National Astronomy and Ionosphere Center
Arecibo Gregorian Antenna Optics Series

Tertiary Noise Shield Geometry

Design II

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1 Tertiary Noise Shield: Introduction

We designed a metallic shield or skirt to be placed around the edge of the tertiary reflector of Arecibo's Gregorian system in order to reduce the noise temperature contribution from the Gregorian dome enclosure. The shield was designed to redirect spillover radiation to the sky through a series of reflections at the secondary and primary reflectors.

Initially, the tertiary skirt was a section of a cone with its cone angle and orientation optimized to effectively reduce the overall system noise temperature and at the same time do not interfere with the main optical path. This report contains a more detailed and precise design specification of the shield shape, that takes into account, in addition to the optics, more geometrical constraints such as the floor of the feed room, platform railing and motion of the tertiary itself. In addition, this design revision take into account the present uncertainties of the back-structure node location, which made the previous design susceptible of interference with the tertiary rib support system. In the current design, the tertiary shield is located 5.08 cm above the tertiary edge itself and supported by the back-structure frame. The uncertainties in the back-structure node location has been removed from the shield geometry design itself and translated to the shield support.

2 Shield Geometry

In the the new specification, the noise shield is a part of an elliptical cone shell. In the Gregorian system the cone axis forms an angle of $\theta_{cY} = 17.5^o$ with respect to the optical axis of the Arecibo Gregorian System, (World Coordinate System or WCS). The origin of coordinates in the WCS is at the apex of the spherical caustic as shown in Figure 1.

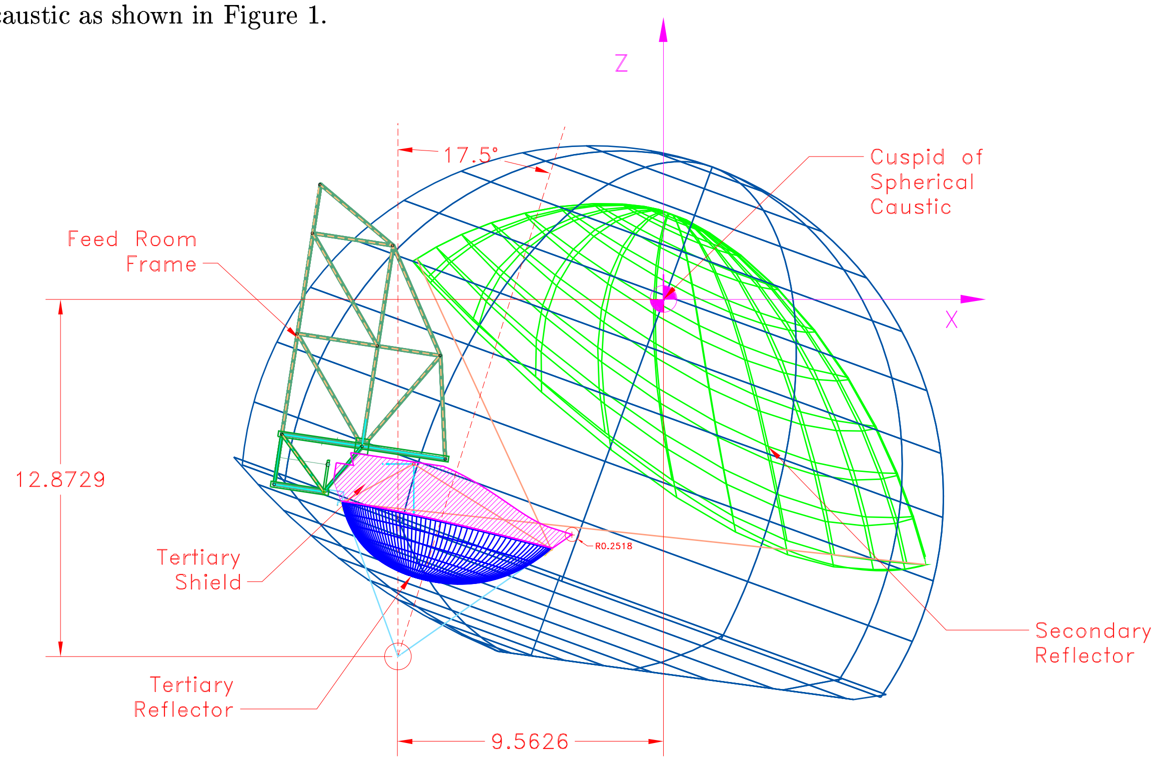

Figure 1. Tertiary Noise Shield Geometry

The cone's vertex position with respect to the WCS is:

$$\mathbf{x}_c = (-9.5626, 0.0000, -12.8729)^T \qquad [\text{m}] \tag{1}$$

In the WCS the cone is rotated with respect to the y-axis by an angle,

$$\theta_{cY} = 17.5^o \tag{2}$$

3 Shield Geometry Description in the Cone's LCS

3.1 Transformation from WCS to Cone's LCS

The noise shield geometry is more easily described in the elliptical cone's local coordinate system. The surface data for the tertiary reflector, which is originally is in WCS form, was converted to the cone's LCS by the following transformation:

$$\mathbf{x}_{LCS} \;=\; [\mathbf{R}]\cdot(\mathbf{x}_{WCS}-\mathbf{x}_c)\,, \tag{3}$$

with,

$$[\mathbf{R}] \;=\; \begin{bmatrix} \cos\theta_{cY} & 0 & -\sin\theta_{cY} \\ 0 & 1 & 0 \\ +\sin\theta_{cY} & 0 & \cos\theta_{cY} \end{bmatrix} \tag{4}$$

3.2 Elliptical Cone Geometry

In a local coordinate system (LCS) centered at the cone's vertex, the cone is described by an equation of the form,

$$\frac{x^2}{a^2}+\frac{y^2}{b^2} \;=\; \frac{z^2}{c^2} \tag{5}$$

The cone's parameters in its LCS are:

a	:	3.9875	m
b	:	3.5000	m
c	:	5.1966	m

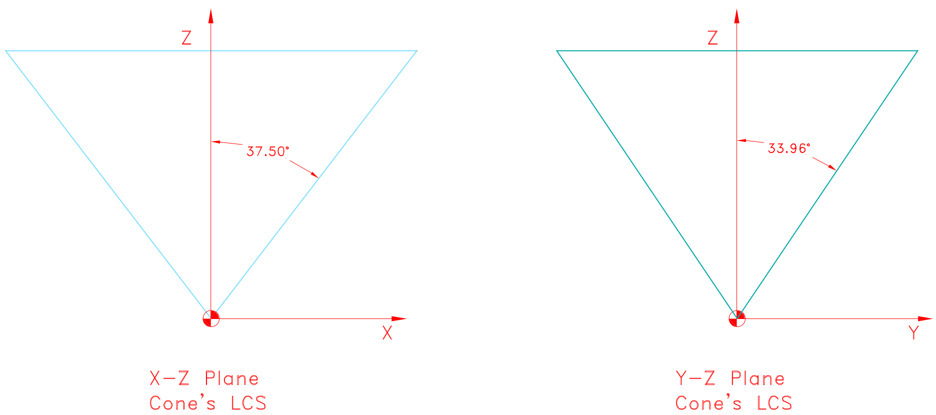

Figure 2. Geometry of the Cone Shell in the Cone's LCS

Figure 2. shows the two different angles that the elliptical cone shell sustain with respect to its axis in the XZ-plane and YZ-plane, respectively, in the cone's LCS.

3.3 Lower Edge Geometry

In order to avoid any mechanical interference with the tertiary rib support, in this design, the shield rests some distance above the tertiary itself, supported by the back-structure frame. Therefore, the lower edge of the shield is 0.0508 m (2 in) above the tertiary edge, as shown in Figure 3. The corresponding gap must be covered by a soft and flexible metallic tape or mesh. The lower edge geometry of the noise shield is determined in two steps in the cone's LCS: first, we projected each point of the edge of the tertiary reflector, perpendicularly to the cone axis, onto the cone surface, then, from that point we move along the cone surface away the cone vertex a distance of 5.08 cm.

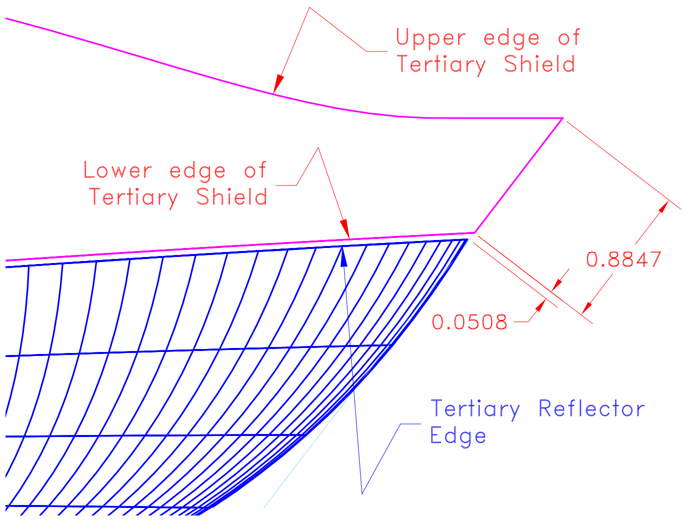

Figure 3. Detail of the Geometry of Shield Lower Edge (in Cone's LCS)

3.4 Upper Edge Geometry

The upper edge of the noise shield is composed of 5 sections. It is largely determined by the constraints of interference with the optical path, mechanical interference with the rotating feed floor, work envelope of the feeds, mechanical interference with the service platform railing, and the motion envelope of the tertiary mirror.

3.4.1 Section I, Optical Clearance

The first section of the upper edge of the noise shield was determined by ray-tracing to avoid any interference with the main optical path. In this section we use the following elliptical cone surface parameterization,

$$x(u,v) = a\,\frac{z}{c}\,\cos v \tag{6}$$

$$y(u,v) = b\,\frac{z}{c}\,\sin v \tag{7}$$

$$z(u,v) = \frac{c\,u}{\sqrt{a^2\cos^2 v + b^2 \sin^2 v + c^2}} \tag{8}$$

The relationship between the polar angle ϕ and the elliptical cone surface angle v is given by,

$$\tan\phi = \frac{y}{x} = \frac{b}{a}\tan v \tag{9}$$

$$v = \begin{cases} \tan^{-1}\left[\frac{a}{b}\tan\phi\right] & \text{for} \quad 0 \leq |\phi| \leq \pi/2 \\ \frac{\phi}{|\phi|}\left(\pi + \tan^{-1}\left[\frac{a}{b}\tan\phi\right]\right) & \text{for} \quad \pi/2 < |\phi| \leq \pi \end{cases} \tag{10}$$

In order to define the upper edge of the shield we make the u-parameter ϕ dependent, in the form,

$$u(\phi) = \begin{cases} R_{max} - h_o & \text{for} \quad 0 \leq |\phi| \leq \phi_1 \\ R_{max} - h_o\,\frac{1-\cos\alpha(\phi)}{2} & \text{for} \quad \phi_1 \leq |\phi| < \phi_2 \end{cases} \tag{11}$$

$$\alpha(\phi) = \pi\,\frac{\phi_2 - |\phi|}{\Delta\phi} \tag{12}$$

with $0 \leq \phi_1 \leq |\phi| \leq \phi_2 \leq \pi$.

We use the following values,

$$\begin{aligned} R_{max} &= 8.900 \quad [\text{m}] \\ h_o &= 1.2437 \quad [\text{m}] \\ \phi_1 &= 30.0^o \\ \phi_2 &= 95.344^o \\ \Delta\phi &= 75.0^o \end{aligned}$$

The intersection with edge Section II occurs at an angle $|\phi| = 95.344^o$.

Figures 4 and 5 show two projections of the upper edge geometry, in the cone's local coordinate system, planes X-Z and X-Y, respectively.

3.4.2 Section II, Feed Room Floor

Section II of the tertiary upper edge is designed to avoid any mechanical interference with the feed room floor; it is defined by the intersection of the elliptical cone shell, with a plane. Figure 4 shows this section of the noise shield geometry in the plane X-Z (in the cone's LCS), including the feed room floor and part of the feed room framing. Figure 5 shows the projection of the noise shield geometry in the plane X-Y (in the cone's LCS).

The intersecting plane is defined by,

$$n_{1_x} x + n_{1_y} y + n_{1_z} z \;=\; d_1 \;=\; \hat{\mathbf{n}}_1 \cdot \mathbf{x}_{o_1} \tag{13}$$

where, $\hat{\mathbf{n}}_1$ is the plane normal unit vector, and $\mathbf{x}_{o_1}$ is a point on the plane. The plane parameters in the cone's LCS are,

$$\begin{aligned} \hat{\mathbf{n}}_1 &= (-\sin\theta_1, 0.0000, \cos\theta_1)^T \\ \theta_1 &= 8.999^o \\ \mathbf{x}_{o_1} &= (0.0000, 0.0000, 7.1000)^T \qquad [\text{m}] \end{aligned}$$

For this case, and with $n_{1_y} = 0$, the intersection projected on the cone's LCS XY-plane is an offset ellipse of the form, (see Appendix B.2),

$$\frac{(x - x_o)^2}{a_p^2} + \frac{y^2}{b_p^2} \;=\; 1 \tag{14}$$

with,

$$x_o \;=\; \frac{a^2\, d_1\, n_{1_x}}{a^2\, n_{1_x}^2 - c^2\, n_{1_z}^2} \tag{15}$$

$$a_p \;=\; \frac{a\, c\, d_1\, n_{1_z}}{c^2\, n_{1_z}^2 - a^2 n_{1_x}^2} \tag{16}$$

$$b_p \;=\; \frac{b\, d_1}{\sqrt{c^2\, n_{1_z}^2 - a^2 n_{1_x}^2}} \tag{17}$$

and, naturally,

$$z \;=\; \frac{(d_1 - n_{1_x}\, x)}{n_{1_z}} \tag{18}$$

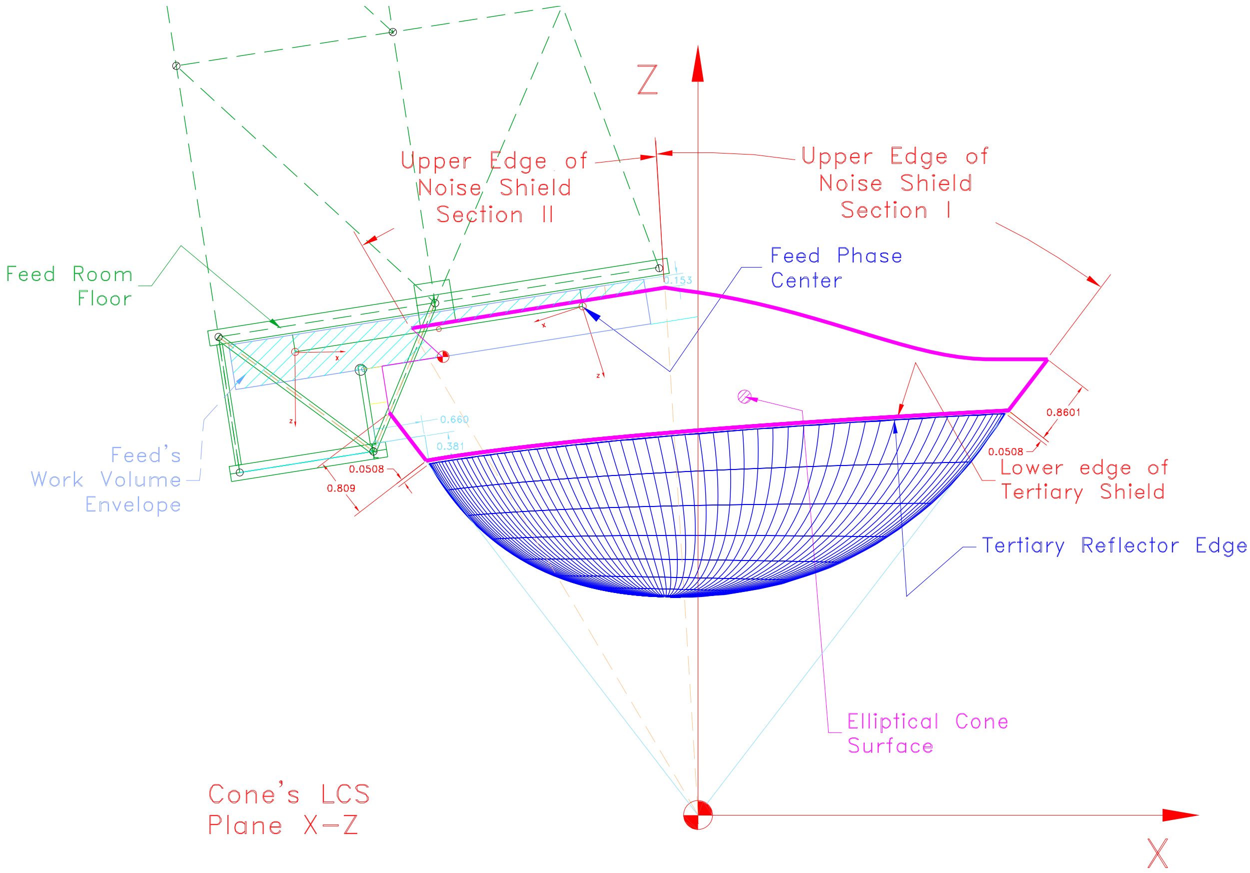

Figure 4. Noise Shield Edge Geometry of Sections I and II, in Cone's LCS, XZ-plane.

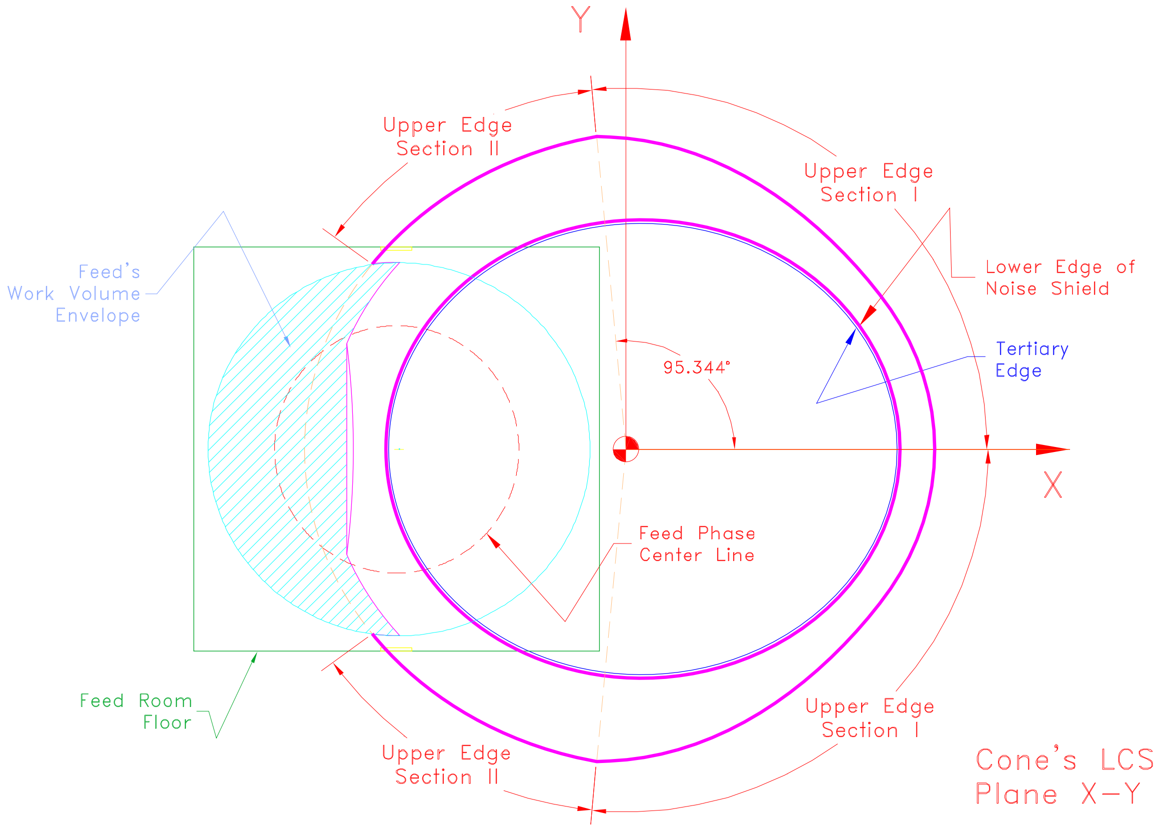

Figure 5. Noise Shield Edge Geometry of Sections I and II, in Cone's LCS, XY-plane.

3.4.3 Section III, Feeds Work Volume Envelope

Section III of the edge of tertiary shield is determined by the intersection of the work volume envelope of the rotating feeds with the elliptical cone shell, as shown in Figure 6 and Figure 7. The work volume envelope of the rotating feeds is defined by a cylinder,

$$x^2 + y^2 = R_{cyl}^2, \qquad \text{with,} \qquad 0 \le z \le h_{cyl} \tag{19}$$

The cylinder in inclined an angle $\theta_{cyl} = 8.999^o$ with respect to the axis of the elliptical cone shell. The orientation of the cylinder axis, $\hat{\mathbf{z}}_{cyl}$, is the same as the previous plane unit vector $\hat{\mathbf{n}}_1$, i.e.,

$$\begin{aligned}
\hat{\mathbf{z}}_{cyl} &= (-\sin\theta_{cyl}, 0.0000, \cos\theta_{cyl})^T \\
\theta_{cyl} &= 8.999^o \\
R_{cyl} &= 2.8000 \qquad [\mathrm{m}] \\
h_{cyl} &= 0.6000 \qquad [\mathrm{m}]
\end{aligned}$$

The center of the bottom cap of the cylinder is located at,

$$\mathbf{x}_{o_{cyl}} = (-3.3965,\ 0.0000, +6.1095)^T \qquad [\mathrm{m}]$$

in the cone's LCS.

3.4.4 Section IV, Service Platform Railing

In order to avoid interference with the service platform railing, the last section of the tertiary shield is defined by the intersection of the elliptical cone shell with a second plane, as shown in Figures 6 and 7, Note that the plane inside the elliptical cone is part of the shield. The plane parameters are the following,

$$\begin{aligned}
\hat{\mathbf{n}}_2 &= (-\cos\theta_2,\ 0.0000, -\sin\theta_2)^T \\
\theta_2 &= 8.999^o \\
\mathbf{x}_{o_2} &= (-4.1162,\ 0.0000, +5.3643)^T \qquad [\mathrm{m}]
\end{aligned}$$

For this case, and with $n_{2_y} = 0$, the intersection projected on the cone's LCS YZ-plane is an offset hyperbola of the form, (see Appendix B.3),

$$\frac{(z - z_{o_h})^2}{c_h^2} - \frac{y^2}{b_h^2} = 1 \tag{20}$$

with,

$$z_{o_h} = \frac{c^2\, d_2\, n_{2_z}}{c^2\, n_{2_z}^2 - a^2\, n_{2_x}^2} \tag{21}$$

$$b_h = \frac{b\, d_2}{\sqrt{a^2 n_{2_x}^2 - c^2\, n_{2_z}^2}} \tag{22}$$

$$c_h = \frac{a\, c\, d_2\, n_{2_x}}{a^2 n_{2_x}^2 - c^2\, n_{2_z}^2} \tag{23}$$

where, $d_2 = \hat{\mathbf{n}}_2 \cdot \mathbf{x}_{o_2}$, and naturally,

$$x = \frac{(d_2 - n_{2_z}\, z)}{n_{2_x}} \tag{24}$$

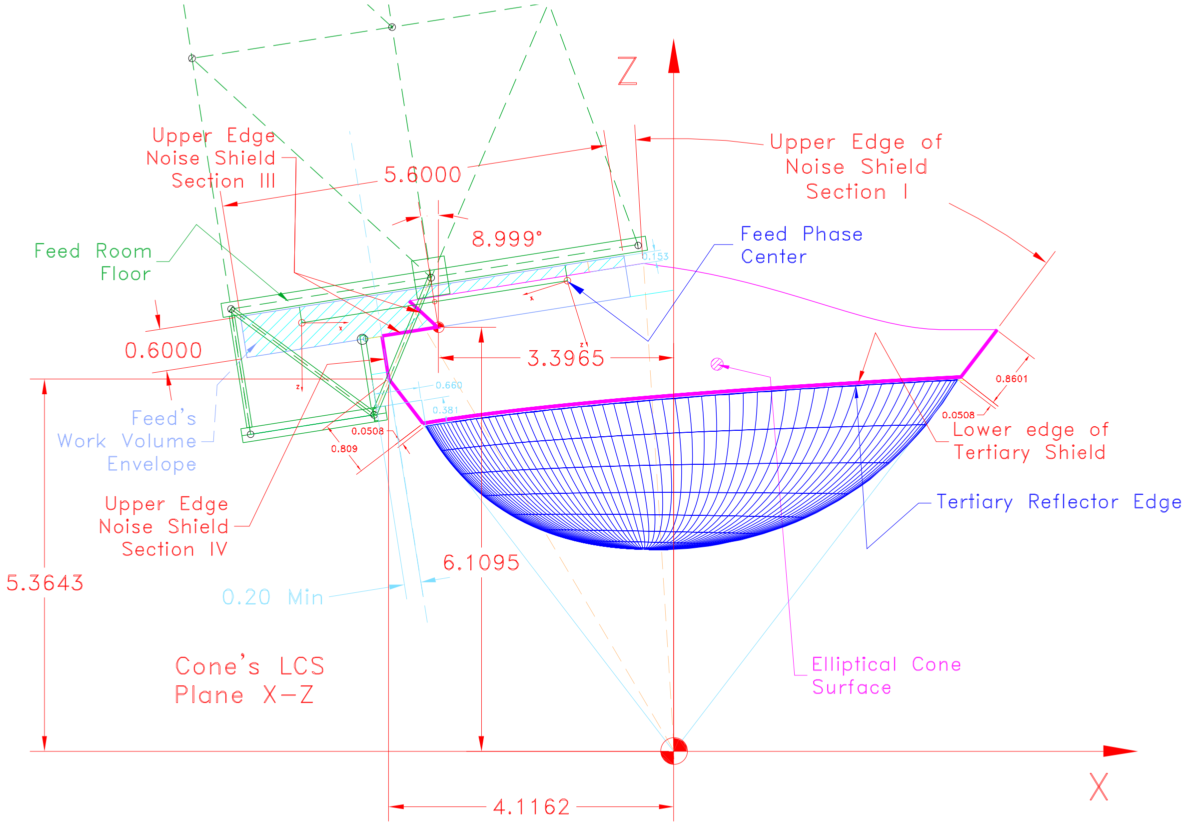

Figure 6. Noise Shield Edge Geometry of Sections III and IV, in Cone's LCS, XZ-plane.

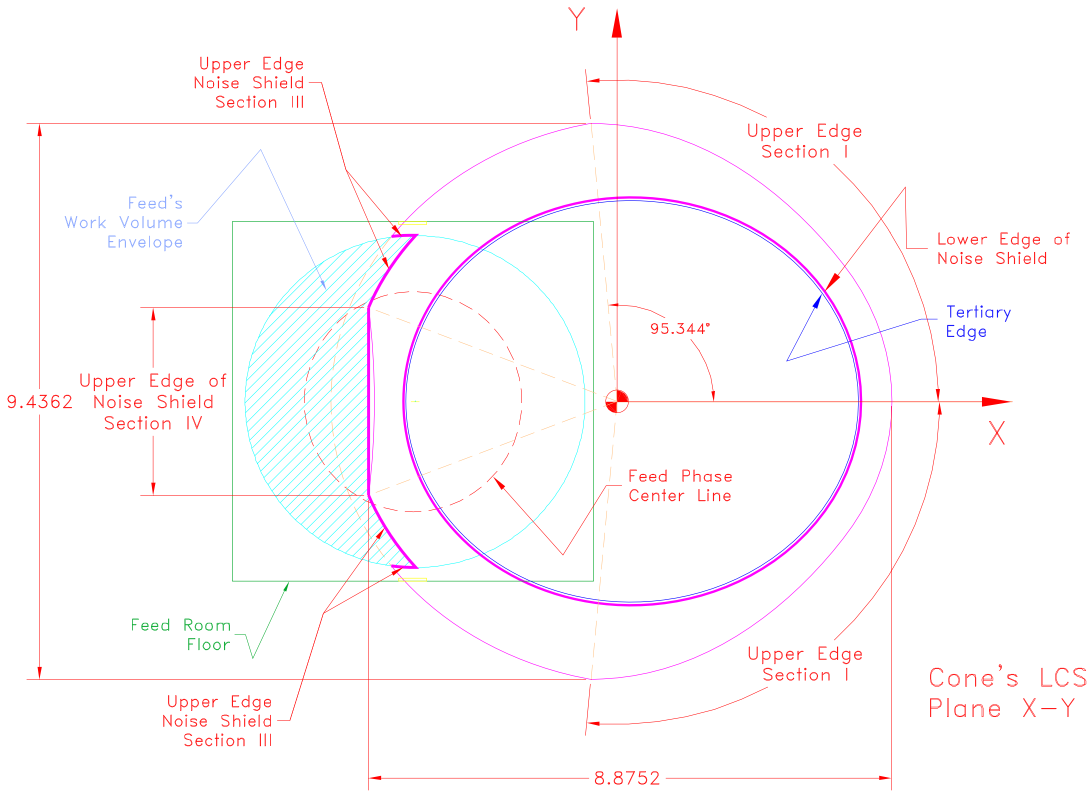

Figure 7. Noise Shield Edge Geometry of Sections III and IV, in Cone's LCS, XY-plane.

Note *The current definition of the noise shield presented here doesn't include provisions to avoid interference with the tertiary back-structure and support frame.*

Appendix

A Elliptical Cone Parameterization

$$\frac{x^2}{a^2}+\frac{y^2}{b^2} = \frac{z^2}{c^2} \tag{25}$$

$$x(\phi_{cone}, z) = a\,\frac{z}{c}\,\cos\phi_{cone} \tag{26}$$

$$y(\phi_{cone}, z) = b\,\frac{z}{c}\,\sin\phi_{cone} \tag{27}$$

$$\tan\phi = \frac{y}{x} = \frac{b}{a}\tan\phi_{cone} \tag{28}$$

$$\phi_{cone} = \begin{cases} \tan^{-1}\left[\frac{a}{b}\tan\phi\right] & \text{for} \quad 0 \leq |\phi| \leq \pi/2 \\ \frac{\phi}{|\phi|}\left(\pi + \tan^{-1}\left[\frac{a}{b}\tan\phi\right]\right) & \text{for} \quad \pi/2 < |\phi| \leq \pi \end{cases} \tag{29}$$

B Intersection of an Elliptical Cone with a Plane

B.1 Parameterization

The Cone

$$\frac{x^2}{a^2}+\frac{y^2}{b^2} = \frac{z^2}{c^2} \tag{30}$$

The Plane

$$n_x x + n_y y + n_z z = d \tag{31}$$

B.2 The Intersection in the XY-plane (eliminating Z)

This is useful when the angle between the plane and the cone axis is greater than the cone angle. In this case the intersection is in general an ellipse.

$$\frac{(n_z z)^2}{c^2} = \frac{[d-(n_x x + n_y y)]^2}{c^2} \tag{32}$$

$$\frac{(n_z z)^2}{c^2} = n_z^2\left[\frac{x^2}{a^2}+\frac{y^2}{b^2}\right] \tag{33}$$

$$d^2 - 2\,d\,(n_x x + n_y y) + n_x^2 x^2 + 2\,n_x n_y x\,y + n_y^2 y^2 = x^2\frac{c^2\,n_z^2}{a^2} + y^2\frac{c^2\,n_z^2}{b^2} \tag{34}$$

$$x^2\left(\frac{c^2\,n_z^2}{a^2} - n_x^2\right) + y^2\left(\frac{c^2\,n_z^2}{b^2} - n_y^2\right) - 2\,n_x n_y x\,y + 2\,d\,(n_x x + n_y y) = d^2 \tag{35}$$

$$x^2\left(\frac{c^2\,n_z^2}{a^2} - n_x^2\right)\frac{1}{d^2} + y^2\left(\frac{c^2\,n_z^2}{b^2} - n_y^2\right)\frac{1}{d^2} - 2\,\frac{n_x n_y}{d^2}x\,y + 2\,\frac{(n_x x + n_y y)}{d} = 1 \tag{36}$$

B.2.1 Solution for the case $n_y = 0$

For the case of $n_y = 0$,

$$x^2\left(\frac{c^2\,n_z^2}{a^2} - n_x^2\right)\frac{1}{d^2} + y^2\left(\frac{c^2\,n_z^2}{b^2}\right)\frac{1}{d^2} + 2\,\frac{n_x\,x}{d} = 1 \tag{37}$$

$$x = \frac{a}{b} \frac{\left(a\,b\,d\,n_x \mp c\,n_z \sqrt{b^2 d^2 + \left(a^2 n_x^2 - c^2\,n_z^2\right)\,y^2}\right)}{\left(a^2 n_x^2 - c^2\,n_z^2\right)} \tag{38}$$

$$y = \pm \frac{b}{a\,c\,n_z} \sqrt{a^2\,(d - n_x\,x)^2 - c^2\,n_z^2 x^2} \tag{39}$$

$$z = \frac{(d - n_x\,x)}{n_z} \tag{40}$$

particular case:

$$x = 0 \qquad y = \pm \frac{b\,d}{c\,n_z} \tag{41}$$

$$y = 0 \qquad x = \frac{a\,d}{a\,n_x \mp c\,n_z} \tag{42}$$

The middle point is at:

$$x = \frac{a^2\,d\,n_x}{a^2\,n_x^2 - c^2\,n_z^2} \tag{43}$$

$$y = 0 \tag{44}$$

B.2.2 Equivalent ellipse

$$x^2 \left(\frac{c^2}{a^2}\,n_z^2 - n_x^2\right) \frac{1}{d^2} + y^2 \left(\frac{c^2}{b^2}\,n_z^2\right) \frac{1}{d^2} + 2\,\frac{n_x\,x}{d} = 1 \tag{45}$$

$$\frac{(x - x_o)^2}{a_p^2} + \frac{y^2}{b_p^2} = 1 \tag{46}$$

$$\frac{x^2}{a_p^2} + \frac{y^2}{b_p^2} - 2\frac{x_o\,x}{a_p^2} + \frac{x_o^2}{a_p^2} = 1 \tag{47}$$

$$\frac{x^2}{a_p^2\left(1 - \frac{x_o^2}{a_p^2}\right)} + \frac{y^2}{b_p^2\left(1 - \frac{x_o^2}{a_p^2}\right)} - 2\frac{x_o\,x}{a_p^2\left(1 - \frac{x_o^2}{a_p^2}\right)} = 1 \tag{48}$$

Solution:

$$x_o = \frac{a^2\,d\,n_x}{a^2\,n_x^2 - c^2\,n_z^2} \tag{49}$$

$$a_p = \frac{a\,c\,d\,n_z}{c^2\,n_z^2 - a^2 n_x^2} \tag{50}$$

$$b_p = \frac{b\,d}{\sqrt{c^2\,n_z^2 - a^2 n_x^2}} \tag{51}$$

B.2.3 Polar Parameterization of Cone-Plane Intersection in Cone's XY-Plane

$$x(\phi_{plane}) = a_p \cos\phi_{plane} + x_o \tag{52}$$

$$y(\phi_{plane}) = b_p \sin\phi_{plane} \tag{53}$$

$$\tan\phi = \frac{b_p \sin\phi_{plane}}{a_p \cos\phi_{plane} + x_o} \tag{54}$$

$$\phi_{plane} = \begin{cases} \frac{\phi}{|\phi|}\cos^{-1}\left[\frac{-a_p \tan\phi^2 x_o + b_p\sqrt{b_p^2 + \tan\phi^2(a_p^2 - x_o^2)}}{b_p^2 + a_p^2\tan\phi^2}\right] & \text{for} \quad 0 \le \ |\phi| \ \le \pi/2 \\ \frac{\phi}{|\phi|}\cos^{-1}\left[\frac{-a_p \tan\phi^2 x_o - b_p\sqrt{b_p^2 + \tan\phi^2(a_p^2 - x_o^2)}}{b_p^2 + a_p^2\tan\phi^2}\right] & \text{for} \quad \pi/2 < \ |\phi| \ \le \pi \end{cases} \tag{55}$$

B.3 The Intersection in the YZ-Plane (eliminating X)

This is useful when the angle between the plane and the cone axis is less than the cone angle. In this case the intersection forms a pair of hyperbola, one for each foil of the mathematical cone.

$$\frac{(n_x x)^2}{a^2} = \frac{[d - (n_z z + n_y y)]^2}{a^2} \tag{56}$$

$$\frac{(n_x x)^2}{a^2} = n_x^2\left[\frac{z^2}{c^2} - \frac{y^2}{b^2}\right] \tag{57}$$

$$d^2 - 2\,d\,(n_z z + n_y y) + n_z^2 z^2 + 2\,n_z n_y z\,y + n_y^2 y^2 = z^2\frac{a^2\,n_x^2}{c^2} - y^2\frac{a^2\,n_x^2}{b^2} \tag{58}$$

$$z^2\left(\frac{a^2\,n_x^2}{c^2} - n_z^2\right) - y^2\left(\frac{a^2\,n_x^2}{b^2} + n_y^2\right) - 2\,n_z\,n_y\,z\,y + 2\,d\,(n_z z + n_y y) = d^2 \tag{59}$$

$$z^2\left(\frac{a^2\,n_x^2}{c^2} - n_z^2\right)\frac{1}{d^2} - y^2\left(\frac{a^2\,n_x^2}{b^2} + n_y^2\right)\frac{1}{d^2} - 2\,\frac{n_z\,n_y}{d^2}z\,y + 2\,\frac{(n_z z + n_y y)}{d} = 1 \tag{60}$$

B.3.1 Solution for the case $n_y = 0$

For the case of $n_y = 0$,

$$z^2\left(\frac{a^2\,n_x^2}{c^2} - n_z^2\right)\frac{1}{d^2} - y^2\left(\frac{a^2\,n_x^2}{b^2}\right)\frac{1}{d^2} + 2\,\frac{n_z\,z}{d} = 1 \tag{61}$$

$$z = -\frac{c}{b}\,\frac{\left(c\,b\,d\,n_z \mp a\,n_x\sqrt{b^2 d^2 + \left(a^2 n_x^2 - c^2\,n_z^2\right)\,y^2}\right)}{\left(a^2 n_x^2 - c^2\,n_z^2\right)} \tag{62}$$

$$y = \pm\frac{b}{a\,c\,n_x}\sqrt{a^2 n_x^2 z^2 - c^2\,(d - n_z\,z)^2} \tag{63}$$

$$z = \frac{(d - n_x\,x)}{n_z} \tag{64}$$

B.3.2 Equivalent hyperbola

$$\frac{(z - z_o)^2}{c_h^2} - \frac{y^2}{b_h^2} = 1 \tag{65}$$

$$\frac{z^2}{c_h^2} - \frac{y^2}{b_h^2} - 2\frac{z_o\,z}{c_h^2} + \frac{z_o^2}{c_h^2} = 1 \tag{66}$$

$$\frac{z^2}{c_h^2\left(1-\frac{z_o^2}{c_h^2}\right)}-\frac{y^2}{b_h^2\left(1-\frac{z_o^2}{c_h^2}\right)}-2\frac{z_o\,z}{c_h^2\left(1-\frac{z_o^2}{c_h^2}\right)} = 1 \tag{67}$$

Solution:

$$z_o = \frac{c^2\,d\,n_z}{c^2\,n_z^2-a^2\,n_x^2} \tag{68}$$

$$b_h = \frac{b\,d}{\sqrt{a^2 n_x^2-c^2\,n_z^2}} \tag{69}$$

$$c_h = \frac{a\,c\,d\,n_x}{a^2 n_x^2-c^2\,n_z^2} \tag{70}$$

C Noise Shield Lower Edge Data Points (in Cone's LCS)

Label	ϕ [deg]	X [m]	Y [m]	Z [m]	Label	ϕ [deg]	X [m]	Y [m]	Z [m]
0	-180.000	-3.623435	0.000000	4.722135	64	0.000	4.137284	0.000000	5.391794
1	-178.008	-3.620941	-0.125914	4.722586	65	3.458	4.127122	0.249405	5.391282
2	-176.016	-3.613457	-0.251683	4.723935	66	6.919	4.096752	0.497112	5.389747
3	-174.021	-3.600982	-0.377165	4.726167	67	10.383	4.046524	0.741453	5.387193
4	-172.022	-3.583513	-0.502217	4.729262	68	13.854	3.977014	0.980820	5.383626
5	-170.019	-3.561046	-0.626697	4.733189	69	17.332	3.889008	1.213692	5.379059
6	-168.010	-3.533578	-0.750466	4.737917	70	20.819	3.783485	1.438665	5.373513
7	-165.993	-3.501107	-0.873386	4.743409	71	24.316	3.661592	1.654474	5.367018
8	-163.967	-3.463632	-0.995322	4.749627	72	27.822	3.524610	1.860010	5.359610
9	-161.931	-3.421154	-1.116141	4.756535	73	31.337	3.373924	2.054338	5.351335
10	-159.883	-3.373672	-1.235710	4.764093	74	34.860	3.210988	2.236695	5.342241
11	-157.821	-3.321188	-1.353899	4.772266	75	38.390	3.037291	2.406493	5.332381
12	-155.744	-3.263704	-1.470580	4.781019	76	41.925	2.854330	2.563318	5.321810
13	-153.650	-3.201219	-1.585623	4.790318	77	45.462	2.663579	2.706914	5.310587
14	-151.536	-3.133734	-1.698901	4.800131	78	48.998	2.466466	2.837173	5.298765
15	-149.402	-3.061247	-1.810284	4.810429	79	52.530	2.264357	2.954121	5.286402
16	-147.244	-2.983754	-1.919641	4.821184	80	56.052	2.058537	3.057900	5.273551
17	-145.061	-2.901248	-2.026840	4.832368	81	59.562	1.850204	3.148752	5.260263
18	-142.852	-2.813720	-2.131744	4.843956	82	63.053	1.640456	3.227002	5.246589
19	-140.612	-2.721158	-2.234211	4.855925	83	66.523	1.430294	3.293043	5.232575
20	-138.341	-2.623549	-2.334096	4.868251	84	69.965	1.220616	3.347317	5.218266
21	-136.037	-2.520874	-2.431244	4.880913	85	73.376	1.012221	3.390306	5.203704
22	-133.696	-2.413113	-2.525493	4.893889	86	76.751	0.805810	3.422519	5.188929
23	-131.318	-2.300246	-2.616673	4.907161	87	80.086	0.601996	3.444475	5.173978
24	-128.899	-2.182249	-2.704602	4.920707	88	83.378	0.401305	3.456704	5.158886
25	-126.437	-2.059099	-2.789084	4.934510	89	86.622	0.204183	3.459729	5.143687
26	-123.931	-1.930774	-2.869912	4.948549	90	89.817	0.011006	3.454066	5.128412
27	-121.378	-1.797253	-2.946862	4.962807	91	92.960	-0.177914	3.440217	5.113090
28	-118.777	-1.658520	-3.019695	4.977265	92	96.050	-0.362324	3.418667	5.097749
29	-116.125	-1.514565	-3.088151	4.991903	93	99.084	-0.542020	3.389879	5.082417
30	-113.422	-1.365385	-3.151952	5.006703	94	102.063	-0.716841	3.354293	5.067117
31	-110.665	-1.210990	-3.210800	5.021645	95	104.986	-0.886666	3.312327	5.051873
32	-107.853	-1.051403	-3.264373	5.036709	96	107.853	-1.051403	3.264373	5.036709
33	-104.986	-0.886666	-3.312327	5.051873	97	110.665	-1.210990	3.210800	5.021645
34	-102.063	-0.716841	-3.354293	5.067117	98	113.422	-1.365385	3.151952	5.006703
35	-99.084	-0.542020	-3.389879	5.082417	99	116.125	-1.514565	3.088151	4.991903
36	-96.050	-0.362324	-3.418667	5.097749	100	118.777	-1.658520	3.019695	4.977265
37	-92.960	-0.177914	-3.440217	5.113090	101	121.378	-1.797253	2.946862	4.962807
38	-89.817	0.011006	-3.454066	5.128412	102	123.931	-1.930774	2.869912	4.948549
39	-86.622	0.204183	-3.459729	5.143687	103	126.437	-2.059099	2.789084	4.934510
40	-83.378	0.401305	-3.456704	5.158886	104	128.899	-2.182249	2.704602	4.920707
41	-80.086	0.601996	-3.444475	5.173978	105	131.318	-2.300246	2.616673	4.907161
42	-76.751	0.805810	-3.422519	5.188929	106	133.696	-2.413113	2.525493	4.893889
43	-73.376	1.012221	-3.390306	5.203704	107	136.037	-2.520874	2.431244	4.880913
44	-69.965	1.220616	-3.347317	5.218266	108	138.341	-2.623549	2.334096	4.868251
45	-66.523	1.430294	-3.293043	5.232575	109	140.612	-2.721158	2.234211	4.855925
46	-63.053	1.640456	-3.227002	5.246589	110	142.852	-2.813720	2.131744	4.843956
47	-59.562	1.850204	-3.148752	5.260263	111	145.061	-2.901248	2.026840	4.832368
48	-56.052	2.058537	-3.057900	5.273551	112	147.244	-2.983754	1.919641	4.821184
49	-52.530	2.264357	-2.954121	5.286402	113	149.402	-3.061247	1.810284	4.810429
50	-48.998	2.466466	-2.837173	5.298765	114	151.536	-3.133734	1.698901	4.800131
51	-45.462	2.663579	-2.706914	5.310587	115	153.650	-3.201219	1.585623	4.790318
52	-41.925	2.854330	-2.563318	5.321810	116	155.744	-3.263704	1.470580	4.781019
53	-38.390	3.037291	-2.406493	5.332381	117	157.821	-3.321188	1.353899	4.772266
54	-34.860	3.210988	-2.236695	5.342241	118	159.883	-3.373672	1.235710	4.764093
55	-31.337	3.373924	-2.054338	5.351335	119	161.931	-3.421154	1.116141	4.756535
56	-27.822	3.524610	-1.860010	5.359610	120	163.967	-3.463632	0.995322	4.749627
57	-24.316	3.661592	-1.654474	5.367018	121	165.993	-3.501107	0.873386	4.743409
58	-20.819	3.783485	-1.438665	5.373513	122	168.010	-3.533578	0.750466	4.737917
59	-17.332	3.889008	-1.213692	5.379059	123	170.019	-3.561046	0.626697	4.733189
60	-13.854	3.977014	-0.980820	5.383626	124	172.022	-3.583513	0.502217	4.729262
61	-10.383	4.046524	-0.741453	5.387193	125	174.021	-3.600982	0.377165	4.726167
62	-6.919	4.096752	-0.497112	5.389747	126	176.016	-3.613457	0.251683	4.723935
63	-3.458	4.127122	-0.249405	5.391282	127	178.008	-3.620941	0.125914	4.722586

These coordinates are with respect to the elliptical cone's local coordinate system. There are 128 points in total[1].

[1] Data stored in XYZ format in file: "*shield_lower_edge_xyz.dat*"

D Noise Shield Upper Edge Sections I and II (in Cone's LCS)

Label	ϕ [deg]	X [m]	Y [m]	Z [m]	Label	ϕ [deg]	X [m]	Y [m]	Z [m]
0	-180.000	-4.852208	0.000000	6.323497	64	0.000	4.660878	0.000000	6.074151
1	-178.008	-4.848820	-0.168612	6.324039	65	3.458	4.649870	0.280995	6.074151
2	-176.016	-4.838661	-0.337021	6.325665	66	6.919	4.616968	0.560237	6.074151
3	-174.021	-4.821742	-0.505027	6.328373	67	10.383	4.562524	0.836001	6.074151
4	-172.022	-4.798080	-0.672434	6.332159	68	13.854	4.487122	1.106624	6.074151
5	-170.019	-4.767699	-0.839052	6.337021	69	17.332	4.391553	1.370528	6.074151
6	-168.010	-4.730627	-1.004697	6.342954	70	20.819	4.276804	1.626249	6.074151
7	-165.993	-4.686895	-1.169193	6.349952	71	24.316	4.144026	1.872459	6.074151
8	-163.967	-4.636535	-1.332372	6.358011	72	27.822	3.994509	2.107986	6.074151
9	-161.931	-4.579577	-1.494073	6.367126	73	31.337	3.830134	2.332119	6.074924
10	-159.883	-4.516052	-1.654141	6.377292	74	34.860	3.657031	2.547397	6.084339
11	-157.821	-4.445986	-1.812428	6.388505	75	38.390	3.476976	2.754863	6.104308
12	-155.744	-4.369401	-1.968791	6.400761	76	41.925	3.290177	2.954729	6.134433
13	-153.650	-4.286314	-2.123090	6.414058	77	45.462	3.096664	3.147045	6.174062
14	-151.536	-4.196735	-2.275188	6.428393	78	48.998	2.896351	3.331669	6.222296
15	-149.402	-4.100666	-2.424949	6.443767	79	52.530	2.689098	3.508247	6.278010
16	-147.244	-3.998103	-2.572237	6.460180	80	56.052	2.474783	3.676222	6.339887
17	-145.061	-3.889030	-2.716915	6.477635	81	59.562	2.253356	3.834853	6.406454
18	-142.852	-3.773425	-2.858841	6.496136	82	63.053	2.024900	3.983257	6.476137
19	-140.612	-3.651254	-2.997868	6.515687	83	66.523	1.789669	4.120452	6.547311
20	-138.341	-3.522475	-3.133844	6.536295	84	69.965	1.548114	4.245420	6.618355
21	-136.037	-3.387034	-3.266607	6.557970	85	73.376	1.300888	4.357163	6.687711
22	-133.696	-3.244868	-3.395983	6.580721	86	76.751	1.048846	4.454764	6.753931
23	-131.318	-3.095907	-3.521787	6.604559	87	80.086	0.793014	4.537431	6.815717
24	-128.899	-2.940069	-3.643816	6.629498	88	83.378	0.534563	4.604545	6.871958
25	-126.437	-2.777265	-3.761851	6.655552	89	86.622	0.274764	4.655681	6.921747
26	-123.931	-2.607401	-3.875653	6.682735	90	89.817	0.014946	4.690629	6.964395
27	-121.378	-2.430375	-3.984959	6.711065	91	92.960	-0.243551	4.709393	6.999427
28	-118.777	-2.246083	-4.089480	6.740557	92	96.050	-0.498960	4.707874	7.020151
29	-116.125	-2.054420	-4.188899	6.771229	93	99.084	-0.744481	4.656106	6.980860
30	-113.422	-1.855283	-4.282866	6.803098	94	102.063	-0.982195	4.595957	6.942818
31	-110.665	-1.648572	-4.370998	6.836178	95	104.986	-1.212092	4.528028	6.906028
32	-107.853	-1.434200	-4.452873	6.870484	96	107.853	-1.434200	4.452873	6.870484
33	-104.986	-1.212092	-4.528028	6.906028	97	110.665	-1.648572	4.370998	6.836178
34	-102.063	-0.982195	-4.595957	6.942818	98	113.422	-1.855283	4.282866	6.803098
35	-99.084	-0.744481	-4.656106	6.980860	99	116.125	-2.054420	4.188899	6.771229
36	-96.050	-0.498960	-4.707874	7.020151	100	118.777	-2.246083	4.089480	6.740557
37	-92.960	-0.243551	-4.709393	6.999427	101	121.378	-2.430375	3.984959	6.711065
38	-89.817	0.014946	-4.690629	6.964395	102	123.931	-2.607401	3.875653	6.682735
39	-86.622	0.274764	-4.655681	6.921747	103	126.437	-2.777265	3.761851	6.655552
40	-83.378	0.534563	-4.604545	6.871958	104	128.899	-2.940069	3.643816	6.629498
41	-80.086	0.793014	-4.537431	6.815717	105	131.318	-3.095907	3.521787	6.604559
42	-76.751	1.048846	-4.454764	6.753931	106	133.696	-3.244868	3.395983	6.580721
43	-73.376	1.300888	-4.357163	6.687711	107	136.037	-3.387034	3.266607	6.557970
44	-69.965	1.548114	-4.245420	6.618355	108	138.341	-3.522475	3.133844	6.536295
45	-66.523	1.789669	-4.120452	6.547311	109	140.612	-3.651254	2.997868	6.515687
46	-63.053	2.024900	-3.983257	6.476137	110	142.852	-3.773425	2.858841	6.496136
47	-59.562	2.253356	-3.834853	6.406454	111	145.061	-3.889030	2.716915	6.477635
48	-56.052	2.474783	-3.676222	6.339887	112	147.244	-3.998103	2.572237	6.460180
49	-52.530	2.689098	-3.508247	6.278010	113	149.402	-4.100666	2.424949	6.443767
50	-48.998	2.896351	-3.331669	6.222296	114	151.536	-4.196735	2.275188	6.428393
51	-45.462	3.096664	-3.147045	6.174062	115	153.650	-4.286314	2.123090	6.414058
52	-41.925	3.290177	-2.954729	6.134433	116	155.744	-4.369401	1.968791	6.400761
53	-38.390	3.476976	-2.754863	6.104308	117	157.821	-4.445986	1.812428	6.388505
54	-34.860	3.657031	-2.547397	6.084339	118	159.883	-4.516052	1.654141	6.377292
55	-31.337	3.830134	-2.332119	6.074924	119	161.931	-4.579577	1.494073	6.367126
56	-27.822	3.994509	-2.107986	6.074151	120	163.967	-4.636535	1.332372	6.358011
57	-24.316	4.144026	-1.872459	6.074151	121	165.993	-4.686895	1.169193	6.349952
58	-20.819	4.276804	-1.626249	6.074151	122	168.010	-4.730627	1.004697	6.342954
59	-17.332	4.391553	-1.370528	6.074151	123	170.019	-4.767699	0.839052	6.337021
60	-13.854	4.487122	-1.106624	6.074151	124	172.022	-4.798080	0.672434	6.332159
61	-10.383	4.562524	-0.836001	6.074151	125	174.021	-4.821742	0.505027	6.328373
62	-6.919	4.616968	-0.560237	6.074151	126	176.016	-4.838661	0.337021	6.325665
63	-3.458	4.649870	-0.280995	6.074151	127	178.008	-4.848820	0.168612	6.324039

These coordinates are with respect to the elliptical cone's local coordinate system. There are 128 points in total[2]. **Note**: The data points with $|\phi| > 143.95^o$ are a mathematical continuation.

[2] Data stored in XYZ format in file: "*shield_upper_edge_I_II_xyz.dat*"