

DESIGN OF A BIO-INSPIRED MICRO AERIAL VEHICLE



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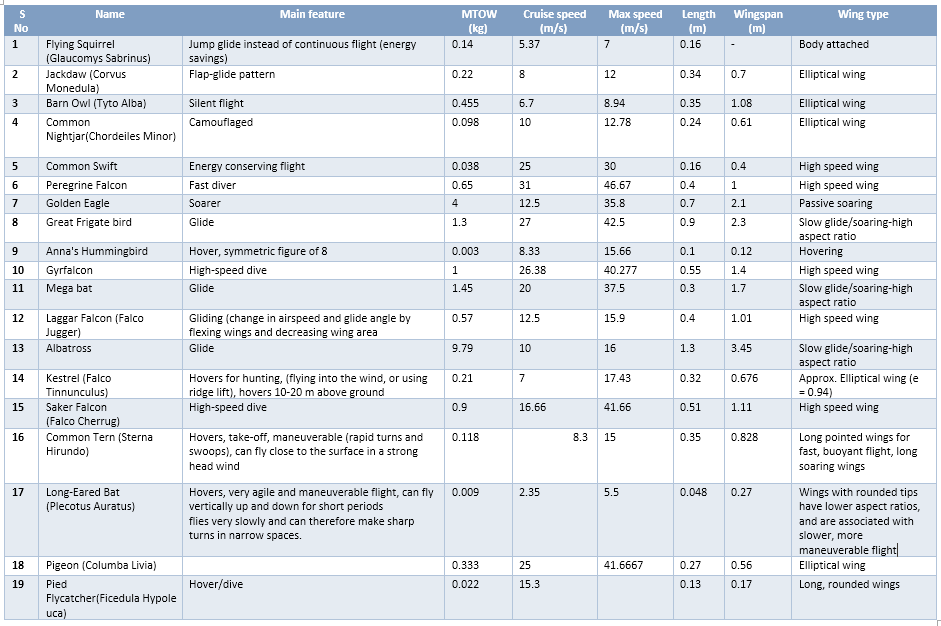
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# Literature Study

## Birds

The table above tabulates basic morphological data for some birds and 2 specific species of bats that have characteristics relevant to the mission profile given [7-15].



The conceptual sketches could be based on following two bird (chosen from the literature survey):

The Common Tern (Sterna Hirundo) and the Kestrel (Falco Tinnunculus) were chosen due to their compact size and ability to hover in the presence of a headwind. Additionally, the former can soar, thereby reducing the necessity to flap throughout the entire mission. **Wing area** for these birds were found to be **0.056 m2** and **0.368 m2** respectively.

## Bats

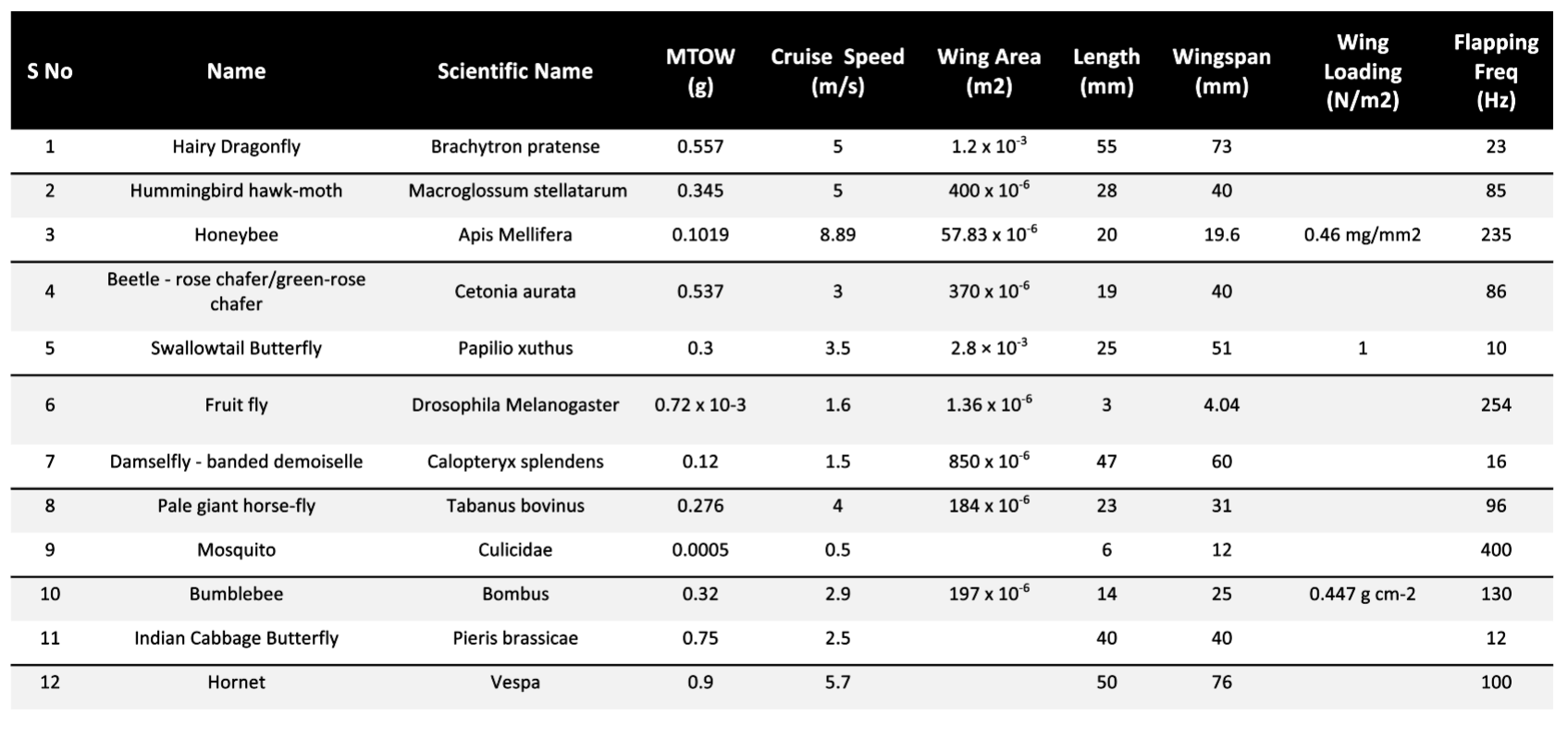
Data of 22 different species of bat were obtained from [3], and are tabulated below:



Two specific species of bats were chosen – *Tadarida Australis* and *Taphozous Hilli*. These have fairly high aspect ratios, making them easy to analyze aerodynamically, since lower aspect ratio models are much more susceptible to be affected by unsteady effects. Additionally, their masses are neither too high not too low, and their size is such that they can be made stealthy.

## Insects

A similar literature study was done for insects with hover capability [16-18]. This was a major condition while performing the study primarily because insects are known to be efficient at hovering.



# Conceptual Sketches

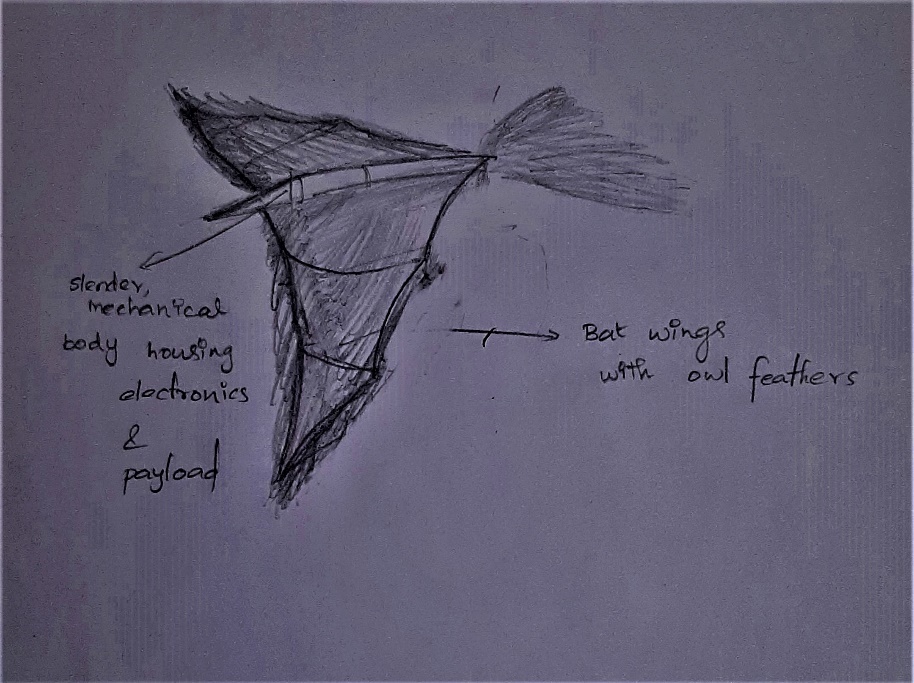


Figure : Bat with Owl Wings

The body is shaped like a bat considering the easier gliding and flapping motion of bats. Owl serrations over the wing are being considered as they have been found to reduce noise.

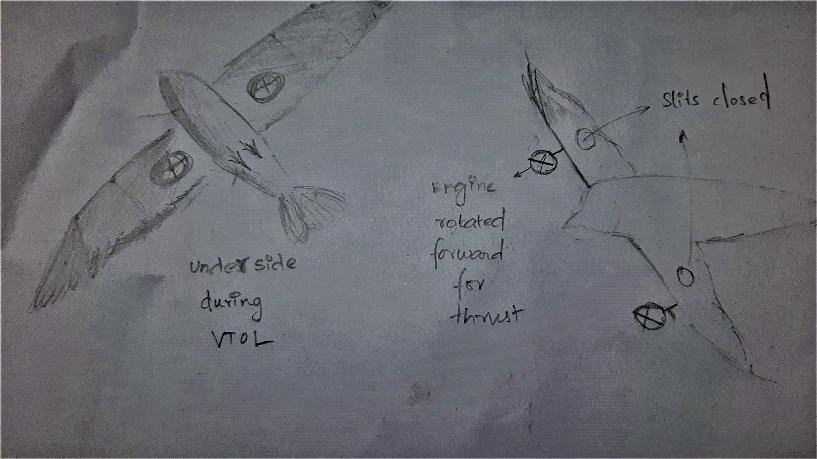


Figure : Common Tern with VTOL Capability by Introduction of Slits on Wing Planform

The idea is to incorporate the VTOL concept into a camouflaged MAV. The wing is shaped like the wing of a tern.

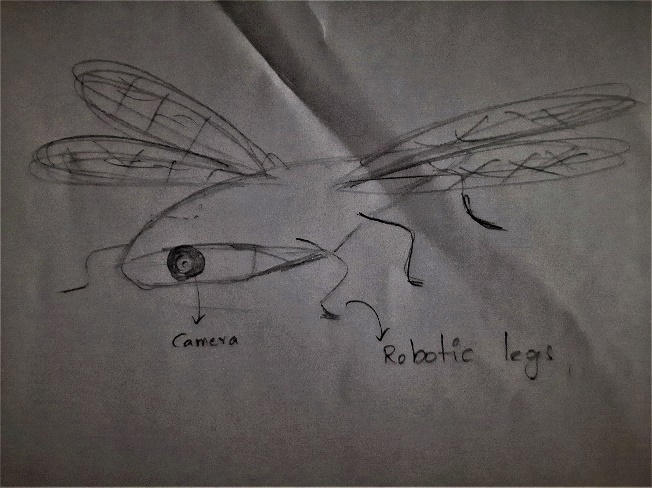


Figure : Insect-sized MAV inspired from Dragonfly

The main inspiration is the dragonfly, it has better hovering characteristics than most birds and insects. The body has been widened to accommodate avionics. Robotic legs for land operations.

# Sizing

The sizing procedure from [2] was used, in which the biological morphological data was used as the initial dimensions for the MAV/SUAV model. It is assumed that bird morphological and kinematic data can be used for an MAV model for similar characteristics [4], and hence, their flight speed was also taken for further calculations. A summary of the dimensions are as follows:

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Species​ | Cruise Speed (m/s)​ | Mass (kg)​ | Wingspan (m)​ | Planform Area ​(m2) | Aspect Ratio​ | MAC​ (m) |
| Tadarida Australis​ | 11.9​ | 0.0353​ | 0.4625​ | 0.02584​ | 8.28​ | 0.055​ |
| Taphozous hilli​ | 10​ | 0.0241​ | 0.4616​ | 0.02736​ | 7.79​ | 0.059​ |
| Common Tern​ | 8.3​ | 0.118​ | 0.828​ | 0.056​ | 12.2​ | 0.067​ |

# Constraint Diagram

## Relations Used [1]

Where,

, which describes the momentary thrust and sea thrust

, the dynamic pressure

is the wing planform area

, the weight of the aircraft

, the load factor for the specific phase of flight

, ratio of the parasite drag coefficient of flapping wing () to the frictional drag coefficient () for a flat sheet, and generally ranges from 2 to 4.4.

, the frictional drag coefficient

the free-stream velocity

The T/W vs W/S relation above is used for 6 different phases of flight:

1. Hand launch at stall speed
2. Cruise flight
3. Climbing flight
4. Horizontal acceleration
5. Accelerated climb
6. Coordinated turn

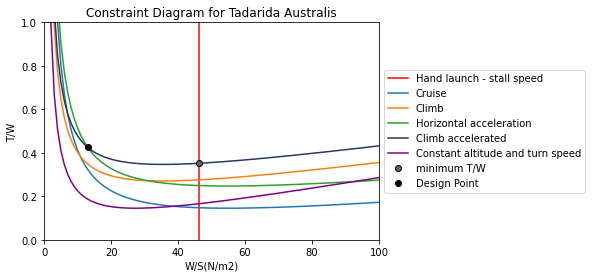
The plots corresponding to all 6 phases are combined into a single graph called the *Constraint Diagram* to obtain the design point. This constraint diagram is done for the 2 bat and the one bird species mentioned in the previous section. The plots are shown in the subsequent section.

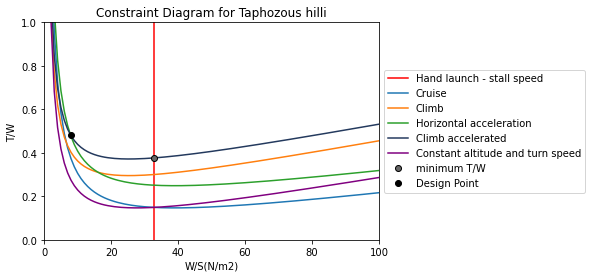
The flapping frequency is given by the relation [5]

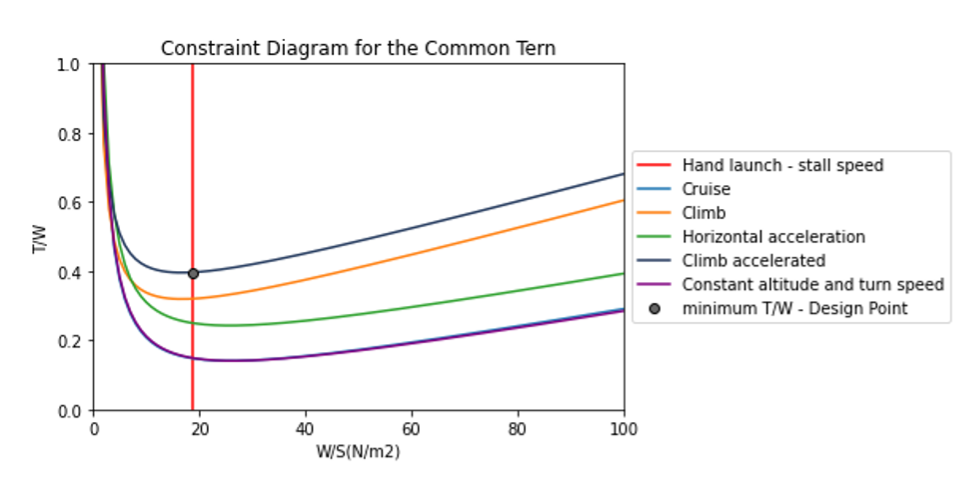
Where, is the mass (in kg), the acceleration due to gravity (in m/s2), the wing span (in m), the planform area (in m2) and the density at flight altitude (in kg/m3).

## Plots

The constraint diagram was used to obtained the design point T/W, and hence, the power value. The diagrams for the *Tadarida Australis, Taphozous Hilli* and *the Common Tern* species are plotted below:







## Results

The results of the constraint plot are tabulated below.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Species​ | Reynolds number​ | Design point – W/S (N/m2)​ | Design Point – T/W ​ | Mass (kg)​ | Power required (W)​ | Flapping Frequency  (Hz) [5]​ |
| Tadarida Australis​ | 100,072​ | 13​ | 0.425​ | 0.0342​ | 1.698 ​ | 6.83​ |
| Taphozous hilli​ | 91,336​ | 8​ | 0.48​ | 0.0223​ | 1.05​ | 5.825​ |
| Common Tern​ | 135,983​ | 18.76​ | 0.39​ | 0.107​ | 3.456​ | 4.75​ |

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