Visual Guidance/Runway Incursion Prevention

Research & Development

Update

IESALC Fall Conference October 22, 2013
Tucson, Arizona

TOPICS

1. Method to determine end-of life for LED fixtures
2. Evaluation of Airport Pavement Linear Source Visual Aid
3. Frangibility
4. Taxiway Fillet Design Geometry:
   Taxiway Edge and Centerline Light Spacing Evaluation

Method to determine end-of life for LED fixtures

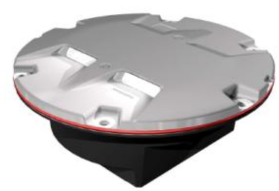
- One of the challenges of using Light Emitting Diode (LED) technology is the time at which the light sources need replacement.
- A typical incandescent fixture (lamp containing a filament) lasts approximately 2,000 hours.
- LED fixture (LEDs and electronics) are claiming 50,000 hours or more.
- The two items that have a direct influence on end-of-life are maintaining required:
  - Light output
  - Chromaticity (Color)

Samples under test

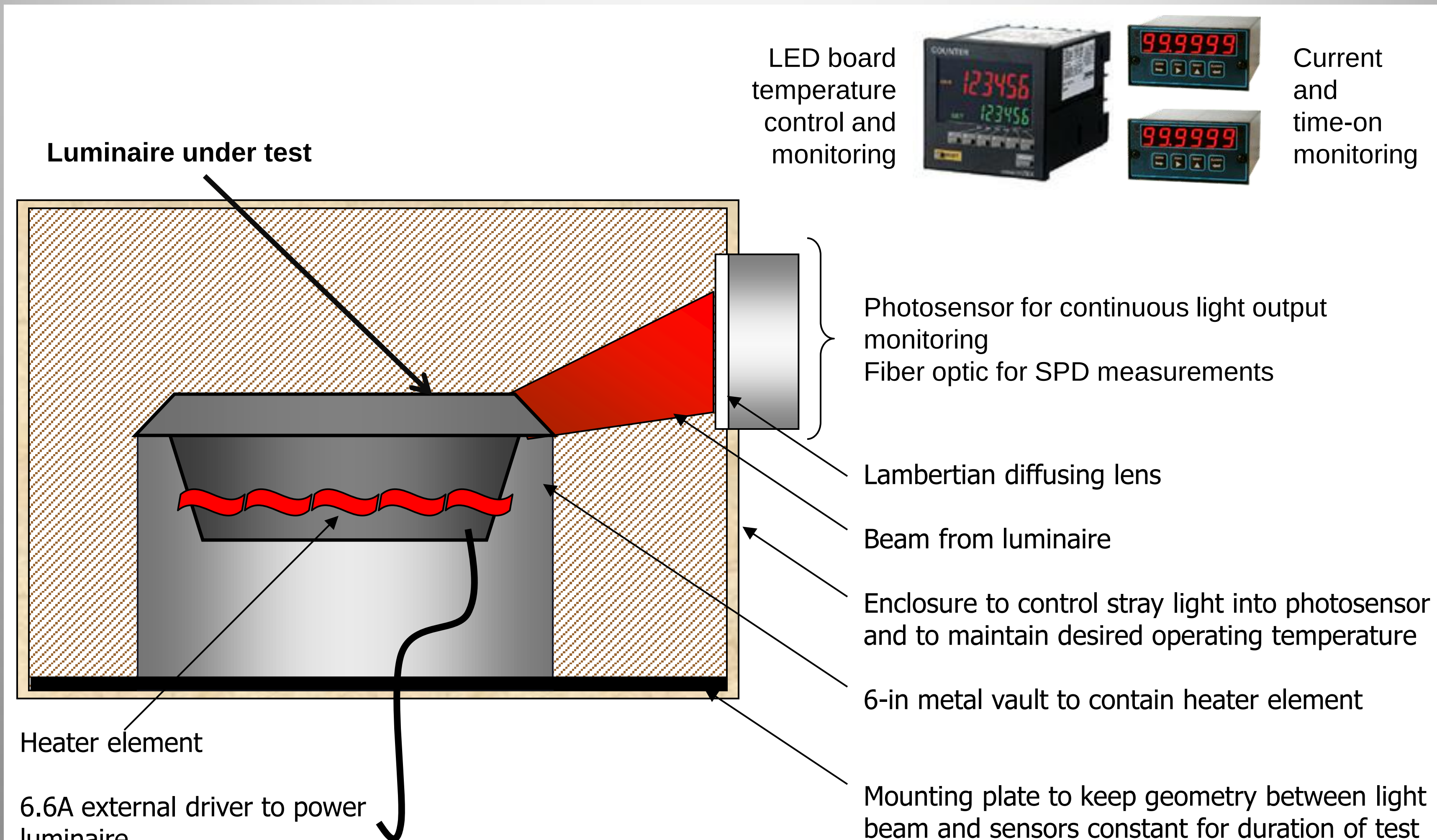
- Three red/white directional Runway Centerline luminaires

- Three white Touchdown Zone luminaires

Tests completed after 10,404 hours



Schematic of test setup



Summary

- Overall test duration 10,404 hours
- Complete system failures due to driver loss:
  - Two touchdown zone luminaires
    - 560 hours of operation (212° F condition)
    - 3,360 hours of operation (176 °F condition)

  - One runway centerline luminaire
    - 7,630 h of operation (212 °F condition)

Summary

- Light output and chromaticity maintenance
  - Runway centerline luminaires (A0 & A3 samples)
    - Relative light output loss of 30-37%
    - Color shift between 32-step and 52-step MacAdam ellipses
  - Touchdown zone luminaires (B1 & B3 samples)
    - Relative light output loss of 5-11%
    - Color shift between 7-step and 16-step MacAdam ellipses

Summary

- Intensity distribution maintenance
  - Runway centerline luminaires (A2 sample at 176 °F)
    - White: 0.5° to 1° change at full-width half-max intensity
  - Runway centerline luminaires (A3 sample at 212 °F)
    - Red: 0.5° to 0.75° change at full-width half-max intensity
  - Touchdown zone luminaires (B2 sample, 176 °F)
    - White: <0.5° change at full-width half-max intensity

Evaluation of Airport Pavement Linear Source Visual Aid

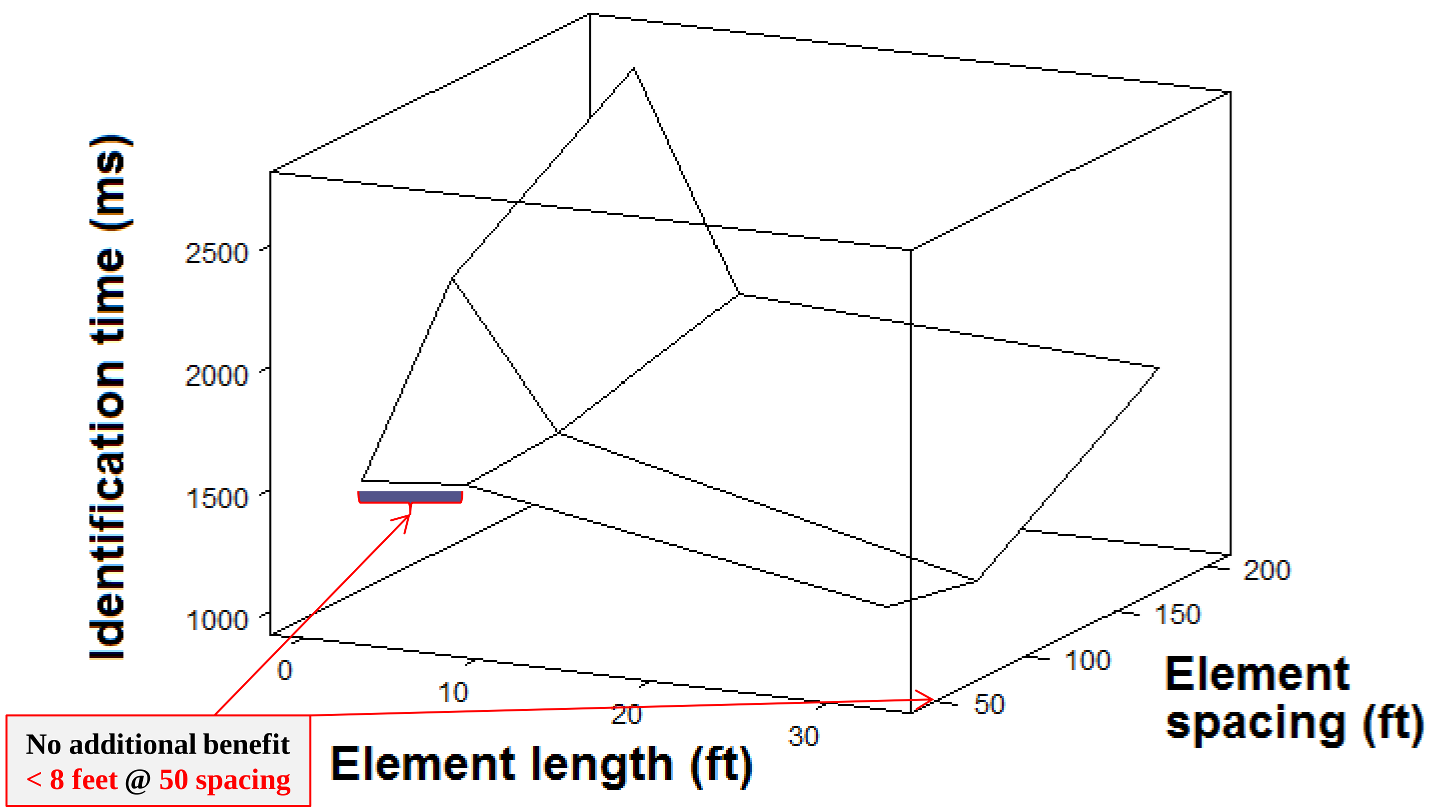
- **PHASE TWO - STATUS**
  - **Identify applications that can benefit from a linear light source compared to an array of point sources for optimum conspicuity for movement and non-movement areas.**
  - **Conduct analysis based on technology capabilities and human vision and identify up to two most promising applications. The analysis will include appropriate colors, optimum length of sources, light level modulation and spacing.**
  - **Conduct a laboratory study to determine if a linear source has advantages in providing visual signal to the user compared to an array of point sources. Identify the key parameters for optimizing this application.**

Experiment 1 Stimuli – "No Noise"

- **Linear element spacing: 50, 100, 200 ft**
- **Linear element length: 2, 8, 32 ft**
- **Configurations: 90º (low-speed taxiway exit) and 30º (high-speed taxiway exit), left and right**

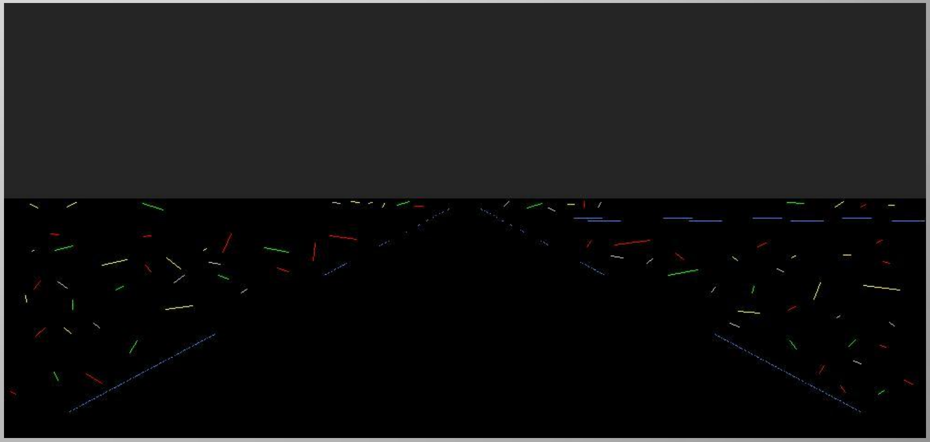
Experiment 1 Results – "No Noise"

Accuracy was always > 90%

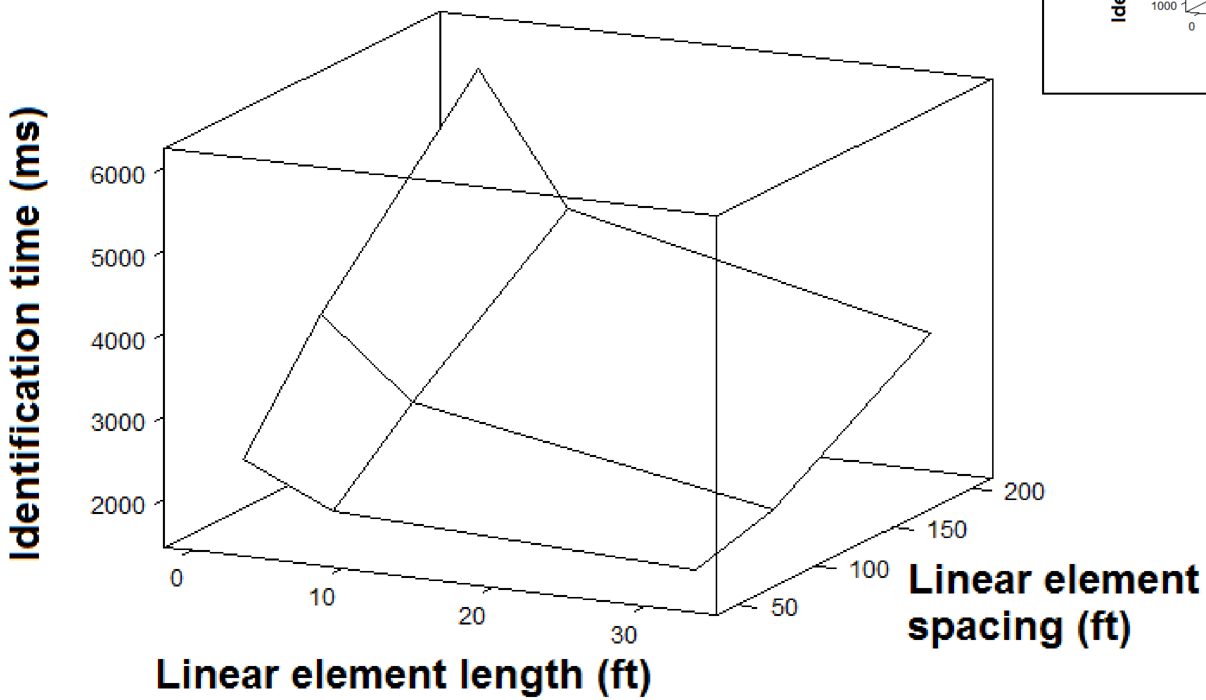


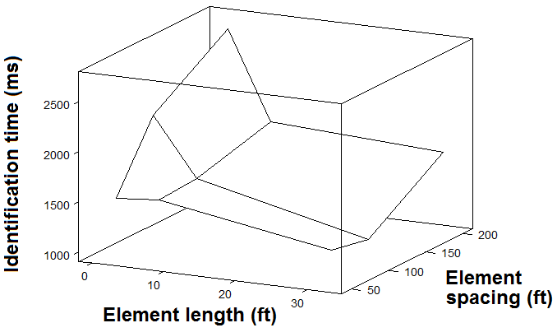
Experiment 2 Stimuli – "Visual Noise"

- Same linear element spacing and lengths
- High density of visual noise (randomly located, colored and oriented linear elements)
- Configurations: 90º and 30º left and right



Experiment 2 Results



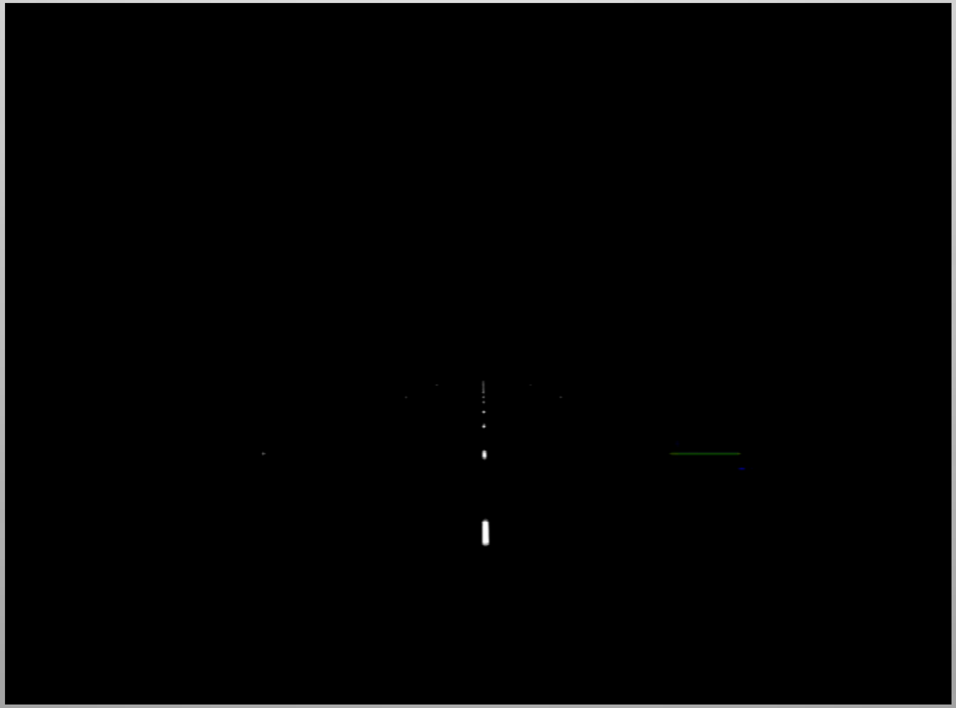


Values **with visual noise** were **strongly correlated** (r^2=0.86) to **those without**

Factor: 1.8x

Experiment 3 - Dynamic

- Dynamic animation starting from 2000 ft away, 50 mph
- $30^{o}/90^{o}$ left/right taxiway from runway
- Centerline delineation (white/runway, green/taxiway)
- 2, 8 or 32 ft element length; 50, 100, 200 ft spacing

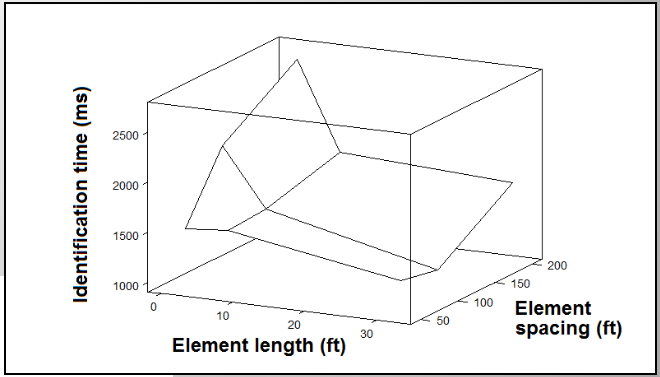


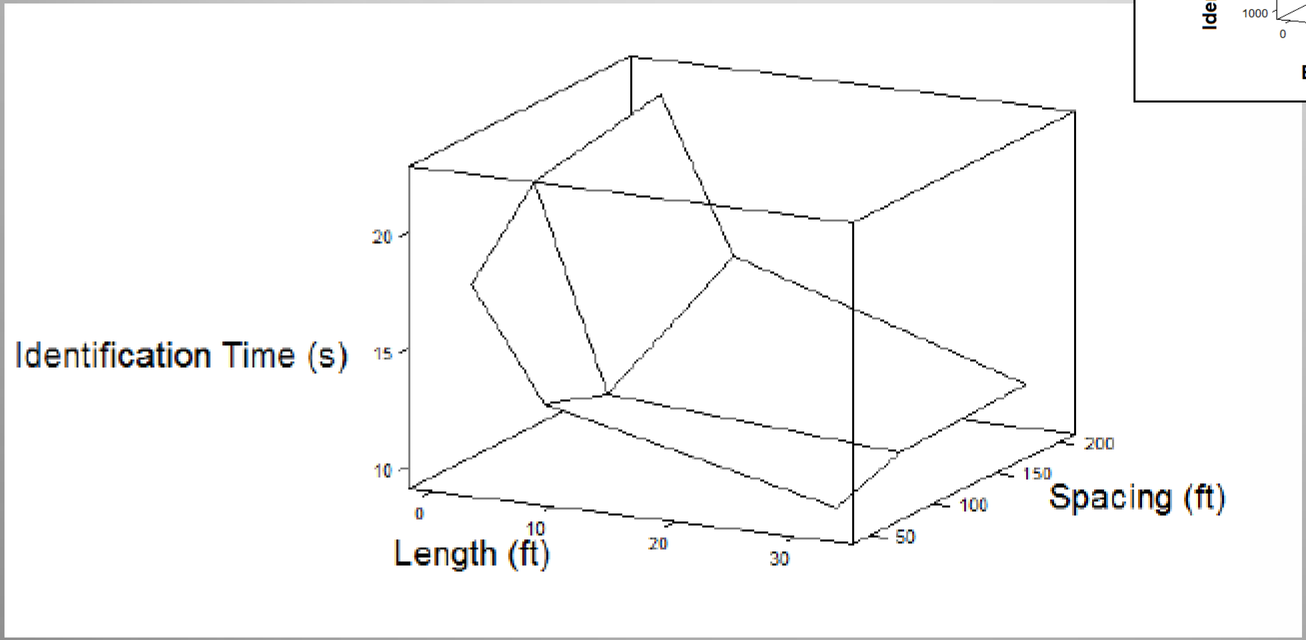
Display Characteristics and Procedure for Experiment 3

- White elements: 120 cd/m^2
- Green elements: 70 cd/m^2
- Blue elements: 7 cd/m^2
- Background: 1 cd/m^2

- Subjects stopped the animation as soon as they could reliably discern the geometry

Experiment 3 Results





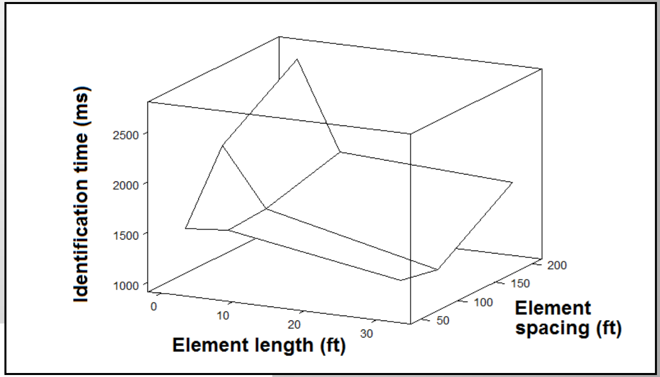
Correlated (r^2=0.73) to Experiment 1& 2 results

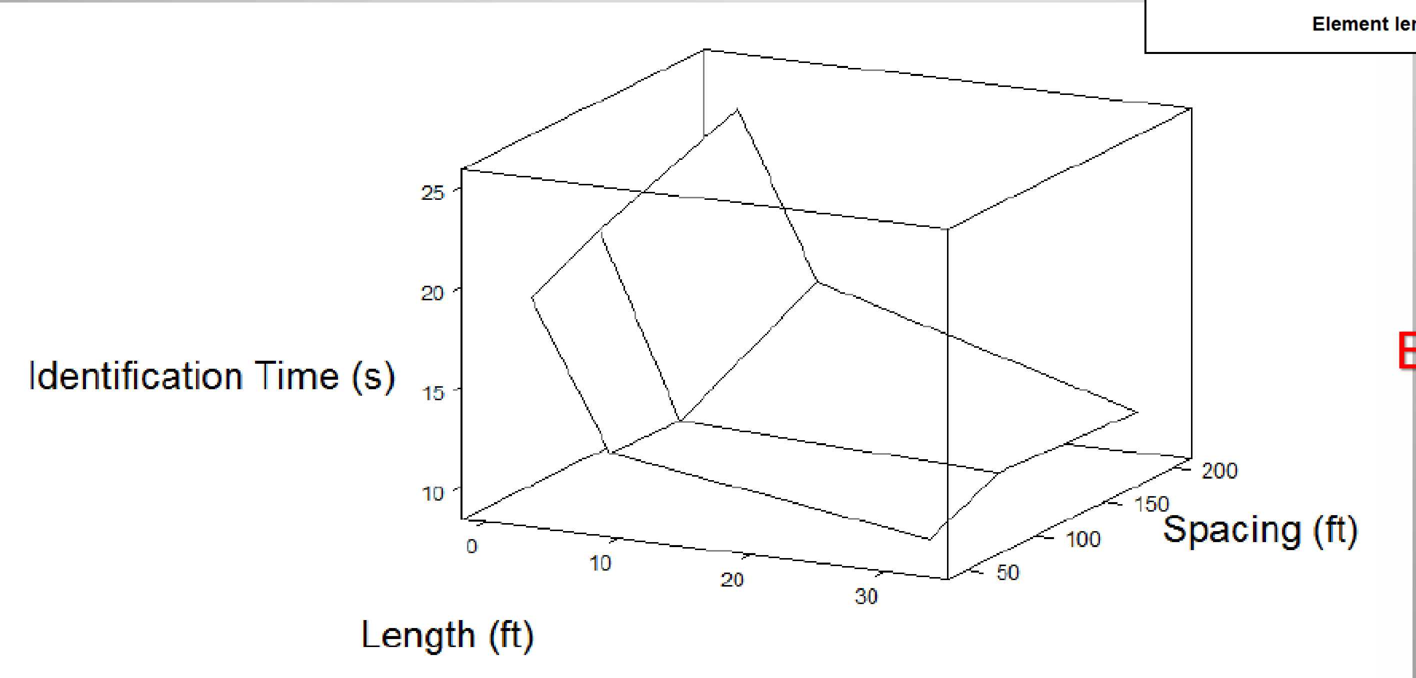
Factor: 8.6x

Experiment 4

- Same as experiment 3 except luminance was decreased to:
  - White 30 cd/m²
  - Green 18 cd/m²
  - Blue 1.8 cd/m²
  - Background 0.25 cd/m²

Experiment 5 Results

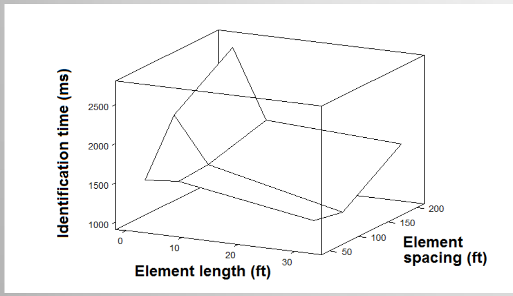




Correlated (r^2=0.69) to Experiment 1 & 2 results

Factor: 8.8x

Developed Predictive Response Time Equation



$$RT\ (ms) = 286 - 607 \log L + 989 \log S$$

Combinations of delineation element length and spacing to achieve the same relative response times expected from 2-ft-long delineation elements spaced at 50 ft and 100 ft.

Base Case 1	Element length	2 ft	**6.2 ft**	**12.0 ft**	**19.2 ft**
	Element spacing	50 ft	100 ft	150 ft	200 ft
	Relative response time	1784 ms	1784 ms	1784 ms	1784 ms
Base Case 2	Element length		2 ft	**3.9 ft**	**6.2 ft**
	Element spacing		100 ft	150 ft	200 ft
	Relative response time		2081 ms	2081 ms	2081 ms

Conclusions from Laboratory Studies

- Data for varied edge/centerline configurations differing in color and in movement (static vs. dynamic) were highly consistent

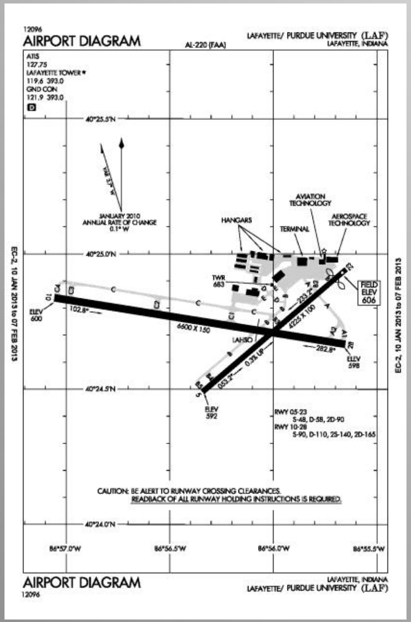
- Results could provide basis for quantitatively trading off linear element length and spacing for various configurations

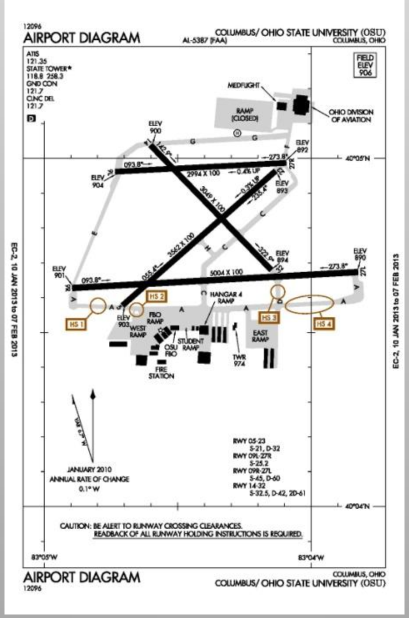
PHASE THREE

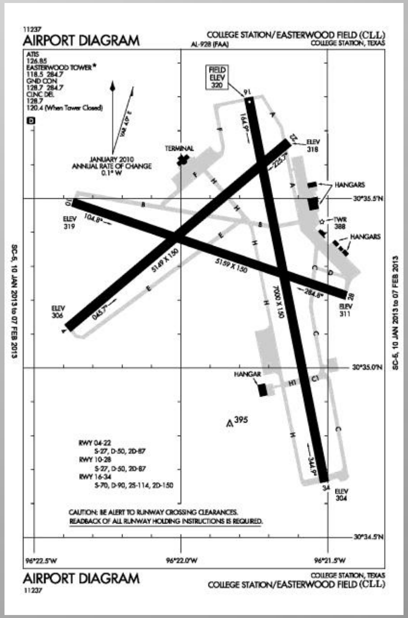
- **Task 1: Conduct a simulation evaluation. (4 months)**
  - **Utilizing the FAA Technical Center's Simulation facility.**

PHASE THREE

- Task 2: Conduct a field evaluation. (6 months)
  - Utilizing the Partnership to Enhance General Aviation Safety, Accessibility and Sustainability (PEGASAS) Center of Excellence.
  - Three of the six core members also own and operate their own airports (Purdue, Ohio State, Texas A&M).







Schedule

Activity	Completion
Test Plan	02/28/12
Phase 1	09/30/12
Analysis/Decision Point	10/31/12
Phase 2	02/15/13
Analysis/Decision Point	02/27/13
Extended Phase 2	**07/31/13**
Phase 3	**06/30/14**
Final Report to Sponsor	**09/30/14**

Frangibility

- A frangible object is defined as “an object of low mass, designed to break, distort or yield on impact, so as to present the minimum hazard to aircraft” in case of impact.

- A frangible object will break up into fragments upon impact, rather than deforming plastically and retaining its cohesion as a single object.

Frangible Structures

- Equipment located in airfield safety areas (e.g. RSAs and TSAs) must be mounted on frangible supports.
- Frangible mechanisms can be designed to withstand high wind loads but remain very sensitive to impact loads.
- Frangible mechanisms tend to be directional in strength, i.e. they carry high tension and bending but very low shear.

FAA Advisory Circulars on Frangibility

- AC 150/5220-23, "Frangible Connections"
- AC 150/5300-13, "Airport Design"
- AC 150/5345-44, "Specification for Taxiway and Runway Signs"
- AC 150/5345-45, "Low-Impact Resistant (LIR) Structures"
- AC 150/5345-46, "Specification for Runway and Taxiway Light Fixtures"
- AC 150/5220-22, "Engineered Materials Arresting Systems (EMAS) for Aircraft Overruns"

FAA AC 150/5220-23

- **Structural Integrity Criteria for Frangible Connections**

  - Withstand wind and jet blast loads

  - Break, distort, or yield when subject to collision force of a 6,600 pound aircraft either moving on the ground at 31 mph or airborne and traveling at 87 mph.

  - Under an aircraft collision condition to not impose a force on an aircraft in excess 13,000 pounds force and limit the energy imparted to the aircraft to 40,500 foot-pounds.

  - Frangibility point no greater than 3.0 inches above surrounding grade.

- **Testing and Approval**

  - Testing performed in accordance with National Cooperative Highway Research Program (NCHRP) Report 350, “Recommended Procedures for the Safety Performance Evaluation of Highway Features”.

  - Results of testing submitted to the FHWA for approval.

FAA AC 150/5220-22

- **Approach light standards mounted in EMAS Beds must be designed to fail at two points.**
- **First point of frangibility to be 3 inches or less above top of EMAS Bed.**
- **Second point of frangibility to be 3 inches or less above the expected residual depth of the EMAS Bed after the passage of a design aircraft.**

Types of Frangible Connections

Application of Fuse Bolts

Examples of Frangible Couplings

Contract Statement of Work

- **Phase 1**
  - **Evaluate results of earlier research and testing.**
  - **Identify frangible connections/structures for evaluation.**
  - **Dynamic Finite Element Modeling**
  - **Develop design for dynamic (crash) test equipment.**
- **Phase 2**
  - **Fabricate and assemble test equipment.**
  - **Conduct dynamic (crash) testing.**
  - **Evaluate dynamic (crash) test data and compare with results of dynamic finite element modeling work.**
  - **Develop guidebook containing dynamic (crash) test performance requirements.**

Taxiway Edge Light Fillet Spacing

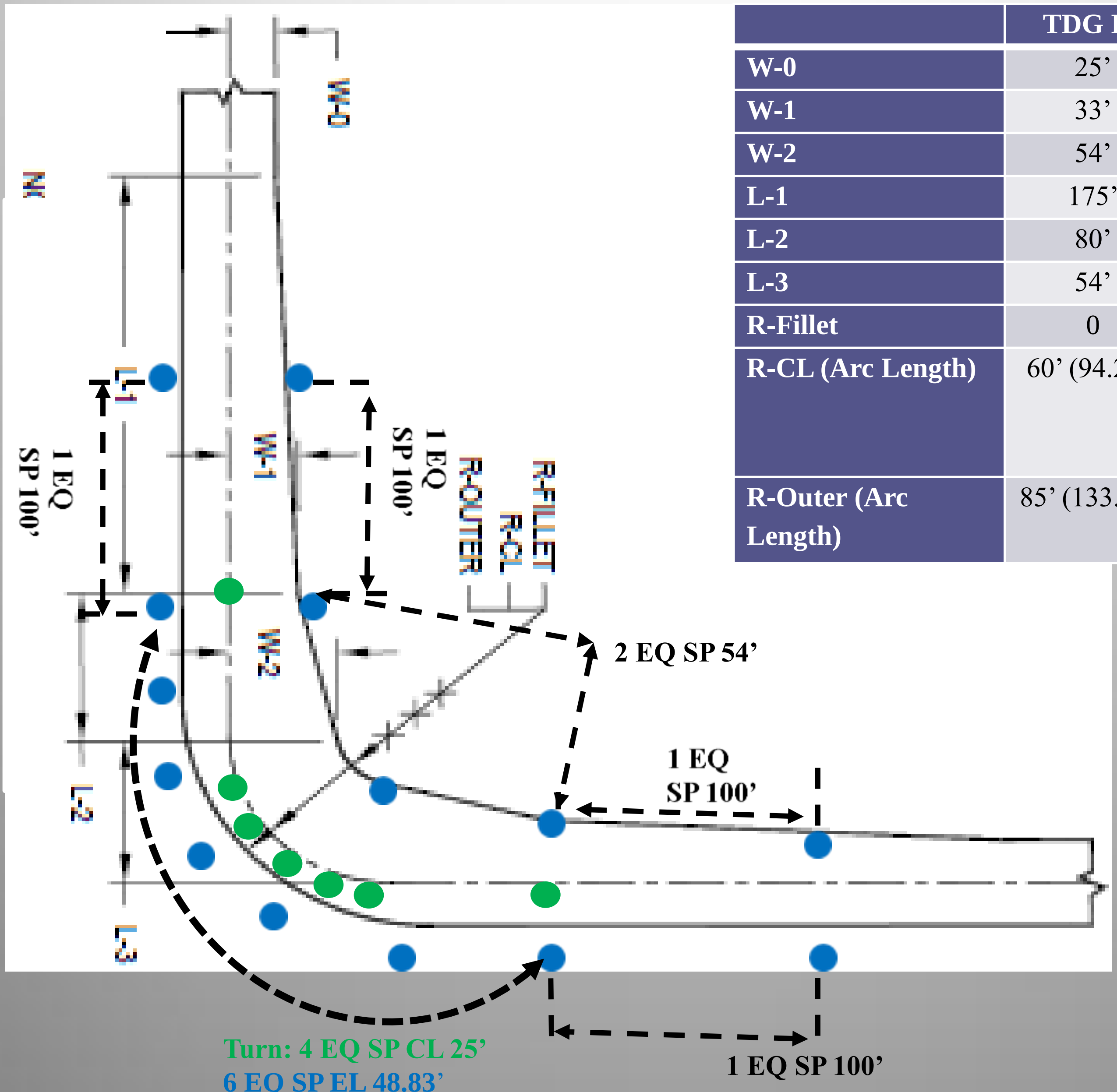
- In Airport Design Advisory Circular, AC 150/5300-13 (cancelled), taxiway design was driven by the Airport Design Group (ADG) criteria which are dependent on wingspan and tail height limits. Taxiway intersections were designed with concentric radii for the outer, center line and inner curves. They were often designed for "judgmental oversteering," which required a pilot to maneuver outside the marked centerline to maintain the main landing gear on the taxiway pavement. AC 150/5300-13A adopted "cockpit over center line" policy with a newly formulated Taxiway Design Groups (TDG).

Taxiway Edge Light Fillet Spacing - Milestones

- Project Plan – 07/12/2013.
- Testing – 07/22, 24, & 25/2013.
- Report – 08/23/2013.

- The testing was conducted at Atlantic City International Airport (ACY) on three nights July 22, 24, and 25 looking at 90 degree turn taxiway, stub taxiway between two parallel taxiways, and a high-speed exit taxiway.

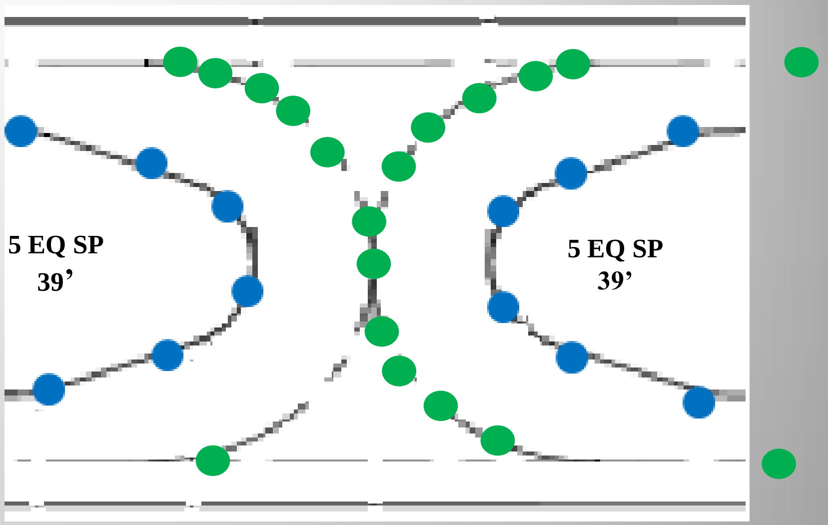
TDG III 90 degree taxiway turn



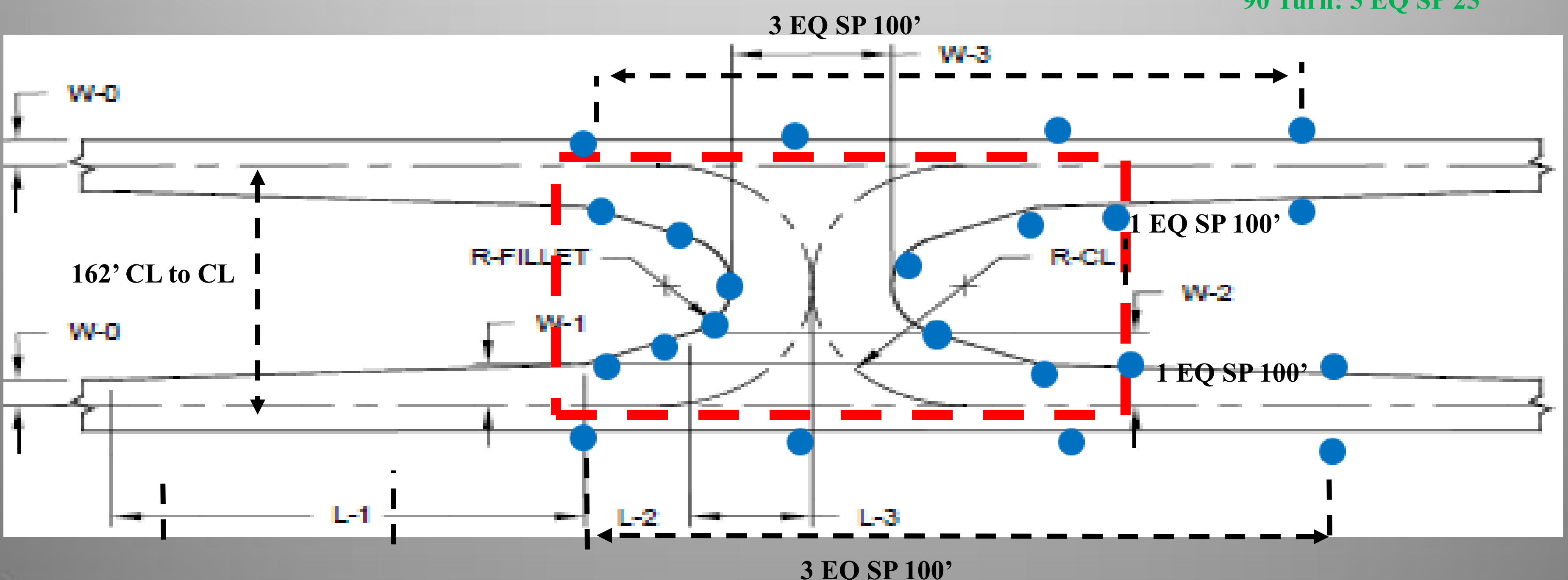
	TDG III	Light Spacing
W-0	25’	
W-1	33’	
W-2	54’	
L-1	175’	1 EQ SP 100’
L-2	80’	2 EQ SP 54’
L-3	54’	
R-Fillet	0	
R-CL (Arc Length)	60’ (94.25’)	Turn: 4 EQ SP 25’ Straight: 1 EQ SP 100’
R-Outer (Arc Length)	85’ (133.52’)	6 EQ SP 48.83’

Stub Taxiway TDG III

	TDG III	Light Spacing
Taxiway CL to CL	162’	
W-0	25’	
W-1	36’	
W-2	62’	
W-3	104	
L-1	198’	
L-2	65’	
L-3	65’	
R-Fillet (Arc Length)	20 (62.83)	
R-CL (Arc Length)	81’ (254.47’)	Turn: 10 EQ SP 25’ Straight = 1 EQ SP 100’

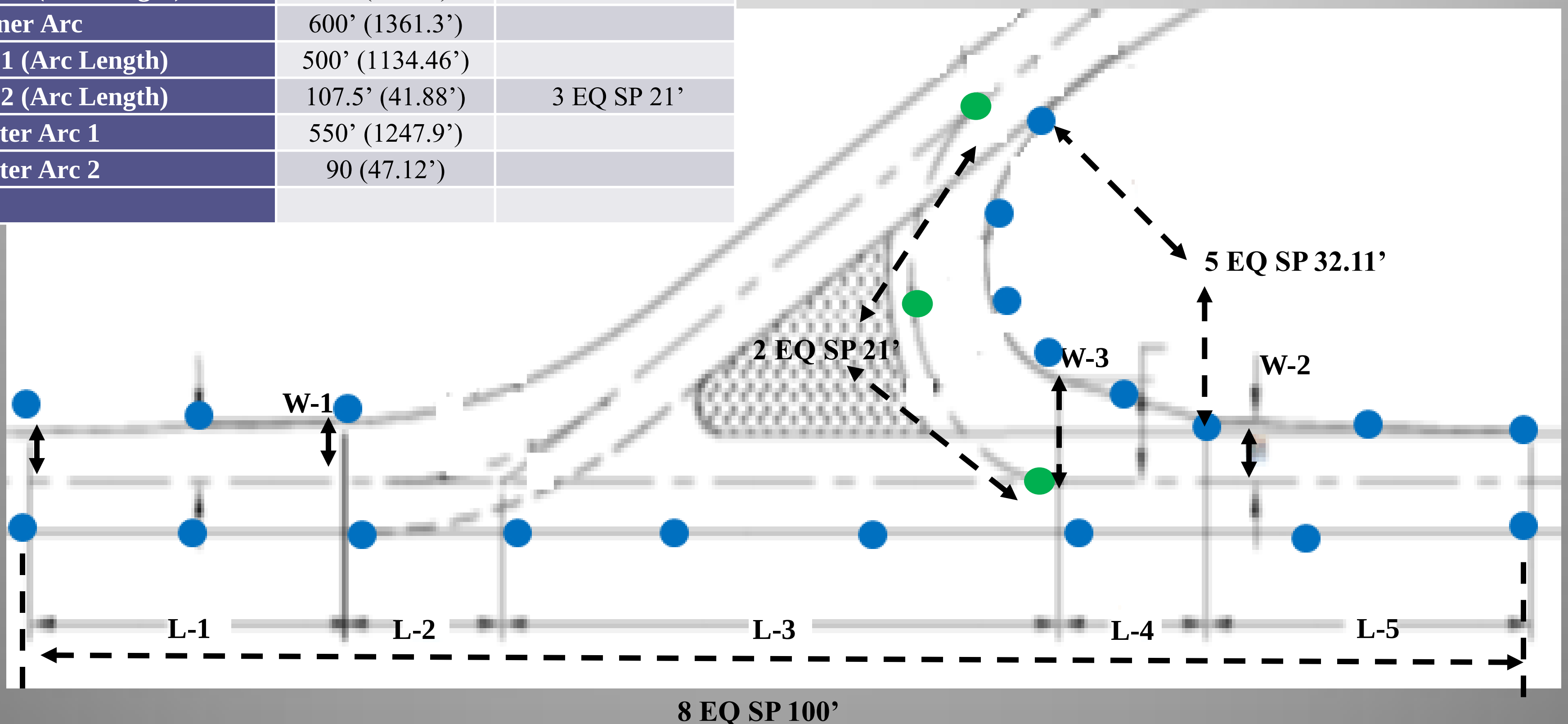


180 Turn: 10 EQ SP CL 25’
90 Turn: 5 EQ SP 25’



High Speed Taxiway (TDG-3 400’ to 150’ Runway)

	TDG V/ADG IV	Light Spacing
W-0	25’	
W-1	53’	
W-2	33’	
W-3	52’	
L-1	153’	
L-2	152’	
L-3	296’	
L-4	70’	
L-5	177’	
R-Fillet (Arc Length)	40’ (20.94’)	
R- Inner Arc	600’ (1361.3’)	
R-CL1 (Arc Length)	500’ (1134.46’)	
R-CL2 (Arc Length)	107.5’ (41.88’)	3 EQ SP 21’
R-Outer Arc 1	550’ (1247.9’)	
R-Outer Arc 2	90 (47.12’)	



Questions/Comments?