(3) 'Turn that light off please': Update on the use of a non-lethal wildlife deterrence device

Donald Ronning[1], Stephen Pelletier[2], Carol R. Foss[3] and Troy Scott[4]
[1]Lite Enterprises, Nashua, New Hampshire USA
[2]Stantec Consulting, Topsham, Maine USA
[3]New Hampshire Audubon Society, Concord, New Hampshire USA
[4]C3I, Inc., Hampton, New Hampshire USA

We tested the hypothesis that high brightness mono-color LEDs can disrupt avian ocular-neuromotor responses and defeat the normal ability to process sensory information, leading to changes in behavior. Field tests with Osprey (*Pandion haliaetus*), Red-tailed Hawk (*Buteo jamaicensis*), and Common Eider (*Somateria mollissima*) during 2014 were statistically significant, validating the hypothesis. The Osprey test involved deploying multiple high brightness LEDs to illuminate flight paths to an uncovered trout rearing pond at a fish hatchery. Activated lights significantly reduced foraging success (x2=8.062, df=1, p=0.005). The Red-tailed Hawk test for the involved deploying multiple high brightness LEDs to illuminate flight path to lure birds at a raptor banding station. Observers documented successful and aborted capture attempts at the treatment site and a control site banding station with no lights. Proportions of aborts and captures differed significantly between the control and treatment sites (x2=23.412, df=1, p<0.001) with aborts being proportionally higher and captures lower at the treatment site. The Common Eider test involved submerging baskets of seed mussels along two sides of a mussel aquaculture raft with multiple high-brightness LEDs and one side of a control raft with no lights. Predation losses were significantly lower in the baskets on the treatment raft (x2=1,210.536, df=2, p<0.001). The behavioral responses observed in our tests suggest that the lights are overloading or 'jamming' the sensory network. This involves an avoidance mechanism that is more complex than visual awareness due to chromatic contrast. We report on our recent research results for high interest species to the air transportation and aviation community; geese, ducks, shore birds, and hawks. We also discuss strategies of integrating the non-lethal wildlife deterrence technology into an airport's wildlife hazard management plan including: (1) regulations, (2) licensing/permitting requirements, (3) types of devices, (4) effective use on different wildlife species, (5) safety, and (6) training.

Ronning, D., S. Pelletier, C.R. Foss and T. Scott. 2015. 'Turn that light off please': Update on the use of a non-lethal wildlife deterrence device. Proceedings of the North American Birdstrike Conference 15. 38 pages.

Non-Lethal Birdstrike Mitigation

'Turn That Light Off Please'

Presented by
Donald Ronning

Bird Strike Canada / Bird Strike Committee USA
Montreal, Canada
15 September 2015

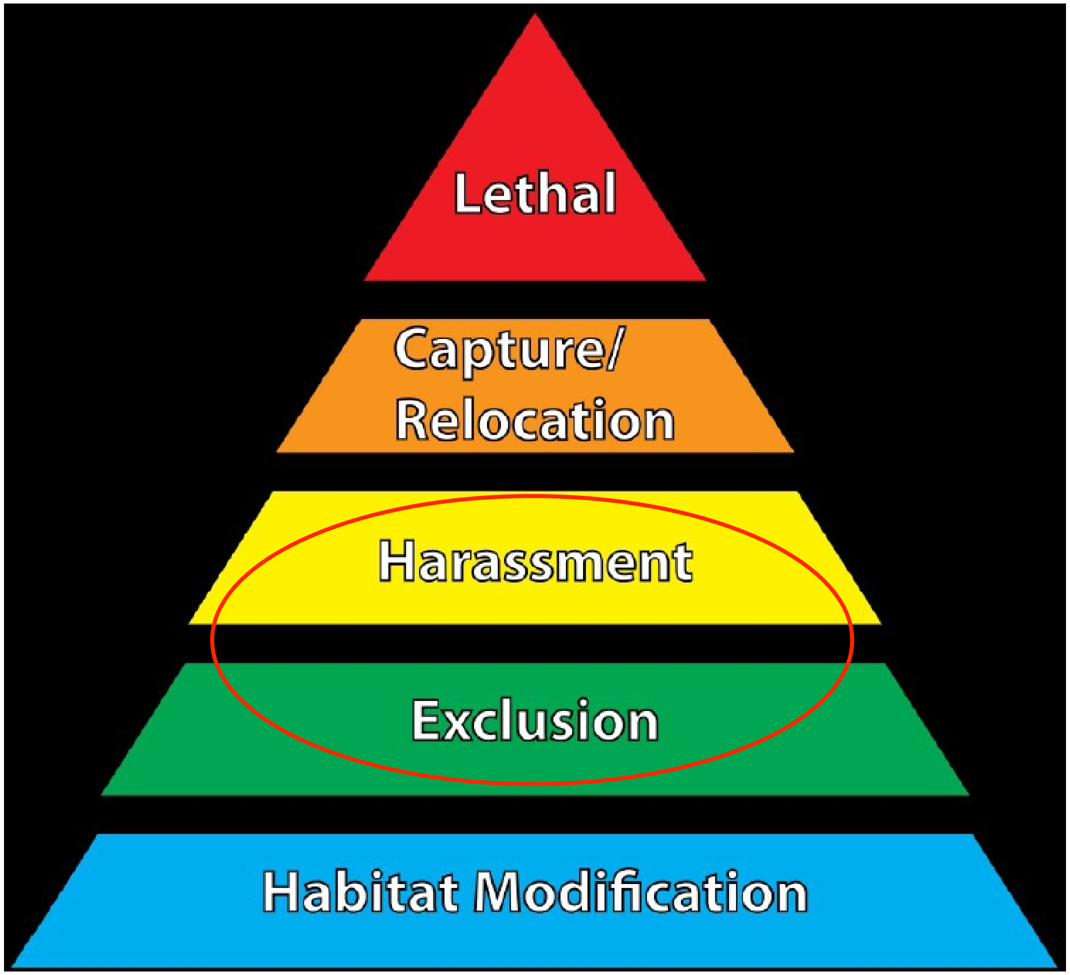
LITE enterprises

Why Consider a Non-Lethal Birdstrike Mitigation System

1. What <u>problem</u> are we solving?
2. How do we <u>approach</u> the problem?
3. How <u>effective</u> is it?
4. Considerations for <u>implementation</u>
   a) Regulations
   b) Licensing/permitting requirements
   c) Types of devices
   d) Different wildlife species
   e) Safety
   f) Training

LITE enterprises

Wildlife Management Hierarchy



LITE enterprises

A novel technique of inducing behavioral changes using high brightness mono-colored LEDs.

Wildlife Collisions with Aircraft, Other Vehicles, and Structures

"Current approaches to reducing wildlife strikes with aircraft primarily fall under one or more of four categories: 1) habitat/food resource management, 2) wildlife dispersal, removal, and exclusion, 3) detection/ prediction of wildlife movements and behavior so that aircraft can avoid high-risk activities, both temporally and spatially, and 4) the integration of sensory ecology, physiology, and anti-predator behavior to understand animal reactions to vehicles, with the goal of developing onboard systems (e.g., lights, paint schemes, sounds) that elicit earlier alert and escape behaviors in response to vehicles."

Project Leader: Dr. Travis L. DeVault
USDA/APHIS/WS/NWRC
Ohio Field Station
Sandusky, OH 44870

LITE enterprises

WS biologists (Dr. DeVault) estimated that technical or direct management assistance resulted in a reduction, suppression, or prevention of hazards from targeted wildlife species at 568 of the 772 airports assisted in 2012.

FAA CFR 139.337a (U.S.)

FAA Regulations, Advisories and CertAlerts

Advisory Circulars – Advisory Guidance to Comply with Regulations

AC 150/5200-32A REPORTING WILDLIFE AIRCRAFT STRIKES 12/22/04

AC 150/5200-34A CONSTRUCTION OR ESTABLISHMENT OF LANDFILLS NEAR PUBLIC AIRPORTS January 26, 2006

AC 150/5200-33B HAZARDOUS WILDLIFE ATTRACTANTS ON OR NEAR AIRPORTS 8/28/2007

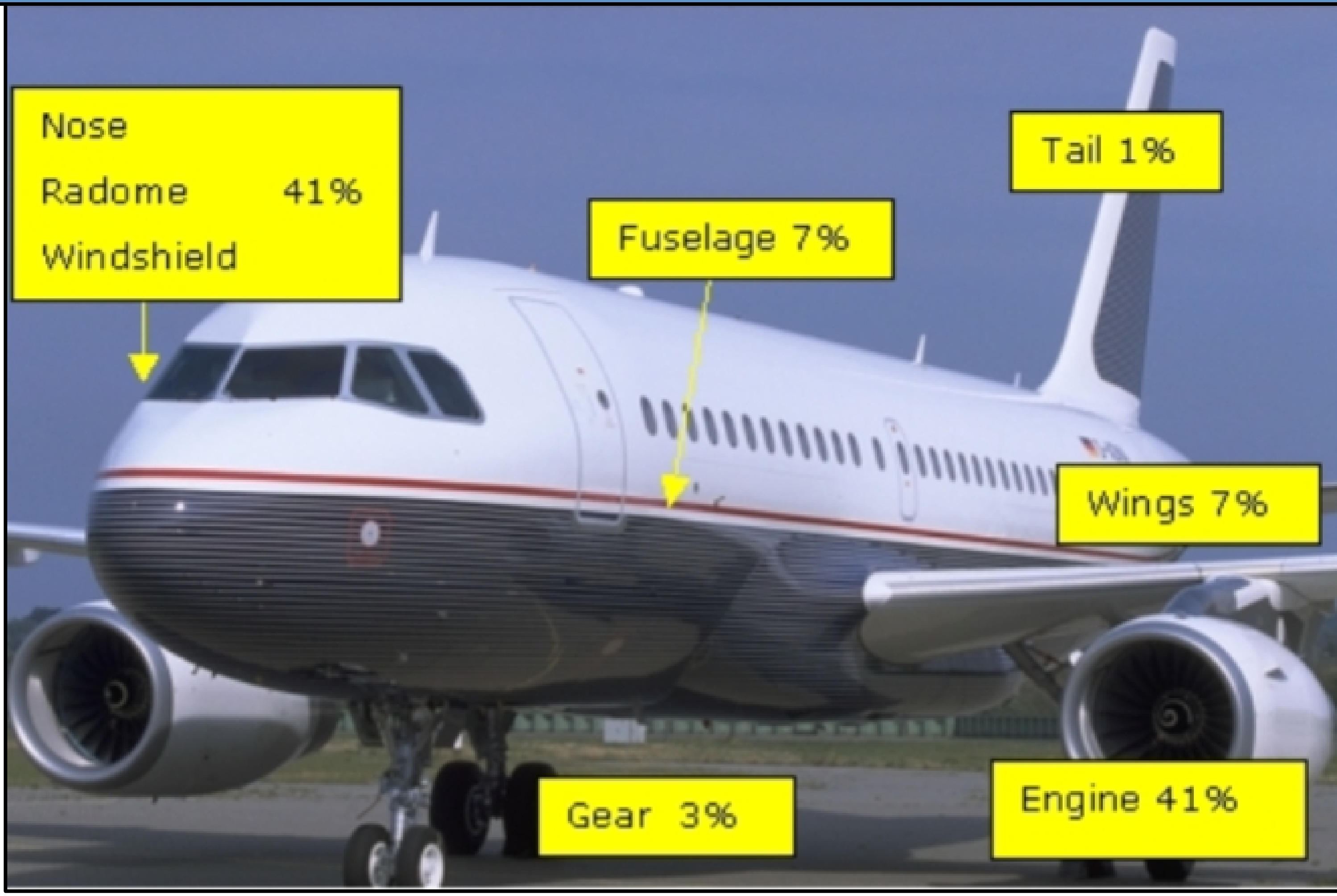
AC 150/5200-36A Qualifications for Wildlife Biologist Conducting Wildlife Hazard Assessments and Training Curriculums for Airport Personnel Involved in Controlling Wildlife Hazards on Airports 1/31/12

AC No: 150/5200-?? PROTOCOL FOR THE CONDUCT AND REVIEW OF WHAs, WHMPs, WHSVs and CONTINUAL MONITORING 2012

LITE enterprises

USDA-APHIS-WS recommended actions are codified by the FAA.

Aircraft Damage by Wildlife Strike



Source: Airbus

Airbus reports ~50% of the engine strikes result in damage.
Therefore, >20% of bird strikes result in damage to the aircraft.

LITE enterprises

Altitude - Bird Strike (U.S.)

Wildlife Strikes to Civil Aircraft in the United States, 1990–2013

Table 11. Number of reported bird strikes to general aviation aircraft[1] by height above ground level (AGL), USA, 1990–2013. See Figure 7 for graphic analysis of strike data from 501 to 12,500 feet AGL[2].

	All reported strikes			Strikes with damage		
Height of strike (feet AGL)	24-year total	% of total known	% cumulative total	24-year total	% of total known	% cumulative total
0	4,785	37	37	588	17	17
1-500	4,786	37	74	1,170	34	51
501-1500	1,892	15	88	880	26	77
1501-2500	768	6	94	388	11	88
2501-3500	346	3	97	183	5	94
3501-4500	180	1	98	90	3	96
4501-5500	89	<1	99	43	1	97
5501-6500	53	<1	>99	26	<1	98
6501-7500	45	<1	>99	18	<1	99
7501-8500	20	<1	>99	10	<1	99
8501-9500	15	<1	>99	9	<1	>99
9501-10500	14	<1	>99	9	<1	>99
10,501-11500	4	<1	>99	2	<1	>99
>11500[3]	20	<1	100	14	<1	100
Total known	**13,017**	**100**		**3,430**	**100**	

A different approach is required for near airport versus high altitude bird strike mitigation.

LITE enterprises

Commercial Aircraft Statistics and Costs

U.S.

- **69.6 million movements (Part 139 and GA)**
- **24.5 million movements (only Part 139)**
- **Damage Cost Reported**
  - **~85% commercial aircraft**
  - **$759 million direct damage to aircraft due to strike ~ $26.33/movement commercial aircraft damage ($759m$_{(2012)}$ x 85%) ÷ 24.5m commercial movements)**
- **5,220 Total strikes reported at 386 Part 139 airports**
  - **2.1 strikes/10,000 aircraft movement**

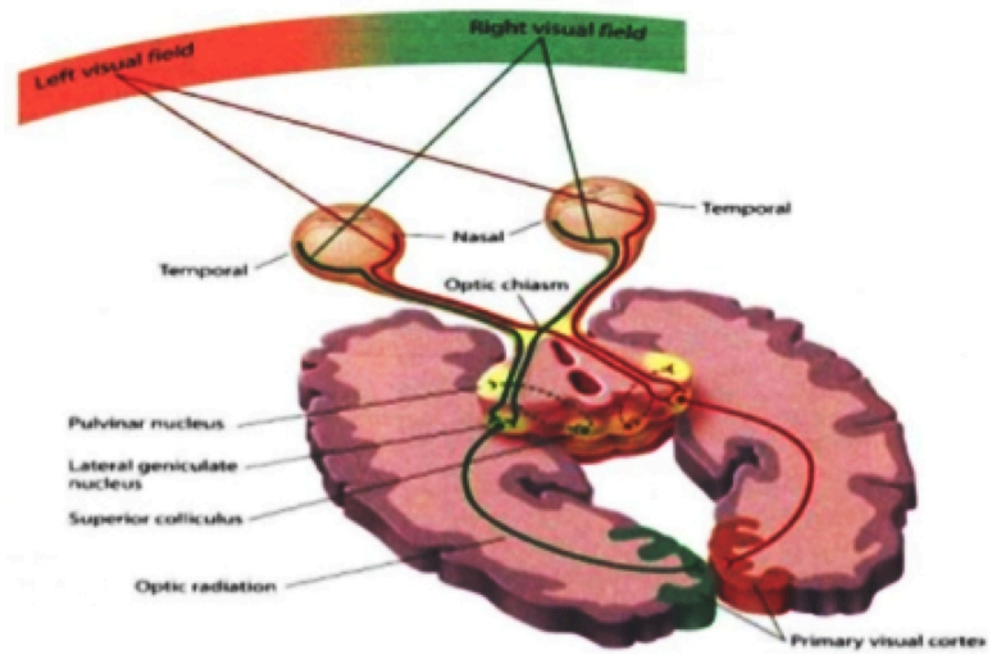
Wildlife Strikes to Civil Aircraft 1990 – 2013

LITE enterprises

An airport with 10,000 aircraft movements (typically 2 runways) has an average economic cost of $553,000/year due to wildlife strikes.

Seeking a Reliable Behavioral Response

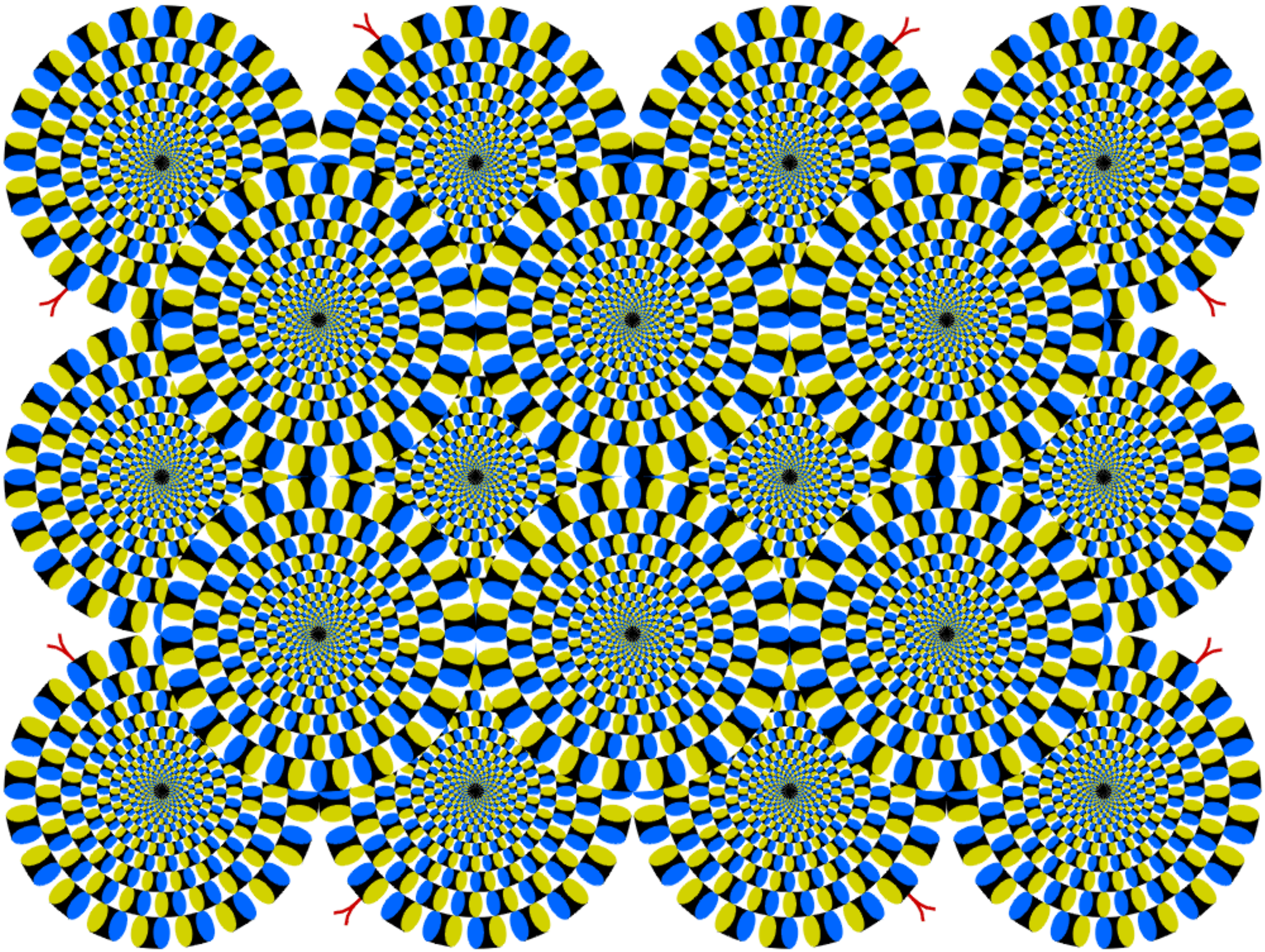
Reference Point for Visual Oculo-Neuro-Physical Mechanisms



- **Incidence of light**
- **Transduction (initiation of vision)**
- **Transmission of visual sensation**
- **Visual perceptions**
- **Behavioral response**

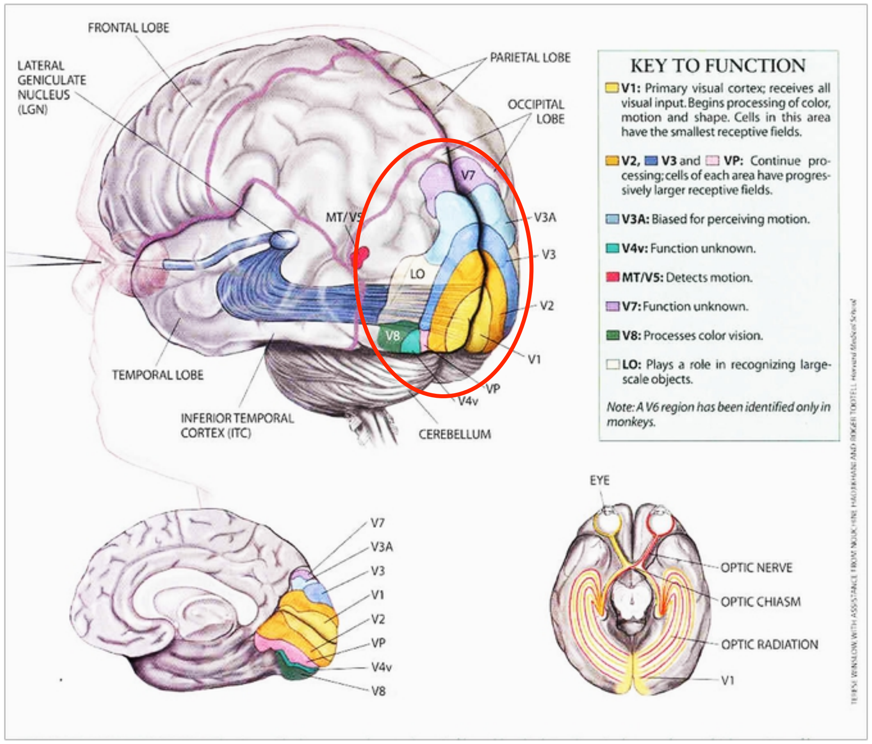
LITE enterprises

Your Neurophysiology At Work
Akiyoshi's illusion - Rotating Snakes



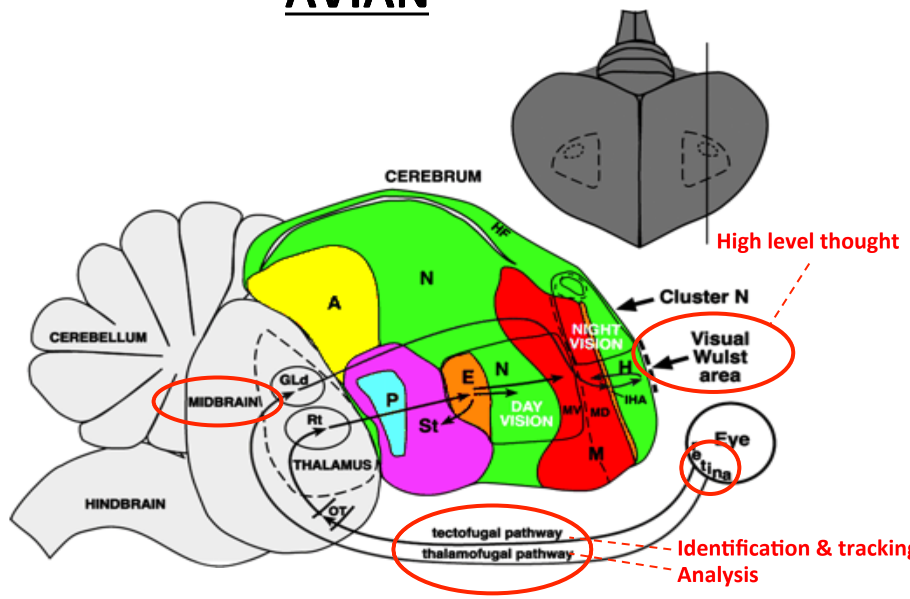
Neurophysiology Enables Behavioral Response

HUMAN



- Human visual and brain functions are complex but also are a good reference point to gaining insight to other species

AVIAN



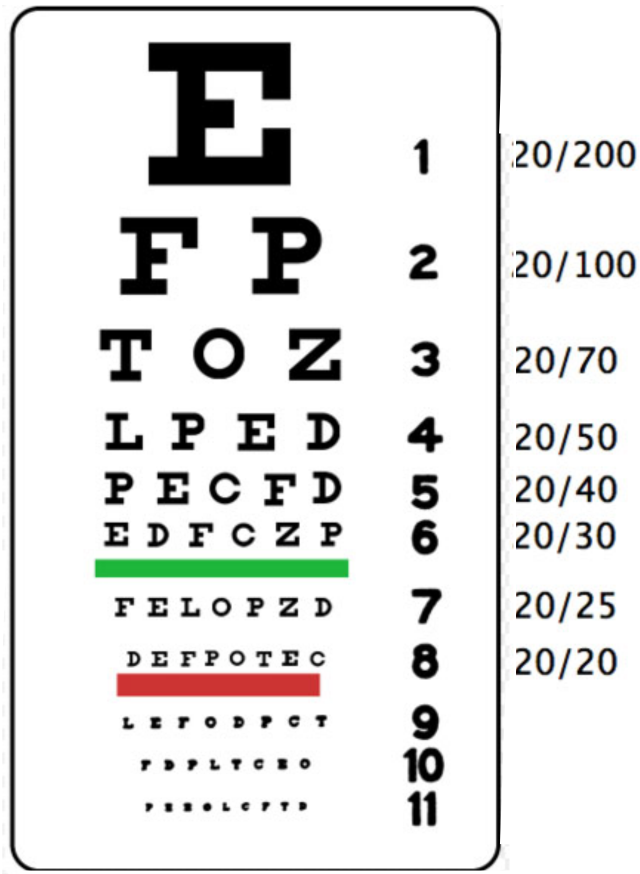
- The optic lobe (midbrain) and cerebellum (coordinates skeletal muscle activity) is relatively large in birds compared to other vertebrates
- The size and close proximity of optic lobe and cerebellum reflect the importance of vision and muscle control needed for precise coordination of muscle activity during flight

Behavioral and neurophysiological responses involve visual sensory inputs as well as brain functions. Unlike humans, avian optic nerves are <u>larger</u> than the spinal cord.

LITE enterprises

Humans Eye Charts

Snellen Acuity Chart



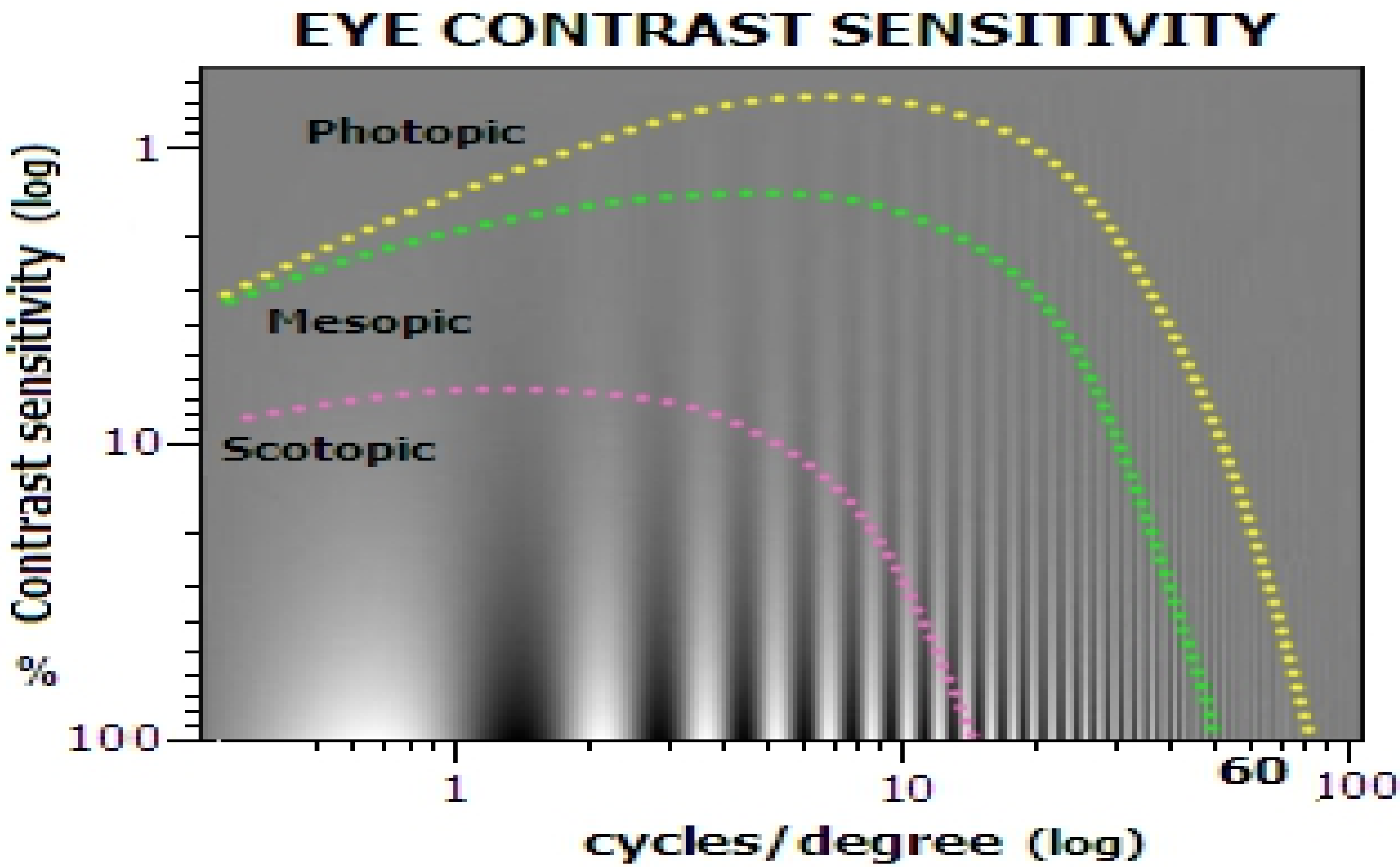
≠

Pelli Robson Contrast Chart

The range of contrast sensitivity is different for avian species than humans.

LITE enterprises

Human Contrast Sensitivity Function



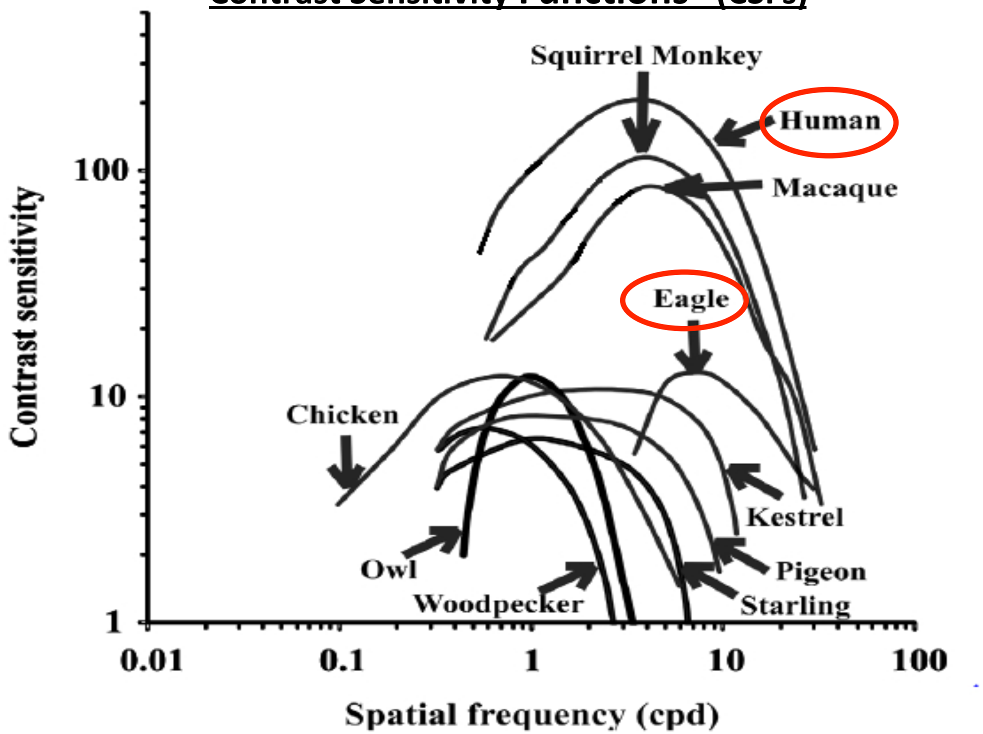
Typical human detection response under varying lighting conditions are overlaid onto a variable frequency sine pattern with variable levels of contrast.

LITE enterprises

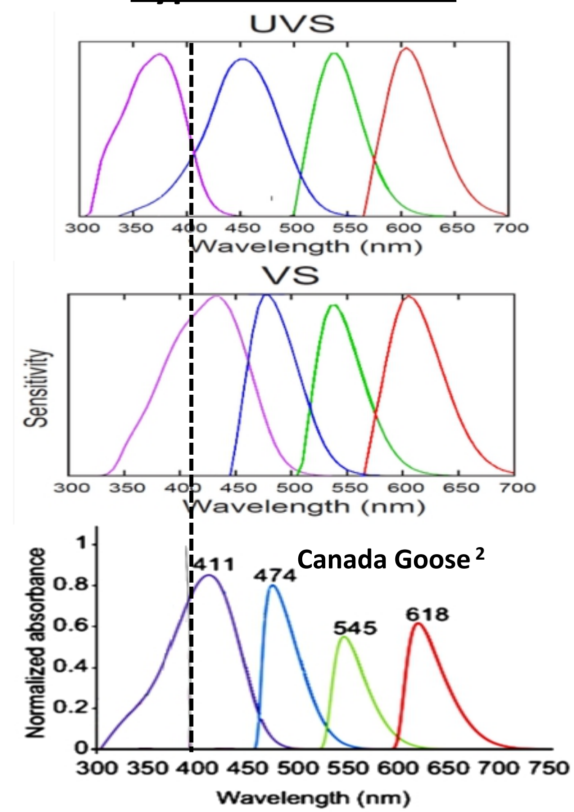
CSF depends on a number of factors including: the mean luminance, the pattern of the luminance profiles, the level of defocus, and the clarity of the optics of the eye.

Avian Visual Physiology Enables Augmented Response
Lite Enterprises (2014)

Contrast Sensitivity Functions[3] (CSFs)



Typical Passerine [1]



[1] Ödeen, et al., Evolution of ultraviolet vision in the largest avian radiation - the passerines, BMC Evolutionary Biology, 2011, 11:313, doi:10.1186/1471-2148-11-313

[2] Moore, et al., Oblique color vision in an open-habitat bird: spectral sensitivity, photoreceptor distribution and behavioral implications, The Journal of Experimental Biology 215, 3442-3452, 2012, doi:10.1242/jeb.073957

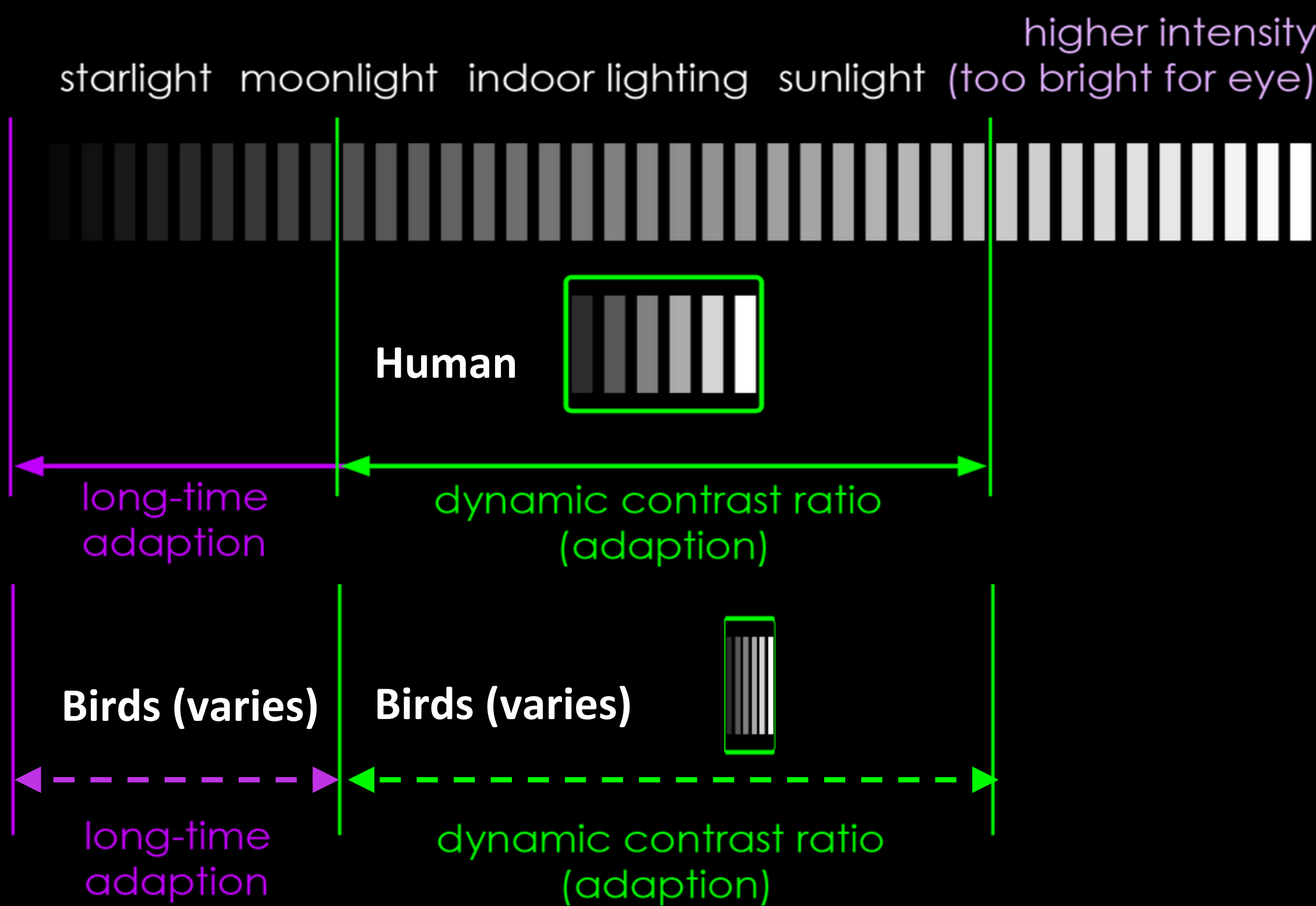
[3] Givago da Silva Souza, et. al., (2011) Comparative neurophysiology of spatial luminance contrast Sensitivity, Psychology & Neuroscience, 2011, 4, 1, 29 – 48, DOI: 10.3922/j.psns.2011.1.005

Avian S-cones are identified by two distinct classes (UVS and VS).

LITE enterprises

Visual physiology of primates and birds share rod and cone amino acid sequences. Photoreceptor density is important to chromatic contrast. Avian contrast sensitivity functions (CSFs) are important to the augmented response.

Comparisons of Different Visual Systems



The visual physiology determines the dynamic range of the species. Humans have a greater dynamic range than birds. Adaption means we can able to adjust to changes in light level by adjusting the eye pupil and other mechanisms. Contrast mechanisms make us sensitive to local changes within the dynamic range of the specie.

LITE enterprises

Field Unit

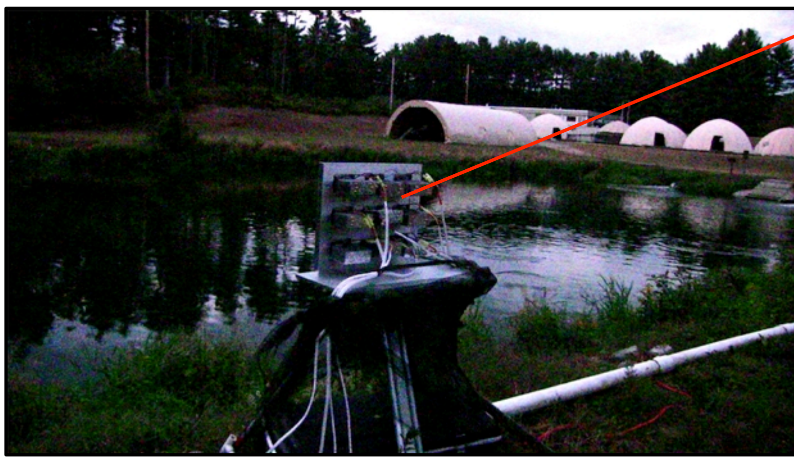
Desired behavioral response is reinforced by multiple sensory inputs.

Tests of Augmented Responses
Osprey and Red-tailed Hawks Test Sites
Lite Enterprises – 2014

Osprey

Red-tail Hawk and a Northern Harrier

LED Lights



LITE enterprises

Fish Hatchery

Banding Station

χ^2

Osprey (*Pandion haliaetus*) and Red-tail Hawk (*Buteo jamaicensis*)

TEST CONDITIONS: ***Wild species in their natural environment foraging for their natural food sources*** **at a fish hatchery and a banding station.**

Osprey
(*Pandion haliaetus*)

Foraging success was significantly higher in the absence of lights (*X*^{2}=8.062, df=1, p=0.005).

Red-tailed Hawk
(*Buteo jamaicensis*)

Proportions of aborts and captures during the test week differed significantly between the control and test sites (*X*^{2}=23.412, df=1, p<0.001) with aborts being proportionally higher and captures lower at the test site with light deterrence.

LITE enterprises

Effectiveness of Non-Lethal Deterrence at a fish hatchery and a migratory bird banding station.

Common Eiders (*Somateria mollissima*) at a Mussel Farm

TEST CONDITIONS: ***Wild species in their natural environment foraging for their natural food source*.**

Lights were not continuously operational during the project period, providing some opportunity for eider depredation on all sides. Mussel counts differed significantly among treatments (X^2=1,210.536, df=2, p<0.001), with the highest number below violet lights, approximately half as many below blue lights, and approximately one tenth as many at the control raft.

LITE enterprises

Experimental evidence that supports our analysis.

Modifying Osprey Nesting Behavior on Cell Tower

Osprey behavior is altered in the presence of the device. Osprey built alternate nests in unprotected locations on the tower.

Endocrine Related Behavior

Mating, nesting and rearing young is strongly driven by endocrine signals which are difficult to overcome.

LITE enterprises

Aircraft Strike Ranking by Specie (U.S.)

Species group	Ranking by criteria: Damage[4]	Major damage[5]	Effect on flight[6]	Composite ranking[2]	Relative hazard score[3]
Deer	1	1	1	1	100
Vultures	2	2	2	2	64
Geese	3	3	6	3	55
Cormorants/pelicans	4	5	3	4	54
Cranes	7	6	4	5	47
Eagles	6	9	7	6	41
Ducks	5	8	10	7	39
Osprey	8	4	8	8	39
Turkey/pheasants	9	7	11	9	33
Herons	11	14	9	10	27
Hawks (buteos)	10	12	12	11	25
Gulls	12	11	13	12	24
Rock pigeon	13	10	14	13	23
Owls	14	13	20	14	23
H. lark/s. bunting	18	15	15	15	17
Crows/ravens	15	16	16	16	16
Coyote	16	19	5	17	14
Mourning dove	17	17	17	18	14
Shorebirds	19	21	18	19	10
Blackbirds/starling	20	22	19	20	10
American kestrel	21	18	21	21	9
Meadowlarks	22	20	22	22	7
Swallows	24	23	24	23	4
Sparrows	25	24	23	24	4
Nighthawks	23	25	25	25	1

Statistically Verified

Field Observations

Source: AC 150/5200-33B - Hazardous Wildlife Attractants On or Near Airports

LITE enterprises

Many specie from the top 25 specie list have shown behavior changes to high brightness mono-colored LED light. More testing is needed.

On-Airport Birdstrike Mitigation

Commercial aircraft experience the majority of the wildlife strikes and damage strikes reported (per 100,000 aircraft movements).

Other Species?

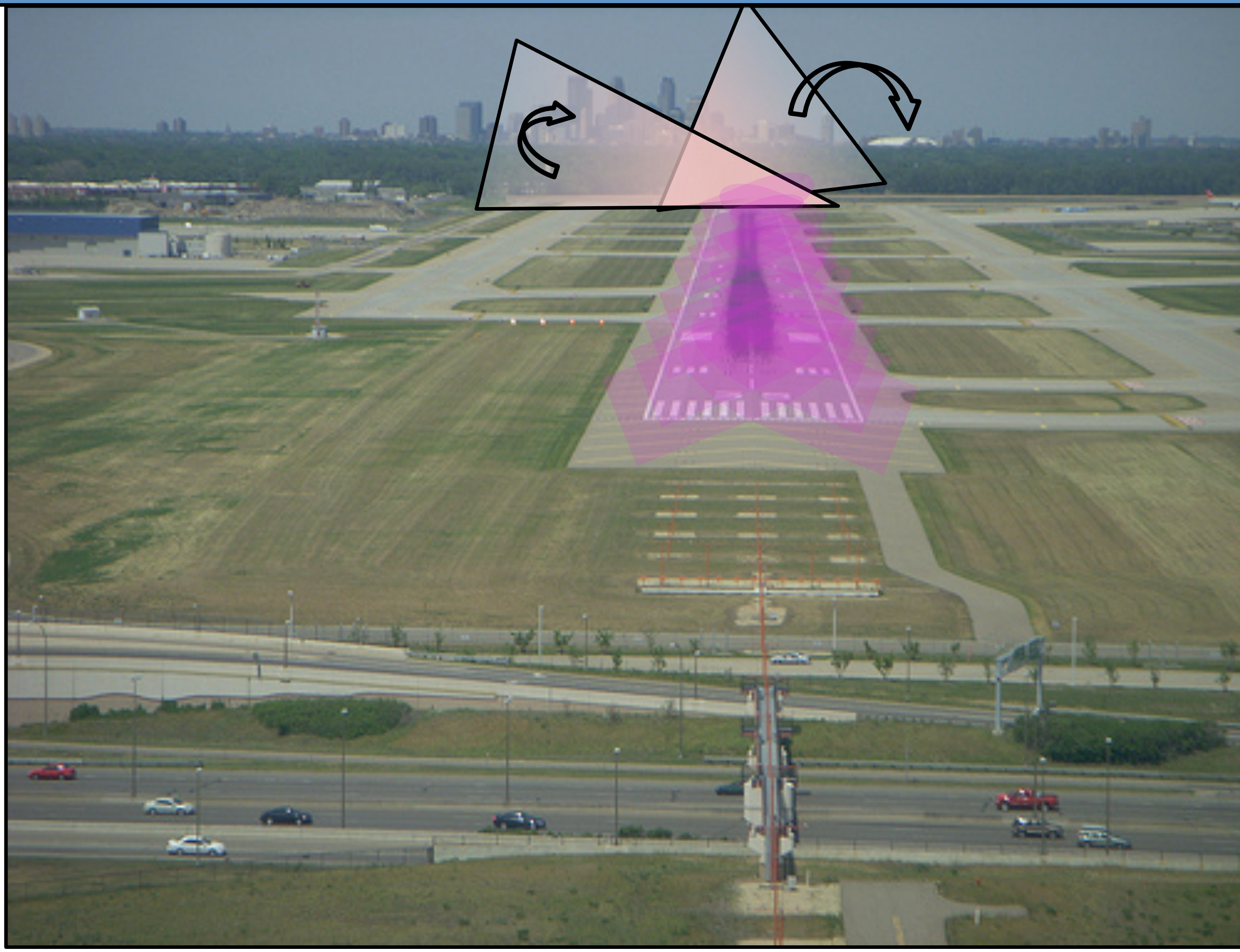
Order	Family	Name		Common name	Type	λ-max
Anseriformes	Anatidae	Anas	platyrhynchos	Mallard duck	VS	405a
Ciconiiformes	Accipitridae	Accipiter	gentilis	Northern goshawk	VS	406
Ciconiiformes	Accipitridae	Accipiter	nisus	European sparrow hawk	VS	405
Ciconiiformes	Accipitridae	Buteo	buteo	Common buzzard	VS	405
Ciconiiformes	Accipitridae	Circus	aeruginosus	Marsh harrier	VS	405
Ciconiiformes	Accipitridae	Pandion	haliaetus	Osprey	VS	405
Ciconiiformes	Ardeidae	Ardea	cinerea	Grey heron	VS	406b
Ciconiiformes	Charadriidae	Charadrius	dubius	Little ringed plower	VS	406
Ciconiiformes	Charadriidae	Haematopus	ostralegus	Common pied oystercatcher	VS	406
Ciconiiformes	Charadriidae	Himantopus	himantopus	Black-winged stilt	VS	406
Ciconiiformes	Falconidae	Falco	peregrinus	Peregrine falcon	VS	405
Ciconiiformes	Gaviidae	Gavia	stellata	Red-throated diver	VS	406b
Ciconiiformes	Laridae	Alca	torda	Razorbill	VS	406
Ciconiiformes	Laridae	Larus	argentatus	Herring gull	UVS	371a, b
Ciconiiformes	Laridae	Larus	fuscus	Lesser blackbacked gull	UVS	371a, b
Ciconiiformes	Laridae	Larus	marinus	Greater blackbacked gull	UVS	371a, b
Ciconiiformes	Laridae	Uria	aalge	Common murre	VS	406
Ciconiiformes	Phalacrocoracidae	Phalacrocorax	carbo	Common cormorant	VS	406b
Ciconiiformes	Phoenicopteridae	Phoenicopterus	sp.	Greater flamingo	VS	408
Ciconiiformes	Procellariidae	Oceanodroma	leucorhoa	Leach's stormpetrel	VS	405
Ciconiiformes	Procellariidae	Puffinus	puffinus	Manx shearwater	VS	402
Ciconiiformes	Spheniscidae	Pygoscelis	adeliae	Adelie penguin	VS	405
Ciconiiformes	Spheniscidae	Spheniscus	humboldti	Humboldt penguin	VS	403
Columbiformes	Columbidae	Columba	livia	Domestic pigeon	VS	405
Coraciiformes	Alcedinidae	Alcedo	atthis	Kingfisher	VS	405

Anders Ödeen†and Olle Håstad, Complex distribution of avian color vision systems revealed by sequencing the SWS1 opsin from total DNA, Mol Biol Evol. 2003 Jun;20(6):855-61. Epub 2003 Apr 25.

Genetic identification of the amino acid sequence and measurements of the peak absorption wavelength of the S – cone.

LITE enterprises

Perspective of Birdstrike "Protected" Departure Airspace



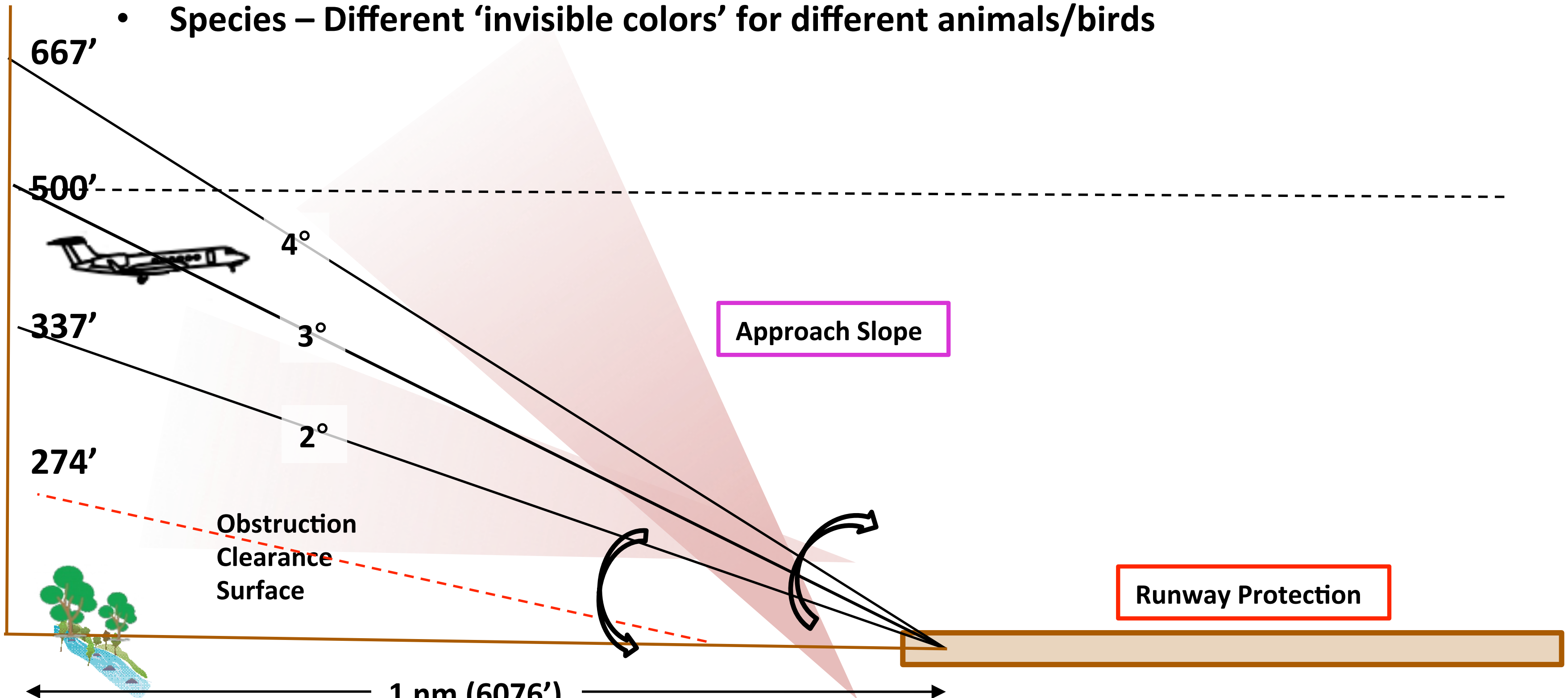
The overlapping illumination pattern is optimized to illuminate the departure airspace and the runway with 'invisible light'.

LITE enterprises

Protecting the ILS Approach Slope and Landing

<u>**Optimize animals deterrence:**</u>

- **Location and setup - prevent birds entering the airspace at 500' AGL and beyond. Approach slopes vary (e.g. London City Airport is 5.5° approach)**
- **Species – Different 'invisible colors' for different animals/birds**



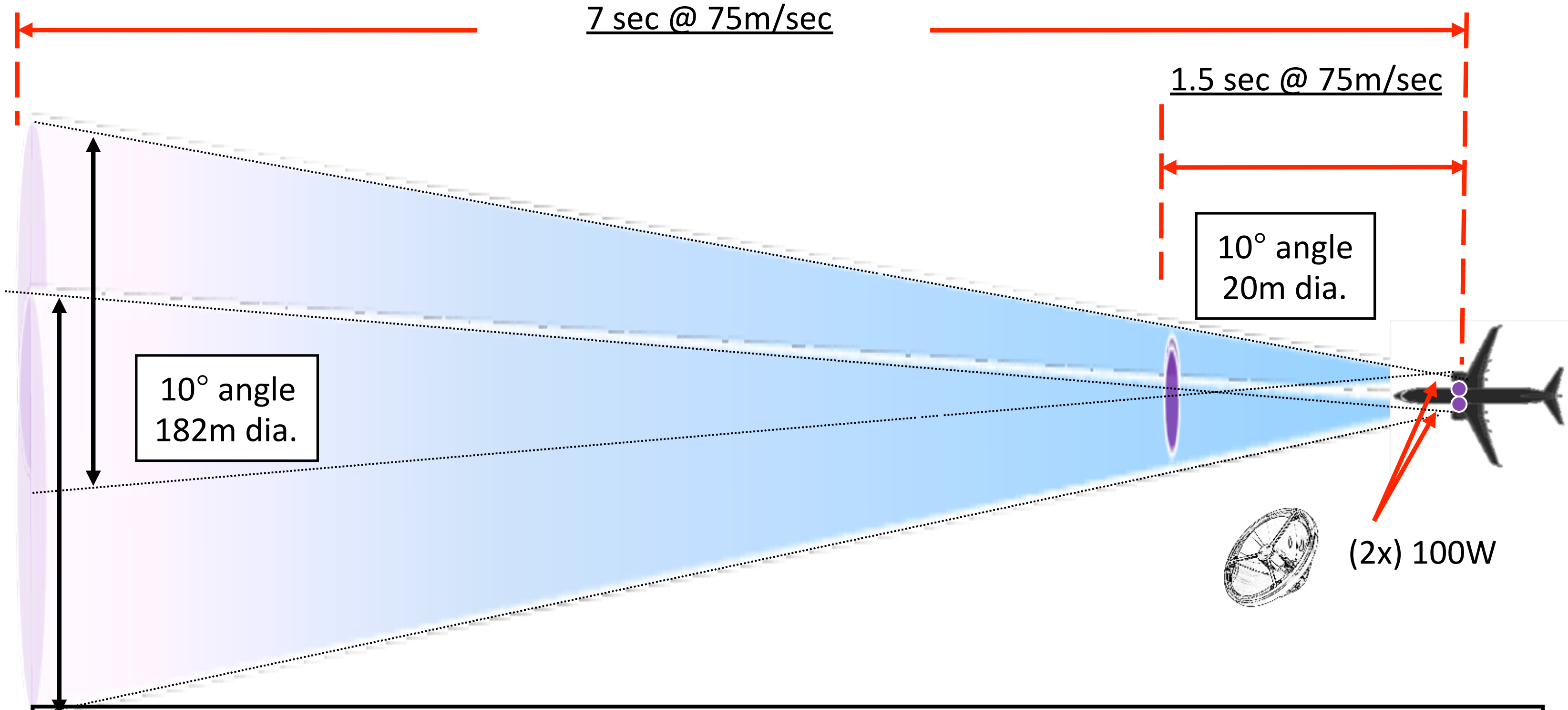
Configuration and setup is optimized to protect the airspace that aircraft are most likely to pass through.

On-Airplane Birdstrike Mitigation

LITE enterprises

Commercial aircraft experience the majority of the wildlife strikes and damage strikes reported (per 100,000 aircraft movements).

On-Aircraft – Bird Strike Mitigation
Boeing 737 @150kts Landing Speed



Voluntary Response (Decreasing Intensity)	Aversion Response	Neurophysical Response (Increasing Intensity)

- Avoidance (discomfort)
- Awareness (contrast, motion)

- (panic)
- (threatened)
- (stress)

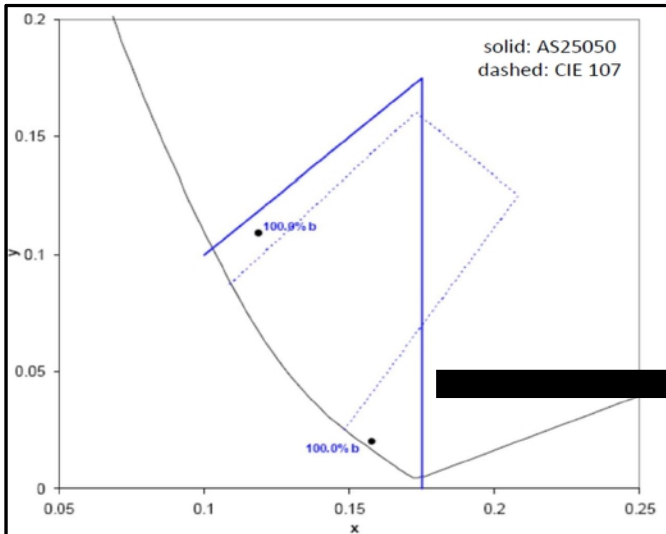
- Visual augmented response (visual shutdown)
- Visual reflex adaptation

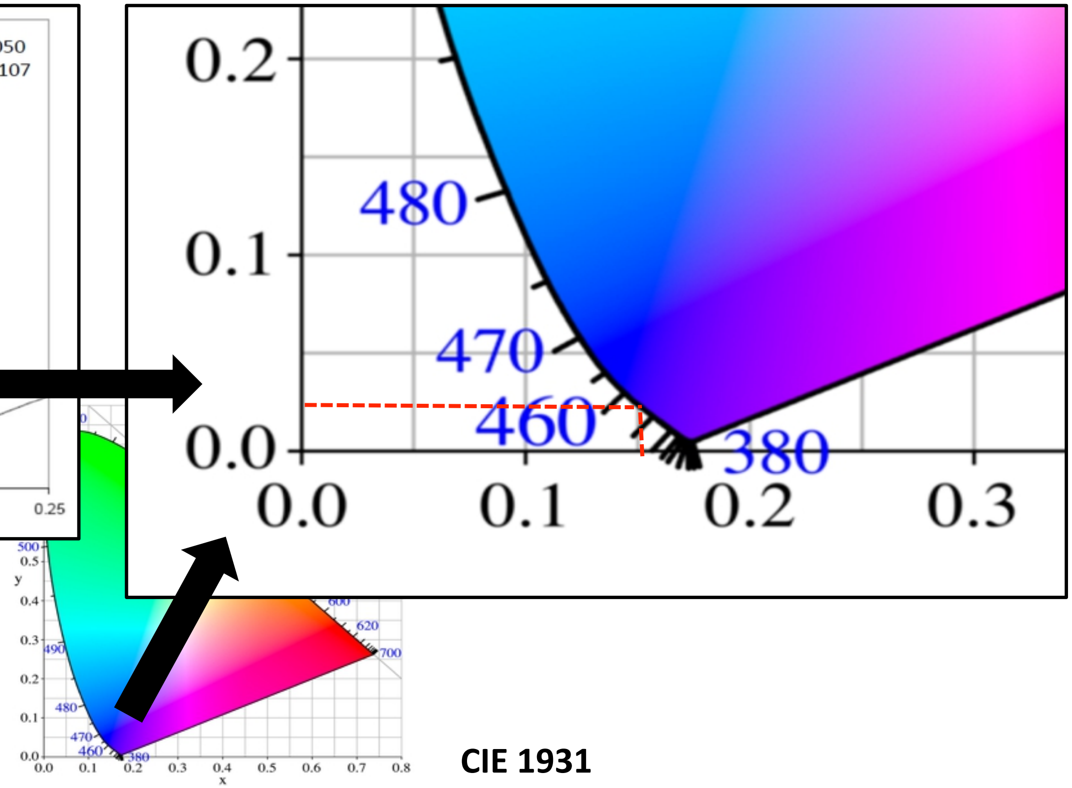
LITE enterprises

Light of the optimum spectrum will induce a behavioral response.

FAA Engineering Brief No.67D
Light Sources Other Than Incandescent and Xenon For Airport and Obstruction Lighting Fixtures (2012)

2.1.2 LED light fixtures that emit aviation green, blue, yellow or red light color must meet the following boundary equations and boundary intersection points:





CIE 1931

Blue boundary intersection points[1]:

x = 0.090, y = 0.137

x = 0.186, y = 0.214

x = 0.233, y = 0.167

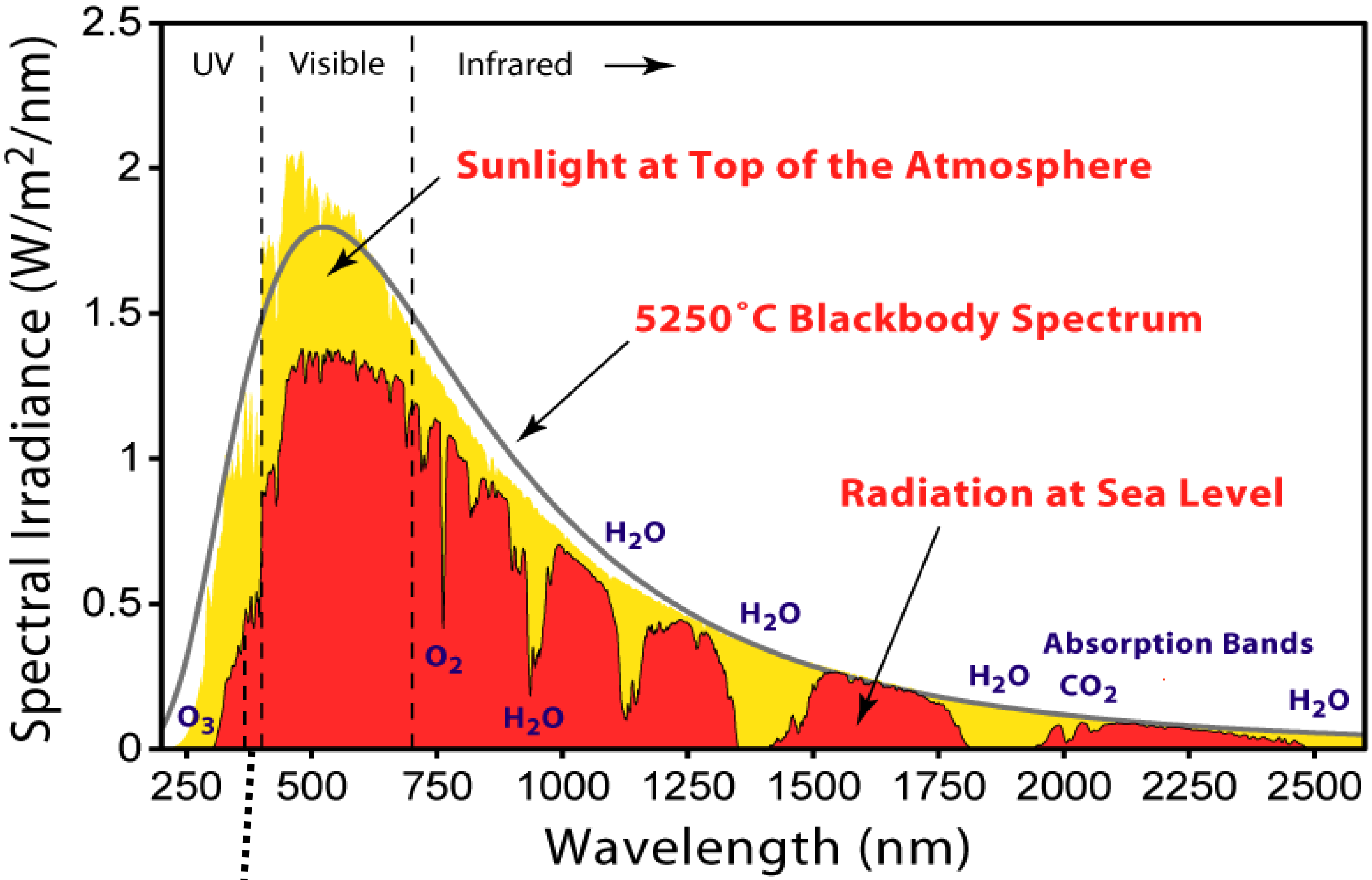
x = 0.148, y = 0.025 (or 450nm)

[1]ST-017B-E ITE Equipment and Material Standard, ST-017B, Chapter 2, Vehicle Traffic Control Signal Heads

LITE enterprises

Blue light has been defined by CIE 1931 standard for the purposes of FAA lighting. UV light is not to be confused with blue light.

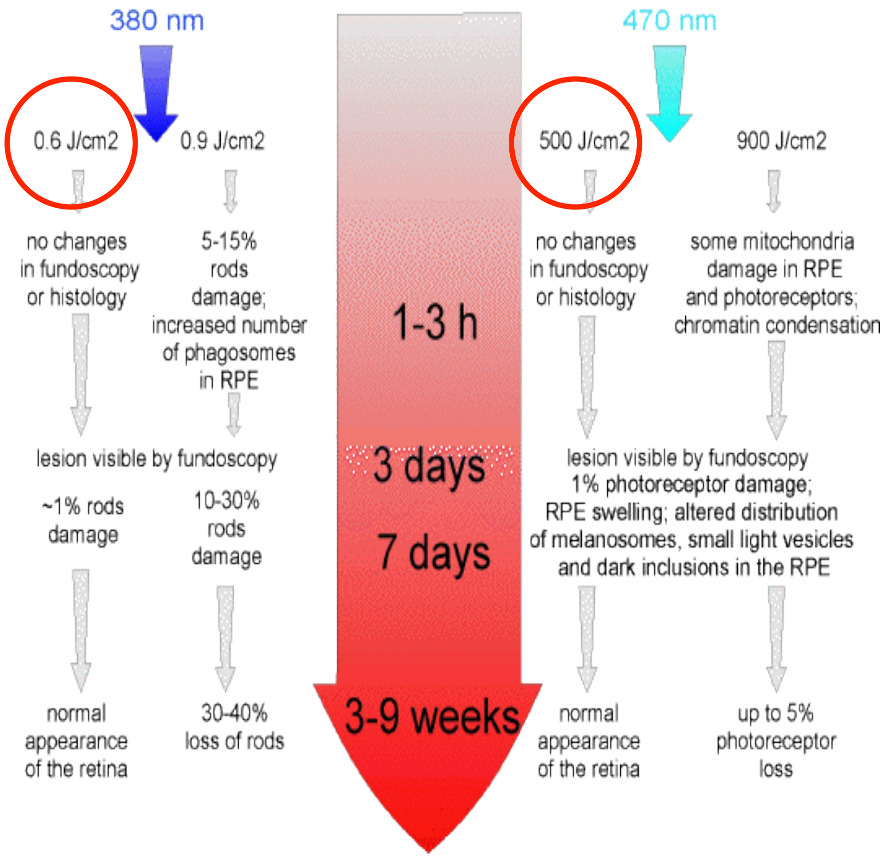
What About Eye Safety?



ASTM G173-03 Reference Spectra for noontime sunlight of UVA light (315 – 400nm) is 6.1 10^{-3} J/cm2

LITE enterprises

Retinal Photo-damage Threshold – Constant Light



The threshold irradiance doses for Rats (*Rattus norvegicus*) and Monkey (*Macaca mulatta*) were nearly identical. Following exposures to narrow-band light centered at 380 nm and 470 nm researchers monitored the time-course of changes in the rat retina using funduscopic examination. The most pronounced damage 3 days after the exposure to damaging light occurred at doses of 0.6 J/cm^2 and 500 J/cm^2 for 380 nm and 470 nm light, respectively. Further examination of histological sections through the retina revealed damage threshold to photoreceptors at a dose of 0.45 J/cm^2 for 380 nm +/-10nm light source exposure for 6-8minutes. [1]

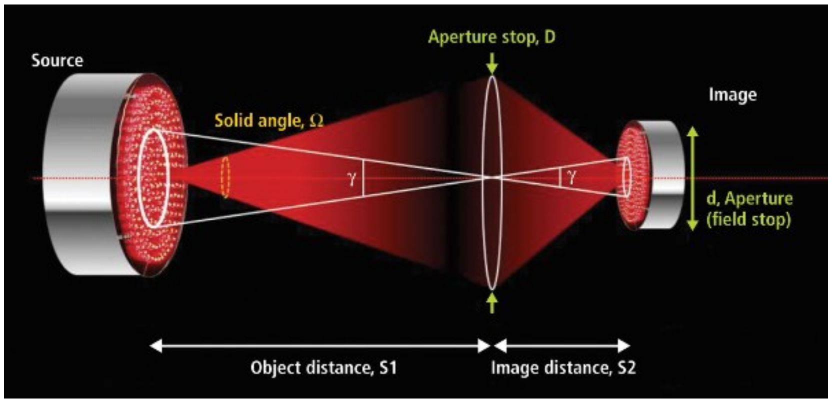
[(6min x 60seconds) x 0.45J/cm^2 = 162W/cm^2]

[1]Busch, et. al, Temporal sequence of changes in rat retina after UV-A and blue light exposure, Vision Res. 1999 Apr;39(7):1233-47, DOI: 10.1016/S0042-6989(98)00233-8

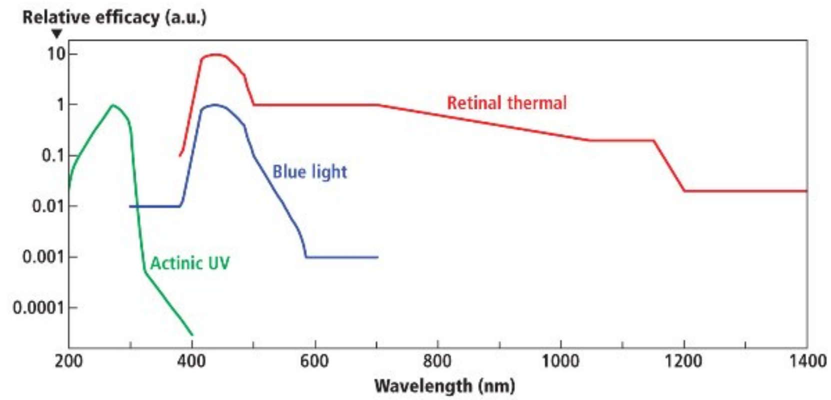
LITE enterprises

UVA$_{380nm}$ (constant 'ON' light) intensity of 162 W/cm^2 causes eye damage.

Worker Exposure to High Brightness LEDs



Measurement of radiance: imaging technique.



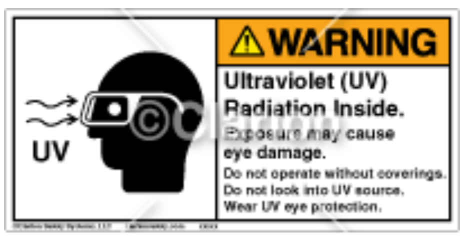
Hazard weighting functions used by IEC62471.

Biological hazards: Issues like retinal damage and other health issues that could arise are always a concern, but currently there is not conclusive research that proves that there is a significant risk involved with using this technology.

Europe: IEC/EN 62471

US: ANSI IESNA RP 27

Others: INTERNATIONAL COMMISSION ON NON-IONIZING RADIATION PROTECTION



High brightness LEDs are <u>not</u> lasers which are temporally and spatially coherent. LEDs have high beam divergence angles.

LITE enterprises

What About Scattering and Diffusion? Fog? Rayleigh Scattering?

Weather and atmospheric conditions may create 'strange' visual effects even with UV lights. Pulsed point light sources will not confuse or attract birds.

LITE enterprises

Does it Attract Insects?

House flies, wasps and mosquitoes require a constant light to see and are believed to be attracted by 365nm UV light.

No indication of a problem. We avoid this problem by using a different "color" of light, and pulse the light source.

Aviation Wildlife Strikes

- **Bird strikes remain a significant problem**
- **Financial burden and safety issues**
- **Current measures are limited**
- **New technology enables new approaches**

LITE enterprises

Non-lethal Birdstrike Mitigation R&D

Lite Enterprises Inc.

4 Bud Way, Ste 15

Nashua, NH 03063

D.Ronning@liteenterprises.com

603-821-0991 x503

www.liteenterprises.com

ACKNOWLEDGMENTS

This work was partially supported by National Science Foundation grant No. IIP-1215067 and IIP-1350562. Generous support at the test sites was provided by Cape May Raptor Banding Project Inc., NH Fish and Game Department-Milford Fish Hatchery, Calendar Island Mussel Co. and U.S. Cellular Corporation.

LITE enterprises