

PAVEMENT EDGE LIGHT SAFETY SYSTEM, PELSS: VISUAL ENHANCEMENT TO AIRFIELD LIGHTING

By:
Scott Stauffer and Warren Hyland
Luminaerospace, LLC
7788 Oxford Court, N Huntingdon, PA 15642 USA
Phone: (412) 613-2186
sstauffer@luminaerospace.com
whyland@luminaerospace.com

PRESENTED FOR THE ANNUAL ILLUMINATING ENGINEERING SOCIETY
AVIATION LIGHTING COMMITTEE FALL TECHNOLOGY MEETING 2016
San Diego, California, USA

OCT
2016

Traditional Taxiway Lighting

Point Reference

- ▶ Single point of illumination, 60 years +
- ▶ Individual nodes of light can cause confusion
- ▶ May appear as a “sea” of random blue lights
- ▶ Inadequate visual cues



PRESENTED FOR THE ANNUAL ILLUMINATING ENGINEERING SOCIETY
AVIATION LIGHTING COMMITTEE FALL TECHNOLOGY MEETING 2016
San Diego, California, USA

OCT
2016

Pavement Edge Light Safety System

Lineal Reference

- ▶ Improved boundary recognition
 - Illuminated horizontal linear bar
- ▶ Provides information related to BOTH
 - Location of the pavement edge
 - Orientation of the taxiway edge



PRESENTED FOR THE ANNUAL ILLUMINATING ENGINEERING SOCIETY
AVIATION LIGHTING COMMITTEE FALL TECHNOLOGY MEETING 2016
San Diego, California, USA

OCT
2016

Runway Incursion Prevention

- ▶ Often included on the NTSB “Most Wanted” list
 - Situational Awareness/Runway Incursions
- ▶ Improved situational awareness
 - IMPROVE recognition of intersections and edges
 - REDUCE incidents, accidents, incursions, and excursions

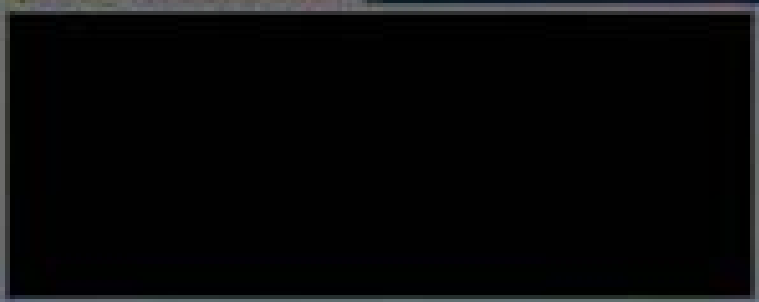
Providence, RI

Close Calls

Effective communication within the cockpit and with ATC is a must. See what happens when that communication breaks down on a foggy night in Providence.

REPLAY

AUDIO TRANSCRIPT



PRESENTED FOR THE ANNUAL ILLUMINATING ENGINEERING SOCIETY
AVIATION LIGHTING COMMITTEE FALL TECHNOLOGY MEETING 2016
San Diego, California, USA

OCT
2016

Traditional Lighting

Confusing



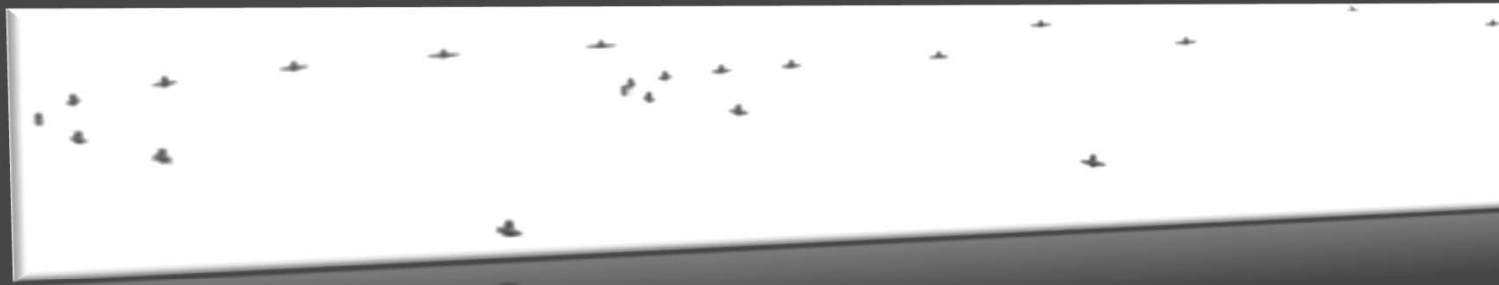
- ▶ Point Source Lighting Poorly Outlines Sections of Taxiway
- ▶ Additional Lamps Needed at Curves and Intersections to Define Edges
- ▶ Visual Interpretation can be Challenging
 - ▶ Worsens with deterioration of weather

PRESENTED FOR THE ANNUAL ILLUMINATING ENGINEERING SOCIETY
AVIATION LIGHTING COMMITTEE FALL TECHNOLOGY MEETING 2016
San Diego, California, USA

OCT
2016

PELSS Lighting Enhancement

Pavement Edge Light Safety System



- ▶ Linear light bars enhance visual feedback
 - Overall situational awareness is improved
 - Fewer lamps are necessary to define edges
 - Less lighting clutter

PRESENTED FOR THE ANNUAL ILLUMINATING ENGINEERING SOCIETY
AVIATION LIGHTING COMMITTEE FALL TECHNOLOGY MEETING 2016
San Diego, California, USA

OCT
2016

Traditional Lighting



► Lets see that again!

PRESENTED FOR THE ANNUAL ILLUMINATING ENGINEERING SOCIETY
AVIATION LIGHTING COMMITTEE FALL TECHNOLOGY MEETING 2016
San Diego, California, USA

OCT
2016

PELSS Lighting Enhancement

Pavement Edge Light Safety System



PRESENTED FOR THE ANNUAL ILLUMINATING ENGINEERING SOCIETY
AVIATION LIGHTING COMMITTEE FALL TECHNOLOGY MEETING 2016
San Diego, California, USA

OCT
2016

Taxiway – Comparison (artistic)



PRESENTED FOR THE ANNUAL ILLUMINATING ENGINEERING SOCIETY
AVIATION LIGHTING COMMITTEE FALL TECHNOLOGY MEETING 2016
San Diego, California, USA

OCT
2016

PELSS Enhancement, Demonstration



PRESENTED FOR THE ANNUAL ILLUMINATING ENGINEERING SOCIETY
AVIATION LIGHTING COMMITTEE FALL TECHNOLOGY MEETING 2016
San Diego, California, USA

OCT
2016

PELSS Enhancement, Night

Pavement Edge Light Safety System



Cleveland Hopkins Airport

Independent endorsement from Jack Swedyk

FAA GREAT LAKES REGION MODIFICATION OF AIRPORT DESIGN STANDARDS COMPLETE FORM IN CONJUNCTION WITH THE USER GUIDE

BACKGROUND

| | | |
|--|---|-------------------------------------|
| 1. AIRPORT: Cleveland Hopkins International Airport | 2. LOCATION (CITY,STATE): Cleveland, OH | 3. LOC ID: CLE |
| 4. EFFECTED RUNWAY/TAXIWAY: West edge of taxiway J between taxiways R & W | 5. APPROACH (EACH RUNWAY): ___ PIR ___ NPI ___ VISUAL | 6. AIRPORT REF. CODE (ARC): D-IV |
| 7. DESIGN AIRCRAFT (EACH RUNWAY/TAXIWAY): B-737 | | |

MODIFICATION TO STANDARDS

| |
|---|
| 8. TITLE OF STANDARD(S) BEING MODIFIED (CITE REFERENCE DOCUMENT): <ul style="list-style-type: none">Advisory Circular 150/5345-46D: SPECIFICATION FOR RUNWAY AND TAXIWAY LIGHT FIXTURES |
| 9. STANDARD REQUIREMENT: AC 150/5345-46D, Chapter 1: Scope and Classification, Section 1.2.5: Optional Items |

The Department of Port Control (DPC) is requesting a Modification of Standards (MOS) to allow for the *addition* of a linear light bar to existing L-861T Elevated Taxiway and Apron Fixtures. The modified fixtures proposed, to be utilized on intersecting and non-intersecting taxiways in order to protect against taxiway excursions and improve situational awareness near hot-spots. Fixtures are currently ready for installation. **Due to the probability of less than ideal weather conditions and an evaluation by the FAA R&D facility, DPC proposes to install the fixtures as soon as possible.**

11. EXPLAIN WHY STANDARD(S) CANNOT BE MET:

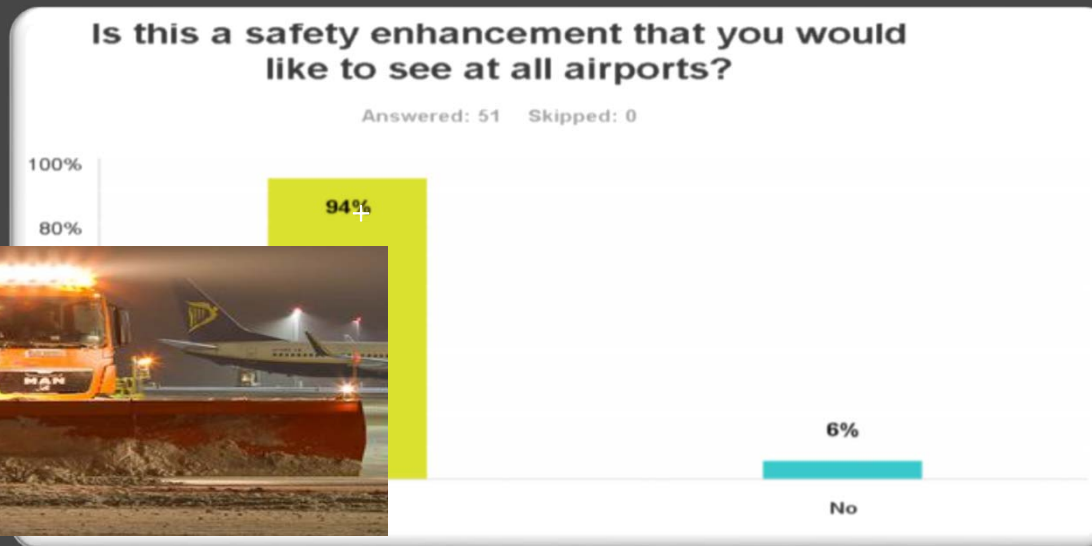
• **Advisory Circular 150/5345-46D :**

Section 1.2.5: Optional Items of Advisory Circular 150/5345-46D does not offer the inclusion of a linear light bar option.

Until and Unless the FAA creates a specification for the proposed modification, the option of adding this additional visual cue will not be present in the AC. The FAA R&D facility is planning a visit to view the Pavement Edge Light Safety System at Cleveland Hopkins Airport in their ongoing evaluation of linear lighting systems. **The FAA R&D facility expects to provide a recommendation related to linear lighting systems specifications during the last quarter of 2013 or first quarter of 2014, therefore expedient approval of this modification is requested.**

Industry Feedback

- ▶ 2013/2014, Cleveland Hopkins International Airport
- ▶ 25 light-bars fitted to taxiway lights along apron edge



PRESENTED FOR THE ANNUAL ILLUMINATING ENGINEERING SOCIETY
AVIATION LIGHTING COMMITTEE FALL TECHNOLOGY MEETING 2016
San Diego, California, USA



OCT
2016

- ▶ Submitted 2015 comments matrix to AC/5345-46D and 5345-43H
- ▶ As of this writing, suggestions have not been incorporated

Constructivist Map

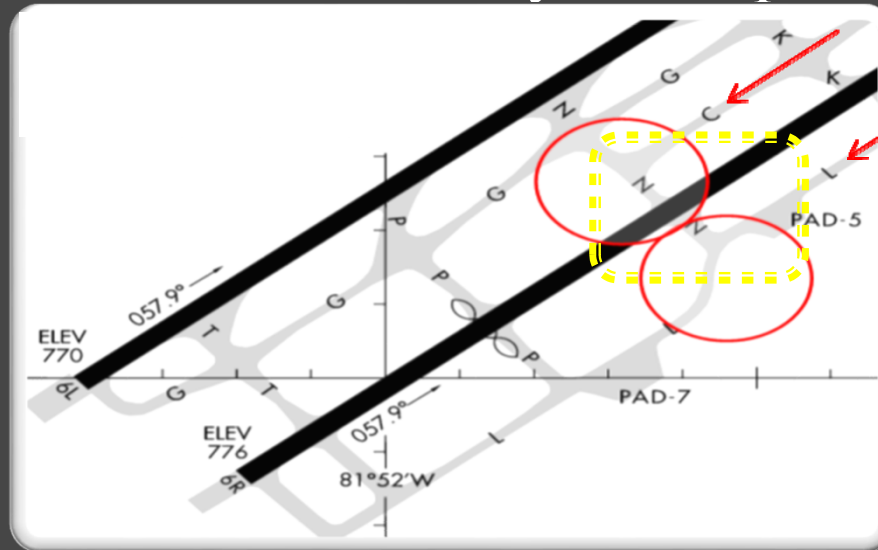
Scott Stauffe

| | |
|----------------|---|
| Scott Stauffer | Luminaerospace 412-613-2186 sstaufer@luminaersp |
|----------------|---|

Case Example

- ▶ Problematic taxiway geometry
 - Expectation - Parallel runways have parallel taxiways

Gestalt Law of past
experience

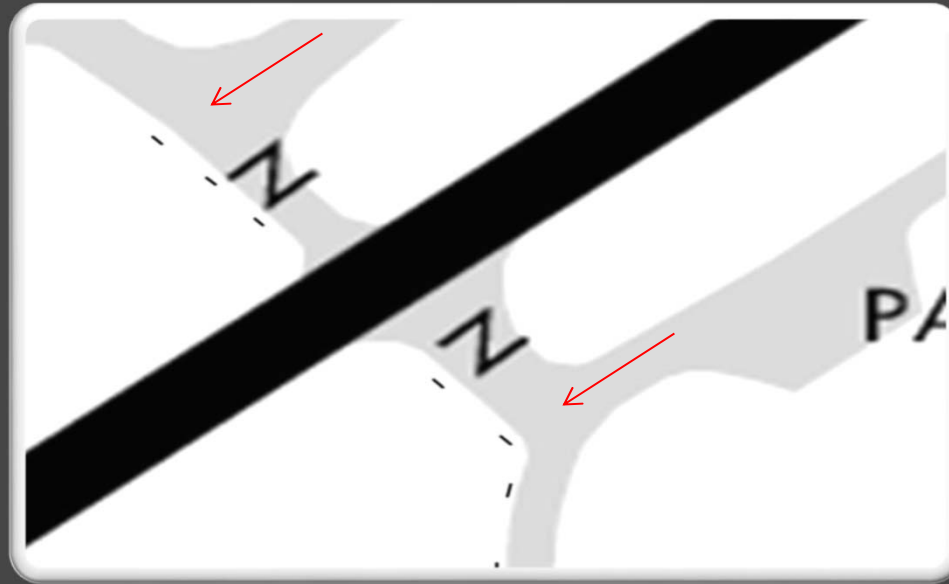


PRESENTED FOR THE ANNUAL ILLUMINATING ENGINEERING SOCIETY
AVIATION LIGHTING COMMITTEE FALL TECHNOLOGY MEETING 2016
San Diego, California, USA

OCT
2016

Case Example

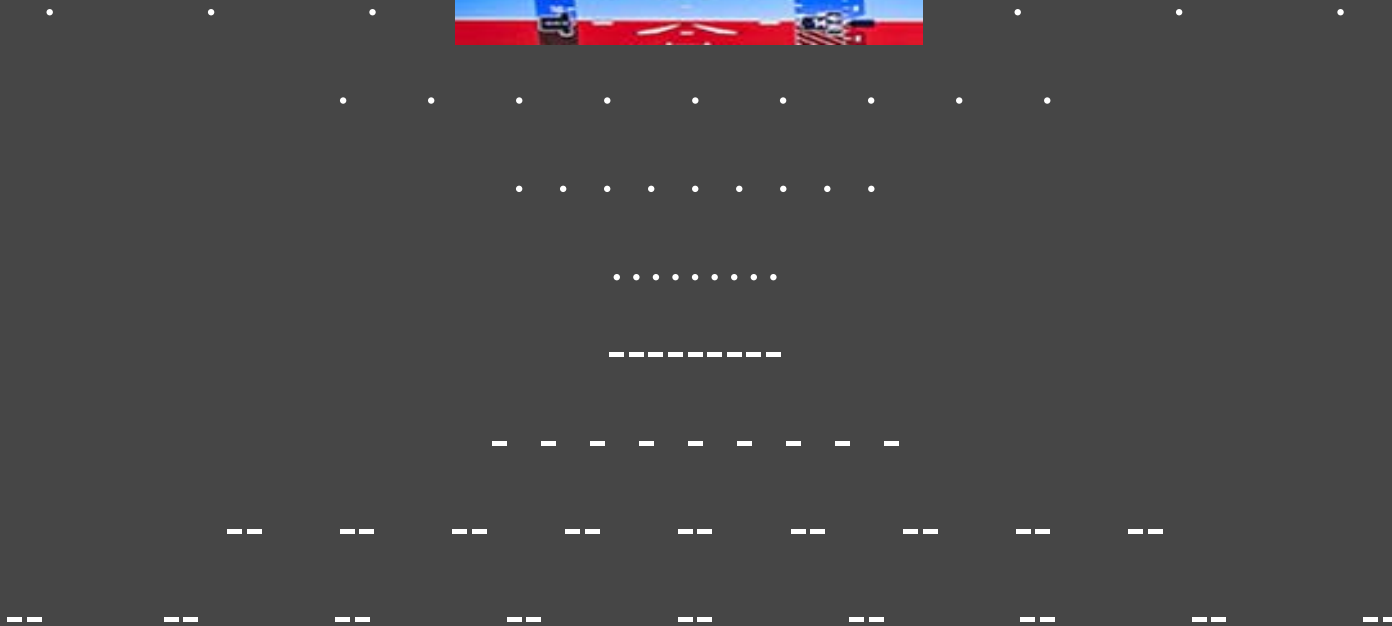
- ▶ A linear marking will prevent an excursion



PRESENTED FOR THE ANNUAL ILLUMINATING ENGINEERING SOCIETY
AVIATION LIGHTING COMMITTEE FALL TECHNOLOGY MEETING 2016
San Diego, California, USA

OCT
2016

Pixelated Foundation



PRESENTED FOR THE ANNUAL ILLUMINATING ENGINEERING SOCIETY
AVIATION LIGHTING COMMITTEE FALL TECHNOLOGY MEETING 2016
San Diego, California, USA

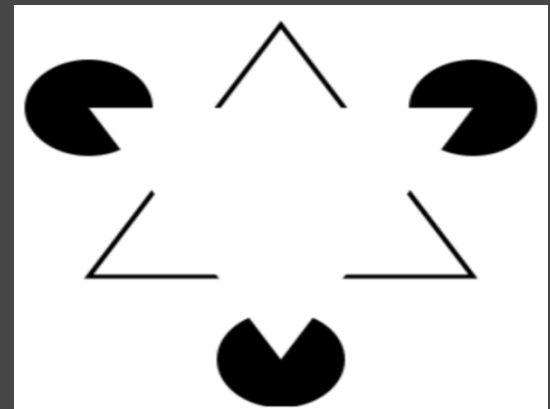
OCT
2016

Illusory Boundaries

- ▶ Recreation of actual boundary in the mind
- ▶ Gestalt Psychology principles ²
 - Mind forms a global whole with self-organizing tendencies

- Symmetry
- Similarity
- Proximity

| Law | Definition |
|------------|---|
| Similarity | Items that are similar are grouped together |
| Prägnanz | Reality is reduced to simplest form, "Good Gestalt" |
| Proximity | Objects that are close are grouped together |
| Continuity | Lines are seen as following smoothest path |
| Closure | Objects grouped together are seen as a whole |

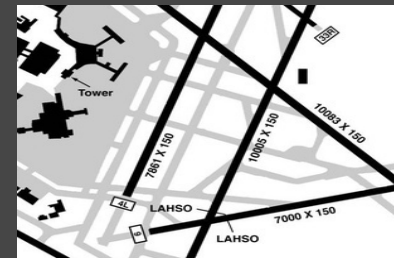


Illusory Boundaries

- ▶ Traditional boundary
 - Nodes of light create illusory boundary
 - Close spacing used to enhance visual aid
- ▶ Recent taxiway geometry guidance from the FAA
 - Will improve boundary recognition
 - Symmetry
 - Similarity



VS

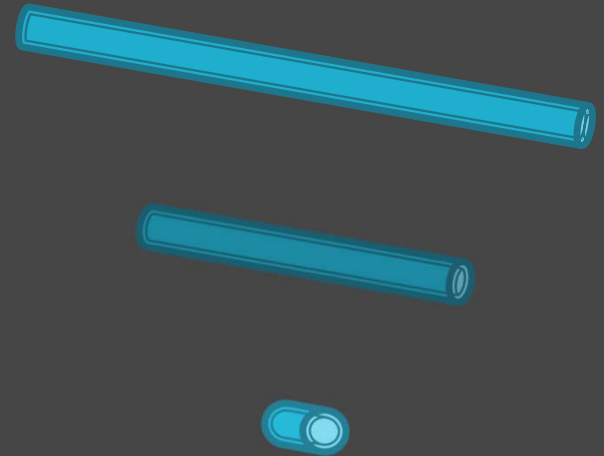


PRESENTED FOR THE ANNUAL ILLUMINATING ENGINEERING SOCIETY
AVIATION LIGHTING COMMITTEE FALL TECHNOLOGY MEETING 2016
San Diego, California, USA

OCT
2016

Perspective

- ▶ Perpendicular viewing Angle
- ▶ Oblique viewing angle
- ▶ Obtuse viewing angle



Linear segments shown are the same length

Distant segments viewed from an obtuse angle will appear as a single node, regardless of length

Dimension and Perspective

- ▶ Degraded visual recognition
 - Viewing angle
 - Lack of foreground and background references
- ▶ Improved linear segment visibility
 - Elevated viewing perspective
 - Off center viewing perspective



PRESENTED FOR THE ANNUAL ILLUMINATING ENGINEERING SOCIETY
AVIATION LIGHTING COMMITTEE FALL TECHNOLOGY MEETING 2016
San Diego, California, USA

OCT
2016

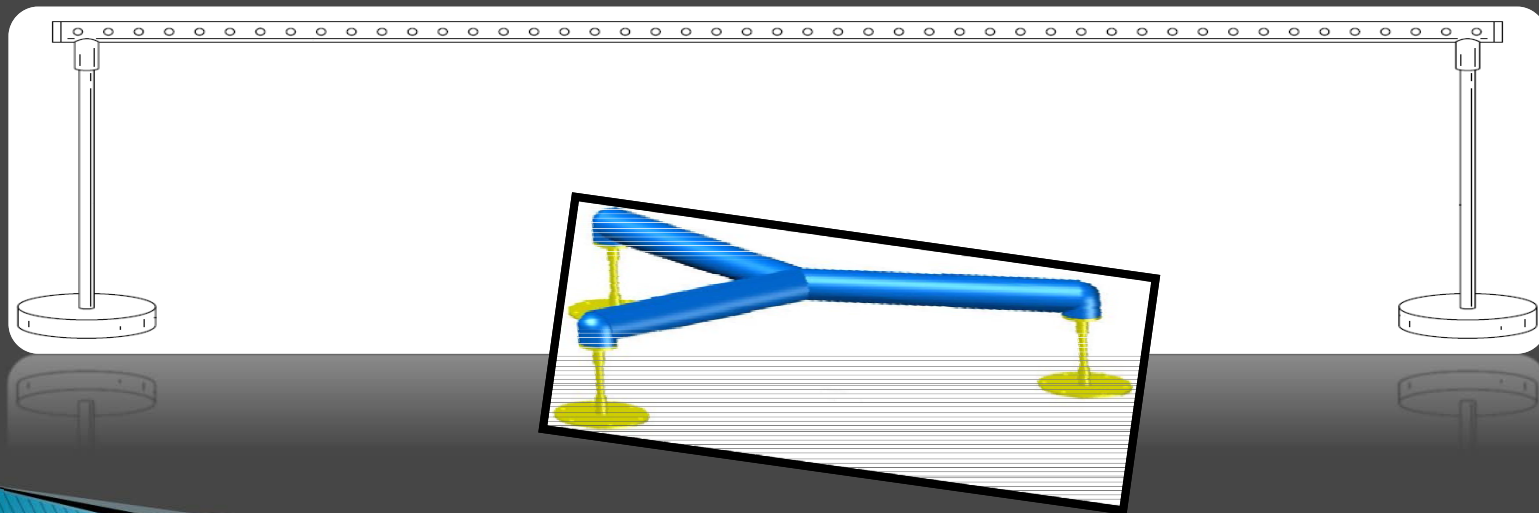
Form Perception

- ▶ Involves a number of psychological mechanisms that function in a complementary manner ⁴
 - Curve marker
 - Vertices marker
 - Mid section marker



Extended Lengths

- ▶ If the FAA specification requires linear sources of greater length, multiple posts may be utilized



PRESENTED FOR THE ANNUAL ILLUMINATING ENGINEERING SOCIETY
AVIATION LIGHTING COMMITTEE FALL TECHNOLOGY MEETING 2016
San Diego, California, USA

OCT
2016

Form Perception

- ▶ Human Image Understanding



PRESENTED FOR THE ANNUAL ILLUMINATING ENGINEERING SOCIETY
AVIATION LIGHTING COMMITTEE FALL TECHNOLOGY MEETING 2016
San Diego, California, USA

OCT
2016

Form Perception

► Human Image Understanding



PRESENTED FOR THE ANNUAL ILLUMINATING ENGINEERING SOCIETY
AVIATION LIGHTING COMMITTEE FALL TECHNOLOGY MEETING 2016
San Diego, California, USA

OCT
2016

Form Perception

▶ Human Image Understanding



PRESENTED FOR THE ANNUAL ILLUMINATING ENGINEERING SOCIETY
AVIATION LIGHTING COMMITTEE FALL TECHNOLOGY MEETING 2016
San Diego, California, USA

OCT
2016

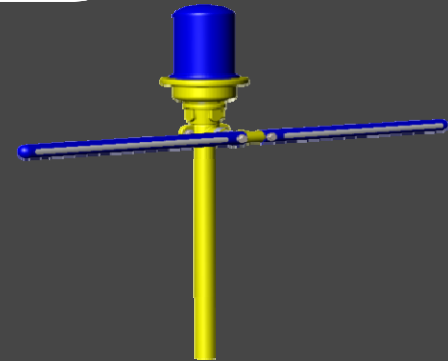
Form Perception

- ▶ “Biederman’s Cup”⁵
- ▶ Perception of Degraded objects
 - Deletions of *either*
 - Contour/Midsection
 - Vertices



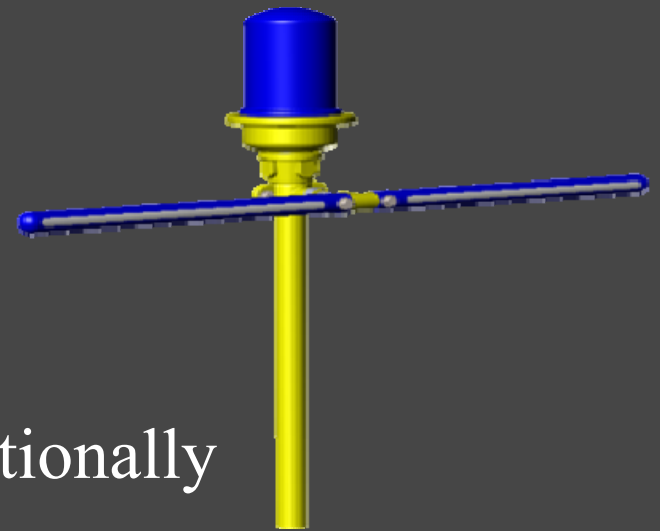
Operational Features

- ▶ Logistics
 - Installation and maintenance
 - Environment
- ▶ Form
 - Low profile
 - Weight distribution
- ▶ Function
 - Visibility, Alignment, Spacing



Operational Features

- ▶ Test version depicted
 - LED
 - Retrofit existing taxiway lights
 - Slots allow light to emanate directionally
 - Hollow plastic tubes diffuse light
 - 13 blue LED's in each arm



Economics

- ▶ Reality – Contract award – Lowest Cost
 - Spacing specifications may decrease overall cost
 - Increased SA LESS project cost
- ▶ LED Retrofit / Interim experiential approach
 - Simple add on
 - 2 LED's



- ▶ Complete Fixture
 - Eliminate traditional bulb
 - Equivalent to current fixture cost

PRESENTED FOR THE ANNUAL ILLUMINATING ENGINEERING SOCIETY
AVIATION LIGHTING COMMITTEE FALL TECHNOLOGY MEETING 2016
San Diego, California, USA

OCT
2016

Scale versus Shape

- ▶ Visual information is a function of “shape only”⁶
- ▶ Size is a factor only for the eye to detect shape



the eye cannot perceive shape
they occupy single points

(A distant short linear segment shape is typically discernable for *one minute*, while travelling toward it at 20 knots, before reaching the pavement edge)

Design Evolution



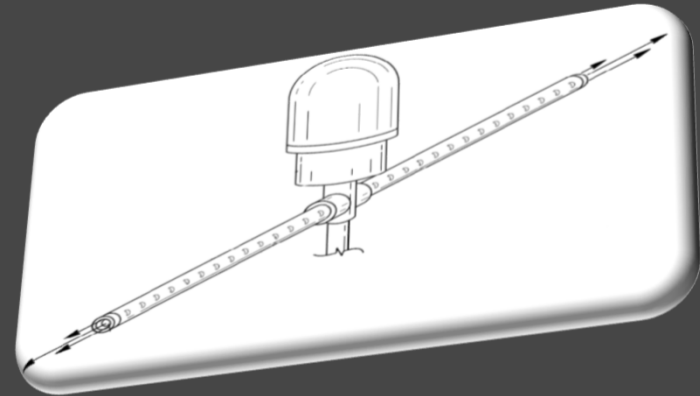
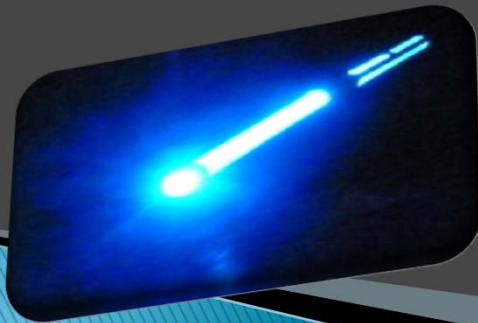
- ▶ Translucent tube
 - Retrofit of existing taxiway lights
 - Metallic tubes with elongated slots
 - light emanates directionally
 - Two translucent plastic tubes fitted within
 - 2 high intensity blue LED's in each fixture

PRESENTED FOR THE ANNUAL ILLUMINATING ENGINEERING SOCIETY
AVIATION LIGHTING COMMITTEE FALL TECHNOLOGY MEETING 2016
San Diego, California, USA

OCT
2016

Design Evolution

- ▶ **Light Beam** – Low Visibility
 - *Focused* beam emitted from tube end
 - Extends the visible beam beyond the physical bar
 - Illuminates Fog and Snow
 - Enhances pilot awareness



PRESENTED FOR THE ANNUAL ILLUMINATING ENGINEERING SOCIETY
AVIATION LIGHTING COMMITTEE FALL TECHNOLOGY MEETING 2016
San Diego, California, USA

OCT
2016

Design Evolution



► Linear reflector

- Fit onto existing taxiway light posts
 - Retroreflective tape or paint
- Dual posts /Lower profile needed to prevent pivot



PRESENTED FOR THE ANNUAL ILLUMINATING ENGINEERING SOCIETY
AVIATION LIGHTING COMMITTEE FALL TECHNOLOGY MEETING 2016
San Diego, California, USA

OCT
2016

Design Evolution

- ▶ Infrared



Concern – HUD/NVG compatibility

solution

Simple low powered IR emitters added

PRESENTED FOR THE ANNUAL ILLUMINATING ENGINEERING SOCIETY
AVIATION LIGHTING COMMITTEE FALL TECHNOLOGY MEETING 2016
San Diego, California, USA

OCT
2016

Airport Construction



PRESENTED FOR THE ANNUAL ILLUMINATING ENGINEERING SOCIETY
AVIATION LIGHTING COMMITTEE FALL TECHNOLOGY MEETING 2016
San Diego, California, USA

OCT
2016

Related Research

- ▶ LED Linear Source project – FAA Technical Center ⁷
 - Decade of stratified research related to LED's
 - Supplemental study by the Lighting Resource Center, Rensselaer Polytechnic Institute
 - Seeks to determine extent of improvement
 - Specification Development – minimum length and spacing
- ▶ Linear LED Lighting –PEGASAS ⁸
 - Project Duration 11JUL2014 to 31DEC2016
 - Seeks to understand spatial orientation benefits
 - Validate other studies, LRC; compare accuracy/reaction time
 - Guidance toward FAA linear LED lighting standards

PRESENTED FOR THE ANNUAL ILLUMINATING ENGINEERING SOCIETY
AVIATION LIGHTING COMMITTEE FALL TECHNOLOGY MEETING 2016
San Diego, California, USA

OCT
2016

Overcoming Obstacles

▶ On-going concerns

- FAA Study suggests that longer linear segments are better
 - Single node comparison, traditional, not clearly presented
 - Additional linear length – rapidly diminishing returns
 - Cost/benefit of additional length must be considered
- Lighting in the immediate vicinity more relevant than distance
 - Quantitative data has been positive
 - Qualitative data related to situational awareness is difficult to obtain through scientific measurement

Next Steps

- ▶ FAA Advisory Circular to include an option for linear light sources
 - May specify length, intensity and spacing
 - Progress will be slow until MOS approved/AC revised



PRESENTED FOR THE ANNUAL ILLUMINATING ENGINEERING SOCIETY
AVIATION LIGHTING COMMITTEE FALL TECHNOLOGY MEETING 2016
San Diego, California, USA

OCT
2016

Discussion



PRESENTED FOR THE ANNUAL ILLUMINATING ENGINEERING SOCIETY
AVIATION LIGHTING COMMITTEE FALL TECHNOLOGY MEETING 2016
San Diego, California, USA

OCT
2016

References

- ▶ 1. Candice Brown Elliott: *No Illusions: Toward Brighter Flat Displays*, EE Times, (December 19, 2005)
- ▶ 2. David Hothersall: *History of Psychology* (4th ed.), chapter seven, (2004). McGraw-Hill, Boston
- ▶ 3. Steven Lehar, “The Dimensions of Visual Experience: A Quantitative Analysis”, Toward a Science of Consciousness Conference (2006)
- ▶ 4. Attneave, F. and Arnoult, M. (1956). *The Quantitative Study of Shape and Pattern Perception*, 470.
- ▶ 5. Biederman, I, *Recognition-by-Components, A Theory of Human Image Understanding*, Psychological Review (1987), Vol. 94, No. 2, 135
- ▶ 6. Jacob Feldman and Manish Singh, Rutgers University—New Brunswick, *Information Along Contours and Object Boundaries*, Psychological Review (2005), Vol. 112, No. 1, 249
- ▶ 7. “Visual Guidance/Runway Incursion Prevention Research & Development Update”, IESALC Fall Conference, October 22, 2013, Tucson, Arizona
- ▶ 8. Research Projects. (n.d.). Retrieved September 24, 2016, from <https://www.pegasas.aero/projects.php?p=16>

Luminaerospace, LLC

- ▶ An intellectual property holding company
 - Founded in 2010
 - More than a dozen members (investors)
- ▶ Mission Statement
 - Pursue FAA approval of practical elevated linear lighting specifications
 - License this technology to existing airport lighting manufacturers
- ▶ Several Patents with priority back to 2009
 - US8,454,189 B2; US9,193,482 B2; EP2606483 B1; CN103262140 (B)
- ▶ Additional protection pending
 - South America

www.luminaerospace.com

PRESENTED FOR THE ANNUAL ILLUMINATING ENGINEERING SOCIETY
AVIATION LIGHTING COMMITTEE FALL TECHNOLOGY MEETING 2016
San Diego, California, USA

OCT
2016