WYVERN Wednesday Webinar

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Unstable Approaches & Energy Management

WYVERN

March 31, 2021

ELEVATING SAFETY & SECURITY WORLDWIDE

Energy Management Issues in Highly Automated Cockpits

q-alpha – Flight Energy Awareness Display

Tiger Century Aircraft

Andrew Skow

Although Aviation is Very Safe -

- Loss of Control and Approach & Landing accidents are the #1 and #2 killers in Commercial Aviation
  - Costing 1,975 lives and $21B over the last 10 years
- Many of these accidents are "human induced" because pilots don't properly manage the <u>flight energy state</u> of the aircraft
  - No excuses but many reasons for this – and the problem is not going away

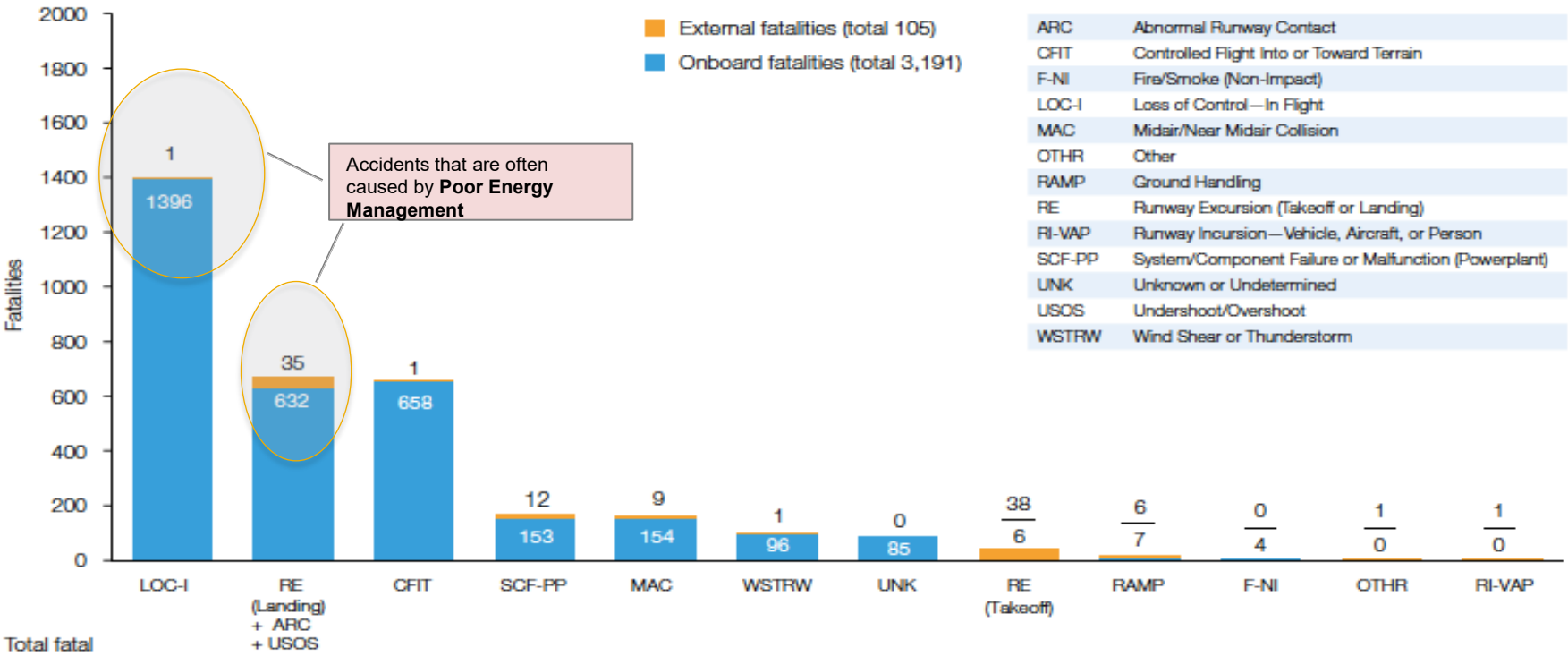
High-Profile Accidents

- **Turkish 1951**
  - Amsterdam 2009
  - **Pilots unaware of loss of energy**
- **Air France 447**
  - South Atlantic 2009
  - **Pilots unaware of loss of energy**
- **Asiana 214**
  - San Francisco 2013
  - **Pilots unaware of loss of energy**

Accident Data

Fatalities by CICTT Aviation Occurrence Categories

Fatal Accidents | Worldwide Commercial Jet Fleet | 2006 through 2015



ARC	Abnormal Runway Contact
CFIT	Controlled Flight Into or Toward Terrain
F-NI	Fire/Smoke (Non-Impact)
LOC-I	Loss of Control—In Flight
MAC	Midair/Near Midair Collision
OTHR	Other
RAMP	Ground Handling
RE	Runway Excursion (Takeoff or Landing)
RI-VAP	Runway Incursion—Vehicle, Aircraft, or Person
SCF-PP	System/Component Failure or Malfunction (Powerplant)
UNK	Unknown or Undetermined
USOS	Undershoot/Overshoot
WSTRW	Wind Shear or Thunderstorm

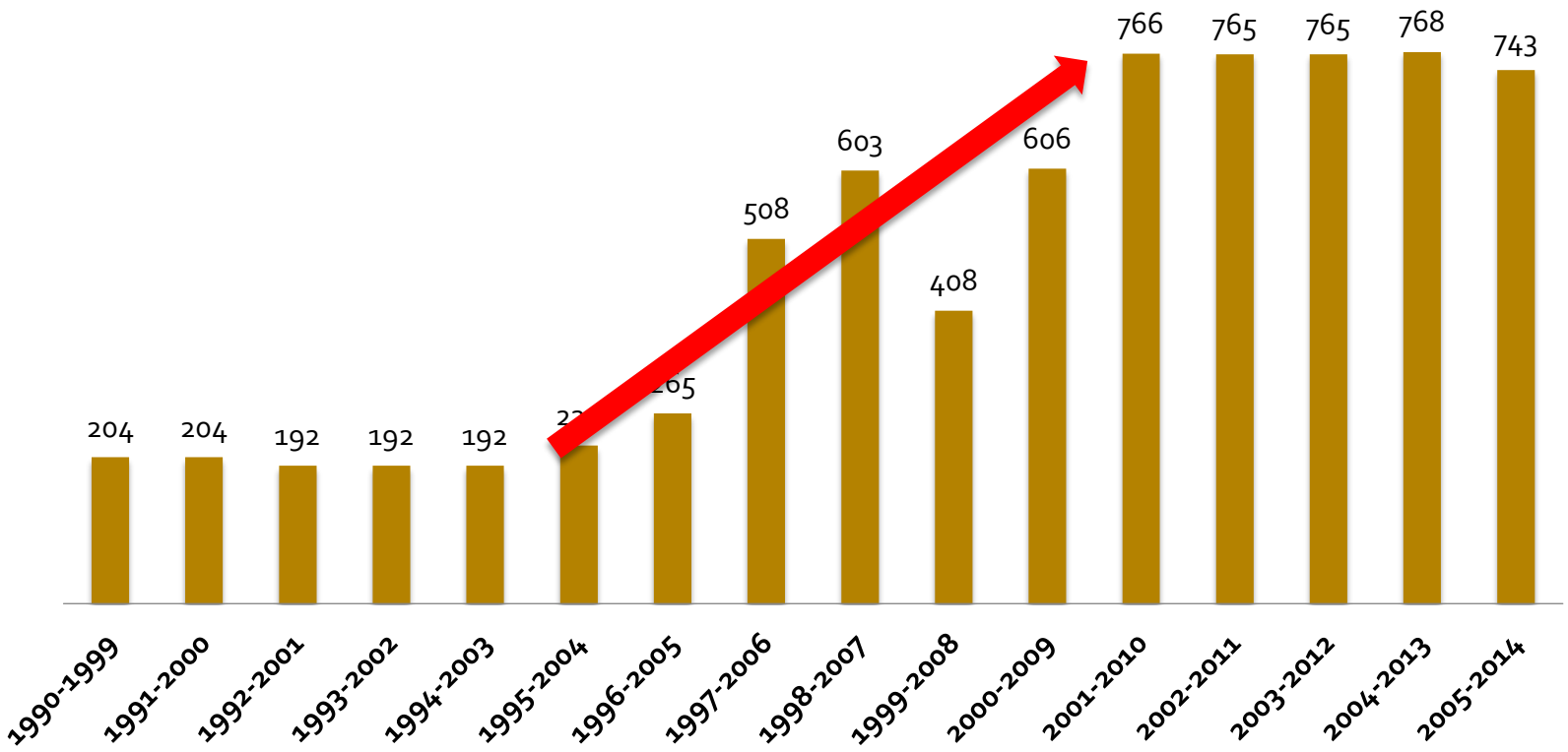
Note: Principal categories as assigned by CAST.

300% Increase in Fatal ALAs

Fatal Approach & Landing Accidents

CAST/ICAO Data

Commercial Aircraft > 60,000 lbs



Reasons?

- Boredom followed by the "startle factor"
- Inattention and Distraction
- Degradation of hand flying skills
- Inadequate training
- Sudden Task saturation
- Fatigue
- Over reliance on or over-confidence in <u>Automation</u>: resulting in: **Complacency**

An Unavoidable Effect of Automation

- Humans are not well-suited to the task of actively monitoring a parameter being controlled by a high-authority automatic system
  - No matter how important the parameter is

Vigilance reduces – **Complacency** results

- When a failure occurs:
  - Pilots are **startled**, corrective action is **delayed**

All human pilots are susceptible to this

Do We Need More Information?

- All of the Information needed to properly manage flight energy is already in the cockpit

"Where is the knowledge we have lost in information?"

T. S. Eliot – "Choruses' from the Rock"

- But…the new way we communicate Airspeed to the pilots has made <u>energy</u> <u>monitoring</u> more difficult
  - Vertical Moving Tape vs Circular Dial

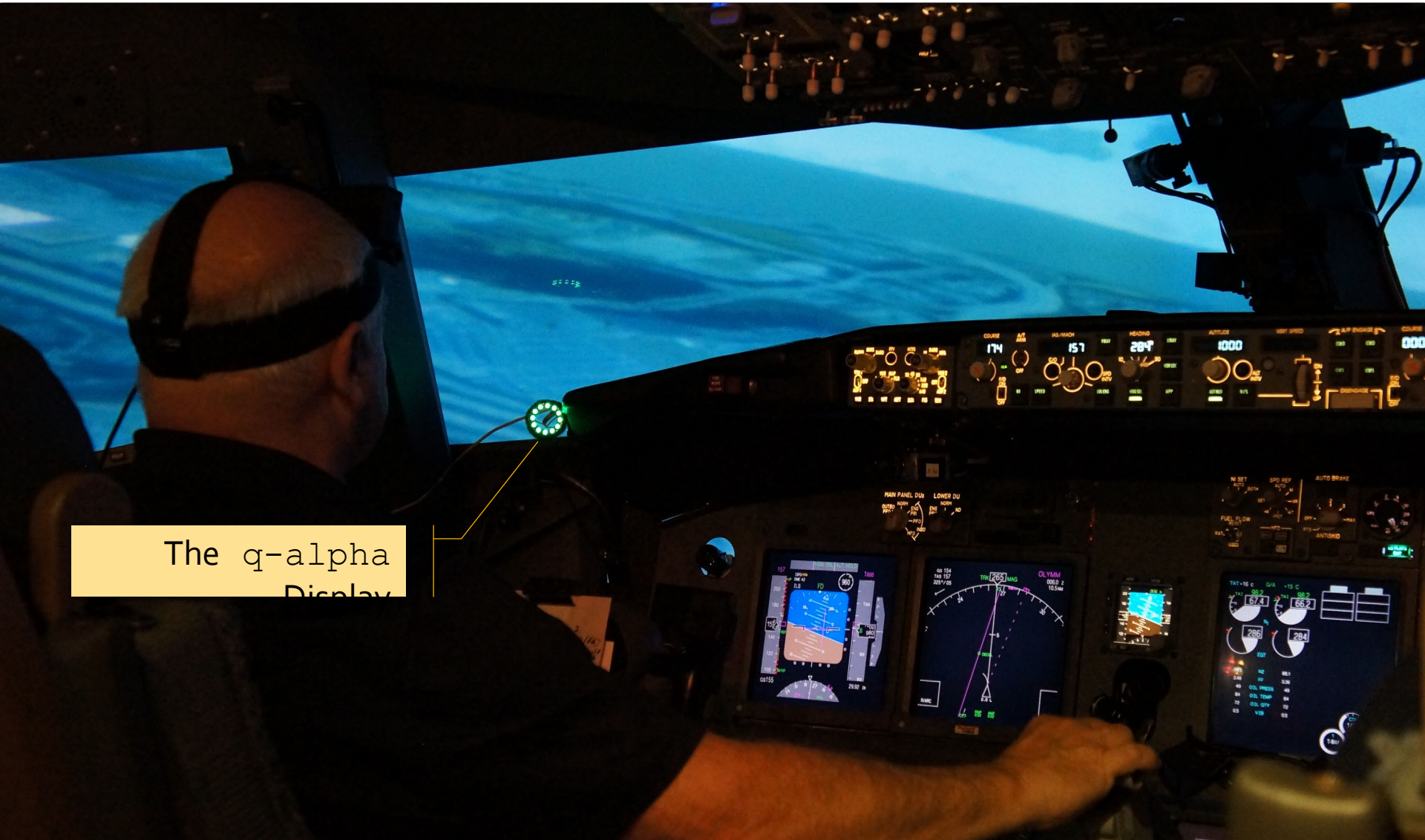
"Developments in cockpit design have changed speed awareness from a <u>visual recognition</u> task into a <u>reading and mental processing</u> task, and psychological research has shown this to require more time and mental attention."

From the Dutch Safety Board report on the 2009 TK1951 Accident in Amsterdam

The ***q-alpha*** Display

- The **`q-alpha`** Flight Energy Awareness Display is a multi-sensory alerting system that has been designed in direct response to the NTSB and CAST calls for an effective low airspeed alerting system
- It provides flight energy state **status** and **trend** information, alerting pilots to a situation where flight energy is too high or too low due to improper control inputs or due to <u>inattention/distraction</u>
- It is the first flight energy state alerting system to be developed that can be easily <u>retrofitted</u>

The q-alpha Display



Design Details

- The **Algorithms**
  - Based on solid flight performance principals that include AoA, Airspeed, Density Altitude and Load Factor
  - Robust and Timely
  - Effective

- The **Sensory Approach**
  - Recognizes that the pilots that need this alert are operating under a high task loading
  - Unambiguous and instantly recognizable
  - Effective

AoA is Not Enough

- Effective stall alerting Algorithms must provide:
  - Timely alerting
  - While minimizing nuisance alerts and false alarms
- An alerting algorithm based on AoA alone (Amber Band) cannot meet these criteria
  - To avoid false alarms and nuisance alerts, the thresholds need to be set too close to the stall AoA
  - Amber Band has been proven to be ineffective in several high-profile accidents

A More Robust Algorithm Needed

- Accidents result when the wing Stalls and loses it ability to generate enough **LIFT**
- To generate **LIFT**, the wing needs 3 things:
  - Alpha (α)
  - Airspeed Squared
  - Air Density

  } **Dynamic Pressure - q**
- To reduce accidents, the alerting algorithm must consider **q** (dynamic pressure) and **alpha** (AoA)

Issues with Amber Band Thresholds

- Visual Alert Threshold – **not timely**
  - Top of the Amber Band set at only 14% above the Stick Shaker (or Stall) airspeed
  - In Asiana 214:
    - 120 knots (17 knots below Vref)
    - 8° AoA (50% of stick shaker AoA)
- Aural Alert Threshold – **even less timely**
  - Set at only 9% above the Stick Shaker airspeed
  - In Asiana 214:
    - 114 knots (Stick Shaker fired 7 seconds later)
    - 10° AoA (65% of stick shaker AoA)

Issues with Sensory Inputs

- **Visual** Channel – useless if you're not looking at it
  - Presented against a highly cluttered background
    - Low salience
    - Small
  - Requires a line-of-sight change to read/interpret
    - Takes more time than a Circular Dial format
- **Aural** Channel – can be ignored/missed easily
  - Tones (such as the "quad Chime") are not easily interpreted or de-conflicted
  - The Aural environment can be very "cluttered", especially during Approach/Landing

Sensory Approach Goal

EASA: The crossing of alert thresholds should be:

*"Instantly recognizable, clear and unambiguous, especially to a **distracted pilot**"*

- `q-alpha` **Aural** alerts:
  - Spoken words "Airspeed", "Airspeed Low" & "Stall"
  - Required, but the aural channel can be cluttered
- `q-alpha` **Visual** alerts:
  - Based on the concept of "Useful Field of View"
  - This is the <u>primary sensory channel</u>

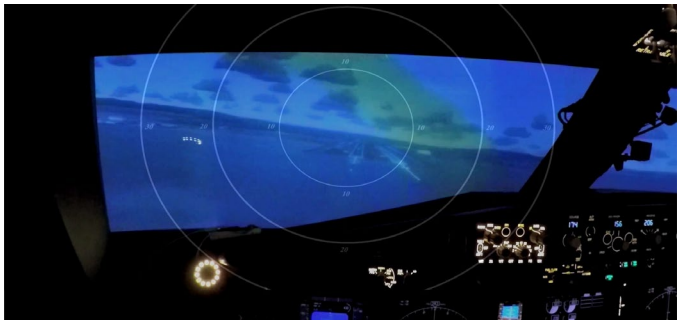
Human Factors – Visual Sense

- Both the <u>location</u> of the *q-alpha* Display and the <u>display formats</u> are unique
  - Location selected so that the alerts can be seen by a pilot that is looking over the nose (as in a straight-in approach) or out the side window (as in a circling approach)
  - Formats selected so that the alert can be instantly recognized and understood by a pilot **without the need to look directly at the display**

q-alpha Display Location

In the pilot's ***Useful Field of View***

- When flying a straight-in approach
- Or when flying a circling approach
- Or when changing radio frequencies or doing 1000 other things!



Useful Field of View - UFoV

In human vision, UFoV is defined as:

"The visual area over which information can be extracted without eye or head movement"

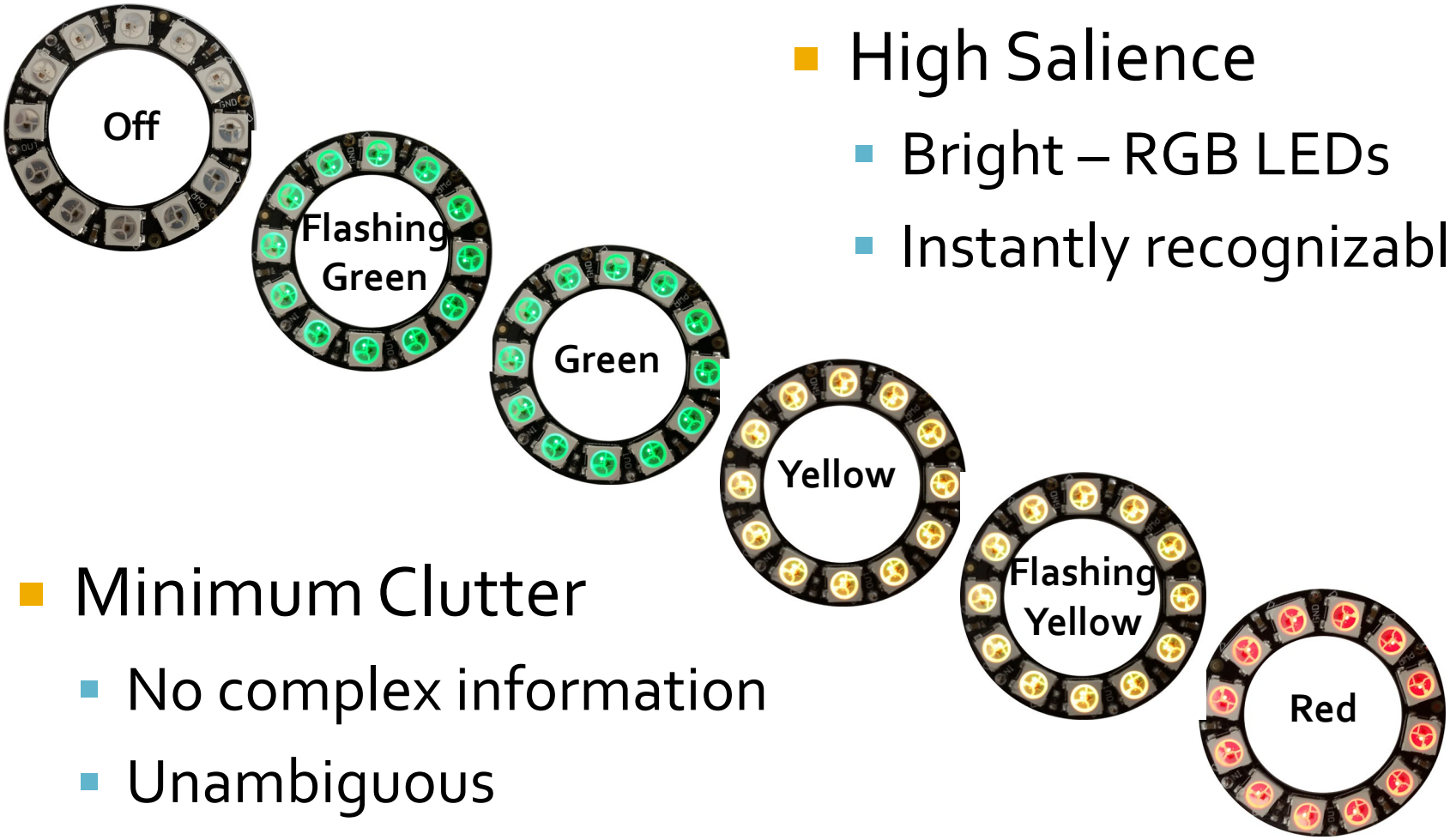
- For maximum effectiveness, a visual alert must be inside of the pilot's Useful Field of View

Ball, K., V.G. Wadley, and J.D. Edwards, Advances in technology used to assess and retrain older drivers. Gerontechnology, 2002. 1(4): p. 251-261.

What Affects UFoV?

- **Cognitive Load**
  - A high task loading reduces a pilot's UFoV
- **Clutter**
  - Placing a visual alert on a display that has too much other information on it reduces UFoV
- **Salience**
  - Placing a visual alert in a position that gives it high contrast with the background increases UFoV

q-alpha Display Formats

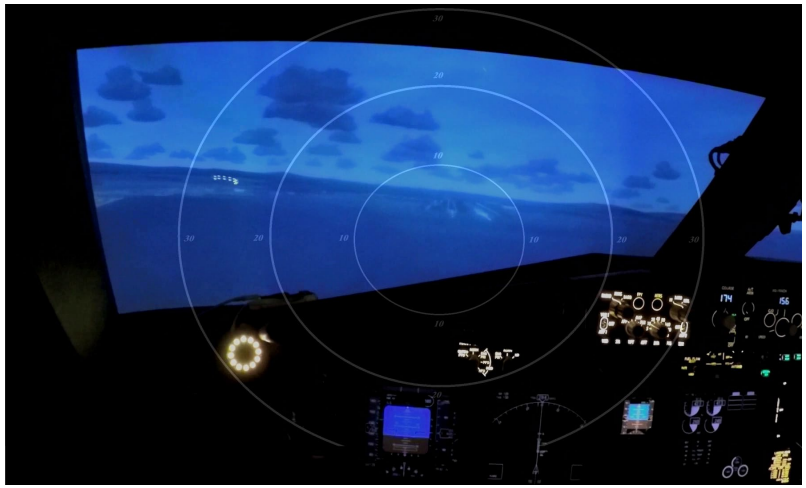


- High Salience
  - Bright – RGB LEDs
  - Instantly recognizable

- Minimum Clutter
  - No complex information
  - Unambiguous

Tests at NASA

- Highly successful tests were conducted at NASA in a Transport simulator
- *q-alpha* Display showed its value in Approaches, Landings and Go-Arounds
- NASA pilots flew several tests and gave strong positive evaluation



Pilot Comments

"This device will help guys fly stable approaches"

"It kept me 'on-speed' without distracting from other tasks"

"After a while, I became so familiar with the display, it sort of receded into the 'background' but having the 'green doughnut' in my peripheral continued to make me comfortable, especially during Go-Arounds. And I never had to look at it."

"This display will reduce FOQA exceedances"

"Go-Arounds will be much less likely"

"It made the Go-Around feel safer, especially ones that were initiated late"

"Although its based on much more than AoA alone, it reminded me of the comfort that I felt when calling 'AoA' when abeam of the carrier"

Asiana 214 – Could *q-alpha* Help?

- Standard system alert @ 114 kts, 100 ft, 11 seconds – no recovery
- *q-alpha* alert @ 132 kts, 480 ft, 31 seconds – easy recovery

TK1951 – Could *q-alpha* Help?

- Standard system alert @ 105 kts, 460 ft, 10 seconds – no recovery
- *q-alpha* alert @ 139 kts, 700 ft, 25 seconds – easy recovery

Take Aways

- The Amber Band is INEFFECTIVE
  - Alerts are late
  - Sensory inputs are imbedded in clutter and are not presented in a salient fashion
- The Q-Alpha low airspeed alert is EFFECTIVE
  - Alerts are much earlier and without false alarms or nuisance alerts
  - Sensory inputs are *"Instantly recognizable, clear and unambiguous, especially to a* ***distracted pilot****"*