Cloud Workload Analysis Study

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June 2011

Outline

- Goal of study
- Description of data
- Analysis methodology
- Workload characterization
- Over-commitment analysis
- Conclusions

Goal of study

- Help make recommendations in managing cloud provisioning so as to maximize resource usage while providing good quality-of-service,
- based on realistic workload,
- characterized through the analysis of vast amount of collected data,
- regarding cloud service request distributions, and resource usage patterns.

Description of data

- Source of data: TDW CCMP
- Number of months: 13
  - (May 25, 2010 to June 5, 2011)
- Number of data centers: 7
- Number of PMs: 463
  - Datacenters range from 138 hosts in Raleigh to 15 hosts in Japan
- Types of VM requests: 9
- Number of VMs: 28,137

PM Counts

Datacenter	DB Analysis Count	Actual Count
All	463	646
Canada	111	141
Germany	113	114
Japan	15	81
Singapore	17	17
US-Boulder	69	107
US-Raleigh	138	138

Database Source

- Table 1: K43_Virtual_Machine

CPU Usage records

36,998,298 rows

Timestamp	Node	UUID	VM_Name	CPU_Count	CPU_Time	Memory_Max
0 min						
15 min						
30 min						

- Table 2: K43_Volume

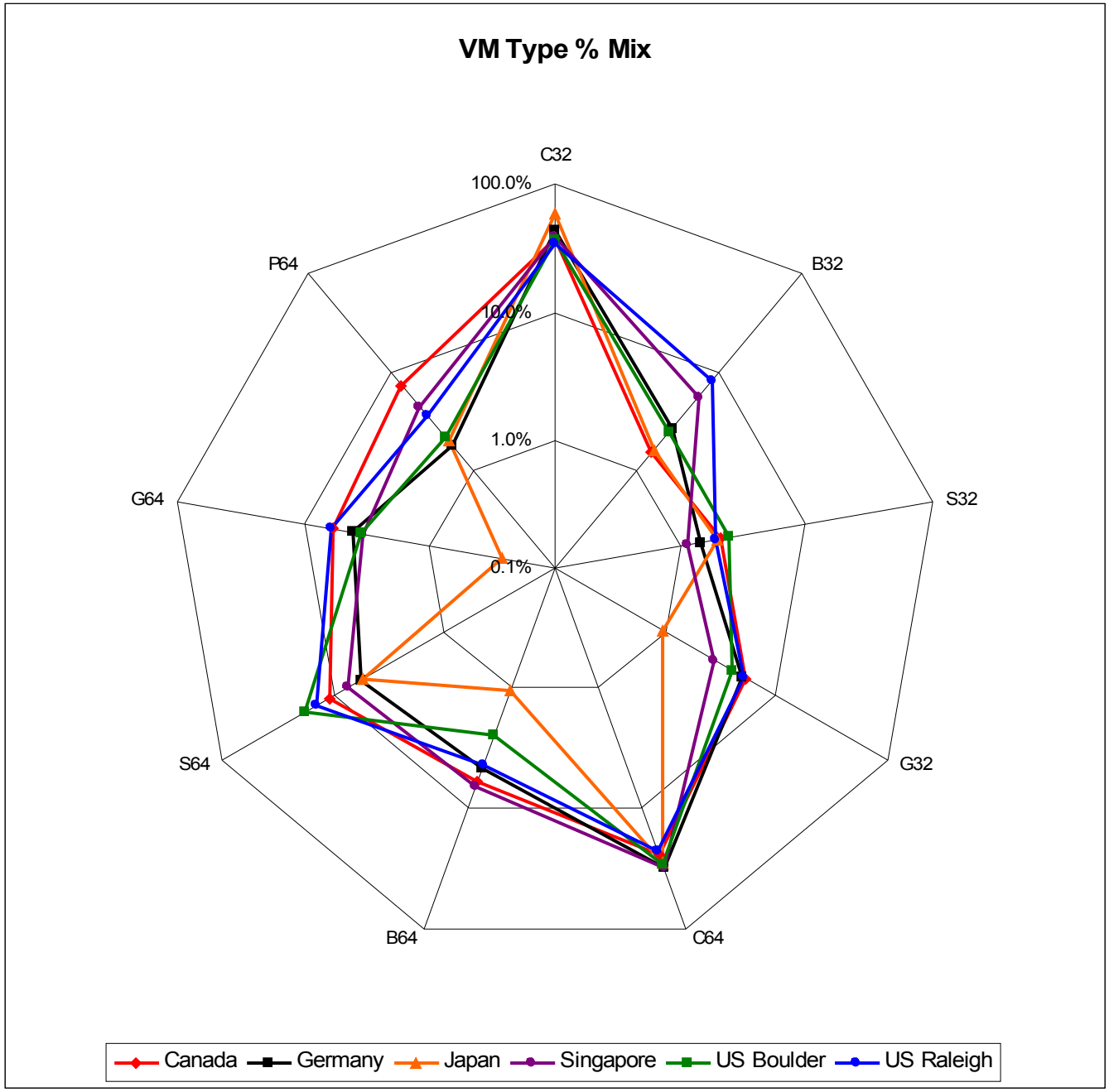
Disk Usage records

48,066,258 rows

Timestamp	Node	Volume_Name	Path	Capacity	Allocation
0 min					
15 min					
30 min					

Identifying VM Types

- 9 VM types
  - Copper32/64, Bronze32/64, Silver32/64, Gold32/64, Platinum64
- From CPU table
  - Using CPU_Count and Memory_Max
  - Gold32, Silver64, Gold64, Platinum64
- From CPU table and storage table
  - CPU = 1, Memory = 2G, with storage Capacity from Storage table
    - Copper32, Bronze32
  - CPU = 2, Memory = 4G, with storage Capacity from Storage table
    - Silver32, Copper64, Bronze64



Note: Log scale used.

Defining Storage Capacities

- Paths considered
  - Image files
    - e.g. /var/lib/libvirt/images/vhost1390/vhost1390.img; /var/lib/libvirt/images/vhost0593/vhost0593_DataDisk4.img
- Paths ignored
  - ISO
  - Floppy
  - Swap
  - UserDisk
    - e.g. /storage/prod/persistent/userdisks/iU4roWdBRoiWHCEFT@1l7

Data Inconsistencies

- Scrubbing details
  - UUID same PM different
- Gaps in the data

gap size	numRecords	percentage
g > 15 min	71,069	0.2294 %
g > 1 hr	2,513	0.0081 %
1 hr < g < 1 day	1,041	0.0034 %
1 day < g < 30 days	1,362	0.0044 %
g > 30 days	110	0.0004 %

Limitations

- Lack of memory usage records
- No distinction between internal and customer VMs
- No correction for failed/rejected requests
- 20% of VMs can not be classified due to missing storage data (Analysis includes 80% of all VMs)
- Swap file growth ignored

Analysis methodology

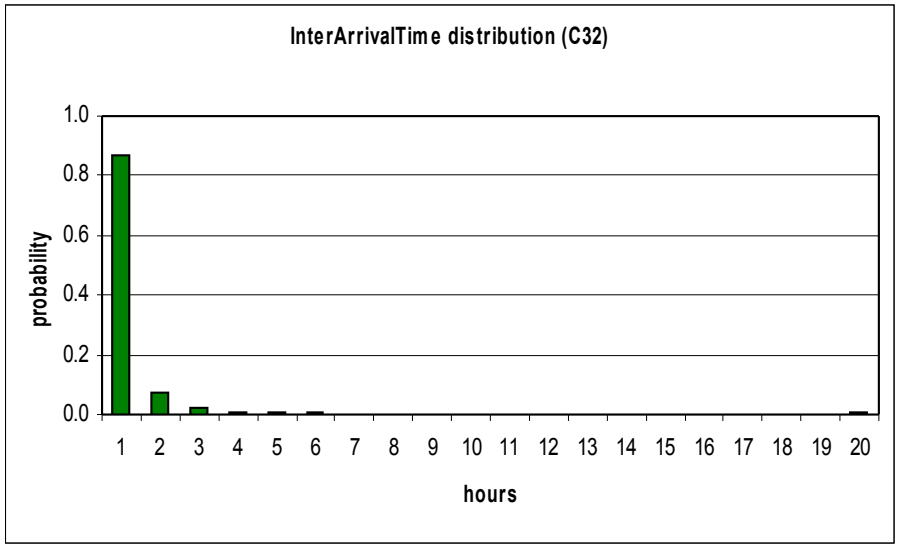
- Retrieve data via DB2 queries to database of logs
- Clean anomalies of records from database
- Develop workload characterization models based on visual observation of data
- Analyze data and estimate model parameters
- Parameterize models to drive cloud simulator and conduct further performance analysis

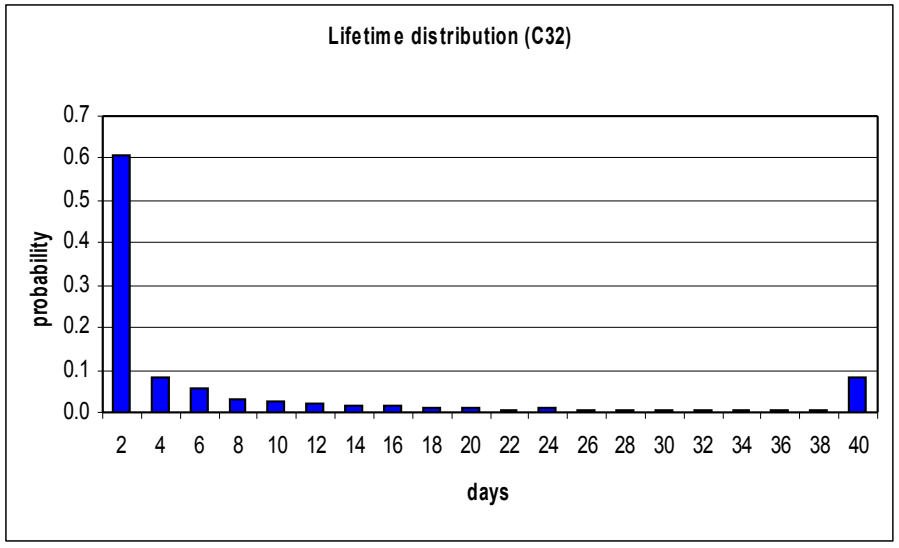
Workload characterization

- For each VM type
  - Request inter-arrival time distribution
  - VM lifetime distribution
  - Resource usage pattern
    - CPU
    - Storage
- VM types Mix
- Per Datacenter Analysis

Arrival and Lifetime Analysis

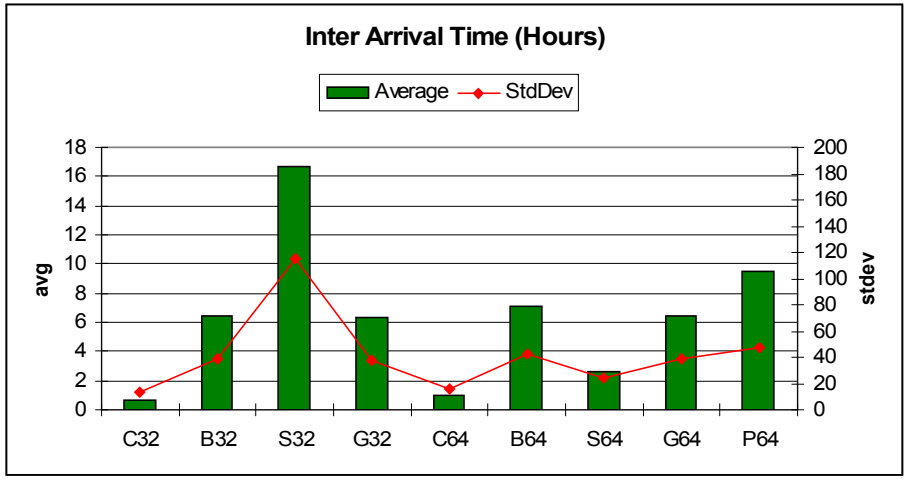
Characterization of VM inter-arrival and lifetime distributions

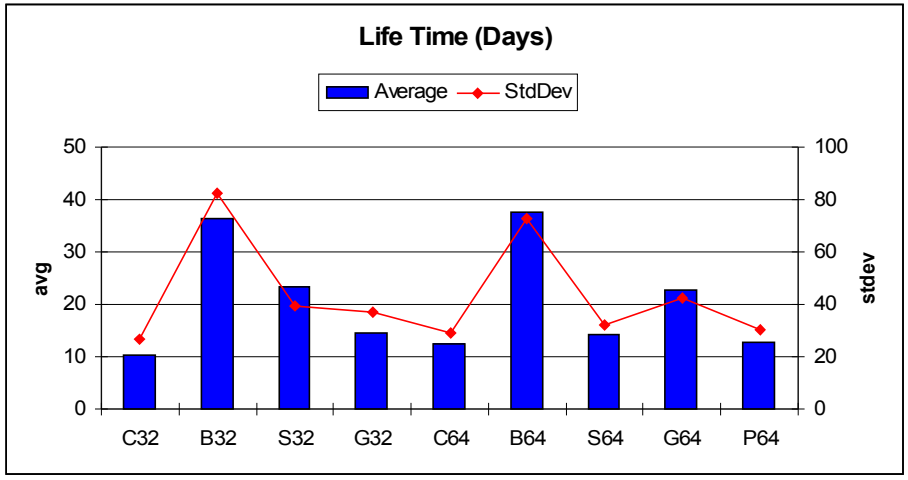


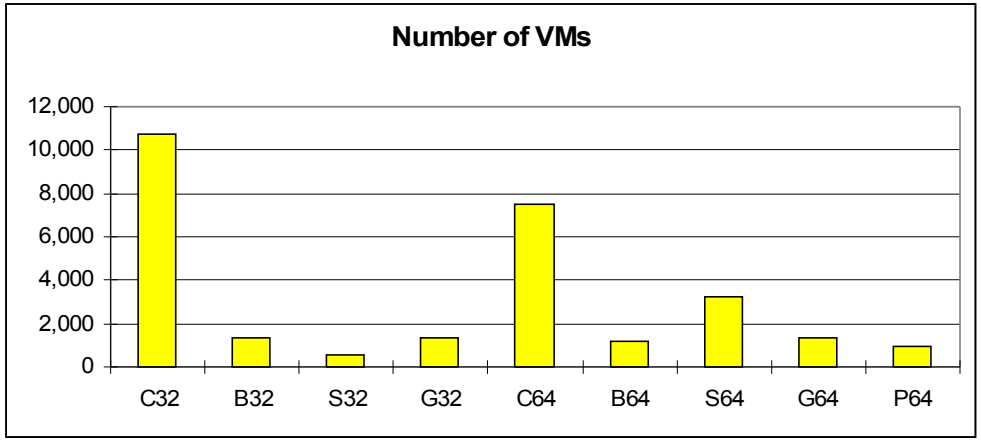


- No dependence found in subsequent values
- Exponential distribution assumption is naïve
  - Underestimates VM request rejections (by about 10%)
  - Overestimates CPU usage (by about 10%)
- Gamma distribution is a very good fit
  - Large variation results in a small shape parameter (about 0.2)

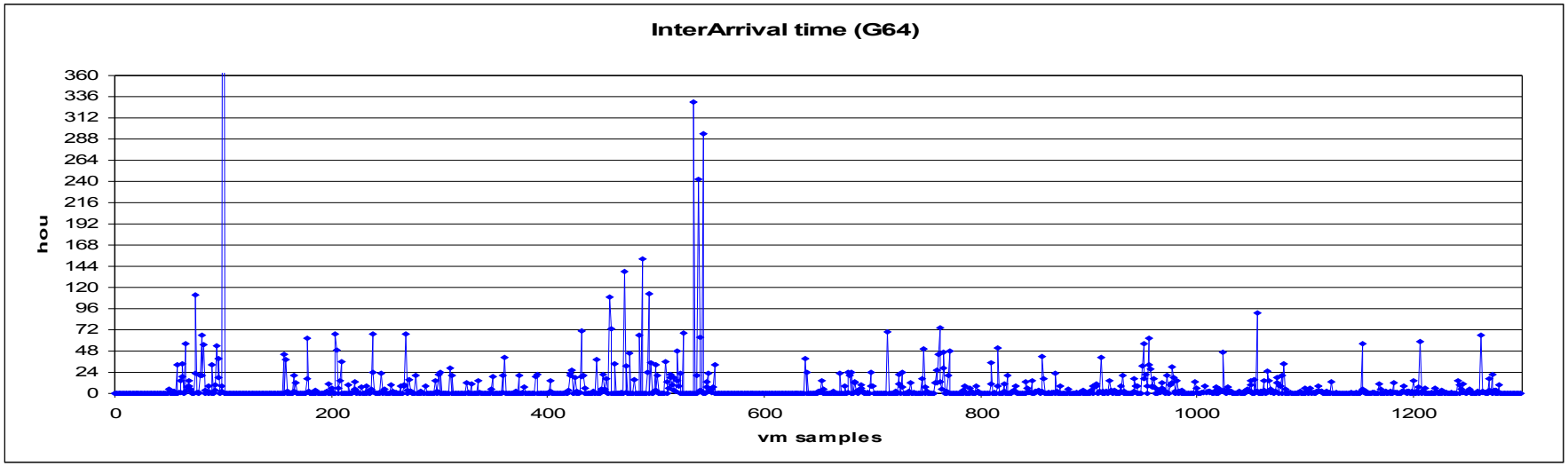
	C32	B32	S32	G32	C64	B64	S64	G64	P64
Interarrival Time (hrs)									
Average	0.66	6.41	16.69	6.37	0.99	7.05	2.64	6.39	9.53
StdDev	13.31	38.21	115.76	37.37	15.48	42.73	23.68	39.00	47.06
LifeTime (days)									
Average	10.34	36.49	23.21	14.57	12.45	37.67	14.29	22.67	12.75
StdDev	26.65	82.59	39.61	36.96	29.01	72.83	32.10	42.43	30.56
Number VMs	10,749	1,319	523	1,352	7,507	1,207	3,204	1,354	922







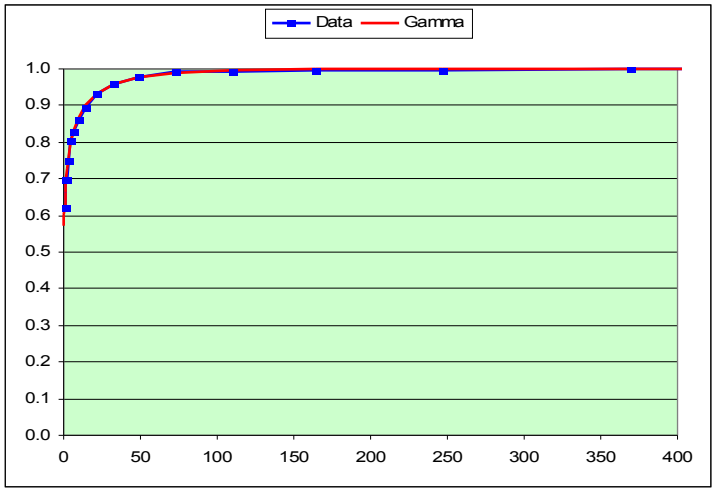
Modeling VM request inter-arrival times



Gamma Distribution

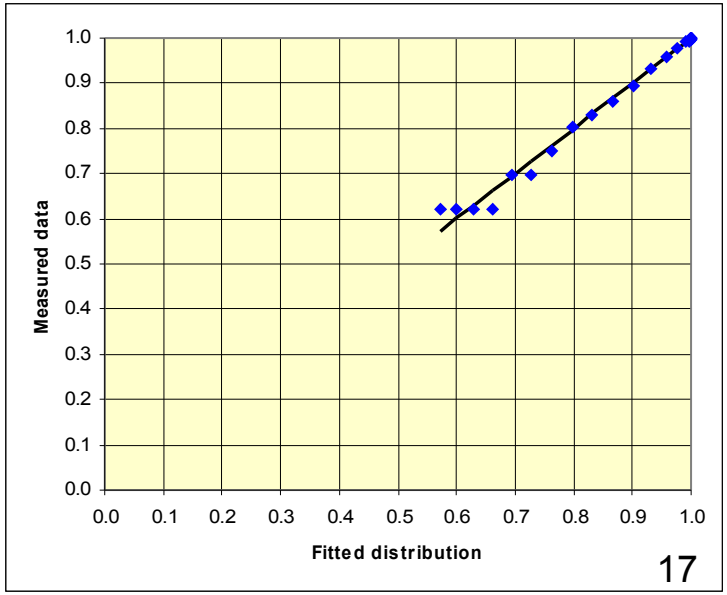
	(shape)	(scale)
parms	alpha	beta
	0.1200	42.0452

	Data	Fit	relDiff
avg	6.39	5.05	-21.02%
stdev	39.02	14.57	-62.67%

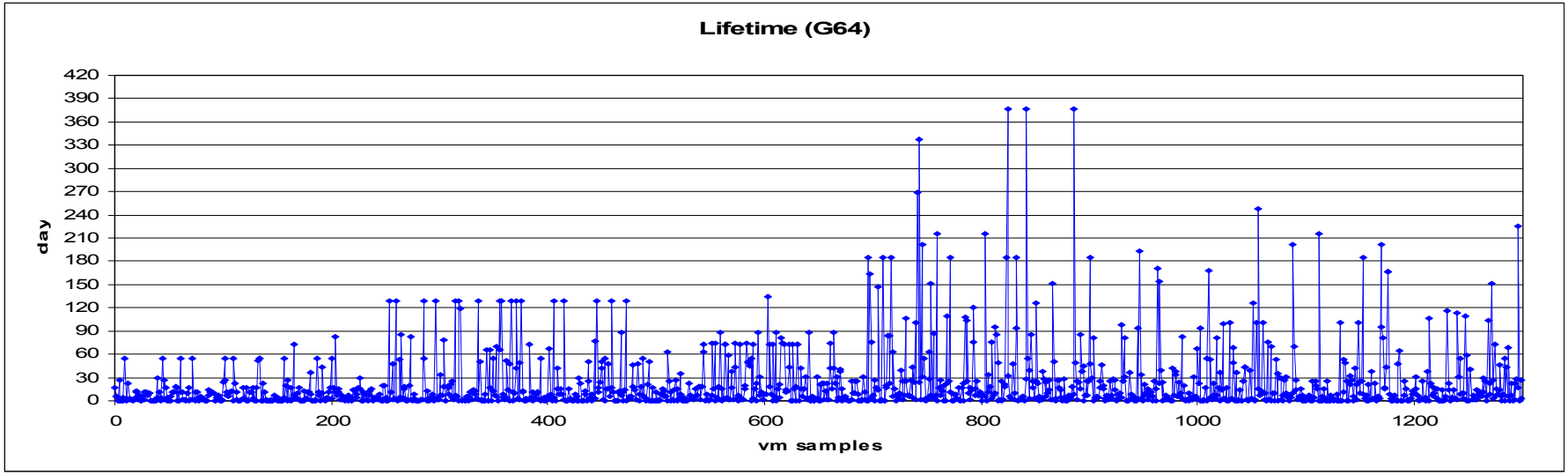


	(days)
avg	6.39
stdev	39.02
cov	6.11
median	0.00
skew	25.65
min	0.00
max	1260.00
count	1,352

MSE = 0.0764



Modeling VM life times



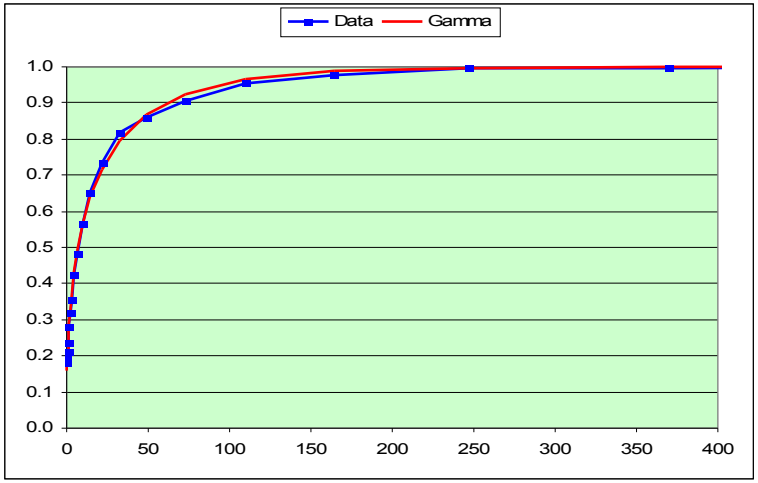
Gamma Distribution

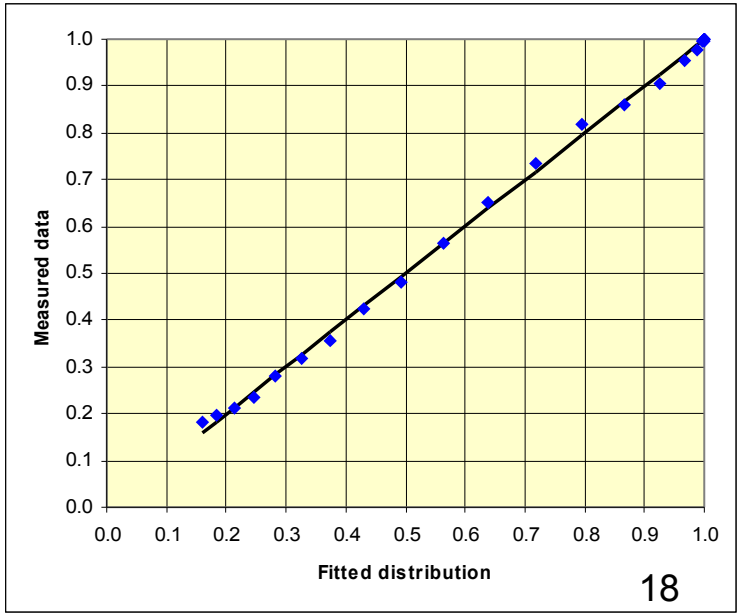
	(shape)	(scale)
parms	alpha	beta
	0.3580	58.7133

	Data	Fit	relDiff
avg	22.67	21.02	-7.28%
stdev	42.44	35.13	-17.24%

	(days)
avg	22.67
stdev	42.44
cov	1.87
median	6.99
skew	3.78
min	0.01
max	376.16
count	1,353

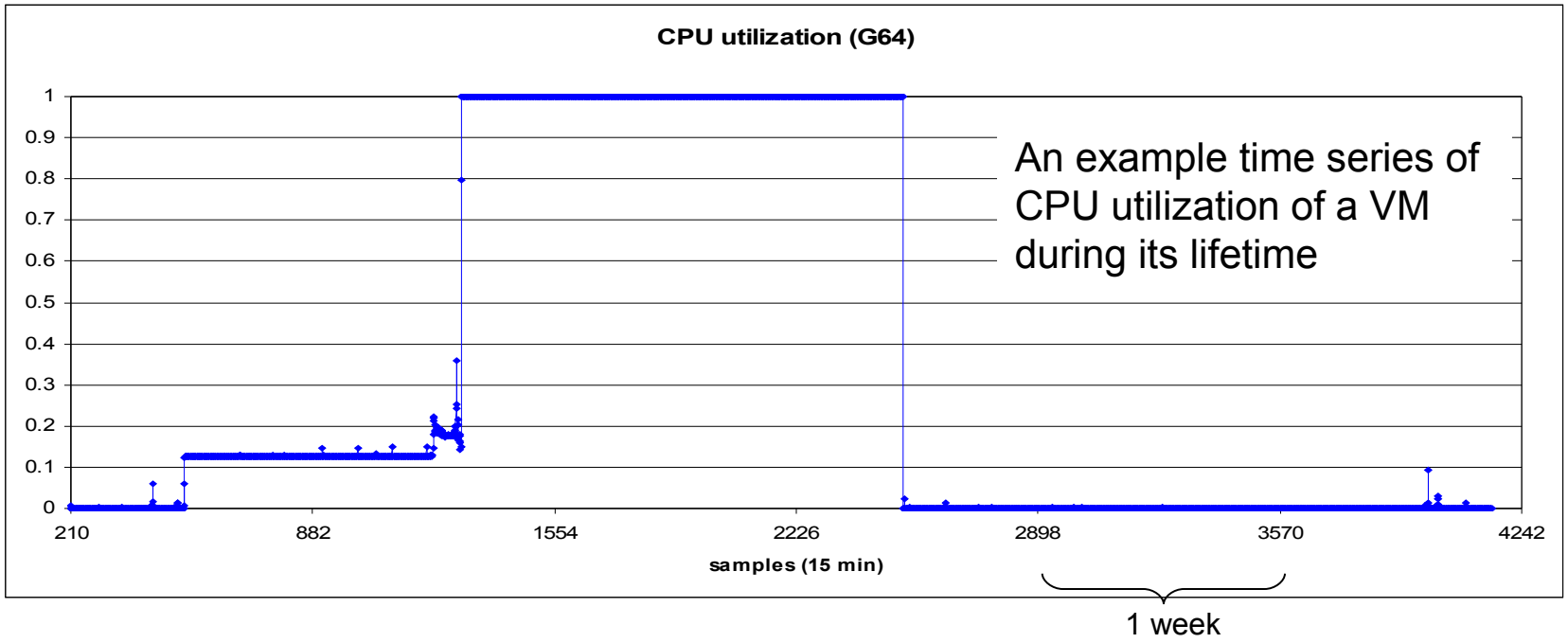
MSE = 0.0569



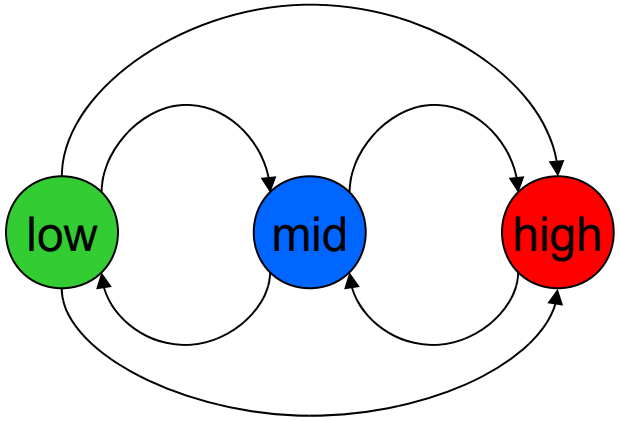


CPU Usage Analysis

Modeling VM CPU usage



CPU usage model

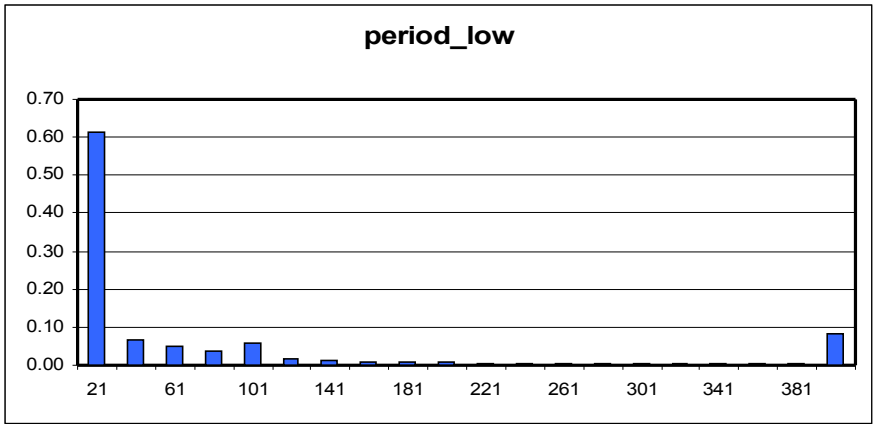


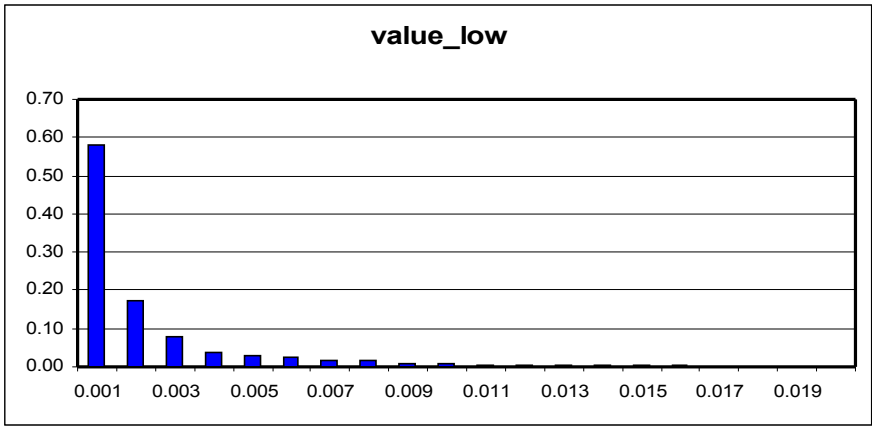
Model parameters:

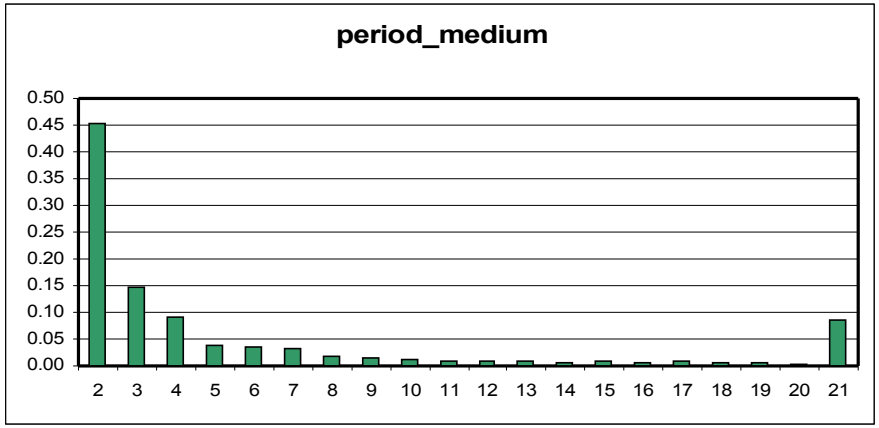
For each state
- residence time period (avg, stdev)
- utilization (avg, stdev)

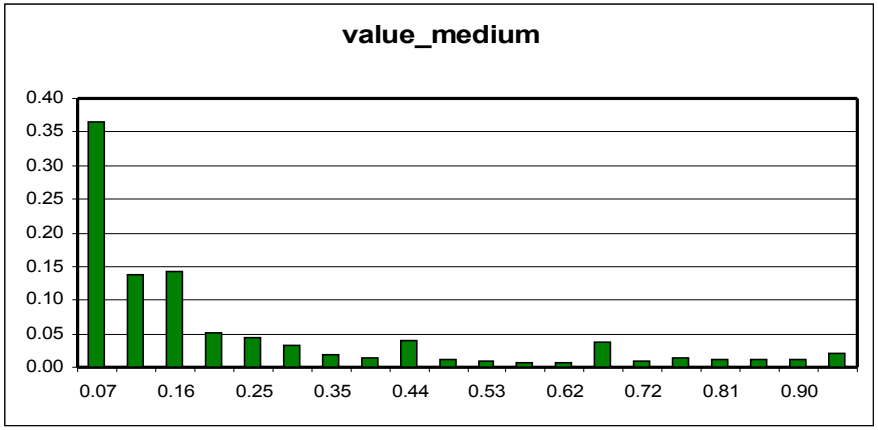
Steady state probabilities

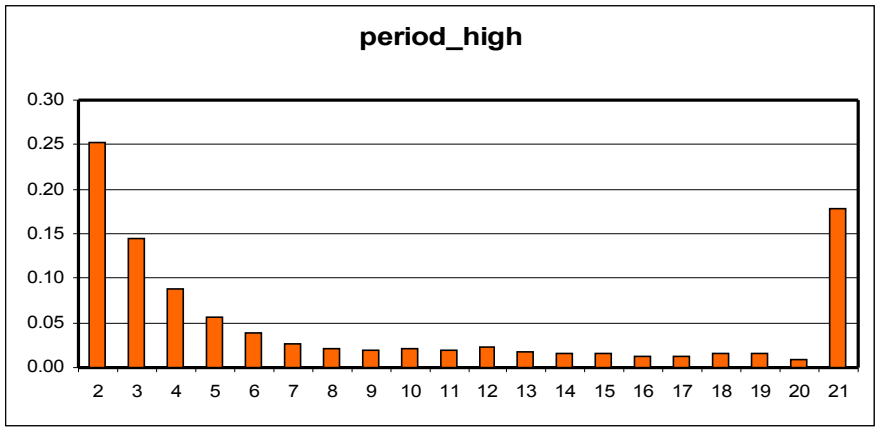
Gold 64

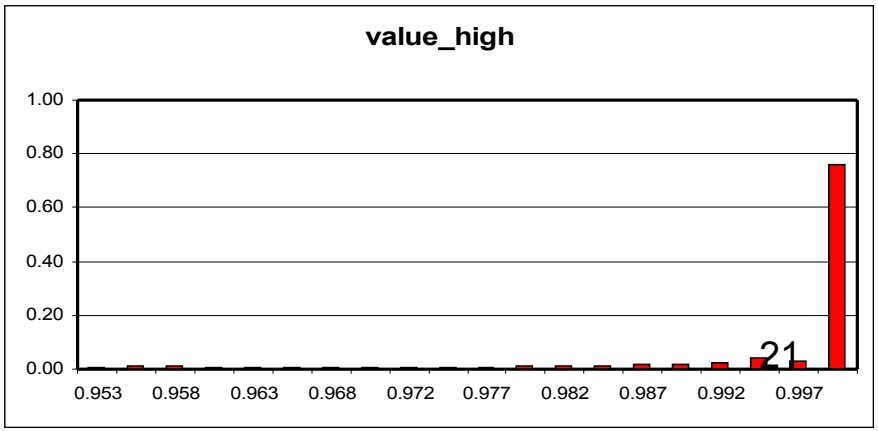

period_low
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
21
61
101
141
181
221
261
301
341
381


value_low
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
0.001
0.003
0.005
0.007
0.009
0.011
0.013
0.015
0.017
0.019


period_medium
0.50
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21

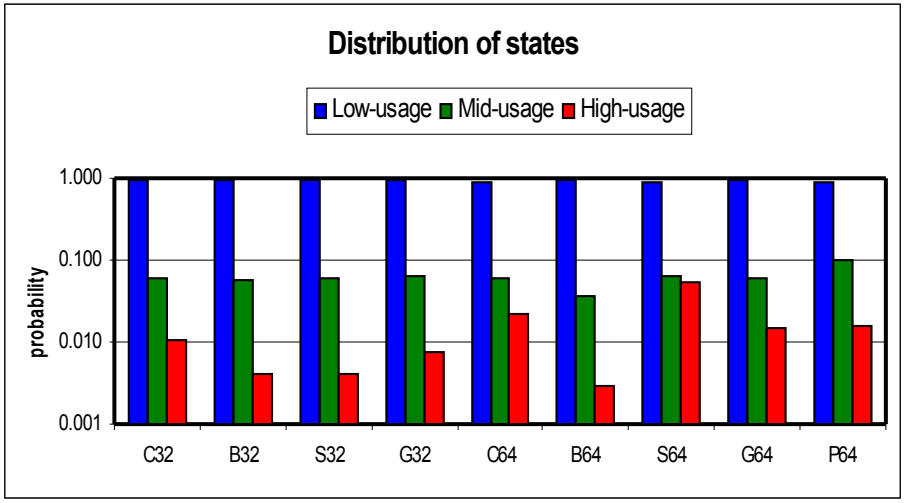

value_medium
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
0.07
0.16
0.25
0.35
0.44
0.53
0.62
0.72
0.81
0.90

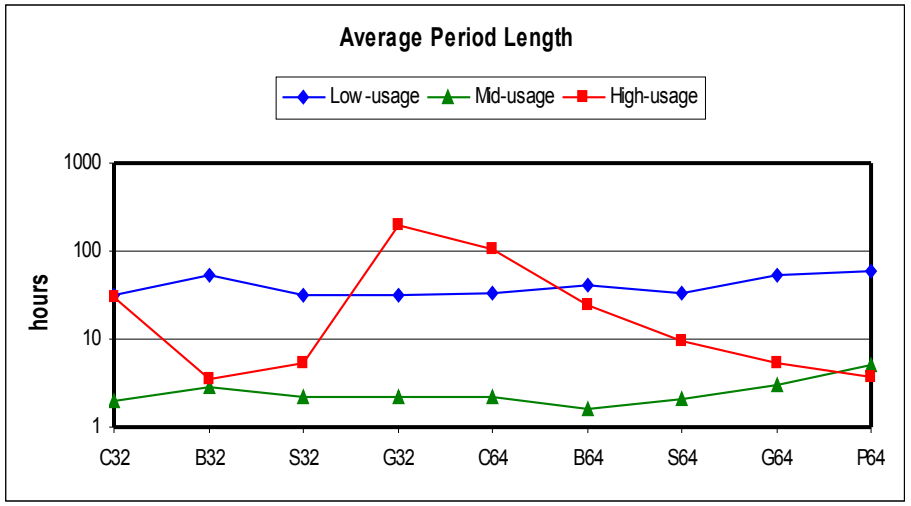

period_high
0.30
0.25
0.20
0.15
0.10
0.05
0.00
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21

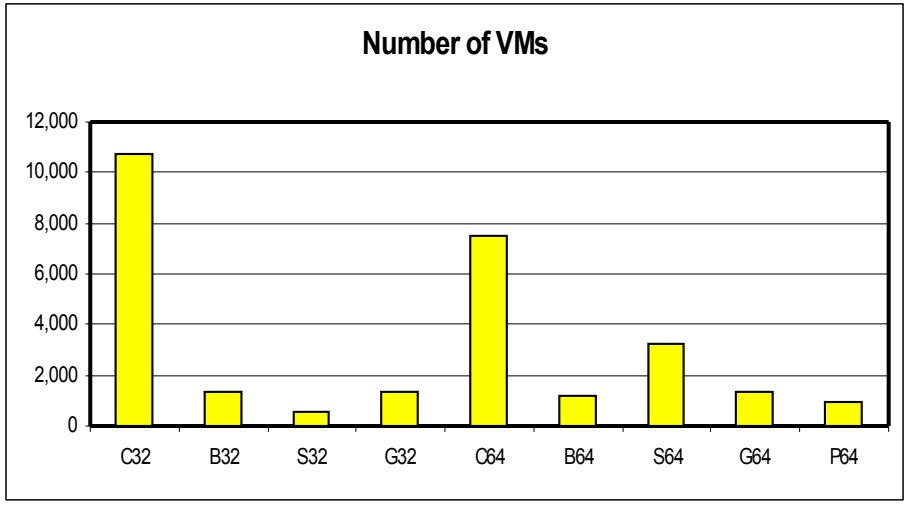

value_high
1.00
0.80
0.60
0.40
0.20
0.00
21
0.953
0.958
0.963
0.968
0.972
0.977
0.982
0.987
0.992
0.997

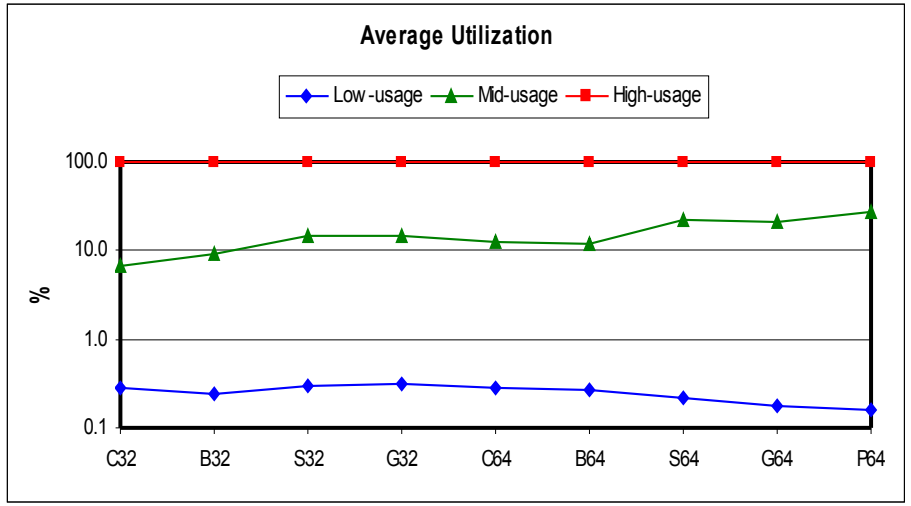
CPU usage analysis

All Datacenters









CPU usage analysis

All Datacenters

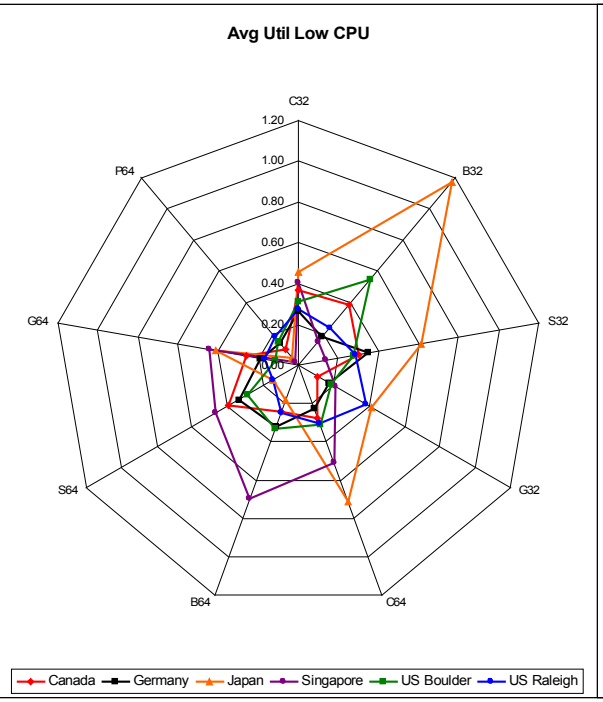
	C32	B32	S32	G32	C64	B64	S64	G64	P64
Low-usage									
(0% - 2%)									
Probability	0.930	0.939	0.936	0.929	0.918	0.961	0.881	0.925	0.887
Period (hrs)									
Average	31.247	52.595	32.194	31.993	33.963	41.046	32.707	52.127	58.028
StdDev	157.021	376.646	166.590	114.848	147.975	262.384	166.067	282.032	302.205
Utilization (%)									
Average	0.289	0.240	0.302	0.319	0.285	0.263	0.219	0.175	0.164
StdDev	0.403	0.405	0.335	0.386	0.386	0.391	0.322	0.275	0.282
Mid-usage									
(2% - 95%)									
Probability	0.060	0.057	0.060	0.064	0.061	0.036	0.064	0.060	0.098
Period (hrs)									
Average	1.962	2.858	2.180	2.141	2.224	1.592	2.048	3.019	4.988
StdDev	30.963	52.107	25.039	29.469	37.615	22.050	32.231	30.002	42.858
Utilization(%)									
Average	6.809	9.147	14.827	14.881	12.258	11.714	22.099	20.901	26.629
StdDev	10.193	14.413	19.413	15.913	17.575	16.915	25.144	24.015	27.693
High-usage									
(95% - 100%)									
Probability	0.010	0.004	0.004	0.008	0.022	0.003	0.055	0.015	0.016
Period (hrs)									
Average	30.386	3.585	5.338	201.676	104.374	24.987	9.557	5.309	3.780
StdDev	149.611	22.321	48.780	250.091	359.136	83.121	29.780	27.087	13.988
Utilization(%)									
Average	99.966	99.784	99.810	99.884	99.874	99.822	99.886	99.503	98.833
StdDev	0.290	0.656	0.830	0.237	0.489	0.472	0.460	1.079	1.066
numCores	1	1	2	4	2	2	4	8	16
numVmProcessed	10749	1318	522	1352	7507	1207	3204	1354	922

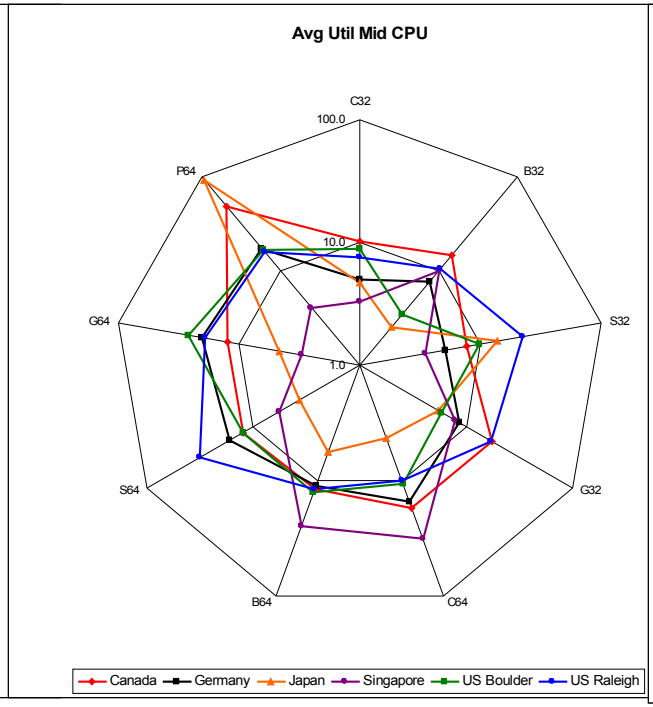
CPU Usage Analysis

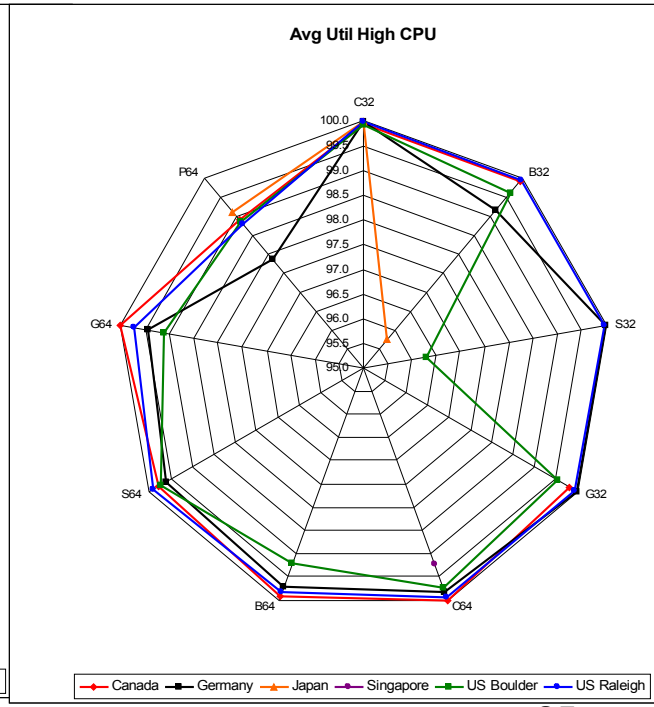
(per Datacenter)

CPU Usage per Datacenter

- No significant difference observed when statistical samples are sufficient.

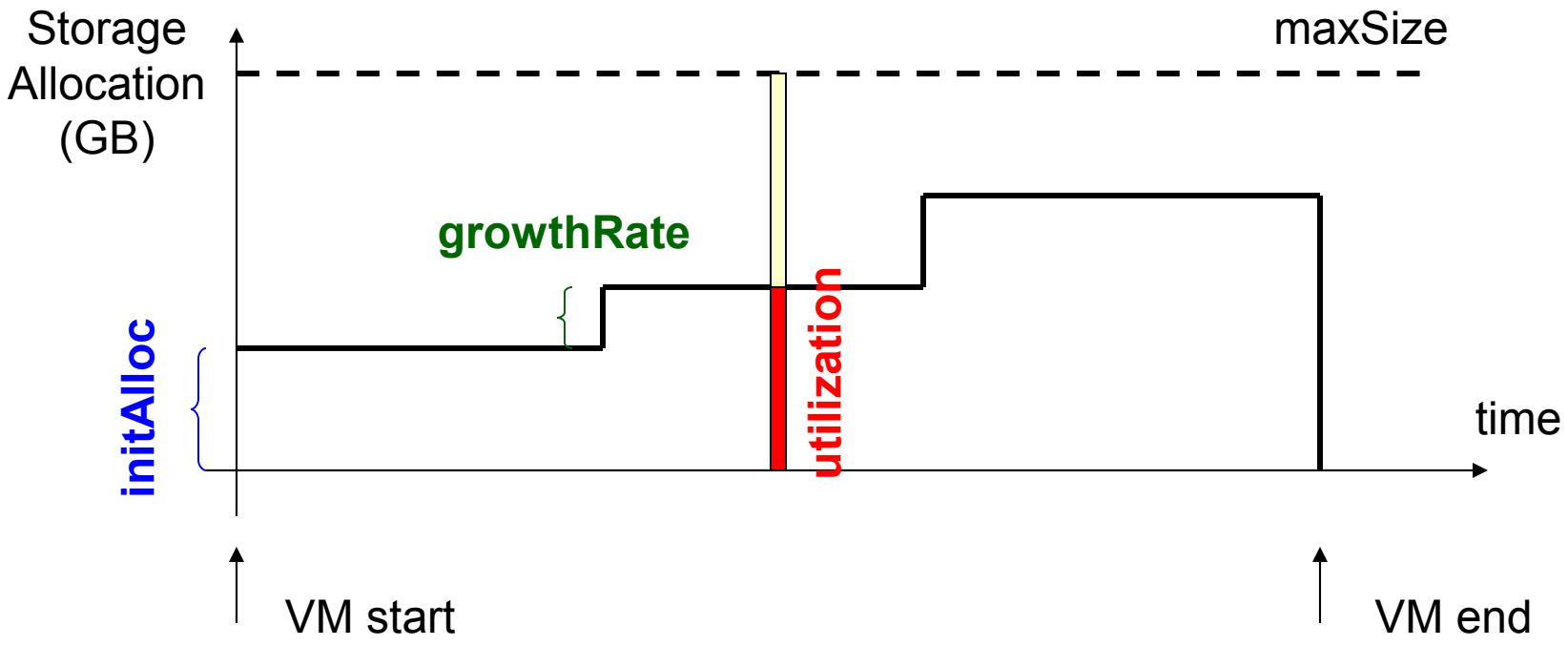






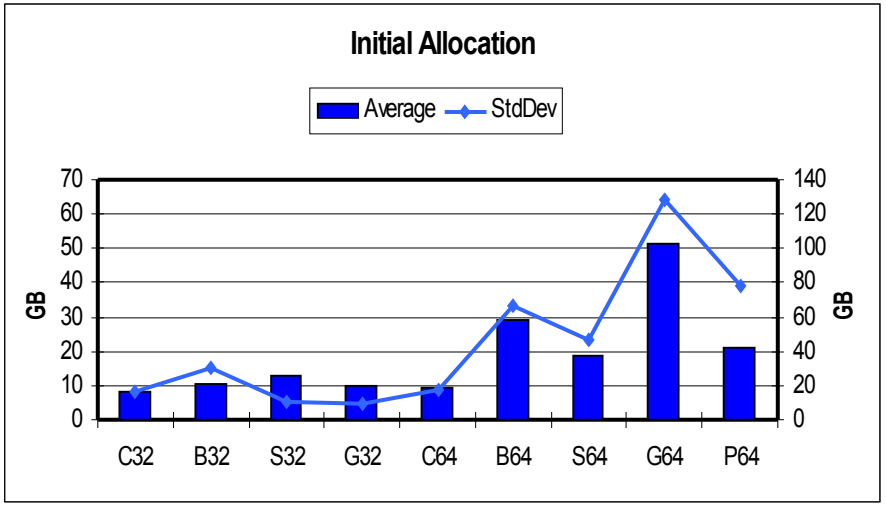
Storage Usage Analysis

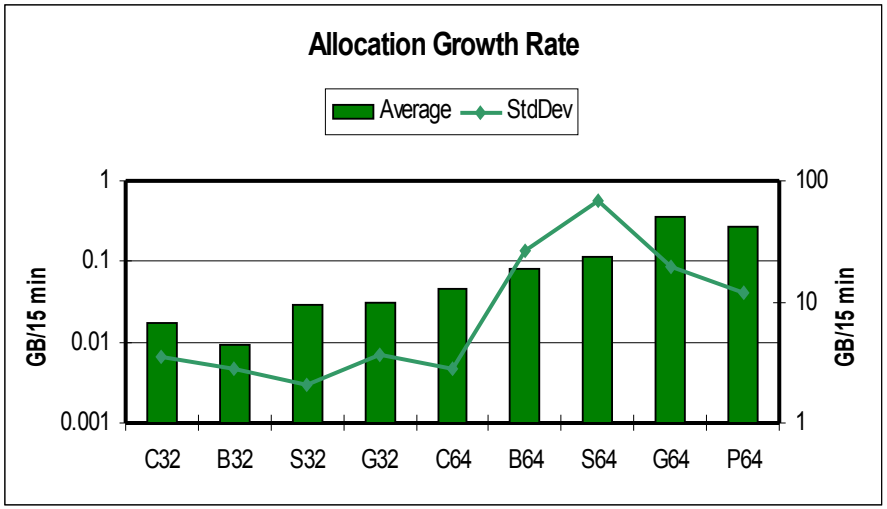
Modeling VM Storage Usage

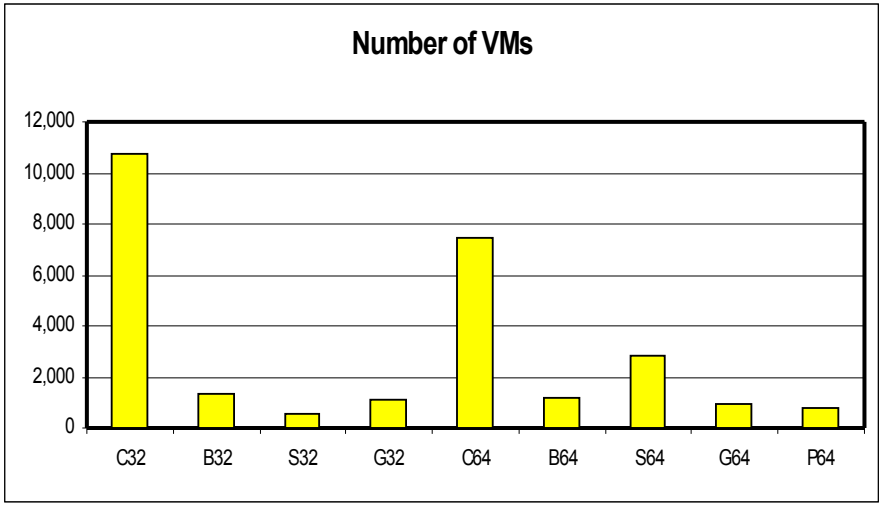


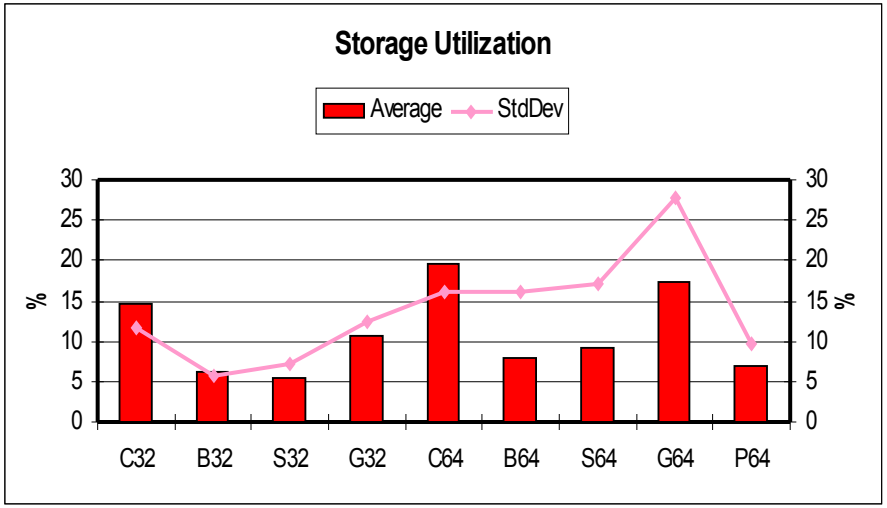
Storage usage analysis

All Datacenters









Storage usage analysis

All Datacenters

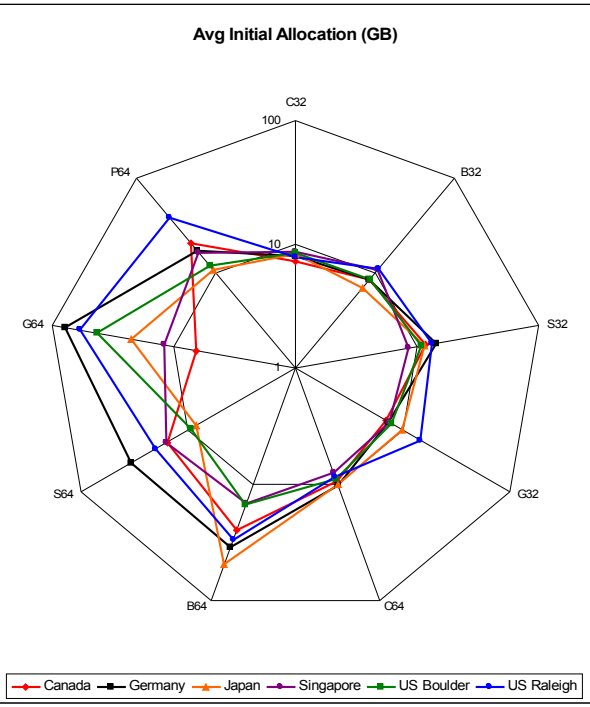
	C32	B32	S32	G32	C64	B64	S64	G64	P64
initAlloc (GB)									
Average	8.0	10.6	12.7	9.7	9.4	29.4	19.0	51.3	20.9
StdDev	16.4	30.6	10.6	9.7	17.1	66.1	46.7	128.1	77.8
growthRate (GB / 15 min)									
Average	0.02	0.01	0.03	0.03	0.04	0.08	0.12	0.37	0.27
StdDev	3.52	2.77	2.10	3.63	2.78	26.42	68.90	19.77	12.01
diskUtilization (%)									
Average	14.73	6.27	5.41	10.74	19.47	7.84	9.19	17.44	6.82
StdDev	11.71	5.67	7.25	12.41	16.08	16.12	17.19	27.72	9.58
Min	0.09	0.37	0.31	0.20	0.19	0.25	0.16	0.23	0.12
Max	99.80	95.77	97.15	97.42	99.42	99.62	99.31	100.00	97.82
storageSize (GB)	60	175	350	350	60	850	1,024	1,024	2,048
numVmProcessed	10715	1317	520	1100	7475	1205	2847	925	809

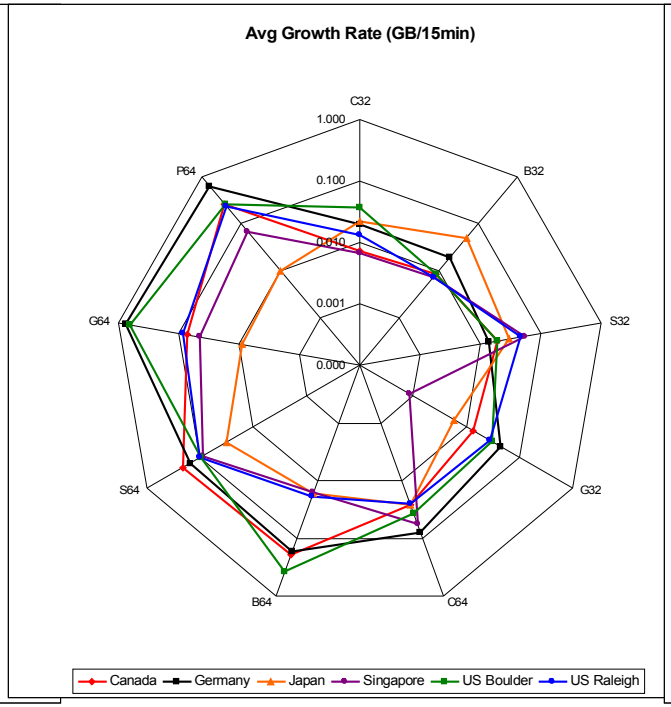
Storage Usage Analysis

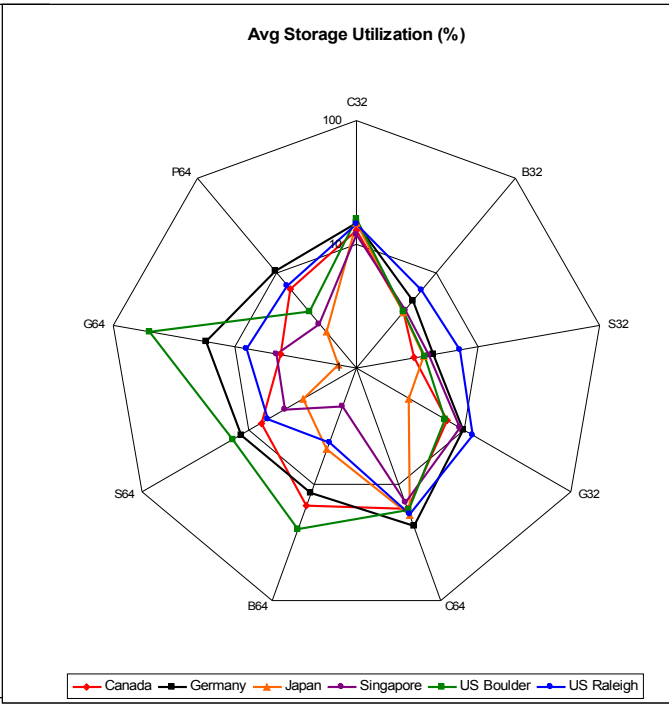
(per Datacenter)

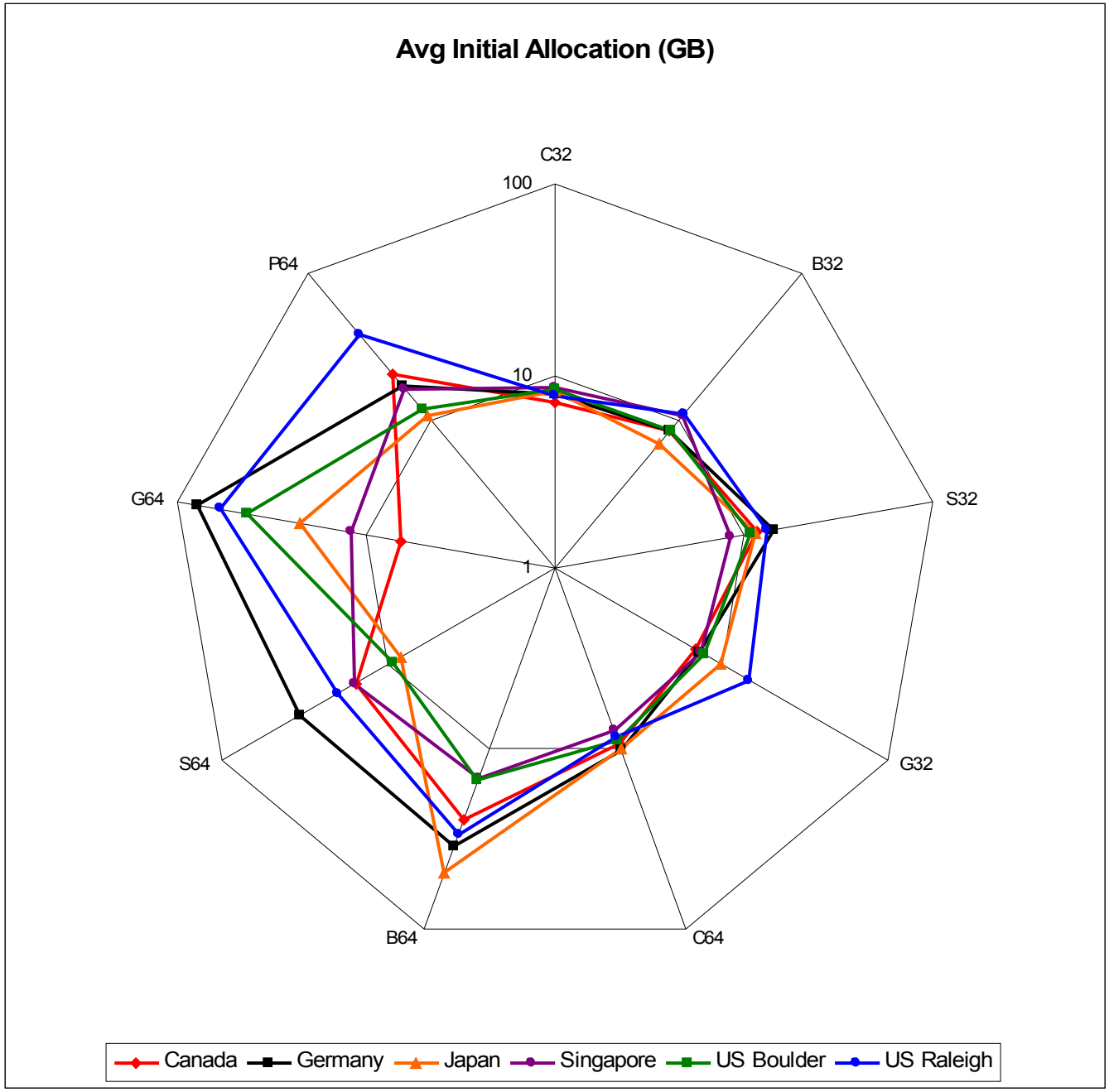
Storage Usage per Datacenter

- Larger VMs tend to use more disk.
- Growth rate variance is within 1G.

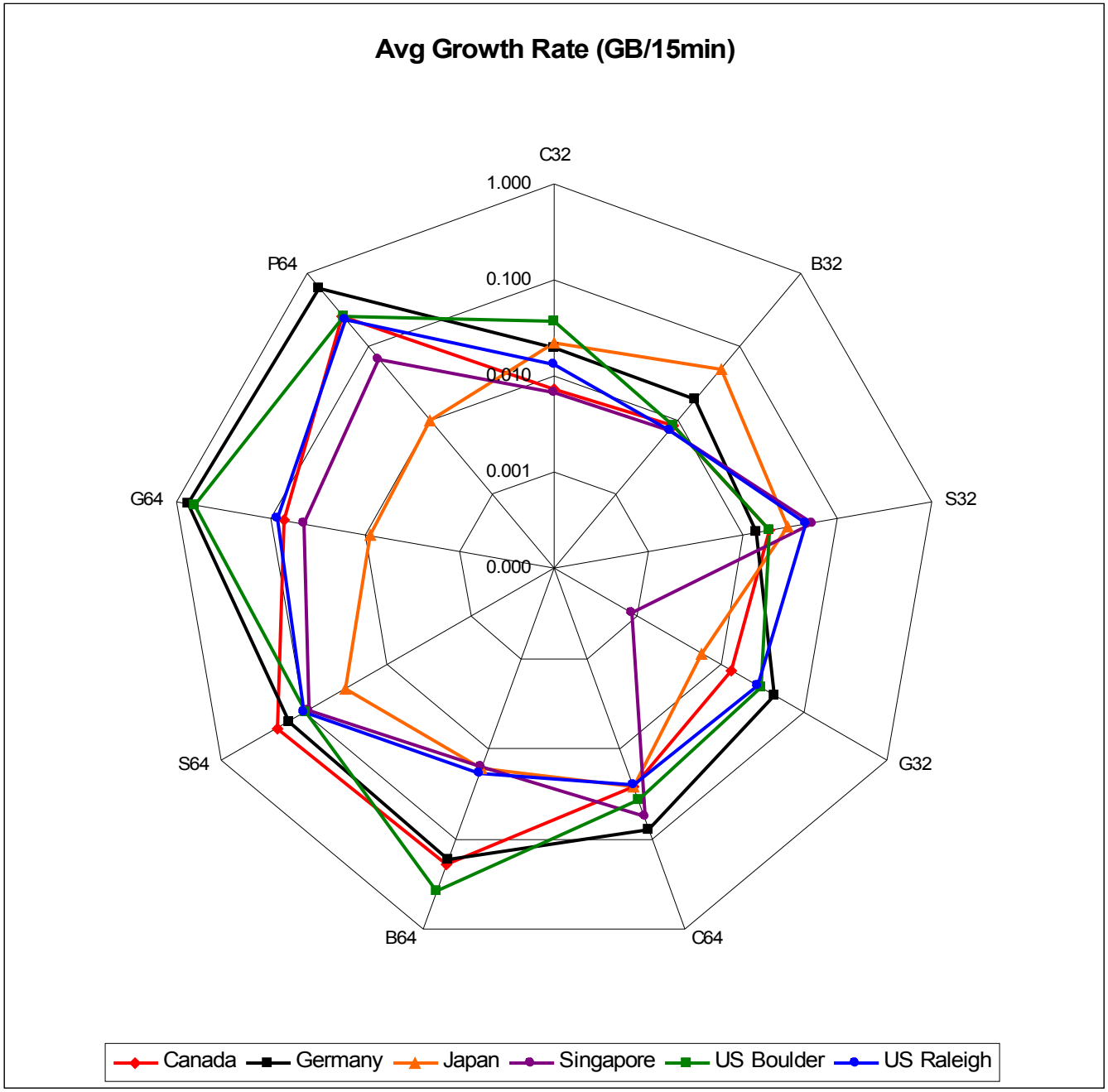




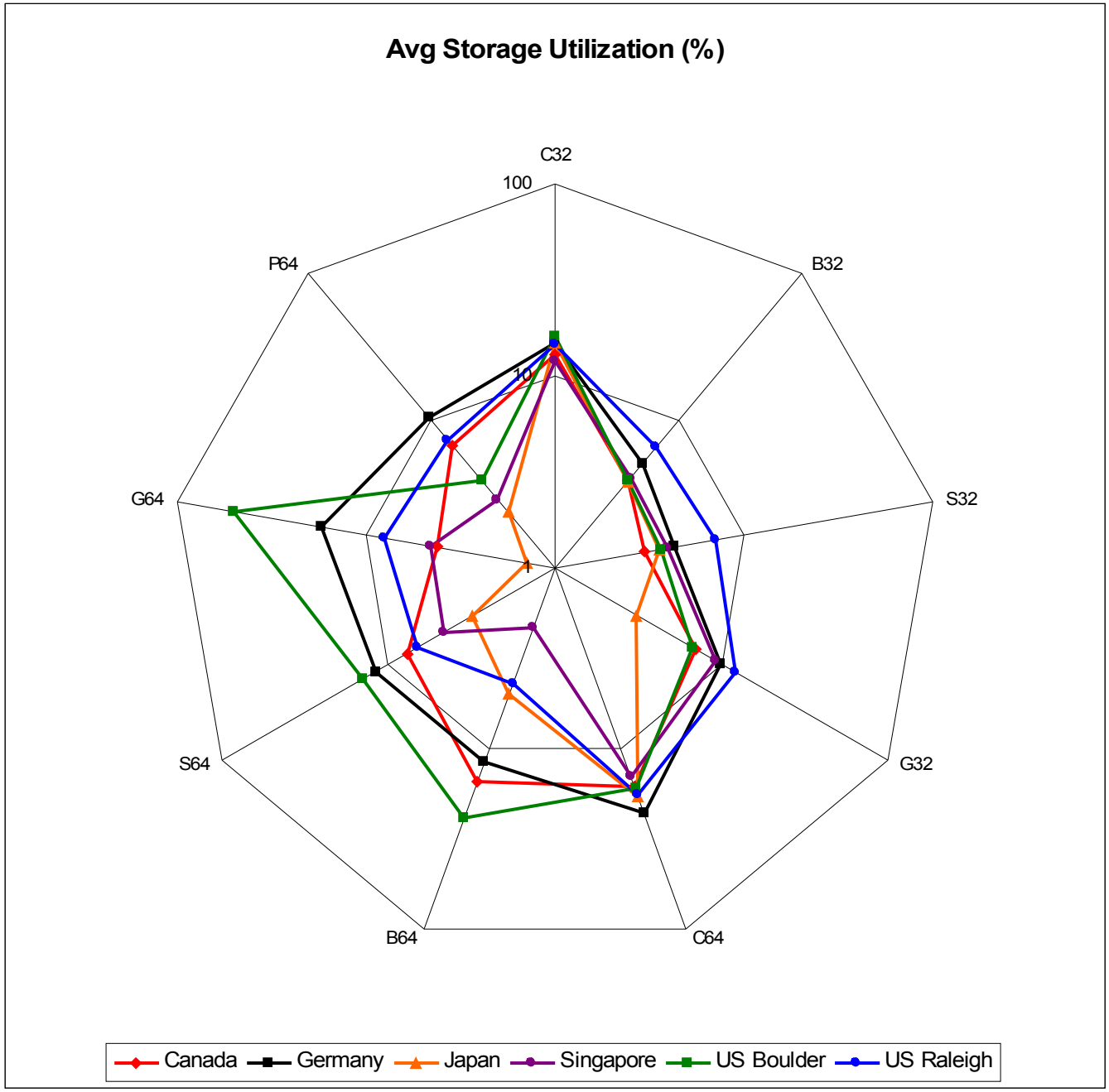




Note: Log scale used.



Note: Log scale used.



Note: Log scale used.

Over-commitment Analysis

- Simulation description
- Simulation results

Overcommitment

(Simulation)

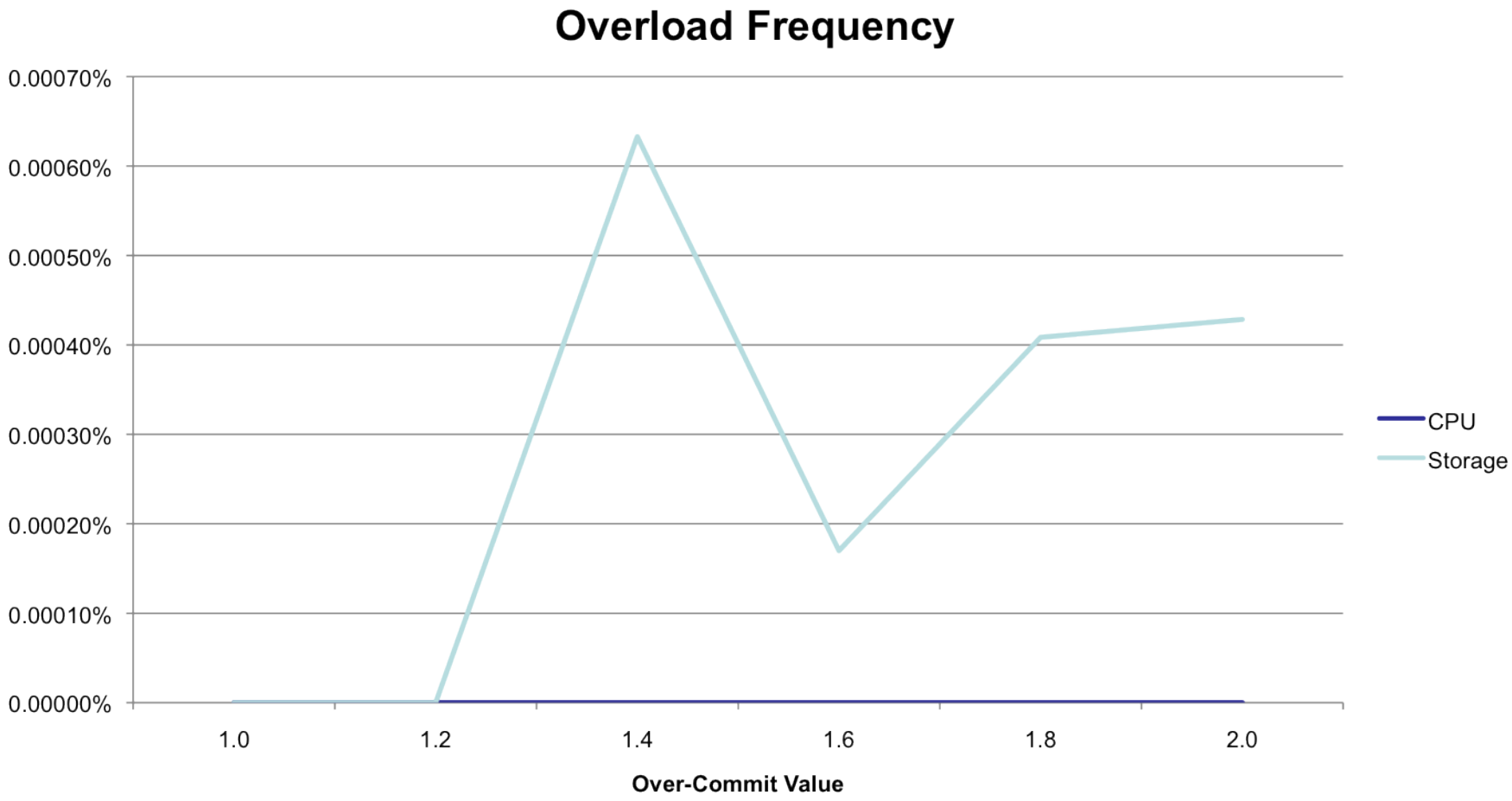
Simulation Description

- PMs (150)
  - 16 Cores Capacity
  - 64G Memory Capacity
  - 4.2T Storage Capacity
- Simulation Time
  - 400 Days
    - 240 Warmup & Shutdown
    - 160 Reporting

Simulation Description

- Simulation Runs
  - Over-commitment values 1.0, 1.2, 1.4. 1.6, 1.8 2.0.
- Evaluations
    - Frequency (Number initial over loads on a PM/Total VM deploys)

Overload Frequency

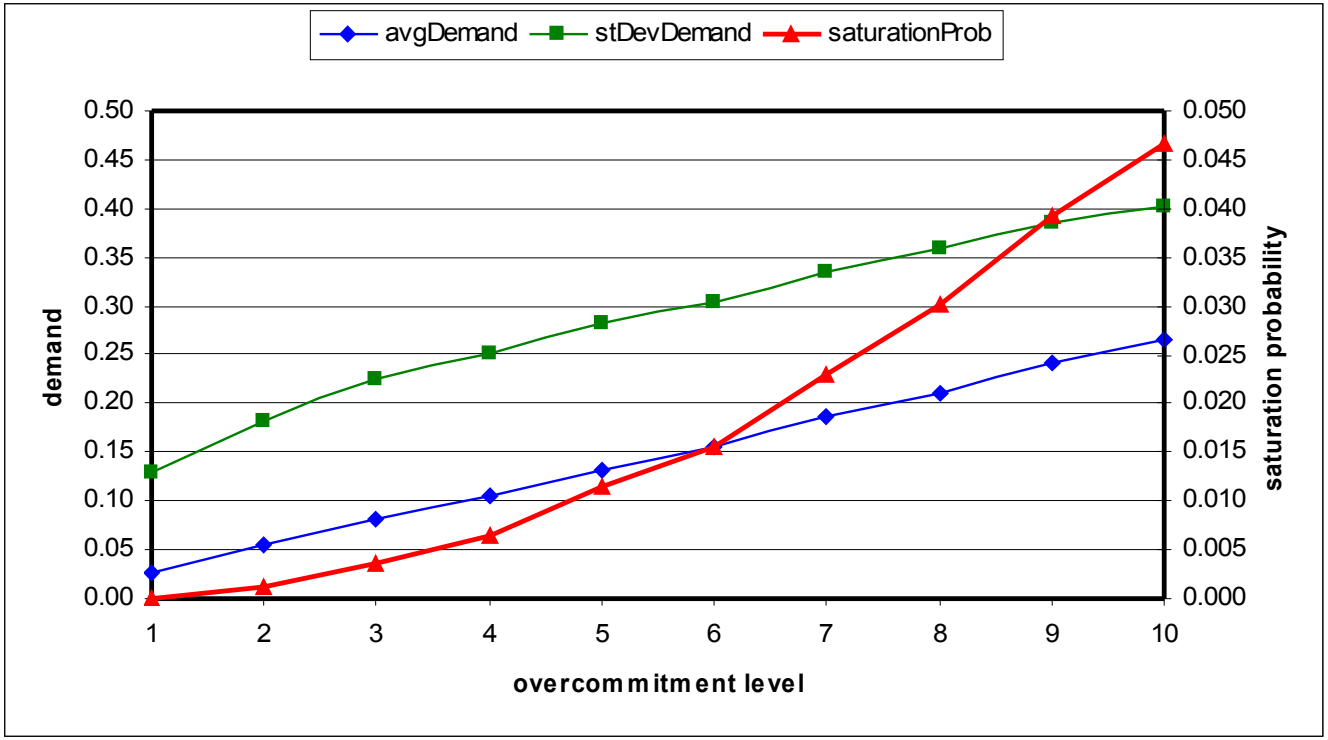


Overcommitment

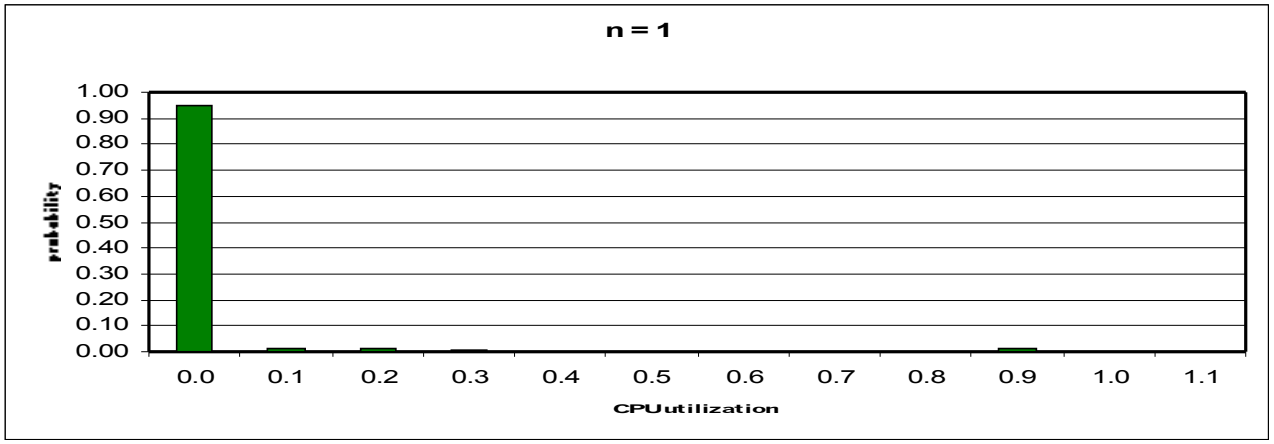
(Analysis)

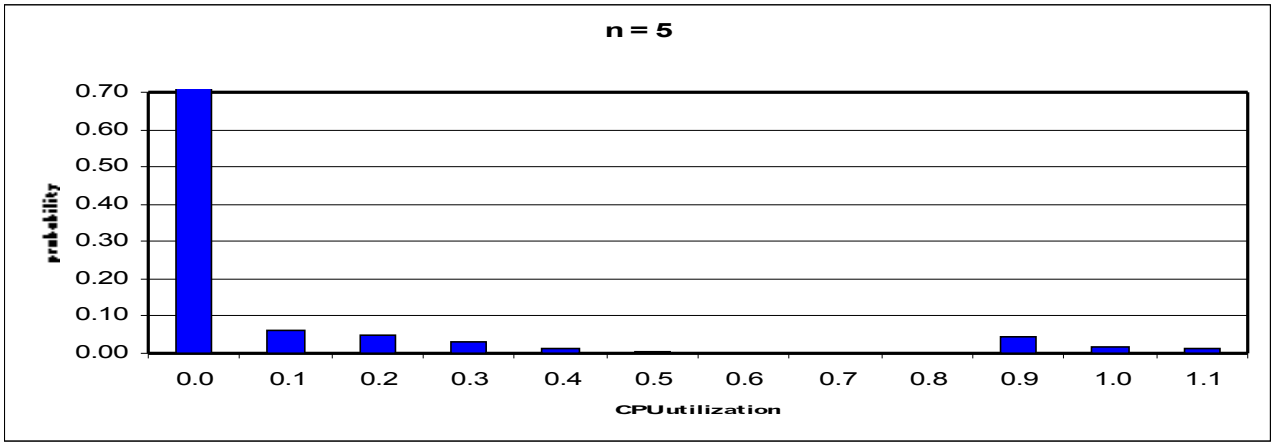
Impact of CPU over commitment

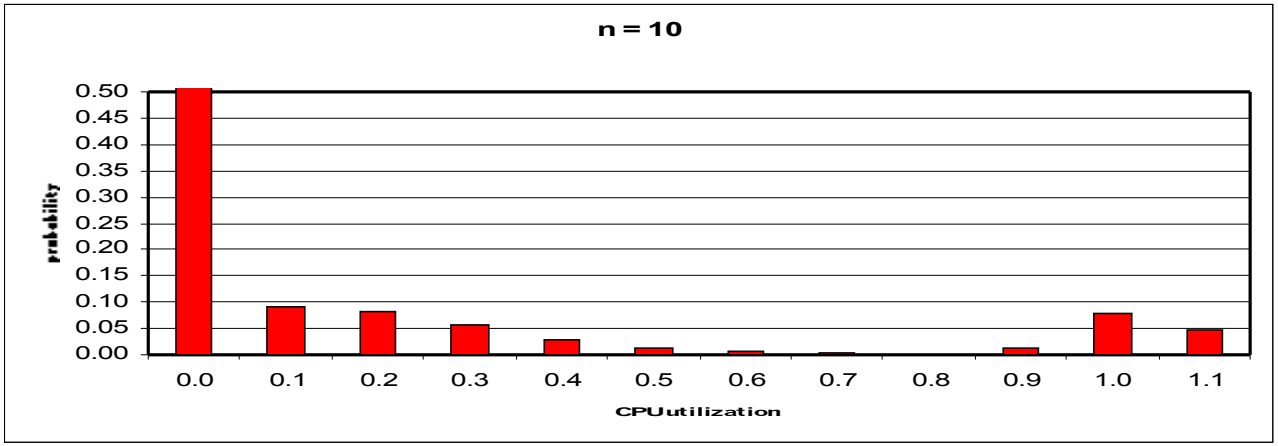
	low	mid	high
1/lambda	39.0	2.4	56.9
mu	0.0027	0.123	0.9813
sigma	0.004	0.16	0.004



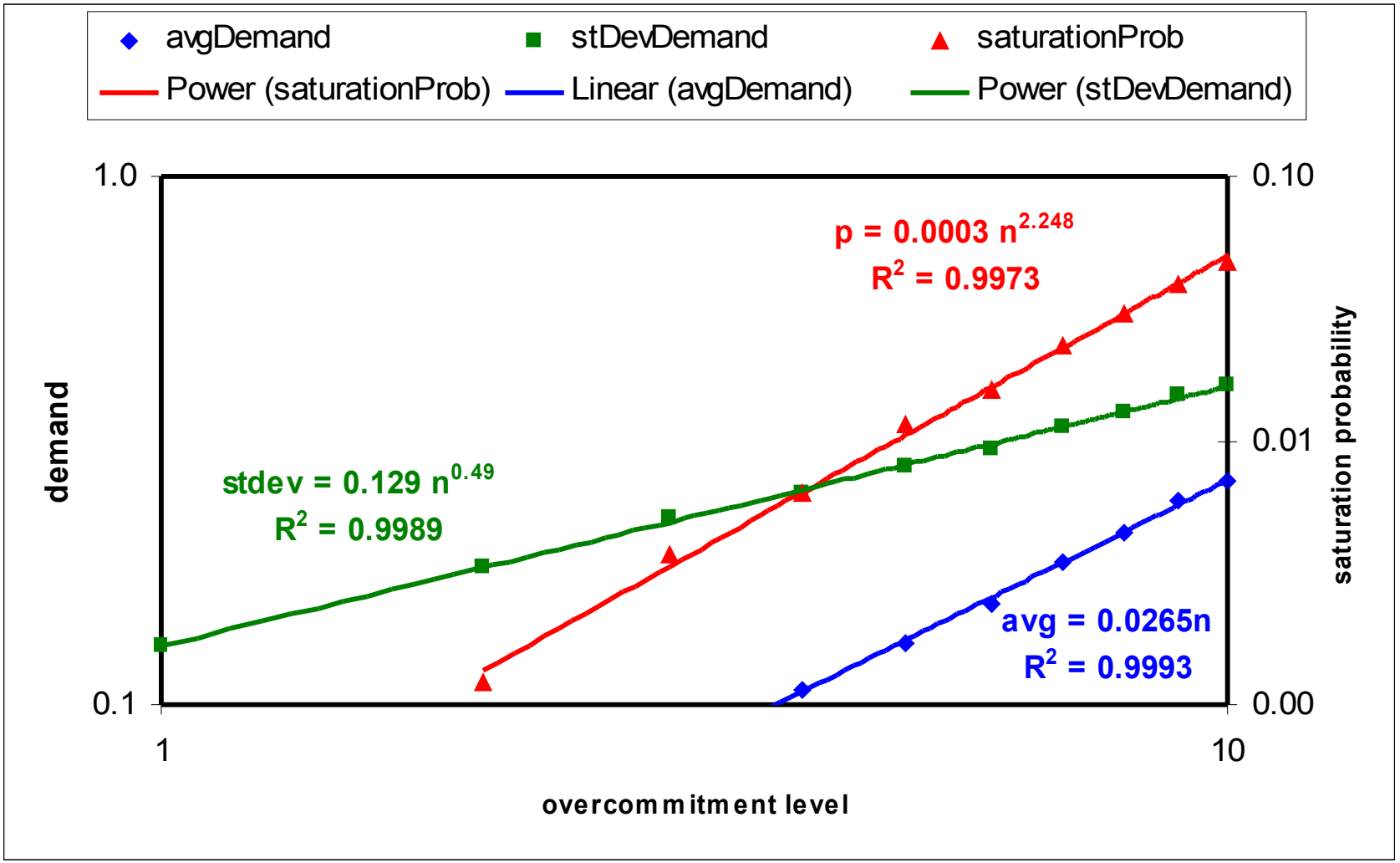
n	avgDemand	stDevDemand	saturationProb
1	0.0274	0.1294	0.0000
2	0.0543	0.1818	0.0012
3	0.0820	0.2249	0.0037
4	0.1063	0.2523	0.0064
5	0.1313	0.2833	0.0114
6	0.1550	0.3031	0.0155
7	0.1866	0.3359	0.0230
8	0.2114	0.3588	0.0300
9	0.2421	0.3852	0.0392
10	0.2652	0.4019	0.0467


n = 1
probability
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
1.1
CPUutilization


n = 5
probability
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
1.1
CPUutilization


n = 10
probability
0.50
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
1.1
CPUutilization

Predicting CPU over commitment



Conclusions

- Able to derive analytic models for an analysis
- Need thorough analysis of data
  - Relying on average measures may be misleading
    - Does not capture significant variations
    - Leads to underestimation of contention
- Consistencies among Datacenters
- Over-commitment levels up to 2 has no significant impact
  - CPU not a bottleneck
  - Slight and rare storage overload
- Unable to study memory due to lack of memory usage reporting

Recommendations

- A staged approach to over-commitment deployment
  - In Stage 1
    - Enable MOM in the production environment for a period of 1-2 months
    - Repeat the study including memory measurements with MOM enabled
    - Based on the study, determine a safe over-commitment factor and validate overload resolution mechanisms
    - Effect over-commitment with a configurable over-commitment factor
    - Periodically repeat the analysis to verify that the chosen over-commitment factor is still a valid one
  - Accelerated plan for Stage 2
    - Include resource-usage-aware VM placement
- Reconsider storage options since overload is infrequent

Backup

VM Counts

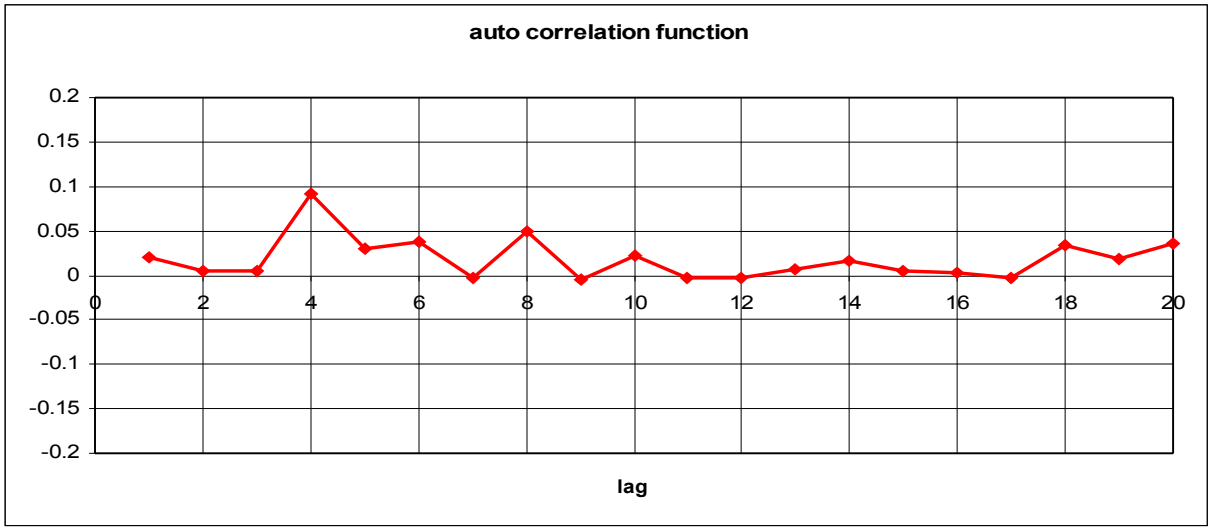
Datacenter	C32	B32	S32	G32	C64	B64	S64	G64	P64
All	10749	1319	523	1352	7507	1207	3204	1354	922
Canada	1269	52	72	180	828	201	372	199	251
Germany	3550	214	115	406	2605	382	456	330	149
Japan	445	12	15	7	207	8	41	2	15
Singapore	68	10	2	5	56	12	13	6	8
US-Boulder	1518	99	100	168	1202	100	733	144	90
US-Raleigh	3899	932	219	586	2609	504	1589	673	409

VM Mix

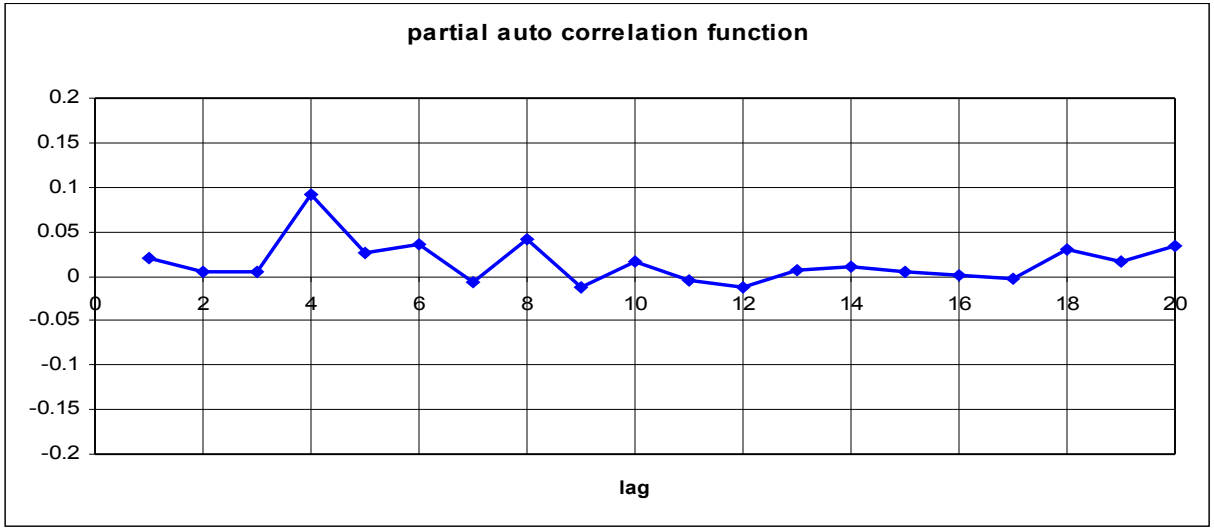
Datacenter	C32	B32	S32	G32	C64	B64	S64	G64	P64
All	38.2%	4.7%	1.9%	4.8%	26.7%	4.3%	11.4%	4.8%	3.3%
Canada	37.1%	1.5%	2.1%	5.3%	24.2%	5.9%	10.9%	5.8%	7.3%
Germany	43.3%	2.6%	1.4%	4.9%	31.7%	4.7%	5.6%	4.0%	1.8%
Japan	59.2%	1.6%	2.0%	0.9%	27.5%	1.1%	5.5%	0.3%	2.0%
Singapore	37.8%	5.6%	1.1%	2.8%	31.1%	6.7%	7.2%	3.3%	4.4%
US-Boulder	36.5%	2.4%	2.4%	4.0%	28.9%	2.4%	17.6%	3.5%	2.2%
US-Raleigh	34.1%	8.2%	1.9%	5.1%	22.8%	4.4%	13.9%	5.9%	3.6%

Modeling Inter-Arrival Times

Autocorrelation in inte-rarrival times



Insignificant autocorrelation, suggesting independent observations



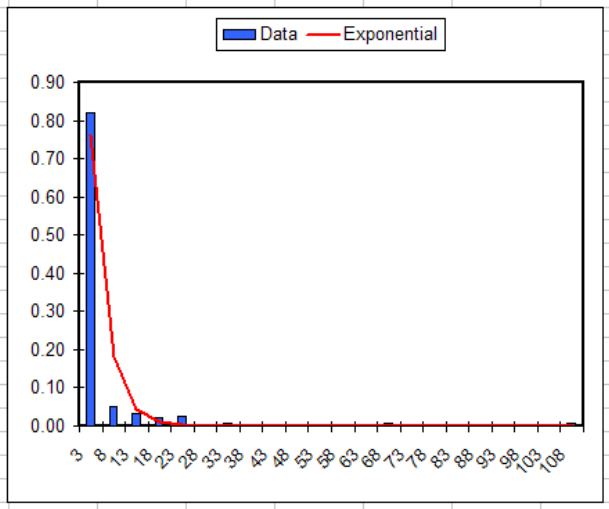
Exponential Distribution

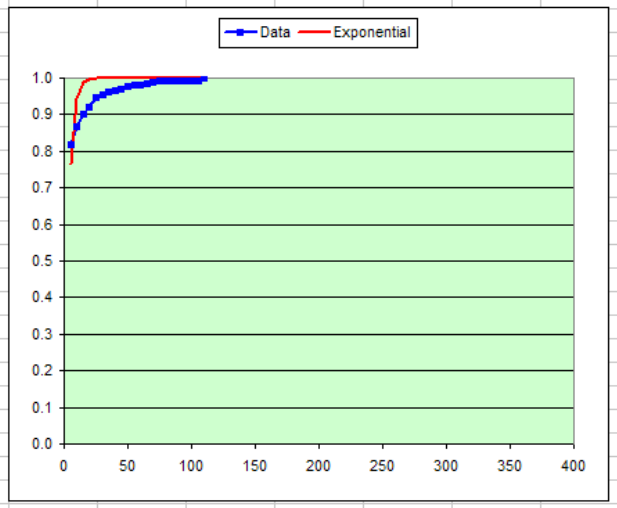
parms	alpha
	0.2884

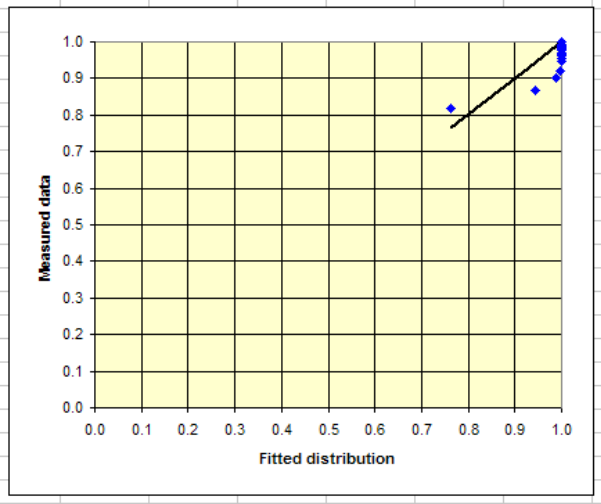
	Data	Fit	relDiff
avg	6.39	3.47	-45.74%
stdev	39.02	3.47	-91.11%

Bins	
oundAvg	6
oundStDev	39
num	20
size	5
min	5
max	100

			Data	Exponential			
x_mid	x	freq	pdf	PDF	PDF	pdf	MSE
3	5	1107	0.8188	0.8188	0.7636	0.7636	0.0031
8	10	67	0.0496	0.8683	0.9441	0.1805	0.0057
13	15	44	0.0325	0.9009	0.9868	0.0427	0.0074
18	20	29	0.0214	0.9223	0.9969	0.0101	0.0056
23	25	35	0.0259	0.9482	0.9993	0.0024	0.0026
28	30	7	0.0052	0.9534	0.9998	0.0006	0.0022
33	35	12	0.0089	0.9623	1.0000	0.0001	0.0014
38	40	6	0.0044	0.9667	1.0000	0.0000	0.0011
43	45	6	0.0044	0.9712	1.0000	0.0000	0.0008
48	50	7	0.0052	0.9763	1.0000	0.0000	0.0006
53	55	4	0.0030	0.9793	1.0000	0.0000	0.0004
58	60	4	0.0030	0.9822	1.0000	0.0000	0.0003
63	65	3	0.0022	0.9845	1.0000	0.0000	0.0002
68	70	8	0.0059	0.9904	1.0000	0.0000	0.0001
73	75	3	0.0022	0.9926	1.0000	0.0000	0.0001
78	80	0	0.0000	0.9926	1.0000	0.0000	0.0001
83	85	0	0.0000	0.9926	1.0000	0.0000	0.0001
88	90	0	0.0000	0.9926	1.0000	0.0000	0.0001
93	95	1	0.0007	0.9933	1.0000	0.0000	0.0000
98	100	0	0.0000	0.9933	1.0000	0.0000	0.0000
103	105	0	0.0000	0.9933	1.0000	0.0000	0.0000
108	110	9	0.0067	1.0000	1.0000	0.0000	0.0000
		1352	1.0000			1.0000	0.1784







Exponential Distribution

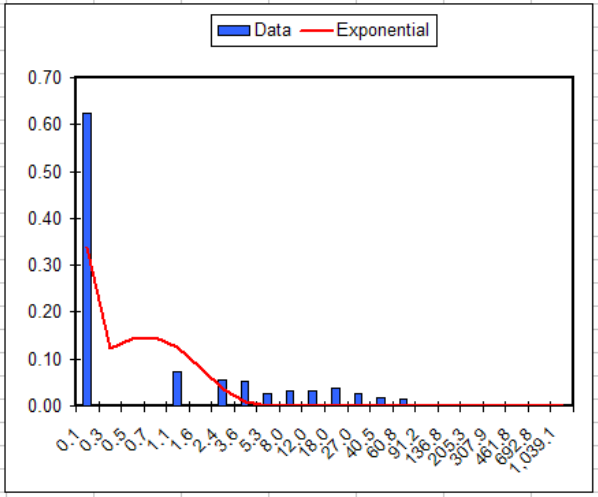
Geometric Bins
1.5

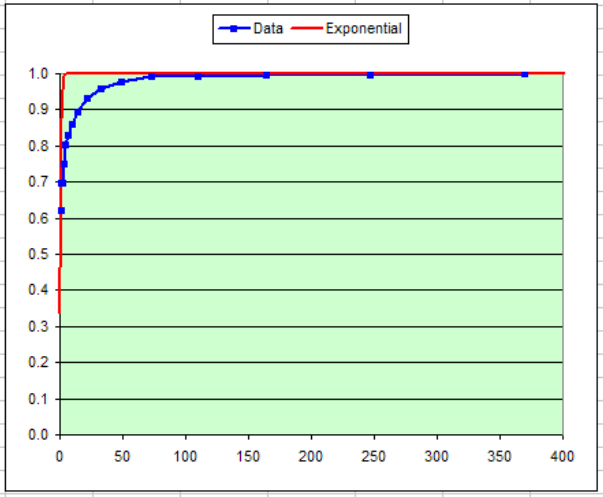
parms	alpha
	1.6498

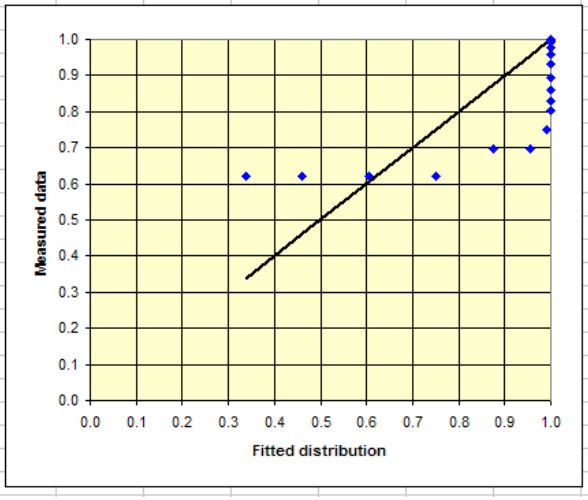
	Data	Fit	relDiff
avg	6.39	0.61	-90.51%
stdev	39.02	0.61	-98.45%

Bins	
roundAvg	6
roundStDev	39
num	20
size	1
min	0.25
max	1

		Data		Exponential			
x_mid	x	freq	pdf	PDF	PDF	pdf	MSE
0.1	0.3	842	0.6228	0.6228	0.3380	0.3380	0.0811
0.3	0.4	0	0.0000	0.6228	0.4613	0.1234	0.0261
0.5	0.6	0	0.0000	0.6228	0.6047	0.1433	0.0003
0.7	0.8	0	0.0000	0.6228	0.7514	0.1468	0.0166
1.1	1.3	99	0.0732	0.6960	0.8761	0.1246	0.0324
1.6	1.9	0	0.0000	0.6960	0.9564	0.0803	0.0678
2.4	2.8	74	0.0547	0.7507	0.9909	0.0345	0.0577
3.6	4.3	72	0.0533	0.8040	0.9991	0.0082	0.0381
5.3	6.4	34	0.0251	0.8291	1.0000	0.0008	0.0292
8.0	9.6	43	0.0318	0.8609	1.0000	0.0000	0.0193
12.0	14.4	44	0.0325	0.8935	1.0000	0.0000	0.0113
18.0	21.6	50	0.0370	0.9305	1.0000	0.0000	0.0048
27.0	32.4	36	0.0266	0.9571	1.0000	0.0000	0.0018
40.5	48.7	25	0.0185	0.9756	1.0000	0.0000	0.0006
60.8	73.0	21	0.0155	0.9911	1.0000	0.0000	0.0001
91.2	109.5	4	0.0030	0.9941	1.0000	0.0000	0.0000
136.8	164.2	4	0.0030	0.9970	1.0000	0.0000	0.0000
205.3	246.3	1	0.0007	0.9978	1.0000	0.0000	0.0000
307.9	369.5	2	0.0015	0.9993	1.0000	0.0000	0.0000
461.8	554.2	0	0.0000	0.9993	1.0000	0.0000	0.0000
692.8	831.3	0	0.0000	0.9993	1.0000	0.0000	0.0000
1,039.1	1,247.0	1	0.0007	1.0000	1.0000	0.0000	0.0000
		1352	1.0000			1.0000	0.6223







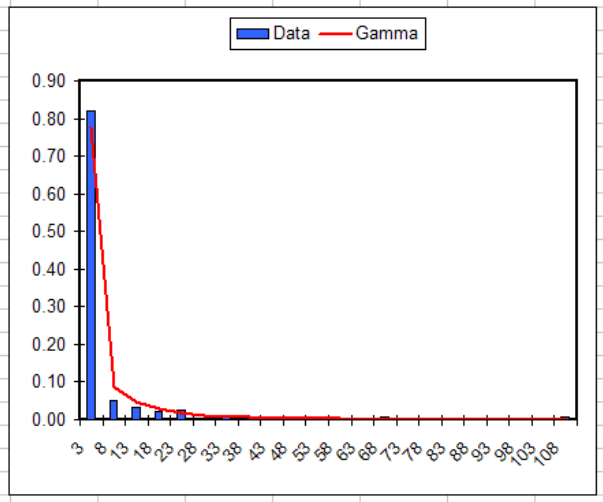
Gamma Distribution

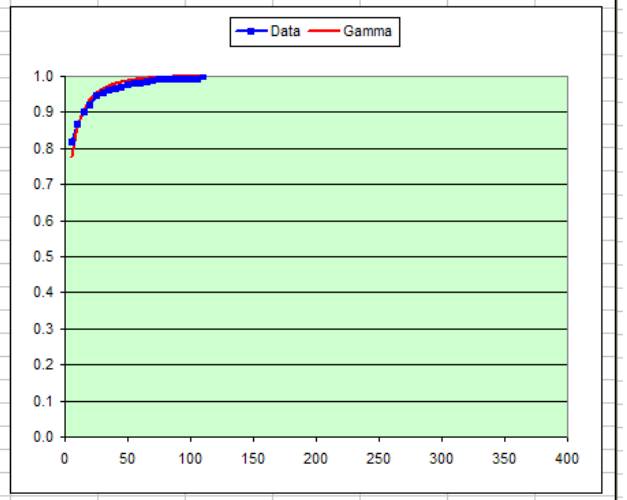
	(shape)	(scale)
parms	alpha	beta
	0.2000	23.0479

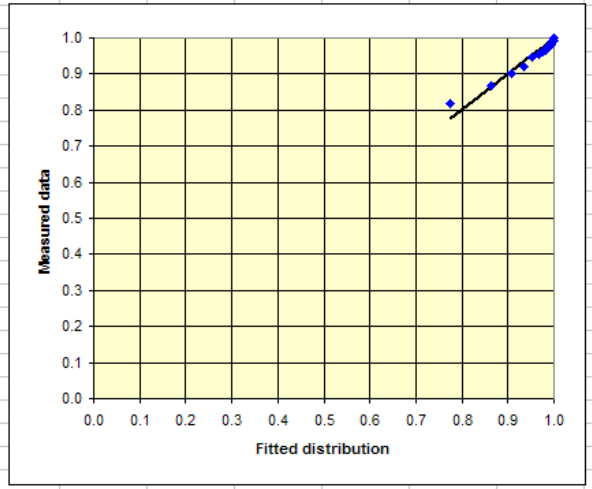
	Data	Fit	relDiff
avg	6.39	4.61	-27.86%
stdev	39.02	10.31	-73.58%

Bins	
roundAvg	6
roundStDev	39
num	20
size	5
min	5
max	100

			Data		Gamma		
x_mid	x	freq	pdf	PDF	PDF	pdf	MSE
3	5	1107	0.8188	0.8188	0.7749	0.7749	0.0019
8	10	67	0.0496	0.8683	0.8621	0.0872	0.0000
13	15	44	0.0325	0.9009	0.9078	0.0456	0.0000
18	20	29	0.0214	0.9223	0.9356	0.0279	0.0002
23	25	35	0.0259	0.9482	0.9539	0.0183	0.0000
28	30	7	0.0052	0.9534	0.9664	0.0125	0.0002
33	35	12	0.0089	0.9623	0.9753	0.0088	0.0002
38	40	6	0.0044	0.9667	0.9816	0.0063	0.0002
43	45	6	0.0044	0.9712	0.9862	0.0046	0.0002
48	50	7	0.0052	0.9763	0.9896	0.0034	0.0002
53	55	4	0.0030	0.9793	0.9921	0.0025	0.0002
58	60	4	0.0030	0.9822	0.9940	0.0019	0.0001
63	65	3	0.0022	0.9845	0.9954	0.0014	0.0001
68	70	8	0.0059	0.9904	0.9965	0.0011	0.0000
73	75	3	0.0022	0.9926	0.9973	0.0008	0.0000
78	80	0	0.0000	0.9926	0.9979	0.0006	0.0000
83	85	0	0.0000	0.9926	0.9984	0.0005	0.0000
88	90	0	0.0000	0.9926	0.9987	0.0004	0.0000
93	95	1	0.0007	0.9933	0.9990	0.0003	0.0000
98	100	0	0.0000	0.9933	0.9992	0.0002	0.0000
103	105	0	0.0000	0.9933	0.9994	0.0002	0.0000
108	110	9	0.0067	1.0000	0.9995	0.0001	0.0000
		1352	1.0000			0.9995	0.0621







Gamma Distribution

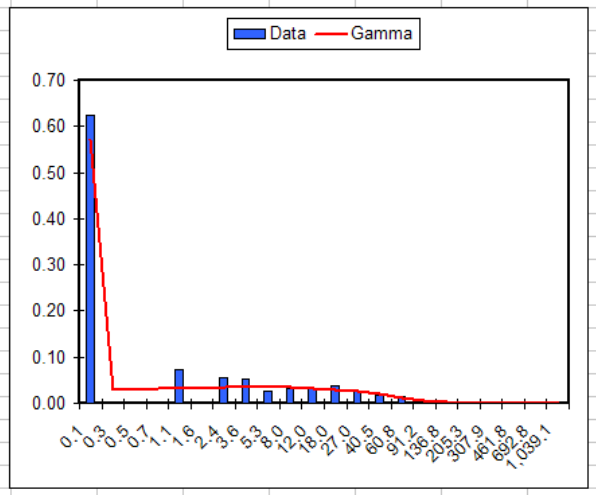
	(shape)	(scale)
parms	alpha	beta
	0.1200	42.0452

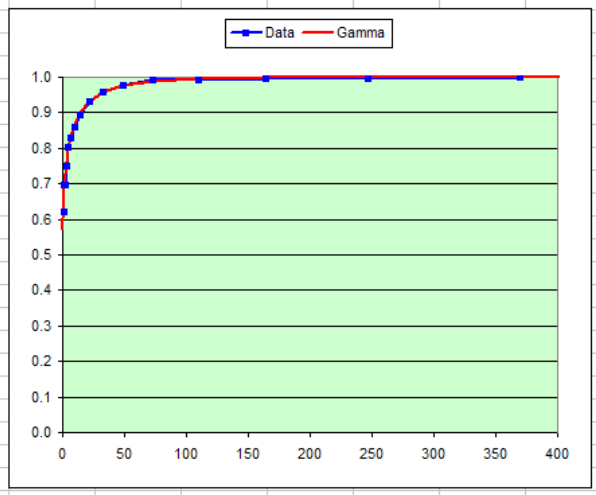
	Data	Fit	relDiff
avg	6.39	5.05	-21.02%
stdev	39.02	14.57	-62.67%

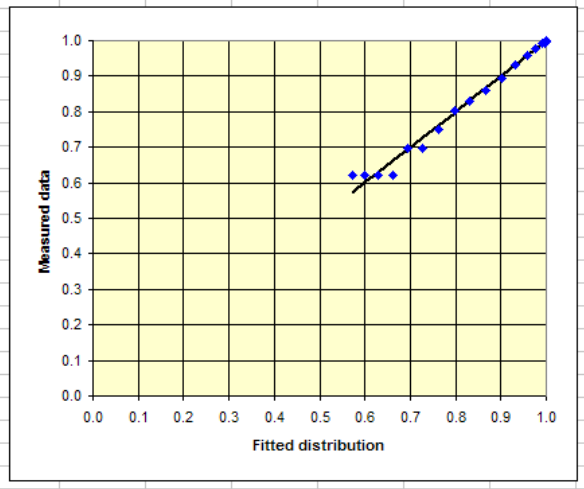
Bins	
roundAvg	6
roundStDev	39
num	20
size	1
min	0.25
max	1

Geometric Bins: 1.5

			Data		Gamma			
x_mid	x	freq	pdf	PDF	PDF	pdf	MSE
0.1	0.3	842	0.6228	0.6228	0.5725	0.5725	0.0025
0.3	0.4	0	0.0000	0.6228	0.6009	0.0284	0.0005
0.5	0.6	0	0.0000	0.6228	0.6306	0.0297	0.0001
0.7	0.8	0	0.0000	0.6228	0.6615	0.0310	0.0015
1.1	1.3	99	0.0732	0.6960	0.6938	0.0323	0.0000
1.6	1.9	0	0.0000	0.6960	0.7272	0.0334	0.0010
2.4	2.8	74	0.0547	0.7507	0.7617	0.0345	0.0001
3.6	4.3	72	0.0533	0.8040	0.7969	0.0352	0.0001
5.3	6.4	34	0.0251	0.8291	0.8323	0.0354	0.0000
8.0	9.6	43	0.0318	0.8609	0.8673	0.0349	0.0000
12.0	14.4	44	0.0325	0.8935	0.9007	0.0334	0.0001
18.0	21.6	50	0.0370	0.9305	0.9311	0.0305	0.0000
27.0	32.4	36	0.0266	0.9571	0.9570	0.0259	0.0000
40.5	48.7	25	0.0185	0.9756	0.9769	0.0199	0.0000
60.8	73.0	21	0.0155	0.9911	0.9900	0.0131	0.0000
91.2	109.5	4	0.0030	0.9941	0.9968	0.0068	0.0000
136.8	164.2	4	0.0030	0.9970	0.9994	0.0025	0.0000
205.3	246.3	1	0.0007	0.9978	0.9999	0.0006	0.0000
307.9	369.5	2	0.0015	0.9993	1.0000	0.0001	0.0000
461.8	554.2	0	0.0000	0.9993	1.0000	0.0000	0.0000
692.8	831.3	0	0.0000	0.9993	1.0000	0.0000	0.0000
1,039.1	1,247.0	1	0.0007	1.0000	1.0000	0.0000	0.0000
		1352	1.0000			1.0000	0.0764







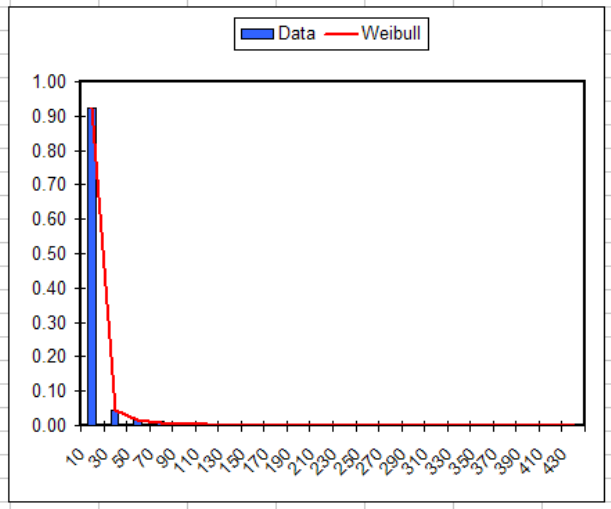
Weibull Distribution

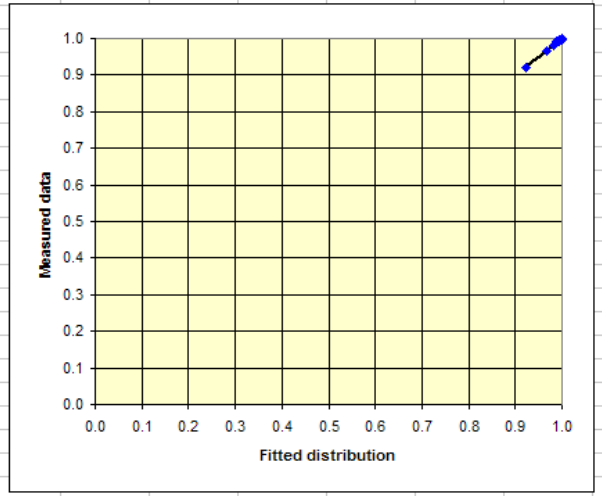
	(shape)	(scale)
parms	alpha	beta
	0.4138	2.0651

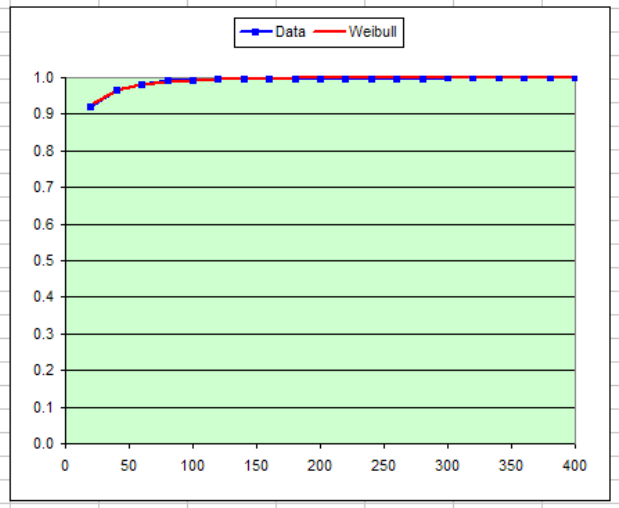
	Data	Fit	relDiff
avg	6.39	6.27	-1.92%
stdev	39.02	18.62	-52.27%

Bins	
roundAvg	6
roundStDev	39
num	20
size	20
min	20
max	400

		Data		Weibull			
x_mid	x	freq	pdf	PDF	PDF	pdf	MSE
10	20	1247	0.9223	0.9223	0.9226	0.9226	0.0000
30	40	60	0.0444	0.9667	0.9669	0.0443	0.0000
50	60	21	0.0155	0.9822	0.9823	0.0153	0.0000
70	80	14	0.0104	0.9926	0.9893	0.0071	0.0000
90	100	1	0.0007	0.9933	0.9931	0.0038	0.0000
110	120	3	0.0022	0.9956	0.9953	0.0022	0.0000
130	140	1	0.0007	0.9963	0.9967	0.0014	0.0000
150	160	1	0.0007	0.9970	0.9976	0.0009	0.0000
170	180	0	0.0000	0.9970	0.9983	0.0006	0.0000
190	200	0	0.0000	0.9970	0.9987	0.0004	0.0000
210	220	0	0.0000	0.9970	0.9990	0.0003	0.0000
230	240	0	0.0000	0.9970	0.9992	0.0002	0.0000
250	260	1	0.0007	0.9978	0.9994	0.0002	0.0000
270	280	0	0.0000	0.9978	0.9995	0.0001	0.0000
290	300	1	0.0007	0.9985	0.9996	0.0001	0.0000
310	320	0	0.0000	0.9985	0.9997	0.0001	0.0000
330	340	1	0.0007	0.9993	0.9997	0.0001	0.0000
350	360	0	0.0000	0.9993	0.9998	0.0000	0.0000
370	380	0	0.0000	0.9993	0.9998	0.0000	0.0000
390	400	0	0.0000	0.9993	0.9999	0.0000	0.0000
410	420	0	0.0000	0.9993	0.9999	0.0000	0.0000
430	440	1	0.0007	1.0000	0.9999	0.0000	0.0000
		1352	1.0000			0.9999	0.0058







Weibull Distribution

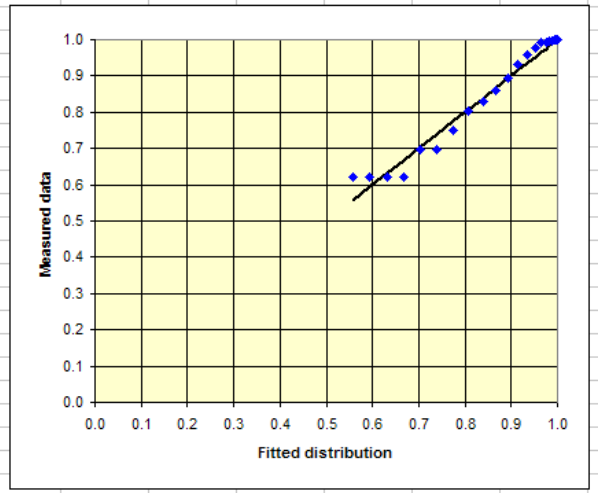
	(shape)	(scale)
parms	alpha	beta
	0.2487	0.5708

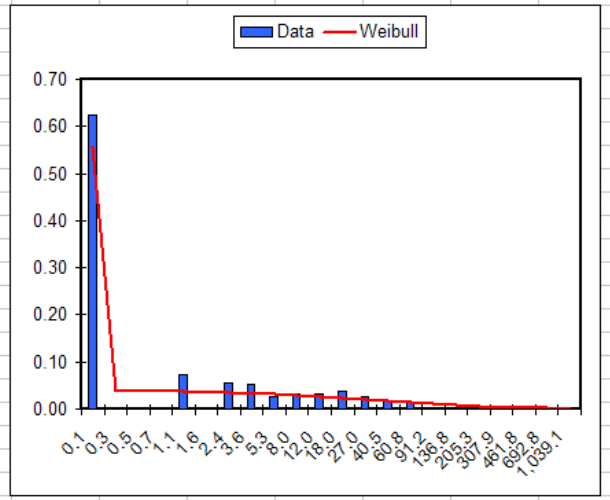
	Data	Fit	relDiff
avg	6.39	14.15	121.50%
stdev	39.02	119.22	205.54%

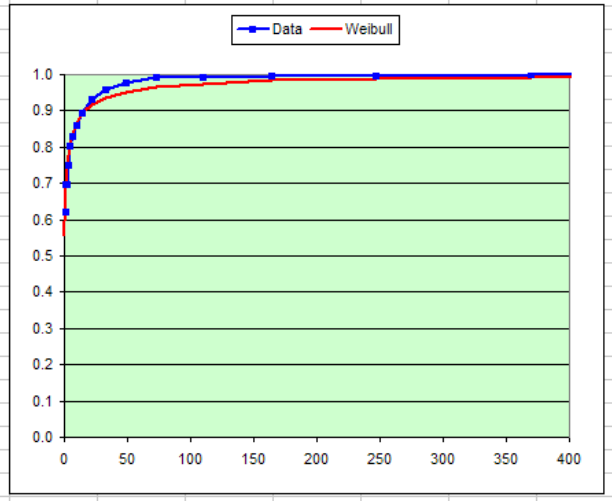
Bins	
roundAvg	6
roundStDev	39
num	20
size	1
min	0.25
max	1

Geometric Bins: 1.5

		Data		Weibull			
x_mid	x	freq	pdf	PDF	PDF	pdf	MSE
0.1	0.3	842	0.6228	0.6228	0.5571	0.5571	0.0043
0.3	0.4	0	0.0000	0.6228	0.5938	0.0367	0.0008
0.5	0.6	0	0.0000	0.6228	0.6308	0.0370	0.0001
0.7	0.8	0	0.0000	0.6228	0.6678	0.0370	0.0020
1.1	1.3	99	0.0732	0.6960	0.7045	0.0367	0.0001
1.6	1.9	0	0.0000	0.6960	0.7403	0.0358	0.0020
2.4	2.8	74	0.0547	0.7507	0.7749	0.0346	0.0006
3.6	4.3	72	0.0533	0.8040	0.8079	0.0329	0.0000
5.3	6.4	34	0.0251	0.8291	0.8387	0.0308	0.0001
8.0	9.6	43	0.0318	0.8609	0.8671	0.0284	0.0000
12.0	14.4	44	0.0325	0.8935	0.8927	0.0256	0.0000
18.0	21.6	50	0.0370	0.9305	0.9153	0.0226	0.0002
27.0	32.4	36	0.0266	0.9571	0.9348	0.0195	0.0005
40.5	48.7	25	0.0185	0.9756	0.9512	0.0164	0.0006
60.8	73.0	21	0.0155	0.9911	0.9646	0.0134	0.0007
91.2	109.5	4	0.0030	0.9941	0.9752	0.0106	0.0004
136.8	164.2	4	0.0030	0.9970	0.9832	0.0081	0.0002
205.3	246.3	1	0.0007	0.9978	0.9891	0.0059	0.0001
307.9	369.5	2	0.0015	0.9993	0.9933	0.0041	0.0000
461.8	554.2	0	0.0000	0.9993	0.9960	0.0028	0.0000
692.8	831.3	0	0.0000	0.9993	0.9978	0.0018	0.0000
1,039.1	1,247.0	1	0.0007	1.0000	0.9988	0.0011	0.0000
		1352	1.0000			0.9988	0.1127

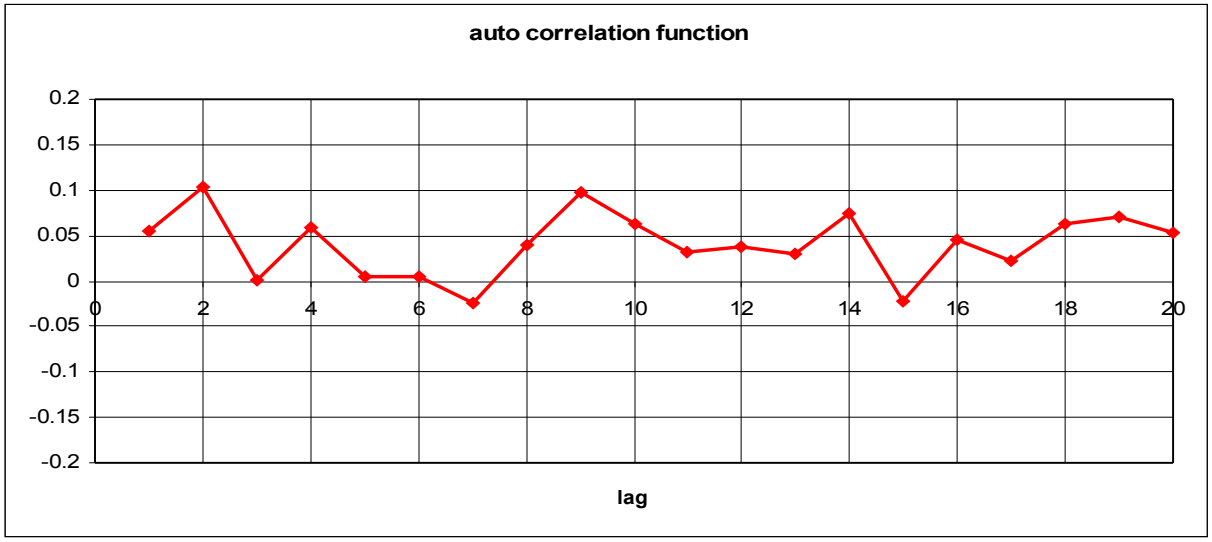




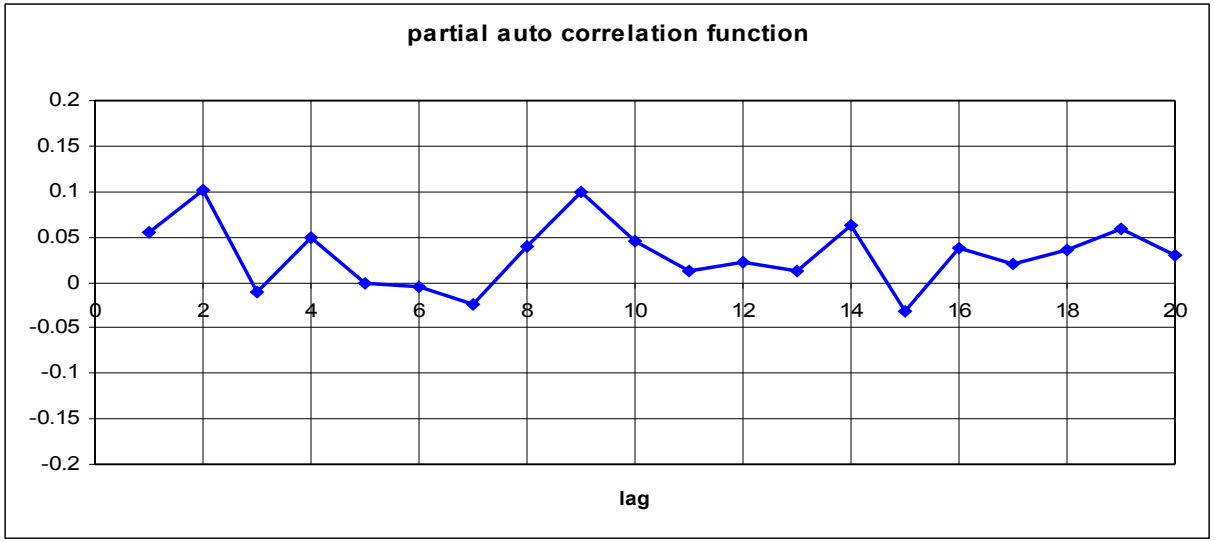


Modeling Lifetimes

Autocorrelation in lifetimes



Insignificant autocorrelation, suggesting independent observations



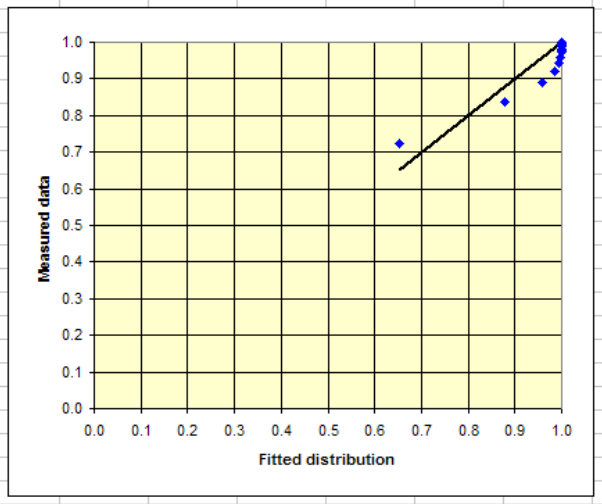
Exponential Distribution

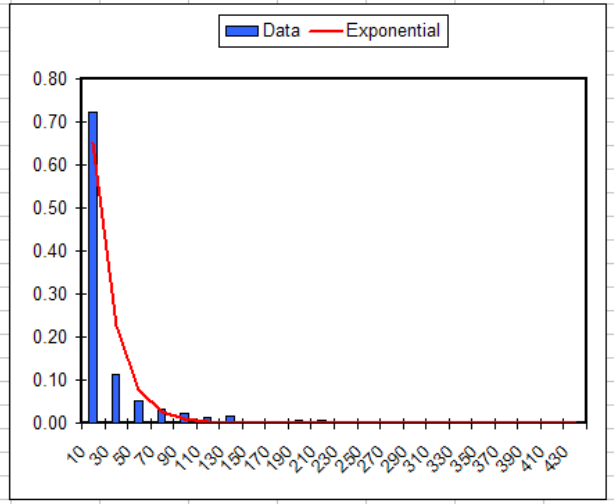
parms	alpha
	0.0528

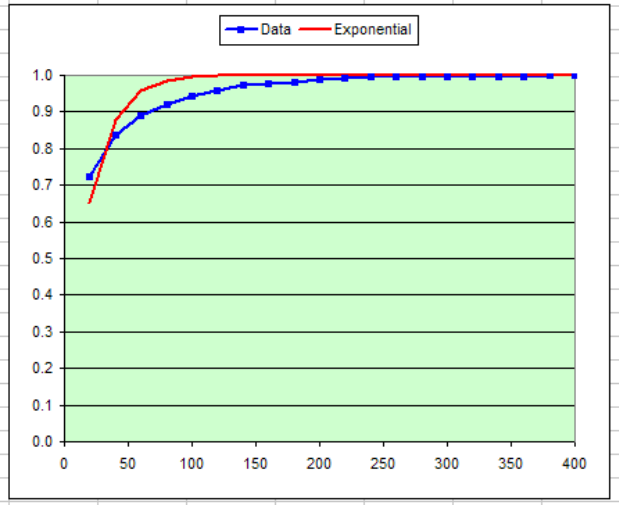
	Data	Fit	relDiff
avg	22.67	18.93	-16.51%
stdev	42.44	18.93	-55.41%

Bins	
roundAvg	23
roundStDev	42
num	20
size	20
min	20
max	400

			Data	Exponential			
x_mid	x	freq	pdf	PDF	PDF	pdf	MSE
10	20	979	0.7236	0.7236	0.6524	0.6524	0.0051
30	40	152	0.1123	0.8359	0.8792	0.2268	0.0019
50	60	72	0.0532	0.8891	0.9580	0.0788	0.0047
70	80	44	0.0325	0.9217	0.9854	0.0274	0.0041
90	100	31	0.0229	0.9446	0.9949	0.0095	0.0025
110	120	18	0.0133	0.9579	0.9982	0.0033	0.0016
130	140	20	0.0148	0.9727	0.9994	0.0012	0.0007
150	160	6	0.0044	0.9771	0.9998	0.0004	0.0005
170	180	6	0.0044	0.9815	0.9999	0.0001	0.0003
190	200	10	0.0074	0.9889	1.0000	0.0000	0.0001
210	220	7	0.0052	0.9941	1.0000	0.0000	0.0000
230	240	1	0.0007	0.9948	1.0000	0.0000	0.0000
250	260	1	0.0007	0.9956	1.0000	0.0000	0.0000
270	280	1	0.0007	0.9963	1.0000	0.0000	0.0000
290	300	0	0.0000	0.9963	1.0000	0.0000	0.0000
310	320	0	0.0000	0.9963	1.0000	0.0000	0.0000
330	340	2	0.0015	0.9978	1.0000	0.0000	0.0000
350	360	0	0.0000	0.9978	1.0000	0.0000	0.0000
370	380	3	0.0022	1.0000	1.0000	0.0000	0.0000
390	400	0	0.0000	1.0000	1.0000	0.0000	0.0000
410	420	0	0.0000	1.0000	1.0000	0.0000	0.0000
430	440	0	0.0000	1.0000	1.0000	0.0000	0.0000
		1353	1.0000			1.0000	0.1474







Exponential Distribution

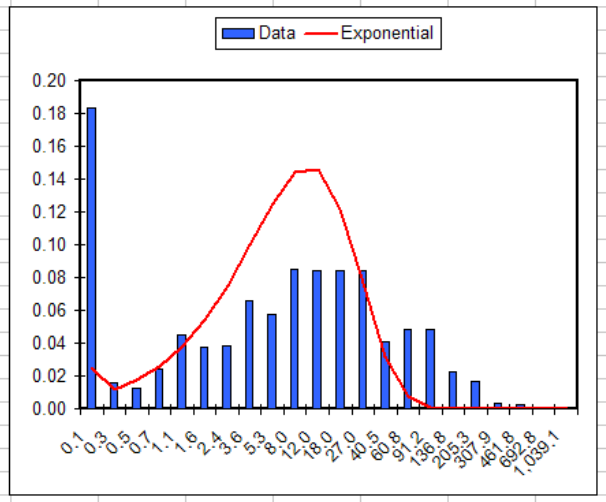
Geometric Bins: 1.5

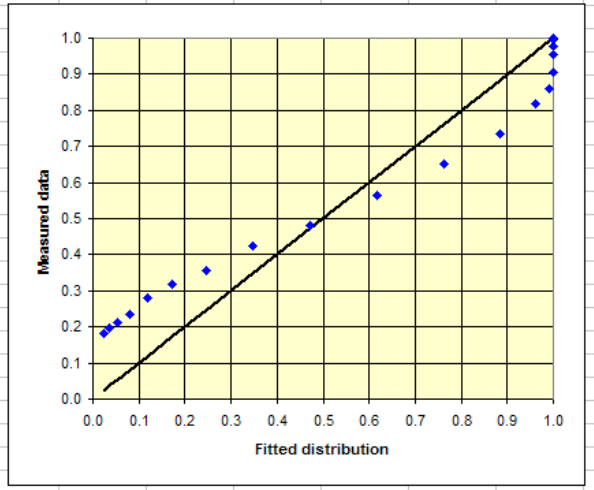
parms	alpha
	0.0997

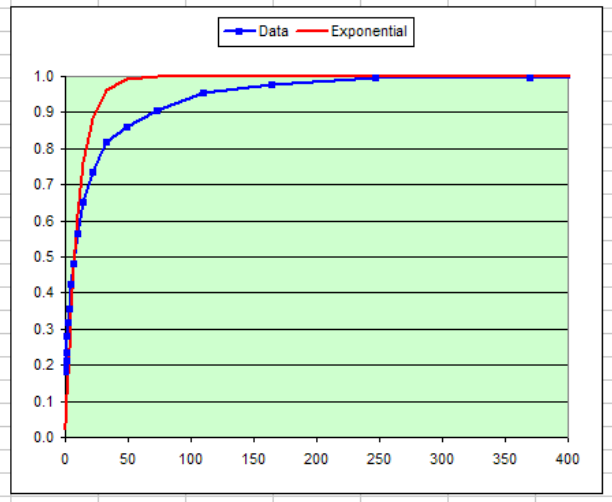
	Data	Fit	relDiff
avg	22.67	10.03	-55.74%
stdev	42.44	10.03	-76.36%

Bins	
roundAvg	23
roundStDev	42
num	20
size	1
min	0.25
max	1

			Data	Exponential			
x_mid	x	freq	pdf	PDF	PDF	pdf	MSE
0.1	0.3	248	0.1833	0.1833	0.0246	0.0246	0.0252
0.3	0.4	21	0.0155	0.1988	0.0367	0.0121	0.0263
0.5	0.6	17	0.0126	0.2114	0.0545	0.0178	0.0246
0.7	0.8	33	0.0244	0.2358	0.0807	0.0261	0.0241
1.1	1.3	61	0.0451	0.2809	0.1185	0.0379	0.0264
1.6	1.9	51	0.0377	0.3186	0.1724	0.0539	0.0214
2.4	2.8	52	0.0384	0.3570	0.2471	0.0747	0.0121
3.6	4.3	89	0.0658	0.4228	0.3467	0.0996	0.0058
5.3	6.4	78	0.0576	0.4804	0.4720	0.1253	0.0001
8.0	9.6	115	0.0850	0.5654	0.6163	0.1443	0.0026
12.0	14.4	114	0.0843	0.6497	0.7624	0.1460	0.0127
18.0	21.6	114	0.0843	0.7339	0.8842	0.1218	0.0226
27.0	32.4	114	0.0843	0.8182	0.9606	0.0764	0.0203
40.5	48.7	55	0.0407	0.8588	0.9922	0.0316	0.0178
60.8	73.0	65	0.0480	0.9069	0.9993	0.0071	0.0085
91.2	109.5	65	0.0480	0.9549	1.0000	0.0007	0.0020
136.8	164.2	31	0.0229	0.9778	1.0000	0.0000	0.0005
205.3	246.3	23	0.0170	0.9948	1.0000	0.0000	0.0000
307.9	369.5	4	0.0030	0.9978	1.0000	0.0000	0.0000
461.8	554.2	3	0.0022	1.0000	1.0000	0.0000	0.0000
692.8	831.3	0	0.0000	1.0000	1.0000	0.0000	0.0000
1,039.1	1,247.0	0	0.0000	1.0000	1.0000	0.0000	0.0000
		1353	1.0000			1.0000	0.5028







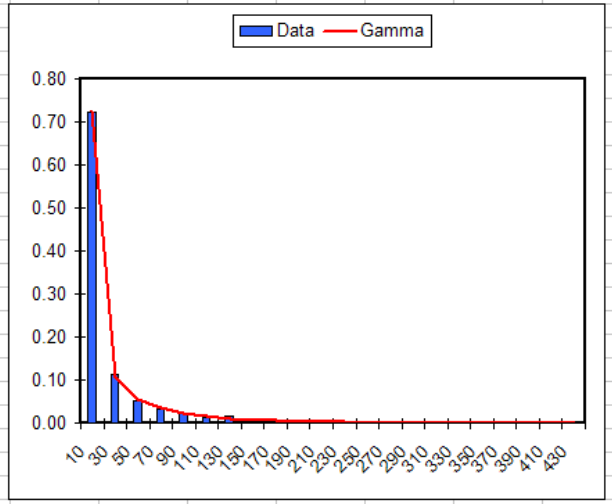
Gamma Distribution

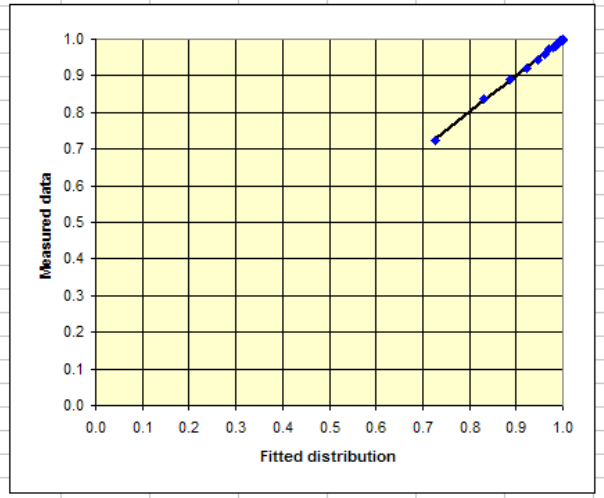
	(shape)	(scale)
parms	alpha	beta
	0.2583	85.2242

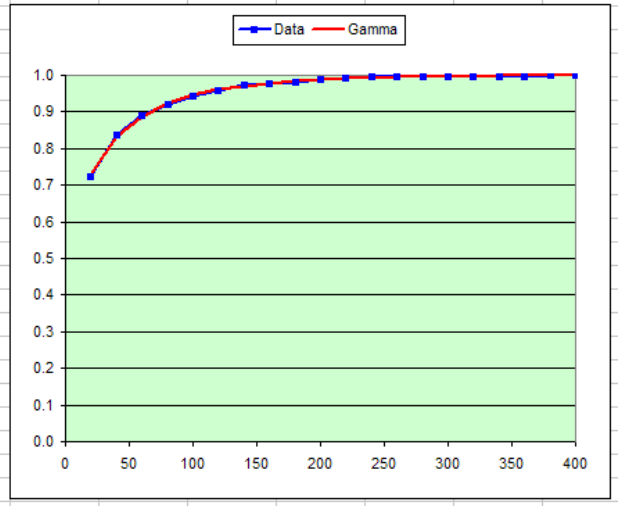
	Data	Fit	relDiff
avg	22.67	22.01	-2.89%
stdev	42.44	43.31	2.04%

Bins	
roundAvg	23
roundStDev	42
num	20
size	20
min	20
max	400

			Data		Gamma		
x_mid	x	freq	pdf	PDF	PDF	pdf	MSE
10	20	979	0.7236	0.7236	0.7258	0.7258	0.0000
30	40	152	0.1123	0.8359	0.8319	0.1061	0.0000
50	60	72	0.0532	0.8891	0.8882	0.0563	0.0000
70	80	44	0.0325	0.9217	0.9226	0.0345	0.0000
90	100	31	0.0229	0.9446	0.9452	0.0226	0.0000
110	120	18	0.0133	0.9579	0.9605	0.0154	0.0000
130	140	20	0.0148	0.9727	0.9713	0.0107	0.0000
150	160	6	0.0044	0.9771	0.9789	0.0076	0.0000
170	180	6	0.0044	0.9815	0.9844	0.0055	0.0000
190	200	10	0.0074	0.9889	0.9884	0.0040	0.0000
210	220	7	0.0052	0.9941	0.9913	0.0029	0.0000
230	240	1	0.0007	0.9948	0.9935	0.0022	0.0000
250	260	1	0.0007	0.9956	0.9951	0.0016	0.0000
270	280	1	0.0007	0.9963	0.9963	0.0012	0.0000
290	300	0	0.0000	0.9963	0.9972	0.0009	0.0000
310	320	0	0.0000	0.9963	0.9979	0.0007	0.0000
330	340	2	0.0015	0.9978	0.9984	0.0005	0.0000
350	360	0	0.0000	0.9978	0.9988	0.0004	0.0000
370	380	3	0.0022	1.0000	0.9990	0.0003	0.0000
390	400	0	0.0000	1.0000	0.9993	0.0002	0.0000
410	420	0	0.0000	1.0000	0.9994	0.0002	0.0000
430	440	0	0.0000	1.0000	0.9996	0.0001	0.0000
		1353	1.0000			0.9996	0.0078







Gamma Distribution

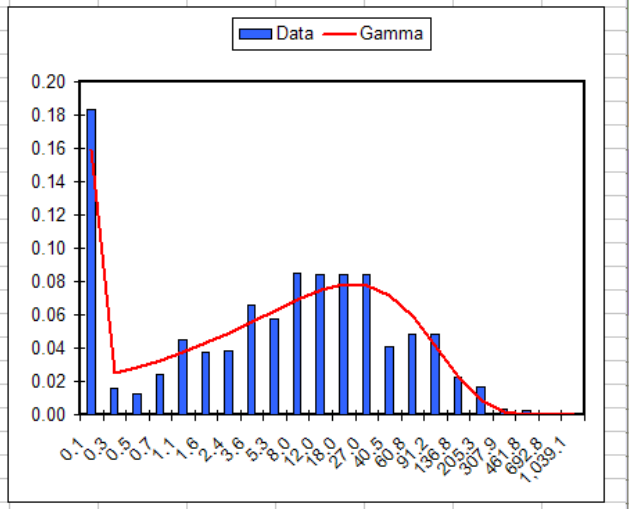
	(shape)	(scale)
parms	alpha	beta
	0.3580	58.7133

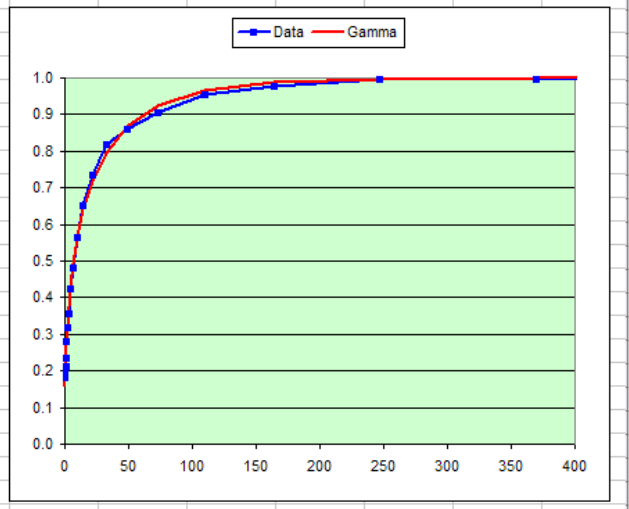
	Data	Fit	relDiff
avg	22.67	21.02	-7.28%
stdev	42.44	35.13	-17.24%

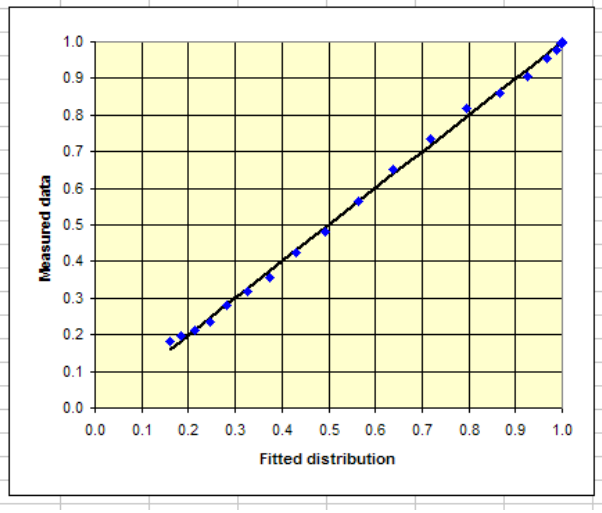
Bins	
roundAvg	23
roundStDev	42
num	20
size	1
min	0.25
max	1

Geometric Bins
1.5

			Data		Gamma		
x_mid	x	freq	pdf	PDF	PDF	pdf	MSE
0.1	0.3	248	0.1833	0.1833	0.1590	0.1590	0.0006
0.3	0.4	21	0.0155	0.1988	0.1837	0.0247	0.0002
0.5	0.6	17	0.0126	0.2114	0.2122	0.0285	0.0000
0.7	0.8	33	0.0244	0.2358	0.2450	0.0328	0.0001
1.1	1.3	61	0.0451	0.2809	0.2828	0.0377	0.0000
1.6	1.9	51	0.0377	0.3186	0.3260	0.0433	0.0001
2.4	2.8	52	0.0384	0.3570	0.3754	0.0493	0.0003
3.6	4.3	89	0.0658	0.4228	0.4313	0.0559	0.0001
5.3	6.4	78	0.0576	0.4804	0.4940	0.0627	0.0002
8.0	9.6	115	0.0850	0.5654	0.5634	0.0694	0.0000
12.0	14.4	114	0.0843	0.6497	0.6383	0.0750	0.0001
18.0	21.6	114	0.0843	0.7339	0.7167	0.0783	0.0003
27.0	32.4	114	0.0843	0.8182	0.7945	0.0778	0.0006
40.5	48.7	55	0.0407	0.8588	0.8663	0.0718	0.0001
60.8	73.0	65	0.0480	0.9069	0.9254	0.0592	0.0003
91.2	109.5	65	0.0480	0.9549	0.9667	0.0413	0.0001
136.8	164.2	31	0.0229	0.9778	0.9893	0.0225	0.0001
205.3	246.3	23	0.0170	0.9948	0.9979	0.0086	0.0000
307.9	369.5	4	0.0030	0.9978	0.9998	0.0019	0.0000
461.8	554.2	3	0.0022	1.0000	1.0000	0.0002	0.0000
692.8	831.3	0	0.0000	1.0000	1.0000	0.0000	0.0000
1,039.1	1,247.0	0	0.0000	1.0000	1.0000	0.0000	0.0000
		1353	1.0000			1.0000	0.0569







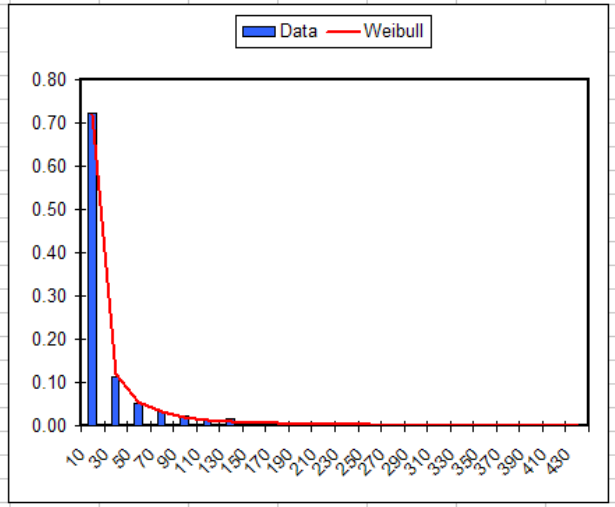
Weibull Distribution

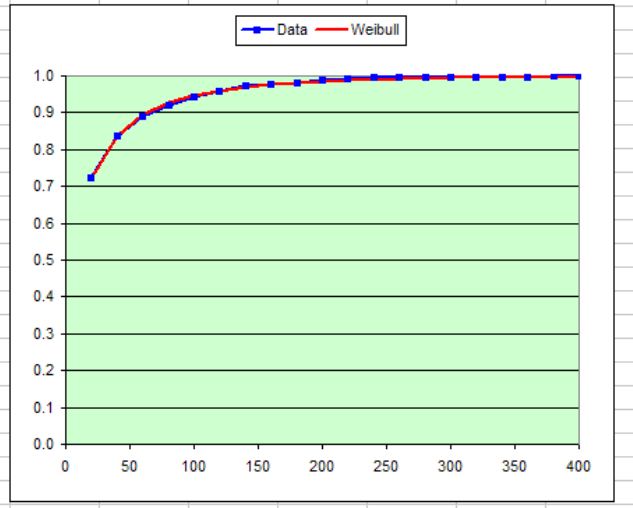
	(shape)	(scale)
parms	alpha	beta
	0.5201	12.6482

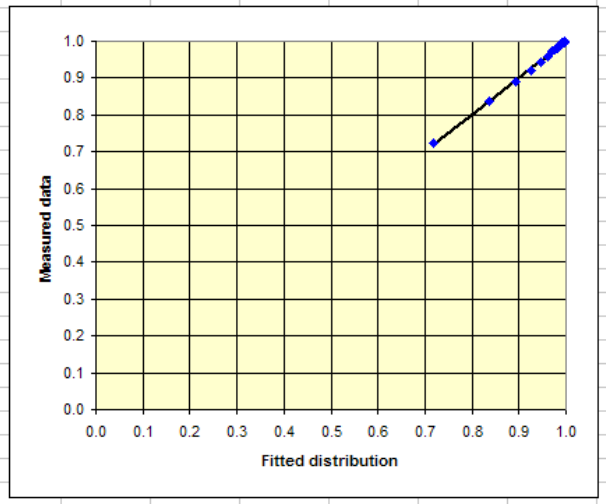
	Data	Fit	relDiff
avg	22.67	23.58	4.05%
stdev	42.44	49.95	17.67%

Bins	
roundAvg	23
roundStDev	42
num	20
size	20
min	20
max	400

			Data		Weibull		
x_mid	x	freq	pdf	PDF	PDF	pdf	MSE
10	20	979	0.7236	0.7236	0.7189	0.7189	0.0000
30	40	152	0.1123	0.8359	0.8380	0.1190	0.0000
50	60	72	0.0532	0.8891	0.8943	0.0563	0.0000
70	80	44	0.0325	0.9217	0.9265	0.0322	0.0000
90	100	31	0.0229	0.9446	0.9467	0.0202	0.0000
110	120	18	0.0133	0.9579	0.9601	0.0135	0.0000
130	140	20	0.0148	0.9727	0.9695	0.0094	0.0000
150	160	6	0.0044	0.9771	0.9763	0.0068	0.0000
170	180	6	0.0044	0.9815	0.9813	0.0050	0.0000
190	200	10	0.0074	0.9889	0.9851	0.0038	0.0000
210	220	7	0.0052	0.9941	0.9879	0.0029	0.0000
230	240	1	0.0007	0.9948	0.9902	0.0022	0.0000
250	260	1	0.0007	0.9956	0.9919	0.0018	0.0000
270	280	1	0.0007	0.9963	0.9933	0.0014	0.0000
290	300	0	0.0000	0.9963	0.9944	0.0011	0.0000
310	320	0	0.0000	0.9963	0.9953	0.0009	0.0000
330	340	2	0.0015	0.9978	0.9961	0.0007	0.0000
350	360	0	0.0000	0.9978	0.9967	0.0006	0.0000
370	380	3	0.0022	1.0000	0.9972	0.0005	0.0000
390	400	0	0.0000	1.0000	0.9976	0.0004	0.0000
410	420	0	0.0000	1.0000	0.9979	0.0003	0.0000
430	440	0	0.0000	1.0000	0.9982	0.0003	0.0000
		1353	1.0000			0.9982	0.0149







Weibull Distribution

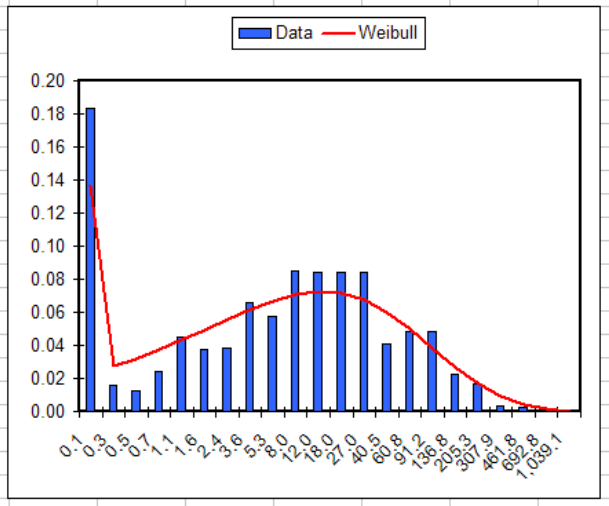
	(shape)	(scale)
parms	alpha	beta
	0.4870	12.8099

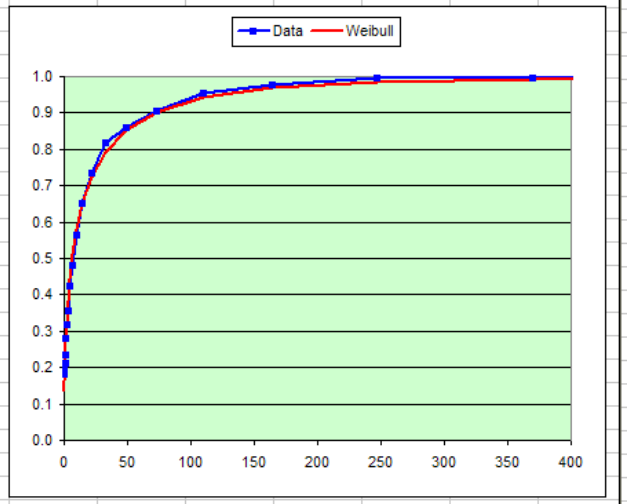
	Data	Fit	relDiff
avg	22.67	26.93	18.80%
stdev	42.44	62.50	47.24%

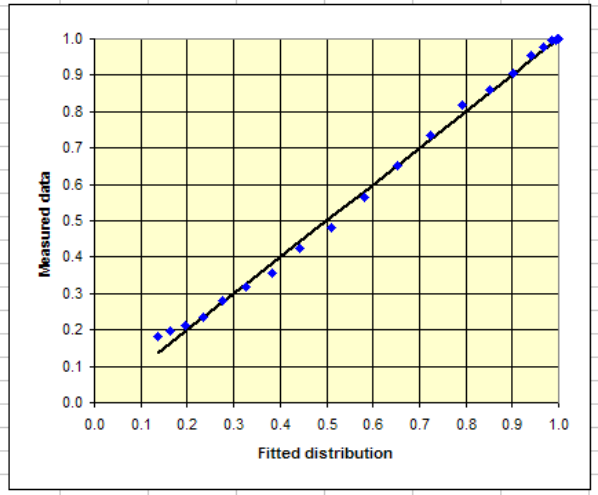
Bins	
roundAvg	23
roundStDev	42
num	20
size	1
min	0.25
max	1

Geometric Bins: 1.5

			Data		Weibull		
x_mid	x	freq	pdf	PDF	PDF	pdf	MSE
0.1	0.3	248	0.1833	0.1833	0.1367	0.1367	0.0022
0.3	0.4	21	0.0155	0.1988	0.1640	0.0273	0.0012
0.5	0.6	17	0.0126	0.2114	0.1961	0.0321	0.0002
0.7	0.8	33	0.0244	0.2358	0.2335	0.0374	0.0000
1.1	1.3	61	0.0451	0.2809	0.2767	0.0432	0.0000
1.6	1.9	51	0.0377	0.3186	0.3261	0.0494	0.0001
2.4	2.8	52	0.0384	0.3570	0.3817	0.0556	0.0006
3.6	4.3	89	0.0658	0.4228	0.4433	0.0616	0.0004
5.3	6.4	78	0.0576	0.4804	0.5101	0.0668	0.0009
8.0	9.6	115	0.0850	0.5654	0.5808	0.0707	0.0002
12.0	14.4	114	0.0843	0.6497	0.6533	0.0725	0.0000
18.0	21.6	114	0.0843	0.7339	0.7249	0.0716	0.0001
27.0	32.4	114	0.0843	0.8182	0.7924	0.0676	0.0007
40.5	48.7	55	0.0407	0.8588	0.8527	0.0603	0.0000
60.8	73.0	65	0.0480	0.9069	0.9030	0.0503	0.0000
91.2	109.5	65	0.0480	0.9549	0.9417	0.0387	0.0002
136.8	164.2	31	0.0229	0.9778	0.9687	0.0269	0.0001
205.3	246.3	23	0.0170	0.9948	0.9853	0.0166	0.0001
307.9	369.5	4	0.0030	0.9978	0.9941	0.0089	0.0000
461.8	554.2	3	0.0022	1.0000	0.9981	0.0039	0.0000
692.8	831.3	0	0.0000	1.0000	0.9995	0.0014	0.0000
1,039.1	1,247.0	0	0.0000	1.0000	0.9999	0.0004	0.0000
		1353	1.0000			0.9999	0.0838

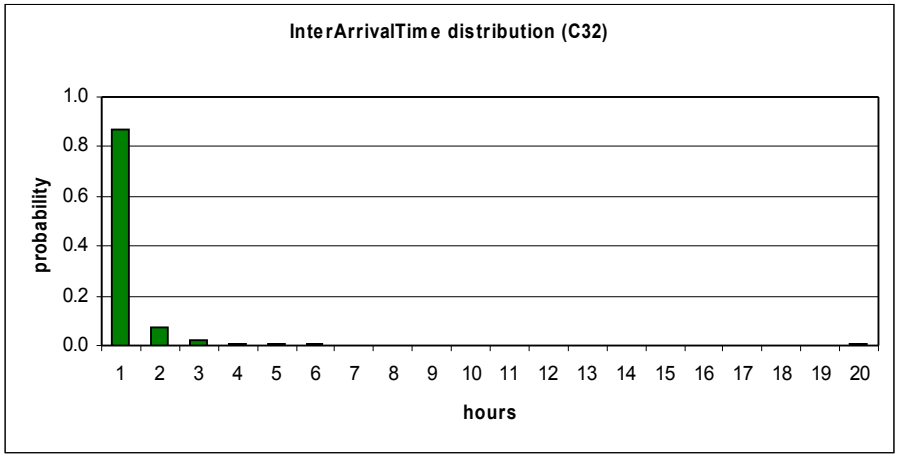


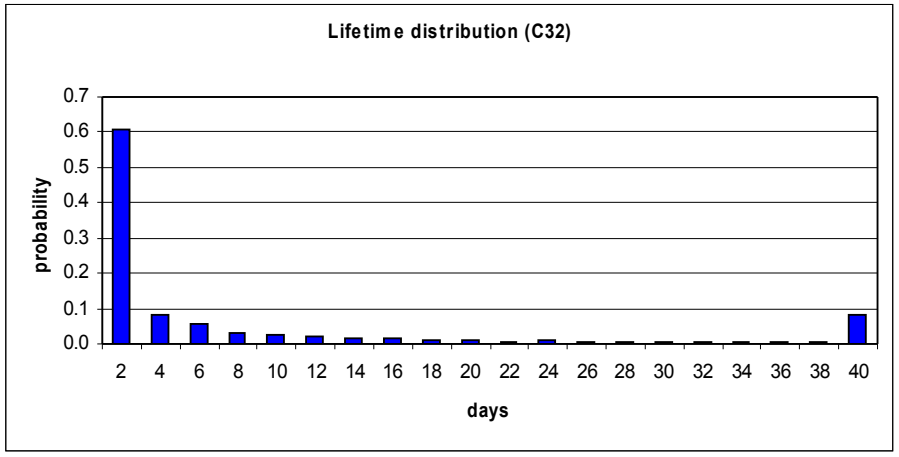


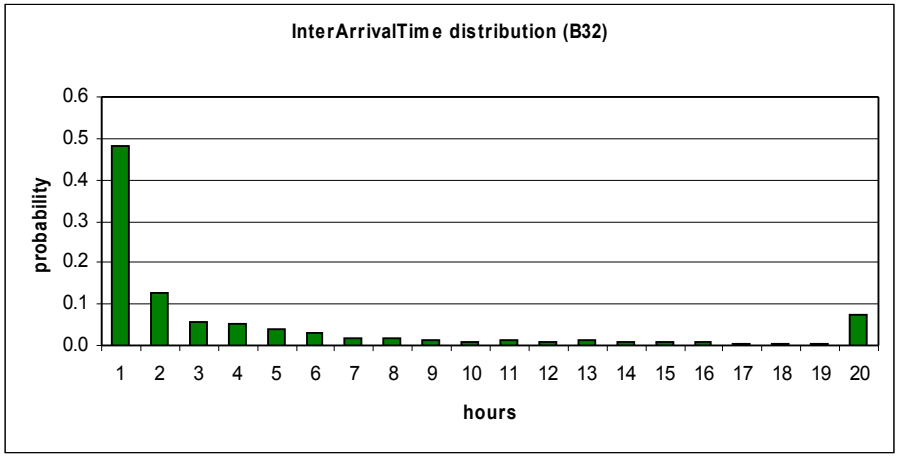


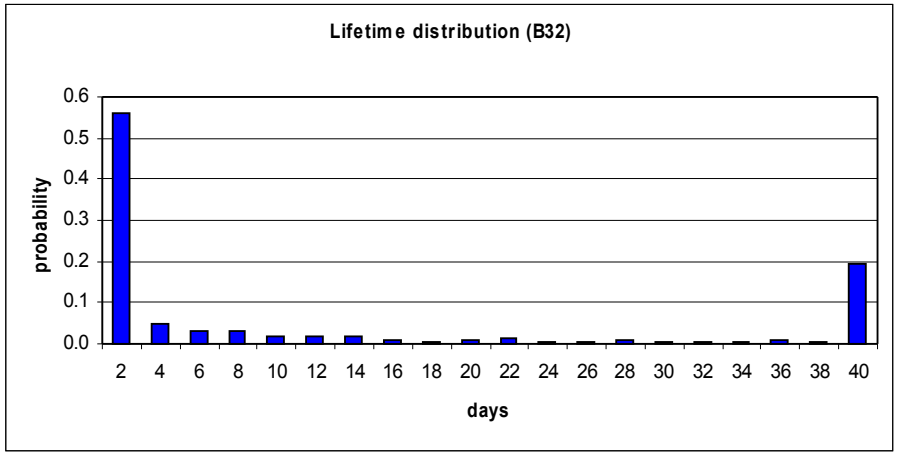
Inter-Arrival and Lifetime

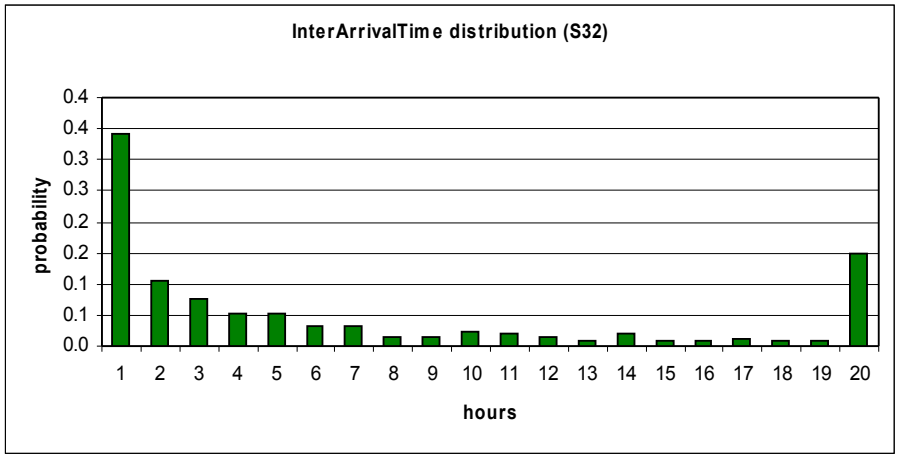
(Histograms)

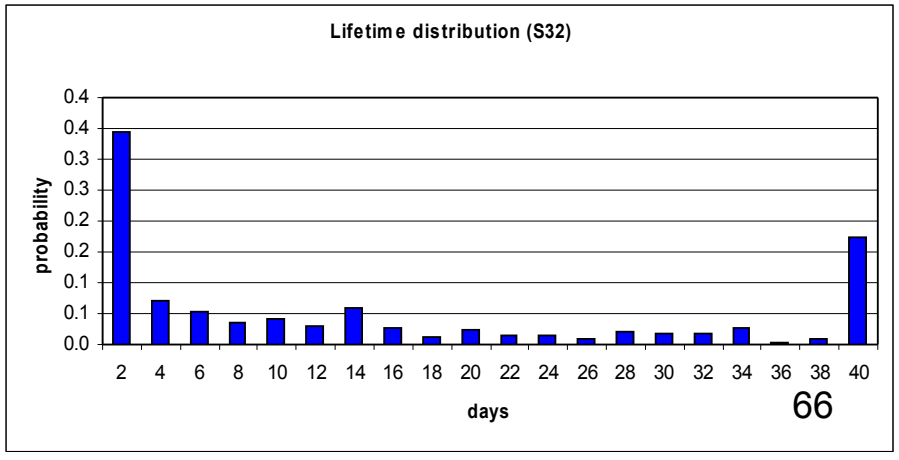

InterArrivalTime distribution (C32)
probability
1.0
0.8
0.6
0.4
0.2
0.0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
hours

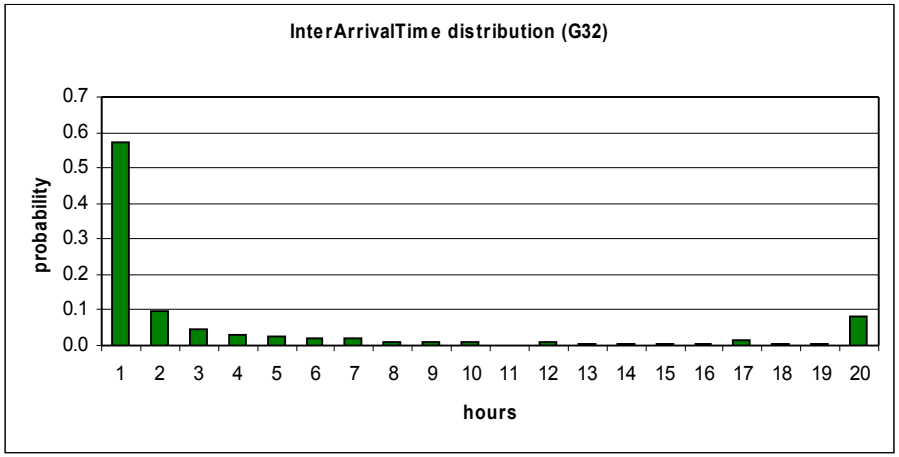

Lifetime distribution (C32)
probability
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40
days

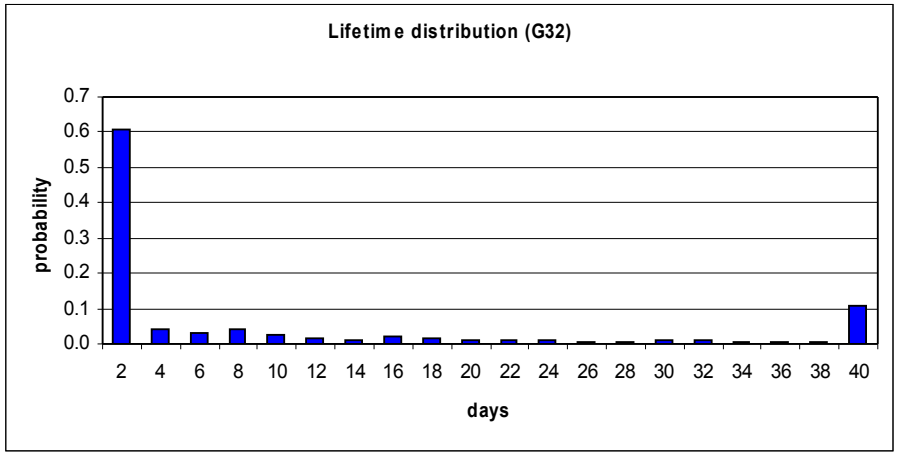

InterArrivalTime distribution (B32)
probability
0.6
0.5
0.4
0.3
0.2
0.1
0.0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
hours

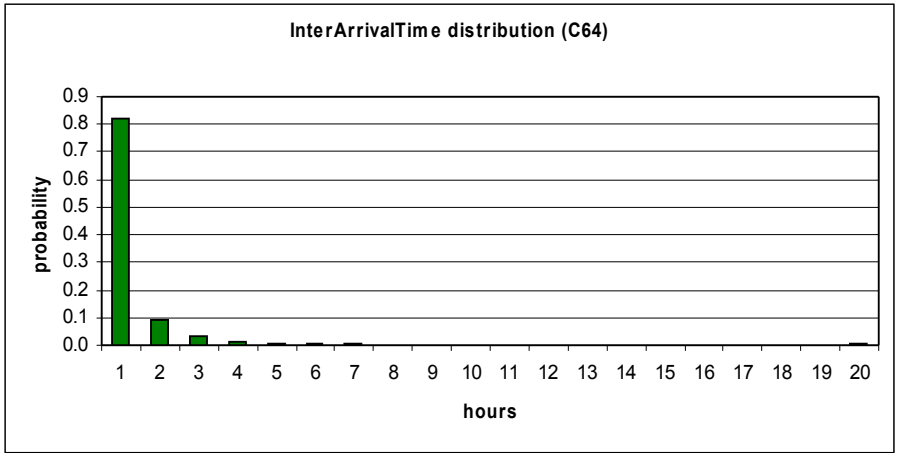

Lifetime distribution (B32)
probability
0.6
0.5
0.4
0.3
0.2
0.1
0.0
2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40
days

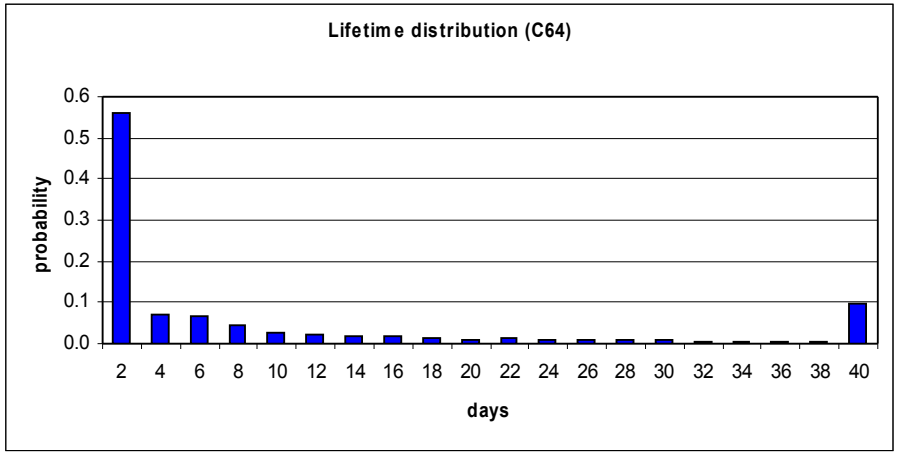

InterArrivalTime distribution (S32)
probability
0.4
0.4
0.3
0.3
0.2
0.2
0.1
0.1
0.0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
hours

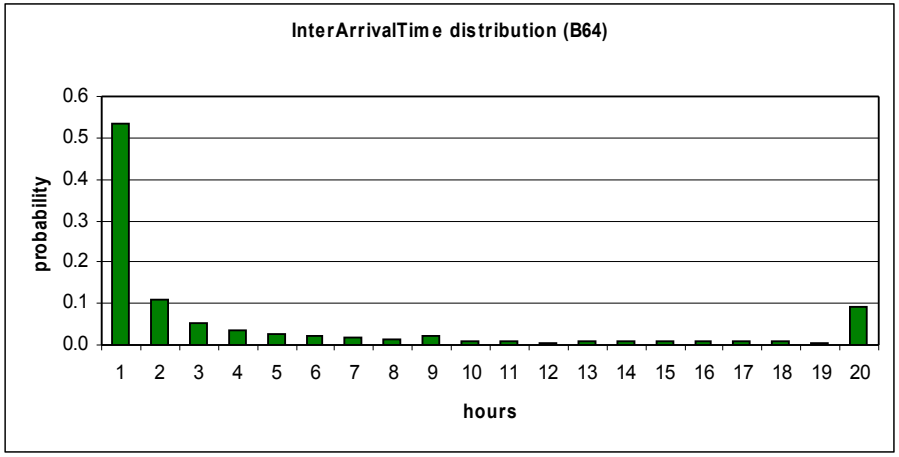

Lifetime distribution (S32)
probability
0.4
0.4
0.3
0.3
0.2
0.2
0.1
0.1
0.0
2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40
days

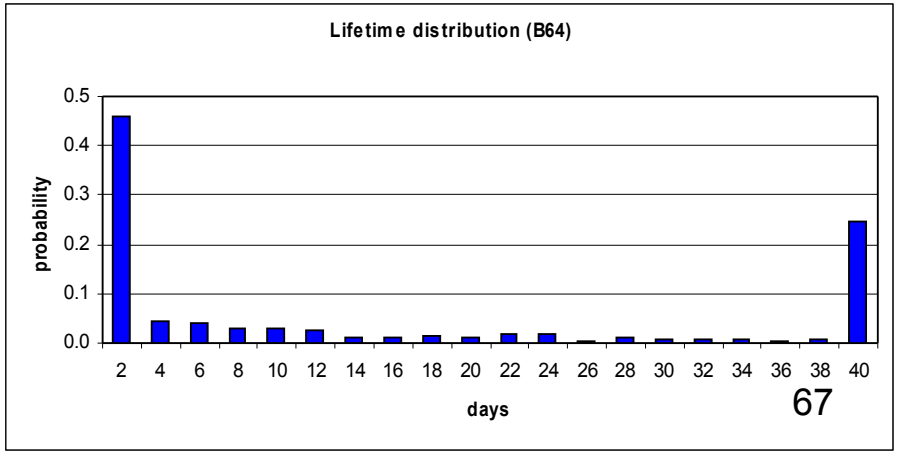

InterArrivalTime distribution (G32)
probability
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
hours

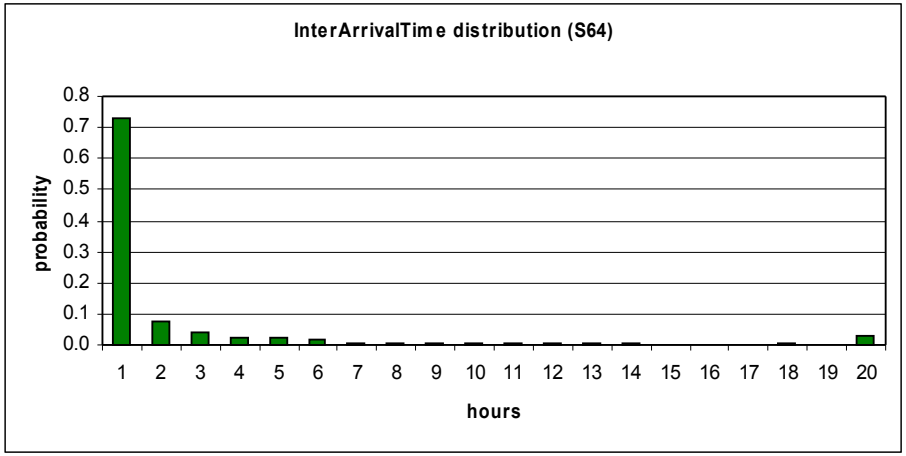

Lifetime distribution (G32)
probability
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40
days

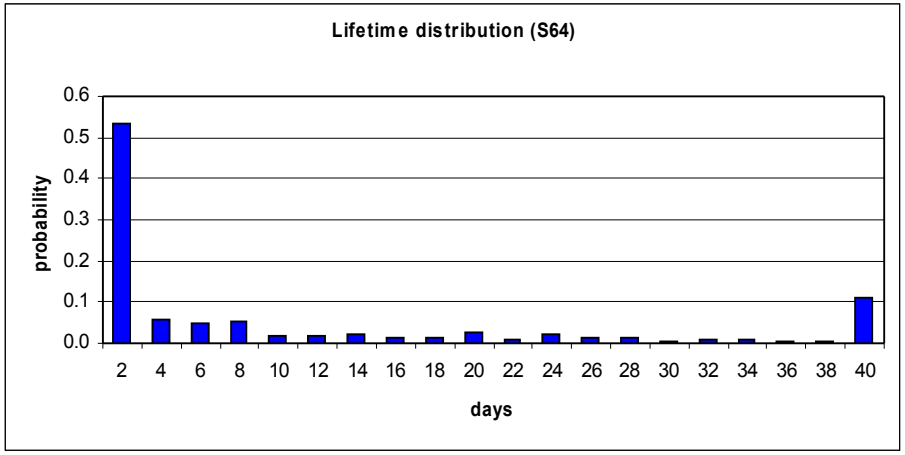

InterArrivalTime distribution (C64)
probability
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
hours

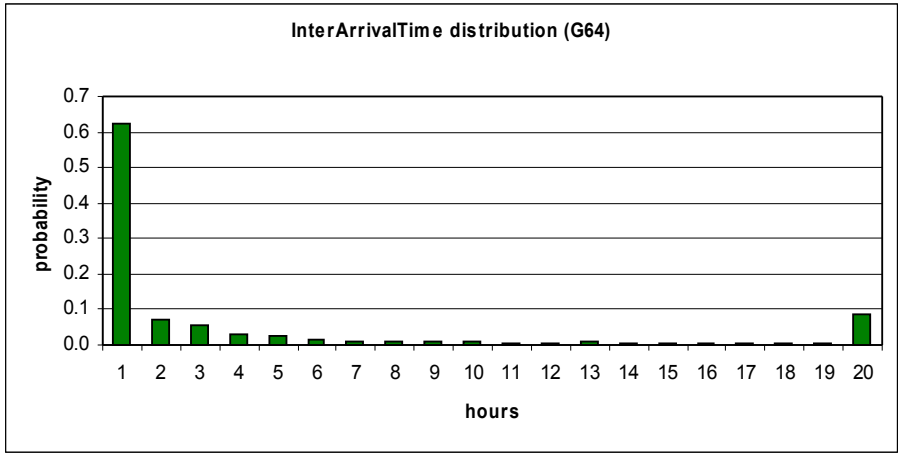

Lifetime distribution (C64)
probability
0.6
0.5
0.4
0.3
0.2
0.1
0.0
2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40
days

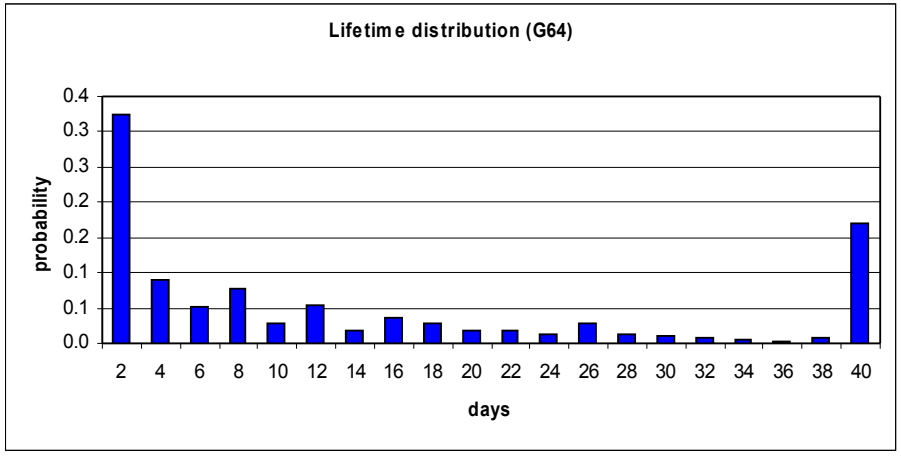

InterArrivalTime distribution (B64)
probability
0.6
0.5
0.4
0.3
0.2
0.1
0.0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
hours

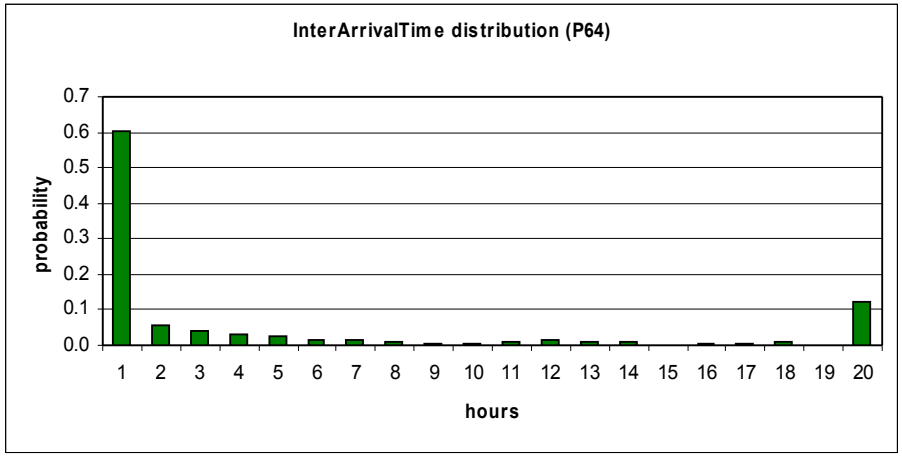

Lifetime distribution (B64)
probability
0.5
0.4
0.3
0.2
0.1
0.0
2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40
days

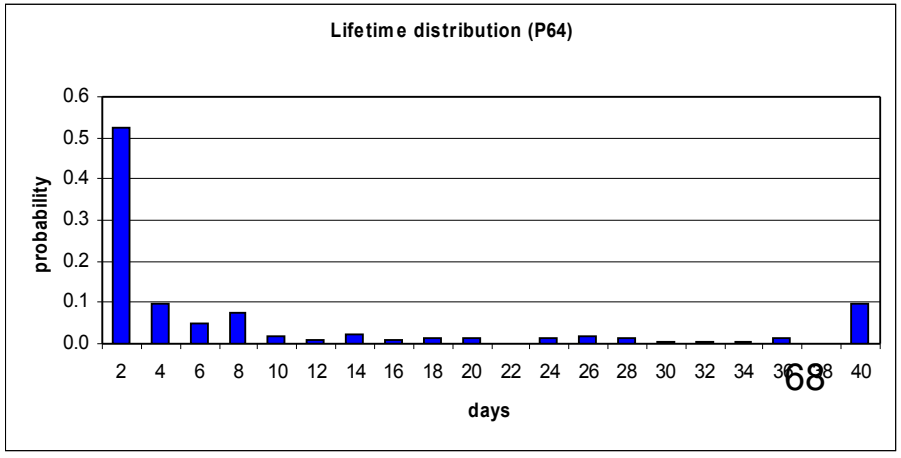

InterArrivalTime distribution (S64)
probability
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
hours


Lifetime distribution (S64)
probability
0.6
0.5
0.4
0.3
0.2
0.1
0.0
2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40
days


InterArrivalTime distribution (G64)
probability
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
hours

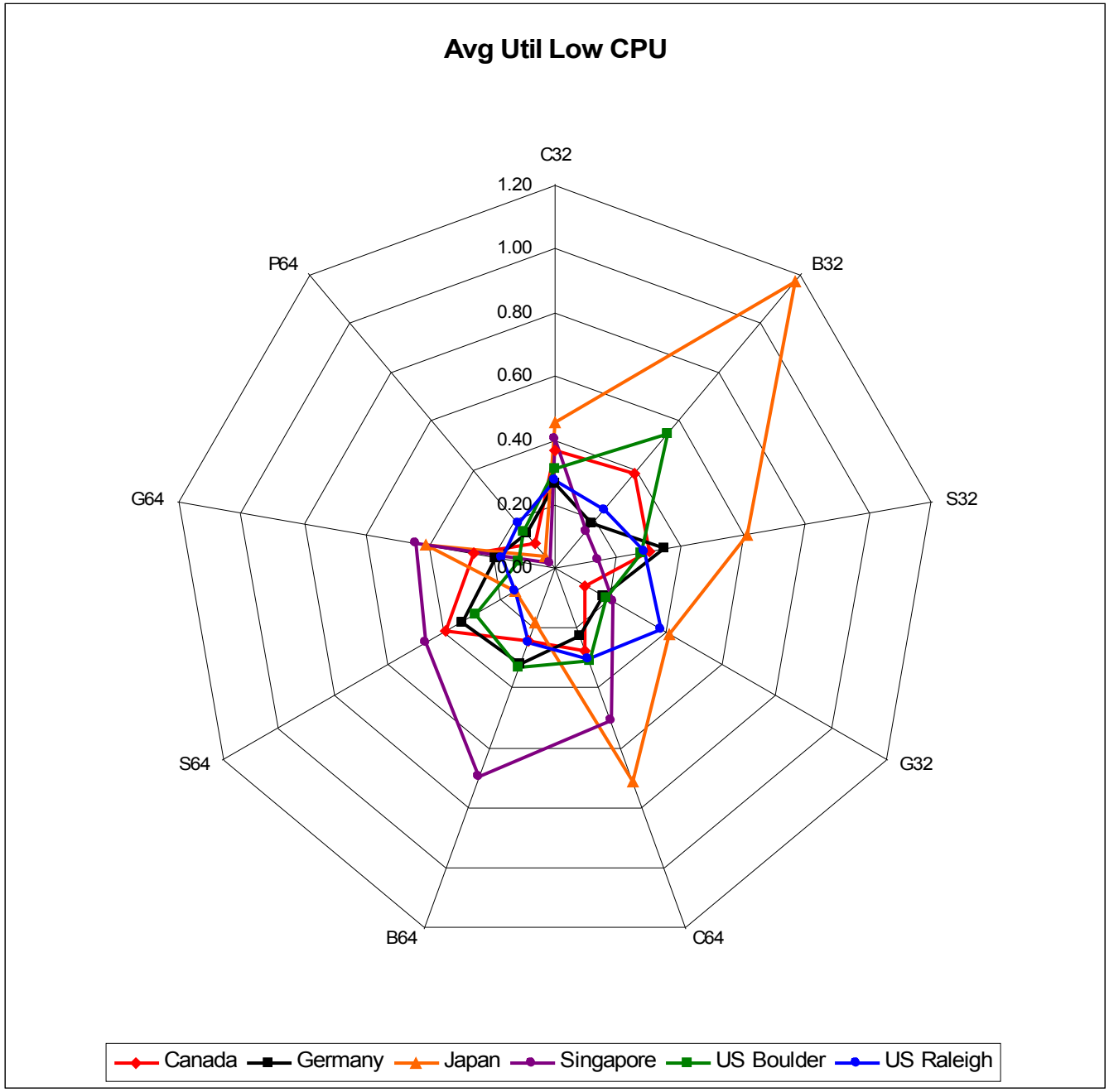

Lifetime distribution (G64)
probability
0.4
0.3
0.3
0.2
0.2
0.1
0.1
0.0
2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40
days

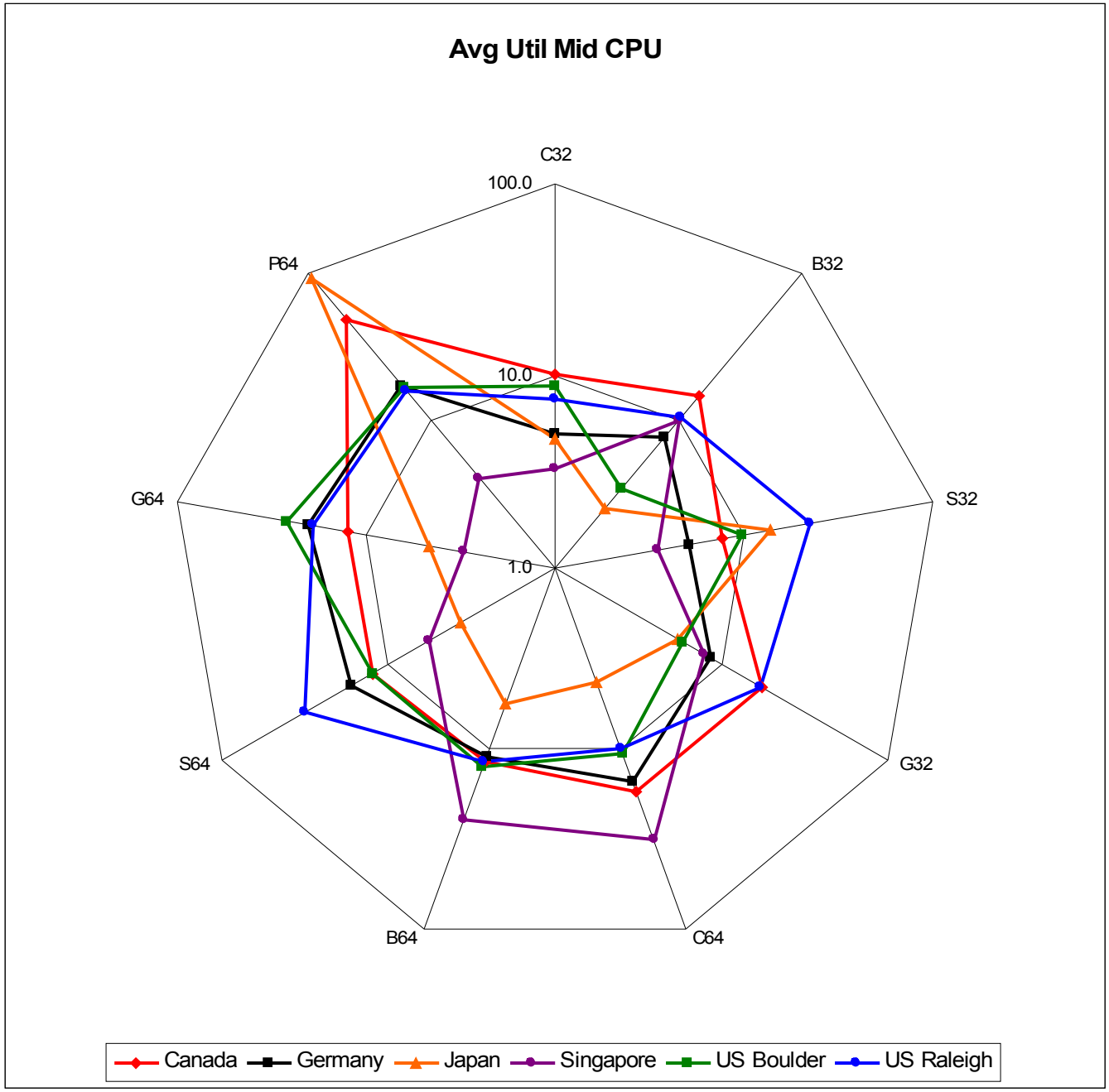

InterArrivalTime distribution (P64)
probability
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
hours


Lifetime distribution (P64)
probability
0.6
0.5
0.4
0.3
0.2
0.1
0.0
2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40
days

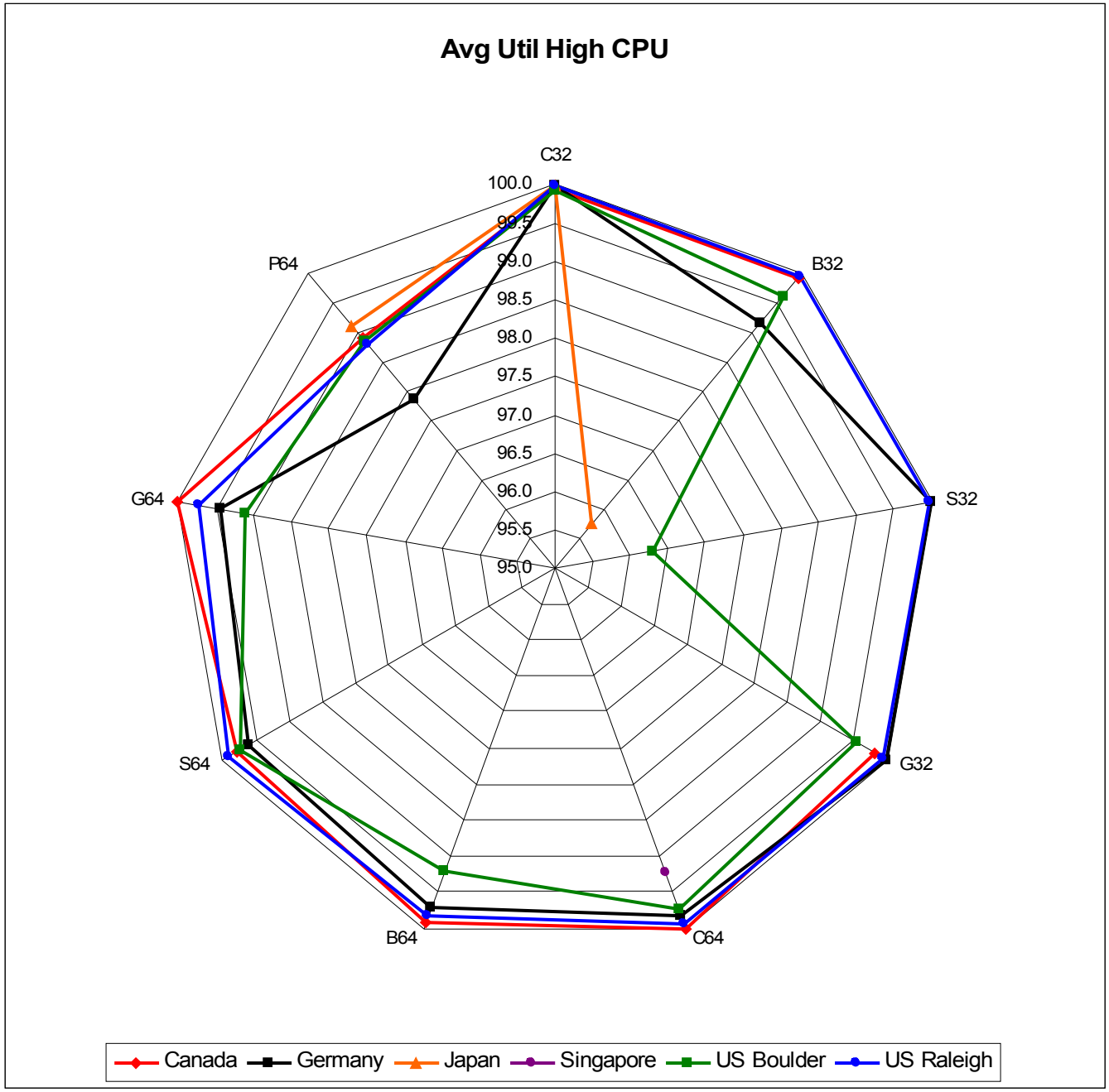
CPU Usage Analysis

(per Datacenter)


Avg Util Low CPU
C32
B32
S32
G32
C64
B64
S64
G64
P64
1.20
1.00
0.80
0.60
0.40
0.20
0.00
Canada
Germany
Japan
Singapore
US Boulder
US Raleigh



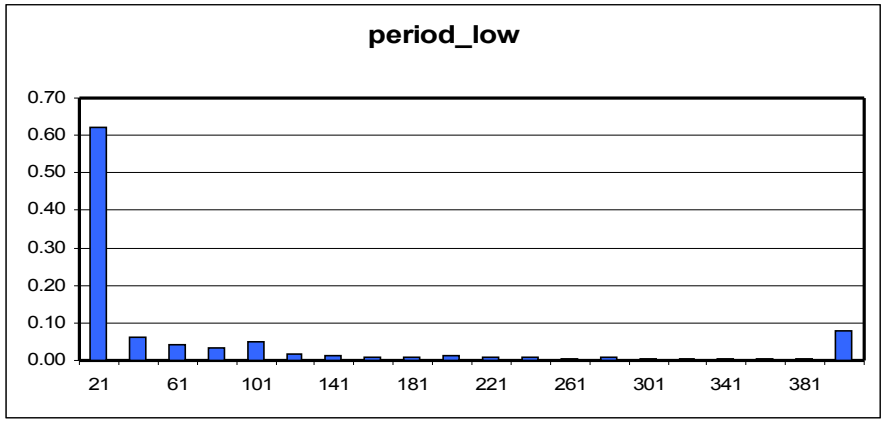
Note: Log scale used.

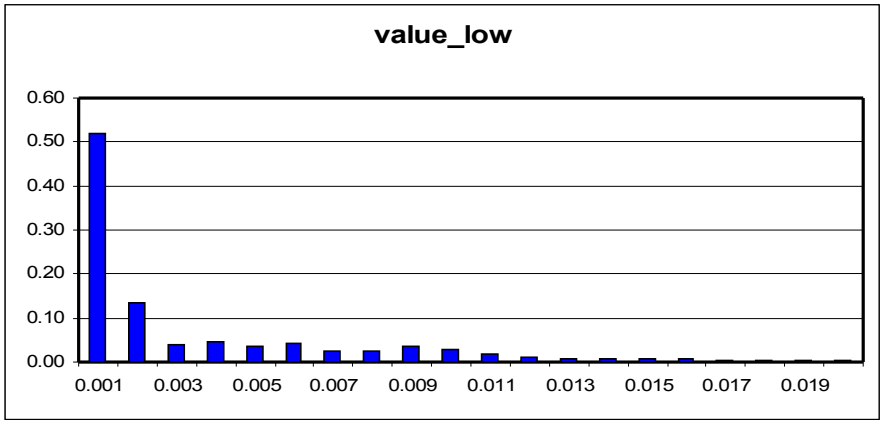

Avg Util High CPU
C32
B32
S32
G32
C64
B64
S64
G64
P64
100.0
99.5
99.0
98.5
98.0
97.5
97.0
96.5
96.0
95.5
95.0
Canada
Germany
Japan
Singapore
US Boulder
US Raleigh

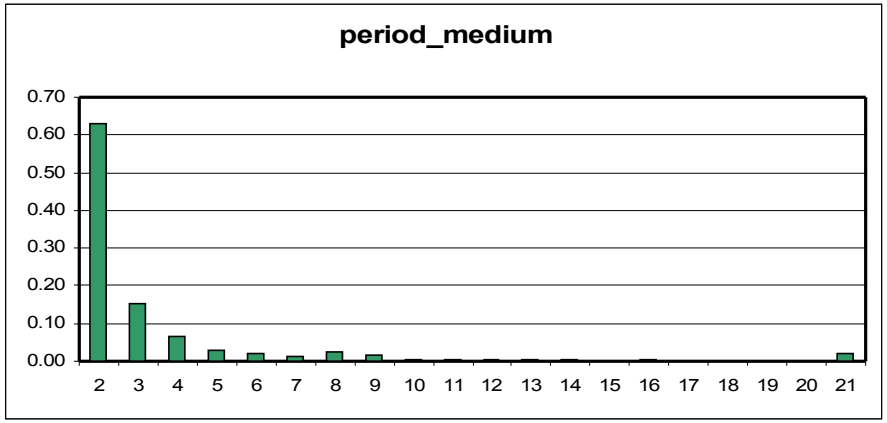
CPU Usage Analysis

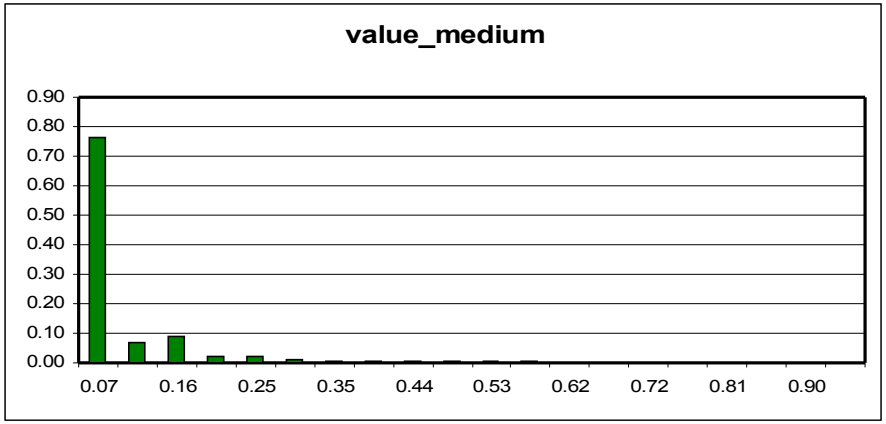
(Histograms)

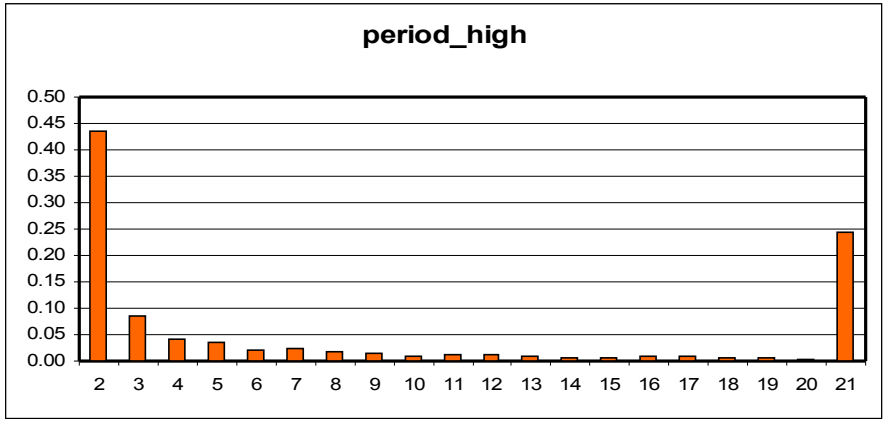
Copper 32


period_low
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
21
61
101
141
181
221
261
301
341
381


value_low
0.60
0.50
0.40
0.30
0.20
0.10
0.00
0.001
0.003
0.005
0.007
0.009
0.011
0.013
0.015
0.017
0.019


period_medium
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21


value_medium
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
0.07
0.16
0.25
0.35
0.44
0.53
0.62
0.72
0.81
0.90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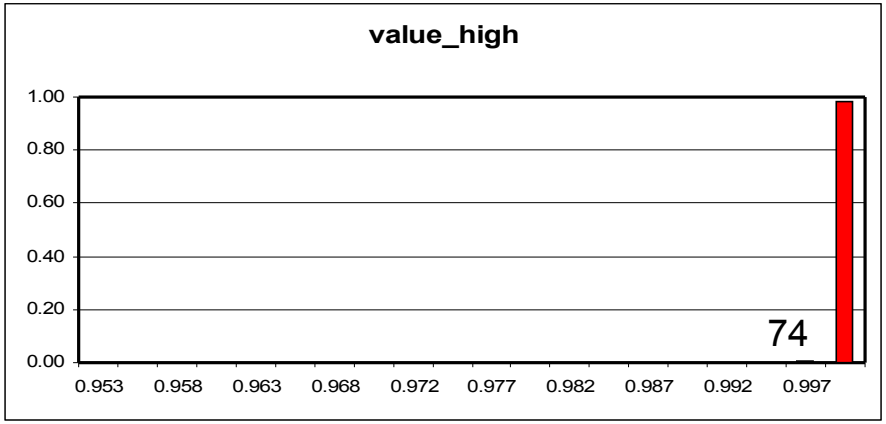
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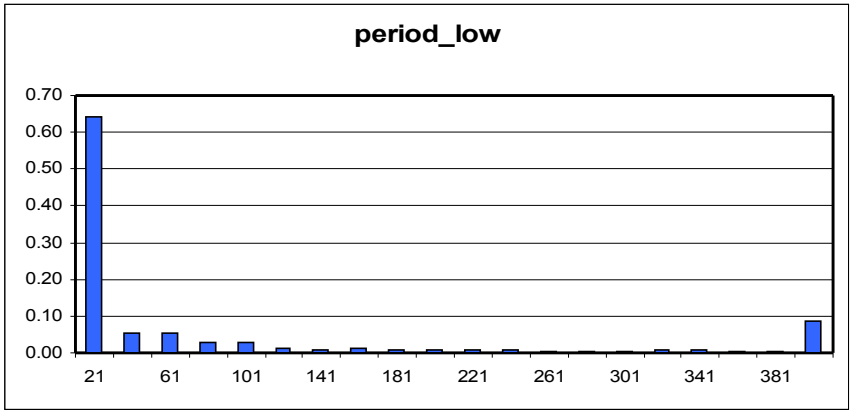
Bronze 32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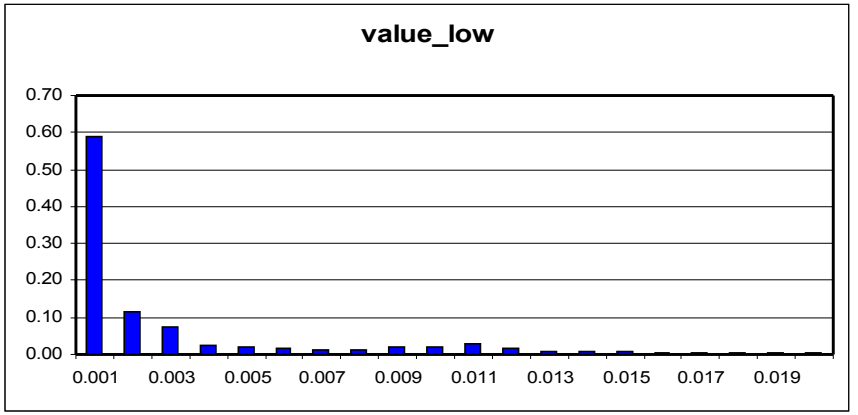
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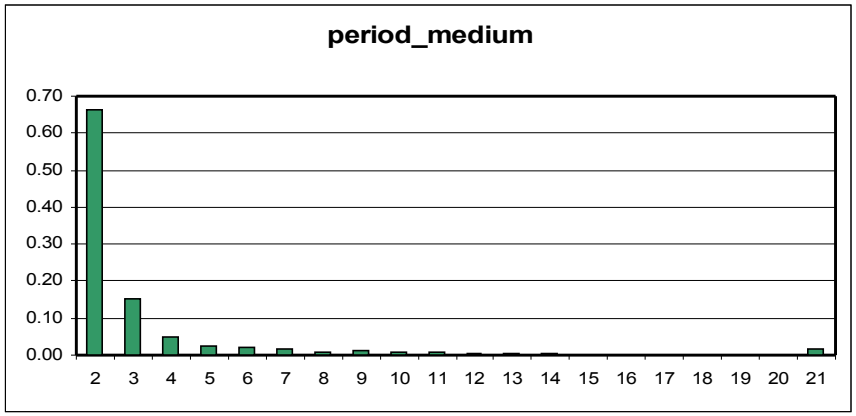
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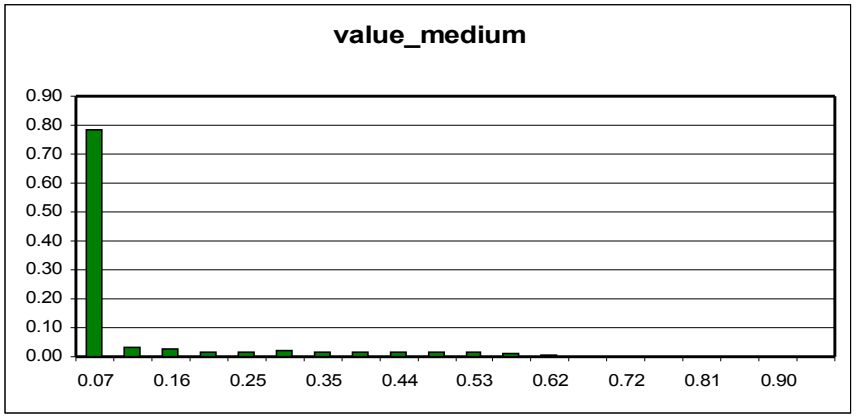
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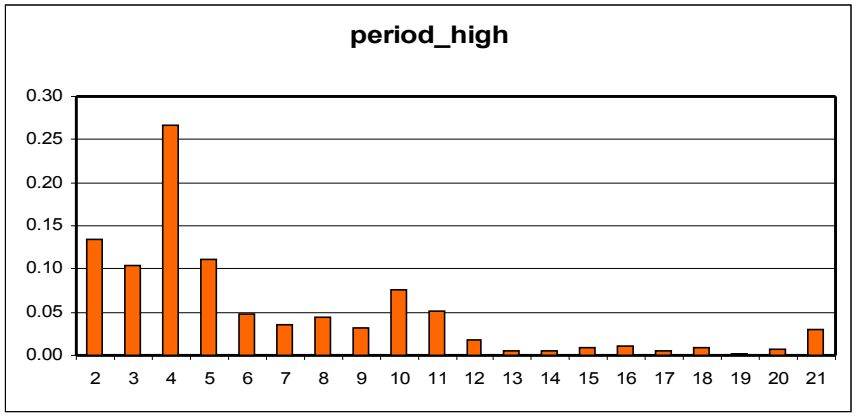
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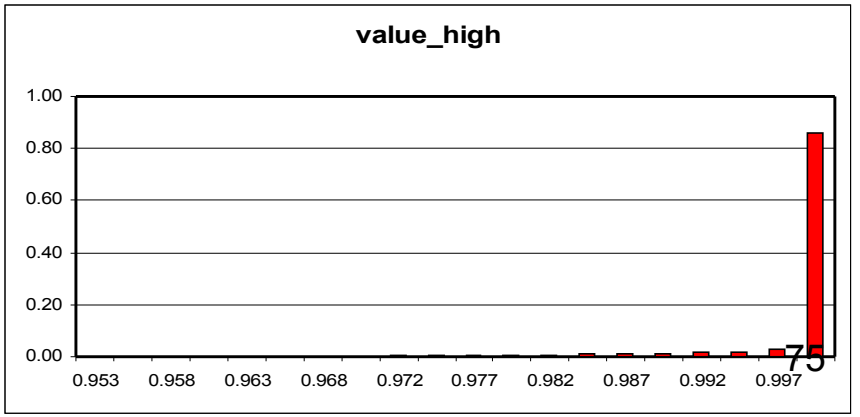
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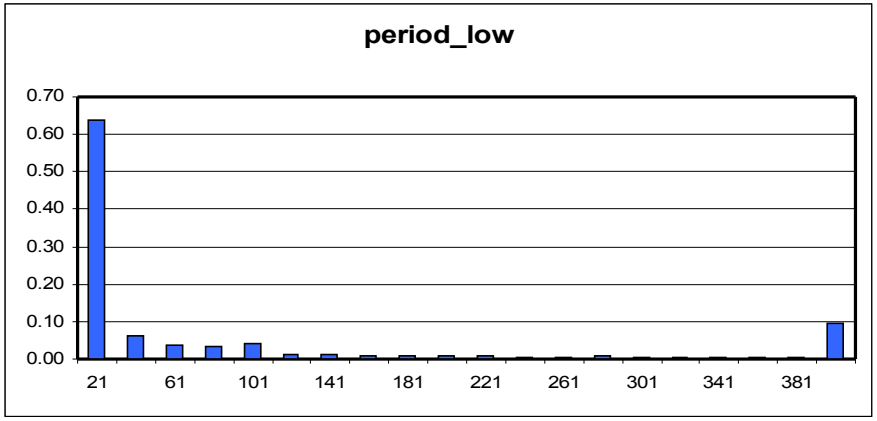
Silver 32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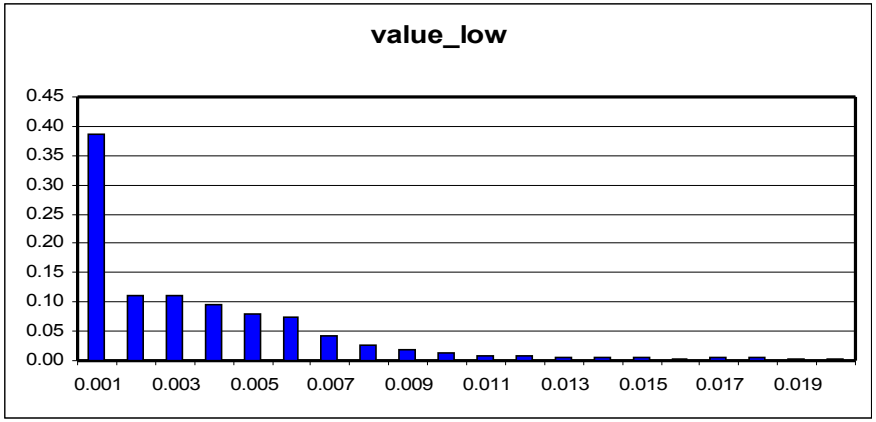
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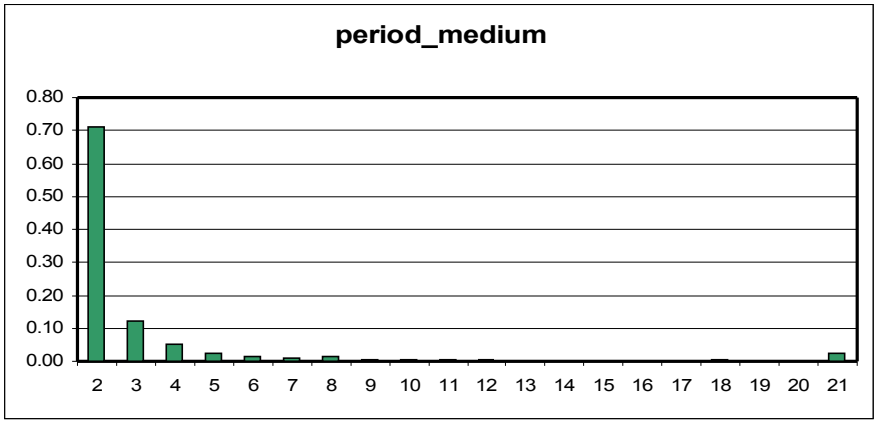
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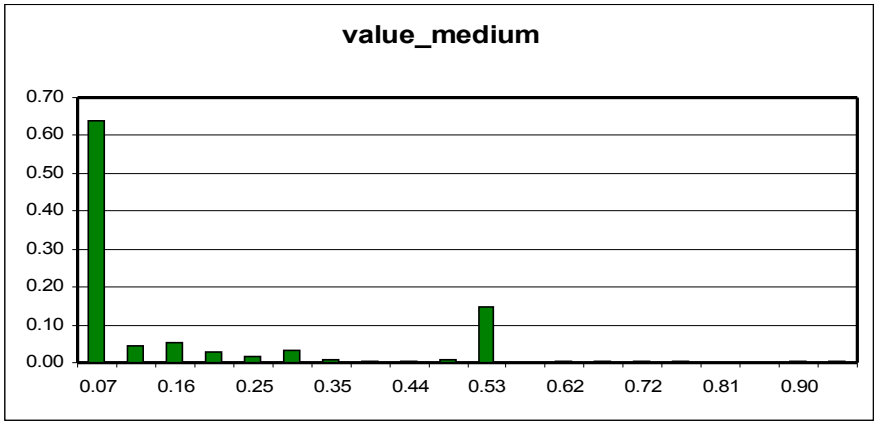
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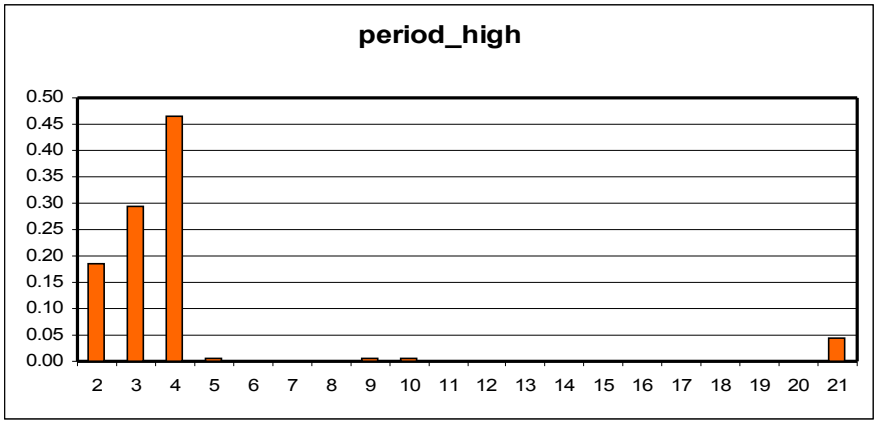
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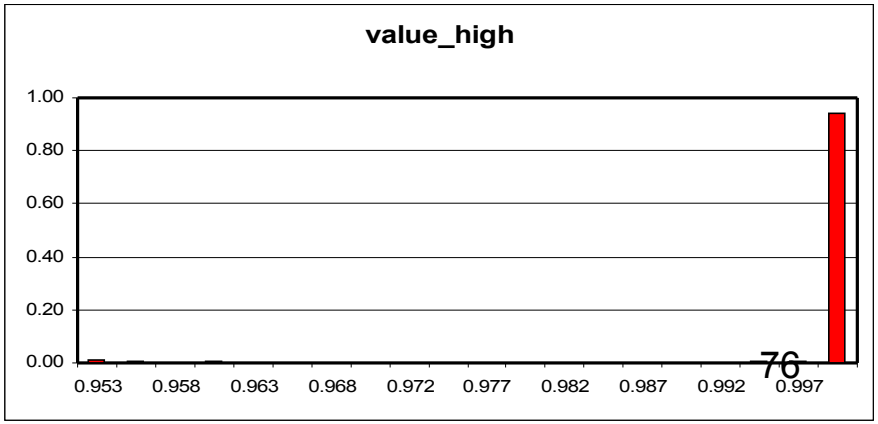
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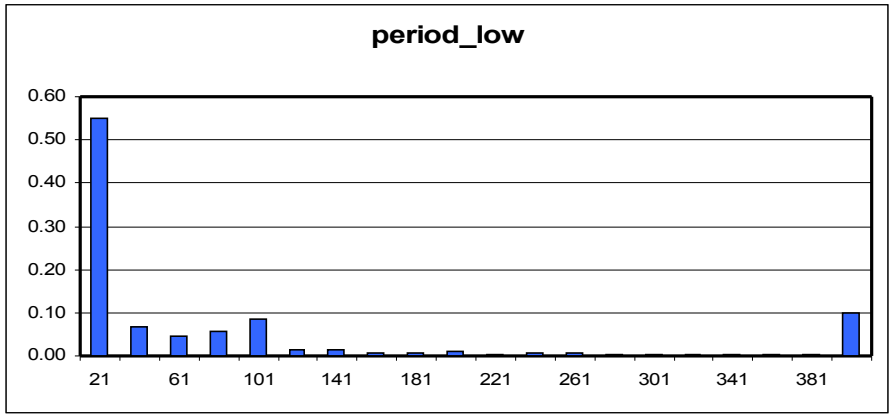
Gold 32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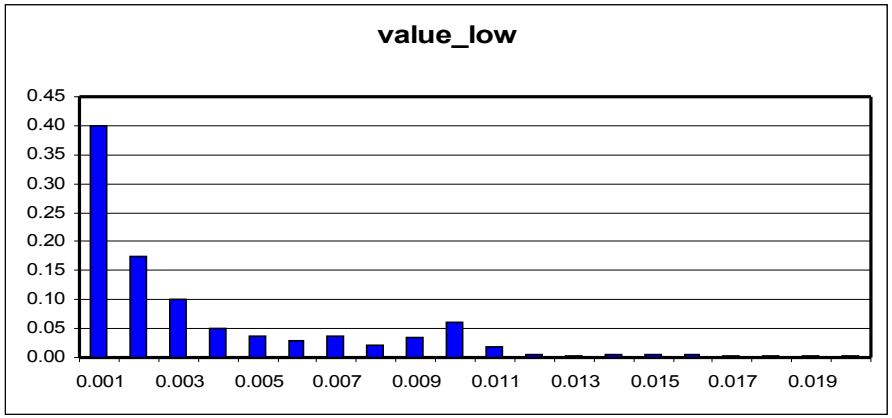
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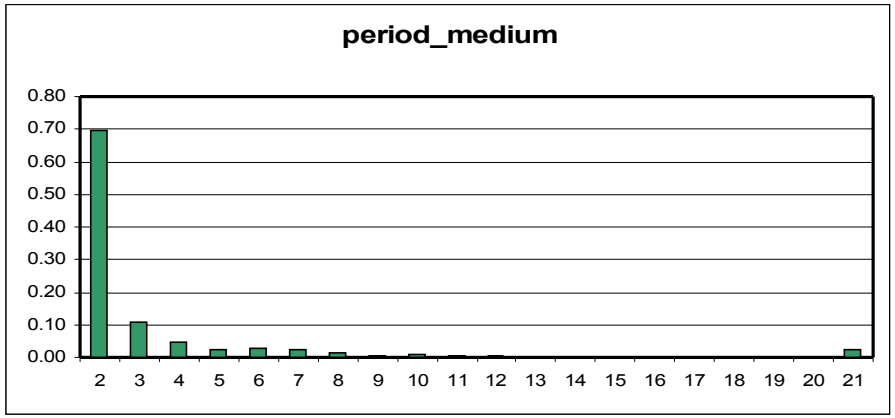
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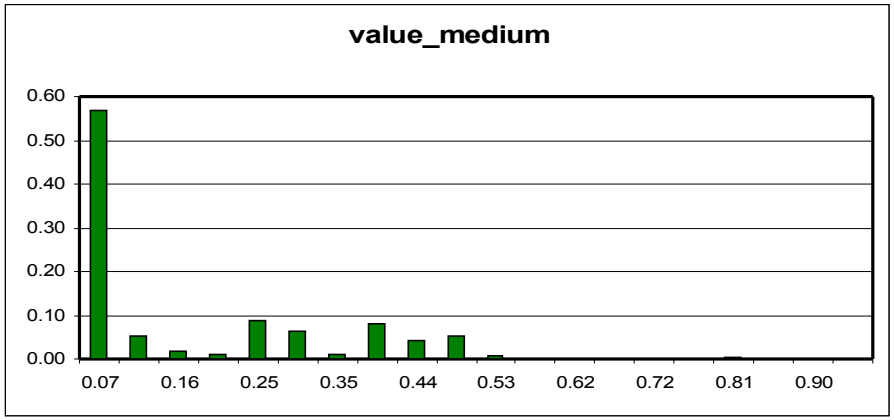
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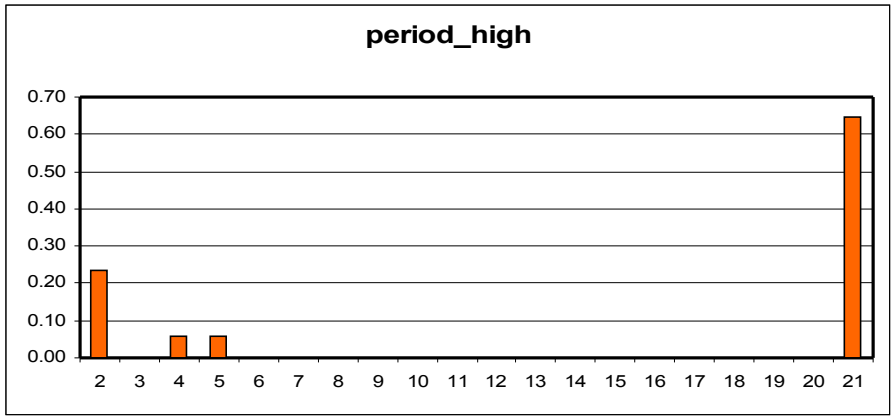
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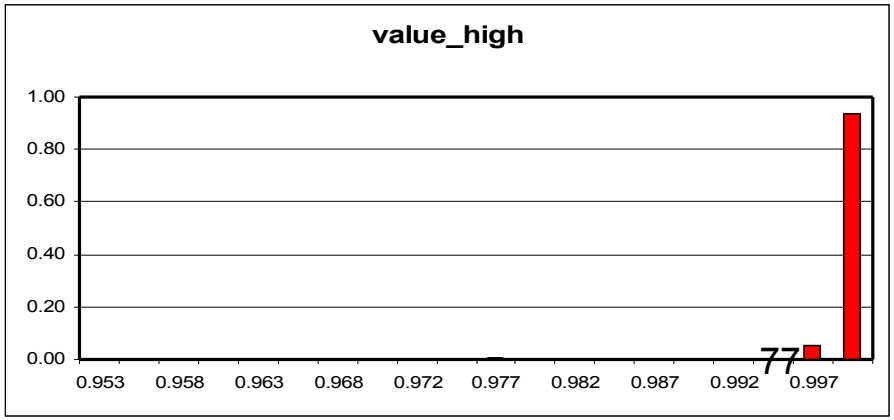
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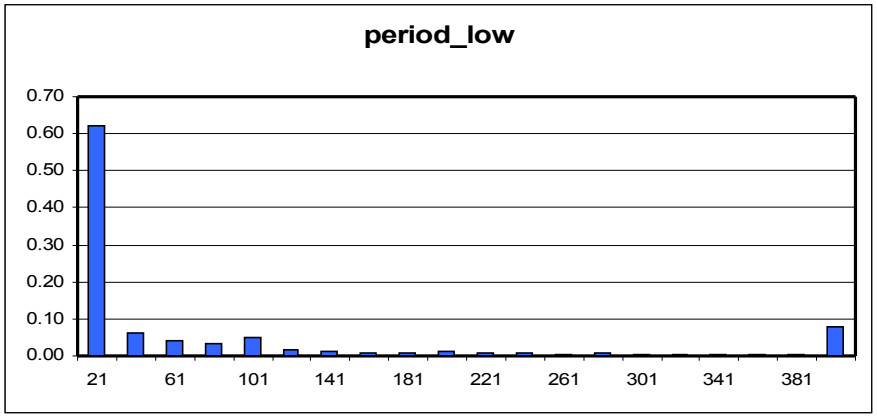
Copper 64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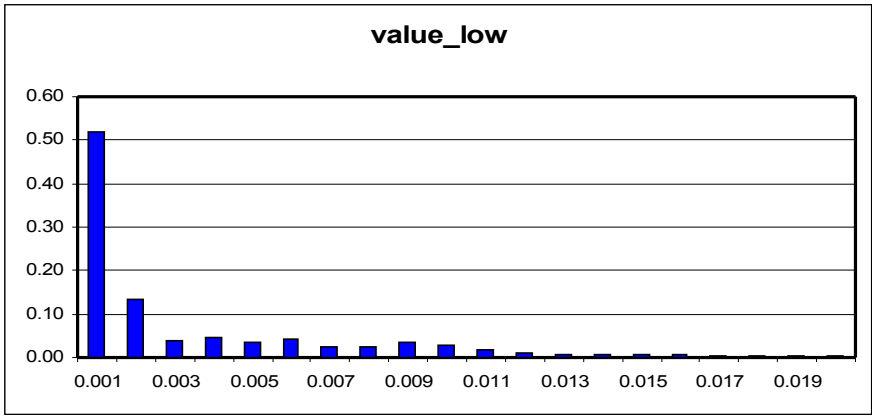
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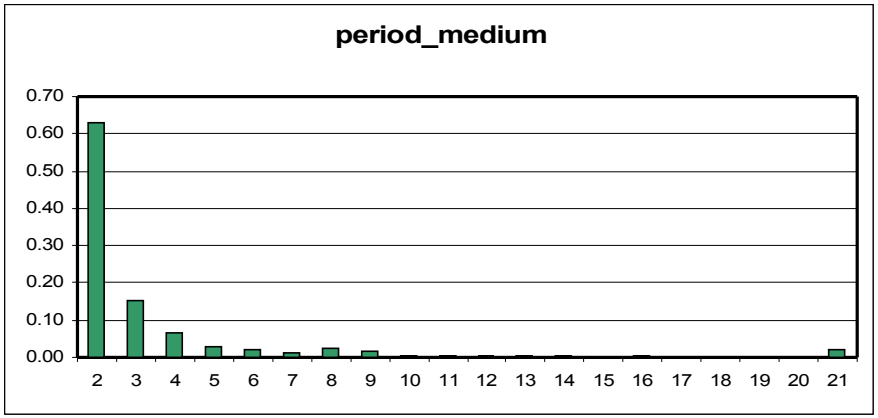
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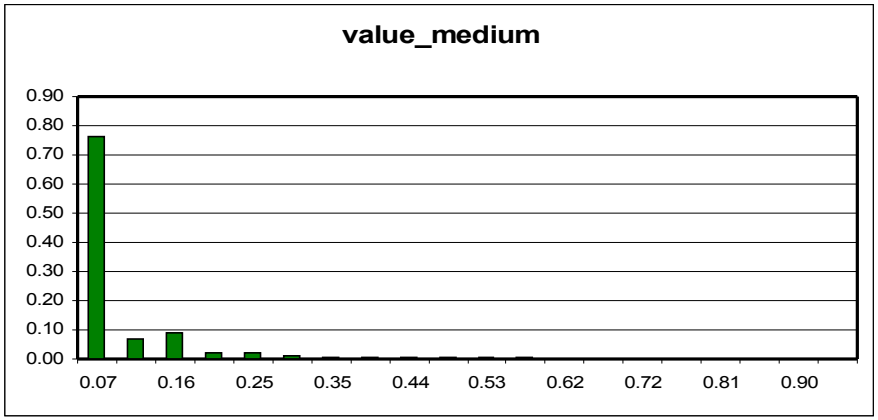
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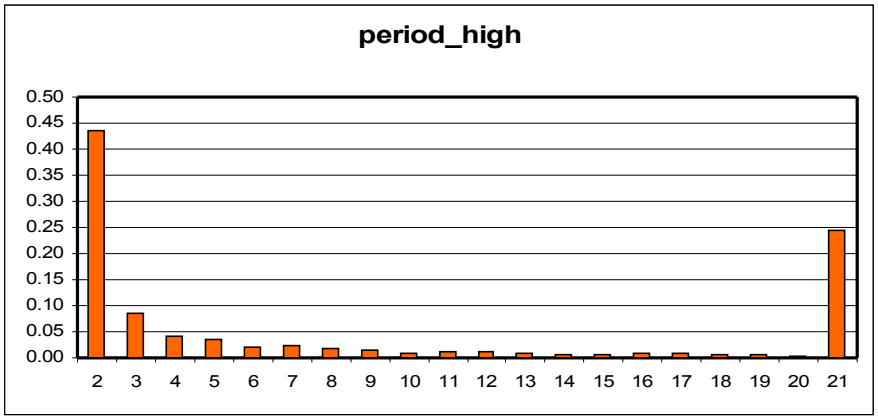
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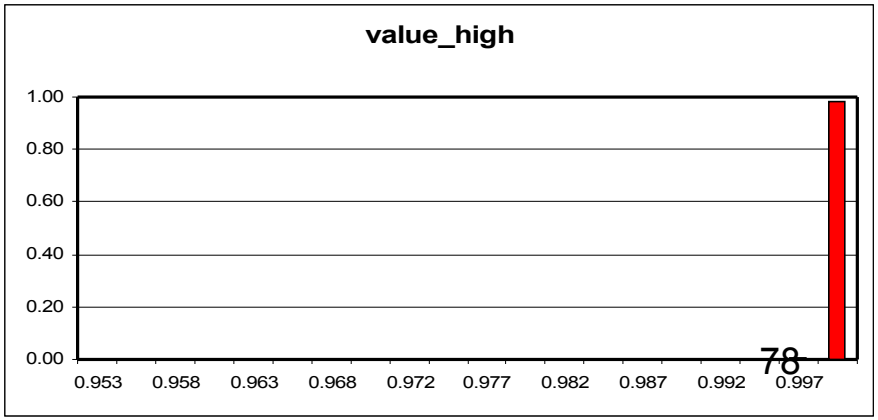
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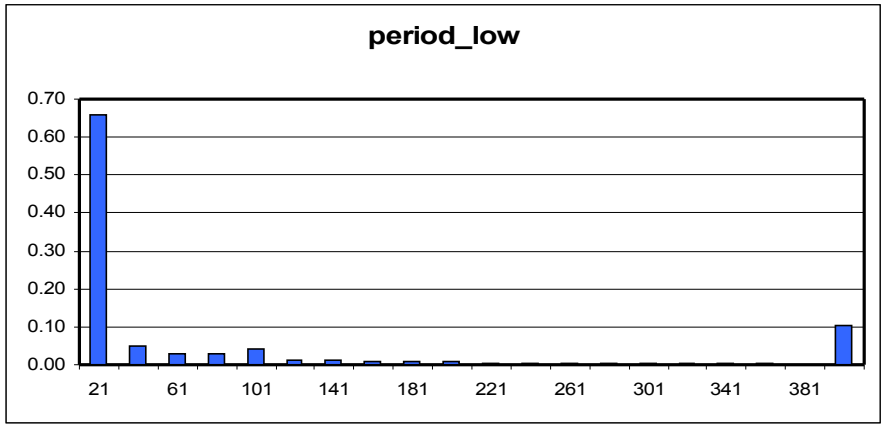
Bronze 64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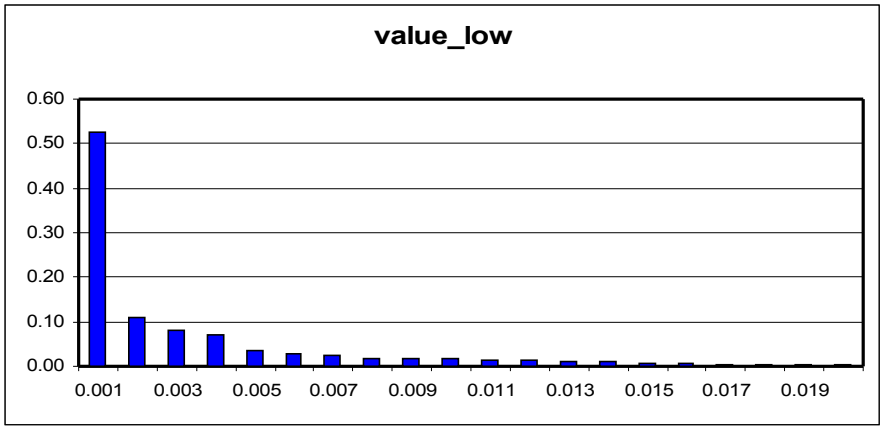
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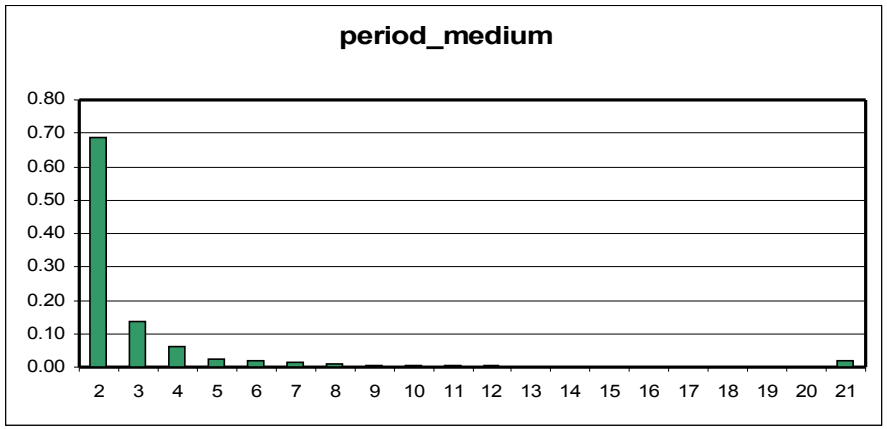
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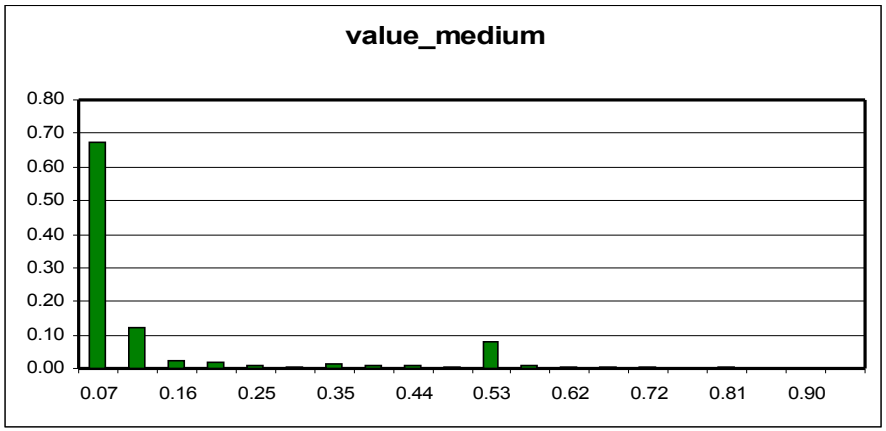
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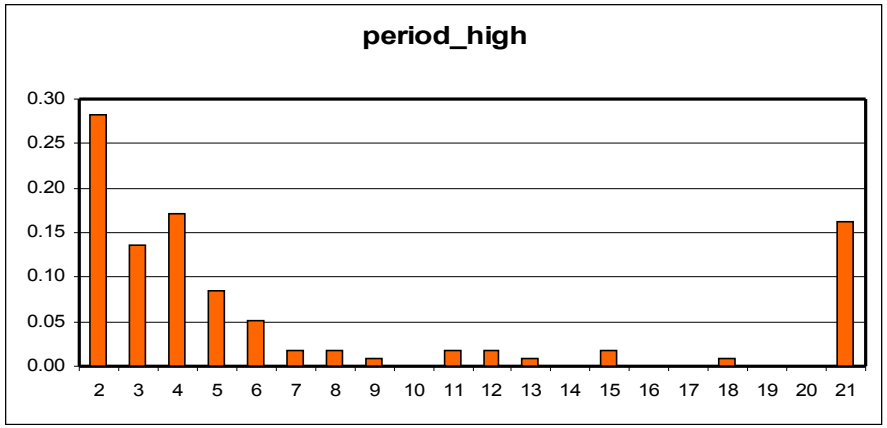
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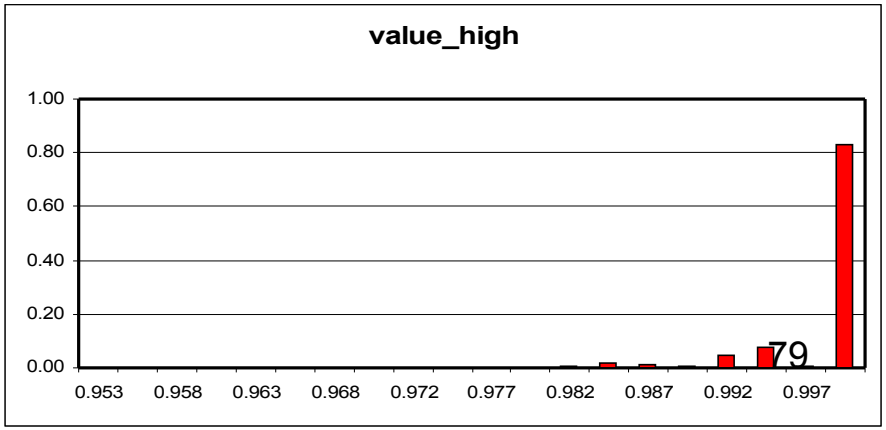
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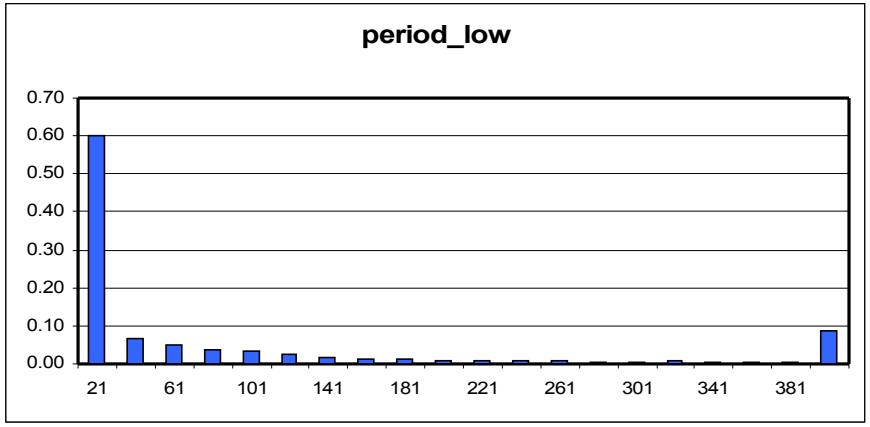
Silver 64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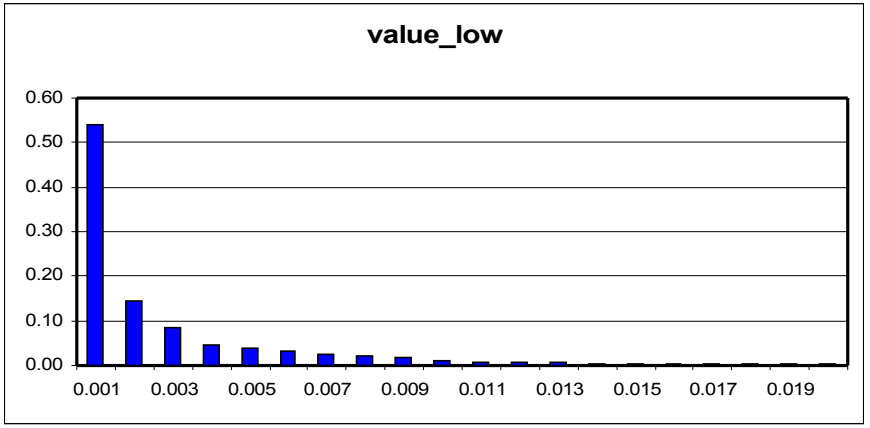
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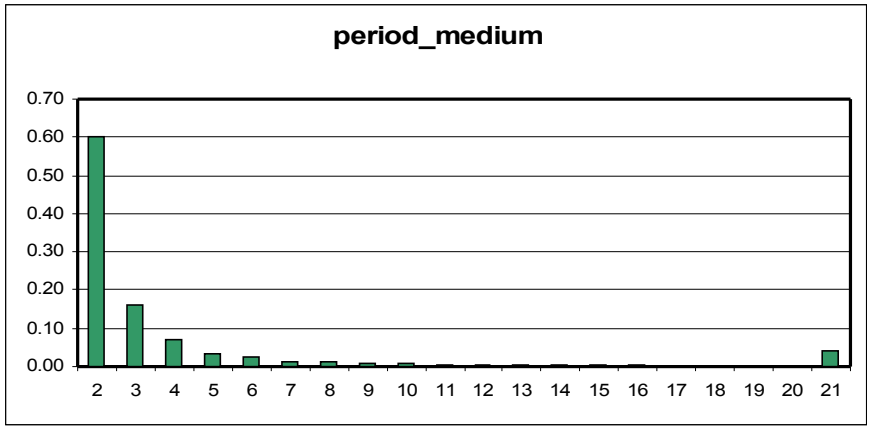
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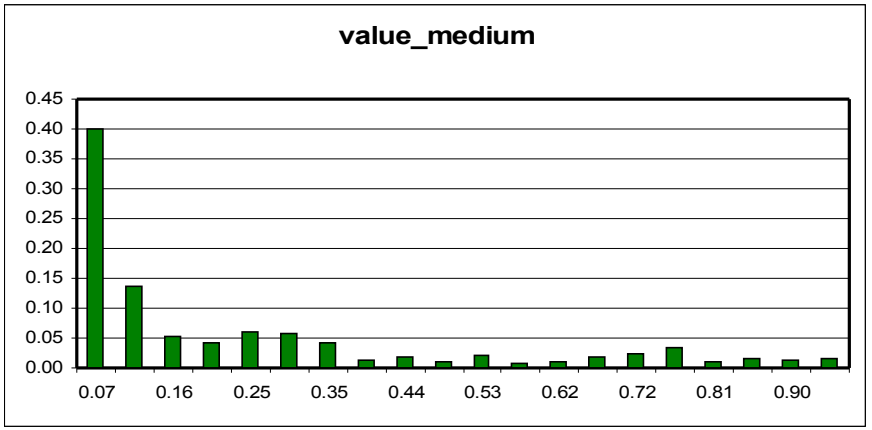
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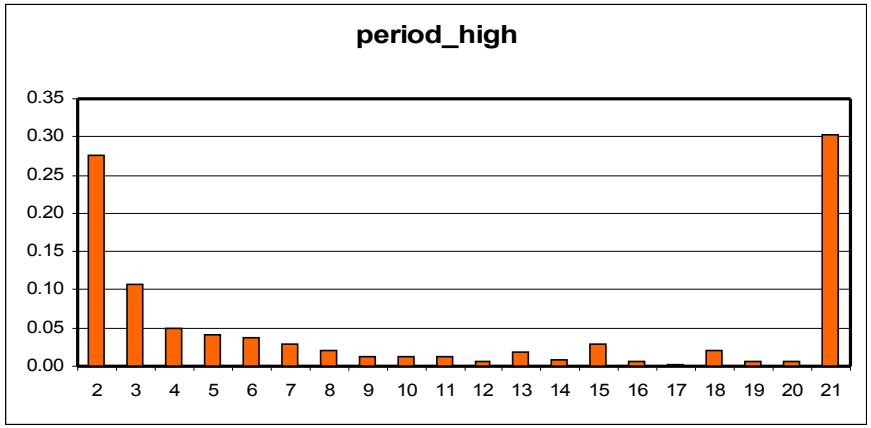
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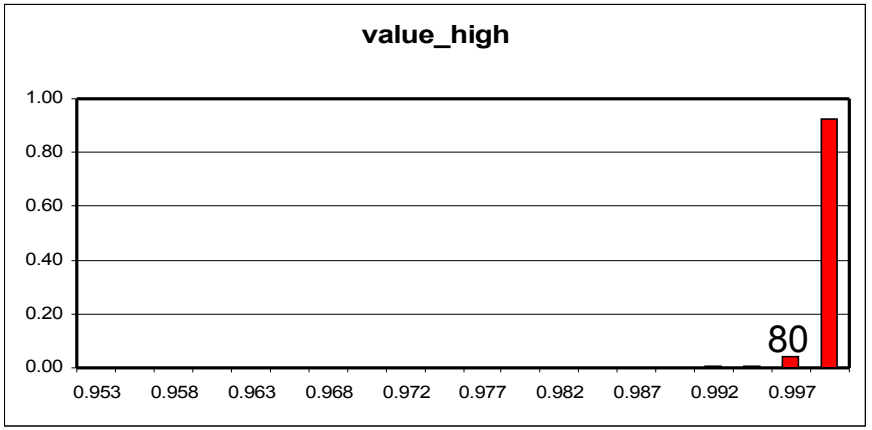
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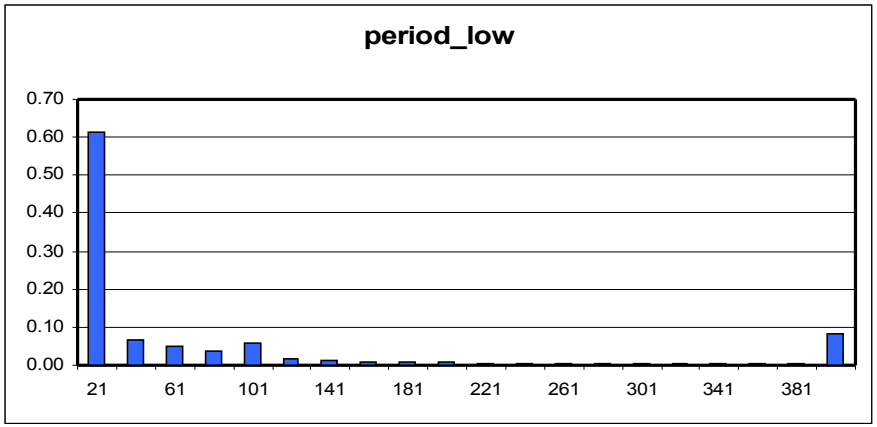
Gold 64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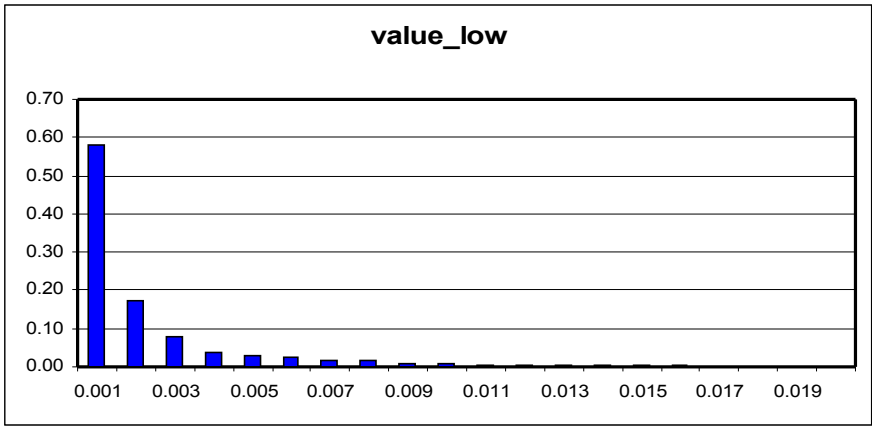
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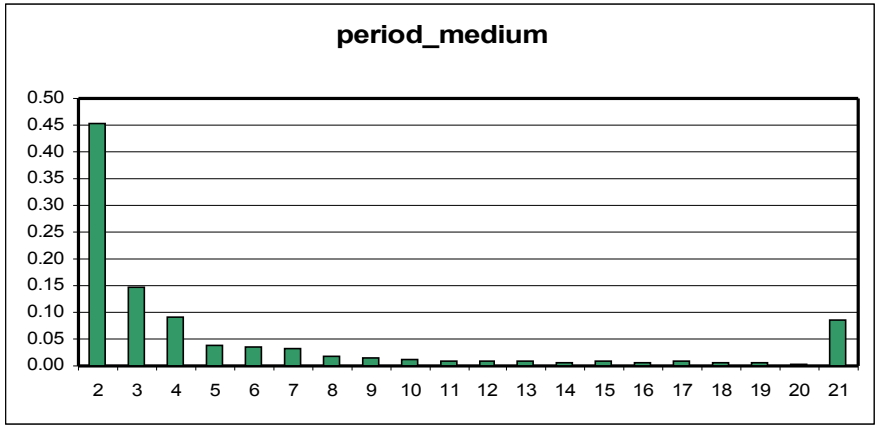
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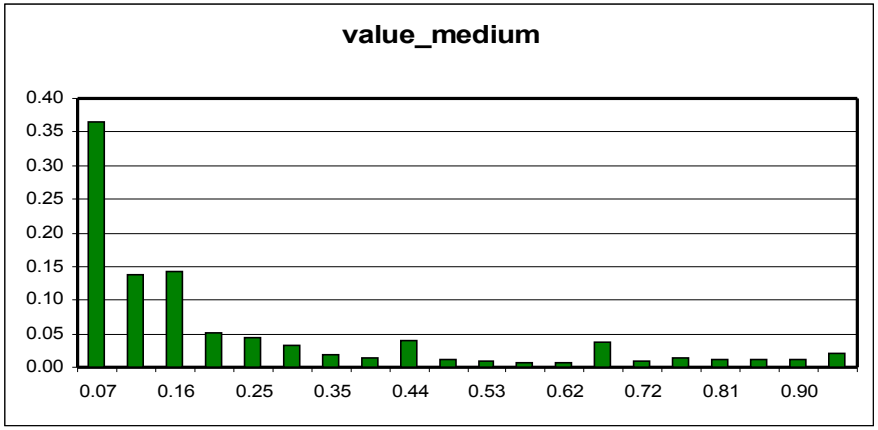
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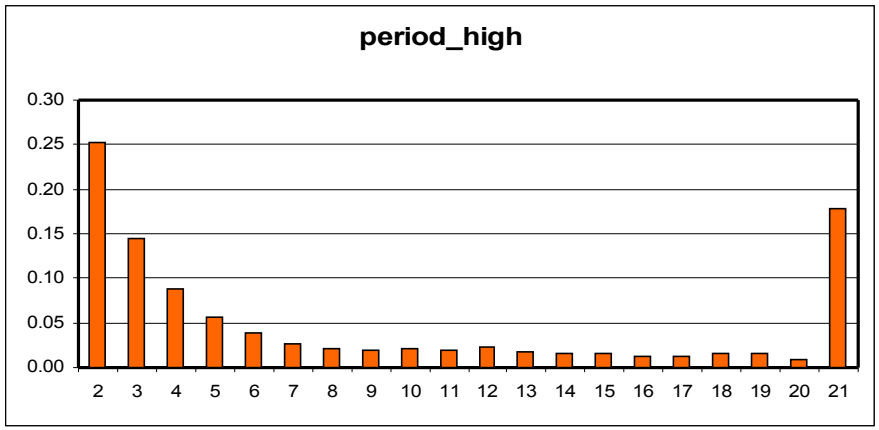
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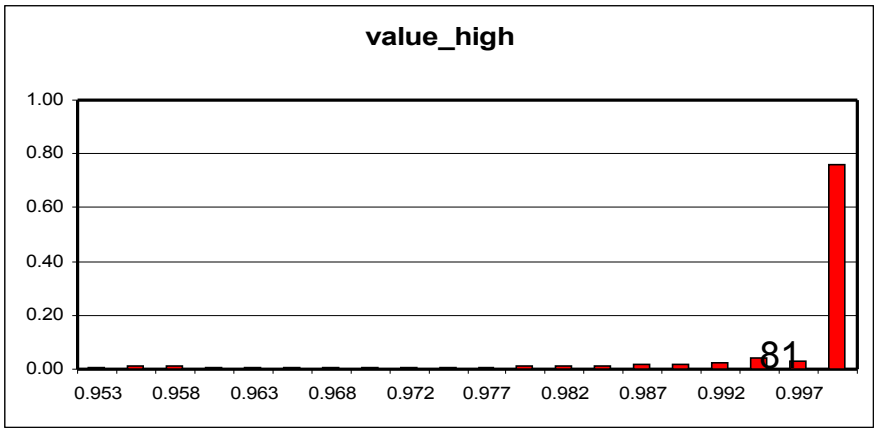
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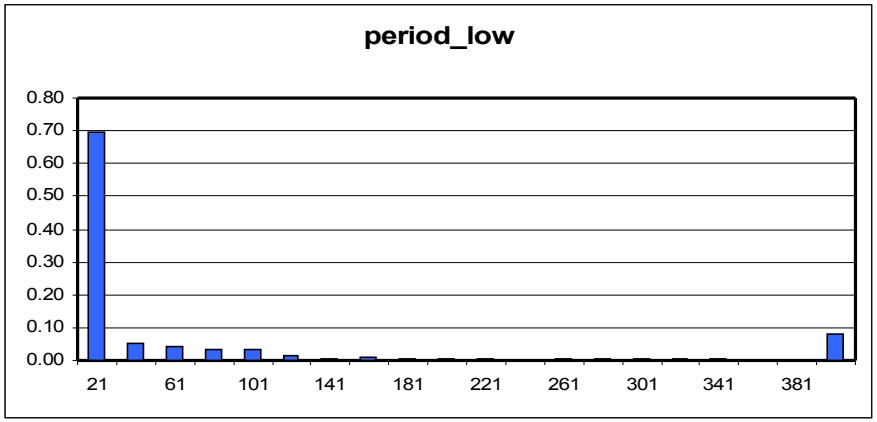
Platinum64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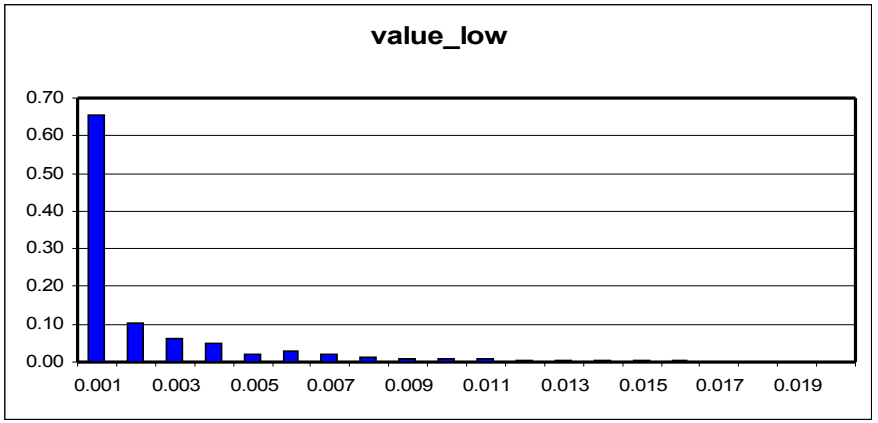
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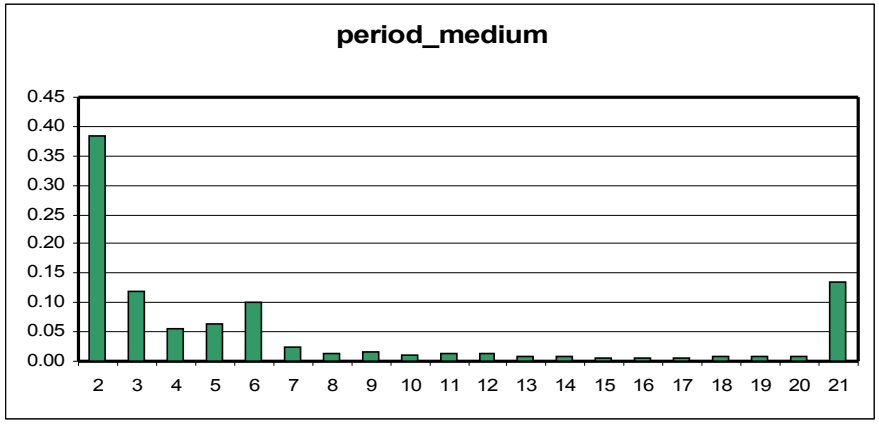
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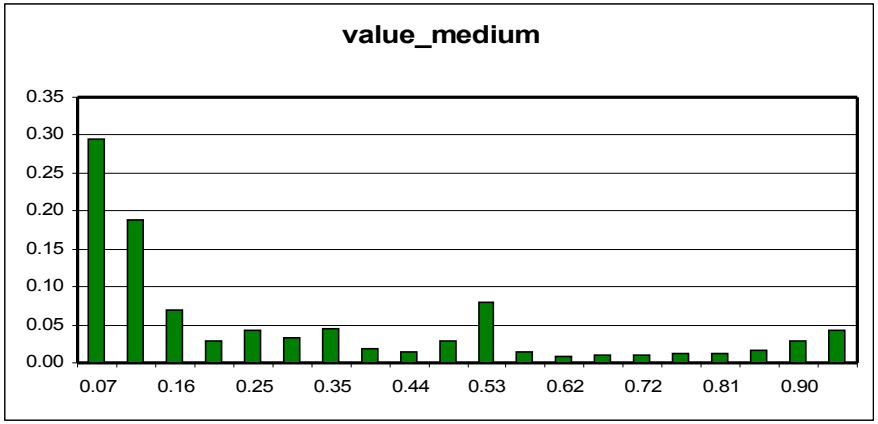
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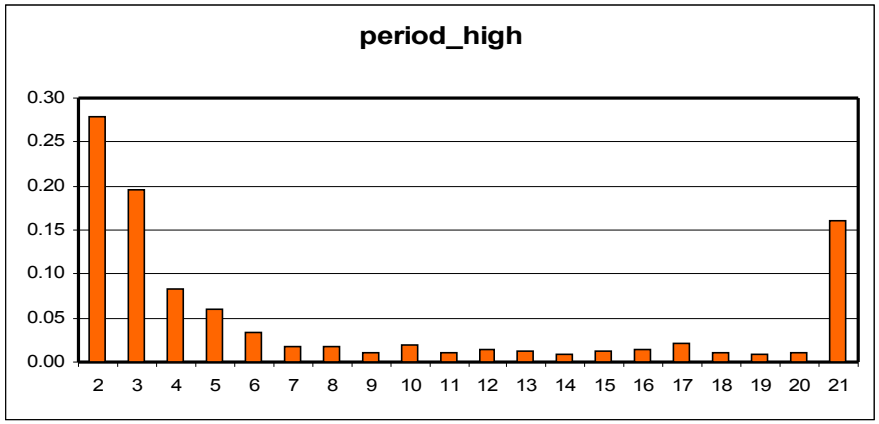
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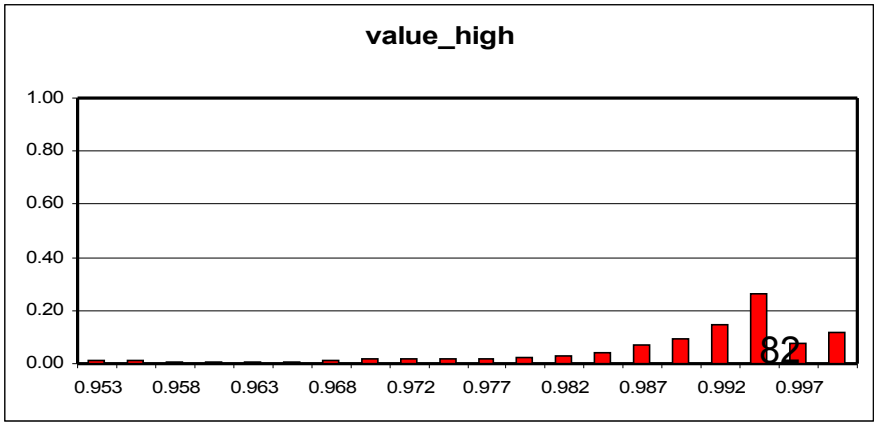
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0.992
0.997

CPU statistics

(per Datacenter)

Canada Datacenter

	C32	B32	S32	G32	C64	B64	S64	G64	P64
Low-usage (0% - 2%)									
Probability	0.940	0.897	0.884	0.893	0.959	0.965	0.928	0.889	0.644
Period (hrs)									
Average	23.775	20.947	26.319	50.056	50.441	42.633	39.637	111.729	55.742
StdDev	111.004	86.176	82.416	110.759	152.819	108.113	115.546	263.205	259.547
Utilization (%)									
Average	0.367	0.383	0.300	0.110	0.276	0.242	0.391	0.259	0.100
StdDev	0.402	0.424	0.393	0.212	0.334	0.308	0.440	0.366	0.239
Mid-usage (2% - 95%)									
Probability	0.045	0.103	0.116	0.064	0.038	0.035	0.039	0.100	0.311
Period (hrs)									
Average	1.198	2.249	3.412	3.225	2.086	1.493	1.708	11.357	9.709
StdDev	16.831	42.673	43.104	11.660	32.434	22.358	19.841	79.673	24.727
Utilization(%)									
Average	10.299	15.021	7.794	17.435	17.461	11.787	12.528	12.458	48.496
StdDev	17.606	13.196	11.116	11.766	18.094	15.116	14.228	5.463	22.851
High-usage (95% - 100%)									
Probability	0.014	0.000	0.000	0.043	0.003	0.000	0.033	0.011	0.045
Period (hrs)									
Average	19.002	0.625	0.000	697.750	81.042	3.792	390.167	104.917	2.520
StdDev	103.394	0.375	0.000	67.500	116.927	7.369	200.562	142.751	2.365
Utilization(%)									
Average	99.928	99.942	0.000	99.805	99.991	99.918	99.782	100.000	98.911
StdDev	0.467	0.116	0.000	0.093	0.111	0.394	0.257	0.000	1.235
numCores	1	1	2	4	2	2	4	8	16
numVmProcessed	1269	52	72	180	828	201	372	199	251

Germany Datacenter

	C32	B32	S32	G32	C64	B64	S64	G64	P64
Low-usage (0% - 2%)									
Probability	0.923	0.855	0.941	0.938	0.926	0.928	0.911	0.935	0.954
Period (hrs)									
Average	29.134	16.278	18.696	51.166	29.540	18.612	25.193	28.721	92.343
StdDev	100.858	128.556	81.735	140.979	131.724	107.929	89.674	178.116	447.579
Utilization (%)									
Average	0.265	0.181	0.346	0.178	0.228	0.323	0.339	0.193	0.141
StdDev	0.383	0.350	0.401	0.236	0.330	0.439	0.396	0.312	0.324
Mid-usage (2% - 95%)									
Probability	0.067	0.134	0.058	0.062	0.065	0.072	0.088	0.057	0.043
Period (hrs)									
Average	2.095	2.202	1.133	3.284	2.058	1.425	2.419	1.615	3.181
StdDev	34.493	43.832	18.267	19.170	29.496	27.110	42.145	7.815	7.225
Utilization(%)									
Average	4.993	7.773	5.049	8.475	15.268	11.127	16.774	20.147	17.415
StdDev	8.004	13.474	9.295	9.014	21.124	14.663	18.346	22.927	24.663
High-usage (95% - 100%)									
Probability	0.010	0.012	0.000	0.000	0.009	0.000	0.001	0.008	0.002
Period (hrs)									
Average	30.235	1.322	3.700	5.250	39.998	1.205	4.380	3.498	0.621
StdDev	145.115	1.214	6.528	0.000	113.183	1.641	13.579	8.267	1.120
Utilization(%)									
Average	99.979	99.169	99.972	99.983	99.806	99.702	99.611	99.425	97.862
StdDev	0.186	1.044	0.239	0.002	0.440	0.773	1.159	1.261	0.852
numCores	1	1	2	4	2	2	4	8	16
numVmProcessed	3550	214	115	406	2605	382	456	330	149

Japan Datacenter

	C32	B32	S32	G32	C64	B64	S64	G64	P64
Low-usage (0% - 2%)									
Probability	0.728	0.485	0.759	0.994	0.922	0.997	0.978	0.332	0.831
Period (hrs)									
Average	4.182	0.664	38.893	52.500	11.309	112.881	50.005	21.750	310.167
StdDev	28.242	2.913	96.751	117.341	36.971	66.830	79.631	28.088	108.390
Utilization (%)									
Average	0.455	1.168	0.609	0.415	0.707	0.182	0.142	0.407	0.044
StdDev	0.605	0.777	0.542	0.430	0.617	0.329	0.262	0.111	0.057
Mid-usage (2% - 95%)									
Probability	0.256	0.515	0.241	0.006	0.078	0.003	0.022	0.668	0.037
Period (hrs)									
Average	1.467	0.878	12.523	0.310	0.964	0.325	1.115	26.306	4.100
StdDev	11.092	1.639	59.607	0.128	8.836	0.275	5.024	72.461	4.108
Utilization(%)									
Average	4.663	2.521	13.789	5.449	4.271	5.617	3.743	4.641	92.715
StdDev	6.832	2.243	4.495	5.744	4.589	3.016	4.449	0.810	7.561
High-usage (95% - 100%)									
Probability	0.016	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.132
Period (hrs)									
Average	38.786	0.250	0.000	0.000	0.000	0.000	0.000	0.000	16.225
StdDev	134.284	0.000	0.000	0.000	0.000	0.000	0.000	0.000	26.262
Utilization(%)									
Average	99.984	95.744	0.000	0.000	0.000	0.000	0.000	0.000	99.109
StdDev	0.211	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.912
numCores	1	1	2	4	2	2	4	8	16
numVmProcessed	446	12	15	7	207	8	41	2	15

Singapore Datacenter

	C32	B32	S32	G32	C64	B64	S64	G64	P64
Low-usage (0% - 2%)									
Probability	0.954	0.996	0.981	0.986	0.979	0.984	0.960	0.999	0.997
Period (hrs)									
Average	10.232	88.812	45.321	1.250	26.531	34.896	27.325	237.125	112.107
StdDev	35.758	80.531	68.131	0.000	52.458	53.907	58.861	82.875	185.551
Utilization (%)									
Average	0.402	0.151	0.132	0.207	0.508	0.692	0.466	0.442	0.019
StdDev	0.481	0.174	0.268	0.293	0.514	0.493	0.464	0.225	0.097
Mid-usage (2% - 95%)									
Probability	0.046	0.004	0.019	0.014	0.021	0.016	0.040	0.001	0.003
Period (hrs)									
Average	0.507	0.333	0.906	0.250	0.579	0.554	1.640	0.250	0.321
StdDev	0.633	0.212	0.838	0.000	3.142	0.707	6.152	0.000	0.113
Utilization(%)									
Average	3.295	10.019	3.495	7.808	32.526	24.696	5.760	3.017	4.094
StdDev	4.615	6.823	1.360	5.731	32.570	23.440	5.159	0.133	2.222
High-usage (95% - 100%)									
Probability	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Period (hrs)									
Average	0.000	0.000	0.000	0.000	0.250	0.000	0.000	0.000	0.000
StdDev	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Utilization(%)									
Average	0.000	0.000	0.000	0.000	99.222	0.000	0.000	0.000	0.000
StdDev	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
numCores	1	1	2	4	2	2	4	8	16
numVmProcessed	69	10	2	5	56	12	13	6	8

US Boulder Datacenter

	C32	B32	S32	G32	C64	B64	S64	G64	P64
Low-usage (0% - 2%)									
Probability	0.955	0.669	0.940	0.945	0.909	0.943	0.866	0.786	0.955
Period (hrs)									
Average	37.481	17.878	43.659	46.472	31.100	19.736	36.395	31.206	204.814
StdDev	111.999	72.222	113.289	149.731	96.719	46.131	153.433	103.442	560.351
Utilization (%)									
Average	0.312	0.547	0.273	0.185	0.312	0.332	0.292	0.113	0.148
StdDev	0.367	0.433	0.300	0.289	0.352	0.407	0.350	0.212	0.237
Mid-usage (2% - 95%)									
Probability	0.040	0.331	0.059	0.055	0.058	0.056	0.112	0.177	0.042
Period (hrs)									
Average	1.462	8.468	3.608	2.548	1.980	2.037	4.745	5.727	9.883
StdDev	14.987	84.434	19.043	25.588	24.453	10.630	61.909	38.672	78.031
Utilization(%)									
Average	8.934	3.471	9.891	5.800	10.534	12.761	12.403	25.911	16.649
StdDev	11.165	2.583	15.484	5.791	13.652	17.773	16.527	25.869	16.991
High-usage (95% - 100%)									
Probability	0.004	0.000	0.001	0.000	0.034	0.000	0.021	0.037	0.003
Period (hrs)									
Average	7.565	0.292	0.546	0.667	80.423	0.721	51.470	2.891	14.893
StdDev	17.819	0.093	0.791	0.312	150.328	1.127	188.008	3.304	22.855
Utilization(%)									
Average	99.918	99.613	96.300	99.525	99.710	99.207	99.717	99.096	98.853
StdDev	0.522	0.455	1.744	1.258	0.651	1.367	0.408	1.425	0.872
numCores	1	1	2	4	2	2	4	8	16
numVmProcessed	1518	99	100	168	1202	100	733	144	90

US Raleigh Datacenter

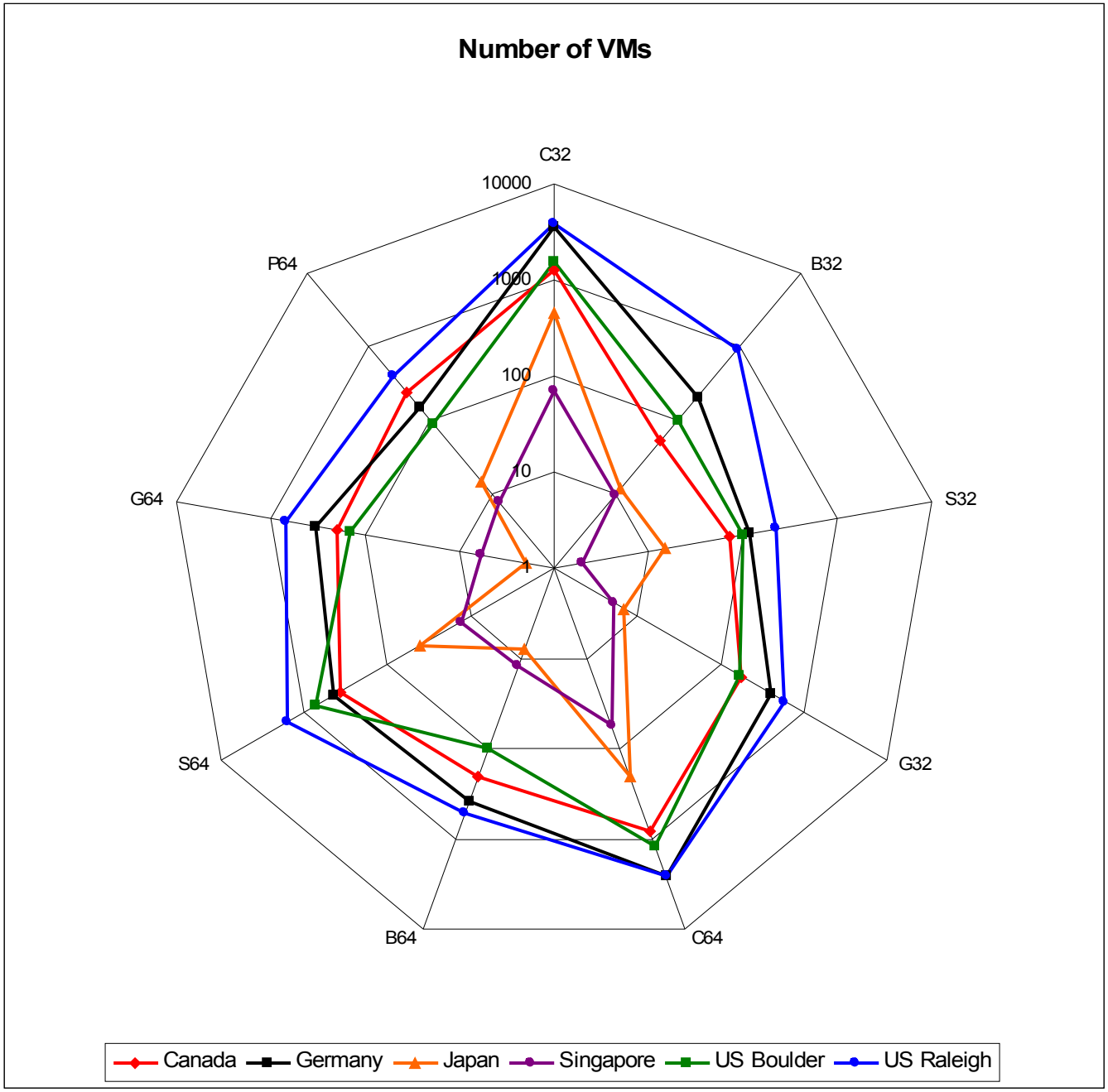
	C32	B32	S32	G32	C64	B64	S64	G64	P64
Low-usage (0% - 2%)									
Probability	0.934	0.955	0.936	0.927	0.904	0.970	0.868	0.952	0.900
Period (hrs)									
Average	43.289	75.640	45.133	27.533	40.208	59.423	35.798	74.609	48.522
StdDev	227.921	468.479	252.896	107.785	186.510	354.313	202.371	375.289	272.173
Utilization (%)									
Average	0.275	0.236	0.284	0.385	0.298	0.247	0.143	0.172	0.179
StdDev	0.409	0.404	0.292	0.415	0.411	0.383	0.238	0.260	0.288
Mid-usage (2% - 95%)									
Probability	0.055	0.042	0.056	0.066	0.062	0.026	0.046	0.035	0.085
Period (hrs)									
Average	2.503	2.997	2.573	1.919	2.771	1.623	1.493	2.390	3.953
StdDev	39.385	55.502	27.926	31.414	51.323	20.106	17.919	31.456	45.703
Utilization(%)									
Average	7.544	10.566	22.293	16.967	10.084	11.883	31.744	18.849	16.113
StdDev	10.025	15.803	22.974	17.324	14.995	18.152	29.995	24.468	23.654
High-usage (95% - 100%)									
Probability	0.011	0.004	0.008	0.007	0.034	0.004	0.086	0.013	0.015
Period (hrs)									
Average	52.322	7.305	8.039	184.159	178.182	49.969	8.997	10.707	5.253
StdDev	212.306	35.887	61.313	190.409	541.269	113.825	21.008	48.876	19.972
Utilization(%)									
Average	99.973	99.963	99.942	99.926	99.932	99.827	99.898	99.707	98.803
StdDev	0.245	0.310	0.340	0.273	0.433	0.452	0.458	0.732	0.988
numCores	1	1	2	4	2	2	4	8	16
numVmProcessed	3899	932	219	586	2609	504	1589	673	409

Number of VMs

	C32	B32	S32	G32	C64	B64	S64	G64	P64	
Canada	1269	52	72	180	828	201	372	199	251	**3424**
Germany	3550	214	115	406	2605	382	456	330	149	**8207**
Japan	446	12	15	7	207	8	41	2	15	**753**
Singapore	69	10	2	5	56	12	13	6	8	**181**
US Boulder	1518	99	100	168	1202	100	733	144	90	**4154**
US Raleigh	3899	932	219	586	2609	504	1589	673	409	**11420**
	10751	**1319**	**523**	**1352**	**7507**	**1207**	**3204**	**1354**	**922**	**28139**

VM Type % Mix

	C32	B32	S32	G32	C64	B64	S64	G64	P64	
Canada	37.1%	1.5%	2.1%	5.3%	24.2%	5.9%	10.9%	5.8%	7.3%	**100%**
Germany	43.3%	2.6%	1.4%	4.9%	31.7%	4.7%	5.6%	4.0%	1.8%	**100%**
Japan	59.2%	1.6%	2.0%	0.9%	27.5%	1.1%	5.4%	0.3%	2.0%	**100%**
Singapore	38.1%	5.5%	1.1%	2.8%	30.9%	6.6%	7.2%	3.3%	4.4%	**100%**
US Boulder	36.5%	2.4%	2.4%	4.0%	28.9%	2.4%	17.6%	3.5%	2.2%	**100%**
US Raleigh	34.1%	8.2%	1.9%	5.1%	22.8%	4.4%	13.9%	5.9%	3.6%	**100%**
	38.2%	**4.7%**	**1.9%**	**4.8%**	**26.7%**	**4.3%**	**11.4%**	**4.8%**	**3.3%**	**100.0%**


Number of VMs
C32
10000
1000
100
10
1
B32
S32
G32
C64
B64
S64
G64
P64
Canada
Germany
Japan
Singapore
US Boulder
US Raleigh

Prob Low CPU

	C32	B32	S32	G32	C64	B64	S64	G64	P64	
Canada	0.940	0.897	0.884	0.893	0.959	0.965	0.928	0.889	0.644	**0.916**
Germany	0.923	0.855	0.941	0.938	0.926	0.928	0.911	0.935	0.954	**0.924**
Japan	0.728	0.485	0.759	0.994	0.922	0.997	0.978	0.332	0.831	**0.798**
Singapore	0.954	0.996	0.981	0.986	0.979	0.984	0.960	0.999	0.997	**0.971**
US Boulder	0.955	0.669	0.940	0.945	0.909	0.943	0.866	0.786	0.955	**0.912**
US Raleigh	0.934	0.955	0.936	0.927	0.904	0.970	0.868	0.952	0.900	**0.921**
	0.926	**0.911**	**0.926**	**0.929**	**0.919**	**0.954**	**0.883**	**0.920**	**0.844**	**0.917**

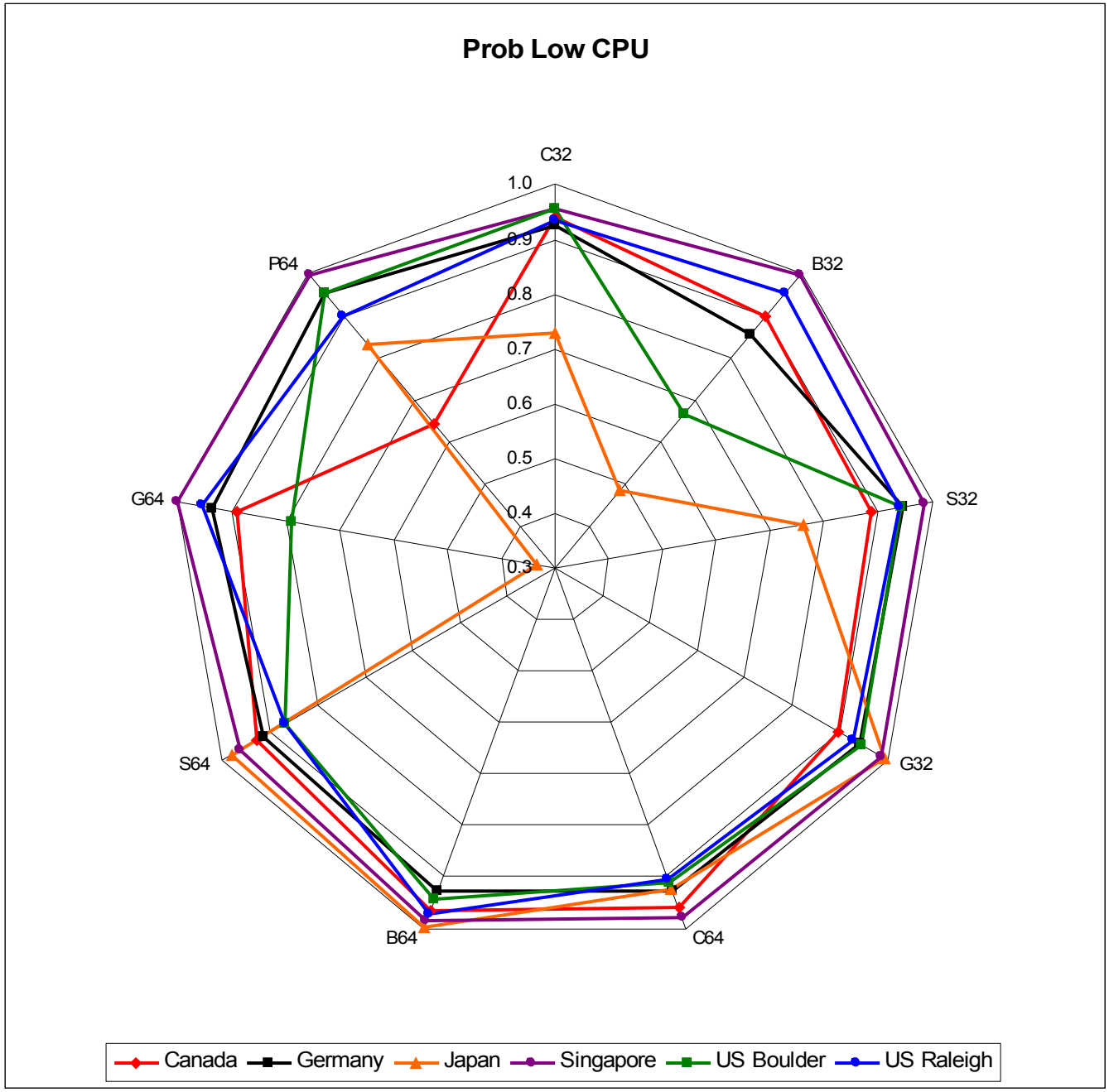
Avg Period Low CPU (hrs)

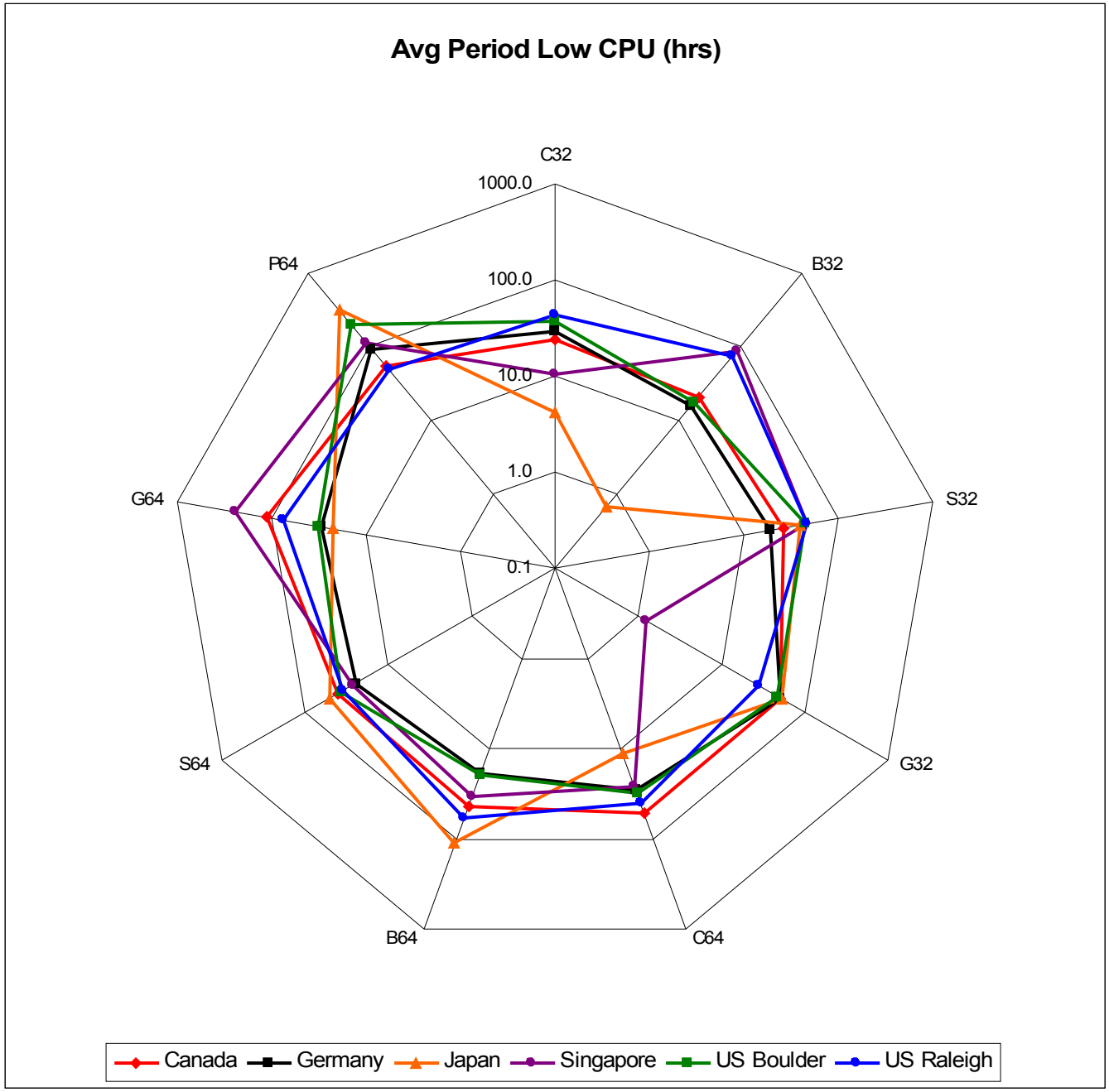
	C32	B32	S32	G32	C64	B64	S64	G64	P64	
Canada	23.8	20.9	26.3	50.1	50.4	42.6	39.6	111.7	55.7	**41.9**
Germany	29.1	16.3	18.7	51.2	29.5	18.6	25.2	28.7	92.3	**30.3**
Japan	4.2	0.7	38.9	52.5	11.3	112.9	50.0	21.8	310.2	**17.0**
Singapore	10.2	88.8	45.3	1.3	26.5	34.9	27.3	237.1	112.1	**34.6**
US Boulder	37.5	17.9	43.7	46.5	31.1	19.7	36.4	31.2	204.8	**38.5**
US Raleigh	43.3	75.6	45.1	27.5	40.2	59.4	35.8	74.6	48.5	**46.2**
	33.7	**58.9**	**36.3**	**40.0**	**35.3**	**40.5**	**35.0**	**64.9**	**77.6**	**39.0**

Avg Util Low CPU

	C32	B32	S32	G32	C64	B64	S64	G64	P64	
Canada	0.37	0.38	0.30	0.11	0.28	0.24	0.39	0.26	0.10	**0.23**
Germany	0.26	0.18	0.35	0.18	0.23	0.32	0.34	0.19	0.14	**0.23**
Japan	0.46	1.17	0.61	0.42	0.71	0.18	0.14	0.41	0.04	**0.43**
Singapore	0.40	0.15	0.13	0.21	0.51	0.69	0.47	0.44	0.02	**0.33**
US Boulder	0.31	0.55	0.27	0.18	0.31	0.33	0.29	0.11	0.15	**0.26**
US Raleigh	0.27	0.24	0.28	0.39	0.30	0.25	0.14	0.17	0.18	**0.22**
	0.30	**0.26**	**0.31**	**0.26**	**0.29**	**0.28**	**0.24**	**0.19**	**0.14**	**0.29**

Note: Aggregate values obtained through a weighted average based on numVMs.


Prob Low CPU
C32
B32
S32
G32
C64
B64
S64
G64
P64
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
Canada
Germany
Japan
Singapore
US Boulder
US Raleigh


Avg Period Low CPU (hrs)
C32
1000.0
B32
100.0
P64
10.0
1.0
G64
S32
0.1
S64
G32
B64
C64
Canada
Germany
Japan
Singapore
US Boulder
US Raleigh

Prob Mid CPU

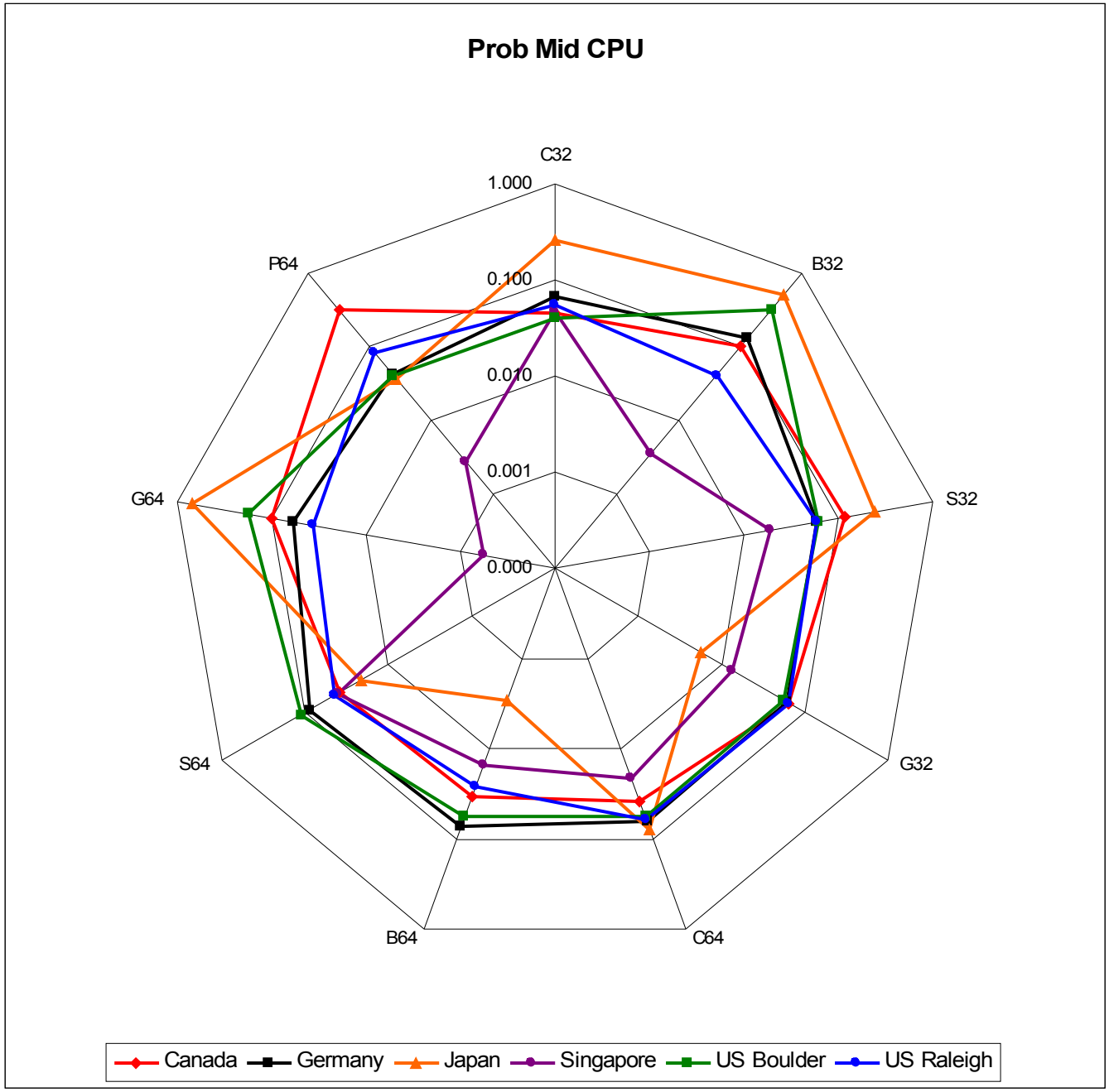
	C32	B32	S32	G32	C64	B64	S64	G64	P64	
Canada	0.045	0.103	0.116	0.064	0.038	0.035	0.039	0.100	0.311	**0.068**
Germany	0.067	0.134	0.058	0.062	0.065	0.072	0.088	0.057	0.043	**0.068**
Japan	0.256	0.515	0.241	0.006	0.078	0.003	0.022	0.668	0.037	**0.190**
Singapore	0.046	0.004	0.019	0.014	0.021	0.016	0.040	0.001	0.003	**0.029**
US Boulder	0.040	0.331	0.059	0.055	0.058	0.056	0.112	0.177	0.042	**0.071**
US Raleigh	0.055	0.042	0.056	0.066	0.062	0.026	0.046	0.035	0.085	**0.054**
	0.064	**0.085**	**0.071**	**0.062**	**0.060**	**0.044**	**0.066**	**0.066**	**0.134**	**0.066**

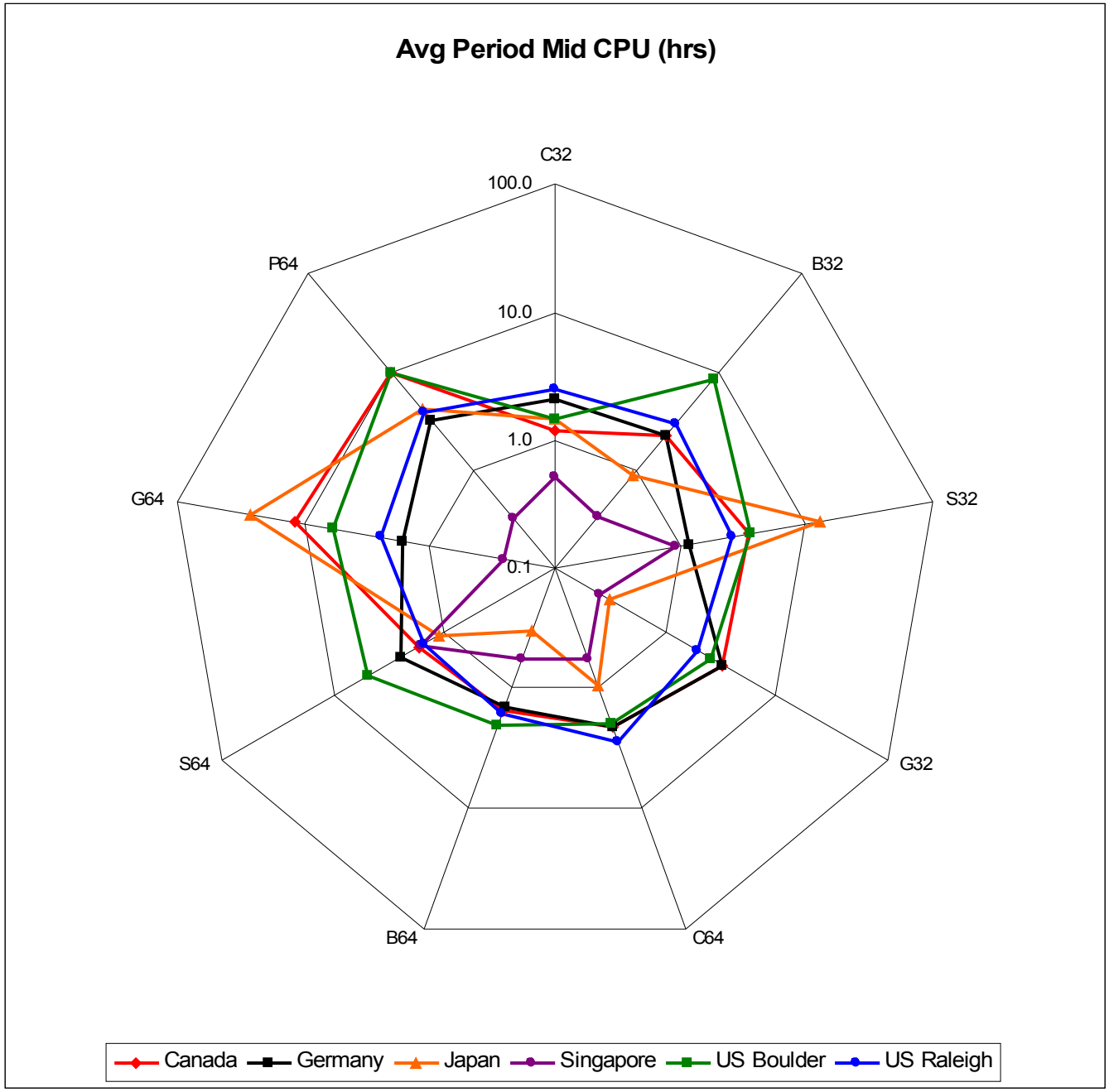
Avg Period Mid CPU (hrs)

	C32	B32	S32	G32	C64	B64	S64	G64	P64	
Canada	1.2	2.2	3.4	3.2	2.1	1.5	1.7	11.4	9.7	**2.9**
Germany	2.1	2.2	1.1	3.3	2.1	1.4	2.4	1.6	3.2	**2.1**
Japan	1.5	0.9	12.5	0.3	1.0	0.3	1.1	26.3	4.1	**1.6**
Singapore	0.5	0.3	0.9	0.3	0.6	0.6	1.6	0.3	0.3	**0.6**
US Boulder	1.5	8.5	3.6	2.5	2.0	2.0	4.7	5.7	9.9	**2.8**
US Raleigh	2.5	3.0	2.6	1.9	2.8	1.6	1.5	2.4	4.0	**2.4**
	2.0	**3.2**	**2.8**	**2.6**	**2.3**	**1.6**	**2.4**	**3.9**	**5.9**	**2.4**

Avg Util Mid CPU

	C32	B32	S32	G32	C64	B64	S64	G64	P64	
Canada	10.3	15.0	7.8	17.4	17.5	11.8	12.5	12.5	48.5	**26.0**
Germany	5.0	7.8	5.0	8.5	15.3	11.1	16.8	20.1	17.4	**13.4**
Japan	4.7	2.5	13.8	5.4	4.3	5.6	3.7	4.6	92.7	**20.1**
Singapore	3.3	10.0	3.5	7.8	32.5	24.7	5.8	3.0	4.1	**12.2**
US Boulder	8.9	3.5	9.9	5.8	10.5	12.8	12.4	25.9	16.6	**13.0**
US Raleigh	7.5	10.6	22.3	17.0	10.1	11.9	31.7	18.8	16.1	**17.5**
	7.1	**9.7**	**13.8**	**13.0**	**12.8**	**11.8**	**22.5**	**18.9**	**26.3**	**17.2**


Prob Mid CPU
C32
1.000
0.100
0.010
0.001
0.000
B32
S32
G32
C64
B64
S64
G64
P64
Canada
Germany
Japan
Singapore
US Boulder
US Raleigh


Avg Period Mid CPU (hrs)
C32
100.0
B32
10.0
P64
1.0
S32
G64
0.1
S64
G32
B64
C64
Canada
Germany
Japan
Singapore
US Boulder
US Raleigh

Prob High CPU

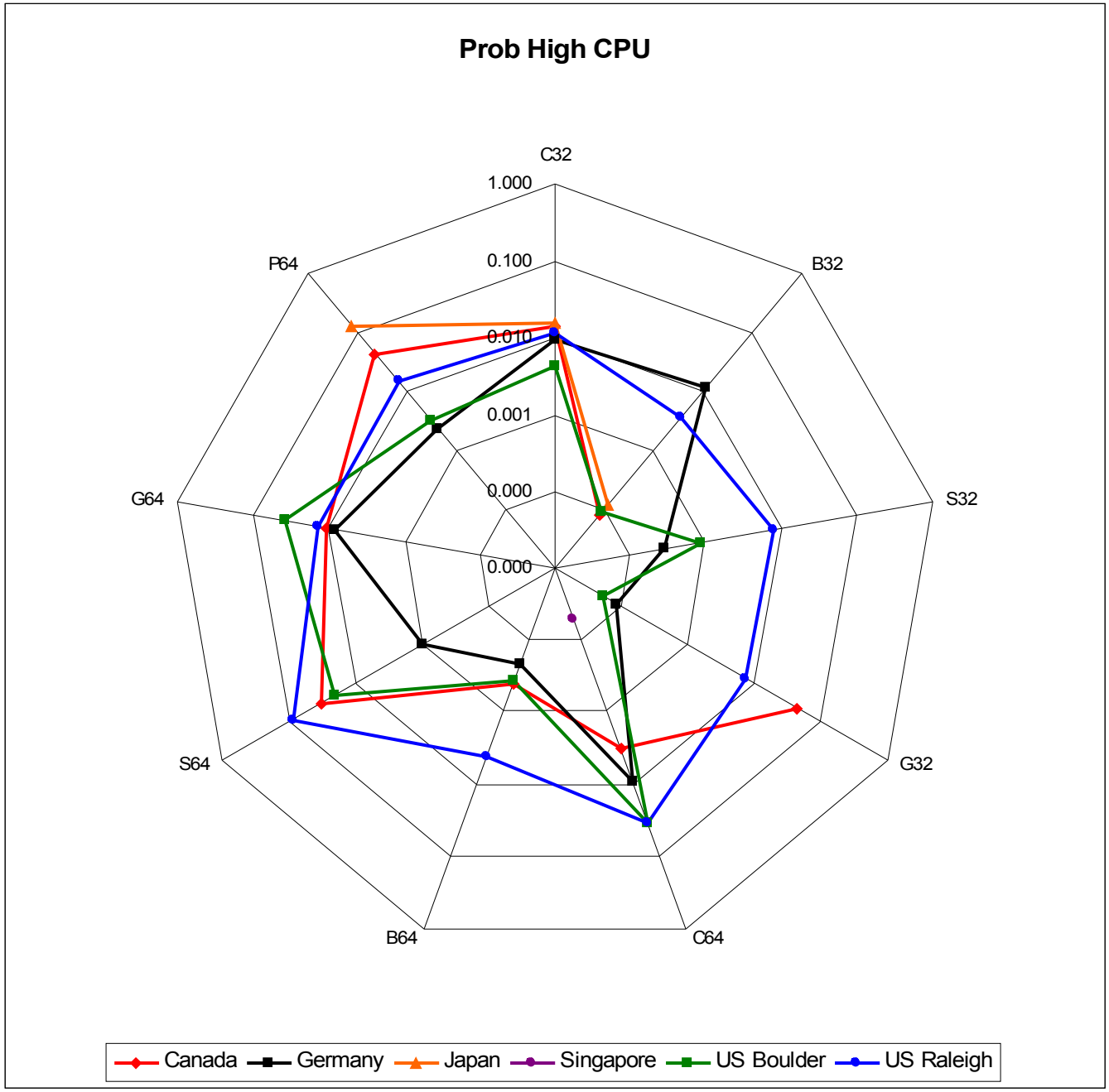
	C32	B32	S32	G32	C64	B64	S64	G64	P64	
Canada	0.014	0.000		0.043	0.003	0.000	0.033	0.011	0.045	**0.016**
Germany	0.010	0.012	0.000	0.000	0.009	0.000	0.001	0.008	0.002	**0.008**
Japan	0.016	0.000							0.132	**0.012**
Singapore					0.000					**0.000**
US Boulder	0.004	0.000	0.001	0.000	0.034	0.000	0.021	0.037	0.003	**0.017**
US Raleigh	0.011	0.004	0.008	0.007	0.034	0.004	0.086	0.013	0.015	**0.026**
	0.010	**0.004**	**0.003**	**0.009**	**0.021**	**0.002**	**0.052**	**0.014**	**0.022**	**0.017**

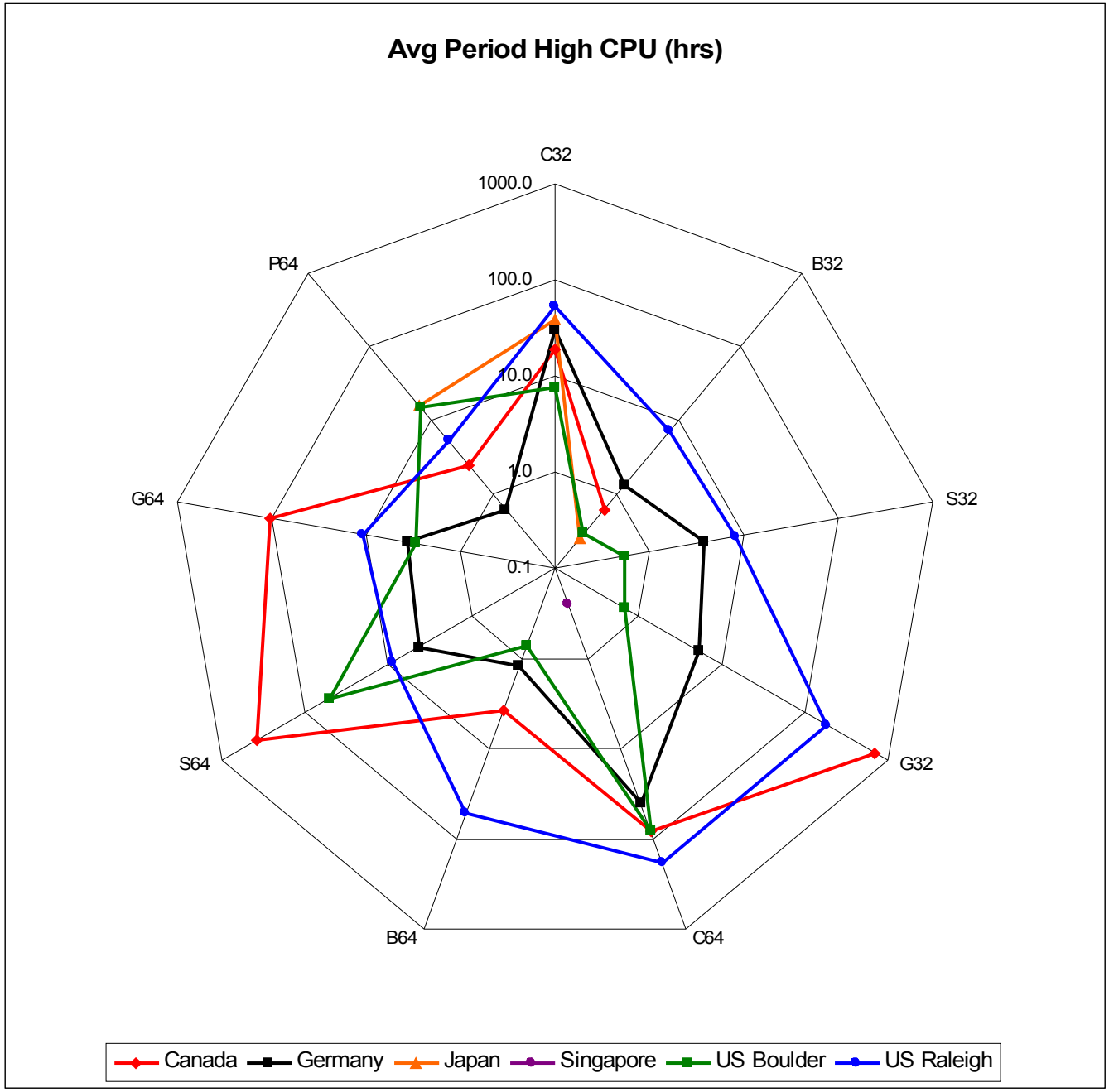
Avg Period High CPU (hrs)

	C32	B32	S32	G32	C64	B64	S64	G64	P64	
Canada	19.0	0.6		697.8	81.0	3.8	390.2	104.9	2.5	**112.2**
Germany	30.2	1.3	3.7	5.3	40.0	1.2	4.4	3.5	0.6	**26.6**
Japan	38.8	0.3							16.2	**23.3**
Singapore					0.3					**0.1**
US Boulder	7.6	0.3	0.5	0.7	80.4	0.7	51.5	2.9	14.9	**35.6**
US Raleigh	52.3	7.3	8.0	184.2	178.2	50.0	9.0	10.7	5.3	**73.0**
	33.9	**5.4**	**4.3**	**174.4**	**97.6**	**21.9**	**62.2**	**21.9**	**4.8**	**56.9**

Avg Util High CPU

	C32	B32	S32	G32	C64	B64	S64	G64	P64	
Canada	99.93	99.94		99.80	99.99	99.92	99.78	100.00	98.91	**99.56**
Germany	99.98	99.17	99.97	99.98	99.81	99.70	99.61	99.43	97.86	**99.52**
Japan	99.98	95.74							99.11	**99.61**
Singapore					99.22					**99.22**
US Boulder	99.92	99.61	96.30	99.52	99.71	99.21	99.72	99.10	98.85	**99.47**
US Raleigh	99.97	99.96	99.94	99.93	99.93	99.83	99.90	99.71	98.80	**99.66**
	99.32	**99.01**	**82.24**	**98.99**	**97.10**	**98.10**	**98.12**	**99.03**	**97.83**	**98.02**

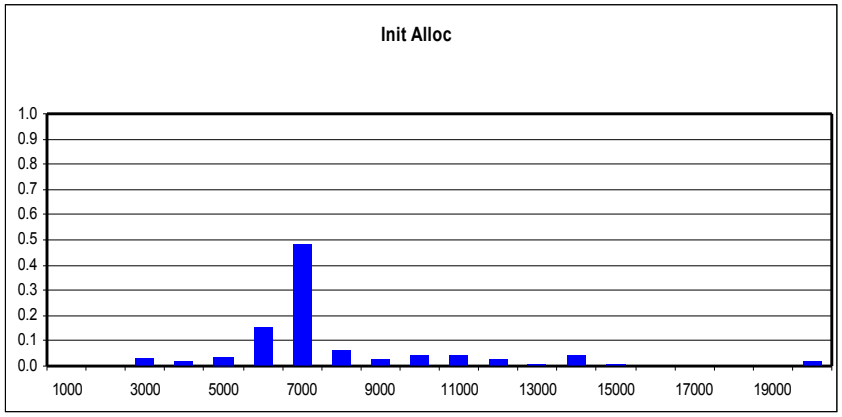

Prob High CPU
C32
1.000
0.100
0.010
0.001
0.000
0.000
B32
S32
G32
C64
B64
S64
G64
P64
Canada
Germany
Japan
Singapore
US Boulder
US Raleigh

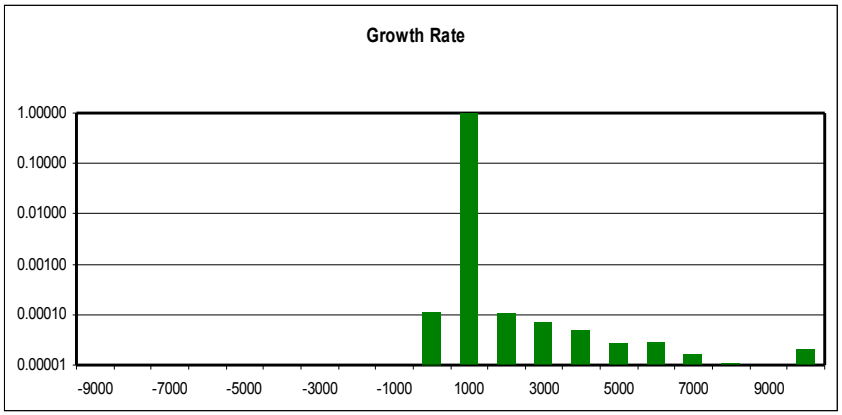

Avg Period High CPU (hrs)
C32
1000.0
100.0
10.0
1.0
0.1
B32
S32
G32
C64
B64
S64
G64
P64
Canada
Germany
Japan
Singapore
US Boulder
US Raleigh

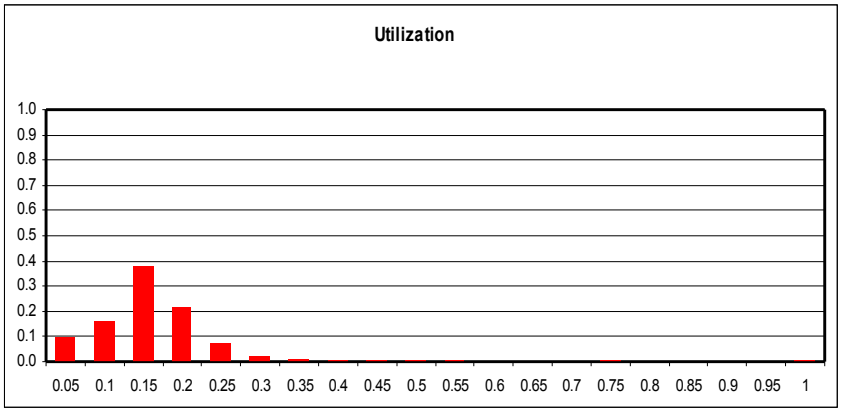
Storage Analysis

(Histograms)

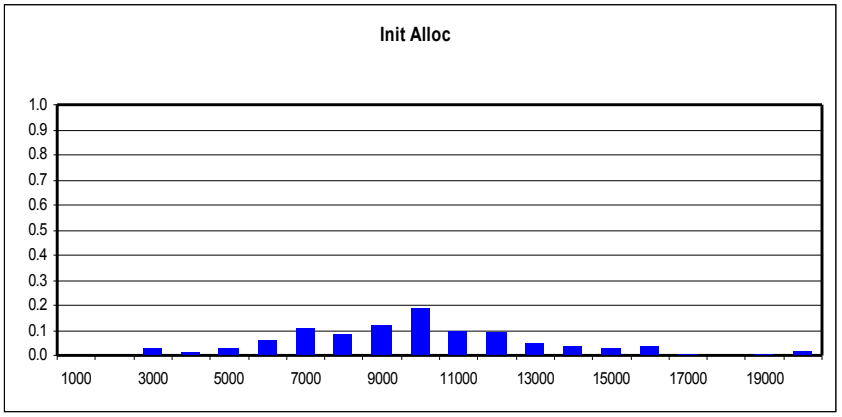
Copper 32

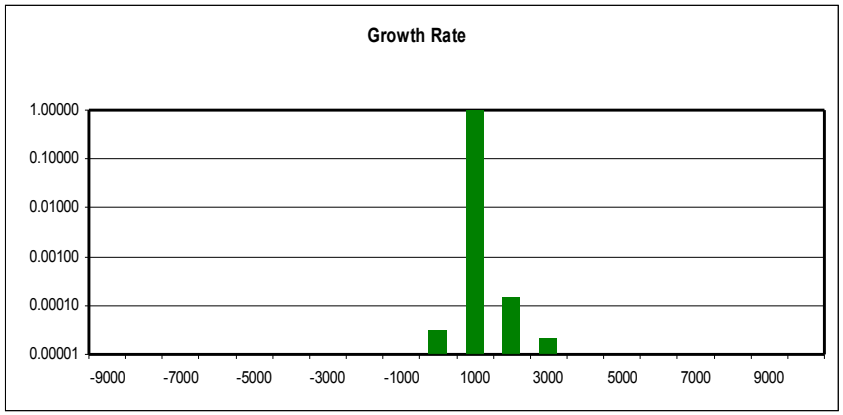


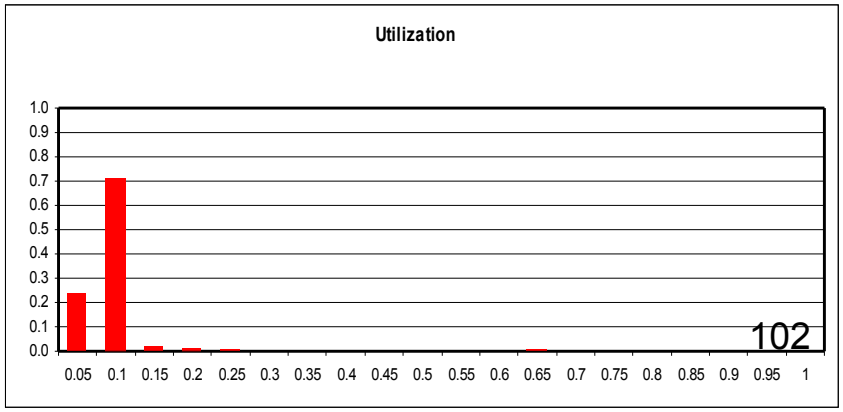




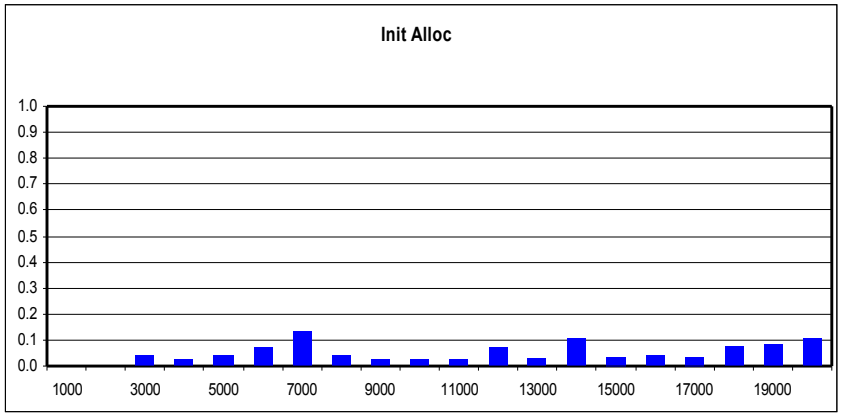
Bronze 32

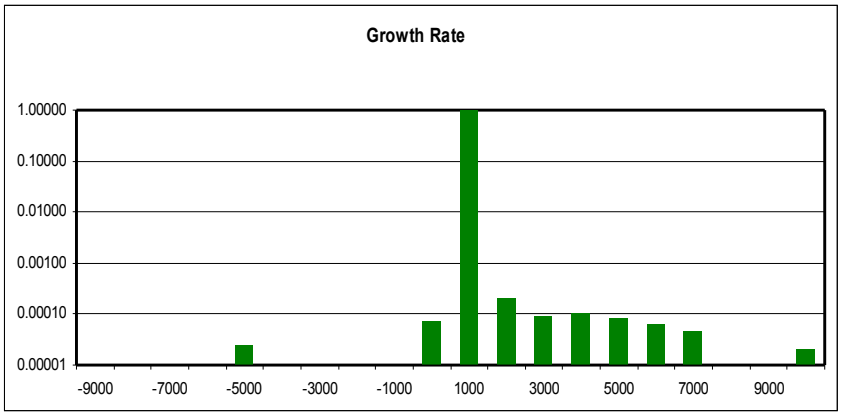


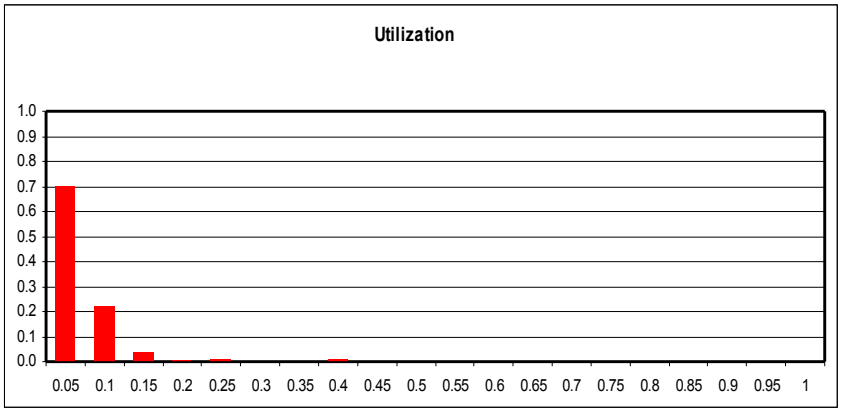




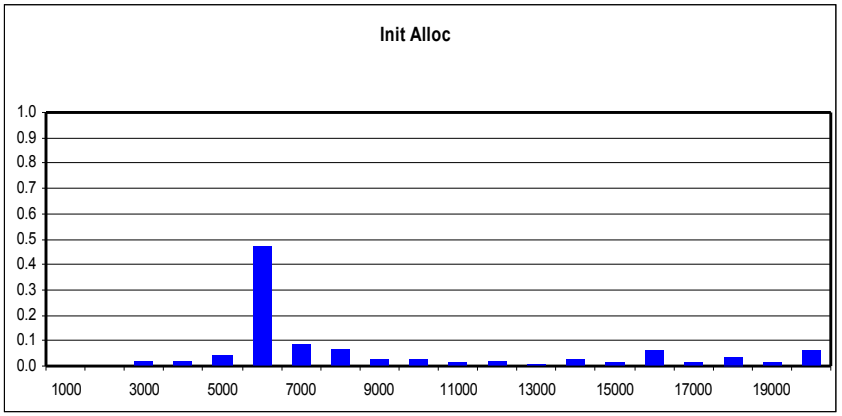
Silver 32

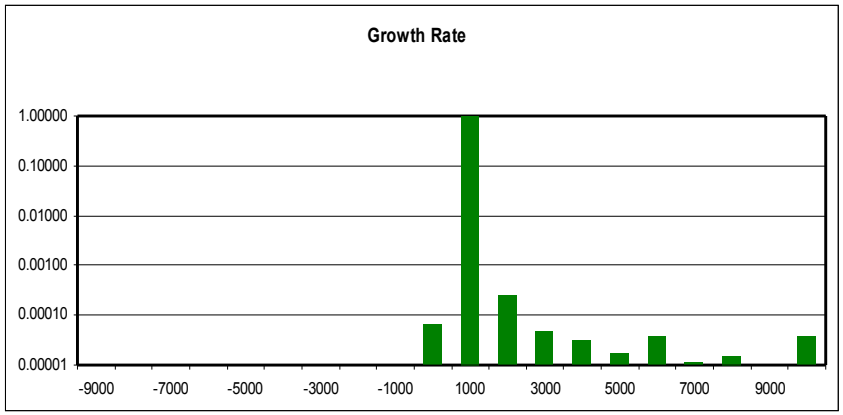


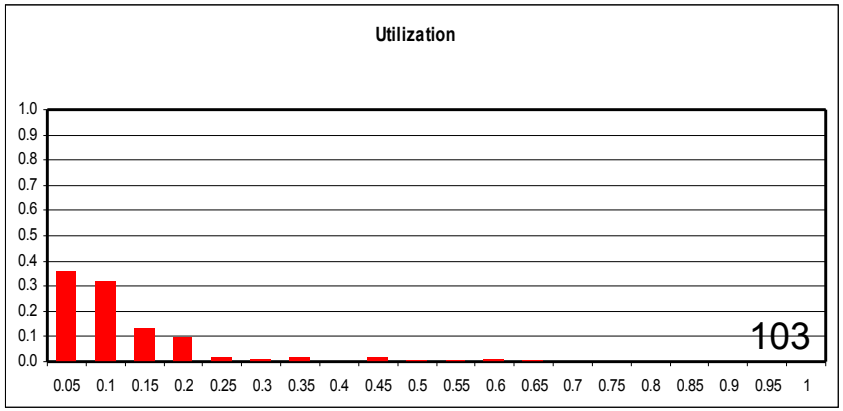




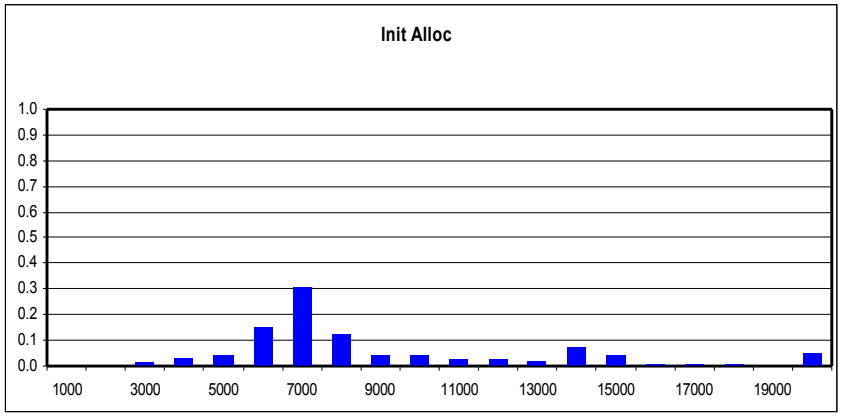
Gold 32

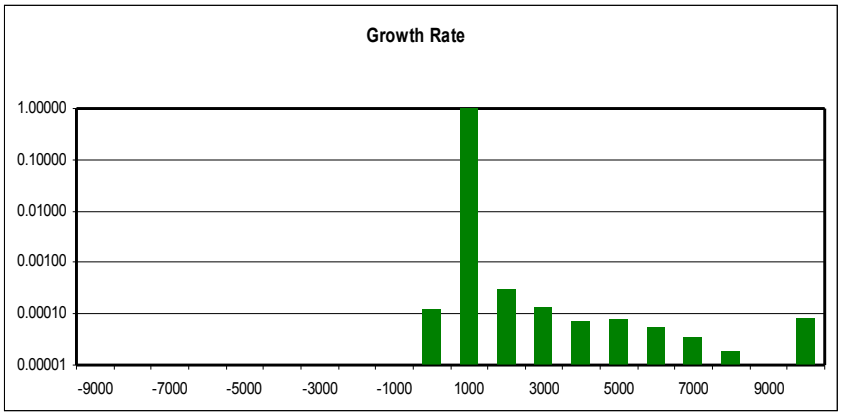


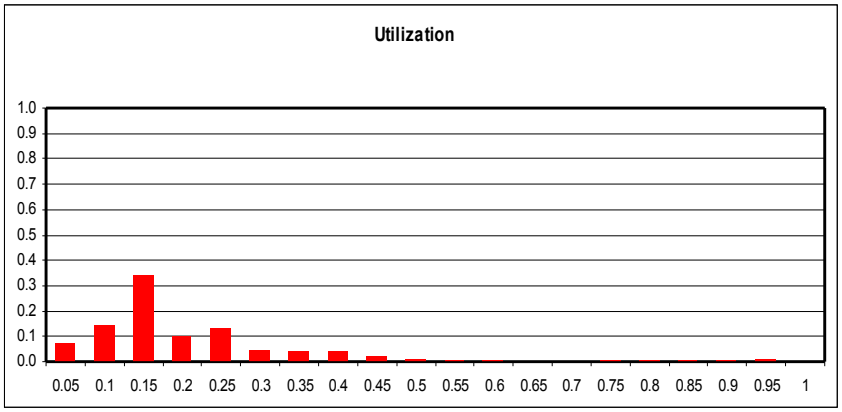




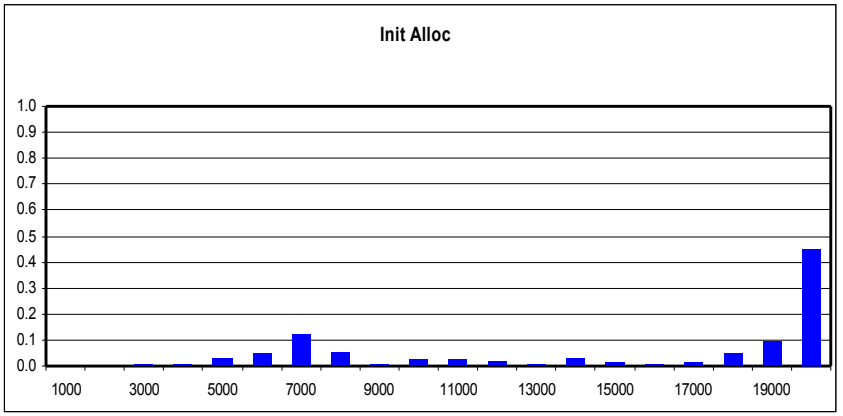
Copper 64

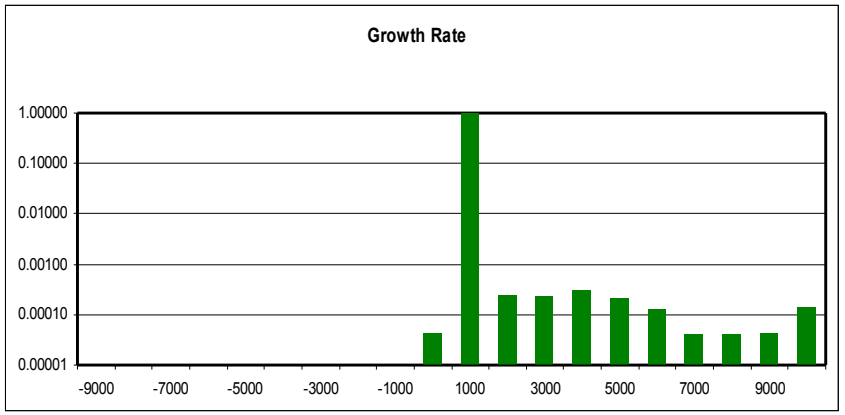


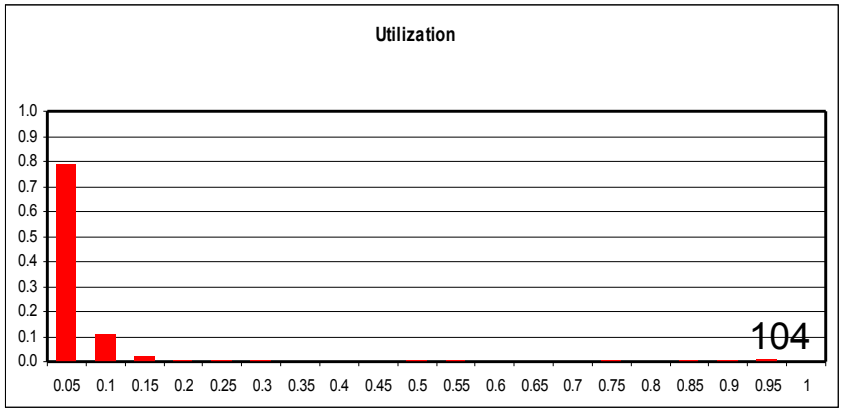




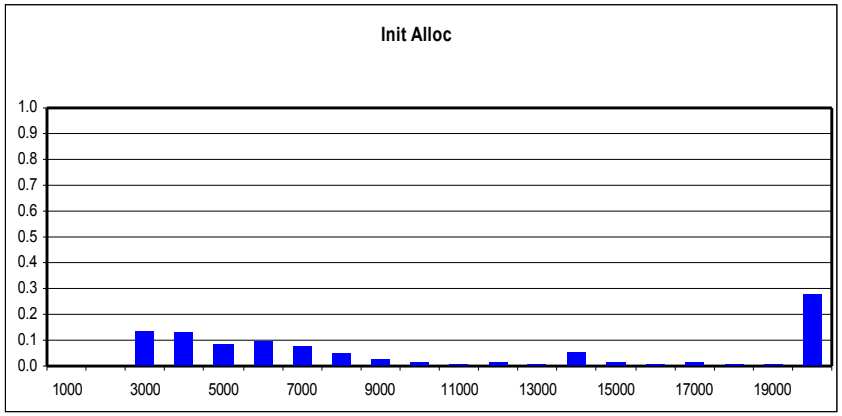
Bronze 64

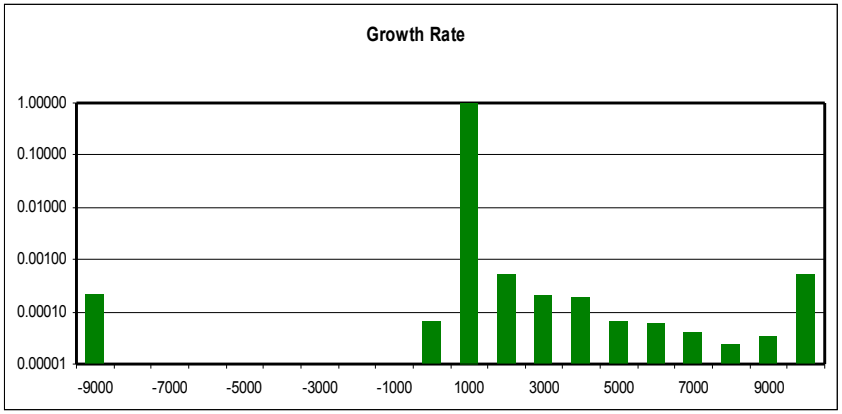


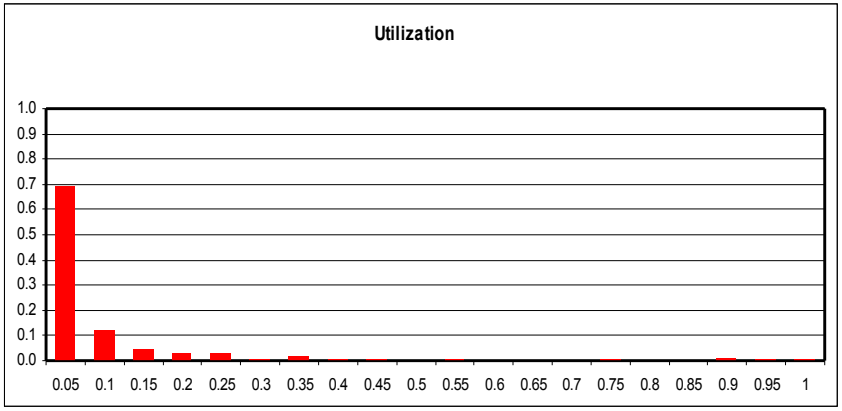




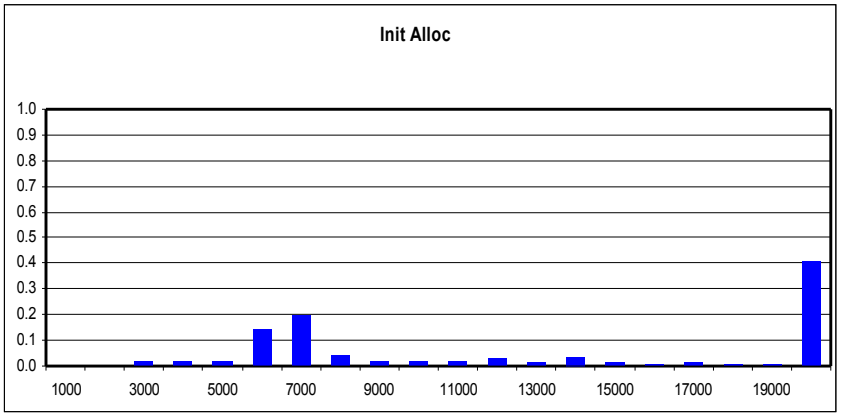
Silver 64

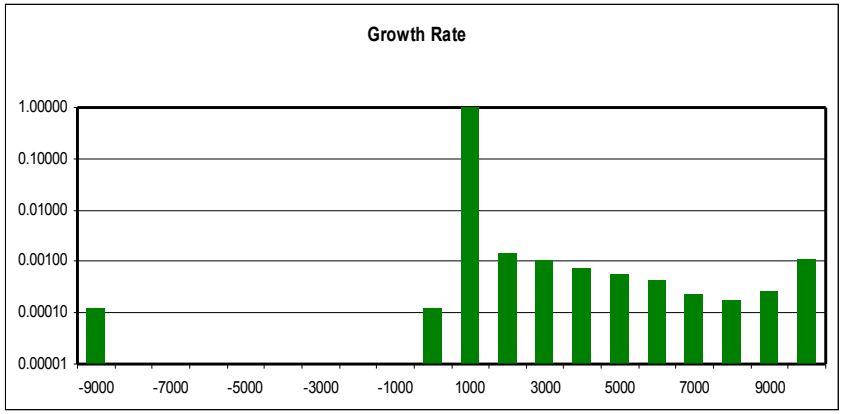


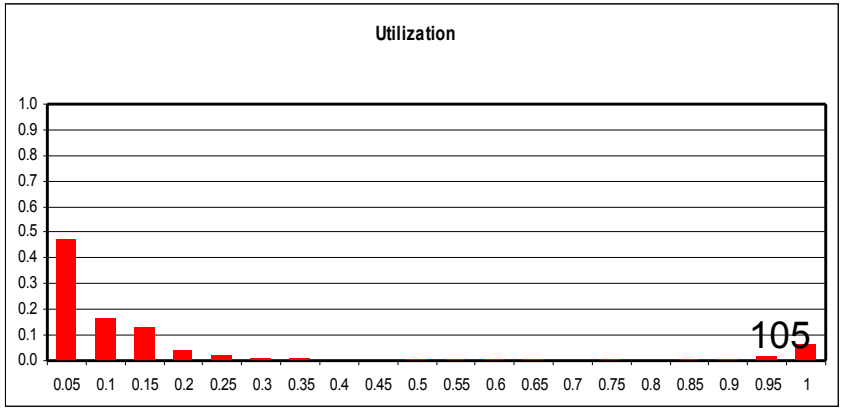




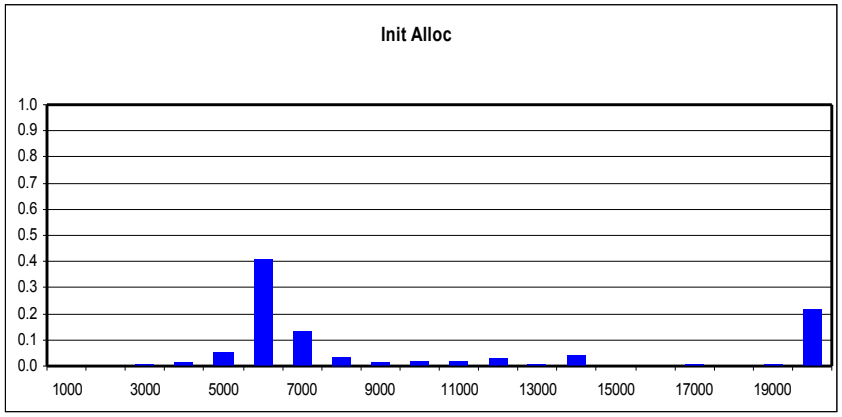
Gold 64

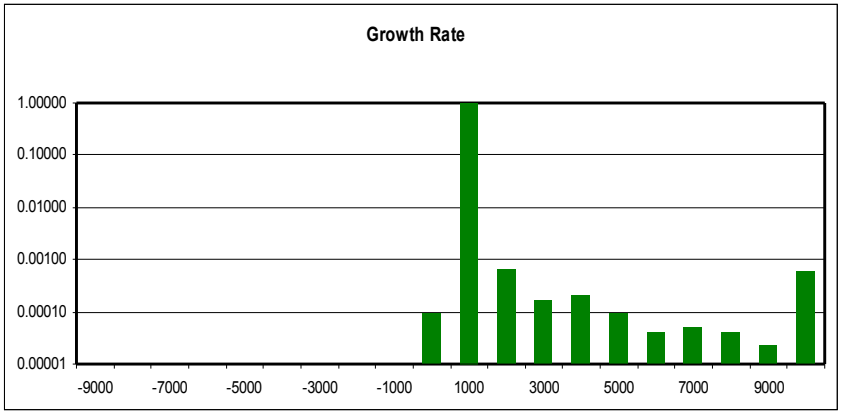


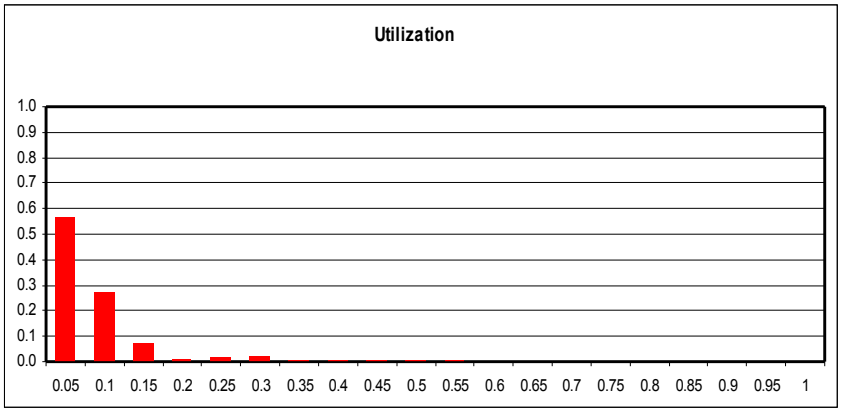




Platinum64


Init Alloc
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
1000
3000
5000
7000
9000
11000
13000
15000
17000
19000


Growth Rate
1.00000
0.10000
0.01000
0.00100
0.00010
0.00001
-9000
-7000
-5000
-3000
-1000
1000
3000
5000
7000
9000


Utilization
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
0.05
0.1
0.15
0.2
0.25
0.3
0.35
0.4
0.45
0.5
0.55
0.6
0.65
0.7
0.75
0.8
0.85
0.9
0.95
1

Storage Analysis

(per Datacenter)

Canada Datacenter

	C32	B32	S32	G32	C64	B64	S64	P64	P64
initAlloc (GB)									
Average	7.2	8.6	11.8	7.0	9.4	25.1	15.7	6.5	20.9
StdDev	2.8	3.8	6.8	7.1	8.6	67.6	62.6	5.0	77.8
growthRate (GB / 15 min)									
Average	0.01	0.01	0.02	0.01	0.03	0.20	0.21	0.07	0.27
StdDev	0.57	0.61	0.89	0.70	2.08	4.38	8.12	2.70	12.01
diskUtilization (%)									
Average	12.94	3.94	2.97	6.98	16.45	15.12	7.65	4.18	6.82
StdDev	7.79	2.60	2.10	5.63	12.08	23.10	15.99	4.90	9.58
Min	0.38	0.99	0.58	1.06	0.26	0.26	0.16	0.12	0.12
Max	99.32	12.78	12.98	95.04	99.27	95.39	97.11	76.81	97.82
storageSize (GB)	60	175	350	350	60	850	1,024	1,024	2,048
numVmProcessed	1263	51	71	175	835	202	333	250	809

Germany Datacenter

	C32	B32	S32	G32	C64	B64	S64	G64	P64
initAlloc (GB)									
Average	8.1	8.6	14.2	7.5	10.3	34.6	34.5	77.0	17.0
StdDev	14.4	4.0	19.3	5.1	19.9	86.0	51.1	182.3	32.3
growthRate (GB / 15 min)									
Average	0.02	0.02	0.01	0.04	0.08	0.17	0.15	0.74	0.64
StdDev	2.21	1.55	1.50	3.76	3.83	6.52	133.67	35.28	21.36
diskUtilization (%)									
Average	14.88	5.08	4.23	9.71	22.90	11.89	12.05	17.04	10.54
StdDev	12.57	3.52	6.32	15.01	18.89	21.85	15.84	25.03	13.60
Min	0.09	0.58	0.42	0.42	0.21	0.25	0.25	0.23	0.16
Max	99.16	89.23	96.32	97.42	99.36	97.48	98.91	99.71	97.82
storageSize (GB)	60	175	350	350	60	850	1,024	1,024	2,048
numVmProcessed	3536	215	115	400	2592	382	447	321	146

Japan Datacenter

	C32	B32	S32	G32	C64	B64	S64	G64	P64
initAlloc (GB)									
Average	8.4	7.0	11.5	9.9	10.1	49.3	8.3	22.3	10.8
StdDev	4.6	3.5	5.3	5.1	4.4	85.6	8.2	11.5	15.1
growthRate (GB / 15 min)									
Average	0.02	0.05	0.03	0.01	0.03	0.02	0.03	0.01	0.01
StdDev	1.31	2.38	0.85	0.15	1.50	0.58	5.61	0.29	0.19
diskUtilization (%)									
Average	14.90	3.82	3.53	3.08	18.61	5.02	3.18	1.40	2.40
StdDev	8.27	3.28	2.63	3.20	11.08	4.54	6.24	0.14	3.76
Min	0.48	1.12	0.82	0.63	0.49	0.83	0.51	0.91	0.28
Max	99.28	55.45	46.55	12.97	99.40	91.48	98.45	3.50	15.90
storageSize (GB)	60	175	350	350	60	850	1,024	1,024	2,048
numVmProcessed	446	13	16	8	207	9	42	3	16

Singapore Datacenter

	C32	B32	S32	G32	C64	B64	S64	G64	P64
initAlloc (GB)									
Average	8.8	10.8	8.5	7.6	7.8	14.5	16.1	12.0	16.4
StdDev	8.6	3.7	6.3	3.5	3.2	10.7	14.5	3.4	19.8
growthRate (GB / 15 min)									
Average	0.01	0.01	0.05	0.00	0.06	0.02	0.09	0.04	0.07
StdDev	0.47	0.31	0.82	0.12	3.01	0.26	2.43	1.66	1.57
diskUtilization (%)									
Average	11.94	4.12	3.91	9.27	14.33	2.12	4.62	4.56	2.91
StdDev	4.70	1.08	0.74	3.23	6.69	1.89	3.70	7.16	3.92
Min	0.27	2.26	0.57	1.21	0.90	0.40	0.59	0.32	0.24
Max	96.32	6.49	4.11	82.16	99.30	10.00	89.23	22.73	12.92
storageSize (GB)	60	175	350	350	60	850	1,024	1,024	2,048
numVmProcessed	70	10	3	6	56	12	14	7	9

US Boulder Datacenter

	C32	B32	S32	G32	C64	B64	S64	G64	P64
initAlloc (GB)									
Average	8.5	8.7	10.9	7.8	9.1	15.0	9.5	42.4	11.9
StdDev	28.0	3.3	5.3	4.0	7.8	10.3	15.6	95.1	15.7
growthRate (GB / 15 min)									
Average	0.04	0.01	0.02	0.03	0.04	0.37	0.09	0.62	0.26
StdDev	8.67	0.50	0.83	8.79	1.73	102.01	6.85	7.46	12.21
diskUtilization (%)									
Average	16.23	3.92	3.66	6.68	16.66	24.56	14.27	50.26	3.96
StdDev	16.23	2.25	2.82	4.29	10.88	36.01	23.84	43.53	6.98
Min	0.38	1.20	0.48	0.42	0.26	0.32	0.18	0.36	0.16
Max	99.80	39.33	36.63	95.50	99.34	93.86	98.66	100.00	89.23
storageSize (GB)	60	175	350	350	60	850	1,024	1,024	2,048
numVmProcessed	1514	100	99	170	1199	101	714	144	91

US Raleigh Datacenter

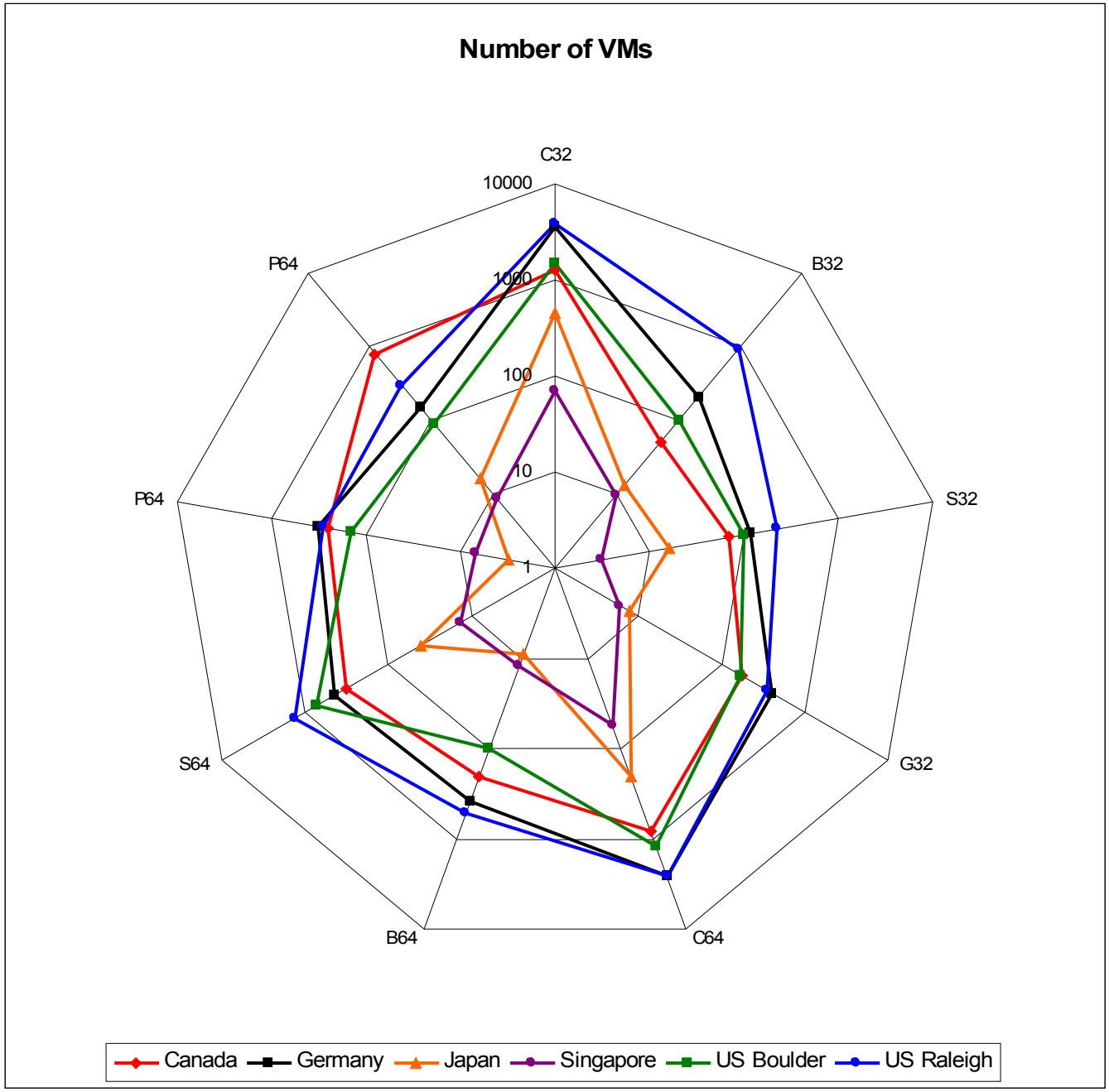
	C32	B32	S32	G32	C64	B64	S64	G64	P64
initAlloc (GB)									
Average	7.9	11.4	13.1	14.7	8.7	29.9	20.2	58.1	38.3
StdDev	15.5	36.2	6.0	14.7	19.7	52.6	51.1	108.0	122.7
growthRate (GB / 15 min)									
Average	0.01	0.01	0.04	0.03	0.02	0.02	0.10	0.08	0.24
StdDev	1.58	2.96	2.76	1.50	2.17	1.86	4.34	5.23	10.15
diskUtilization (%)									
Average	14.56	6.56	7.11	12.27	18.31	4.34	6.74	8.10	7.48
StdDev	10.39	5.97	8.89	12.83	15.49	4.36	15.43	9.01	9.56
Min	0.31	0.37	0.31	0.20	0.19	0.32	0.19	0.25	0.20
Max	99.41	95.77	97.15	97.02	99.42	99.62	99.31	97.04	97.24
storageSize (GB)	60	175	350	350	60	850	1,024	1,024	2,048
numVmProcessed	3891	933	220	351	2591	504	1306	281	303

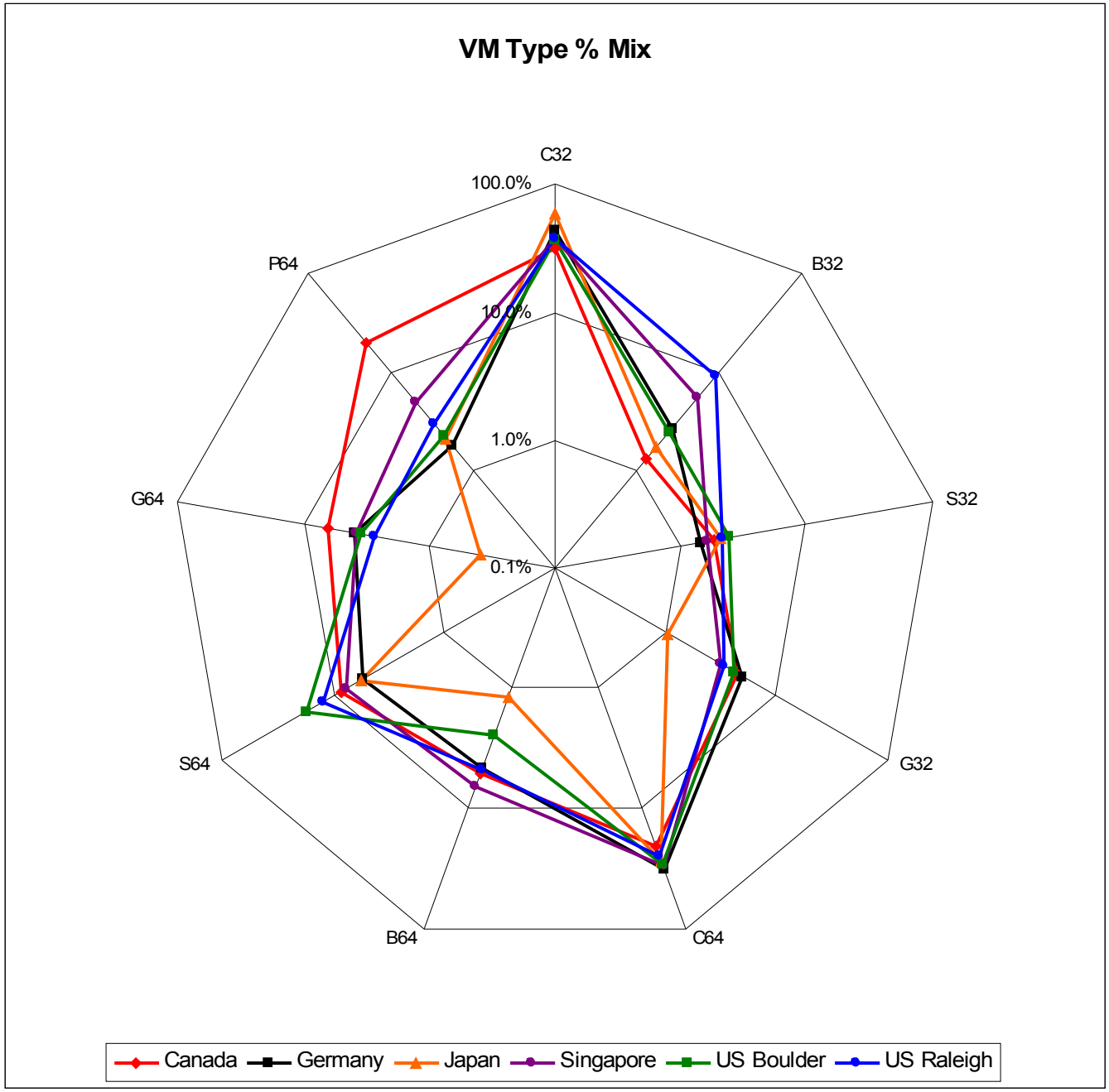
Number of VMs

	C32	B32	S32	G32	C64	B64	S64	P64	P64	
Canada	1263	51	71	175	835	202	333	250	809	3989
Germany	3536	215	115	400	2592	382	447	321	146	8154
Japan	446	13	16	8	207	9	42	3	16	760
Singapore	70	10	3	6	56	12	14	7	9	187
US Boulder	1514	100	99	170	1199	101	714	144	91	4132
US Raleigh	3891	933	220	351	2591	504	1306	281	303	10380
	10720	1322	524	1110	7480	1210	2856	1006	1374	27602

VM Type % Mix

	C32	B32	S32	G32	C64	B64	S64	G64	P64	
Canada	31.7%	1.3%	1.8%	4.4%	20.9%	5.1%	8.3%	6.3%	20.3%	100%
Germany	43.4%	2.6%	1.4%	4.9%	31.8%	4.7%	5.5%	3.9%	1.8%	100%
Japan	58.7%	1.7%	2.1%	1.1%	27.2%	1.2%	5.5%	0.4%	2.1%	100%
Singapore	37.4%	5.3%	1.6%	3.2%	29.9%	6.4%	7.5%	3.7%	4.8%	100%
US Boulder	36.6%	2.4%	2.4%	4.1%	29.0%	2.4%	17.3%	3.5%	2.2%	100%
US Raleigh	37.5%	9.0%	2.1%	3.4%	25.0%	4.9%	12.6%	2.7%	2.9%	100%
	38.8%	4.8%	1.9%	4.0%	27.1%	4.4%	10.3%	3.6%	5.0%	100.0%


Number of VMs
C32
10000
1000
100
10
1
B32
S32
G32
C64
B64
S64
P64
P64
Canada
Germany
Japan
Singapore
US Boulder
US Raleigh


VM Type % Mix
C32
100.0%
B32
10.0%
P64
1.0%
S32
G64
0.1%
S64
G32
B64
C64
Canada
Germany
Japan
Singapore
US Boulder
US Raleigh

Avg Initial Allocation (GB)

	C32	B32	S32	G32	C64	B64	S64	G64	P64	
Canada	7.2	8.6	11.8	7.0	9.4	25.1	15.7	6.5	20.9	**12.1**
Germany	8.1	8.6	14.2	7.5	10.3	34.6	34.5	77.0	17.0	**14.4**
Japan	8.4	7.0	11.5	9.9	10.1	49.3	8.3	22.3	10.8	**9.5**
Singapore	8.8	10.8	8.5	7.6	7.8	14.5	16.1	12.0	16.4	**10.0**
US Boulder	8.5	8.7	10.9	7.8	9.1	15.0	9.5	42.4	11.9	**10.3**
US Raleigh	7.9	11.4	13.1	14.7	8.7	29.9	20.2	58.1	38.3	**13.6**
	8.0	**10.6**	**12.7**	**9.8**	**9.4**	**29.3**	**19.0**	**48.7**	**23.6**	**13.0**

Avg Growth Rate (GB/15min)

	C32	B32	S32	G32	C64	B64	S64	G64	P64	
Canada	0.01	0.01	0.02	0.01	0.03	0.20	0.21	0.07	0.27	**0.10**
Germany	0.02	0.02	0.01	0.04	0.08	0.17	0.15	0.74	0.64	**0.09**
Japan	0.02	0.05	0.03	0.01	0.03	0.02	0.03	0.01	0.01	**0.02**
Singapore	0.01	0.01	0.05	0.00	0.06	0.02	0.09	0.04	0.07	**0.03**
US Boulder	0.04	0.01	0.02	0.03	0.04	0.37	0.09	0.62	0.26	**0.08**
US Raleigh	0.01	0.01	0.04	0.03	0.02	0.02	0.10	0.08	0.24	**0.04**
	0.02	**0.01**	**0.03**	**0.03**	**0.05**	**0.13**	**0.12**	**0.37**	**0.30**	**0.07**

Avg Storage Utilization (%)

	C32	B32	S32	G32	C64	B64	S64	G64	P64	
Canada	12.9	3.9	3.0	7.0	16.4	15.1	7.7	4.2	6.8	**7.5**
Germany	14.9	5.1	4.2	9.7	22.9	11.9	12.1	17.0	10.5	**13.3**
Japan	14.9	3.8	3.5	3.1	18.6	5.0	3.2	1.4	2.4	**6.8**
Singapore	11.9	4.1	3.9	9.3	14.3	2.1	4.6	4.6	2.9	**4.8**
US Boulder	16.2	3.9	3.7	6.7	16.7	24.6	14.3	50.3	4.0	**16.8**
US Raleigh	14.6	6.6	7.1	12.3	18.3	4.3	6.7	8.1	7.5	**7.9**
	14.7	**6.0**	**5.1**	**9.6**	**19.4**	**10.2**	**9.5**	**16.0**	**7.1**	**10.2**

Overcommitment

(Simulation)

Simulation Description

- VMs

	C32	B32	S32	G32	C64	B64	S64	G64	P64
vCPU(s)	1	1	2	4	2	2	4	8	16
Memory (GB)	2	2	4	4	4	4	8	16	16
Storage (GB)	60	175	350	350	60	850	1(TB)	1(TB)	2(TB)
Mix (%)	38.2	4.7	1.9	4.8	26.7	4.3	11.4	4.8	3.3
Lifetimes (days)	10.34	36.49	23.21	14.57	12.45	37.67	14.29	22.67	12.75

Cpu Time

- The CPU time from the DB is the number of CPU seconds the guest has used within the 15 minutes window. The maximum number of seconds used by a guest in the 15 minute window is calculated as
  - #vCPUs x 15 Minutes x 60 Seconds.

- So for a Copper32, max = 900 since it has 1vCPU. For Platinum64, max = 900 x 16 = 14,400. Percentages are then calculated as:
  - # of CPU seconds/max
    - for each 15 minute period. Note that the CPU time is cumulative so we have to diff the times between records to get the usage within a time period.

- Documented description of CPU : “Zero if guest is stopped. Otherwise, the number of CPU seconds that the guest has used. Example: if a 4CPU machine is running at a constant 33% utilization for 15 minutes, CPU Time is 4 x 33% x (15 x 60) = 1188. This is a cumulative number. It is not reset every 15 minutes. So, next CPU time would be 1,188 + whatever CPU was consumed during next 15 minutes."