Determining the Position of the PSUP LED's

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Introduction

Comparison of the laserball and the LED air-fill data indicate a severe discrepancy (~50 cm) between the positioning references used by the two systems. The positions of the LED's are fixed to the PSUP, while the manipulator used in deploying the laserball is referenced against the acrylic vessel and the deck. Analyses done by Bill Frati[1] indicated that the discrepancies could be explained if the LED coordinates listed in the references by Schülke[2] are incorrect.

We have performed an independent study of the LED positions using a three-dimensional model in a CAD system. Results of this computer modeling were checked against another independent calculation of the LED positions. Results from these two studies agree very well with each other, and disagree with those previously obtained by Schülke. We shall summarize the results of these studies in the following.

Coordinate System

The PSUP coordinate system is defined in the Figure 1. The "PSUP North" is 0°7'00" east of the "Construction North."[3] Unless stated otherwise, all the coordinates in this report use the PSUP coordinate system as the reference.

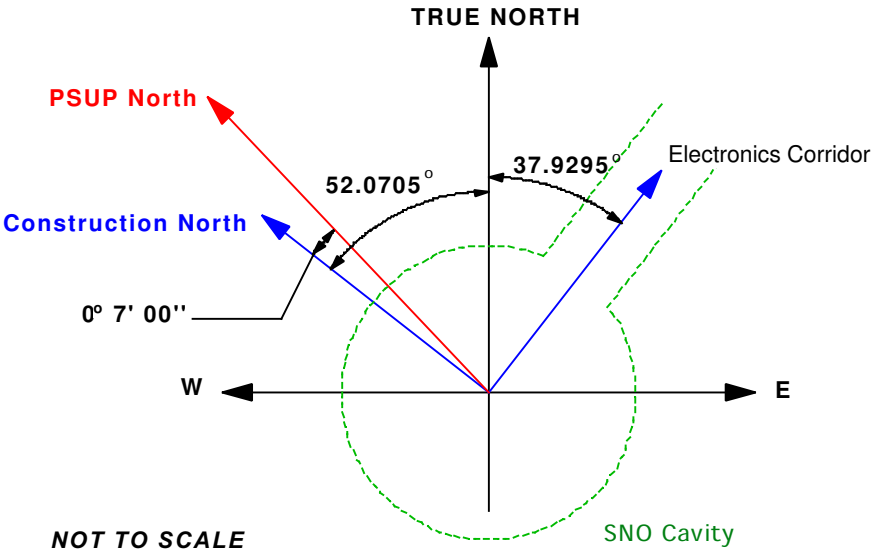

Figure 1: The PSUP Coordinate System

[1] See Frati's report at the Penn WWW site: http://www.hep.upenn.edu/SNO.
[2] A. Schülke, http://snohp1.lbl.gov/~snoman/pled.htm.
[3] Pelto Consulting issued a survey drawing on April 6, 1994 on this 7 minutes rotation. Drawing number for this drawing is unknown. See also the document DC-17-280-01-C-3 for of the construction coordinate system.

Input Data

Six LED's were installed on the PSUP. They are mounted to the back of the H25, H35, H45, H55, H71 and H79 hubs. Table 1 lists the surveyed coordinates of these hubs.

Table 1: PSUP Hub (LED installed) Locations

HUB	PSUP coordinates (inches)		
	x	y	z
H25	297.73	96.74	156.53
H35	-70.62	291.60	-180.22
H45	-299.16	22.95	-180.22
H55	0	-313.05	-156.53
H71	299.16	22.95	-180.22
H79	0	0	-350.00

The LED is enclosed in a stainless steel cylindrical housing. One end of this cylindrical housing is a lens constructed out of acrylic. This is shown in Figure 2. The distance between the front face of the lens and the LED bulb is 0.60" (+ 0.13"/-0.00"). In this report we will determine the center of the front face of the lens.

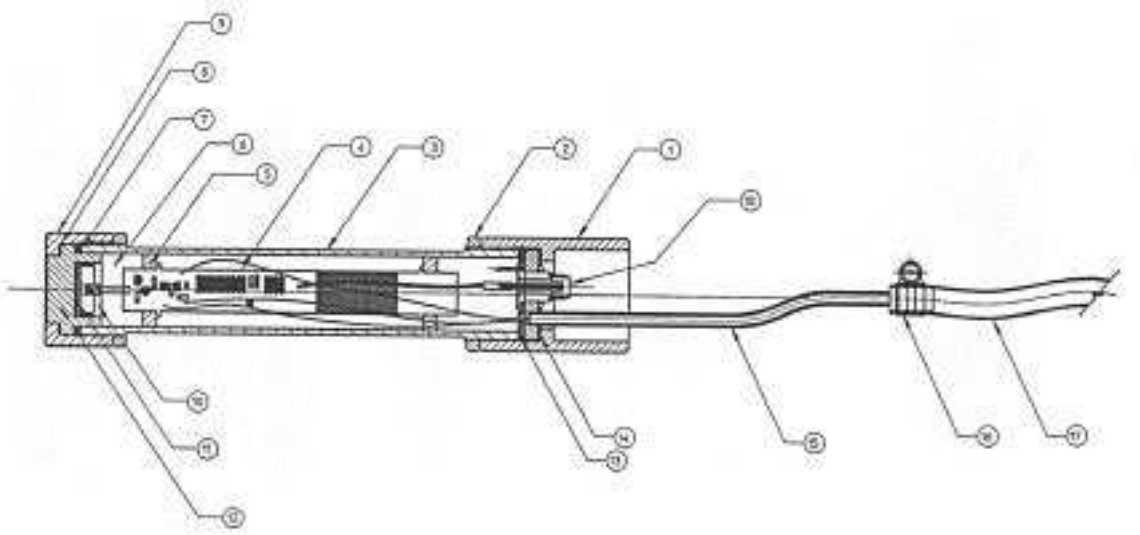

Figure 2: Assembly drawing of the LED housing. **1**: Rear end connector;; **2**: Thread lock nut; **3**: Main body tube; **4**: Circuit board; **5:** Circuit board centering ring; **6**: Filled with silicone gel; **7**: Lens gasket; **8**: Front lens teflon ring; **9**: Front lens mount; **10**: Front lens filter holder; **11**: Neutral density filter; **12**: Front lens; **13**: Rear end gasket; **14**: Rear cover plate teflon cover; **15:**Rear cover plate weldment; **16**: Hose clamp; **17**: Silicone tubing; **18:** Connector.

This housing is then mounted on a cylindrical support, which in turn is mounted to the back of a hub. For detailed mechanical drawings of the mounting mechanism, the reader is referred to drawing 23H4894. In Figure 3 and Figure 4 the orientation of the LED mount to the hub and the installed hexpanels are shown. After the installation of each LED, the as-installed parameters L1, L2, S1, S2 and D were measured and recorded. The hub and the strut identification numbers were also recorded. These parameters are summarized in Table 2.

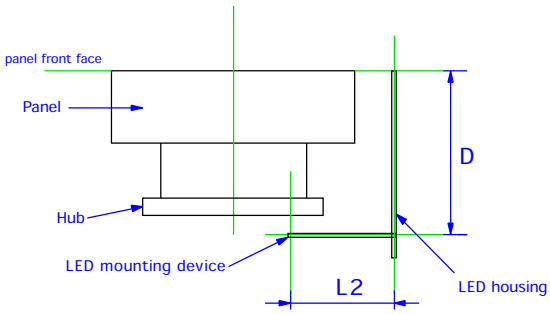

Figure 3: Side view of LED mounting

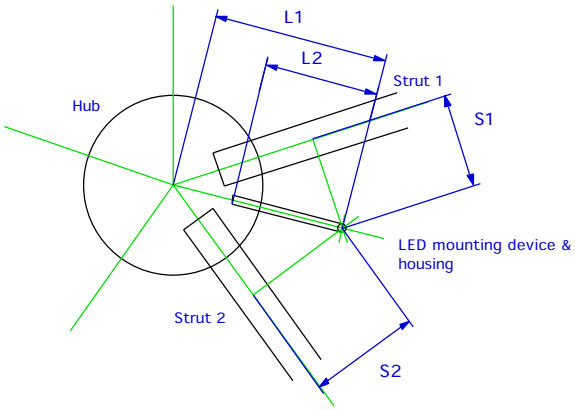

Figure 4: Back view of LED mounting

Table 2: LED Mounting Parameters ‡

Hub	Strut 1 ID	Strut 2 ID	L1 (in.)	L2 (in.)	S1 (in.)	S2 (in.)	D (in.)
H25	H25-H26	H25-H29	14.25	9.25	8.35	7.65	18.0
H35	H35-H81	H35-H82	14.35	9.85	10.25	4.25	18.0
H45	H45-H83	H45-H85	13.65	9.05	7.75	6.50	17.5
H55	H55-H56	H55-H60	13.15	8.65	4.85	10.05	18.0
H71	H71-H92	H71-H89	14.75	10.15	5.15	9.65	18.0
H79	H79-H90	H79-H78	14.65	10.25	5.05	11.45	17.7

CAD Modeling Method

We used a three dimensional CAD modeling method to determine the positions of the LED's. We started off with a tetrahedron with its apex fixed to the center of the PSUP geodesic sphere. The corners of the base are fixed to the centers of the following hubs:

1. The hub to which the LED is mounted ("Hub-0")
2. The hub that is connected to Hub-0 by Strut 1 listed in Table 2 ("Hub-1")
3. The hub that is connected to Hub-0 by Strut 2 listed in Table 2 ("Hub-2")

‡ **L1**: Hub center to LED housing pipe center; **L2**: Pivot bolt center to LED housing pipe center; **S1**: Strut 1 center to LED housing pipe center; **S4**: Strut 2 center to LED housing pipe center. Please note that some of these numbers were adjusted from the pipe edge to pipe edge measurements as recorded in the installation sheet.

The center of each hub is defined as the intersection of the center lines of the struts. The positions of these hubs are summarized in Table 3. The orientation of the hexpanel on Hub-0 with respect to the base of this tetrahedron is then determined by "cutting" in from Hub-0 along the Hub-0-to-apex axis. This is shown as the circular wedge in Figure 5. The flat plane represents the surface of the hexpanel front face. Because the LED's were installed with its housing flush with the hexpanel front face (see Figure 3), the LED front aperture lies on this plane. The radius of the cut out wedge is arbitrary as long as one is certain that the LED front aperture will lie on the resulting plane. We chose a radius of 48 inches. The depth of this cut out wedge is the difference between radial distances of Hub-0 and the center of the hexpanel front face, which is 19.95 inches[4].

The position of the LED front aperture is determined by finding the intersection of the parallels to the sides of this circular plane. These parallels are at distances S1 and S2 (see Table 2). This is shown in Figure 6.

Table 3: Reference Points for the 3-D Model

	Hub	x (in.)	y (in.)	z (in.)
LED25				
Hub-0	H25	297.73	96.74	156.53
Hub-1	H26	228.53	74.26	254.48
Hub-2	H29	228.53	194.40	180.22
LED35				
Hub-0	H35	-70.62	291.60	-180.22
Hub-1	H81	-141.24	194.40	-254.48
Hub-2	H82	0.00	212.47	-278.13
LED45				
Hub-0	H45	-299.16	22.95	-180.22
Hub-1	H83	-228.53	-74.26	-254.48
Hub-2	H85	-202.07	65.66	-278.13
LED55				
Hub-0	H55	0.00	-313.05	-156.53
Hub-1	H56	-70.62	-337.50	-60.07
Hub-2	H60	70.62	-337.50	-60.07
LED71				
Hub-0	H71	299.16	22.95	-180.22
Hub-1	H92	202.07	65.66	-278.13
Hub-2	H89	228.53	-74.26	-254.48
LED79				
Hub-0	H79	0.00	0.00	-350.00
Hub-1	H90	114.27	-37.13	-328.73
Hub-2	H78	70.62	97.20	-328.73

[4] The radial distance of the hub "centers" is 350 inches, while the radial distance of the center of installed panel is 330.05 inches (ref: Drawings 23H8606, 23H8646).

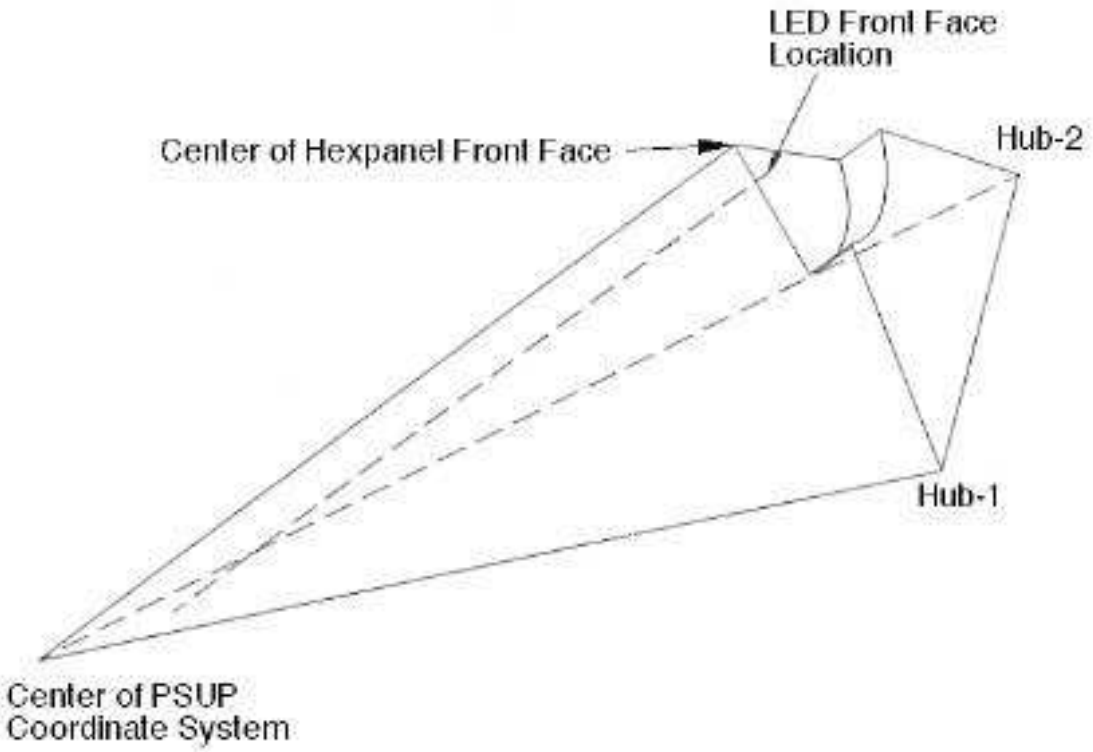

Figure 5: 3-D CAD Model

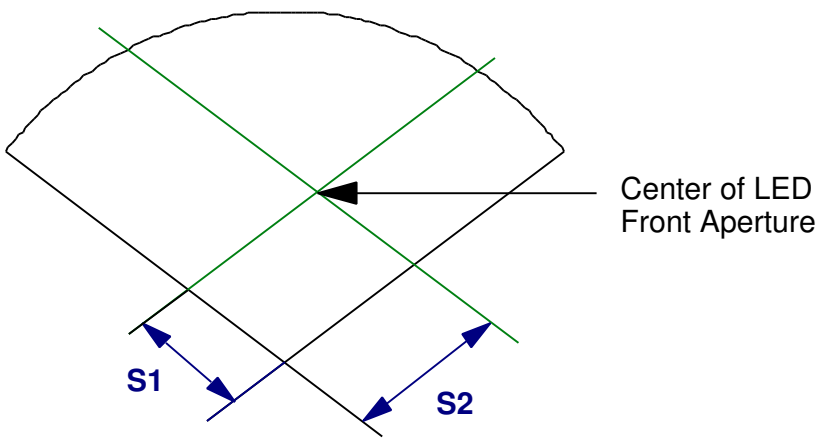

Figure 6: Finding the LED Front Aperture

Results

The positions of the LED's were determined using the method described above. The results are summarized in Table 4.

Table 4: 3-D Model Determined PSUP LED Coordinates

	x (cm)	y (cm)	z (cm)
LED25	694.94	248.12	399.35
LED35	-162.43	680.63	-463.11
LED45	-698.98	49.13	-461.54
LED55	-8.15	-764.21	-346.11
LED71	697.53	53.55	-463.39
LED79	37.01	1.45	-838.32

This 3-D model study used only the as-installed measured parameters S1 and S2, and the surveyed hub and hexpanel radial distances. The measured parameters have an uncertainty better than ±1/8 inch. To double-check the results of this 3-D model study, we did an analytic calculation to determine the LED positions. The as-installed parameters L1 and D were included, in addition to S1 and S2, in this analytical calculation. Table 5 shows the results from this analytic calculation. Also shown in this table is the deviation between the calculated LED positions in these two studies (ΔR). It is clear that the agreement between the two studies is excellent. Because the different input parameters were used, this excellent agreement indicates consistency in the measured parameters and the calculations.

Table 5: Analytically Determined PSUP LED Coordinates

	x (cm)	y (cm)	z (cm)	ΔR (cm)
LED25	692.48	248.97	400.77	2.97
LED35	-162.1	679.23	-463.17	1.39
LED45	-698.68	49.28	-462.14	2.00
LED55	-8.24	-763.72	-344.39	0.69
LED71	695.71	53.14	-464.11	1.79
LED79	38.28	1.78	-837.87	1.44

We recommend using the 3-D model results (Table 4) as the standard LED locations. The deviations (ΔR) in Table 5 indicate that the uncertainty of the LED locations is better than 1 inch.