FAA Electrical Infrastructure Research Team (EIRT) Update

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October 20, 2015

AGENDA

- What is the EIRT ???
- Team Background and Structure
- Project Scope and Roadmap
- Preliminary Findings
- Current Activities
- Next Steps

Electrical Infrastructure Research Team (EIRT) History

CHARTER – The EIRT was formed by the FAA to investigate LED infrastructures to find a more suitable architecture for emerging LED circuit.

The initial Kickoff Meeting was held in July 2011.

The responsibilities of each member included:

- Discussion and planning of test activities
- Attendance and participation in the testing of the various architectures being conducted at the FAA Technical Center
- Providing comments and feedback on direction
- Review of Test Data and analysis
- Recommending improvement of the test and evaluation processes.

Collaborative Effort

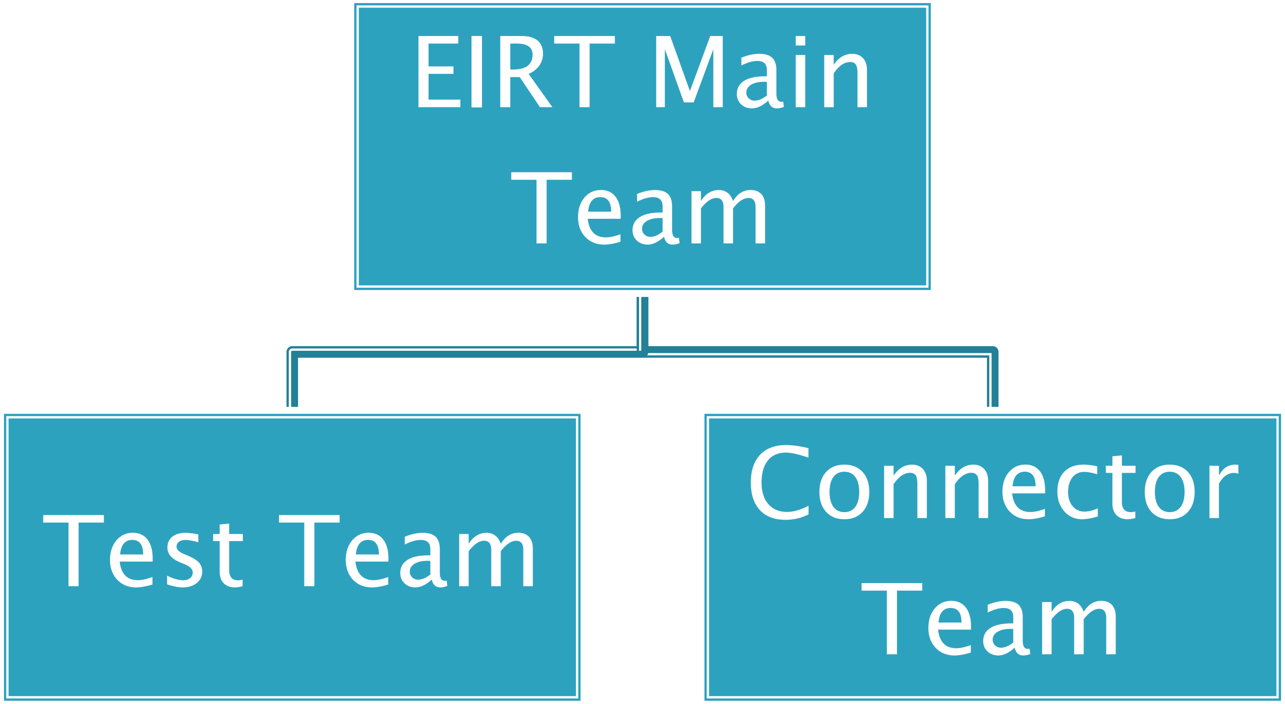
Participants:

- FAA Researchers
- Manufacturers
  - Lighting Product Design Engineers
  - Transformers and Connectors
  - Lighting Base and Related Items
- Consultants
  - Electrical Design
  - Airfield Lighting Electrical Maintenance
- Academic Researchers

Expertise in

- Airfield Lighting Equipment Product Design
- Airport Operation and Maintenance
- Installation and Constructability
- Safety
- Photometric Behavior
- Regulatory Issues
- Lighting equipment

EIRT Structure



Project Phases

- Phase I -- Investigation of LED Infrastructures, test, characterize and evaluate identify optimal characteristics of system.
- Phase II – Optimize on results from Phase I, resolve and test prototypes to answer remaining questions.
- Phase III- Draft preliminary specifications for review, and build systems to spec check out and adjust as needed for final report.

Phase I Evaluation - Overview

Objective:

- Evaluate and collect data on several experimental LED systems from different manufacturers
- Identify desirable best characteristics that could be incorporated into a standardized architecture that best suit lighting applications

Activities:

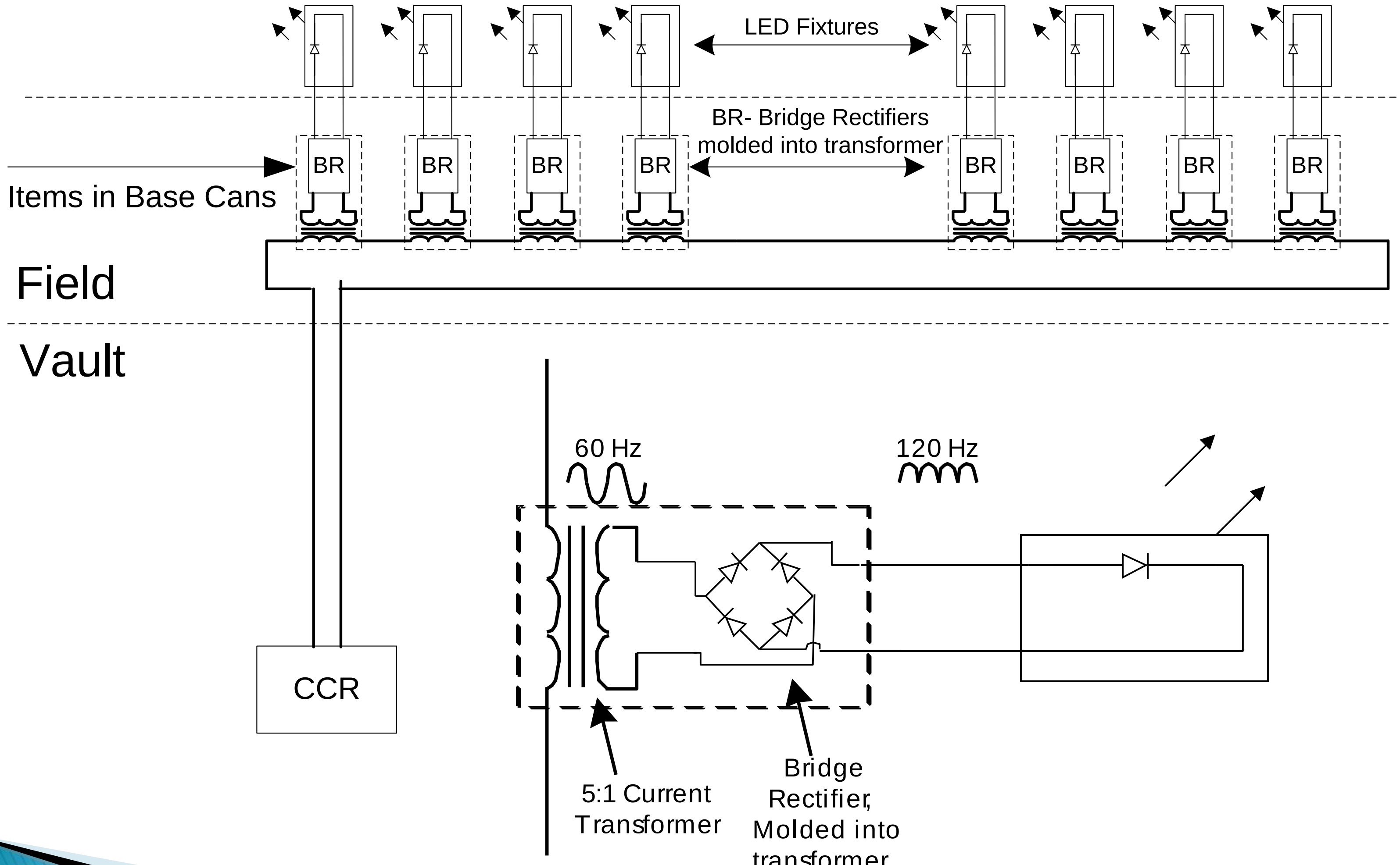
- Began at the FAA Technical Center Oct 2011
- Included--
  - Architectural Investigation
  - Data Collection
  - Characterization through testing
  - Site visits
  - Manufacturer Lab Visits
- Each was brought to a Test Bed at the FAA Technical Center that included 50 Fixtures.
- Primarily Electrical testing with some Photometric to characterize the different approaches
- Most of the Test team present for tests and provided valuable comments and inputs to help focus the efforts
- The Investigation and test data provided the basis for an evaluation matrix.

Phase I Evaluation – Technologies Tested

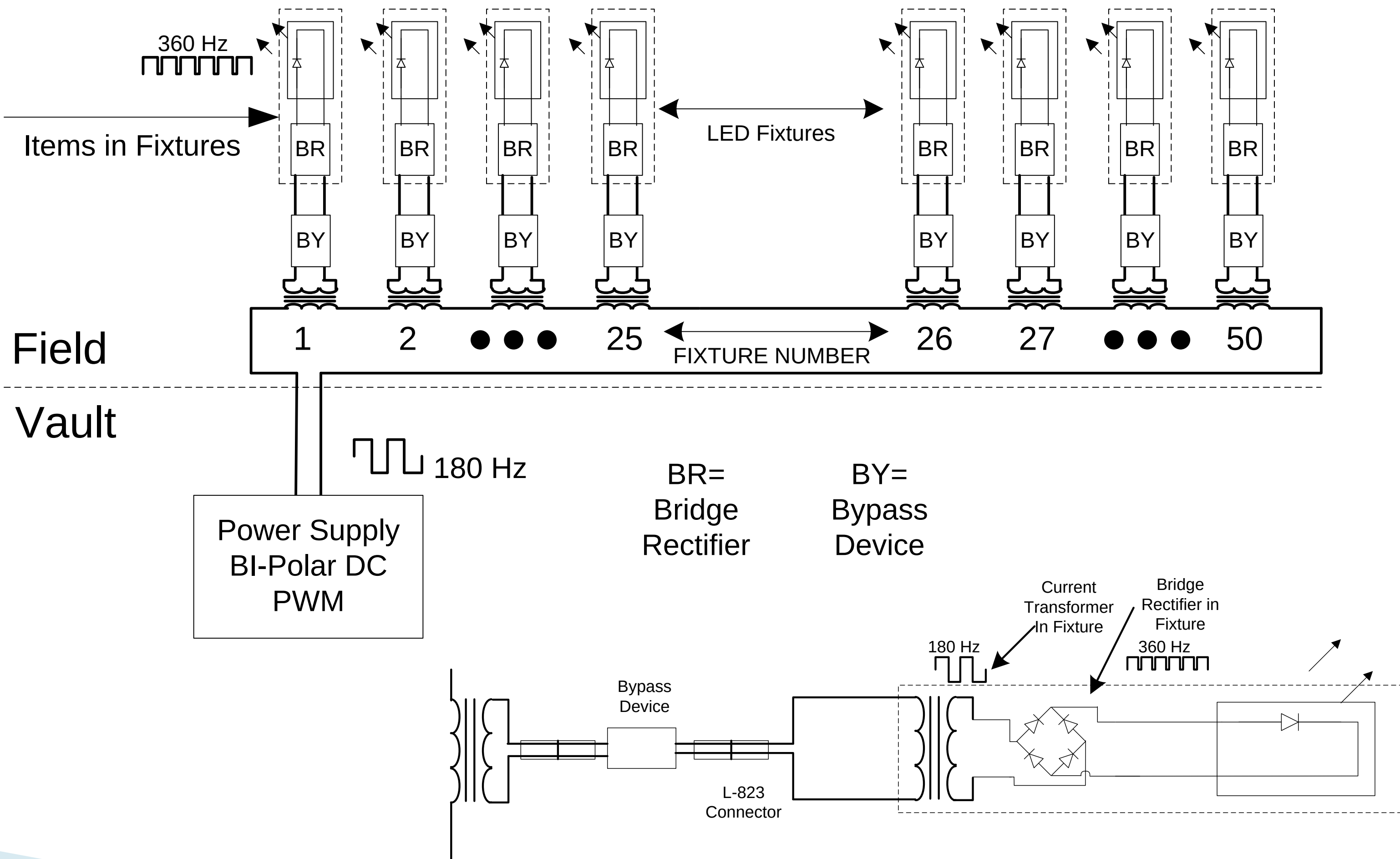
Different alternative infrastructures considered included:

- Low Current, Series Powered, LED Driver in the Vault, Sinusoidal Drive
- Low Current, Series Powered, LED Driver in the Vault, Pulse Width Modulation Drive
- Parallel Powered, Power line Carrier, LED Driver in Fixture
- Low Current Series Powered, Power line Carrier, LED Driver in the Fixture

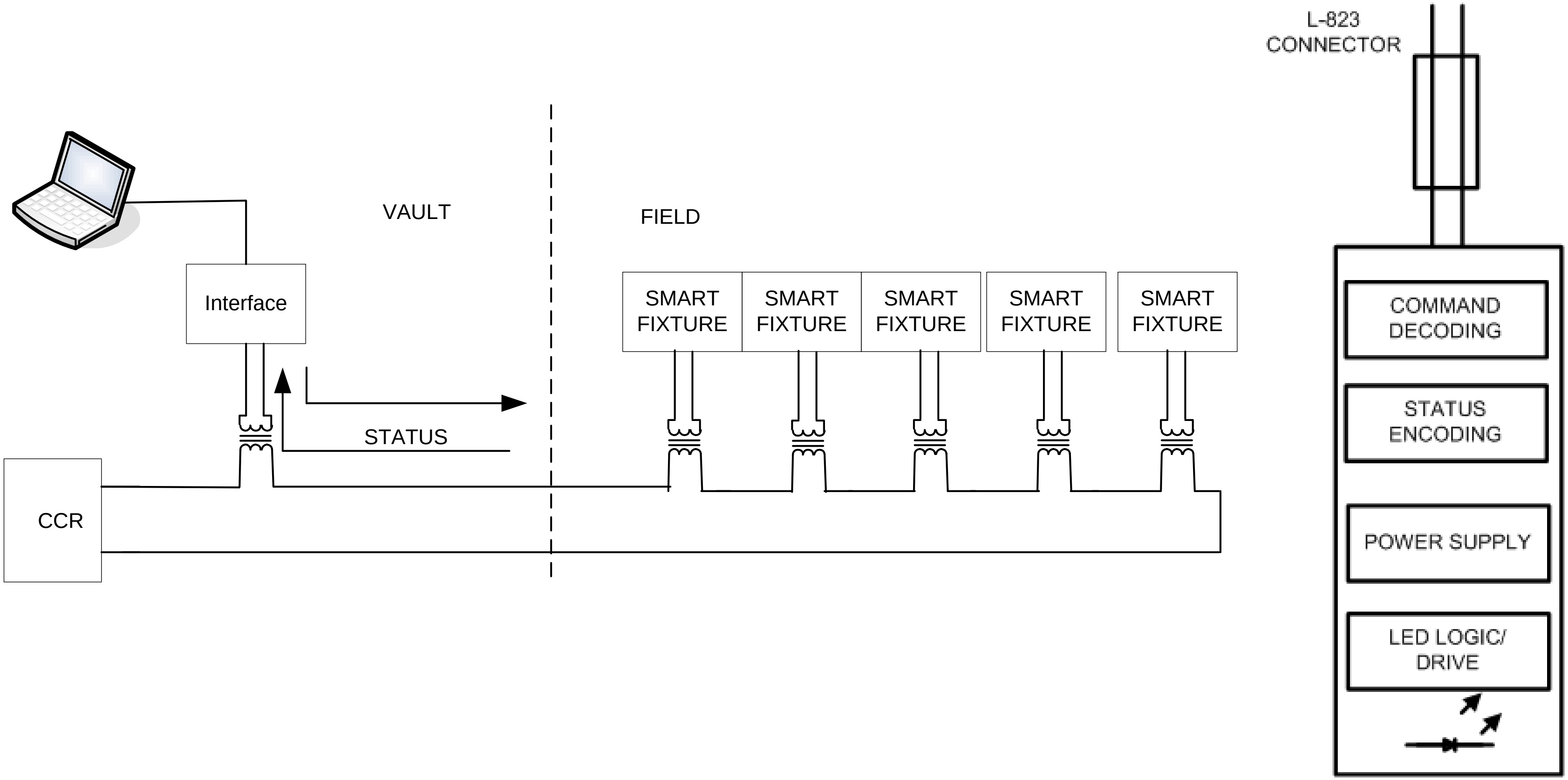
Phase I Topologies Tested - Low Current, Series Powered, LED Driver in the Vault, Sinusoidal Drive



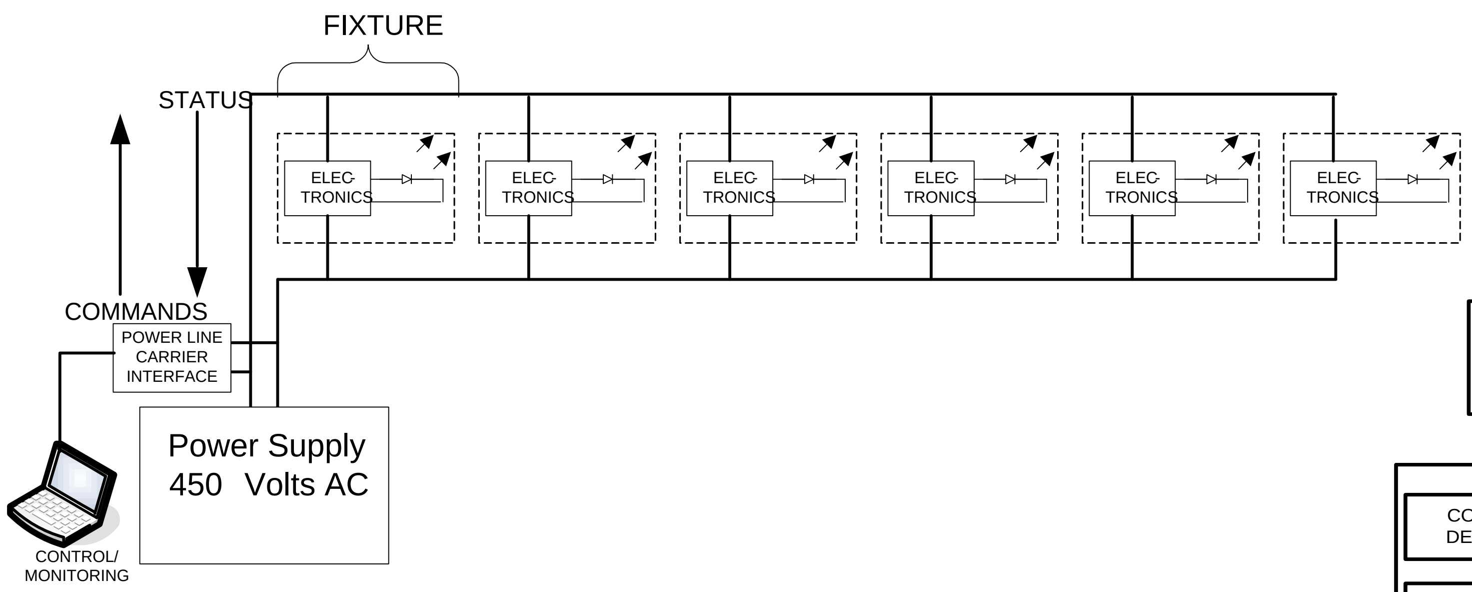
Phase I Topologies Tested - Low Current, Series Powered, LED Driver in the Vault, PWM Pulse Drive

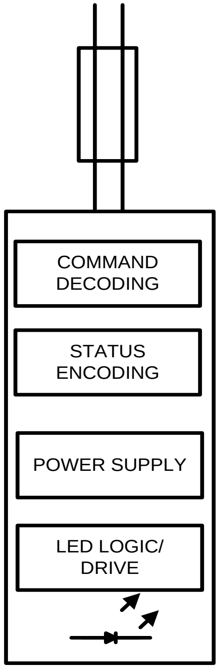


Phase I Topologies Tested - Low Current Series Circuit, Power Line Carrier Intensity Selection



Phase I Topologies Evaluated - Parallel Fed, Power Line Carrier Intensity Selection





Fixture Detail

Phase I Evaluation – Data Collected

- Power Consumption – fixture/circuit
- Circuit Current/ Voltage Characteristics
- Efficiency
- Input Side PF
- System Performance – Intensity Selection
- Fixture Performance
- Power Quality – conducted emissions
- FAA Laboratory Photometric testing

Background - "Vault Centric" Architectures

- Investigation and testing revealed two fundamental architectural characteristics
- **Vault Centric-** where intensity is controlled by a power source for the entire circuit. The fixture directly tracks circuit current
- Advantages –
  - Least expensive; Fixture includes essentially passive components and LED(s)
  - Lowest power
- Disadvantages –
  - All infrastructure elements (power source, cables transformers, cable layout, insulation leakage and crosstalk) influence fixture intensity.
  - Lower intensities may not provide predictable intensity performance with sufficient margin that is suitable for standardization
  - Heater and other high power options are not really practical
  - PWM version can be a source of emissions on the circuit
  - Will not readily support add on capability for SMGCS

Background - “Fixture Centric” Architectures

- **Fixture Centric** - Fixture controls its intensity level after intensity information is conveyed to it.
- Advantage-
  - Discrete intensity step information is sent to the fixture
  - Lights in groups can be independently controlled (for example bidirectional fixtures)
  - Fixture intensity not dependant or impacted on infrastructure. Tolerances in circuit current or voltage, transformers, and leakage do not impact intensity
  - Fixture can compensate for its own changes in performance such as temperature. Compensation is on the fixture level.
  - Heater or other loads are supported and can be independently controlled
  - The allowance for infrastructure related manufacturing tolerances and with less dependence on circuit layout and field conditions, provides suitability for standardization.
- Disadvantages
  - Fixture Cost is similar to conventional 6.6 amp LED fixture
  - Consumes more power than Vault Centric; power management will be key minimizing power consumption
  - Will require detailed architectural development to ensure performance and interoperability.

Existing Technology Evaluation – Phase I Preliminary System Level Results

- Isolation of Components is desirable, for safety, performance and maintenance
- Parallel architecture has load limitations and is not well suited for dealing with circuit configuration changes. In addition, retrofit may be a challenge, and incremental upgrades of the airfield could be more of an issue
- Power Line Carrier Approaches are highly functional but are proprietary and require special setup to operate.
- Vault Centric technologies will require more testing and studies for some applications to determine suitability.
- Field connections and Cabling could be optimized (a separate team was formed).

These Findings Defined the Path Forward

Existing Technology Evaluation – Phase I Preliminary Fixture Level Results

- Vault Centric was lowest cost and power, but can be degraded by its electrical environment
- Fixture Centric was similar cost and structure to existing fixtures with reduced power, but had operational benefits, and can withstand a poor electrical environment
- Needed some Field Data and simulation studies on each approach to better define behavior and evaluate trade off data
- Architectural refinement does not rule out more than one application specific infrastructure

Remaining questions need to be addressed for both approaches

Phase I Evaluation - Test Bed Arrangement
FAA Technical Center

Phase I Summary – Identified Key Architectural Features

- Need to meet photometric and radiometric output requirements.
- Interoperability
- Non-proprietary technology
- Account for real world circuit conditions, so there are large operating margins.
- High system availability and reliability.
- ‘Easy’ Installation.
- Safety considerations for maintainers of the systems
- Lower system life cycle costs in terms of initial equipment outlay, maintenance costs, and energy consumption.

Phase I System Results – System Recommendation

During the evaluation, an FAA experimental technology was proposed to address the desirable architectural features highlighted in Phase I.

- This approach was a Series Circuit topology using low current, that was proposed to operate as a "Fixture Centric" architecture.
- This method conveys intensity information to the fixtures digitally. Intensity selection is therefore discrete.
- Vault Centric architectures will continue to be studied in Phase II.

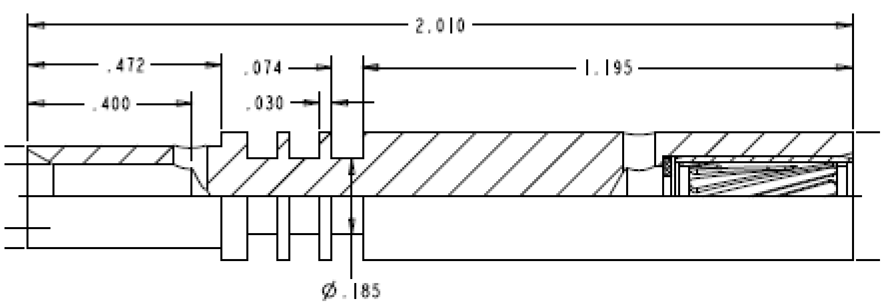
Recommendation – Develop a Fixture Centric Constant Current Prototype System to determine suitability.

Connectors and Cables Team Phase I Preliminary Results

GOALS

- Non-proprietary technology
- Improved pins and sockets, current approach proposes using a rifled mating surface
- Improved Insulators, current approach proposes using a twist lock key
- Improved termination technique

NEXT STEPS

- Design and Prototype Connectors -12/31/15
- Design and Prototype Cable – 12/31/15
- 

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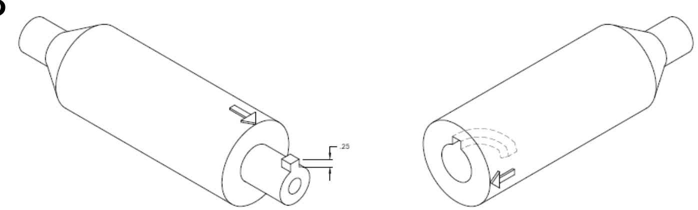
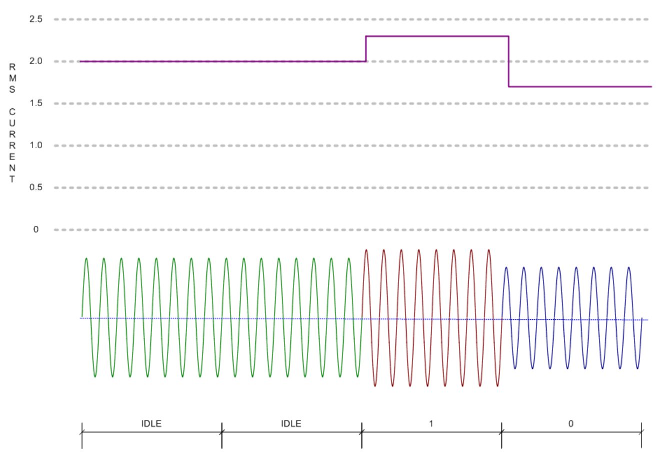


Phase II Infrastructure Under Consideration

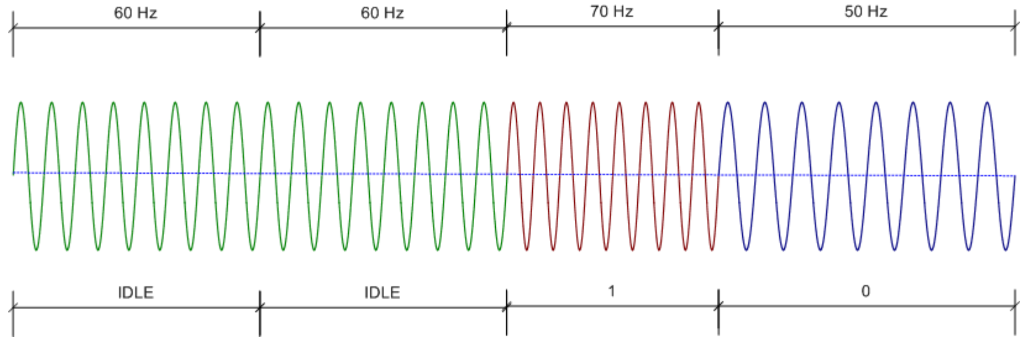
Two Low Current Approaches to FAA Experimental Architecture

- Current amplitude at nominally 60 Hz is slightly shifted (+/-0/.3 amp) in a defined sequence to form a digital message that defines an intensity command. This method is **Amplitude Shift Keying (ASK)**
- Frequency at nominally 60 Hz is narrowly shifted (+/-4 to 10 Hz) in a defined sequence to form a digital message that defines an intensity command. This method is **Frequency Shift Keying (FSK)**

ASK



FSK



1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
PREAMBLE				SEQUENCE NUMBER					PAYLOAD					CRC								EOM	
1	2	3	4	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	6	7	8	1	2
p3	p2	p1	p0	s4	s3	s2	s1	s0	d4	d3	d2	d1	d0	c7	c6	c5	c4	c3	c2	c1	c0	e1	e0
1	1	0	1	n	n	n	n	n	x	x	x	x	x	x	x	x	x	x	x	x	x	1	0

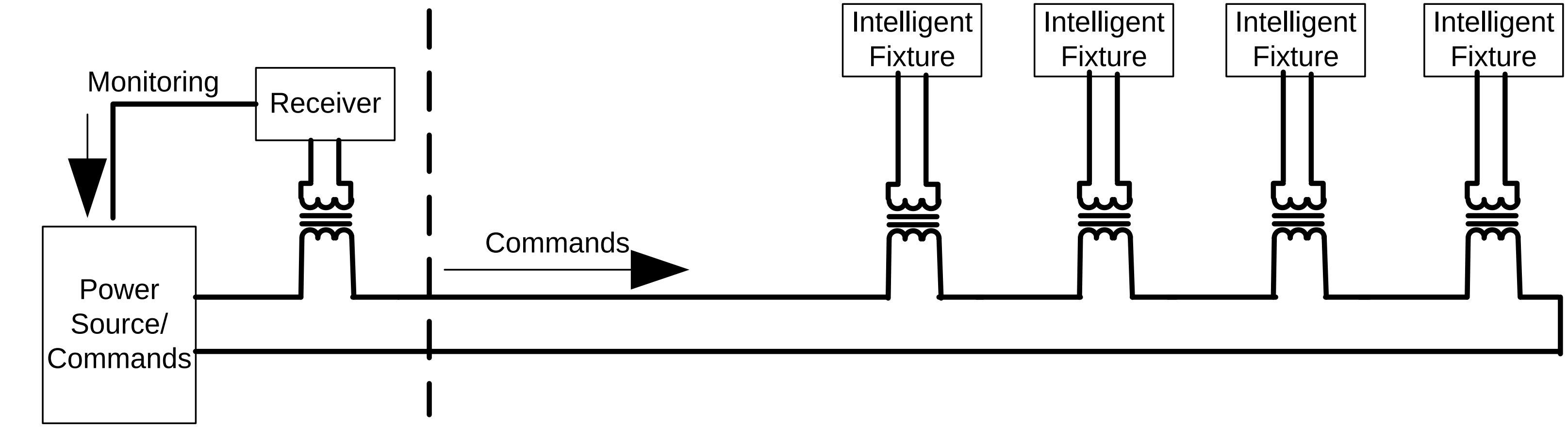
Phase II Infrastructure Benefits

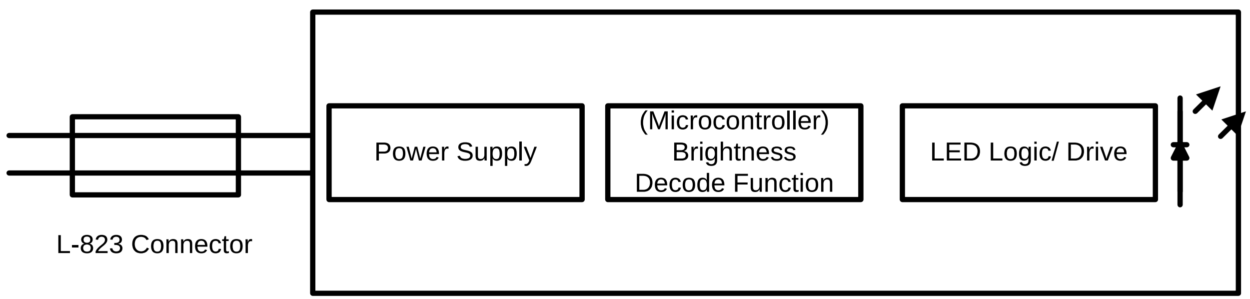
Characteristics

- FSK/ ASK non proprietary architectures
- Can select one or both sides of a directional fixture
- Can select fixtures in groups
- FSK/ ASK allow SMGCS add on capability (using power line carrier or other method) to be supported for more advanced applications
- Arctic kit option can be independent of intensity, and only on when needed
- Cost should be roughly equivalent to existing fixtures
- Nominal current can be dynamic–lower for low loads and increase for large loads

Proposed Architecture will Exceed Current System Capability.

Proposed topology - Low Current Series Powered, Amplitude Shift Keying (ASK) & Frequency Shift Keying (FSK)





Fixture Detail – Same as an existing 6.6 amp Fixture

Phase II Fixture Centric Testing Plan

Purpose– Investigate Candidate architectures for refinement. Assemble circuit components, install, and address any issues that arise. For successful completion, all circuit components will be operating properly.

Fixture Centric Work:

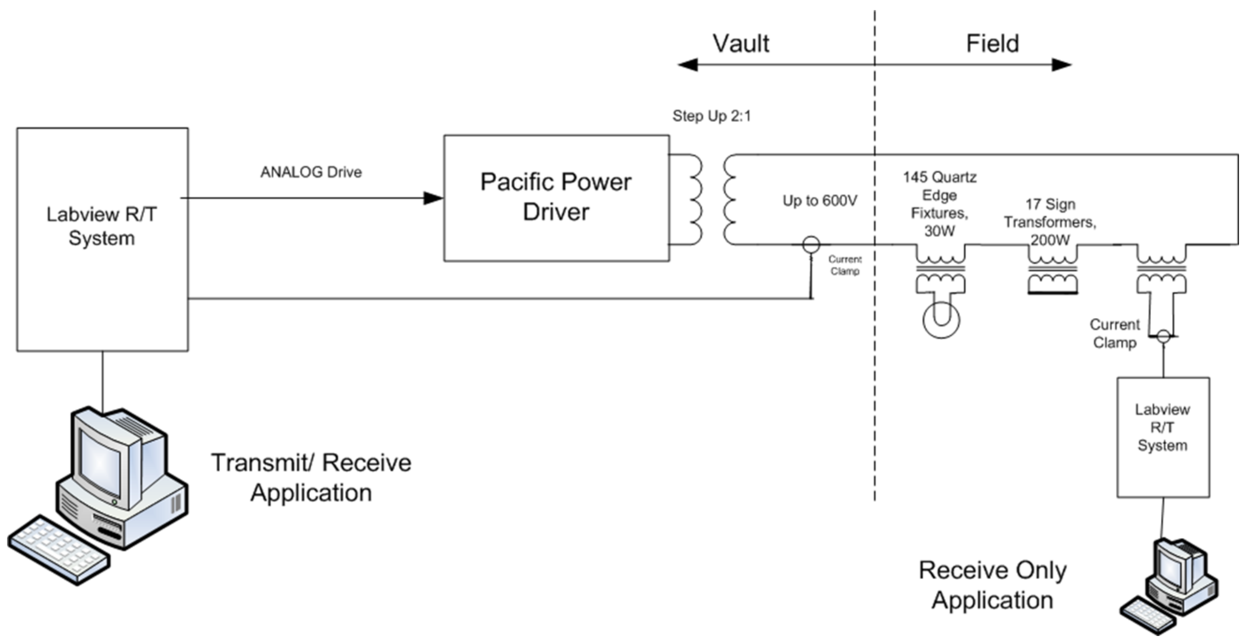
- Perform Alpha testing at FAA Tech Center **- complete**
- Look for a really bad circuit! (worst case actual environment, less than 100 ohm insulation resistance) – **complete**
- Perform basic ASK/FSK communication tests -**complete**
- Obtain 150 modified off the shelf inset fixtures (50 from each of 3 manufacturers) to operate on the Purdue Taxiway C Circuit. **- complete**
- Operate from 3-6 months at the Purdue Test Bed – **in process**
- Collect data

Vault Centric:

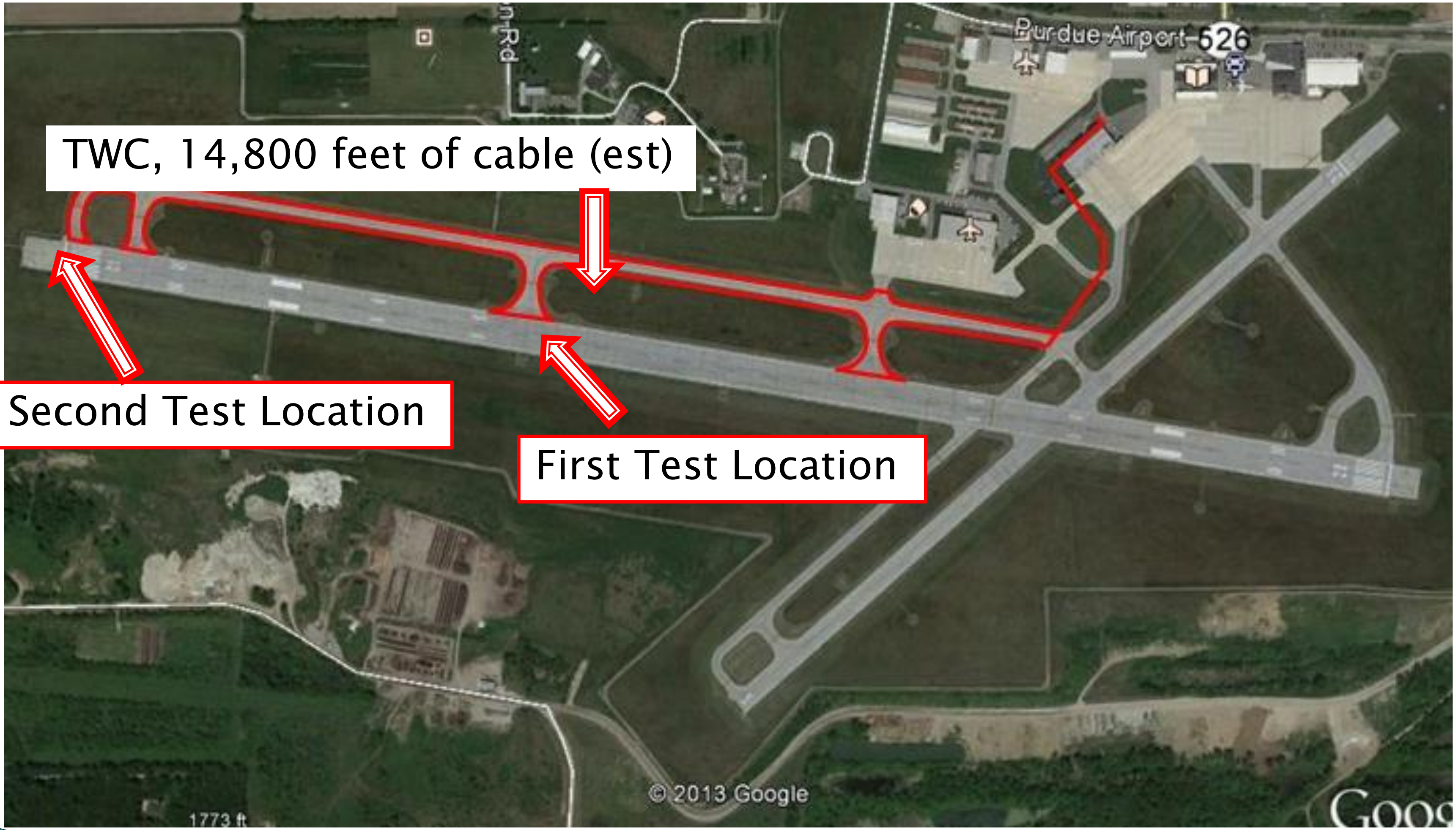
- Will follow same process

Phase II - ASK/FSK Purdue Initial Checkout June 2014

- Purpose – to gain an understanding of ASK and FSK behavior on a large circuit with poor electrical conditions.
- Access to existing circuit to place experimental vault equipment and field equipment that represents a fixture to check out operation on large circuit
- Circuit length about 14,800 feet
- 145 L830 30/45 watt transformers with MITL 30 watt incandescent fixtures
- 17 Signs with 200 W L830 Transformers, with shorting plugs
- Insulation Resistance of the circuit: Less than 100 Ohms



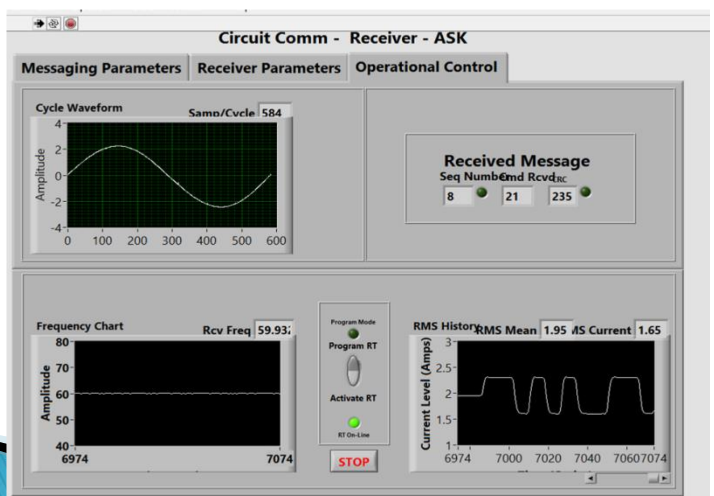
ASK/FSK Initial Checkout Test Location - Purdue (LAF)

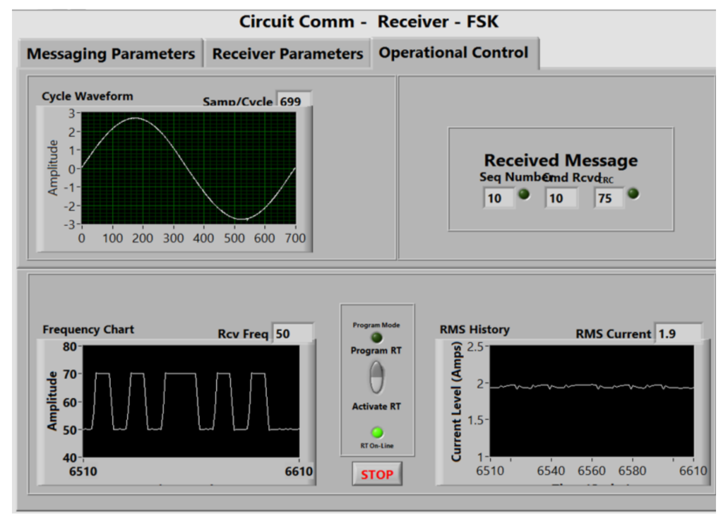


Initial Checkout Results (No Fixtures), Purdue June 2014

- Circuit was basically grounded at more than one location
- There was a reduction in current at the C4 sign location of about 0.2 amps, with no change in performance
- This was due to circuit leakage, resulting in uneven current distribution
- Tested at several levels of current between 0.25 and 3.5 amps without issues
- Two deliberately Interfering circuits sharing the some of the conduit did not impact performance

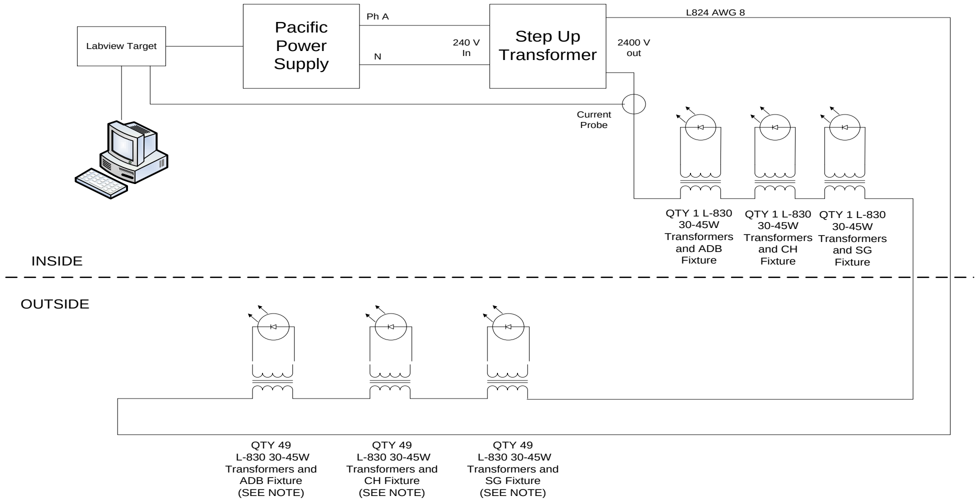
No message errors occurred





ASK/FSK Initial Fixture (Alpha) Test

- Operated All 150 Fixtures at all Intensities on the same circuit in ASK and FSK Mode on the side of the runway (last chance before install).
- Demonstrated Unidirectional and Bidirectional Control
- A number of items were documented for improvements and system specifications by the test team, relating to more robust operation and performance



Test Successful, Continue With Installed Fixtures (Beta Test)

ASK/FSK Beta Test Circuit (Purdue Existing Circuit)

Circuit as Received

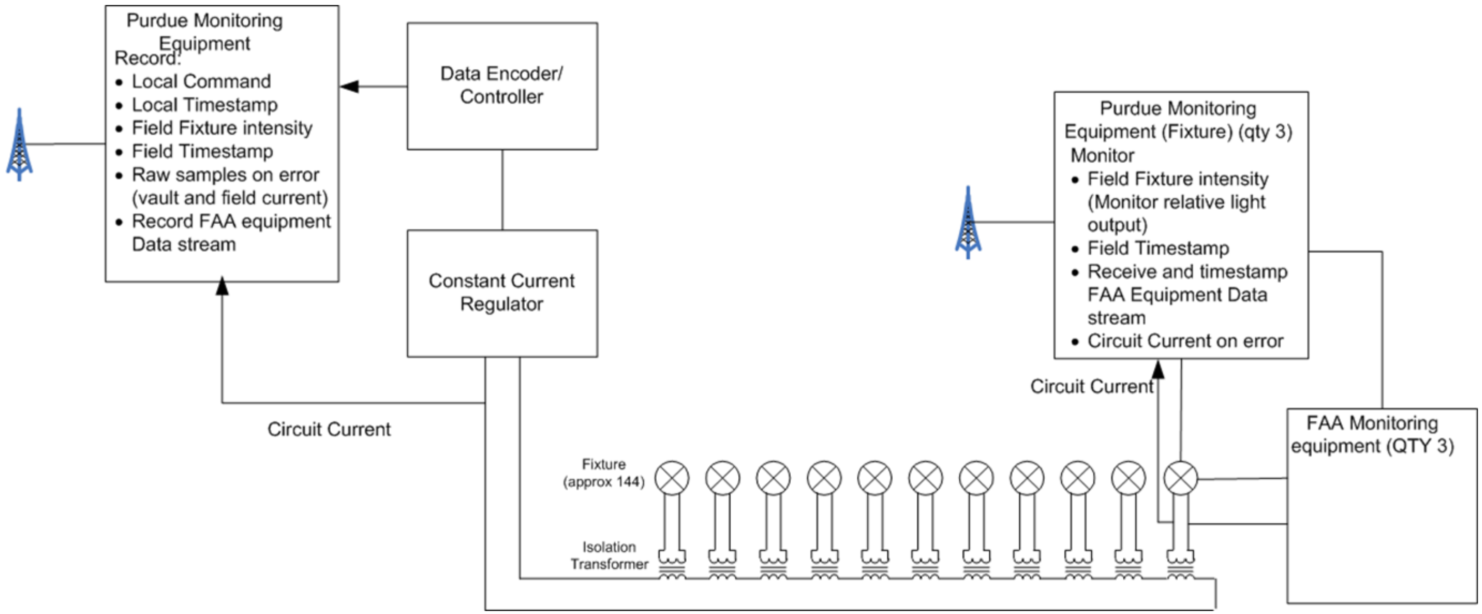
- TWY C circuit
- Circuit in 2" PVC Conduit
- Fixtures all in 24" deep Bases
- Cables 4 yrs old, Some replaced after recent lightning hit.
- Insulation essentially shorted to ground
- 144 TWY edge, 14 Signs

Modifications For the Test

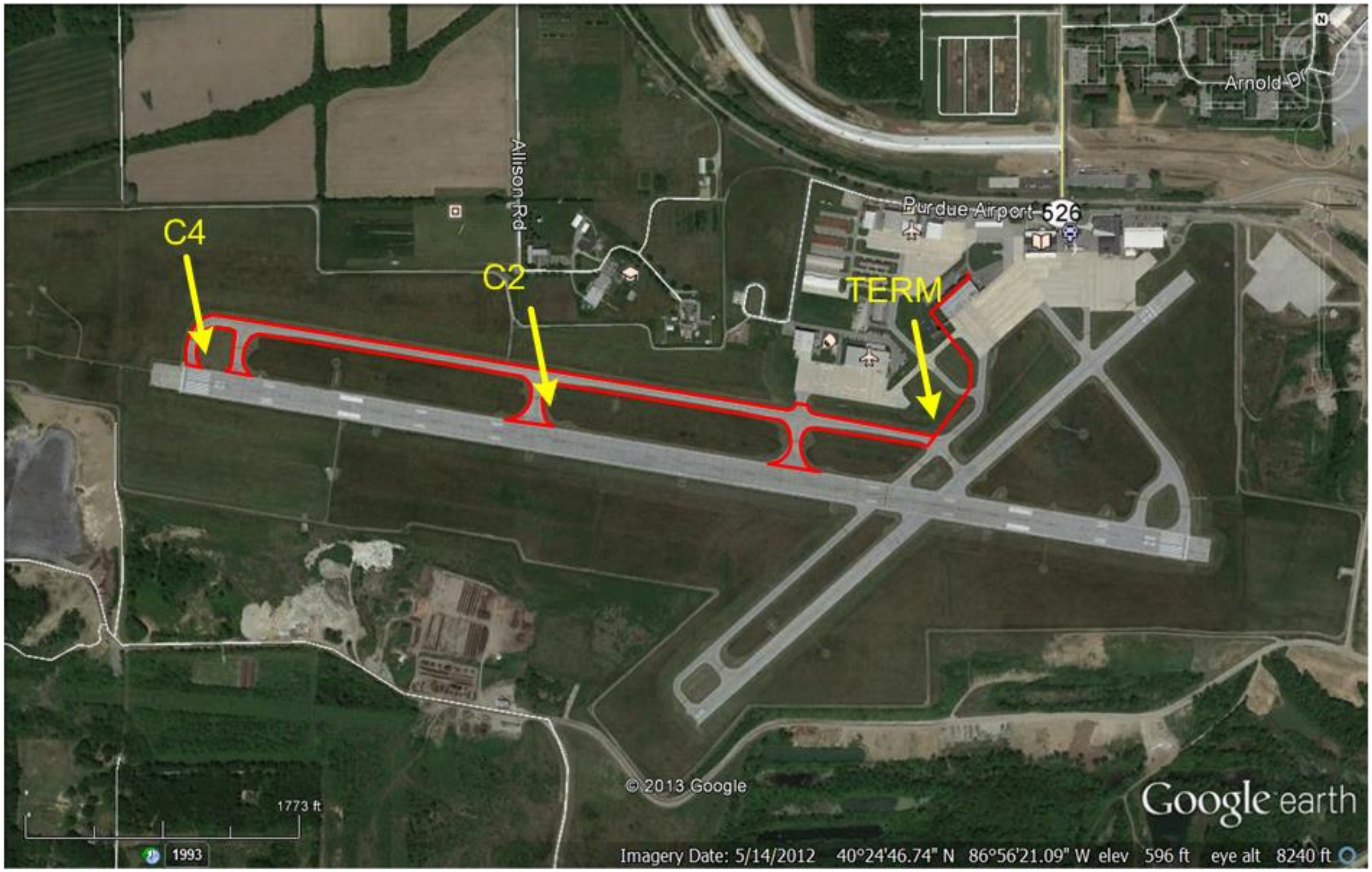
- Existing circuit was left in place, with LED fixtures installed on existing transformers
- New Circuit and transformers have been installed in the same pathway and , and existing lights and signs were transferred to the new circuit.
- Three sign locations will support monitored fixtures
- Remaining Sign Transformers will have secondaries shorted

Fixture Centric Next Steps - Purdue Beta Test

- Circuit was populated with 147 fixtures from three manufacturers
- Three fixtures will be instrumented to provide data on communication effectiveness (% commands received)
- Monitoring Enclosures for instrumented fixtures will be installed at three locations;
  - C4,C2,“Term” sign
- Data will be collected over a period of a few months
- Installation of equipment is in process, expecting to integrate within the next two weeks



ASK/FSK Next Steps - Purdue Beta Test Monitoring Locations



PEGASAS Participation

Technical Support

- Fixture Centric Power Stability Modeling and Simulation– a study to model and simulate the power stability of a fixture centric circuit. The goal is to parameterize how fixture power supplies and circuit power sources should behave on the circuit.
- Vault Centric Circuit Analysis-- a study to model and simulate energy distribution to fixtures around the circuit accounting for circuit related effects such as insulation leakage, pulse propagation, and other environmental conditions.

Operational Support

- Purdue is also providing the circuit monitoring infrastructure to conduct testing on the Taxiway C circuit test. Selected fixtures will be instrumented to determine their response to intensity changes that are set for the circuit

Next Steps

Testing

- Simulation results – 4Q, 2015
- Complete Fixture Centric testing at Purdue – 2Q2016
- Complete Vault Centric testing – 3Q, 2016

Report

- Draft Technical Report – 2Q, 2017

Field work

- Outfit circuits with products that are built to requirements – 2Q, 2018
- Check out and adjust if needed – 3Q, 2018
- Finalize Technical Report – 4Q 2018

THANK YOU!