DETERRENT EFFECTIVENESS
PAR46 LANDING LIGHT WITH UVLED ON BIRD BEHAVIOR

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Near Miss Event Starts @ 04.717 sec.

Birds Comes Into View
Cessna 310 @150 kts, 3500' Alt

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Near Miss Event @ 08.294 sec.

First Avoidance Response is 3.8 seconds after entering camera field of view
Cessna 310 @150 kts, 3500’ Alt

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Near Miss Event @ 08.762 sec.
(Reaction time: 0.45 sec.)

0.45 sec between start of reaction and near-miss b irdstrike
Cessna 310 @150 kts, 3500’ Alt

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Near – Miss Event Video
(Total Elapse time: 4.045 sec.)

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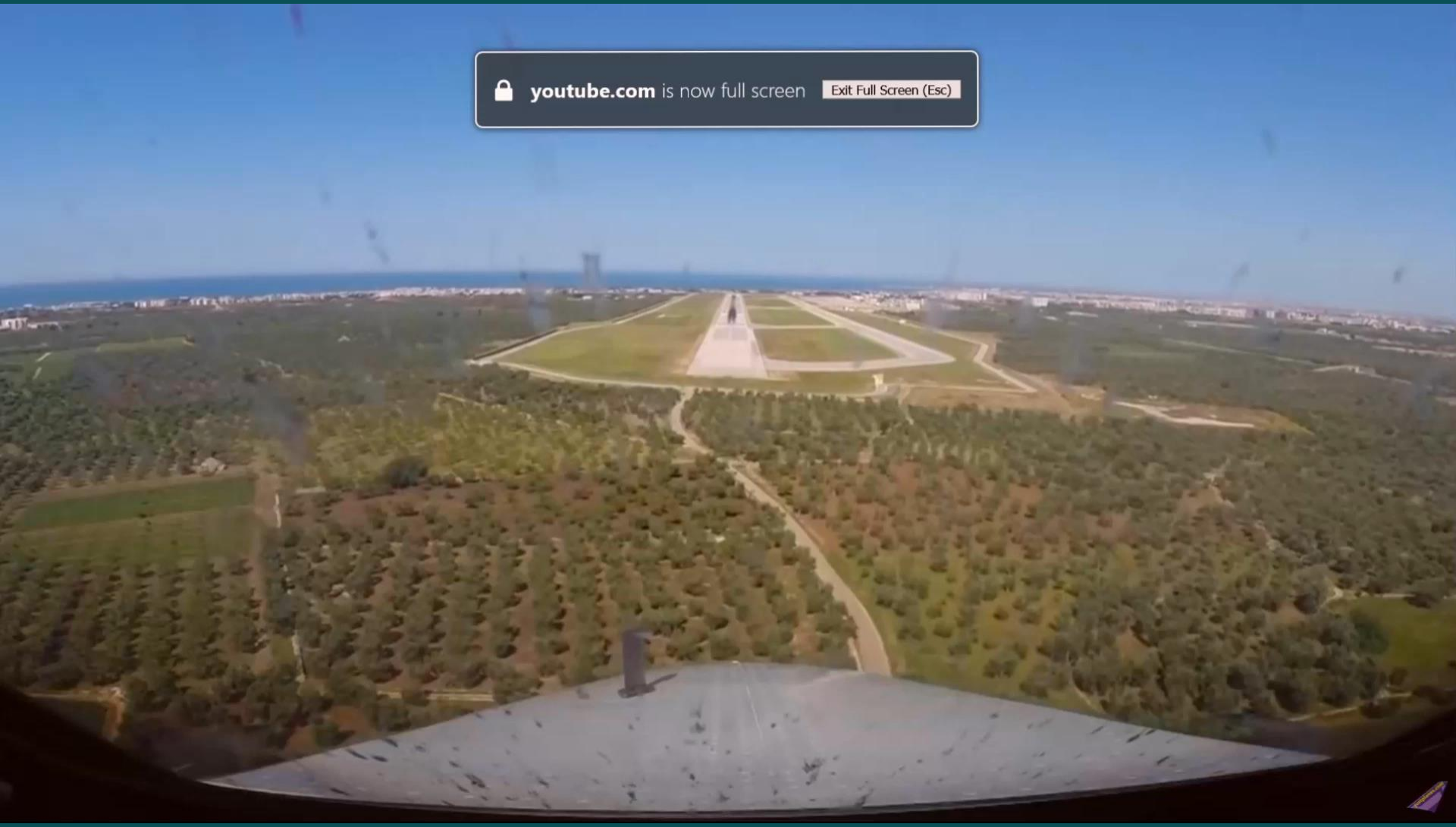
VIDEO – Observe the bird's reaction was ~ 0.5 sec before passing under the plane.

Birds Often Try to React Before a Birdstrike

VIDEO - bird attempted to avoid by reversing direct at the last moment.

Increase Distance (Time) to React Enables Birdstrike Mitigation



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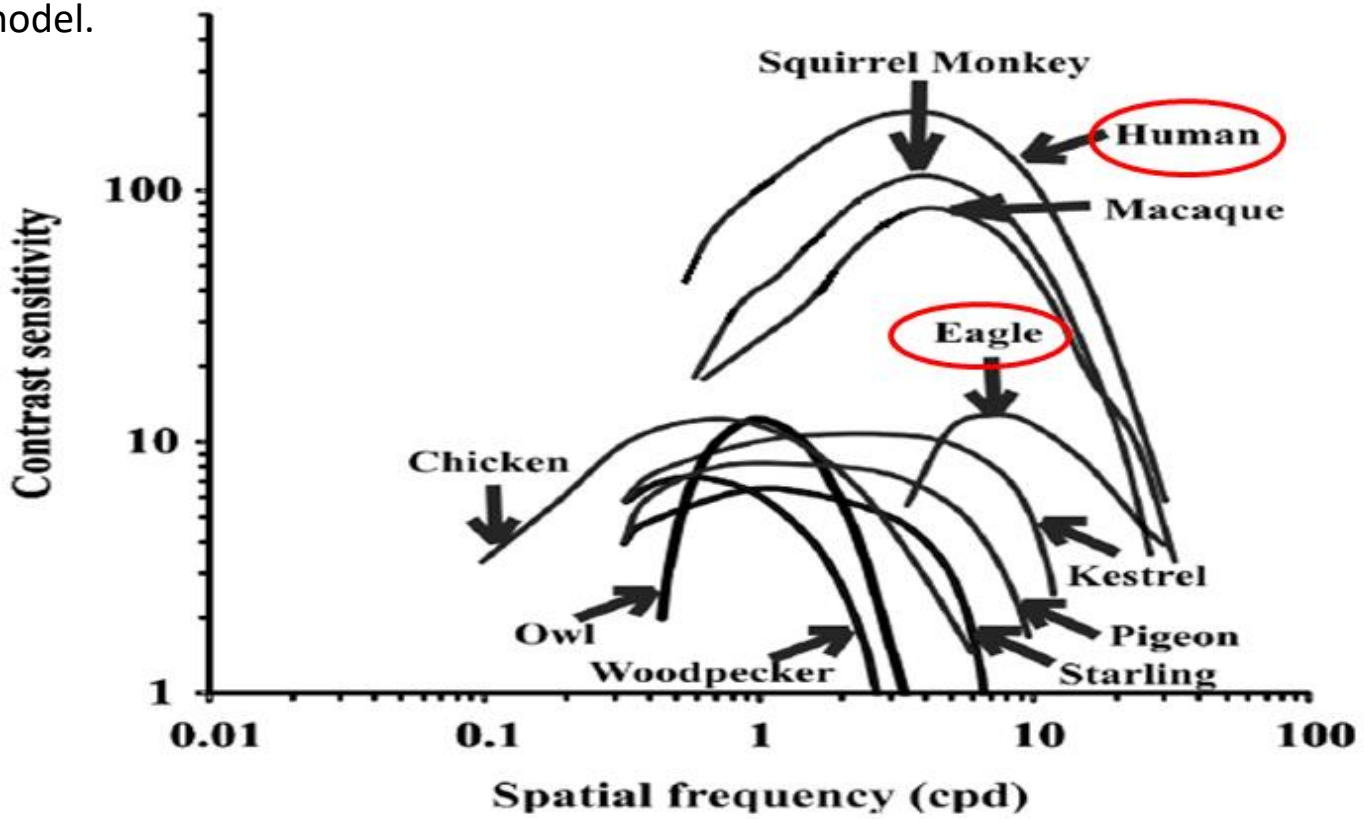
VIDEO – Observe the bird's reversal of flight direction.

Modify Bird Behavior Through Non-lethal Deterrence

Contrast Sensitivity Function vs Chromatic Contrast

Contrast Sensitivity: The ability to detect sharp boundaries (stimuli) and to detect slight changes (temporal and spatial) in luminance at regions without distinct contours.

Chromatic Contrast: Young-Helmholtz theory (1850) of color vision (human RGB Color Balancing) is a simple, static model. Dieter Burkhardt (1989) introduced the avian Tetrachromatic Color Vision (RGB and UV) model.



[1] Givago da Silva Souza, et. al., (2011) Comparative neurophysiology of spatial luminance contrast Sensitivity, Psychology & Neuroscience, 2011, 4, 1, 29 – 48, DOI:10.3922/j.psns.2011.1.005

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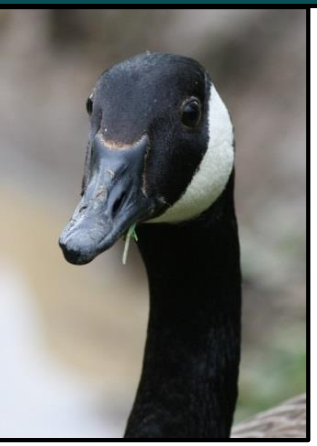
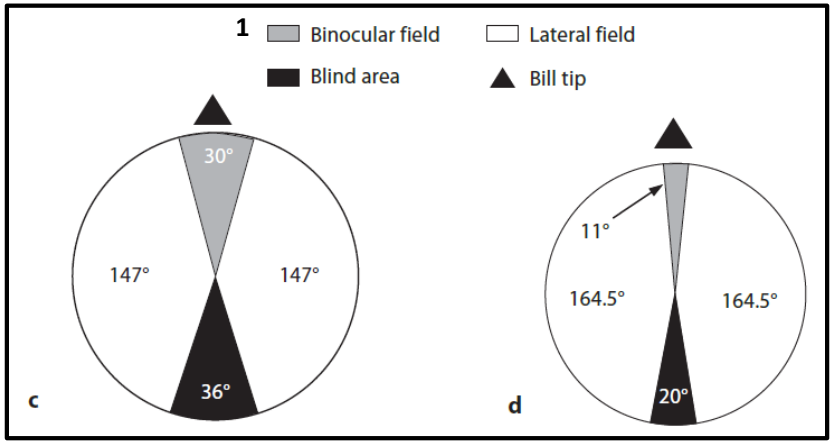
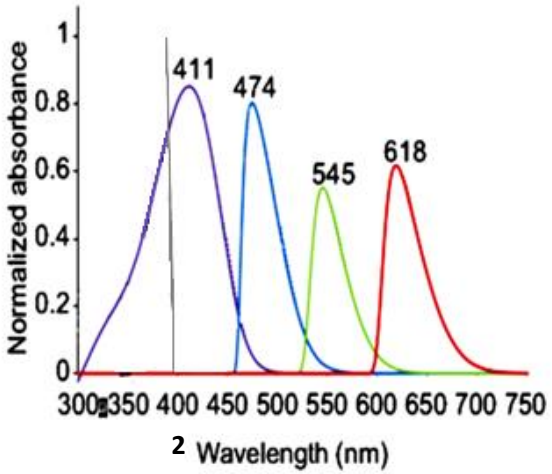
Historical perceptual models are based upon chromatic contrast do not consider complex neural cognition functions involved in motion and object detection.

Canada Goose Visual System







c , **d** Horizontal sections through the horizontal plane (90–270°) showing the visual field configuration when the eyes were fully converged (eyes rotated fully forward; **c**), which maximizes the size of the binocular and blind areas, and fully diverged (eye rotated fully backward; **d**), which minimizes the size of the binocular and blind areas.

Geese are capable of between 324° to 340° horizontal field of view.

- The optics, eye movements, relative photoreceptor proportions, and retinal cell density has been identified for many species.
- Complex mechanism involved in object and movement detection utilize all photoreceptors (including UV light color sensitive cones), retinal horizontal cells, and brain centers.

[1] Esteban Fernández-Juricic, et. al., (2011) Testing the Terrain Hypothesis: Canada Geese See Their World Laterally and Obliquely, Brain Behav Evol 2011;77:147–158 DOI: 10.1159/000326053
[2] B. Moore, , et. al., (2012) Oblique color vision in an open-habitat bird: pectral sensitivity, photoreceptor distribution and behavioral implications,, The Journal of Experimental Biology 215, 3442-3452, doi:10.1242/jeb.073957

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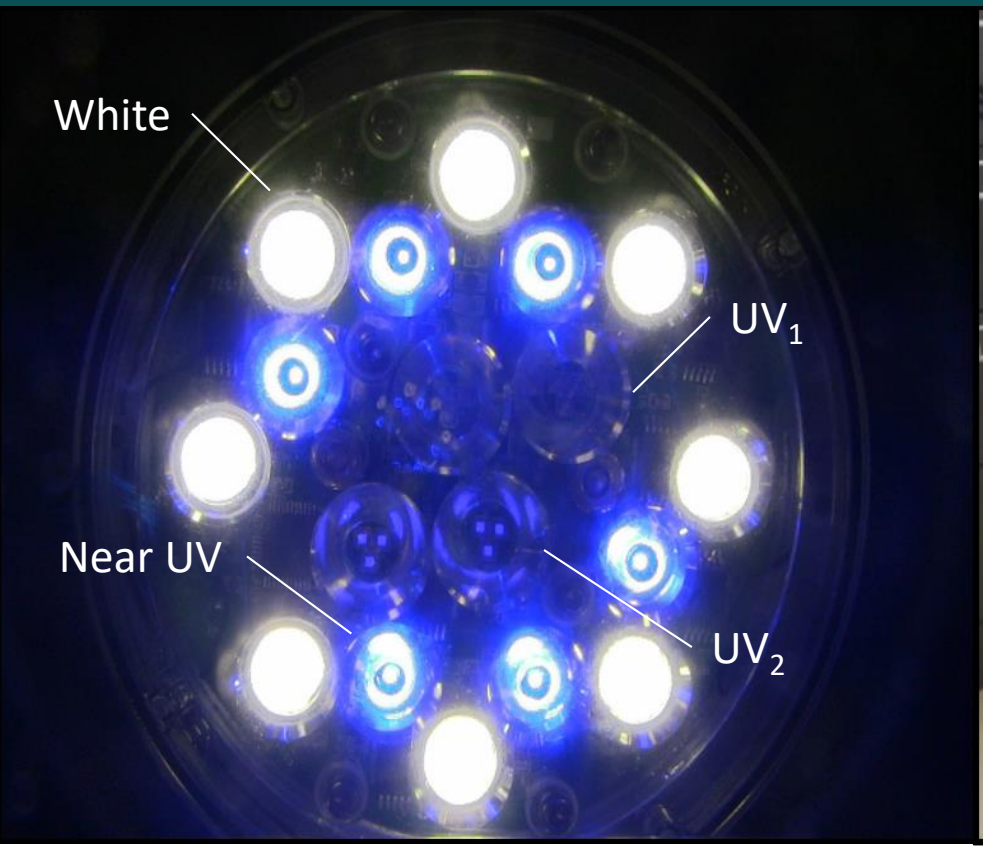
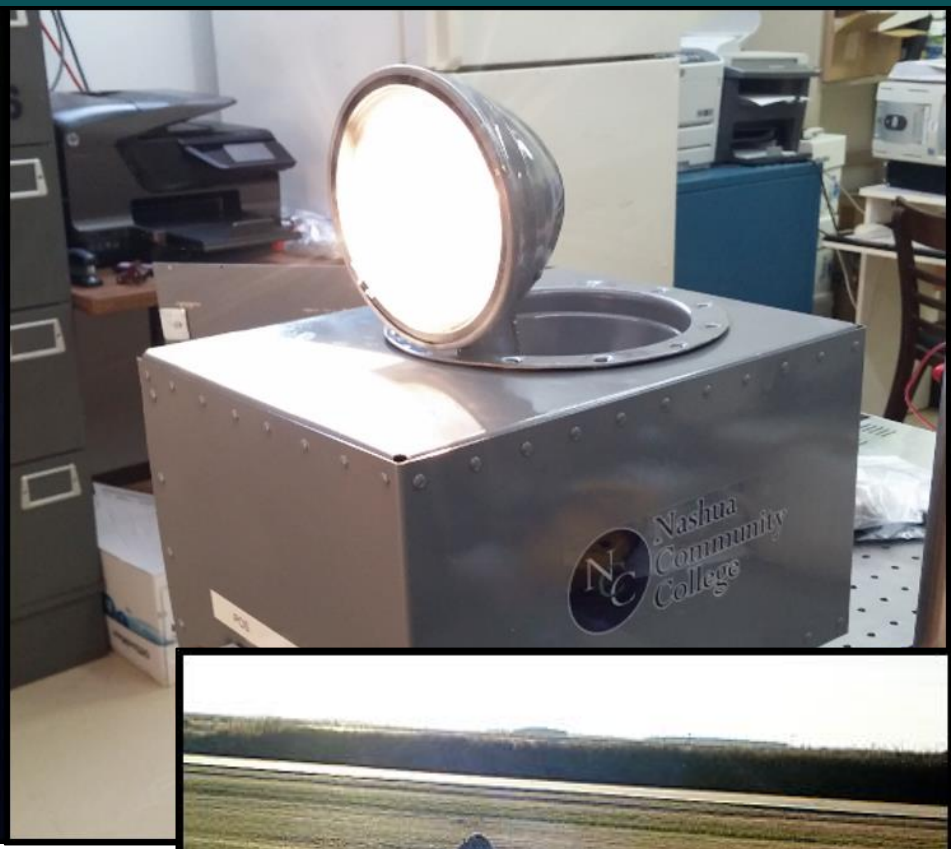
An interdisciplinary relationships is required to completely consider neural and cognitive systems involved in visual perception and recognition.

Equipment Supporting a Test in an Aviation-like Environment





PAR46 w/ UVLEDs was mounted onto a ¼ scale RC plane to measure the reaction of flocks of birds in a 'natural' aviation environment.

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Test Site and Equipment

Birds

Rank[1]	Bird species	Number	% causing damage
1	Turkey vulture	639	50.9
2	Canada goose	1,584	49.3
3	Mallard	867	22.4
4	Osprey	326	21.2
5	Great blue heron	366	20.2
6	Red-tailed hawk	2,243	14.4
7	Herring gull	1,210	9.6
8	Cattle egret	378	8.7
9	Rock pigeon	2,899	8.5
10	Ring-billed gull	1,534	8.0

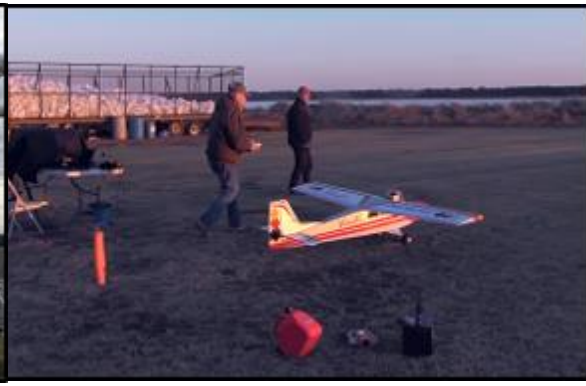
[1]Wildlife Strikes to Civil Aircraft in the United States, 1990–2015, p.63

Radar

DeTect Inc. - Merlin

- S-band frequency
- 200W
- Dopplerized
- 24° AGL detection
  - ground level and above
  - 'cone of silence'
- 1.6 sec (360° sweep)

Plane



Valiant (RC controlled)

- 110" wingspan
- DLE 56RA (gas)
- <96db @ 20'
- 11.5 ft^2 wing area
- ~3.3 lbs/ft^2 wing load
- 25-50 kts (typical)
- ~15min. flight time
- HD camera

Field cameras, audio recordings, and spotters.

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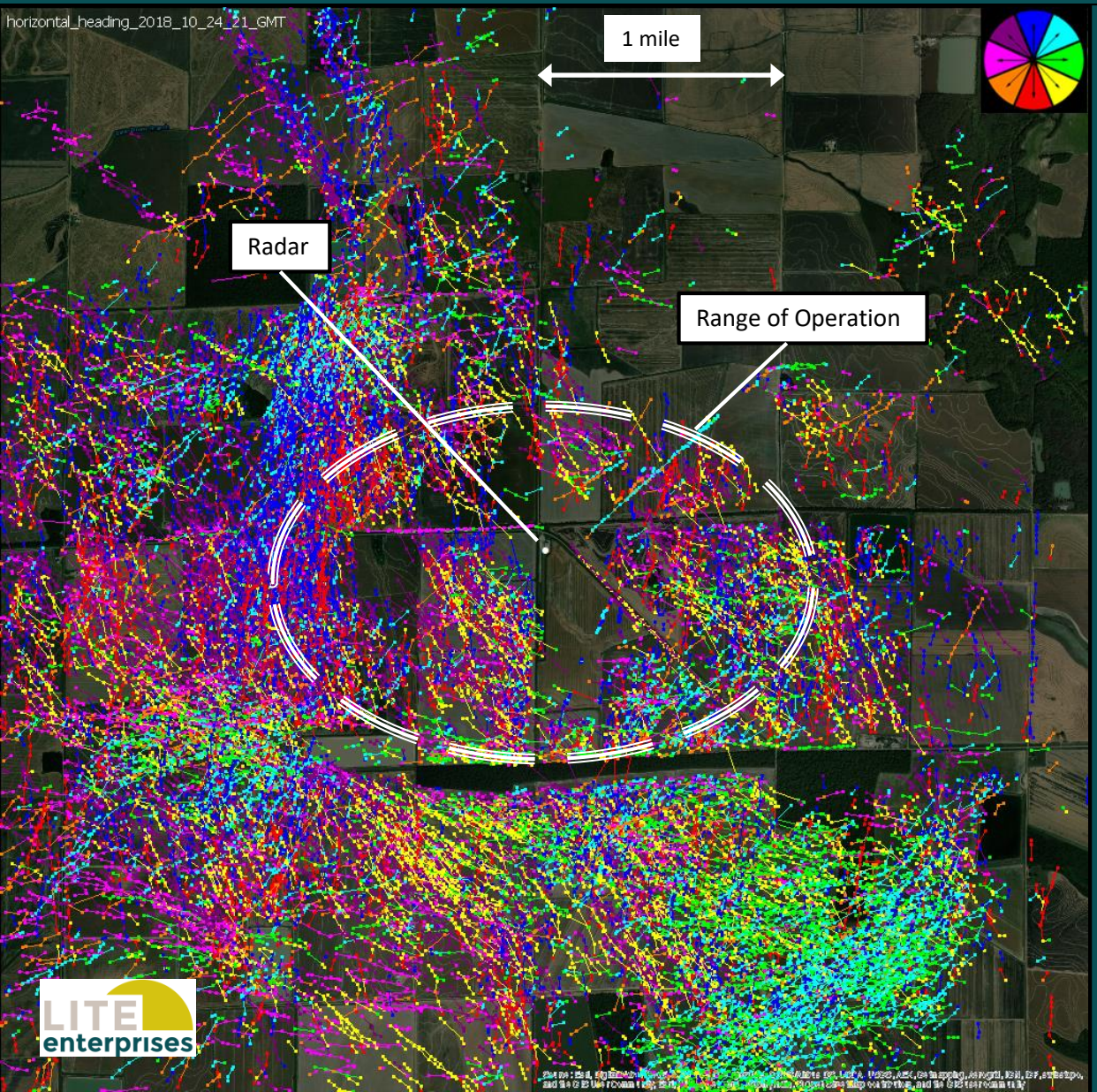
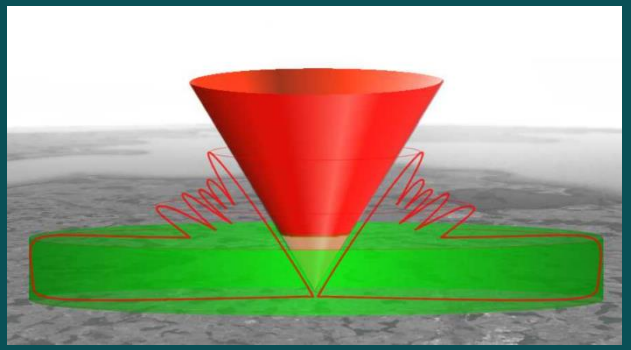
Test Site Challenges
Fisher, AR



- Radar 'Cone of Silence'
- Too many birds (at times)
- Weather (flooding, ice buildup, wind speed)
- Equipment Failure (engines, landing gear, etc.)
- Distance of operations (line of sight, flight control)

Radar Cone of Silence:



The volume of space, usually approximately conical with its vertex at the antenna, that cannot be scanned by an antenna because of limitations of the antenna radiation pattern and mount.

Test Hypothesis: Bird's Mean Reaction Distance when PAR46 w/UVLEDs Powered is ON is equivalent to Powered OFF

Materials and Methods

- PAR46 landing light w/UVLEDs flown on a ¼ scale RC plane
- Flooded rice fields during migration season (Nov 2018)
- RC plane flown in the direction of flocks of high priority birdstrike species
- Measure distance of reaction when PAR46 landing light w/UVLEDs is ON vs OFF

Study Design (ON/OFF)

Weather
- Temp
- Wind speed
- Wind direction
- Precipitation
- Brightness
- Cloud Cover

Birds
- Specie
- Number
- Direction
- Speed
- Altitude

Plane
- Direction
- Speed
- Altitude
- Sun Backlit
- Head-On Course

Reaction
- Distance
- Reaction Energy
- Diversion Direction

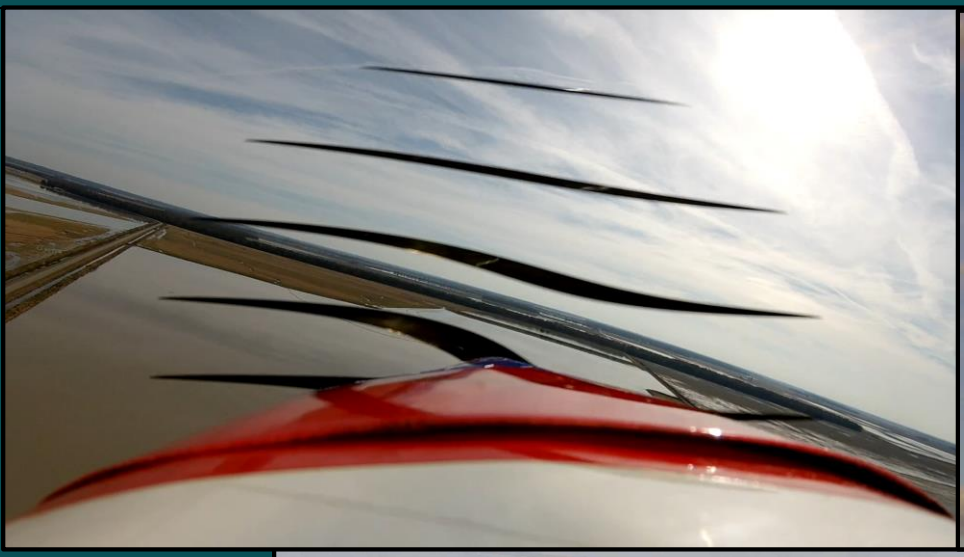
Limitations of the Study

- Number of species
- Type, speed, color, and operating range of plane
- Position of plane (radar 'cone of silence')
- Flock size vs single bird
- Control of Illumination direction PAR46 w/UVLEDs
- Range of weather conditions
- Range of altitudes
- Dependency of 'correct color' of UVLEDs
- Many additional uncontrollable variables…

Species

- Specklebelly geese (*Anser albifrons*)
- Snow geese (*Anser caerulescens)*
- Canada geese (*Branta canadensis*)
- Ross's geese (*Anser rossii*)
- Multiple 'dabbling ducks' species
- Starlings and Blackbirds

Test Site Challenges
Fisher, AR



Large Flock - Par46 with UVLEDs ON

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VIDEO – PAR46 w/UVLEDs illuminates large flock at ~2600’ distance.

Large Flock – Light OFF

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VIDEO – Observe the bird's close distance and mild reaction.

Large Flock – Par46 with UVLEDs ON

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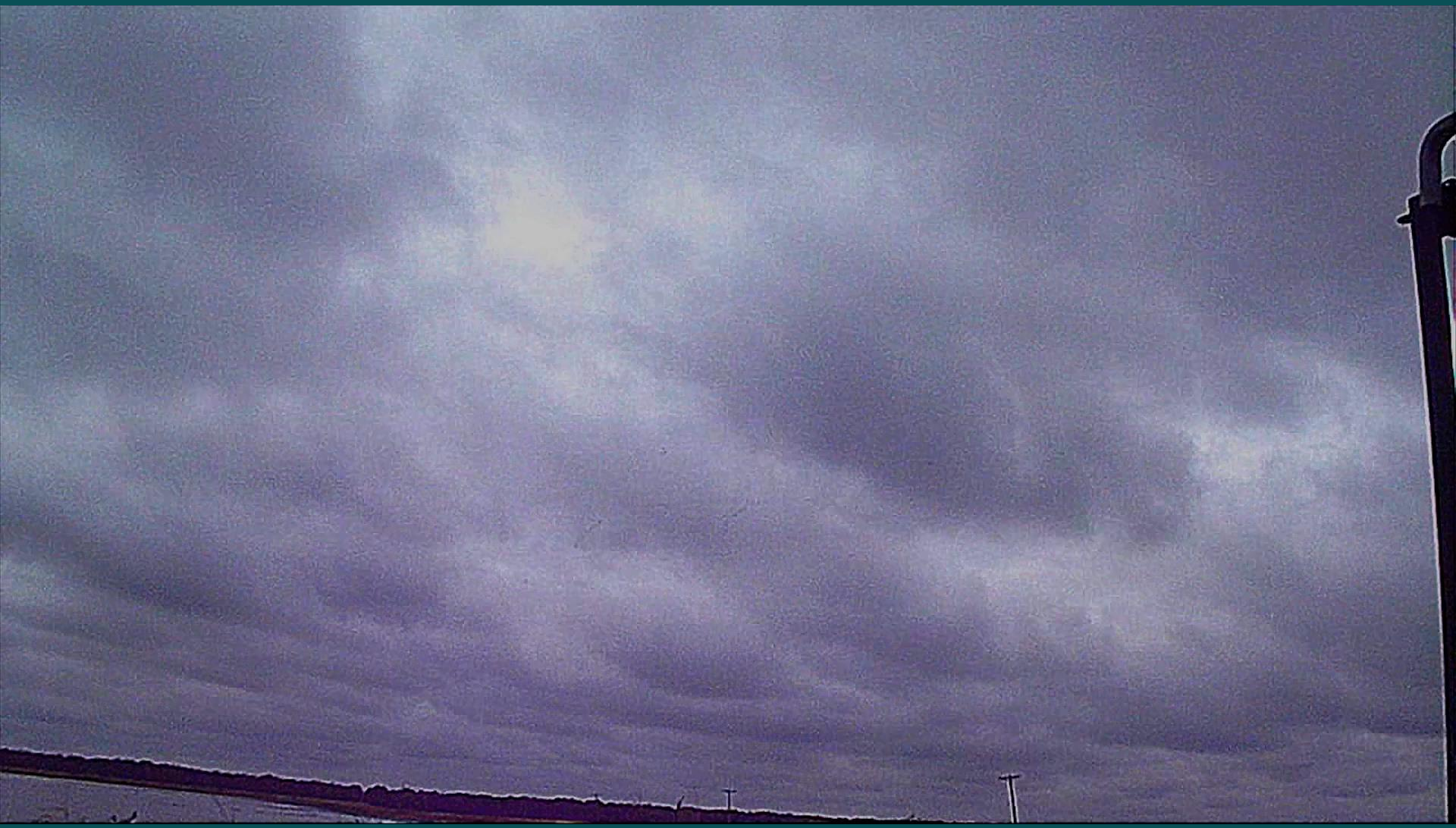
VIDEO – Observe the bird's increased distance and energetic reaction.

Large Flock – Par46 with UVLEDs ON

VIDEO (3X speed)– Observe the bird ‘wave’ reaction as the PAR46 light sweeps the closest edge of the geese flocks.

Camera View of Multiple Events - Par46 with UVLEDs ON



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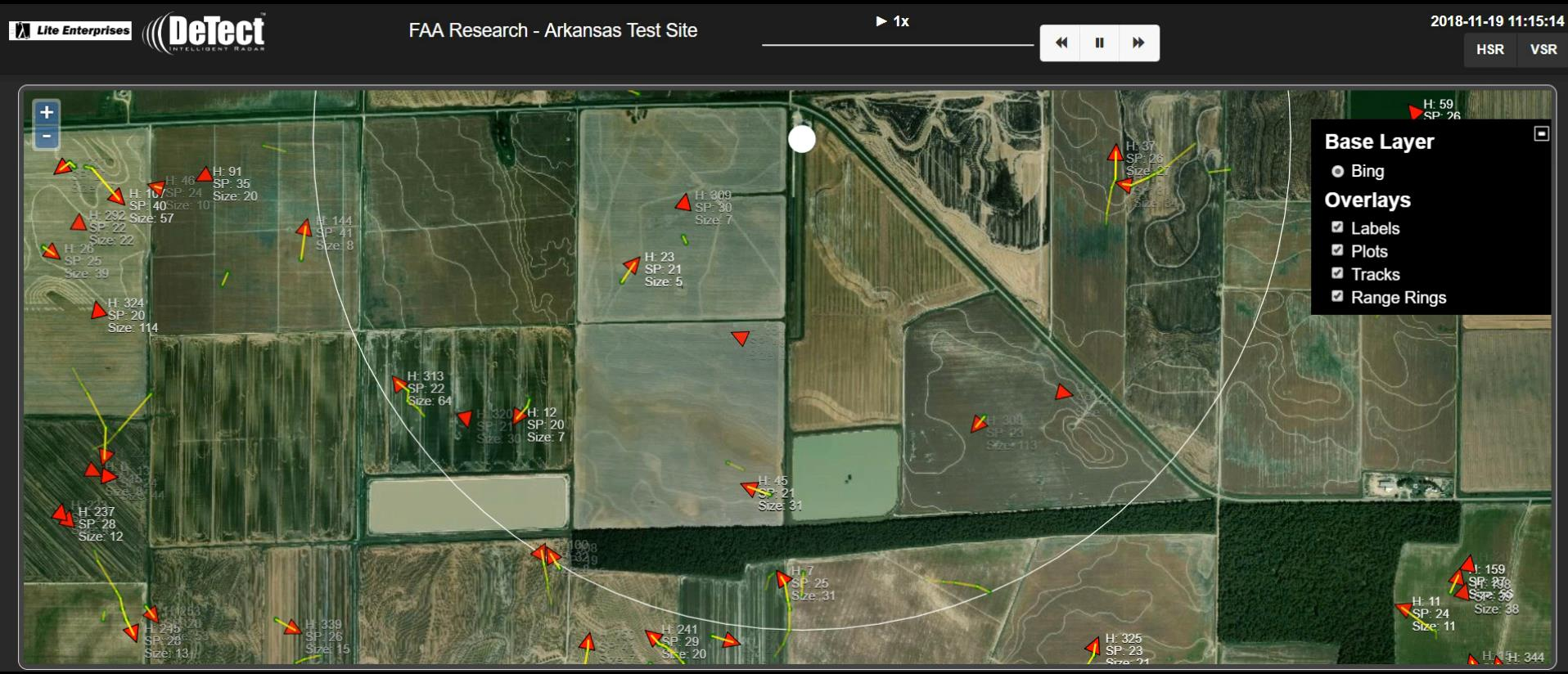
VIDEO (2X speed) – Note ‘localized’ portion of flock reacting to the light.

Radar View of Multiple Events
Flock Distance and Altitude Tracks

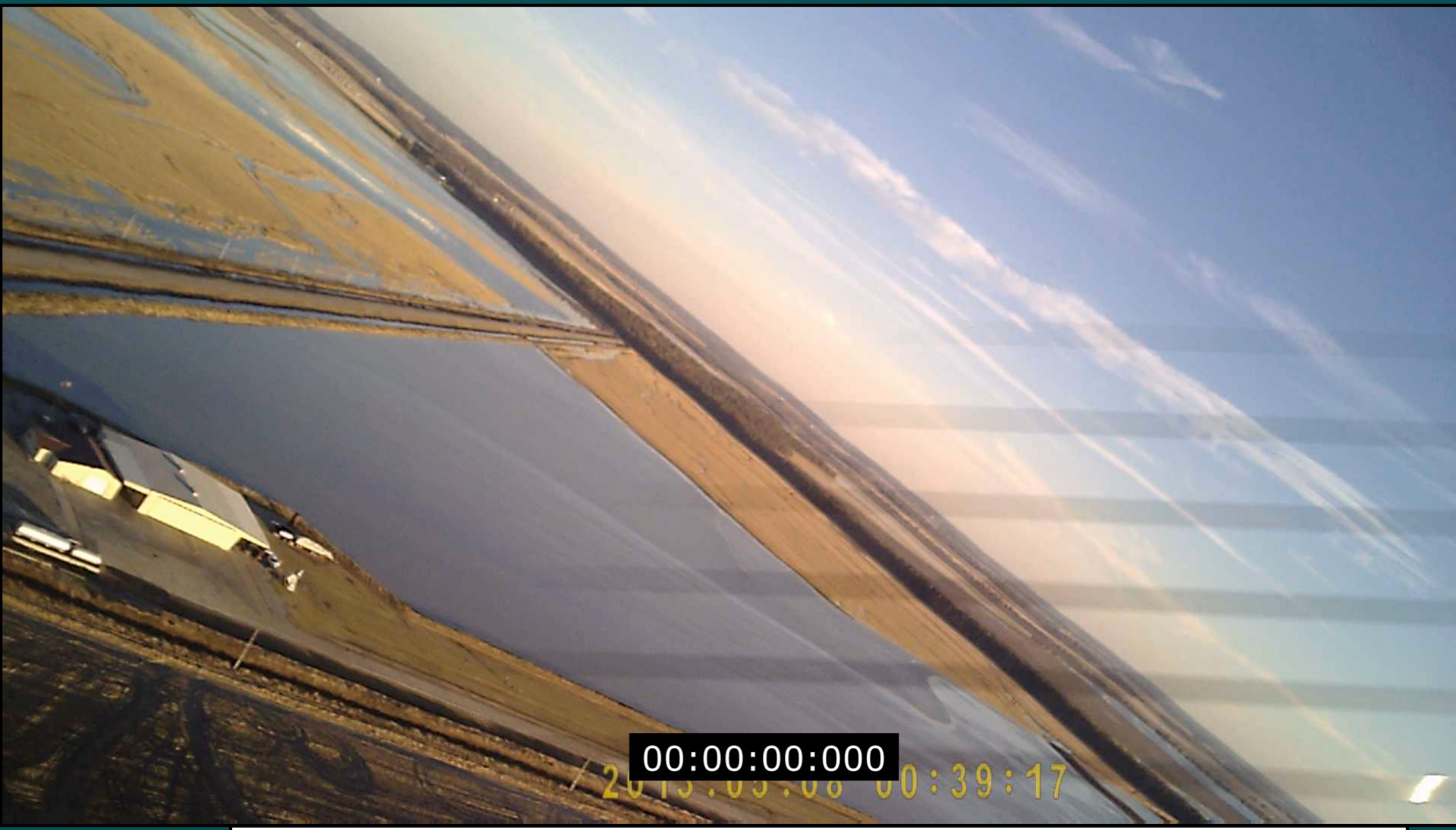


Radar (2x speed): bird's location, altitude, and track after plane and PAR46 w/UVLEDs interaction.

Plane Integrated into Flock with Par46 – OFF

VIDEO – Observe the bird's reaction distance and behavior.
Intensity of bird response at plane-bird interaction: LOW

Plane Head-on to Flock with Par46 - OFF



VIDEO – Observe the bird's reaction distance and behavior.
Intensity of bird response at plane-bird interaction: MODERATE

Plane Head-on into Flock with Par46 - ON

VIDEO – Observe the bird's reaction distance and behavior.
Intensity of bird response at plane-bird interaction: HIGH

Flock of Blackbirds and Starlings with Par46 - ON

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VIDEO – Illuminated murmuration reacts to the PAR46 w/UVLEDs.

Plane Crossing Blackbirds with Par46 - OFF

VIDEO – No reaction to the plane flying an intercept flight path.

Ag Flight Operations - AirTractor 802

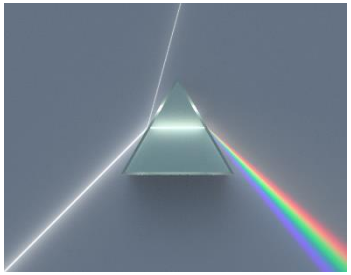
Flight Validation Tests - Ongoing

AirTractor 802
Birdstrike Test Validation
Standard PAR46 - Blinking

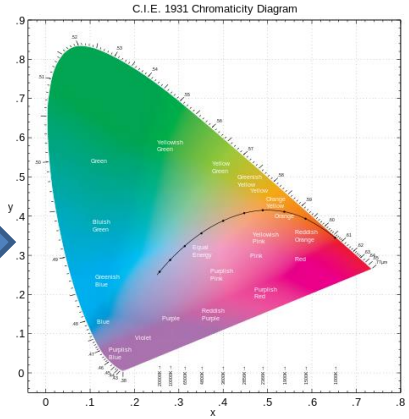
Flight Validation Tests - Ongoing

AirTractor 802
Birdstrike Test Validation
PAR46 with UVLEDs -ON

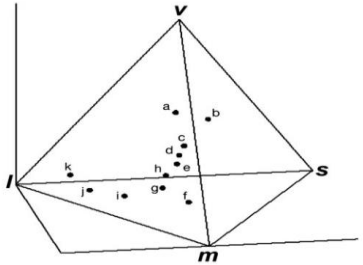
Visual Perception



Isaac Newton (1894)
published ***Opticks***

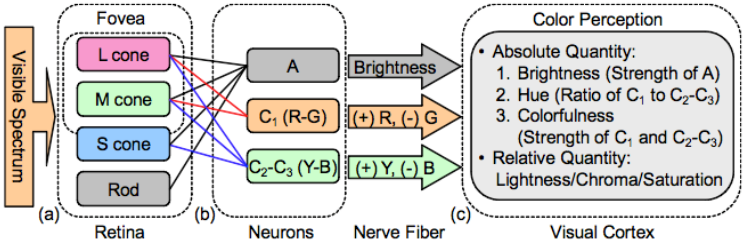


CIE 1931 RGB color space
by William Wright



Endler and **Mielke (2005)**
described a ***tetrahedral avian color vision space*** in which they explicitly attempt to model the sensory experience of the visual signal receiver.

Hermann von Helmholtz (1867)
published ***Handbook of Physiological Optics***



Karl Hering (1892) Processing signals from cones and rod cells in an antagonistic manner. Proposed ***opponent color theory***.

Sensing color light is different than visual perception.

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Cognitive Processing Models

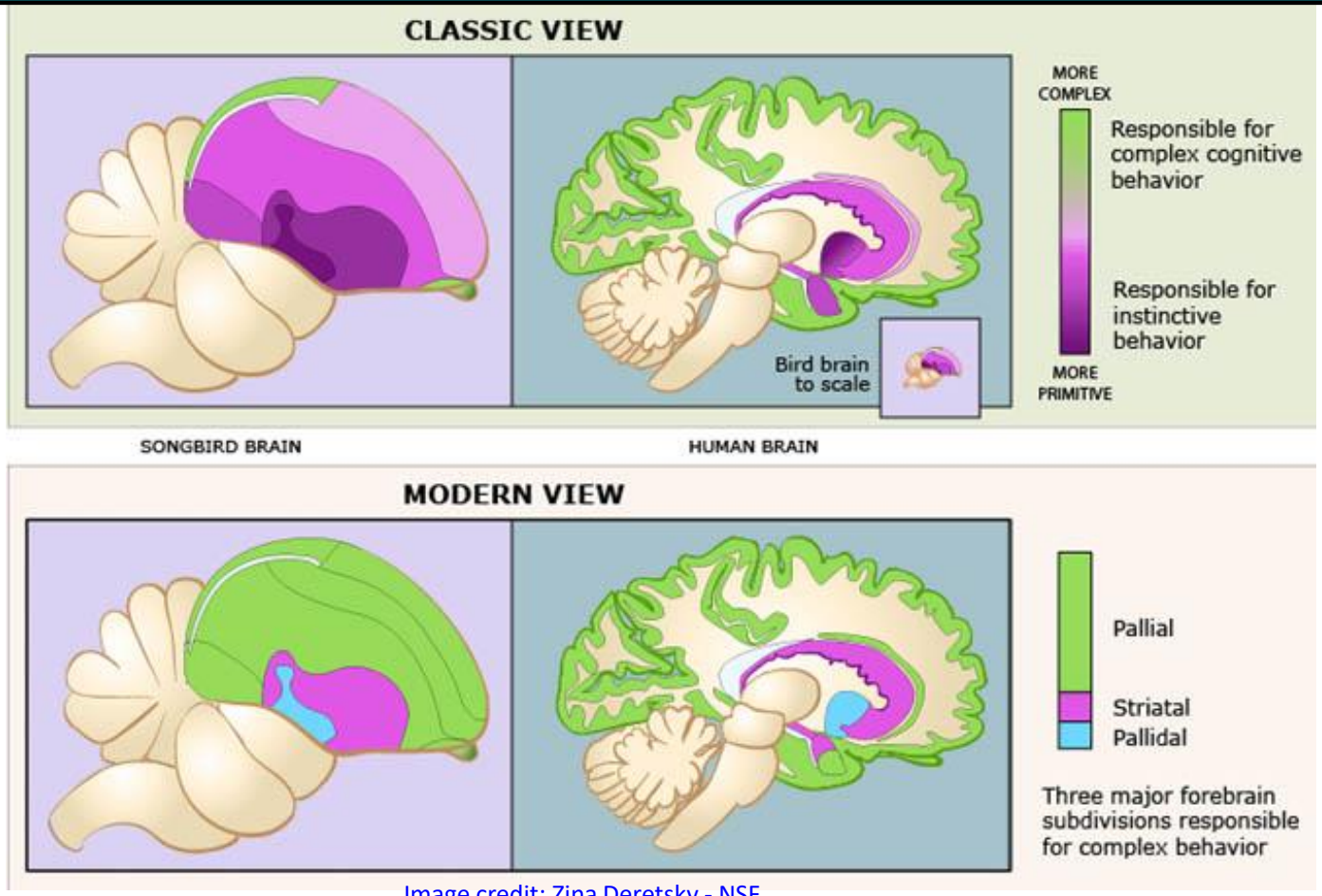

Image credit: Zina Deretsky - NSF

Ludwig Edinger (1885), father of comparative neuroanatomy, presented the classical model.

A consortium of neuroscientists (**Jarvis et al. 2005**) proposed the modern model.

[1] Jarvis, E.D., O. Güntürkün, L. Bruce, A. Csillag, H. Karten, W. Kuenzel, L. Medina, G. Paxinos, D. J. Perkel, T. Shimizu, G. Striedter, M. Wild, G. F. Ball, J. Dugas-Ford, S. Durand, G. Hough, S. Husband, L. Kubikova, D. Lee, C.V. Mello, A. Powers, C. Siang, T.V. Smulders, K. Wada, S.A. White, K. Yamamoto, J. Yu, A. Reiner, and A. B. Butler. 2005. Avian brains and a new understanding of vertebrate brain evolution. Nature Reviews Neuroscience 6:151-159.

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A vast amount of neuroscience research has documented many mechanisms underlying neural and cognitive systems of both birds and mammals.

Science is not about consensus, and consensus is not science.

— Burt Rutan —

Conclusions and Observations

Results/Conclusions:

- Mean distance ON ≠ Mean distance OFF (alpha = 0.01)
- Neurophysiological Patterned Model (3 variables) predicts Bird Reaction Distance (R^2=0.99)

Observations:

- Behavioral responses varies between species (geese, ducks, blackbirds and starlings).
- Bird's Intensity of Response (greater for ON vs OFF condition)
  - Occurs more frequently
  - Occurs at greater distances

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Perspective of Birdstrike "Protected" Departure Airspace

The overlapping illumination pattern is optimized to illuminate the departure airspace and the runway with "invisible light".

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High Brightness UVLEDs - Research History

High Brightness Ultraviolet LEDs (new technology): Inducing behavioral responses equivalent to solar glint/glare.

- **NSF Award 1350562 (grant):**
  - The development of the first-of-a-kind lighting systems utilizing high brightness UV LED of various wavelengths was manufactured and tested against various species to act as a new class of wildlife deterrence. Multiple field studies led to the validation of the effectiveness (i.e. alter behavioral responses) across a range species. The observed deterrence effectiveness of the bright light UVLED lights from these tests are well aligned with the published literature describing the UV and UVS cone genetic material of various species and the neurophysiological characteristics of visual system of birds. A multi-year field study supported by the Audubon Society involved wild birds in their natural environment successfully proved that this approach is effective. The Condor, 119(3):431-439 (2017). https://doi.org/10.1650/CONDOR-16-230.1
  - 1350562 CC (now closed): Teamed with a community college resulted in the development of the initial prototype design of an aircraft landing light which incorporates the wildlife deterrence capabilities. The start of the effort to qualify the prototype design as an FAA STC design was initiated.
  - 1350562 TECP: Several material problems were addressed in the development of the design of the aircraft landing light. Production molds for cast aluminum and polycarbonate parts were fabricated. A product redesign effort was initiated which enabled enhanced waste heat management techniques enabling an increased light output. A long term burn-in study identified a material stability problem which is currently being addressed. Once these parts are qualified, they will be fabricated as production parts to be used in the FAA STC qualification tests.
  - 1350562 IIA: Teaming with a university is underway to develop a 3D printing technique suitable for fabricating a new class of aviation lighting system that could be incorporated on the aircraft surfaces or wind screen to deter birds from critical areas of the aircraft without interfering with air flow or adding significant weight. The material requirements are also addressing the UV transparency and durability problems.

- **FAA Contract# DTFACT-17-C-00006 (research contract):**
  - Research Bird Strike mitigation utilizing a PAR46 landing light w/ UVLEDs in an aviation-like environment.

- **Special thanks to DeTect Inc. for providing the bird detection radar system used in this study and assistance in interpretation of the data.**

- **FAA Technical Center PIs Paul Swindell and Traci Stadtmueller for their efforts on this contract. Dr. Nancy Dirubbo for valuable advice on the experimental design. Whirlwind Aviation (FAA Identifier 48AR) for the use of the airfield, hangar space, and other facilities. We also thank the following people who worked tirelessly to provide the operational support required to execute this test: Dr. Nancy Dirubbo, Donald Ducharme, Elizabeth Keefe, David Newberry, Chrissy and Rodney Shelley.**

Field study results presented herein were conducted by Lite Enterprises personnel in the performance of FAA Contract# DTFACT-17-C-00006.

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Q & A

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