Modelica Library for Balloon Assisted Unmanned Aerial Vehicle

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Agenda

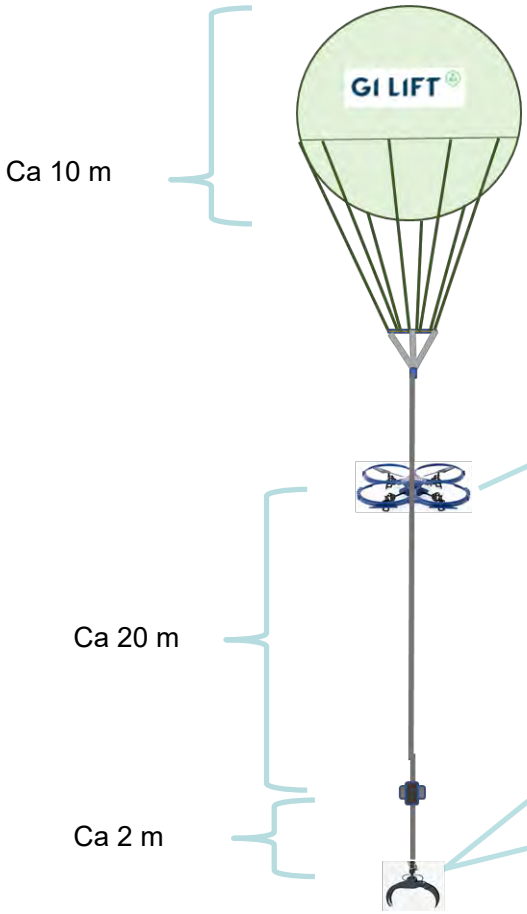
1. Introduction to Balloon Assisted Unmanned Aerial Vehicle (BUAV)
2. Components of BUAV
3. Integration Systems
4. Simulation Case Study
5. Next Steps

Today's clearcut approach – damages ground

Increased demands on future forestry

- Improved economics
  - Big forestry machines are expensive and have to run 24h
- Environmental and climate demands on less fossil fuel usage (avoid diesel)
- Handle challenges:
  - Increased climate change
  - Avoid damage on land and water
  - Risk of forest fire
- Possibilities for efficient forestry without clearcut areas
  - For example, close to cities
- Increased efficiency
  - In productive forests in areas which are difficult to access
- More environmentally friendly and robust forestry – pick only selected trees, allow a mix of different trees

An autonomous ground independent lifting system



Aerostat

Balances the system weight without load

Multicopter

Provides lift power without load. Manuevering and control

Energy package (batteries, also hydrogen in balloon)

Storage of energy

Grapple and sensors for localizing tree trunk

Patent application has been made for this system

Transportation of timber

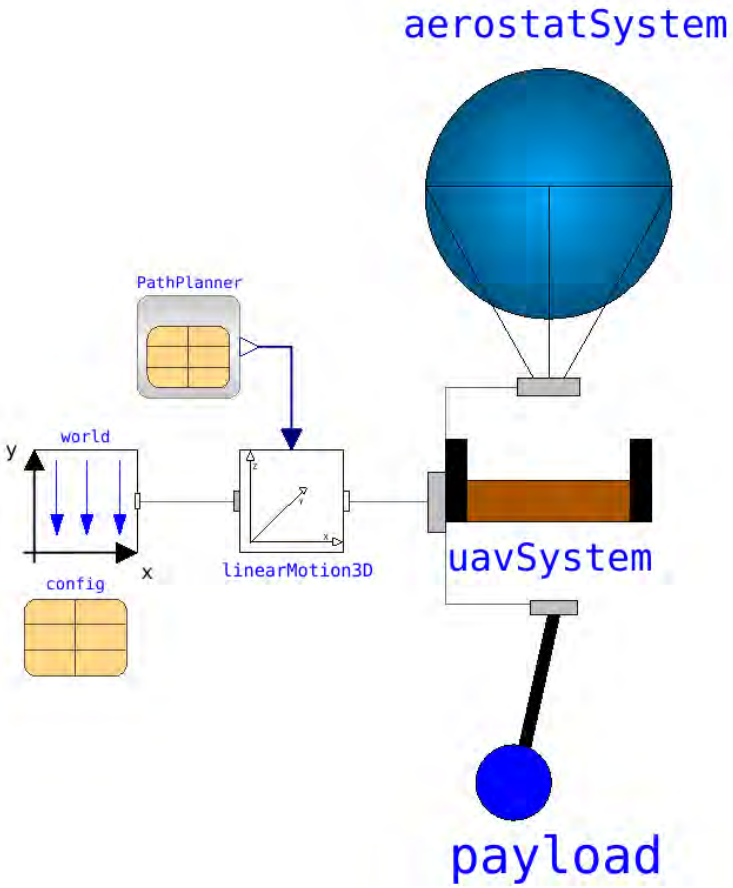
Timber

Branches

Whole tree

Early Prototype Demo Flight by GI LIFT AB

Outside Linköping December 2019

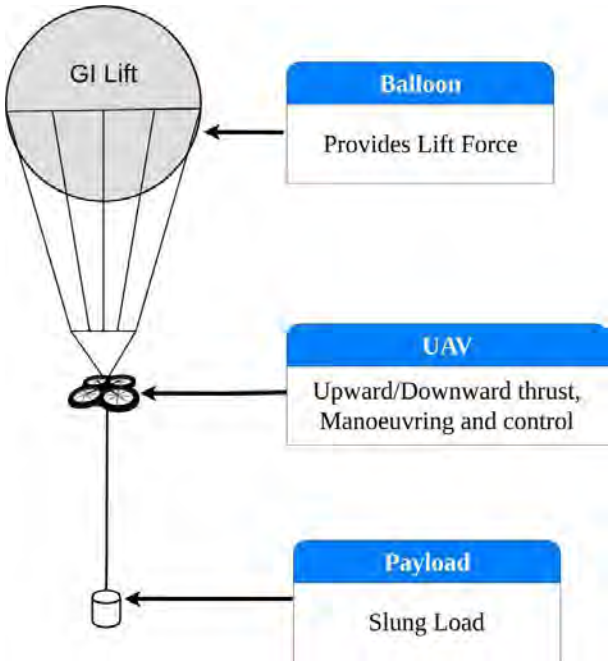


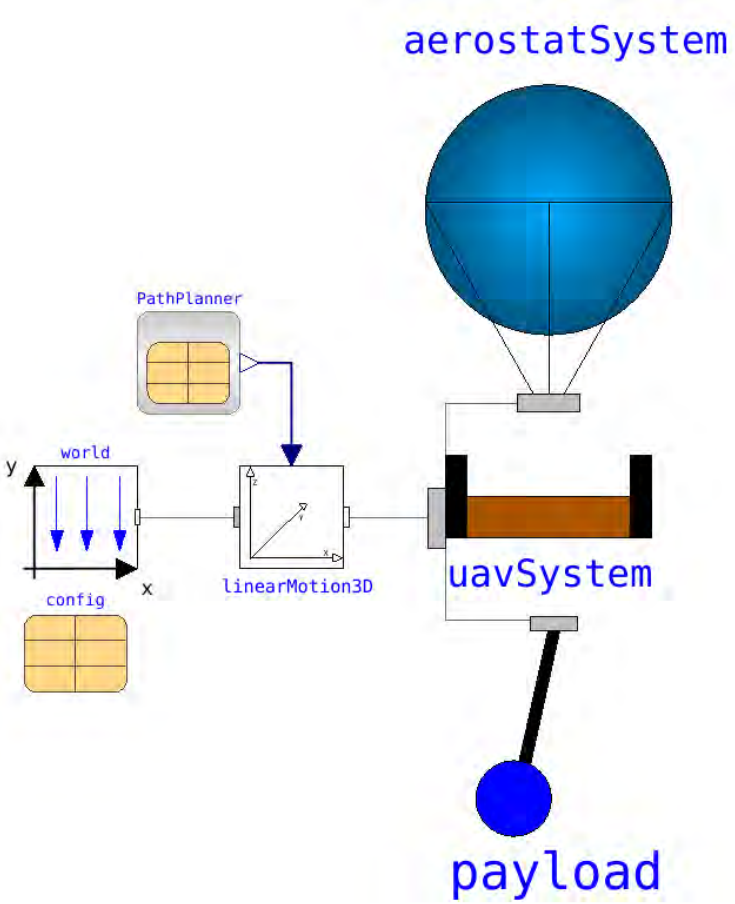
Introduction to Balloon Assisted Unmanned Aerial Vehicle Model (BUAV)

14th MODPROD Workshop 2020; Linköping; Sweden

Introduction

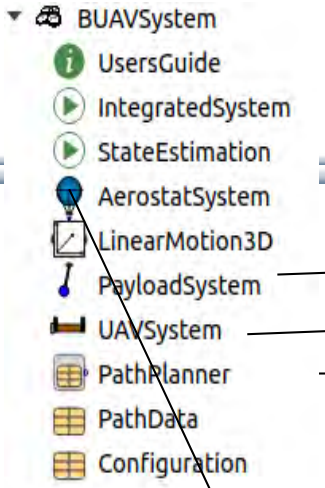
- Balloon assisted UAV (Unmanned Aerial vehicle) is an integrated device having a hydrogen/helium balloon attached to a multicopter.
- BUAV can be used to transport heavy objects, high altitude surveillance, provide extended flight time for UAV and so on.
- Multibody BUAVSystems library has been developed in Modelica/ OpenModelica.
- This library can be used for:
  - Stability Analysis of the UAV and Control System Design
  - Stability Analysis of the Payload including oscillationa
  - Path Planning- Time, Power and Energy
  - Load Analysis

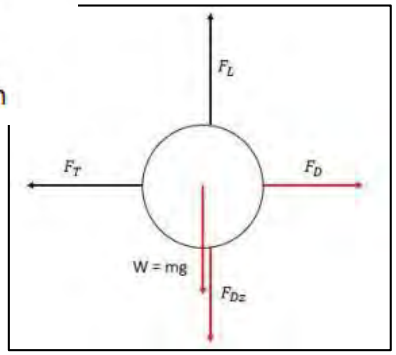


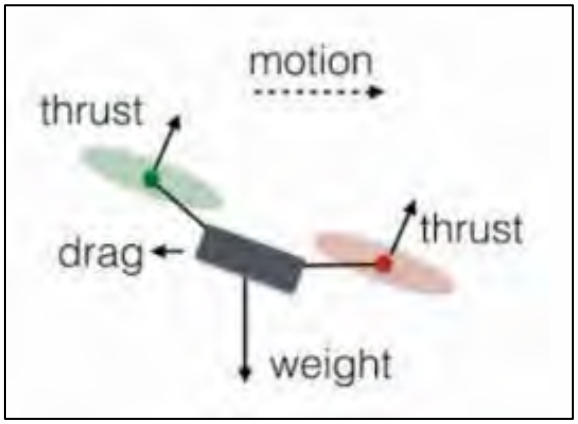


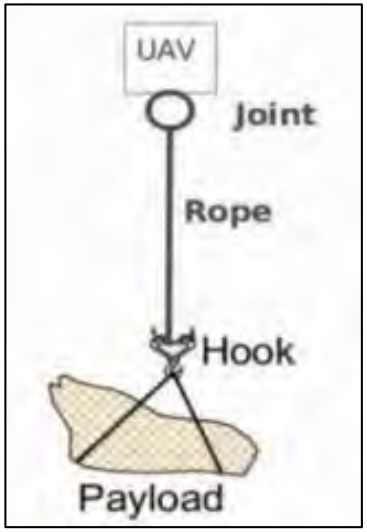
Components of BUAVSystems

Library Architecture









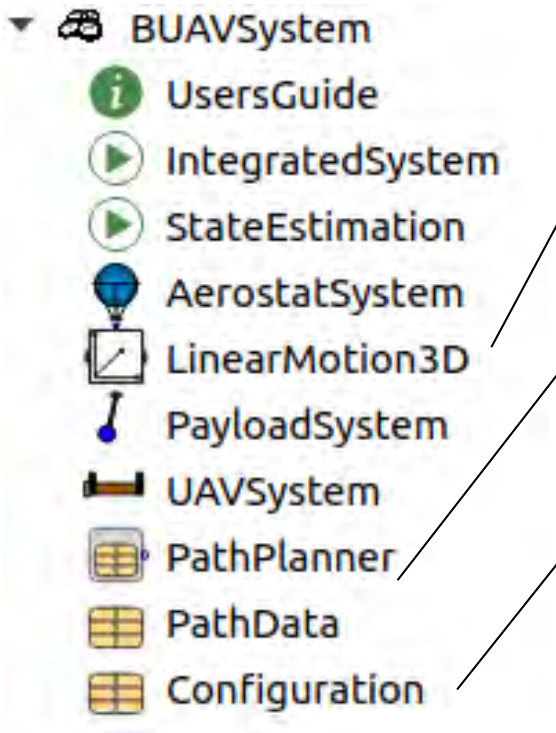
AerostatSystem simulates the drag and lift dynamics of a balloon filled with a buoyant gas.

UAVSystem model captures the force and torque exerted on the USV for a given input profile.

PayloadSystem model captures the dynamics of a hanging payload in motion.

Library Architecture

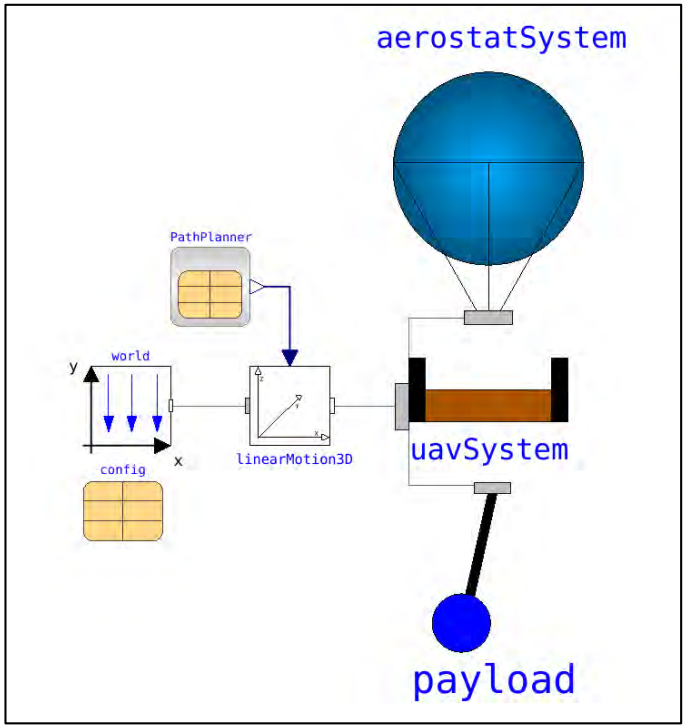
OpenModelica Library- Extending the MultiBody Library



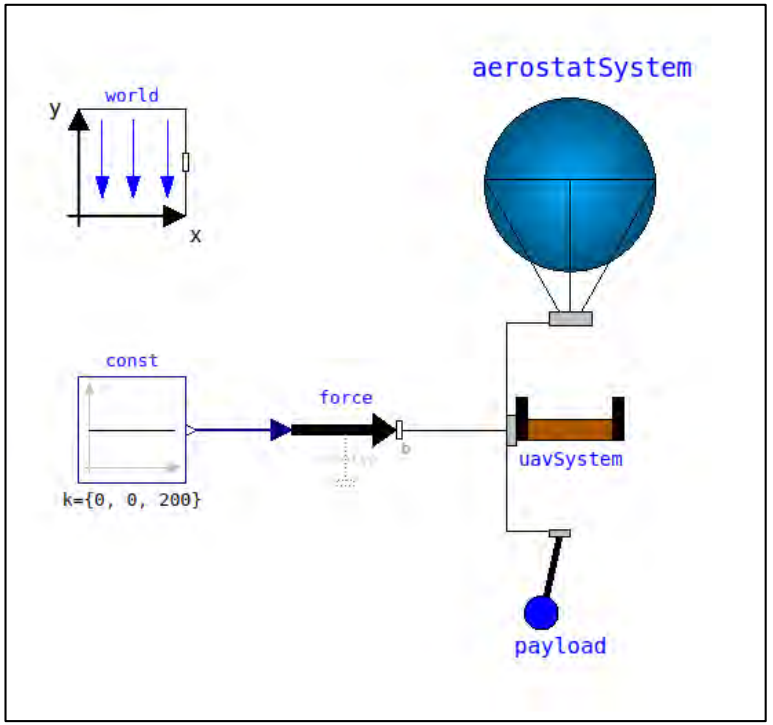
- **LinearMotion3D** takes velocities in 3 dimensions and generates the combined force input
- **PathPlanner** and **PathData** provide the velocity profile inputs based on user waypoint selection.
- **Configuration** model takes all parametric inputs for the system like UAV, payload mass, Balloon dimensions, payload cable length etc.

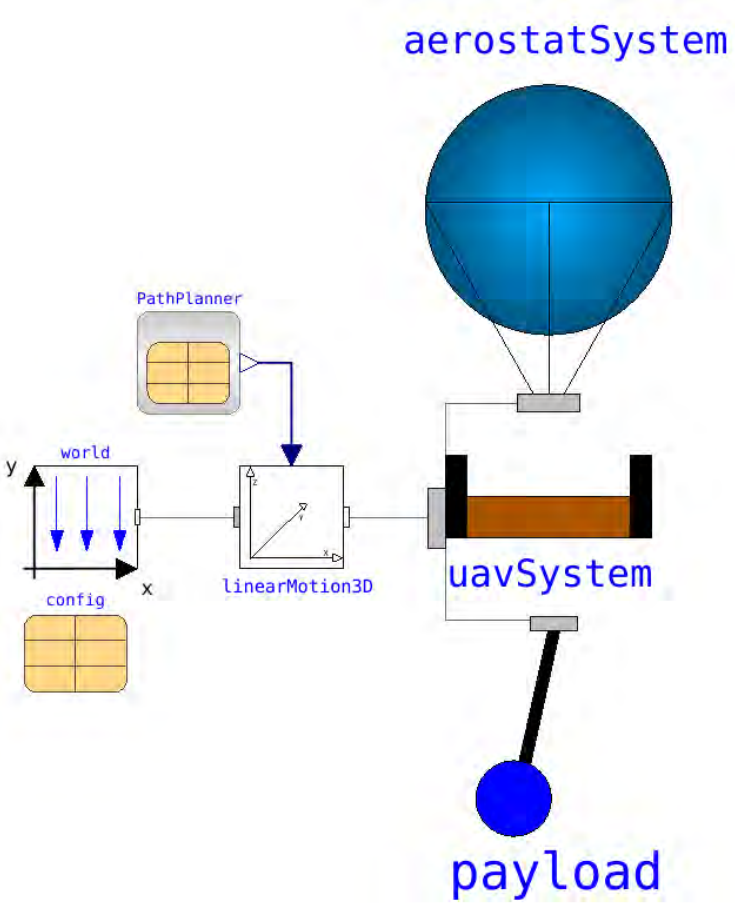
Example Models

IntegratedSystem example model **calculates the total force and torque exerted on the uav and the payload** oscillation for a predefined path input.



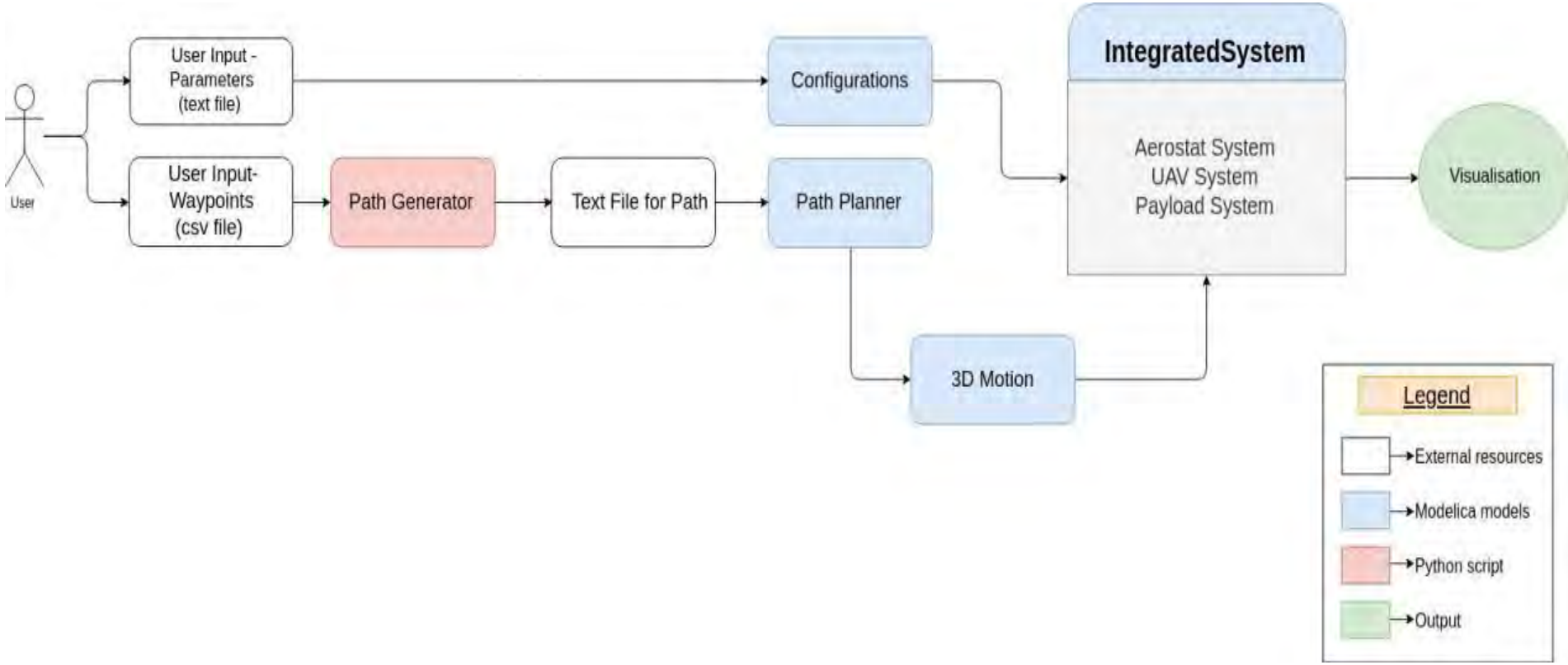
StateEstimation example model is an integrated system of balloon, UAV and the payload which **stimulates how the system moves** for a given set of UAV propeller inputs





IntegratedSystem

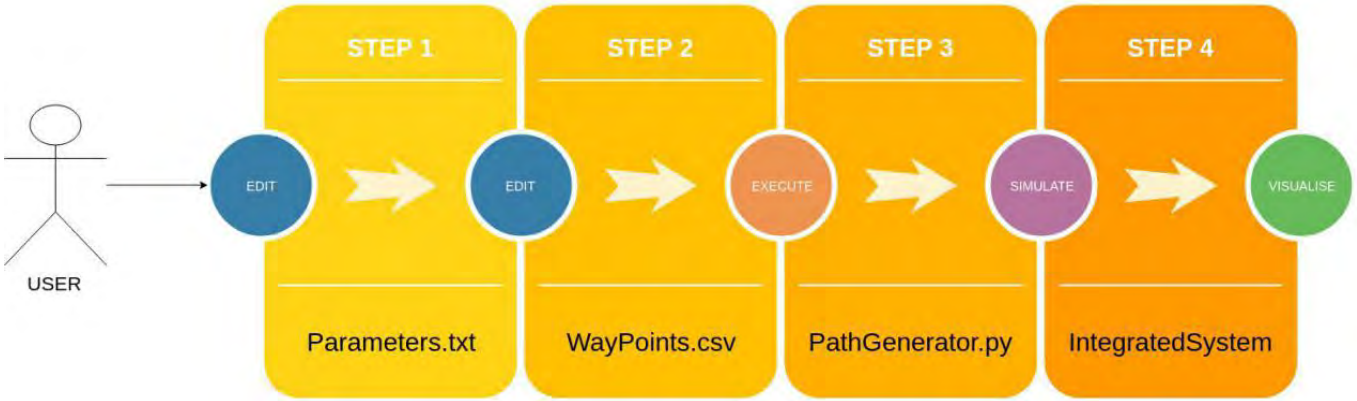
Architecture of IntegratedSystem



Workflow of IntegratedSystem

Parameters.txt

- maxHorizontalVelocity=10
- maxVerticalVelocity=1
- horDelay=2
- verDelay=2
- windVelocity=4
- windDirection=0
- uavMass=55
- payloadMassOnward=50
- deadWeight=6
- dragCoefficientSphere=0.47
- gasDensity=0.08988
- payloadRadius=0.2
- payloadLength=0.5
- dragCoefficientCylinder=0
- cableLength=1
- aerostatMass=70
- aerostatRadius=2.7
- airDensity=1.23

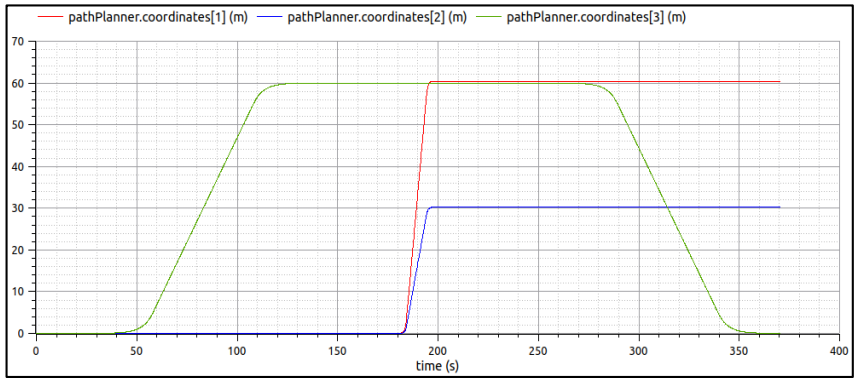


Waypoints.csv

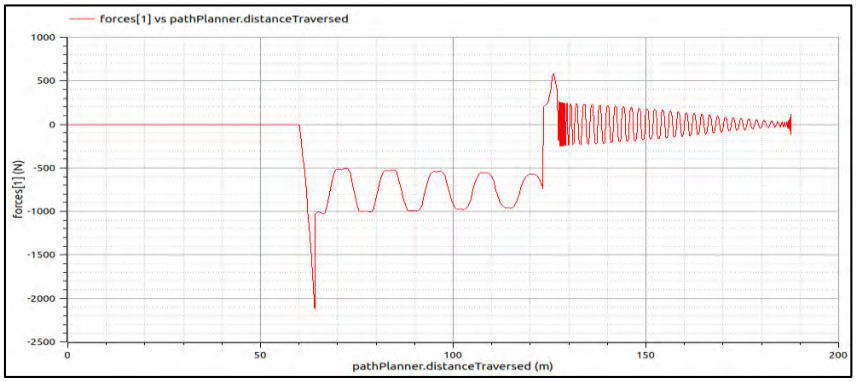
X	Y	Z
0	0	0
0	0	60
60	30	60
60	30	0

Plots of IntegratedSystem

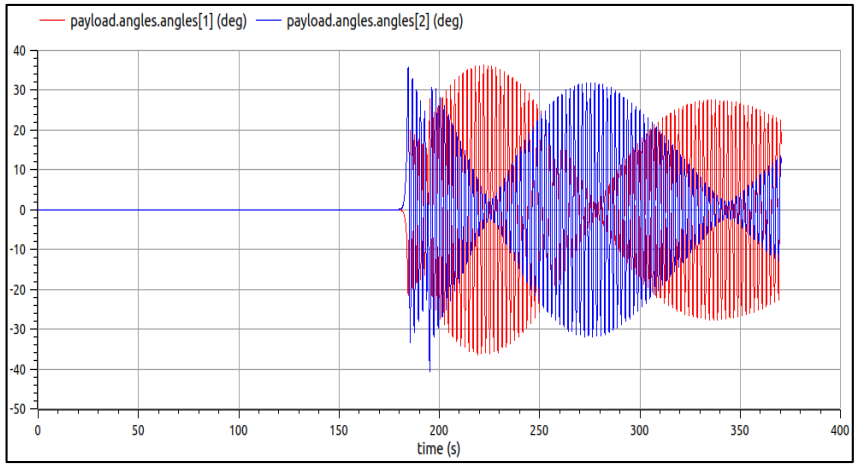
Coordinate Plot



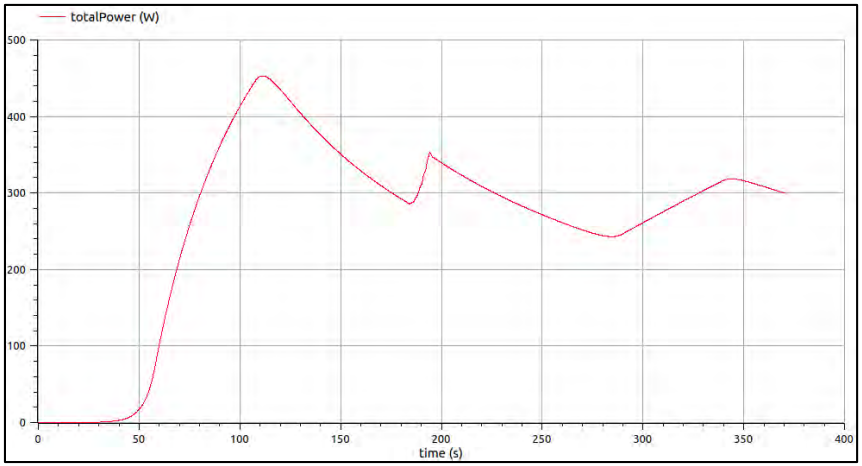
Force Plot

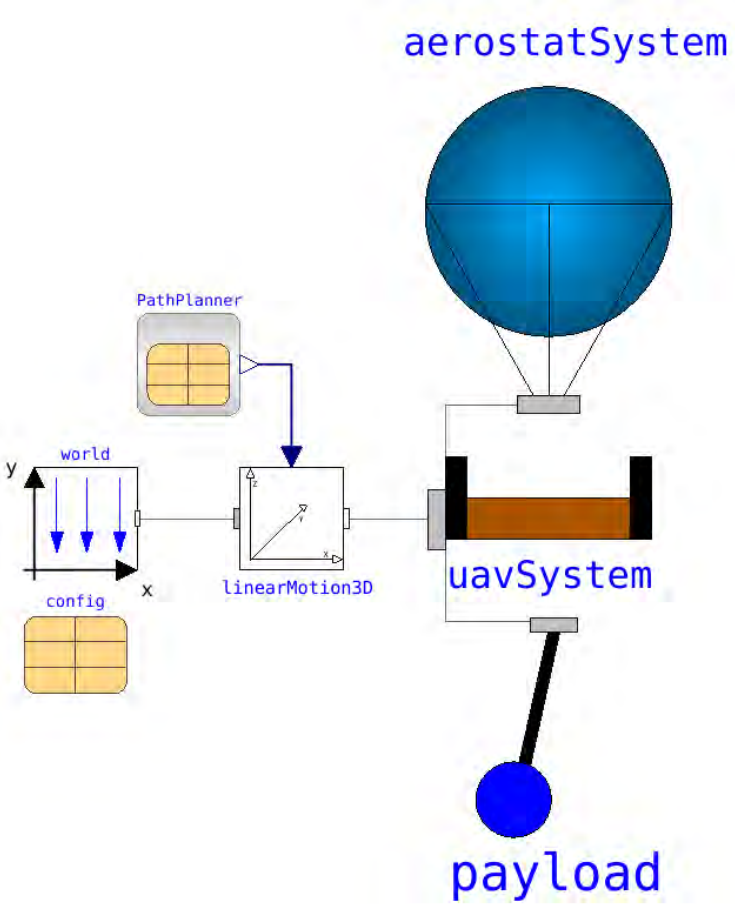


Payload Oscillation Plot



Energy Plot





Simulation Case Studies

BUAV vs UAV Simulation

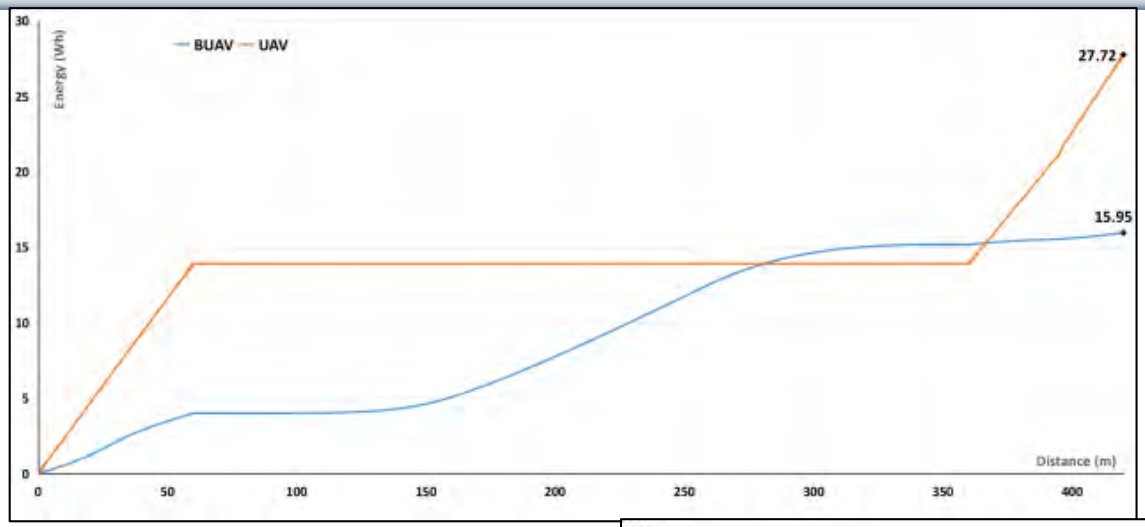
Parameter	Value	Unit
UAV Mass	35	kg
Payload Mass	50	kg
Maximum lift velocity	2	m/s
Maximum horizontal velocity	3	m/s
Balloon mass with harness	76.6	kg
Balloon radius	3.1	m
Balloon drag coefficient	0.47	-

Parameters

X (m)	Y (m)	Z (m)
0	0	0
0	0	60
300	0	60
300	0	0

Waypoints

BUAV vs UAV Simulation

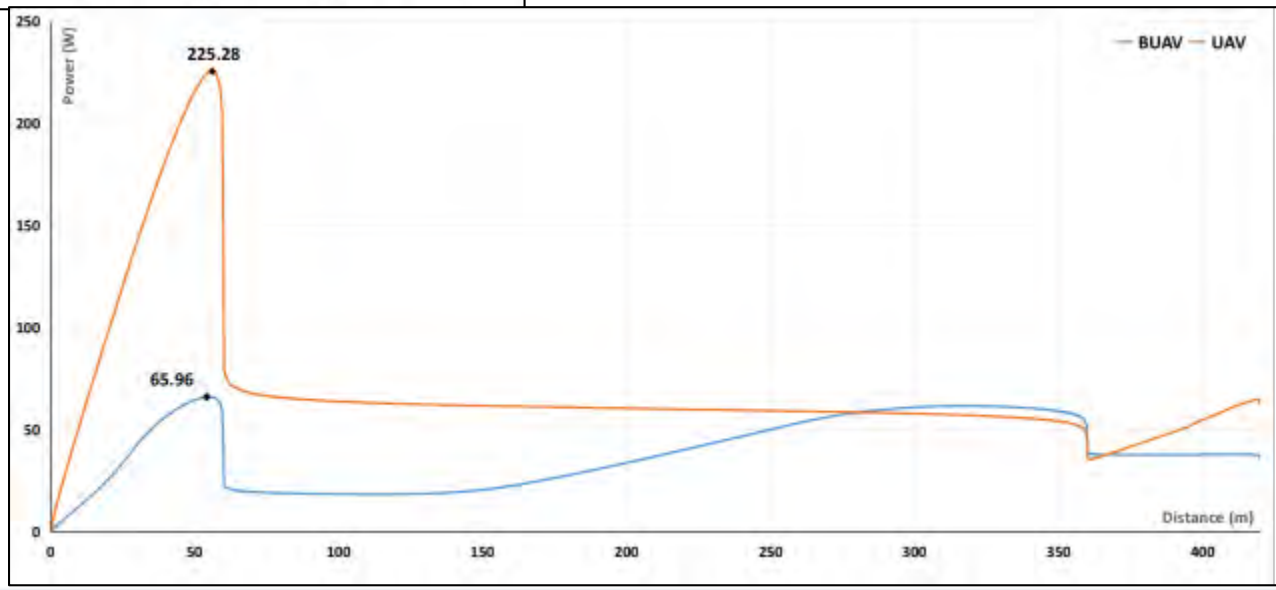


Energy vs Distance

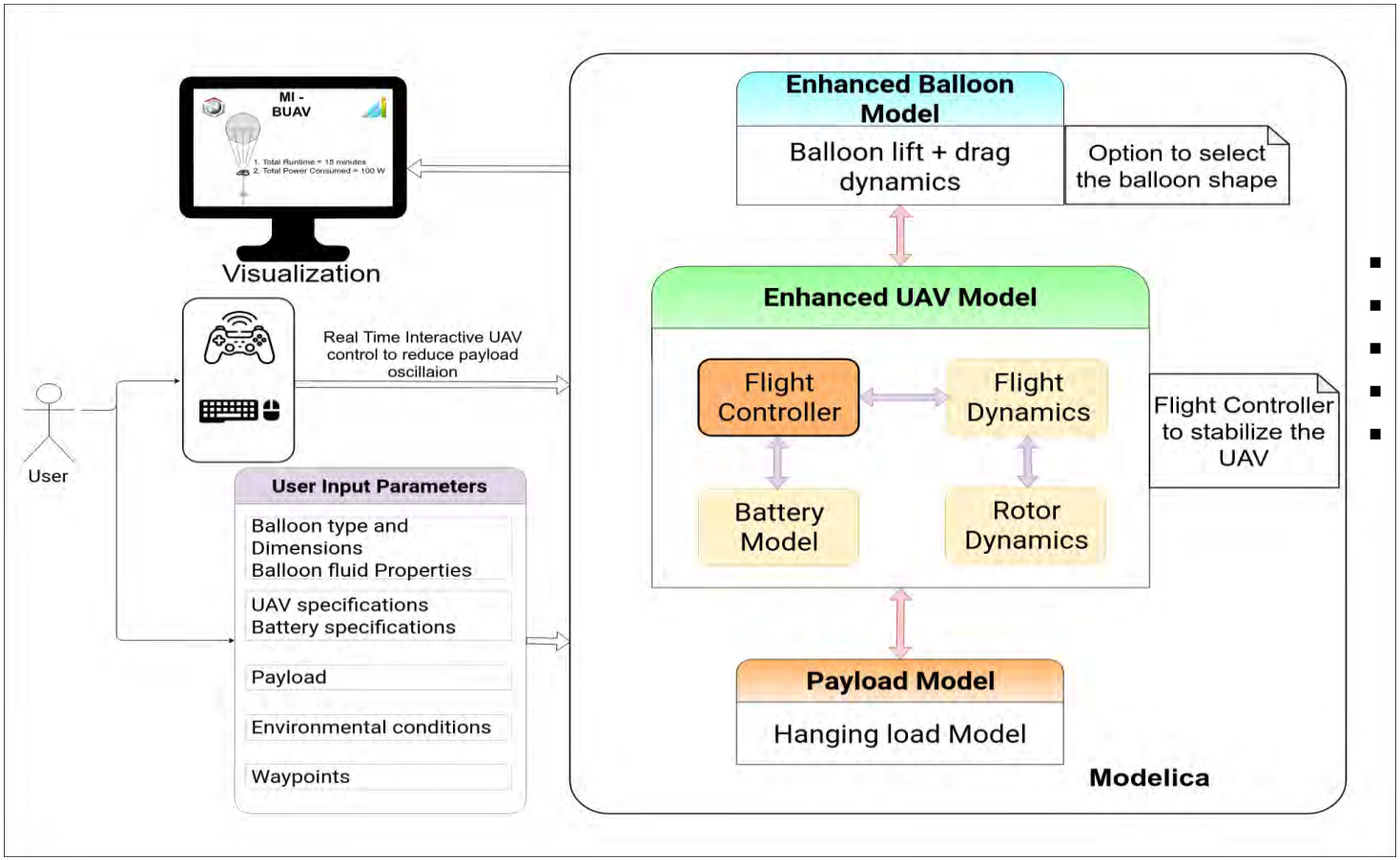
70% reduction in power consumption

Power vs Distance

46% reduction in Max Thrust required by UAV



Next Steps



- **Control System Design**
- Flight Controller
- Payload Controller
- **Path Optimization**
- **Interactive Simulation**

Project Jointly Developed by GI Lift, Linköping University, ModeliCon InfoTech LLP and funded by Linköping University

Thank You