

Lander Lighting to Reduce Pilot Approach Errors

Project Design Assumptions & Model Constraints

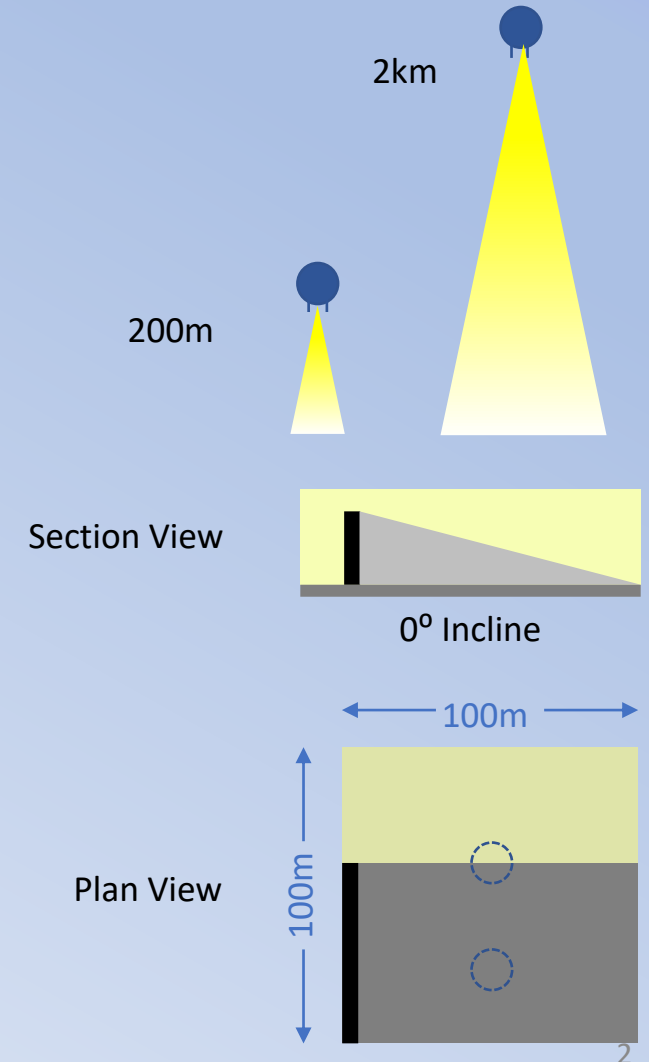
Toni A. Clark, P.E. & Jared Gunlock

JSC Lighting Lab

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Lander & Landing Assumptions

- 20ft diameter (6m) Lander
- No power restrictions
- All lamps mounted to bottom surface or along perimeter
- 2km lamps turn on
- 200m is the NASA Reference for go-no go decision
- A lunar surface incline greater than 12° isn't an option
- A landing zone in full shade requires the most lander lighting
- A landing zone in partial sun will have the greatest contrast to overcome
- 2 orders of magnitude contrast ratio on lunar surface needed
- Touchdown Site is 60ft x 60ft (18m x 18m) or 3x Lander diameter
- Landing Zone is 100m x 100m
- 13,000 lux average strikes the lunar surface with sun inclination angle of 2-7 degrees
- 130 lux average, therefore, is the absolute minimum



Choosing the Optimal Light Source and Optics

- LED COB (chip on board) technology needed for performance
- “Cool White” CCT is more efficient for LEDs and better represents daylight, so 6500 K chips with 80+ CRI are optimal
- All COTS LEDs were considered, and Cree had best performing chips meeting our criteria
- A TIR (total internal reflection) lens with the tightest beam control needed for 200+ meter distances
- The optimal combination, therefore, was the 1310 series CXB LED chip coupled with the Carclo TIR 60036 lens for a 7-degree beam pattern

	Brand = CREE, Family = Xlamp, Model = CXB-S						Model = CXB-HD	
LED	3590	3070	2540	1830	1820	1512	1520	1310
Light Emitting Surface (mm)	30	23	19	14	12	9	9	6
Substrate Width (mm)	35	30	24	18	18	15	15	13
Voltage	36, 72	36, 72	36	36	36	18, 36	36	18, 36
Typical Power (W)	100	78	45	31	22	13	17	12
Binning I/V (mA/V)	2400	1900	1100	800	550	350	500	350
Max Power (W)	137	106	76	52	40	22	40	24
Min Lumens (6500K, 80 CRI)	14340	11074	6653	4633	3280	1871	2631	1733
Typical Lumens (6500K, 80 CRI)								
Max Lumens (6500K, 80 CRI)								
Lumens per Watt	144	142	147	148	148	145	177	203
Carclo TIR 60036 (degrees)			19	14.5	11.5			7
Carclo TIR 60037 (degrees)			28	25	23		19.5	
LEDil TIR Ilona RS (degrees)					23	19	19	13
HEKLA Socket D								

Choosing the Optimal Lamp Quantity

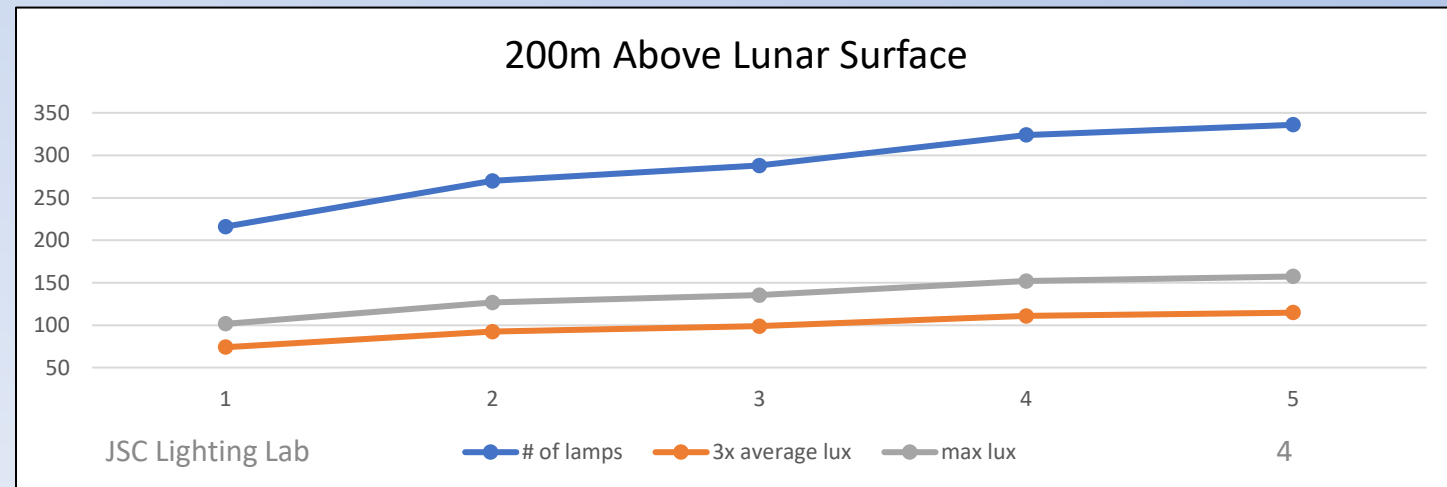
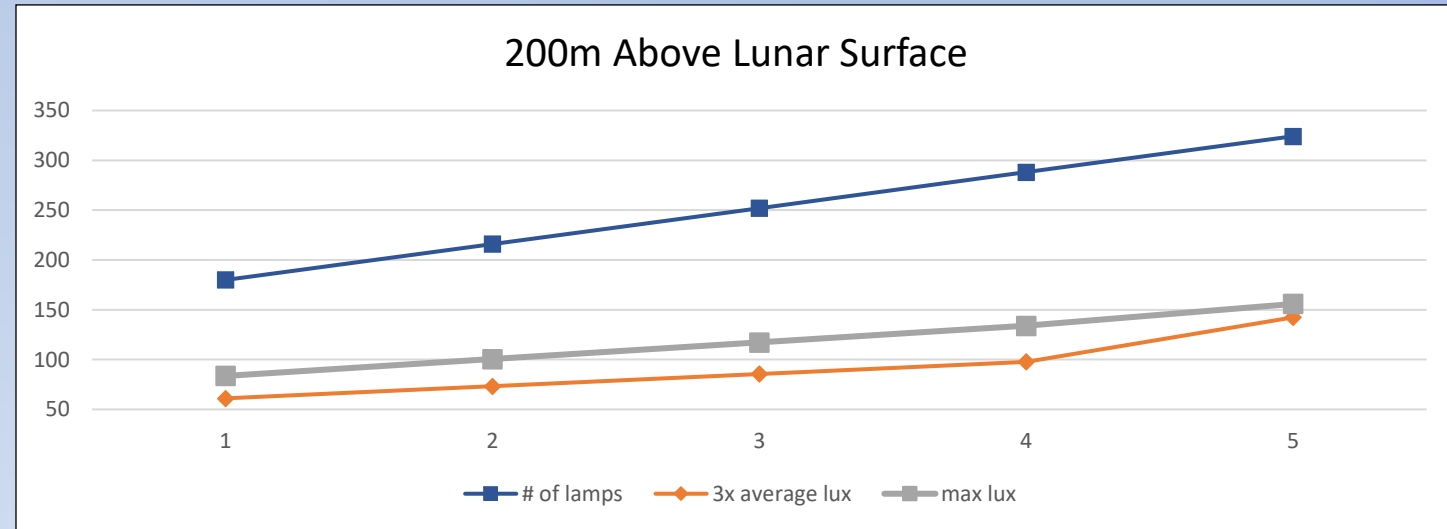
- The absolute minimum lux average for the 3x touchdown site needs to be 130 lux
- The absolute minimum lamp quantity needs to consist of 300 LEDs.

0° Lunar Terrain Incline

Circumferential Clustered		5	6	7	8	9
# of lamps		180	216	252	288	324
3x average lux		61.1	73.3	85.6	97.8	110
max lux		83.7	100.5	117.2	133.9	150.7

0° Lunar Terrain Incline

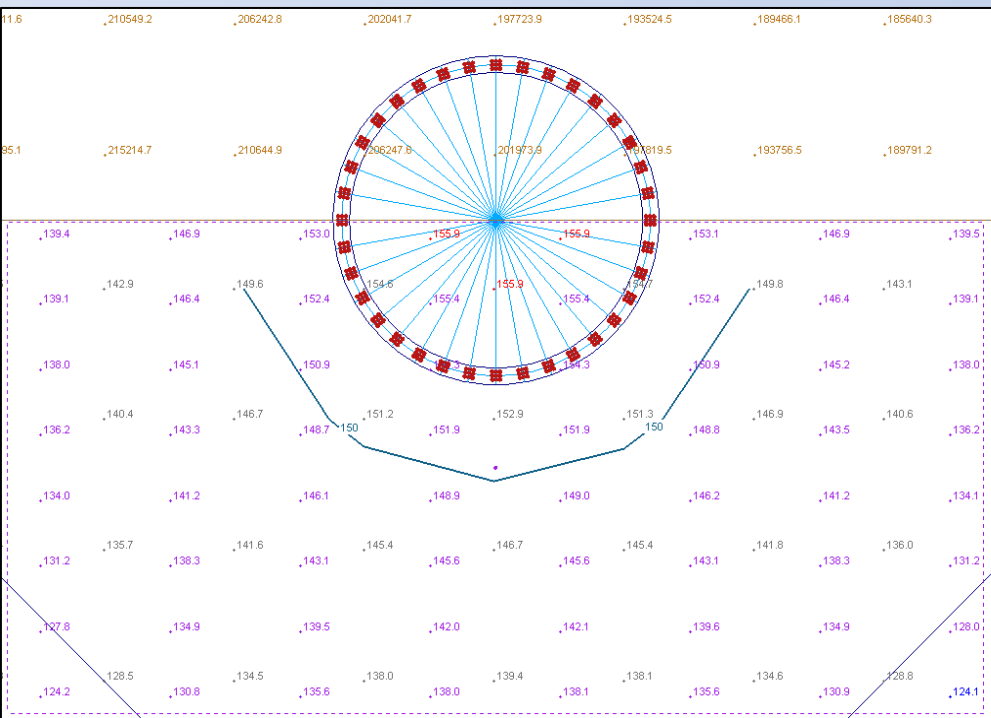
Perpendicular Radial Clustered					
# of lamps	216	270	288	324	336
3x average lux	74.1	92.5	98.8	111	114.8
max lux	101.6	126.8	135.5	152	157.4



Choosing the Optimal Lamp Layout

- Lamp/cluster layout does not matter at 200m

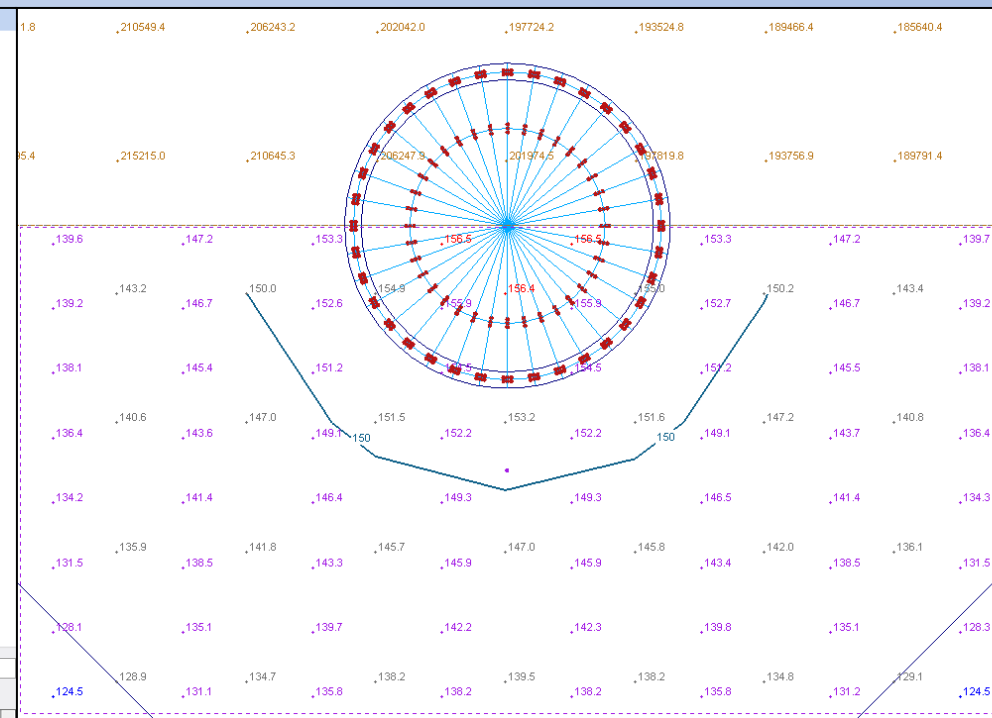
Circumferential Clustered



Landing Zone	
Average	142.5 lux
Maximum	155.9 lux
Minimum	124.1 lux
Max/Min	1.3:1
Average/Min	1.1:1
Lunar Surface - In Shadow	
Average	25.6 lux
Maximum	155.9 lux
Minimum	1.8 lux
Max/Min	86.6:1
Average/Min	14.2:1
Lunar Surface - In Sun	
Average	130963.3 lux
Maximum	319279.8 lux
Minimum	36977.5 lux
Max/Min	8.6:1
Average/Min	3.5:1

20ft
6m

Perpendicular Radial Clustered

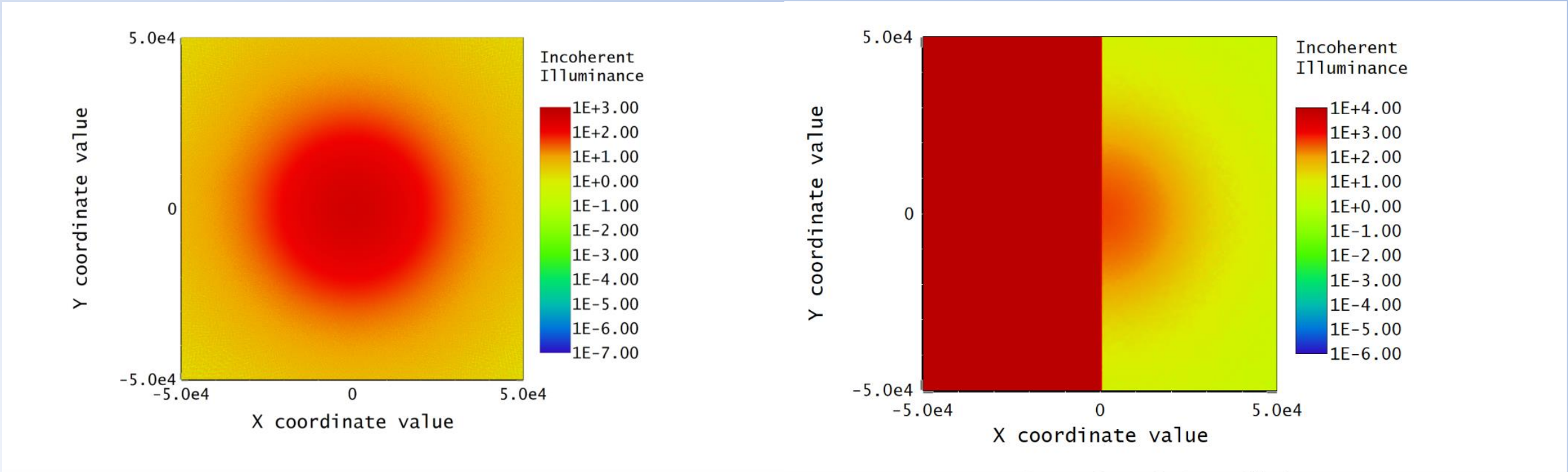


Landing Zone	
Average	142.7 lux
Maximum	156.5 lux
Minimum	124.5 lux
Max/Min	1.3:1
Average/Min	1.1:1
Lunar Surface - In Shadow	
Average	25.6 lux
Maximum	156.4 lux
Minimum	1.8 lux
Max/Min	86.9:1
Average/Min	14.2:1
Lunar Surface - In Sun	
Average	130963.3 lux
Maximum	319279.8 lux
Minimum	36977.4 lux
Max/Min	8.6:1
Average/Min	3.5:1

Zemax Results of Lamp Layout

Landing Zone, 300 LEDs, 362 lux max, log10 scale, no sun

Landing Zone, 300 LEDs, 362 lux max, log10 scale, half sun



Detector Image: Incoherent Illuminance

Detector Image: Incoherent Illuminance

8/23/2022
Detector 12, NSCG Surface 1: 100m x 100m Landing Zone
Size 100000.000 W X 100000.000 H Millimeters, Pixels 900 W X 900 H, Total Hits = 4992066
Peak Illuminance: 3.6285E+02 Lumens/M²
Total Power : 3.8367E+05 Lumens

Zemax
Zemax OpticStudio 21.3
2022.08.23-ICA_LunarLanderLighting.ZMX
Configuration 1 of 1

9/12/2022
Detector 13, NSCG Surface 1: 100m x 100m Landing Zone
Size 100000.000 W X 100000.000 H Millimeters, Pixels 900 W X 900 H, Total Hits = 5427436
Peak Illuminance: 1.7758E+04 Lumens/M²
Total Power : 7.7858E+07 Lumens

Zemax
Zemax OpticStudio 21.3
2022.09.06-ICA_LunarLanderLighting.ZMX
Configuration 1 of 1