**Theoretical Background**

Mode shapes are an orthonormal basis for the shape of the wing, these Modes are determined by the physical attributes of the wing, can be calculated in lab conditions using S-POD and remain constant throughout the movement of the wing.

The wings shape can be expressed with the following equation:

where:

(Mode Shape) - A tensor that describes a distinct shape of the wing.

These Mode Shapes can be calculated in lab conditions using S-POD

and remain constant in non-intertial systems.

(Scale at time-point t) - These scales are independent of each other, continuous and unique for each wing shape.

(Natural frequency of the Mode Shape) – These frequencies form an increasing series.

In reality, due to drag the higher frequencies will diminish fast and so only the first few Mode Shapes determine the shape of the wing, the rest have negligible effects.

We can estimate the Scales at time-point t from measuring the displacement of a discrete set of location on the wing at time-point t.

There are multiple methods for measuring the displacement of the wing at discrete locations:

1. Using multiple IMUs at different points around the wing and integrating twice over the acceleration we can find the displacement, this method is very inaccurate due to accumulated measurement mistakes and numerical errors.

It also requires a lot IMUs which change the structural qualities of the wing itself and as such not used in practice.

1. By measuring strain with optical fibers, this method is precise but the optical fibers themselves are very expensive.
2. Using multiple IR cameras, and light reflecting stickers placed in different position on the wing, this method is sensitive in sunlight and as such only works in lab conditions.

From these discrete measurements we can approximate the scales of the Mode Shapes of the wing.