HELIOSTAT SYSTEM
TECHNICAL OVERVIEW
20.06.2014

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1 Executive Summary

Kennovations was engaged by Billbergia Group to complete a feasibility assessment on a Heliostat system's capacity to manage the shading impact of a proposed high rise tower on an adjoining public space. The capacity for the system to manage this amenity has been reviewed; results of this review, conceptual design details of the proposed system, and general details on heliostat technology are contained within this report.

2 Concept Overview for Rhodes

The Rhodes Station Precinct development includes four (4) high rise towers. The proposed thirty-six (36) storey tower in the south west of the site will cast a shadow onto a public park nearby (corner of Mary St and Rider Boulevard) at certain times throughout the day and calendar year. The design concept is to install a Heliostat mirror system on the roof of this building to redirect sunlight into the park, thus minimising the solar shading impact of this structure.

Heliostats are motorised mirrors controlled by computer software; they track the sun during the day in order to redirect reflections at a known target. The Heliostats in this application will be used to redirect sunlight up to a second set of static mirrors called the Secondary Reflector Array. This array is mounted above the Heliostats and incorporates individual mirrored panels designed to redirect sunlight into the park area. The position of the moving Heliostats combined with the angle of each fixed Secondary Reflector panel determines where the sunlight is ultimately redirected.

To simplify the flow of sunlight = Sun > Heliostats > Secondary Reflectors > Park Area

As a general rule, the amount of sunlight that can be reflected into the park is proportional to the total surface area of the mirror panels mounted on the Heliostats. The amount of sunlight that can be reflected can be measured in two ways:

1) Total approximate surface area of reflected light
2) Average intensity of reflected light

The two modes of measurement can be traded off against each other in order to deliver an agreed value that best serves the functionality of the nominated target area.

As light is reflected off each of the two surfaces (Heliostats then Secondary Reflectors) there are intensity losses of approximately 10% per reflection. The actual percentage loss is a result of the material properties and environmental factors such as dirt and pollution on the mirrors.

During the planning phase, each of the individual sunlight reflections can be positioned closer together or moved further apart in order to control the average intensity of sunlight in a given target zone.

For example:

- The park in question has a surface area of approximately 1215 sq mtrs
- The proposed heliostat system can deliver approximately 645 sq mtrs of sunlight to the park.
- The resulting reflection intensity for the proposed system is in the order of 80% of the original sun light intensity.

The system will be operating daily, it is effective during daylight hours only, and operates as if there is always sun present i.e. if the sky is heavily clouded the system will operate however the resulting effect is zero as only direct sunlight will cause reflections. In this instance there is no loss of direct solar to the park to compensate for.

The ray tracing and sun tracking software utilised for this project has been specifically developed for industrial heliostat solar fields and has been adapted for this lighting application. Comprehensive simulation modelling will enable each mirror component on in the Secondary Reflector array to be manufactured to achieve specific angular positions so as to define and control the lighting strategy. Simulations will also provide an understanding of the changing luminosity and orientation of reflections during daily and seasonal transitions. The sun tracking software position the heliostats accordingly so that the reflected light always hits the same group of mirrors on the cantilever, providing strict control over the ultimate destination for the reflections.

When the system is operating the reflections on the ground do not move. All of the reflections remain in the nominated positions as a result of adjustments in the heliostat positions. Whilst remaining in the same position the intensity and shape of the reflections will alter according to the amount of sunlight and its relative position in the sky.

The lighting strategy for the park will be further developed in consultation with the client.

Refer to the following images (Images 1 to 5) which provide an overview of the proposed system components and flow of light.

Major components:

1) Proposed Tower
2) Heliostat array
3) Secondary Reflector array
4) Target zone

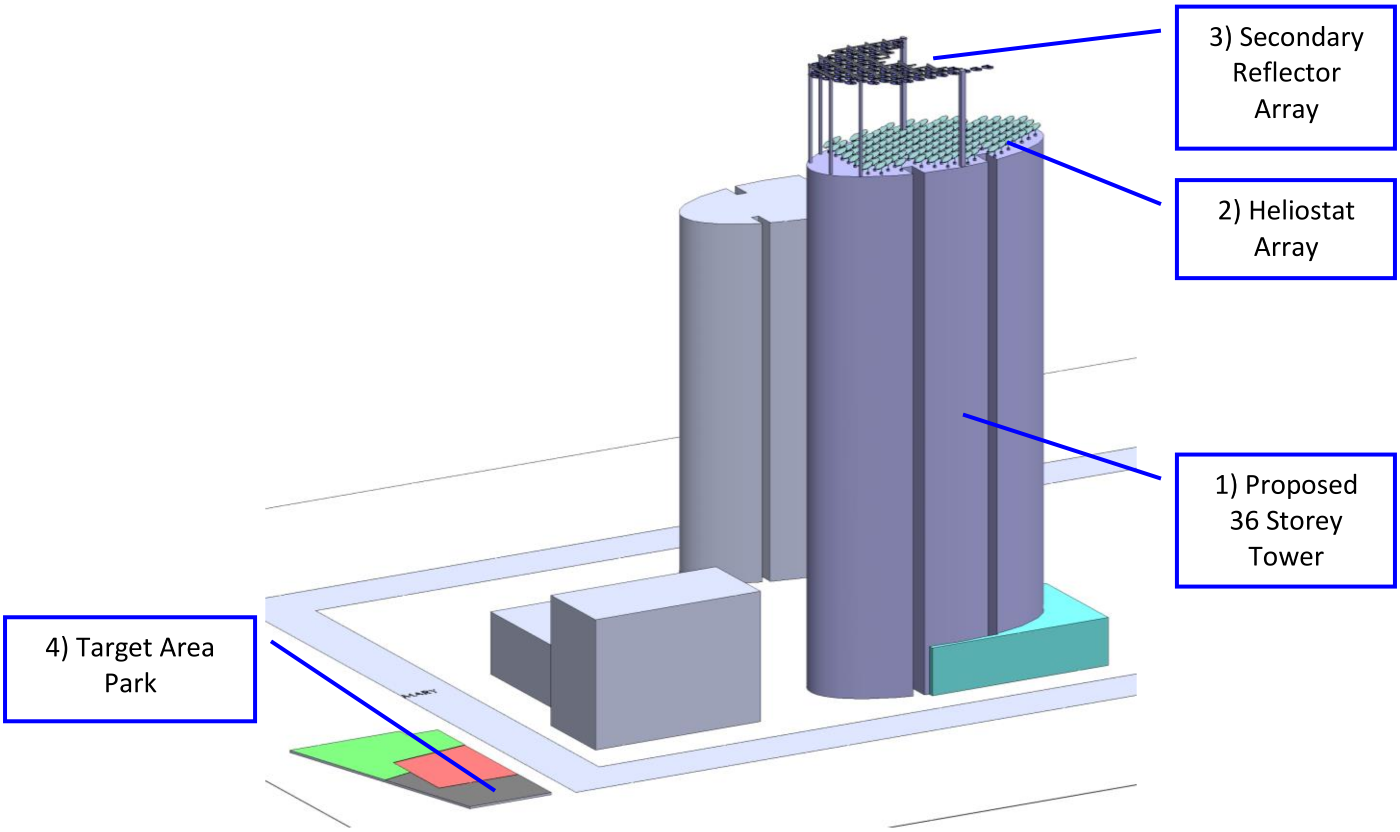

Image 1 – Key Components

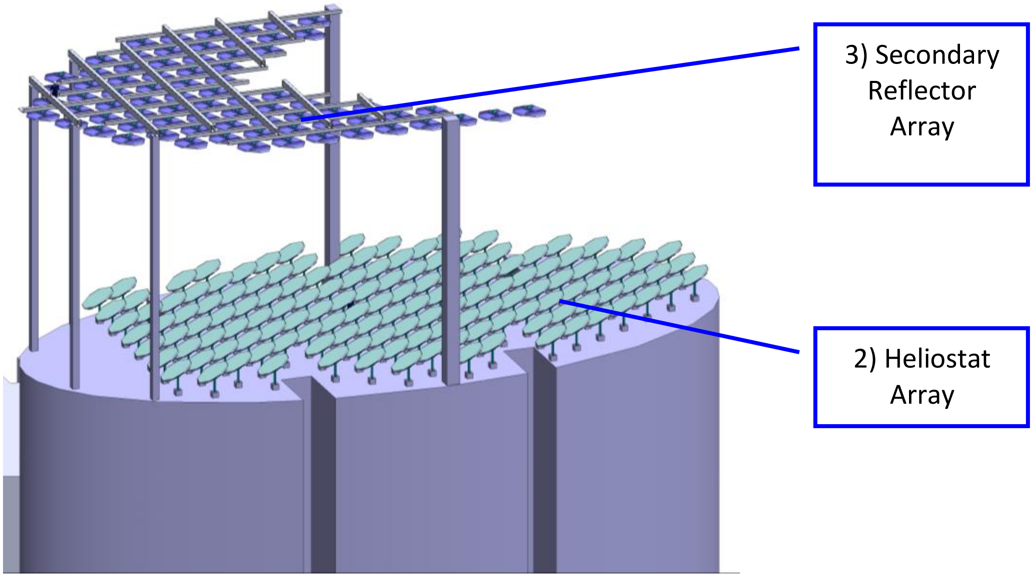

Image 2 – Close Up

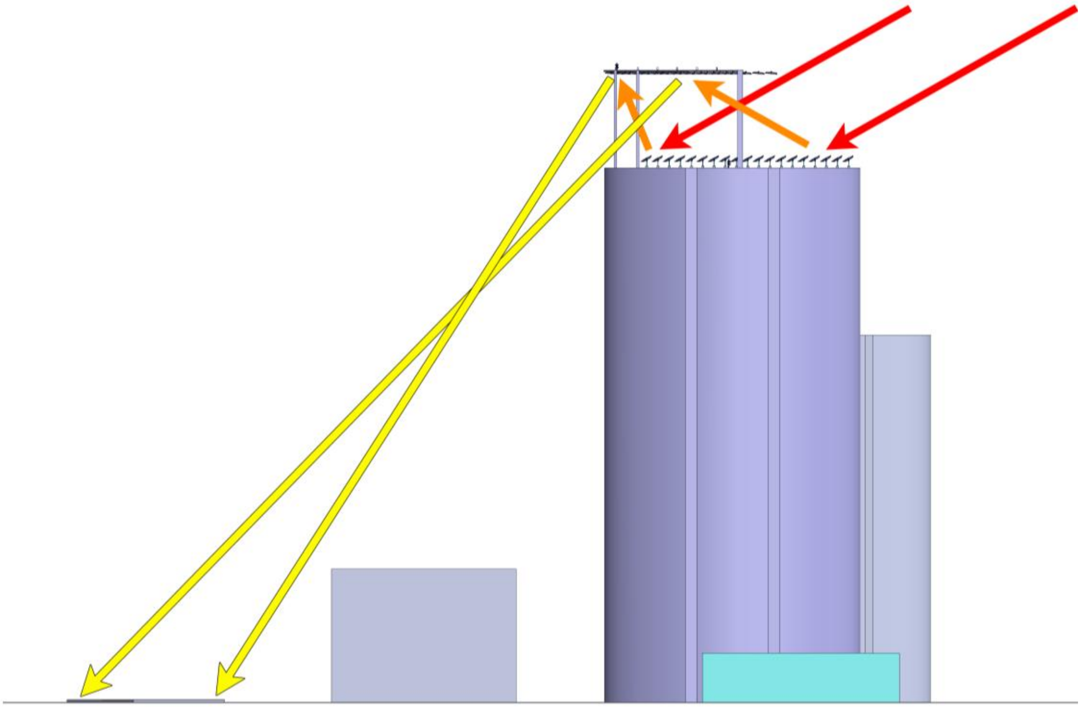

Image 3 – Solar Path
System overview – red arrows indicate sun rays entering the system from above, orange arrows indicate reflection from Heliostat to Reflectors, yellow arrows indicate reflection from Reflectors down to park area . ***Note: Image is conceptual only.***

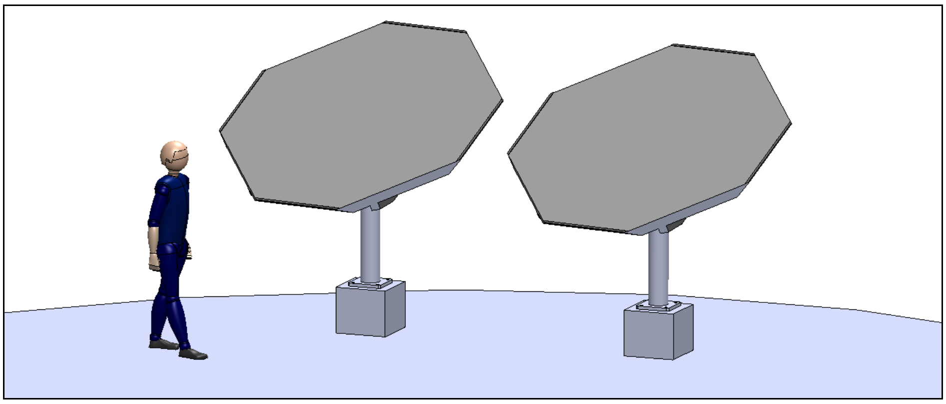

Image 4 – Heliostat Scale

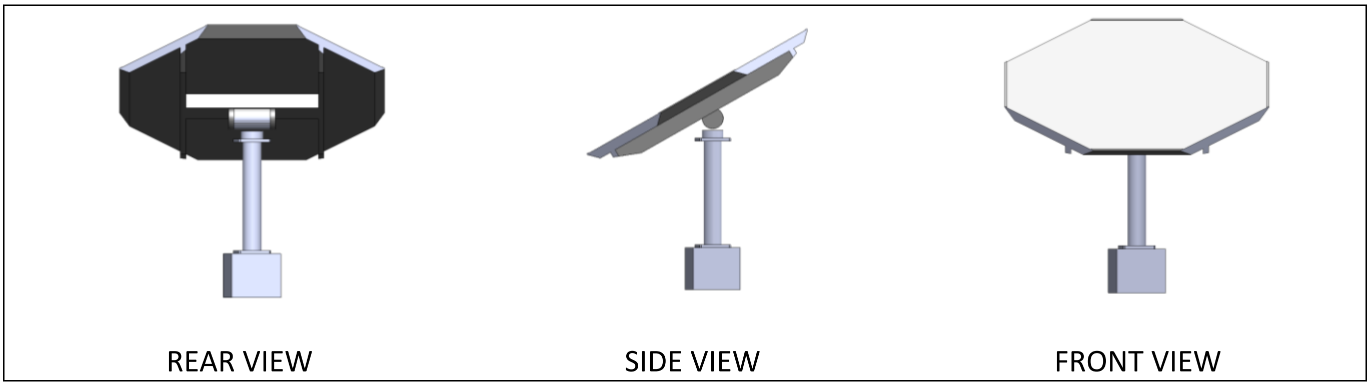

Image 5 – Heliostat General Views - Mirror Panel is 2.4m x 2.4m with corners cut off to allow panels to be nested closely

3 EXAMPLE OF A SIMILAR HELIOSTAT SYSTEM

3.1 One Central Park (OCP), Chippendale

Central Park occupies 5.8 hectares of Sydney in Chippendale and is the visionary redevelopment of the old Carlton & United Brewery site, bordered by Broadway and Abercrombie Streets.

The first residential stage of Central Park called 'One Central Park' was designed by French architect Jean Nouvel. It comprises two towers of 16 and 33 storeys, above a 5 level retail and recreation podium

Kennovations was contracted to Design & Construct the 40 motorised Heliostats on the rooftop of the western tower, and the 320 fixed Secondary Reflector Panels suspended beneath the cantilever on the eastern tower.

The system features a similar combination of sun tracking and static mirrored panels (to that proposed for Rhodes) which capture sunlight and redirect it into the retail atrium and landscaped terraces. At night the heliostat's integrated lighting system displays video interpretations of Sydney landscapes. The installation is a key contributor to both the functionality of daylight planning for the site and the Public Artwork requirements.

The Rhodes system will utilises the same advanced design techniques, control software, and risk management techniques to ensure the safe and reliable operation of the product.

The OCP mirrored system is the largest architectural installation of its kind anywhere in the world however it will be surpassed by the Rhodes project.

The One Central Park system also incorporates 2880 LED lights within the 320 mirrored panels which form a public art work display at night. The overall energy of the LED system uses no more than a few domestic hair dryers and provides maximum effect for the public domain with minimum disruption to the adjacent residents. A similar lighting system may be considered for Rhodes.

The following images highlight key components and the effects of the system at OCP.

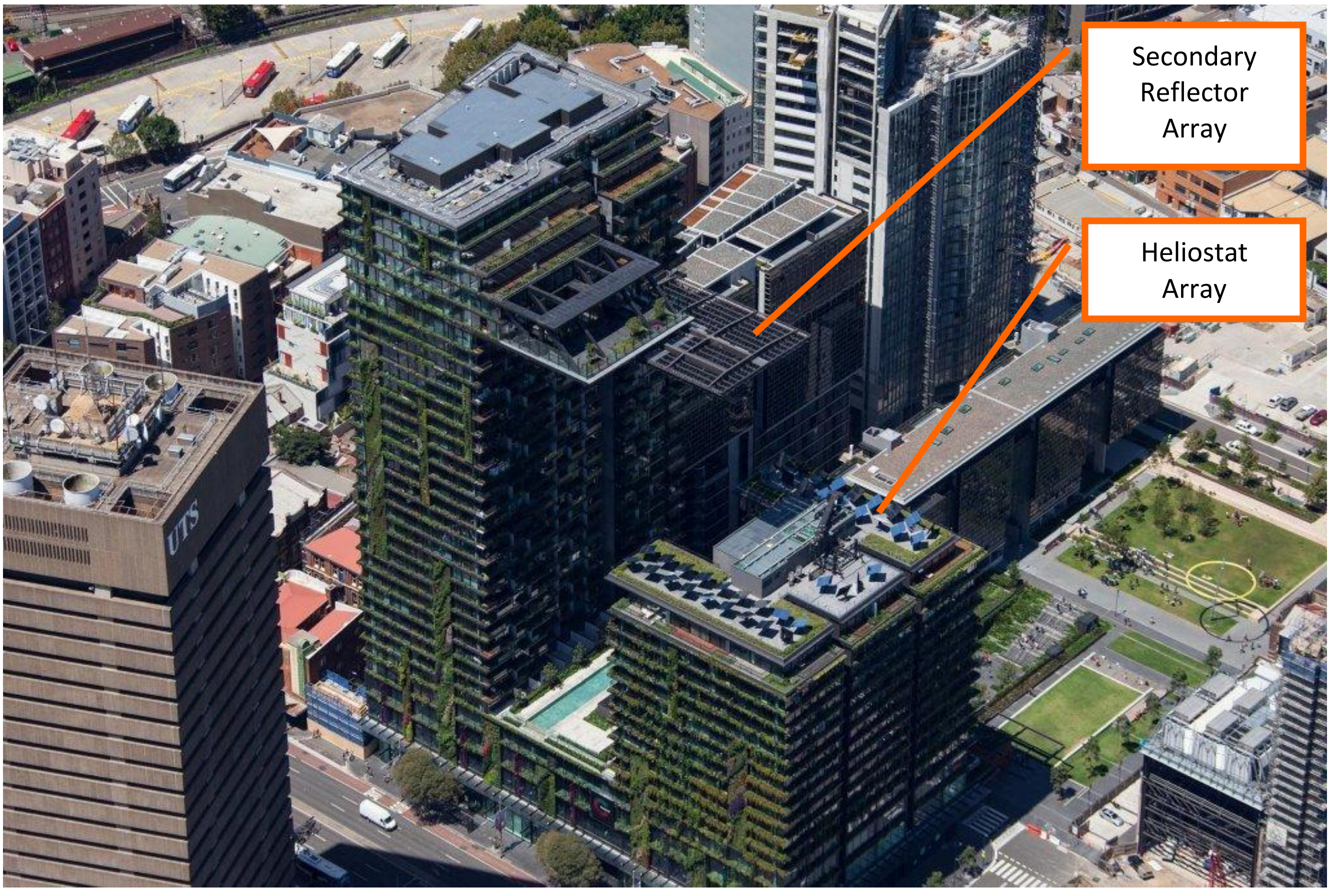

Image 6 – OCP site

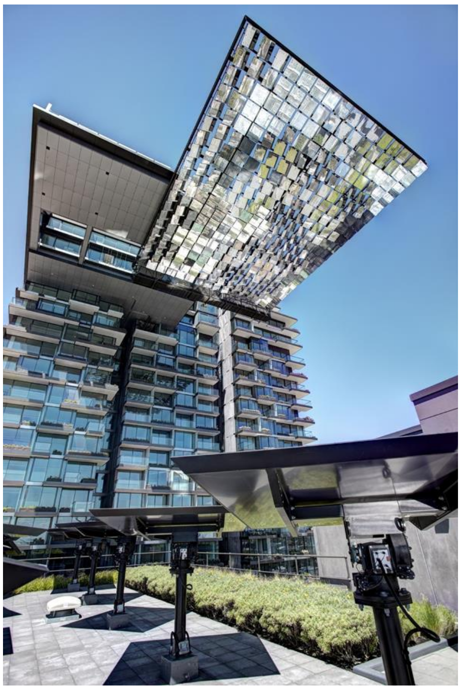

Image 7 – Heliostats targeting Reflectors

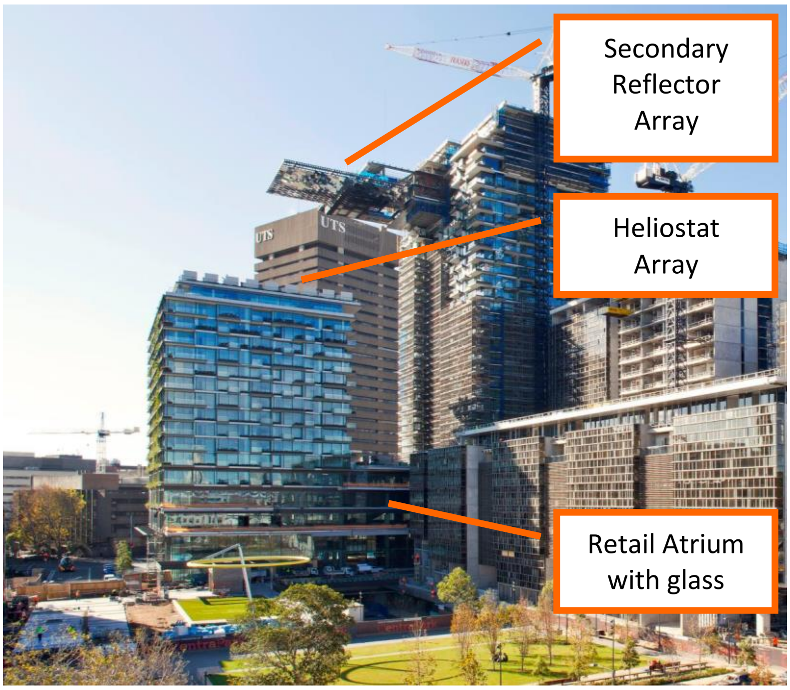

Image 8 – OCP site

Image 9 - Heliostat Installation – One Central Park, Sydney

Image 10 - Heliostat array with protective covers use to protect the mirror panel during installation and also put in place in the event of unit mechanical failure. The covers stop the mirror from producing stray reflections

Image 11 – Heliostats tracking the sun and redirecting the sunlight

Image 12 – This is the Retail Atrium which is being lit by the Heliostat System

4 SYSTEM COMPONENTS AND FUNCTION OVERVIEW FOR RHODES

4.1 Heliostats

The Heliostats are to be positioned on the roof of the 36 storey tower. The details of the Heliostat array have been outlined below:

General Features:

- The Heliostat array is to be made up of approximately 146 individual heliostats
- The mirrored surface area will be approximately 4.25sq mtrs per Heliostat
- The mirror surface is positioned so that it always reflects the sun's rays up to the Secondary Reflectors
- Each Heliostat aims its reflection at a single Secondary Reflector and always aims at the same one
- Two Heliostats will target the same Secondary Reflector to minimise component numbers for this system element.

Mirror surface and structural frame:

- The mirrored surface is a highly polished aluminium skin on a composite panel material (as opposed to glass). This provides a lightweight and unbreakable surface for light reflection.
- The structural frame is made of aluminium and steel construction. The structural rigidity ensures that the heliostats vibration and movement is limited and suitable for function.
- Material selection is based on Australian Standards for building and construction.
- Full specification production drawings will be submitted by Kennovations, reviewed internally by Billbergia Group, SJB Architects, and the nominated Builder prior to approval for construction.

Mechanical features:

- The Heliostats are motorised and use a mechanical drive system to move the mirrored surface.
- The mirrored surface moves in both the elevation (up and down) and the azimuth (side to side).

1.2 Heliostat Control Software

- The heliostat array is controlled by computer software housed in a control room within the building.
- The control software manages daily sun tracking accuracy and any system errors.
- Control software is linked to the Building Maintenance Services (BMS) to provide alarms and monitor daily activity.
- Control software is also remotely monitored by the software supplier in order to respond to any alarms and monitor daily activity.
- The software controls all shutdown procedures which involve stowing the Heliostats in a slightly downward and south facing position to ensure the sun is not shining on the mirrors and no subsequent unwanted reflections can occur. (See Risk Management for more details)
- The proven control technology has been adapted from large scale solar power plants and offers a high level of customisation for this system.

4.2 Secondary Reflectors

The Secondary Reflectors are to be positioned approximately 20 metres above the Heliostat array on a supporting structural steel frame. The structural steel framework is to be designed to suit the architecture of the building. The details of the Secondary Reflectors have been included below:

General Features:

- The Reflector array is to be made up of approximately 76 individual Reflector mirrored panels.
- The mirror surface area will be approximately 4.25sq mtrs per Secondary Reflector

Mirror surface and structural frame:

- The mirrored surface is the same mirrored composite panel as used on the Heliostats
- All other materials are similar to the Heliostat construction and quality.

Mechanical features:

- The units are not motorised and do not move once commissioned
- Each panel is manually adjusted during commissioning to a calculated angle which determines where the reflected image is to land on the ground.

5 PROTOTYPING & TESTING

All elements in the Heliostat system will be prototyped and tested before committing to production. Structural and aesthetic prototypes of the Heliostats and Reflectors will be developed during the design phase.

Wind tunnel testing will be conducted in order to manage the effects of movement on the mirror arrays during low and high wind events. Understanding the impact of movement within the lighting system is important for structural engineering developments as well as considering public responses to the movement of reflected light.

Images 13 -15 show the set up for testing a prototype Secondary Reflectors in a wind tunnel for OCP

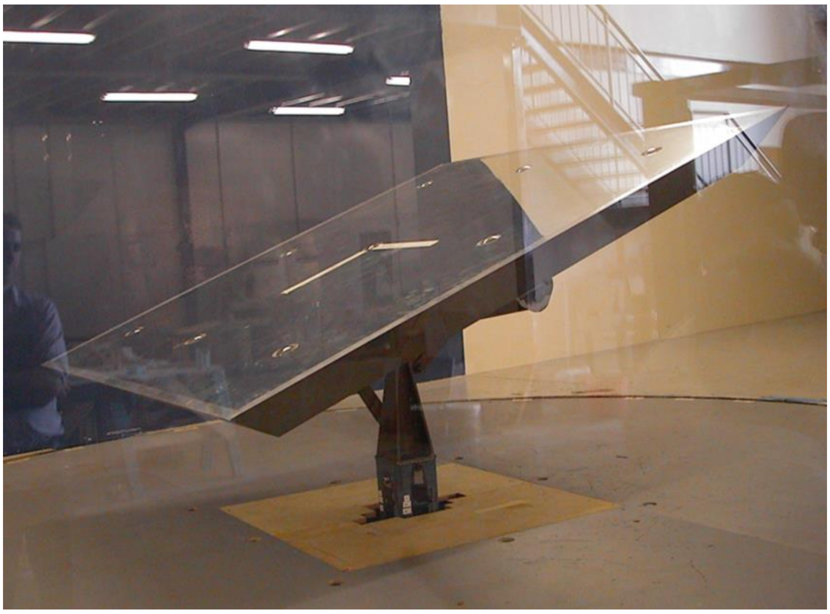

Image 13 - Wind Tunnel examination of a Reflector

Image 14 - Wind Tunnel examination of a Reflector

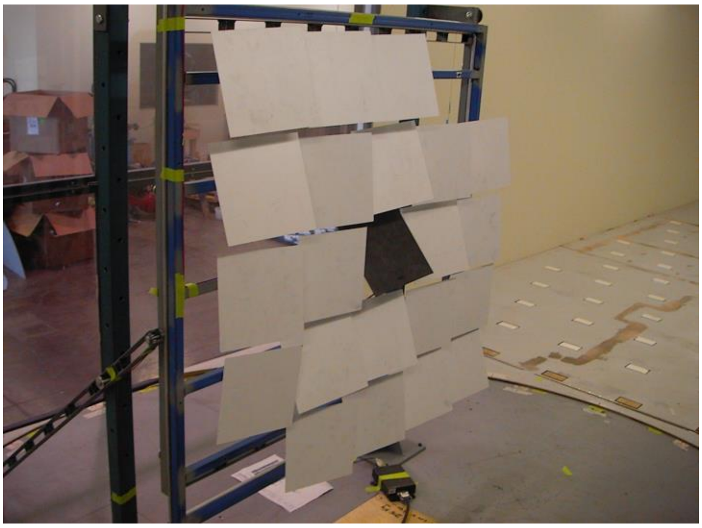

Image 15 – Wind Tunnel examination of Reflector Array

6 LIGHT MODELLING

Light Modelling – detailed light modelling will be completed in order to establish the anticipated results of implementing the Heliostat and Secondary Reflector system. The project has several key objectives with respect to how the reflected light is controlled and distributed, and a detailed process of analytical assessment is to be completed. The modelling will establish exactly how much light can be reflected; where the light needs to be targeted, and establish control measures for any negative impacts resulting from the installation. The light modelling will ensure system operation will not cause unwanted solar exposure and will investigate the effects of seasonal changes. Please refer to Images 16-18 which show some of the typical modelling outputs from OCP.

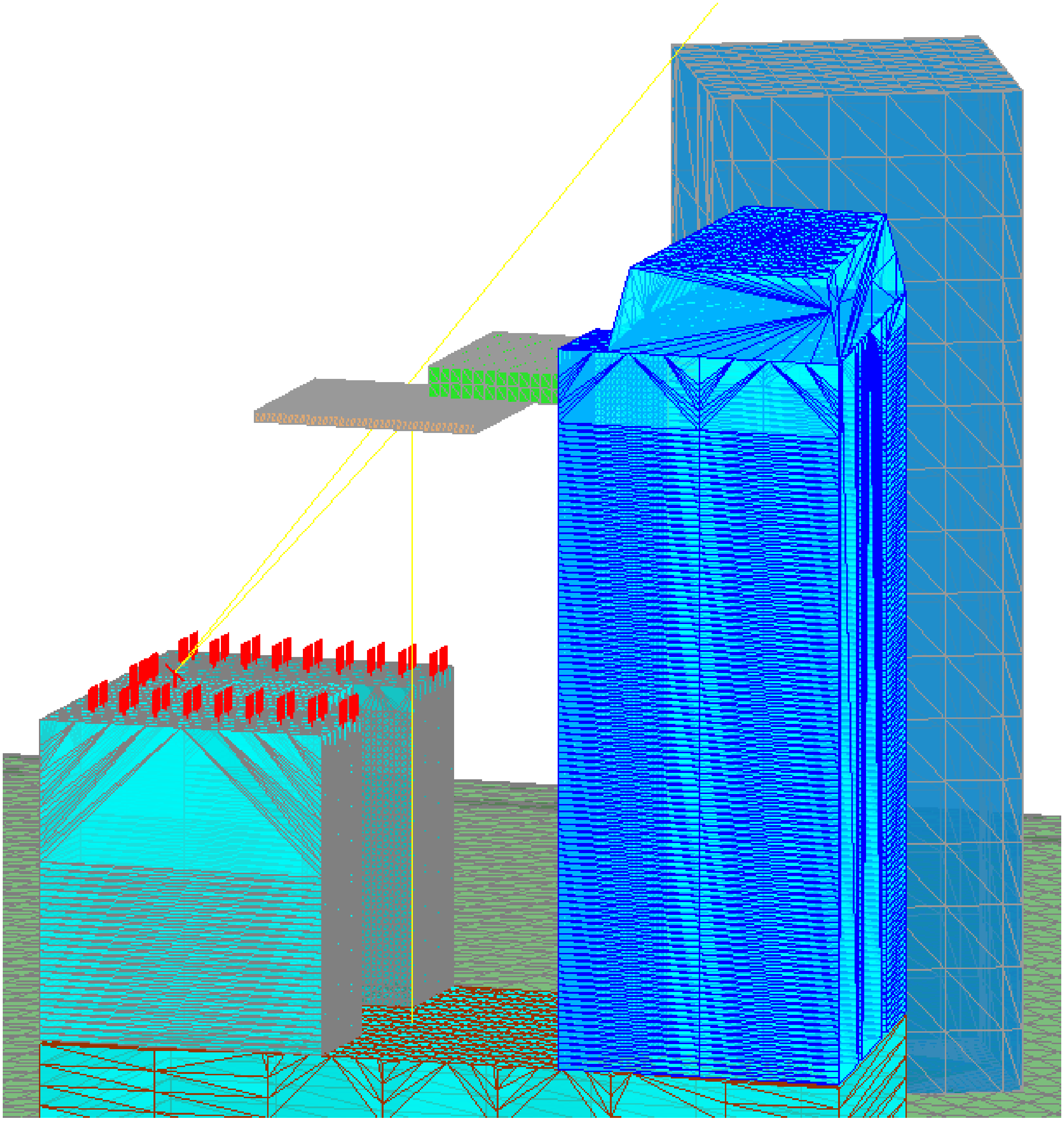

Image 16 - Shows computer models used in ray tracing simulations as seen from the south of One Central Park. An example ray reflected off heliostat #20, and a secondary reflector on the mirror cantilever is directed into the atrium in the lower floors.

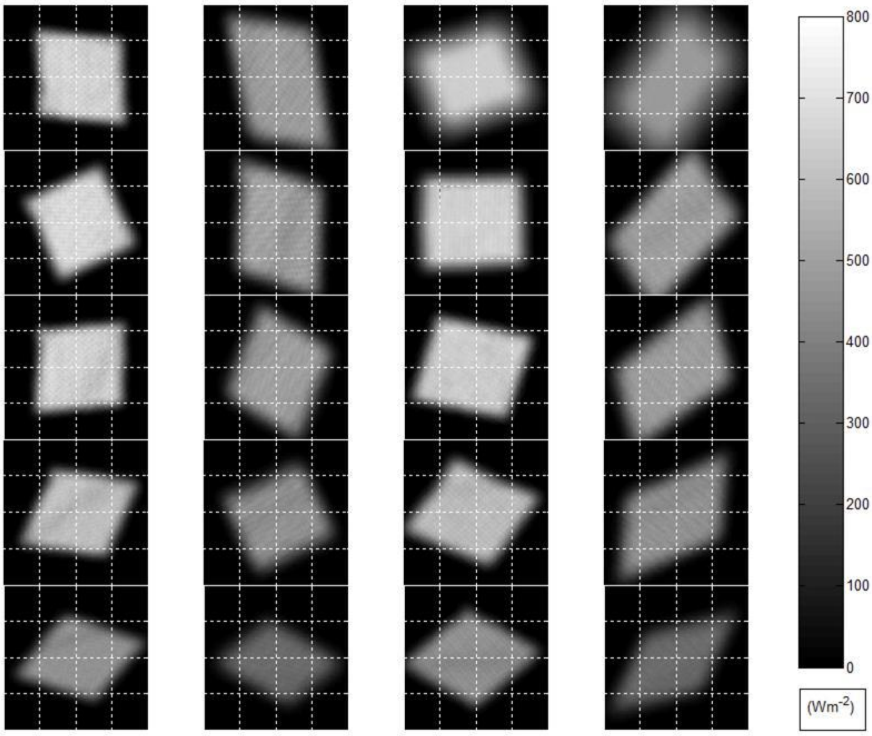

Image 17 - Heliostat reflections generated on the plane of the cantilever for the One Central Park project. Results show that the image cast by the heliostat changes in shape, orientation and intensity throughout the day. The rotation of the images is caused by the rotation of the heliostat actuation mechanism as it angles the mirror to catch the sun. The change in intensity of the images is due to the combined effects of mirror reflectivity, cosine losses, as well as variation in the solar irradiance throughout the day.

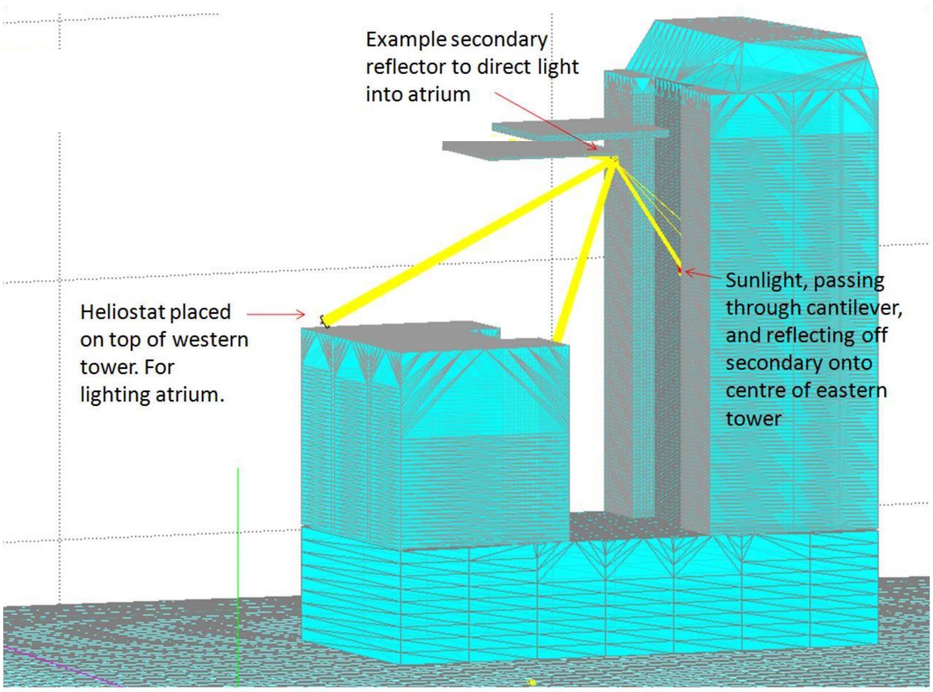

Image 18 - Examination of stray reflection modelling for the One Central Park project – The sun may deflect off the Secondary Reflector panels onto apartments on the eastern tower. The Light Modelling study will help to establish risk and control measures for stray light.

7 RISK MANAGEMENT

Several risks present themselves when utilising a system with solar energy potential. Developing control system and risk minimisation strategies in order to reduce the frequency and intensity of these risks is vital for the systems successful implementation.

Several risk strategies are currently being utilised:

a) Solar exposure:
- The system design does not concentrate any solar radiation at ground level.
- All reflecting surfaces are flat and ensure that no light can be focused at ground level.
- The system is developed so that no ‘multiple’ exposures will occur. No two Reflector panels will be aimed at the same target area.
- The system will not cause increased solar exposure. When a reflection is bounced from a Heliostat to a Reflector it loses approximately 10% of its solar potential on each surface. The resulting reflections on the ground are approximately 80% of 1 x sun.

b) Mechanical Failure:
- In the event of a mechanical failure (Heliostats gets stuck in position) an alarm system will notify building maintenance personnel and key suppliers in order to correct the issue, or
- If a full mechanical failure occurs covering the Heliostat/s with the supplied fabric cover will eliminate the potential of stray reflections.

c) Electrical / Software System Failure
- In the event of an electrical or system failure (any error in software controls) an alarm system will notify building maintenance personnel. The control system will shut down the Heliostats. All units will face slightly down and southward as no reflections are possible from this position.
- The unit has an uninterruptable power supply (battery backup) which will enable the units to all stow into the safe position in the event of a power failure

d) Unusual responses:
- To eliminate the possibility that the reflections under cyclic vibration may induce an epileptic response in the public: engineering developments can ensure that the reflected images avoid critical response frequencies and zones.

8 WARRANTIES & MAINTENANCE

Detailed materials analysis and structural engineering ensure the heliostats and mirror structures can endure the exposed locations whilst maintaining a high level of accuracy and reliability with regards to lighting performance. The products combine a broad range of specialist materials balancing the architectural and mechanical design criteria necessary for this application.

WARRANTIES

- The Heliostats and Reflectors will be designed for a 25yr Design Life.
- All material coatings are to be warranted for 10yrs from Date of Practical Completion.
- All moving parts (motors / gears / bearings etc) are to be warranted for 3yrs from Date of Practical Completion.

REGULAR MAINTENANCE
All components will require regular maintenance to maintain good working order. The general requirements and approximate cost for these maintenance checks are outlined below:

- Reflectors are to be washed and maintenance checked every 6 months: *Maintenance procedures include a review of all material coatings, mechanical items, structural items, completion of repairs as required.*
- Heliostats are to be washed every 3 months.
- Heliostat maintenance checks are to be carried out every 6 months: *Maintenance procedures include a review of all material coatings, mechanical items, structural items, completion of repairs as required.*
- Heliostat control software checks: *Monthly windows update maintenance and remote fault checking (e.g. event log), 6 monthly communication & tracking test (1 day), visual inspection of junction boxes, Annual test (on top of 6 monthly) inc voltage checks, removing heliostat covers and, checking all cables for abrasion, etc, checking limit switch nut security.*
- Estimated annual cost = $16,500 (ex. GST)

The Heliostats have moving parts which may require replacement over the life of the building.
The motors may require changing over a 10yr period. There are 2 motors per Heliostat @ approximately $250/motor, so $500 / Heliostat x 146 = say $75,000 over 10yrs.
- Amortised annual cost = $7,500 / yr (ex. GST)

Estimated Annual Total $24,000 (ex. GST)

9 KENNOVATIONS CONTACT DETAILS

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END OF REPORT