UNIVERSITY OF HAWAI‘I AT MĀNOA

Institute for Astronomy

Pan-STARRS Project Management System

Power, Cooling, and Cables Wraps in the PS-1 Telescope

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15 August 2005

PSDC-300-018-03

Revision History

Version/Revision	Date	Comments
DR	10 Mar 2005	Creation of report
00	16 Mar 2005	Release of report
01	4 May 2005	Modified table 6, deleted spec. for spare glycol lines through the azimuth wrap. Added amperage estimates and actual cable call-outs for the Pan-STARRS cable wrap cables. Revise Fig 2 to have pixel servers reside in support building. Add EOS cable wrap figures.
02	7 July 2005	Add EOS doc. no.s, revise Fig. 2 to match EOS's FCU designations, added shutter controller in Fig 2
03	15 August 2005	Revise Fig 2 to include split PSEs and Ken's revisions. Changed cable call-out for power on Andrew G.s suggestions

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1 Scope of Document

This document describes the cooling, power, and azimuth wrap cable requirements that the Pan-STARRS equipment shall place on the IceStorm II enclosure. It also details the expected components and their placements in the enclosure.

2 Referenced Documents

Table 1. PSDC Documents

Pan-STARRS ID	Title	Authors
PSDC-310-004-01	The PS-1 Civil Construction Bid Package	Hafner
https://svn.ifa.hawaii.edu/gpc/wiki/PixelServerPowerConsumption	Pixel Server Power Consumption	Isani

Table 2. External Documents

Source Reference	Title	Authors
http://www.helukabel.de/pdf/english/ohnejcat/1000.pdf	Helukabel Unshielded Wire Catalog, JZ-500 Series	Helukabel
http://www.helukabel.de/pdf/english/ohnejcat/1020.pdf	Helukabel Shielded Wire Catalog	Helukabel
http://www.igus.com/pdf/cflg-6g.pdf	igus Fiber Optic Cables/LWL	igus
http://baen.tamu.edu/users/stark/AGSM325_files/Lecture/4%20WiringVoltDrop%20Handout.325.pdf	Wire Characteristics, Table 310-16, NEC Ampacities of Insulated Conductors	Gregory Stark, Texas A&M University
EOS Drawing No. MDD500152	PS1 Azimuth Cable Chain & Coolant Hose Layouts	Gray

3 Introduction

The Pan-STARRS instrumentation on the telescope is divided into two sections which are separated by the M1 mirror cell. Most of the corrector optics, including the Atmospheric Dispersion Corrector (ADC), lie on the skyward face of the M1 mirror cell. This part of the instrumentation is referred to as the Upper Cassegrain Core. Below the M1 mirror cell, attached to the instrument rotator lie the filter mechanism, the shutter, and the giga-pixel camera itself. This section of the instrumentation along with its support structure is called the Lower Cassegrain Core.

The PS-1 enclosure is an IceStorm II dome manufactured by EOS in Australia. This enclosure utilizes a number of glycol cooled heat exchanger fan coils to cool the dome during the day and to cool equipment during both night and day. Figure 1 shows a cross section of the IceStorm II enclosure and illustrates the location of the different levels referred to in this document. The Level 4 service platform is a partial floor behind the telescope. Its location is indicated in Figure 1, but the floor itself is not shown in the rendering.

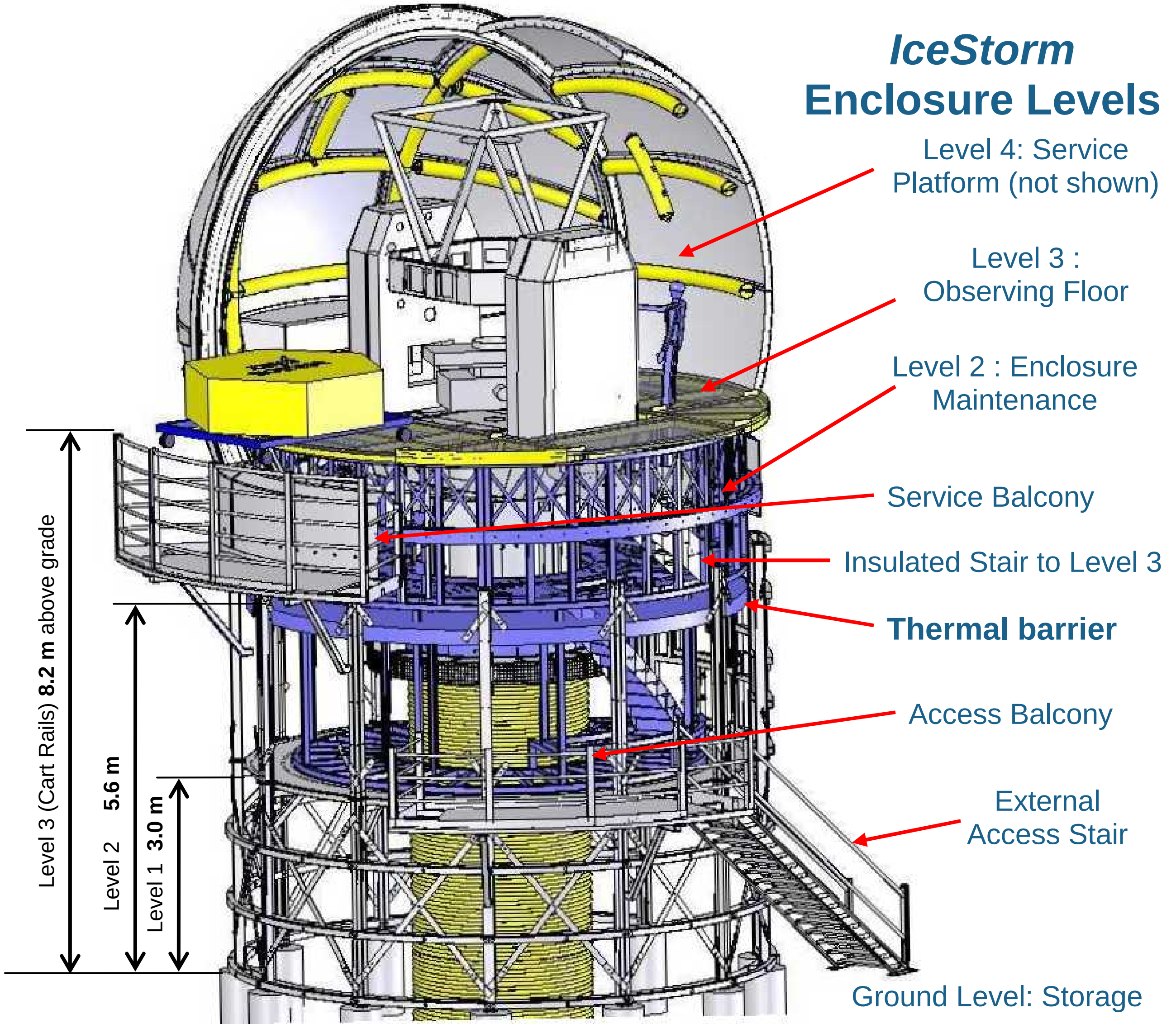

Figure 1. A cut-away rendering of the Pan-STARRS IceStorm II enclosure is shown here.

Levels 1 through 4 all co-rotate with the dome. The dome rotates by means of polyurethane bogies that run on a ring girder that lies just below Level 3 in Figure 1. This ring girder is not shown in the figure. Large support beams on either side of the telescope extend down from the roof of the enclosure all the way down to the floor of Level 1. These roof supports are not shown in Figure 1. There is an interior annulus on Levels 1 and 2 that co-rotates with the dome. The enclosure "ring wall" is the fixed outer wall that wraps around the Ground Level and Levels 1 and 2. In Figure 1 the transition between the fixed ring wall and the co-rotating inner annulus is seen as the grey annulus of flooring near the dimension showing a height of 3 m for the floor in Level 1. All of Level 3 co-rotates with the dome.

On 9 March 2005 a Polycom meeting was held with EOS representatives in which the UH requirements for cooling, component placement, and cabling through the enclosure azimuth wrap were discussed. Attendees in this meeting included Adam Seedsman, Jason Chapman, and Andrew Gray of EOS-AU; Jeff Morgan, Dave Hafner, Will Burgette, Klaus Hodapp, Carol Hude, Alan Ryan, Andy Douglas, Dan Ogara, Mark Waterson, and Walter Siegmund of Pan-STARRS; and Kevin Harris of EOST.

One day prior to that Polycom, a meeting was held with John Tonry, Sidik Isani, Peter Onaka, Jeff Morgan, Will Burgette, Andy Douglas, and Carol Hude on the same topic in order to obtain input from the camera group on these items. This report is the result of those discussions.

Revisions to the initial document were made based on detailed discussions with the EOS and EOST personnel regarding space constraints in the azimuth cable wrap.

4 Component Placement

Figure 2 shows the expected components and their placement by floor level in the IceStorm II enclosure. This figure is an attempt to show the major paths of interconnections between these components. The color of each line illustrates its basic function. These functions are listed in the figure's key. The heavy horizontal lines with the floor labels can be thought of as the floors for each level. For example, blocks that lie between the "1st Floor" and "2nd Floor" lines reside on Level 1. The blue bar below the 2nd Floor line shows the location of the main thermal insulation layer that separates the instrumentation contained on Level 1 with the observing levels. The 3rd Floor is a porous grating, therefore Levels 2 and 3 are thermally coupled. Likewise, the 4th Floor is a partial floor grating that sits behind the telescope. Thermally, there is no distinction between the 2nd, 3rd, and 4th floors. The support building, ground floor, and parking lot are all on the same level. In these cases the horizontal lines separating them denote physical locations rather than floor levels. There is a dashed vertical line in the space denoting the support building and parking lot. Items to the left of this dashed line are in the support building. Items to the right of this line are in the parking lot.

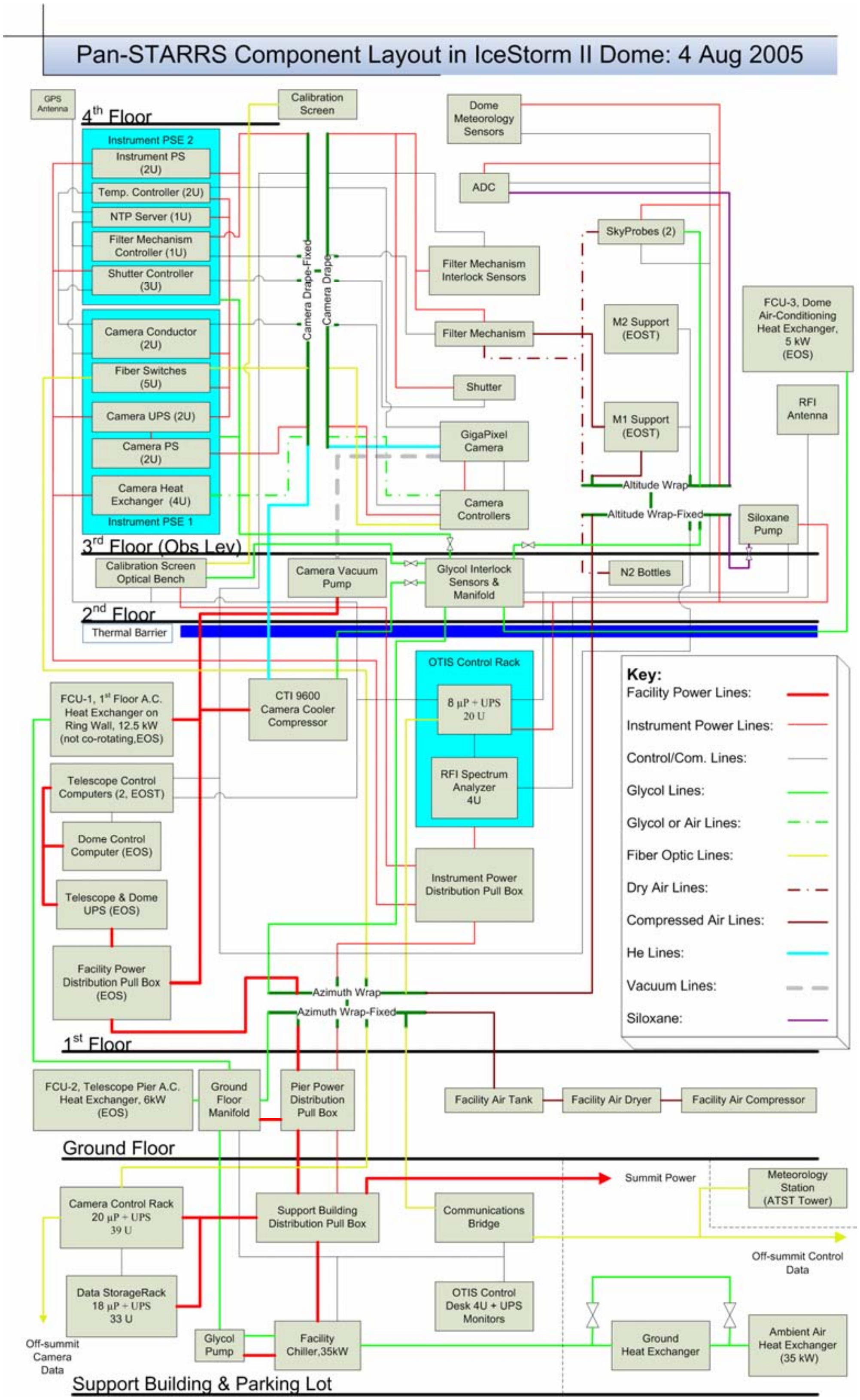

Figure 2. The distribution of Pan-STARRS components by floor is shown here.

The “Ground Heat Exchanger” is actually under the parking lot. It is conceived as being a series of pipes buried under the parking lot concrete. A by-pass line with cut-off valves is depicted around the Ground Heat Exchanger. The by-pass line would be used only if leaks developed in the ground pipes. Since the area available for the ground heat exchange is limited to about 150 m^2, it is not expected that it will dissipate more than about 15 kW of heat. This might be sufficient for nighttime operations, but will clearly not be capable of dealing with the daytime cooling loads. The “Ambient Air Heat Exchanger” will be sized to take the full expected thermal load, but will normally have to deal only with the load not dissipated by the system of ground pipes.

There are two cable wraps in the enclosure and two cable drapes. One cable wrap services the azimuth bearing on the enclosure. Since the dome and telescope co-rotate, only one cable wrap is required for both enclosure and telescope azimuth motions. The second cable wrap services the altitude axis on the telescope. The camera electronics are quite sensitive to variations in voltages from its power supply. Because of this, the sizes of the power supply cables are quite sensitive to the distance between the camera controllers and the power supply. The power supply cables must remain shorter than 15 feet to keep their diameters to practical dimensions. This is too short for these cables to fit through the normal altitude wrap on the telescope. Therefore there is need for a shorter, direct way to feed power cables to the camera electronics. The camera drapes are the solution to this restriction. The cable wraps and the drapes are shown in Figure 2 as parallel, dark green bus lines; one represents the side of the wrap that is fixed and the other line the side that is movable. Adjacent lines on both sides of the cable wrap are intended to represent the continuation of the same line over the cable wrap. The camera drape is shown as a single unit, but will actually consist of two drapes coming up from the two Instrument Power Supply Enclosures which will sit next to both telescope fork tines on the Level 3 floor.

From the perspective of the Pan-STARRS instrumentation, the cable drape services the instrumentation located on the Lower Cassegrain Core. The instrumentation in the Upper Cassegrain Core is serviced by the altitude cable wrap. And support equipment is serviced by the enclosure azimuth wrap. The two exceptions to this are the gas lines that service the filter mechanism. The filter mechanism requires a source of high pressure gas for the manipulation of the filters. It requires a source of reliable, low pressure dry gas in order to keep the dewar window from frosting over. These gas lines come up into the M1 mirror cell through the altitude wrap.

Figure 2 is not intended to be a cable list. No attempt has been made to illustrate the numbers of wires, fibers, or gas lines in each connection. The signal types, direction of signal or gas flow, band-passes of each signal, and electrical isolation needed by each of the signals are not included here. Nor are the lengths and sizes of these lines illustrated. Figure 2 is essentially a cable run list.

It is good to keep in mind that Figure 2 is not even a complete list of all of the cable runs in the enclosure. It is nearly a complete list of all of the Pan-STARRS cable runs required, but there are many important facility cable runs that have been intentionally left out of the figure. For example, this figure does not show many critical telescope control cable runs. The cables to the telescope axis controllers, motors, and encoders are missing. On the enclosure side, the azimuth motor cables and encoder cables are missing. The enclosure slit motor cables are missing. Lighting cables, emergency stop cables, fire alarm cables, the cables to the service balcony crane, and the control cables to the air conditioning heat exchangers are all missing from this figure. Missing Pan-STARRS equipment would include the enclosure web cameras and their cable runs and the enclosure environmental sensors and their cable runs.

Figure 2 shows several components that are provided by either EOS in Australia or EOST in Tucson. With the exception of the facility compressed air components, all of the EOS or EOST supplied components are labeled in the figure. But this figure is not intended to be a definitive representation of these components. It is currently unclear who will be responsible for the design and construction of the facility air dryer and compressor. As these are important parts of the mirror support system it might be appropriately designated as EOST supplied equipment. This figure is not meant to imply that Pan-STARRS wishes to take responsibility for these components. This issue is left to future discussions with EOST.

There are three separate fan coil heat exchangers in the IceStorm II enclosures. Only one of them actually lies in the rotating part of the enclosure. This unit is labeled "Dome Air Conditioning Heat Exchanger" in Figure 2 and will only have about 5 kW of cooling capacity. This unit is the only facility cooling that requires its glycol lines to run through the azimuth cable wrap. By itself, this unit is not sufficient to cool the observing space (Levels 2, 3, and 4) during the daytime. A second unit that blows cool air up through the hollow pier is located on the ground floor. This unit is labeled "Telescope Pier A.C. Heat Exchanger" in Figure 2. A third unit is located on Level 1 and is used to cool this floor, but it is fixed to the telescope ring wall and therefore does not rotate with Level 1 as the dome turns. Figure 2 shows this unit (1^{st} Floor A.C. Heat Exchanger) to have a cooling capacity of 12.5 kW. This capacity is sufficient for the Pan-STARRS equipment, which we show below will require approximately 7.6 kW of cooling power on Level 1.

The glycol lines which go through the telescope azimuth wrap need to be sized for the capacity of both the Dome A.C. Heat Exchanger and the instrumentation cooling expected. There are two main needs for instrumentation glycol. The first and foremost is the CTI 9600 compressor that will be used to cool the camera. The manufacturer states that this unit has a power load of 5.5 kW and a typical glycol flow rate of 2.75 gpm. These are manufacturer specifications, rather than real measurements of what is required from this unit when applied to the Pan-STARRS camera. They therefore probably represent maximum rather than typical heat loads from this unit. Nevertheless, this power load is as large as the total capacity of the Dome A.C. Heat Exchanger on Level 3 and may indicate that it will be impractical to keep this unit on Level 1. One option may be to place the compressor in the support building, but this would require threading the He gas lines several hundred feet through the azimuth cable wrap. Another option may be to attempt to cool this compressor with a combination of glycol and airflow from the 1^{st} Floor A.C. Heat Exchanger.

The second instrumentation sink for glycol cooling is the Instrument Power Supply Enclosure (labeled Instrument PSE in Figure 2). This enclosure, which must reside on the 3rd or 4th Floors, is shown in light blue in Figure 2 and houses the Instrument Power Supply, the Camera Power Supplies, the Camera UPS, and the Camera Heat Exchanger. As will be tabulated in the tables in the next section, this enclosure is likely to require 1.3 kW of cooling power. The Camera Heat Exchanger is required to cool the Camera Controllers, which reside on the telescope. In its simplest form, this heat exchanger is nothing more than two glycol lines that travel through the Camera Drape to the Camera Controllers. It is safer to keep glycol lines out of the camera enclosure. For this reason it is desirable to have an air plenum run through the camera drape, rather than glycol lines. Under these circumstances, the Camera Heat Exchanger may be a fan coil which blows air across the Camera Drape into the controllers. A third option would be to run the air plenum down to the first floor where a fan would blow cool air from Level 1 up across the Camera Drape to the controllers. This option would require greater cooling loads on Level 1 and probably larger air plenums through the Camera Drape. The heat load from the controllers is predicted to be 640 W.

5 Level 1 Components

It is expected that the Pan-STARRS equipment will occupy 3 standard 40 U size 19” racks. Two of these racks will be located in the support building. The third rack will reside on Level 1. The dimensions of a typical 40 U vertical rack are: 77” H x 24.38” W x 32” D. The following tables list the expected contents of the Pan-STARRS electronics racks. The power levels of each of the items are listed along with the vertical rack space required for that item. The rack space is listed in “U” units. A standard 1U rack slot has a height of 1.75”. It is expected that the equipment in these racks will be cooled by airflow from the 1st Floor A.C. Heat Exchanger fan coil. The rack on Level 1 will be configured without walls to promote airflow to the electronics. The racks in the support building are likely to be enclosed and incorporate their own internal cooling system.

In addition to these 3 racks there will be a CTI 9600 compressor that will reside on Level 1. The footprint for the compressor is approximately equivalent to a 19” rack. The specifications for the CTI 9600 He Compressor are as follows:

- Nominal input power: 5.5 kW
- Nominal input voltage: 180-253 VAC
- Full Load/Locked Rotor Current: 16.2/80 A
- 2.75±1.25 gpm glycol flow rate [10.4±4.7 lpm]
- Maximum/minimum inlet glycol temperature: 32/10° C
- 26.54” H x 19.52” W x 21.50” D
- 250 lbs.

Table 3. Rack 1 (Camera Control, Support Building)

Description of Electronics	**Peak Power Consumption (W)**	**1 minute Average Power Consumption (W)**	**Rack Space (U)**
16 Active Pixel Servers	4500	3200	16
3 Backup Pixel Servers	360	360	3
3 Data Switchers	300	300	3
1 Fiber Demultiplexer	130	130	4.5
Subtotals	5290	3990	26.5
1 UPS (appx. 9kVA, 92% efficiency)	423	319	12
Totals	**5713**	**4309**	**38.5**

Table 4. Rack 2 (Data Storage, Support Building)

Description of Electronics	**Peak Power Consumption (W)**	**1 minute Average Power Consumption (W)**	**Rack Space (U)**
16 Disk Storage Servers	3200	2400	16
2 Data Switchers	200	200	3
1 Fiber Router	240	200	2
Subtotals	3640	2800	21
1 UPS (appx. 6kVA, 92% efficiency)	291	224	12
Totals	**3931**	**3024**	**33**

Table 5. Rack 3 (OTIS Control, Level 1)

Description of Electronics	**Peak Power Consumption (W)**	**1 minute Average Power Consumption (W)**	**Rack Space (U)**
8 µProcessors	2240	1600	8
RFI Spectrum Analyzer	350	350	4
Subtotals	2590	1950	12
1 UPS (appx. 4kVA, 92% efficiency)	207	156	12
Totals	**2797**	**2106**	**24**

In summary, in the Support Building we have the following average cooling requirements:

- Rack 1: 4300 W
- Rack 2: 3000 W

Total in the Support Building: 7.3 kW

And on Level 1 we have the following average cooling requirements:

- Rack 3: 2100 W
- Compressor: 5500 W
- Calibration Optical Bench: 500 W

Total on Level 1: 7.6 kW

6 Components on Levels 2 through 4

The only items on Level 2 are equipment that will only be turned on during the daytime for calibration and during servicing of the camera. We can safely ignore the cooling requirements of the vacuum pump.

The calibration screen and its associated optical bench is estimated to have an average heat load of approximately 500 W. This system is assumed to be a screen of approximately 2-m diameter mounted on the back of the enclosure that the telescope will point to when flat field and throughput calibrations are made. The screen is assumed to be illuminated by a bundle of several hundred fibers that are used to transport the output from a tunable laser which will reside on the calibration optical bench on Level 2. The laser requires temperature stabilization through the use of the glycol lines. Peak power usage from this system can be as high as 1000 W.

The main heat generating items on levels 3 and 4 and their estimated heat loads are as follows:

- Camera controllers, 640 W
- Camera power supply, 160 W
- SkyProbe instrumentation, 450 W
- Instrument power supply, 100 W
- Camera UPS, 60 W
- Shutter, 50 W

Note that all of these items except the SkyProbe will reside within two Instrument Power Supply Enclosures (Instrument PSE 1 and Instrument PSE 2) which will have there own glycol cooling system. The Instrument PSEs will reside on the Level 3 floor right next to each side of the telescope fork tines. The cable drape will actually consist of two drapes coming up from each of the Instrument PSEs. This will allow for more uniform loading on the instrument rotator. The SkyProbe instrumentation will also have its own glycol cooling lines. Therefore, the dome heat exchanger on the 3rd floor does not need to take these items under consideration, but the glycol supply line sizing must include them.

7 Azimuth Wrap Contents

In this section we detail the requirements for cabling through the azimuth cable wrap only for the support of the Pan-STARRS instrumentation. In particular, this list is not meant to cover the facility needs of the telescope, like facility power and cooling, which represent additional demands on the cable wrap.

Power and communications are the sole needs for the Pan-STARRS instrumentation. Communications and control of the camera and OTIS electronics will be done over fiber optics cables. Power for the camera must be kept as isolated from noisy inductive loads as possible, and so requires a separate power cable through the azimuth wrap. Table 6 shows the amperage estimates for each type of Pan-STARRS instrumentation with the assumption of 208V input to the rack UPS. Table 7 shows the expected azimuth wrap cable requirements based on the estimates given in Table 6. And Table 8 gives a detailed description of the cables called-out in Table 7. Table 9 gives a detailed description of the fiber cable call-outs in Table 7.

Figure 3 and Figure 4 show diagrams of the EOS supplied cable wraps. These figures show the layout of cables in the wraps as of 28 April 2005. Both Pan-STARRS instrumentation cables and cables required by EOS for operation of the telescope are shown in these figures. Figure 5 shows cross section details of the glycol coolant lines seen in Figure 3 and Figure 4.

Some of the items in Table 6 require further explanation. The NTP server power estimates come from assuming a True-time NTS-200 server. The fiber switch power estimate assumes that there will be a total of 32 multi-mode fibers that come across the camera drapes to the Instrument PSE. These fibers are time delay multiplexed at a ratio of 4:1 into 1-Gbps multi-mode fibers through the use of a MRV Communications LD800/AC Chassis loaded with 8 EM2009-EM4/P multiplexer modules which feed 8 SFP-G-SX transceivers. These transceivers then output to 8 1-Gbps fibers that traverse the azimuth wrap in a 12 fiber bundle. The extra fibers will provide redundancy in case of a fiber break. These items are important to note because the igus fiber cables listed below are multi-mode and must be matched by the appropriate hardware for the 1-Gbps link. The Temperature controller is assumed to be a Lakeshore Model 332 Controller. Items below the heavy line in Table 6 are powered through the Instrument Power Supply. Note that the Instrument Power Supply could easily end up being split into a few smaller supplies distributed between Levels 1 and 4.

Table 6. Current Load Estimates from Pan-STARRS instrumentation*

Location	Equipment Description	Rack Space	Peak Current (A)	Ave. Current (A)	No. in Rack	Total Current (A)
Camera Control Rack	Active Pixel Servers, dual Pentium	1U	1.35	0.96	16	21.6
Camera Control Rack	Idle Pixel Servers	1U	0.58	0.58	3	1.7
Camera Control Rack	Fiber Demultiplexer (130 W)	4.5U	0.63	0.63	1	0.7
Camera Control Rack	Camera Control UPS (9kVA)	12U	2.08	1.58	1	2.1
Camera Control Rack Current Load (A)						**26.1**
Data Storage Rack	Disk Server, dual Pentium	1U	0.96	0.96	16	15.4
Data Storage Rack	Data Storage UPS (6kVA)	12U	1.39	1.07	1	1.4
Data Storage Rack Current Load (A)						**16.8**
OTIS Control Rack	OTIS Server, dual Pentium	1U	1.35	1.35	10	13.5
OTIS Control Rack	RFI Spectrum Analyzer	4U	1.68	1.68	1	1.7
OTIS Control Rack	OTIS UPS (4kVA)	12U	1.0	0.75	1	1.0
OTIS Control Rack Current Load (A)						**16.2**
Level 1 Floor	CTI 9600 Compressor	-	26	16.2	-	26
Level 2 Floor	Vacuum Pump (21.2 cfm scroll)	-	9?	2.9	-	3
Pan-STARRS Instrumentation Current Load on Facility Power (A)						**29**
Level 3 Floor	Temperature Controller (150 W)	2U	0.7	0.7	1	0.7
Level 3 Floor	NTP server (20 W)	1U	0.1	0.1	1	0.1
Level 3 Floor	Camera Conductor, dual Pentium (240 W)	2U	1.15	1.15	1	1.2
Level 3 Floor	Fiber Multiplexer (130 W)	4.5U	0.63	0.63	1	0.7
Level 3 Floor	Camera Controllers (60W/controller x 8)	-	2.3	2.3	-	2.3
Level 3 Floor	Camera Power Supply (500 W @ 90%)	2U	0.25	0.25	1	0.25
Level 3 Floor	Camera UPS (1.1 kVA @ 90%)	2U	0.5	0.5	1	0.5
Level 3 Floor	Camera Heat Exchanger (200 cfm duct booster fan, 60W)	4U	0.3	0.3	1	0.3
Level 3 Floor	Camera Shutter (240 W)	-	1.15	0.25	-	1.2
Level 3 Floor	Filter Mechanism (10.5W/active valve, 6 valves active+μP)	-	0.5	0.2	-	0.5
Level 3 Floor	ADC (2 size 23 motors @72W each+μP)	-	0.8	0.2	-	0.8
Level 3 Floor	SkyProbes (2 CCDs @ 100 W each,3 size 17 motors @ 48W each+μP)	-	2.1	1.0	-	2.1
Level 3 Floor	Web Cameras (5 @ 10W each)	-	0.25	0.25	-	0.25
Level 3 Floor	Instrument Power Supply (2100 W, 90%)	2U	1.0	0.5	1	1.0
Level 2 Floor	Calibration Bench (500 W)	-	4.8	2.4	-	4.8
Level 1 Floor	Glycol Interlock Sensors (50 W)	-	0.25	0.25	-	0.25
Total Instrument Current Load x 1.5 (A)						**25.4**

*Assuming 208V input to the rack UPS

The last column in Table 7 gives suggested call-outs for the Pan-STARRS cables. These cable call-outs have not been reviewed by a licensed electrician and are therefore only initial estimates of the cable diameters and types. The cable call-outs in this table have been selected based primarily on amperage loads and flexibility. The continual flexing of cables in the azimuth wrap places a large importance on the flexibility of the cables that go through the wrap. We estimate that cables going through the wrap need to be capable of withstanding about 100,000 flex cycles over the life of the PS-1 project. The fiber cable call outs have also been selected with this flexibility in mind. The minimum bend radius in the EOS-supplied cable wrap is 9.35”. The minimum bend radius in the fiber cables called out is about 6.75”.

Note that the listing of the facility power line in Table 7 is not meant to be in addition to the facility power that would normally be supplied through the cable wrap for the support of normal telescope needs. It is included here simply to emphasize that the Instrument Power cable is in addition to the Facility Power cable. The wire gauges shown in the table are only approximate and should be sized according to standard building codes for the amperage loads given. Also note that the cables used for this application must be flexible enough to handle continuous flexures from the azimuth motions of the telescope. To this end, the cable call-outs listed in Table 8 have been chosen with cable flexibility in mind. The minimum bend radii for the cables come from the Helukable catalog specification of 10 times the cable O.D. for the shielded cable and 7.5 times the cable O.D. for the unshielded cable. Note that these minimum bend radii are slightly larger than the 238 mm radius imposed by the cable wrap. This may result in premature wear on the cables

Table 7. Azimuth Wrap Cable List

Cable Name	Cable Maximum Amperage (A)	Cable Diameter (in) [mm]	Suggested Cable Part Numbers*
Fiber Bundle 1 (to Pixel Servers)	-	0.45 [11.5]	CFLG-12G-50/125-T
Fiber Bundle 2 (to OTIS)	-	0.45 [11.5]	CFLG-12G-50/125-T
Instrument Power (208/120V, 3Ø)	55	0.95 [24.1]	11605
Facility Power (208/120 V, 3Ø)	130	1.153 [29.3]	10162

*See Table 8 and Table 9 for a description of these cables.

Table 8. Azimuth Wrap Power Cable Descriptions

Cable P/N*	No. of Conductors	Conductor Area (mm^2)	AWG	Max. Voltage	Minimum Bend Radius (mm)	Shielding
11605	5	10	8	600-1000	241	Cu Braid
10162	5	35	2	500	220	None

*From Helukabel (www.helukabel.de), JZ-500 cable series (+80° C to -5° C) and JZ-600-Y-CY series (+90° C to -5° C)

Table 9. Azimuth Wrap Fiber Cable Descriptions

Cable P/N*	No. of Fibers	Fiber Core (μm)	Minimum Bend Radius (in)	No. of Flexures
CFLG-12G-50/125-T	12	50	6.75	10-20M

*igus Fiber Optic Cables (http://www.igus.com/pdf/cflg-6g.pdf)

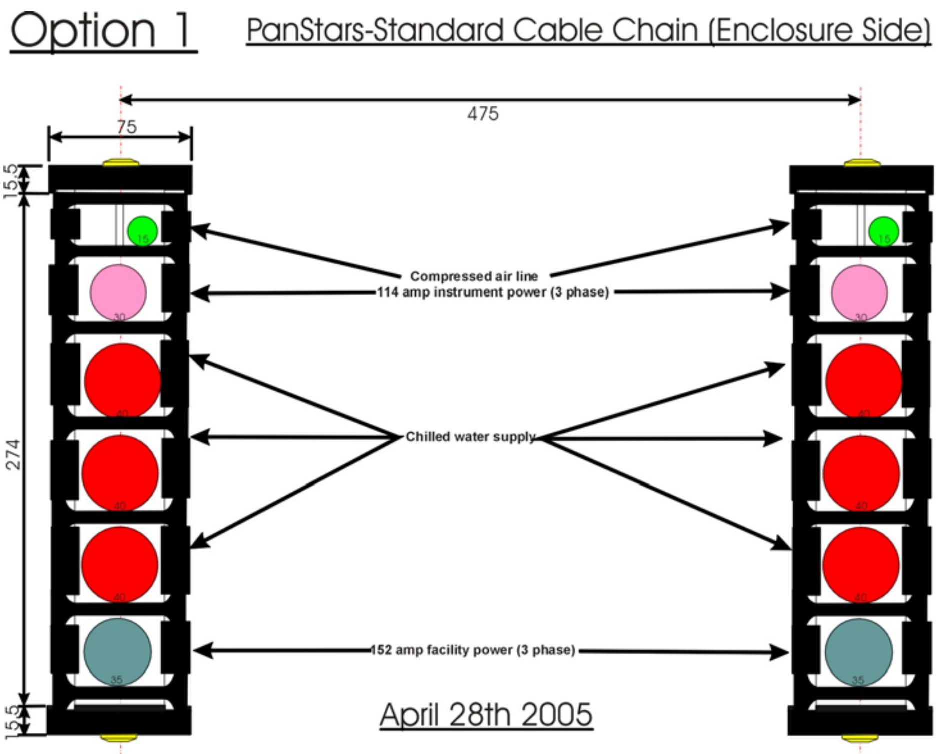

Figure 3. Cable Wrap Layout, Enclosure Side, as of 4/28/05

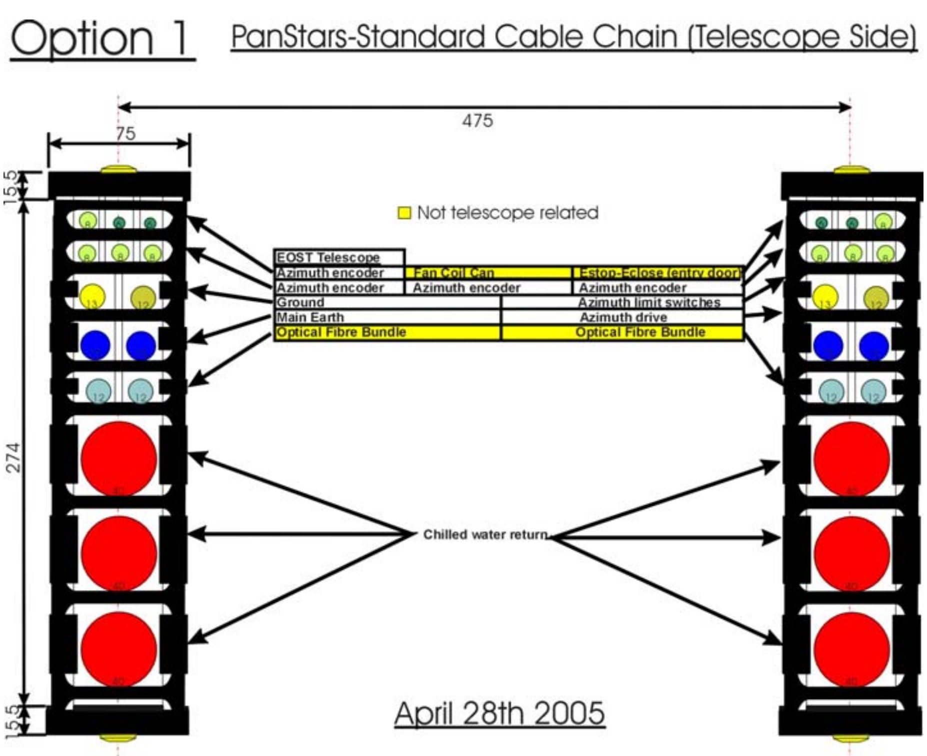

Figure 4. Cable Wrap Layout, Telescope Side, as of 4/28/05

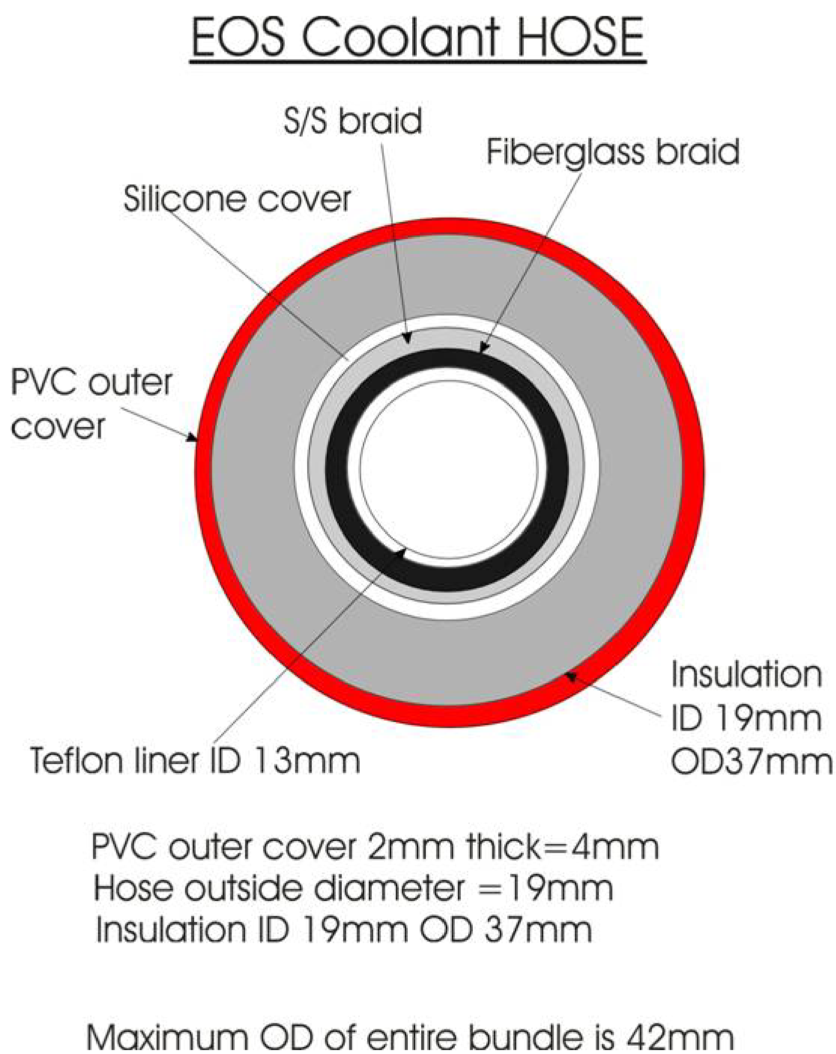

Figure 5. Details of the chilled water lines

8 Altitude Wrap Cable Contents

There are several lines that are required to go through the altitude cable wrap in order to support components of the upper Cassegrain Core and instrumentation that will mount to the center support section of the M1 mirror (the SkyProbe instrumentation). These are shown as single line connections in Figure 2. In Table 10 we give more details about those lines.

Table 10. Altitude Wrap Cable List

Cable Description	Number of Cables	Approximate Diameter (per cable)
SkyProbe glycol cooling lines	2	0.25”
SkyProbe power lines	2	0.125” (2 conductors, TBR)
SkyProbe control lines	TBD	TBD
ADC control lines	1	0.125” (3 conductors, TBR)
ADC power lines	1	0.5” (14 conductors, TBR)

9 System Interlock Requirements

There are currently only two items which will be required to have inputs to the telescope interlock system. A monitor of the clamping of the filter mechanism will require a single input and a monitor of the glycol flow rate and temperature will be needed. These items are listed in Table 11. The electrical formats of the inputs need to be specified by EOS in an interlock ICD.

Table 11. System Interlock Signals

Interlock Name	Interlock Description	Interlock Action
Filter Mechanism Clamped	This signal should indicate that the filter mechanism is properly clamped in place	In the absence of this signal the telescope axes (including the instrument rotator) should be disabled
Glycol Temperature	This signal should indicate that the glycol temperature is below a user defined maximum.	In the absence of this signal the camera compressor should be shut down.
Glycol Flow Rate	This signal should indicate that the glycol flow rate is above a user defined minimum.	In the absence of this signal the camera compressor should be shut down.