
"I can see clearly now!"

Operational Based Vision Assessment

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USAF School of Aerospace Medicine

Headquarters U.S. Air Force

Integrity - Service - Excellence

Operational Based Vision Assessment (OBVA)

ICASM

12 November 2018

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711 HPW/USAFSAM

Operational Based Vision Assessment

The Centennial Anniversary of the USAF School of Aerospace Medicine and the History of 100 years of US Army/Air Corps/USAF Aviation Color Vision Testing

12 Nov 2018

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Integrity ★ Service ★ Excellence

Disclaimer

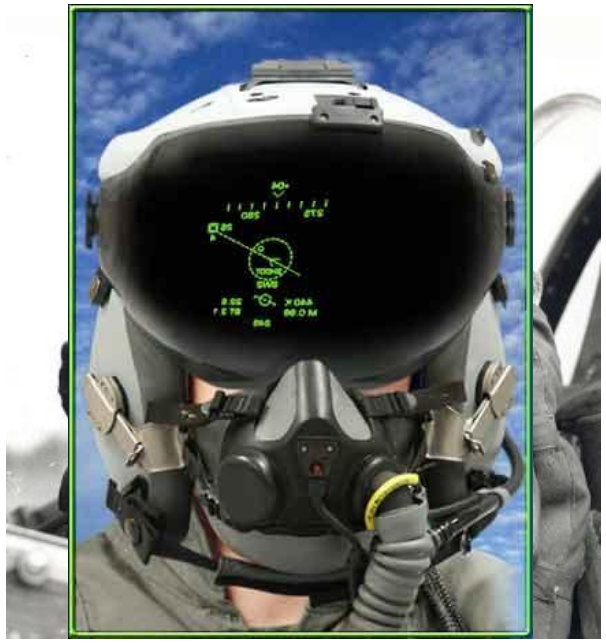
- **The views expressed are those of the author and do not necessarily reflect the official policy or position of the U.S. Air Force, the Department of Defense, or the U.S. Government**
- **This work was supported by U.S. Air Force contract FA8650-12-D-6280 to Wyle Laboratories and was funded by the AFMS SG 3/5 (DHP) and AFLCMC (S&T) through the 711 HPW/USAFSAM**
- **There are no off label use of medications discussed**
- **Special thank you to Dr. Doug Ivan, MD, Col (ret) USAF (mentor)**

Cleared, 88PA, Case # 2016-0245, Sep 2016

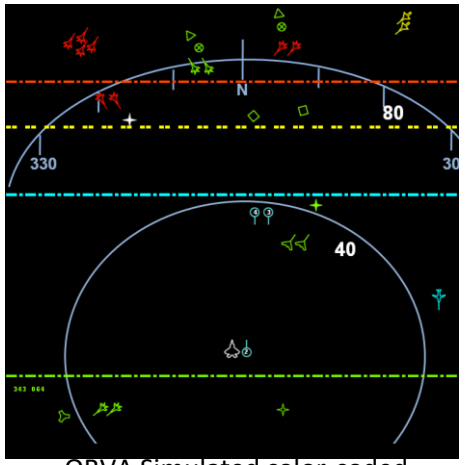
Introduction to the Operational Based Vision Assessment Laboratory

OBVA Program Purpose

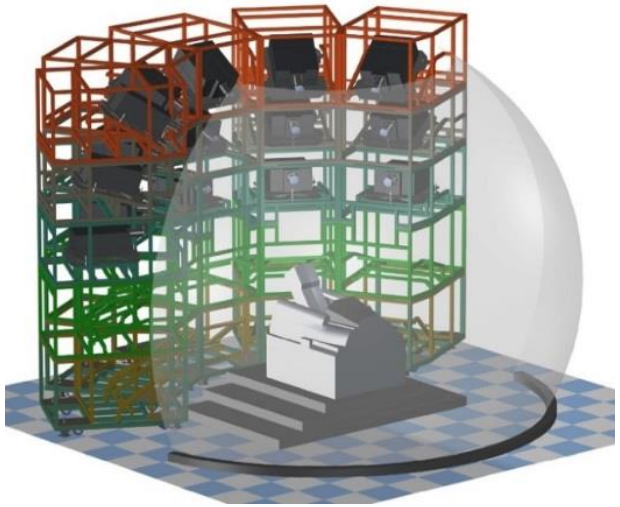
- **Are medical vision standards, and test methods, developed in early-mid 1900s applicable today?**
  - **Initial flying standards developed pre-WWI; most still used today**
  - **Electronic displays, enhanced vision systems, head-mounted displays, remote vision systems, etc.**
- **Develop vision standards and tests to support human performance optimization**



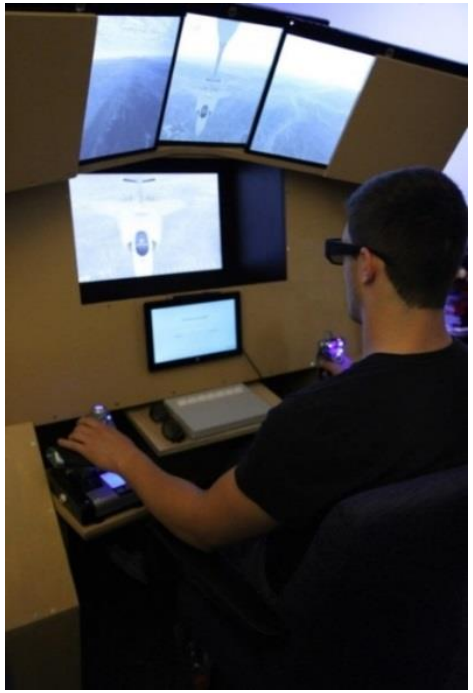
OBVA Laboratory Research



OBVA Simulated color-coded situation awareness display

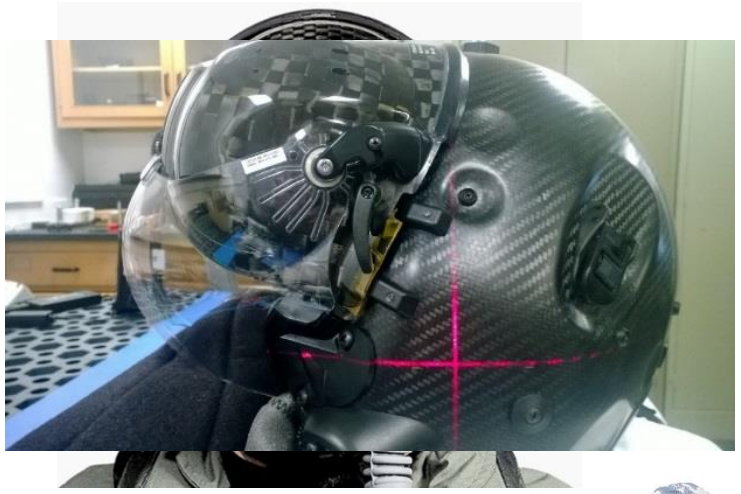


OBVA high-bay simulation facility. CAD drawing generated by OBVA personnel.



OBVA KC-46 remote vision system simulation. Photo by USAFSAM media department.

Unmanned aerial vehicle ground control station color displays. Source: DIMOC.



OBVA Collaborative R&D

- **International, industry, academic and tri-service collaboration**
  - **Enhanced mutual reliance, cost sharing, augmented data collection**
  - **Technology transition and development**

MINDEF SINGAPORE

Australian Government
Department of Defence
Defence Science and Technology Organisation

Institute of Aviation Medicine
Royal Australian Air Force
Salus Per Scientiam

Israel Air Force

DSO National Laboratories

DRDC
RDDC

JASDF 航空自衛隊

CFEME · CMEFC
Fines Humanos Pandimus

NVIDIA

scalable DISPLAY TECHNOLOGIES

FlightSafety international

SA Photonics

KONAN MEDICAL

Vulintus

Hedgefog Research Inc.

The University of Mississippi

York University
Université York

Ohio State

The University of Melbourne
Postera Crescam Laude

University of Waterloo
Concordia Cum Veritate

Naval Medical Research Unit Namru Dayton

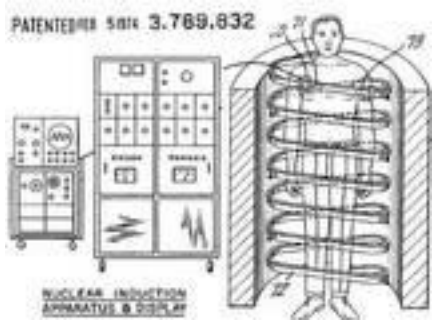
Naval Aerospace Medical Institute

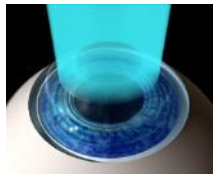
United States Army
Aeromedical Research Laboratory

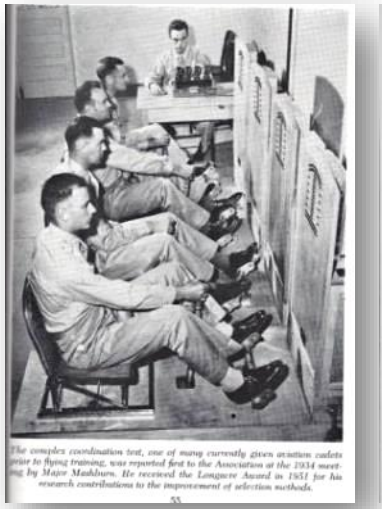
AFRL

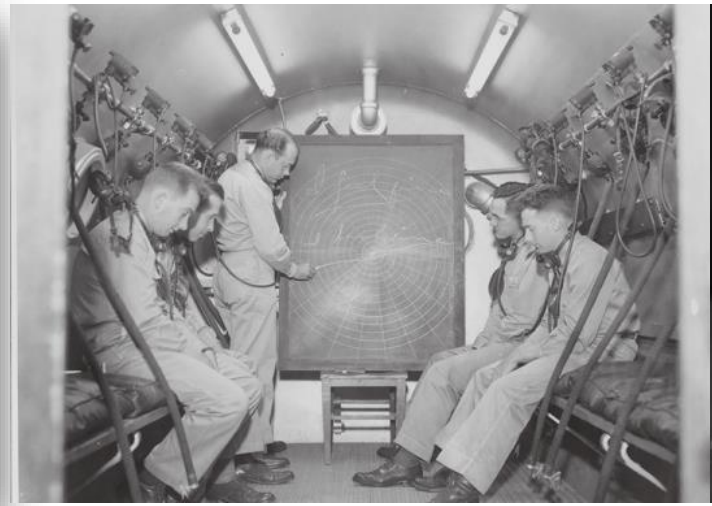
Celebrating a 100-Year Legacy
USAF School of Aviation Medicine (USAFSAM)

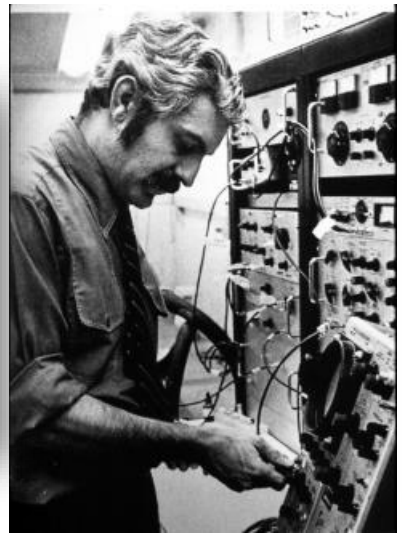
Celebrating a 100-Year Legacy
1918-2018

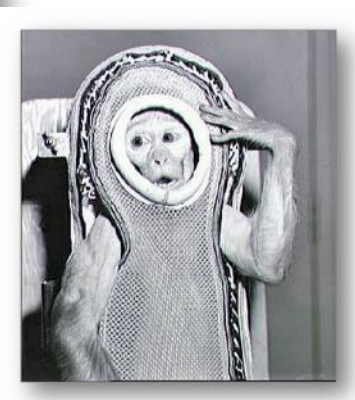












Cleared, 88PA, Case # 2018-2197, 27 Apr 2018.

USAFSAM

- Established January 1918 as school and laboratory at Hazelhurst Field, New York
- Graduated first Flight Surgeon class – May 1918; also trained Navy FS through 1939

1923 – First international student (Brazil) – now from 133 countries

Moved to Brooks and Randolph Field, San Antonio, Texas, 1926 – 2010

School of Air Evacuation integrated into USAFSAM in 1944

Moved to AFRL and Wright-Patterson AFB, Ohio – 2010

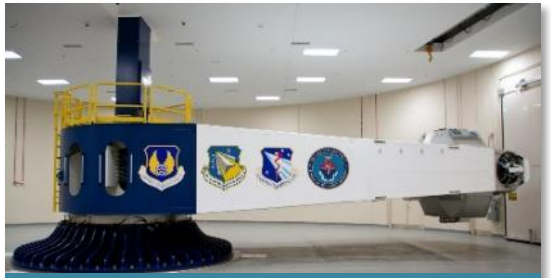
Education – Consultation – Research

USAFSAM Facilities

Research Altitude Chamber

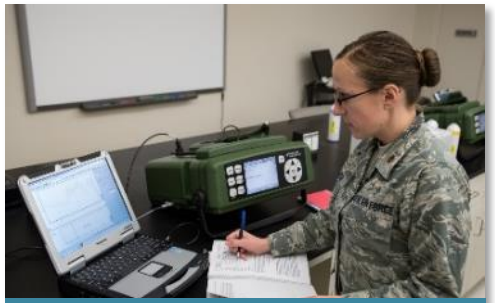
USAFSAM

- 3 Buildings
- 520,000 ft^2
- 55 Laboratories
- 47 Classrooms
- 2 Auditoria
- 1 High bay + outdoor facilities with 7 aircraft trainers



Centrifuge

Classroom



Occupational & Env. Health

Epi Laboratories

3 C-STARS sites, 1 SMART site

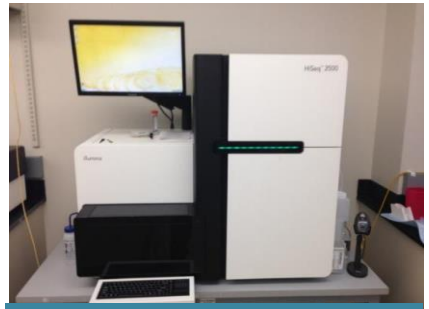
MIST Studio

OBVA

High Bay

Bioenvironmental

Franzello Aeromedical Library

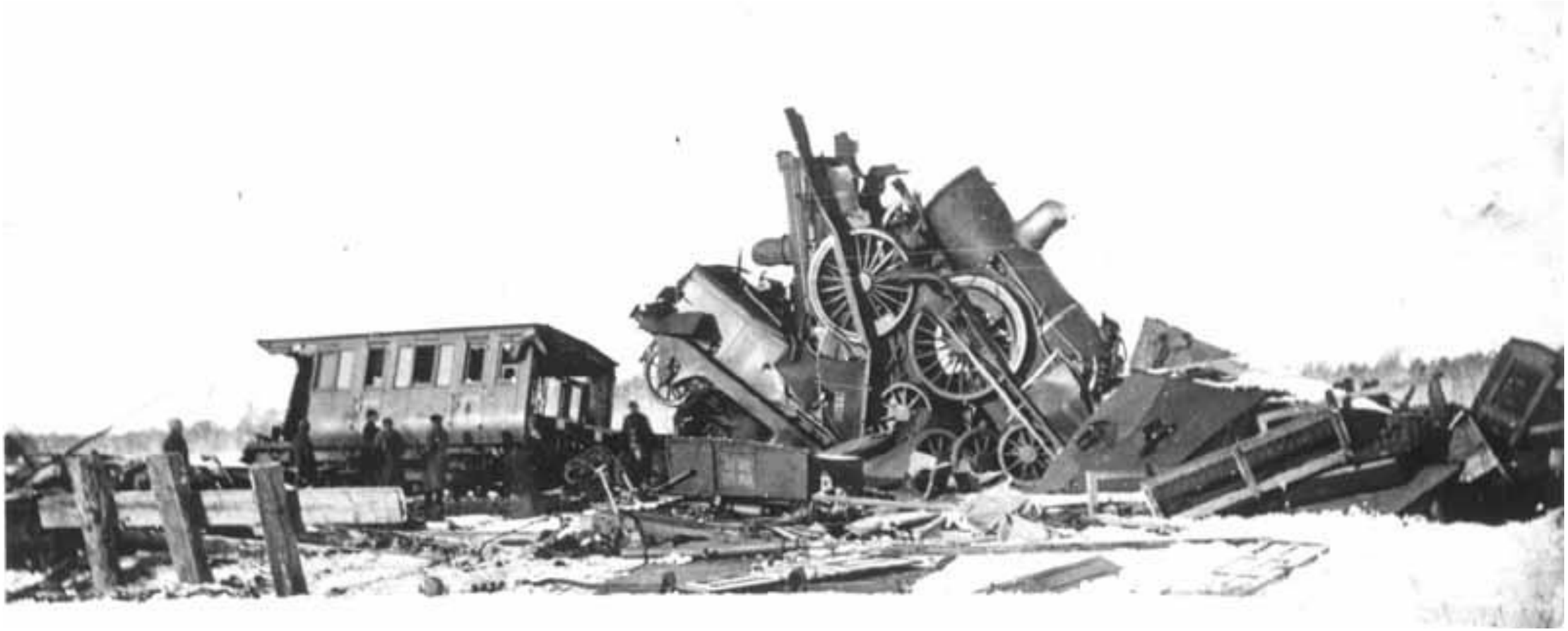


Next-Generation Sequencers

Celebrating a 100-Year Legacy

USAF Color Vision Testing

Historic color vision transportation mishap



Lagerlund train site a few days after the collision

WWI Aviation Color Vision Standards

Color Vision (in the A.E.F.)

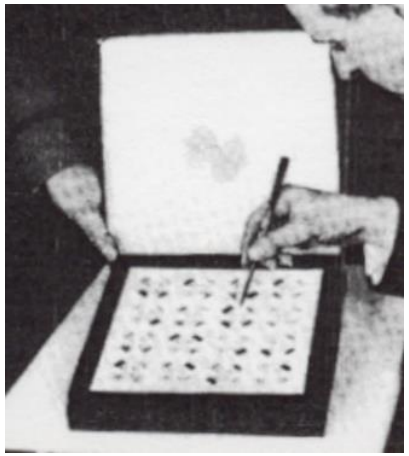
“We consider that (color vision) is most important for the aviator to be able to recognize colors rapidly in a reduced light and in a fog.”

Wilmer and Berens
Aviation Medicine in the A.E.F.

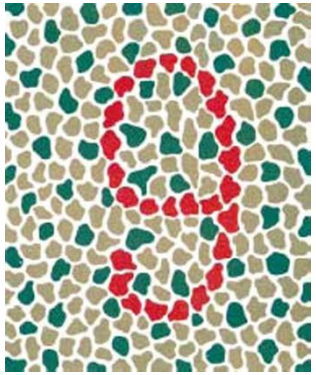
Army Air Corps (1919 – 1935)

“Aviation Medicine in the A.E.F.”

(Wilmer And Behrens, Chap 6, Feb 1920)

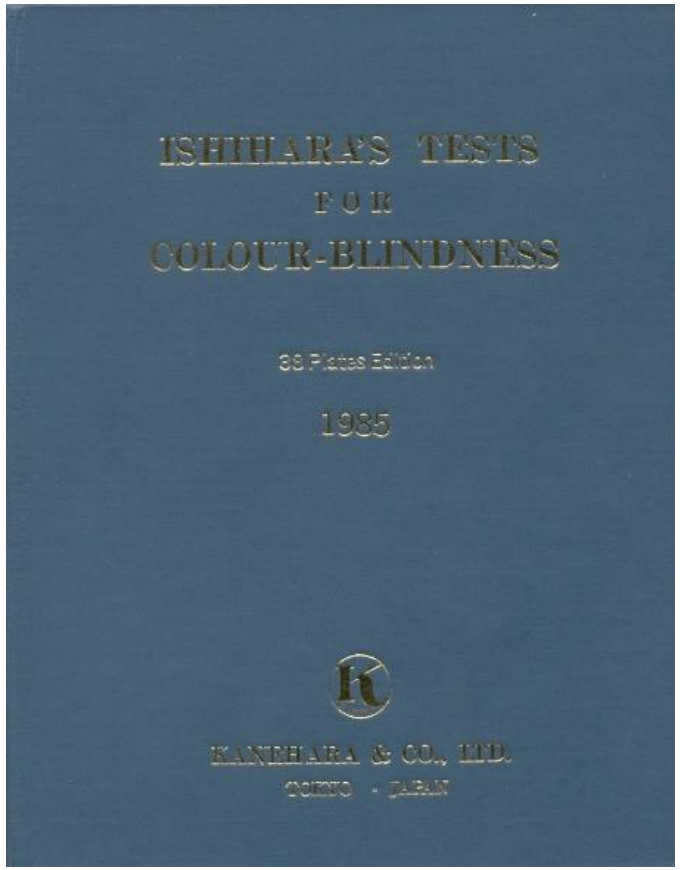


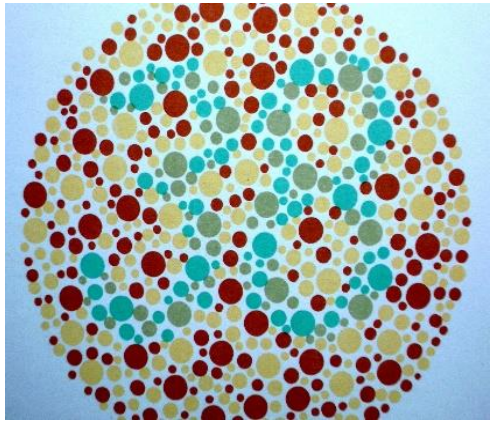
- **Primary test**
  - **Jennings Self-Recording Color Test (1896)**
    - **Modified Holmgren wool test**
    - **Perforated cardboard score sheet with red (rose) / green confusion colors**
- **Secondary tests**
  - **Holmgren wool test (1877)**
  - **Williams lantern (1892)**
  - **Stilling plates (1877)**
  - **Colored lights at 20 feet**



Army Air Corps (1935 – 1940)

- **Considerable color vision research at Army Air Corps School of Aviation Medicine (SAM)**
  - **Louise Sloan (Sloan-Rowland)**
- **Primary and <u>only</u> test**
  - **Ishihara plates, 1st edition (1917)**
    - **If you failed, you were rejected**

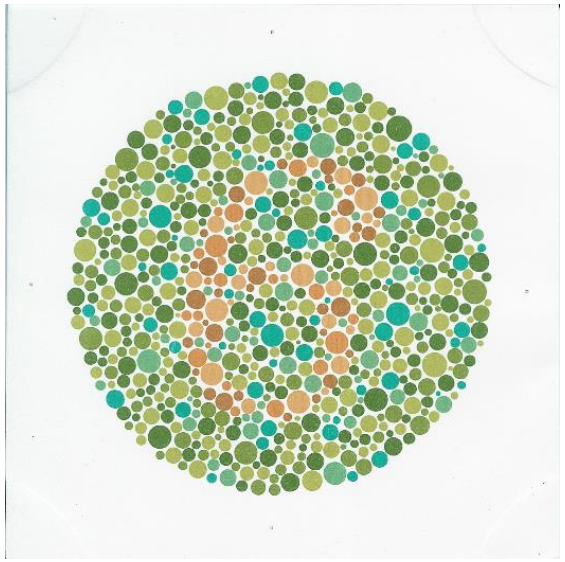


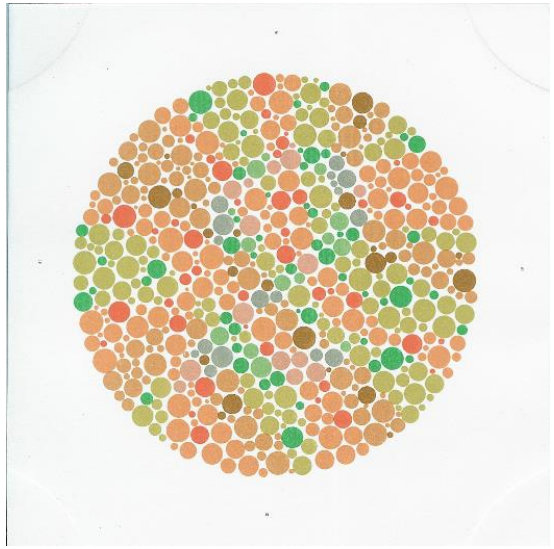


Ishihara Plates (1917)

Dr Shinobu Ishihara, Japanese medical officer, introduced worlds most well known color blindness test

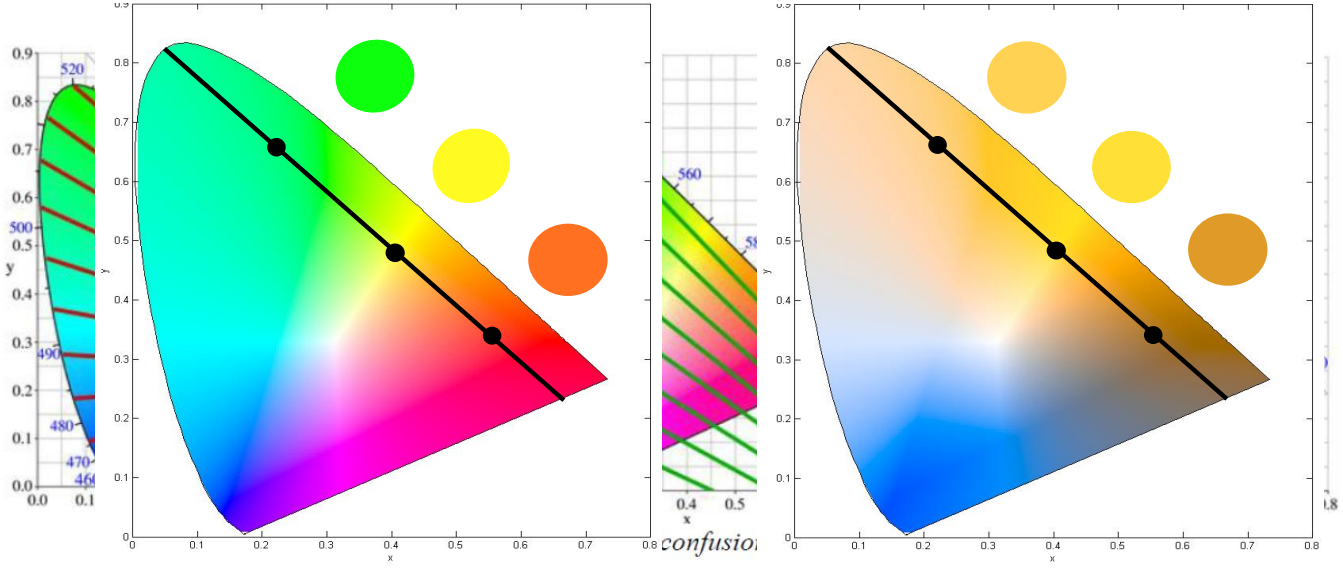
- **Later became a General Officer**
- **Principles similar to Stilling plates**





Normal

Deuteranope



Published "No Cures for Color Blindness"

- No "Cures" for color blindness, including
  - Colored lights / colored filters
- Noted improved scores with practice
  - PIP plates are "obviously not suitable for repeated use…"
- Standardized illuminant (true "daylight")
- Dispelled myth that vitamin A improved color vision
- Lack of understanding of important precautions concerning PIP use and interpretations

Louise L. Sloan, Ph.D., "The Air Surgeon's Bulletin," Vol. I, No. 2, February 1944

Problem with PIP Plates

- **Pseudoisochromatic (PIP) tests (Linksz)**
  - **"…not meant to be a scoring device, [they were intended] to be a separator of wheat from chaff, of color normal from color defectives."**
  - **"Test improvements [were] meant to improve diagnostic facility [not scoring of different types of color defectives]"**

Arthur Linksz, MD

"An Essay on Color Vision"

Army Air Corps (1940-1945)

WWII Color Vision Testing Strategy:

Employ two types of color vision tests

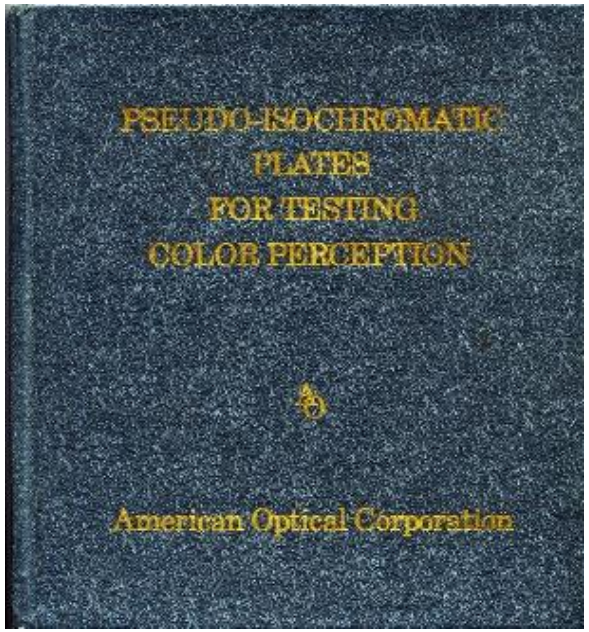
- Basic screening test
  - Simple, rapid, reliable separation of color normal and color defective: PIP test
- Secondary test (if fail basic screening test)
  - Reliable and valid estimate of degree of defects
    - Anomaloscope is best
- Reserve test (to counter PIP memorization)
  - Sole use of Armed Forces

(Louise L. Sloan, PhD, "The Air Surgeon's Bulletin," Vol. I, No. 2, pp 22-23, February 1945)

American Optical (AO) Plates (1940)

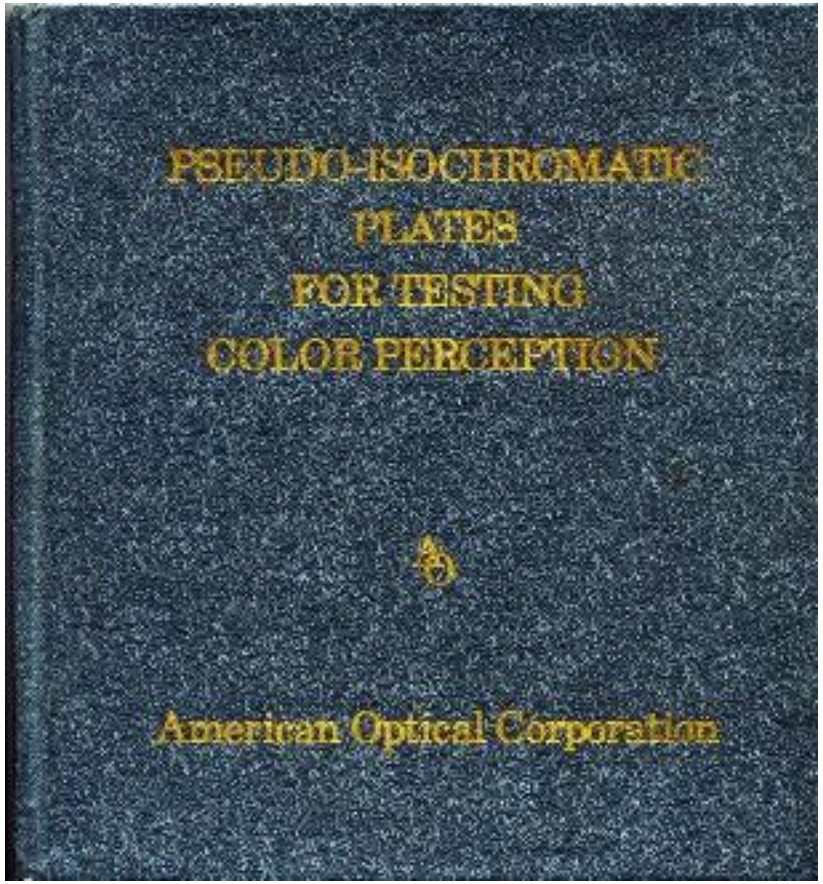
46-plate AO test compiled for U.S. Armed Services (1st ed)

- Plates "stolen" from Stillings-Hertel and Ishihara
  - "It was wartime and both tests were alien property"
  - Some optotypes were "Japanese or German looking" so suspect
  - Ishihara/Stillings hard to obtain in the vast numbers needed
  - No authors names; no credits given
- Comprehensive test instructions
  - Backlighting with true daylight
  - 2-3 feet testing distance
  - Prompt response (2 sec)
    - "' Tarrying' indicates certain amount of color deficiency"
  - Never allow to hold or touch plates
  - Errors never revealed



American Optical (AO) Plates

- **46-plate AO set (First Edition)**
  - **“Too long”**
  - **Failed some normals**
  - **Not much in the way of diagnostics**
- **Shortened versions produced**
  - **1942: 19-plate “first abridged” version (L. Sloan)**
    - **4 or more errors = color defective**
  - **1945: 36-plate “second edition” (D. Farnsworth)**
    - Germanic optotypes (letters) changed to block letters
    - Uniform background used
    - Removed “white rivers”
    - Improved colorimetrics
  - **1946: 20-plate Navy version**

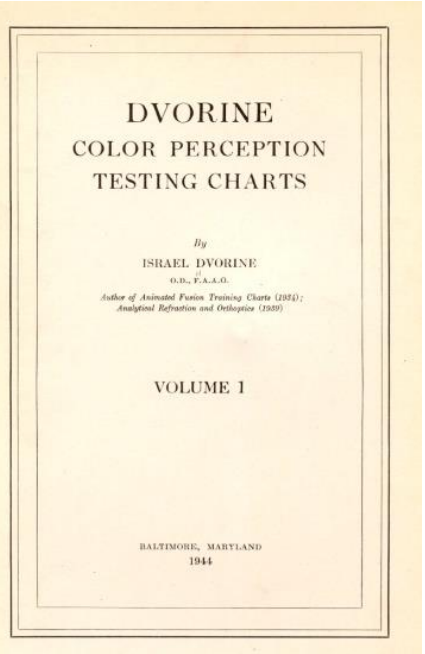


SAM-CTT (1943)

- School of Aviation Medicine Color Threshold Test (SAM-CTT)
- Devised to measure ability to distinguish colored signal lights existing at the time
  - 8 different colored lights (2 reds, 2 yellows, 2 greens, 1 blue, 1 white)
    - Provided color “close to limiting” standards of Bureau of Standards for Aviation Colors

Additional Developments (1942 – 1947)

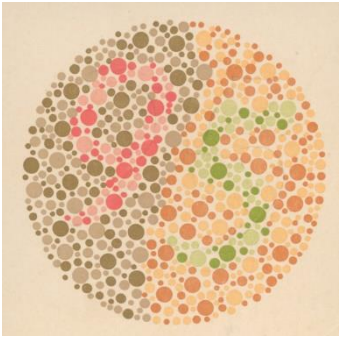
- 1942: ~~Holmgren wool test discontinued~~
- 1944: ~~46 plate version of AO discontinued~~
- 1944: ~~Abridged version of AO developed by Sloan discontinued~~
- 1944: 1st edition of Dvorine PIP printed
- 1945: Abridged 38 plate version of AO developed by Farnsworth
- 1946: 20 plate version of Farnsworth adopted by US Navy
- 1946: Original Farnsworth Lantern (FALANT) developed for Navy signalman
- 1947: Birth of the USAF


DVORINE
COLOR PERCEPTION
TESTING CHARTS

By
ISRAEL DVORINE
O.D., F.A.A.O.
Author of Animated Fusion Training Charts (1934); Analytical Refraction and Orthoptics (1939)

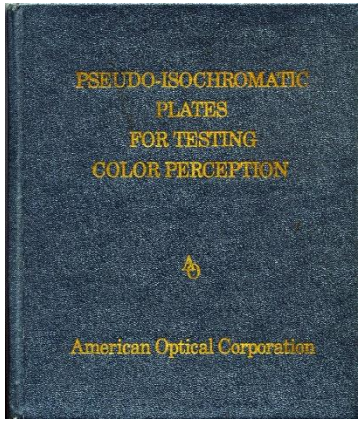
VOLUME 1

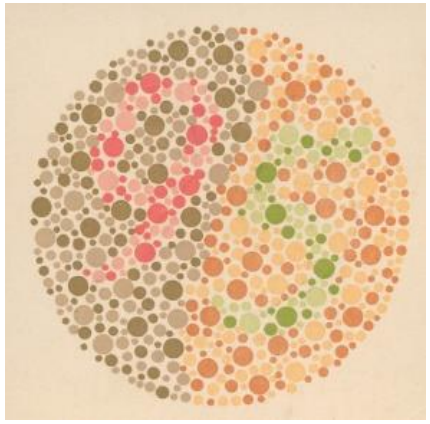
BALTIMORE, MARYLAND
1944

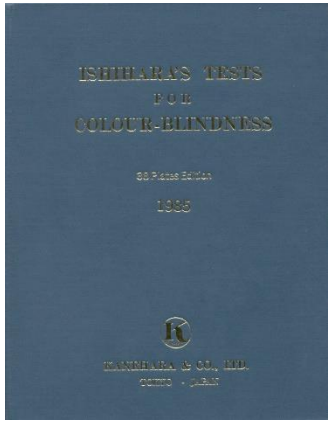


USAF (1947 – 1952)

- **Primary Tests**
  - **Ishihara PIP (8th edition)**
  - **Original American Optical Company PIP (19 plate "2nd abridged" version)**
- **Adjunct Tests ("color safe")**
  - **SAM-CTT**

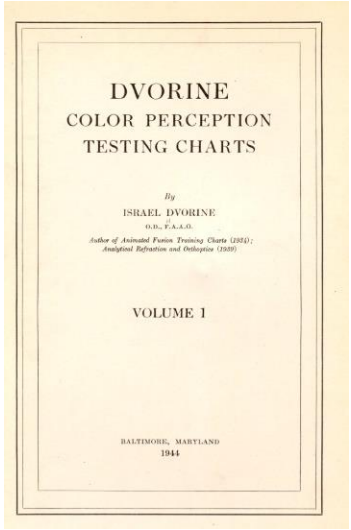


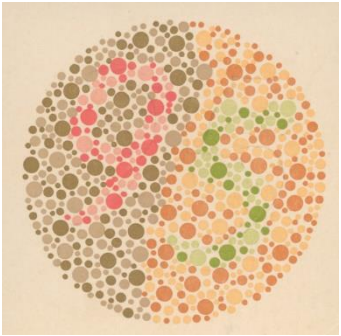


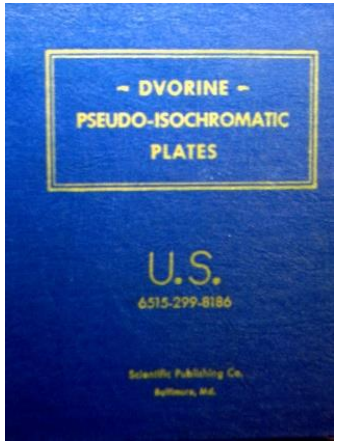


Developments (1953 – 1959)

- **1953: 2nd edition of Dvorine printed**
  - **15 plates (1 demo plate)**
- **1953: Armed Forces - National Research Council's Vision Committee**
  - **Adopts Sloan, Judd, and Farnsworth's 15 plate AOC as the "official" USAF test (AF-CVT)**
- **1954: FALANT adopted for Navy aviation**
- **1954: Dvorine (2nd edition) approved by A.M.A.**
- **1959: 2nd edition Dvorine approved by military**







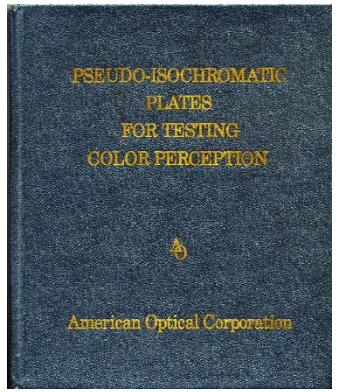
“In this country there was one test published that is worth serious consideration, the Dvorine Test.”

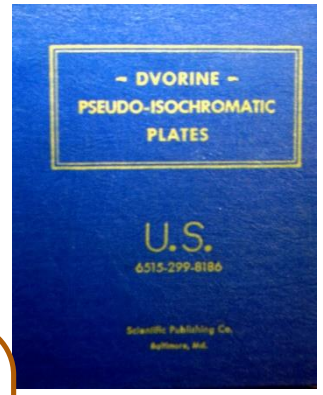
Arthur Linksz, MD

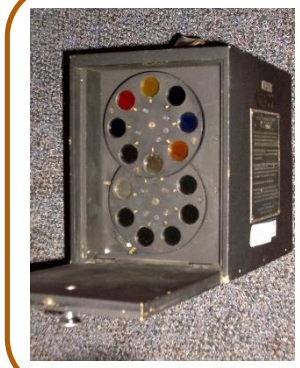
“An Essay on Color Vision”

USAF (1959 – 1995)

- **Primary tests (standard color vision tests: VTS-CV)**
  - AO
  - Dvorine (2nd edition)
  - Both had 15 plates (1 demo plate)
    - Passing criteria: 10 or more correct out of 14

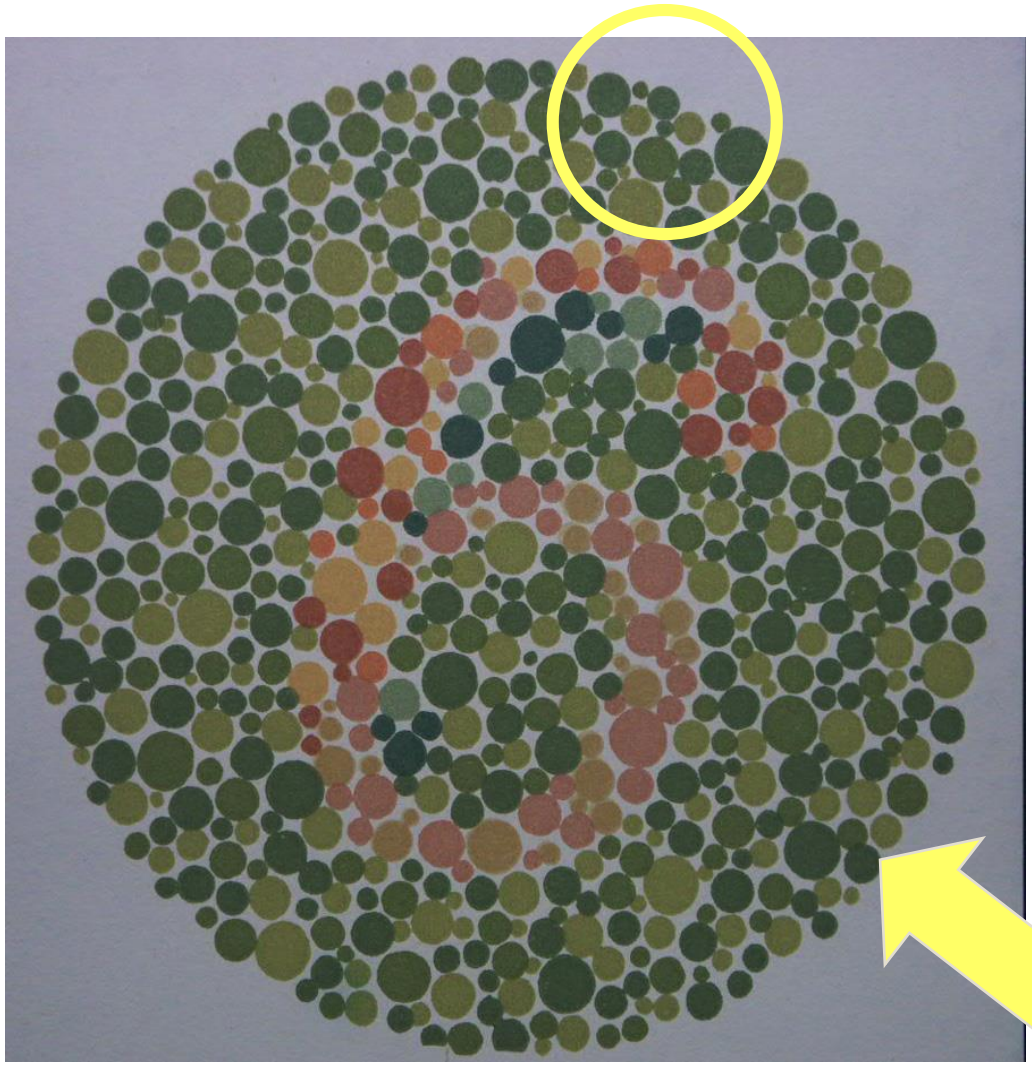


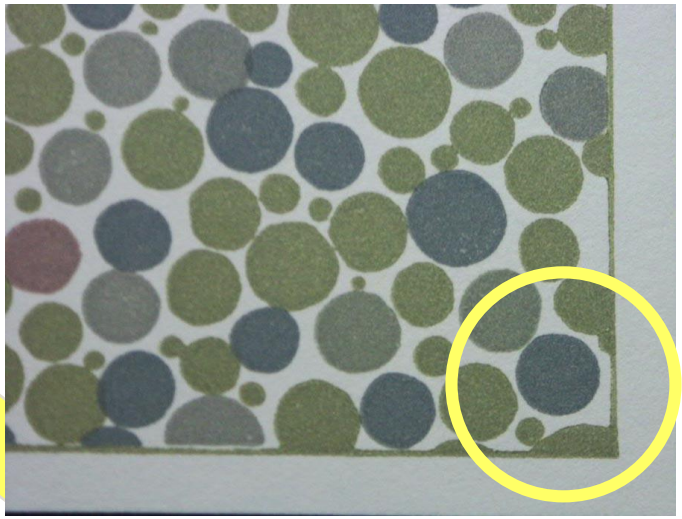




- **Secondary tests (if failed PIP)**
  - Farnsworth lantern (FALANT)
    - Applicants rejected if failed
    - SAM-CTT could be used only for trained aircrew and flight surgeons
  - 1989: ~~SAM-CTT discontinued due to faded and irreplaceable filters~~
  - 1991: Routine FALANT production stopped
  - 1993: ~~USAF dropped test as a qualifying test:~~ Unavailability and undependable results

Color Vision Caper – 1994





Memorization of PIPs or "SCAMMING the PIPs"

PIP I Sensitivity

Percent of Color Defectives That Fail Test

PIP I Passing Criterion: 12 of 14 correct

USAF Pilots & Aircrew (n=1329)

PIP I	PIP II	PIP III	F2
96%	78%	65%	88%

USAF Pilots Applicants (n=1279)

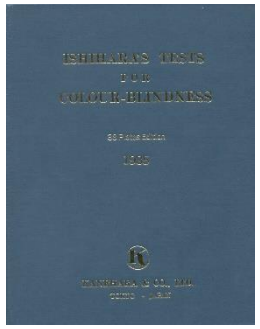
PIP I	PIP II	PIP III	F2
78%	47%	53%	76%

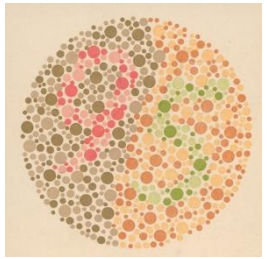
Fail to detect 22%!

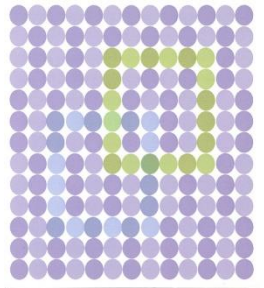
USAF (1998 – 2011)

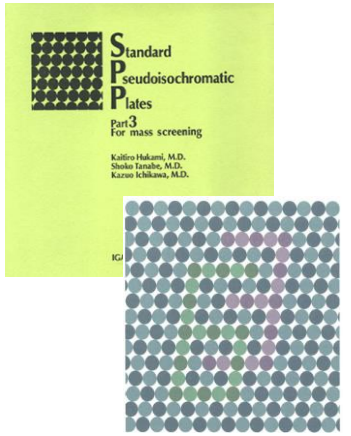
1998-2018: all USAF pilot applicants required normal color vision

- **MFS centers at (Brooks AFB and USAF Academy)**
- **Must pass 4-test screening battery (1998-2011)**
- **No waivers granted**





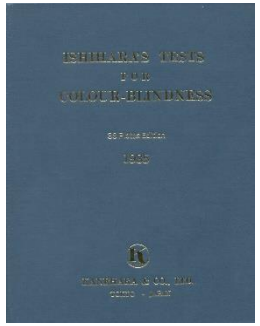


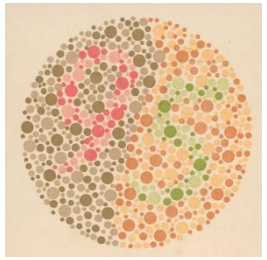


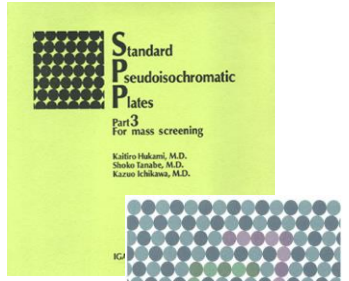
USAF (1998 – 2011)

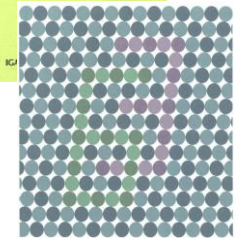
Pilot applicants

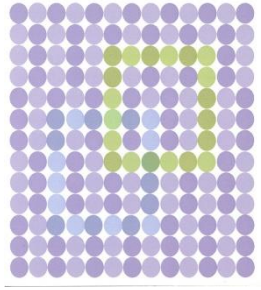
- Screened in field by PIP I
  - Ishihara, Dvorine, or original AO
- If pass PIP I, Applicant goes to Medical Flight Screening (MFS)
  - PIP I (R/G; congenital)
  - PIP II (B/Y; some R/G; acquired)
  - PIP III (R/G + B/Y; mixture)
  - F2 (R/G + B/Y)
- Color vision test took over 20 min to perform







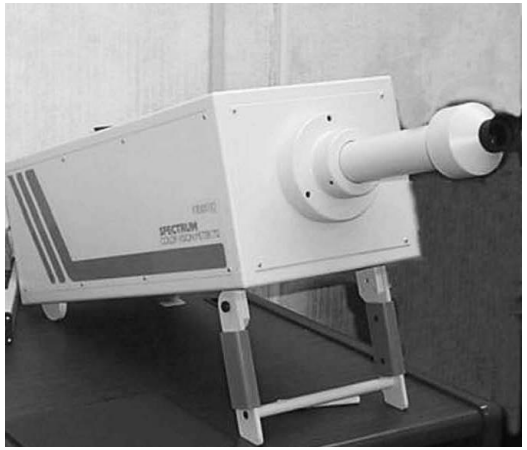


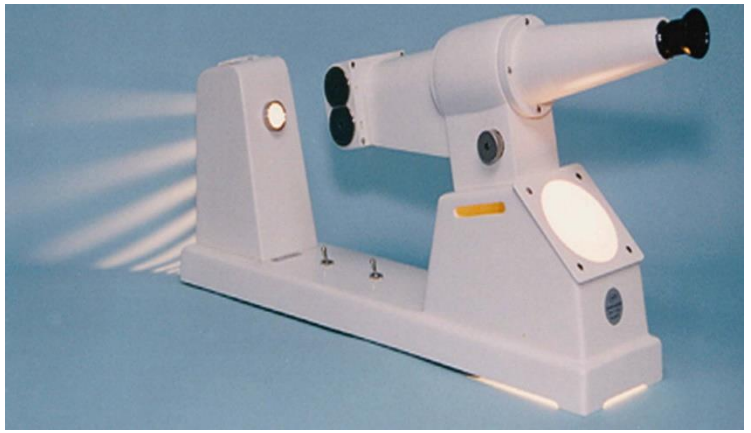


USAF (1999 – 2011)

Pilot applicant

- If fail any of the 4 tests
  - Complete color vision evaluation (CAD, D15, FM 100 hue)
  - Anomaloscope is final determining test

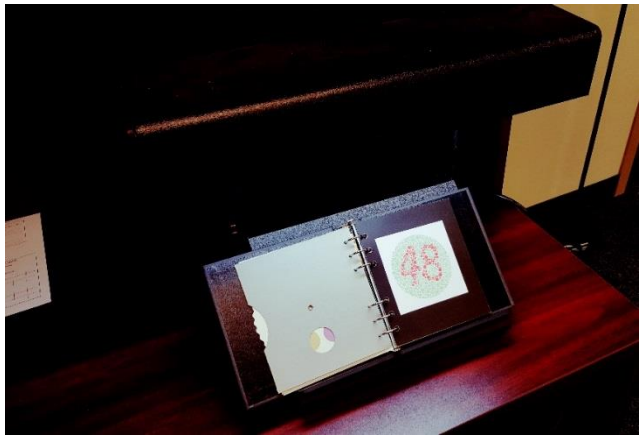




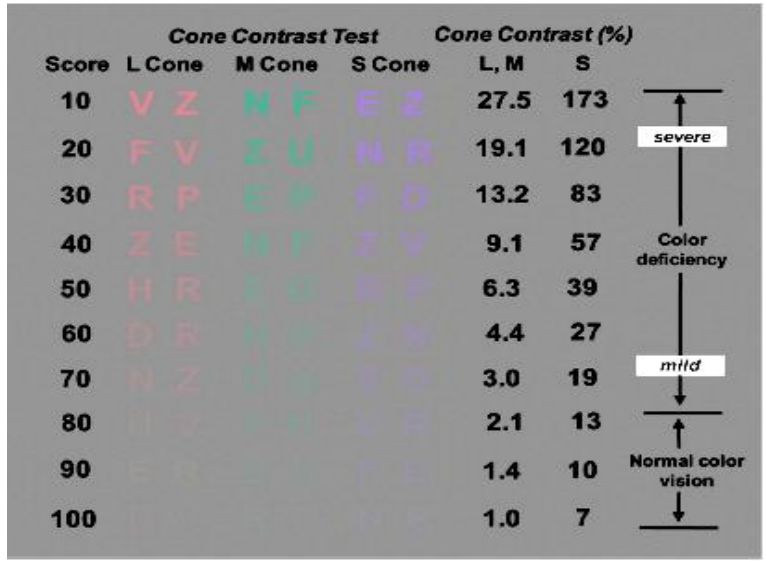
No waivers allowed for entry

USAF (2011 – present)

- **2011, the USAF introduced a new computer-based color vision screening test - the Rabin cone contrast test (RCCT)**
  - **Replace pseudoisochromatic plate (PIP) tests**
  - **Demonstrated to very reliably screen for color deficiency (Rabin et al, 2011; Hovis, 2016)**



Dvorine PIP test. OBVA Lab photo.



Rabin CCT L (red), M (green) , S (red) cone test letters. OBVA Lab image.

Rabin CCT Color test new Gold Std

AFRL-SA-WP-TR-2016-0008

	Cone Contrast Test (CCT Staircase)	Colour Assessment and Diagnosis (CAD)	Computerized Color Vision Test (CCVT)	Oculus Anomaloscope
Subjects evaluated	98 Total Subjects 48 Color Normal, 50 Color Deficient (based on test battery)*			
Sensitivity (Color deficiency correctly diagnosed)	100.0% (50/50)	100.0% (50/50)	96.0% (48/50)	96.0% (48/50)
Specificity (Normal color vision correctly diagnosed)	100.0% (50/50)	100.0% (50/50)	96.0% (48/50)	98.0% (49/50)
Nature of deficiency correctly diagnosed (i.e. deutan vs. protan)	100.0% (50/50)	94.0% (47/50)	78.0% (39/50)	96.0% (48/50)

STINFO COPY

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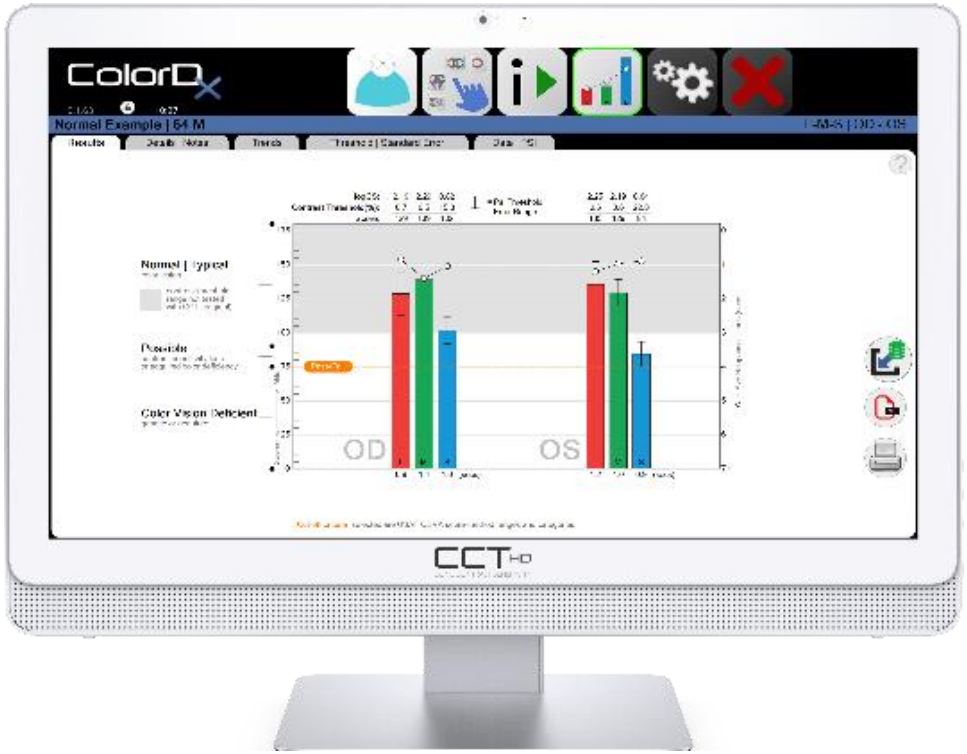
USAF High Precision Color Testing

- **USAF Academy identified the current Rabin color test as:**
  - **“better than any previous color test”**
  - **“but the most significant reason the cadets don’t trust cadet standards” Lt Col Ruth German, DO, Mar 2015**
- **OBVA developed a new high fidelity color test 2014-2016**
- **Partnered with industry on CRADA (Konan medical) 2016-2018**
- **Validated on >2000 USAF pilot applicants compared to Rabin CCT, UK CAD, anomaloscope**
- **Six peer review presentations/publications**
- **USAFSAM ACS perfected interface/algorithm**
- **Adjusting for mild CVD (2018)**

Konan CCT-HD

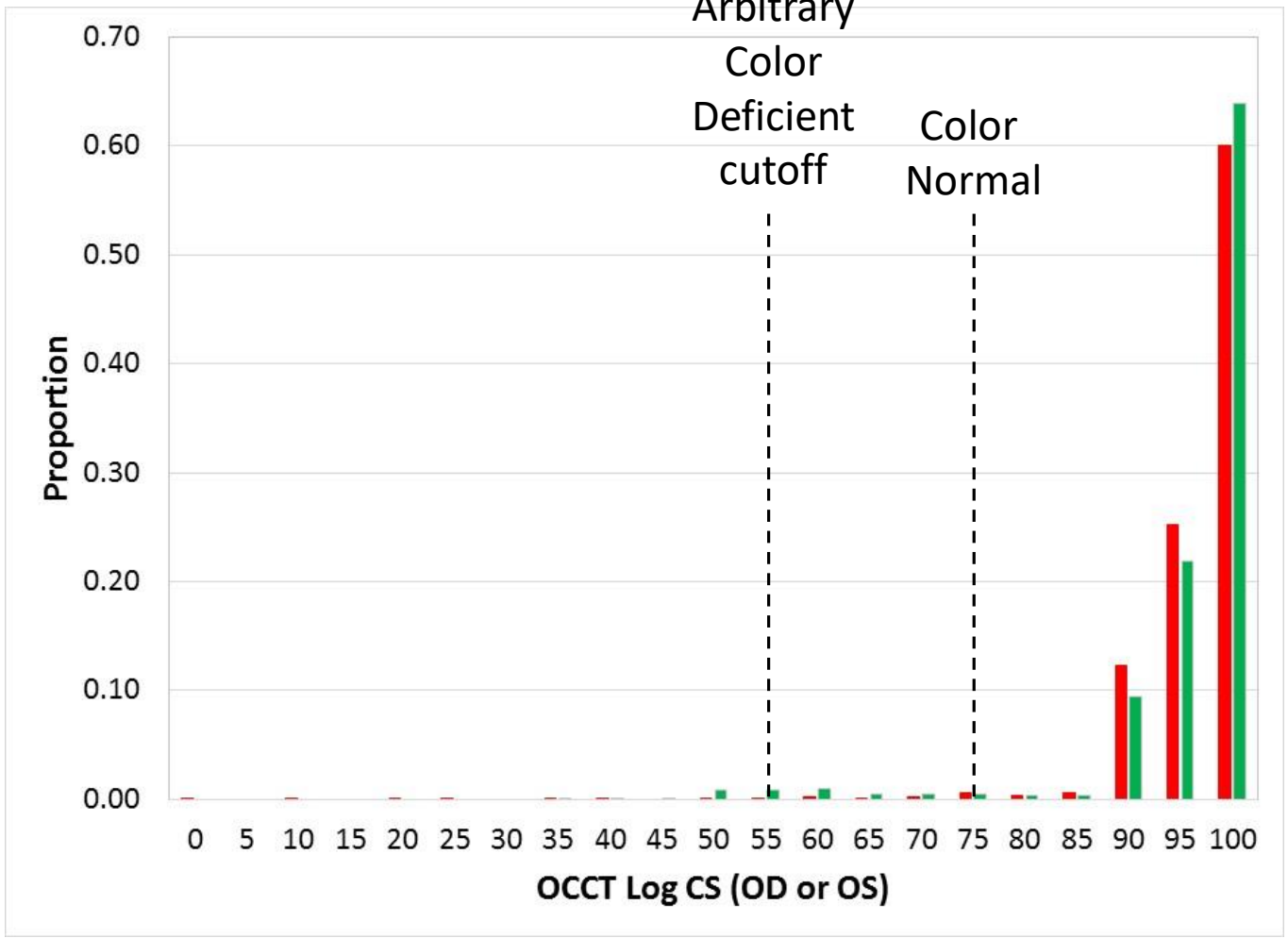
New USAF Color test



AVT research – Konan Medical CCT-HD CRADA

Photo provided by Konan Medical, used with permission

Rabin CCT Distribution (OD, OS)

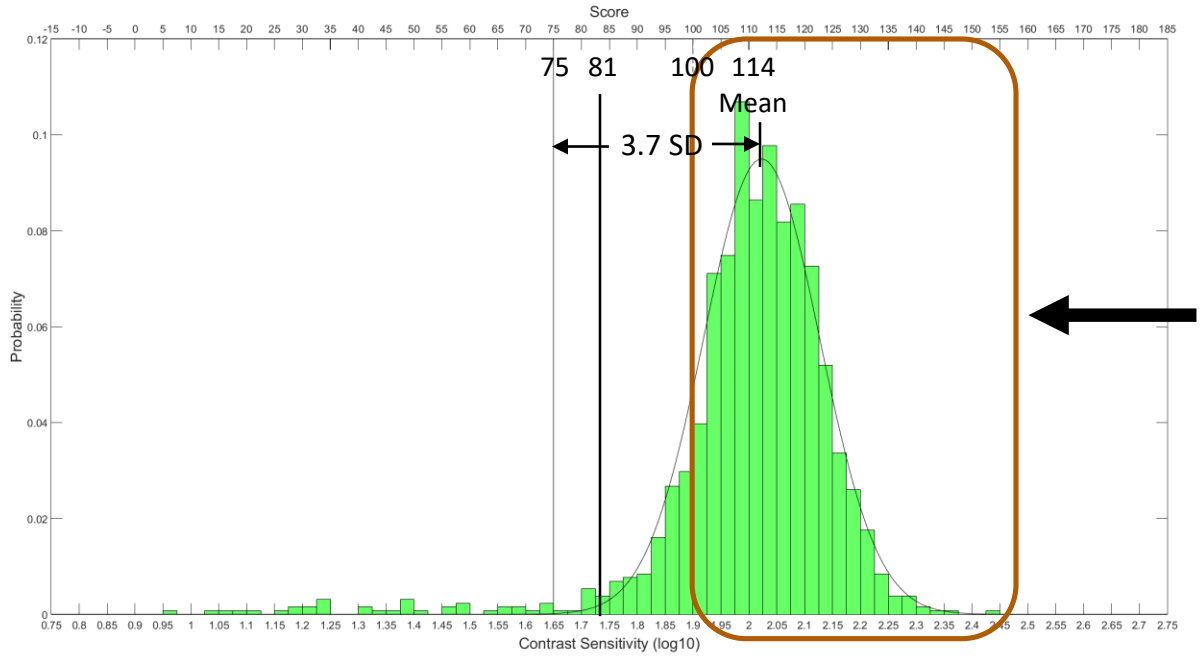


- **RCCT distribution**
  - **Monocular scores (0 – 100)**
- **L-cone: 2,182 eyes tested**
- **M-cone: 2,168 eyes tested**
- **CVN Mean, SD**
  - **L: 97.2, 4.2**
  - **M: 97.7, 3.8**
- **Protans: 0.92%**
- **Deutans: 3.8%**
- **Ceiling effect: >80% of USAF pilot applicants score 100**
- **Floor effect: All scores below 40 unreliable**
- **Arbitrary score of 55 includes significant number of moderate color deficient**

CCT-HD Distribution (OU)

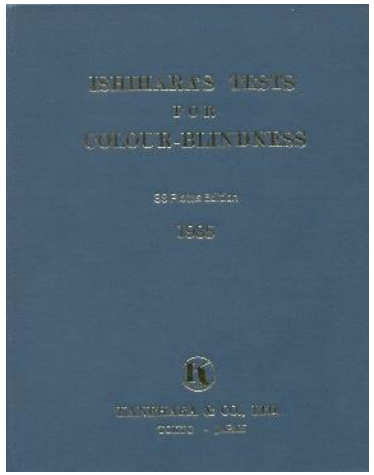
Benefit of CCT-HD -- *No Ceiling Effect; No Floor Effect*

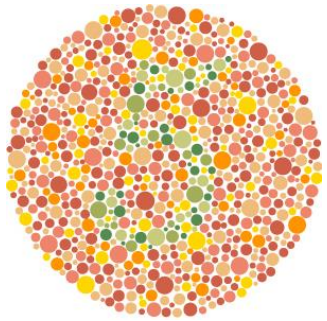
- M cone (green) test results distribution
- The bottom horizontal axis identifies contrast sensitivity and the top horizontal axis shows the equivalent CCT scores.
  - The normal pass/fail criterion (1.65 logCS, 75 CCT score) is shown by the solid line.
  - The maximum measurable contrast sensitivity in for the RCCT (1.9 logCS, 100 CCT score) is shown using the dotted line.
  - Contrast Sensitivity values to the right of the dotted line (~ 86% of normal observers (90% male, 95% female) cannot be measured using the RCCT

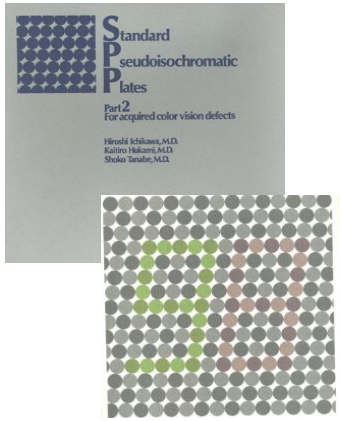


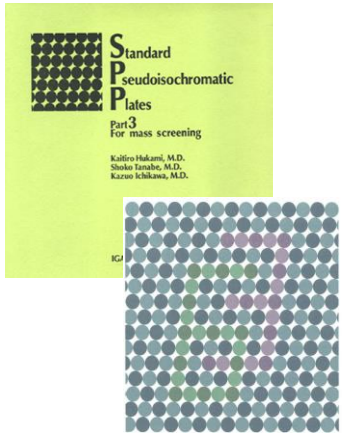
RCCT scores all these results at 100% due to ceiling effect

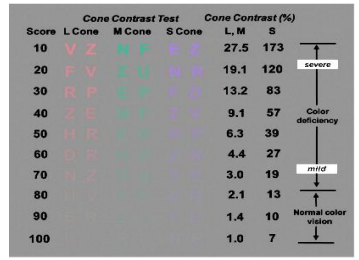
USAF Color Tests Summary





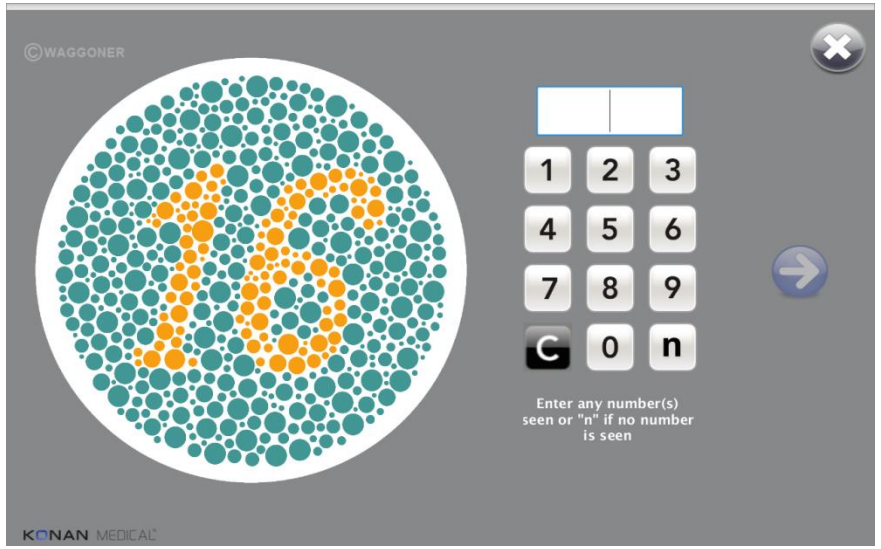




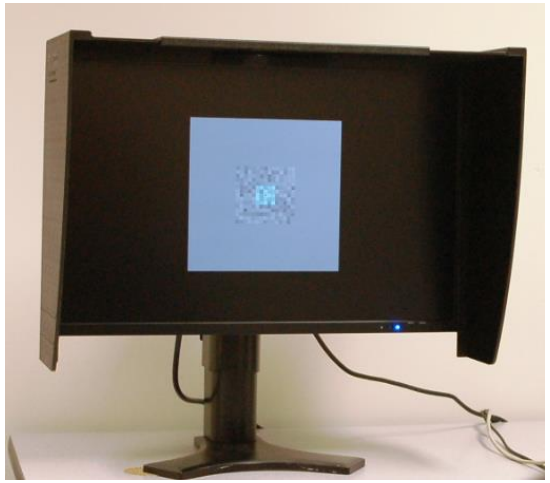


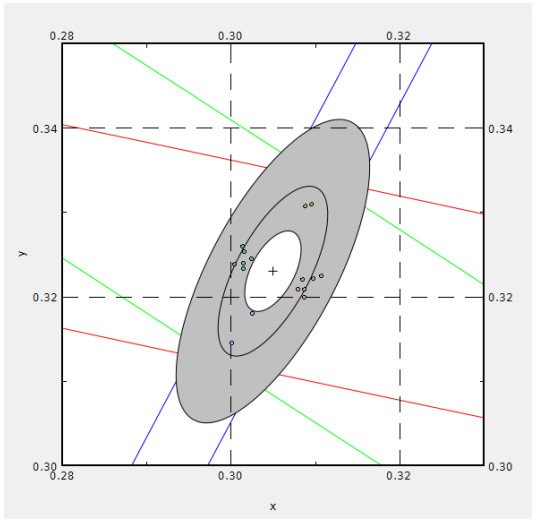
USAF Color Tests Summary

Digital Color Tests

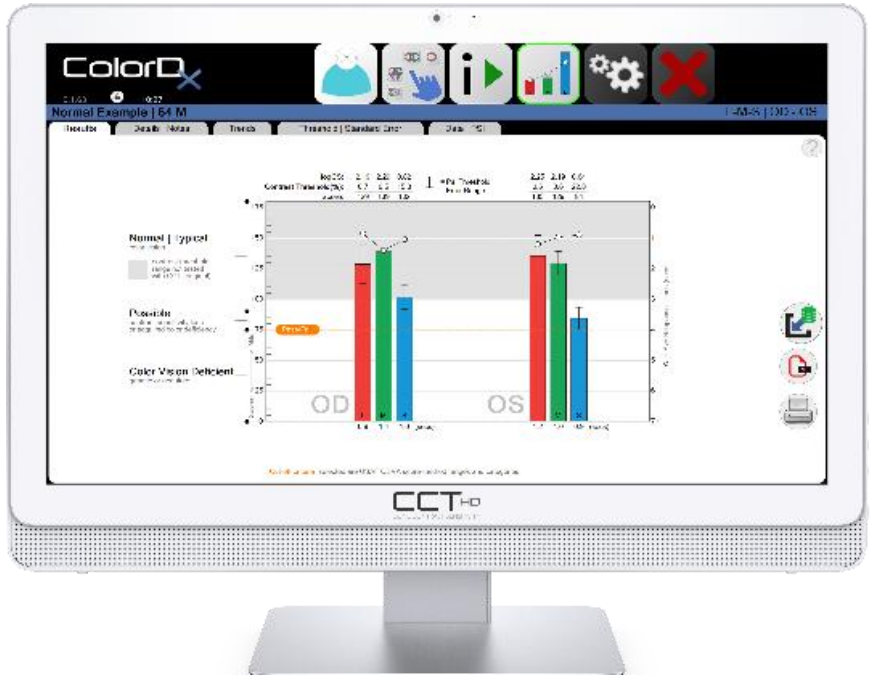


Waggoner CCTV





Colour Assessment and Diagnosis (CAD)



Konan CCT-HD

“I can see clearly now!”

Questions?