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Optimizing the Performance of Elevated Runway Guard Lights with LEDs

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Elevated Runway Guard Lights (ERGLs)

- ◆ From AIM:

“Runway guard lights are installed at taxiway/runway intersections. They are primarily used to enhance the conspicuity of taxiway/runway intersections during low visibility conditions, but may be used in all weather conditions.”



Incandescent and LED Technology

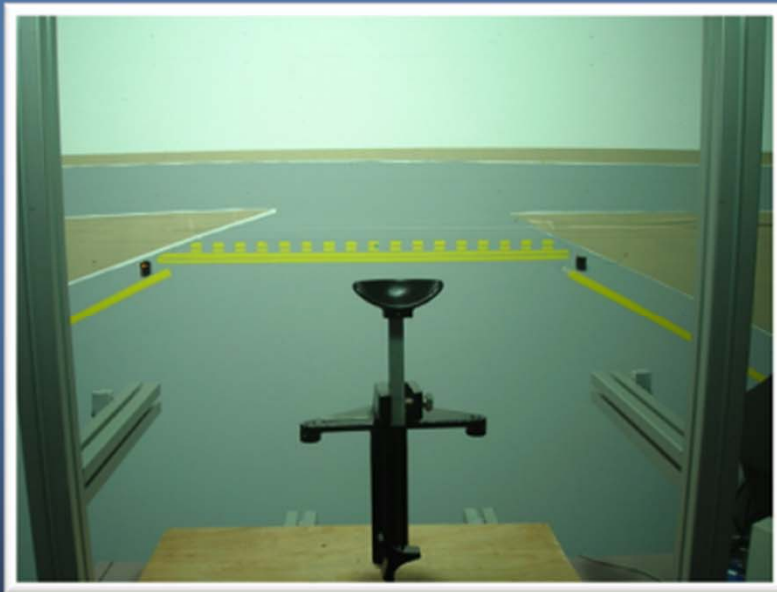
- ◆ Many ERGLs are incandescent
 - › Flash at 45-50 flashes per minute (FPM)
 - › Intensity = 3000 cd
 - › Defined by AC150-5345-46D
- ◆ LED technology
 - › Offers more flexibility with flash rate and duty cycle (on-time during flash period)
 - › Possibility to optimize for greater conspicuity (safety implications)
 - › May offer energy and maintenance savings also

Background: Lab Study

- ◆ LRC recently completed laboratory study
 - › Investigated combinations of flash rate, duty cycle, wave form, brightness, and visibility conditions
 - › Evaluated by subjective ratings, reaction time to stimulus onset
- ◆ Used scale model of taxiway/runway intersection
- ◆ Subjects were “naïve” (non-pilots)

Lab Study Apparatus

Subject view



Clear day setup

Lab Study: Findings

- ◆ "... LED based RGLs with appropriate frequency and duty cycle can provide equal or better visibility [to incandescent] at reduced light levels (nearly one-third)..."
- ◆ Identified promising LED configurations for further study
 - › with intensity set to 30% of incandescent

Preliminary Field Study

Flash Patterns for Preliminary Field Study

- ◆ Developed with guidance from LRC lab study findings
- ◆ Specification for incandescent:
 - › 45 - 50 FPM
 - › 3000 candela (per AC150-5345-46D)
- ◆ LED conditions:
 - › Intensity set to 1000 candela

Flash Rate (flashes/min)	Frequency (Hz)	Duty Cycle (%)
45	0.75	100
90	1.5	30
		70
135	2.25	30
		70
180	3.0	30
		70

Equipment

- ◆ Commercial LED Runway Guard Lights
- ◆ Driver electronics bypassed
- ◆ Custom fitted driver unit
 - › Programmed with flash patterns
- ◆ Incandescent unit also fitted with custom 120 VAC driver

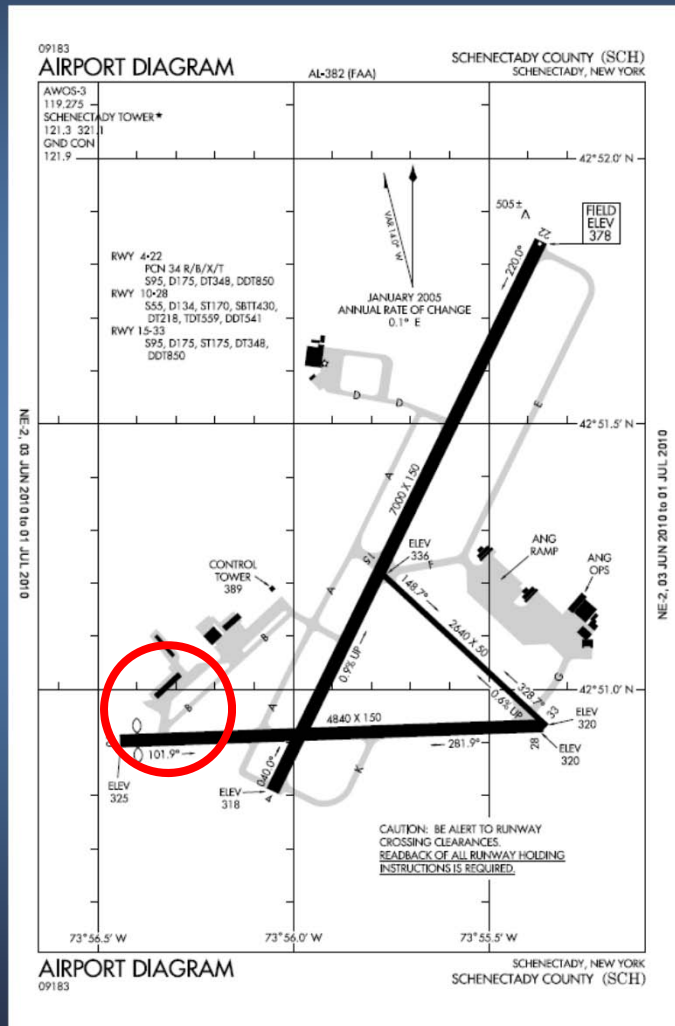


LED ERGL as received from mfr

Experimental Site

- ◆ Schenectady County Airport (KSCH)
 - › Class D
 - › ~170 Operations/Day
 - › Coordination necessary only with controllers
 - › Study site available with little to no traffic

Site



- ◆ Hold line adjacent to RWY 10
- ◆ Taxiway width ~90 ft.
(at hold line)



LED ERGLs in Operation



Subject Pool

- ◆ Total Subjects: 9
 - › 5 Private Pilot or higher
 - › 3 w/aviation experience
 - › 1 w/limited experience
- ◆ Pilots
 - › 3 Commercial
 - › 2 Private
 - › All >100 hrs. (2 >500, 1 >10,000)
 - › Subjects with RGL experience: 4

Procedure

- ◆ Subjects briefed and given rating form
- ◆ Lighting condition setup by experimenters (waiting area out of sight)
- ◆ Subjects driven one at a time through the ERGL set
- ◆ All subjects in each group see the same condition before it is changed.
- ◆ Incandescent set run either first or last



Experimental variables

- ◆ Independent variables
 - › Flash frequency
 - › Duty cycle
 - › Source (LED vs. Incandescent)
- ◆ Dependent variables
 - › Seen vs. Not seen
 - › Subjective evaluations
 - Noticeability
 - Distraction
 - Brightness

Subject Number _____

Condition Number: _____

Please rate the Elevated Runway Guard Light (ERGL) on the following criteria by circling your response:

Conspicuity:

Did you see the ERGL?

Yes No

If YES, please answer the following questions:

Noticeability:

I think that the visual appearance of the ERGL is:

5	4	3	2	1
Very		Satisfactorily		Not Prominent
Noticeable		Noticeable		Enough

Distraction:

I think that the visual appearance of the ERGL is:

5	4	3	2	1
Very		Somewhat		Not Distracting
Distracting		Distracting		At All

Brightness

I think that the brightness of the ERGL is:

5	4	3	2	1
Too Bright		Acceptable		Too Dim

Subjective Ratings

- ◆ Noticeability

- › Very Noticeable (5) ... Satisfactorily Acceptable (3) ... Not Prominent Enough (1)

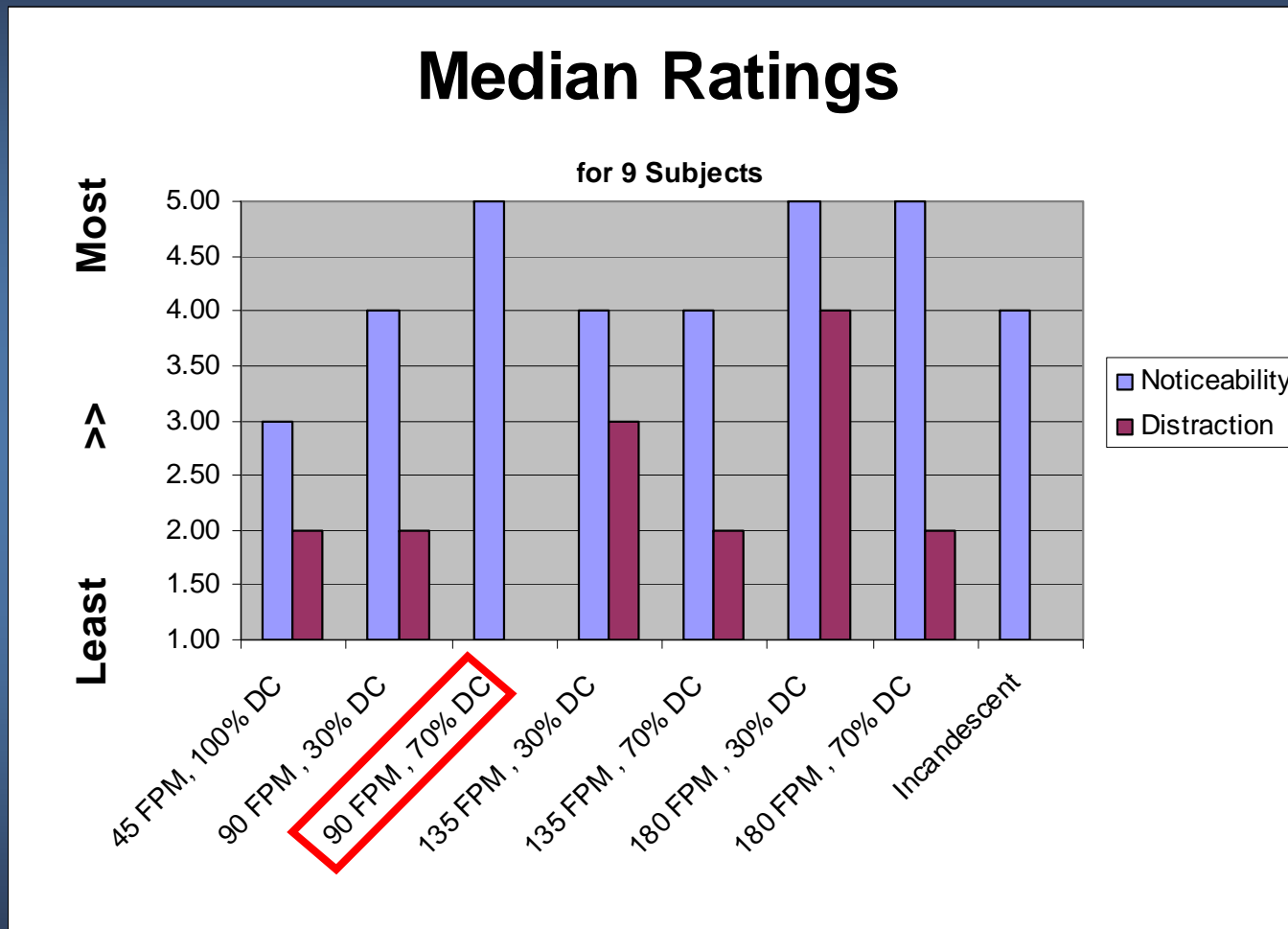
- ◆ Distraction

- › Very Distracting (5) ... Somewhat Distracting (3) ... Not Distracting at All (1)

- ◆ Brightness

- › Too Bright (5) ... Acceptable (3) ... Too Dim (1)

Median Ratings for all Conditions



Brightness Ratings: Incandescent = 2.5, ALL LED = 3.0

Statistical Comparison

LED: 90 FPM, 70% DC

◆ Noticeability

- › Median = 5.0
- › Mean = 4.22

Incandescent: 45 FPM

◆ Noticeability

- › Median = 4.0
- › Mean = 3.89

Paired T-Test, LED > Inc. vs. LED = Incandescent: P=0.22

◆ Distraction

- › Median = 1.0
- › Mean = 1.89

◆ Distraction

- › Median = 1.0
- › Mean = 1.56

Paired T-Test, LED > Inc. vs. LED not = Incandescent: P=0.524

Preliminary conclusions:

- ◆ LED ERGLs set to 90 FPM, 70% DC will perform as well as incandescent ERGLs
- ◆ Data means suggest this configuration of LED ERGLs may perform better than incandescent (not significant)
- ◆ The distraction ratings of incandescent and LEDs (90FPM, 70%DC) are not statistically different
- ◆ 90FPM, 70%DC selected to be used in larger scale investigation by ERAU

Field Study: Pilot Perception of ERGL



Pilot Perception of ERGL: Methods

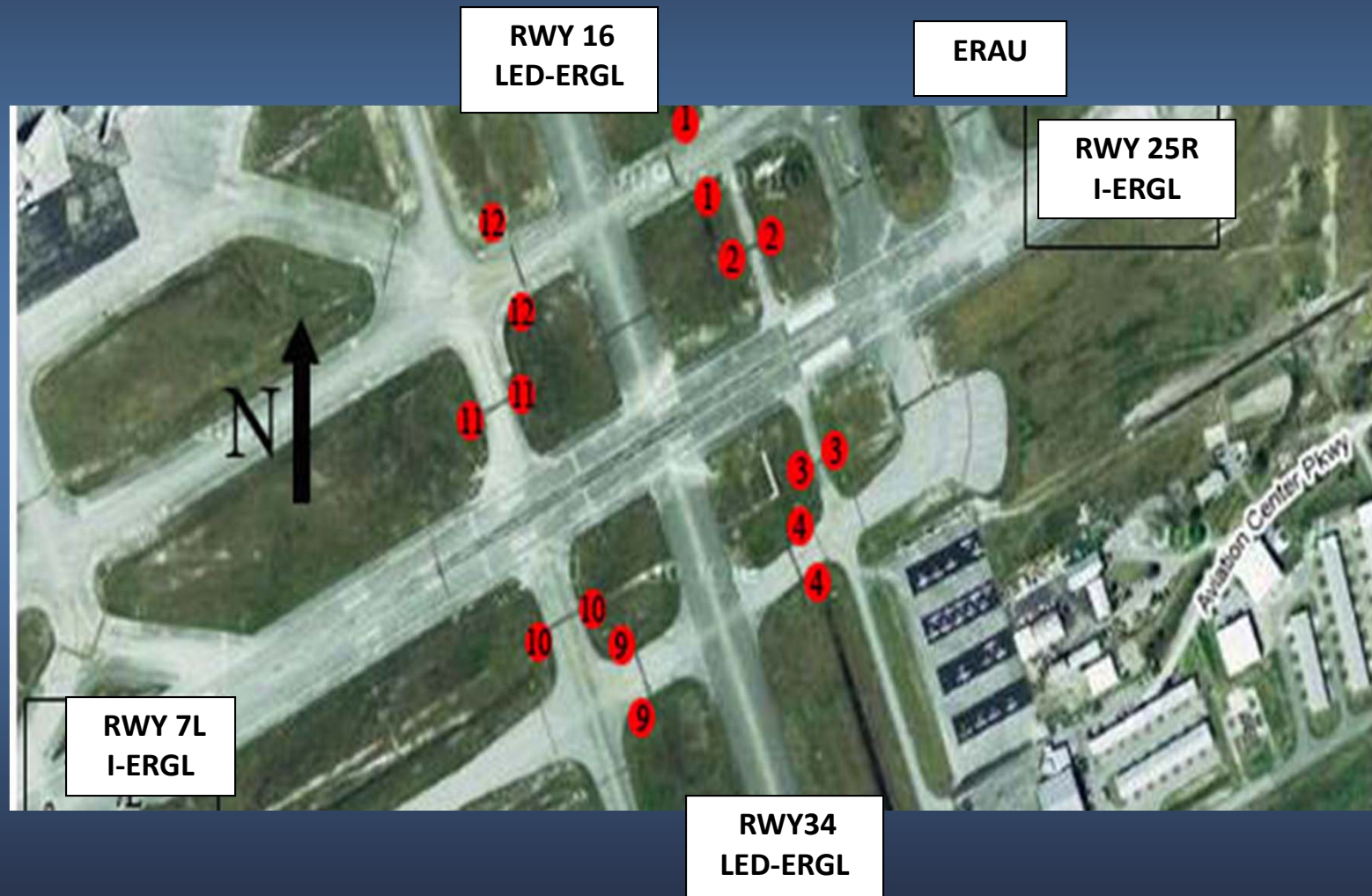
- ◆ 86 Pilot Participants
 - › 26 Student Pilots
 - › 23 Private Pilots
 - 14 with IFR
 - 12 Commercial
 - 25 CFI/CFII
 - › 82 % male
 - › 21 with < 50 hours
 - › 17 with 50 < > 150 hours
 - › 16 with 151 < > 250 hours
 - › 11 with 250 < > 500 hours
 - › 21 with > 500 hours

"As a flight instructor, take the flight controls while taxiing and passing a set of elevated runway guard lights (wigwags). Hand the survey to the student and have him/her circle the numbers.

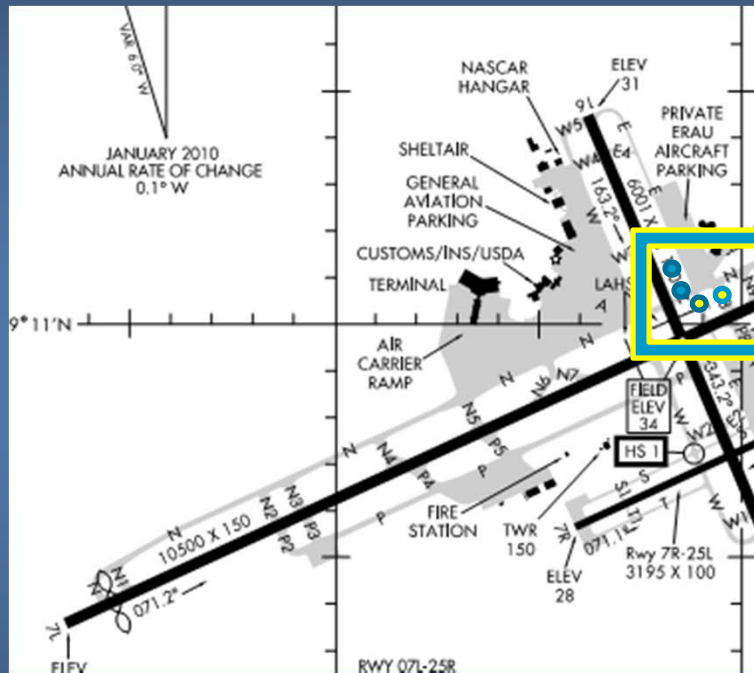
Taxi at a slow and safe speed, (about 10 knots) creating enough time for the student to make an educated decision."



Airport Intersections with Elevated Runway Guard Lights



Placement of LED Guard Lights



Pilot Perception of ERGL: Methods

Noticeability:

I think that the visual appearance of the ERGL is:

1	2	3	4	5
Very Noticeable	Satisfactorily Noticeable			Not Prominent

Distraction:

I think that the visual appearance of the ERGL is:

1	2	3	4	5
Very Distracting	Somewhat Distracting			Not Distracting

Brightness:

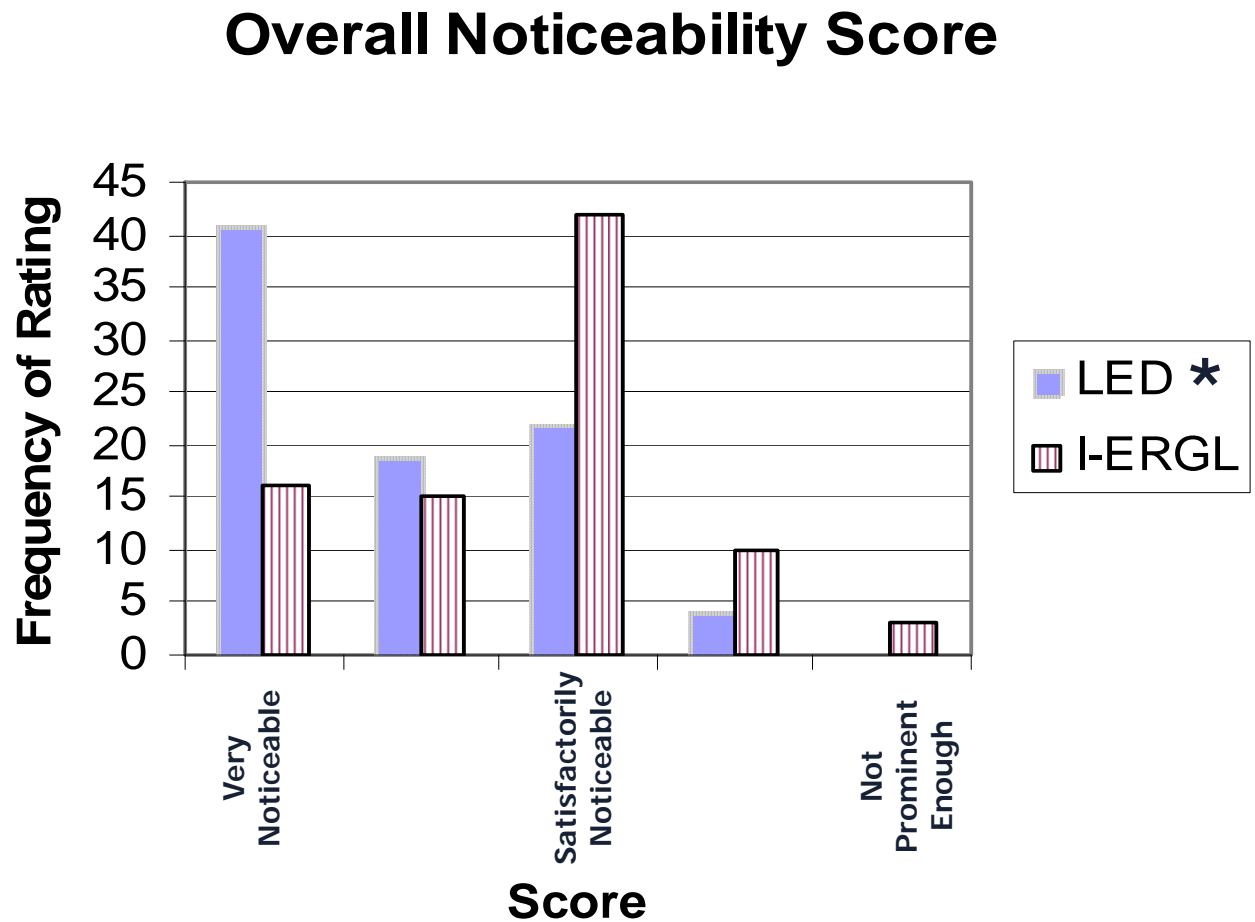
I think that the brightness of the ERGL is:

1	2	3	4	5
Too Bright		Acceptable		Too Dim

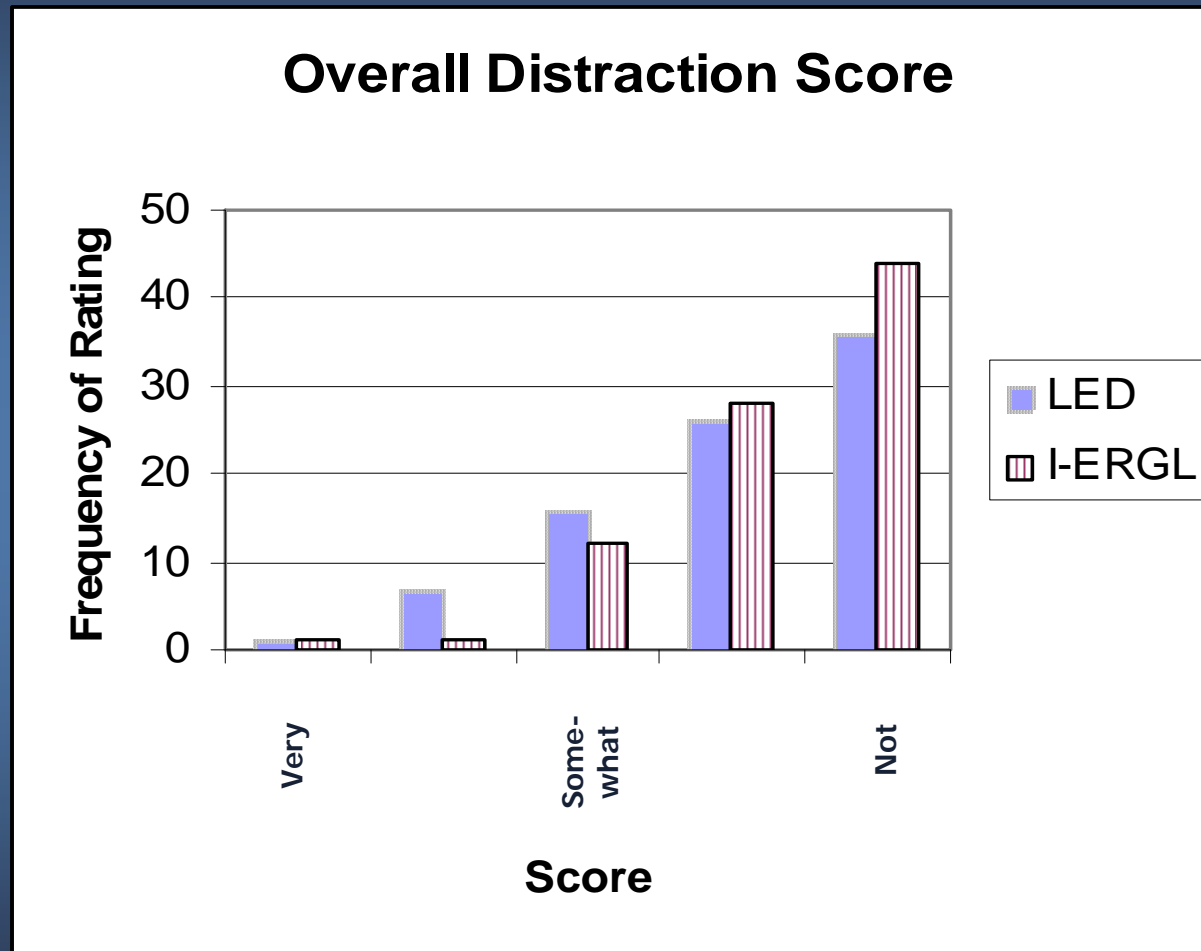
I prefer the ERGLs on:
a. 16-34 b. 25R-7L

Pilot Perception of ERGL

- ◆ For all 3 tests, Wilcoxon matched pairs test. Two tailed alpha level $p < 0.001$
- ◆ Non-parametric T-test
- ◆ Not equal intervals
- ◆ Conservative alpha for small sample size and field conditions

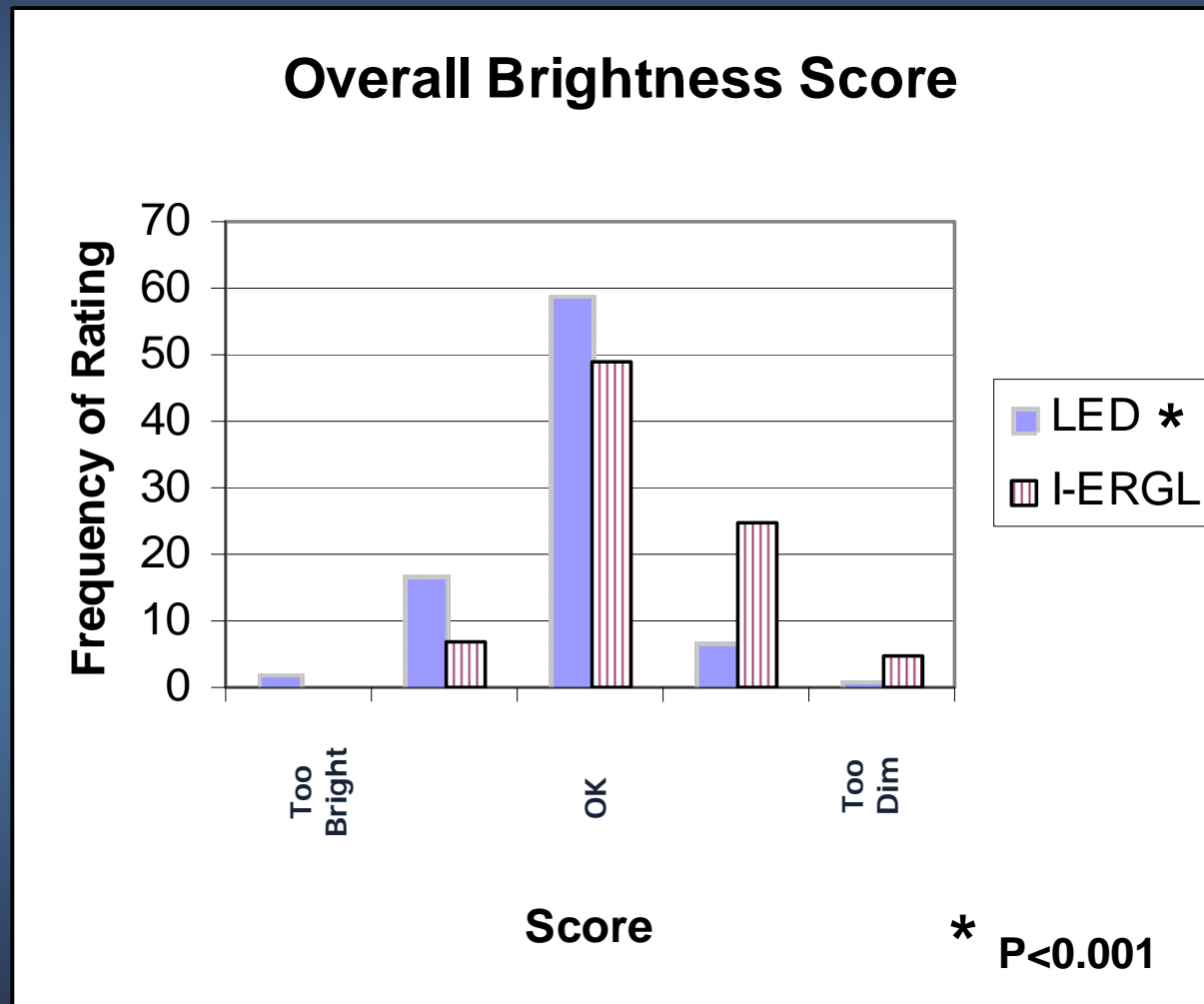


Pilot Perception of ERGL



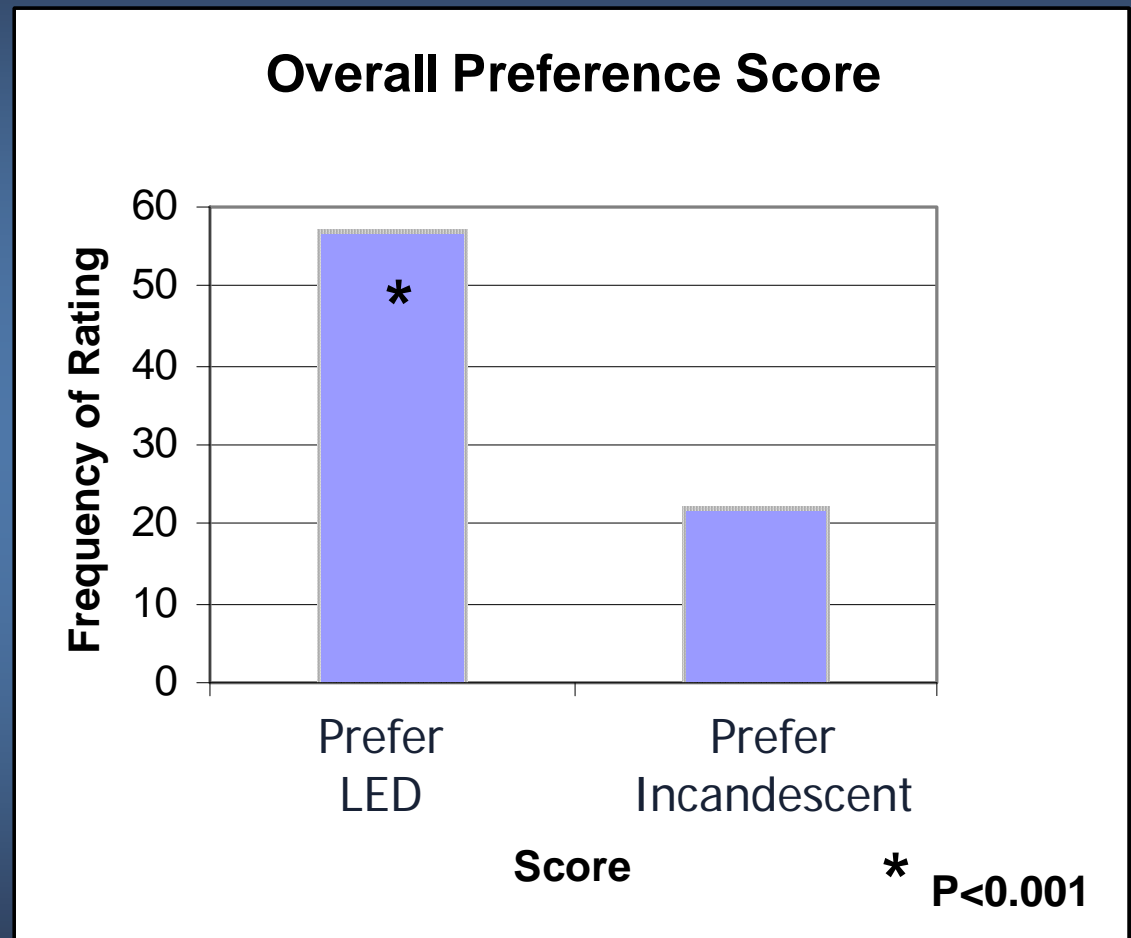
* Not Significant at $p < 0.001$

Pilot Perception of ERGL

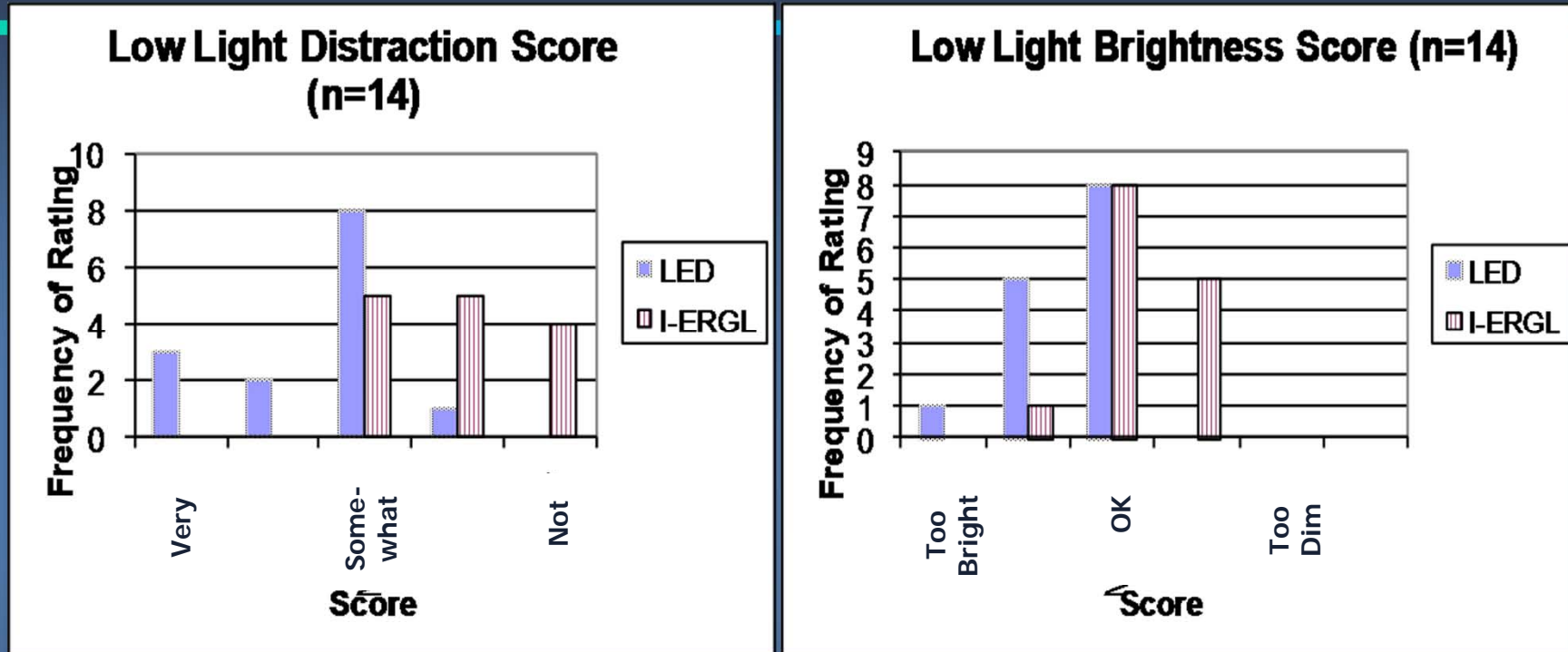


Pilot Perception of ERGL

- ◆ A single sample Wilcoxon signed rank test for a dichotomous variable (prefer LED or prefer incandescent lights)
- ◆ $p < 0.001$ *



Low Light and Visibility



	Noticeability	Distraction	Brightness	Preference
Low Light n=14	Not Significant	Not Significant	p=0.008	64%
Low Visibility n=9	Not Significant	Not Significant	Not Significant	71%

Video

- ◆ Day
 - › Greater than 5sm visibility



Video

- ◆ Dusk
 - › Greater than 5 sm



Video

- ◆ Night
 - › 4 miles visibility, Haze and Smoke



Comments from Pilots

- ◆ LED
 - › GREAT
 - › Noticeable
 - › Seem brighter from straight on, but not from side
 - › Perfect brightness
- ◆ Incandescent
 - › Can still see light, but dull at a distance
 - › Good level of light
 - › Perfect for daytime
- ◆ Preference
 - › More noticeable and pointed for a lower cockpit
 - › They seem to "pop" more than the others

Conclusions: LED-ERGL

- ◆ Some Remedial education on RWY lighting and markings would benefit many pilots and could improve safety
- ◆ LED rated more noticeable and is preferred over I-ERGL
- ◆ The use of LED-ERGL for RWY lighting is supported by this study



Acknowledgements



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Under Contract
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Thank you.
