Challenges of Meeting Aviation Color Requirements with LED Light Sources

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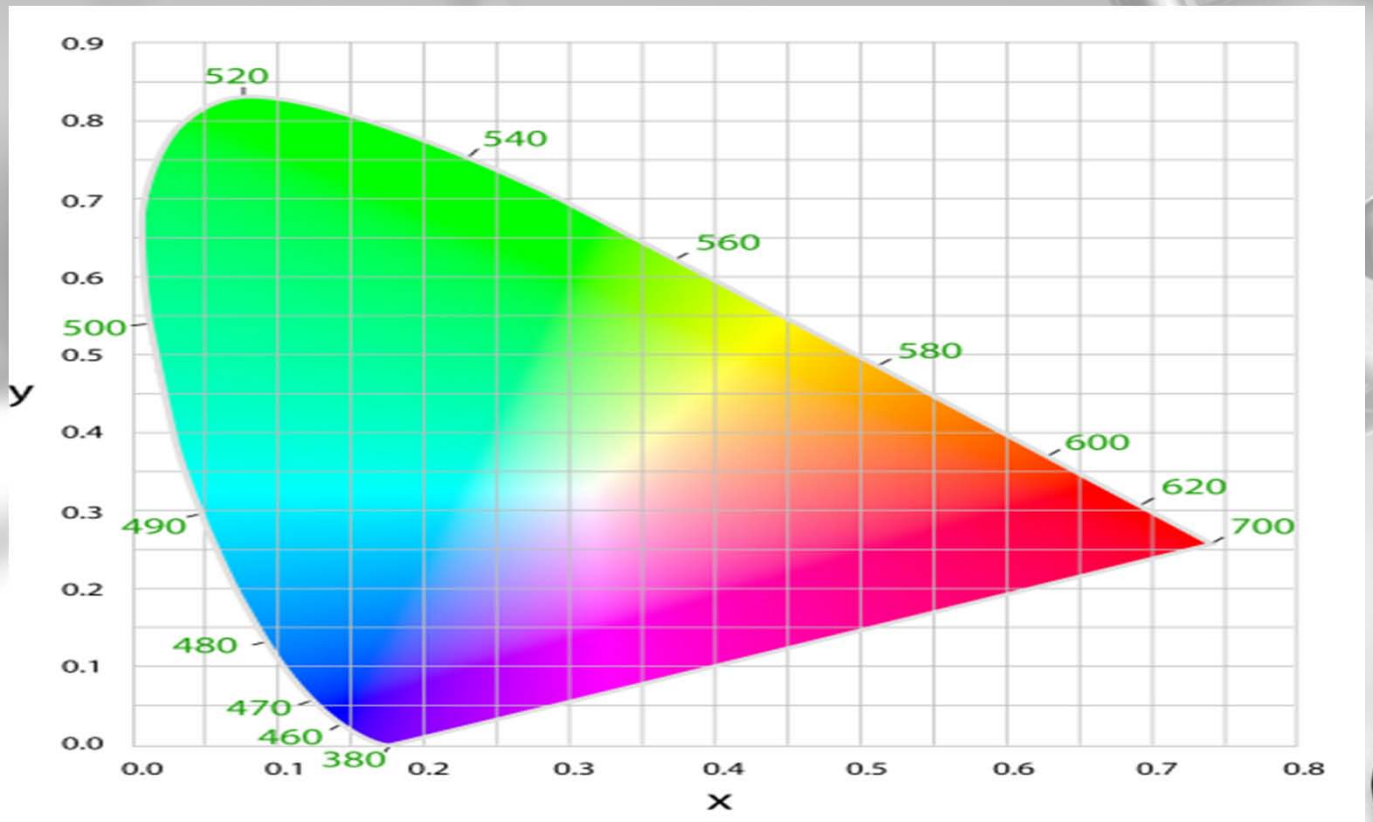
Outline

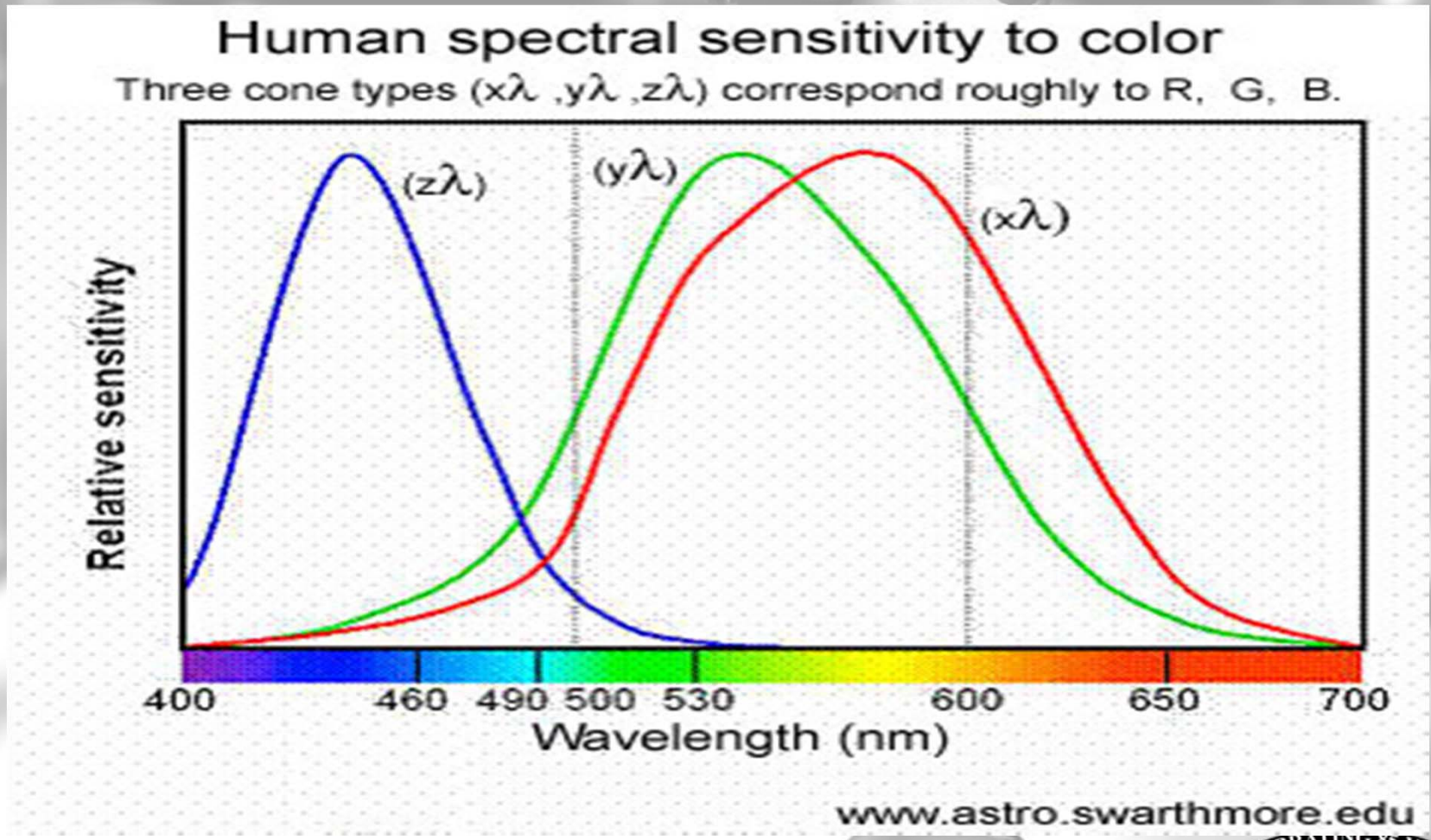
- Chromaticity Background
- Aviation Specifications
- LED/Glass Results
  - White, Green, Blue, Red, Yellow
- Conclusions

Chromaticity

- The CIE (Commission Internationale de l'Eclairage), in 1931, they developed the first standard for designating and matching colors.



Chromaticity: Human Eye Response



Chromaticity: Human Eye Response

- Color coordinates x, y, and z are calculated from the tristimulus values X, Y, and Z.

$$X = K \sum P(\lambda)\, X(\lambda)\, T(\lambda)\, \Delta(\lambda) \qquad \lambda = 380\text{nm to } 780\text{nm}$$

$$Y = K \sum P(\lambda)\, Y(\lambda)\, T(\lambda)\, \Delta(\lambda)$$

$$Z = K \sum P(\lambda)\, Z(\lambda)\, T(\lambda)\, \Delta(\lambda)$$

- Where:
  - $P(\lambda)$ → light source power at wavelength
  - $X(\lambda)$, $Y(\lambda)$, and $Z(\lambda)$ → eye response at wavelength
  - $T(\lambda)$ → Filter Transmission at wavelength
  - $\Delta(\lambda)$ → Wavelength difference
  - K → a constant that divides out for x, y, and z

- Therefore:

  The coordinates of x, y are decimal percentages of the total color for red, green, and blue.

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Aviation Specifications

SAE AS25050

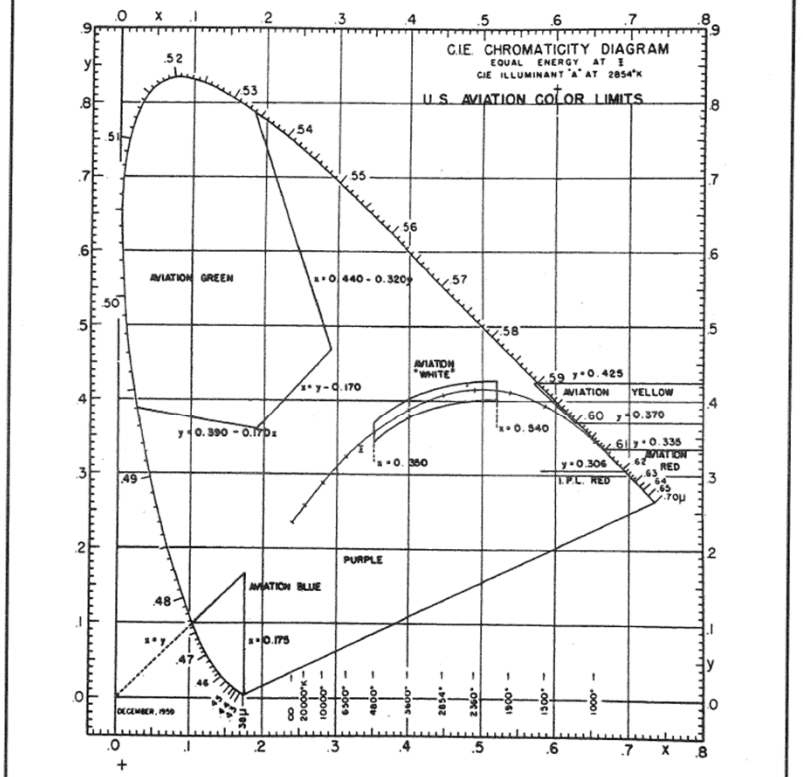

FIGURE 1. C.I.E. Mixture diagram showing aviation color limits

3.1 Aviation colors:

Standards for aviation colors shall conform to the following fundamental colorimetric definitions. In figure 1, these limits are shown graphically in the coordinate system of the International Commission on Illumination (C.I.E.) in which they are stated numerically. Figure 2 is a transformation of figure 1 which the spacing of the colors more nearly corresponds to their apparent differences in chromaticity as seen by an average observer. (Reference: Journal of the Optical Society, Vol. 29, page 370; September 1939.) (See 6.3.1.)

3.1.1 Aviation red, type I(a), is any color for which:

y is not greater than 0.335, and
z is not greater than 0.002.

3.1.2 Instrument and panel lighting red, type I(f) is any color which:

y is not greater than 0.306
z is not greater than 0.001.

3.1.3 Aviation yellow, type I(b), is any color which: 1/

y is not less than 0.370, or greater than 0.425, and
z is not greater than 0.007.

3.1.4 Aviation green, type I(c), is any color for which:

x is not greater than 0.440 - 0.320 y, or greater than y - 0.170, and
y is not less than 0.390 - 0.170 x.

1/ The chromaticity requirements for aviation yellow are adjusted to require the same type of glass as identification yellow, but allowance is made for the difference in color temperature ranges of the lamps.

FAA - Engineering Brief 67 D

U.S. Department of Transportation

Federal Aviation Administration

Memorandum

Subject:	**INFORMATION:** Engineering Brief 67D Light Sources Other Than Incandescent and Xenon For Airport and Obstruction Lighting Fixtures	Date:	**Jun 27, 2011** **DRAFT**
From:	Manager, Airport Engineering Division, AAS-100	Reply to Attn. of:	
To:	All Regions Attn: Manager, Airports Division		

Engineering Brief 67C provides additional requirements for light sources other than incandescent and xenon technologies subject to certification under Advisory Circular 150/5345-53, *Airport Lighting Equipment Certification Program*, and other applicable documents as required. It includes the required specific test and design requirements for alternative light sources that will be used in certified airfield lighting fixtures. This Engineering Brief ensures these new lighting technologies are seamlessly integrated with existing lighting technologies on the airfield.

Airfield Lighting Equipment Manufacturers employing alternative light sources in equipment certified under Advisory Circular 150/5345-53 must meet the requirements contained in each applicable AC. The third party certification activity must verify the airfield lighting manufacturers' equipment meets the design and operational provisions as dictated by changing illuminating technology.

This DRAFT includes the incorporation of comments and additional clarification on warranty and chromaticity.

Michael T. McNerney

Attachment

1

FAA - Engineering Brief 67D

2.1.1 Aviation Chromaticity Boundaries — All fixtures must meet the following chromaticity boundaries.

Boundary Equations:

White:

Green boundary: y = 0.643x + 0.150
Blue boundary: x = 0.320
Purple boundary: y = 0.757x + 0.050
Yellow boundary: x = 0.440

Yellow:

Green boundary: y = 0.727x + 0.054
White boundary: y = 0.980 – x
Red boundary: y = 0.387

Red:

Yellow boundary: y = 0.320
White boundary: y = 0.980 - x
Purple boundary: y = 0.290

Green:

Blue boundary: y = 0.768 – 1.306x
White boundary: y = 0.600
Yellow boundary: y = 3.470 – 9.200x

Blue:

Green boundary: y = 0.805 + 0.065
White boundary: y = 0.400 - x
Purple boundary: y = 1.668x – 0.222

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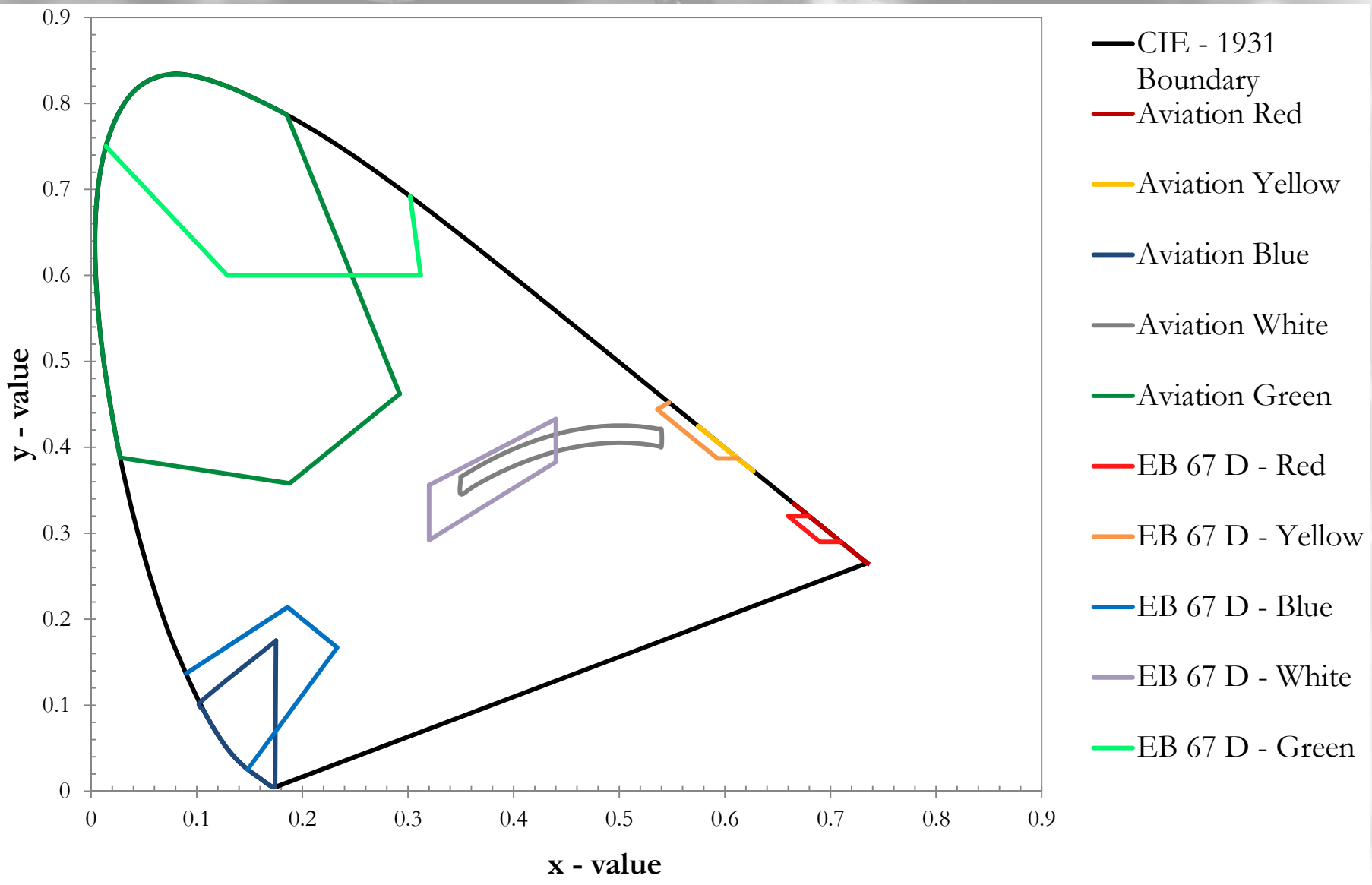
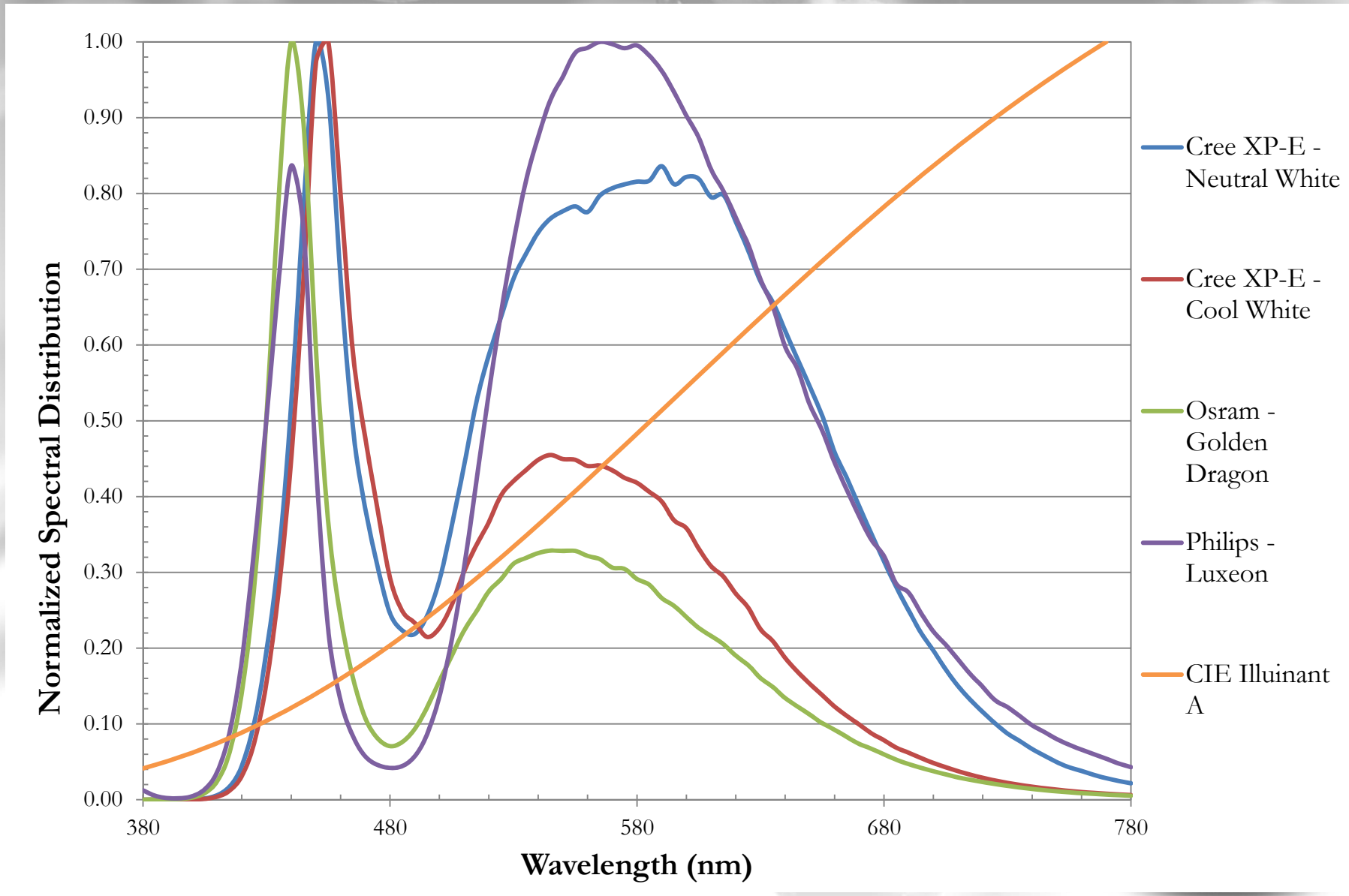
FAA - Engineering Brief 67D



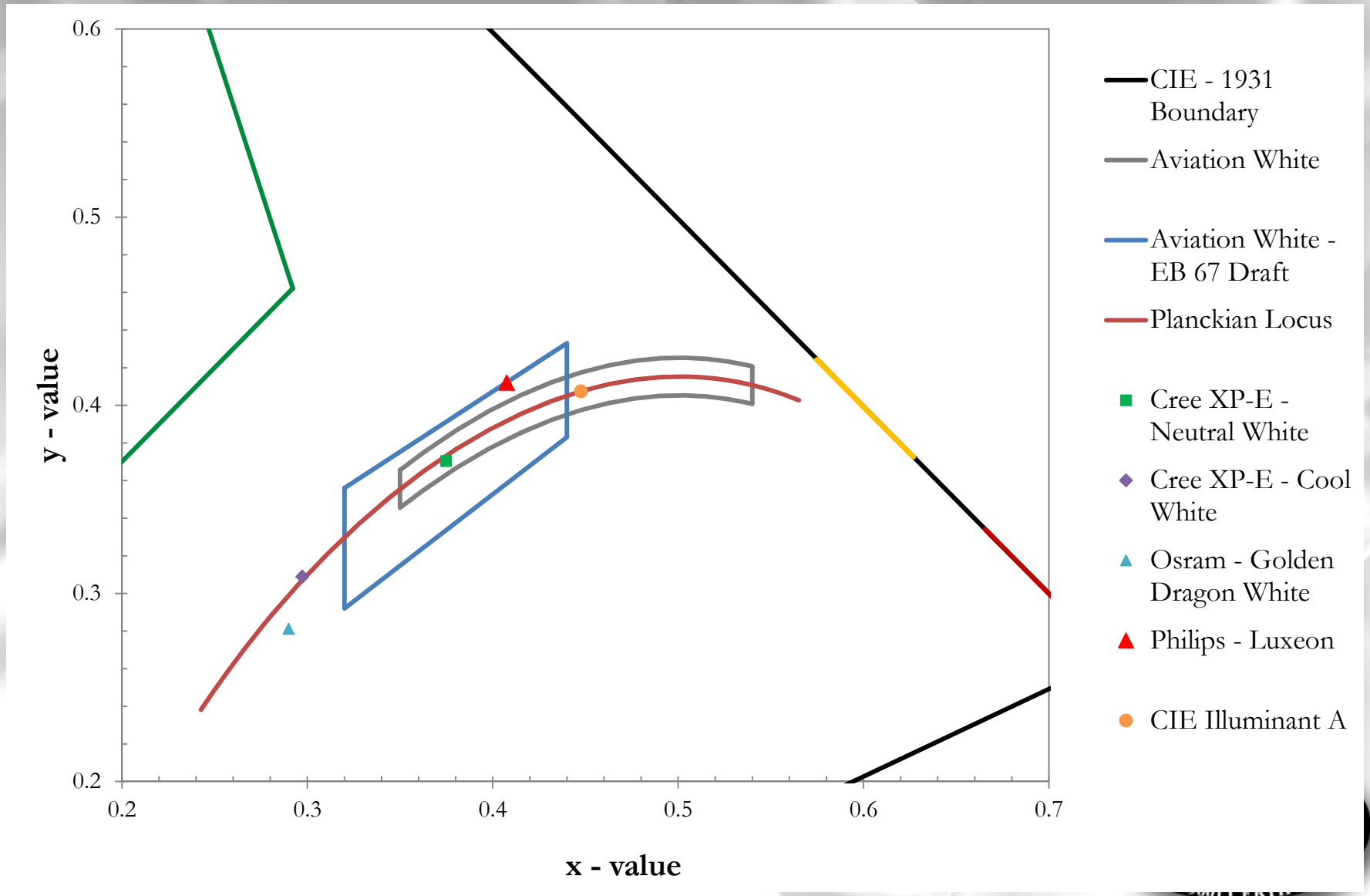
White Light Sources



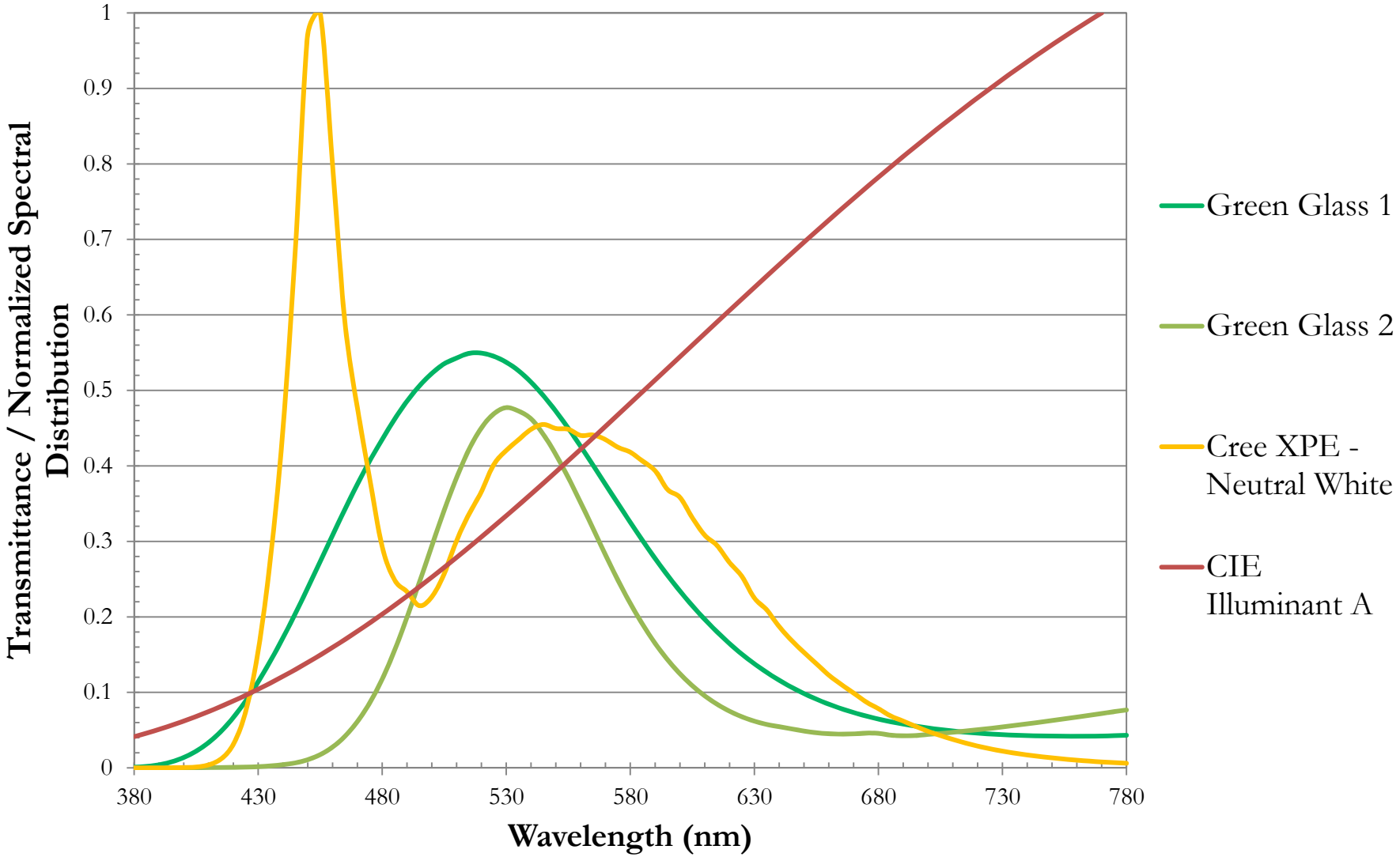
Incandescent vs. LED

Light Source	x - value	y-value	Color Temperature (K)
Cree XP-E Neutral White	0.3749	0.3703	4100
Cree XP-E Cool White	0.2973	0.3089	7740
Osram - Golden Dragon	0.2899	0.2812	9350
Phillips - Luxeon	0.4075	0.4120	3620
CIE Illuminant A	0.4476	0.4074	2854

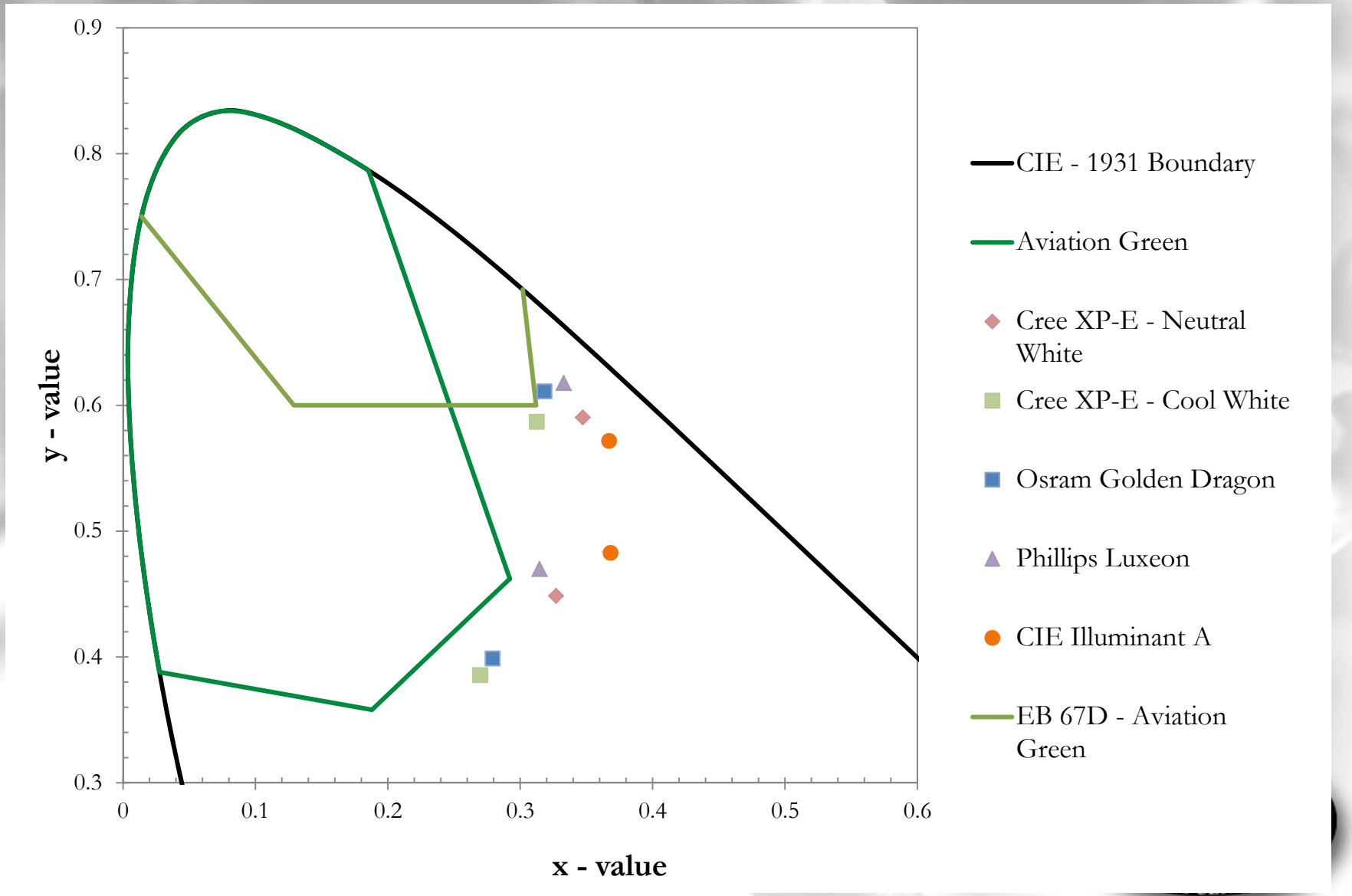
Incandescent vs. LED



Aviation Green



Aviation Green



Aviation Green

Light Source	Glass Color	x-value	y-value	Tranmission (%)
Cree XP-E - Neutral White	Green 1	0.347	0.590	28.5
	Green 2	0.327	0.449	37.8
Cree XP-E - Cool White	Green 1	0.312	0.587	30.2
	Green 2	0.270	0.386	40.0
Osram - Golden Dragon	Green 1	0.318	0.611	30.8
	Green 2	0.279	0.399	40.1
Philips - Luxeon	Green 1	0.333	0.618	30.8
	Green 2	0.315	0.470	39.7
CIE Illuminant A	Green 1	0.367	0.572	26.0
	Green 2	0.368	0.483	35.4

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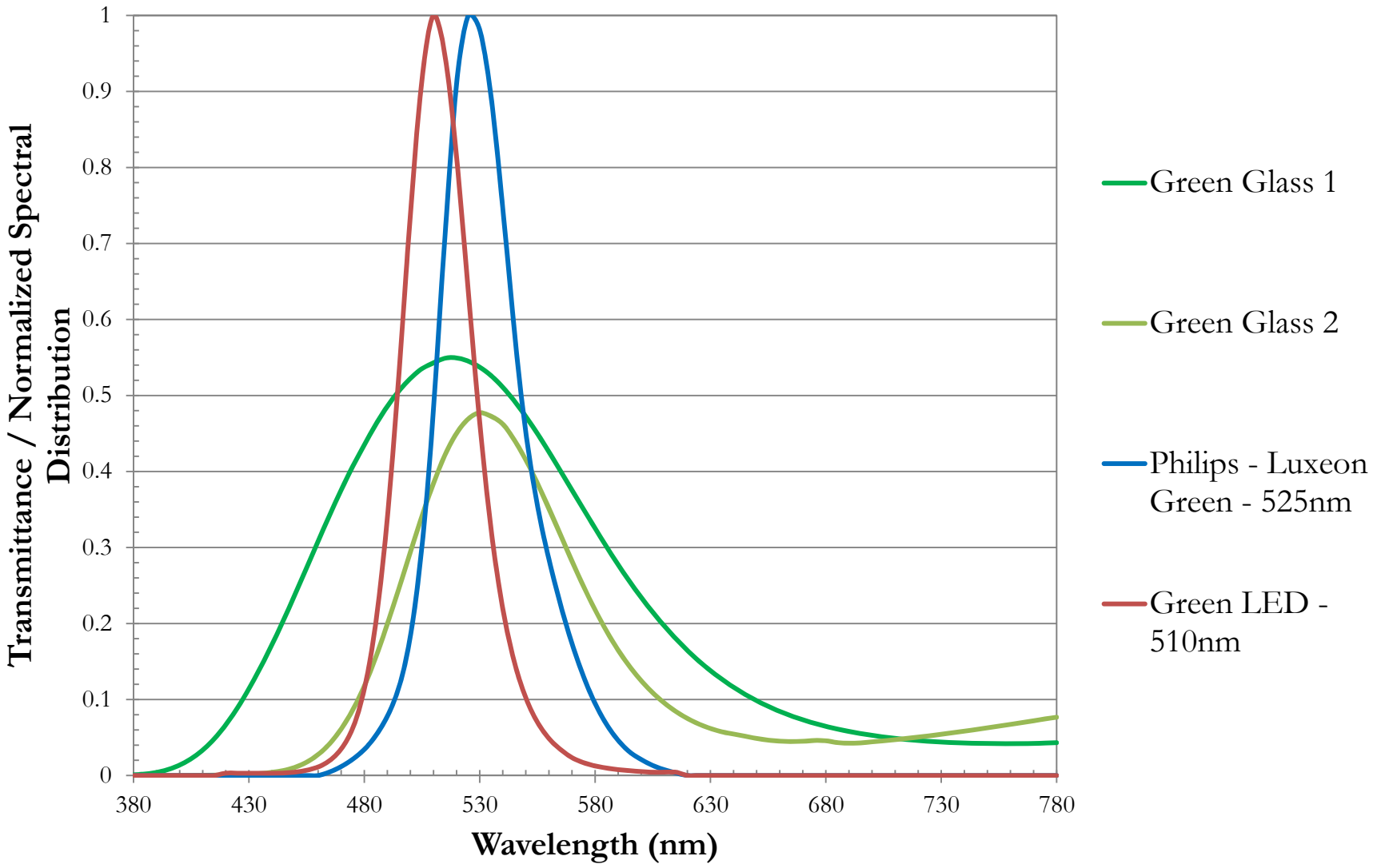
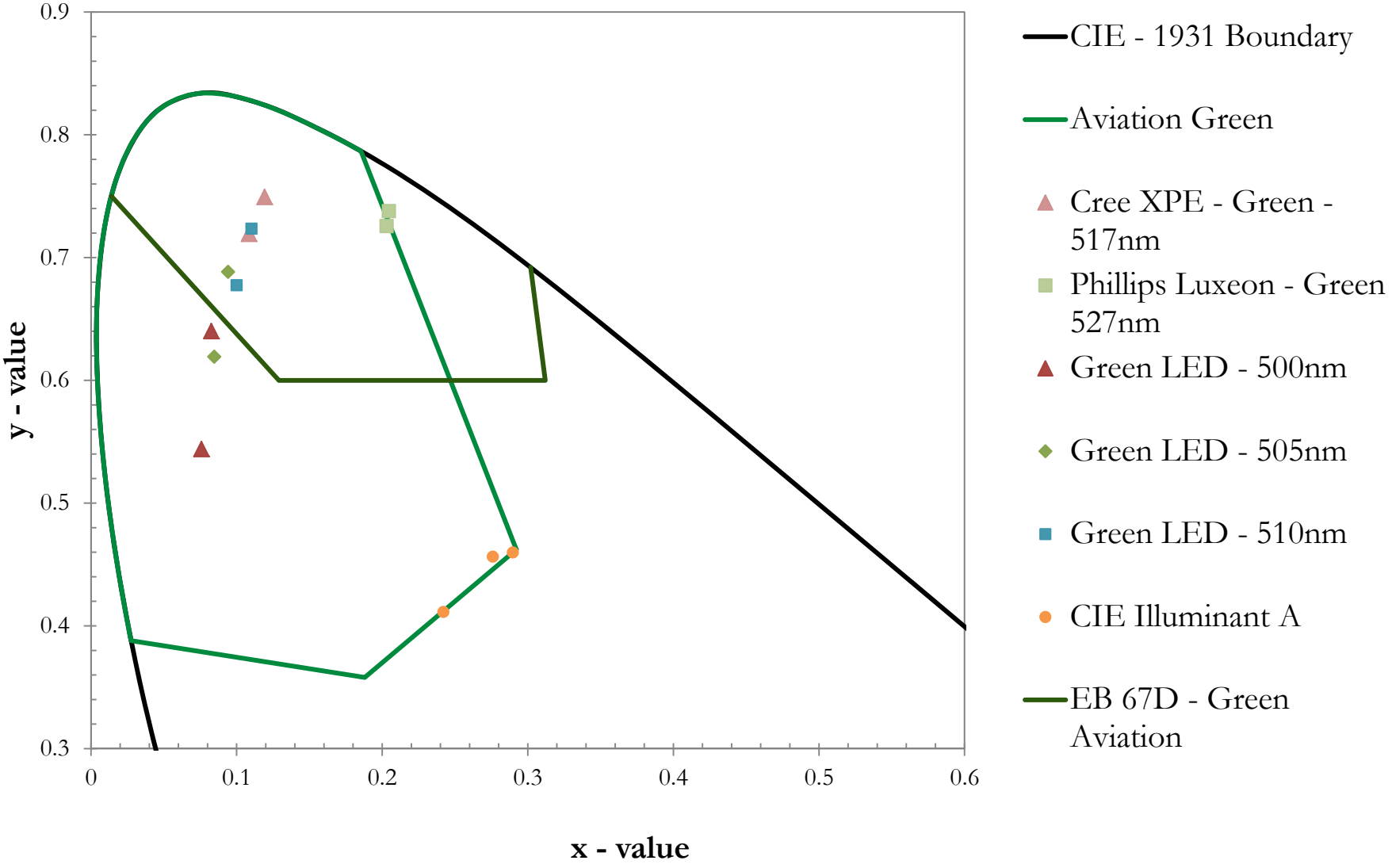
Aviation Green



Aviation Green



Aviation Green

Light Source	Glass Color	x-value	y-value	Tranmission (%)
Green LED 505nm	Green 1 Green 2	0.082 0.076	0.640 0.544	36.6 52.1
Green LED 515nm	Green 1 Green 2	0.110 0.100	0.724 0.678	40.5 52.5
Cree XP-E - Green LED	Green 1 Green 2	0.119 0.108	0.749 0.719	42.4 53.0
Phillips - Luxeon Green	Green 1 Green 2	0.204 0.203	0.738 0.726	42.0 50.0

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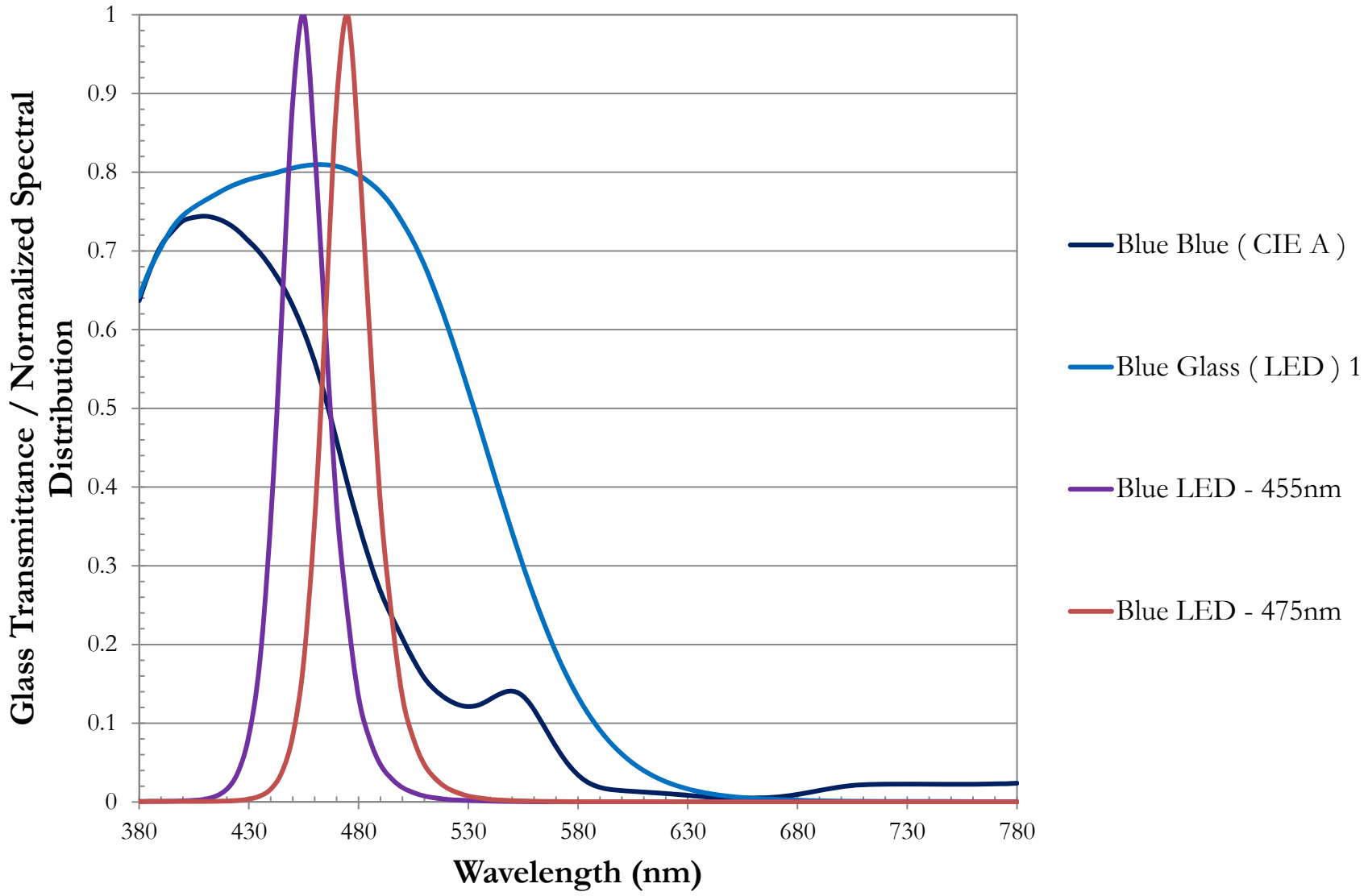
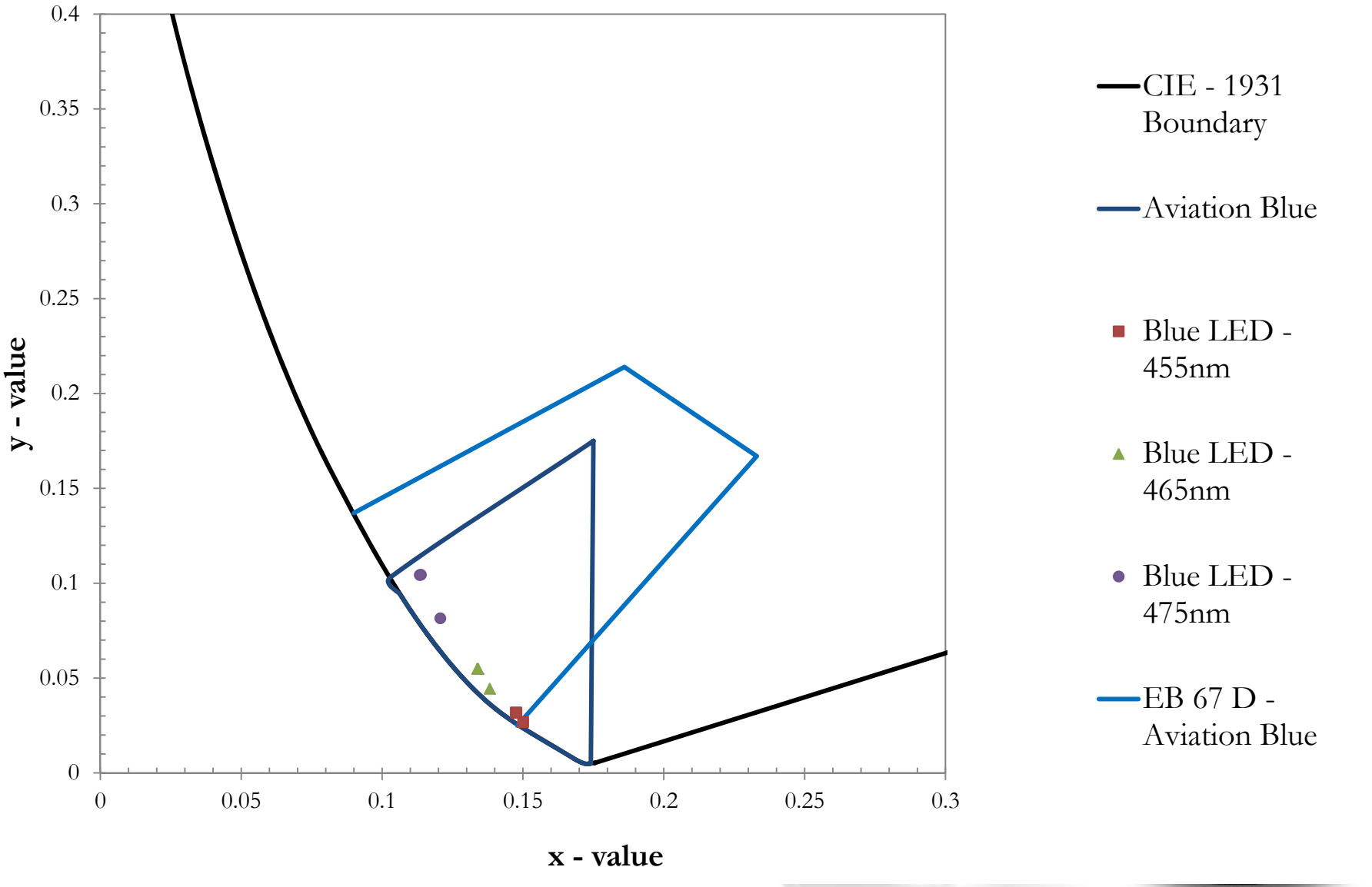
Aviation Blue



Aviation Blue



Aviation Blue

Light Source	Thickness (in)	x-value	y-value	Transmission (%)
Blue LED 455nm	Blue 1 (CIE A) Blue 2 (LED) Blue 3 (LED)	0.1501 0.1475 0.1477	0.0268 0.0318 0.0317	48.37 78.67 74.72
Blue LED 465nm	Blue 1 (CIE A) Blue 2 (LED) Blue 3 (LED)	0.1382 0.1338 0.1341	0.0444 0.0549 0.0548	40.73 77.91 73.63
Blue LED 475nm	Blue 1 (CIE A) Blue 2 (LED) Blue 3 (LED)	0.1207 0.1134 0.1138	0.0815 0.1043 0.1044	32.8 76.28 71.87

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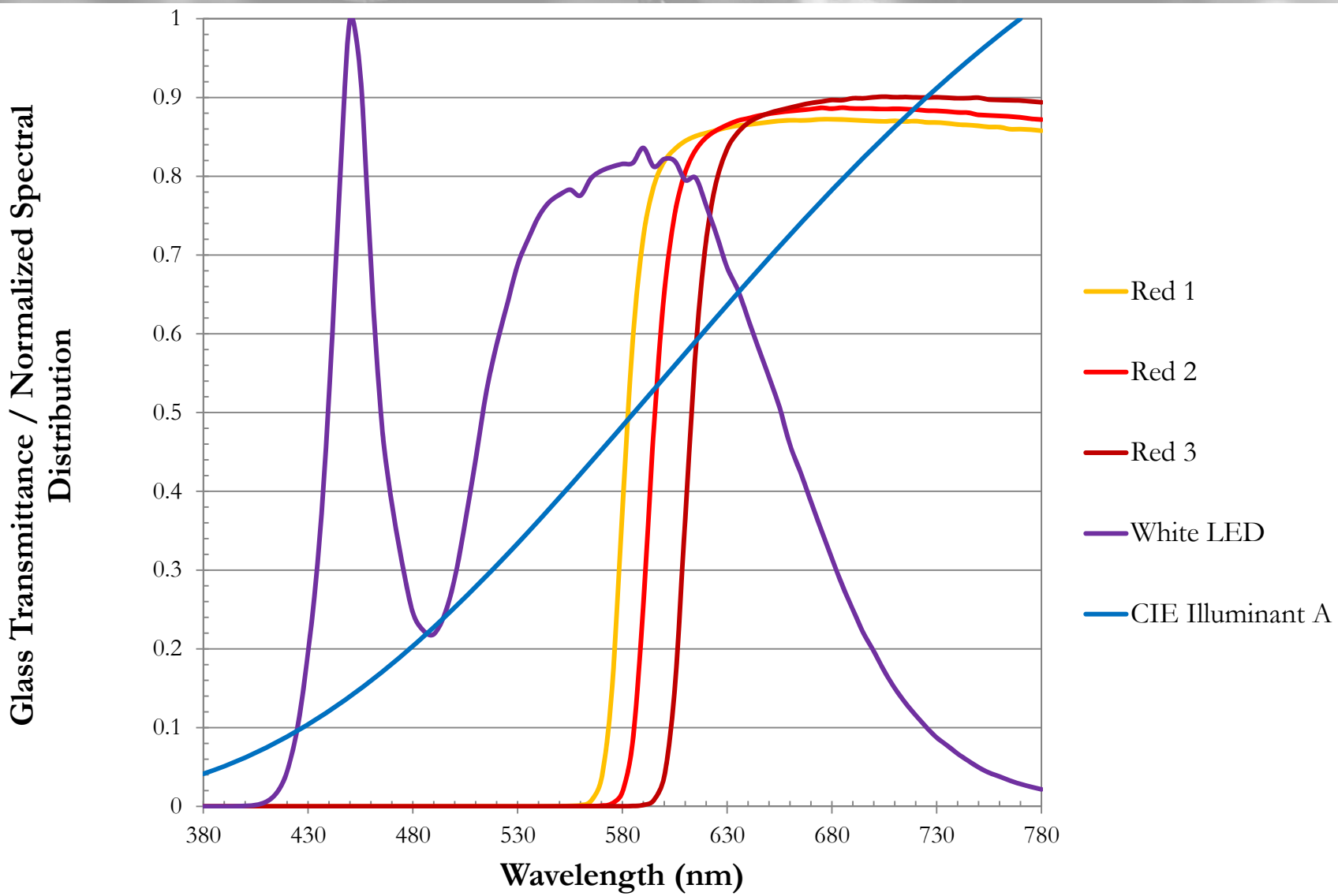
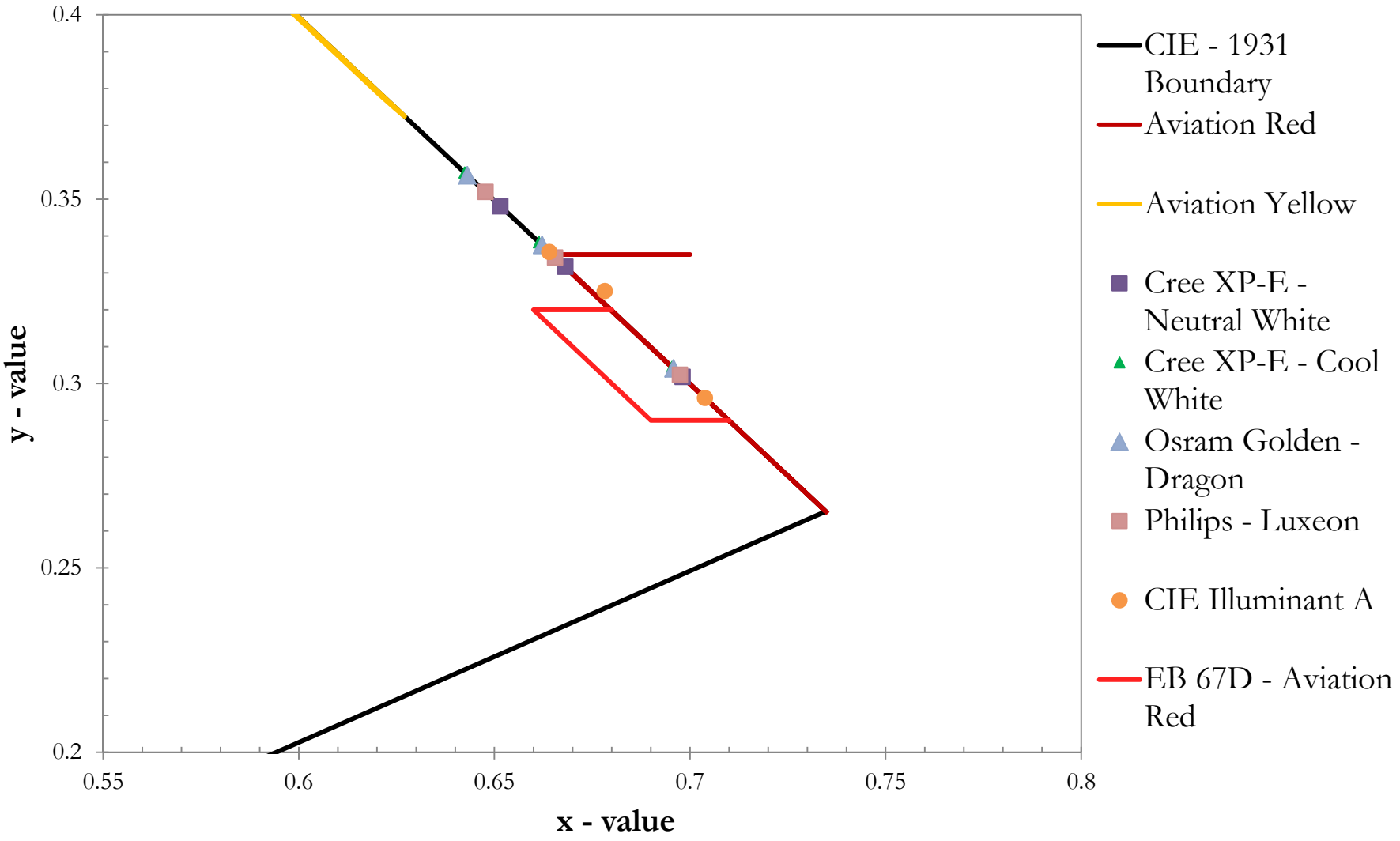
Aviation Red



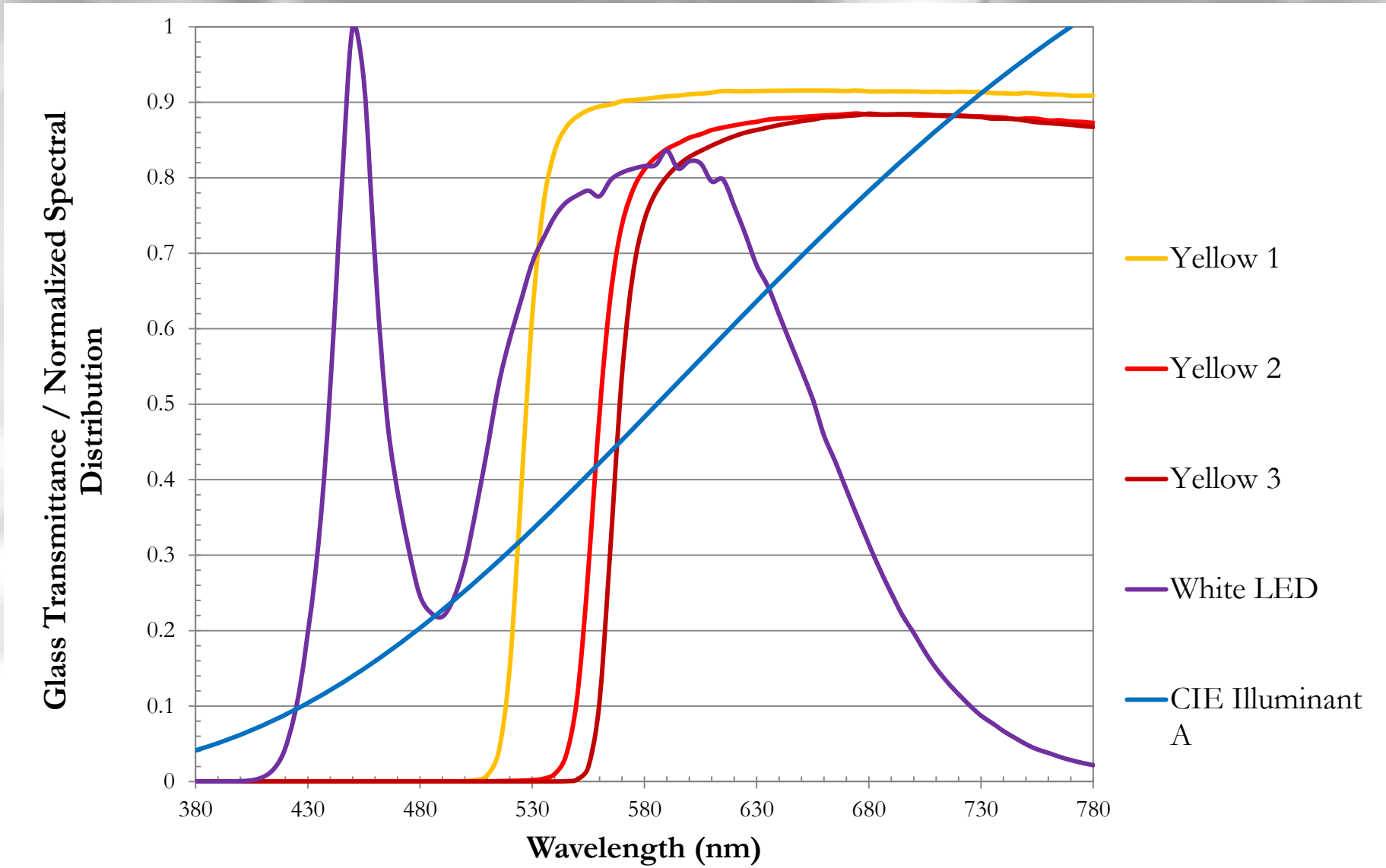
Aviation Red



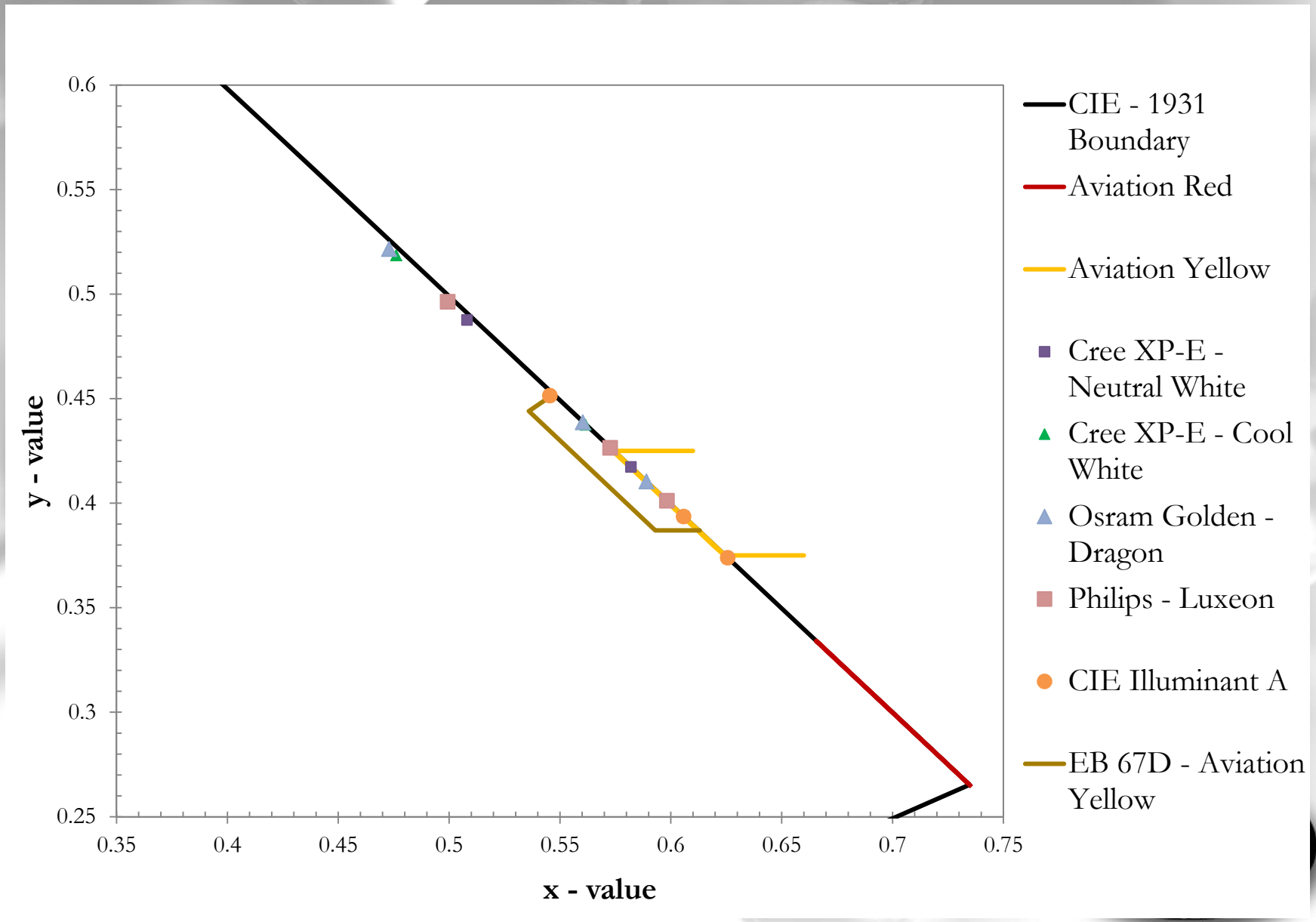
Aviation Red

Light Source	Glass Color	x-value	y-value	Transmission (%)
Cree XP-E - Neutral White	Red 1 Red 2 Red 3	0.652 0.668 0.698	0.348 0.332 0.302	24 19 10
Cree XP-E - Cool White	Red 1 Red 2 Red 3	0.642 0.661 0.695	0.357 0.338 0.305	18 14 6
Osram - Golden Dragon	Red 1 Red 2 Red 3	0.643 0.662 0.696	0.357 0.338 0.304	18 13 6
Philips - Luxeon	Red 1 Red 2 Red 3	0.648 0.666 0.697	0.352 0.334 0.302	24 18 9
CIE Illuminant A	Red 1 Red 2 Red 3	0.664 0.678 0.704	0.336 0.325 0.296	31 25 15

Aviation Yellow



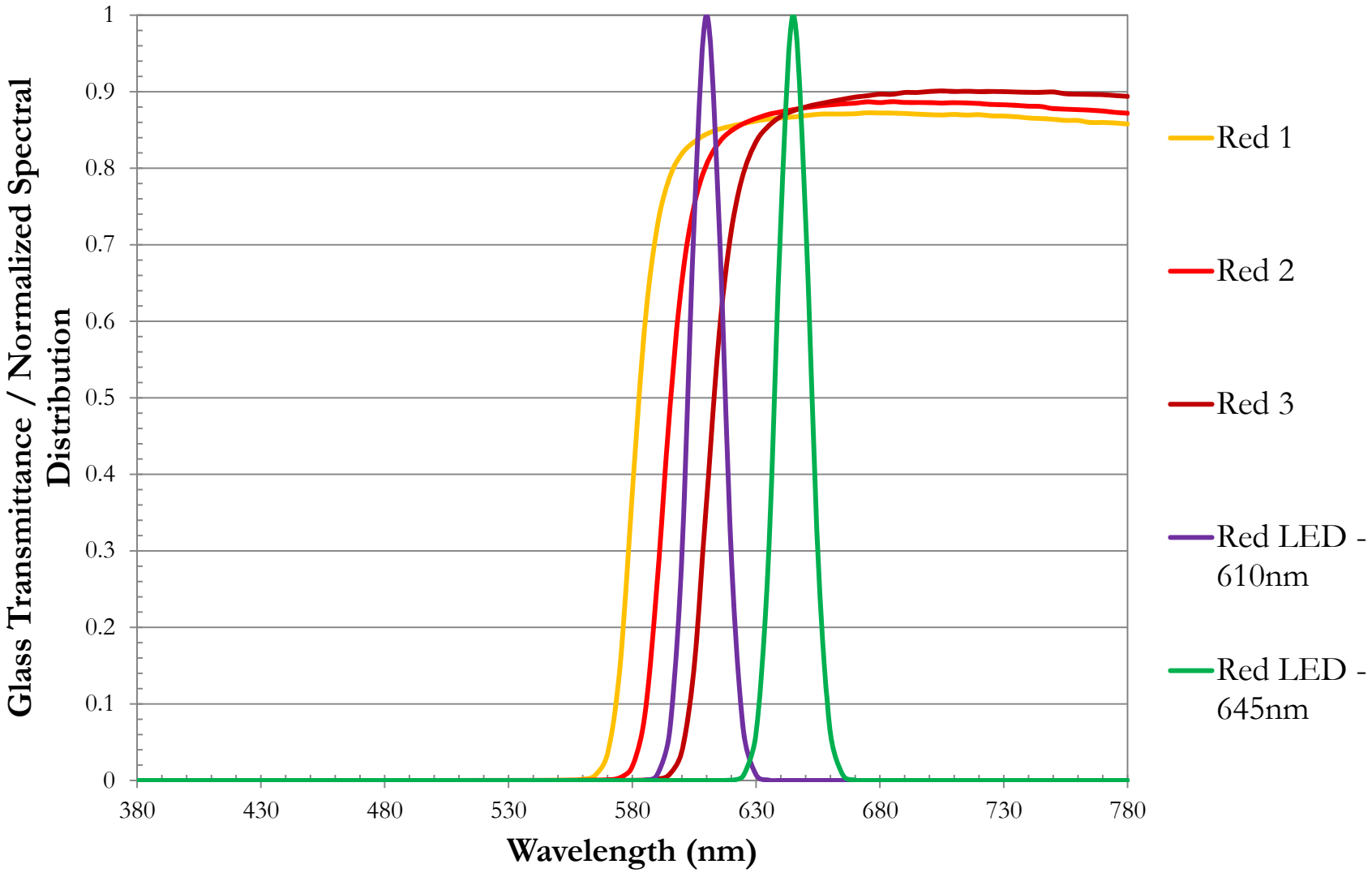
Aviation Yellow



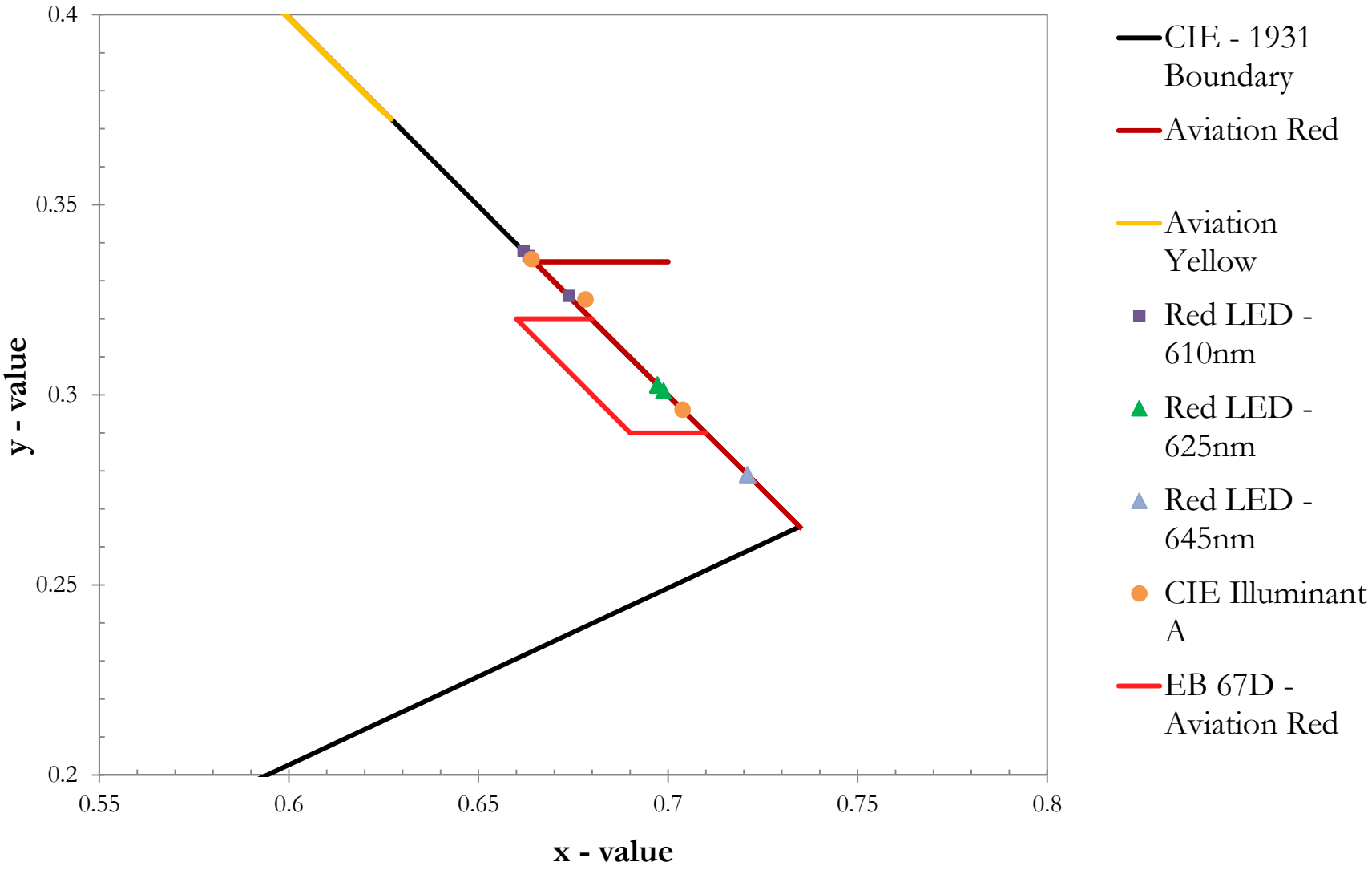
Aviation Yellow

Light Source	Glass Color	x-value	y-value	Transmission (%)
Cree XP-E - Neutral White	Yellow 1 Yellow 2 Yellow 3	0.508 0.582 0.606	0.488 0.417 0.394	77 47 39
Cree XP-E - Cool White	Yellow 1 Yellow 2 Yellow 3	0.476 0.562 0.589	0.519 0.438 0.410	72 40 32
Osram - Golden Dragon	Yellow 1 Yellow 2 Yellow 3	0.473 0.560 0.589	0.522 0.439 0.410	73 40 32
Philips - Luxeon	Yellow 1 Yellow 2 Yellow 3	0.499 0.573 0.598	0.496 0.427 0.401	81 49 39
CIE Illuminant A	Yellow 1 Yellow 2 Yellow 3	0.545 0.606 0.626	0.452 0.394 0.374	78 52 44

Aviation Red



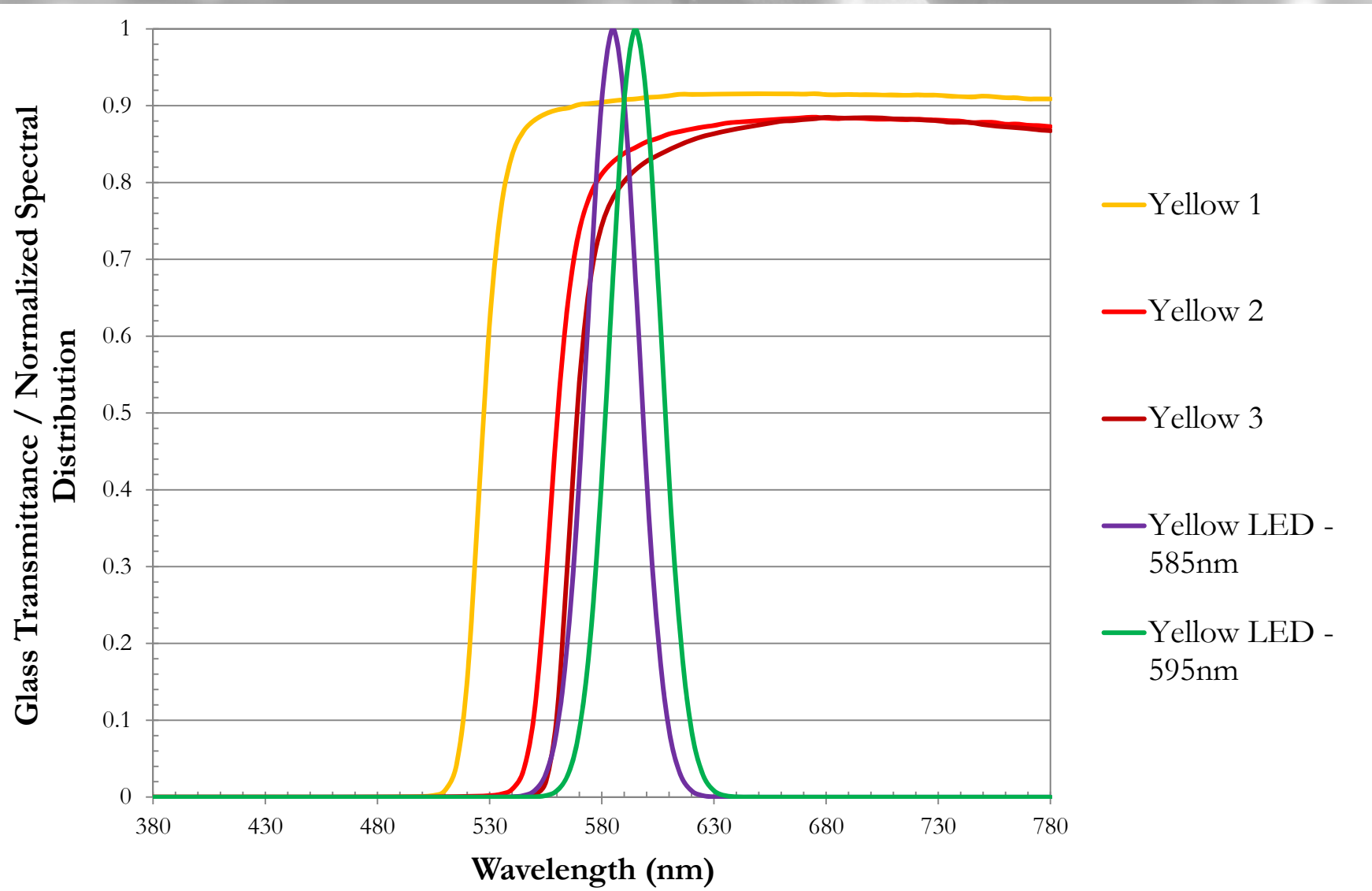
Aviation Red



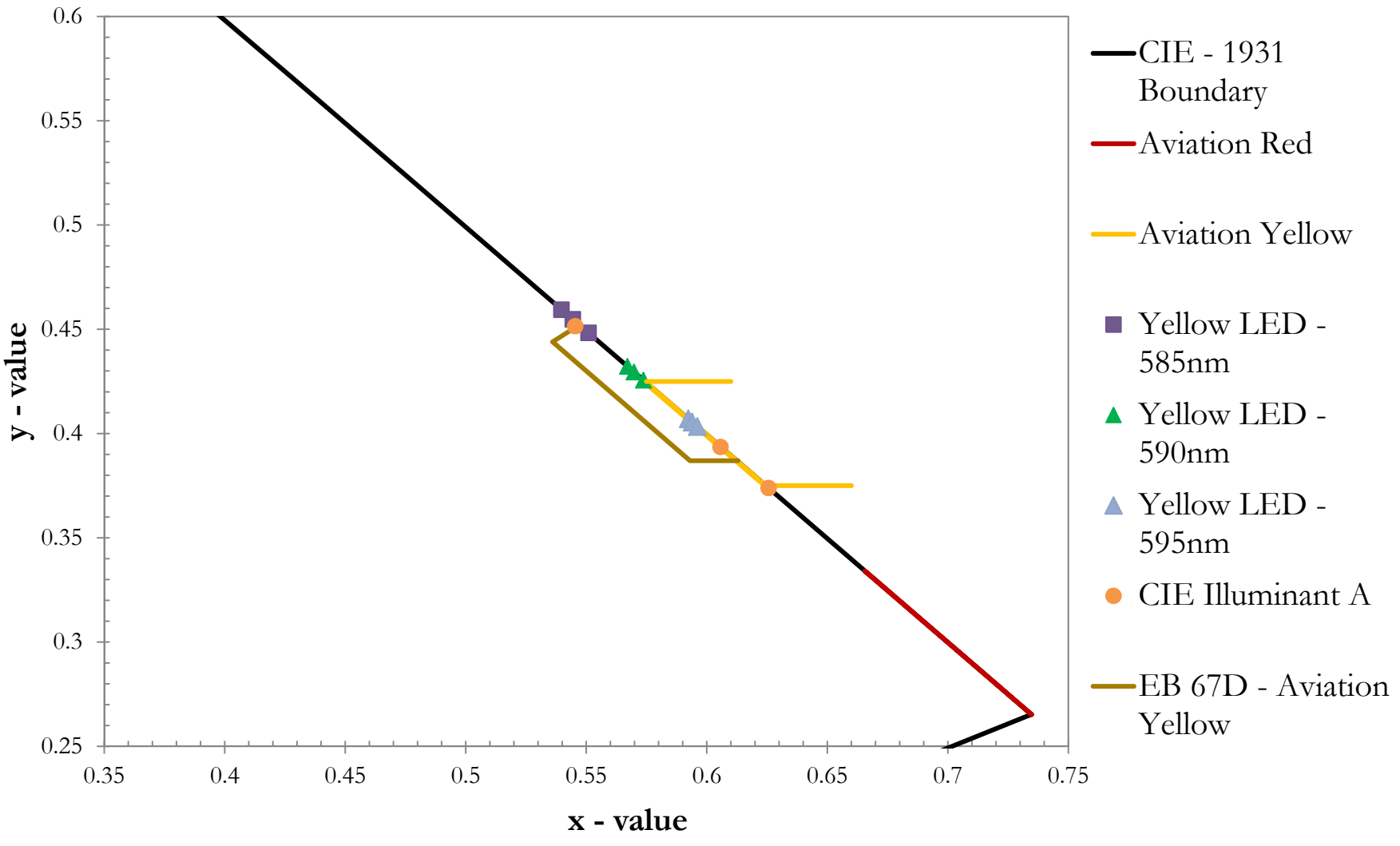
Aviation Red

Light Source	Glass Color	x-value	y-value	Transmission (%)
Red LED 610nm	Red 1 Red 2 Red 3	0.662 0.663 0.674	0.338 0.337 0.326	82 77 33
Red LED 625nm	Red 1 Red 2 Red 3	0.697 0.697 0.699	0.303 0.303 0.301	85 85 74
Red LED 645nm	Red 1 Red 2 Red 3	0.721 0.721 0.721	0.279 0.279 0.279	86 88 87
Philips - Luxeon	Red 1 Red 2 Red 3	0.648 0.666 0.697	0.352 0.334 0.302	24 18 9
CIE Illuminant A	Red 1 Red 2 Red 3	0.664 0.678 0.704	0.336 0.325 0.296	31 25 15

Aviation Yellow



Aviation Yellow



Aviation Yellow

Light Source	Glass Color	x-value	y-value	Transmission (%)
Yellow LED 585nm	Yellow 1	0.540	0.459	91
	Yellow 2	0.544	0.455	80
	Yellow 3	0.551	0.448	71
	Yellow 4	0.588	0.412	34
Yellow LED 590nm	Yellow 1	0.567	0.432	91
	Yellow 2	0.570	0.430	82
	Yellow 3	0.574	0.426	76
	Yellow 4	0.601	0.399	46
Yellow LED 595nm	Yellow 1	0.592	0.407	91
	Yellow 2	0.594	0.406	83
	Yellow 3	0.596	0.403	79
	Yellow 4	0.615	0.385	57
CIE Illuminant A	Yellow 1	0.545	0.452	78
	Yellow 2	0.606	0.394	52
	Yellow 3	0.626	0.374	44
	Yellow 4	0.664	0.336	31

Light Source Considerations

- White LED –
  - One LED in inventory
  - May be more difficult to meet specifications
  - Binning will be important
- Colored LED
  - Easy to meet color requirements
  - Higher transmission than with typical white light sources
  - Need to keep many different color types in stock

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Thank you!

Questions?

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