



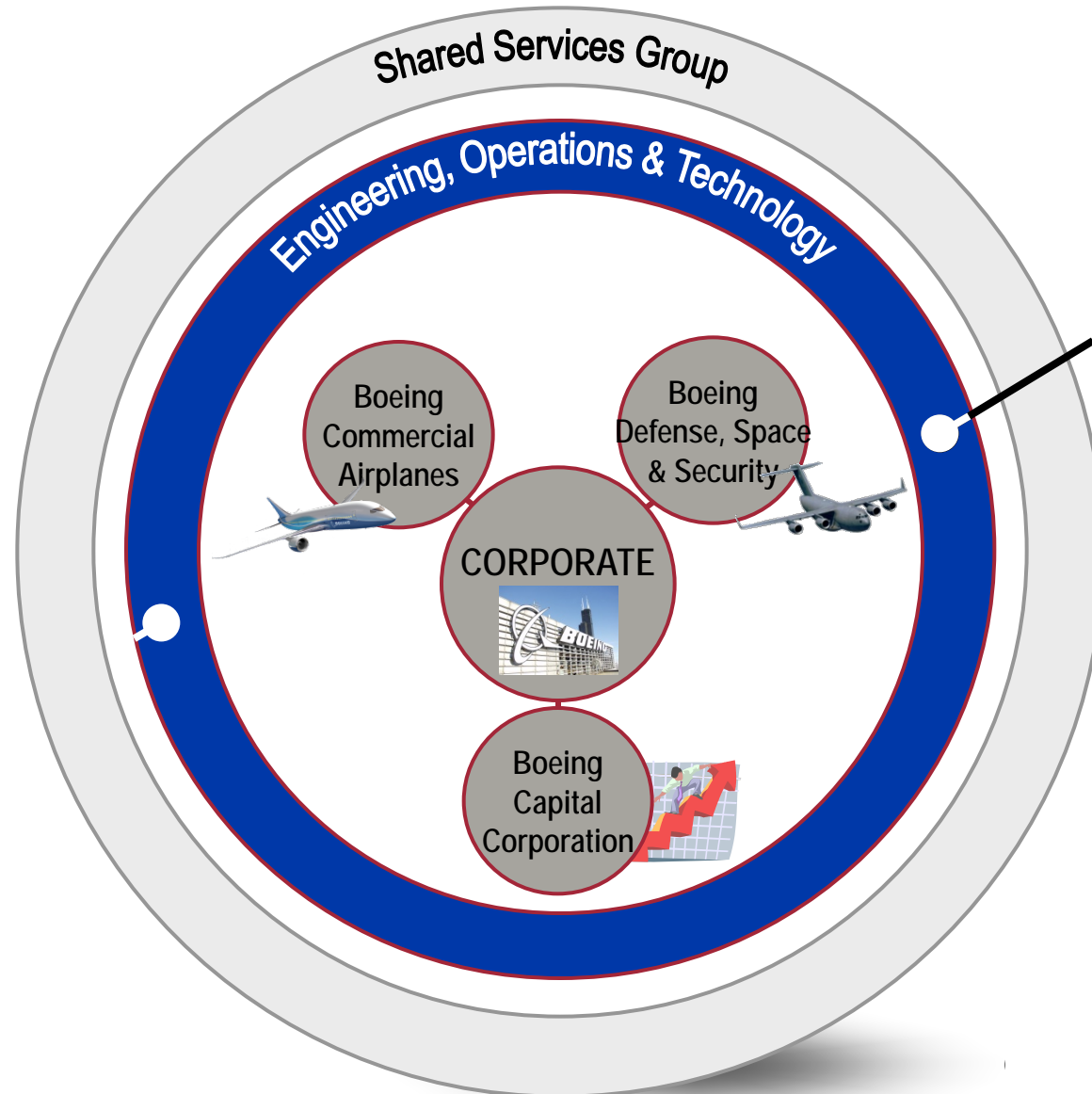
Research & Technology

Overview – The Boeing Company and Boeing Research & Technology & COWA Interests

William P Krug

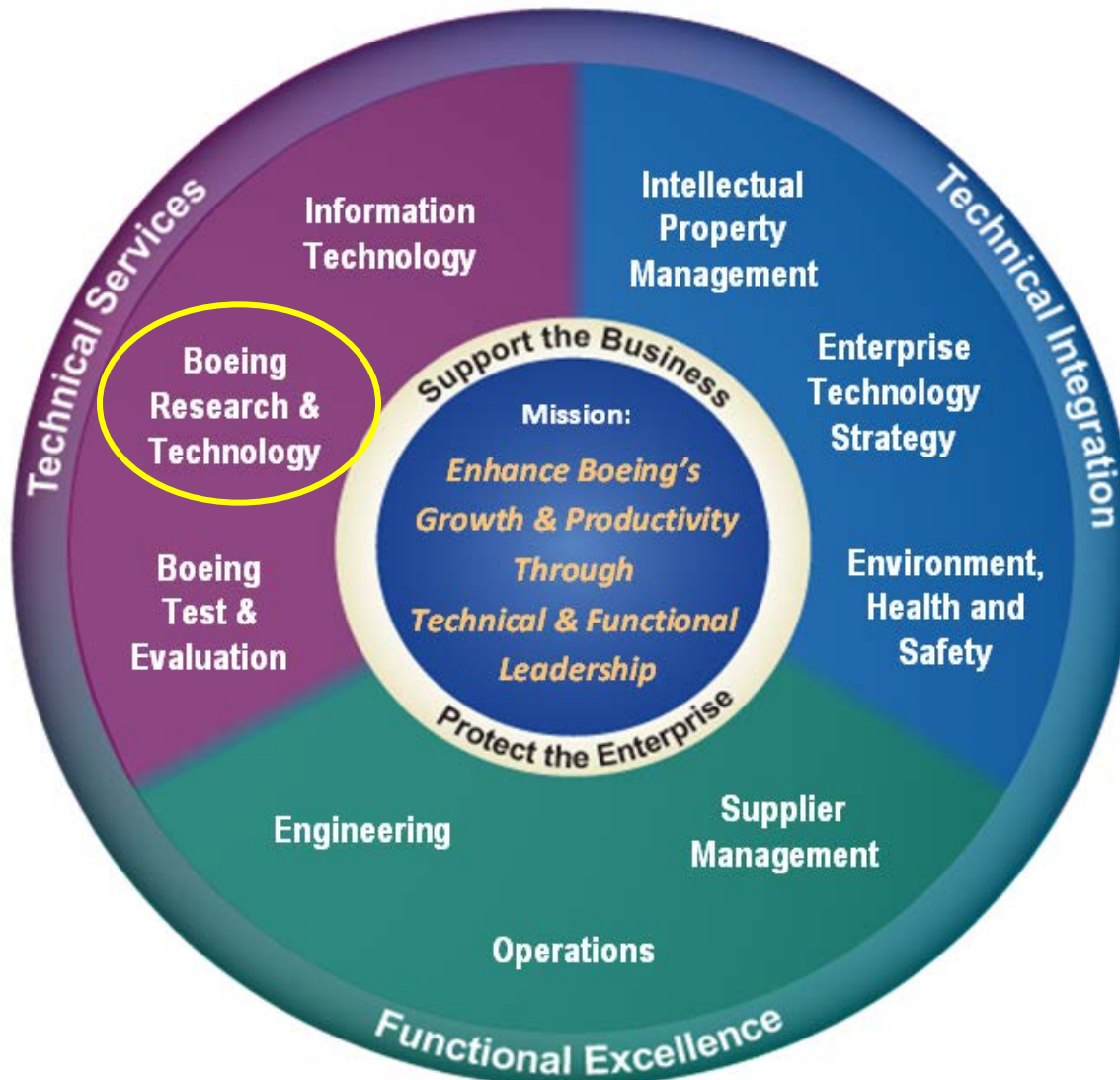
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The Boeing Company



**Boeing
Research &
Technology**

EO&T Mission



Boeing Research & Technology

Engineering, Operations & Technology | Boeing Research & Technology

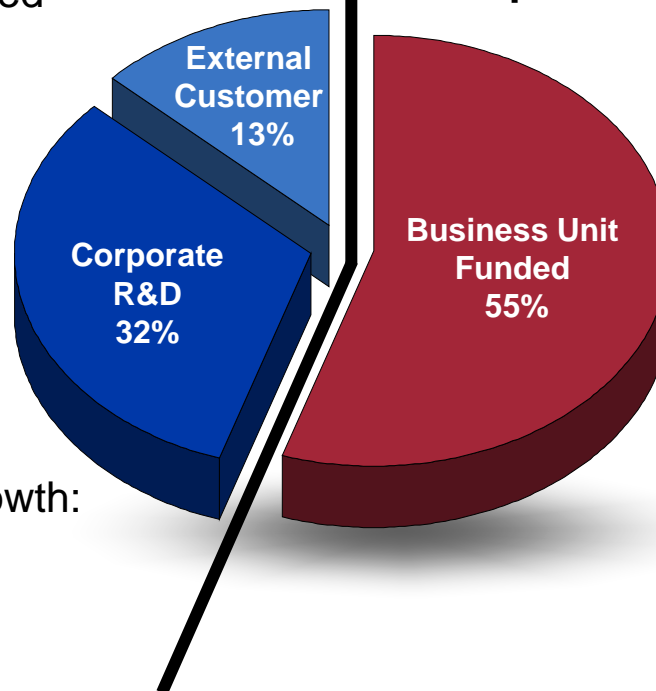
Vision: One team – anticipating, shaping, delivering, and supporting innovation and technology for Boeing’s growth and productivity

Develop or acquire enabling technologies for next generation products & services and protect against potentially disruptive technologies

- Internally & contractually funded research in:
 - Materials
 - Structures
 - Aerodynamics
 - Guidance & control
 - Systems & Subsystems
 - Electronics
 - Networked systems
 - Tools & processes
 - ...
- Development for Strategic growth:
 - Air Traffic Management
 - Homeland Security
 - Cyber Security
 - Energy systems
 - ...

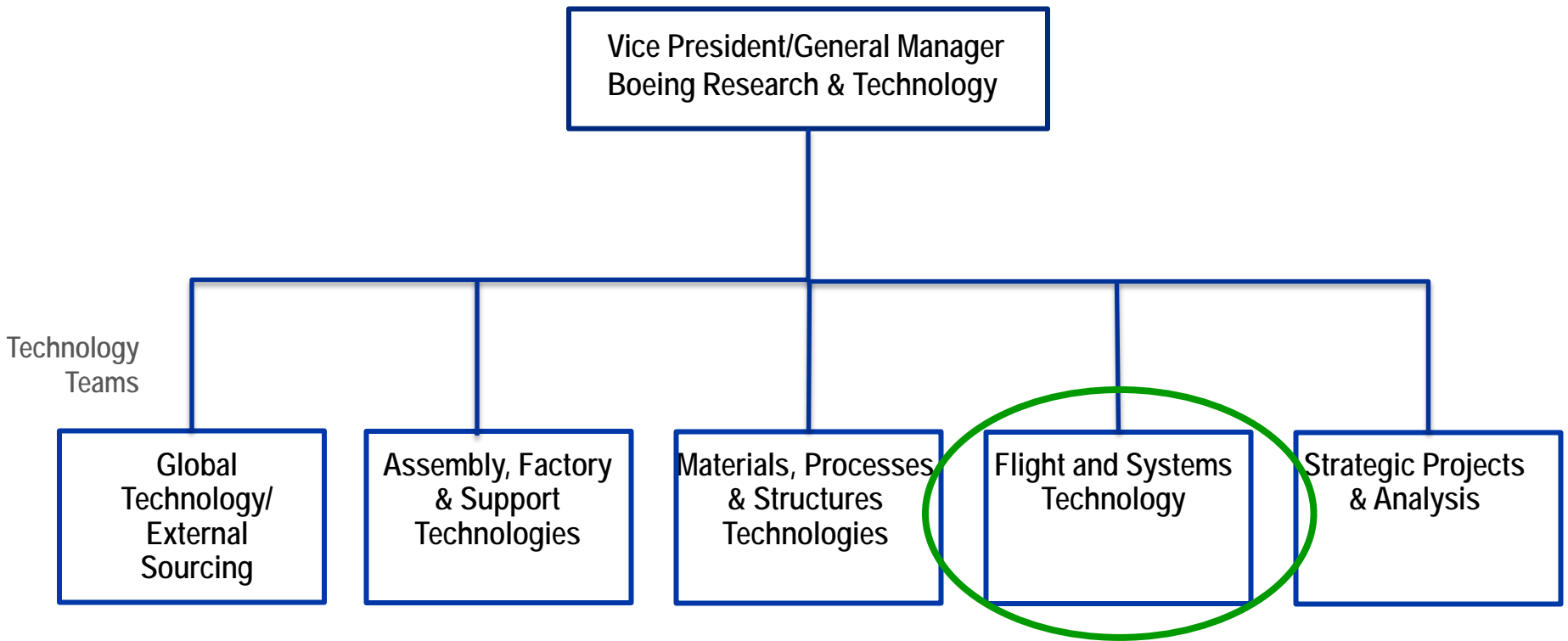
Provide technical services on current product lines to maintain their viability, enhance their performance, and improve overall productivity of the Boeing enterprise

- All Materials & Processes engineering for the enterprise
- All manufacturing R&D for the enterprise
- As-needed support in:
 - Structures
 - Aerodynamics
 - Guidance & control
 - Systems & Subsystems
 - Electronics
 - Networked systems
 - Tools & processes
 - ...



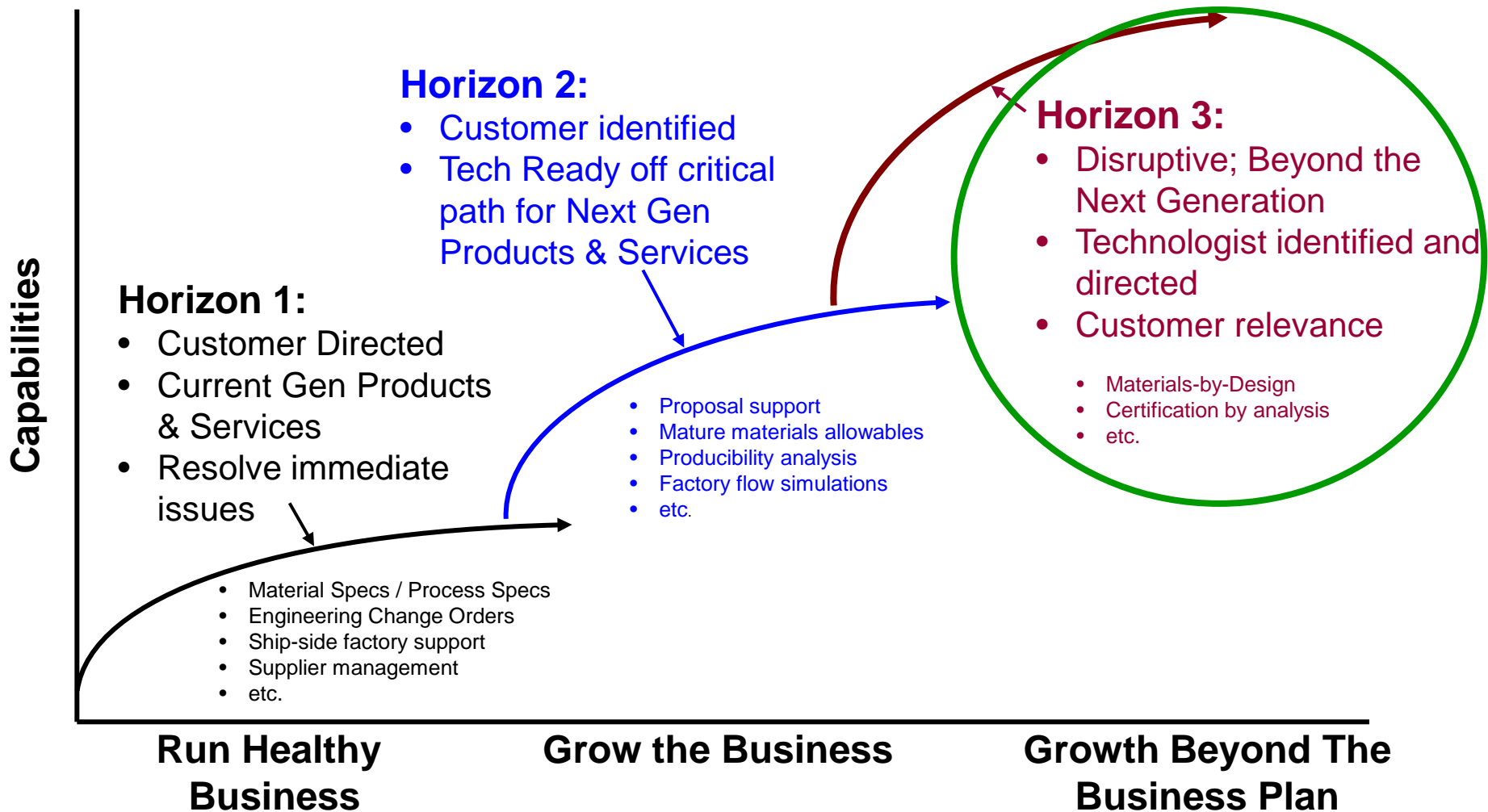
BR&T Organization

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Portfolio Balanced Over Different Time Horizons

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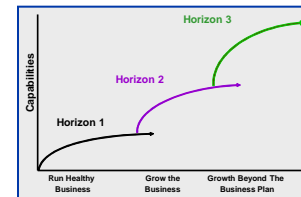
BR&T Technology Investment Priorities

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- **Develop responsive plans which support BCA and BDS' top technology needs**



- **Protect the Enterprise – Maintain healthy investments in long-term research**



- **Leverage U.S. Government technology investments**



- **Develop “next square” business opportunities leveraging existing technologies and capabilities**

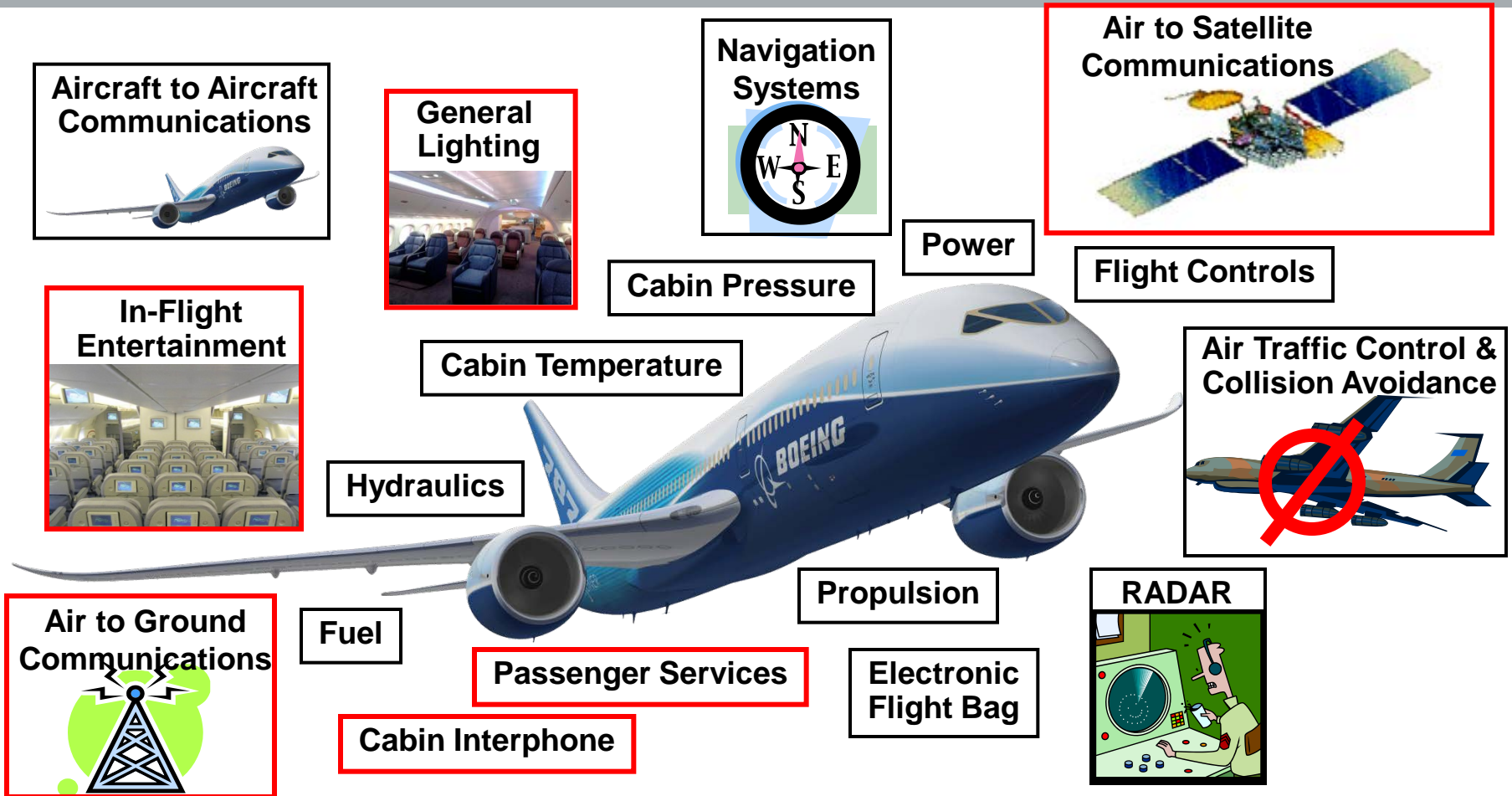


- **Leverage & integrate global technology sources – support collaborations, Strategic Universities, Research Centers**



The Aircraft is a Complex System of Systems

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And Must All Coexist Without Interference!

Boeing, Samsung Electronics to explore joint technology research



Bumcoo Cho, Samsung Electronics senior vice president of the Enterprise Business Team, and Paul Pasquier, Boeing Research & Technology vice president of Global Technology, recently met in Seattle to discuss how the two companies can work together to research and develop technologies that improve in-flight entertainment and communications, as well as enhance factory productivity. (Marian Lockhart photo)

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"Onboard communications and networking are key elements to the passenger in-flight experience, and connecting the airplane with ground crews during flight is vital to airline operational efficiency," said Larry Schneider, Boeing Commercial Airplanes vice president of Product Development. "The collaboration between Boeing and Samsung Electronics will explore the use of innovative technologies to advance the science in these areas."

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software solutions and services, and building relationships with valued partners.

"The aviation industry is one of the most complex and sophisticated landscapes in business, with millions of passengers and employees passing safely through aviation systems every day," said Bumcoo Cho, Samsung Electronics senior vice president of the Enterprise Business Team. "I am delighted that Samsung will work with Boeing to satisfy the fast growing demand of airline customers around the world. We will bring our expertise in multimedia and information technology to the forefront of aviation for a richer and more fulfilling connected experience while traveling."

Boeing Research & Technology, the company's advanced, central research and technology organization, will oversee the collaborative relationship for Boeing.

<http://thenextweb.com/insider/2012/10/23/samsung-and-boeing-link-up-promising-to-improve-in-flight-entertainment/>

Samsung and VLC Standards

Outline

- Part 1 (Samsung, ETRI)
 - VLC introduction
 - LED introduction
 - VLC potential application
- Part 2 (VLCC)
 - Introduction of VLCC members
 - A characteristic of the visible light communications
 - Field experiments and demonstrations using visible light communications
 - Approach to Commercialization
- Part 3 (University of Oxford)
 - VLC components
 - Technical challenges



(19) **United States**
 (12) **Patent Application Publication** (10) **Pub. No.: US 2008/0320200 A1**
Pederson et al. (43) **Pub. Date: Dec. 25, 2008**

(54) **LED LIGHT DONGLE COMMUNICATION SYSTEM**

(75) **Inventors:** John Pederson, St. Cloud, MN (US); Paul R. Brown, St. Cloud, MN (US); Timothy A. Vogt, Elk River, MN (US)

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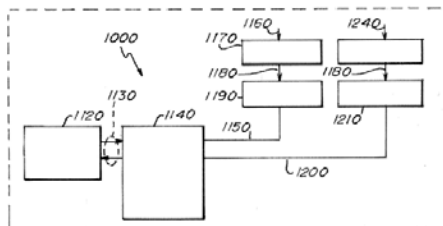
(21) **Appl. No.:** 12/126,227

(22) **Filed:** May 23, 2008

Related U.S. Application Data
 (60) Provisional application No. 60/931,611, filed on May 24, 2007.

Publication Classification
 (51) **Int. Cl.** G06F 13/00 (2006.01)
 (52) **U.S. Cl.** 710/305 (57)

ABSTRACT
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IEEE802.15.7 Draft D2

IEEE Standard for Information technology—Telecommunications and information exchange between systems—Local and metropolitan area networks—Specific requirements—

Part 15.7: PHY and MAC standard for short-range wireless optical communication using visible light

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COWA Project Summary

Vision

Visible Light Communications (VLC) is an emerging technology that utilizes the high-speed switching properties of white LED's as a method of wireless data communication with data rates equivalent to conventional 802.11 wireless networks and additional benefits of: (1) Energy efficiency; (2) Wider spectrum; (3) Improved Security; and (4) No EMI. Moreover, VLC combined with low power optical/ RF tags may also lead to high resolution real time position sensing capabilities over a scalable RF infrastructure.

Mission

The mission of the NSF - I/UCRC is to provide leadership to develop a new generation of environment-friendly (GREEN), multi-purpose optical wireless technology applications, employing solid-state visible lighting and lasers for internal communications, networking, imaging, and real time position sensing applications

COWA Project Schedule and Milestones

Task	2012		2013				2014	
	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2

VLC for Cabin Lighting (Proposed)

① Demo 10 Mbps VLC link under variable lighting conditions

② Demo 10 Mbps host controller dongle with

- variable lighting
- line of sight blockage

Task	2012		2013				2014	
	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2

Visible LED Lighting for Location Sensing (Proposed)

① Integrate location sensing

② combine lighting with position sensing

Milestones

COWA Project Milestone Descriptors

Task	Milestone	Description	TRL	Date
VLC for Cabin Lighting (Proposed)	1	Demo 10 Mbps VLC link under realistic range of variable lighting conditions and typical distances in cabin environment.	2	5/31/13
	2	Demo 10 Mbps host controller dongle with bidirectional link under <ul style="list-style-type: none"> • variable lighting • line of sight blockage • typical distances in cabin environment 	3	5/25/2014
Visible LED Lighting for Location Sensing (Proposed)	1	Show VLC based position sensing with better than 1 cm accuracy	2	5/31/13
	2	Show VLC based position sensing with better than 1 cm accuracy and with wireless optical tag	3	5/25/2014



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Research & Technology

Onboard Wireless Applications - “Challenges And Opportunities”

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Onboard Wireless Applications - “Challenges And Opportunities”

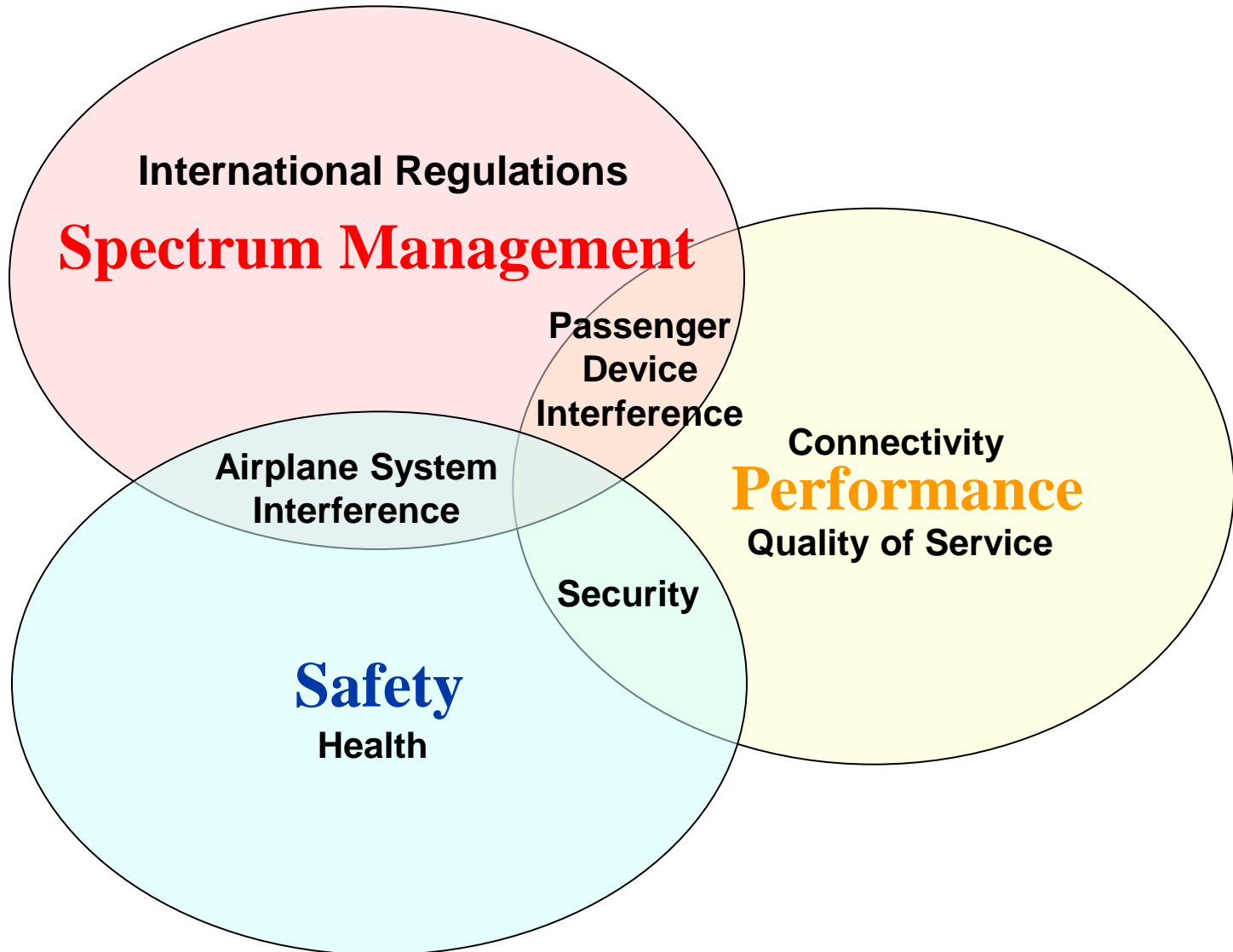
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■ Outline

- Airplane System and Design Considerations
- Wireless Alternatives
- Why Visible Light Communications (VLC)?
- Data Links from VLC Devices
- Cabin Applications for VLC
- VLC Use in Cabins
 - Challenges
 - Opportunities
- Conclusions

Primary Cabin Systems Considerations

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Aircraft Design Challenges

- **Commercial aircraft depend on many complex command, control, navigation and communication systems to function properly and safely.**
- **Because of these systems, introducing new technologies into the aircraft is not trivial**
- **System of system integration across platform models with extensive supply chain**
- **Structural integration**

Onboard Wireless Applications - “Challenges And Opportunities”

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Wireless Alternatives

- **WiFi (802.11ac)**
- **60 GHz (802.11ad)**
- **Visible Light Communications (VLC)(802.15.7)**

Onboard Wireless Applications - “Challenges And Opportunities”

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VLC Features/ Opportunities

- LED lighting pervasive in cabins
- Multimodal use: lighting, communications, and position sensing
- Diffuse lighting schemes may alleviate LOS blockage
- Leverage PLC rather than additional digital, RF, or fiber optics wiring infrastructure (no new wires)
- No Frequency and spectrum management
- Synergy with automotive applications; home and office

VLC Challenges

- Lighting and VLC have different device figures of merit
 - lumens/W for lighting
 - low drive current per W and modulation rates for comm
- Although international interest, no established suppliers
- Line of sight blockage and dependence on lighting levels

Onboard Wireless Applications: Why VLC?

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- **Greater Harmony with Onboard Systems**
 - Better coexistence (if emissions are controlled)
- **Lower Installation & Maintenance Costs**
 - Fewer cables & connectors to install and/or repair
- **Passenger & Crew Safety**
 - Reduced potential/perceived RF exposure hazard
 - Reduced electrical/shock hazards
- **Fewer International Regulatory & Cert Issues**
 - Less electro-magnetic interference (EMI) to mitigate
- **Fewer Cables**
 - VLC/ PLC may lead to savings in many areas including weight

VLC Opportunities and Challenges

Opportunities to Replace Wired and RF Wireless Links

- Access for flight crew cabin interphones
- Dual use for passenger service unit (PSU) reading lights
- Interface to passenger user devices in cabin

Benefits

- Leverages low energy LED lighting for cabin, auto, home, office, ...
- May reduce wiring from power line communication (PLC)
- Health and international regulatory compliant

Impacts

- IFE, Cabin Lighting, Seat, and Power Integration

Ambient Light and Data Rate Targets

- Ambient: 10 Mbps @ 100 lux reading & ? lux in darkness)
- Directivity and uniformity of coverage

Opportunities: Potential VLC Applications

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VLC for Flight Crew Cabin Interphone

VLC for Passenger Services

Dual Use: VLC Plus ...

- **Reading Light Passenger Service Units (PSUs)**
- **Ceiling Cabin Lighting**
 - **Dimming**
 - **Mood Lighting**
- **PLC**

VLC for Flight Crew Cabin Interphone

- **Attendants require constant communication throughout the aircraft cabin**
- **Bandwidth requirement for voice is relatively low but QoS is important**
- **Wireless handsets improve flexibility but can VLC meet QoS requirement?**

VLC for Passenger Services

- **Embedded IFE systems are IP based and include audio & video on demand (AVOD)**
- **IFE must provide enough bandwidth to support all passengers in the cabin and may exceed 400 people**
- **High density, dynamic cabin environment makes line-of-sight transmissions very difficult**
- **Bandwidth of LED VLC is not yet adequate, but may be acceptable when combined with WPANs and video compression**

Dual Use VLC and Lighting: Challenges

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- **Reading Light Passenger Service Units (PSUs)**
- **Ceiling Cabin Lighting**
 - **WPAN (802.15.7), multicast (?), & broadcast capable (?)**
 - **Robust or ad-hoc networking with non-interfering adjacent links**
 - **Practical downlinks and uplinks**
 - **Must function over wide range of lighting conditions: levels, mood, ...**
 - **Need diffuse lighting, MIMO, or redundant ad-hoc network to obviate LOS blockage**
 - **Maximum data rates are a function of lighting level**
 - **Must simplify ceiling and seat wiring: PLC at 60 Hz, 400 Hz, DC...**
 - **Must be structurally integrated into panels**
 - **Share economies of scale with automotive**
 - **Need dongle interface to passenger PEDs**

LED Cabin Lighting for VLC

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The momentum for LEDs in both the forward and retrofit markets has been built on steady technology improvements. “On a lumens per watt basis, over 10 years it has doubled the output, so now we are looking at 140 to 150 lumens per watt where 10 years ago it was tough to get to 85 or 95,” said de Young. Those latter chips represented “the top of the market then ... (and cost) \$25 a package, and now they are down to (about) \$3.50,” said Doug Daman, IDD’s senior electrical engineer.

VLC Cabin Lighting System

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VLC Cabin Lighting System

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VLC w Extended Dynamic Range for Low Light

VLC/ IrLC Cabin Lighting System

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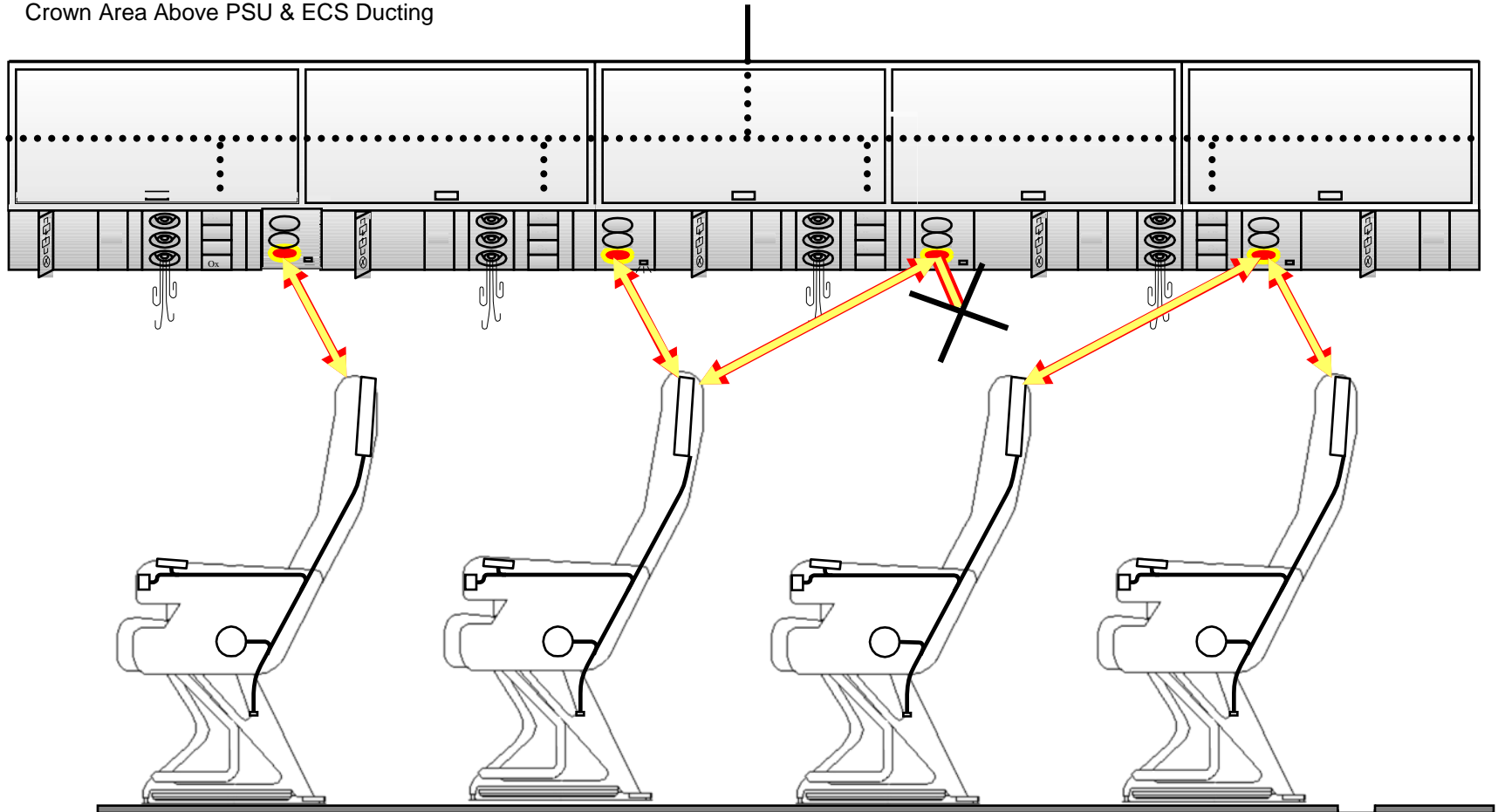


VLC Downlink w IR Uplink

VLC & IRLC Redundance & Sharing & to Overcome “Darkness” and LOS Blockage

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Crown Area Above PSU & ECS Ducting



To Overcome Line of Sight (LOS) Blocking

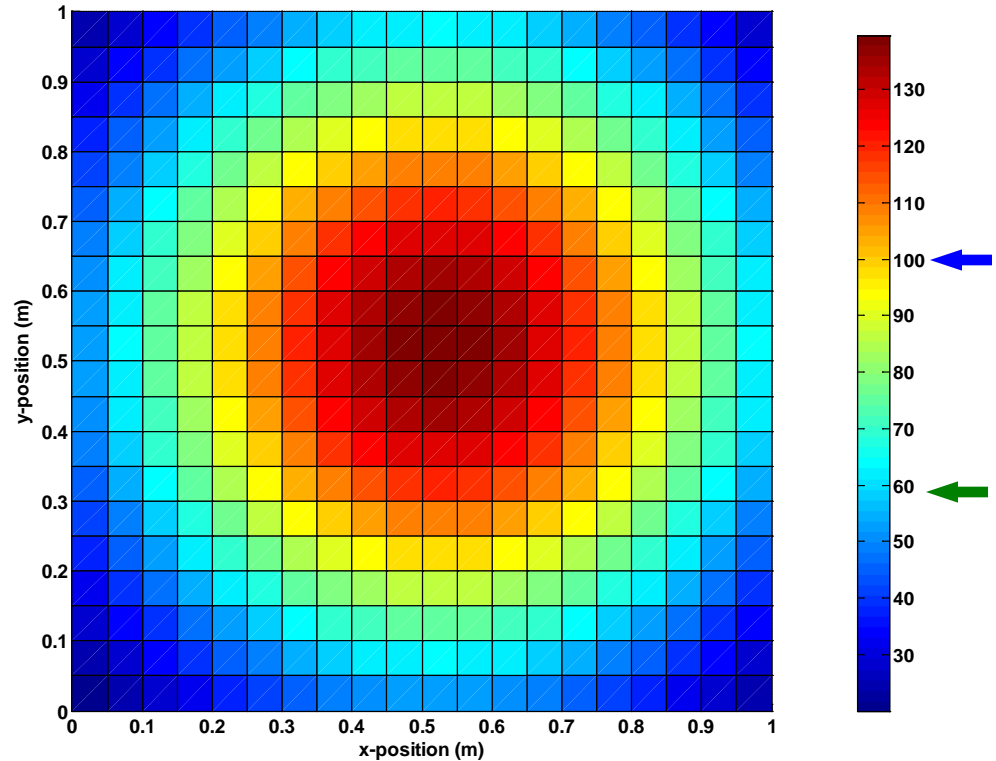
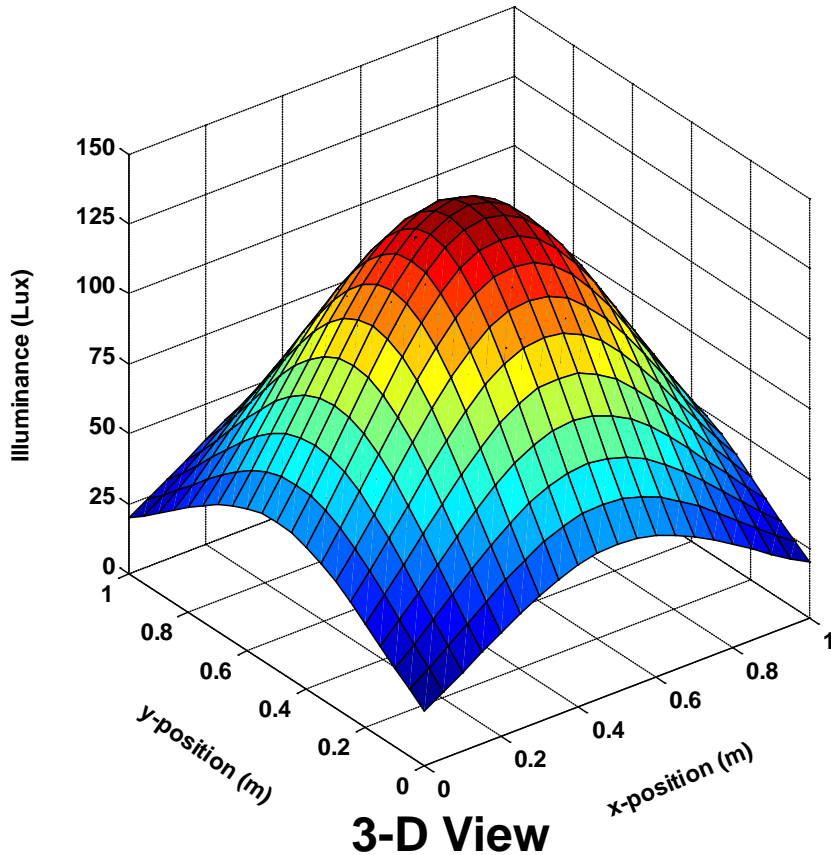
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WLED Array w Diffuse Optics

9-Luxeon Star WLED Array

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$a=b=0.066$ m, $d=0.76$ m, $\theta=29^\circ$, $N=M=3$, $L=W=1$ m



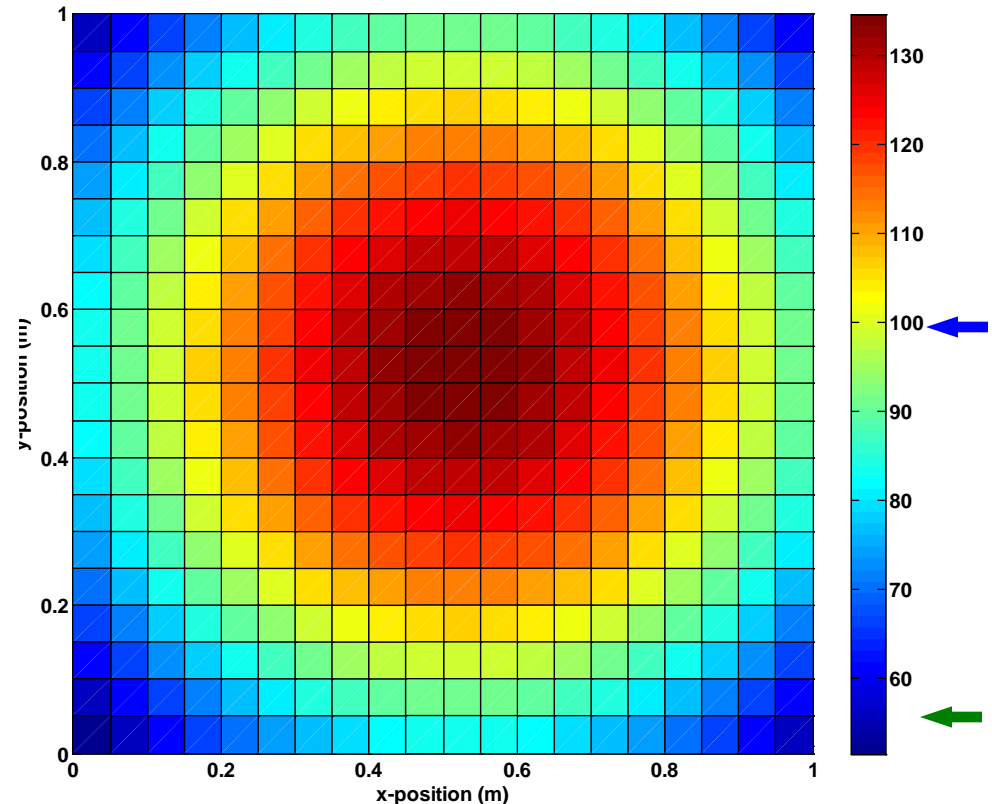
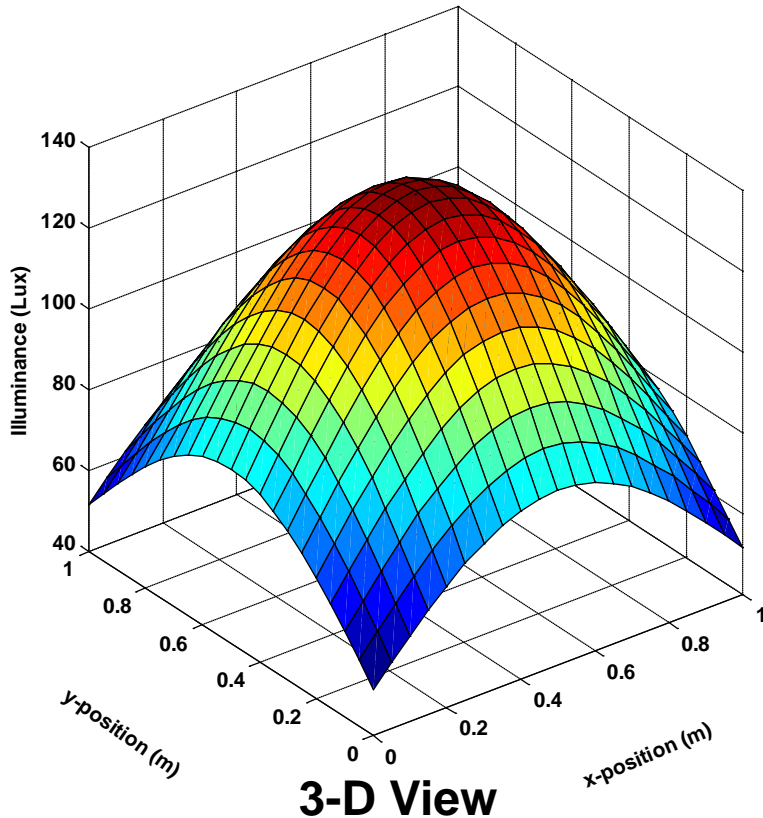
$a = b =$ WLED area; $d =$ WLED Array Spacing
 $\theta =$ WLED Half Power Angle (measured)
 $I_v =$ Peak Illuminance (derive from measured data)
 N, M number of WLED in x and y directions

Comm. link target ←
 Illumination target ←

4-Luxeon Star/O WLED Array

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$a=b=0.1$ m, $d=4$ m, $\theta=8.5^\circ$, $N=M=2$, $L=W=1$ m



$a = b =$ WLED area; $d =$ WLED Array Spacing

$\theta =$ WLED Half Power Angle (measured)

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N, M number of WLED in x and y directions

Comm. link target 
 Illumination target 

Illuminance in Different Environments

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100000 Lux – Sunny day

10000-100000 Lux – Sunny day with some clouds

100-10000 Lux – Overcast sky

100-1000 Lux – Home/Office lighting

1-10 Lux – Street lighting

0.1 Lux – Full moon

0.01 Lux - Young moon

0.001 Lux – Clear night without moon

0.0001 Lux – Dark cloudy night

Bandwidth for VLC communications vs illumination is also a challenge for use in automotive applications

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VLC USB Dongle to PED

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INLUMINATIO ET LVX INTRA LVCEM
"Information from Light within Light"

Visible Light Embedded Wireless Data Communication

BUSINESS OVERVIEW

LVX System is a technology company focused on the development and commercialization of a portfolio of patented LED (Light Emitting Diode) based wireless communication technology. LVX System intends to launch a unified national service offering as well as enter into license agreements and contracts with strategic and synergistic partners for the further development, application and utilization and the commercial exploitation of this revolutionary technology.

CURRENT SITUATION

Advances in technology have made it possible to electronically communicate with LED lights through free-space - no hard or wired connection is required. This new technology is faster and more secure system than traditional wireless technology (i.e. Wi-Fi), and can be used in traditional devices such as room lights, computers, televisions, and cell phones. The technology can yield fiber-optic rate data communications 'without the fiber' and, more importantly, can be used in environments where traditional wireless radio frequency communication (RF) is prohibited. The medical and airline industries, schools, emergency vehicles and other environments not suitable for RF use will benefit from Visible Light Embedded Data Communication.

MARKET OPPORTUNITY

LVX System holds exclusive domestic and international patent rights to this new Light Emitting Diode (LED) communication technology. The new technology has great upside potential across multiple markets and applications. Potential markets include government, commercial, consumer, education, health care, sports and recreation. Potential applications include communication, security, and energy. This new LED communication technology will change markets much the same way that previous disruptive technologies has, and will be similar to the effect that digital photography had over traditional photography. Opportunities exist to license or sell the technology by market and/or application to strategic partners. Opportunities also exist to create joint ventures across multiple geographical and industry segments in creating a comprehensive system of delivery which will accelerate and maximize the potential of this technology.

Applications that will use this revolutionary technology include:

COMMUNICATION

- Ordinary household fixtures, such as light bulbs, televisions, and cell phones, can become multi-functional data transmission tools.
- Secure high-speed internet access can be offered in environments where RF-based technology is not allowed.

SECURITY

- Visible Light Embedded Data Communications offers a secure wireless environment for transferring highly sensitive data.
- The technology can be used to track assets (auto, people, etc).

ENERGY

- Government, business and education markets will realize savings in lower energy use and consumption.
- Mercury-free lighting source.

Benefits

- High-Speed Fiber Optic comparable data rates are possible through a 'wireless' connection.
- Greater energy savings (Green) - LEDs use less energy than traditional light sources.
- Secure Communication - Provides greater security in wireless communication.

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HEADQUARTERS

LVX System

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St. Cloud, MN 56301

CORPORATE INFORMATION

Light Visually Transmitted System, Inc.

DBA: LVX System

Effort Started: 2007 Structure: C-CORP

Ownership: Private

FOUNDERS

John Pederson

Chairman of the Board

Founder and former CEO of 911EP

Awarded more than 75 U.S. and

international patents.

Irene Pederson

CFO and Treasurer, LVX System

CORPORATE

Paul Weltzel, President and CEO

LVX System

REGIONAL SERVICE COMPANY

Michael Muggli, President

Northwestern LVX

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US 20080320200A1

(19) United States

(12) Patent Application Publication Pederson et al.

(10) Pub. No.: US 2008/0320200 A1
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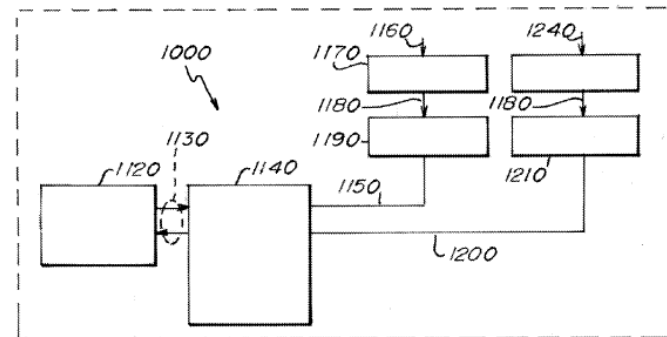
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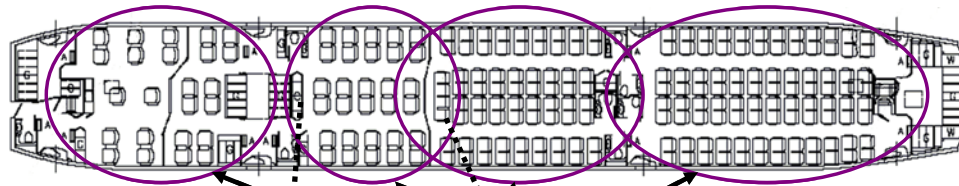
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visible light**

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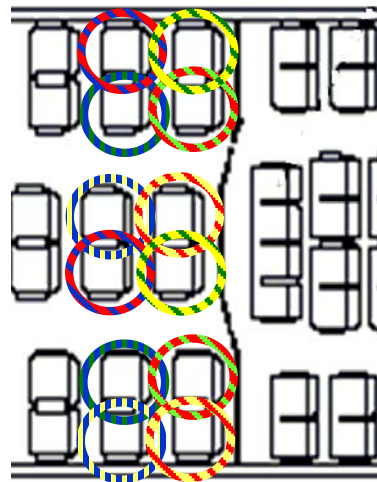
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Piscataway, NJ 08855-1331, USA

Broad-, Multi-cast Zones for VLC Comm



Each circle could represent a broadcast channel for a zone

VLC for WPAN



The overlapping areas represent a potential for cross-channel interference
That may be overcome by WPAN cells w multi-colored LED hopping patterns

Some Conclusions

- **Although full IFE systems are very demanding, VLC combined with WPANs and video compression may support them.**
- **The high density of users requires significant bandwidth (>5Mbps per seat). 1 WPAN per seat?**
- **VLC will limit high throughput (AVOD), but simple connectivity for new services is more important**
- **VLC may be better suited for low to moderate bit rate apps like data connectivity, multicasting or voice**
- **It may also be a good supplemental solution for off-loading data traffic and adding new services to main IFE network without adding more RF emissions and wiring**

Meeting Key Aircraft Objectives

Engineering, Operations & Technology | Boeing Research & Technology

**When adding any new technology
the question is always...**

Will it support the goal of making the aircraft

Safe
Durable
Efficient
Affordable
& Profitable?

