LASER INTERFEROMETER GRAVITATIONAL WAVE OBSERVATORY

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Title

LDAS HVAC requirements for upgrades: LHO/LLO

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Document Title

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1. INTRODUCTION

According to Section 3.5.1 of "Sun Microsystems Data Center Site Planning Guide (Data Centers' Best Practices)", computer rooms ideally should be maintained at 72 F +/- 2 F and the relative humidity at 48% +/- 3% [1]. According to this document most electronic equipment can operate in the ranges of 50-90 F and 20-80% RH. However, below 30% RH electrostatic discharge can become a critical problem and of course at very high humidity condensation can become an issue.

The goal of this document is to target the power and air conditioning needs for the LDAS computer rooms at LHO and LLO for S5 and beyond. For the purposes of the plans presented here, we adopt in-room precision air conditioning with humidifiers and dehumidifiers by Liebert Corporation.

To obtain recommendations for room power we will follow this electrical engineering rule of thumb: do not use more than 80% of the power rating of any electrical panel. To compute the number of tons of air conditioning needed, we will first calculate the worst-case efficiency of each air conditioner, using the ratio of the worst case cooling numbers, as supplied by the Liebert's technical documents [2-3], to the nominal cooling expected by taking the number of tons times 60000 BTU/hr. As a sanity check, we will also give the sensible cooling numbers at 72 F and 45% RH. (These are close to the conditions we plan to operate under. However, note that at LHO the humidity in the LDAS room rarely reaches above 40%. This will not affect the comparison however, since below 45% RH the sensible cooling numbers are not expected to vary significantly with RH.) This method should give us plenty of air conditioning for all conditions a fully loaded room might experience, without dramatically over-estimating the need.

We will also maintain a 3 ft clearance in front and behind any electrical panel and all racks. A 2 ft clearance will be maintained in front of and to the side of all Liebert air conditioners (the minimum recommended by Liebert) . This will be increased to 3 ft as required on the side of the Liebert unit with its internal electrical panel.

2. LHO

2.1. Present Room

Figure 1 shows the layout of the LDAS LHO room as of April 2005. The room contains two power panels. One is rated at 36000 kW, which can be upgraded to 45000 kW, and the other is already at 45000 kW. The room also contains three air conditioners: an air-cooled 5 ton Liebert Challenger (BU067A-AGEI), an air-cooled 10 ton Liebert Deluxe System (VH125-AAOI), and a 5 ton portable water-cooled Ocean Aire system (OWC6012).

The most significant power and heat source in the room is the 140 node cluster. Each node is a 1U dual Xeon 2.67 Ghz CPU, 2 GB RAM, 2x 200 GB HD rack-mounted workstation. This and the other hardware in the room are given in Table 1.

Additional heat sources, such as the transformers, are also given in Table 1. A typical transformer loses up to 5% of its input power to heat when running at maximum capacity. At LHO the transformers have a percent impedance of 4.5%. We will calculate the heat produced in the transformers via 0.045*output-power/(1 – 0.045). The air conditioners are on separate power sources from outside the room; Liebert give the net capacity sensible cooling numbers with the fan moter heat already factored into them [3]. However, the heat from humidification is probably not included and the humidifiers can add significant heat to the room. This is included in our calculations.

Table 1 show the total power and air conditioning requirements as follows. Cell N37 shows the maximum power usage of the room is 52.25 kW, based on actual measurements. This is converted to BTU/hr by multiplying by 3.42 BTU/hr/W (Cell P2) and to Tons by then multiplying by 8.33333e-5 Tons/BTU/hr (Cell R2). Cell R37 thus shows that the current room nominally requires 21.40 Tons of air conditioning at 100% efficiency. In Row 38 after Column M, totals with extra margins allowing for less than 100% efficiency are given. We divide the actual total power in Cell N37 by 0.8 to make sure we do not use more than 80% of a panels' power ratings. This gives in Cell N38 that the room currently requires a total power of 66.57 kW. Cell K38 shows that we have 81 kW of total power in the room, so we currently have enough power. We also divide the cooling rates by the air conditioners worst-case efficiency, which is given by the fraction in Cell H39. The efficiency is computed by the ratio of the worst-case cooling given in Cell F39 from Liebert's technical specifications [2-3] to the nominal cooling expected, given as .91 in Cell D39. Cell R38 shows that the room should have 21.00 tons of air conditioning to keep the room cool under the most difficult conditions to maintain as listed by Liebert (corresponding to 72 F at 50% RH; see Cells F36-38, G36-38). Finally Row 39 after Column M shows the requirements if we simply replaced existing racks with systems that required twice the power (e.g, because dual CPU workstations become quad CPU workstations, or because CPU speed doubles as per Moore's Law, and we double memory and hard drive spaces as well).

Since we only have 20 tons of air conditioning in the room (Cell C39), the numbers show we probably cannot maintain the room conditions when the room is under its maximum heat load, at least at 72 F and 50 % RH. Our experience is that in the past the mean ambient temperature in the room rises up to 73-75 F when the cluster is fully loaded. The exact temperature depends on the load from the rest of the equipment in the room and whether the humidifiers are on or not. The efficiency of the air conditioners rises at the temperature rises, and either eventually

equilibrium is reached, or in extreme cases we have had to shutdown some of the cluster. This has happened when the air conditioners' belts have become worn or stretched, and their efficiency has been reduced. We have several alarm systems that alert the control room and LDAS LHO system administrators if the temperature goes above 80 F, and a thermal trip that shuts down the room's power at (or several degrees below) 90 F. However, since replacing the belts in all the air conditioners we find we are able to maintain 72 F in the room even when the cluster is fully loaded. However, we are probably not maxing out everything else in the room at the same time, so 20 tons is sufficient for our current configuration.

The plans presented below will show a coherent way to grow from the present room configuration with 140 nodes to 210 nodes for S5. Several optional paths to take will be given, up to a final room configuration with 500 nodes. Suggestions for expansion beyond the present room will also be presented. For S5 as well as beyond S5, we will recommend air conditioning that can keep the room near 72 F under all conditions.

2.2.S5 Plans

For S5 LDAS plans to increase the number of nodes in the cluster from 140 to 210. No other significant changes are planned. Table 2 shows that this will require adding at least 10 tons of air conditioning and upgrading the 36 kW panel to 45 kW. Figure 2 shows the proposed layout of the room during S5. This layout involves adding two back racks and a 20 ton air conditioner, while trading in the existing 5 ton unit, for a net gain of 15 tons. This also involves moving an electrical switch. An alternative room configuration is shown in Figure 3, where a 30 ton air conditioner is added to the right side of the room, and we trade in the 10 ton air conditioner and put the 5 ton portable into storage, again for a net gain of 15 tons. The disadvantage is that this would probably have to move moved later on (to progress to the beyond S5 plans), though this might be a more straight forward solution for the short-term, as we do not have to move the electrical switch.

2.3.Summary of LHO changes for S5

- Upgrade the 36 kW electrical panel to 45 kW.
- Increase number of cluster nodes from 140 to 210, adding two racks to the room.
- Move electrical switch and replace 5 ton Liebert air conditioner with 20 ton unit (recommended if final goal is 80 tons) or replace 10 ton Liebert air conditioner with a 30 ton

unit (recommended if final goal is 60 tons) and put the 5 ton portable unit into storage or give to GSA.

2.4. Beyond S5

After S5 there are several options that we can consider.

The easiest would be to just upgrade the air conditioning so that we have 20 tons on the left side of the room and 30 tons on the right side of the room (See Figures 2 and 3), and then just add nodes into the existing space until we reach the maximum this amount of air conditioning can handle. (This would correspond to about 400 of the present nodes, or a total of 800 2.67 Ghz Xeon CPUs).

However, more efficient uses of the room are possible, and we plan to upgrade the CPUs as well. Several possibilities are discussed below. It is important to note that all of these require an rearrangement of the room (the position of all racks in the room will have to be either shifted by several feet or repositioned all together), the removal of all transformers from the room, and the addition of air ducts (plenum) to the room. (Note the plenum is not shown in any of the drawings.)

Figure 4 shows the ultimate configuration with 12.5 racks for 500 nodes, 1.5 racks for network switches, 1 rack for rack-mounted servers, 1 rack for raid systems (such as the current Sun 3511 models), plus 1 floor mounted server. Note however, that disk space will grow as hard drives become denser without increasing the footprint or probably the power requirements. The total air conditioning is 80 tons. This would be reached in two stages, as a 30 ton unit is moved or placed on the top wall, and then later a second 30 ton unit is added beside it. (Note that three 20 ton units will not fit along that wall. Also, 40 ton units exist, but their increased width to 50 inches would cause violation of our aisle space rules. Thus, growing that wall in increments of 30 tons is shown. We could also just grow to two 30 ton units, trading in anything else, and still almost have enough air conditioning for 500 nodes.)

Table 3 shows the room hardware based on 12 Sun 3511s for disk space and 500 nodes with maximum power usage or 306 W. This latter number comes from the specification of a fully loaded HP ProLiant DL145 with 2 AMD 2.4 GHz Opteron CPUs, 16 GB RAM, and 2 HD, plus an additional 6 W per CPU for dual core CPUs [4]. (According the web, AMD dual core CPUs will use 95 W compared with 89 W per CPU for single core models. The dual core CPUs have not yet been released, however, but if we do put something like this in the room, 500 nodes will correspond to 2000 CPUs.) If the actual power usage of the nodes we purchase in the future turns out to be less than 306 W, then more nodes can be purchased and vice versa. The

maximum computing power obtainable will be constrained by not exceeding 80 tons of AC in the configuration shown in Figure 4.

Figure 5 shows an alternative configuration with 2 tape library systems. (Note this configuration could work with only 50 tons of air conditioning and 300 nodes at 306 W per node.)

Figure 6 shows a comb configuration. This configuration is sometimes optimal, but with air conditioners along the top wall we do not gain rack space, and we lose aisle space in this configuration. Also note that an additional column of racks cannot be added, even if the 20 ton air conditioner is removed from the left side of the room. Thus, this configuration is not recommended.

Finally, beyond the present room, it may be possible to expand further. If a door can be added to the right wall of the room, or if that wall can be removed altogether (to gain space from the neighboring computer users room) then we can expand beyond the "beyond S5" configurations shown here by growing the configuration in Figure 4 to the right.

2.5.Summary of LHO plans beyond S5

1. The easiest plan would be to keep racks in place and have 20 tons of AC on the left and 30 tons on the right. This could support 400 of the present nodes or 300 nodes at 306 W per node.

2. Figure 4 shows the recommended configuration for a goal of 500 nodes at 306 W per node. This would be reached in two stages; the 30 ton air conditioners would be added along the top wall one at a time.

3. Figure 5 shows an alternative configuration where we double the tape library space and have fewer nodes. This configuration could be supported by 50 tons of AC.

4. Figure 6 shows a comb configuration that is not recommended, since it does not gain any rack space and loses aisle space.

5. Not shown in any of these figures are air ducts (plenum). The addition of plenum will be essential to the success of our plans beyond S5.

6. Their may be an option to grow the room beyond the right wall in the future.

3. CHAPTER 2: LLO

3.1. Present Room

Figures 7 shows the layout of the LDAS LLO room as of April 2005. The current room contains 70 nodes identical to those at LHO and is cooled using an air-cooled 15 ton Liebert Deluxe System (VH199AUAAEI). Table 4 shows the current hardware inventory, and power and air conditioning requirements. The total power shown in Cell N38 is 38.55 kW, which agrees well with what has been measured. The current air conditioning is adequate for the room, even under a maximum load and worst-case cooling conditions.

3.2. S5 And Beyond

Figures 8-11 show suggested layouts of the LDAS LLO, and Tables 4 and 5 show the expected hardware inventory and power and air conditioning requirements, for S5 and beyond S5. The recommended air conditioning in tons is given in Cell R38 of these tables.

The number and type of nodes at LLO, as well as most of the other equipment, will be identical as that at LHO for S5 and beyond. Thus, only summaries of the recommended changes are given here.

3.3. Summary of LLO changes for S5

- Upgrade electrical power in the room to 96 kW.
- Increase number of cluster nodes from 70 to 210, adding four racks to the room.
- Replace the 15 ton Liebert air conditioner with a 30 ton unit.

3.4. Summary of LLO plans beyond S5

- Upgrade electrical power in the room to at least 240 kW.
- Increase number of cluster nodes from 210 to 500, adding eight racks to the room.
- Increase the air conditioning in the room to at least 60 tons (the most that Liebert advertised in a single unit). (Since more than 60 tons is recommended in Table 6, depending on the actual power usage of the node, additional air condition outside the room may be needed.)

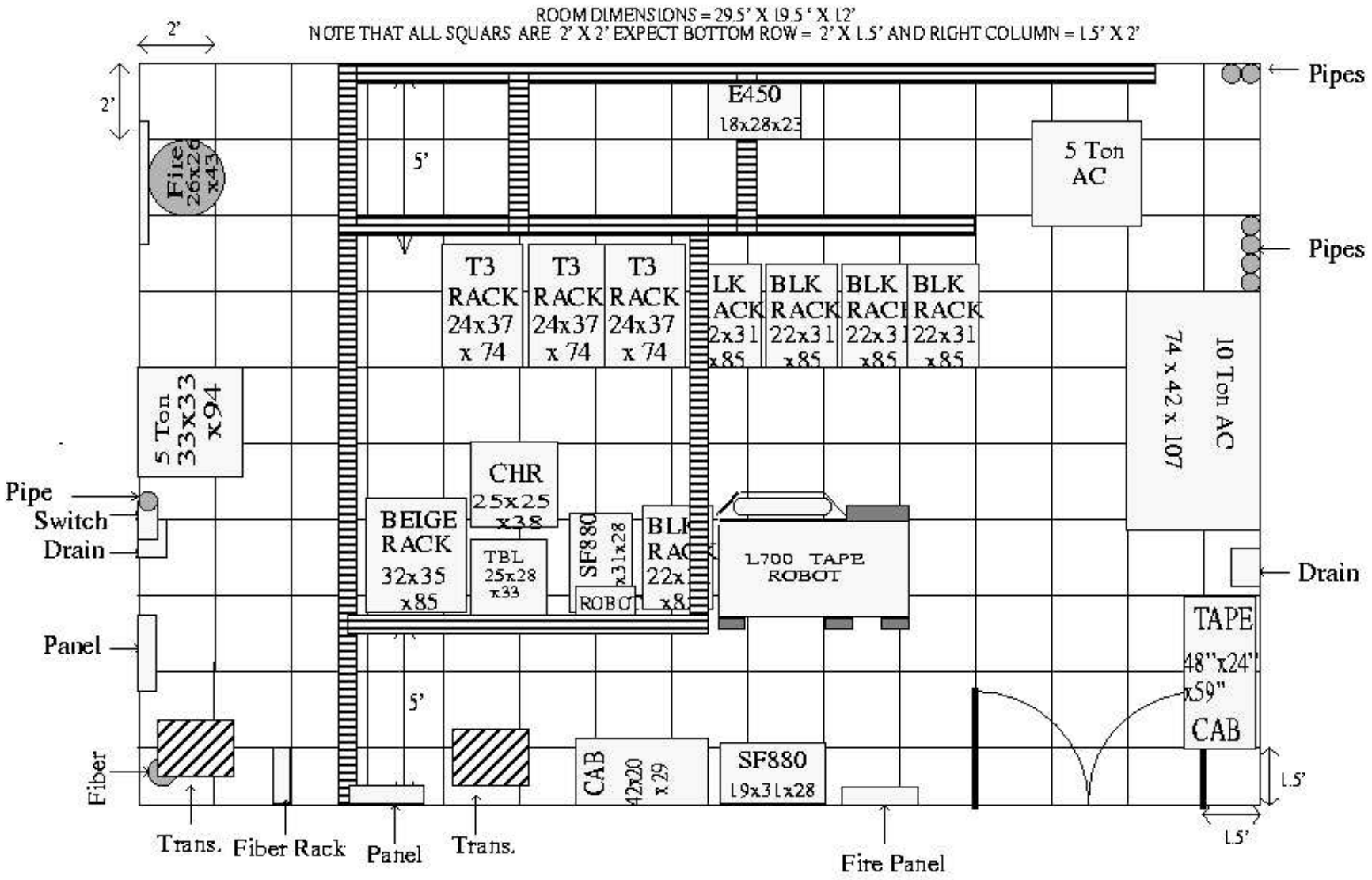
REFERENCE

[1] “Sun Microsystems Data Center Site Planning Guide (Data Centers' Best Practices)”, see http://www.sun.com/

[2] “Deluxe System/3 Technical Data”, see http://www.liebert.com/default.asp

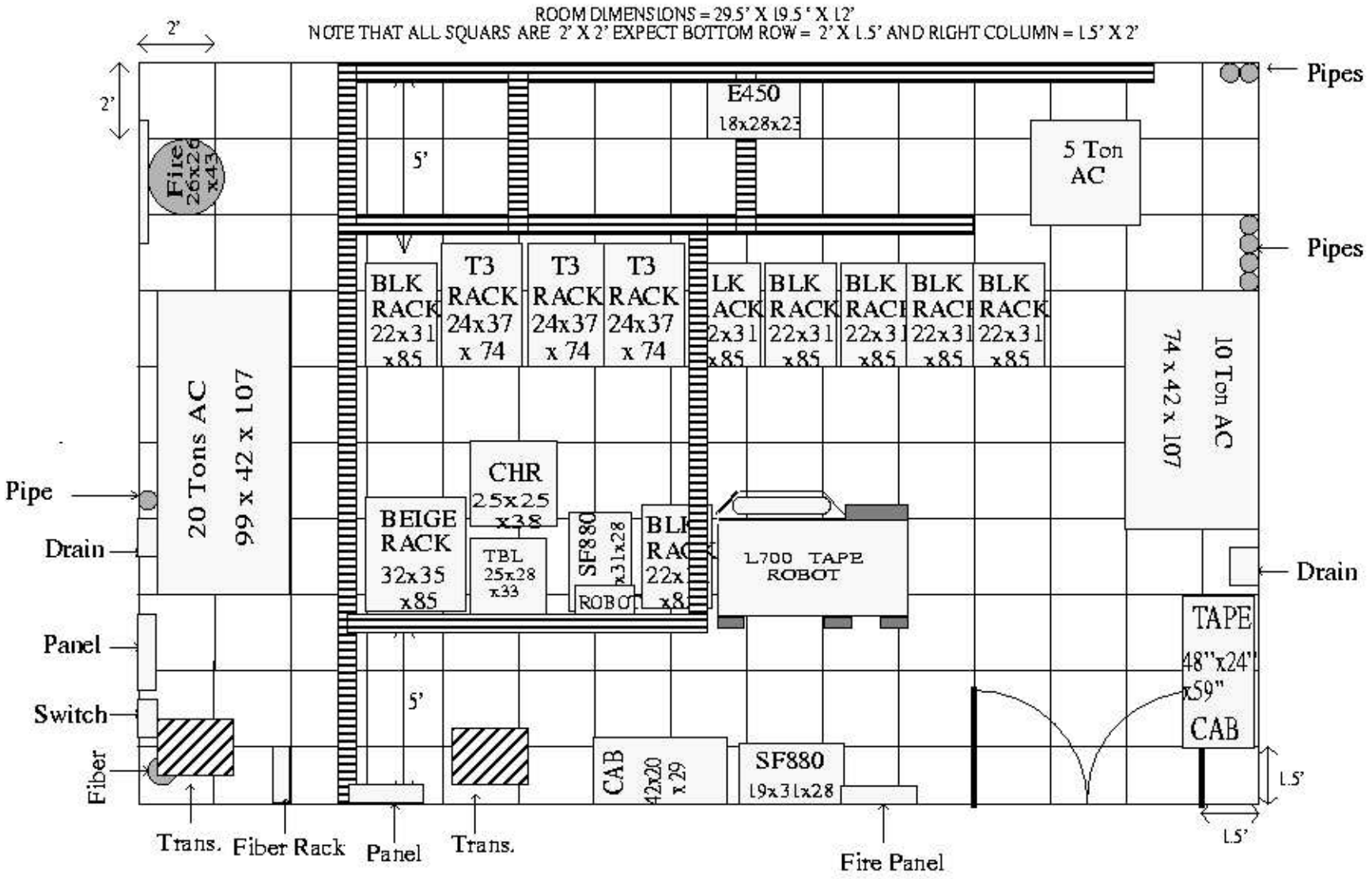
[3] “Chalenger 3000 Technical Data”, see http://www.liebert.com/default.asp

[4] “QuickSpecs HP ProLient DL145”, see http://h18004.www1.hp.com/products/servers/proliantdl145/



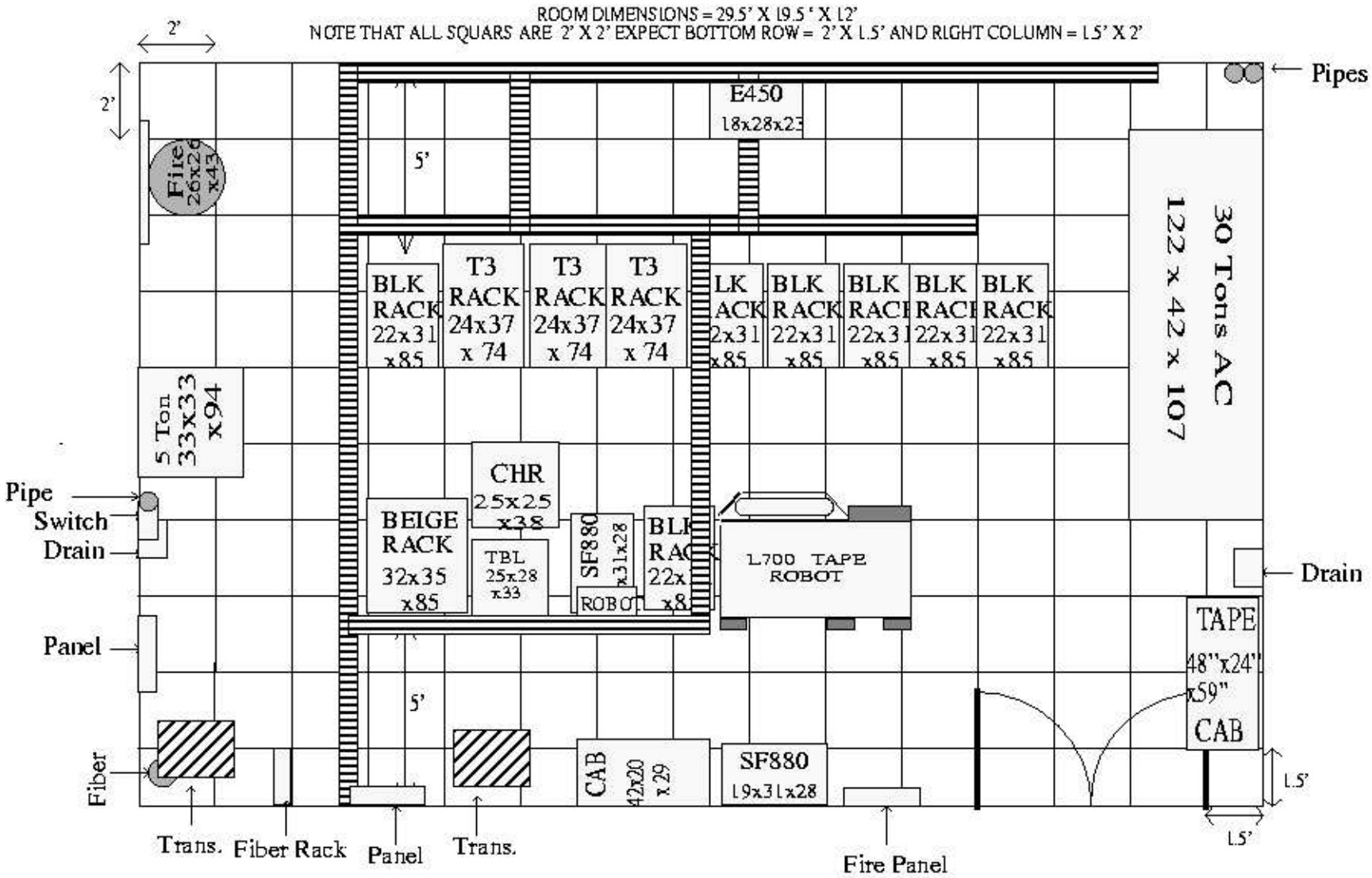
LDAS LHO ROOM LAYOUT, AS OF APRIL 2005

Figure 1



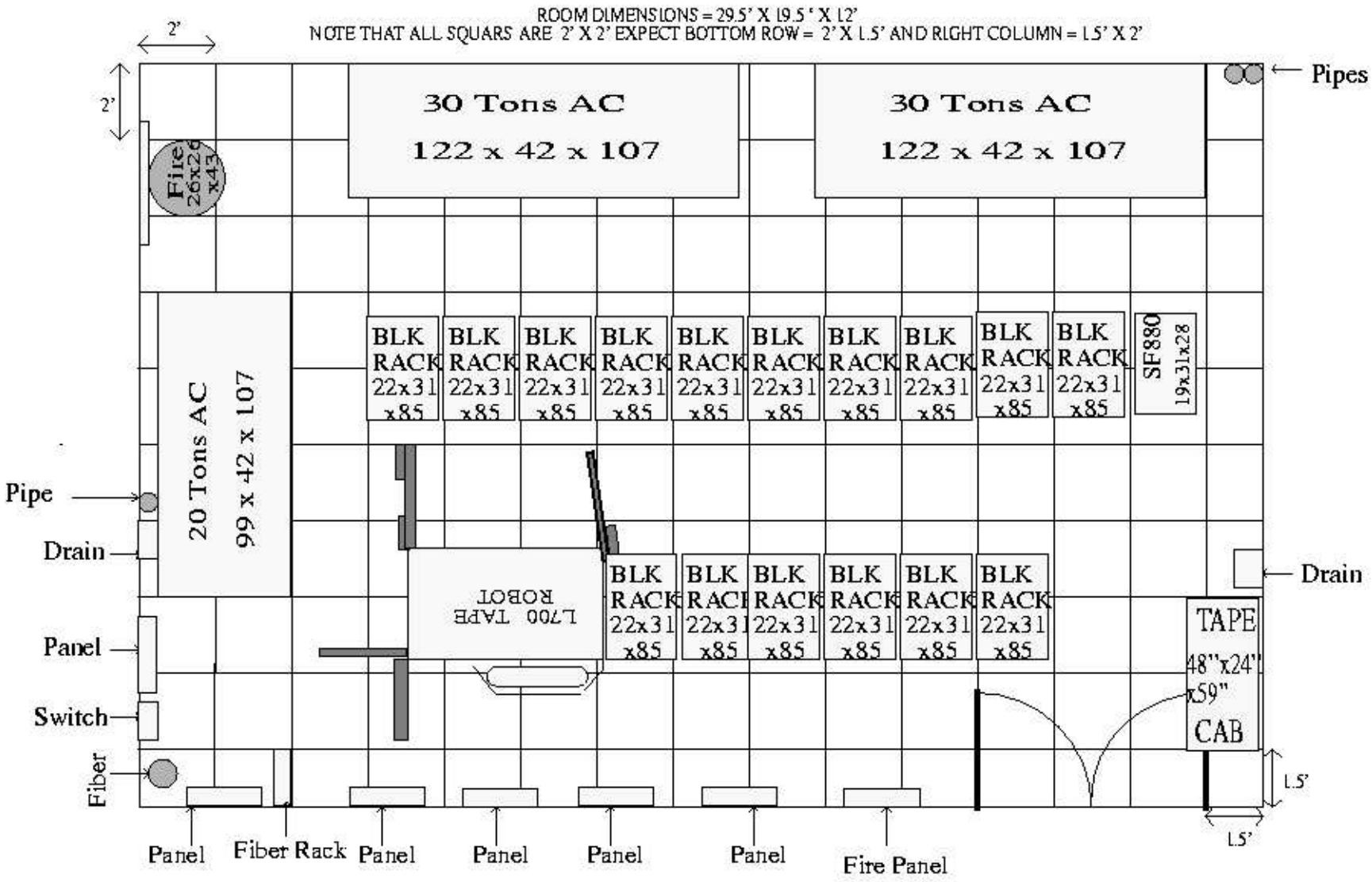
LDAS LHO ROOM LAYOUT FOR S5

Figure 2



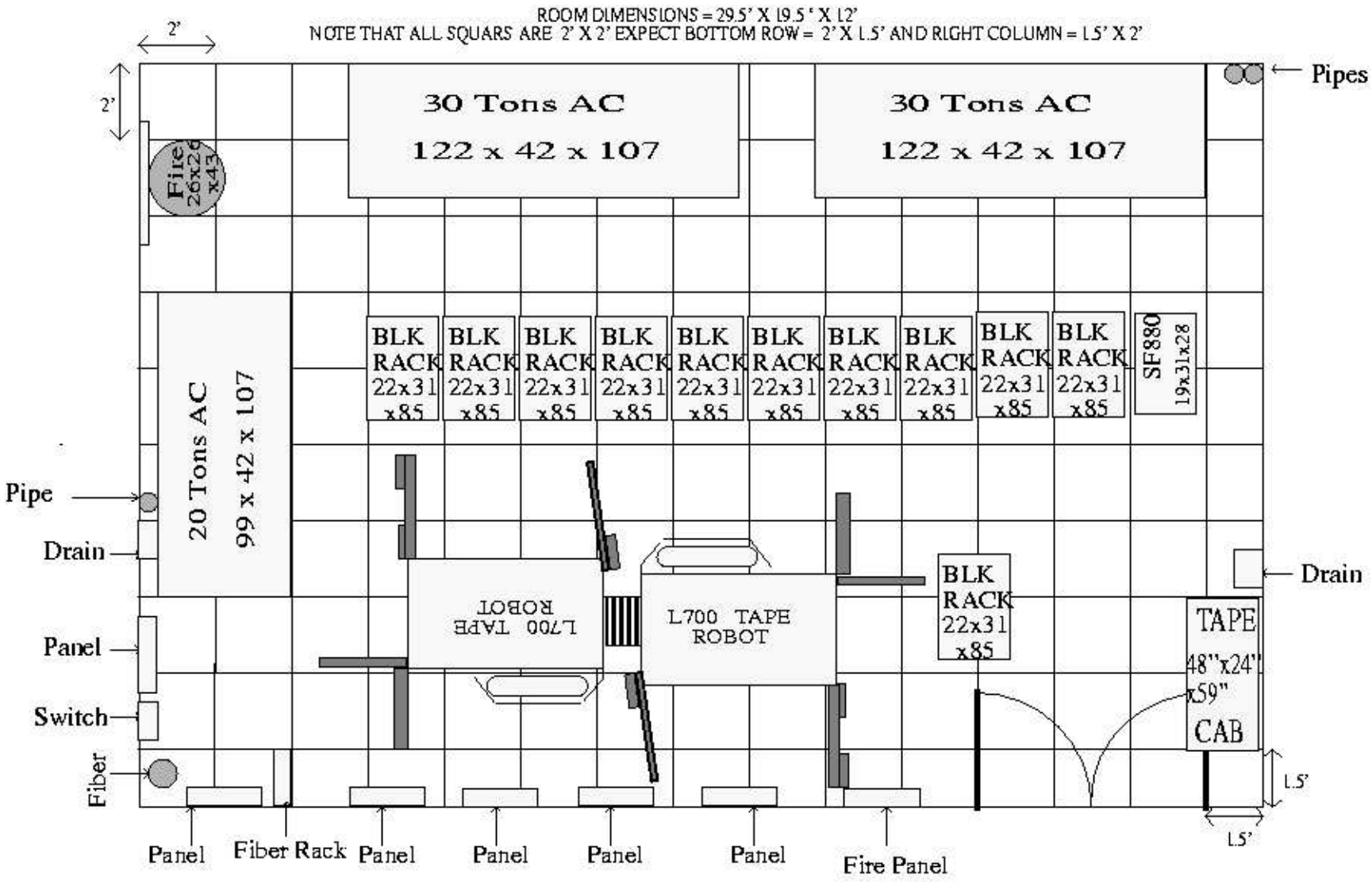
LDAS LHO ROOM LAYOUT FOR S5, ALTERNATIVE

Figure 3



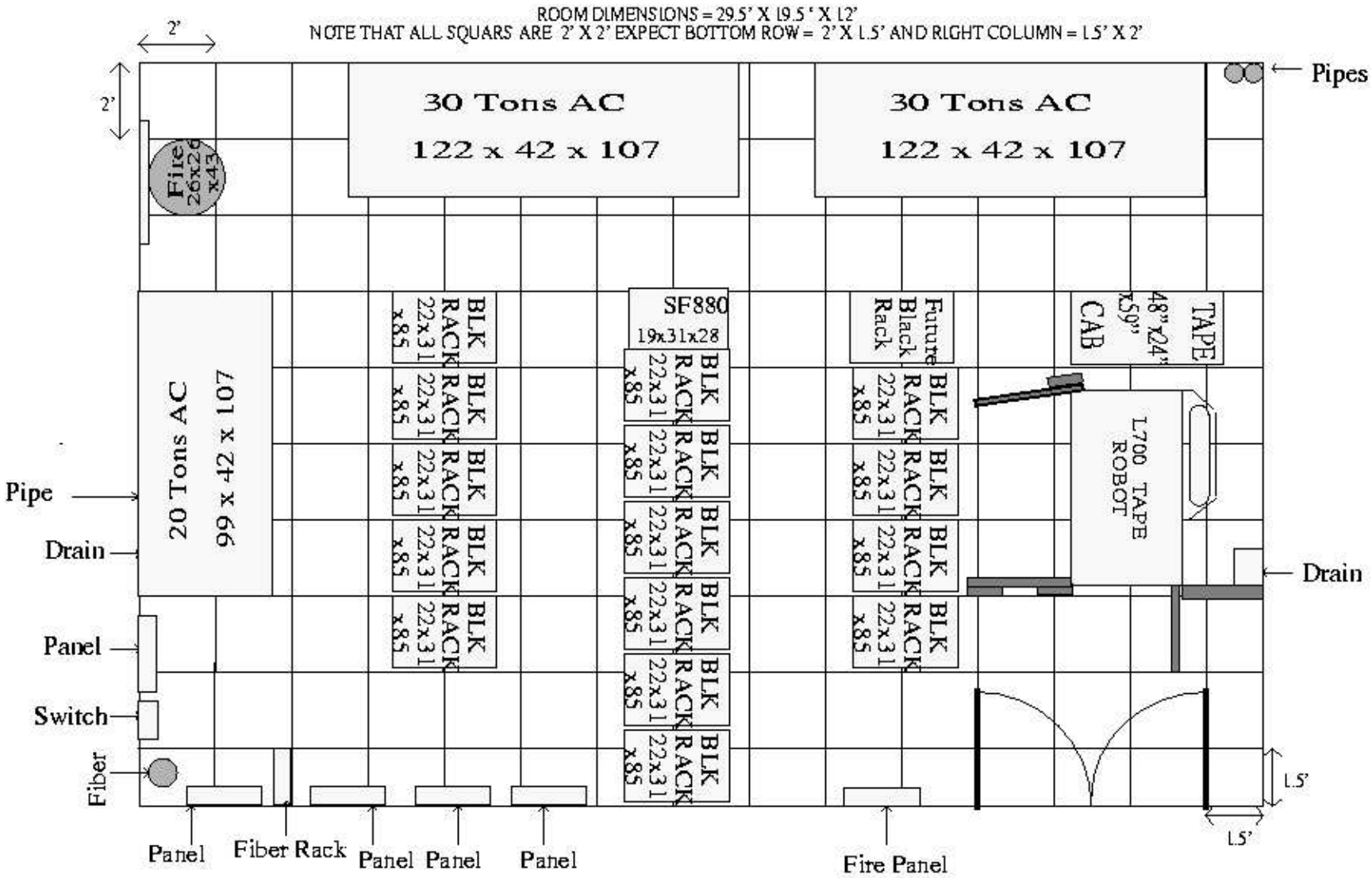
LDAS LHO ROOM LAYOUT BEYOND S5

Figure 4



LDAS LHO LAYOUT BEYOND S5, ALTERNATIVE

Figure 5



LDAS LHO LAYOUT BEYOND S5; COMB CONFIG.

Figure 6

Current layout of LDAS room at LLO, 04/24/2005

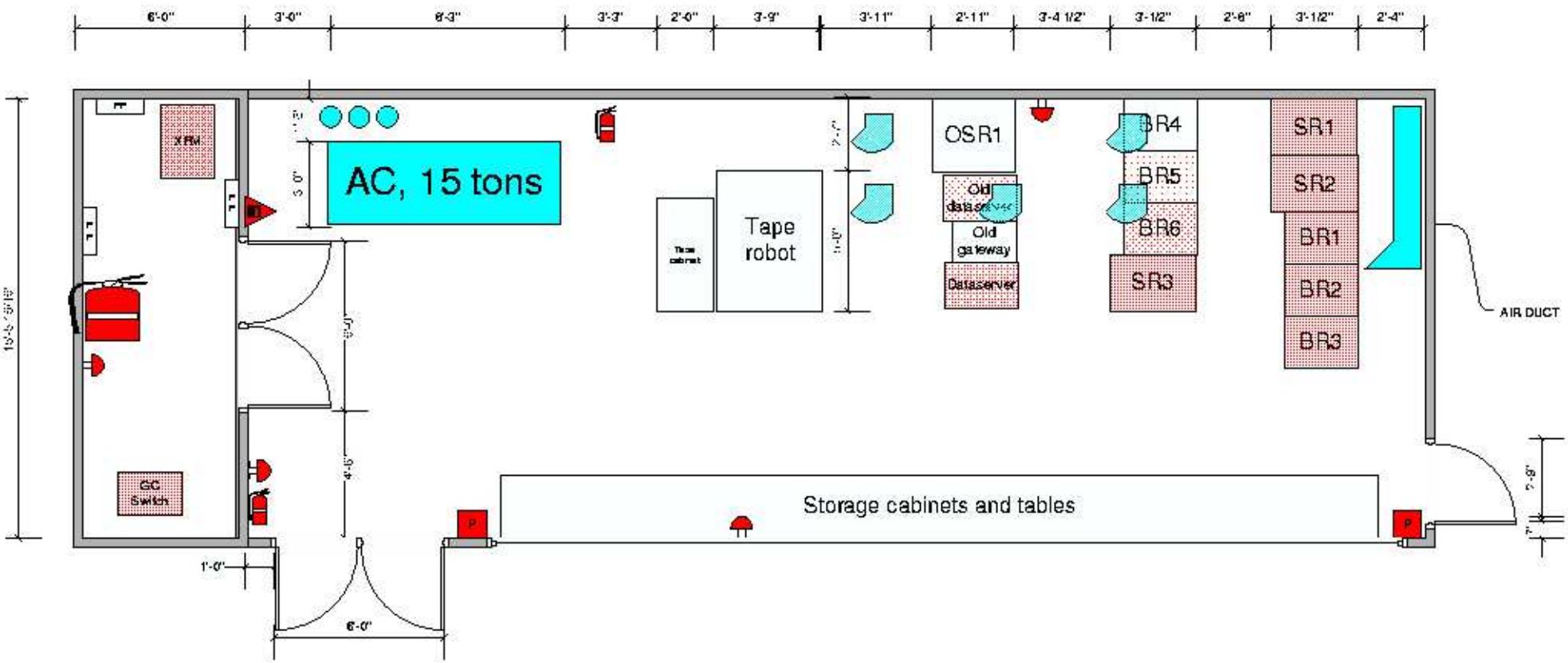


Figure 7

Suggested S5 layout of LDAS room at LLO for 210 nodes

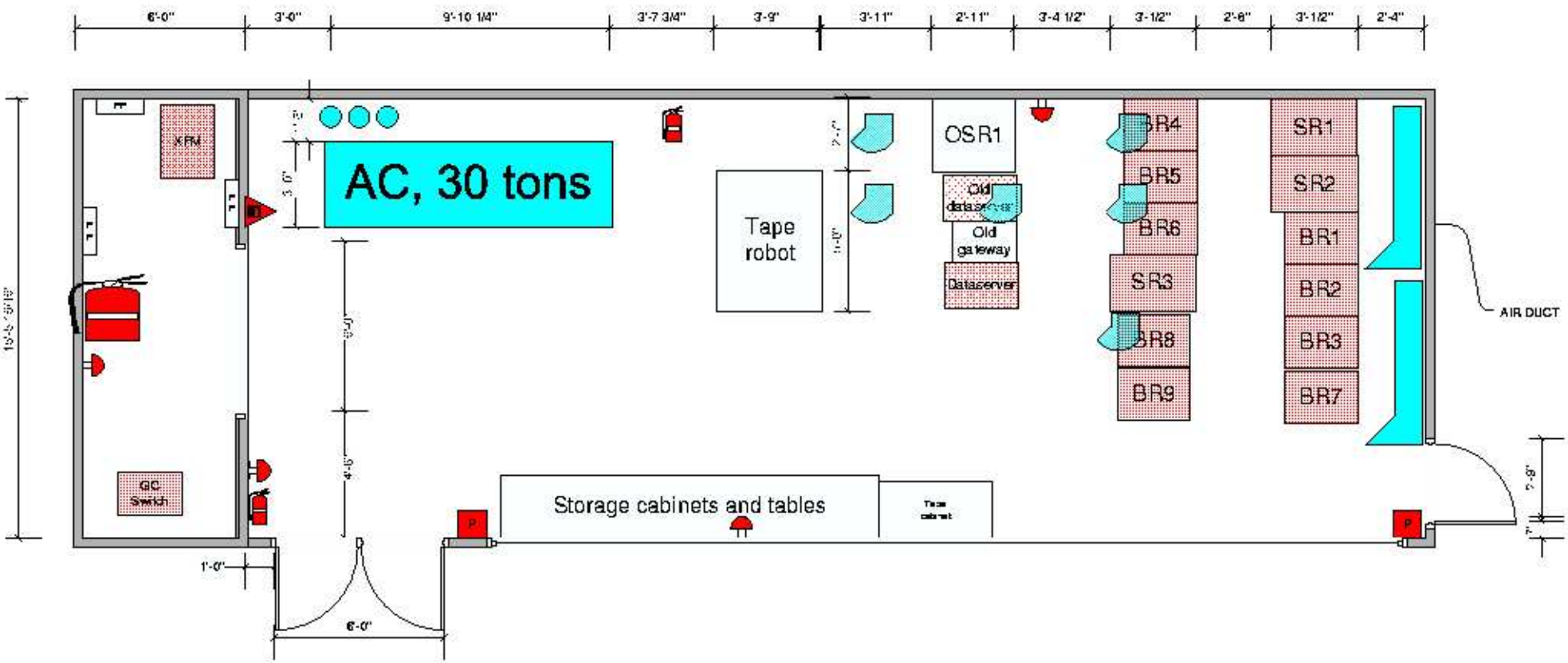


Figure 8

Suggested after S5 layout of LDAS room at LLO for 500 nodes

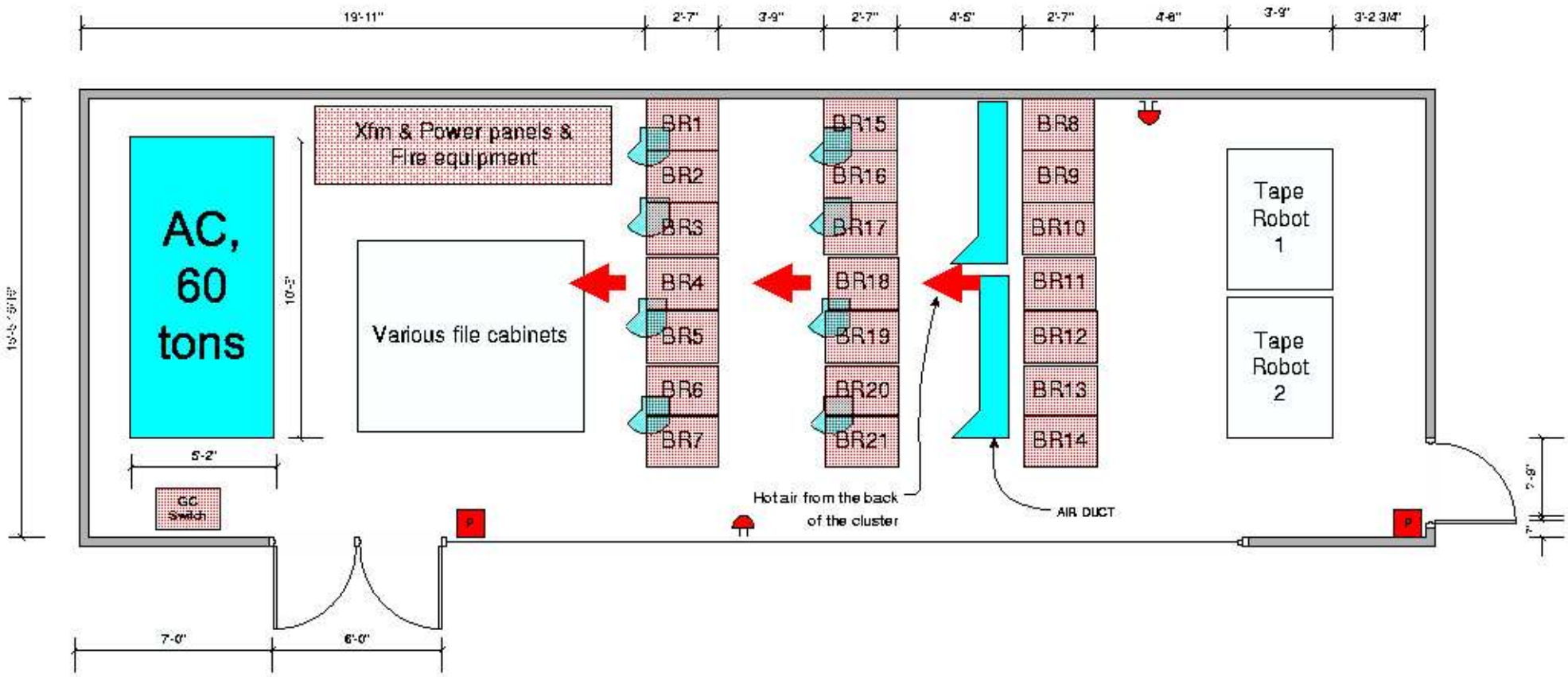


Figure 9

Suggested after S5 layout of LDAS room at LLO for 500 nodes

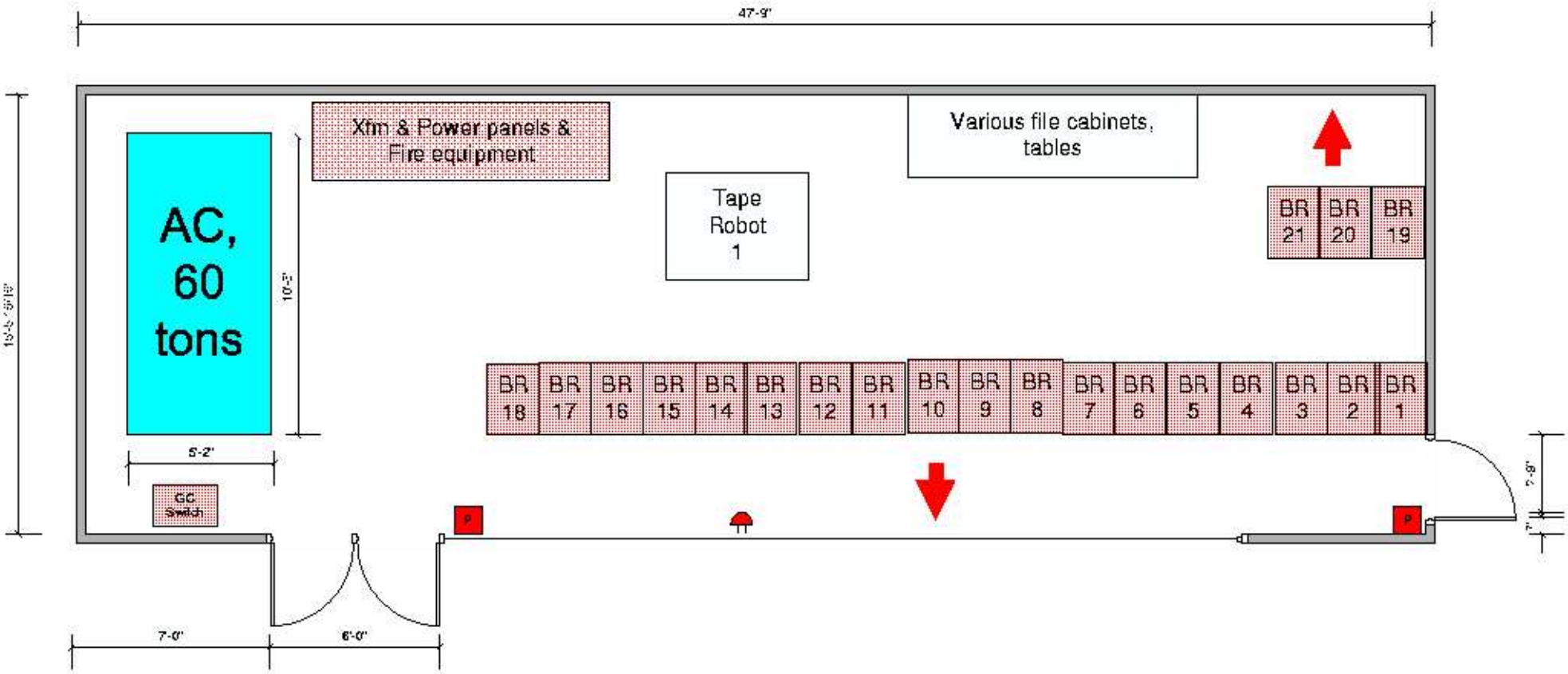


Figure 10

Suggested after S5 layout of LDAS room at LLO for 500 nodes

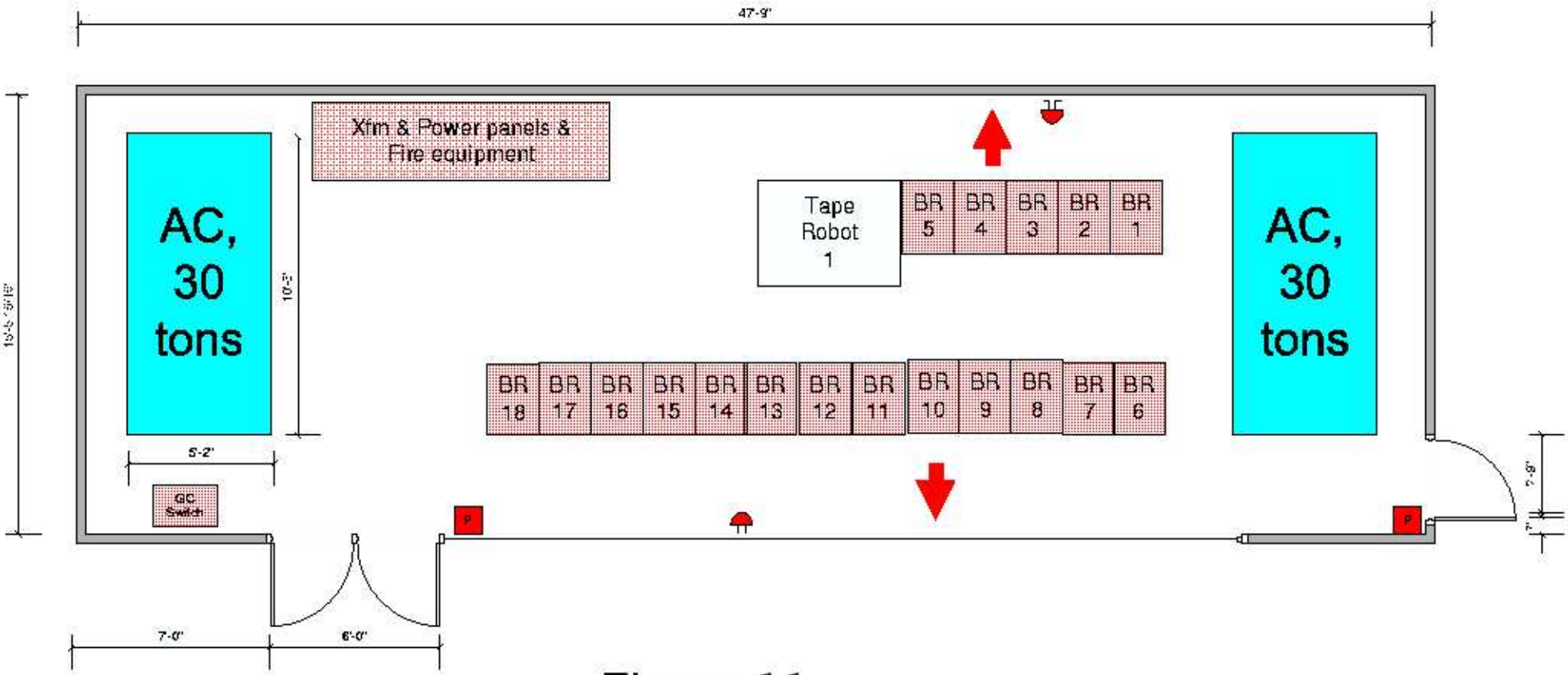


Figure 11

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R
1	Table 1. LDAS LHO Hardware & Power/HVAC Requirements for 140 nodes, April 2005																	
2	Subsystem: Data Strorage														BTU/hr/W =	3.42	Tons/BTU/hr	8.33E-05
3		Unit(s)	Number/Capacity	Vendor	Location	Form Factor	Number of Units	Function	Unit Electrical Power rating (Volt-Ampere)	Current Draw Idle State (A)	Current Draw Full Use State (A)	Power Idle State (W)	Power Full Use State (W)	Subsystem Total Power (W)	Unit BTU/hr	Subsystem Total BTU/hr		
4		Tape system	200TB	Sun L700 STK	Stand-alone	6x6x4 ft.	1	Tape Archive		6	6	700	700	700	2394	2394		
5		RAID	500 GB	T3 Sun	T3 Racks	4U	18	Samfs /frames		3.4	3.4	400	400	7200	1368	24624		
6		IDE RAID 200	2.4TB	ASA	Sun Rack	4U	1	User Data		2.18	2.52	254	300	300	1026	1026		
7		IDE RAID 160	1.9TB	ASA	Black Rack	4U	1	User Data		3.68	4.44	210	514	514	1757.88	1757.88		
8		Switch	48x2Gb Fibre	Sun	T3 Rack 3	4U	1	FC Fabric switch		5.77	5.77	5.77	675	675	2308.5	2308.5		
9		RAID	1.7 TB	3510/3511 Sun	Sun and Black Racks	3U	5	Samfs metadata and / export, / archive, / cluster		2.7	2.7	306	306	1530	1046.52	5232.6		
10																		
11	Subsystem: Data Servers																	
12		Gateway	SF 280R	Sun	Sun Rack	4U	1	Network gateway/NFS server		3.24	3.24	380	380	380	1299.6	1299.6		
13		Dataserver	SF V880 (8CPU)	Sun	Stand-alone	N/A	1	Main SAMFS Server		11.4	11.4	1335	1335	1335	4565.7	4565.7		
14		Old Ldas-pcdev1	Quad x86 Box	Dell	Stand-alone	Mid-tower	1	Condor post-processing		1.65	2.19	183	249	249	851.58	851.58		
15		Linux servers	2x x86 4GB	ASA	Node racks/black rack	1U	6	LDAS metadata/data con/beowulf/ldas-grid/ldas-pcdev1/ldas-gridmon		1	2	115	230	1380	786.6	4719.6		
16		Old dataserver	SF V880 (2CPU)	Sun	Stand-alone	N/A	1	Filesystem backups		5.47	5.47	640	640	640	2188.8	2188.8		
17		Old gateway	E450	Sun	Stand-alone	N/A	1	Backup gateway		4.1	4.1	480	480	480	1641.6	1641.6		
18		Vpn	1x x86 1GB	ASA	Black Rack	2U	2	Db2 replication VPN		1.28	1.28	150	150	300	513	1026		
19																		
20	Subsystem: Comptational Cluster																	
21		Node type 1	2.67 GHz Dual CPU	ASA	Node racks	1U	140	Cluster node		1.04	2.08	125	250	35000	855	119700		
22																		
23	Subsystem: Network Switches																	
24		Switch	168 Gig-E ports	Foundry	Node rack 1	17U	1	TCP/IP Switch		16.5	17	1930	1990	1990	6805.8	6805.8		
25																		
26	Subsystem: Misc. Administrative																	
27		Monitor	19" CRT	Sun/Dell	Mobile cart	19"	2	Mobile console		1.8	1.8	210	210	420	718.2	1436.4		
28		Console multiplexer	8 ports	NTI	Mobile cart	2U	1	Terminal Multiplexer		0.8	0.8	100	100	100	342	342		

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R
29		H0ldas	Sparcstation5	Sun	Sun Rack	Desktop	1	CDS Temperature Alarm		0.5	0.5	60	60	60	205.2	205.2		
30	Other Heat Sources																	
31		Liebert 5 Ton Humidifer					1						4800		16416	16416		
32		Liebert 10+ Ton Humidifier					1						6400		21888	21888		
33		Transformers					2					Total W from N38:	53253		Total BTU/hr from Transformers:	8581.82		
34																		
35	Air Conditioner Sensible Cooling	Model	Tons	Total Cooling Based on Tons	Sensible Cooling (BTU/hr) at 72F, 45% RH	Worst-case cooling (BTU/hr)	Worst-case conditions	Efficiencey Factor = F40/D40	Number of 45kW Panels Needed									
36	Liebert	BU067A-AGET	5	60000	58300	51100	72F, 50% RH											
37	Liebert	VH125-AAOI	10	120000	120000	108700	72F, 50% RH		1.18	0.8*Actual Room Input Power (W):	64800		Total Power (W)	53253	Total BTU/hr	229,011.08	Total Tons	19.08
38	Ocean Aire	OWC6012	5	60000	58300	58300	Numbers from Liebert BU067A		1.48	Actual Room Input Power (W):	81000	Totals with safety margins:	Totals / 0.80	66566.25	Totals / Efficiency	252006.69	Totals / Efficiency	21.00
39			20	240000	236600	218100		0.91	2.96				2x Above	133132.50	2x Above	504013.38	2x Above	42.00

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R
1	Table 2. LDAS LHO Hardware Inventory & Power/HVAC Requirements For S5																	
2	Subsystem: Data Strorage														BTU/hr/W =	3.42	Tons/BTU/hr	8.33E-05
3		Unit(s)	Number/Capacity	Vendor	Location	Form Factor	Number of Units	Function	Unit Electrical Power rating (Volt-Ampere)	Current Draw Idle State (A)	Current Draw Full Use State (A)	Power Idle State (W)	Power Full Use State (W)	Subsystem Total Power (W)	Unit BTU/hr	Subsystem Total BTU/hr		
4		Tape system	200TB	Sun L700 STK	Stand-alone	6x6x4 ft.	1	Tape Archive		6	6	700	700	700	2394	2394		
5		RAID	500 GB	T3 Sun	T3 Racks	4U	18	Samfs /frames		3.4	3.4	400	400	7200	1368	24624		
6		IDE RAID 200	2.4TB	ASA	Sun Rack	4U	1	User Data		2.18	2.52	254	300	300	1026	1026		
7		IDE RAID 160	1.9TB	ASA	Black Rack	4U	1	User Data		3.68	4.44	210	514	514	1757.88	1757.88		
8		Switch	48x2Gb Fibre	Sun	T3 Rack 3	4U	1	FC Fabric switch		5.77	5.77	5.77	675	675	2308.5	2308.5		
9		RAID	1.7 TB	3510/3511 Sun	Sun and Black Racks	3U	5	Samfs metadata and / export, / archive, / cluster		2.7	2.7	306	306	1530	1046.52	5232.6		
10																		
11	Subsystem: Data Servers																	
12		Gateway	SF 280R	Sun	Sun Rack	4U	1	Network gateway/NFS server		3.24	3.24	380	380	380	1299.6	1299.6		
13		Dataserver	SF V880 (8CPU)	Sun	Stand-alone	N/A	1	Main SAMFS Server		11.4	11.4	1335	1335	1335	4565.7	4565.7		
14		Old Ldas-pcdev1	Quad x86 Box	Dell	Stand-alone	Mid-tower	1	Condor post-processing		1.65	2.19	183	249	249	851.58	851.58		
15		Linux servers	2x x86 4GB	ASA	Node racks/black rack	1U	6	LDAS metadata/data con/beowulf/ldas-grid/ldas-pcdev1/ldas-gridmon		1	2	115	230	1380	786.6	4719.6		
16		Old dataserver	SF V880 (2CPU)	Sun	Stand-alone	N/A	1	Filesystem backups		5.47	5.47	640	640	640	2188.8	2188.8		
17		Old gateway	E450	Sun	Stand-alone	N/A	1	Backup gateway		4.1	4.1	480	480	480	1641.6	1641.6		
18		Vpn	1x x86 1GB	ASA	Black Rack	2U	2	Db2 replication VPN		1.28	1.28	150	150	300	513	1026		
19																		
20	Subsystem: Comptational Cluster																	
21		Node type 1	2.67 GHz Dual CPU	ASA	Node racks	1U	210	Cluster node		1.04	2.08	125	250	52500	855	179550		
22																		
23	Subsystem: Network Switches																	
24		Switch	168 Gig-E ports	Foundry	Node rack 1	17U	1	TCP/IP Switch		16.5	17	1930	1990	1990	6805.8	6805.8		
25																		
26	Subsystem: Misc. Administrative																	
27		Monitor	19" CRT	Sun/Dell	Mobile cart	19"	2	Mobile console		1.8	1.8	210	210	420	718.2	1436.4		
28		Console multiplexer	8 ports	NTI	Mobile cart	2U	1	Terminal Multiplexer		0.8	0.8	100	100	100	342	342		

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R
29		H0ldas	Sparcstation5	Sun	Sun Rack	Desktop	1	CDS Temperature Alarm		0.5	0.5	60	60	60	205.2	205.2		
30	Other Heat Sources																	
31		Liebert 20 Ton Humidifer					1						9600		32832	32832		
32		Liebert 10+ Ton Humidifier					1						6400		21888	21888		
33		Transformers					2					Total W from N38:	70753		Total BTU/hr from Transformers:	11401.98		
34																		
35	Air Conditioner Sensible Cooling	Model	Tons	Total Cooling Based on Tons	Sensible Cooling (BTU/hr) at 72F, 45% RH	Worst-case cooling (BTU/hr)	Worst-case conditions	Efficiencey Factor = F39/D39	Number of 45kW Panels Needed									
36	Liebert	VH245A-AAOI	20	240000	221800	197700	72F, 50% RH											
37	Liebert	VH125-AAOI	10	120000	120000	108700	72F, 50% RH		1.57	0.8*Actual Room Input Power (W):	72000		Total Power (W)	70753	Total BTU/hr	308,097.24	Total Tons	25.67
38	Ocean Aire	OWC6012	5	60000	58300	58300	Numbers from Liebert BU067A		1.97	Actual Room Input Power (W):	90000	Totals with safety margins:	Totals / 0.80	88441.25	Totals / Efficiency	354814.48	Totals / Efficiency	29.57
39			35	420000	400100	364700		0.87	3.93				2x Above	176882.50	2x Above	709628.95	2x Above	59.14

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R
1	Table 3. LDAS LHO Hardware Inventory & Power/HVAC Requirements Beyond S5																	
2	Subsystem: Data Strorage														BTU/hr/W =	3.42	Tons/BTU/hr	8.33E-05
3		Unit(s)	Number/Capacity	Vendor	Location	Form Factor	Number of Units	Function	Unit Electrical Power rating (Volt-Ampere)	Current Draw Idle State (A)	Current Draw Full Use State (A)	Power Idle State (W)	Power Full Use State (W)	Subsystem Total Power (W)	Unit BTU/hr	Subsystem Total BTU/hr		
4		Tape system	200TB	Sun L700 STK	Stand-alone	6x6x4 ft.	1	Tape Archive		6	6	700	700	700	2394	2394		
5		RAID	500 GB	T3 Sun	T3 Racks	4U	0	Samfs /frames		3.4	3.4	400	400	0	1368	0		
6		IDE RAID 200	2.4TB	ASA	Sun Rack	4U	0	User Data		2.18	2.52	254	300	0	1026	0		
7		IDE RAID 160	1.9TB	ASA	Black Rack	4U	0	User Data		3.68	4.44	210	514	0	1757.88	0		
8		Switch	48x2Gb Fibre	Sun	T3 Rack 3	4U	1	FC Fabric switch		5.77	5.77	5.77	675	675	2308.5	2308.5		
9		RAID	1.7 TB	3510/3511 Sun	Sun and Black Racks	3U	12	Samfs metadata and / export, / archive, / cluster		2.7	2.7	306	306	3672	1046.52	12558.24		
10																		
11	Subsystem: Data Servers																	
12		Gateway	SF 280R	Sun	Sun Rack	4U	1	Network gateway/NFS server		3.24	3.24	380	380	380	1299.6	1299.6		
13		Dataserver	SF V880 (8CPU)	Sun	Stand-alone	N/A	1	Main SAMFS Server		11.4	11.4	1335	1335	1335	4565.7	4565.7		
14		Old Ldas-pcdev1	Quad x86 Box	Dell	Stand-alone	Mid-tower	0	Condor post-processing		1.65	2.19	183	249	0	851.58	0		
15		Linux servers	2x x86 4GB	ASA	Node racks/black rack	1U	6	LDAS metadata/data con/beowulf/ldas-grid/ldas-pcdev1/ldas-gridmon		1	2	115	230	1380	786.6	4719.6		
16		Old dataserver	SF V880 (2CPU)	Sun	Stand-alone	N/A	0	Filesystem backups		5.47	5.47	640	640	0	2188.8	0		
17		Old gateway	E450	Sun	Stand-alone	N/A	0	Backup gateway		4.1	4.1	480	480	0	1641.6	0		
18		Vpn	1x x86 1GB	ASA	Black Rack	2U	0	Db2 replication VPN		1.28	1.28	150	150	0	513	0		
19																		
20	Subsystem: Comptational Cluster																	
21		Node type 1	2.67 GHz Dual CPU	ASA	Node racks	1U	500	Cluster node		?	?	?	306	153000	1046.52	523260		
22																		
23	Subsystem: Network Switches																	
24		Switch	168 Gig-E ports	Foundry	Node rack 1	17U	3	TCP/IP Switch		16.5	17	1930	1990	5970	6805.8	20417.4		
25																		
26	Subsystem: Misc. Administrative																	
27		Monitor	19" CRT	Sun/Dell	Mobile cart	19"	1	Mobile console		1.8	1.8	210	210	210	718.2	718.2		
28		Console multiplexer	8 ports	NTI	Mobile cart	2U	0	Terminal Multiplexer		0.8	0.8	100	100	0	342	0		

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R
29		H0ldas	Sparcstation5	Sun	Sun Rack	Desktop	1	CDS Temperature Alarm		0.5	0.5	60	60	60	205.2	205.2		
30	Other Heat Sources																	
31		Liebert 20 Ton Humidifer					1						9600		32832	32832		
32		Liebert 30 Ton Humidifier					2						9600		32832	65664		
33		Transformers					0					Total W from N38:	167382		Total BTU/hr from Transformers:	0		
34																		
35	Air Conditioner Sensible Cooling	Model	Tons	Total Cooling Based on Tons	Sensible Cooling (BTU/hr) at 72F, 45% RH	Worst-case cooling (BTU/hr)	Worst-case conditions	Efficiencey Factor = F39/D39	Number of 45kW Panels Needed									
36	Liebert	VH245A-AAOI	20	240000	221800	197700	72F, 50% RH											
37	Liebert	VH380A-AAOI	30	360000	337000	295600	72F, 50% RH		3.72	0.8*Actual Room Input Power (W):	180000		Total Power (W)	167382	Total BTU/hr	670,942.44	Total Tons	55.91
38	Liebert	VH380A-AAOI	30	360000	337000	295600	72F, 50% RH		4.65	Actual Room Input Power (W):	225000	Totals with safety margins:	Totals / 0.80	209227.50	Totals / Efficiency	816459.30	Totals / Efficiency	68.04
39			80	960000	895800	788900		0.82	9.3				2x Above	418455.00	2x Above	1632918.61	2x Above	136.08

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R
1	Table 4. LDAS LLO Hardware Inventory & Power/HVAC Requirements for 70 nodes, April 2005																	
2	Subsystem: Data Strorage														BTU/hr/W =	3.42	Tons/BTU/hr	8.33E-05
3		Unit(s)	Number/Capacity	Vendor	Location	Form Factor	Number of Units	Function	Unit Electrical Power rating (Volt-Ampere)	Current Draw Idle State (A)	Current Draw Full Use State (A)	Power Idle State (W)	Power Full Use State (W)	Subsystem Total Power (W)	Unit BTU/hr	Subsystem Total BTU/hr		
4		Tape system	200TB	Sun L700 STK	Stand-alone	6x6x4 ft.	1	Tape Archive		6	6	700	700	700	2394	2394		
5		RAID	500 GB	T3 Sun	T3 Racks	4U	25	Samfs /frames		3.4	3.4	400	400	10000	1368	34200		
6		IDE RAID 200	2.4TB	ASA	Sun Rack	4U	1	User Data		2.18	2.52	254	300	300	1026	1026		
7		IDE RAID 160	1.9TB	ASA	Black Rack	4U	1	User Data		3.68	4.44	210	514	514	1757.88	1757.88		
8		Switch	48x2Gb Fibre	Sun	T3 Rack 3	4U	1	FC Fabric switch		5.77	5.77	5.77	675	675	2308.5	2308.5		
9		RAID	1.7 TB	3510/3511 Sun	Sun and Black Racks	3U	5	Samfs metadata and / export, / archive, / cluster		2.7	2.7	306	306	1530	1046.52	5232.6		
10																		
11	Subsystem: Data Servers																	
12		Gateway	SF 280R	Sun	Sun Rack	4U	1	Network gateway/NFS server		3.24	3.24	380	380	380	1299.6	1299.6		
13		Dataserver	SF V880 (8CPU)	Sun	Stand-alone	N/A	1	Main SAMFS Server		11.4	11.4	1335	1335	1335	4565.7	4565.7		
14		Old Ldas-pcdev1	Quad x86 Box	Dell	Stand-alone	Mid-tower	1	Condor post-processing		1.65	2.19	183	249	249	851.58	851.58		
15		Linux servers	2x x86 4GB	ASA	Node racks/black rack	1U	6	LDAS metadata/data con/beowulf/ldas-grid/ldas-pcdev1/ldas-gridmon		1	2	115	230	1380	786.6	4719.6		
16		Old dataserver	SF V880 (2CPU)	Sun	Stand-alone	N/A	1	Filesystem backups		5.47	5.47	640	640	640	2188.8	2188.8		
17		Old gateway	E450	Sun	Stand-alone	N/A	1	Backup gateway		4.1	4.1	480	480	480	1641.6	1641.6		
18		Vpn	1x x86 1GB	ASA	Black Rack	2U	2	Db2 replication VPN		1.28	1.28	150	150	300	513	1026		
19																		
20	Subsystem: Comptational Cluster																	
21		Node type 1	2.67 GHz Dual CPU	ASA	Node racks	1U	70	Cluster node		1.04	2.08	125	250	17500	855	59850		
22																		
23	Subsystem: Network Switches																	
24		Switch	168 Gig-E ports	Foundry	Node rack 1	17U	1	TCP/IP Switch		16.5	17	1930	1990	1990	6805.8	6805.8		
25																		
26	Subsystem: Misc. Administrative																	
27		Monitor	19" CRT	Sun/Dell	Mobile cart	19"	2	Mobile console		1.8	1.8	210	210	420	718.2	1436.4		
28		Console multiplexer	8 ports	NTI	Mobile cart	2U	1	Terminal Multiplexer		0.8	0.8	100	100	100	342	342		

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R
29		H0ldas	Sparcstation5	Sun	Sun Rack	Desktop	1	CDS Temperature Alarm		0.5	0.5	60	60	60	205.2	205.2		
30	Other Heat Sources																	
31		Liebert 15 Ton Humidifier					1						6400		21888	21888		
32																		
33		Transformers					1					Total W from N38:	38553		Total BTU/hr from Transformers:	6212.89		
34																		
35	Air Conditioner Sensible Cooling	Model	Tons	Total Cooling Based on Tons	Sensible Cooling (BTU/hr) at 72F, 45% RH	Worst-case cooling (BTU/hr)	Worst-case conditions	Efficiencey Factor = F39/D39	Number of 45kW Panels Needed									
36	Liebert	VH199UAAEI	15	180000	177600	162700	72F, 50% RH											
37									0.86	0.8*Actual Room Input Power (W):	38400		Total Power (W)	38553	Total BTU/hr	159,952.15	Total Tons	13.33
38									1.07	Actual Room Input Power (W):	48000	Totals with safety margins:	Totals / 0.80	48191.25	Totals / Efficiency	176959.97	Totals / Efficiency	14.75
39			15	180000	177600	162700		0.9	2.14				2x Above	96382.50	2x Above	353919.93	2x Above	29.49

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R
1	Table 5. LDAS LLO Hardware Inventory & Power/HVAC Requirements for S5																	
2	Subsystem: Data Strorage														BTU/hr/W =	3.42	Tons/BTU/hr	8.33E-05
3		Unit(s)	Number/Capacity	Vendor	Location	Form Factor	Number of Units	Function	Unit Electrical Power rating (Volt-Ampere)	Current Draw Idle State (A)	Current Draw Full Use State (A)	Power Idle State (W)	Power Full Use State (W)	Subsystem Total Power (W)	Unit BTU/hr	Subsystem Total BTU/hr		
4		Tape system	200TB	Sun L700 STK	Stand-alone	6x6x4 ft.	1	Tape Archive		6	6	700	700	700	2394	2394		
5		RAID	500 GB	T3 Sun	T3 Racks	4U	25	Samfs /frames		3.4	3.4	400	400	10000	1368	34200		
6		IDE RAID 200	2.4TB	ASA	Sun Rack	4U	1	User Data		2.18	2.52	254	300	300	1026	1026		
7		IDE RAID 160	1.9TB	ASA	Black Rack	4U	1	User Data		3.68	4.44	210	514	514	1757.88	1757.88		
8		Switch	48x2Gb Fibre	Sun	T3 Rack 3	4U	1	FC Fabric switch		5.77	5.77	5.77	675	675	2308.5	2308.5		
9		RAID	1.7 TB	3510/3511 Sun	Sun and Black Racks	3U	5	Samfs metadata and / export, / archive, / cluster		2.7	2.7	306	306	1530	1046.52	5232.6		
10																		
11	Subsystem: Data Servers																	
12		Gateway	SF 280R	Sun	Sun Rack	4U	1	Network gateway/NFS server		3.24	3.24	380	380	380	1299.6	1299.6		
13		Dataserver	SF V880 (8CPU)	Sun	Stand-alone	N/A	1	Main SAMFS Server		11.4	11.4	1335	1335	1335	4565.7	4565.7		
14		Old Ldas-pcdev1	Quad x86 Box	Dell	Stand-alone	Mid-tower	1	Condor post-processing		1.65	2.19	183	249	249	851.58	851.58		
15		Linux servers	2x x86 4GB	ASA	Node racks/black rack	1U	6	LDAS metadata/data con/beowulf/ldas-grid/ldas-pcdev1/ldas-gridmon		1	2	115	230	1380	786.6	4719.6		
16		Old dataserver	SF V880 (2CPU)	Sun	Stand-alone	N/A	1	Filesystem backups		5.47	5.47	640	640	640	2188.8	2188.8		
17		Old gateway	E450	Sun	Stand-alone	N/A	0	Backup gateway		4.1	4.1	480	480	0	1641.6	0		
18		Vpn	1x x86 1GB	ASA	Black Rack	2U	2	Db2 replication VPN		1.28	1.28	150	150	300	513	1026		
19																		
20	Subsystem: Comptational Cluster																	
21		Node type 1	2.67 GHz Dual CPU	ASA	Node racks	1U	210	Cluster node		1.04	2.08	125	250	52500	855	179550		
22																		
23	Subsystem: Network Switches																	
24		Switch	168 Gig-E ports	Foundry	Node rack 1	17U	1	TCP/IP Switch		16.5	17	1930	1990	1990	6805.8	6805.8		
25																		
26	Subsystem: Misc. Administrative																	
27		Monitor	19" CRT	Sun/Dell	Mobile cart	19"	2	Mobile console		1.8	1.8	210	210	420	718.2	1436.4		
28		Console multiplexer	8 ports	NTI	Mobile cart	2U	1	Terminal Multiplexer		0.8	0.8	100	100	100	342	342		

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R
29		H0ldas	Sparcstation5	Sun	Sun Rack	Desktop	1	CDS Temperature Alarm		0.5	0.5	60	60	60	205.2	205.2		
30	Other Heat Sources																	
31													6400		21888	0		
32		Liebert 30 Ton Humidifier					1						9600		32832	32832		
33		Transformers					1					Total W from N38:	73073		Total BTU/hr from Transformers:	11775.85		
34																		
35	Air Conditioner Sensible Cooling	Model	Tons	Total Cooling Based on Tons	Sensible Cooling (BTU/hr) at 72F, 45% RH	Worst-case cooling (BTU/hr)	Worst-case conditions	Efficiencey Factor = F39/D39	Number of 45kW Panels Needed									
36																		
37	Liebert	VH380UAAEI	30	360000	337000	295600	72F, 50% RH		1.62	0.8*Actual Room Input Power (W):	76800		Total Power (W)	73073	Total BTU/hr	294,517.51	Total Tons	24.54
38									2.03	Actual Room Input Power (W):	96000	Totals with safety margins:	Totals / 0.80	91341.25	Totals / Efficiency	358681.68	Totals / Efficiency	29.89
39			30	360000	337000	295600		0.82	4.06				2x Above	182682.50	2x Above	717363.35	2x Above	59.78

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R
1	Table 6. LDAS LLO Hardware Inventory & Power/HVAC Requirements Beyond S5																	
2	Subsystem: Data Strorage														BTU/hr/W =	3.42	Tons/BTU/hr	8.33E-05
3		Unit(s)	Number/Capacity	Vendor	Location	Form Factor	Number of Units	Function	Unit Electrical Power rating (Volt-Ampere)	Current Draw Idle State (A)	Current Draw Full Use State (A)	Power Idle State (W)	Power Full Use State (W)	Subsystem Total Power (W)	Unit BTU/hr	Subsystem Total BTU/hr		
4		Tape system	200TB	Sun L700 STK	Stand-alone	6x6x4 ft.	1	Tape Archive		6	6	700	700	700	2394	2394		
5		RAID	500 GB	T3 Sun	T3 Racks	4U	0	Samfs /frames		3.4	3.4	400	400	0	1368	0		
6		IDE RAID 200	2.4TB	ASA	Sun Rack	4U	0	User Data		2.18	2.52	254	300	0	1026	0		
7		IDE RAID 160	1.9TB	ASA	Black Rack	4U	0	User Data		3.68	4.44	210	514	0	1757.88	0		
8		Switch	48x2Gb Fibre	Sun	T3 Rack 3	4U	1	FC Fabric switch		5.77	5.77	5.77	675	675	2308.5	2308.5		
9		RAID	1.7 TB	3510/3511 Sun	Sun and Black Racks	3U	12	Samfs metadata and / export, / archive, / cluster		2.7	2.7	306	306	3672	1046.52	12558.24		
10																		
11	Subsystem: Data Servers																	
12		Gateway	SF 280R	Sun	Sun Rack	4U	1	Network gateway/NFS server		3.24	3.24	380	380	380	1299.6	1299.6		
13		Dataserver	SF V880 (8CPU)	Sun	Stand-alone	N/A	1	Main SAMFS Server		11.4	11.4	1335	1335	1335	4565.7	4565.7		
14		Old Ldas-pcdev1	Quad x86 Box	Dell	Stand-alone	Mid-tower	1	Condor post-processing		1.65	2.19	183	249	249	851.58	851.58		
15		Linux servers	2x x86 4GB	ASA	Node racks/black rack	1U	6	LDAS metadata/data con/beowulf/ldas-grid/ldas-pcdev1/ldas-gridmon		1	2	115	230	1380	786.6	4719.6		
16		Old dataserver	SF V880 (2CPU)	Sun	Stand-alone	N/A	0	Filesystem backups		5.47	5.47	640	640	0	2188.8	0		
17		Old gateway	E450	Sun	Stand-alone	N/A	0	Backup gateway		4.1	4.1	480	480	0	1641.6	0		
18		Vpn	1x x86 1GB	ASA	Black Rack	2U	0	Db2 replication VPN		1.28	1.28	150	150	0	513	0		
19																		
20	Subsystem: Comptational Cluster																	
21		Node type 1	2.67 GHz Dual CPU	ASA	Node racks	1U	500	Cluster node		?	?	?	306	153000	1046.52	523260		
22																		
23	Subsystem: Network Switches																	
24		Switch	168 Gig-E ports	Foundry	Node rack 1	17U	3	TCP/IP Switch		16.5	17	1930	1990	5970	6805.8	20417.4		
25																		
26	Subsystem: Misc. Administrative																	
27		Monitor	19" CRT	Sun/Dell	Mobile cart	19"	1	Mobile console		1.8	1.8	210	210	210	718.2	718.2		
28		Console multiplexer	8 ports	NTI	Mobile cart	2U	0	Terminal Multiplexer		0.8	0.8	100	100	0	342	0		

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R
29		H0ldas	Sparcstation5	Sun	Sun Rack	Desktop	1	CDS Temperature Alarm		0.5	0.5	60	60	60	205.2	205.2		
30	Other Heat Sources																	
31		Liebert 30 Ton Humidifier					2						9600		32832	65664		
32																		
33		Transformers					0					Total W from N38:	167631		Total BTU/hr from Transformers:	0		
34																		
35	Air Conditioner Sensible Cooling	Model	Tons	Total Cooling Based on Tons	Sensible Cooling (BTU/hr) at 72F, 45% RH	Worst-case cooling (BTU/hr)	Worst-case conditions	Efficiencey Factor = F39/D39	Number of 45kW Panels Needed									
36																		
37	Liebert	VH380UAAEI	30	360000	337000	295600	72F, 50% RH		3.73	0.8*Actual Room Input Power (W):	180000		Total Power (W)	167631	Total BTU/hr	638,962.02	Total Tons	53.25
38	Liebert	VH380UAAEI	30	360000	337000	295600	72F, 50% RH		4.66	Actual Room Input Power (W):	225000	Totals with safety margins:	Totals / 0.80	209538.75	Totals / Efficiency	778167.55	Totals / Efficiency	64.85
39			60	720000	674000	591200		0.82	9.31				2x Above	419077.50	2x Above	1556335.10	2x Above	129.69