										large Power Supplies
										and the second se
							10	1.00E+05	1.00E+06	electronics modules esp PS controllers
				1.20			3	2.50E+05	7.50E+05	flowswitches
										first klystrons and related hardware
										(should be done with redundancy)
warm2	20.5	79.5	70.6	8.9	4.08	16.4	5	3.60E+05	1.80E+06	small electrical < 0.5 MW
										all water cooled magnets (total
										improvement)
							5	5.00E+04	2.50E+05	linac RF movers electronics modules esp PS controllers
1.18							20	1 005 05	2.005.06	(total improvement)
warm3	16.6	83.4	73.5	9.9	3.1	13.5				linac vacuum mechanical devices
wanno	10.0	00.4	13.5	5.5	5.1	10.0	10	0.002+04	0.002+03	
warm4	12	88	85.1	2.9	5.15	6.87				warm3 but with conventional e+ target
- 11-	01393	C ACO AO	10 m	Sere.	11 - A (C)	- 10	0125	A CIER		
										warm3 but 0.5x all MTBFs, 2x all
warm5	52.1	47.9	24.6	23	2.64	49.4		1.1.1	15.11.20	tunetimefraction, 2x all MD times
1354		A CONT	1215	132	2022	135-	1.25	Contraction of the	1388	
warm6	30.8	69.2	66.8	2.4	13.6	17.2	Carl C		S. K. Sterry	warm 5 but with conventional e+ target

Cold MTBF budgets

			and and all the	1			- Carlos			
run numb er	incl	% time fully up integrati ng lum or sched MD	integra	sch	% time actual opport unistic MD	% time usele ss down	MTBF impro veme nt factor	MTBF before	MTBF now	devices
cold1	30.9	69.1	58.6	11	1.49	29.4	194 million	2014		initial run with nominal MTBFs
Sec. Sta	1250	1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1	1120	1923	152622	2.5%	12/2/2012	19111	1925	TO BE WELL AND A REAL PROPERTY OF THE PARTY
							10	1.00E+06	1.00E+07	all water cooled magnets
							3	5.00E+04	1.50E+05	vacuum valve controllers
							5	2.00E+05	1.00E+06	large Power Supplies
							10	1.00E+05	1.00E+06	electronics modules esp PS controllers
							3	1.00E+05	3.00E+05	DR coupler interlocks
							5	1.00E+05	5.00E+05	DR VACP
							5	3.00E+05	1.50E+06	vacuum insulating vacuum leaks
										energy overhead increase from 2 to 3%
cold2	18	82	71.1	11	1.09	16.9	3	3.60E+05	1.08E+06	small electrical < 0.5 MW
	12.23	Call State		223		2.225				
							4	5.00E+04	2.00E+05	linac vacuum mechanical device
		S. S. S.					13			energy overhead increased to 4% (total improvement)
								STAL SS		all water cooled magnets (total
							30	1.00E+06	3.00E+07	improvement)
										first klystrons and related hardware
							10	2.50E+04	2.50E+05	(should be done with redundancy)
cold3	16.6	83.4	72.5	11	1.11	15.5				cryo JT valve
	1277	S. Castler		1	182226	1223	in state	1.100	11.22.62	
cold4	35.2	64.8	54.2	11	1.41	33.8				cold 3 but with 1 tunnel
	and the	SUSSESSION STREET	1.000	1.54	198853	Atomic .	ALC: NO	12112	1255123555	
										cold4 but with improved MTBFs. Got
cold5										tired, so not done yet.
	10000	BALL P. T. BALLING	The Allowed	1		100000		Contraction of the	C. C	

Comments

 Many parts means each must be quite reliable.
 Of initial 30% unavail, 10% is for lumped systems, 20% for linac+DR. Hence need factor of 4 overall improvement for them.

- Wiggler e+ source really hurts availability for 3 reasons
 - MD can't be done in parallel
 - Less MD can be done during recovery

Sequential recovery is slower

* Cold and warm are remarkably similar

Some serious engineering will be needed to attain the required MTBFs.

Plans

Cleanup input deck more
Rerun simulations – very similar results expected
Write it up
Celebrate