

ICAO AP-WHM/WG/8

Christopher Wee
Managing Director
Mastermark Pte Ltd

MASTERMARK® 



About Mastermark

- Established 1981, headquarters in Singapore
- Over 100 staff supporting 6 offices across Singapore, Malaysia and the Philippines.
- Changi Airport Group's principal wildlife consultant
- Principal wildlife consultant to all the Republic of Singapore Air Force bases
- Singapore Government's (National Parks Board) national contractor for all urban wildlife management
- Singapore Government's (Animal and Veterinary Services) primary contractor for all 7 animal quarantine, rehabilitation & husbandry centres in Singapore



On a Map

Malaysia

Kuala Lumpur Int Airport 1 & 2

Singapore

Changi Int Airport
Seletar Airport
Changi Air Base
Tengah Air Base
Paya Lebar Air Base
Sembawang Air Base

Cambodia

Sihanoukville Int Airport
Techo Int Airport

Philippines

Davao Int Airport
Iloilo Int Airport
Puerto Princessa Int Airport
Zamboanga Int Airport
Bicol Int Airport
Laoag Int Airport
Tacloban Airport

Why Mastermark

Tailored Solutions

We strive to fit what's best for you, meticulously. Not run-of-the-mill generic solutions.

Not Just Theoretical

Our company's history means that our solutions are built from ground up using practical approaches. We'll only recommend what's feasible.

Expert Professionals

Our wildlife specialists possesses a collective range of skills and experiences that is suited for dealing with aerodrome wildlife, the environment and everything in-between.

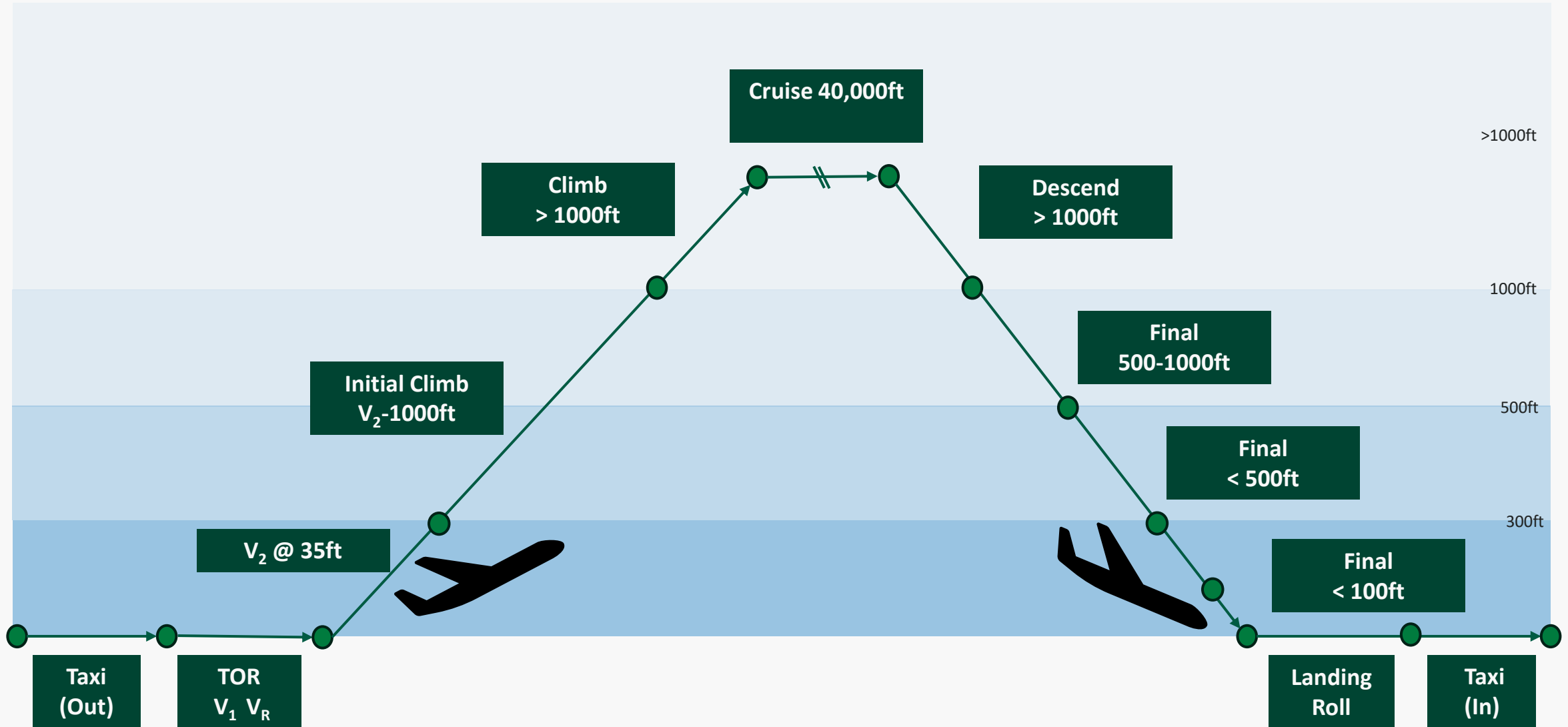
Partners, not Consultants

We take responsibility for all recommendations and will readily assist in the implementation of solutions we provide.

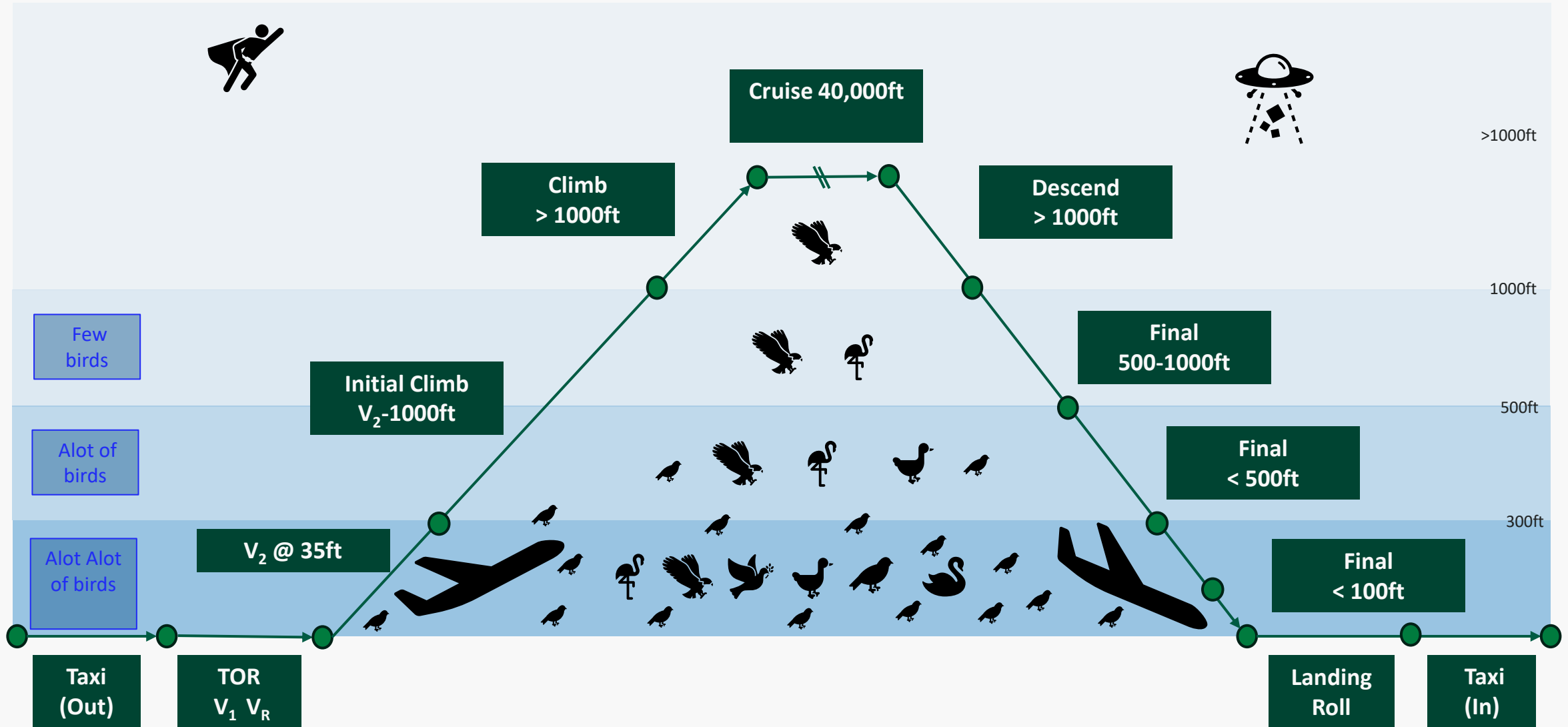
Greater Efficiency in WHMP

**Wildlife Strike Concerns During TOR
& Initial Climb**

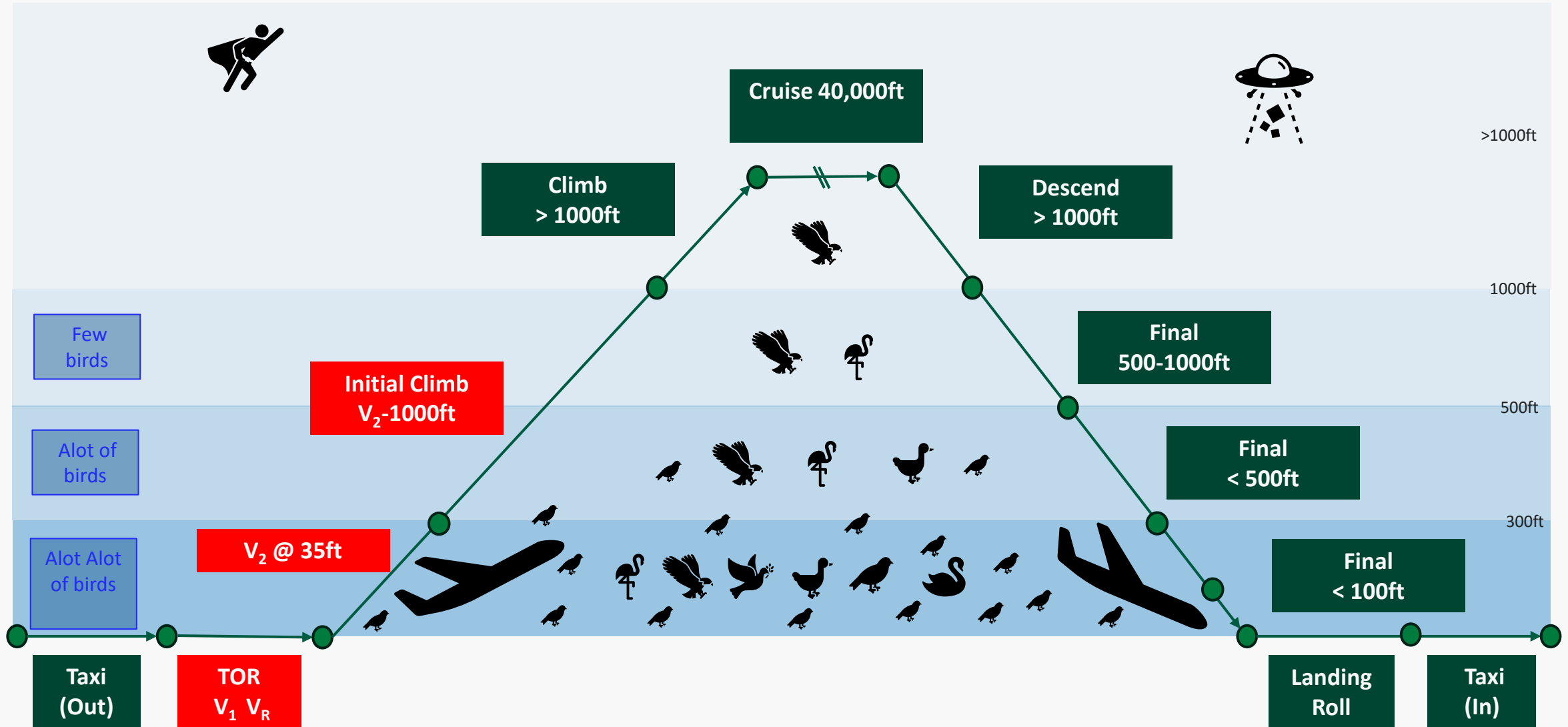
Bird Abundance Relative to Altitude



Bird Abundance Relative to Altitude



Bird Abundance Relative to Altitude



The Worst Phase for a Severe Wildlife Strike to Occur...

At $V_1 - V_2$, the aircraft is at its most vulnerable:

1. **Slowest** — minimum airspeed, least aerodynamic lift available
2. **Heaviest** — maximum takeoff weight, full fuel and payload
3. **At peak power utilisation** — engines at maximum thrust, with virtually no performance margin to spare



Prioritising Wildlife Risk Across Phases-of-Flight

Typical phases-of-flight that are within the aerodromes area of influence(wildlife)

Take Off

- Taxi
- Take-Off-Run
- Initial Climb

Landing

- Final Approach
- Landing Roll
- Taxi



Prioritising Wildlife Risk Across Phases-of-Flight

Typical phases-of-flight that are within the aerodromes area of influence(wildlife)

Take Off

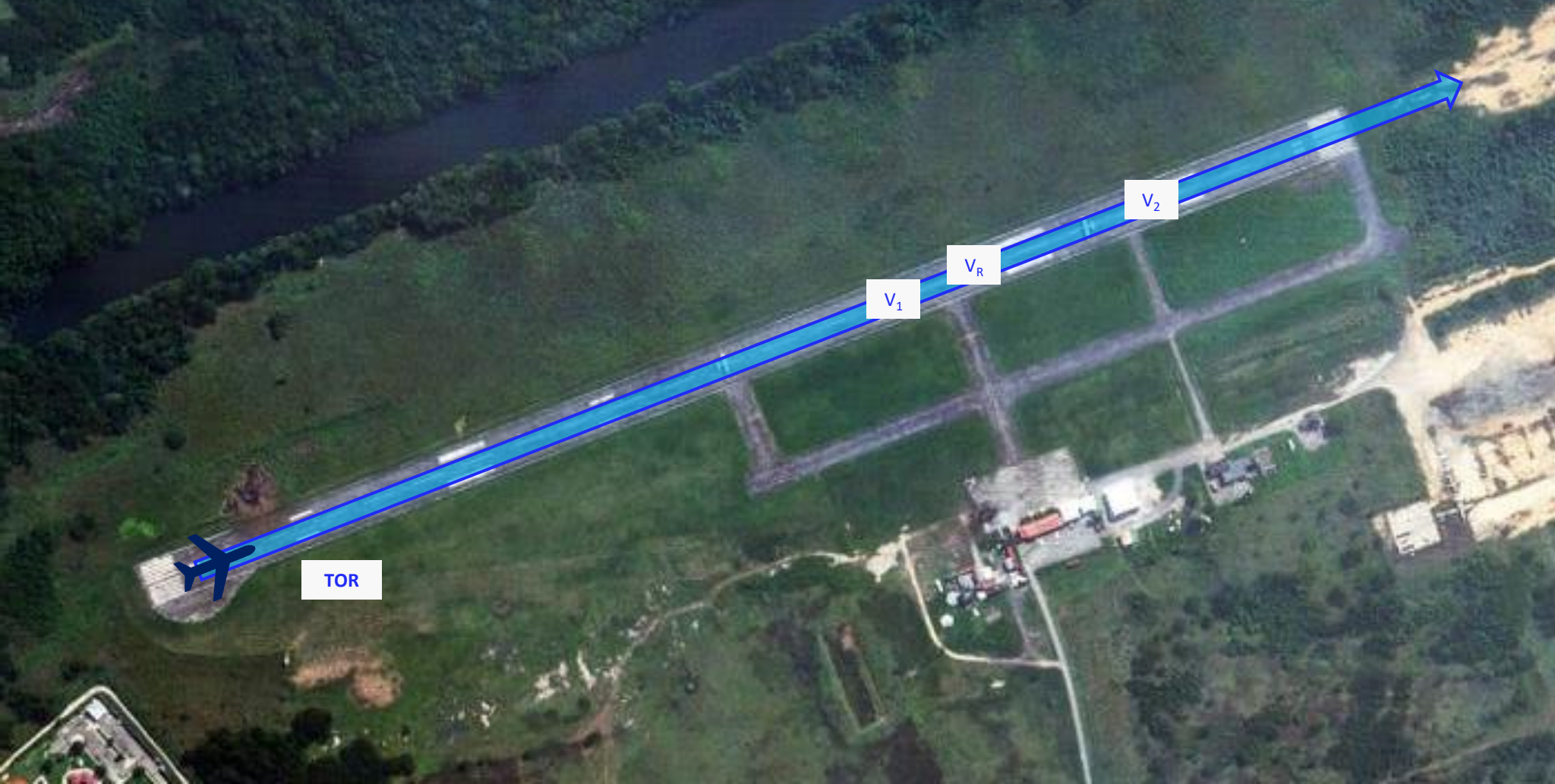
- Taxi
- Take-Off-Run
- Initial Climb

Landing

- Final Approach
- Landing Roll
- Taxi



Aircraft Take-Off Run V_1 V_R V_2



Aircraft Take-Off Run V_1 V_R V_2



Focus Here...



Types of Bird Strikes

Damaging

- Engine ingestion
- Structural / instrument damage

Non-Damaging

- No consequence
- Loss of use

Near Miss

- Usually only significant cases reported



Types of Bird Strikes

Damaging

- **Engine ingestion**
- **Structural / instrument damage**

Non-Damaging

- No consequence
- **Loss of use**

Near Miss

- Usually only significant cases reported

Greatest \$ Cost to Airlines



Types of Bird Strikes

Damaging

- **Engine ingestion**
- Structural / instrument damage

Non-Damaging

- No consequence
- Loss of use

Near Miss

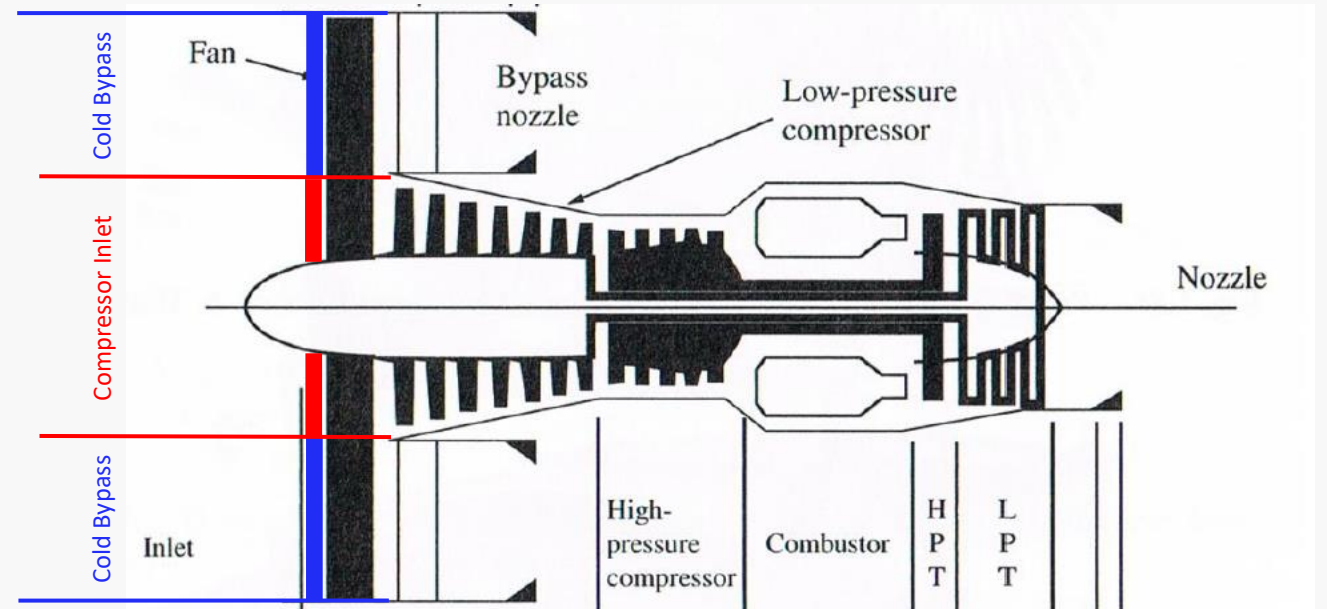
- Usually only significant cases reported

Beyond \$, Greatest Safety Concern to Airlines



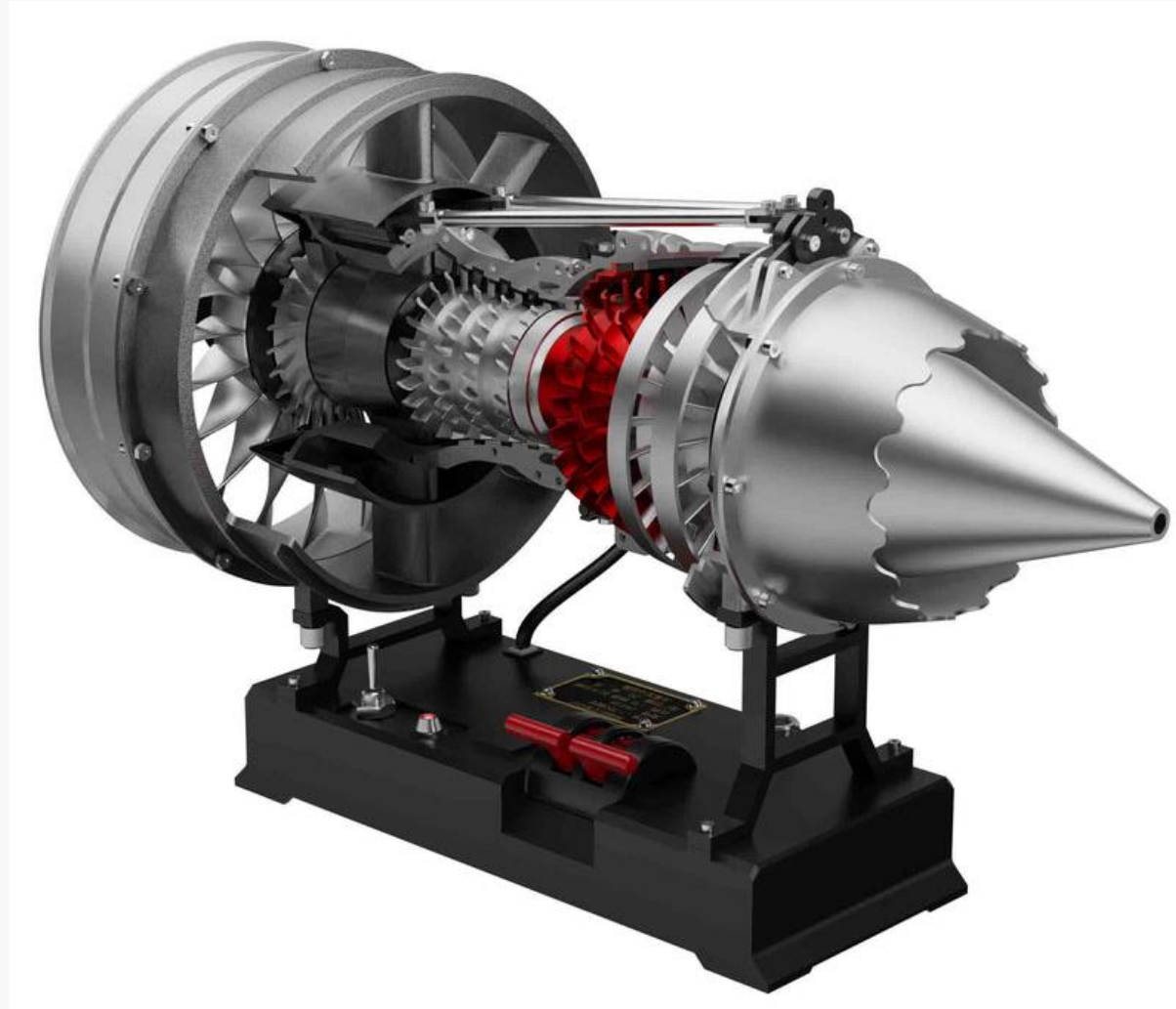
Engines

High Bypass Ratio Turbofan Engine

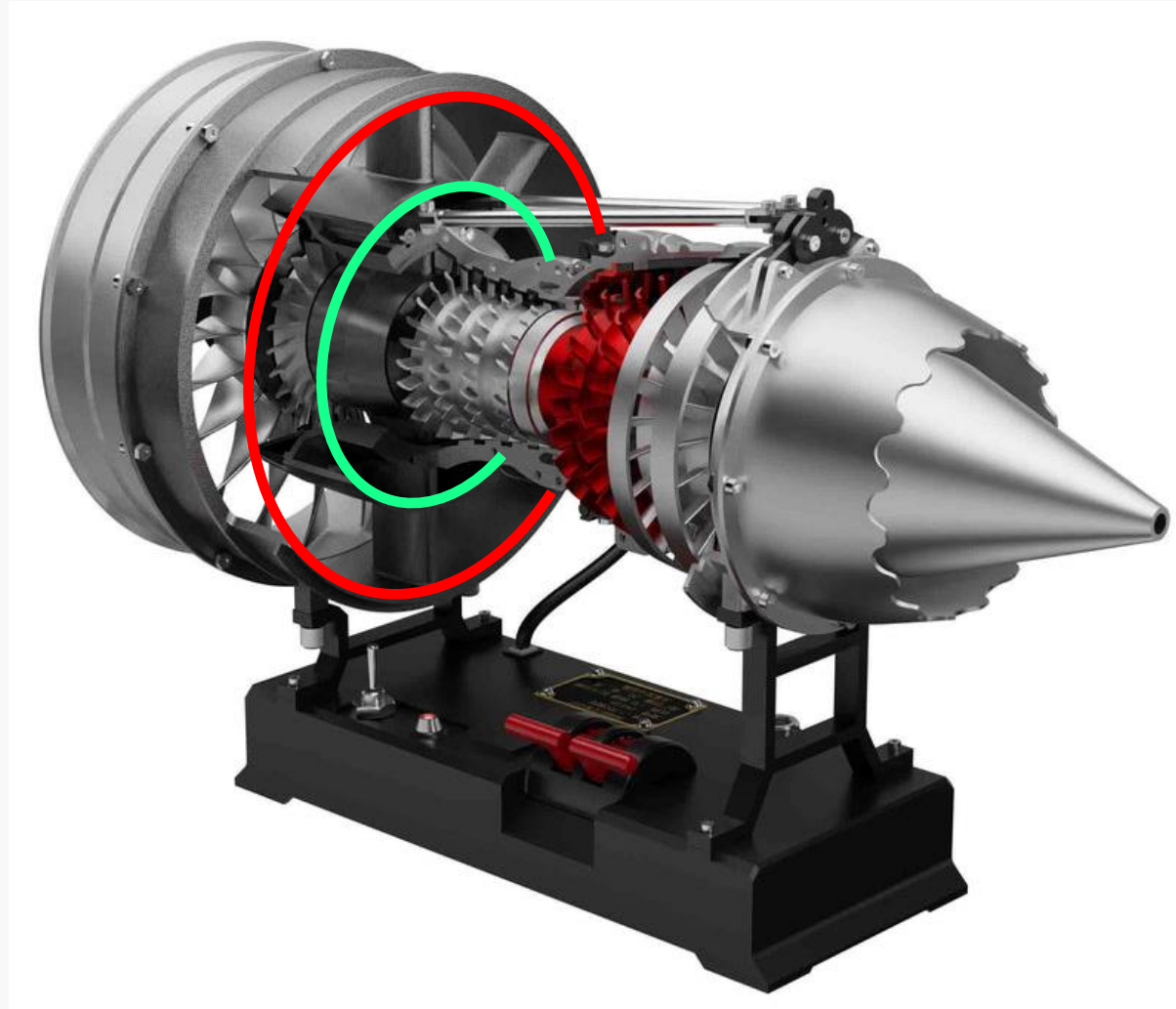


Credit: chegg.com

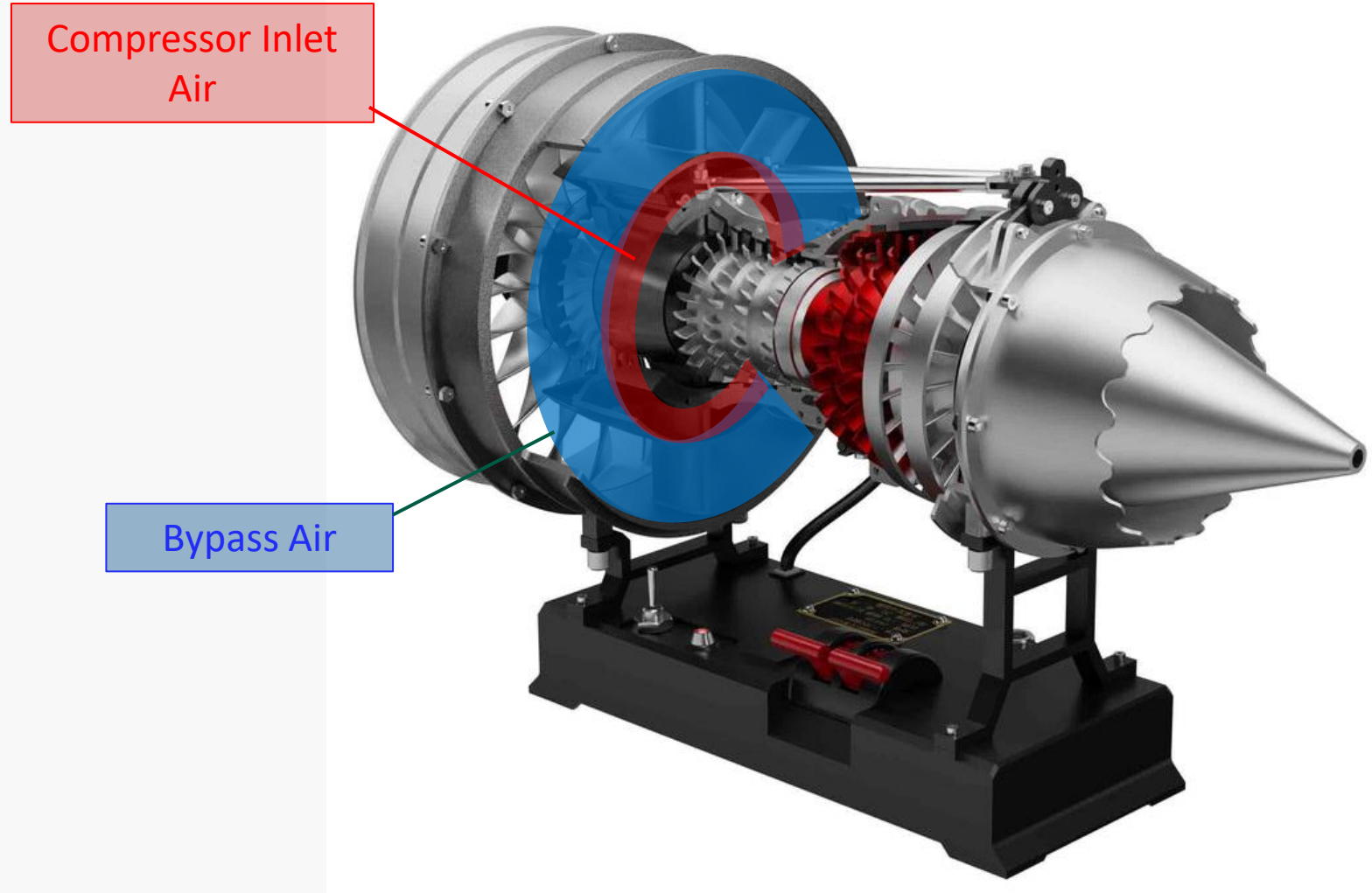
High Bypass Ratio Turbofan Engine



High Bypass Ratio Turbofan Engine



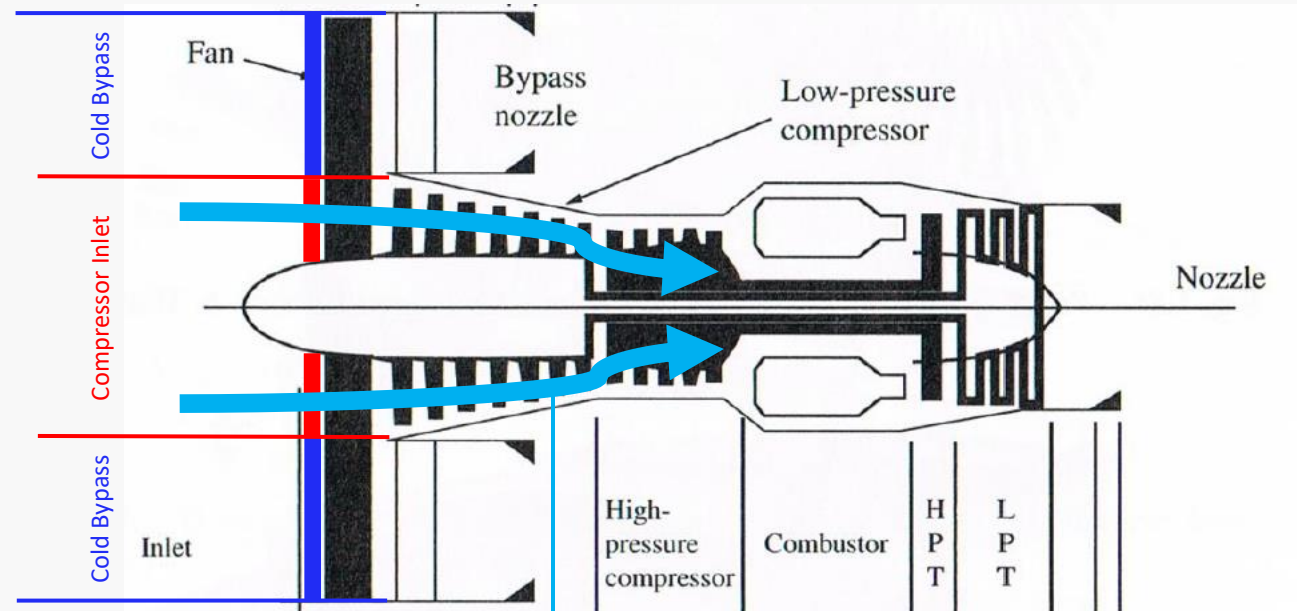
High Bypass Ratio Turbofan Engine



Bird Strike Leading to Compressor Stall



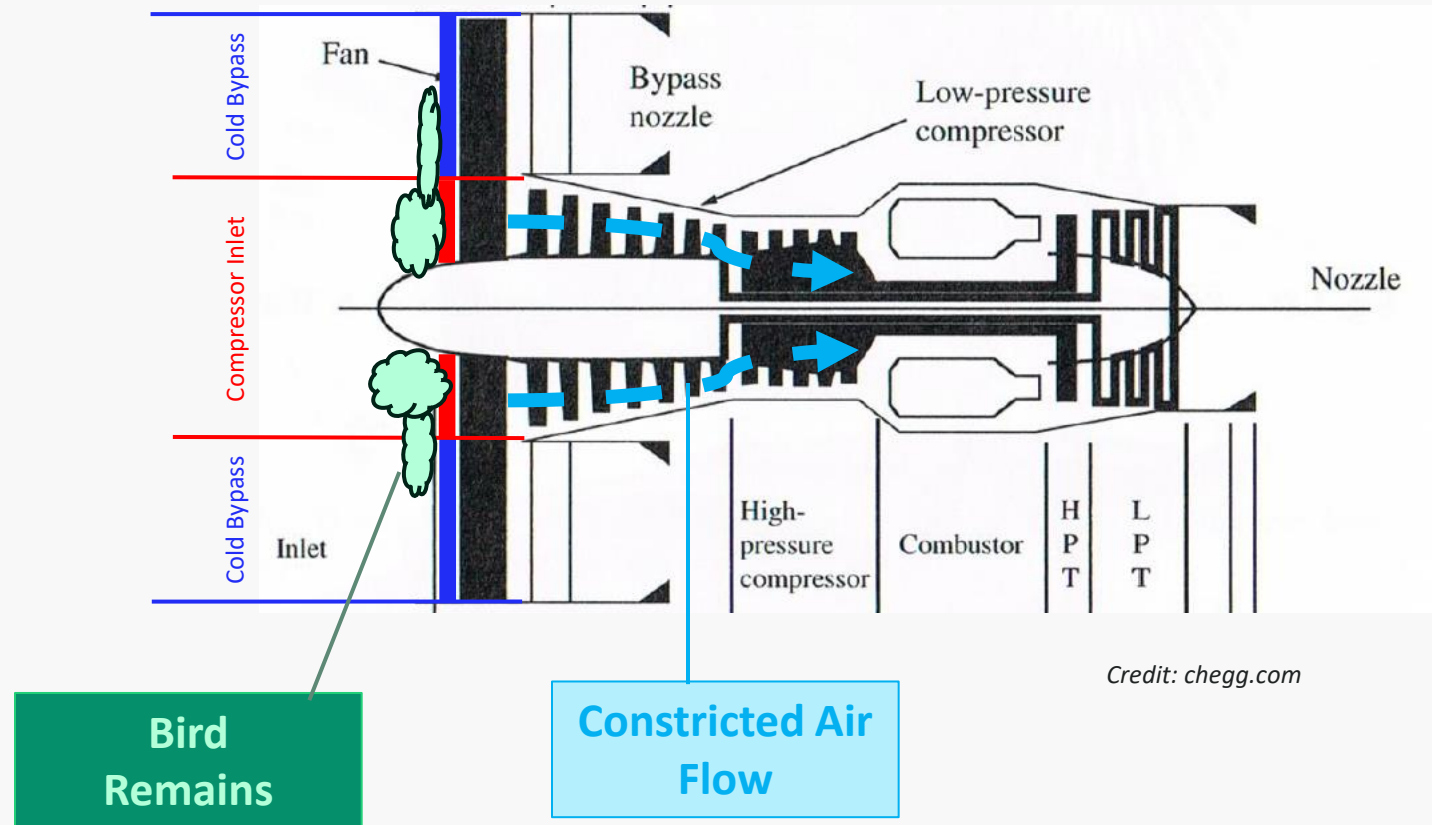
High Bypass Ratio Turbofan Engine



Credit: chegg.com

Free Air Flow

High Bypass Ratio Turbofan Engine



A350 vs A320 Engine Size Comparison



Credit: www.infiniteflight.com

Engine Size Matters

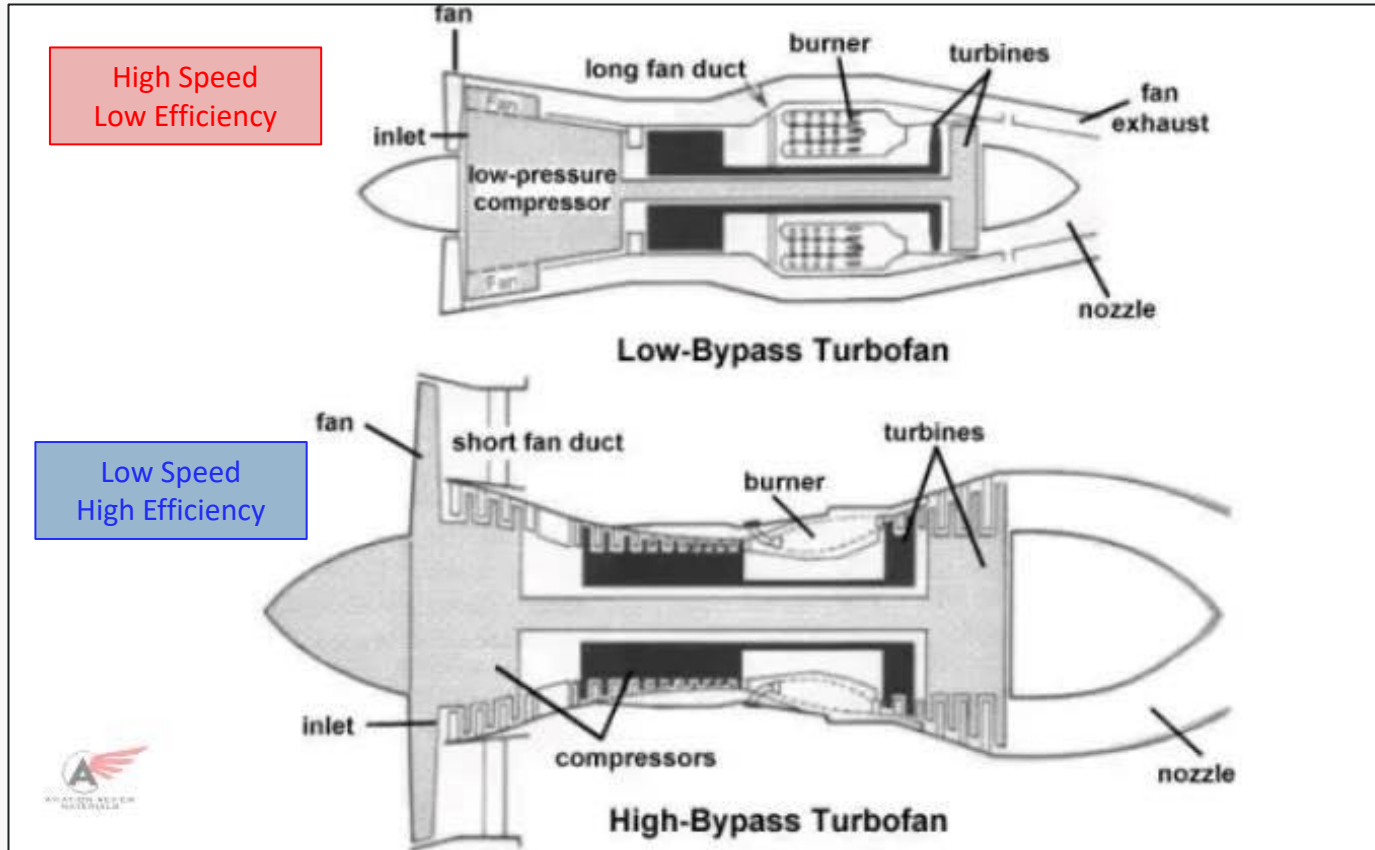
	Small Turbofan (CFM56 class, ~25k lbf)	Large Turbofan (GE90 / Trent class, ~90k+ lbf)
Inlet Diameter	~50-60 inches	~110-130 inches
Fan Blade Count	~38	~22
Bird Ingestion	Smaller target, higher RPM risk	Larger target, designed for big bird tolerance
Certification Standard	4 lb single bird, 2.5 lb flocking bird	8 lb single bird (GE90), higher flocking mass

Engine Size Matters

	Small Turbofan (CFM56 class, ~25k lbf)	Large Turbofan (GE90 / Trent class, ~90k+ lbf)
Inlet Diameter	~50-60 inches	~110-130 inches
Fan Blade Count	~38	~22
Bird Ingestion	Smaller target, higher RPM risk	Larger target, designed for big bird tolerance
Certification Standard	4 lb single bird, 2.5 lb flocking bird	8 lb single bird (GE90), higher flocking mass

*** Smaller engines more susceptible to compressor stall caused by bird ingestion**

High Bypass Ratio vs Low Bypass Ratio Turbofan Engine



Credit: Aviation Review Materials

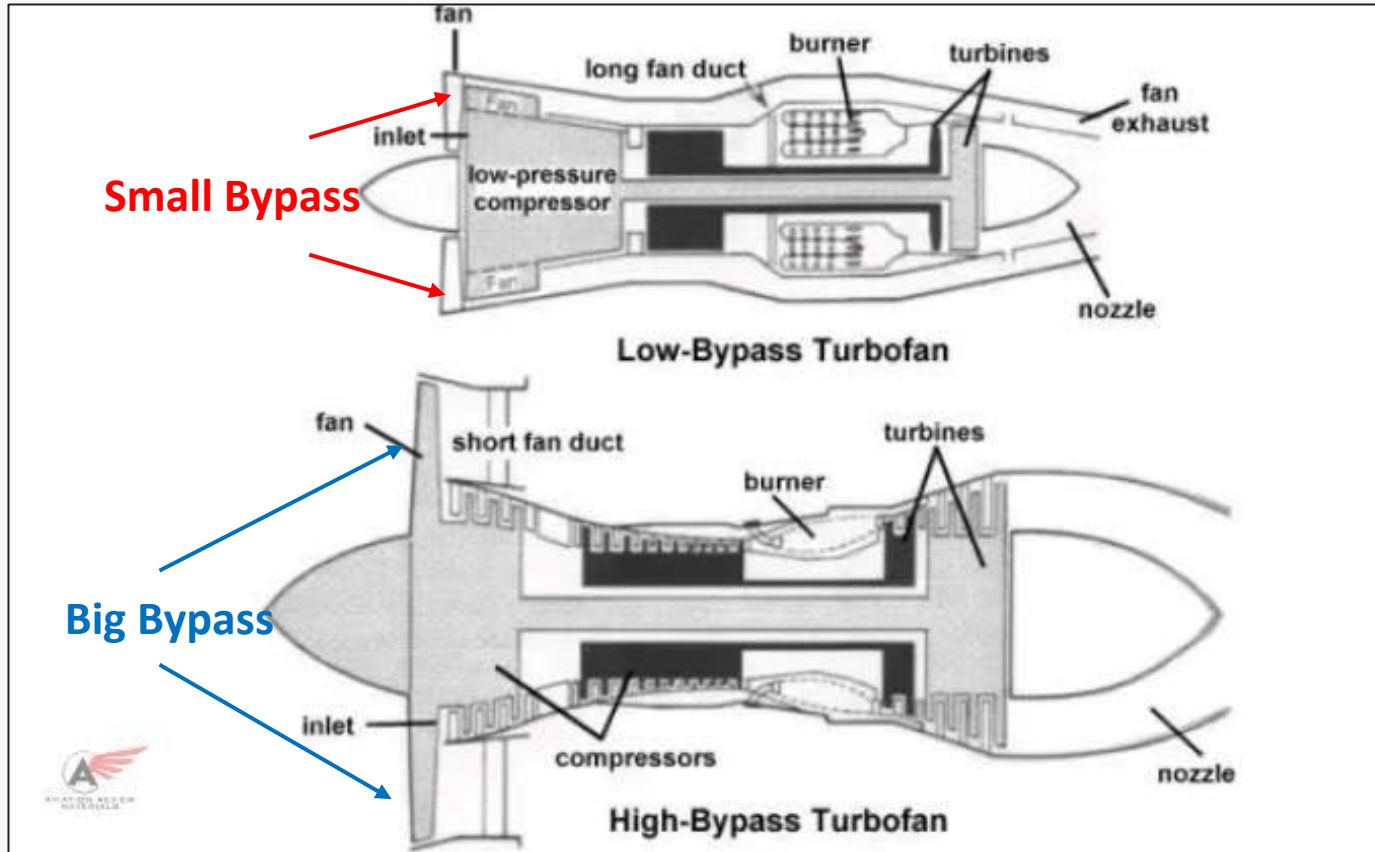
Military Fighter Jets



Commercial Jet Airlines



High Bypass Ratio vs Low Bypass Ratio Turbofan Engine



Credit: Aviation Review Materials

Military Fighter Jets



Different Risks to Different Types of **Aerodromes**

Wide-body Aircraft

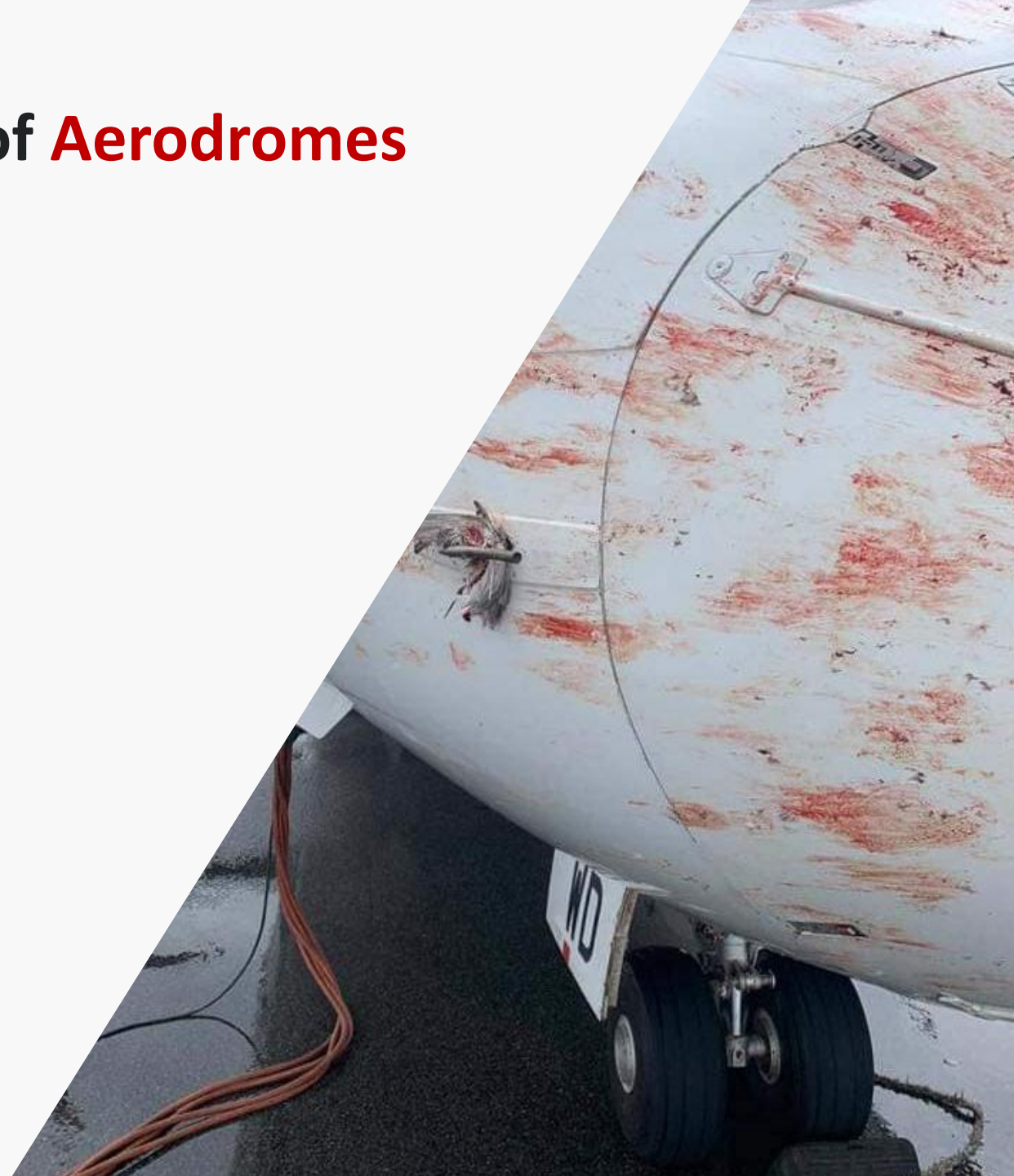
- Large International Airports
- Lower Risk of Catastrophic Incident

Narrow-body Aircraft

- Domestic/Regional Airports
- Higher Risk of Catastrophic Incident

Private Jets & Fighter Jets

- GA & Military Air Bases
- Highest Risk of Catastrophic Incident



RECAP !!!

- Preventing 'Damaging Strikes' and 'Loss of Use Strikes' take priority over bird strikes with no consequence
- Most Catastrophic accidents resulting in a hull loss were caused by compressor stalls in narrow body aircraft (Jeju Air 2216, US Airways 1549)
- Mass of the Plane, Engine Size/Type, Velocity, Phase-of-Flight are all determinants of damage severity

NOW LET'S LOOK AT BIRD MASS

Birds

Determinants of Damage Severity

Mass

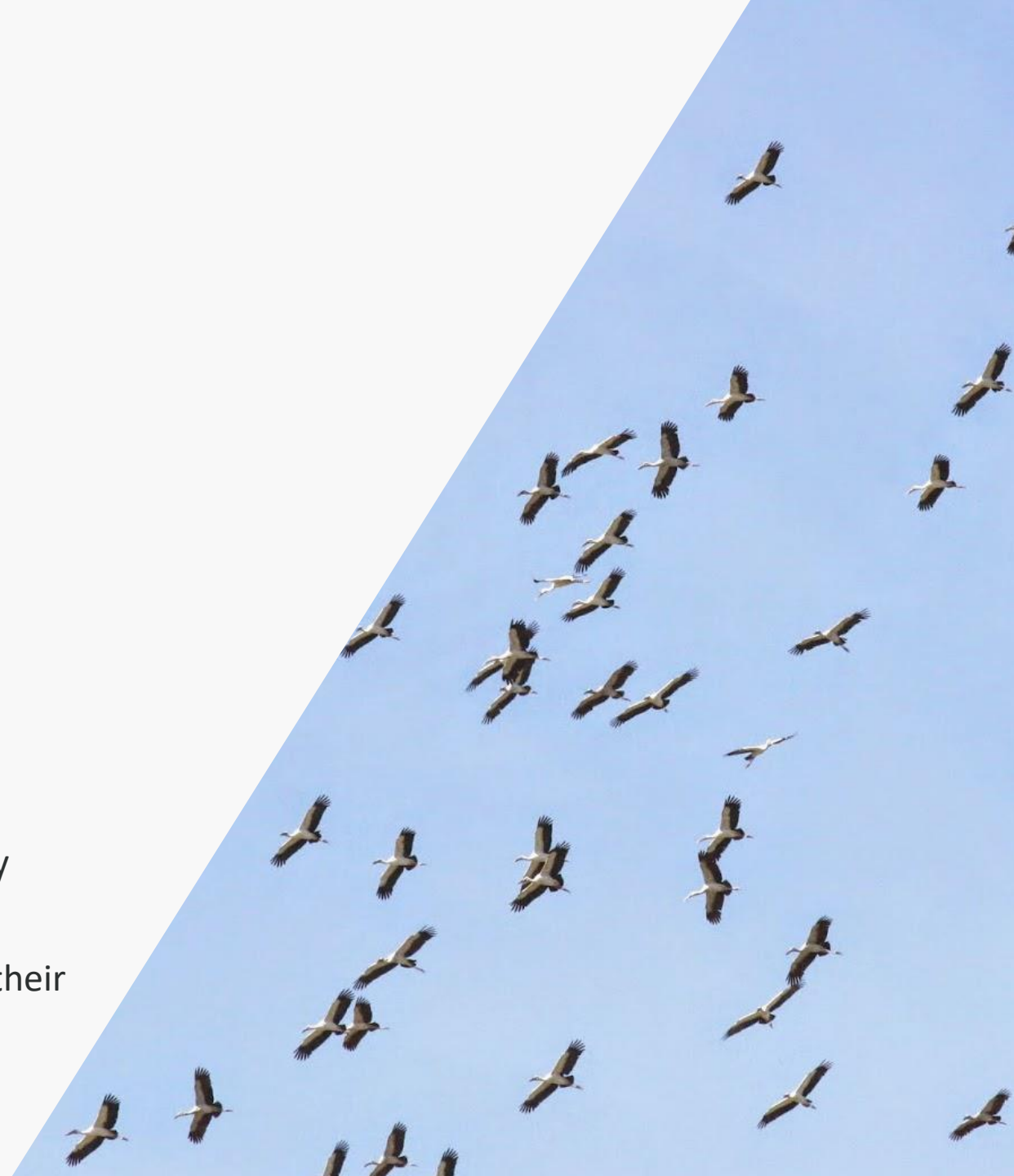
- Big bird / small plane
- Big plane / small bird

Flocking Behaviour

- Flock size & altitude
- Loosely / tightly flocked

Flying Skills

- Raptors are big, but have excellent flying dynamics / many aquatic birds are big and slow
- Juvenile birds are often the most struck birds because of their flying inexperience



Determinants of Damage Severity

Mass

- Big bird / small plane
- Big plane / small bird

Flocking Behaviour

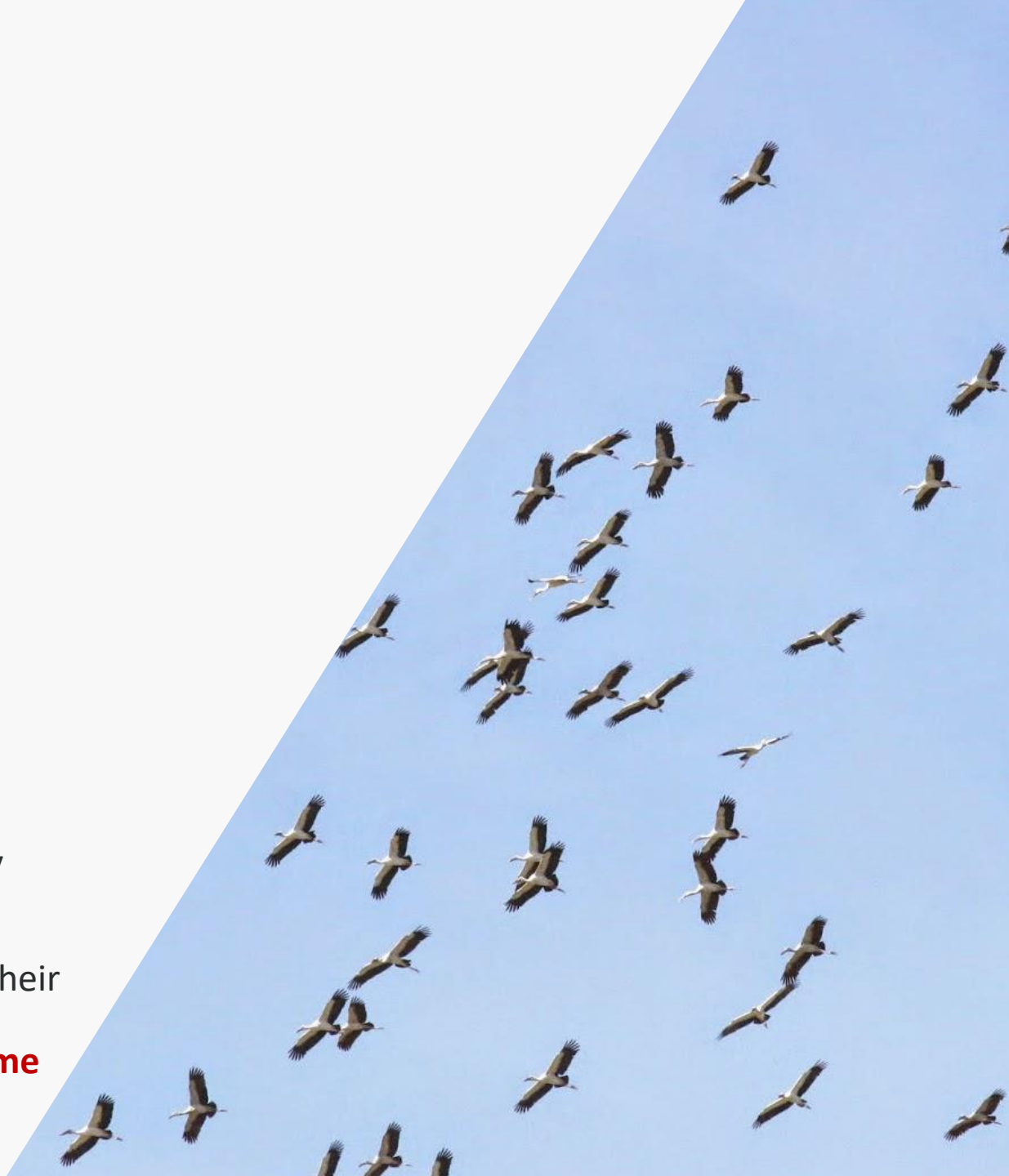
- Flock size & altitude
- Loosely / tightly flocked

Flying Skills

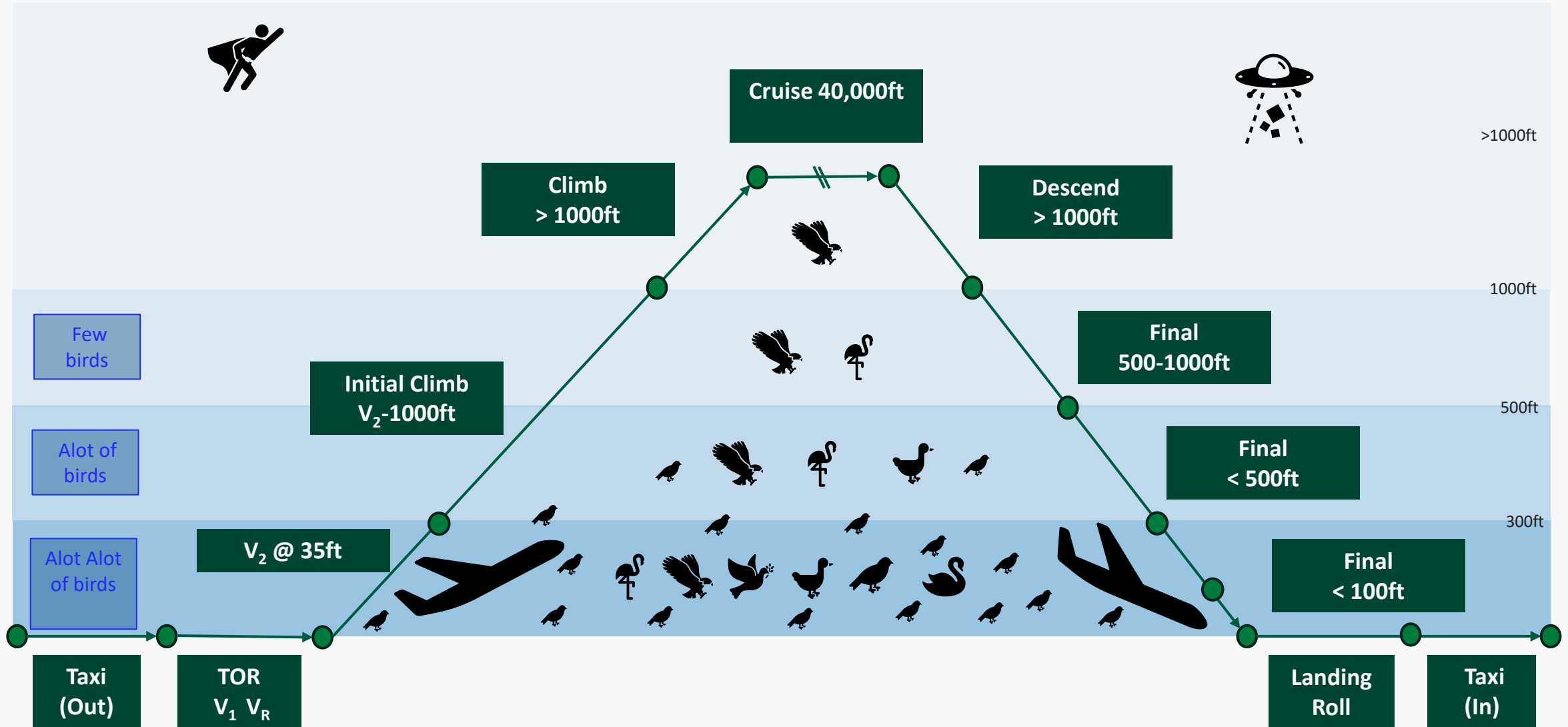
- Raptors are big, but have excellent flying dynamics / many aquatic birds are big and slow
- Juvenile birds are often the most struck birds because of their flying inexperience



Another Day Another Time



Bird Abundance Relative to Altitude



Size of Flock



Asian Glossy Starling



White-headed Munia



Big Flock, Big Bird



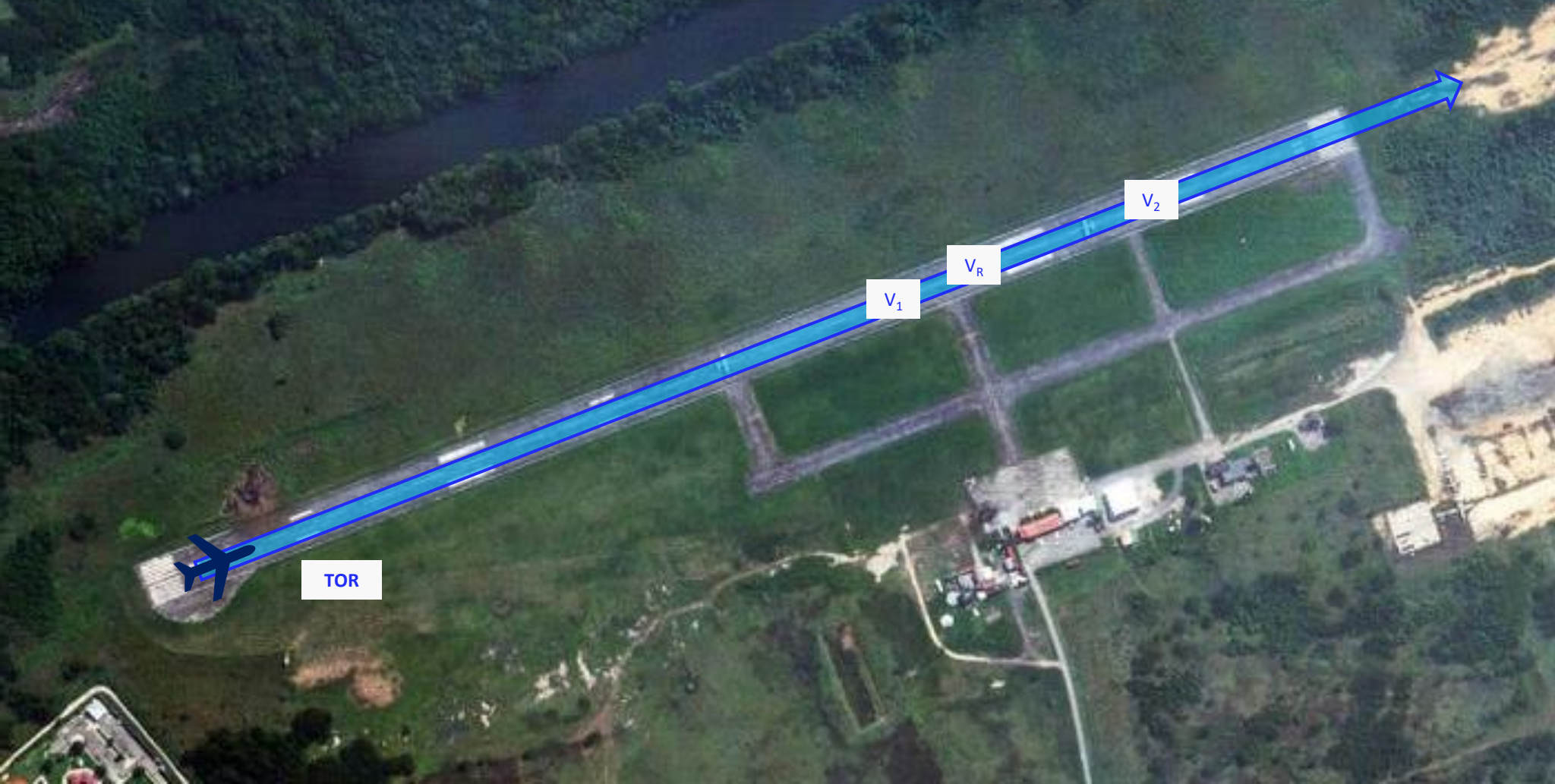
Asian Openbill Stork



Prioritising Resources

- Focus mitigation efforts on the most critical areas of the runway first. Priority should always be given to the most dangerous phases-of-flight for aircraft
- Ensure that the mitigation programme is sensitive to the different seasons, species & activities of the birds
- Break the airport space into smaller zones and set performance indicators to each zone.
- Develop a mini mitigation programme specific to each zone, which cumulatively should form your greater WHMP

Aircraft Take-Off Run V_1 V_R V_2



Aircraft Take-Off Run V_1 V_R V_2

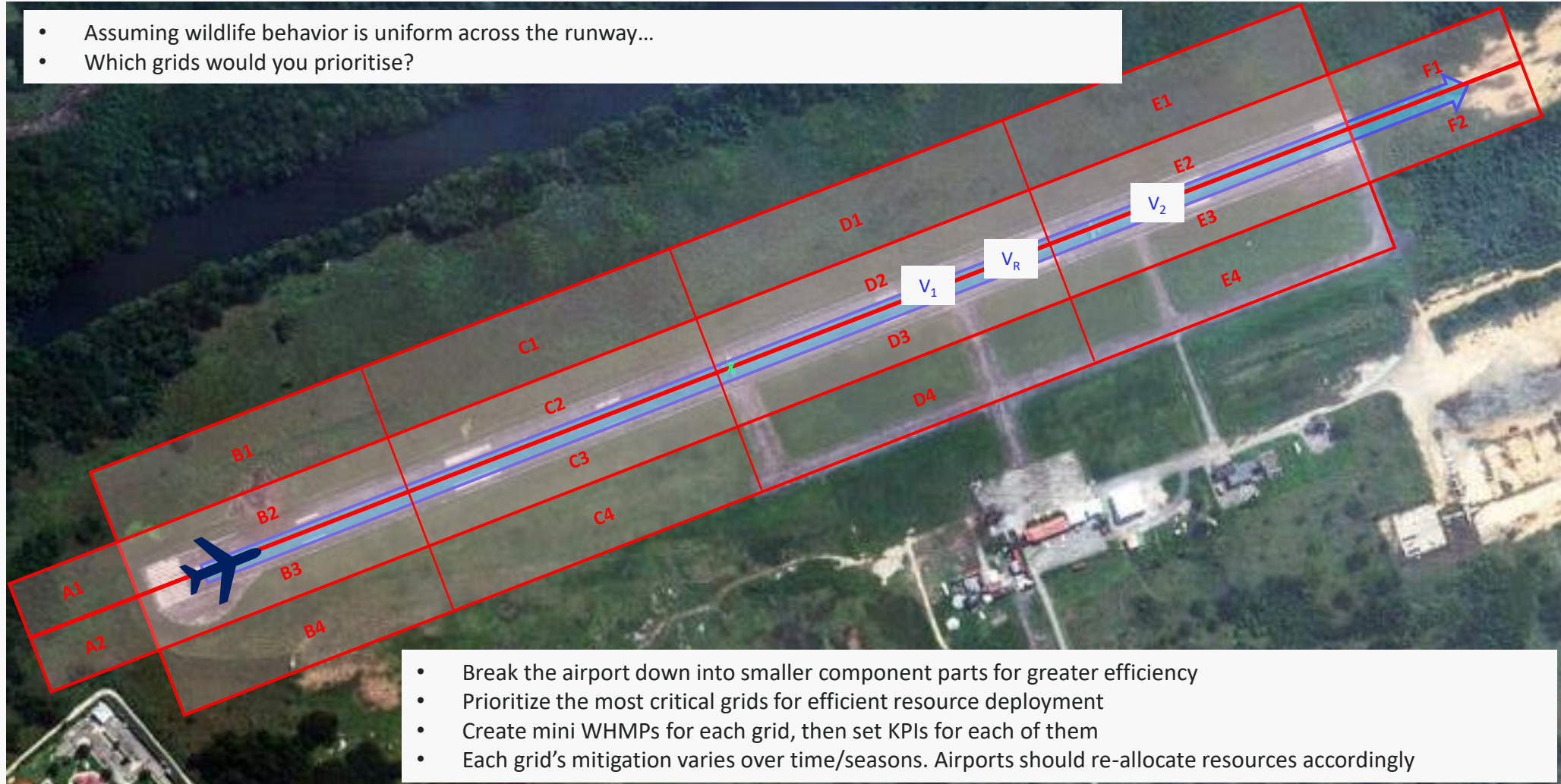


Aircraft Take-Off Run V_1 V_R V_2



Aircraft Take-Off Run V_1 V_R V_2

- Assuming wildlife behavior is uniform across the runway...
- Which grids would you prioritise?



- Break the airport down into smaller component parts for greater efficiency
- Prioritize the most critical grids for efficient resource deployment
- Create mini WHMPs for each grid, then set KPIs for each of them
- Each grid's mitigation varies over time/seasons. Airports should re-allocate resources accordingly

SUMMARY

1. With Limited Resources, focus on the most critical areas near your runway, create zoning
2. Smaller engines are more susceptible to compressor stalls, which may lead to catastrophic accidents
3. Bigger birds and large flocks are the greatest contributors to catastrophic accidents
4. Catastrophic accidents aside, Airlines are very concerned about the dollar cost of damaging strikes & loss-of-use strikes
5. An effective WHMP requires a 3D approach comprising
 - Strategic understanding airport's ecological environment & how it relates to aircraft operations
 - Tactically competent airside operations team that is well & correctly resourced for effective wildlife mitigation
 - Constant training at all levels

Mastermark's 3D Approach

Airport Wildlife Training

Not sure where to begin? Get ICAO-certified in airport wildlife management through our courses offered in partnership with Embry-Riddle Aeronautical University. Build your skills to effectively reduce wildlife risks at your airport.

Consultancy

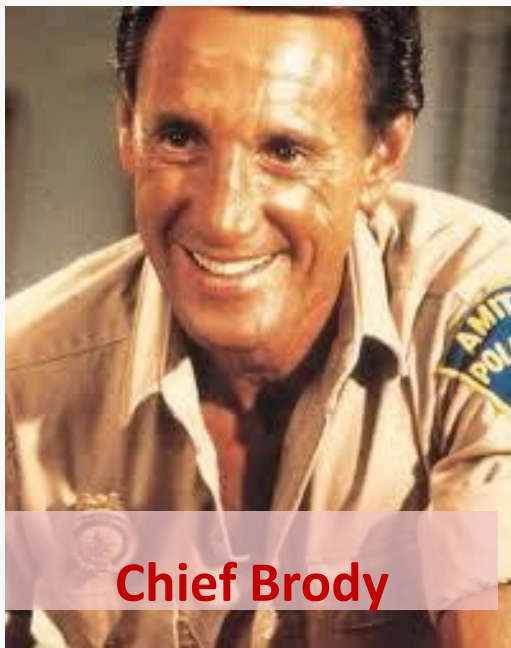
Don't know what your game plan is? Our Airport Biologists reduce bird strike risks with a clear, data-driven framework that turn complex challenges into actionable steps; making implementation of your Wildlife Hazard Management Plan a seamless process.

Ground Operations

Have the report but need the action? Our Ground Ops team are wildlife specialists, executing effective mitigation strategies through bird scaring, trapping habitat modification, and deterrent systems ensuring your airport has the right experts on the ground.

Three's a Charm

JAWS



Chief Brody

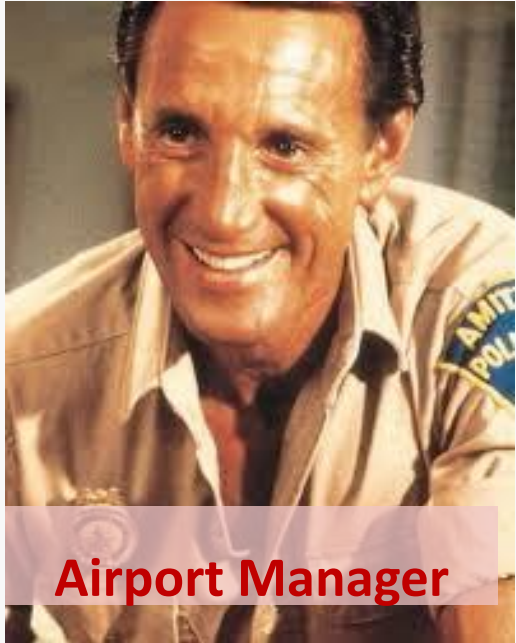
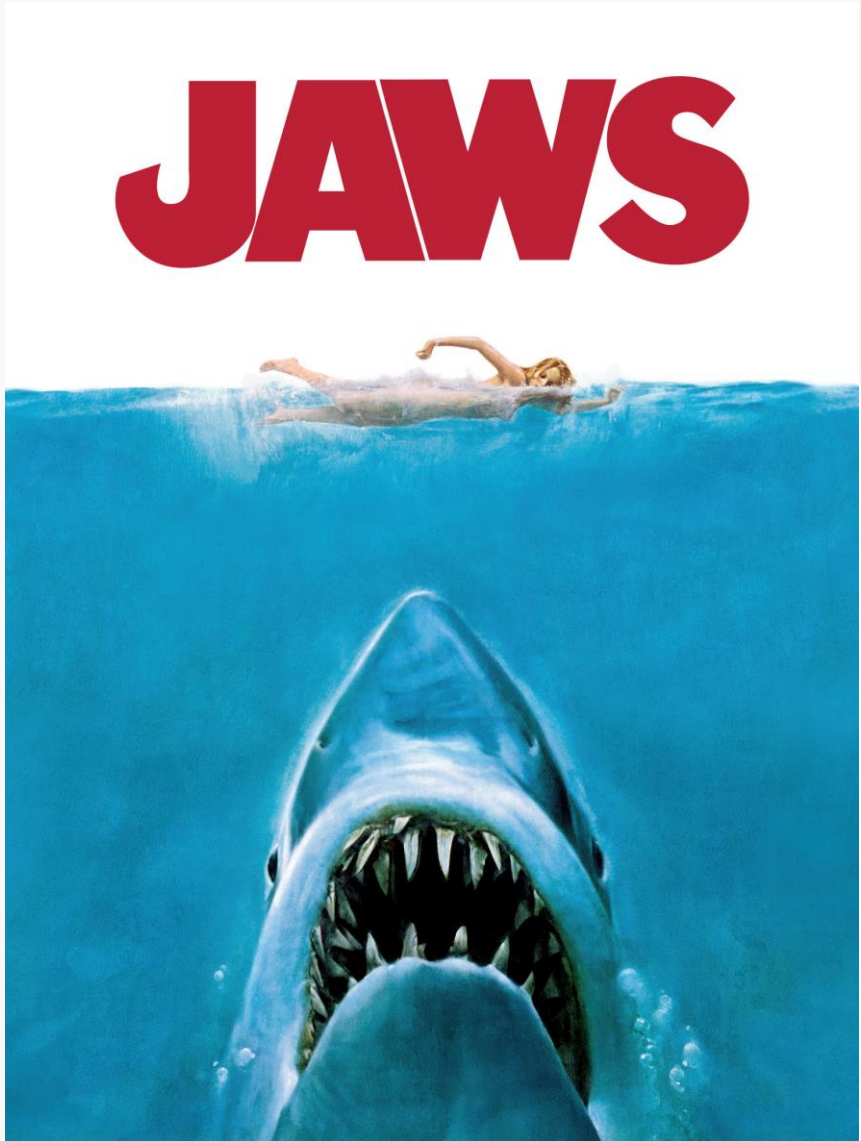
It Takes 3 to get a job done



Hooper



Quint



Airport Manager

It Takes 3 to get a job done



Biologist



Airside Operations

ICAO Airport Wildlife Training

Wildlife Management Training Courses can be conducted in-person or virtually.

Next in-person courses will be held at Embry-Riddle Asia Campus located within Seletar Airport in Singapore:

- ICAO Airport Wildlife Management – **16-18 November 2026**
- ICAO Airport Wildlife Operations – **19-20 November 2026**



TRAINAIR PLUS™
Bronze Member

EMBRY-RIDDLE
Aeronautical University
ASIA



Thank you.

Join our community at airportbiologist.com to learn how to protect planes and animals, and get your airport wildlife questions answered by real biologists!

Connect with us at info@mastermark.com.sg.

