

# Visual signaling: Aerial Refueling Tanker's PDL (Pilot Director Lights) Improvement for Pilot's Visual Acuity

Julian Chang  
Lighting System  
The Boeing Company



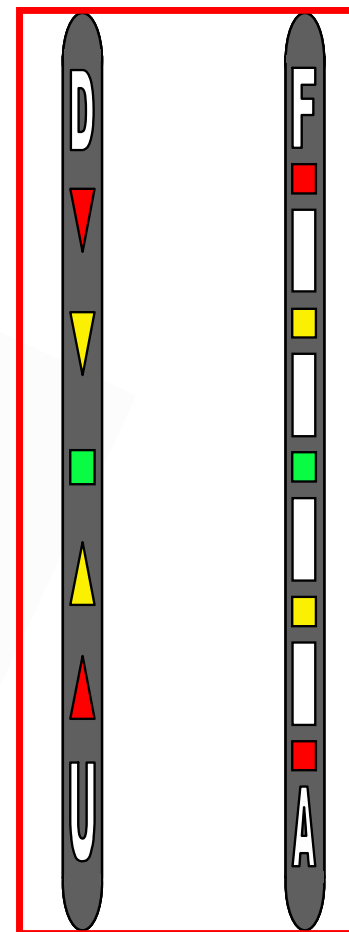
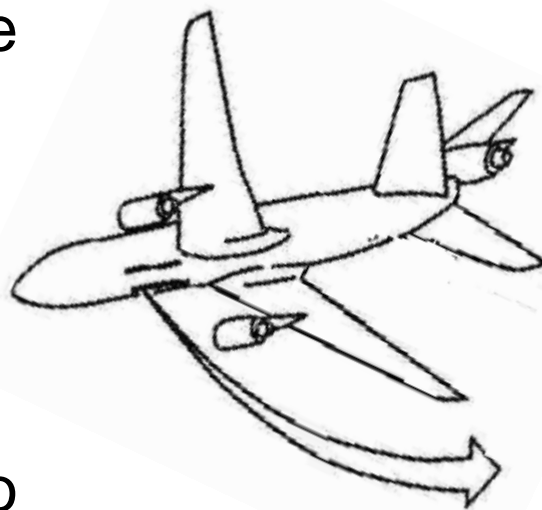
# Contents

- PDL signal light design description
- PDL lights evolving from Incandescent light to LED light
- LED v.s. Incandescent Light source
- Improvement of PDL in consideration of Pilot Vision
- Human Factor Design Consideration
- New measurement method required for the PDL light due to LED light source

# Pilot Director Lights

The Pilot Director Lights (PDL) are an array of signal lights located forward of the wing-body joint and on the underside of the tanker aircraft. (See Figure)

These lights provide positional and trend information with respect to the receiver aircraft position within the refueling envelope by the color indication and white characters.



# LED Pilot Director Lights (PDL)

- The new PDLs are made of Light Emitting Diodes (LED) arranged in a number of modules per lighted segment
- One of the most noticeable differences between LEDs and incandescent lights is that the output of the LED is directional where the output of the incandescent light radiates omni-directionally. The effective light outputs for LEDs are considerably much higher (brighter.)
- IF the PDLs are dim as traffic signal lights to be acceptable in daylight conditions, the LED light maybe too bright by receiver pilots. In night condition, the LEDs will need to have lower dimming curve to eliminate possible distractions to receiver pilots

# LED Pilot Director Lights (PDL)



# LED vs. Incandescent Light sources

- LED have less electrical power consumption
- LED provide more efficient fL output, achieve high contrast and high luminance
- LED has longer life expectancy than Incandescent lamp resulting in lower life cycle cost
- Easy redundant design through multi LED sources
- Function with better dimming control curve (2% to 100%)
- LED circuits provide better vibration resistance and hermetic seal availability in comparison to incandescent light
- Green for the environment, LED is mercury free and Lead free

# Consideration of Pilot Vision

- Pilots need to detect small targets and require high acuity
- Physiology limits image quality for both near and far focus.
- Focus (accommodation) contributes to image quality
- Binocular Fusion (vergence) contributes to image quality
- No distant high-contrast objects with sharp edges on which to focus
- Darkness, haze, smoke, clouds or other restrictions to distant visibility
- Presence of close objects on which to focus (spots on windscreen, instrument panel, reflections off of windscreen)

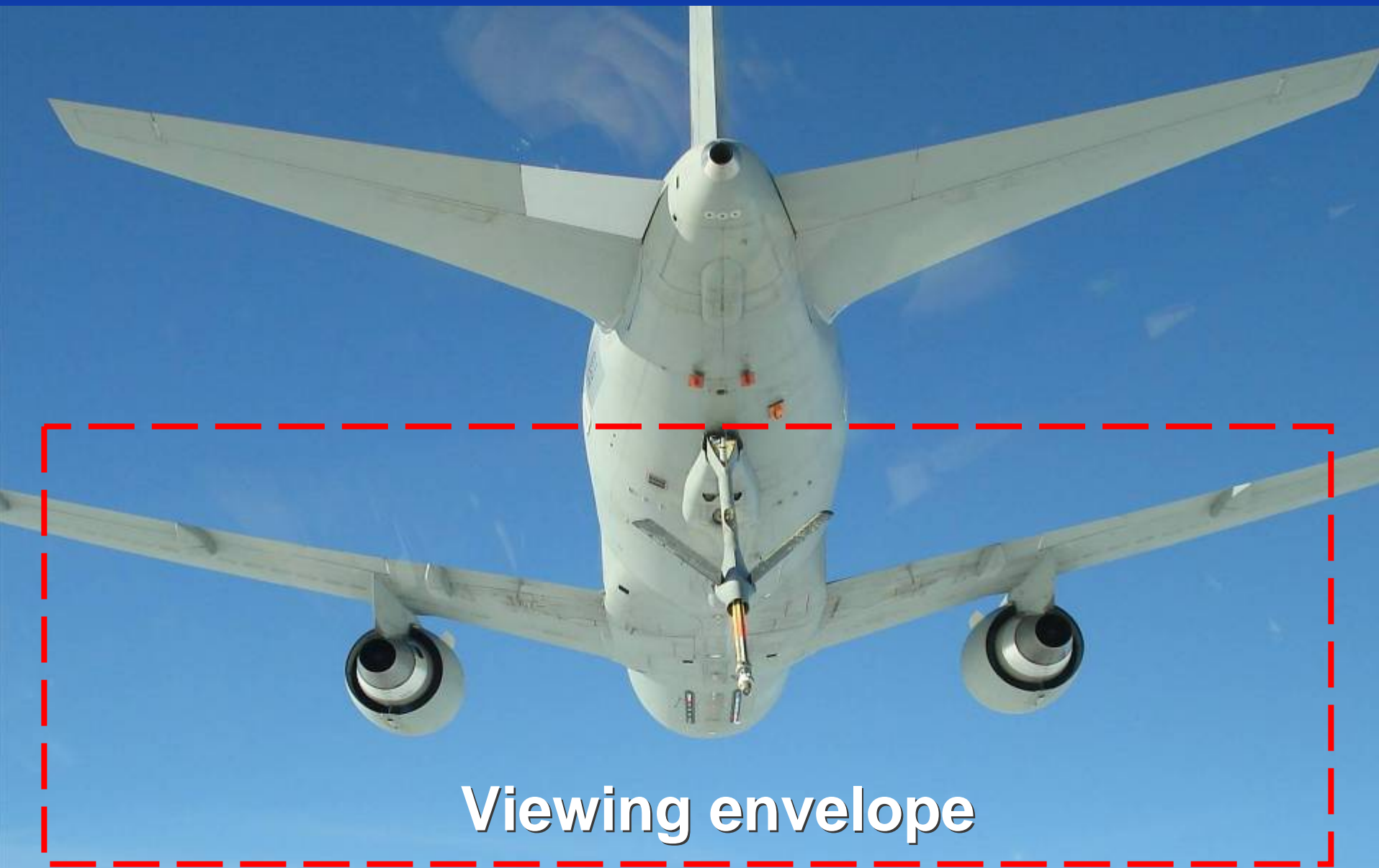


# Focus: Accommodation and Vergence

- Accommodation
  - Physiological mechanism
    - Lens system
    - Pupil
    - Optical aids
  - Cues to accommodation
    - Sharp edges
    - High contrast
    - Distance cues
    - Vergence feedback
    - Volitional control
- Vergence (How do we fuse the image from the two eyes?)
  - Physiological mechanisms
    - Ocular muscles
    - Head movements
  - Cues to Vergence
    - Image fusion –minimize diplopia (“double vision”)
    - Image contrast-maximize
    - Volitional/attentional effects
    - Accommodation
    - Distance cues

# Refuel by KC-135 Receiver Pilot view





**Viewing envelope**

# Human Factor Design Consideration

- The human eye responds to a bright light source within the field of view by closing the iris to restrict the amount of light entering the eye. This results in difficulty seeing any surrounding object detail within the field of view
- In order to conduct safe aerial refueling operations, the receiver pilot needs to be able to observe the tanker aircraft movement as well as the PDL lights
- The challenge for Boeing was to resolve the issue of how to keep PDLs bright enough for daylight AR operations and dim enough for safe night AR operations

# LED Light source Measurement

- New measurement method is needed for the viewing angles of LED based PDL lights
- Standardized Individual LED, wide angle or narrow angle, vary from one manufacturer to another, resulting in additional optical modification
- In the Automotive industry, rear LED lights viewing angle vary for different car models, where lights on some models are dim and others distract trailing drivers

