MCEVS

Multi-**C**onfigurational **EV**tol **S**izing

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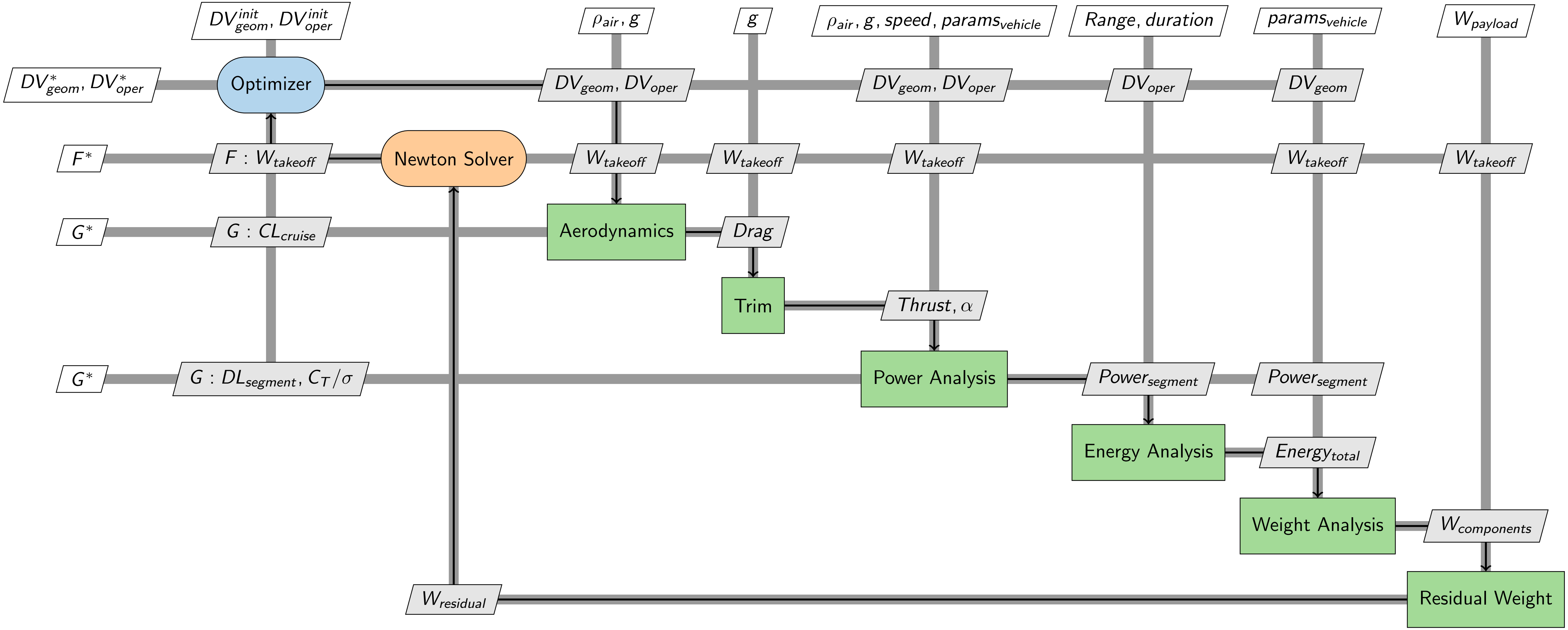
MCEVS: Multi-Configurational EVtol Sizing

- ***Sizing*** means estimating the weight of the vehicle, typically done at the conceptual phase
- MCEVS is currently capable of sizing **multirotor** and **lift+cruise** eVTOL configurations
- Given a **mission requirement** (payload, range, cruise speed, and flight profiles) and the **vehicle's geometric and operation variables**, MCEVS will estimate the *feasible* total and component weights.
- MCEVS is also capable of orchestrating **configuration optimization**, i.e., finding the geometric and operation variables that result in the optimal overall weight of the vehicle.

XDSM: General optimization



Optimizing a multirotor configuration (1/2)

With the parameters given, the following optimization is performed.

Minimize: $W_{takeoff}$

With respect to:

$$v_{cruise}, r_{rotor}, \mu_{rotor}$$

Subject to:

$$Disk\ Loading_{climb} \leq 600 \quad \text{[N/m2]}$$
$$Disk\ Loading_{cruise} \leq 600 \quad \text{[N/m2]}$$
$$Disk\ Loading_{descent} \leq 600 \quad \text{[N/m2]}$$
$$C_T/solidity \leq 0.14$$

Boundaries:

$$20 \leq v_{cruise} \leq 60 \quad \text{[m/s]}$$
$$0.5 \leq r_{rotor} \leq 1.5 \quad \text{[m]}$$
$$0.01 \leq \mu_{rotor} \leq 0.5$$

With an optimizer called SLSQP, aided by the analytical derivatives of the model, a gradient-based optimization is performed.

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Optimization terminated successfully    (Exit mode 0)
            Current function value: 735.0199168104233
            Iterations: 5
            Function evaluations: 17
            Gradient evaluations: 5
Optimization Complete
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Multirotor Initial Design

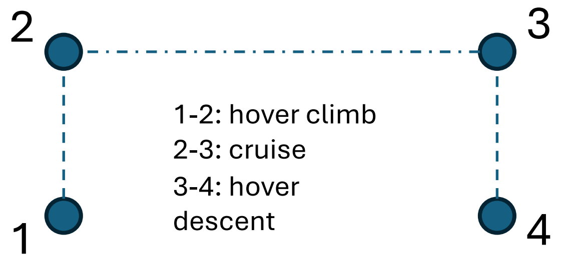
$W_{takeoff}$ = **975.30** kg
v_{cruise} = 30.0 m/s
r_{rotor} = 1.0 m
μ = 0.3

-24.63%
weight reduction

Multirotor Optimized Design

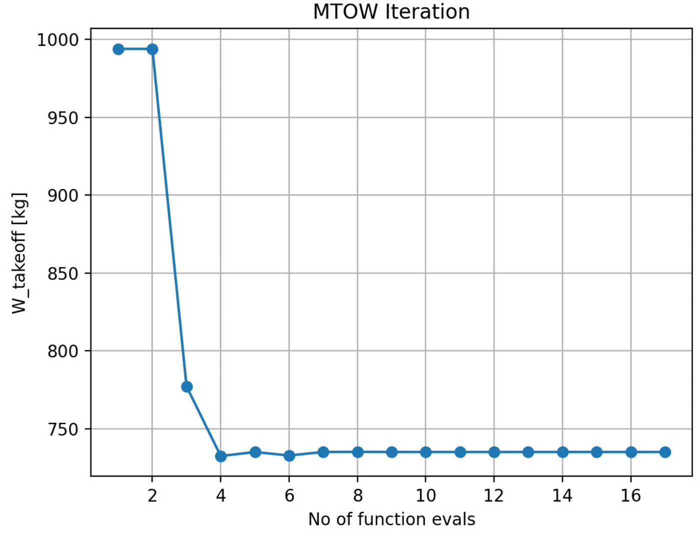
$W_{takeoff}$ = **735.02** kg
v_{cruise} = 20.0 m/s
r_{rotor_lift} = 1.5 m
μ = 0.25

Mission

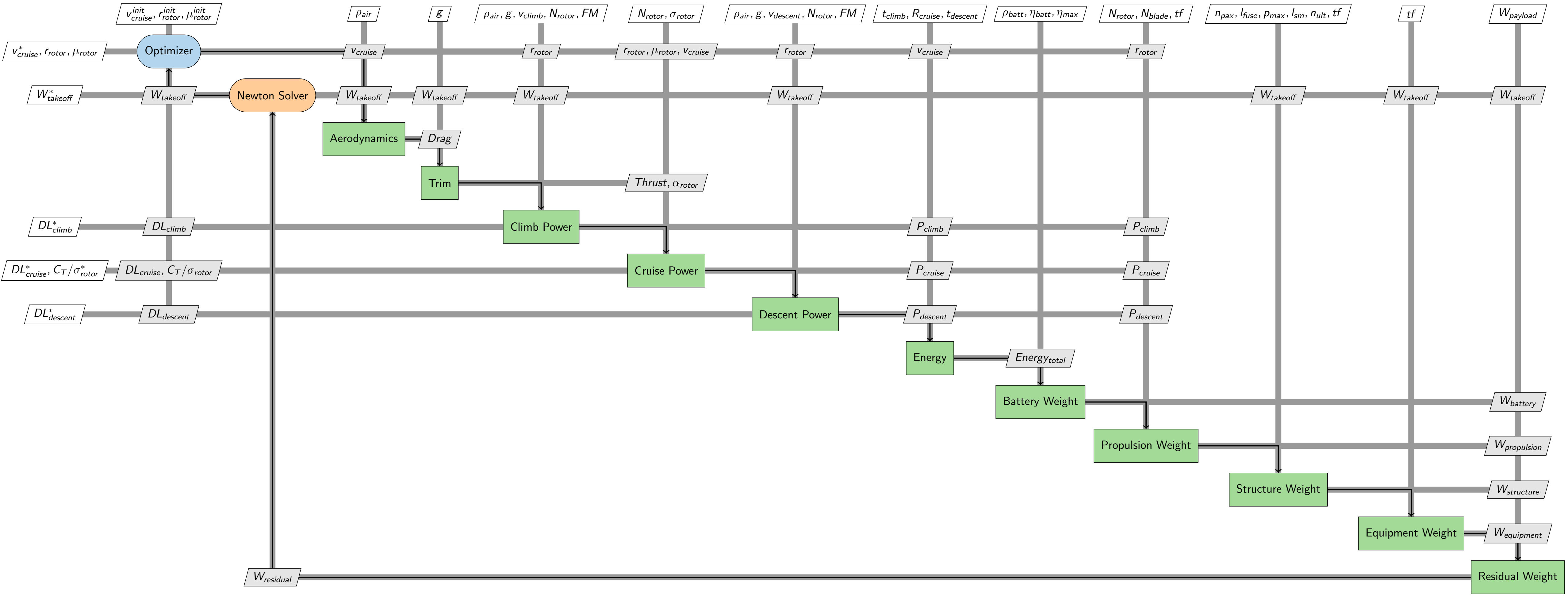


$v_{1\to2} = 2.54$ m/s
$\Delta t_{1\to2} = 120$ s
$v_{3\to4} = 1.524$ m/s
$\Delta t_{3\to4} = 200$ s

$payload = 400$ kg
$d_{2\to3} = 30{,}000$ m
$v_{2\to3}$ **is varied**
$\Delta t_{2\to3}$ **is varied**



Optimizing a multirotor configuration: XDSM (2/2)



Optimizing a lift+cruise configuration (1/2)

With the parameters given, the following optimization is performed.

Minimize: $W_{takeoff}$

With respect to:

$$v_{cruise}, AR_{wing}, S_{wing}, r_{rotor}, r_{propeller}, \ J$$

Subject to:

$$C_L \leq 0.6$$

$$Disk\ Loading_{climb} \leq 600 \quad \text{[N/m2]}$$

$$Disk\ Loading_{cruise} \leq 600 \quad \text{[N/m2]}$$

$$Disk\ Loading_{descent} \leq 600 \quad \text{[N/m2]}$$

$$C_T/solidity \leq 0.14$$

Boundaries:

$$20 \leq v_{cruise} \leq 60 \quad \text{[m/s]}$$

$$4.0 \leq AR_{wing} \leq 12.0$$

$$4.0 \leq S_{wing} \leq 12.0 \quad \text{[m2]}$$

$$0.5 \leq r_{rotor} \leq 1.5 \quad \text{[m]}$$

$$0.5 \leq r_{propeller} \leq 1.5 \quad \text{[m]}$$

$$0.01 \leq J_{propeller} \leq 1.3$$

```
Optimization terminated successfully    (Exit mode 0)
            Current function value: 805.1884809435229
            Iterations: 7
            Function evaluations: 8
            Gradient evaluations: 7
Optimization Complete
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Lift+Cruise Initial Design

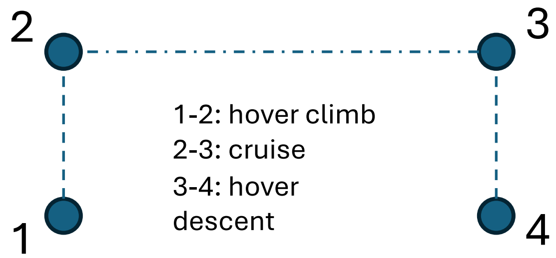
$W_{takeoff} = \mathbf{1066.32}$ kg
$v_{cruise} = 30.0$ m/s
$AR_{wing} = 10.0$
$S_{wing} = 8.0$ m^2
$r_{rotor} = 1.0$ m
$r_{propeller} = 1.0$ m
$J_{propeller} = 1.0$

-24.49%
weight reduction

Lift+Cruise Optimized Design

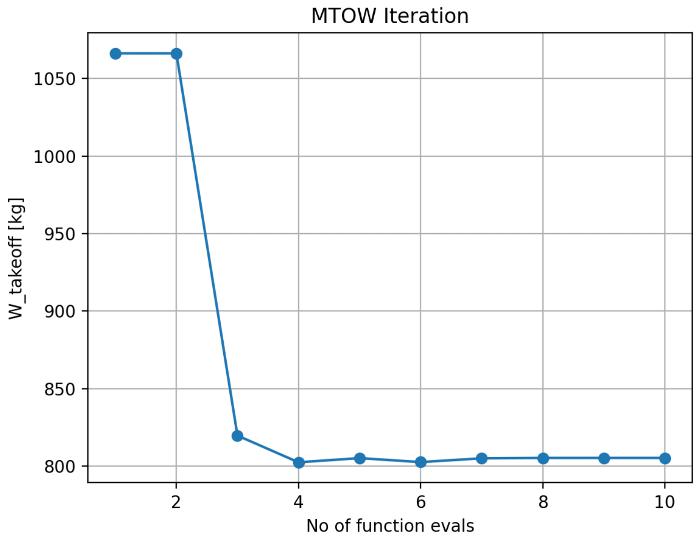
$W_{takeoff} = \mathbf{805.19}$ kg
$v_{cruise} = 42.31$ m/s
$AR_{wing} = 6.0$
$S_{wing} = 12.0$ m^2
$r_{rotor\_lift} = 1.5$ m
$r_{rotor\_cruise} = 0.85$ m
$J = 1.3$

Mission



$v_{1\to2} = 2.54$ m/s
$\Delta t_{1\to2} = 120$ s
$v_{3\to4} = 1.524$ m/s
$\Delta t_{3\to4} = 200$ s

$payload = 400$ kg
$d_{2\to3} = 30{,}000$ m
$v_{2\to3}$ **is varied**
$\Delta t_{2\to3}$ **is varied**



Optimizing a lift+cruise configuration: XDSM (2/2)