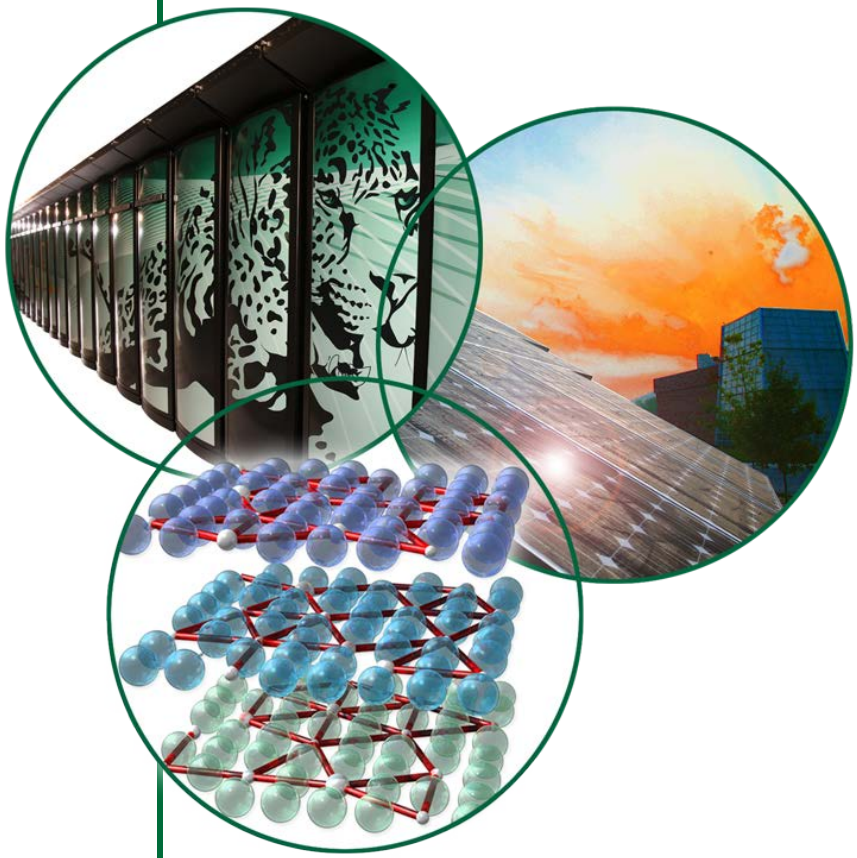
Modeling SNS Availability Using BlockSim

Geoffrey Milanovich

Spallation Neutron Source



U.S. DEPARTMENT OF ENERGY

OAK RIDGE NATIONAL LABORATORY

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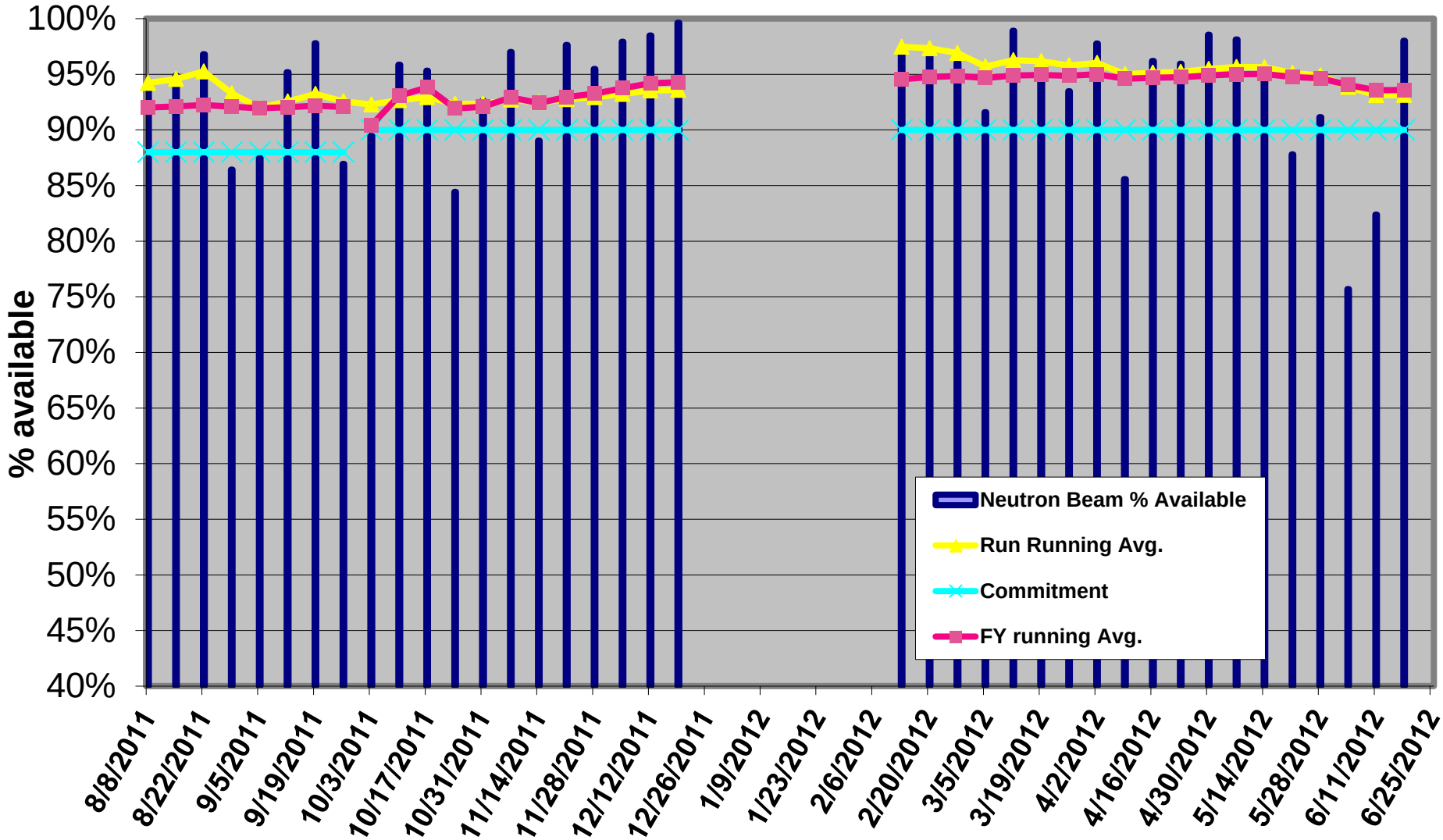
Contributors

- G. Dodson for providing initial reliability study and discussion
- Vivian Chang (summer student from Carnegie Mellon) for building much of the accelerator reliability block diagram

Outline

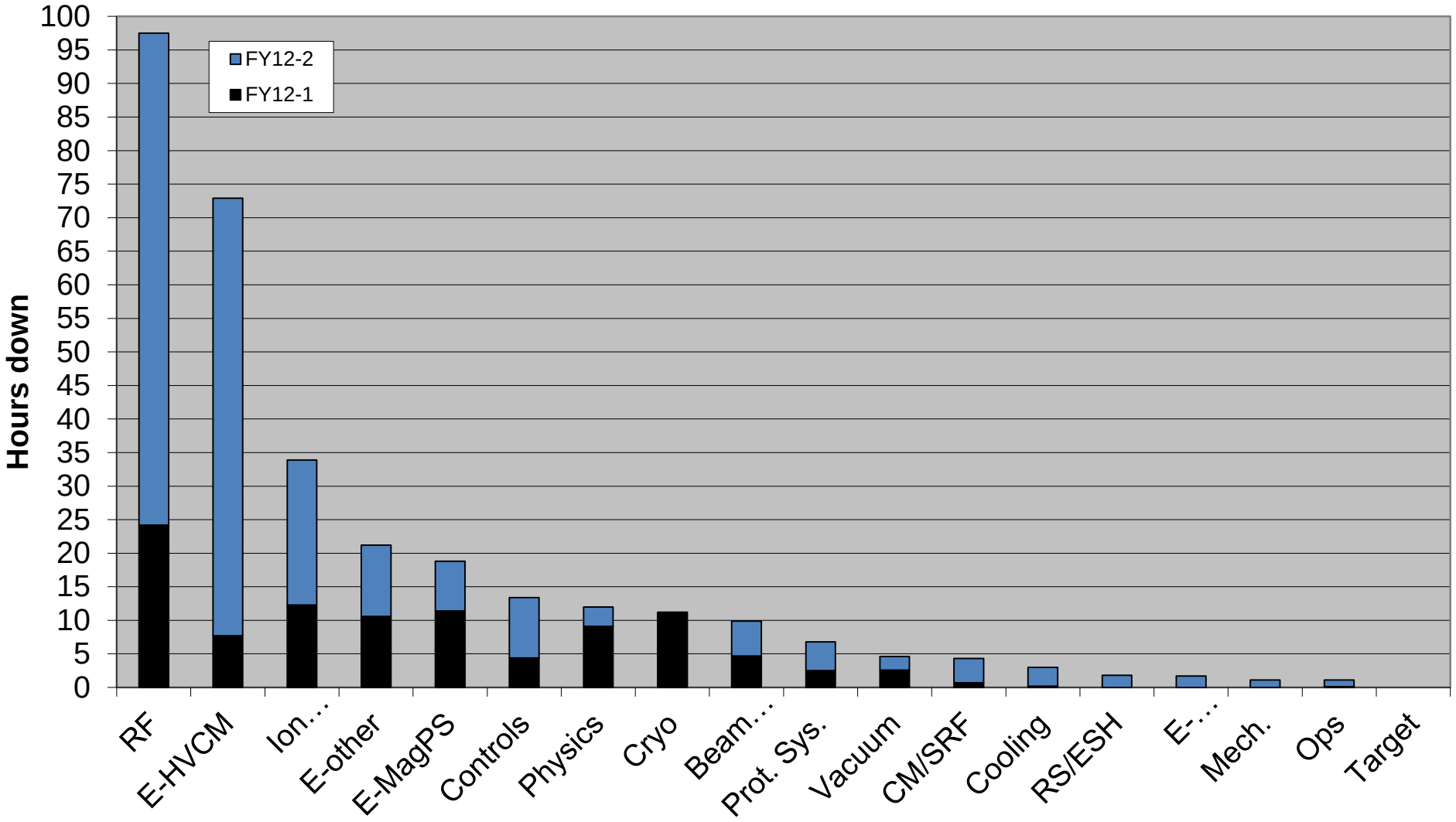
- SNS Availability Numbers
- Modeling an Entire Accelerator in BlockSim
- Modeling Klystron End of Life Behavior

Availability for Last 2 Runs



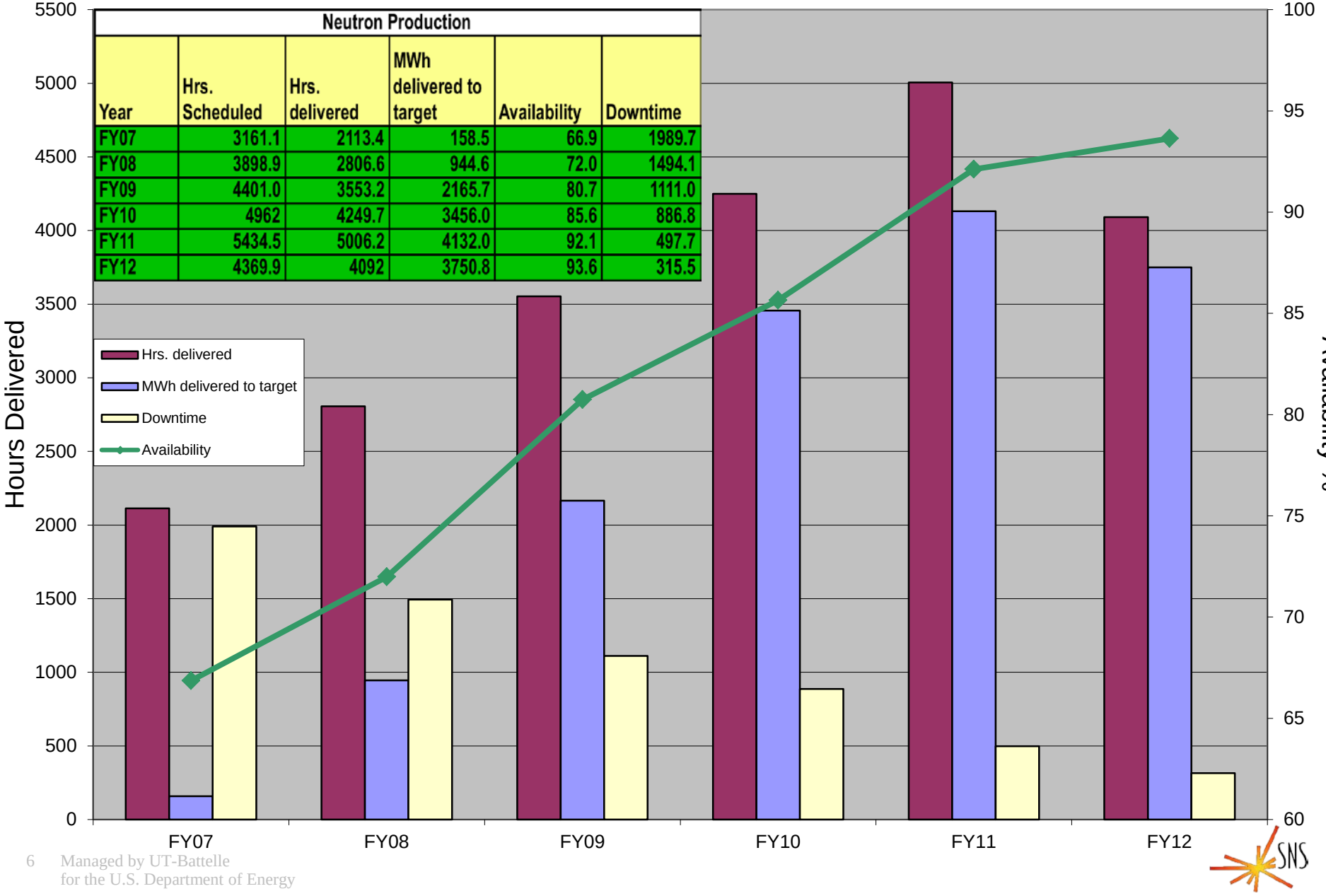
FY12 Availability – 93.6%

FY 12 Downtime by Group

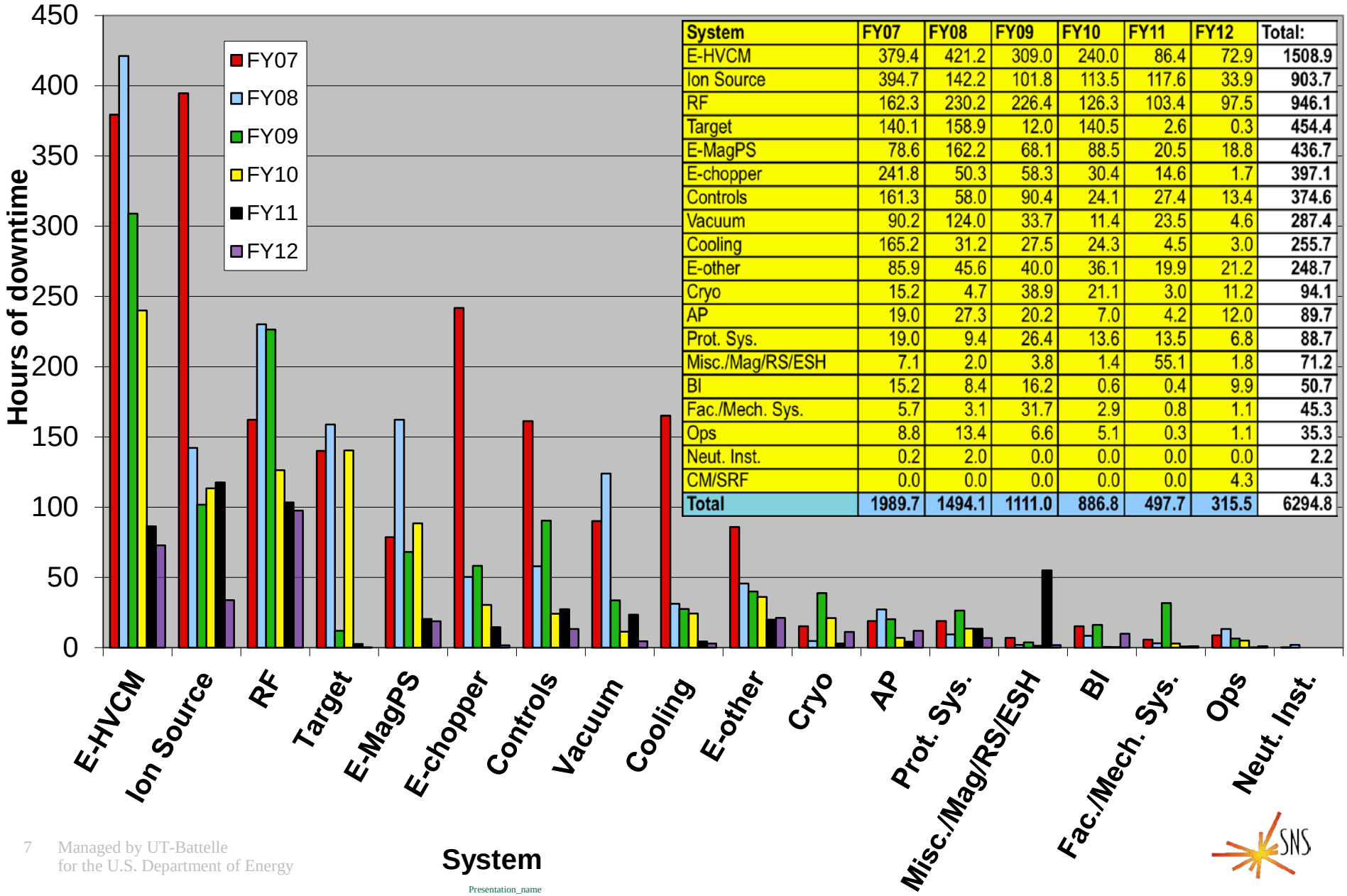


Neutron Production Hrs, MWhrs, & Downtime by Year

Neutron Production					
Year	Hrs. Scheduled	Hrs. delivered	MWh delivered to target	Availability	Downtime
FY07	3161.1	2113.4	158.5	66.9	1989.7
FY08	3898.9	2806.6	944.6	72.0	1494.1
FY09	4401.0	3553.2	2165.7	80.7	1111.0
FY10	4962	4249.7	3456.0	85.6	886.8
FY11	5434.5	5006.2	4132.0	92.1	497.7
FY12	4369.9	4092	3750.8	93.6	315.5



Downtime by Fiscal Year (07-12) Comparison



System	FY07	FY08	FY09	FY10	FY11	FY12	Total:
E-HVCM	379.4	421.2	309.0	240.0	86.4	72.9	1508.9
Ion Source	394.7	142.2	101.8	113.5	117.6	33.9	903.7
RF	162.3	230.2	226.4	126.3	103.4	97.5	946.1
Target	140.1	158.9	12.0	140.5	2.6	0.3	454.4
E-MagPS	78.6	162.2	68.1	88.5	20.5	18.8	436.7
E-chopper	241.8	50.3	58.3	30.4	14.6	1.7	397.1
Controls	161.3	58.0	90.4	24.1	27.4	13.4	374.6
Vacuum	90.2	124.0	33.7	11.4	23.5	4.6	287.4
Cooling	165.2	31.2	27.5	24.3	4.5	3.0	255.7
E-other	85.9	45.6	40.0	36.1	19.9	21.2	248.7
Cryo	15.2	4.7	38.9	21.1	3.0	11.2	94.1
AP	19.0	27.3	20.2	7.0	4.2	12.0	89.7
Prot. Sys.	19.0	9.4	26.4	13.6	13.5	6.8	88.7
Misc./Mag/RS/ESH	7.1	2.0	3.8	1.4	55.1	1.8	71.2
BI	15.2	8.4	16.2	0.6	0.4	9.9	50.7
Fac./Mech. Sys.	5.7	3.1	31.7	2.9	0.8	1.1	45.3
Ops	8.8	13.4	6.6	5.1	0.3	1.1	35.3
Neut. Inst.	0.2	2.0	0.0	0.0	0.0	0.0	2.2
CM/SRF	0.0	0.0	0.0	0.0	0.0	4.3	4.3
Total	1989.7	1494.1	1111.0	886.8	497.7	315.5	6294.8

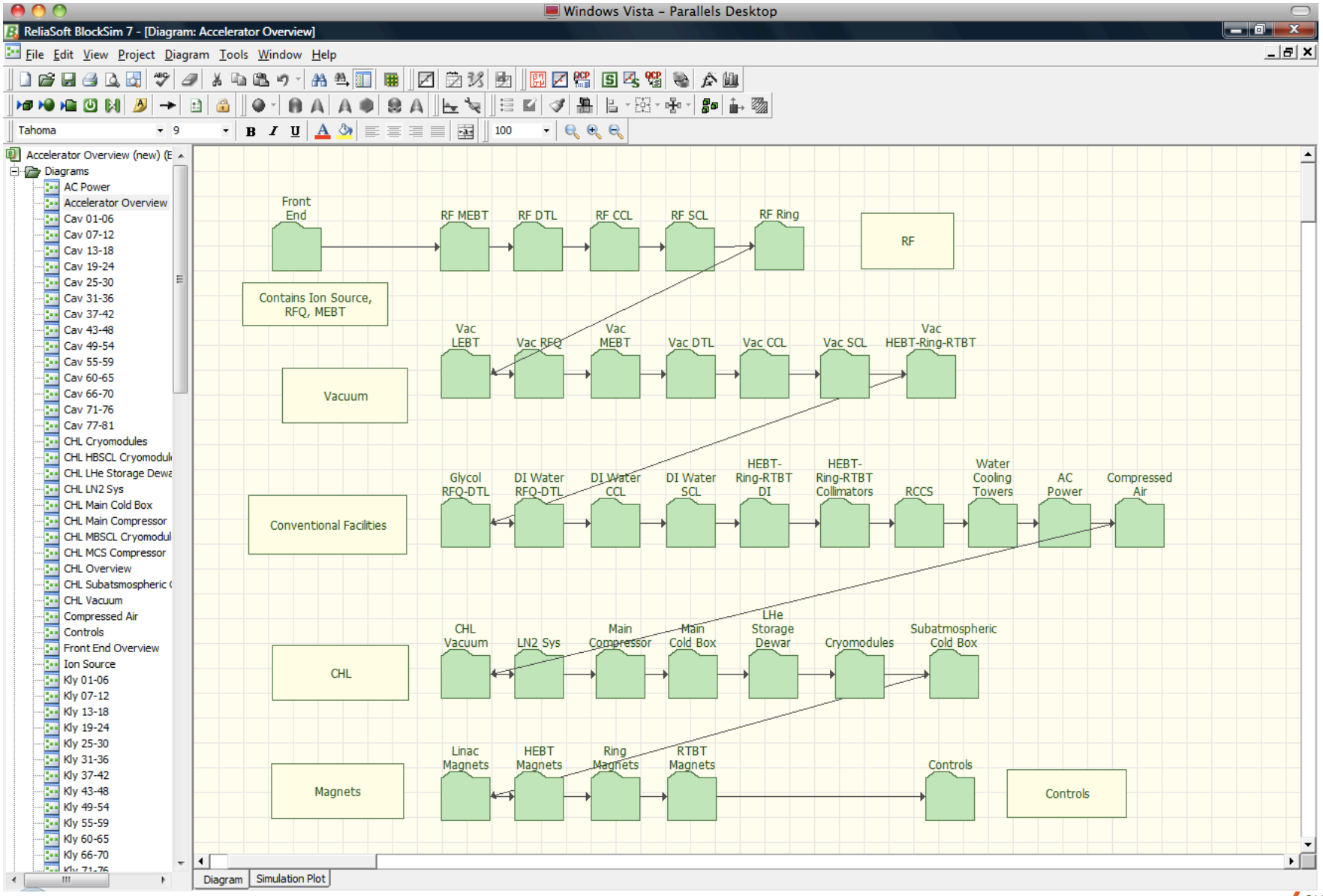
Reliability Estimates, in the Beginning

- "the spreadsheet" – numbers from industry, design specs, LANL, JLab, experts, and guesses
- Exponential distributions only (constant failure rate)
- For 160 hours mission time, availability:
  - Source – 87%
  - Linac – 80%
  - Modulators – 99%
  - Overall - ??

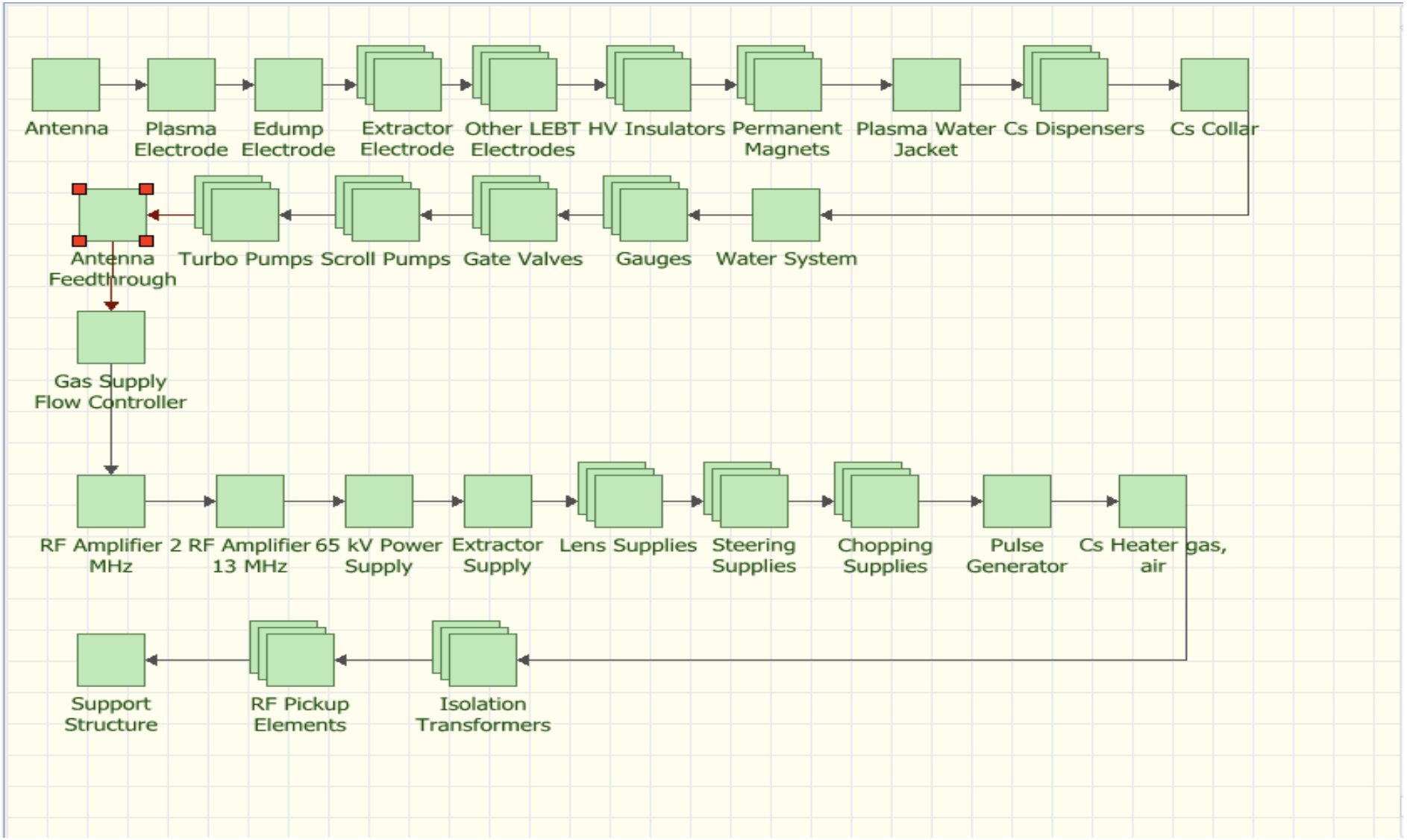
RBD/BlockSim Advantages

- Reliability Block Diagram (RBD) – “graphical representation of the components of the system and how they are reliability-wise related”
- Many failure distributions allowed
- Standby, load share, failure of switching to standby
- Analytical solution of very complex diagrams (but not an accelerator)
- Monte Carlo simulation – maintenance phases, spares, crews

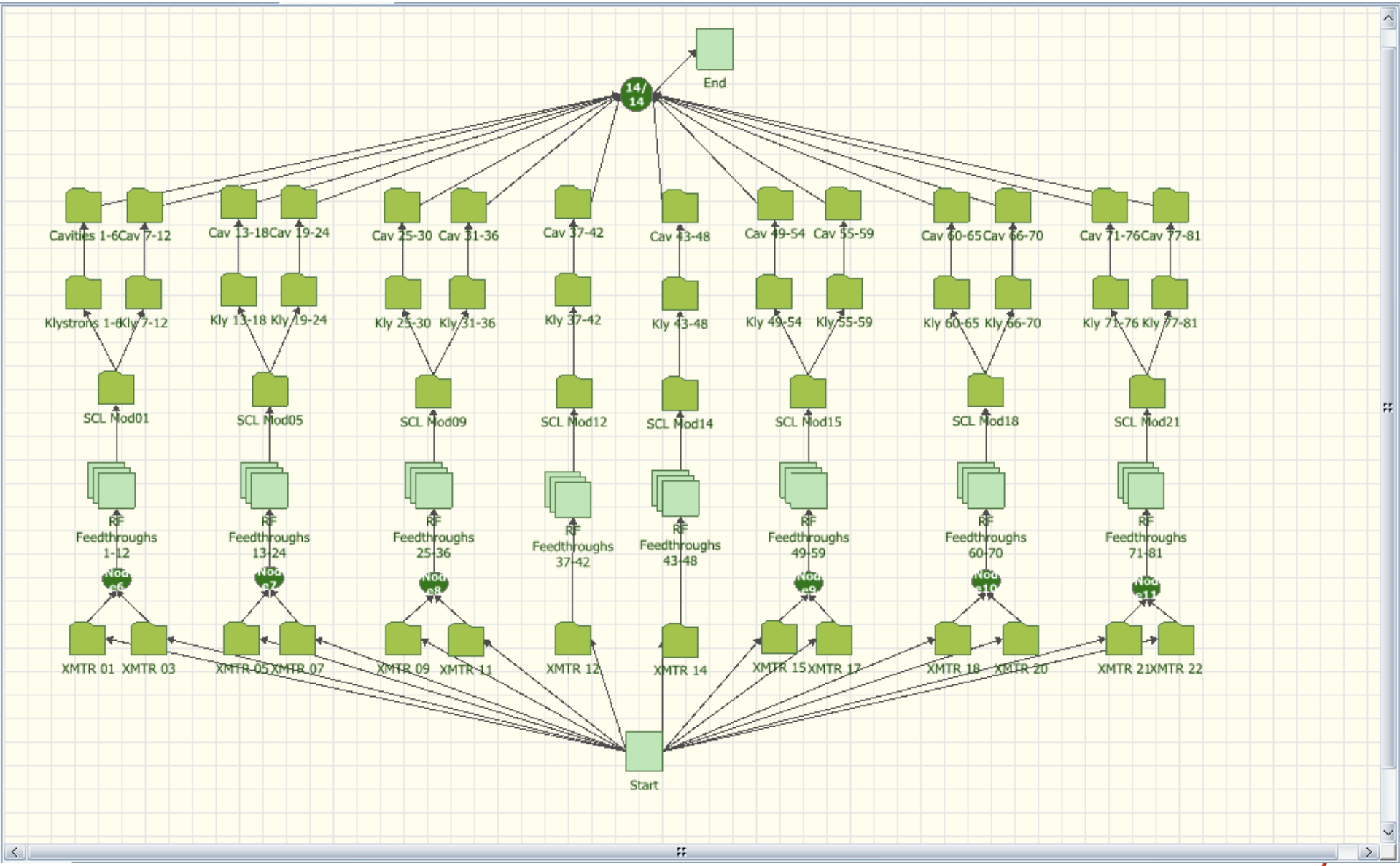
BlockSim 7/8 Model



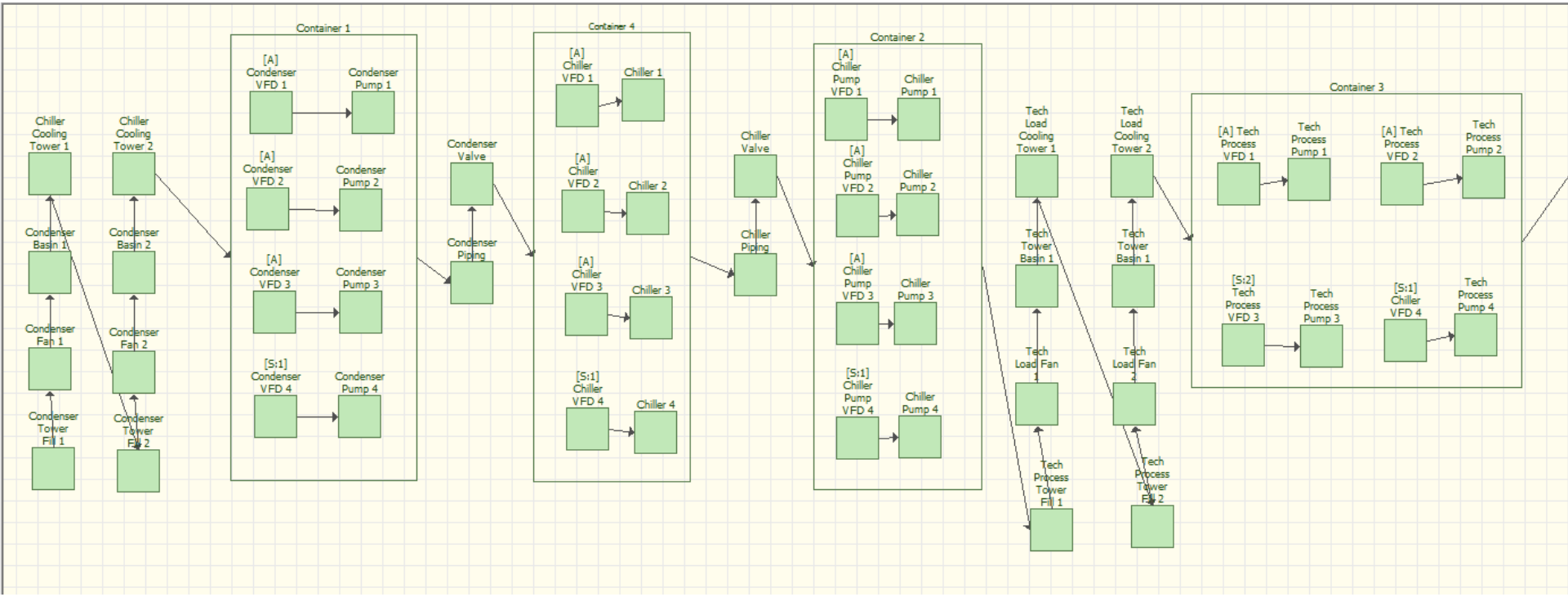
Ion Source


Antenna
Plasma Electrode
Edump Electrode
Extractor Electrode
Other LEBT Electrodes
HV Insulators
Permanent Magnets
Plasma Water Jacket
Cs Dispensers
Cs Collar
Antenna Feedthrough
Turbo Pumps
Scroll Pumps
Gate Valves
Gauges
Water System
Gas Supply Flow Controller
RF Amplifier 2 MHz
RF Amplifier 13 MHz
65 kV Power Supply
Extractor Supply
Lens Supplies
Steering Supplies
Chopping Supplies
Pulse Generator
Cs Heater gas, air
Support Structure
RF Pickup Elements
Isolation Transformers

RF Systems


End
14/14
Cavities 1-6
Cav 7-12
Cav 13-18
Cav 19-24
Cav 25-30
Cav 31-36
Cav 37-42
Cav 43-48
Cav 49-54
Cav 55-59
Cav 60-65
Cav 66-70
Cav 71-76
Cav 77-81
Klystrons 1-6
Kly 7-12
Kly 13-18
Kly 19-24
Kly 25-30
Kly 31-36
Kly 37-42
Kly 43-48
Kly 49-54
Kly 55-59
Kly 60-65
Kly 66-70
Kly 71-76
Kly 77-81
SCL Mod01
SCL Mod05
SCL Mod09
SCL Mod12
SCL Mod14
SCL Mod15
SCL Mod18
SCL Mod21
RF Feedthroughs 1-12
RF Feedthroughs 13-24
RF Feedthroughs 25-36
RF Feedthroughs 37-42
RF Feedthroughs 43-48
RF Feedthroughs 49-59
RF Feedthroughs 60-70
RF Feedthroughs 71-81
XMTR 01
XMTR 03
XMTR 05
XMTR 07
XMTR 09
XMTR 11
XMTR 12
XMTR 14
XMTR 15
XMTR 17
XMTR 18
XMTR 20
XMTR 21
XMTR 22
Start

Standby Containers

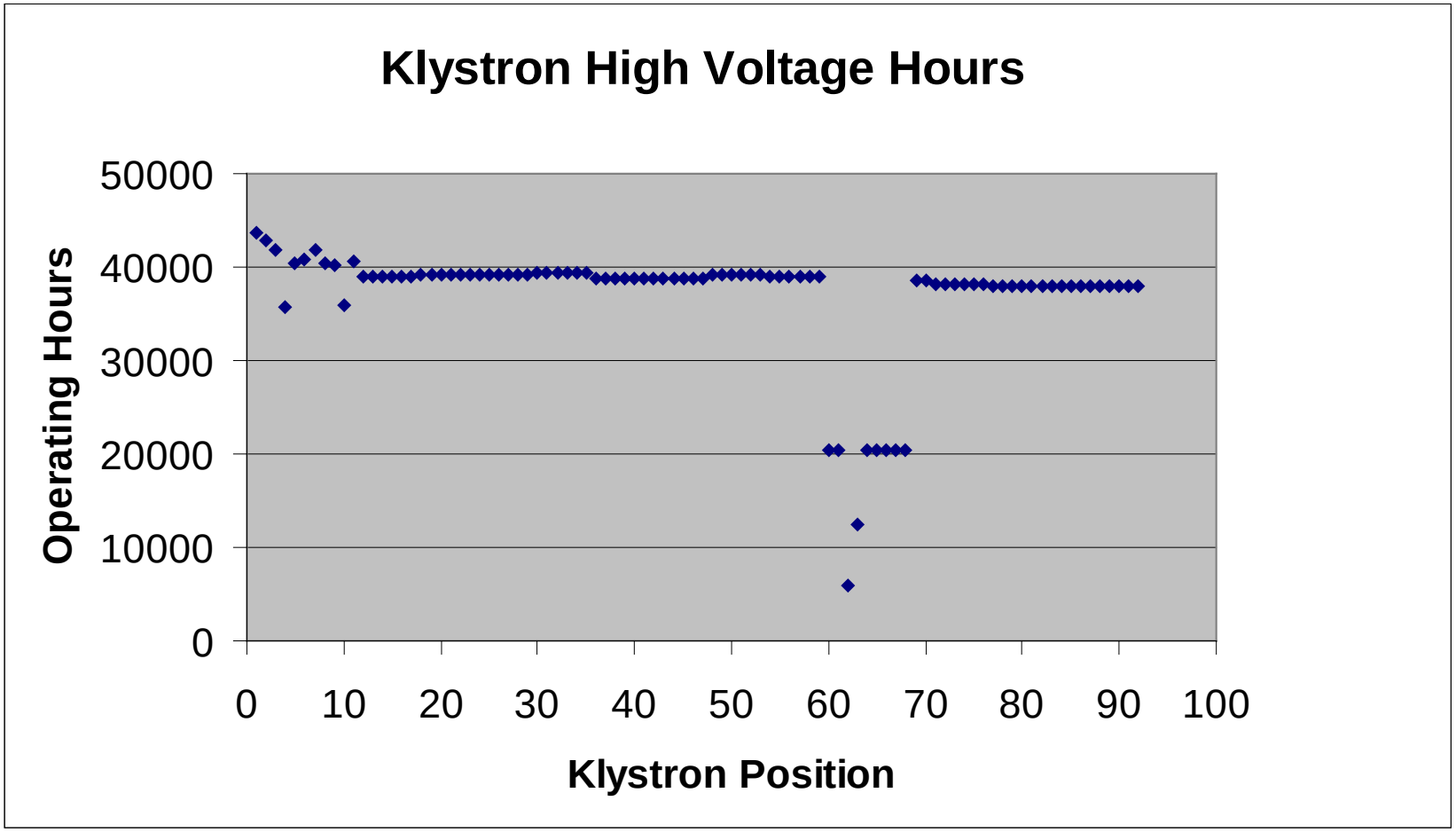


Full Accelerator Simulation Results

- Used exponential distributions (random failures)
- 86% - corrector power supplies, circulators, PPS modules, water valves, JT valves, etc.
- Change values for PS controllers and circulators from 50k to 100k
- 89% - RF feedthroughs, JT valves, etc.
- Change RF feedthrough from 100k to 4m (1 every 7 years), JT valves from 87k to 400k (1 every 5 years), etc
- 92% - Finally! But only for 1 seed

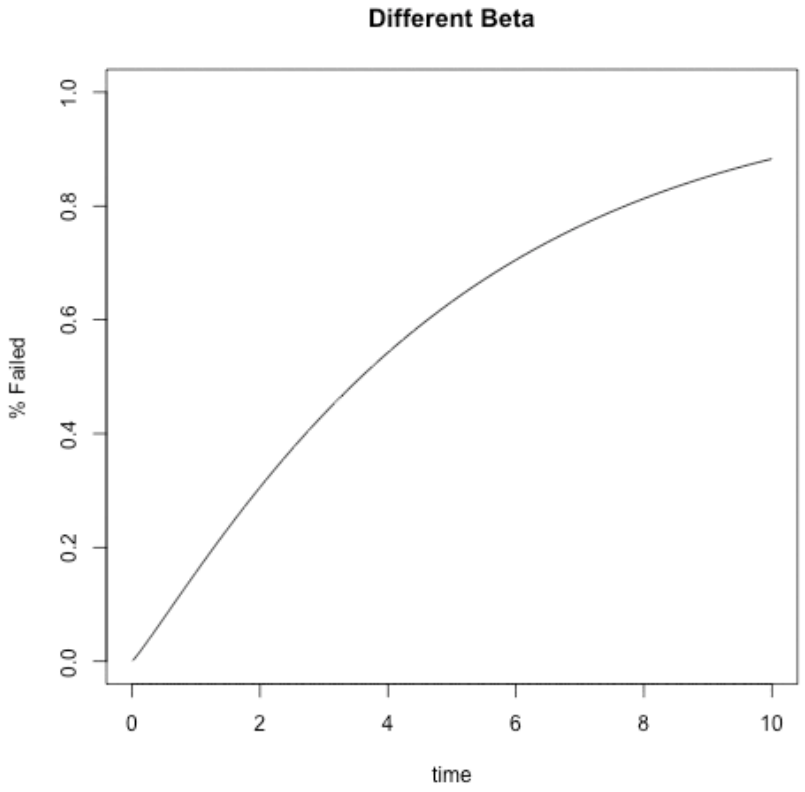
Klystron Spares Study

- 805 MHz, 550 (700) kW peak, 50 kW average power, 1.5 ms pulse length, 9% duty cycle
- M type cathode, 0.6-0.7 A/cm^2 density, manufacturer predicted lifetime > 100,000 hours
- 81 in service, 70 with ~40000 hours on filament
- How many spares to order and how quickly?

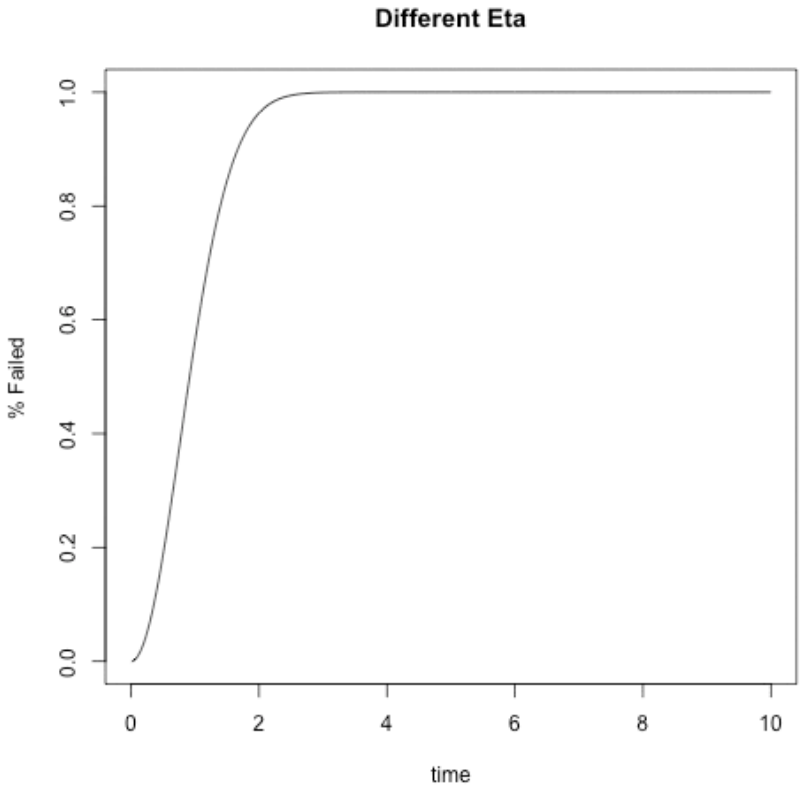

Klystron High Voltage Hours
Operating Hours
50000
40000
30000
20000
10000
0
0
10
20
30
40
50
60
70
80
90
100
Klystron Position

Weibull Distribution Parameters

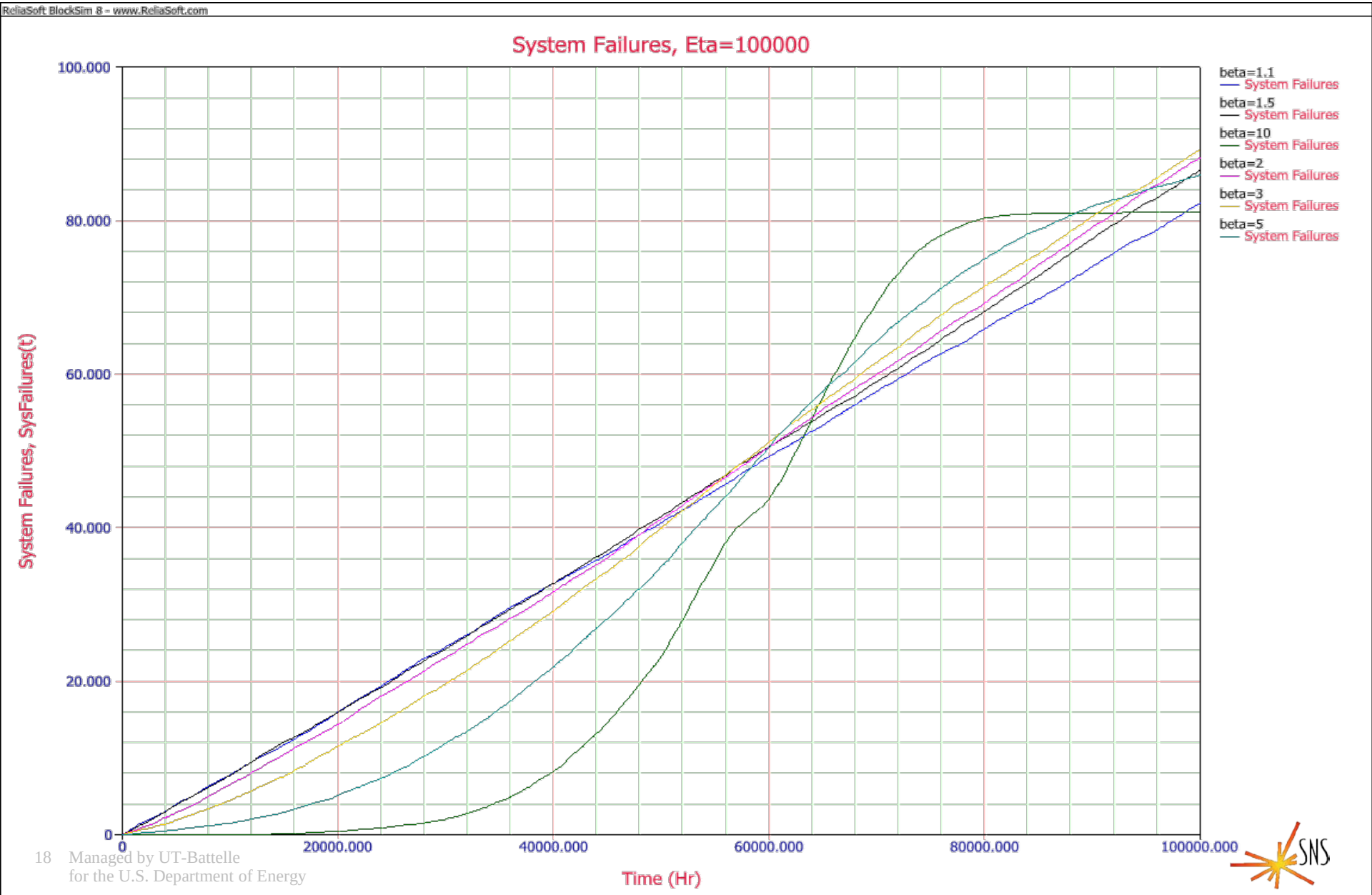
Beta – "Shape" Parameter



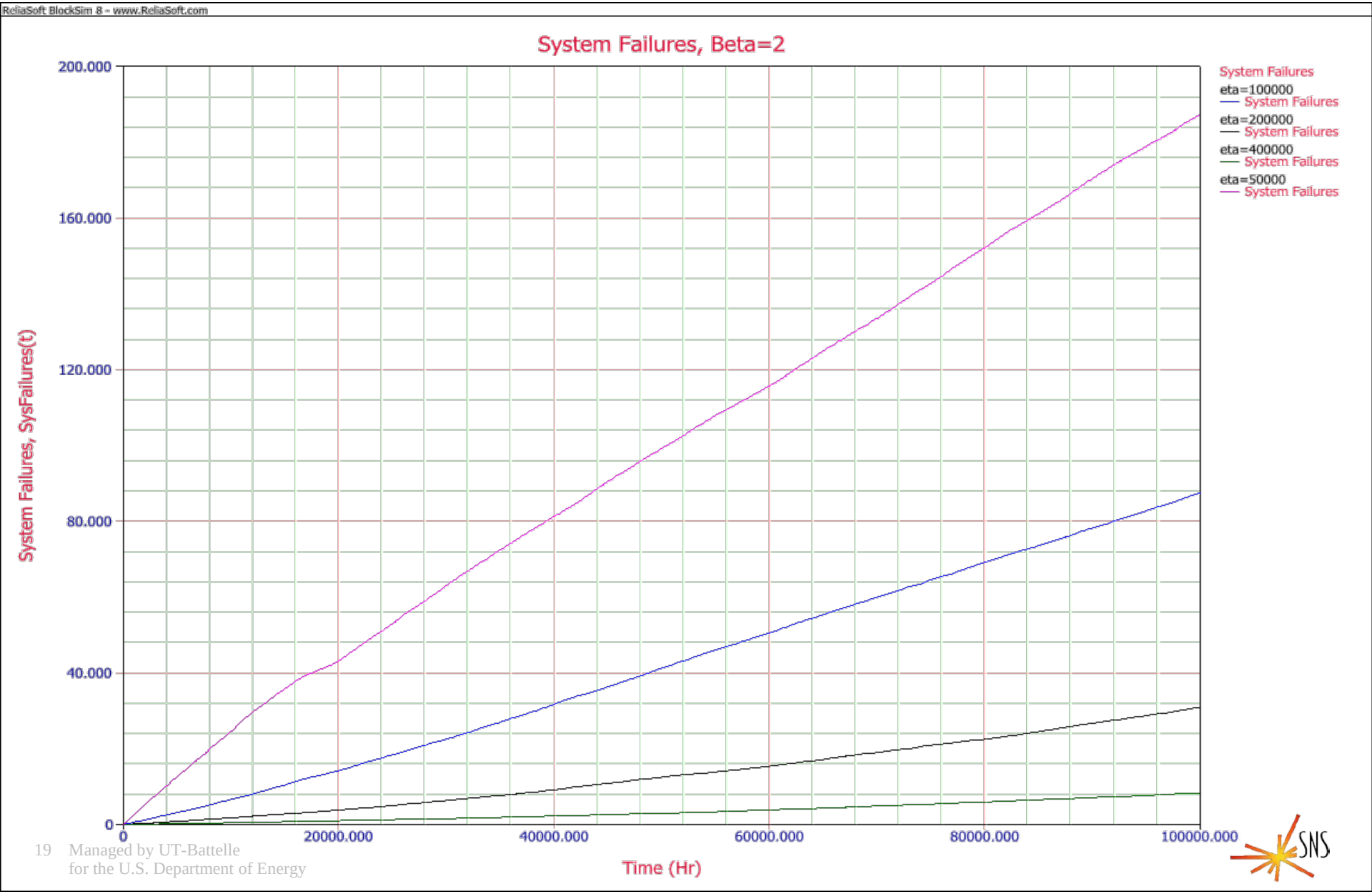
Eta – "Scale" Parameter



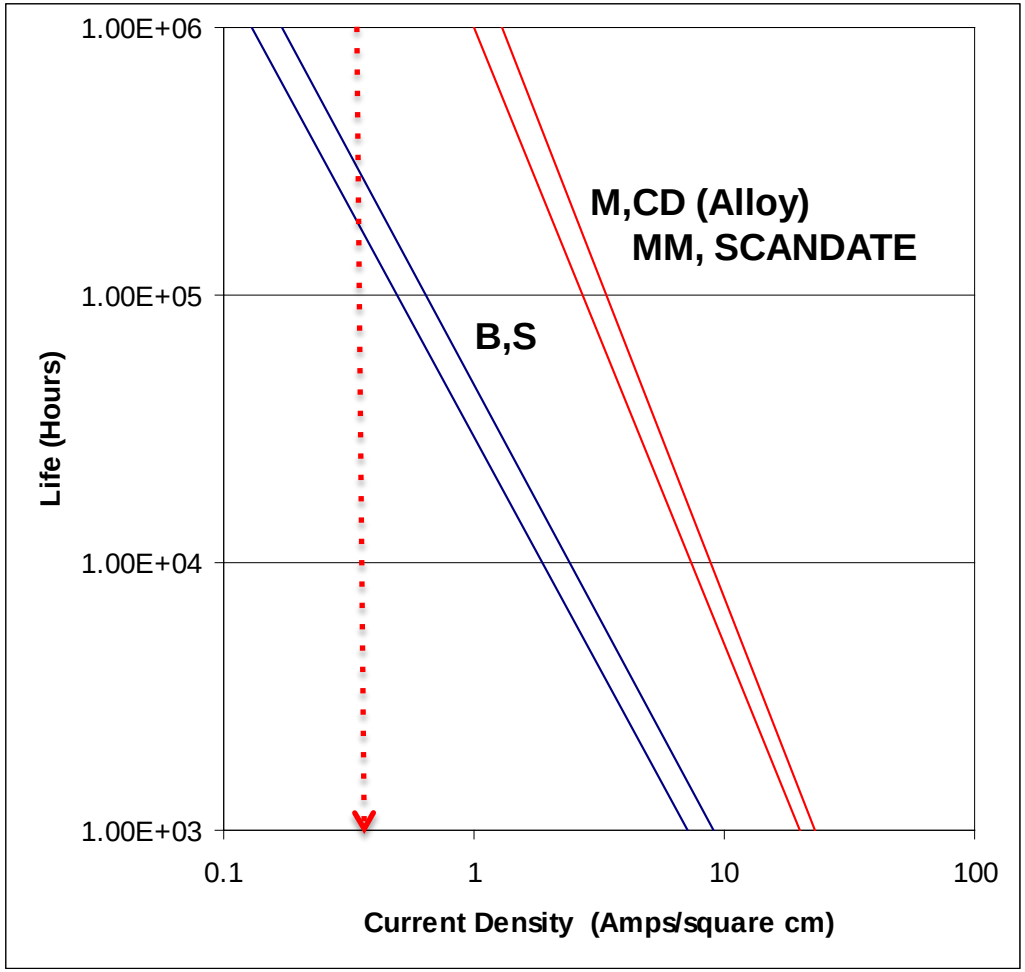
Klystron failures, different values of β



Klystron failures, different values of η



Cathode Life Time



- Dispenser Cathodes: The Current State of the Technology
  - L. R. Falce, Hughs Aircraft Company, Electron Dynamics Division, IEDM 83

Conclusions

- SNS is middle aged - how long will it last?
- We still can not predict the wear-out curve – until it begins!
  But we can model maintenance plans
- Cathode lifetime may not be a major concern
- Klystron spares can be ordered at a steady rate