How to Photograph Birds

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MIT
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FNAL

Brown Falcon
Queensland, Australia

Birds in Comparison

- Warm-blooded flying species
  - 1,000 bats
  - 9,721 birds
- Speed
  - Humans 3-4 body lengths/sec (bl/s)
  - Race Horse 7 bl/s
  - Cheetah 18 bl/s
  - SR71 (Mach 3) 32 bl/s
  - Swifts 140 bl/s
- Maneuverability roll rate
  - Stunt plane A-4 Skyhawk 720^0/s
  - Barn swallow 5,000^0/s
- G-forces
  - Select military aircraft 8-10 g
  - Birds up to 14 g
- Altitude record for a bird
  - 11,000 m Ruppell's Vulture (ingested by a jet engine over Ivory Coast)

Smallest Living Bird: Bee Hummingbird (*Mellisuga helenae*) 1.6-2 g endemic in Cuba

Heaviest flying bird: Kori Bustard in Africa (*Ardeotis kori struthiunculus*), 16 to 19 kg.

Largest Living Bird: Common Ostrich (*Struthio camelus) ~ 115 kg in Africa*

'First' bird: *Archaeopteryx* lived during the late Jurassic period, approximately 150.8–148.5 million years ago.

Wei Shyy et. al, "Aerodynamics of Low Reynolds Number Flyers", Cambridge Aerospace Series

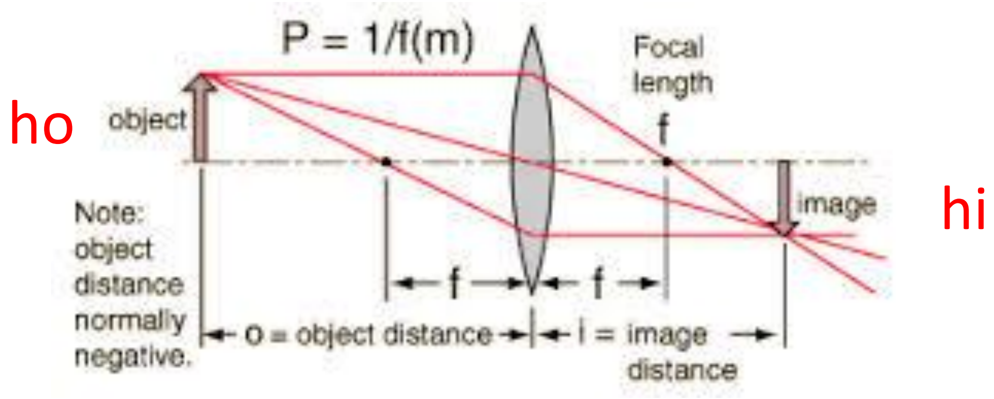
Outline

- The Measurement problem
  - Small size, quick movement, non-proximity
- Photography Fundamentals
  - Lens
    - Focal length, aperture, vibration reduction, continuous focusing
  - Camera
    - Aperture priority, light metering and focusing, auto-ISO, burst mode, GPS tag
  - Data
    - JPEG/RAW and Image processing
- Photographing birds in different settings
  - Birds at rest
  - Birds in flight & measuring their ground speed
- Digression into a little Aerodynamics of low Reynolds numbers
  - Gliding
  - Flapping Energetics
- Obsession of an Extreme Bird

‘Measurement’ Problem

- Driven by small size and quick movements
  - Typical passerine (perching bird) size ≈ 10 cm
  - Typical distance ~ 30 m
  - Typical observation time ~ 2 seconds

- Long focal length
- Large aperture
- Fast shutter
- Fine-grained sensor



$$\frac{hi}{ho} = -\frac{i}{o} \approx -\frac{f}{o}$$

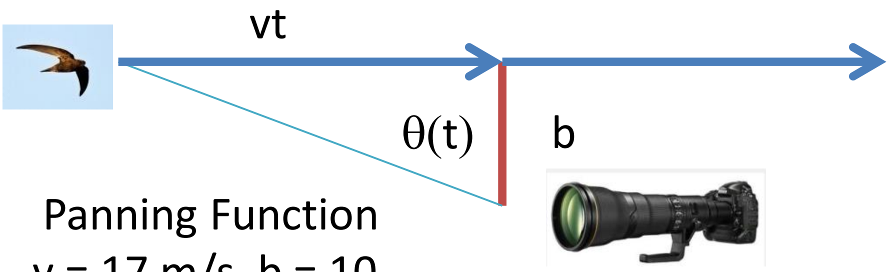
<u>Size of image for f = 300 x 1.7 mm lens 10 cm bird @ 30 m</u>

hi ≈ |ho (-f/o)| = 10 (0.51/30) = 0.17 cm

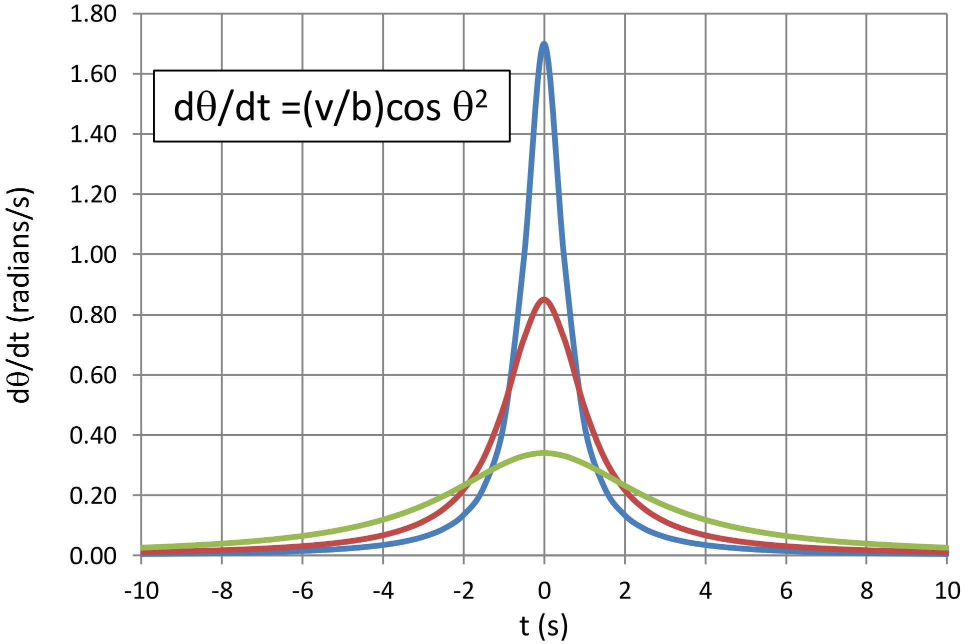
For Nikon D300s ((5.5 μm)^2 pixels) image would be <u>310x310 pixels</u>

Panning & Visual Acuity

To photograph a Bird flying by

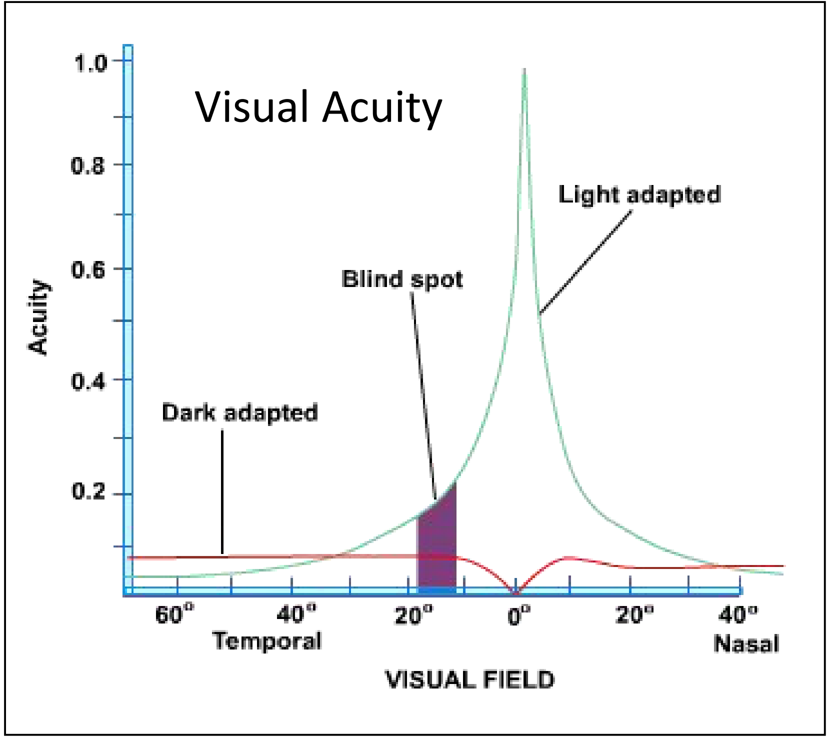


Panning Function
v = 17 m/s, b = 10,
20, 50 m



$d\theta/dt = (v/b)\cos\theta^2$

To photograph a Skylark



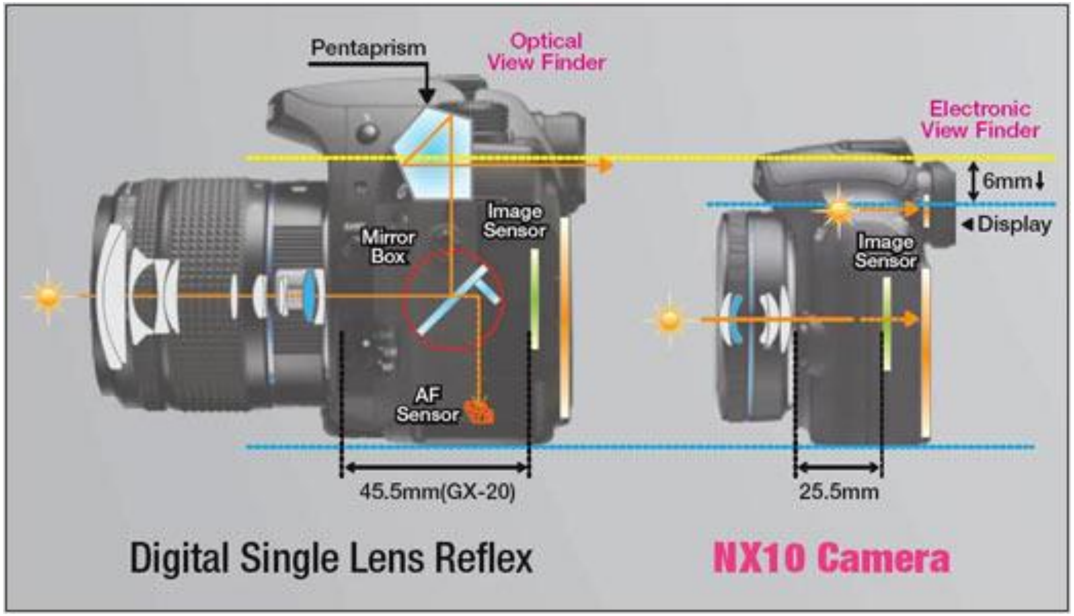
Audubon – early 19th Century

Great Blue Heron (*Ardea herodias*) off the coast of Texas with Nikon D300s, 300x1.7 mm, f/5, 1/1250 s, ISO 200

Audubon shot (killed), then propped up his birds with wire in order to paint them. Hence none of his bird pictures is in flight

Digital Single Lens Reflex Camera

- Speed is of the essence
  - In bird photography have no time for camera startup, focusing, exposure parameters, etc.
  - A DSLR is the (presently) only option



Nikon and Cannon are the two major companies

I have a Nikon D7200, D300s, D700 and a D80 and use the D7200 for most shots.

The technology is rapidly changing to ever-more capable cameras. I am comparatively low-end.

NIKKOR (Nikon) Lenses

f-Number = Focal length/diameter of lens – small f-number = fast & $$$

- Up to 800 mm f/5.6 (Canon has a similar family)
  - Need at least 300 mm for wildlife but for birds a longer lens is better
  - I have a 300 mm f/2.8 lens that I use with a 1.4X, 1.7X and 2.0X teleconverter (equivalent to 600 mm f/5.6)

Tripod & Flash – The 'high end'

- 'Professionals' use:
  - Wimberley™ Mount and sturdy tripod with long lens (600 mm prime f/4.0)
  - Flash with a Fresnel Concentrator
  - Remote/cable shutter release for low vibration
  - Enables the best shots of distance birds but is heavy and not very mobile
- I prefer hand-held lens which I can pack in backpack and carry all day @ 15 lbs

Uses of a Telephoto Lens

Galapagos Flycatcher (*Myiarchus magnirostris*)

[S 0^0 14.479’, W 90^0 51.707’]

Telephoto lenses are not really needed in the Galapagos! Birds are completely habituated there and will walk over you shoe or land on your head!

My lens is a Nikkor 300 mm f/2.8

Camera Settings

- Aperture Priority – lens wide open
  - Want the fastest shutter speed possible for the given light
  - Short depth of field blurs the background but makes focusing less forgiving
- Raw format 12 bit
  - Can fix many mistakes
  - 14 bit is possible but lose burst speed
- Continuous focus
  - Objects are always moving – have to track them
- Burst shutter mode (4 to 5 shots/second)
- Auto ISO
  - Minimum shutter speed 1/320 second
  - Maximum ISO 6400
- Color space
  - sRGB with auto white balance

Set up camera before going shooting

One has no time to mess with the settings
Concentrate on getting the pictures

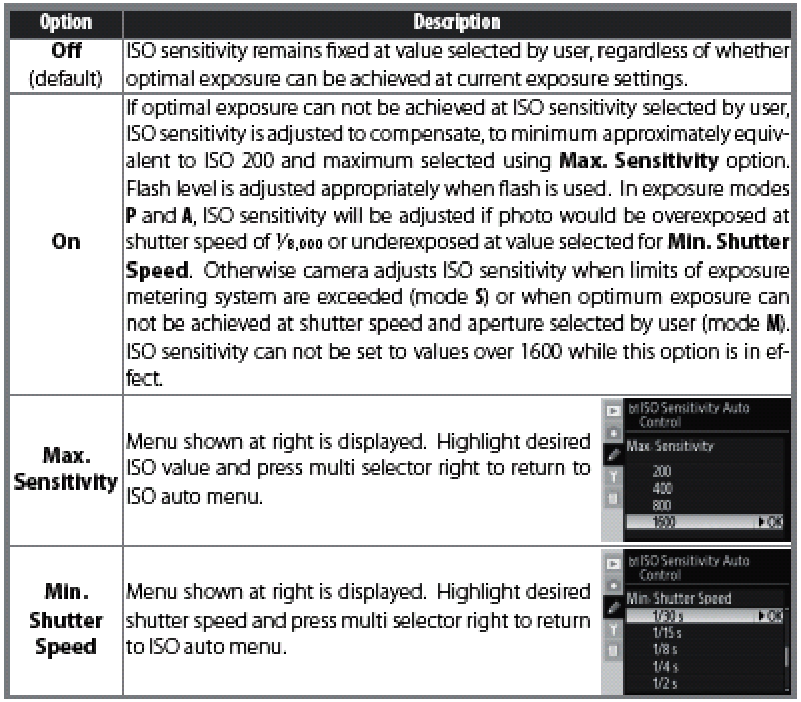
Focus & Metering Region

- Camera menu has many options
  - Generally use spot focusing
    - Focus on the bird and not the tree limb
  - 51 point with 3D tracking possible
    - Use sometimes on a fast bird flying in a clear sky
  - Generally use spot metering
    - Want the bird to be properly exposed – don’t care about the sky or the tree
- Other settings sometimes used
  - I do a fair amount of playing with these settings

Auto ISO (International Organization of Standardization)

- ISO quantifies the sensitivity of the CMOS light sensor
  - Low ISO – least sensitive but good quality and low noise
  - High ISO – more sensitive but becomes noisy
- Auto ISO selects the optimal ISO between minimum shutter speed and the maximum ISO for the best picture quality
- EV (Exposure value) adjustments sometimes done to change the shutter speed without changing the ISO
  - Positive EV means more exposure by less shutter speed
    - +1 is one f/stop more open

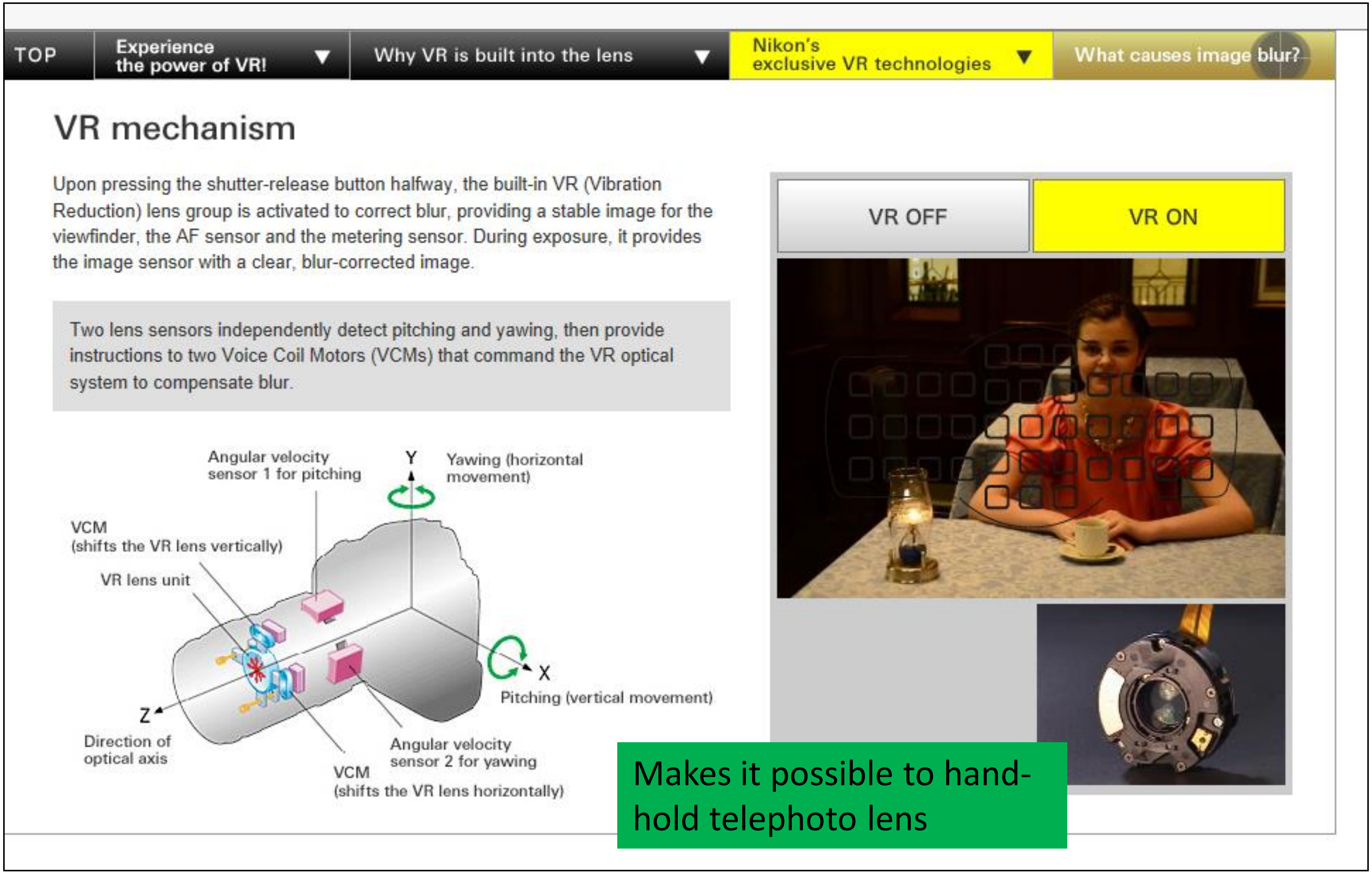
From Nikon D300s



Option	Description
Off (default)	ISO sensitivity remains fixed at value selected by user, regardless of whether optimal exposure can be achieved at current exposure settings.
On	If optimal exposure can not be achieved at ISO sensitivity selected by user, ISO sensitivity is adjusted to compensate, to minimum approximately equivalent to ISO 200 and maximum selected using **Max. Sensitivity** option. Flash level is adjusted appropriately when flash is used. In exposure modes **P** and **A**, ISO sensitivity will be adjusted if photo would be overexposed at shutter speed of 1/8,000 or underexposed at value selected for **Min. Shutter Speed**. Otherwise camera adjusts ISO sensitivity when limits of exposure metering system are exceeded (mode **S**) or when optimum exposure can not be achieved at shutter speed and aperture selected by user (mode **M**). ISO sensitivity can not be set to values over 1600 while this option is in effect.
Max. Sensitivity	Menu shown at right is displayed. Highlight desired ISO value and press multi selector right to return to ISO auto menu.
Min. Shutter Speed	Menu shown at right is displayed. Highlight desired shutter speed and press multi selector right to return to ISO auto menu.

Makes it possible to get the right exposure automatically

Vibration Reduction



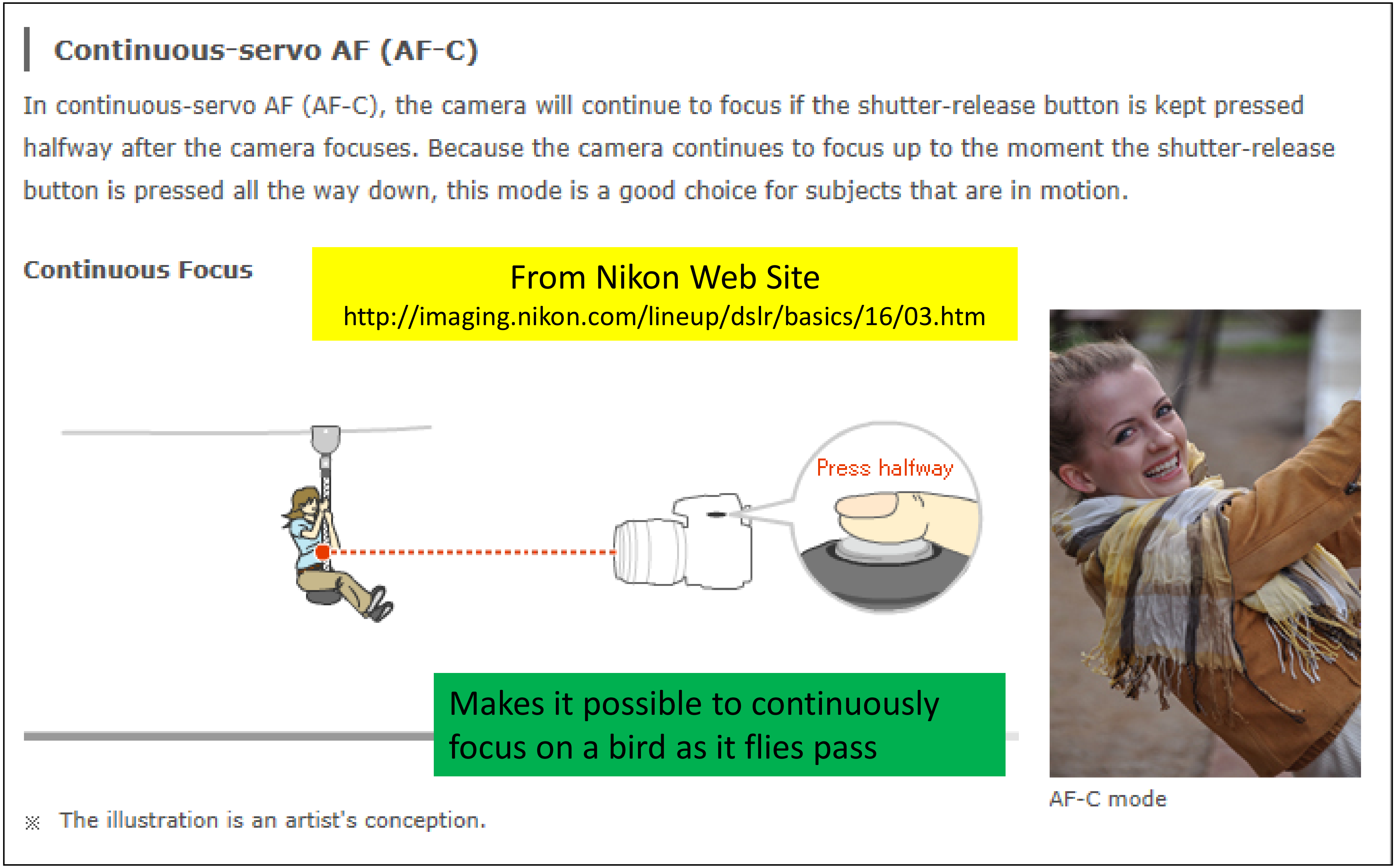
VR mechanism

Upon pressing the shutter-release button halfway, the built-in VR (Vibration Reduction) lens group is activated to correct blur, providing a stable image for the viewfinder, the AF sensor and the metering sensor. During exposure, it provides the image sensor with a clear, blur-corrected image.

Two lens sensors independently detect pitching and yawing, then provide instructions to two Voice Coil Motors (VCMs) that command the VR optical system to compensate blur.

Makes it possible to hand-hold telephoto lens

Continuous Autofocus



Continuous-servo AF (AF-C)

In continuous-servo AF (AF-C), the camera will continue to focus if the shutter-release button is kept pressed halfway after the camera focuses. Because the camera continues to focus up to the moment the shutter-release button is pressed all the way down, this mode is a good choice for subjects that are in motion.

Continuous Focus

From Nikon Web Site
http://imaging.nikon.com/lineup/dslr/basics/16/03.htm

Makes it possible to continuously focus on a bird as it flies pass

AF-C mode

※ The illustration is an artist's conception.

Hardware

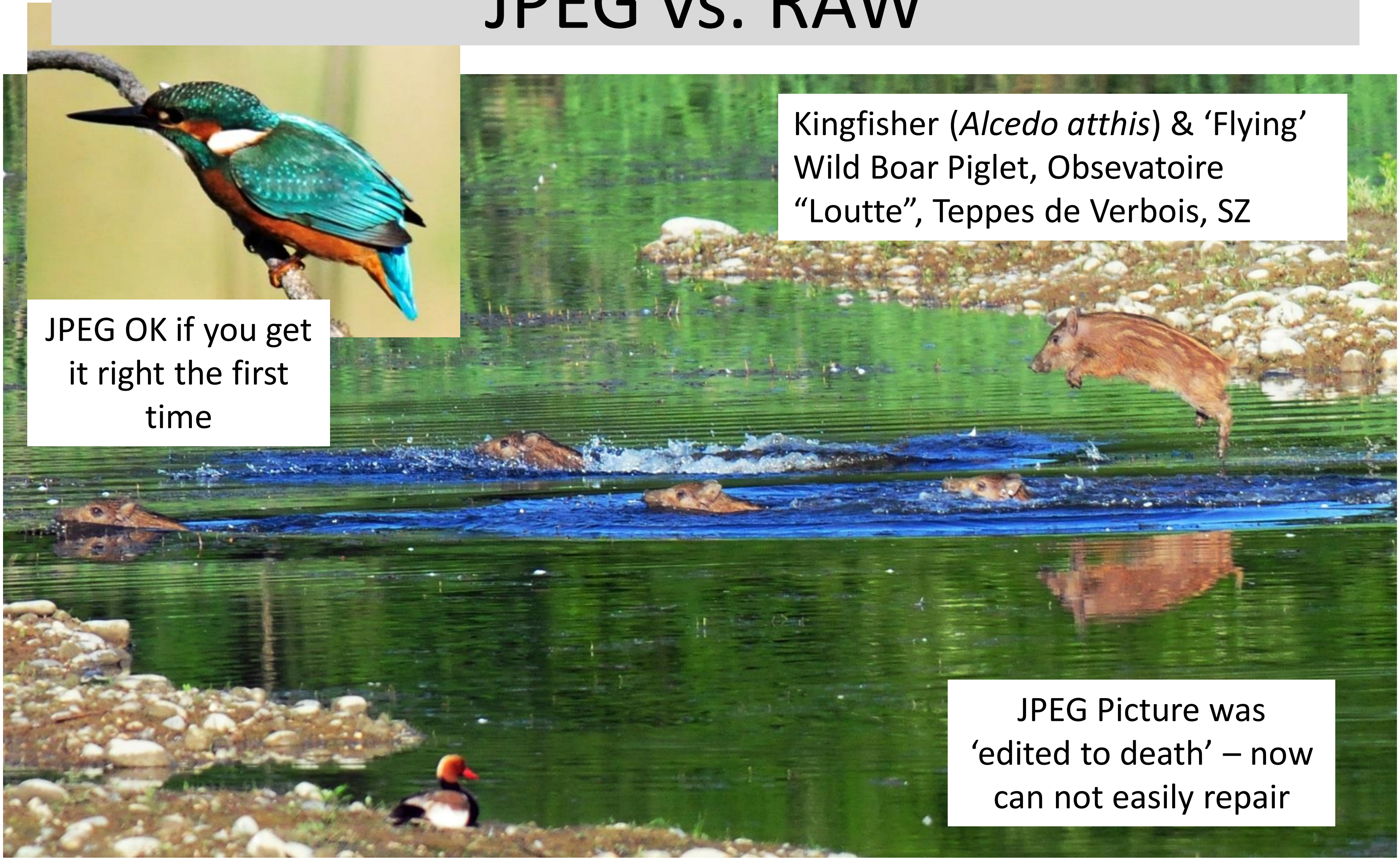
Cameras: D7200, D700, D300s, D80; Lens: 300 mm VR f/2.8, 70-300 mm VR f/4.5-5.6 zoom, 18-135 DX f/3.5-5.6, 1.7X & 2.0X Teleconverter; Accessories: memory cards, extra batteries, GPS, remote release, Fresnel Flash, tripod, Laptop & external HD, logbook, backpack, Camera suitcase and many plastic bags

JPEG vs. Raw

- JPEG (Joint Photographic Expert Group)
  - Photograph is compressed in the camera according to enhanced color scale, file size etc.
  - Information of the original photo is lost forever
  - Every edit of photo can change the compressed information
  - Can not go back to original file – get creep of quality
  - Advantage is smaller file size (~ 1 to 2 Mb) and less editing needed
- Raw
  - Like the 'negative' of a film – with 12 or 14 bit color/intensity depth
  - All information is preserved
  - Forced to edit but original is untouched
  - Mistakes in exposure can be better corrected
  - Can experiment with different versions of the same picture without copying the original
  - Disadvantage is that each picture is large file ~ 28 Mb @ 12 bit

Shooting in RAW makes it possible to correct a variety of mistakes in original picture taking & in editing.

JPEG vs. RAW



Kingfisher (*Alcedo atthis*) & ‘Flying’ Wild Boar Piglet, Obsevatoire “Loutte”, Teppes de Verbois, SZ

JPEG OK if you get it right the first time

JPEG Picture was ‘edited to death’ – now can not easily repair

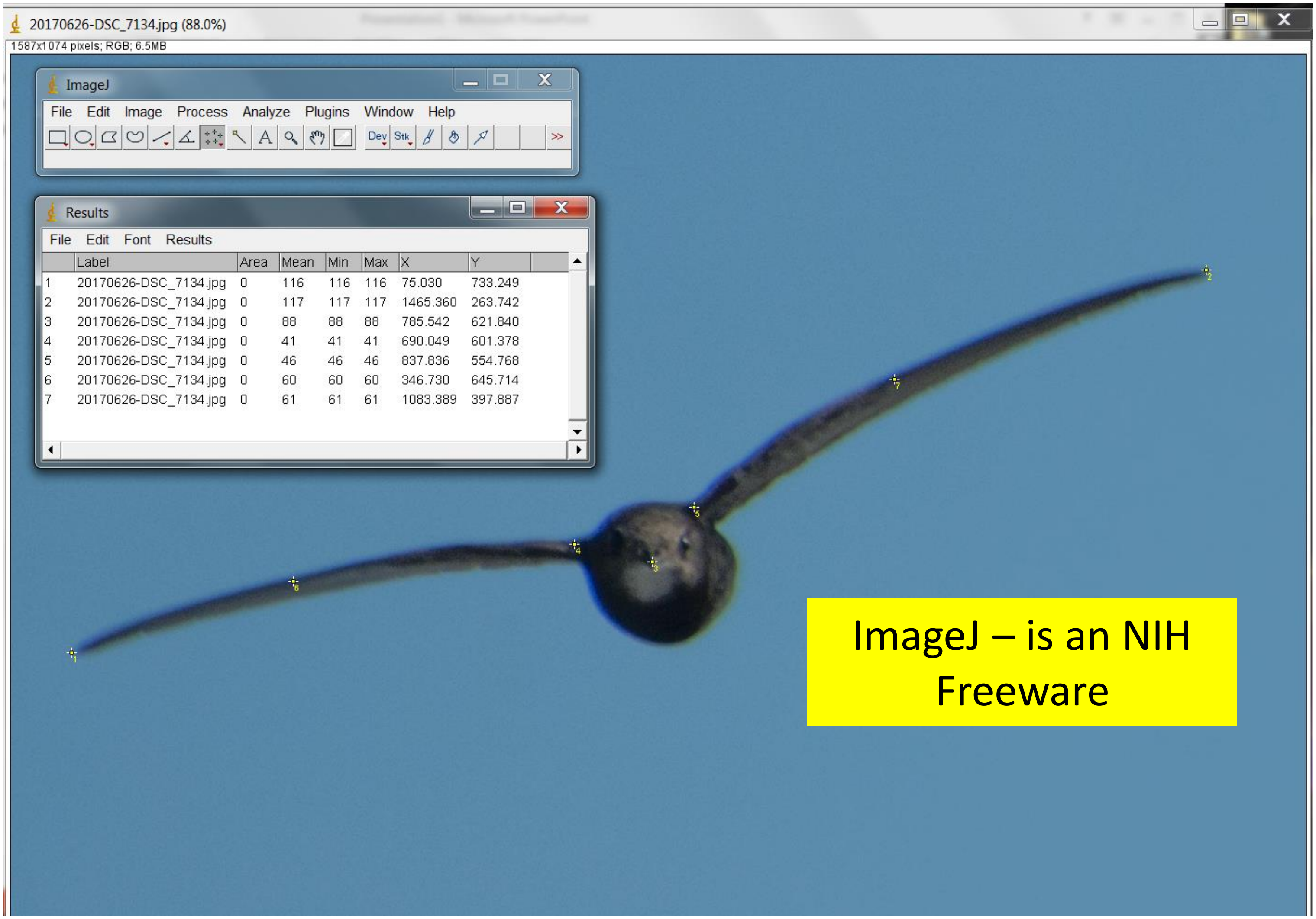
RAW Format & Editing

Great Egret (*Ardea alba*) St. Marks NWR, Florida
Nikon D300s 300 mm x1.7 f/4.8 Lens, ISO 200 Shutter 1/640

A great deal of 'science'/effort can go into editing RAW format. Usually I do just the minimum by cropping (***digital enlargement***), adjusting the color temperature to 5000 and slightly increasing the contrast. I use *Adobe Lightroom* but the pros generally use *Adobe Photoshop.*

A mistake that can not be fixed is to **over expose**. Check the color histograms when 'chimping' to make sure there is no saturation. If needed, change the EV setting for a faster shutter speed.

Software to Measure Pictures



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2	20170626-DSC_7134.jpg	0	117	117	117	1465.360	263.742
3	20170626-DSC_7134.jpg	0	88	88	88	785.542	621.840
4	20170626-DSC_7134.jpg	0	41	41	41	690.049	601.378
5	20170626-DSC_7134.jpg	0	46	46	46	837.836	554.768
6	20170626-DSC_7134.jpg	0	60	60	60	346.730	645.714
7	20170626-DSC_7134.jpg	0	61	61	61	1083.389	397.887

ImageJ – is an NIH Freeware

Photographing Day and Night

Daytime: 300 mm x 1.7
f/4.8, shutter 1/400 s,
ISO 400

Frogmouth – Queensland, Australia
Night photo: 300 mm f/2.8, shutter 1/160 s,
ISO 3200 illuminated with flashlight

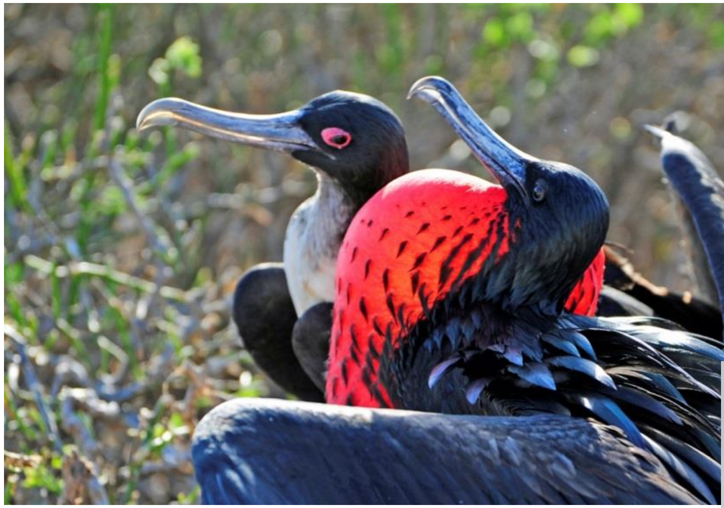
Learning how to Photograph birds in flight

Good practice game: airplanes fly in predictable trajectories and at relatively slow angular speeds

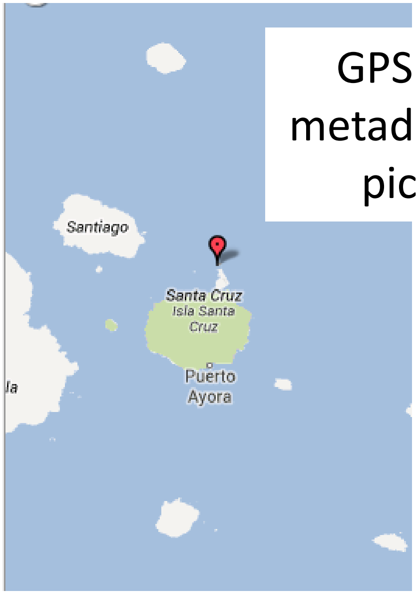
Elliot’s Storm Petrel - Galapagos

Nikon D700, 300 x 1.7 mm f/4.8, 1/1250 s, ISO 800, Matrix metering, Aperture Priority

Galapagos Frigate Birds



Great Frigatebirds
(*Fregata minor ridgwayi*)
Nikon D700, 300 mm f/5.6,
1/2500s, ISO 250
Plenty of light on the equator

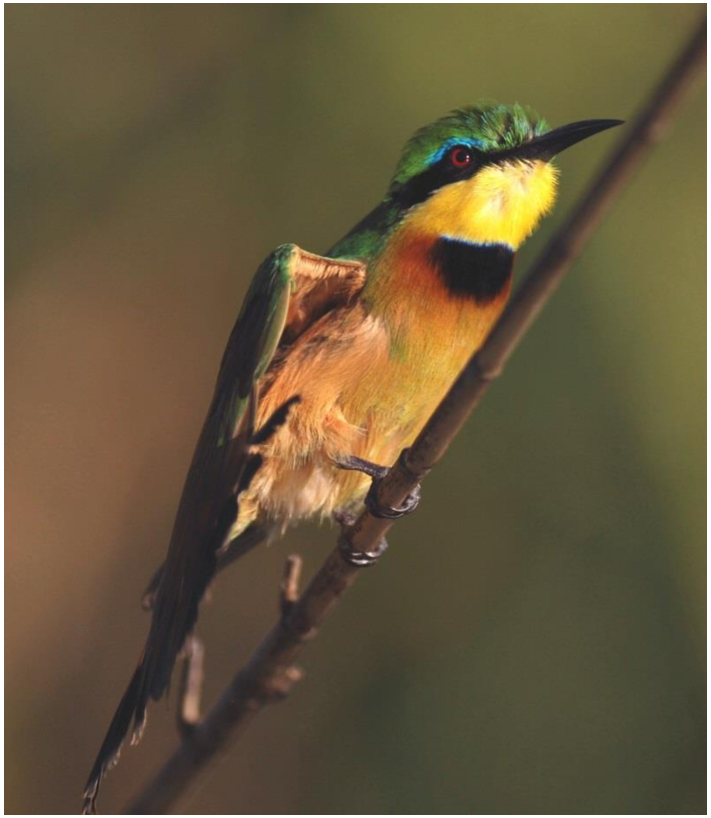


GPS Tag written into metadata tells where the picture was taken

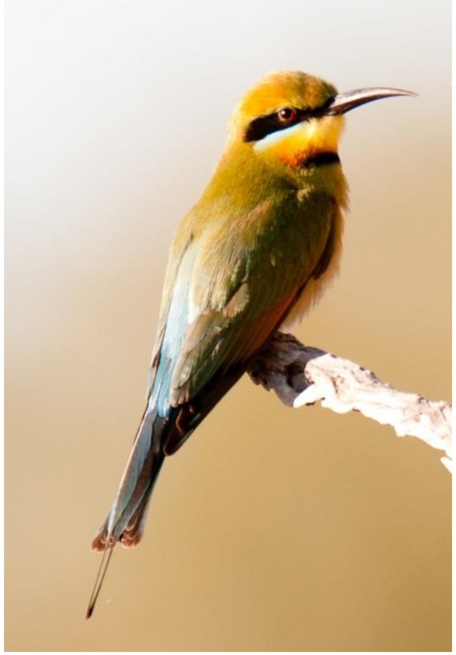
Bee-eaters – Genus *Merops*

Some Genera (Genuses) can be found throughout the world

European Bee-eater –
Penthaz, Switzerland
(Merops apiaster)

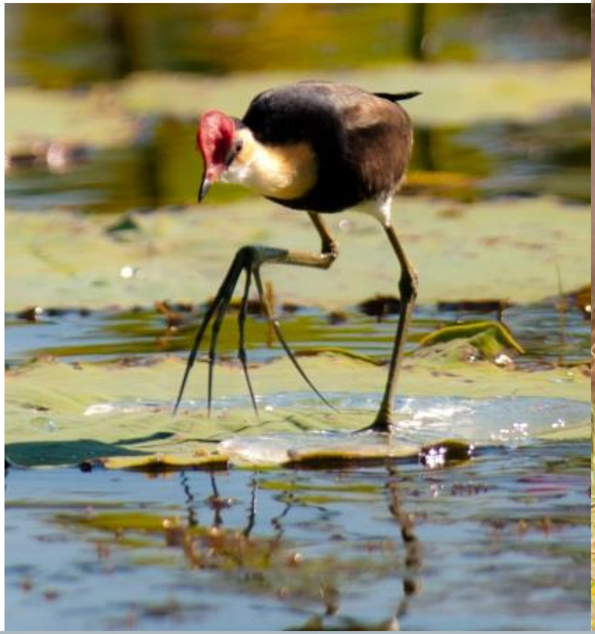


Little Bee-eater –
Okavanga Delta, Botswana
(Merops pusillus)



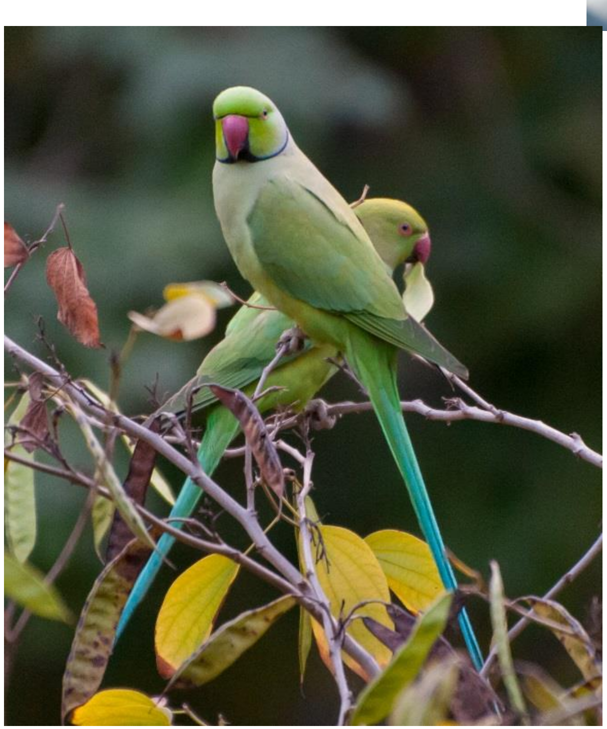
Rainbow Bee-eater –
Northern Territory,
Australia
(Merops ornatus)

Australian Birds – Queensland & NT



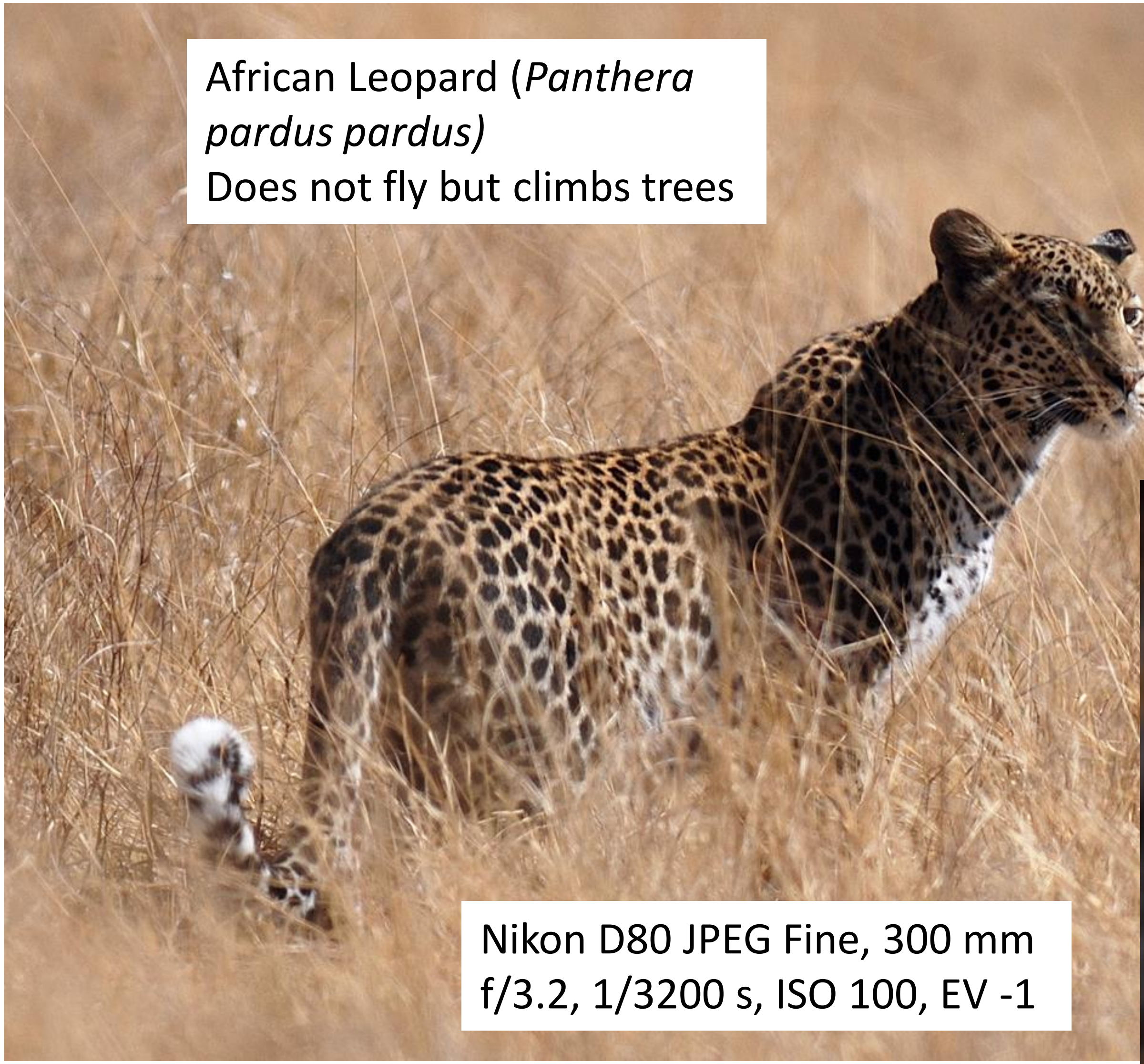
CW: Comb-crested Jacana, White-necked Heron, Black-necked stork, Palm Cockatoo, Royal Spoonbill

India Montage



CW: Peacock, Demoiselle Crane, Hoopoe, Red-billed Leiothrix, Egyptian Vulture, Rose-ringed Parakeet

Okavango Delta - Botswana



African Leopard (*Panthera pardus pardus)*
Does not fly but climbs trees

Nikon D80 JPEG Fine, 300 mm
f/3.2, 1/3200 s, ISO 100, EV -1

Malachite Kingfisher

Lilac-breasted Roller

Local Birds

Marsh wren – Concord, White throated sparrow – Mt. Auburn, Greater Yellow legs – Parker River

Local Birds

Northern Gannet – LI Sound, Redwing Blackbird – Concord, MA, Osprey – Concord, MA – note fish

Hummingbirds

Anna's HB (m) (*Calypte anna*), Palo Alto, CA

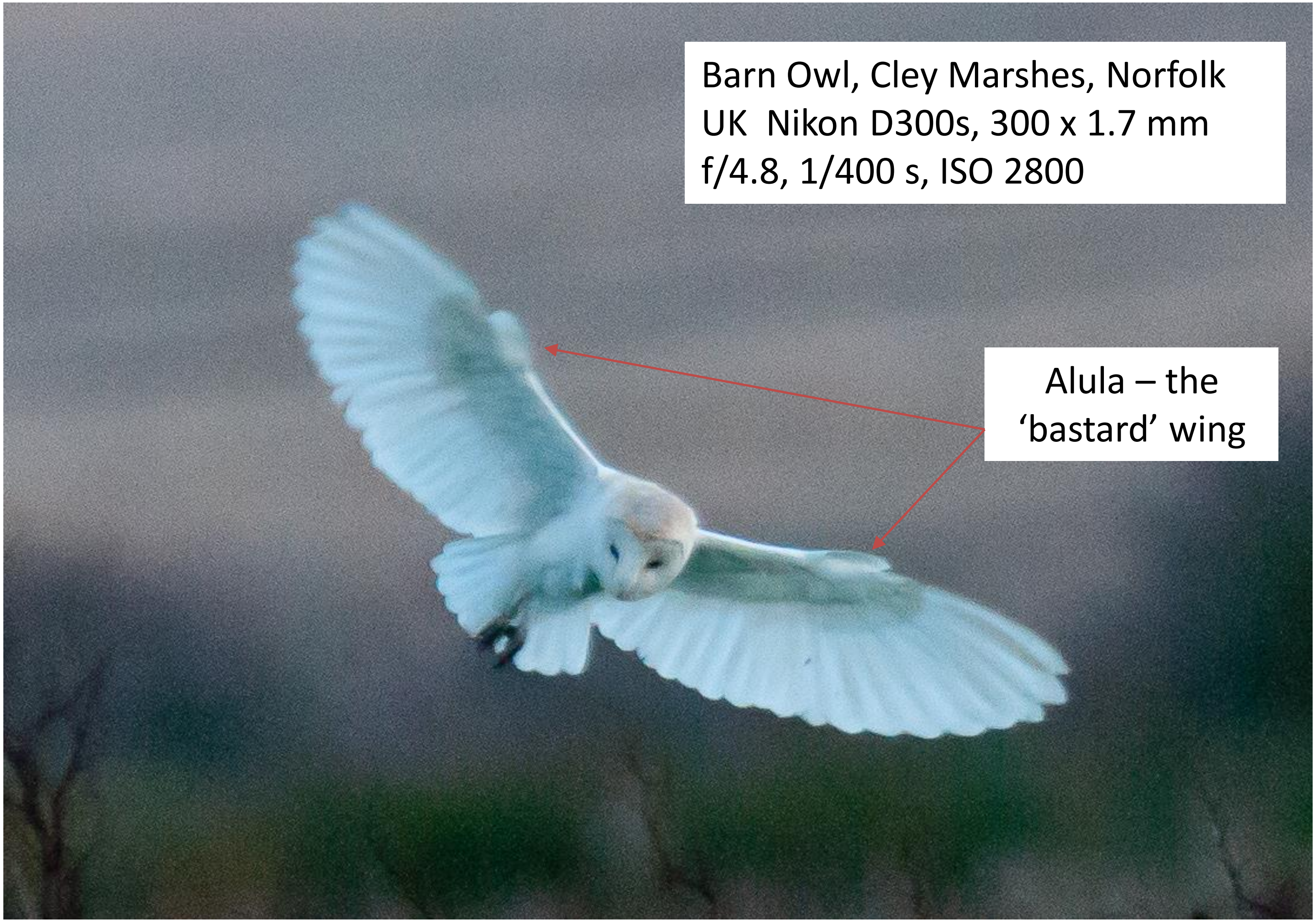
Ruby-throated HB (m) (*Archilochus colubris*), Ithaca, NY

Rufus HB (f) (*Selasphorus rufus*), Sisters, OR

Ruby-throated HB (f) (*Archilochus colubris*), Lexington, MA
300 mm f/8, 1/2500 s, ISO 1000 SB-700 Flash

Hovering accomplished by wrist rotation to generate lift on the wing upstroke. The camber of the wing is reversed ensuring efficient lift.

Limit @ Low Light



Barn Owl, Cley Marshes, Norfolk UK Nikon D300s, 300 x 1.7 mm f/4.8, 1/400 s, ISO 2800

Alula – the 'bastard' wing

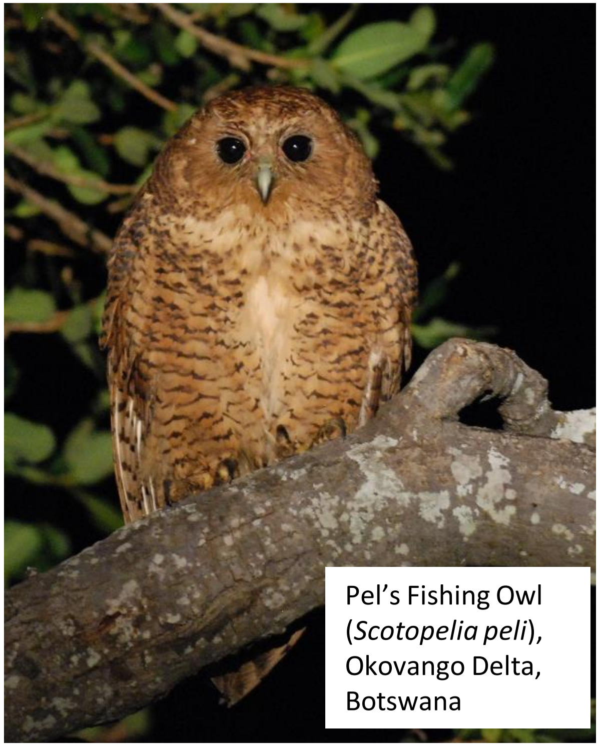
Owls

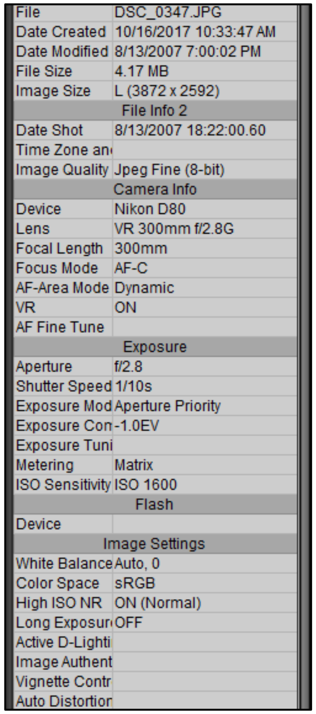
- Daytime when they are sleepy
- Nighttime when they are resting


Spotted Owlet (*Athene brama*), Ranthambor Park, India


Great Horned Owl (*Bubo virginianus*), St. George Island, FL


Verreaux's Eagle Owl (*Bubo lacteus*) Okavango Delta, Botswana


Pel's Fishing Owl (*Scotopelia peli*), Okovango Delta, Botswana



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Camera Info	
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Lens	VR 300mm f/2.8G
Focal Length	300mm
Focus Mode	AF-C
AF-Area Mode	Dynamic
VR	ON
AF Fine Tune	
Exposure	
Aperture	f/2.8
Shutter Speed	1/10s
Exposure Mod	Aperture Priority
Exposure Con	-1.0EV
Exposure Tuni	
Metering	Matrix
ISO Sensitivity	ISO 1600
Flash	
Device	
Image Settings	
White Balance	Auto, 0
Color Space	sRGB
High ISO NR	ON (Normal)
Long Exposur	OFF
Active D-Lighti	
Image Authent	
Vignette Contr	
Auto Distortion	

Aerial insectivores: House Martins

These are some of the hardest birds to photograph since they fly fast and feed on the wing

Nikon D300s, 300 x 1.7 mm f/4.8, 1/4000 s, ISO 500, Spot Meter (Thoiry, France)

Swifts (Apus apus) in Flight

Note the thin wing and large eye. Head always turned to be parallel to the ground. Wings frequently swept back.

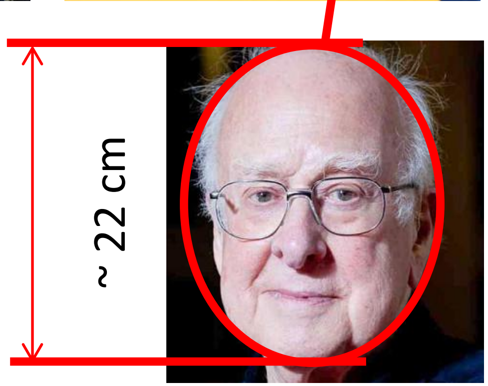
Camera: Nikon D700
ISO: 400
Lens: 300 mm f/2.8
Shutter: 1/6400 s in burst mode
Thoiry, France

How to Measure Bird Flight Speeds

- While waiting for a train to Edinburgh I realized that by measuring the ratio of apparent size to true size I could determine the distance of the object
-

Train V ≈ 37 m/s ≈ 133 km/hr

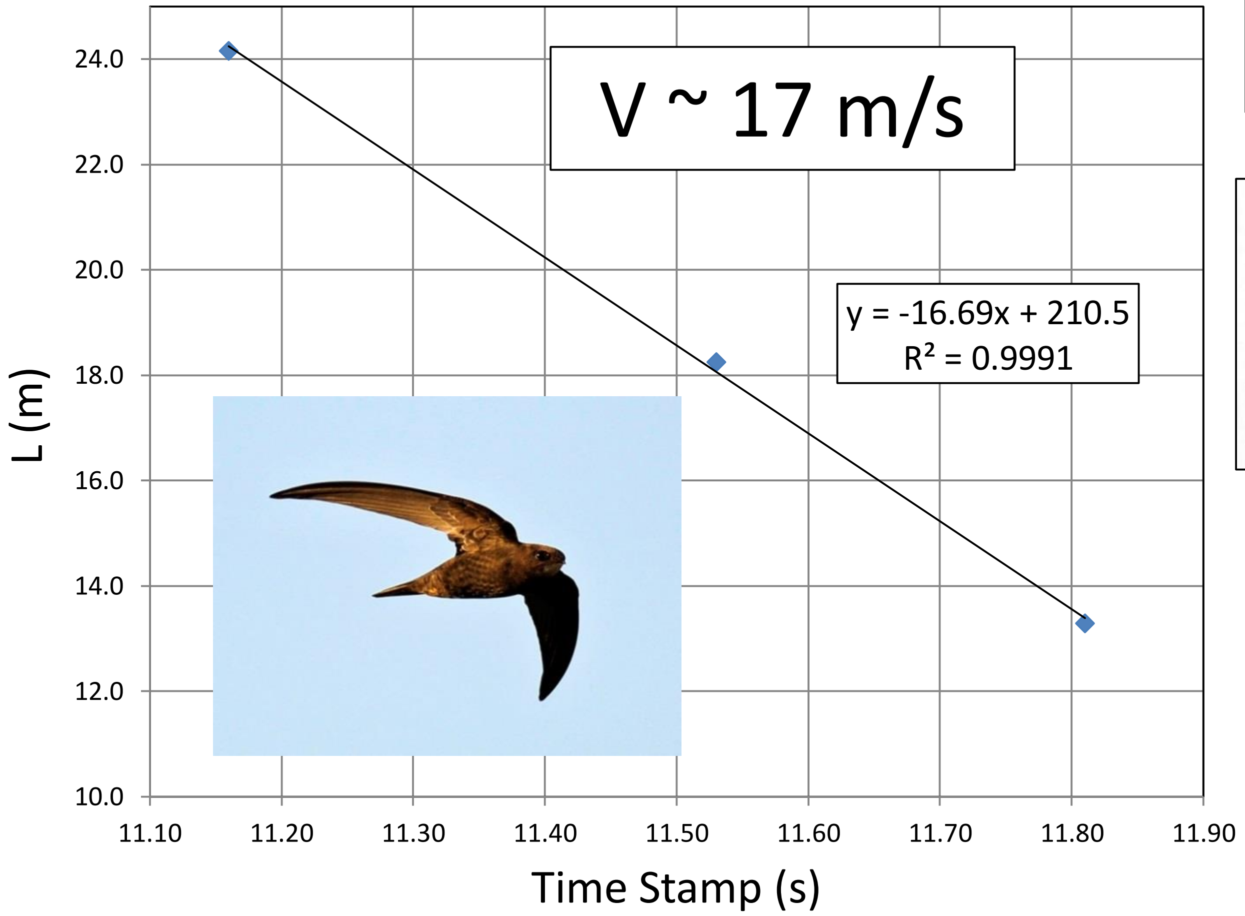
- Assume bird has 'standard' wingspan
- Calibrate camera-lens combinations
  - Relative size vs. distance to determine distance
  - Time stamp of photo to 1/100 second
  - Several cross checks – including car & Airbus 319
- Errors from wing size variation & configuration and cosθ



'Train Engineer'
Scientific Name
Peter Higgs

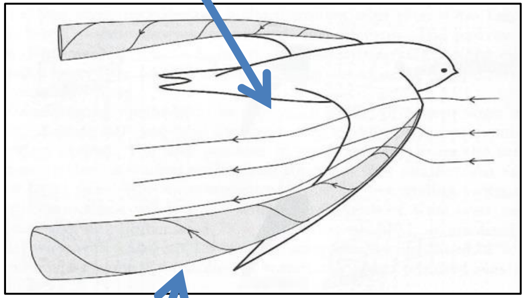
Flight speed of Swift (Apus apus)

Wing span: b = 38 to 40 cm



V ~ 17 m/s

Conventional lift down-wash on arm-wing



Conical Leading Edge Vortex (LEV) on hand-wing contributes to lift

From: Avian Flight, John J. Videler
Oxford University Press

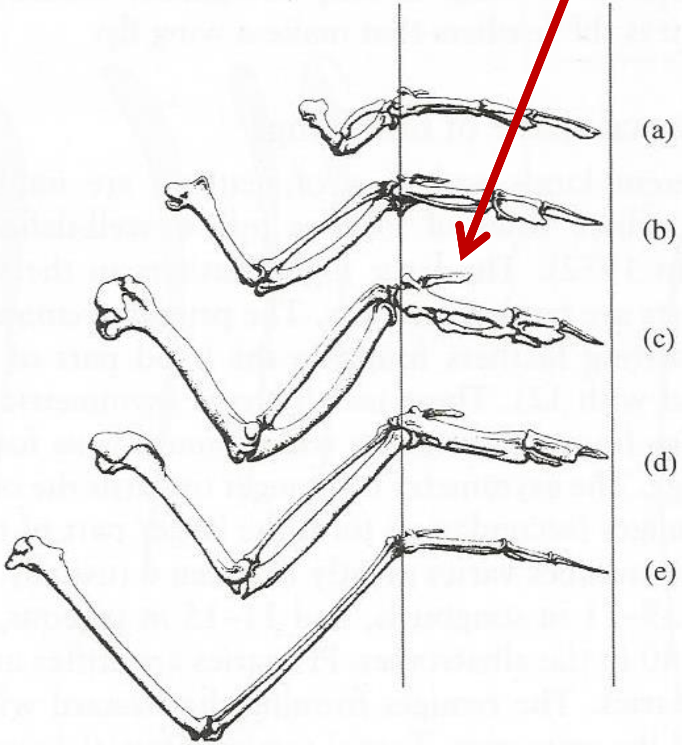
Bird Adaptions

- Under ‘evolutionary pressure’ bird physiology shows many remarkable adaptations
  - An efficient 2-phase respiratory system
  - Very high endurance – efficient consumption of stored fat
  - Optimized wing designs for different ecological niches
- Wings
  - Oceanic birds – high aspect ratio $AR=b^2/A=b/L$, $A = bL$
    - Efficient generation of lift with lower lift-induced drag from wing tip vortices
  - Raptor & Soaring – broader chord length & lower aspect ratio
    - Less efficient generation of lift but good for taking off, low airspeed, heavy lifting and maneuverability
  - Flexible wing
    - Lift & Propulsion through Flapping and Burning of Sugar & Fat

Bird Wing Bones

From: <u>Avian Flight</u>, John J. Videler
Oxford University Press

“Thumb”: Alula (“Bastard Wing”)



Hummingbird & Swifts – all “wrist”

Albatross – “wrist” relatively small

Fig. 2.2 Relative dimensions of the skeleton of the forelimb of five species: (a) Calliope hummingbird; (b) Rock dove; (c) Blue grouse; (d) European starling; (e) Laysan albatross. The skeletons of the hand are drawn at the same length (from Dial (1992)).

Large Aspect Ratio Wings

Black Skimmer (*Rynchops niger*) Biloxi, MS   AR ≈ 10

Common Terns (*Sterna hirundo*) in nuptial flight, Teppes de Verbois, Switzerland, AR ≈ 8

Predator & Soaring Bird Wings

Northern Harrier (Circus cyaneus) Duck under tow - Delaware

Buzzard *(Buteo buteo)* France

Long-Eared Owl *(Asio otus*), Switzerland

Lower AR – Heavy Lifting with Maneuverability

Turkey Vulture (*Cathartes aura*) Delaware

Brown Pelican (*Pelecanus occidentalis*), Texas

Darwin's Finches


Isla Espanola

Isla Santa Cruz



Isla Espanola


Isla San Cristobal


Isla Espanola


Isla Espanola


Isla Espanola


Isla San Cristobal

<u>Shape of Beak</u> a profound window into natural selection

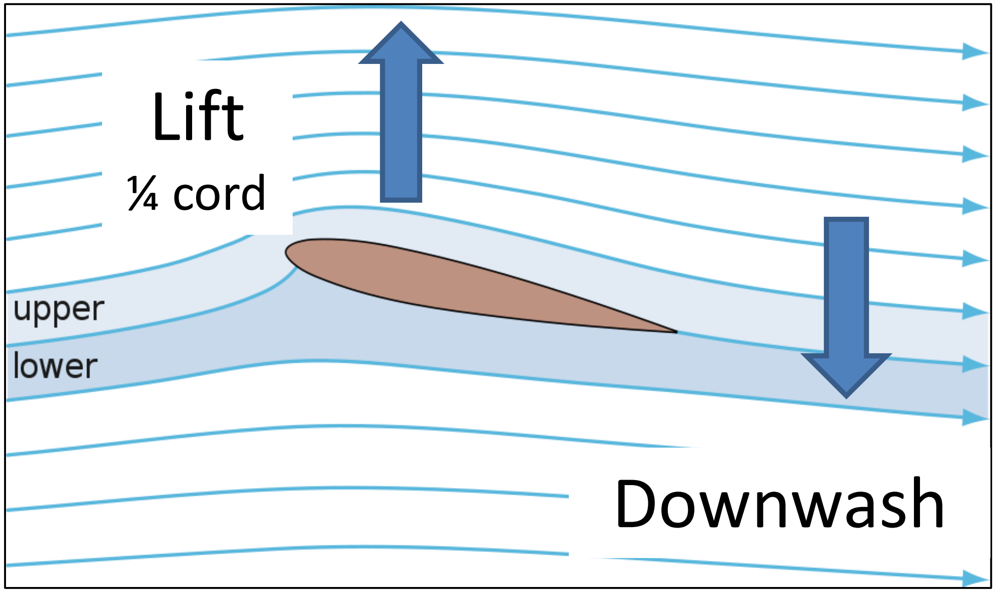

Isla Santa Cruz


Isla Santa Cruz


Isla Santa Cruz


Isla Santa Cruz

Lift

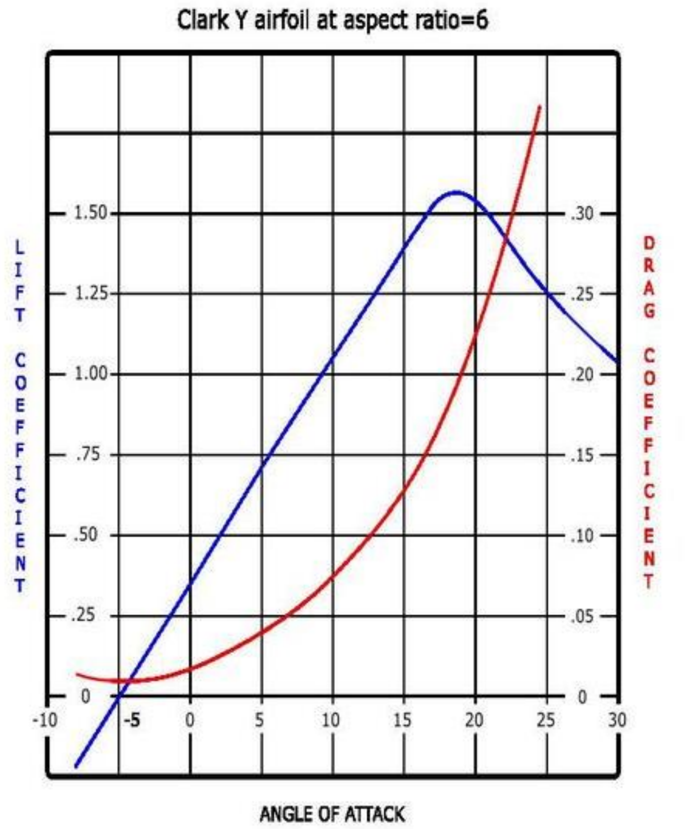


Wing pushes air downward – wing reacts upward comprising the lift

$$L = Cl \times \frac{\rho \times V^2}{2} \times A$$

Lift = coefficient x $\frac{\text{density x velocity squared}}{\text{two}}$ x wing area

Coefficient Cl contains all the complex dependencies and is usually determined experimentally.


Clark Y airfoil at aspect ratio=6

Lindberg’s Spirit of St. Louis used the Clark Y airfoil

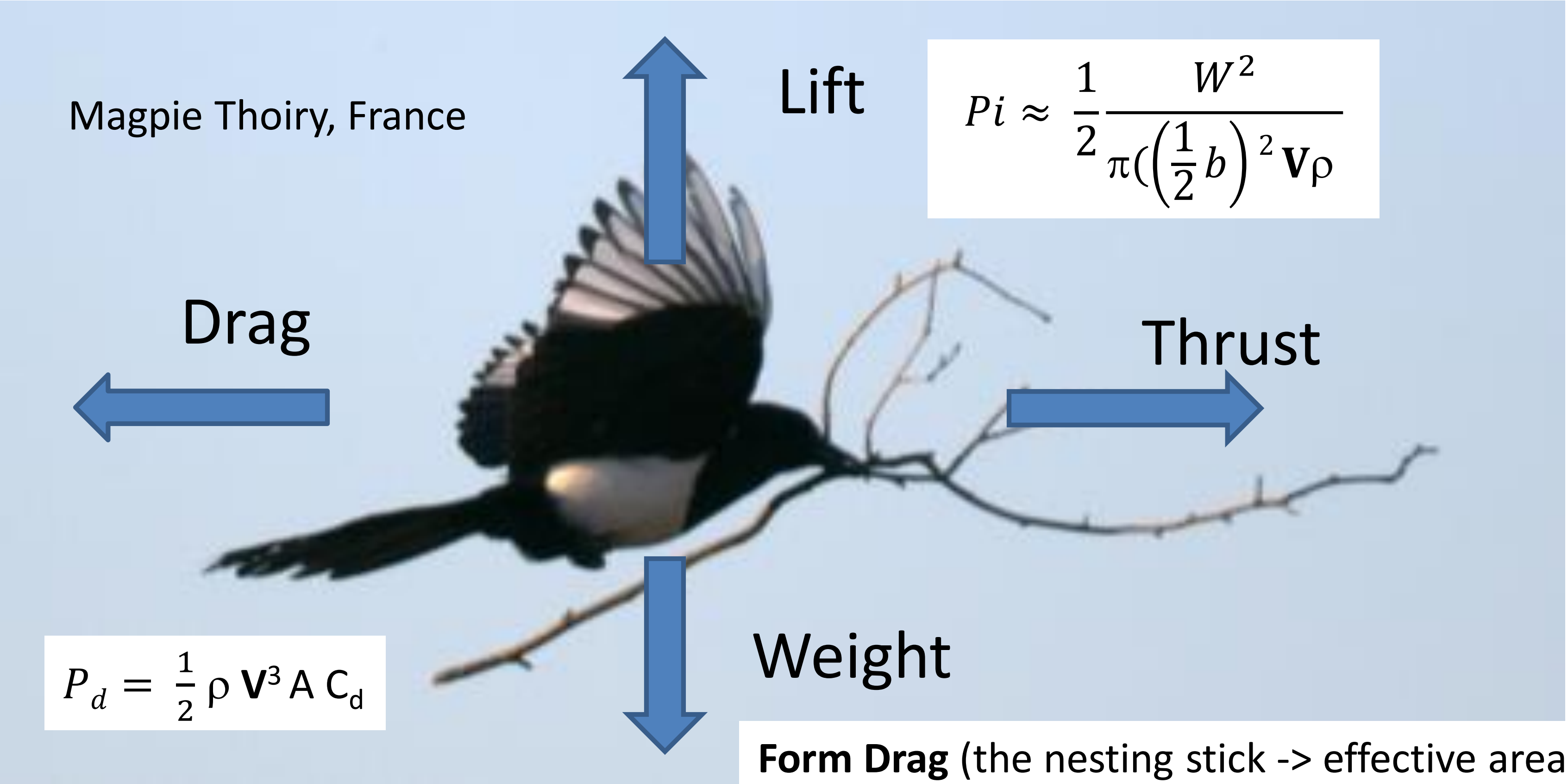
Very roughly Cl ≈ $2\pi\,\alpha$

Bird Aerodynamics

- Low Reynolds numbers regime
  - Viscous forces play an important part
  - Modest camber yields better L/D
- Soaring & High AR wings
  - Roughly similar to fixed airfoils
- Some smaller birds and insects utilize Leading Edge Vortex (LEV) to provide lift
  - The Swift uses this trick
- Flexible wings and flapping
  - Wing provides both Thrust and Lift, Tail provides lift at low speeds and steering for soaring birds
  - Variable deployment of arm-wing vs. hand-wing
  - There are different patterns of flapping: Wingtips of Albatross in an oval, Wingtips of a pigeon in a figure-8
- It’s a good thing that aerodynamics engineers abandoned the bird model because bird flight is quite complicated

Forces on a Bird: Lift, Weight, Drag, Thrust

Induced power (associated with lift) with wingspan b and speed **V** and air density ρ.
It is the penalty to pay for the privilege of flight. W = weight = L = lift for steady flight



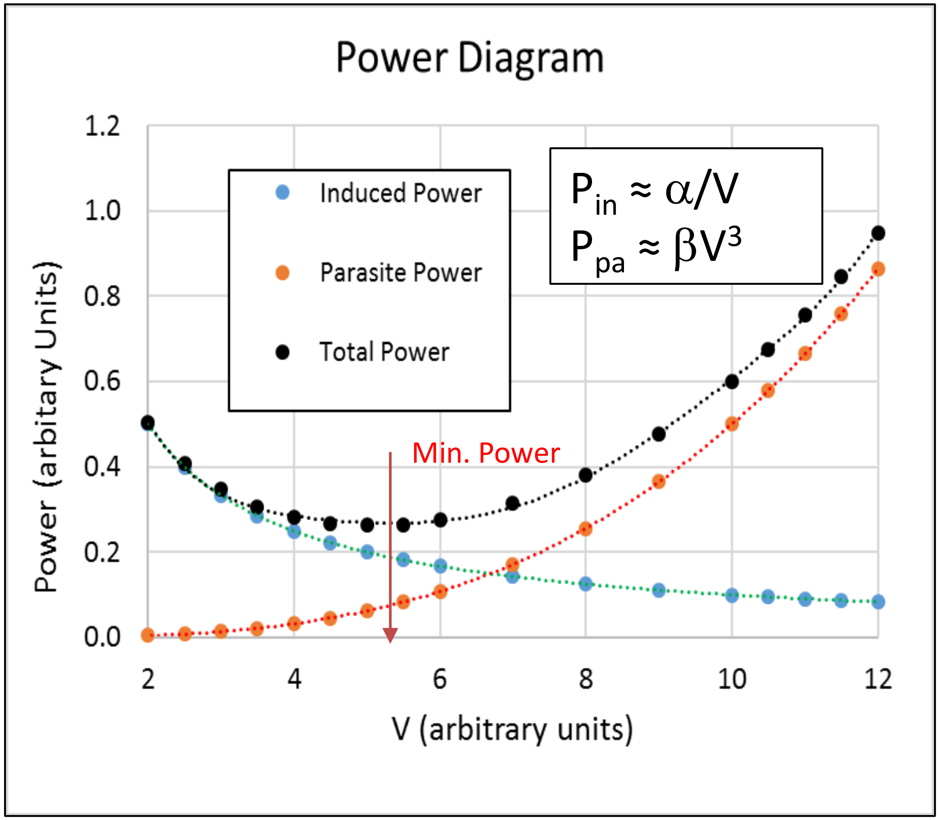
Magpie Thoiry, France

$$Pi \approx \frac{1}{2}\frac{W^2}{\pi(\left(\frac{1}{2}b\right)^2 \mathbf{V}\rho}$$

$$P_d = \frac{1}{2}\rho\, \mathbf{V}^3 A\, C_d$$

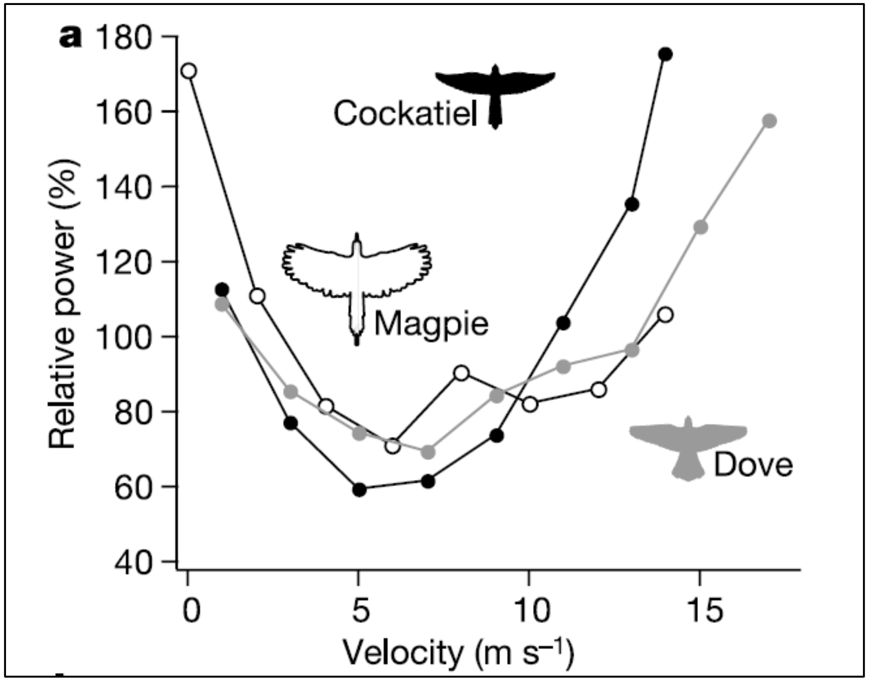
Form Drag (the nesting stick -> effective area A), C_d is the coefficient of drag, ρ is air density.

Power Consumption – Flying Efficiently



$P_{in} \approx \alpha/V$

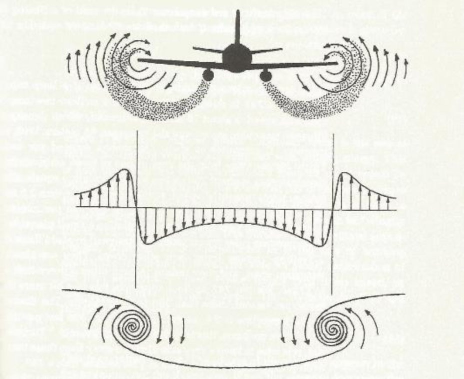
$P_{pa} \approx \beta V^3$



“Comparative power curves in bird flight”, B. W. Tobalske, et al., Nature February 2003

Formation Flying & Wingtip Vortices

Geese in formation-flying may use wingtip vortices to reduce effort



H. Tennekes, The Simple Science of Flight, MIT Press, 2009

Canada Goose leading Greater White-fronted Geese, Lodi, CA
Nikon D80
AF-S VR Zoom Nikkor 70-300 mm @ 300 mm f/5.6, ISO 200, 1/1000 s

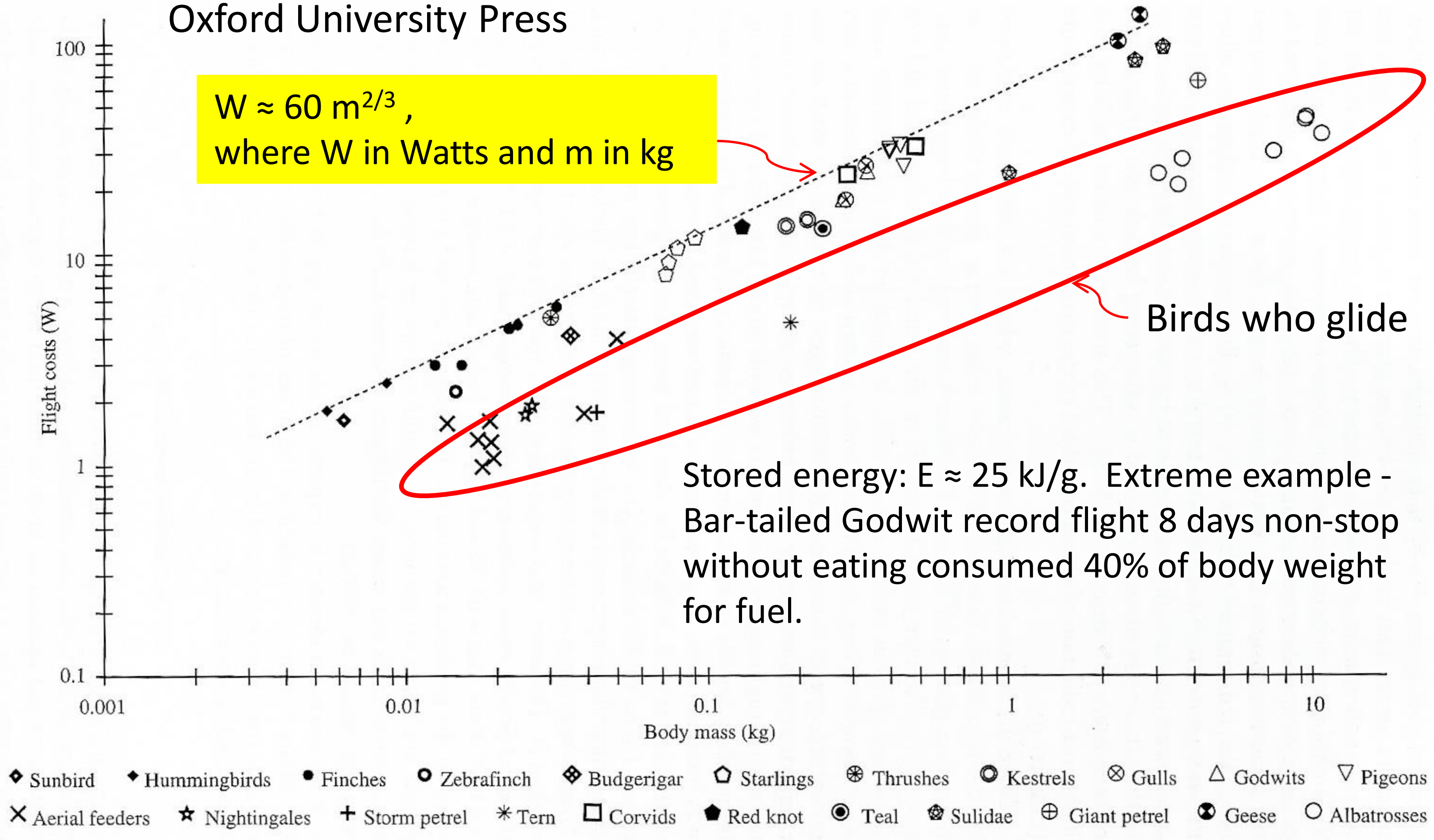
Takeoffs

Mute Swans – *Cygnus olor* (Teppes de Verbois, Switzerland) require a lot of paddling and flapping to become airborne. **Weight ~ 12 kg**

Lift over water boosted by the **ground effect: ΔL = G = 2L/AR**. It is speculated that Howard Hughes' *Spruce goose* was able to just fly by the ground effect.

Cruising Flight Power vs. Weight

From: <u>Avian Flight</u>, John J. Videler
Oxford University Press

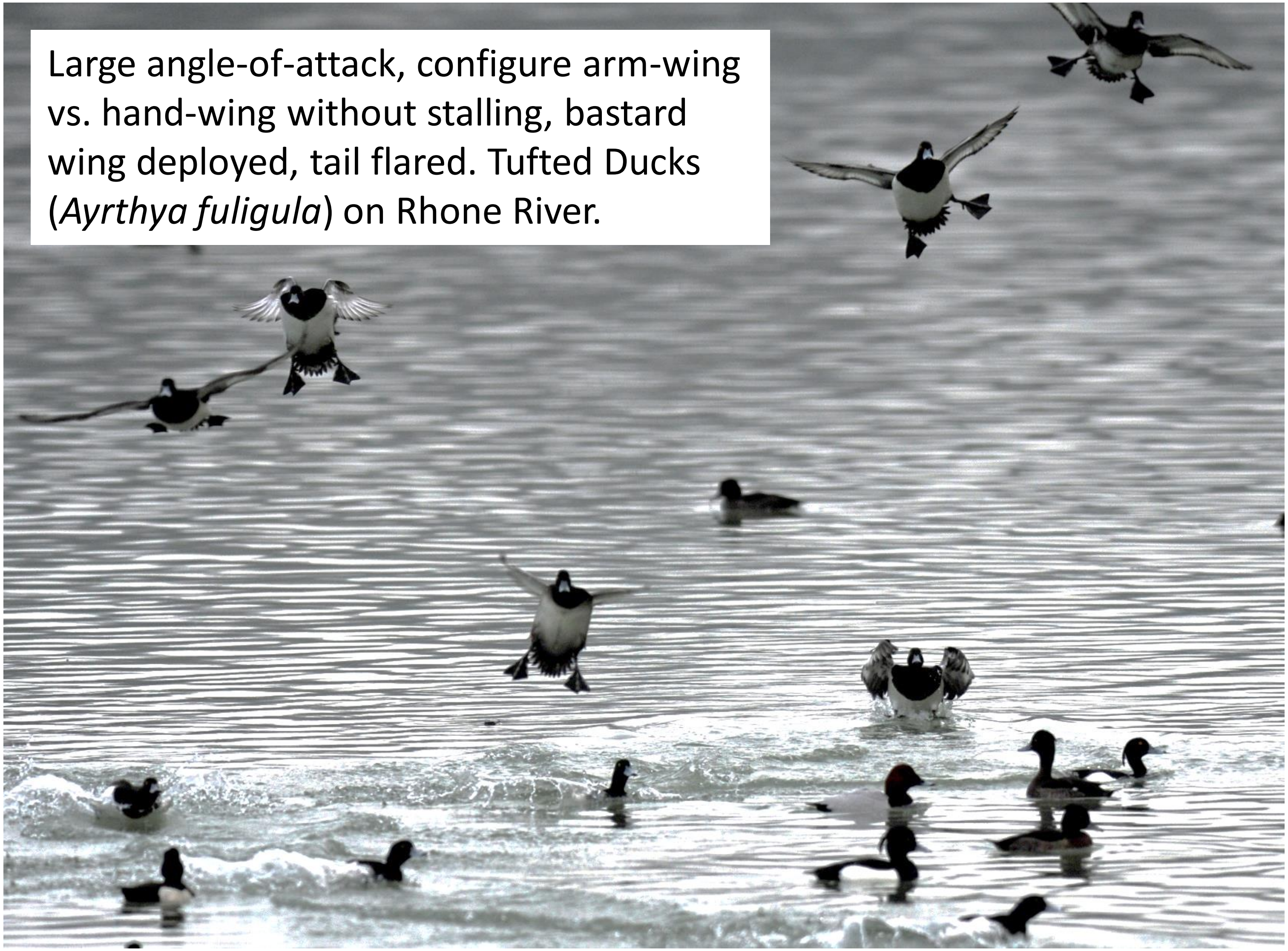


$W \approx 60\, m^{2/3}$,
where W in Watts and m in kg

Birds who glide

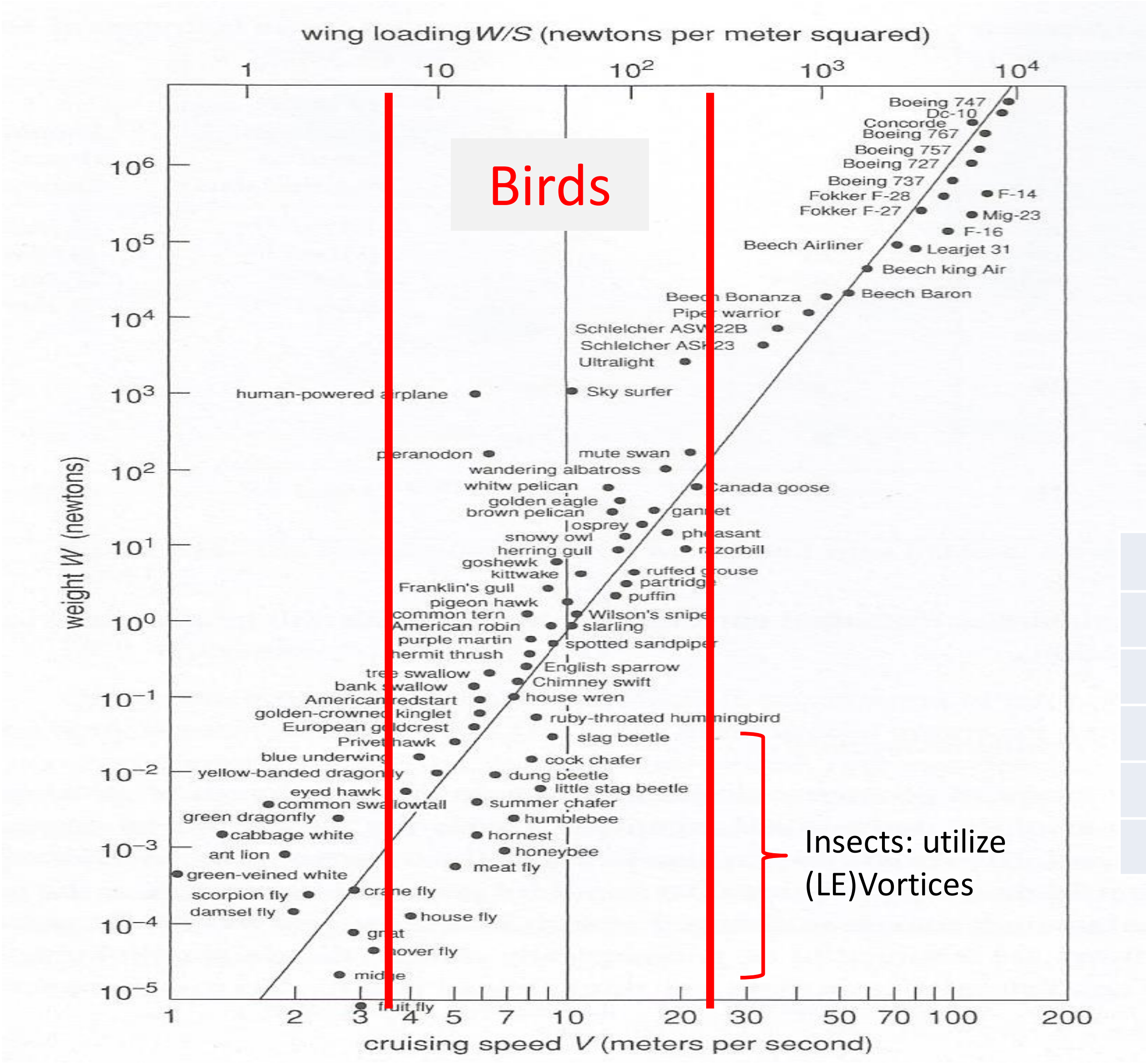
Stored energy: $E \approx 25$ kJ/g. Extreme example - Bar-tailed Godwit record flight 8 days non-stop without eating consumed 40% of body weight for fuel.

Landings



Large angle-of-attack, configure arm-wing vs. hand-wing without stalling, bastard wing deployed, tail flared. Tufted Ducks (*Ayrthya fuligula*) on Rhone River.

Almost Everything that Flies



Birds

Insects: utilize (LE)Vortices

Adopted from Tennekes in Wei Shyy et. al, <u>Aerodynamics of Low Reynolds Number Flyers</u>

ISBN 978-0-521-20401-9

My measurements

Bird	Speed (m/s)	km/hr
Swift	16.7	60.1
Cormorant	17.7	63.7
Canada Goose	8.1	29.2
Mallard	17.1	61.6
Airbus 319	57	205.2

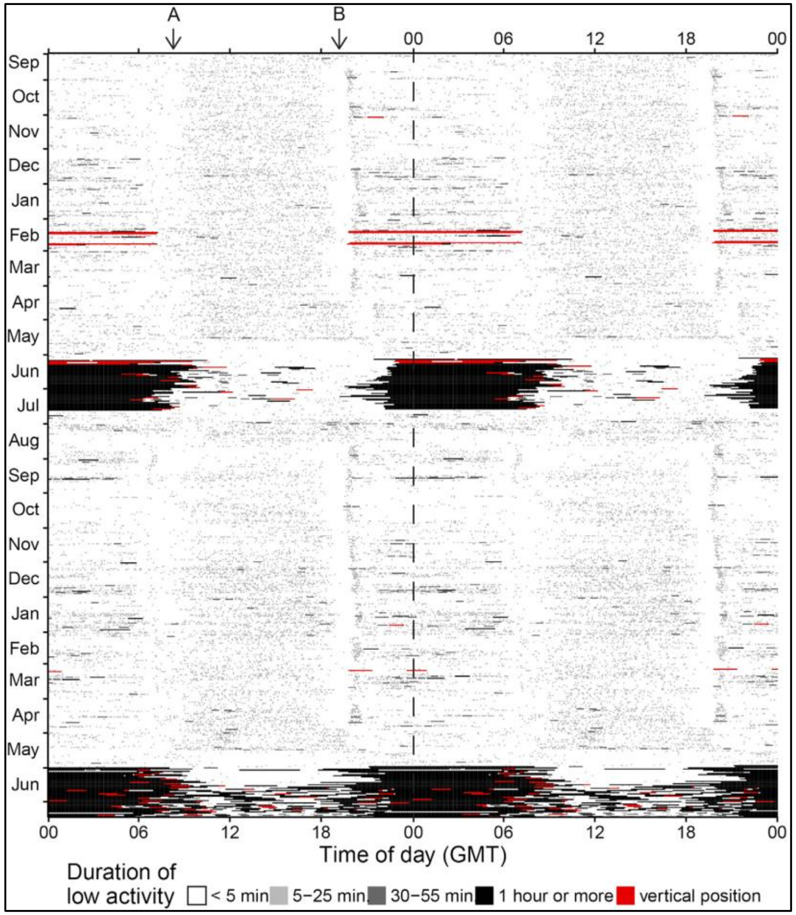
Most measurements of bird flight speeds are made with radar.

Swift (Apus apus) – The ‘ultimate’ land bird

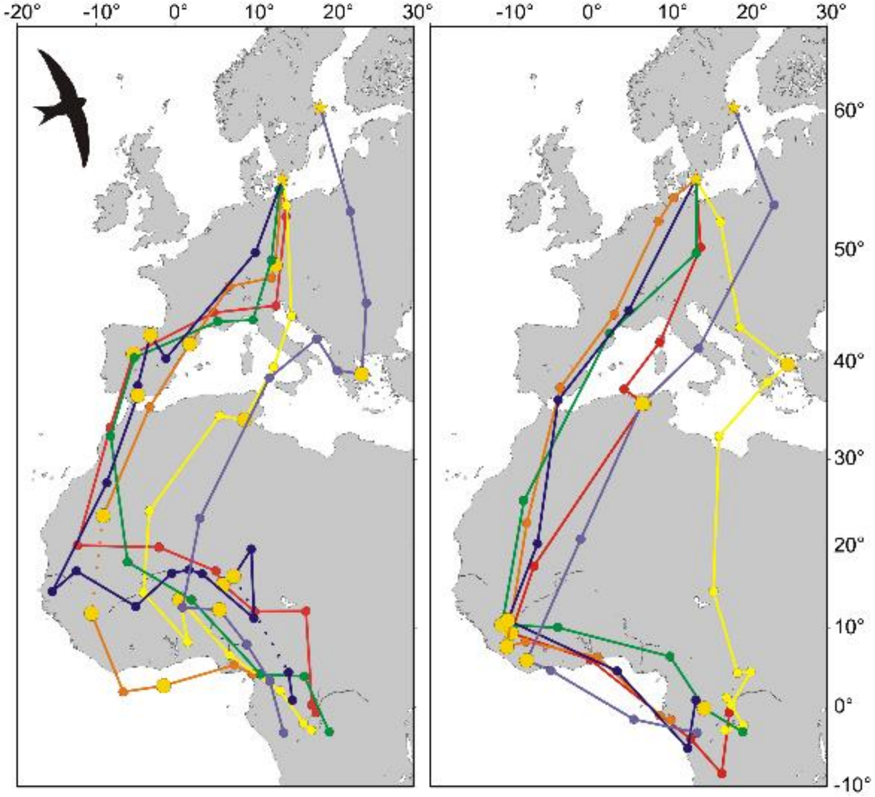
- Extreme adaptation for flying
  - Once fledged it stays airborne for ≤ 10 months
    - Scientific name “Apus apus” means ‘without legs’
      - Can only perch on the side of a tree or building
      - Has extreme difficulty taking off from the ground
  - Performs all of life’s functions on the wing except for nesting & raising chicks
    - Sleeps in the air – often 1,000 to 2,200 m @ 8 m/s
  - Can fly as high as 3,500 m & lives within a colony
  - Flies over 500 km/day in search of insect food @ 17 m/s
  - Migrates from Europe to southern Africa
  - Lives up to 21 years

Apus apus

- Migration between Europe and sub-Saharan Africa



A. Hedenstrom, et al., Current Biology 26, 3066–3070, November 21, 2016



Akesson S, et al. “Migration Routes and Strategies in a Highly Aerial Migrant, the Common Swift, Apus apus, Revealed by Light-Level Geolocators”. PLoS ONE 7(7): e41195.

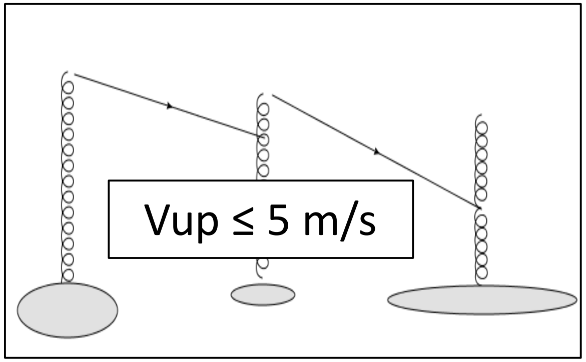
Migration by Soaring and Coasting

- European Stork (*Ciconia ciconia)*

Near the Dead Sea
03/09/2016

Storks have been badly affected by industrialization.

<u>NaturOparC</u>
<u>ex Centre de Réintroduction</u>
Route du Vin
68 150 HUNAWIHR - Alsace
07/09/2009



These are thermals – not gluons

Using thermals to migrate requires a land-based route – either the Levant or Gibraltar

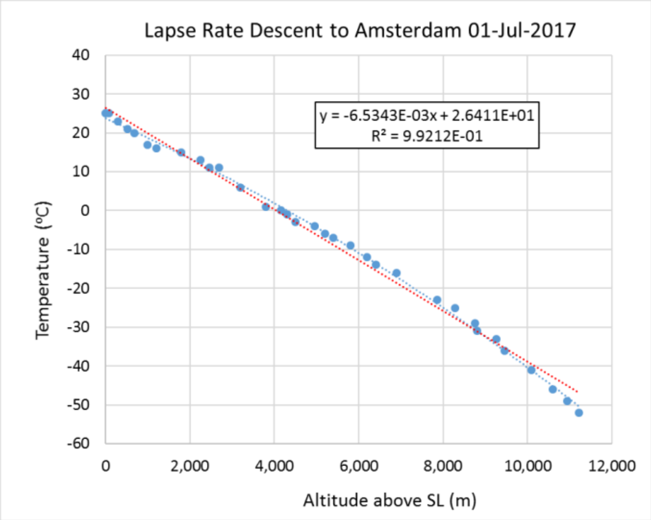
Flying Upside Down

- Istanbul Tumbler Pigeons (*Columba livia domestica)*

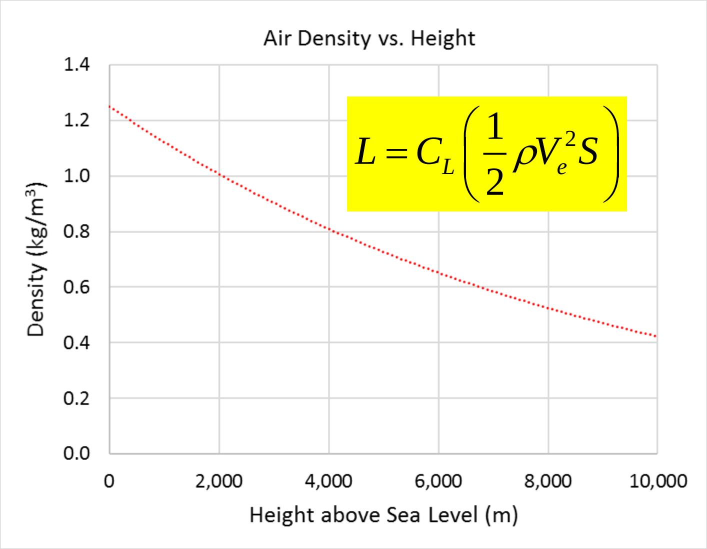
Flying High

- Bar-headed Goose (*Anser indicus*)
  - Migrates over the Himalaya
  - Has to contend with lower air density and extreme cold

Chambal River, India

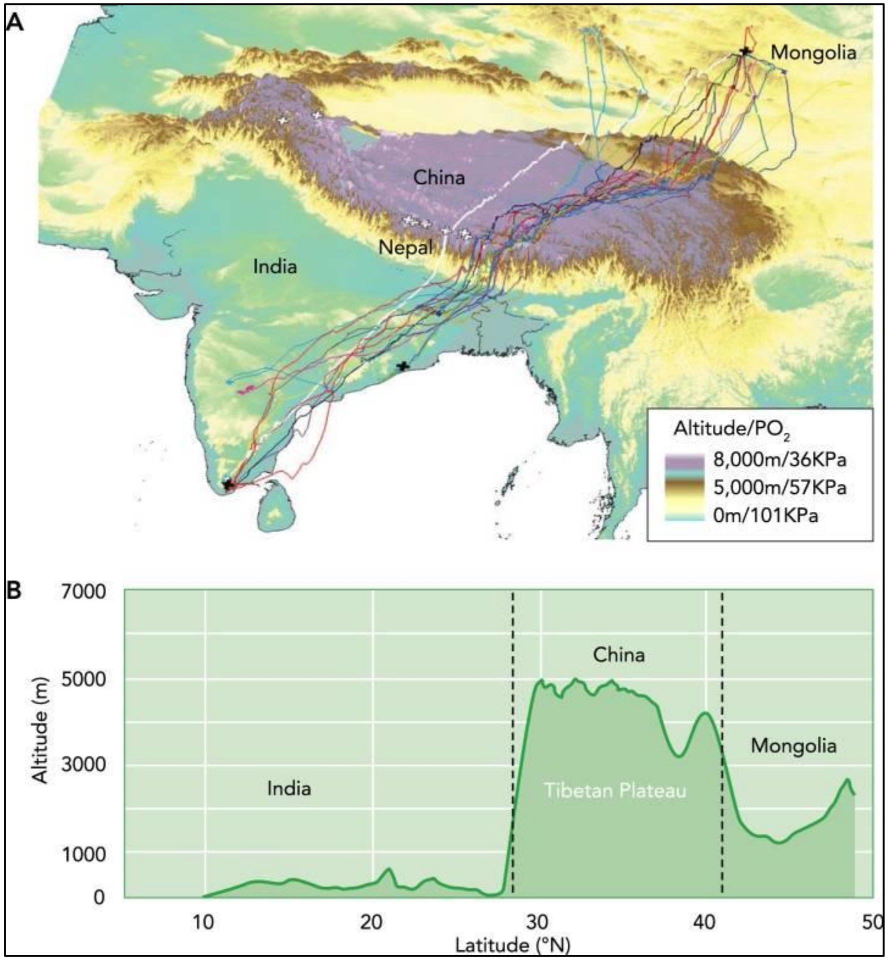


$dT/dh = (-6.5 \pm 0.1) \times 10^{-3}$ (ºC/m)



$$L = C_L \left(\frac{1}{2} \rho V_e^2 S \right)$$

Migration of Bar-headed Goose



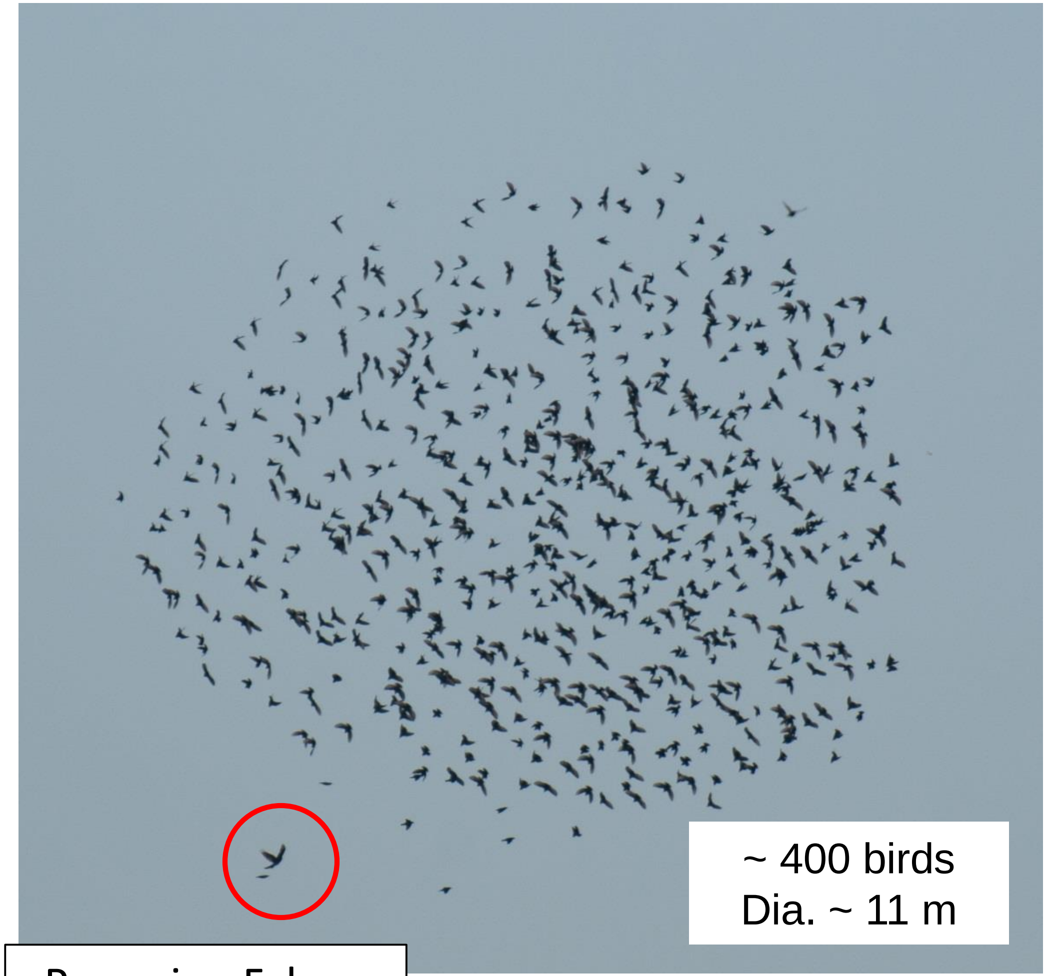
Northward 8 hr @ 1.1 km/h altitude gain
Southward 4.5 hr from the Tibetan Plateau

Migrates over the Himalayas
Flies mostly at night when winds are calm
Has hemoglobin that can especially absorb oxygen
Powerful lungs

Why this route? Perhaps evolution – a distant ancestor started this migration when the Himalayas were less tall. From USGS: $dH(t)/dt \geq 1$ cm/y → ΔH = 5 km in 500,000 years

G. R. Scott, et al. "How Bar-Headed Geese Fly Over the Himalayas", Physiology (Bethesda). 2015 Mar; 30(2): 107–115.

Murmurations of Starling Flocks



~ 400 birds
Dia. ~ 11 m

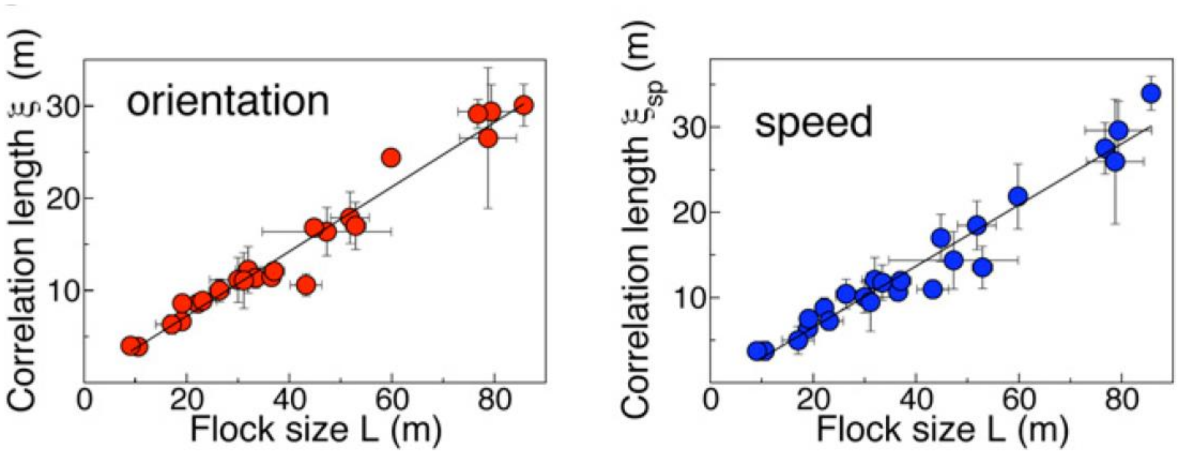
Peregrine Falcon

Starlings *(Sturnus vulgaris)* collect in large flocks - sometimes in response to predation.

Nikon D300s, 300 x 2 mm, f/5.6, 1/6400s, ISO 200, (Parker River NWR)

Murmurations - Analysis

- Movement remarkably coherent
  - Birds in flock seem to move as a 'living blob'
  - By photographing flock in stereo can analyze the motion vectors and study correlations through the flock
- Analysis has been done – a beautiful paper on starlings in Rome
  - "Scale-free correlations in starling flocks"; Andrea Cavagna, Alessio Cimarelli, Irene Giardina, Giorgio Parisi, Raffaele Santagati, Fabio Stefanini and Massimiliano Viale, US Pro. Nat'l Academy of Science (2010)
  - Developed a correlation function (average inner product of velocity fluctuations of birds separated by distance r)



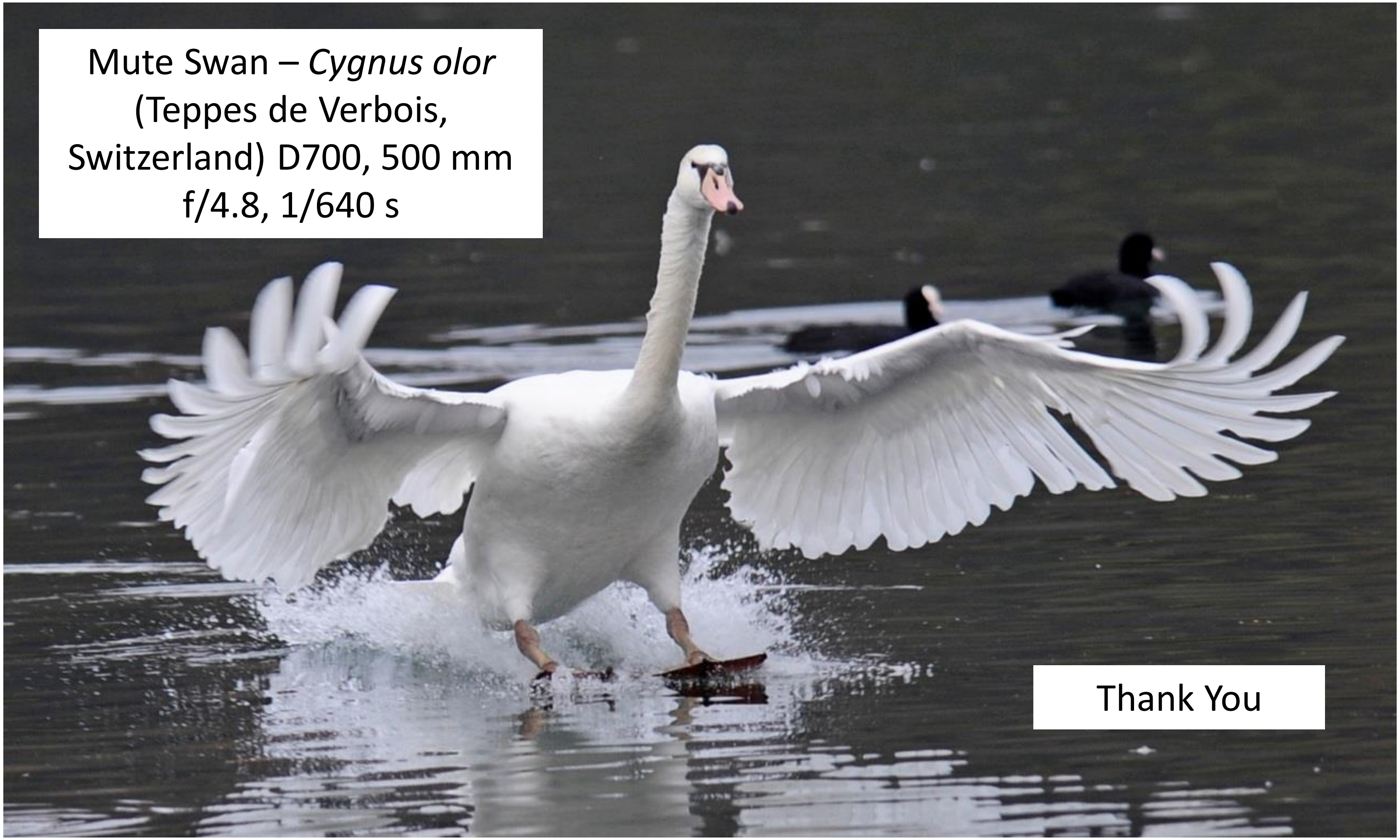
Correlation lengths of orientation and speed seem to **scale as size of flock**.

Hence there is **no intrinsic correlation length** – not 10 m or 10 birds!

Summary: “Trees, Loops, Feather Plots”

- What started as means to identify birds by taking their picture turned into an interesting look at bird behavior
  - I have >20ks of photographs of birds
    - On an ‘expedition’ I take 500 to 600 pictures per day
  - Many interesting aspects are captured in the pictures
    - Aerodynamic principles are evident (AoA, AR, Energetics)
    - Unexpected behaviors
    - Murmurations of starlings show remarkable coherence
- There are birds in every part of the world
  - They show a wide range of adaptations to environment as well as a stubborn will not to adapt, but rather some migrate extreme distances in order to maintain their diet, home territory and ecological niche.
  - There is much more to photograph and study – including some of the places already visited (Fermilab!)
- Birds & Aviation @ FNAL
  - Peter Kasper compiles a list of Birds of FNAL
    - http://www.fnal.gov/ecology/wildlife/list.shtml
  - David F. Anderson & Scott Eberhardt wrote a book: Understanding Flight

Time to Land this Flight of Fancy



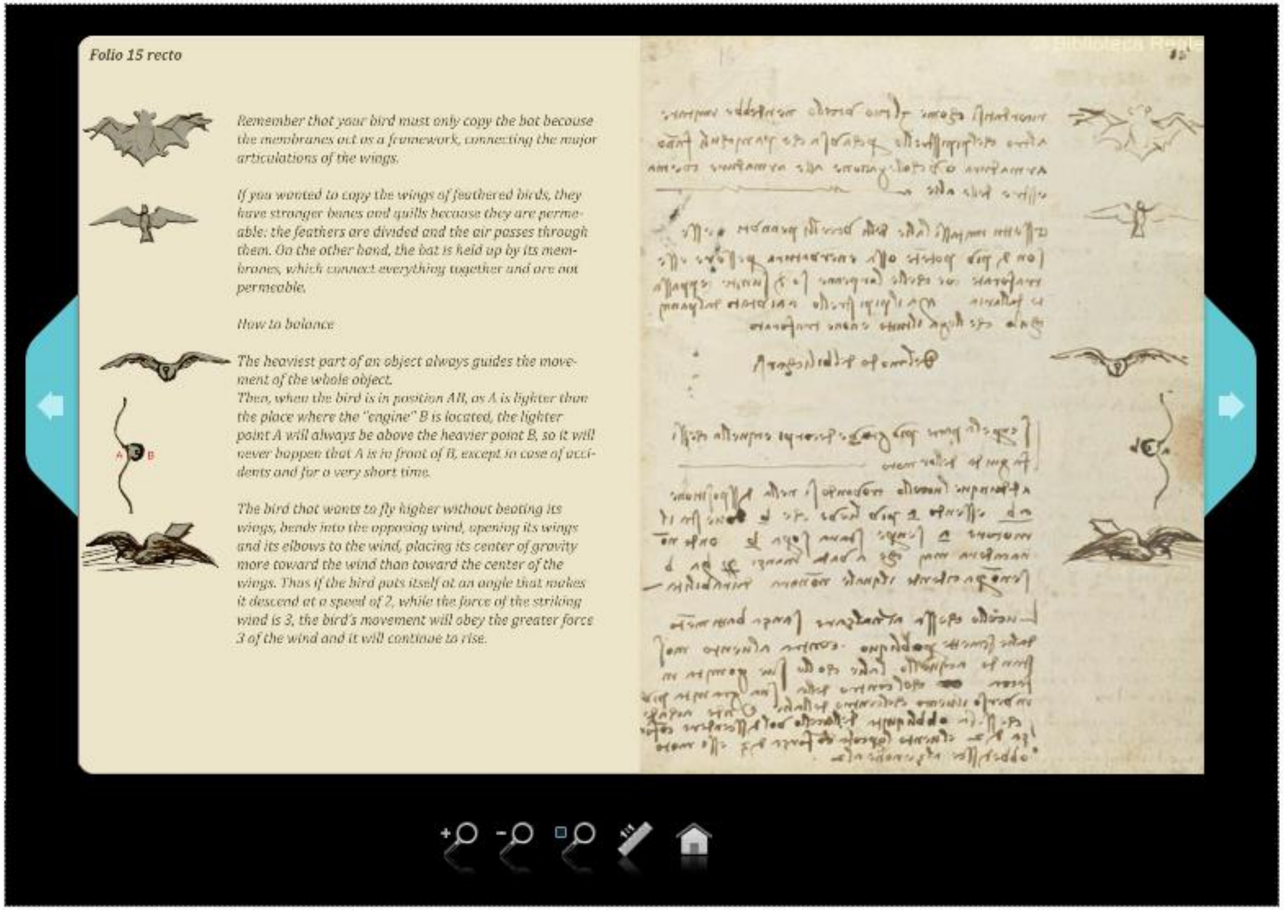
Mute Swan – *Cygnus olor* (Teppes de Verbois, Switzerland) D700, 500 mm f/4.8, 1/640 s

Thank You

Backup Slides

Leonardo de Vinci

Leonardo da Vinci's Codex on the Flight of Birds



Folio 15 recto

Remember that your bird must only copy the bat because the membranes act as a framework, connecting the major articulations of the wings.

If you wanted to copy the wings of feathered birds, they have stronger bones and quills because they are permeable: the feathers are divided and the air passes through them. On the other hand, the bat is held up by its membranes, which connect everything together and are not permeable.

How to balance

The heaviest part of an object always guides the movement of the whole object.
Then, when the bird is in position AB, as A is lighter than the place where the "engine" B is located, the lighter point A will always be above the heavier point B, so it will never happen that A is in front of B, except in case of accidents and for a very short time.

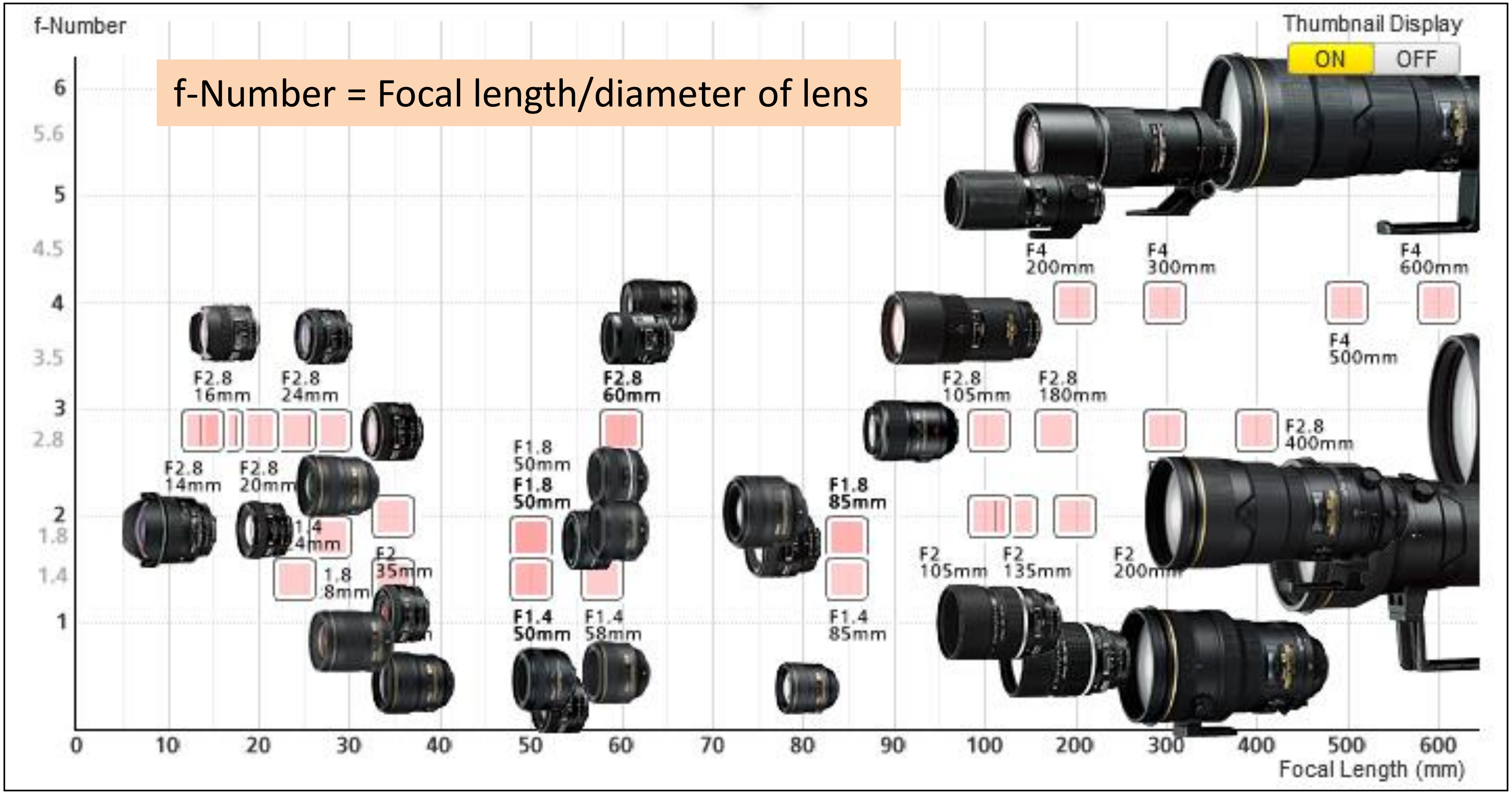
The bird that wants to fly higher without beating its wings, bends into the opposing wind, opening its wings and its elbows to the wind, placing its center of gravity more toward the wind than toward the center of the wings. Thus if the bird puts itself at an angle that makes it descend at a speed of 2, while the force of the striking wind is 3, the bird's movement will obey the greater force 3 of the wind and it will continue to rise.

Images of Codex pages courtesy Ministry of Cultural Heritage, Activities and Tourism; Regional Administration for the Cultural Heritage of the Piemonte; Biblioteca Reale, Turin, Italy. (Ministero dei beni e delle attività culturali e del turismo - Direzione regionale per i beni culturali e paesaggistici del Piemonte - Biblioteca Reale di Torino.) Unofficial English translation prepared by Culturando and Smithsonian Institution.

Recorded different phases of bird flight with remarkable accuracy.

Ponder how difficult it was to study bird flight before photography!

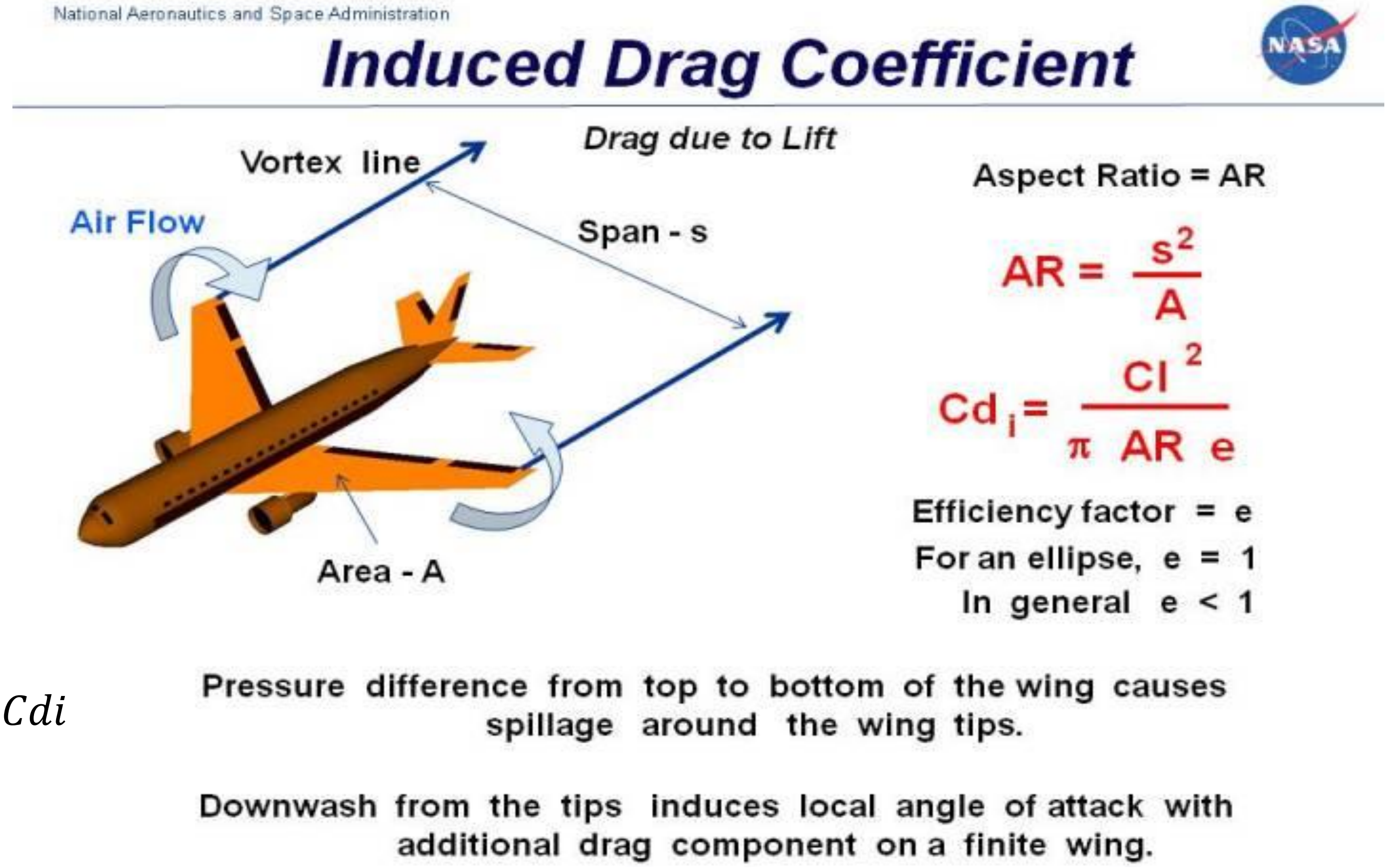
Lens Family defines Camera Body



f-Number = Focal length/diameter of lens

Big lenses cost much more than camera body. Once invested you become a member of the ‘tribe’ (Cannon vs. Nikon is like MAC vs. PC)

Larger AR Wings have higher L/D



National Aeronautics and Space Administration

Induced Drag Coefficient

Drag due to Lift

Aspect Ratio = AR

$$AR = \frac{s^2}{A}$$

$$Cd_i = \frac{Cl^2}{\pi \ AR \ e}$$

Efficiency factor = e

For an ellipse, e = 1

In general e < 1

Pressure difference from top to bottom of the wing causes spillage around the wing tips.

Downwash from the tips induces local angle of attack with additional drag component on a finite wing.

$$Di = \frac{1}{2} \rho \, V^2 \, A \, Cdi$$

$$Di = \frac{L^2}{\frac{1}{2} \rho V^2 \, A \, \pi \, AR \, e}$$

Dimensionless Numbers & Wing Section

Reynolds Number (Newtons/Newtons)

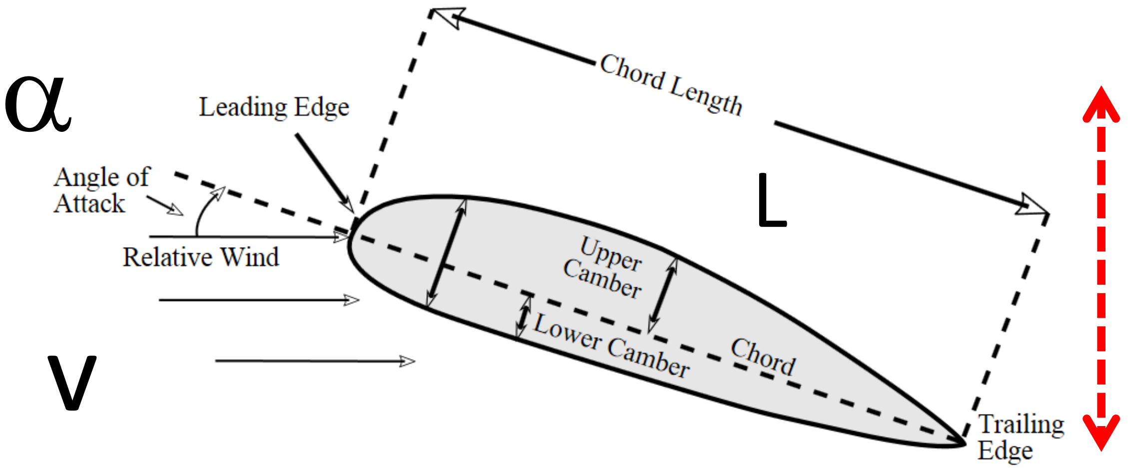
Re is ratio of inertial resistance to viscous resistance in fluid motion. Determines the aerodynamic regime and is useful in scaling models: **$Re = vL/(\mu/\rho)$**, where μ = viscosity of air ($1.79x10^{-5}$ Nsm^{-2}) and ρ = air density (1.23 kgm^{-3})

Swift: Re ~ $5x10^4$ for v=15 m/s, L = 5 cm

B747: Re ~ $2x10^9$ at cruise

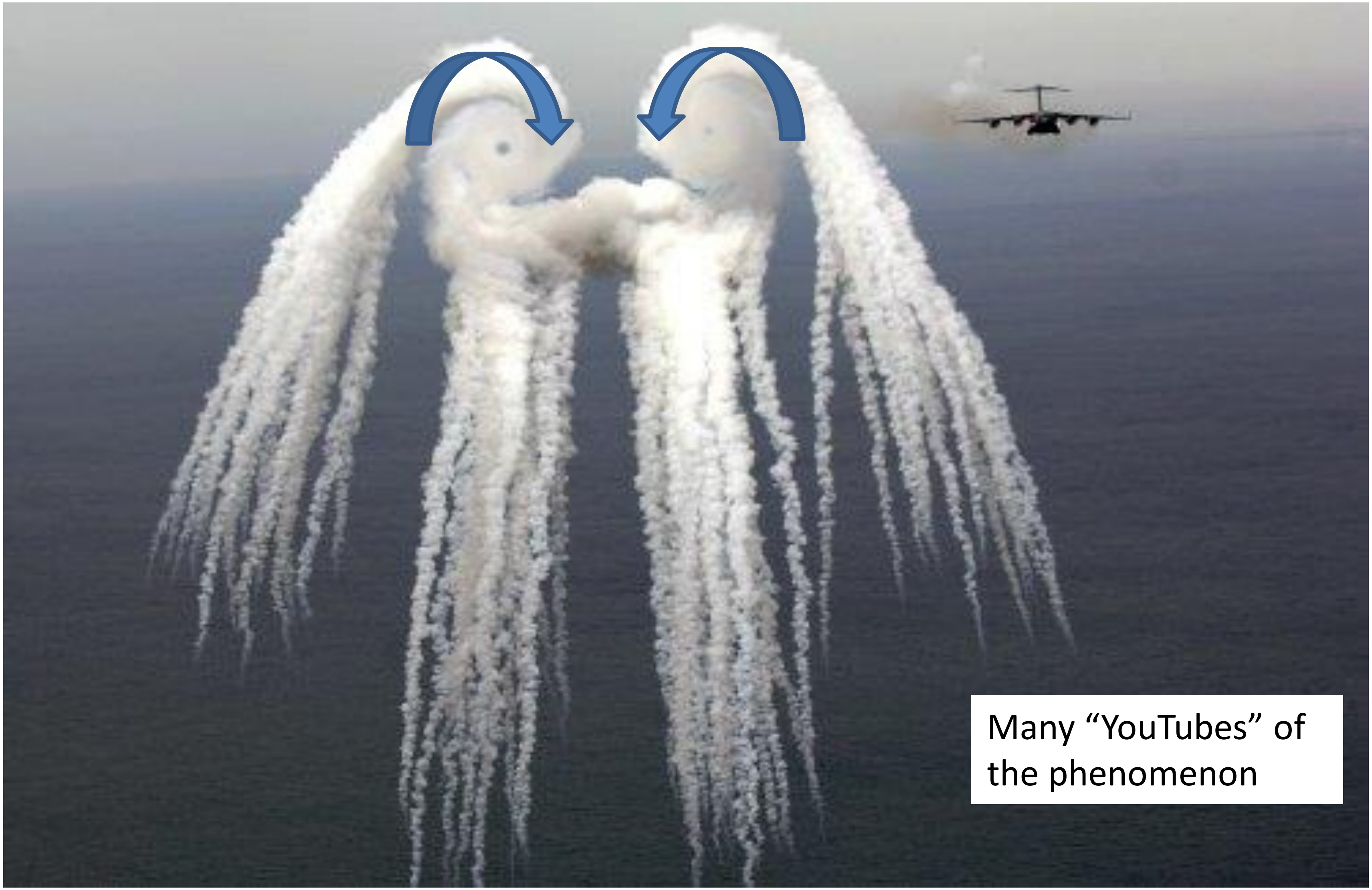
Strouhal Number (Speed/Speed)

In flapping wing dynamics the Strouhal number controls vortex formation and shedding: **$St = 2f\,h_a/v$**, where f is the frequency of flapping, h_a is the flapping stroke and v is the forward speed. Typically ***$St \approx 0.2$ to 0.4*** **=> relation f vs. h_a**



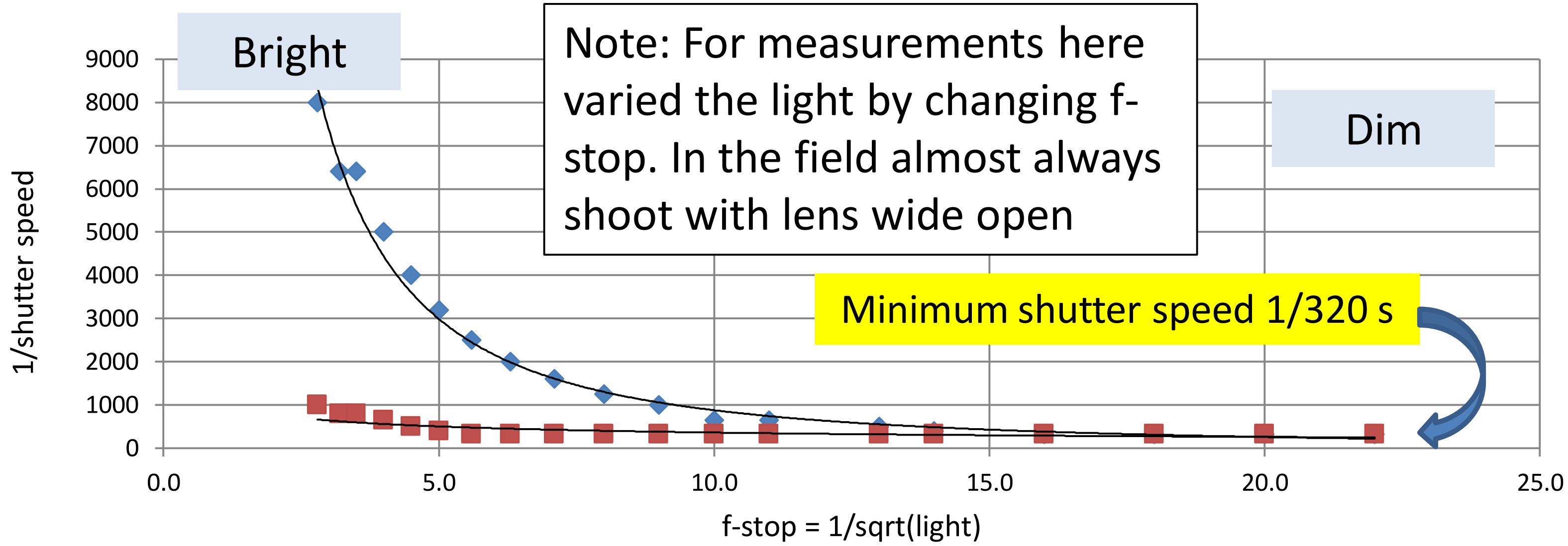
h_a stroke will generate trailing edge vortices

Wingtip Vortices & Downwash



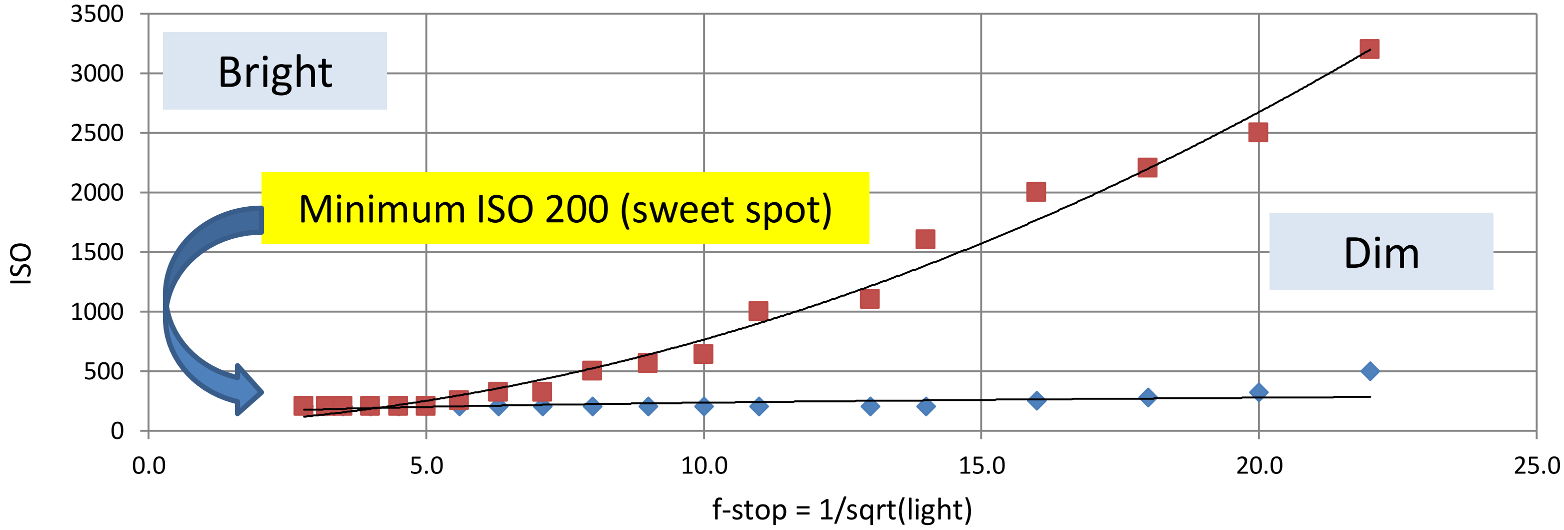
Many “YouTubes” of the phenomenon

How my D300s is Programed



Note: For measurements here varied the light by changing f-stop. In the field almost always shoot with lens wide open

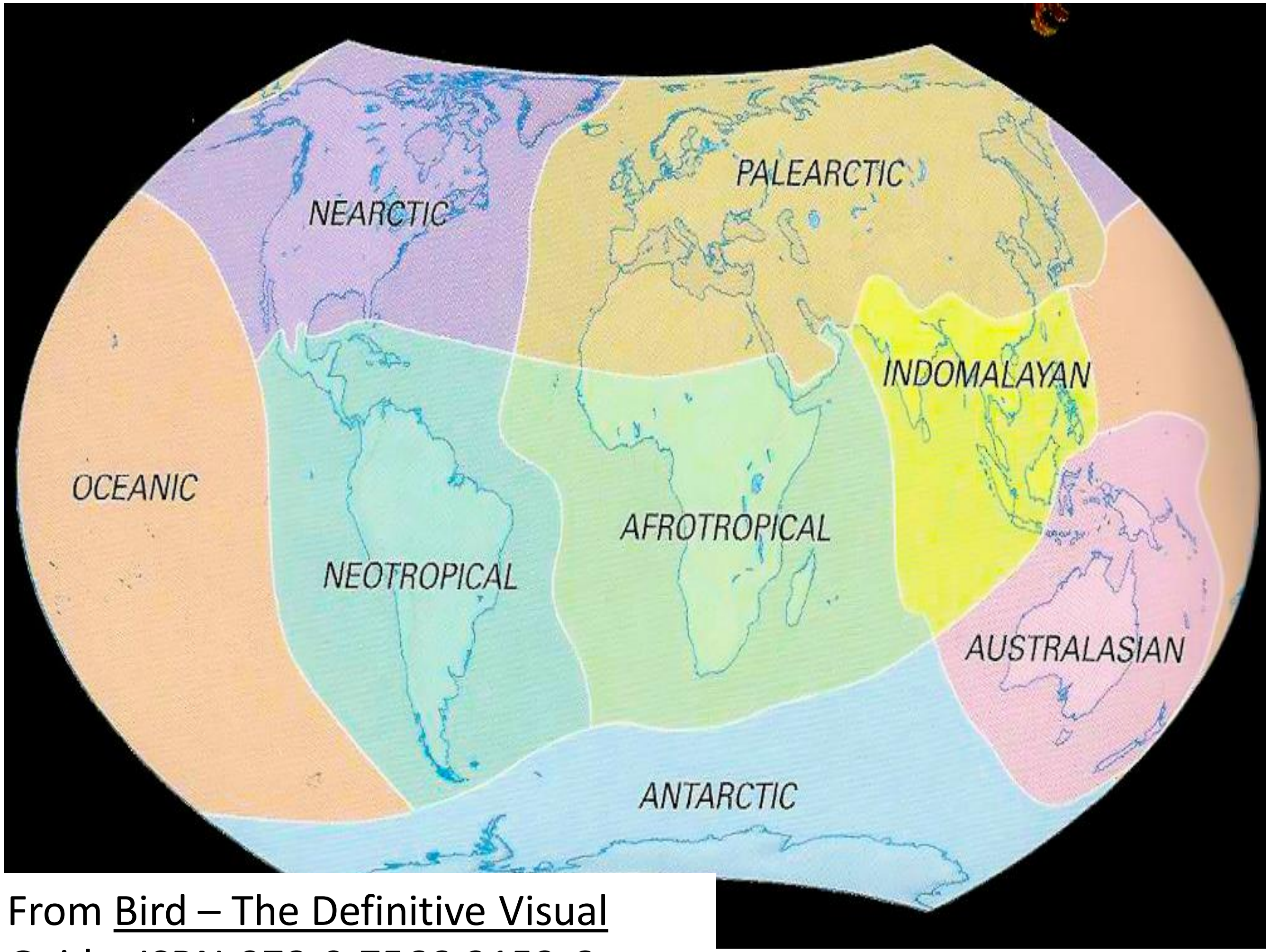
Minimum shutter speed 1/320 s



Minimum ISO 200 (sweet spot)

Bird Geography

Families 204 Species 9,721

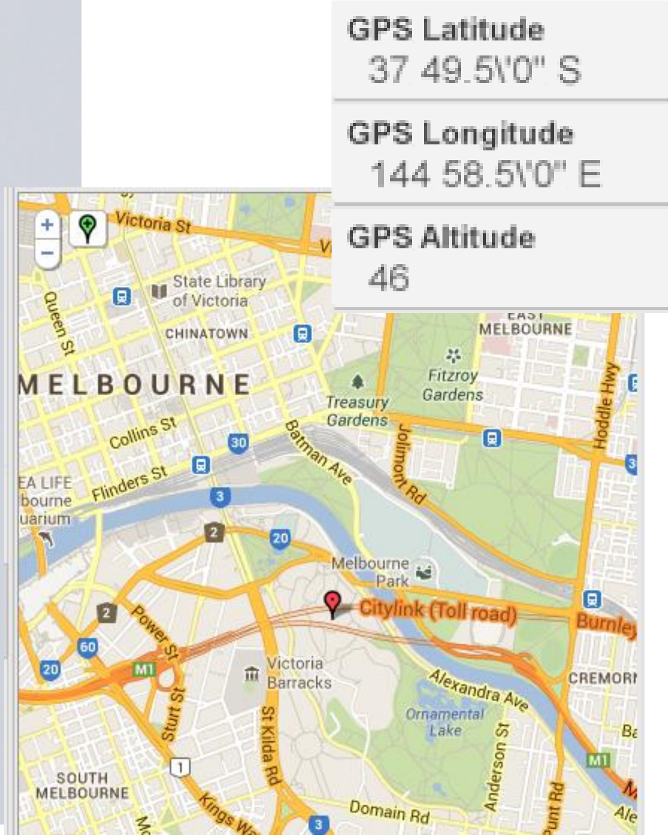


From Bird – The Definitive Visual Guide, ISBN-978-0-7566-3153-6

- Nearctic
  - Families 61
  - Species 732
- Oceanic
  - Families 35
  - Species 200
- Antarctic
  - Families 12
  - Species 85
- Neotropical
  - Families 95
  - Species 3,370
- Afrotropical
  - Families 6
  - Species 1,950
- Palearctic
  - Families 69
  - Species 937
- Indomalayan
  - Families 69
  - Species 1,700
- Australasian
  - Families 64
  - Species 1,590

Example - **Indian Myna** (*Acridotheres tristis*)

D300s, 300 x 1.7 mm f/4.8,
shutter 1/800 s, ISO 200
Metadata GPS coordinate

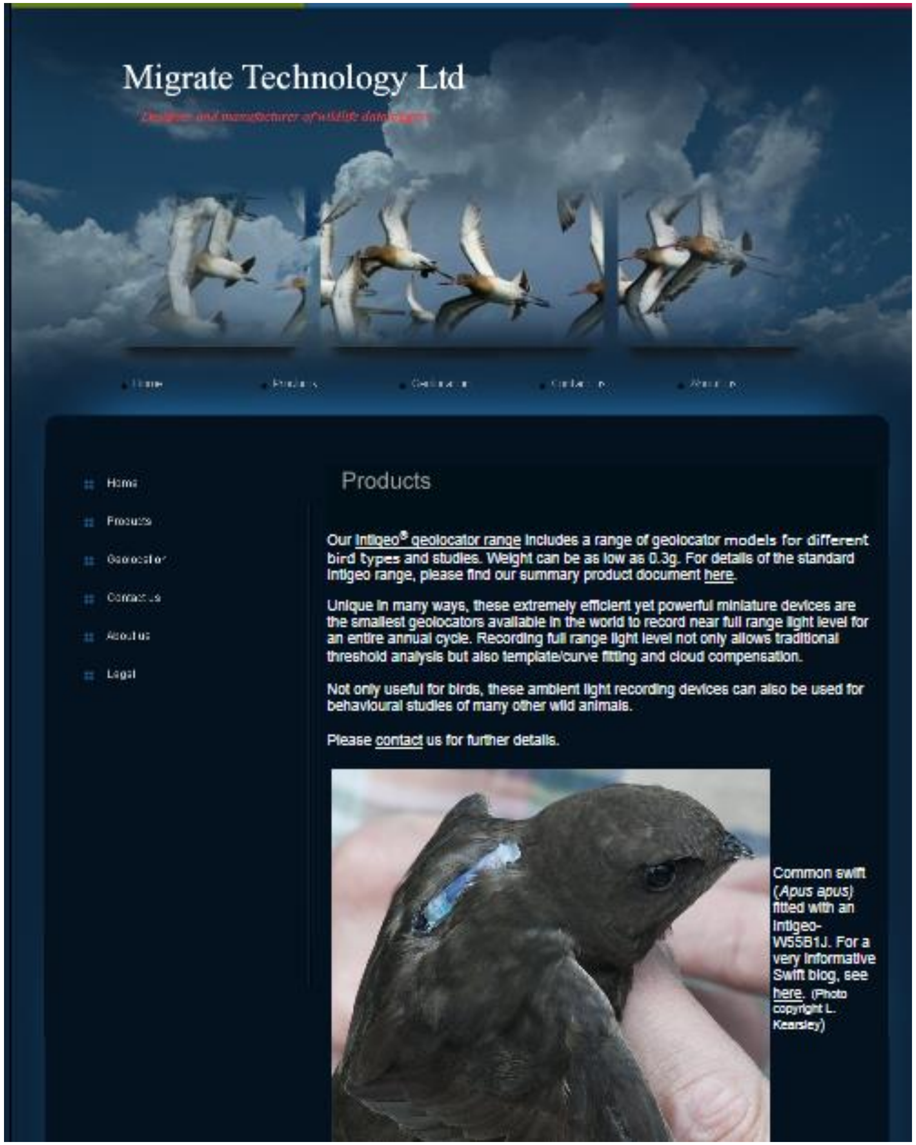


GPS Latitude
37 49.5\'0" S

GPS Longitude
144 58.5\'0" E

GPS Altitude
46

Geolocators



Migrate Technology Ltd

Products

Our Intigeo® geolocator range includes a range of geolocator models for different bird types and studies. Weight can be as low as 0.3g. For details of the standard Intigeo range, please find our summary product document here.

Unique in many ways, these extremely efficient yet powerful miniature devices are the smallest geolocators available in the world to record near full range light level for an entire annual cycle. Recording full range light level not only allows traditional threshold analysis but also template/curve fitting and cloud compensation.

Not only useful for birds, these ambient light recording devices can also be used for behavioural studies of many other wild animals.

Please contact us for further details.

Common swift (*Apus apus*) fitted with an Intigeo-W55B1J. For a very informative Swift blog, see here. (Photo copyright L. Kearsley)

- Company near Cambridge, UK
- Longitude determined by local noon vs. standard clock
- Latitude (less accurate) determined by duration of day vs. night.
- Operates best north of Tropic of Cancer or south of Tropic of Capricorn
- Data are logged on device to be later recovered.

Flamingos at the Camargue, France

Nikon D80 with 300 mm f/2.8 Lens
ISO 200, Shutter 1/3200, Aperture
Priority, JPEG Fine

Easy Shots - Birds in Captivity

Indian Peafowl (*Pavo cristatus*)
Nikon D300s, 135 mm f/5.6,
1/400s, ISO 1000

Photographing Famous Birds

Field telephone

Cher Ami, one of 600 carrier pigeons deployed by the U.S. Army Signal Corps, was awarded the French Croix de Guerre with Palm for his heroic service.

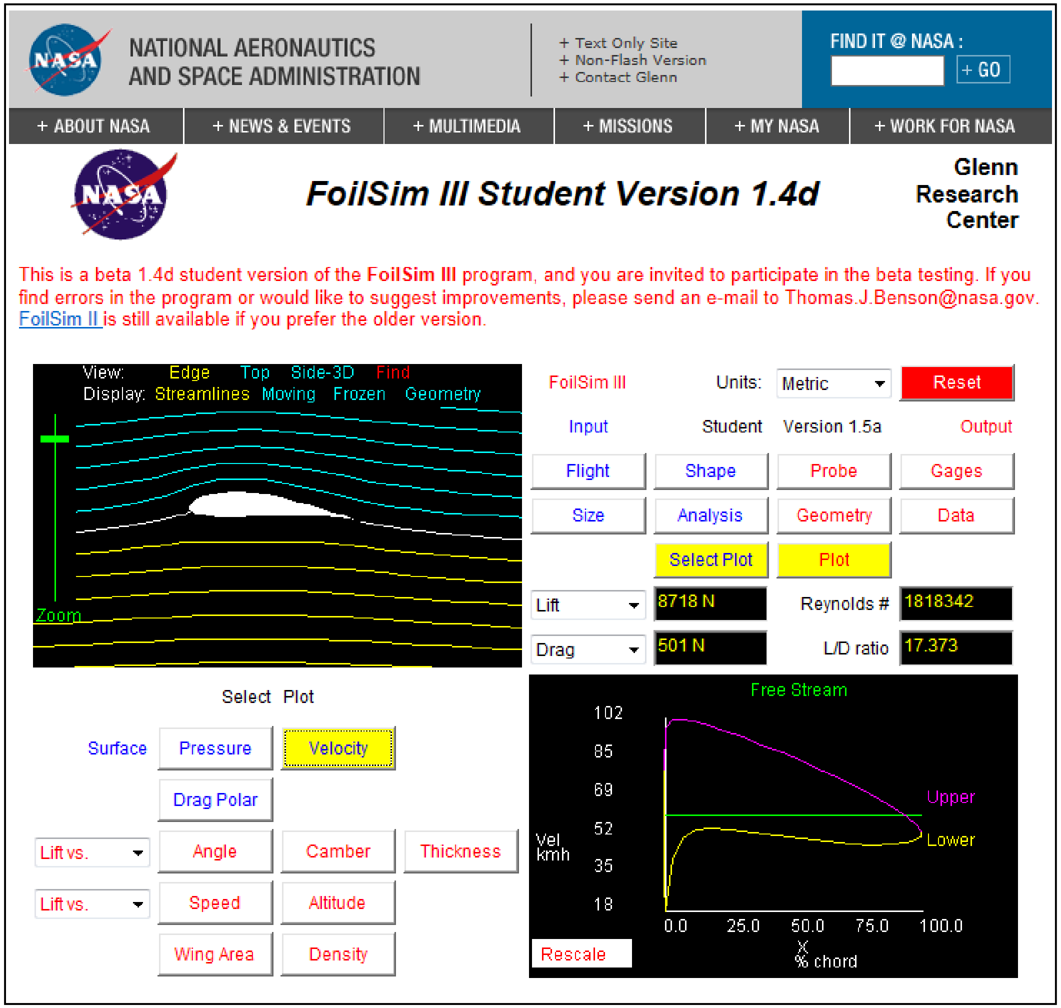
Carrier Pigeon (*Columba livia)*

Cher Ami helped save 194 US troops on October 3, 1918 who were being decimated by friendly fire. The field phone wires were cut and all pigeons except **Cher Ami** were killed. Shot through the breast, blinded in one eye, covered in blood and with a leg hanging only by a tendon, **Cher Ami** carried her message back to HQ 25 miles in 65 minutes with desperate message to stop shelling.

For her bravery she was awarded the Croix de Guerre by General Pershing and was allowed lived out her life pleasantly. Stuffed for eternity, **Cher Ami** is now on display in the Smithsonian in Washington

Aerodynamics 101

- There are many airfoil simulation programs online
  - Can vary the airfoil shape
    - Camber
    - Aspect ratio
  - Angle of attack
- Output
  - Lift and Drag and L/D
  - Reynolds Number
  - Various plots
  - Streamline configuration



FoilSim III Student Version 1.4d

This is a beta 1.4d student version of the **FoilSim III** program, and you are invited to participate in the beta testing. If you find errors in the program or would like to suggest improvements, please send an e-mail to Thomas.J.Benson@nasa.gov. FoilSim II is still available if you prefer the older version.

Units: Metric

Version 1.5a

Lift: 8718 N

Drag: 501 N

Reynolds #: 1818342

L/D ratio: 17.373

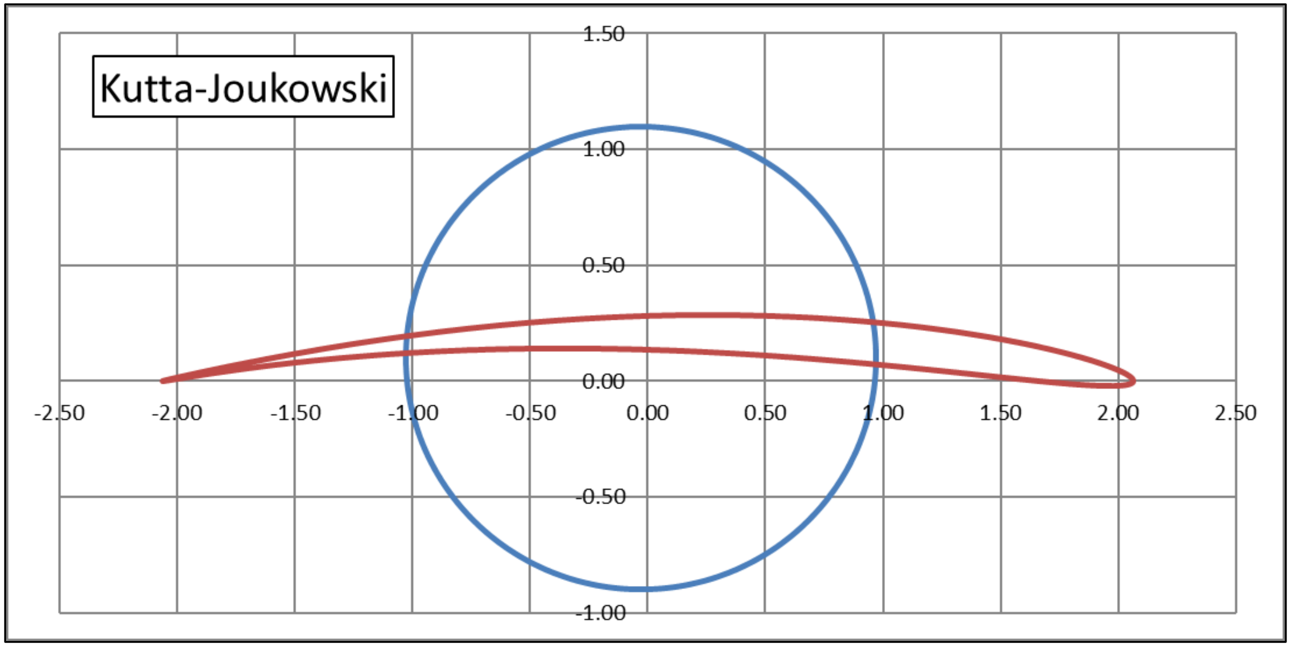
Airfoil Shape – Joukowski Transformation

- Generate an airfoil shape by conformal mapping of circle
- Develop a theory of lift by transforming a circulation around a cylinder to the airfoil while constraining the stagnation points on leading and trailing edges

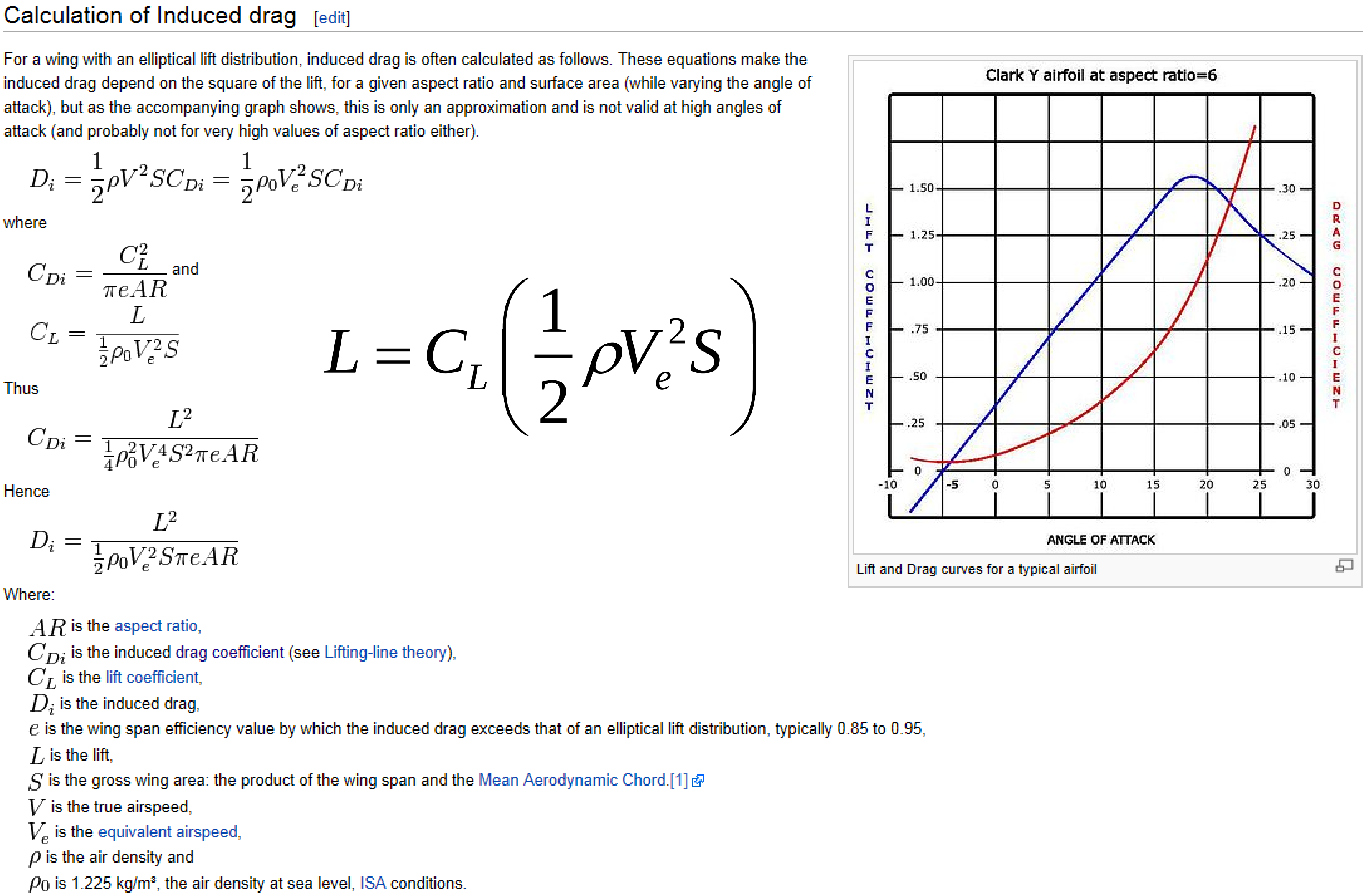
$$\zeta = z + \frac{c_1^2}{z}$$

$$z = re^{i\theta}$$

Parameters	
c1	1.03
x0	-0.03
y0	0.10
R	1.00



Calculation of Induced Drag



Calculation of Induced drag [edit]

For a wing with an elliptical lift distribution, induced drag is often calculated as follows. These equations make the induced drag depend on the square of the lift, for a given aspect ratio and surface area (while varying the angle of attack), but as the accompanying graph shows, this is only an approximation and is not valid at high angles of attack (and probably not for very high values of aspect ratio either).

$$D_i = \frac{1}{2}\rho V^2 S C_{Di} = \frac{1}{2}\rho_0 V_e^2 S C_{Di}$$

where

$$C_{Di} = \frac{C_L^2}{\pi e AR} \text{ and}$$

$$C_L = \frac{L}{\frac{1}{2}\rho_0 V_e^2 S}$$

Thus

$$C_{Di} = \frac{L^2}{\frac{1}{4}\rho_0^2 V_e^4 S^2 \pi e AR}$$

Hence

$$D_i = \frac{L^2}{\frac{1}{2}\rho_0 V_e^2 S \pi e AR}$$

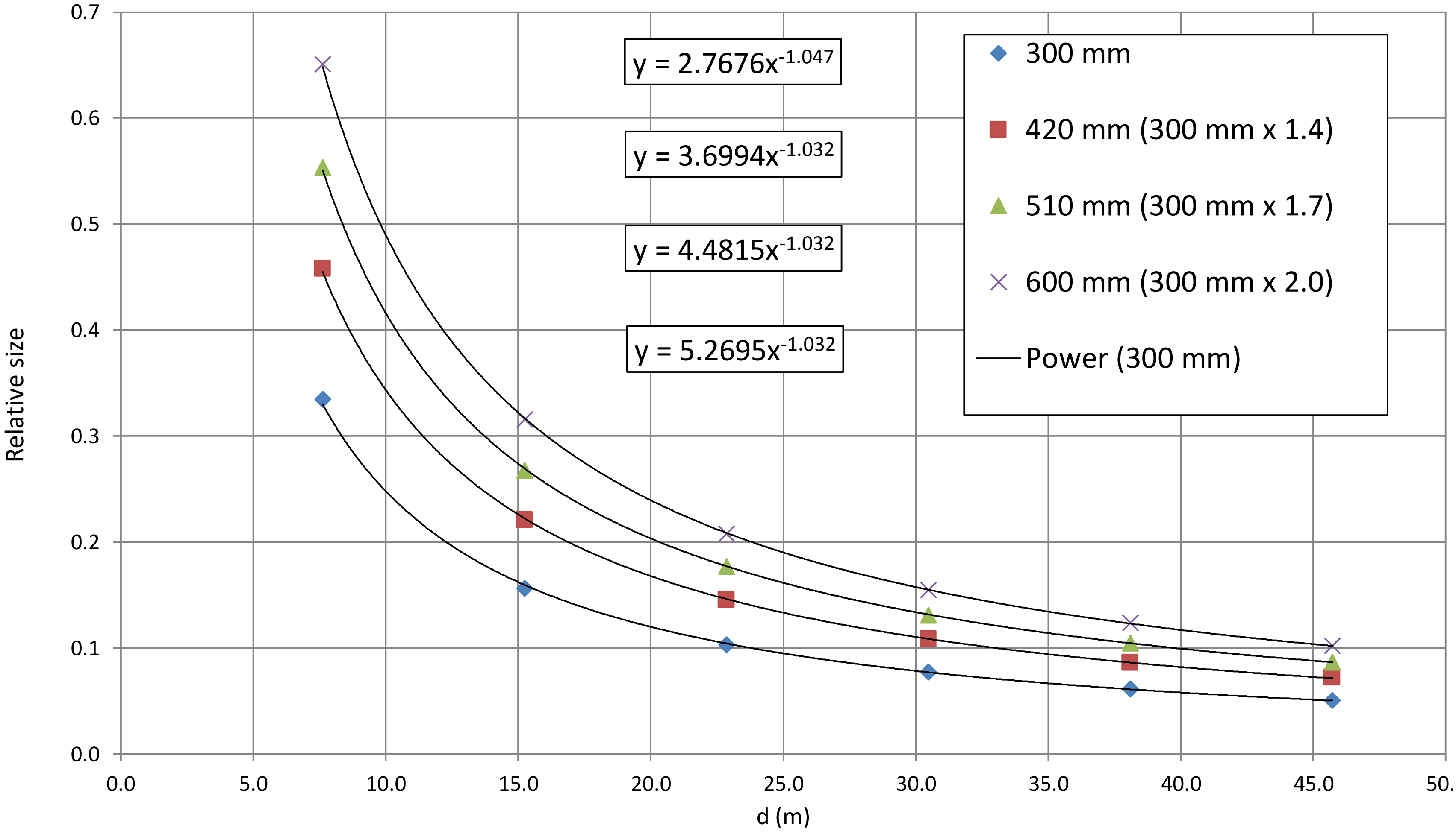
Where:

AR is the aspect ratio,
C_{Di} is the induced drag coefficient (see Lifting-line theory),
C_L is the lift coefficient,
D_i is the induced drag,
e is the wing span efficiency value by which the induced drag exceeds that of an elliptical lift distribution, typically 0.85 to 0.95,
L is the lift,
S is the gross wing area: the product of the wing span and the Mean Aerodynamic Chord.[1]
V is the true airspeed,
V_e is the equivalent airspeed,
ρ is the air density and
ρ_0 is 1.225 kg/m³, the air density at sea level, ISA conditions.

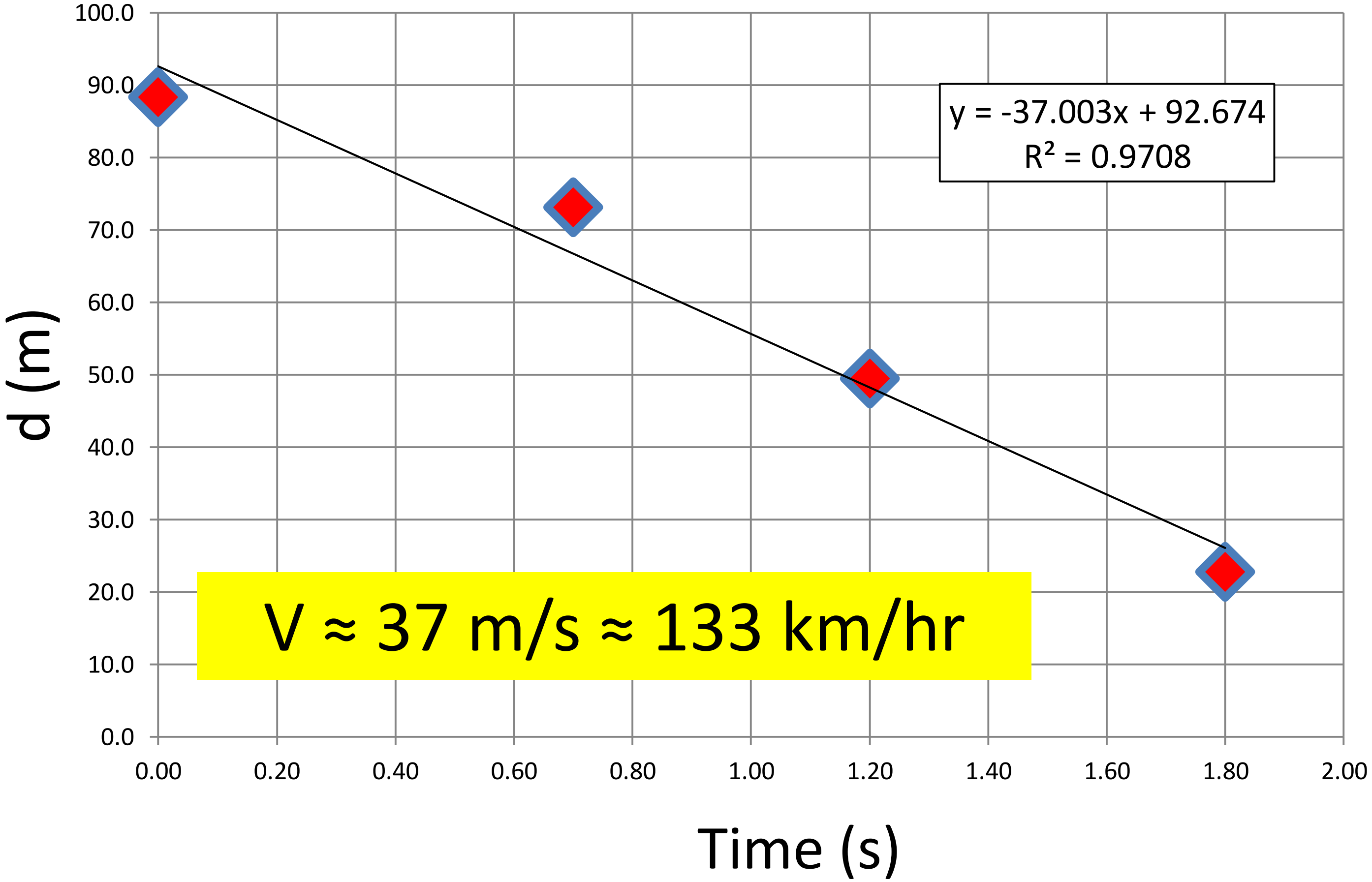
$$L = C_L\left(\frac{1}{2}\rho V_e^2 S\right)$$

Lift and Drag curves for a typical airfoil

Calibration Relative Size vs. Distance



The Train Speed



V ≈ 37 m/s ≈ 133 km/hr

Embraer ERJ 145 Flying across sun

No sunspots on this cloudy day

Scaling apparent fuselage to solar diameter and knowing the specification of the plane the distance to the plane can be estimated.

D = 41 km.

With GPS tag and UTC time stamp and position of the sun one can compute the position of the airplane.

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