APPENDIX N

GLARE AND LIGHT SPILLAGE ANALYSIS

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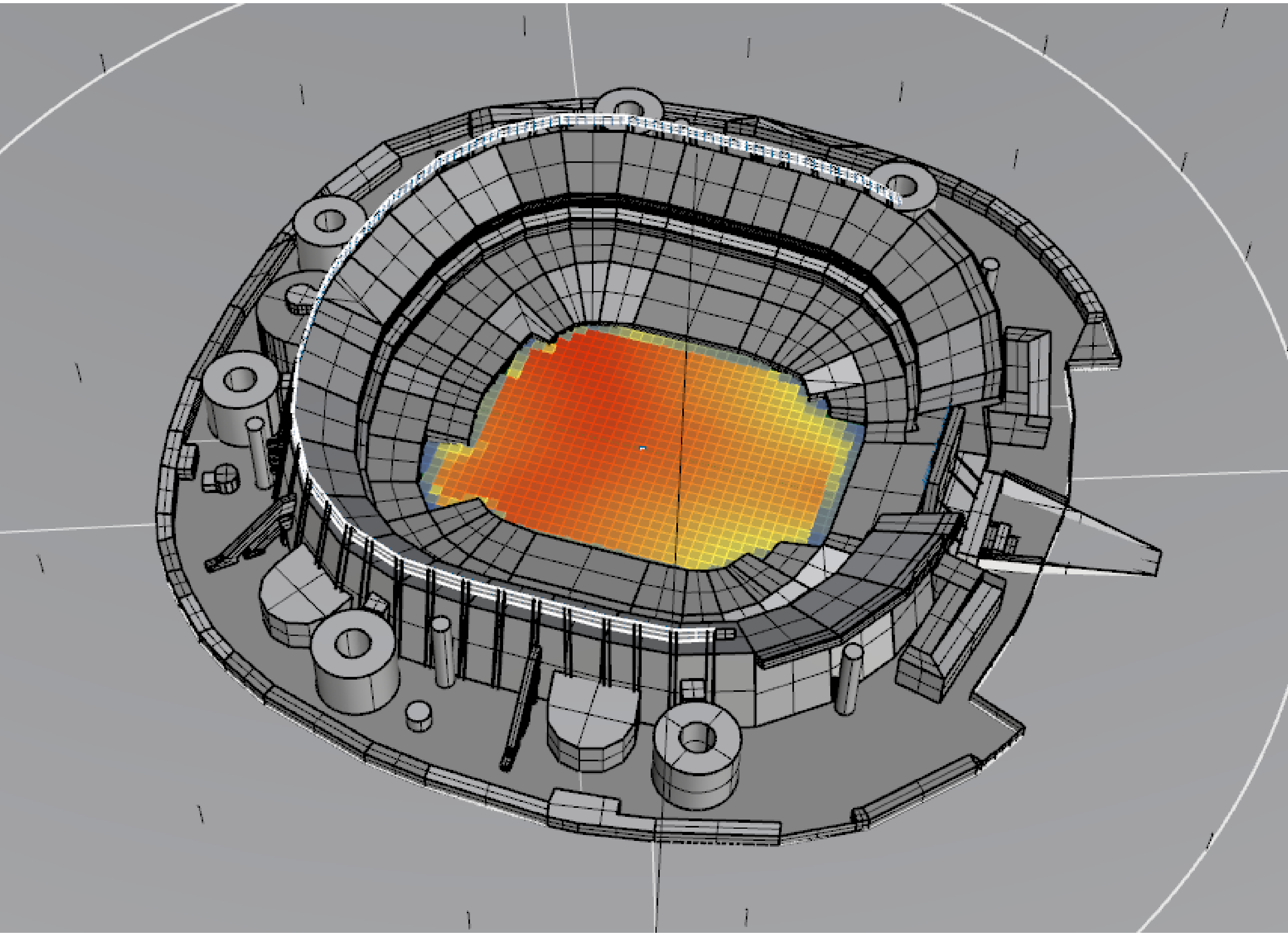

STADIUM RECONSTRUCTION
Glare and Light Spillage Analysis

July 20, 2015

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Executive Summary

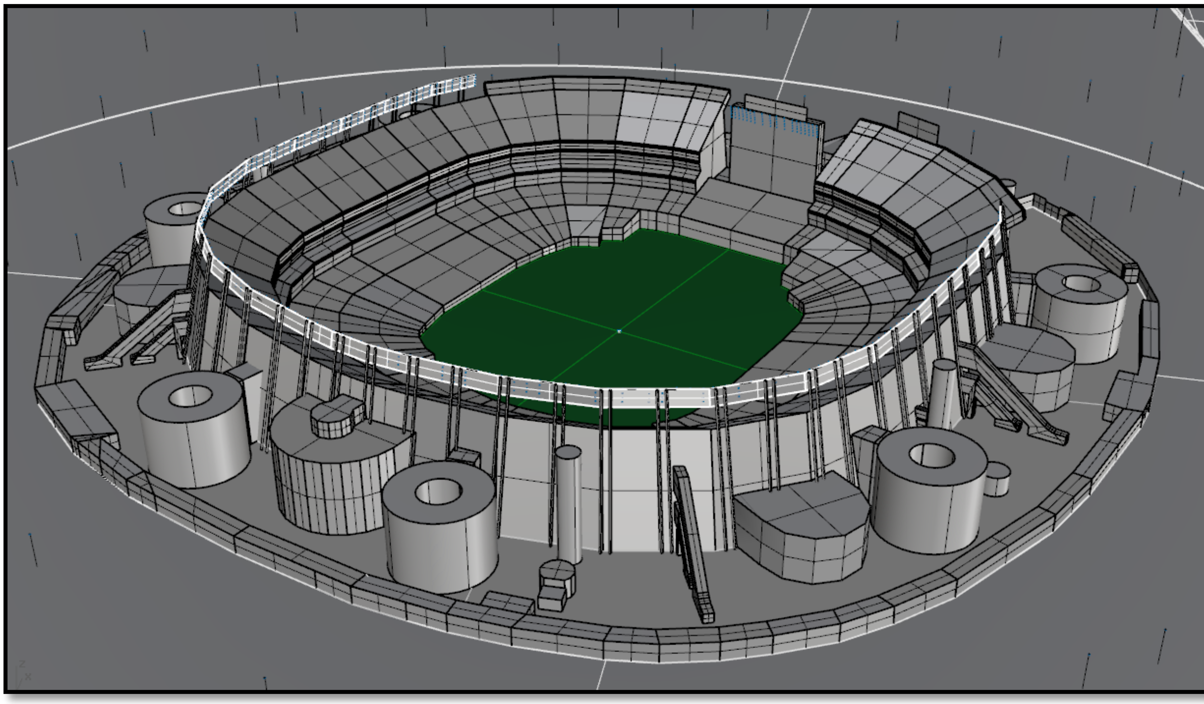

Fig 1. Stadium Simulation Model

A glare analysis simulation was conducted for Qualcomm Stadium and the new stadium using Rhinoceros v5 and Diva for Rhino v3 to assess the potential for glare from several identified key observation points. Rhinoceros allows conducting this type of analysis for either a specific moment in time or for a whole year. The simulation was conducted for an hour (11 pm to 12 midnight) in the night with clear sky conditions which are considered to be worst case conditions for glare perception. Three scenarios were developed in the simulation. Firstly the Qualcomm Stadium as existing, secondly the stadium moved to the new location, and lastly the new stadium (addition of partial roof) in the new location.

The results and therefore conclusions drawn in the report are based on the assumptions detailed. The following is a summary of the key results from the simulation:

- The probability of glare from flood lights is very low at all key observation points for all the three cases modeled.
- Comparatively between the three cases the scenario with partial roof (new stadium) has the minimum glare probability which performs better than the Qualcomm Stadium.
- The analysis of Qualcomm Stadium lighting shows no significant light spillage of the interior floodlighting onto the parking lot.

- Parking lot analysis shows certain region where illuminance levels are low. It is recommended that any new lighting improvement be tailored to location and need of parking lot and the stadium's back of the house areas.

The height of the new stadium is expected to be between 120 feet (height of existing stadium) to 250 feet (expected height of the floodlight tower). Higher location and grouping of floodlights can lead to lower illuminance levels on the field and more light pollution. The results from an illuminance simulation validates this and shows that in order to achieve the desired average of foot-candles (240fc) from six tower floodlights 250 feet high 1,284 floodlight fixtures would be required, which can lead to increase in electricity consumption and a higher glare probability and light spillage compared to a low height peripheral arrangement, which requires 1,150 fixtures. The daylight glare potential (dgp) from the closest key observation point is 0.1 which is significantly higher than 0.0098 and closer to 0.3, the perceptible glare threshold.

A detailed discussion of the results is provided in the results section of the report. The following are recommendations for stadium floodlighting good practices:

- Professionally recommended lighting levels should be determined for each activity areas to prevent over-lighting and reduce electricity consumption.
- Floodlights should be aimed out of the line of sight of the players to prevent any glare.
- The location, height, cutoff and angle should be correctly focused on the pitch and should be appropriately determined so that it doesn't trespass into neighboring areas giving rise to objections from the local community.
- The beam spread of each floodlight should be selected to put the maximum amount of light on the field without producing a hot spot on the pitch.
- A good floodlight design should provide uniform lighting levels over the entire area of the pitch and reduce the shadow effect caused by the players to an absolute minimum. This could be achieved by ensuring the appropriate positioning, height, focus and angle of the lights.
- The modern stadium lighting should be attuned to the latest television broadcasting requirements. High-definition, 3D and 4K TV broadcasting requires significantly higher illuminance levels on the pitch. It is recommended that a sports lighting specialist be involved in the lighting design process which is attuned to such advanced broadcasting technologies.
- Shielded fixtures with efficient light bulbs should be used in the parking lot to prevent any glare and light spillage beyond the property line. Shielded fixtures also help in preventing light pollution of the dark sky.
- The floodlighting and exterior parking lot lighting design should allow also for varying intensities of light and control, to suit the requirements of a particular event or purpose. Appropriate lighting control design could facilitate a flexible and coherent lighting strategy and also rationalize energy usage and therefore cut energy costs.

Introduction

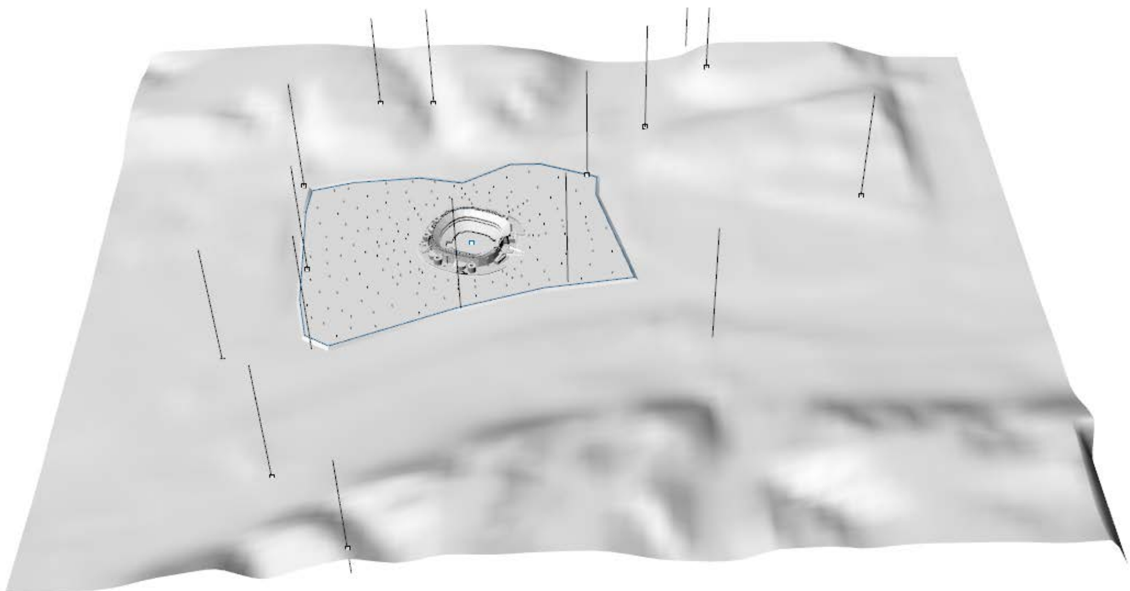

Fig 2. Site Simulation Model

This report discusses the results of glare analysis from stadium flood lighting at several identified key observation points around the stadium. The simulation also analyses the change in glare probability from moving the stadium from its current location towards northeast and adding a roof. This report also analyses the light spillage around the stadium from interior flood lighting to outside for all the three cases. The analysis is conducted from twelve (12) identified key observation points around the stadium (Fig 2).

Analysis Methodology

The analysis is conducted in DIVA v3 and Rhinoceros v5 (Rhino) modeling software. The existing stadium is modeled in Rhino and used as a baseline case for glare and light spillage.

The height of the new reconstructed stadium is expected to between 120 feet (height of existing stadium) to 250 feet (expected height of the floodlight tower). Higher location and grouping of floodlights can lead to lower illuminance levels on the field and more light pollution. The results from an illuminance simulation (Fig 3) validates this and shows that in order to achieve the desired average of foot-candles (240fc) from six tower floodlights 250 feet high, 1,284 floodlight fixtures would be required, which can lead to increase in electricity consumption and a higher glare probability and light spillage compared to a low height peripheral arrangement (Fig 4), which requires 1,150 fixtures. The daylight glare potential (dgp) from the closest key observation point is 0.1, which is significantly higher than 0.0098 and closer to 0.3, the perceptible glare threshold.

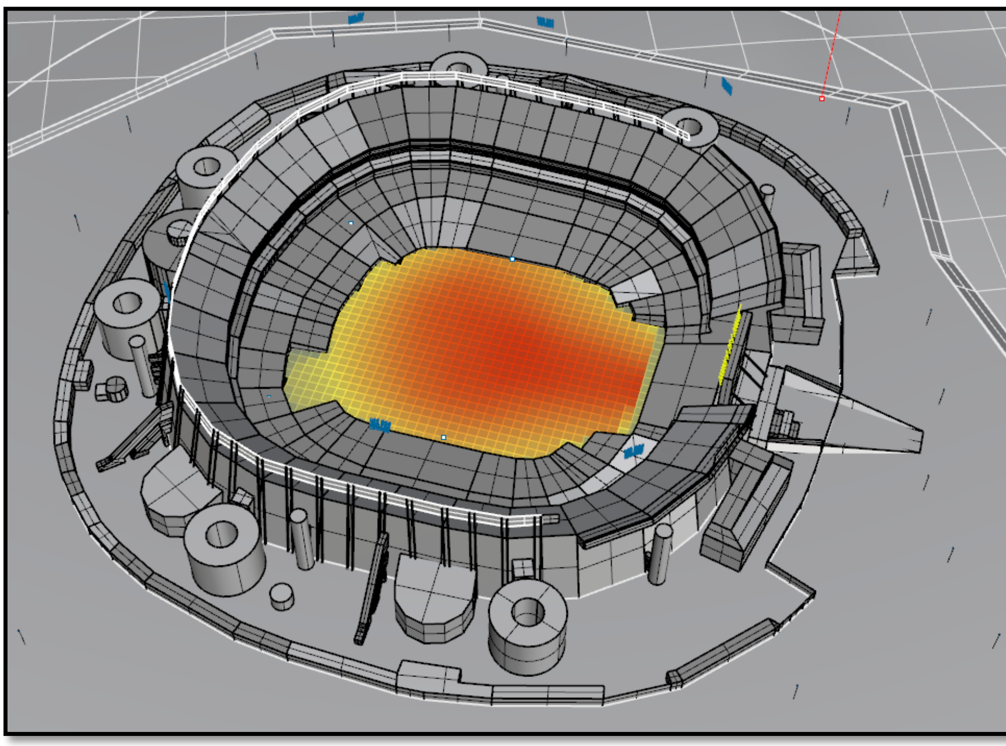

Fig 3. Illuminance Levels in the New Stadium with Six Tower Flood Lights.

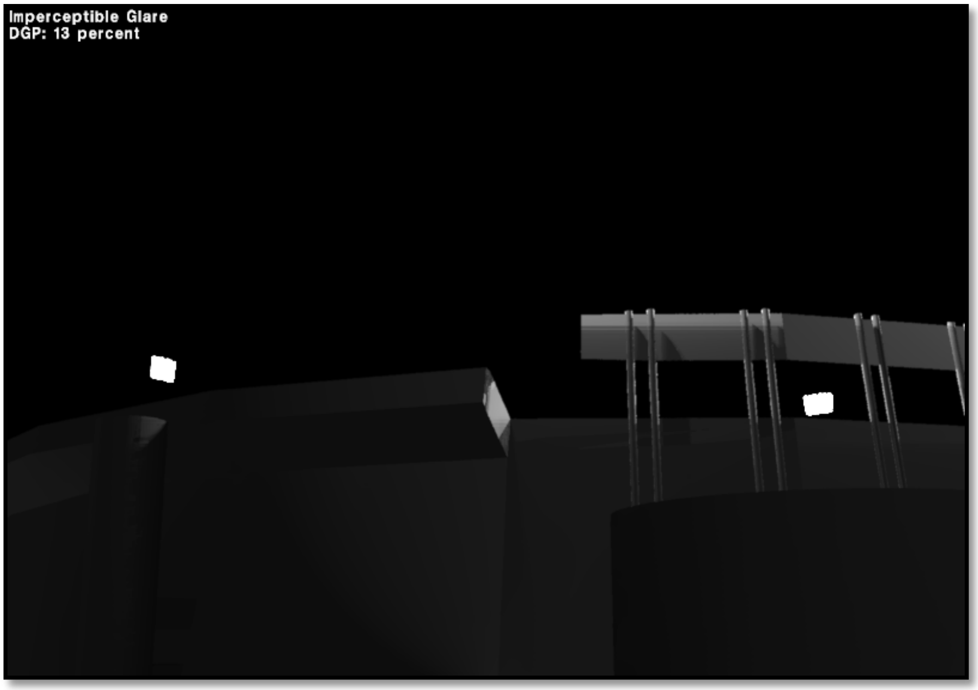

Fig 4. Daylight Glare Potential from KOP3.

With the prevalence of high definition sports broadcasting a more distributed lighting at lower height in the field is recommended. Thus, in order to best represent the proposed stadium, existing stadium geometry is used with similar light distribution. The following map shows the location of the new reconstructed stadium used in the simulation (Fig 5).

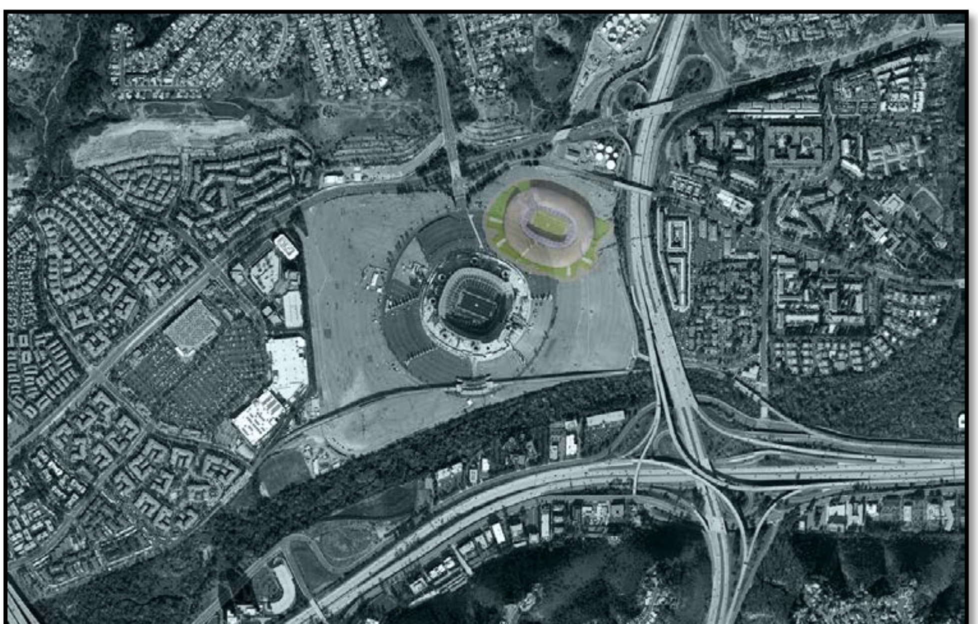

Fig 5. Location of New Stadium

In the third scenario, an approximate roofing structure is added on the new stadium structure (Fig 6).

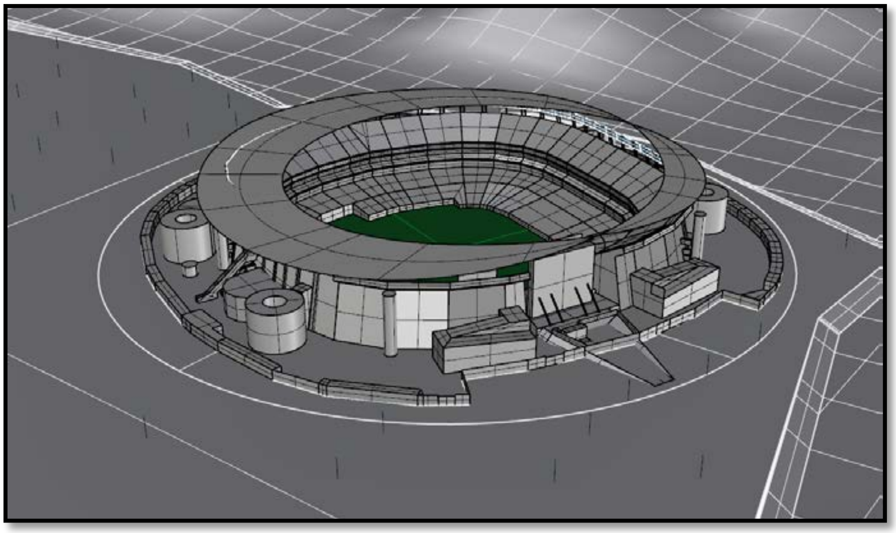

Fig 6. New Stadium with Roof

Visual discomfort from glare is calculated by DIVA using the daylight glare probability (dgp) metric. The number of floodlight fixtures is determined by the recommended average foot-candles (fc) levels achieved inside by them (240 fc). The fixtures are aligned along the periphery and directed downwards towards the pitch. More information about the fixtures used in the photometric analysis is provided in the simulation assumptions section. The following image (Fig 7) shows the lighting distribution with the selected fixtures.

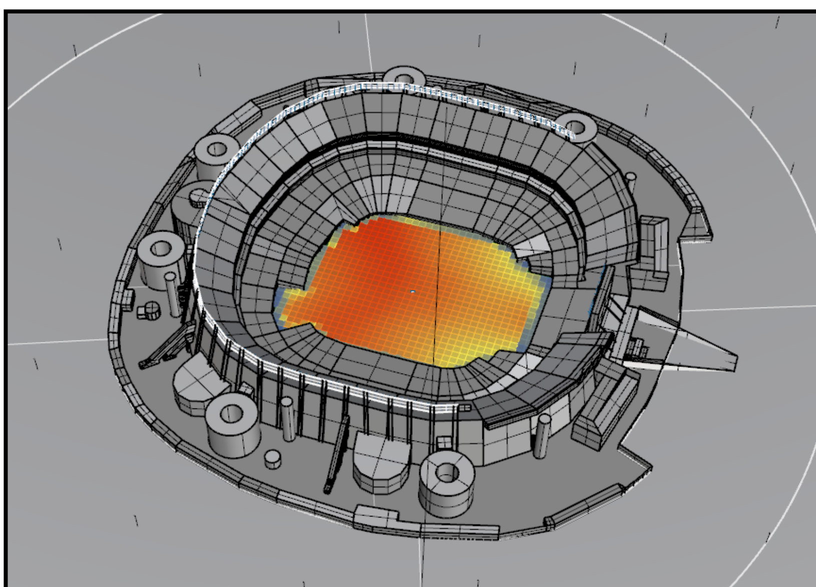

Fig 7. Illuminance Levels Inside Qualcomm Stadium.

36fc *240fc* *322fc*

Analysis Metric

In a dgp metric, glare sources are detected by contrast ratios. The glare visualization marks the areas with high contrast ratio (potential for causing glare) in the scene by different colors. Using a point-in-time glare simulation in DIVA, the visual comfort of a person under the simulated conditions at the camera viewpoint is simulated. The Daylight Glare Probability (DGP) metric is used in the comfort evaluation which considers the overall brightness of the view, position of 'glare' sources, and visual contrast. The simulation uses *evalglare v1.0*[1] to calculate Daylight Glare Probability (DGP) from a luminance image based on total vertical eye illuminance and contrast[2].

The dgp scale identifies three thresholds as such:

imperceptible/barely perceptible 0.3 < perceptible < 0.45 intolerable

The simple linear formula is $DGP(s) = 6.22 \cdot 10^{-5} \cdot Ev + 0.184$, where Ev is the vertical eye illuminance[3]. A glare analysis is conducted from the selected key observation points for all the three scenarios.

Key Observation Points

The simulations are run from the selected 12 key observation points (KOPs). In all the three cases, KOPs point towards the stadium pitch and are located at appropriate altitude with respect to the topography. The following plan shows the marked location of the KOPs numbered from 1 through 12 (Fig 8).

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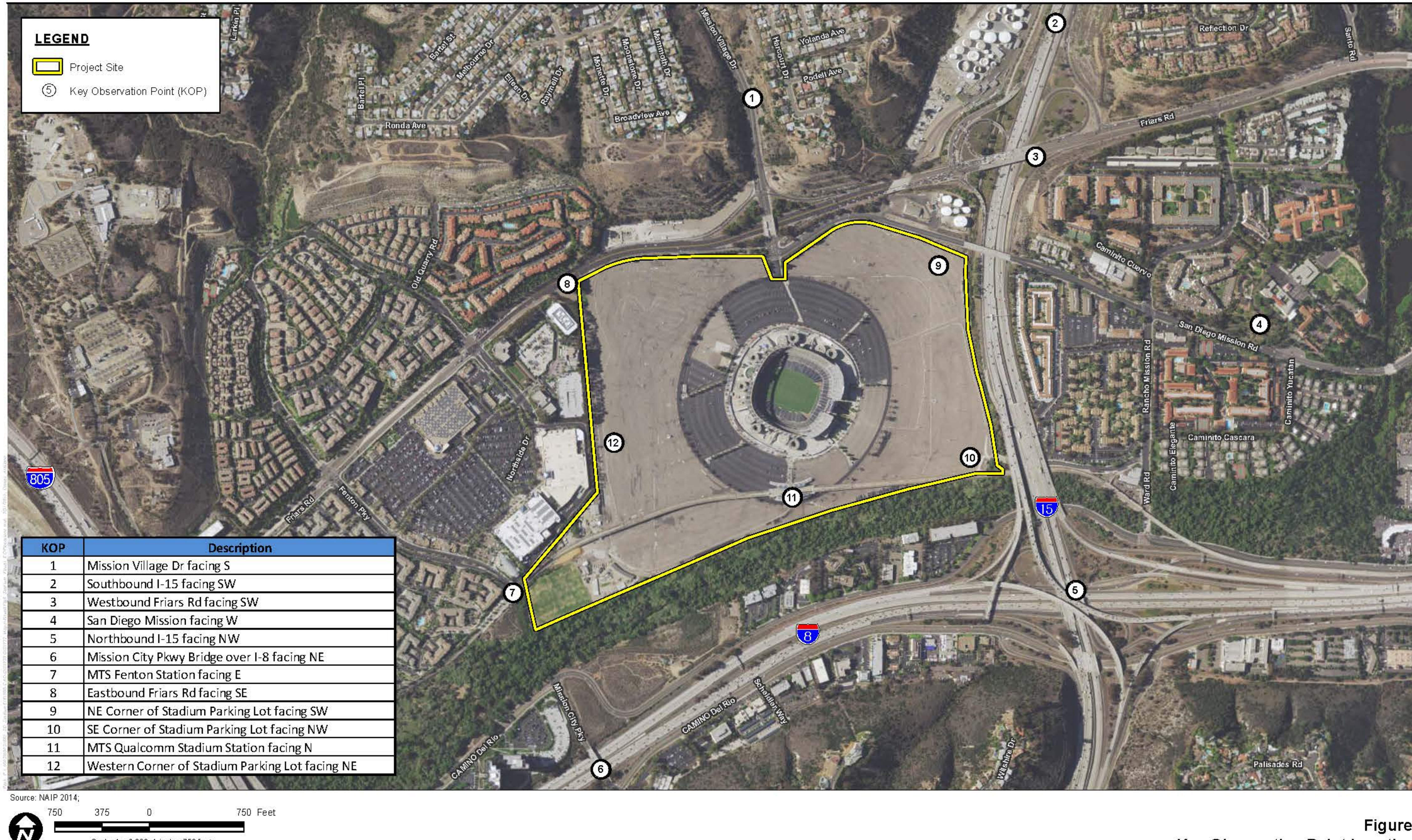
[1] *http://www.ise.fraunhofer.de/acl_users/credentials_cookie_auth/require_login?came_from=http%3A//www.ise.fraunhofer.de/en/admin-folder/archiv/ applied-optics-and-functional-surfaces/lighting-technology/lighting-simulations/radiance/radiance*

[2] *http://diva4rhino.com/user-guide/simulation-types/point-in-time-glare*

[3] *Wienold J, Christoffersen J. Evaluation methods and development of a new glare prediction model for daylight environments with the use of CCD cameras. Energy Build 2006;38:743–57.*



KOP	Description
1	Mission Village Dr facing S
2	Southbound I-15 facing SW
3	Westbound Friars Rd facing SW
4	San Diego Mission facing W
5	Northbound I-15 facing NW
6	Mission City Pkwy Bridge over I-8 facing NE
7	MTS Fenton Station facing E
8	Eastbound Friars Rd facing SE
9	NE Corner of Stadium Parking Lot facing SW
10	SE Corner of Stadium Parking Lot facing NW
11	MTS Qualcomm Stadium Station facing N
12	Western Corner of Stadium Parking Lot facing NE

Figure 8
Key Observation Point Locations

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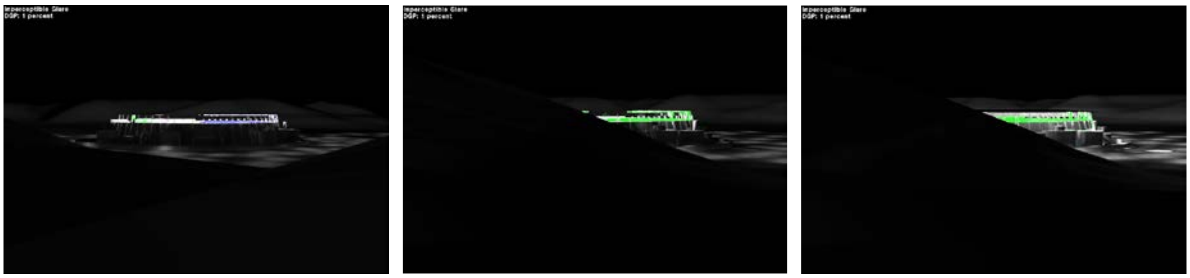
Analysis Results

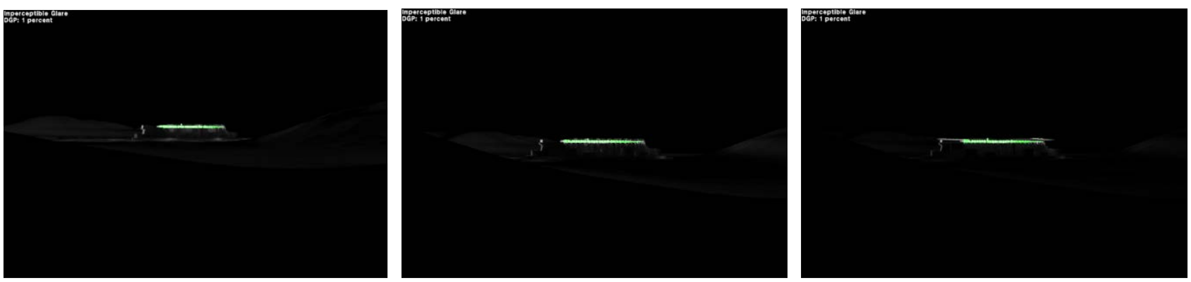
Glare Analysis

The following images show the summary of the glare analysis results for all identified key observation points. Please refer to appendix for detailed information on each view.

Qualcomm Stadium | Reconstructed Stadium | Reconstructed Stadium with Roof

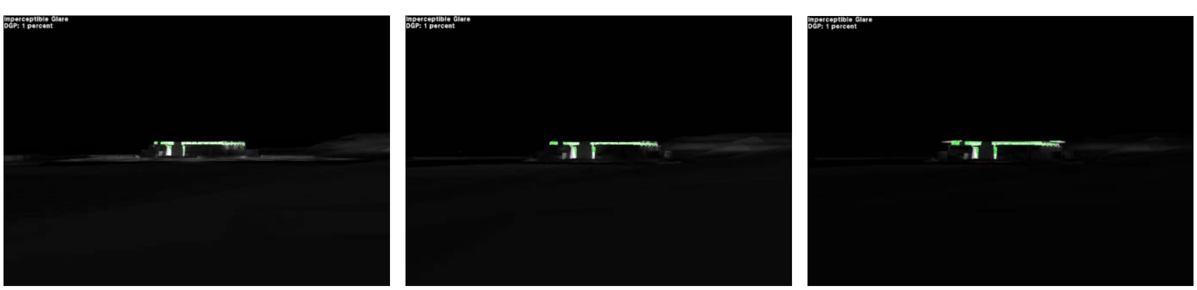


KOP1 Reconstructed stadium with room has significantly lower glare probability.



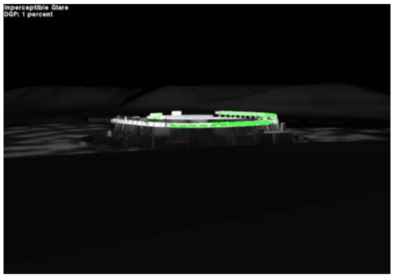
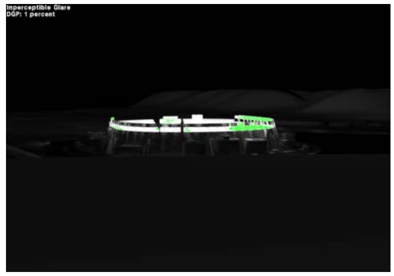
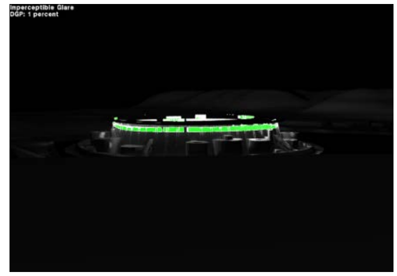
KOP2 All the cases have similar glare potential (0.0094-0.0095).

KOP3 Reconstructed Stadium has higher DGP (0.0093) as it is close to observation point.



KOP4 Qualcomm Stadium has higher glare probability.

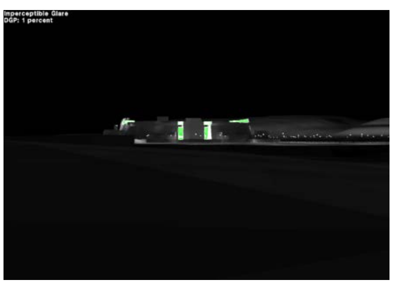
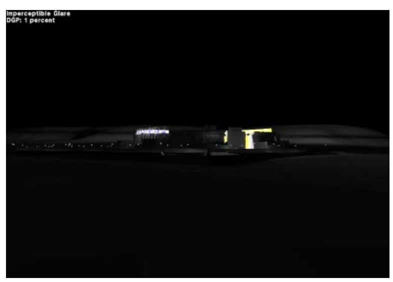
Qualcomm Stadium | Reconstructed Stadium | Reconstructed Stadium with Roof

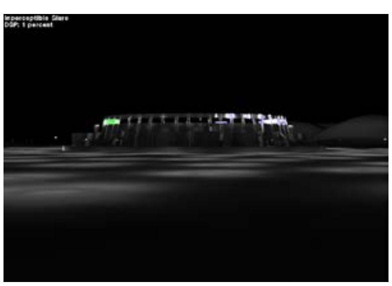
KOP5 Qualcomm Stadium has higher glare (0.01) probability.

KOP6 All the cases have similar glare potential (0.0093-0.0092).

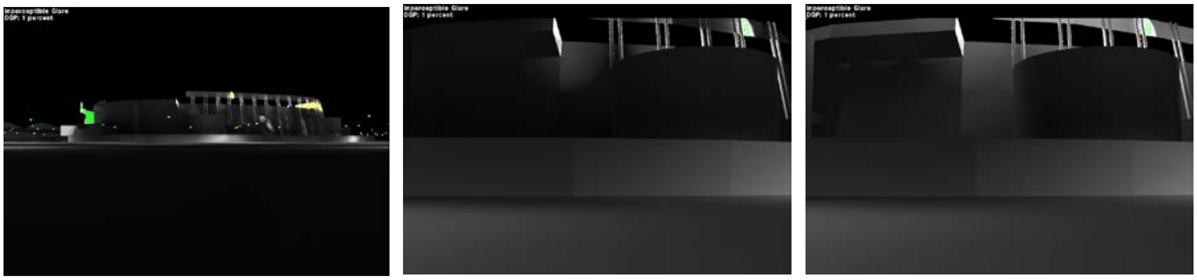
  

KOP7 Qualcomm Stadium has higher glare probability than both other cases.

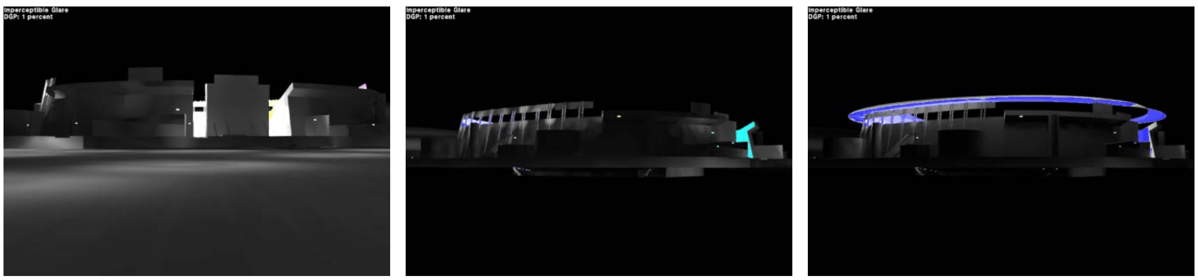
  

KOP8 Reconstructed stadium has slightly higher glare probability (DGP 0.0078).

Qualcomm Stadium | Reconstructed Stadium | Reconstructed Stadium with Roof

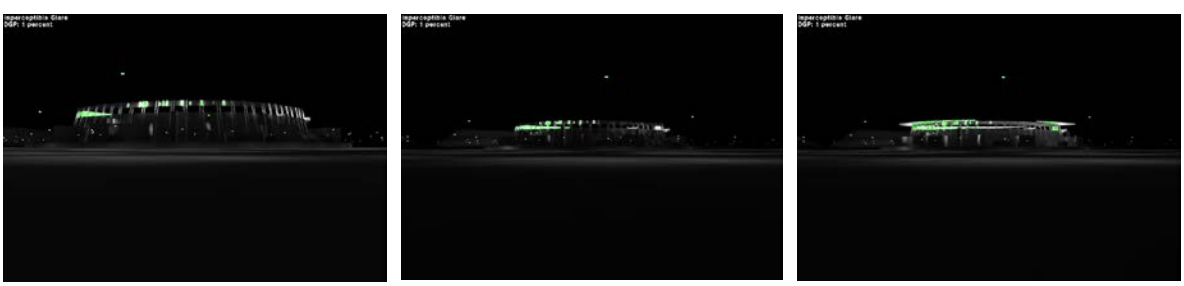


KOP9 The reconstructed stadium scenarios have higher glare probability (DGP 0.0098)



KOP10 Qualcomm Stadium has higher glare probability than both other cases.

KOP11 Qualcomm Stadium has higher glare probability than both other cases.



KOP12 Qualcomm Stadium has higher glare probability than both other cases.

Light Spillage Analysis

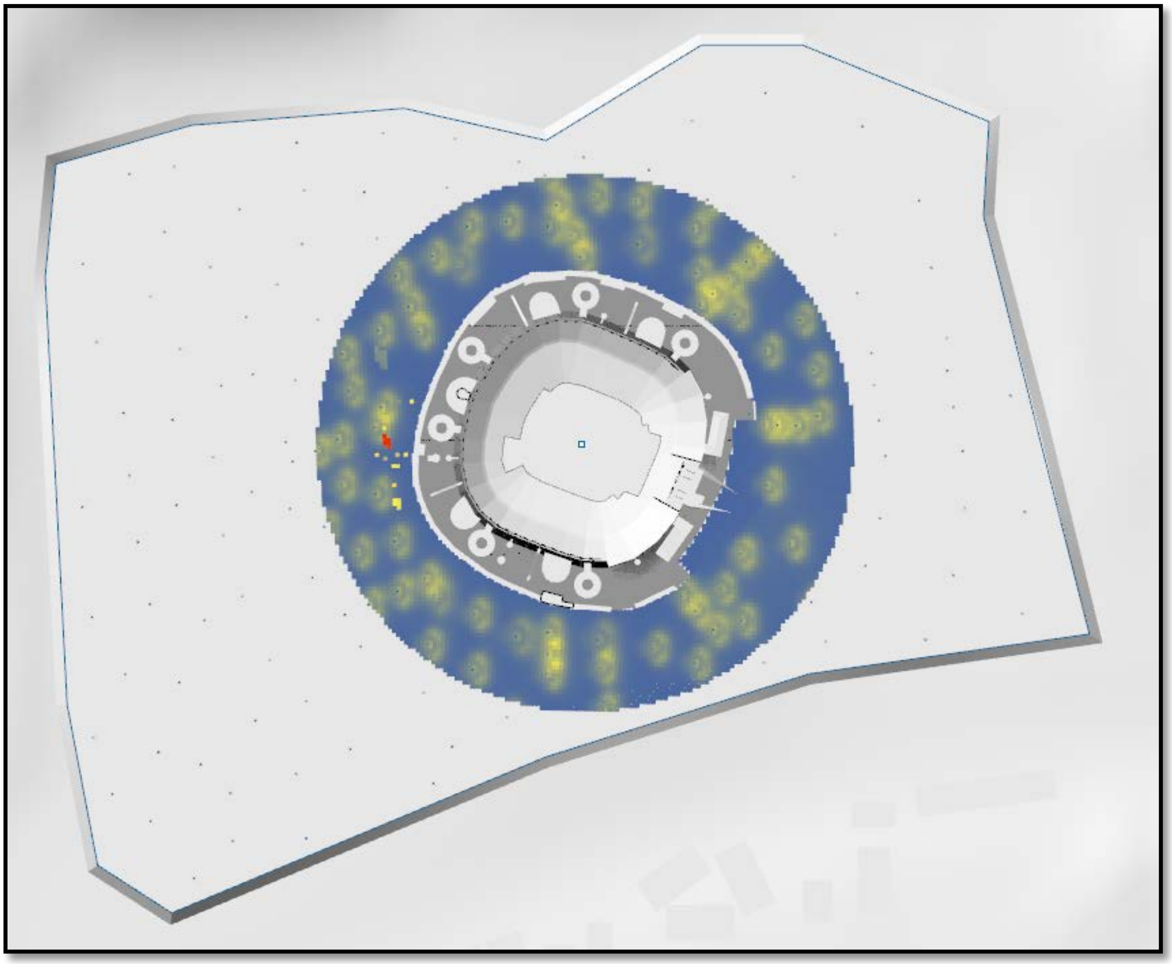


Fig 9. Stadium Light Spill Simulation Model

In the simulation of parking lot lighting, a mean illuminance level of 0.9 is achieved. This is attributed to large open parking space without lamp posts. The lighting levels under the lamp posts are around 2-5 fc. The simulation indicates that there is no significant light spillage from the interior flood lighting into the surrounding parking lot. The lighting on the parking lot is affected by lamp posts and no the stadium floodlighting (Fig 9).

Results and Discussion

The following table shows the comparative dgp values for all three cases from the 12 KOPs. In both scenarios, there is a slight reduction in dgp compared to the baseline case (Qualcomm Stadium). In case 3 (new stadium with partial roof in new location), as expected, the results are better because of the roof, which cuts off the light spillage from floodlights.

KOP	Qualcomm Stadium (dgp)	New Stadium (dgp)	New Stadium with Partial Roof (dgp)
1	**0.0081**	0.0075	0.0070
2	0.0094	**0.0095**	**0.0095**
3	0.0092	**0.0093**	0.0086
4	**0.0095**	0.0086	0.0085
5	**0.0100**	0.0080	0.0070
6	**0.0093**	0.0092	0.0092
7	**0.0097**	0.0088	0.0088
8	0.0070	**0.0078**	0.0077
9	0.0096	**0.0098**	**0.0098**
10	**0.0110**	0.0081	0.0060
11	**0.0096**	0.0078	0.0067
12	**0.0086**	0.0082	0.0079

Table1. DGP Values in Three Scenarios at KOPs

Following are the key deductions from the glare analysis results:

- In all the cases the dgp is below the perceptible glare level of 0.3 and there is very slight probability of imperceptible glare from floodlighting at the KOPs (owing to simulation assumptions).
- In comparison between three cases, the scenario with partial roofing performs the best with minimum glare probability. This can be attributed to the roofing structure which cuts off any direct glare from floodlighting.

Following are the key deductions from the light spillage analysis results:

- The lighting around the stadium is affected by lamp posts in the parking lot. The stadium lighting does not have any significant effect on the illuminance levels in the parking lot.
- This would hold true for the new stadium and new stadium with roof as well, where there is no change in the stadium floodlighting quantity and quality.

Simulation Assumptions

The simulation uses three stadium models which differ in location and roofing as follows:
Case 1: Qualcomm Stadium
Based on existing stadium geometry at existing site.
Case 2: Qualcomm Stadium moved to new location
Based on current stadium geometry moved to new proposed location.
Case 3: New Stadium
Based on Qualcomm Stadium geometry with the addition of a partial roof and new proposed location.

Surface reflectances (percentages) used in simulation model:
Ground surfaces- 20%
Proposed roof- 70%
Interior floors- 20%, 35%
Stadium walls- 30%
Stadium ancillary surfaces- 30%
Surrounding buildings and site topography- 10%

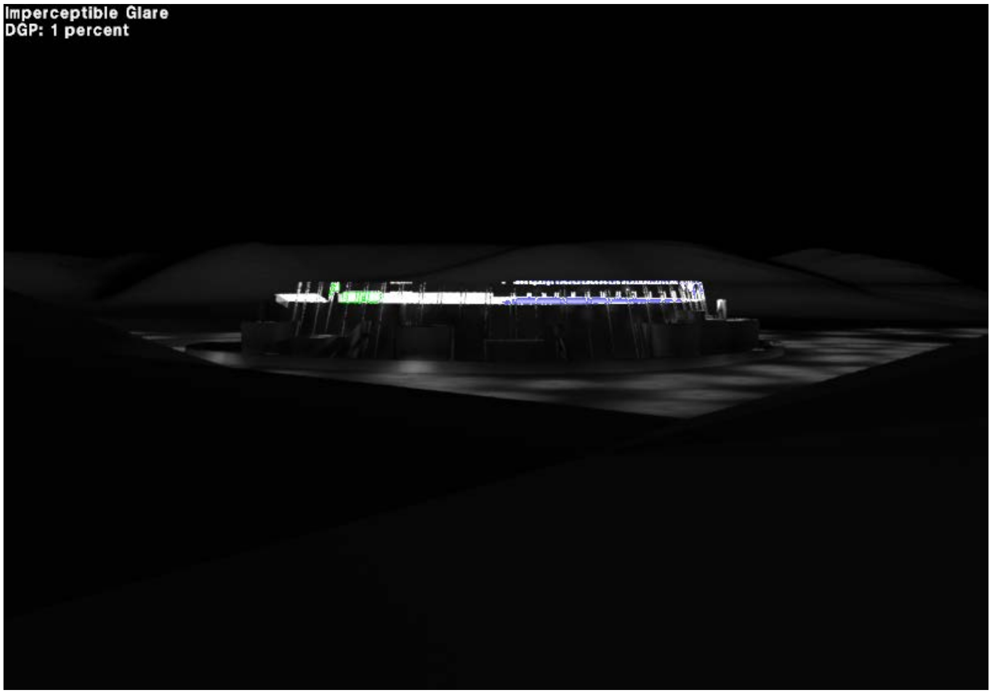
Conducted at 2300hrs on September 10 under clear sky parameter. The analysis grid is at 100mm height 4x4m wide.

Fixtures in stadium modeled:
Daybright FL-41070, 1,500 watt luminaire, 1150 fixtures
http://www.daybritelighting.com/nitebrites/NiteBritesfixture.cfm?ID=2048

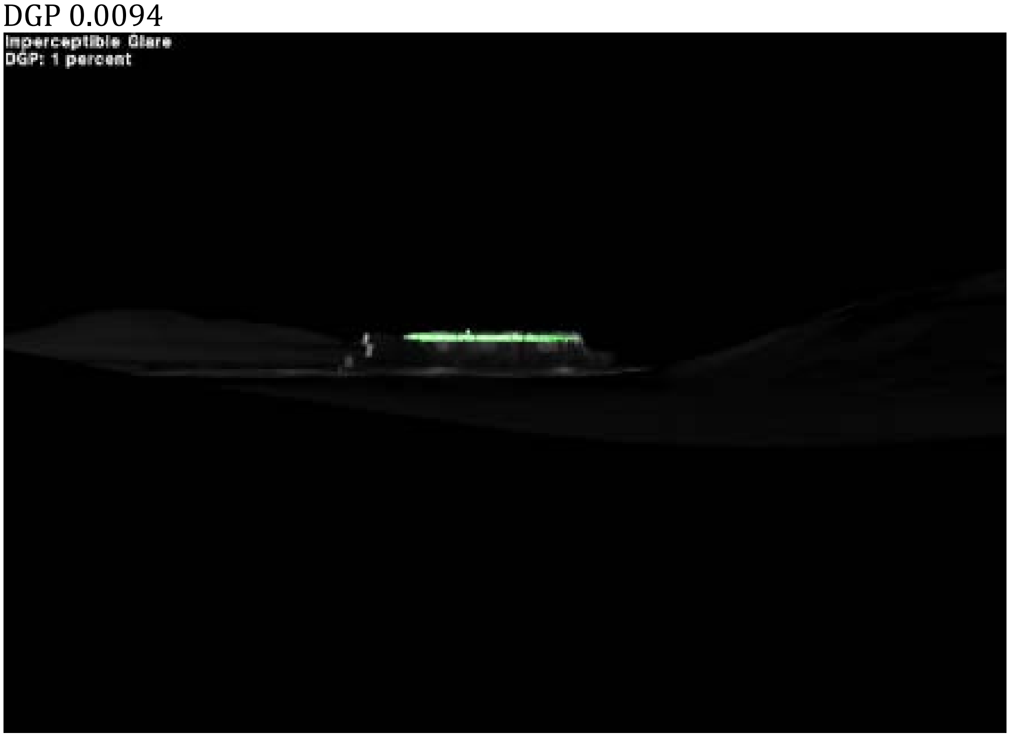
Outdoor parking fixtures modeled:
Daybright AS-42014, 95.1 watt luminaire, 4312 lumens, 348 fixtures (proposed) 612 fixtures (baseline). This is due to different parking lot pole layout in the new Stadium site.http://www.lightingproducts.philips.com/Documents/webdb2/DAYBRITE/PDF_Archived/AS-42014.pdf

Appendix

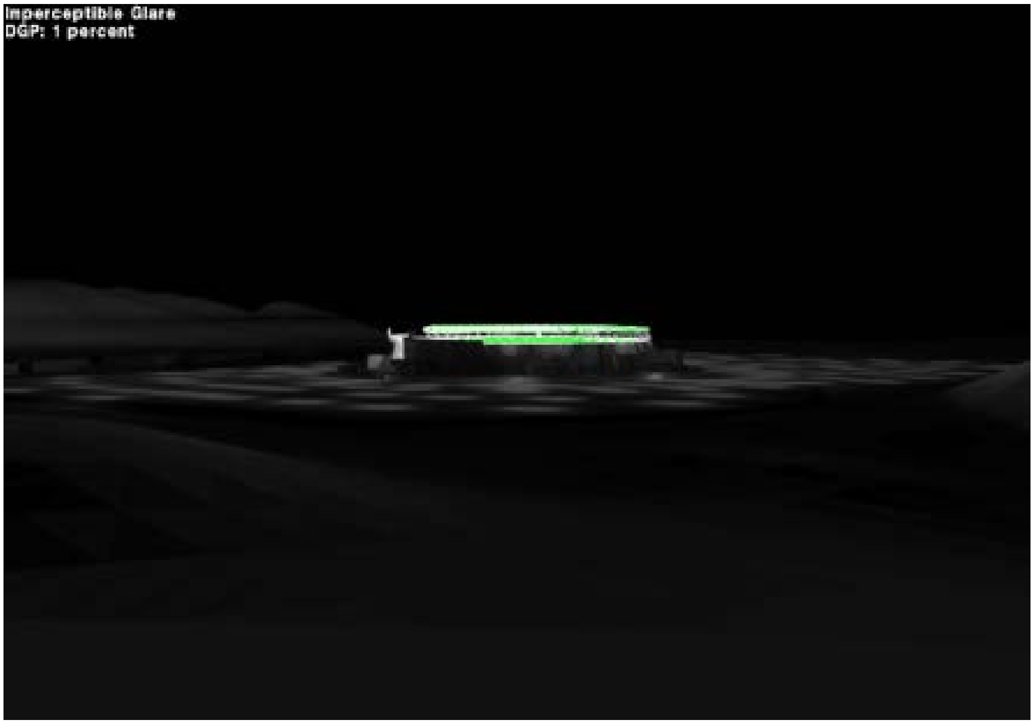
Qualcomm Stadium - KOP 1 - DGP 0.0081



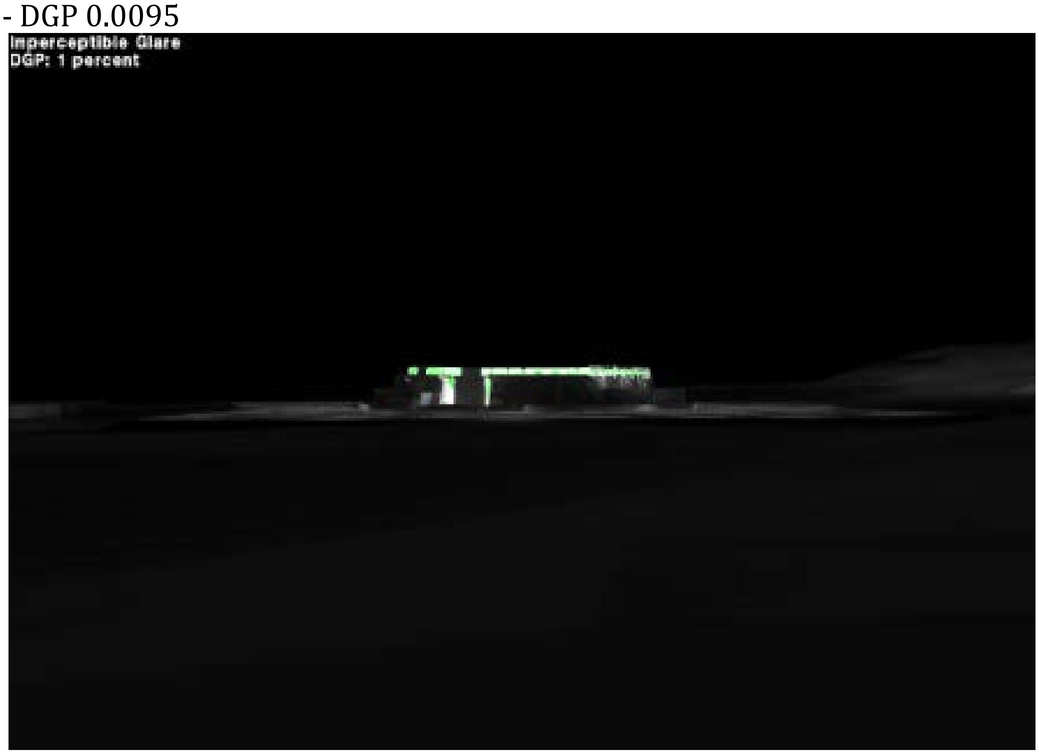
KOP 2 - DGP 0.0094



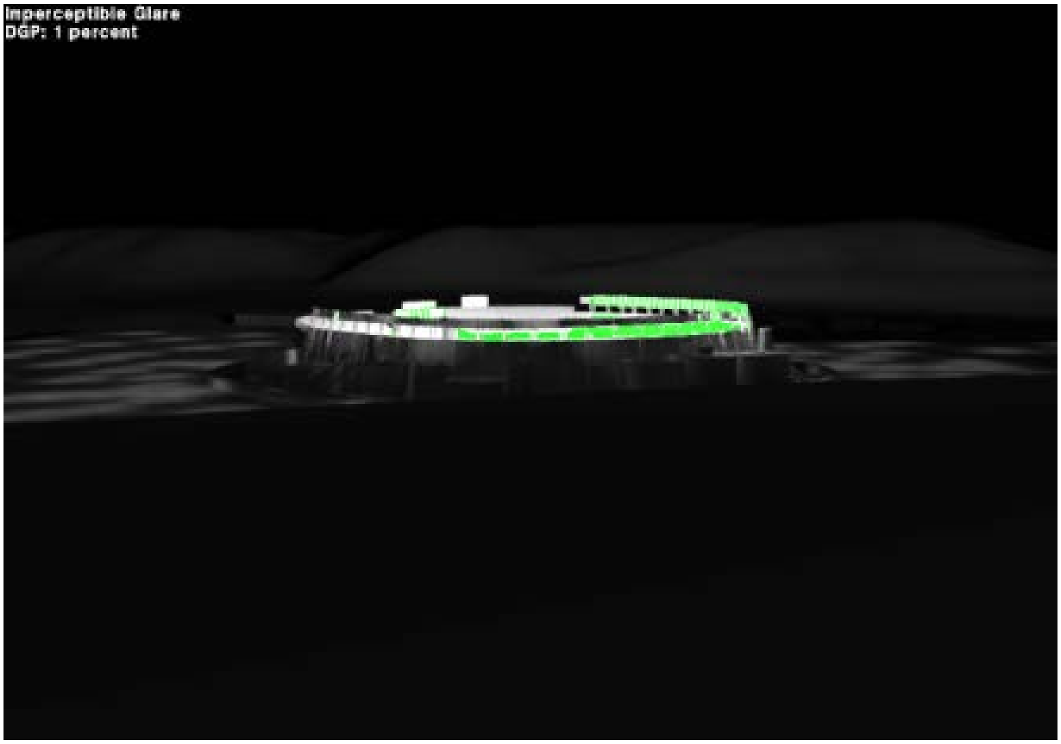
KOP 3 - DGP 0.0092



KOP 4 - DGP 0.0095

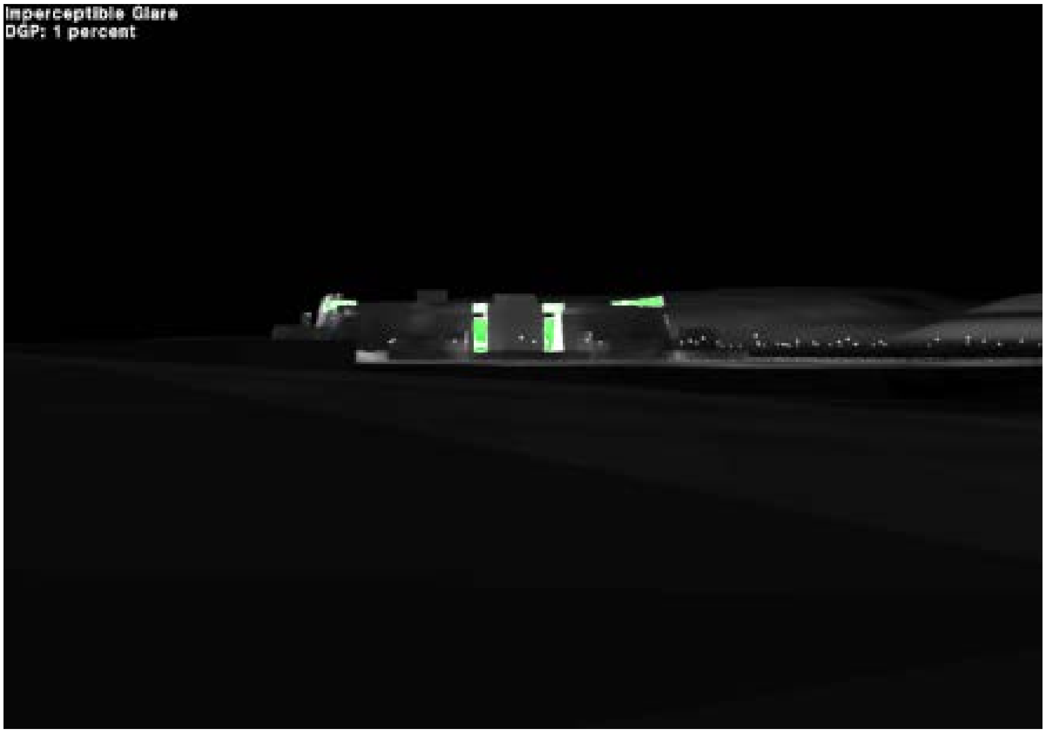


KOP 5 - DGP 0.0100



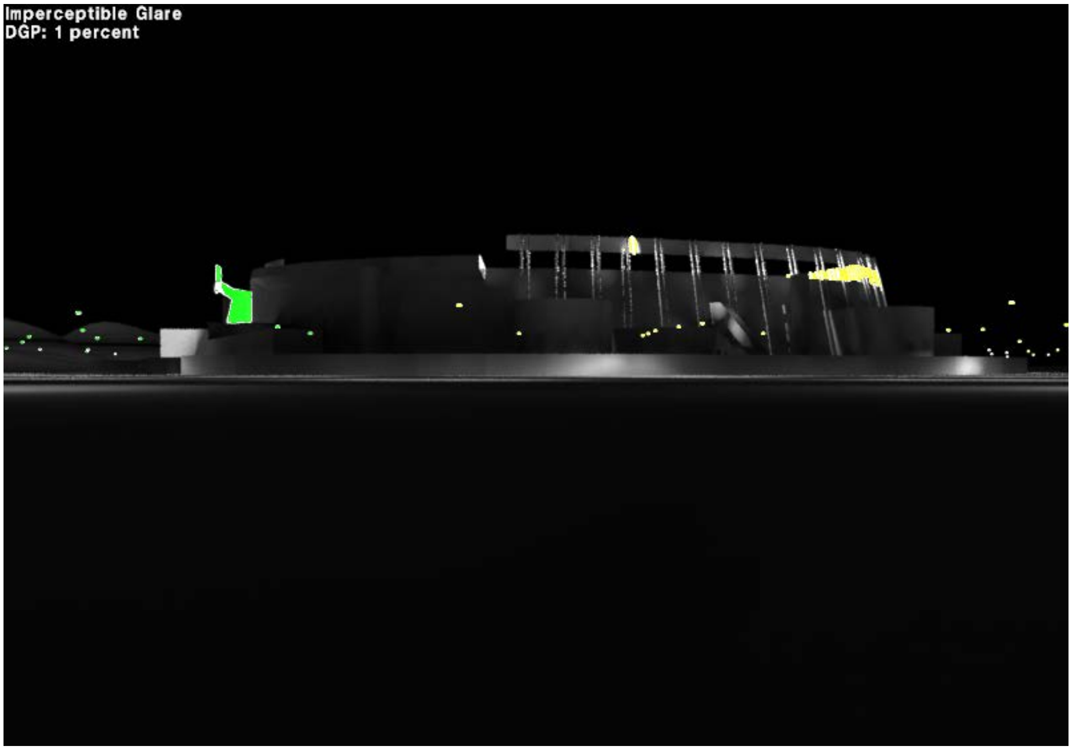
KOP 6 - DGP 0.0093

KOP 7 - DGP 0.0097

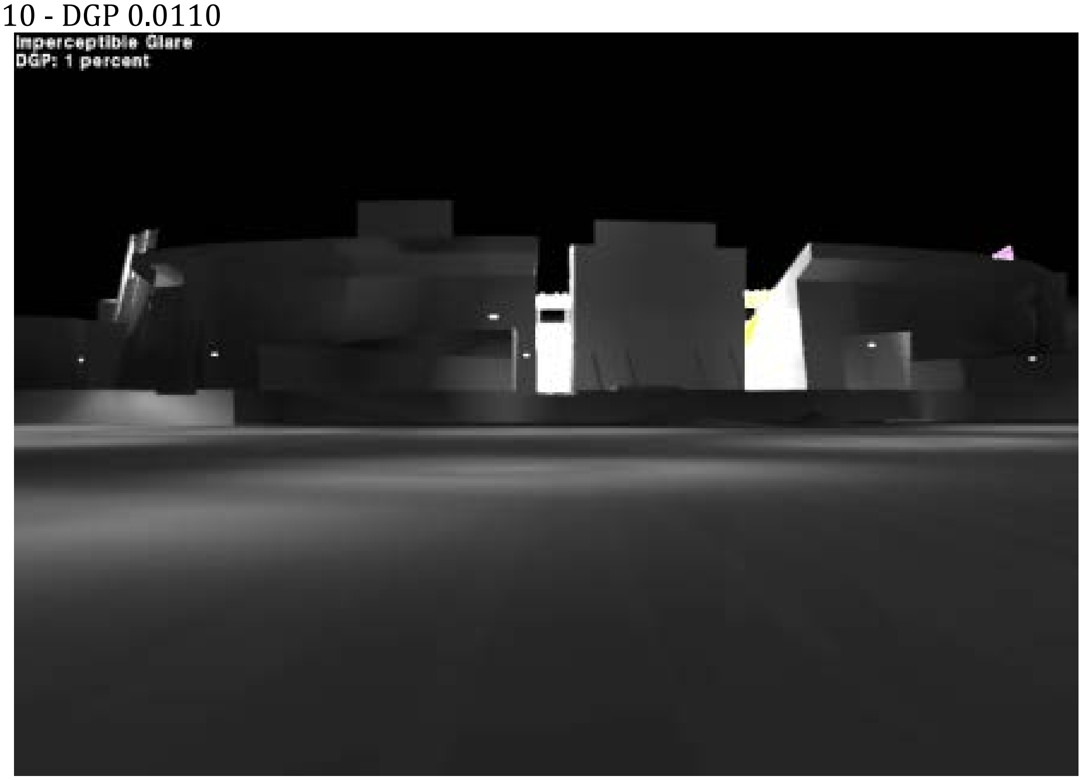


KOP 8 - DGP 0.0070

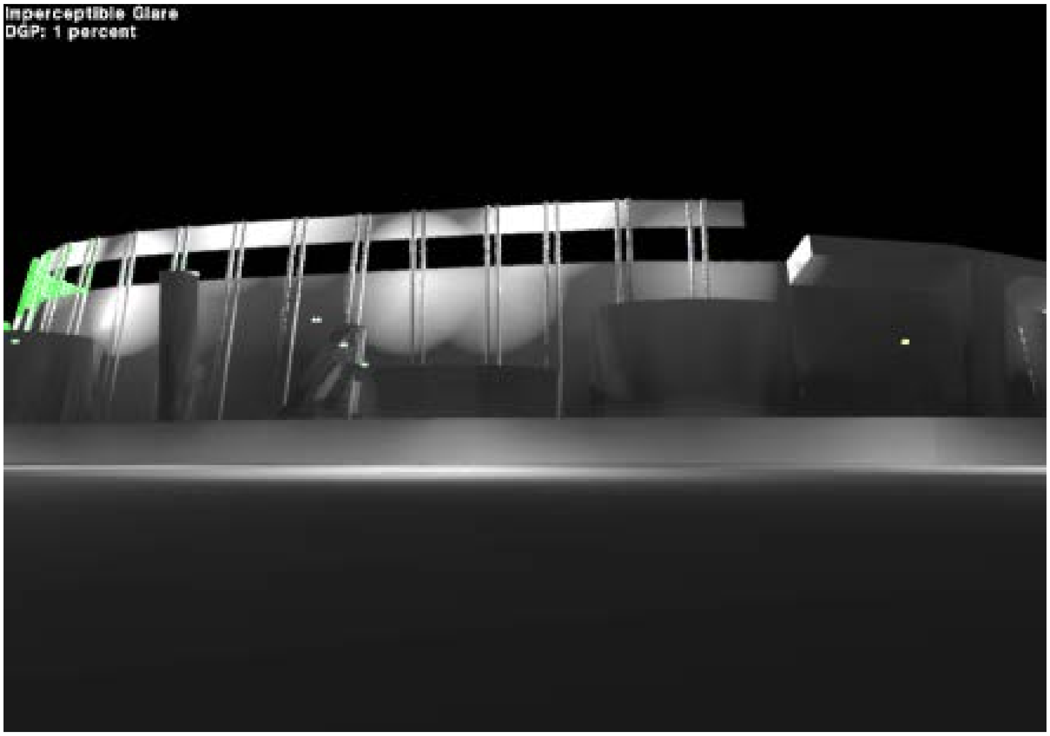
KOP 9 - DGP 0.0110



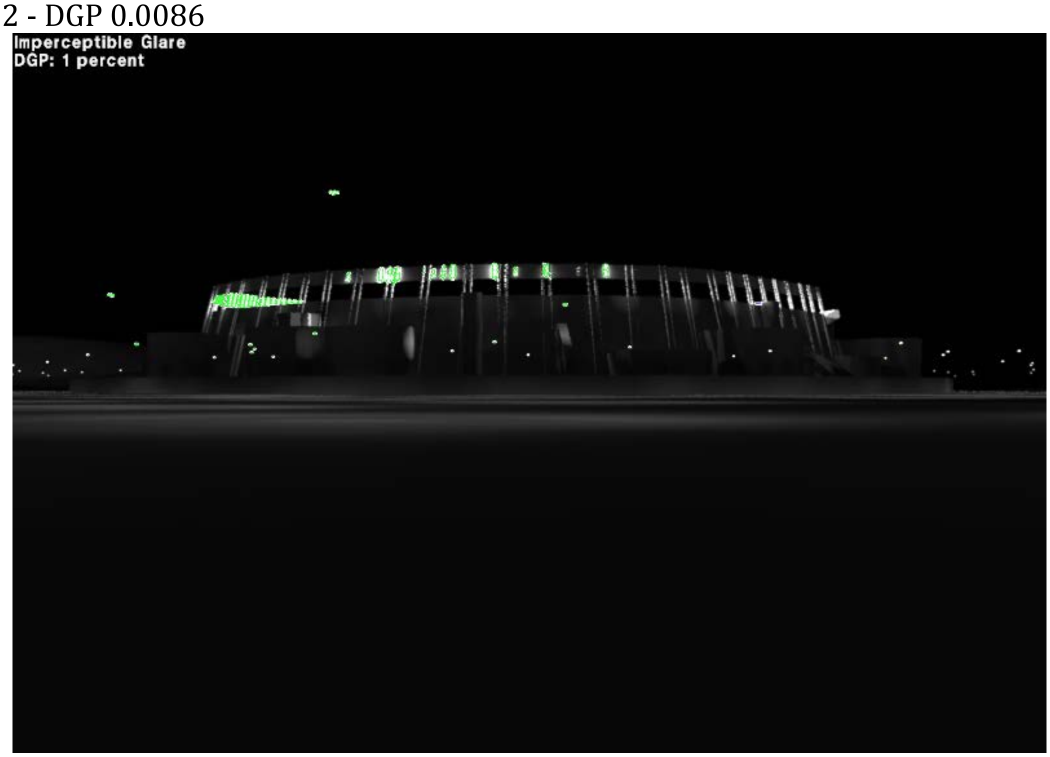
KOP 10 - DGP 0.0110



KOP 11 - DGP 0.0096

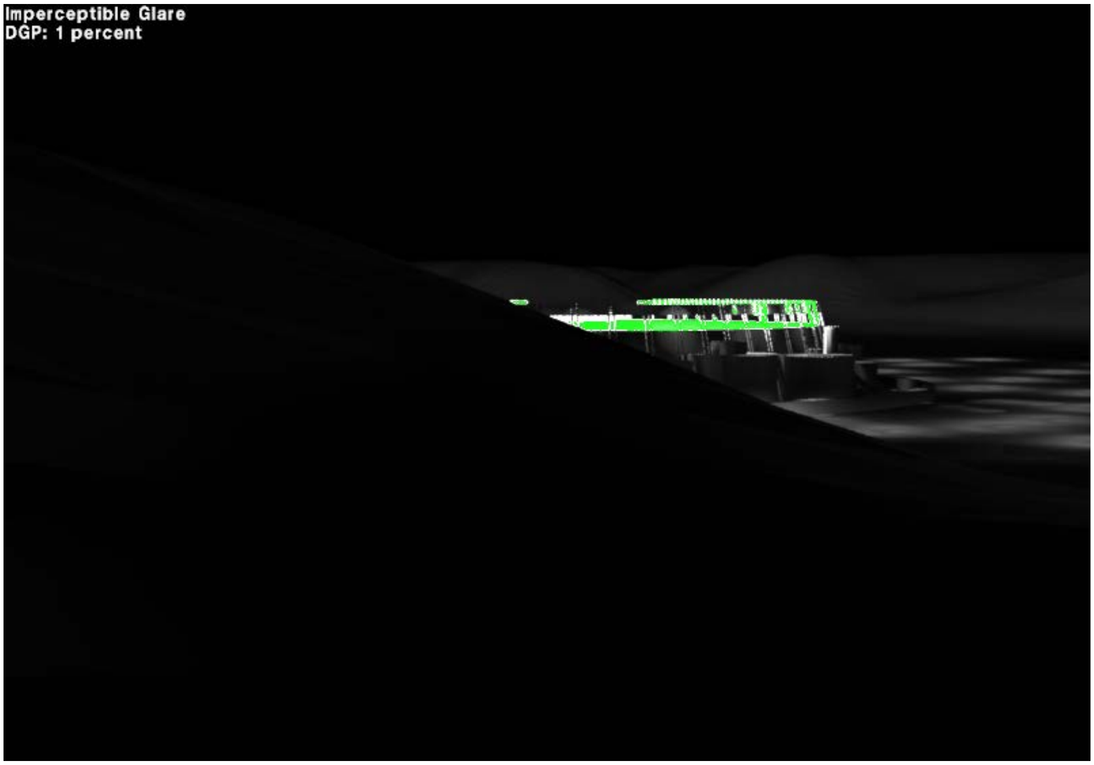


KOP 12 - DGP 0.0086

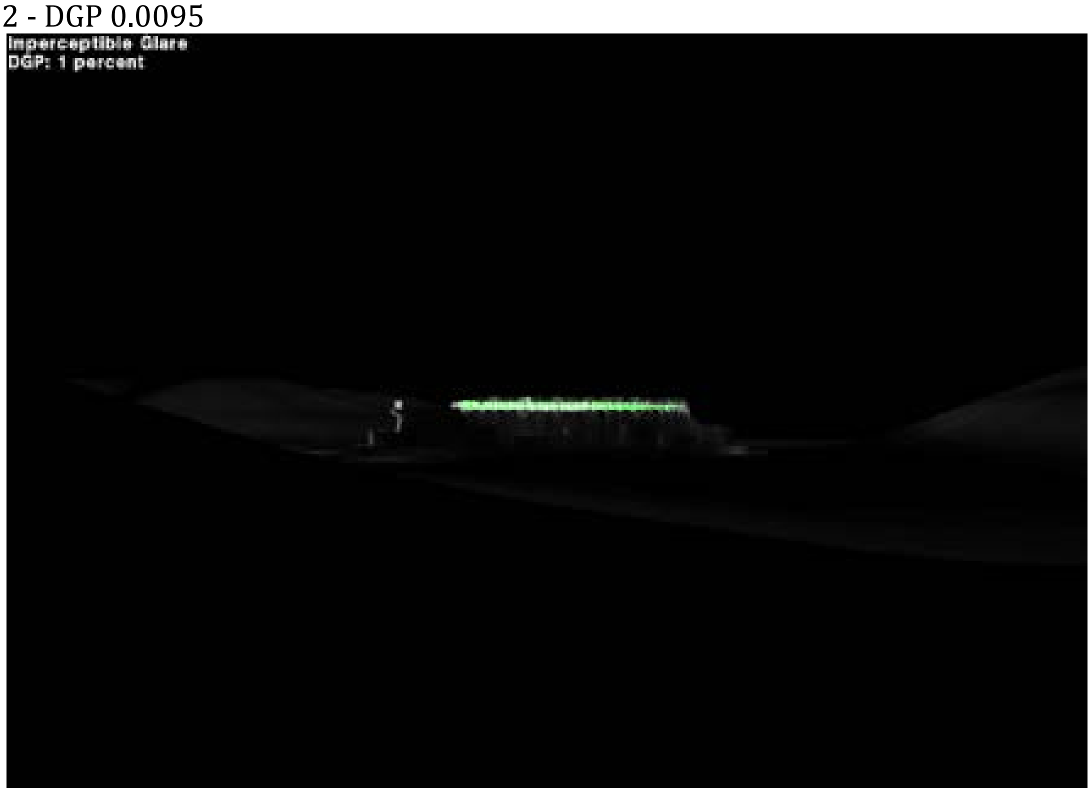


New Stadium – New Location

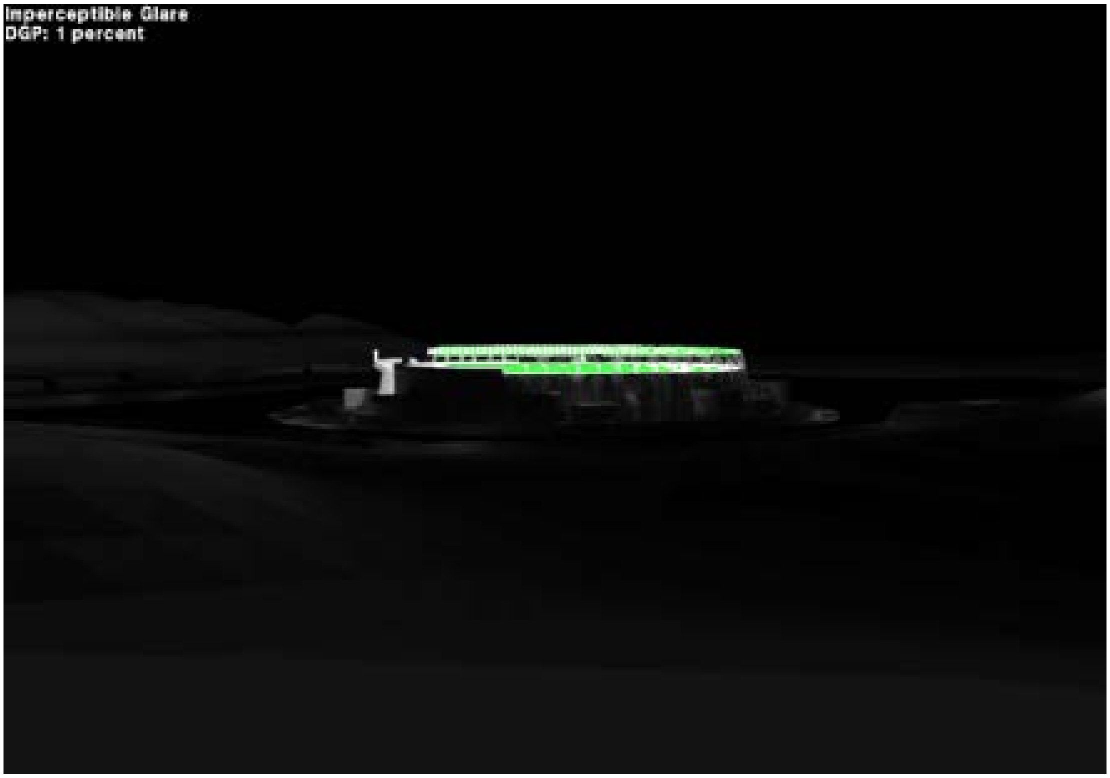
KOP 1 - DGP 0.0075



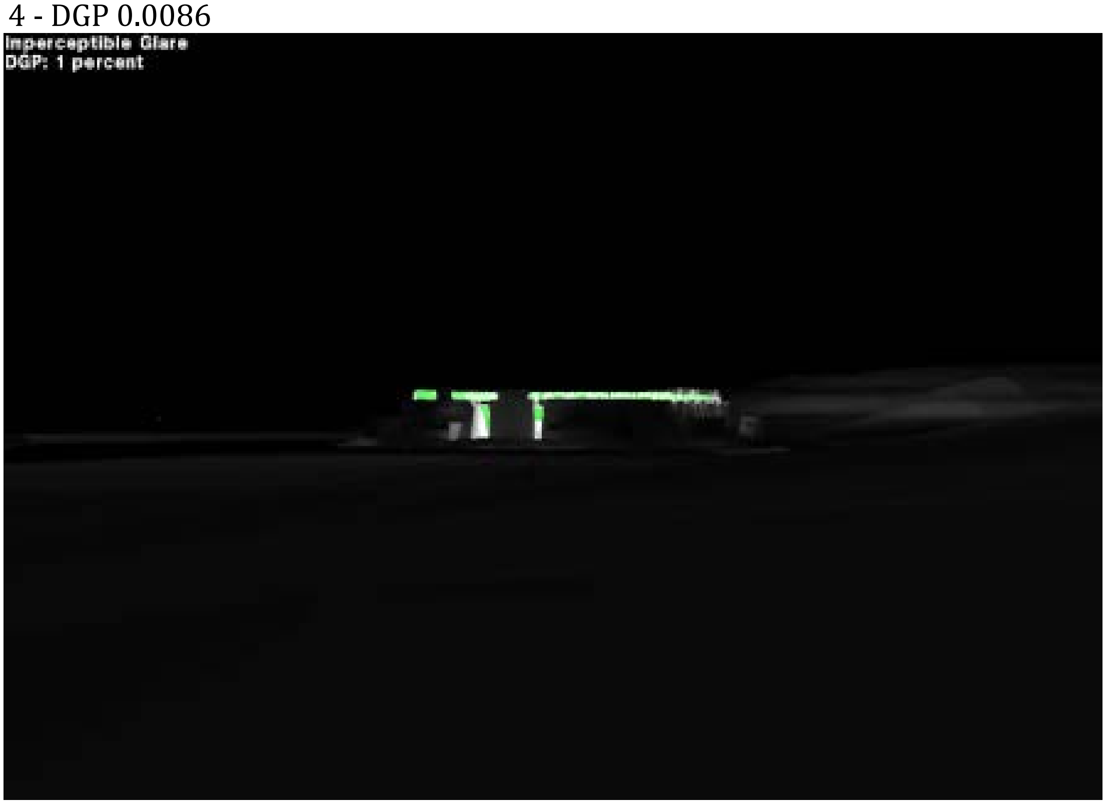
KOP 2 - DGP 0.0095



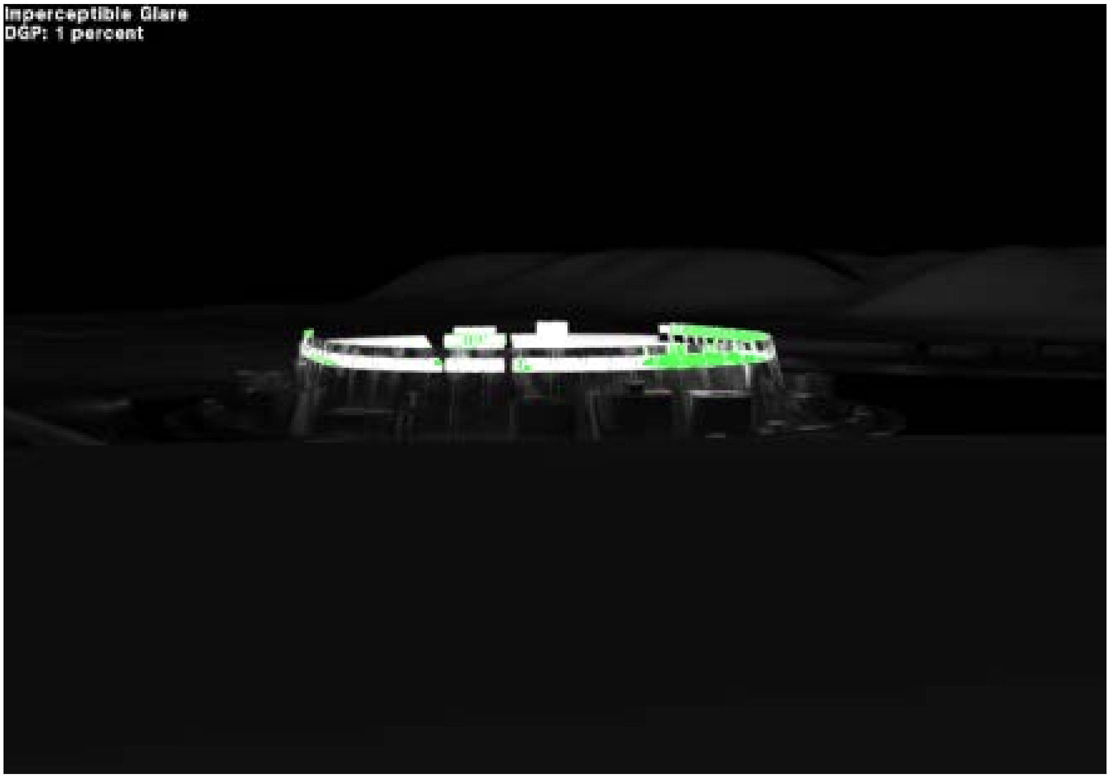
KOP 3 - DGP 0.0093



KOP 4 - DGP 0.0086



KOP 5 - DGP 0.0080

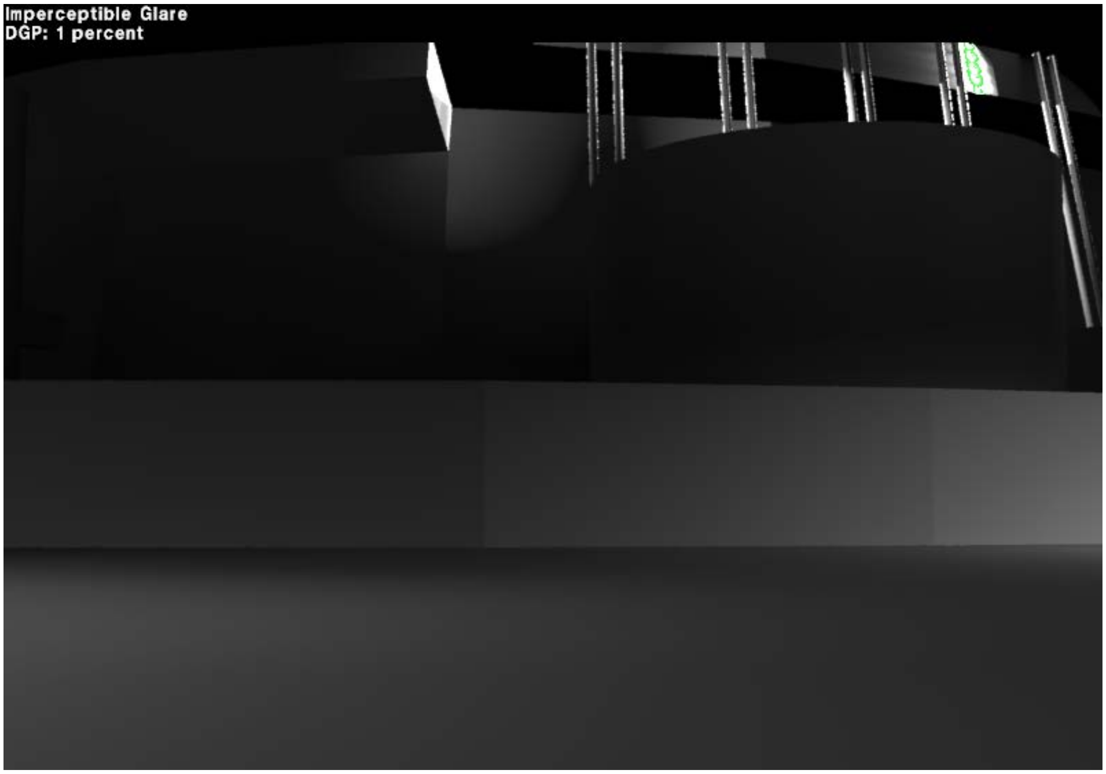


KOP 6 - DGP 0.0092

KOP 7 - DGP 0.0088

KOP 8 - DGP 0.0078

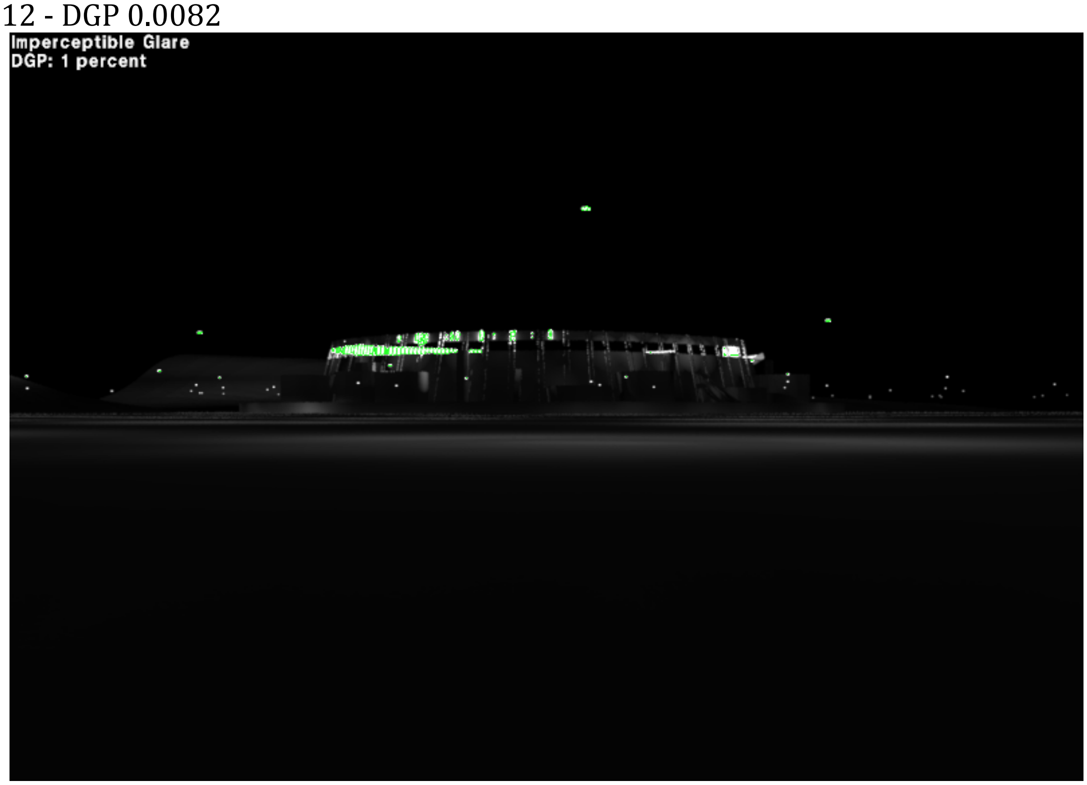
KOP 9 - DGP 0.0098



KOP 10 - DGP 0.0081

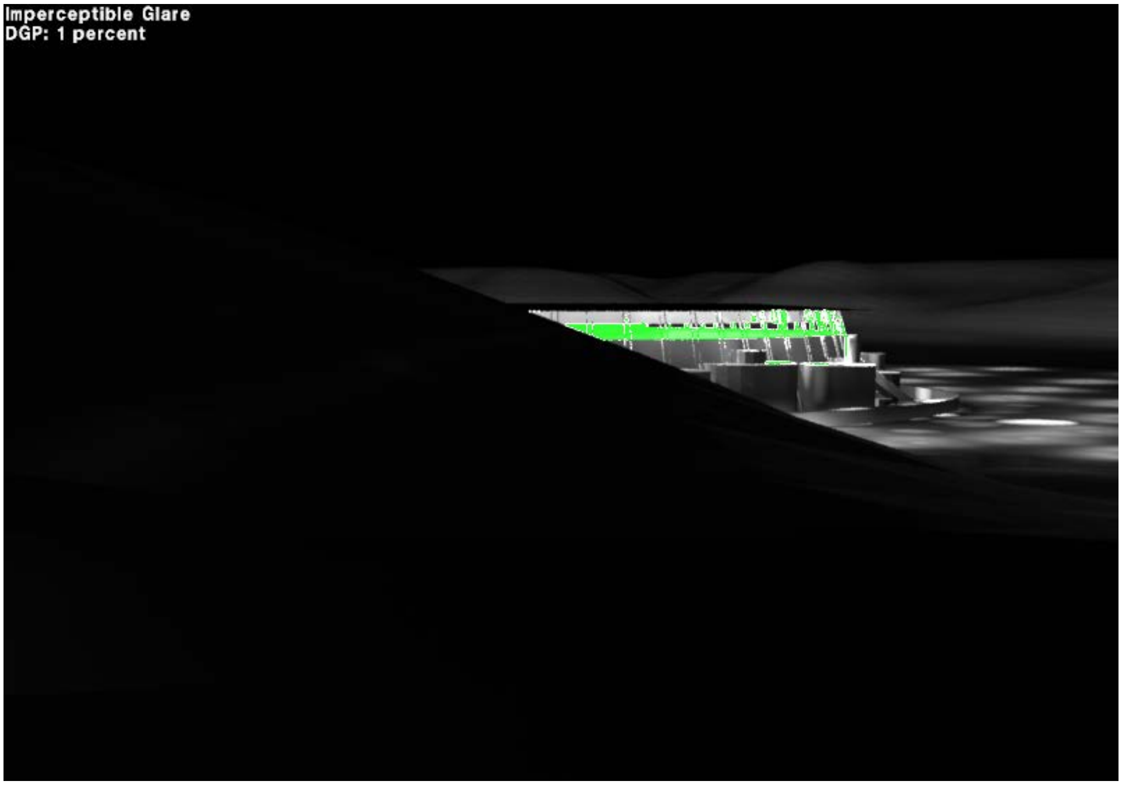
KOP 11 - DGP 0.0078

KOP 12 - DGP 0.0082

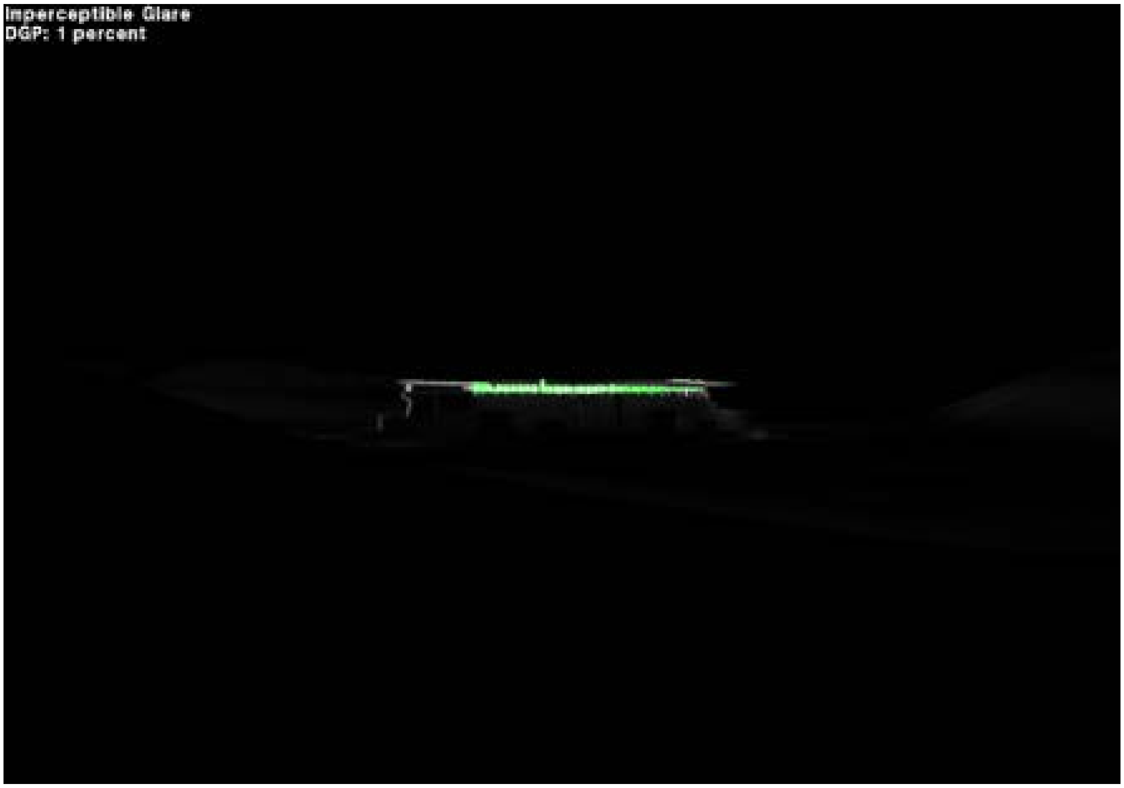


New Stadium with Partial Roof - New Location

KOP 1 - DGP 0.0070

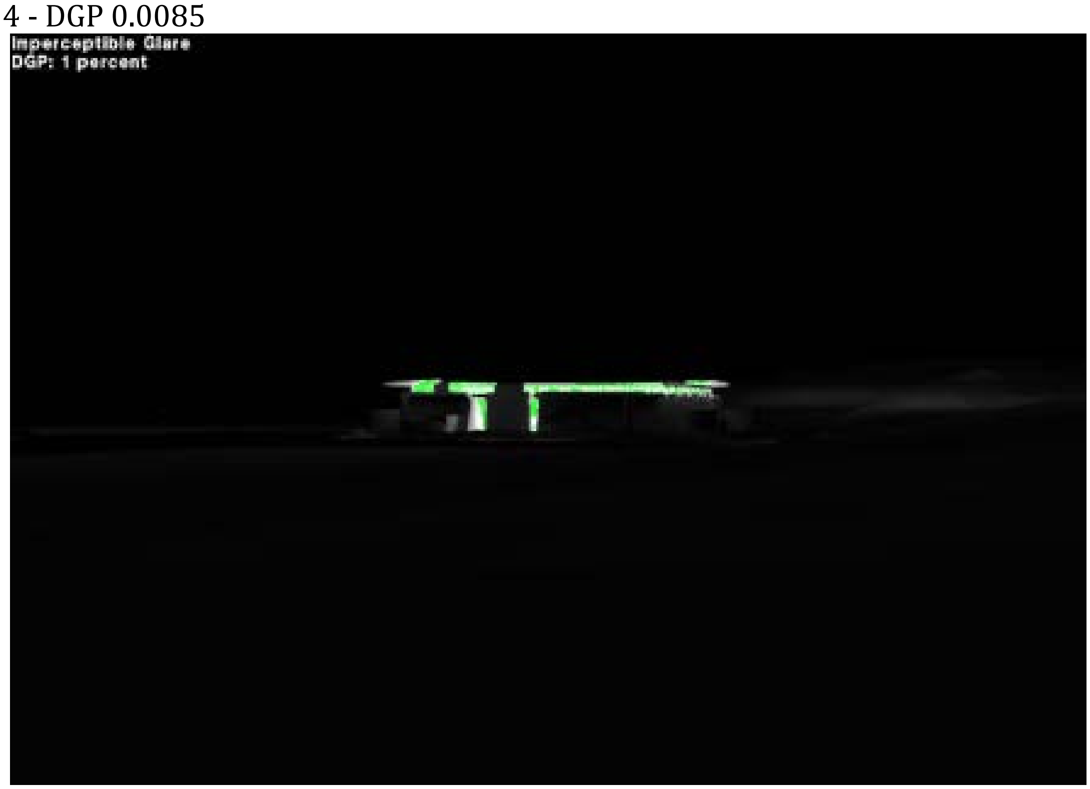


KOP 2 - DGP 0.0095

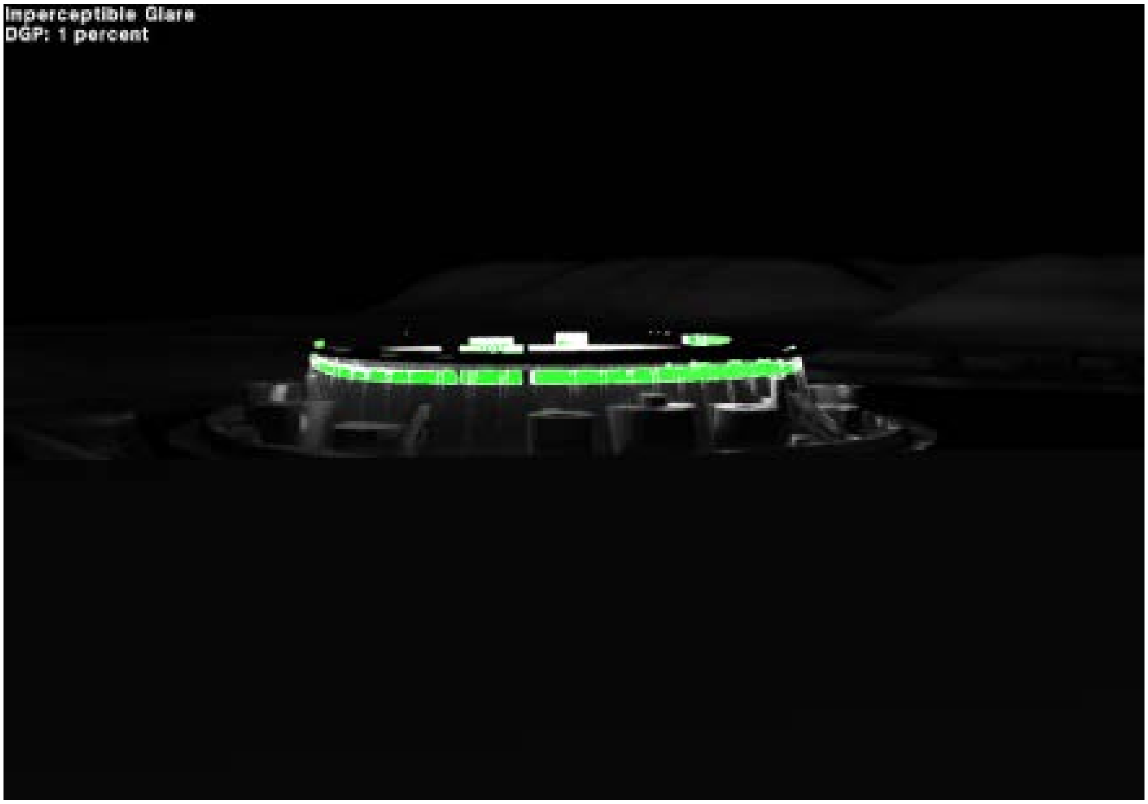


KOP 3 - DGP 0.0086

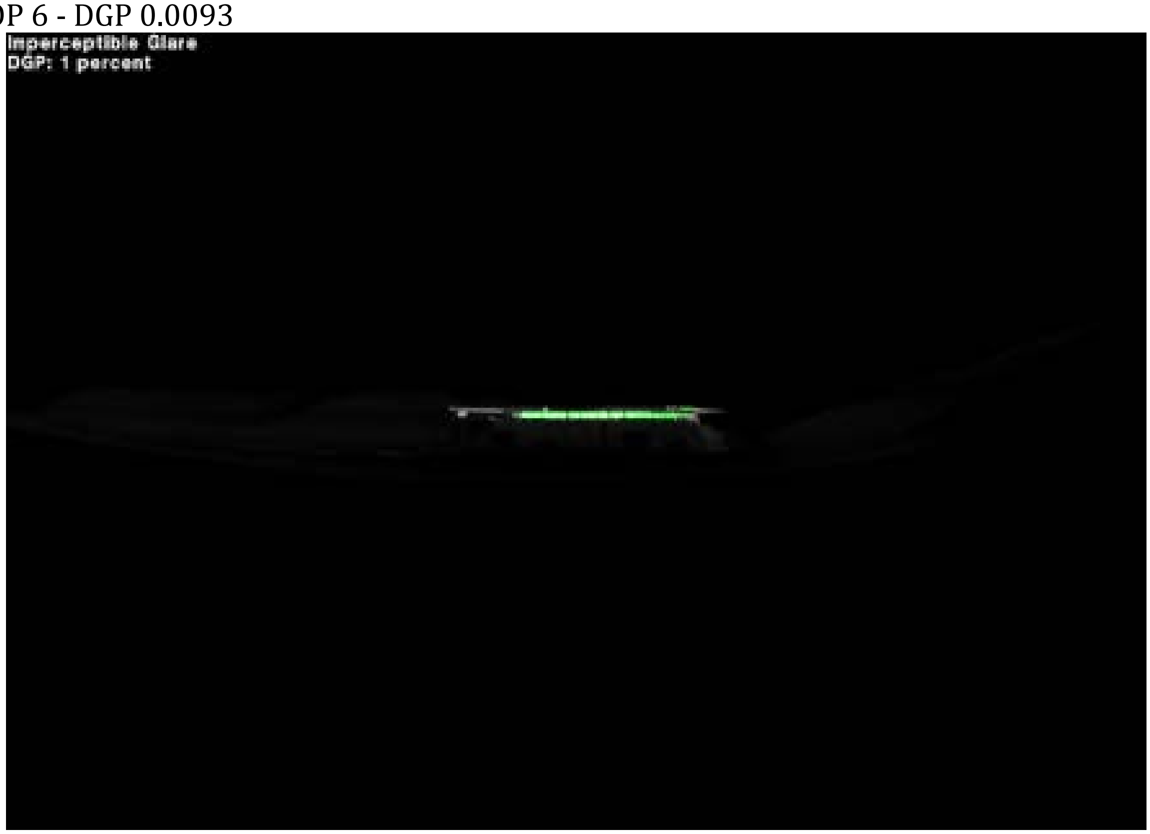
KOP 4 - DGP 0.0085



KOP 5 - DGP 0.0070



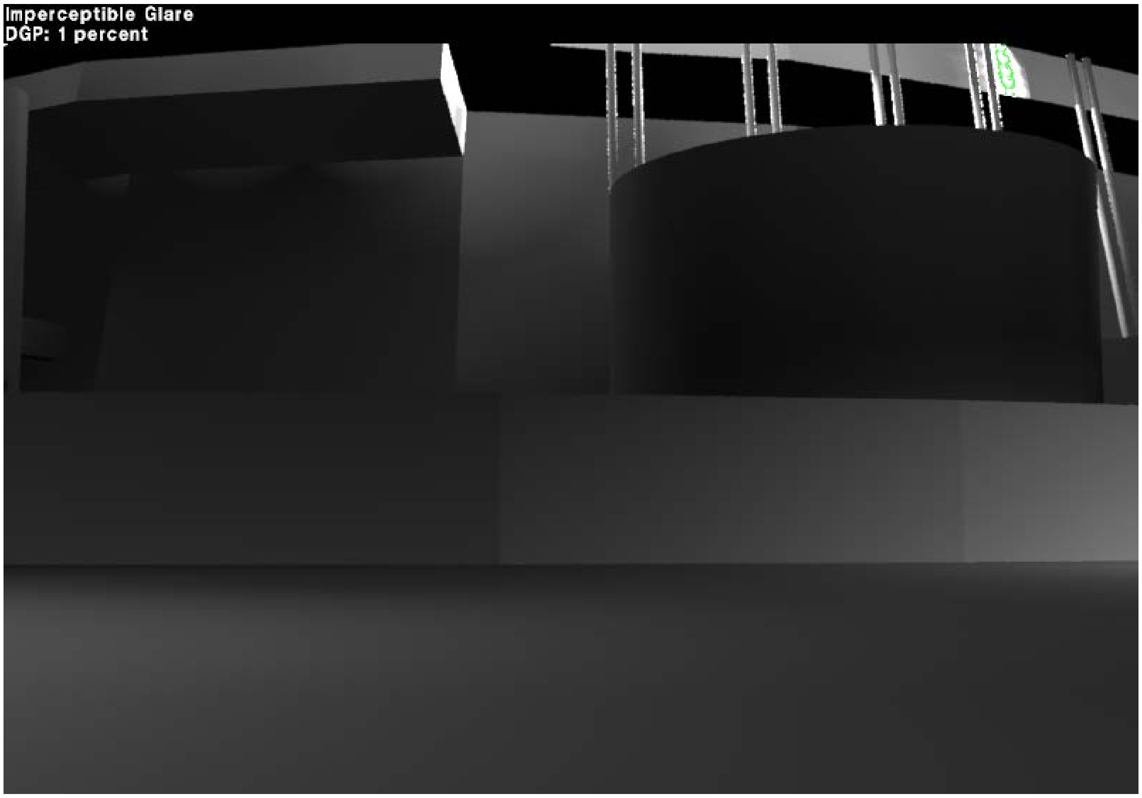
KOP 6 - DGP 0.0093



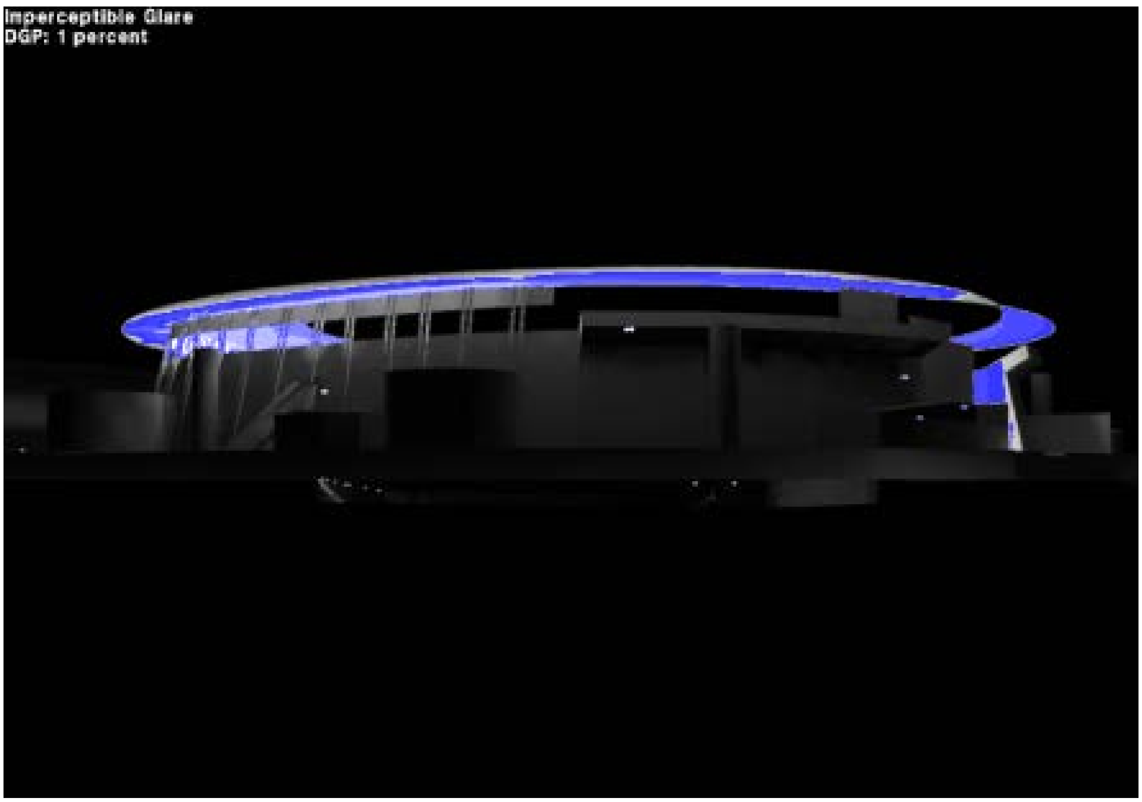
KOP 7 - DGP 0.0088

KOP 8 - DGP 0.0077

KOP 9 - DGP 0.0098



KOP 10 - DGP 0.0060



KOP 11 - DGP 0.0067

KOP 12 - DGP 0.0079