



**IES AVIATION LIGHTING COMMITTEE**  
**ILLUMINATING ENGINEERING SOCIETY OF NORTH AMERICA**  
**ANNUAL AVIATION LIGHTING CONFERENCE**

**October 20, 2011**  
**Wilmington, NC**

**Latest Developments in the Application of  
White Runway LEDs on Airfields**

**Ed Runyon**  
**Advanced Technology Manager**

**ADB Airfield Solutions**

*The innovative  
approach™*



## Overview

- Resolution of White Runway LED Brightness Issue (RDU)
- High Intensity Runway Lighting Research at Manchester, UK
- Experience with Implementation of Medium Intensity Runway (MIRL) LEDs
- Future Implementation and Issues with High Intensity Runway Edge Lighting

# White LED Runway Issue Timeline

- Several airports installed LED Runway Centerline and TDZ lights in 2010
- Lights at RDU operational June 2010
- Pilot complaint at RDU during night VFR conditions August 2010
  - Summary of report of problem reported by pilot:

In our particular aircraft (Citation Excel) the landing lights ordinarily assist with our peripheral and forward vision to provide additional visual cues to make the rotation and adjust for rate of descent. With the current intensity of the lights on Step 1, the landing lights do not penetrate the lighting from the runway.

# White LED Runway Issue Timeline

- Flight testing at RDU Aug 31, 2010
- Various FAA/Industry EB67 meetings beginning in Sept 2010 to discuss white intensity (and other) LED issues
- FAA issued Moratorium on installation of LED Runway Centerline and TDZ lights September 17, 2010



# White LED Runway Issue Timeline

- In order to understand and resolve the issue, testing was conducted by a group of technical experts at RDU with reduced intensity settings Nov 16, 2010
- Objective: Collect data both from the air (subjective data) and circuit/CCR data (objective) to isolate the problem

# White LED Runway Issue Timeline

- What dimming should the lights be changed to?
  - Results of this research study was used:

## **BRIGHTNESS/LUMINOUS INTENSITY VALUES FOR BLUE, WHITE AND GREEN AVIATION SIGNAL LIGHTS USING LIGHT EMITTING DIODES**

by

J. D. Bullough, Z. Yuan and M. S. Rea

Lighting Research Center, Rensselaer Polytechnic Institute

Project No. FAA/05-C-AT-RPI    November 21, 2006

# White LED Runway Issue Timeline

- For white light, the study indicated:
  - White LED intensity should be reduced by a Brightness/Luminance factor of 1.6
  - Saturated light can appear less bright than de-saturated light when the two are viewed through fog
- Therefore, to attempt to resolve the white light glare issue, intensity should be reduced in the lower CCR steps (clear night) and may not need to be reduced in the higher steps (fog)

# White LED Runway Issue Timeline

- RDU revised dimming curve testing
  - CCRs were manually adjusted such that the light output in B1 was 0.7% (original level was 1.0%)
  - “More of a getting used to problem”
- Ultimately, the testing at RDU indicated it was appropriate to lower the dimming curve
- EB67C updated December 29, 2010 to include reduced white intensity settings for steps B1 and B2
- Moratorium rescinded Jan 3, 2011

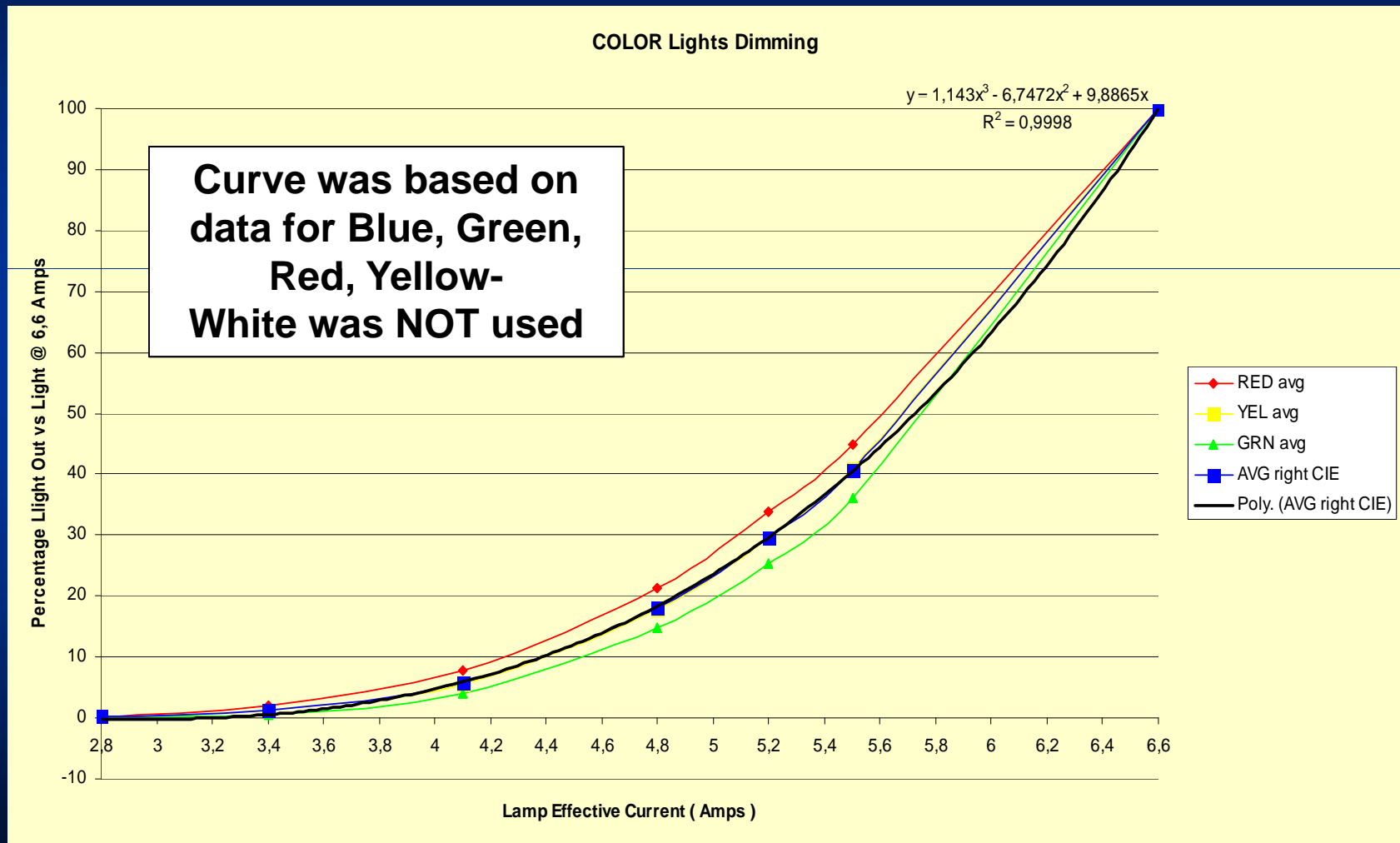


## Draft EB67C Discussion

- During industry discussion on possible EB67C changes, a number of interesting issues were raised
- Why is the glare issue more prominent with white LEDs?
- A: FAA Engineering Brief 67 was created in 2004 by a committee of industry experts. At that time, no white High Intensity LEDs were even close to being bright enough for HI airfield applications
  - $\therefore$  the dimming curve did not include white

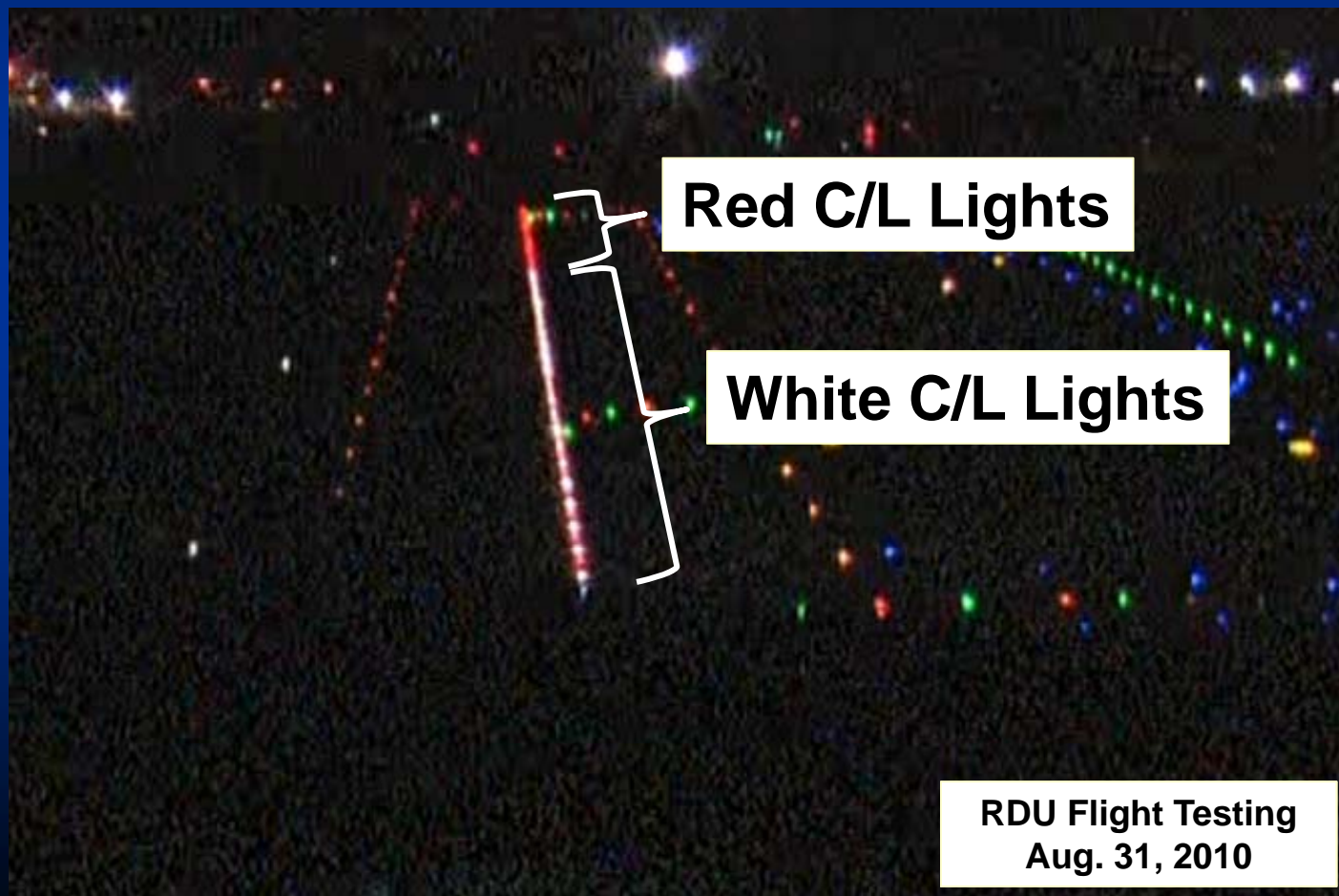
**Example of Original  
2004 Data from EB67  
Industry Discussion on  
Dimming Curves**

## Average Taxiway Light Dimming Curve for all Color Filters (incl. Dichroic & Absorption)



## Draft EB67C Discussion

- Why is the glare issue more prominent with white LEDs?
- It is interesting to note that no glare issues have been reported with the red side of the runway centerline lights

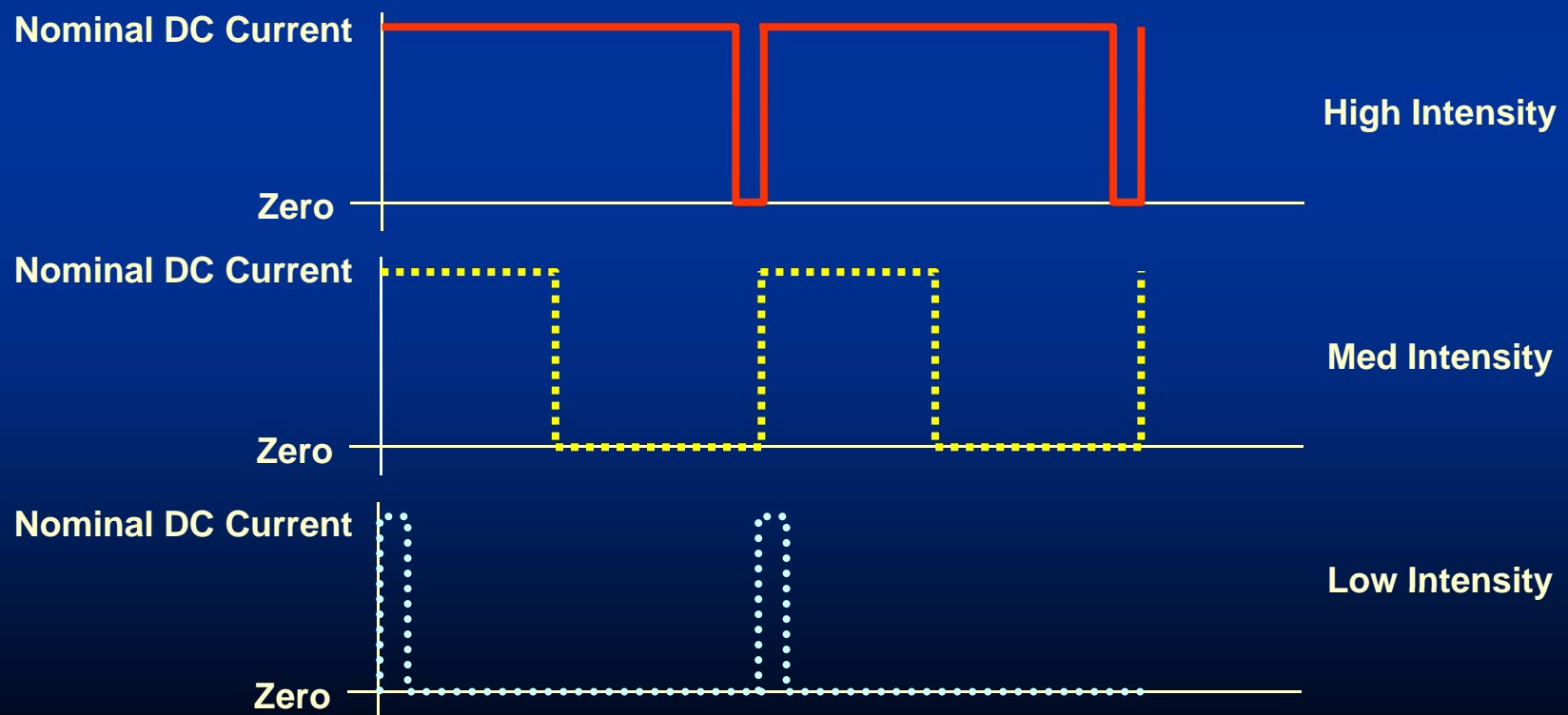


## Draft EB67C Discussion

- Is it technically feasible to dim white LEDs to such extremely low levels?
- This concern had merit depending on how light intensity is reduced
- There are 2 methods:
  - Constant current reduction

## Draft EB67C Discussion

- Is it technically feasible to dim white LEDs to such extremely low levels?
- There are 2 methods:
  - Pulse Width Modulation (PWM): Vary width of ON time at a high frequency, but (when ON) current is at nominal level



## Dimming guidance from Lumileds

- Q: How low can you dim White HBLEDs?
- A: YES you can DIM LEDs down to very low levels as low as 0.1% but the method required would be to use PWM as Constant Current Reduction methods will only be useful down to about 10%.
- Q: What is the effect on color for white LEDs when dimming down to a very low levels?
- A: Dimming does effect chromaticity slightly, but PWM inherently produces the very least chromaticity shift effect.

## Draft EB67C Discussion-

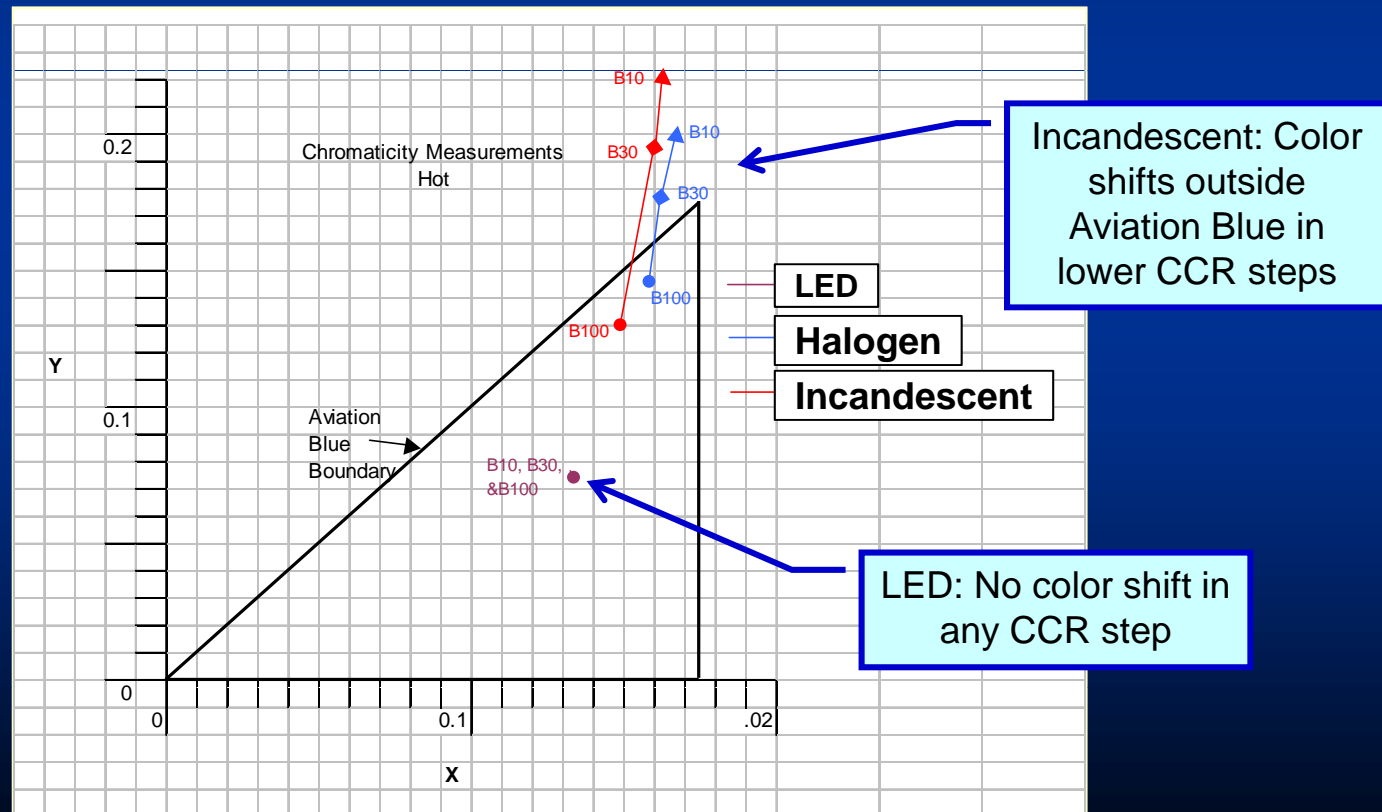
Is it really a problem or only a perception issue?

- Reports of complaints were so few compared to many thousands of operations at RDU and other airports (such as DFW)

## Draft EB67C Discussion- Is it really a problem or only a perception issue?

- Is this just a different look? Incandescent lights often have a large variation of light & color, esp. at lower step settings. LEDs stay consistent.

Note: Per specification requirements, color is tested only in high intensity





## Draft EB67C Discussion-

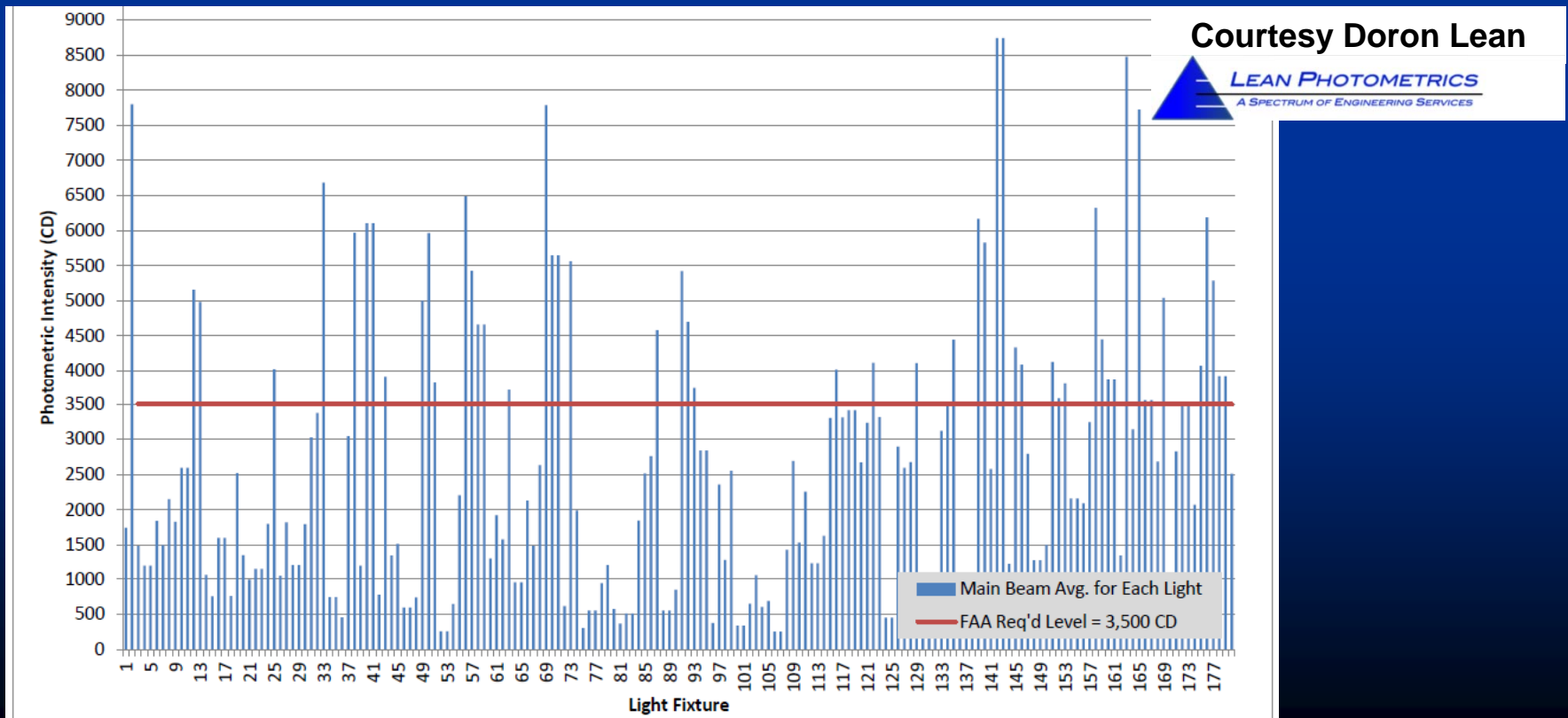
Is it really a problem or only a perception issue?

- Compared to what?
  - Often new LED fixtures are being compared to dirty/old fixtures; abraded lens

# Draft EB67C Discussion-

## Is it really a problem or only a perception issue?

- Compared to what?
  - In some cases, lamps may not be changed until they are dim. LEDs meet spec requirements for a longer period of time.



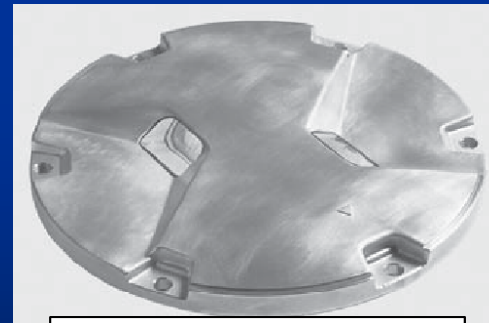
## Draft EB67C Discussion-

### Is it really a problem or only a perception issue?

- Introduction of new technology
  - “It looks different and seems to be brighter”
  - Similar comments were made many years ago when (for example) in-pavement taxiway centerline fixtures were changed from ductile iron using absorption filters to newer aluminum fixtures using dichroic filters



**Ductile Iron  
Absorption Filter**



**Aluminum  
Dichroic Filter**

## What has happened since the Moratorium was lifted?

- RDU
  - While RDU is waiting for funding to make modifications to equipment to change the dimming curve, they have been operating since May 2011 under a Mod to Standard with the LED C/L and TDZ intensity manually reduced
  - Since that time, RDU has reported that there have been no further pilot complaints

## What has happened since the Moratorium was lifted?

- A number of other airports have installed LED C/L & TDZ lighting in the US (B1 set at 0.5%; ~30% less than max white LED FAA limit of 0.7%)
- To assess the status, a survey of airports with White Runway LED Lighting was conducted
- Survey Questions:
  - When were the lights first operated?
  - What step are the lights normally operated in?
  - Has there been any pilot feedback (brightness/conspicuity)?

# Results of Airport Survey Responses

Airport	Oper. Since	Intensity (Night)	Comments
St. Augustine, FL RW Centerline	July 2011	Pilot controlled at night	"Nothing but positive comments from pilots about how nice they are seen from air on approach."
Tampa TDZ Runway 19L	May 2011	Step 1 or 2 3 - >5 mi.	"We have lots of ambient light and have had no comments about the fixtures."
Richmond, VA C/L and TDZ	Sept 2011	Step 1 or 2	"Pilots have had no complaints. The lights do not appear to be too bright or dim- they seem to be just right."
DFW C/L and TDZ	Dec 2009	Step 1 or 2 3 - >5 mi.	"Everything is OK- No problems reported."
Columbia, SC C/L and TDZ	May 2011	Low	"No complaints."

# Manchester LED Trials

- Trials on LED runway centerline lights are being conducted at Manchester Airport in the UK
- Trials conducted by a Technical Committee of the AOA (Airports Operators Association)
  - Chairman – Andy Dunn, Hd Electrical Infrastructure Team, Defense Infrastructure Organization, Professional and Technical Services
  - CAA
  - Airports - Heathrow, Gatwick, Manchester, Birmingham ...
  - Manufacturers - ADB, ATG, Safegate
  - Support Organizations - TMS Photometrics
  - Consultant - AJ Smith
  - AOA Representative

# Manchester LED Trials

- The Technical Committee was meeting during the same timeframe (Nov 2010) when the white LED issues were known at RDU
- The question they had was- what dimming curve should be used?
- It was decided to use the guidance in CAP 168 which already has a definition for the dimming curve for halogen lights

Safety Regulation Group



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**CAP 168**

**Licensing of Aerodromes**



# CAP 168 Dimming Curve

- The 6.6A CCR used for the trial has 6 steps and the % settings are 100%, 30%, 10%, 1%, 0.3%

**Table 6.6** AGL Luminous Intensity RMS Current Limits

Luminous Intensity		Current (amps)			Current (amps)			Current (amps)		
Setting %	Tolerance %	6.6	+	-	12.0	+	-	20	+	-
100	±9	6.6	6.7	6.4	12.0	12.18	11.64	20	20.4	19.62
80	±9	6.34	6.36	6.2	11.52	11.56	11.27	19.21	19.28	18.78
30	±20	5.35	5.76	5.26	9.72	10.47	9.56	16.21	17.45	15.90
10	±40	4.55	4.80	4.20	8.28	8.73	7.64	13.79	14.54	12.72
3	±40	3.89	4.05	3.70	7.08	7.36	6.72	11.79	12.27	11.21
1	±40	3.37	3.58	3.26	6.12	6.51	5.92	10.20	10.85	9.87
0.3	±40	2.90	3.18	2.76	5.28	5.78	5.01	8.79	9.64	8.36
0.1	±40	2.57	2.65	2.39	4.68	4.82	4.34	7.79	8.03	7.24
0	-	0	0	0	0	0	0	0	0	0

**NOTE:** The specifications contained in this table have been derived through consultation with equipment manufacturers.

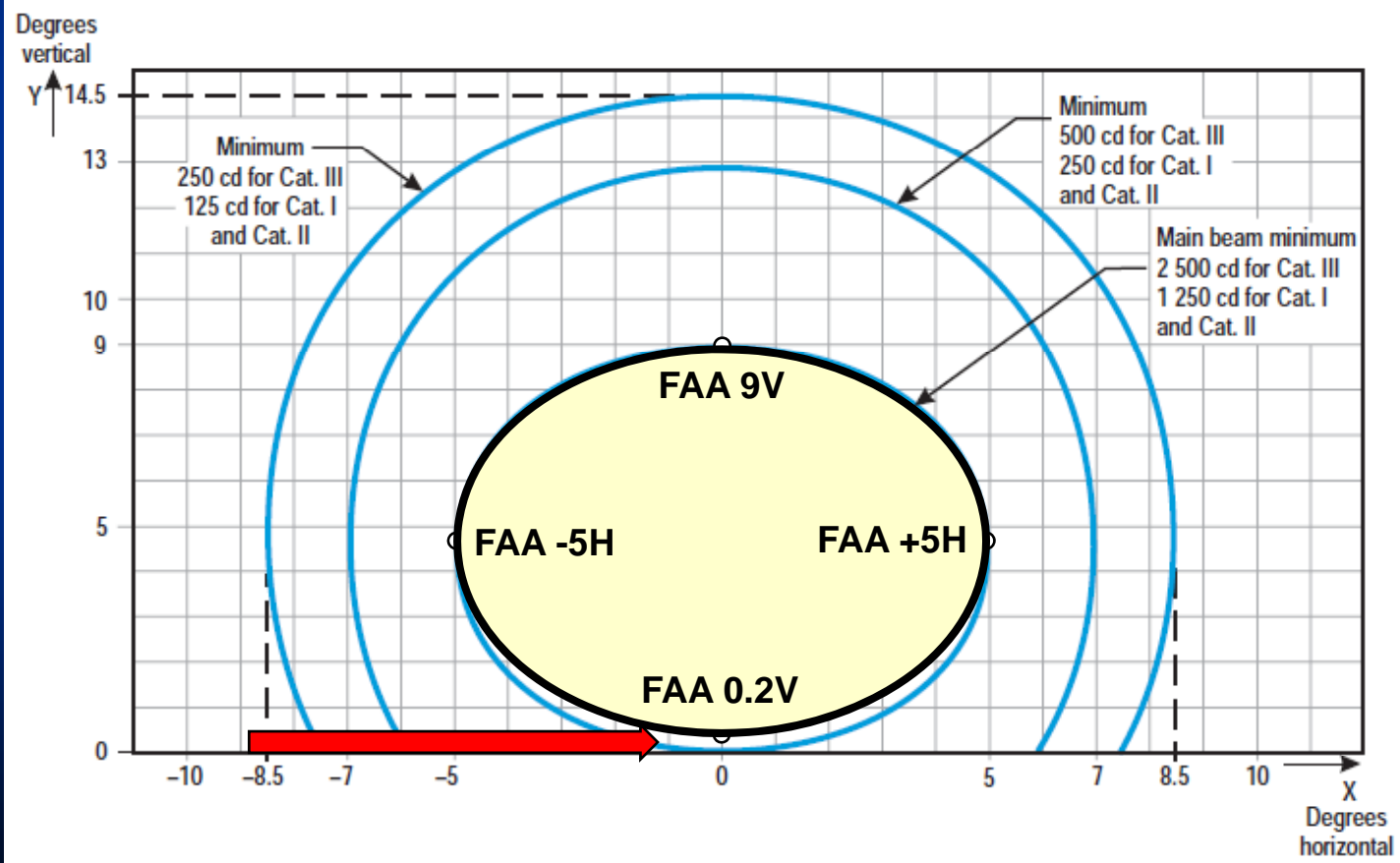
- Comparison of FAA vs. ICAO dimming curve
  - B1 nominal 0.3%; FAA 0.425%
  - B2 nominal 1%; FAA 1.5%

# ICAO vs. FAA Photometric Requirements

- Adopting a lower dimming curve for ICAO fixtures may also be a good idea because, for white runway centerline and TDZ fixtures, ICAO lights generally need to be ~10 to 15% brighter than FAA fixtures because:

# ICAO vs. FAA Photometric Requirements

- The bottom of the beam is at  $0^\circ$  for ICAO while it is at  $0.2^\circ$  for FAA



# ICAO vs. FAA Photometric Requirements

- Average intensity is calculated differently:
  - ICAO is calculated using the average intensity over the complete surface of the ellipse

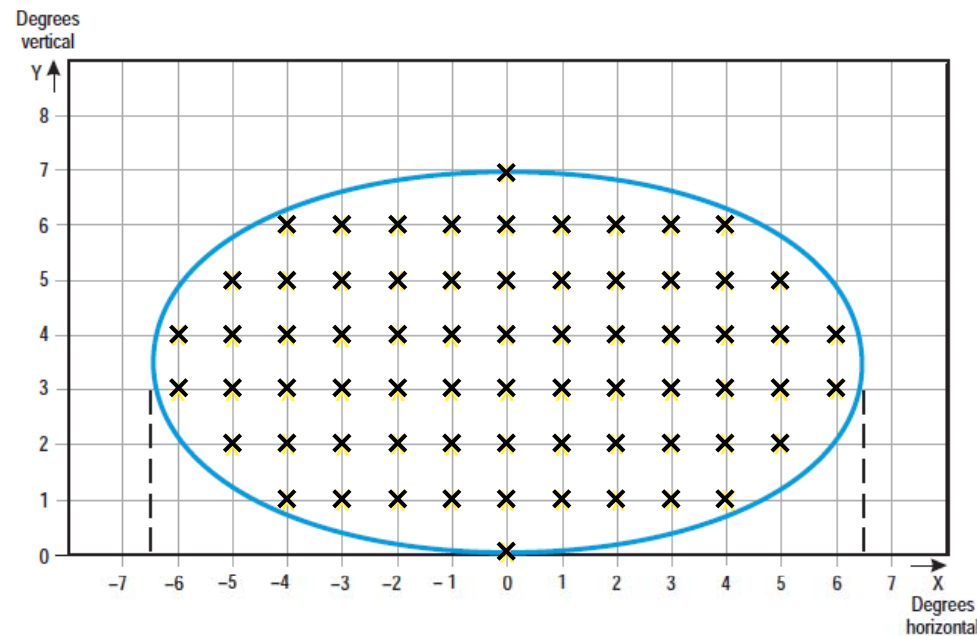
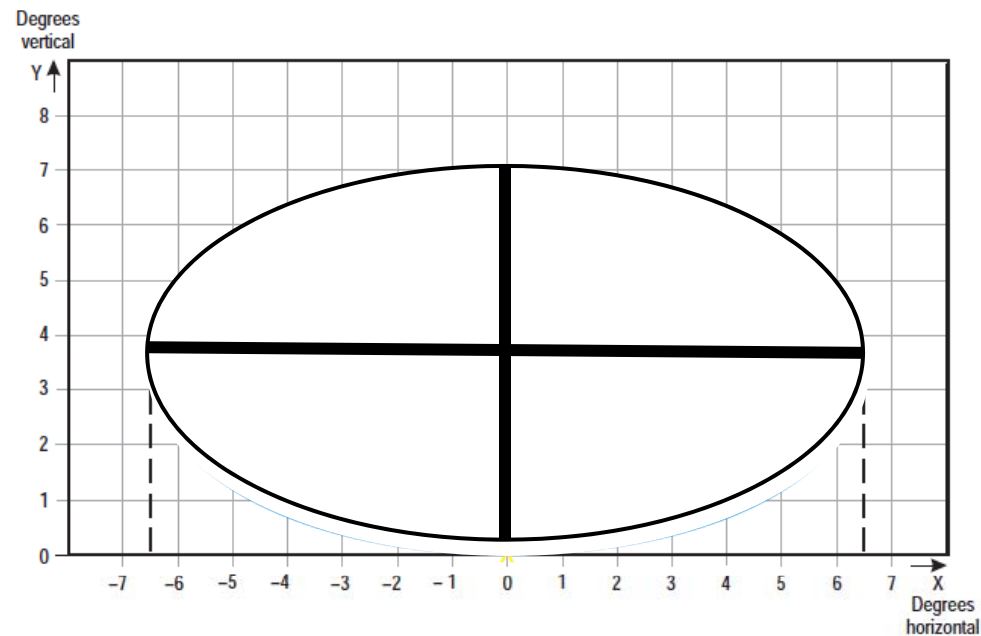


Figure A2-11. Grid points to be used for the calculation of average intensity of approach and runway lights

# ICAO vs. FAA Photometric Requirements

- Average intensity is calculated differently:
  - FAA is calculated using only vertical and horizontal cuts along the axes of the beam



**Figure A2-11. Grid points to be used for the calculation of average intensity of approach and runway lights**

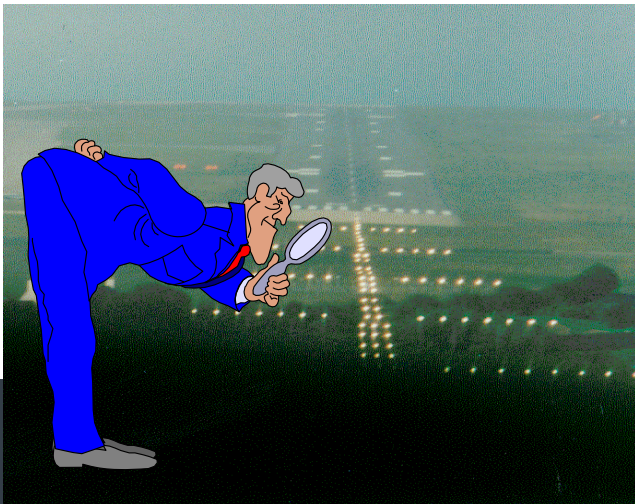


MINISTRY OF DEFENCE

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## **LED TRIAL AT MANCHESTER AIRPORT**

**Presented by Eur Ing A M Dunn BEng CEng MIEE MSLL**



Professional & Technical Services

# Manchester LED Trial RWY 23L

- Objective: To demonstrate LEDs can be used as the light source in HI RWY lights.
- AGL Service:
  - RWY Centre Line (White & Red) – 30M Spacing
  - 33 light units to be installed, first 1000m of RWY 23L. (28 units actually installed – remainder TH light sources.)
  - Secondary current 6.6A, Series Cct. Tx (100W) with directional control via switching unit
  - Installed in existing SR13 shallow base
- LED Light Unit: ADB Type 'DRC'

## **Reported Pilots' Remarks on LED installation**

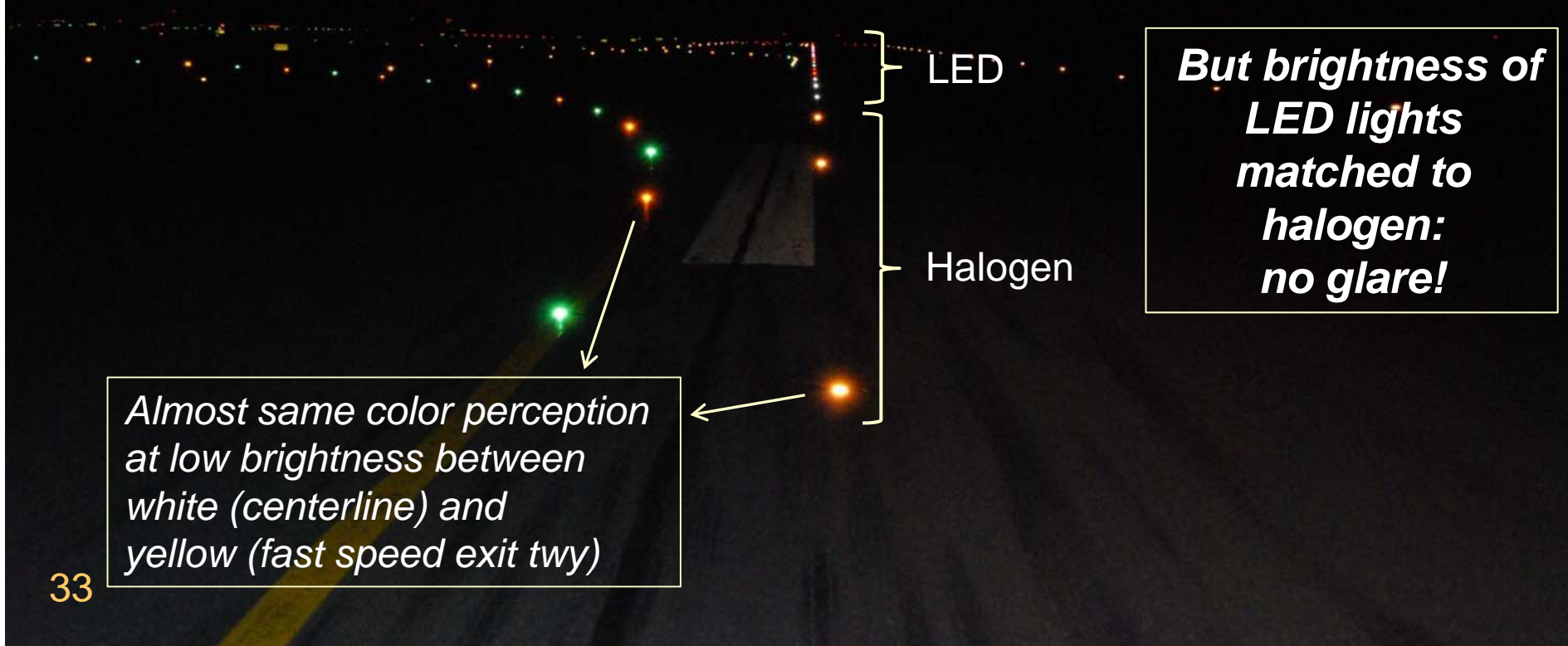
- **'LED'S are fantastic, purer white than other lights and probably don't need to be as bright as old ones'**
- **'LED lights better than previous lights'**
- **Pilot while vacating at VC asked if lights ahead were new LEDs and that they were very good. Later reported that they were bright but did not glare which would be excellent in LVPs**
- **'Really brilliant – crystal clear'**
- **'LEDs looked whiter than rest, crisp'**
- **'We like the lights by the way'**

**Slides Courtesy Andy Dunn**



# Better Centerline Color Discrimination

- In this example, LED runway centerlines would provide better color discrimination from the yellow high-speed turn off lights



# Status of Manchester Trials

- Operational since Feb 15, 2011
- Final report to be issued shortly



Manchester Trial



**Randolph County Airport, Indiana  
First LED Runway Edge MRL Installation  
November 2010**

## Medium Intensity Elevated Runway Edge/End Lighting LED L-861/L-861E

- A number of airports have implemented white elevated LED fixtures on Medium Intensity Runways (MIRL) beginning in Nov 2010
- There have been no reports of white light intensity issues. To verify, another survey was conducted.



**Randolph County Airport, Indiana  
First LED Runway Edge MIRL Installation  
November 2010**

# Results of Airport Survey Responses

Airport	Oper. Since	Intensity (Night)	Comments
Randolph County, IN	Nov 2010	Low unless lower vis	"So far, the landing lights are exceeding our expectations. Visibility wise, the landings are phenomenal. They are so much crisper than they were before."
Vero Beach, FL	Jan 2011	Medium	"Easier to see than incandescent." "More conspicuous, but not as glaring."
Merrill Field, AK	Late Nov 2010	Medium	"Have received positive feedback on the lights. Pilots are happy with the appearance of the lights."

# Results of Airport Survey Responses

Airport	Oper. Since	Intensity (Night)	Comments
Hollis, OK	Mar 2011	Low	"They show up better and pilots seem to like them better."
Raleigh Durham, NC GA RW 14-32	Dec 2010	Low unless lower vis	"No issues and no complaints."
Plant City, FL	July 2011	Low	"LEDs look nice. Have received no comments from pilots."

## Medium Intensity Elevated Runway Edge/End Lighting LED L-861/L-861E

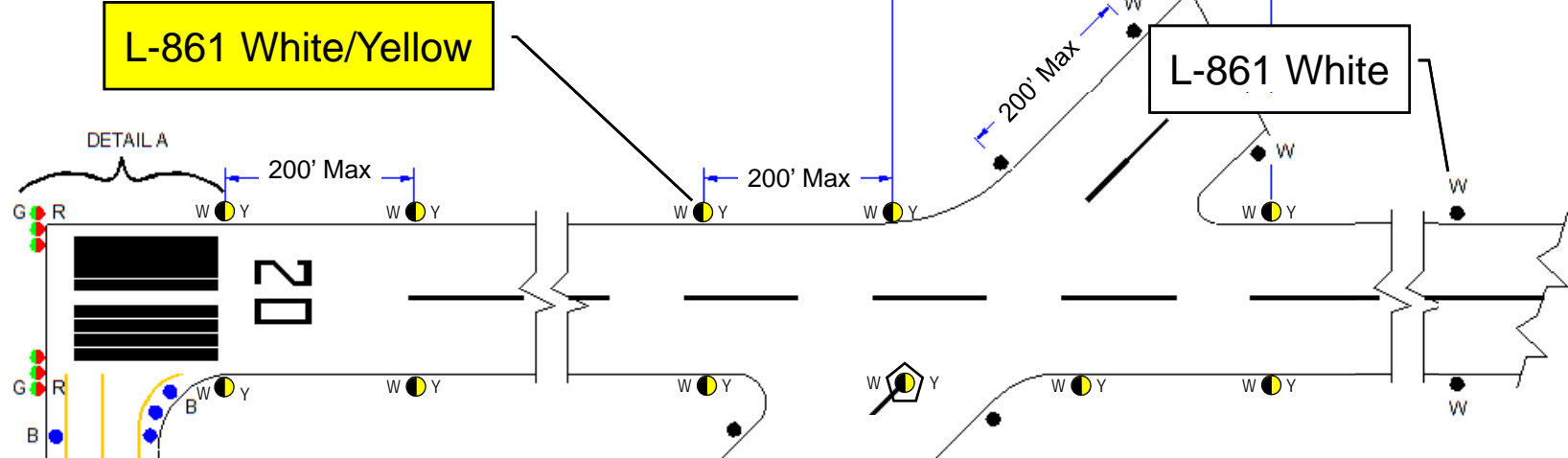
- A couple of application questions have come up regarding the use of MIREL LEDs

MIRL is used on  
visual runways or  
non-precision  
instrument runways

# Runway and Threshold Lighting

## MIRL Non-Precision Instrument Runways

AC 150/5340-30 Modified Fig. 2



White lights the entire length of the runway, except White/Yellow in the Caution Zone (the last 2,000 feet of runway, or one-half the runway length, whichever is less)

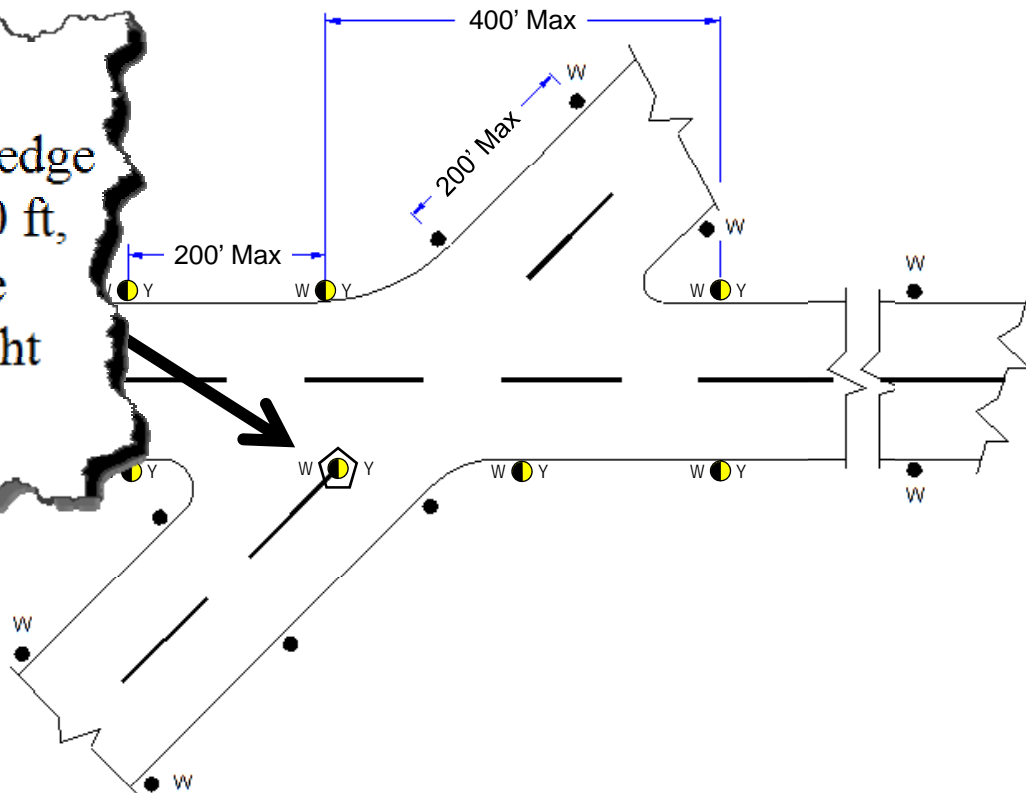
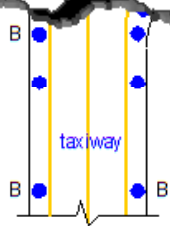


MIRL is used on  
visual runways or  
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## Runway and Threshold Lighting

MIRL Non-Precision Instrument Runways  
AC 150/5340-30 Modified Fig. 2

(Per -30E) For MIRL, if the distance between the runway edge lights units is greater than 400 ft, install an L-852D light fixture modified to produce white light (by removing the filters).



M  
vis  
inst



If LED, use L-852D  
emitting  
White/Yellow here

Raleigh Durham, NC  
GA Runway 14-32

ng  
ys



## MIRL Displaced Threshold Lighting

- Although not common, MIRL can have a displaced threshold

Since LED optics are better able to more precisely focus light output to comply with specification requirements, this light could look way dimmer than the other 3 green lights by a factor of  $300/46=6.5$ !

MIRL Displaced Threshold Lighting, if Elevated  
Ref: FAA AC 150/5340-30 Fig. 6

The yellow side is a continuation of the runway lights so it must be a L-861 which implies you should use L-861 Green/Yellow

The green bar is the beginning of the runway for landing airplanes, so these three lights must be: L-861E Uni-directional Green

L-861E Uni-Green is listed in the -46D and is 300cd

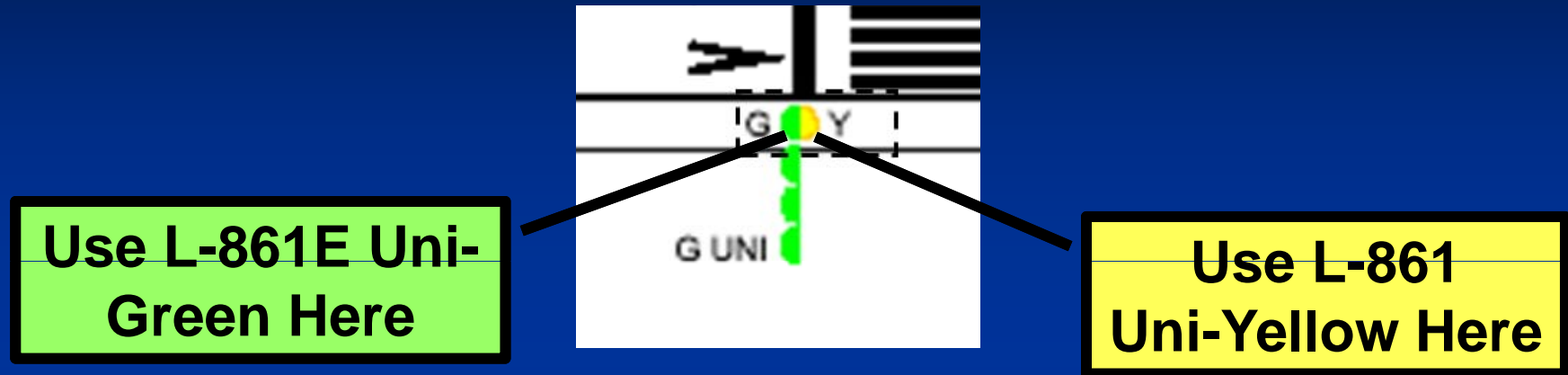
But, the L-861 Green in the -46D is only 46cd

Type	Notes	Minimum Beam Coverage (Degrees)				Intensity (candelas) (b)			
		Main beam (e)		10 percent (e)		White	Yellow	Green	Red
		H	V	H	V				
L-804	(f)	±8	±8	±25	±25		3,000 (g)		
L-861E	(d)	±1.5	3.5 to 5.5					300	
	(d)	±3	1.5 to 7.5					180	
	(d)	±5	0 to 9					90	10
L-861SE	(a)	±15	2 to 10	±20	-3 to 15			600	
	(d)	±5	0 to 9						20
L-862	(a)	-2 to 9	0 to 7	-4 to 11	-2.5 to 9.5	10,000	5,000	2,500	2,000
	(c)								
L-862E	(a)	±6	0.2 to 4.7	±7.5	-2.5 to 7.5				2,500
	(a)	-2 to 9	1 to 10					3,200	

Table 3. Photometric Requirements for Omnidirectional Elevated Lights.

Type	Color	Intensity (candelas) (a)		
		2 to 10 degrees		10 to 15 degrees
		Minimum	Minimum Average Intensity	Minimum
L-860	White	15	25	10
L-860E	Green	10	15	5
	Red	3	5	1
L-861	White	75	125	40
	Yellow	37	67	20
	Green	28	46	14
	Red (c)	3	5	1

## MIRL Displaced Threshold Lighting G/Y Solution

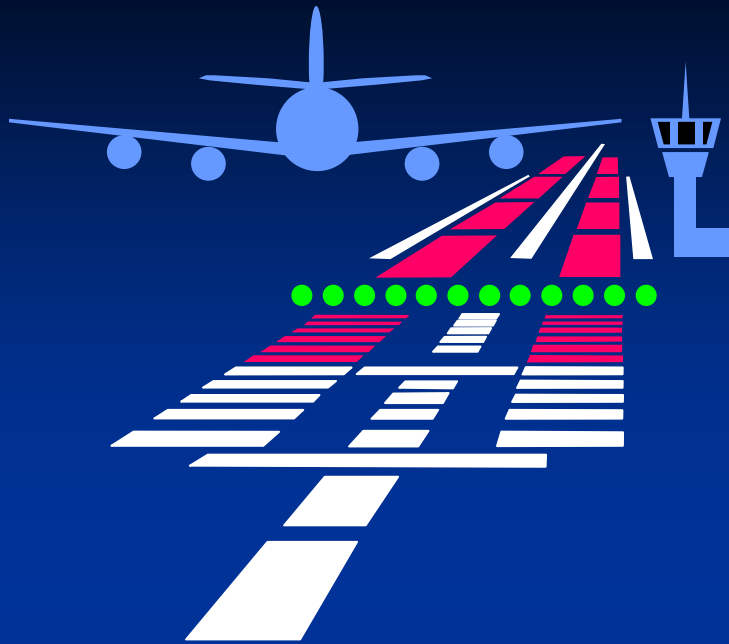


- These application questions have been coordinated with FAA for consideration for future clarification in the Advisory Circulars

## MIRL- Conclusion

- Since MIRL are operated on the top three CCR steps (white dimming of 100%, 34%, 14.8%), this tends to confirm that the brightness/glare issue with white LEDs is only associated with the bottom steps of the dimming curve





## Future Implementation and Issues with High Intensity Runway Edge Lighting

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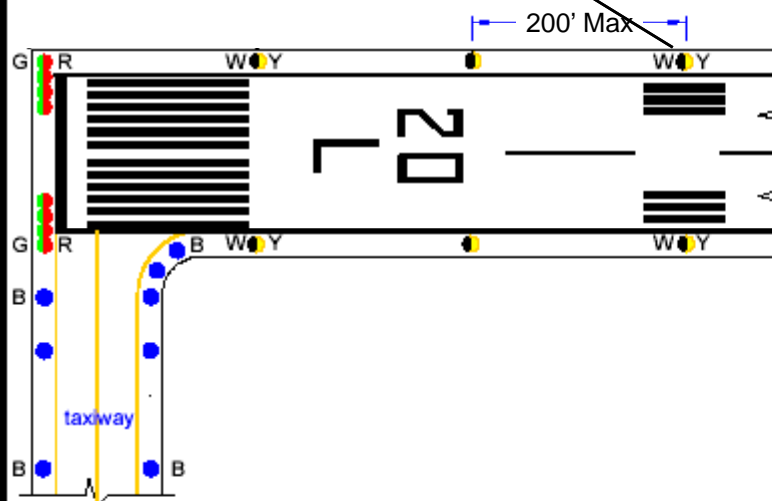
## High Intensity Runway Edge Lights

- Many airports that have installed LED runway in-pavement lights are asking when LED runway edge lights will be available
- Several manufacturers have shown high intensity runway edge lights (FAA L-862)
- It is anticipated that installations will begin in the next year
- But- there is an application issue to be aware of!

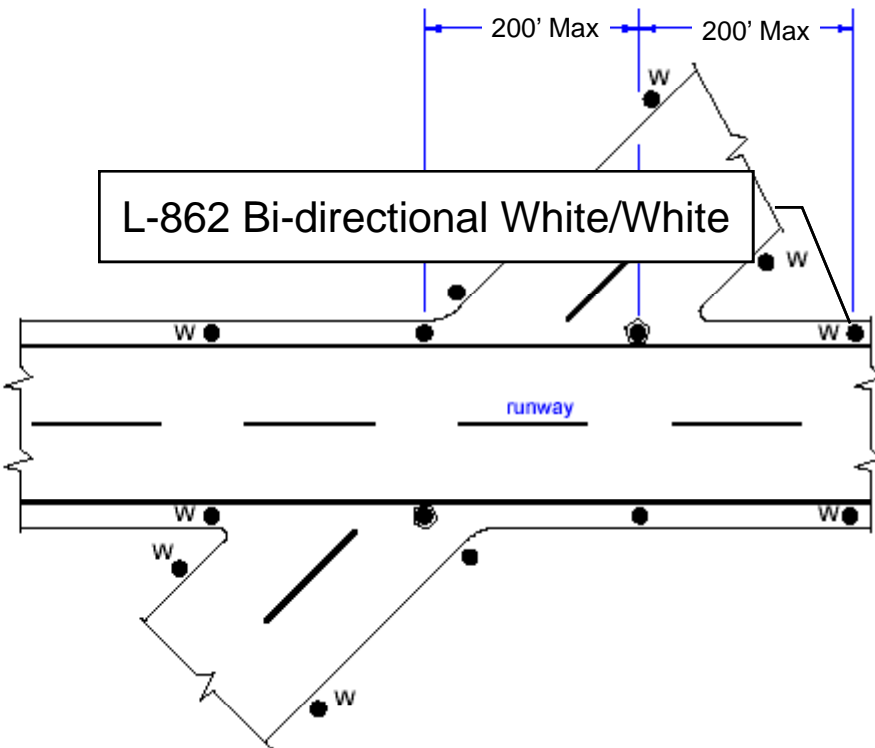


Runway and Threshold Lighting  
High Intensity Runway Lighting (HIRL)  
AC 150/5340-30 Fig. 3

L-862 White/Yellow



L-862 Bi-directional White/White

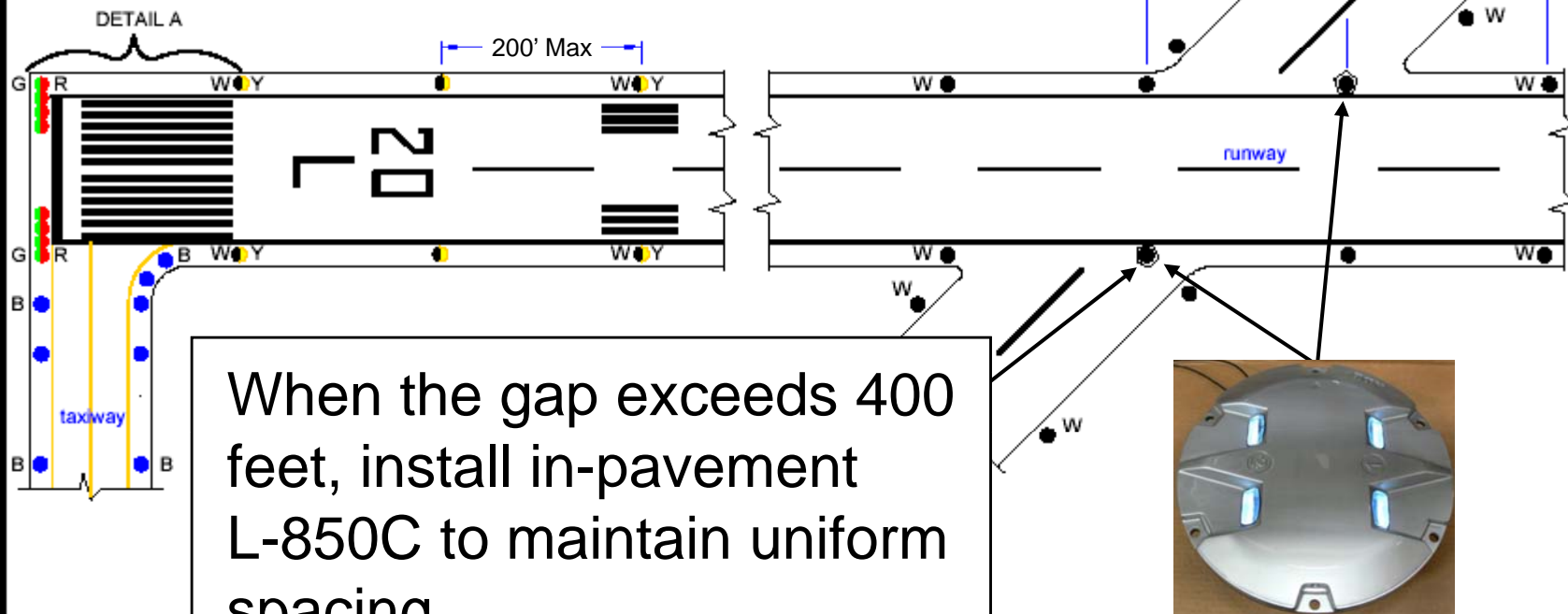


White lights the entire length of the runway, except White/Yellow in the Caution Zone (the last 2,000 feet of runway, or one-half the runway length, whichever is less)

# Runway and Threshold Lighting

## High Intensity Runway Lighting (HIRL)

AC 150/5340-30 Fig. 3

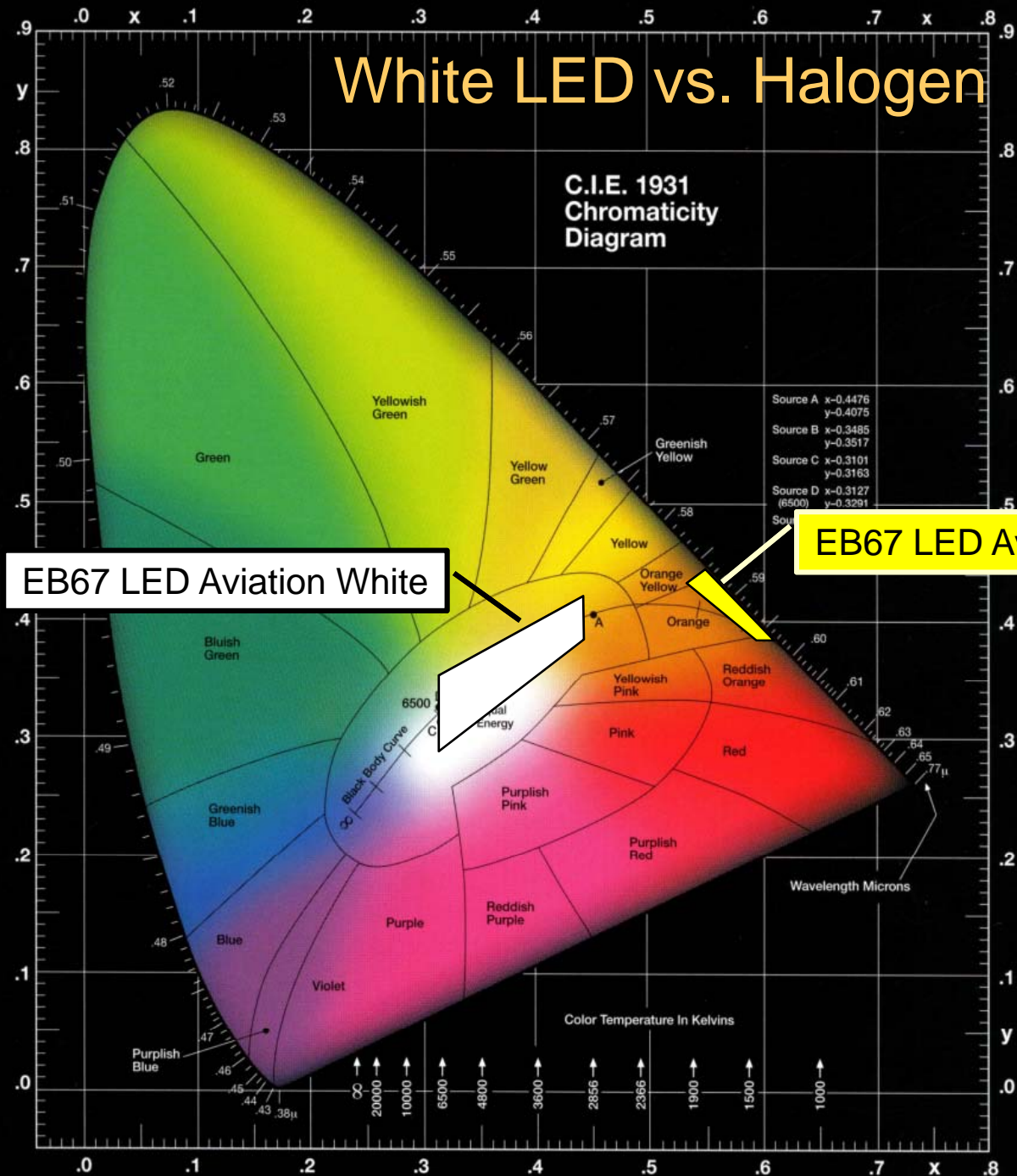


## Color Mismatch

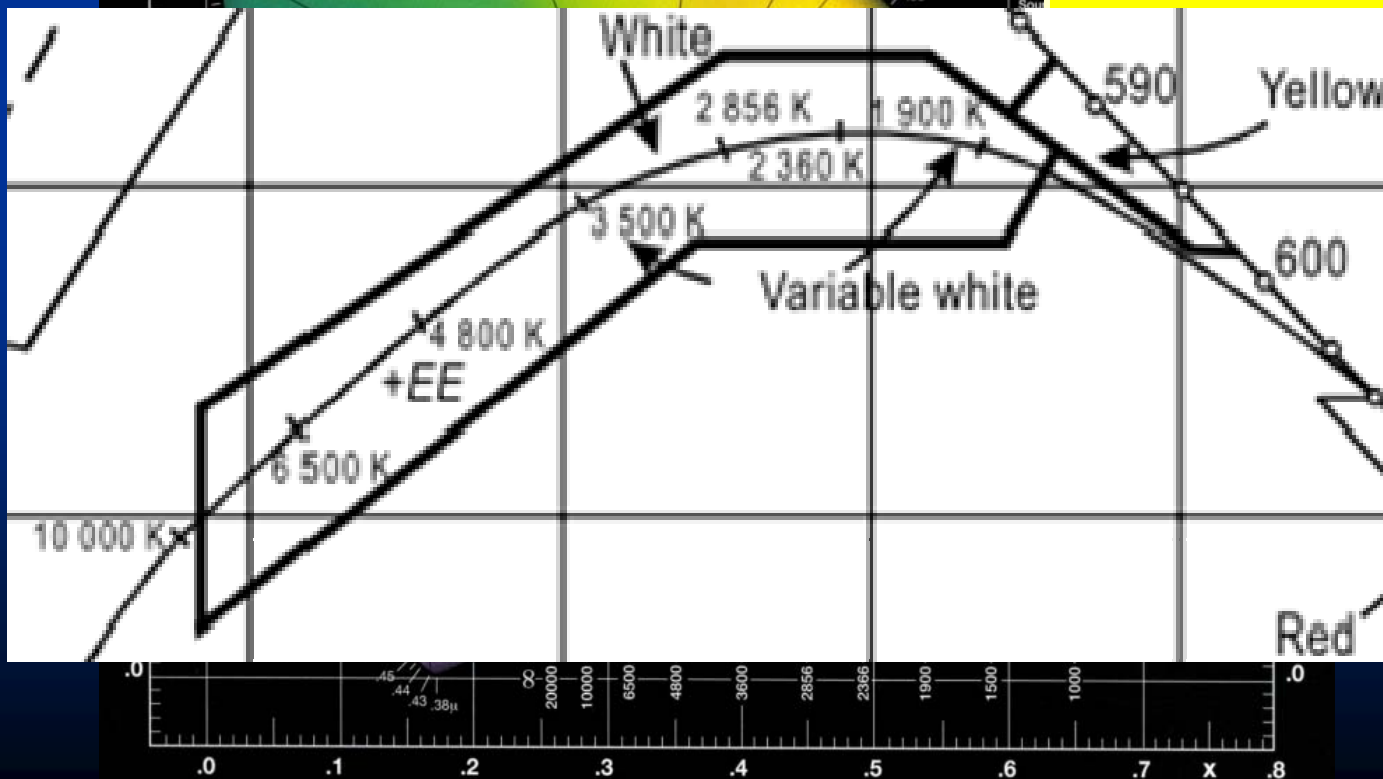
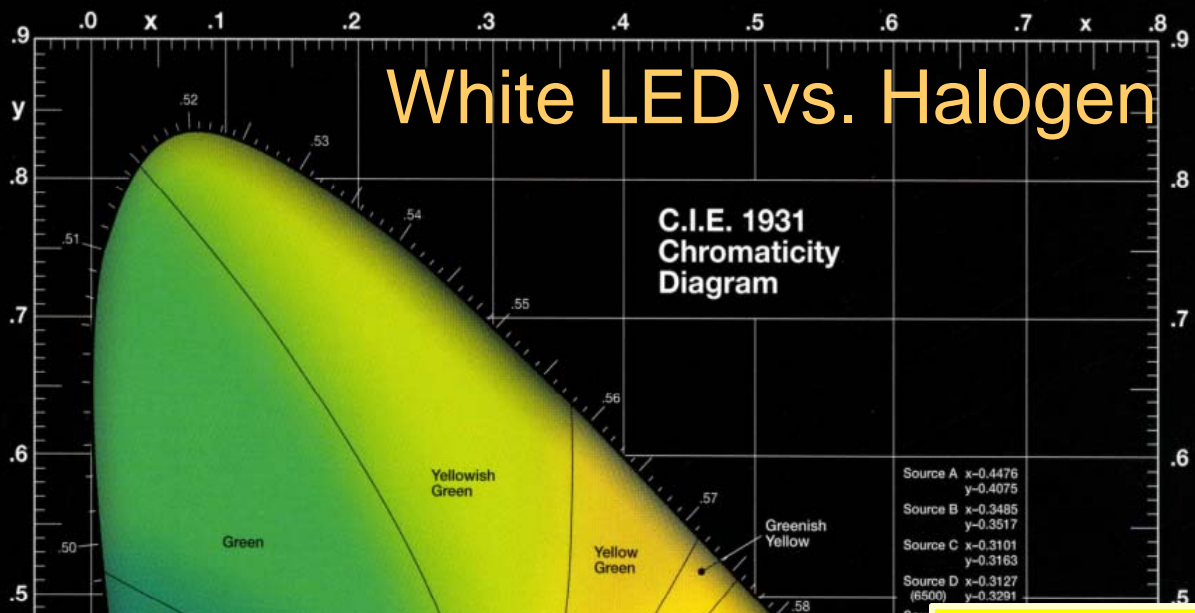
- It is even more important to avoid Color Mismatch between LED and Halogen for White Runway Edge Lights
- Here is some color data we took on some halogen fixtures:

	☀ 120W Halogen L-862		☀ 105W Halogen L-850C White	
STEP	CIE X	CIE Y	CIE X	CIE Y
1 (2.8A)	0.547	0.406	0.580	0.370
2 (3.4A)	0.513	0.417	0.550	0.380
3 (4.1A)	0.482	0.420	0.520	0.380
4 (5.2A)	0.449	0.412	0.490	0.380
5 (6.6A)	0.421	0.401	0.420	0.410

# White LED vs. Halogen

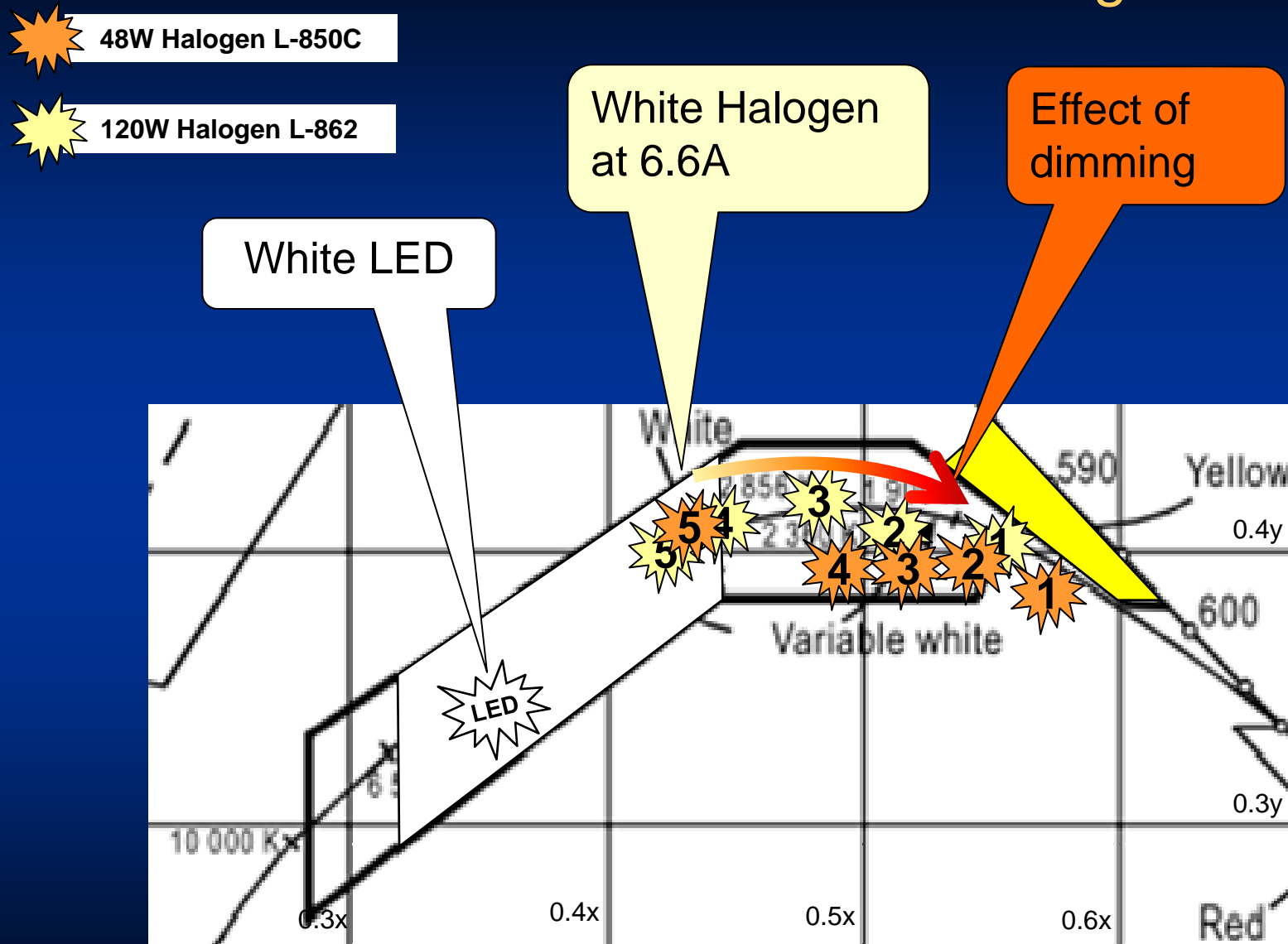


# White LED vs. Halogen



on Yellow

# White LED vs. Halogen



## Visual Comparison of LED vs. Halogen

- At low brightness, there is almost no difference between Yellow LED and White Halogen
- If LEDs are used on the runway edge, you would not want to intersperse halogen (L-862 or L-850C) to avoid pilot confusion in the lower intensity settings

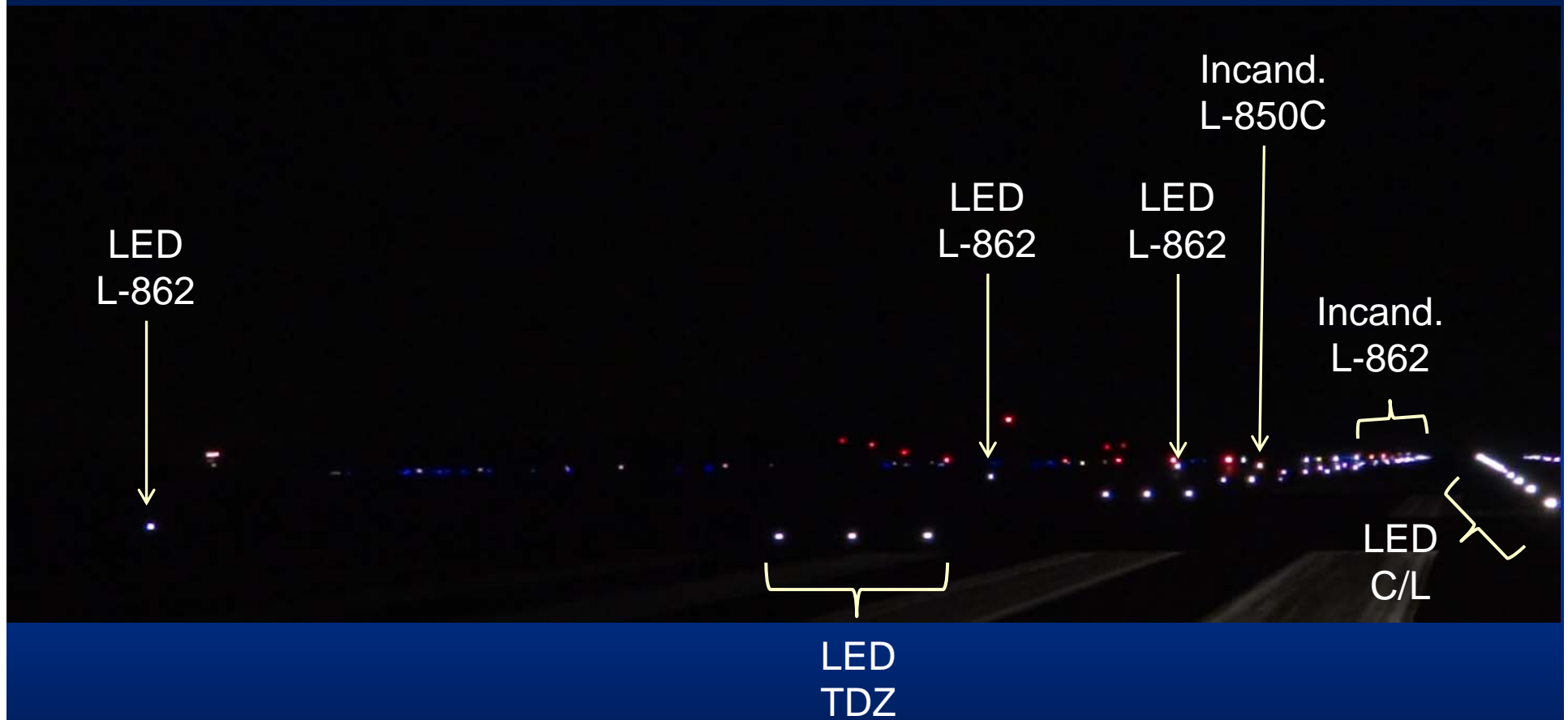


**HI Yellow LED  
Elevated**

**HI White  
Halogen  
In-pavement**

**HI White LED  
Elevated**

## LED L-862 Installation at RDU







## Conclusions

- Reducing the dimming curve for FAA white LED applications has, so far, shown to be effective
- Testing in the UK with a reduced dimming curve for runway LEDs with light output per ICAO requirements also has shown to be effective
- For runway edge applications, it is very important that the same technology (LED vs. incandescent) be used for all elevated and in-pavement lights
- User feedback on use of LEDs on runways (including Medium Intensity runway edge fixtures) has been overwhelmingly positive
  - Conspicuity (Safety)
  - Reduced need to close down a runway, reducing risk of runway incursions (Safety)
  - Better Color discrimination- no color shifts (Safety)

# QUESTIONS?

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