Valbal Altitude Control

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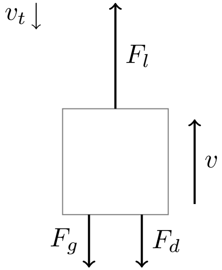
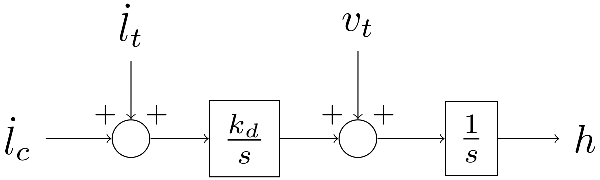
System Dynamics

- Assumptions
  - v_t is small
  - $F_d \propto v$ i.e. drag is linear.
  - $F_l - F_g = F_d$ i.e. the balloon is always at terminal velocity
- Equations of motion
  - let $l = F_l - F_g$ be the net lift on the balloon
  - $\dot{l}$ is commanded by controller
  - $v = k_d \int \dot{l}\, dt$
  - $h = \int v\, dt$
  - $\mathcal{L}\{\cdot\} = k_d / s^2$



F_d: Force of drag
F_g: Gravity
F_l: Buoyant force
v: vertical velocity of balloon
v_t: vertical velocity of surrounding air

Open Loop Block Diagram



$\dot{l}_c$: commanded change in lift (valve and ballast actions)
$\dot{l}_t$: atmospheric lift disturbance
v_t: atmosphereic velocity disturbance
h: altitude

Spaghetti Controller Motivation

- Use a simple linear compensator to stabilize altitude with robust stability margins
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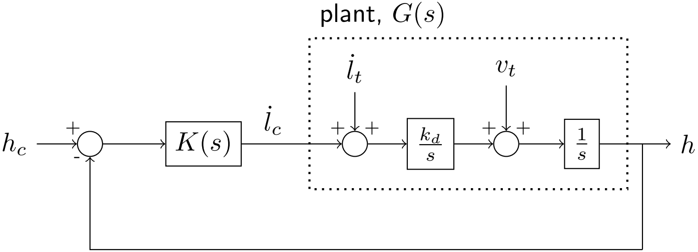
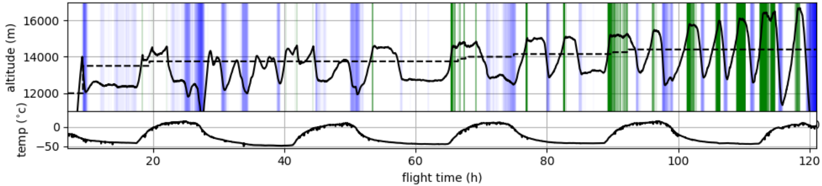
Spaghetti Block Diagram



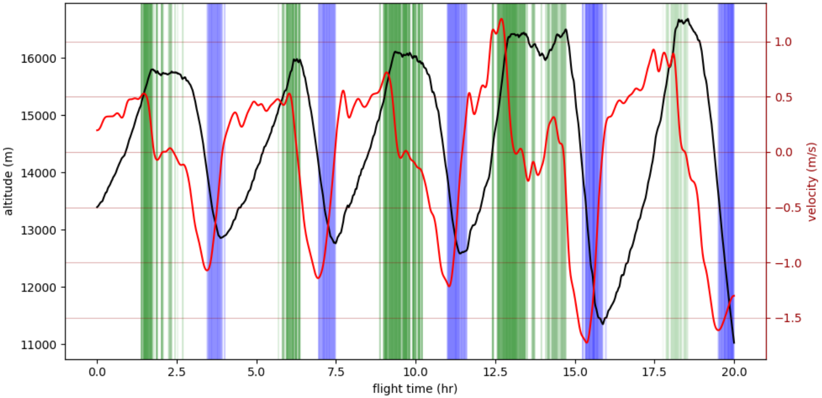
$K(s)$: First order lead compensator.

Spaghetti Flight



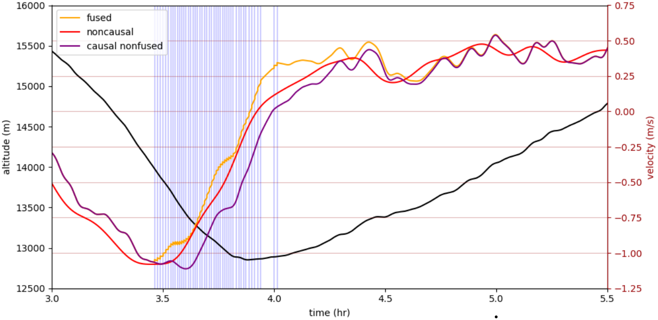
- 120hr flight from December with spaghetti as controller
  - blue shows ballast events, green shows vent events
  - temperature shows sunset/sunrise, large effect on ballast use
- issues durring flight:
  - valve controller had software bug, instead of changing duty cylce, one threshold met valve was repeatedly opened
  - At end of flight, balloon has low overpressure–opening valve has no effect until balloon rises high enough

Oscillations



Velocity Estimator

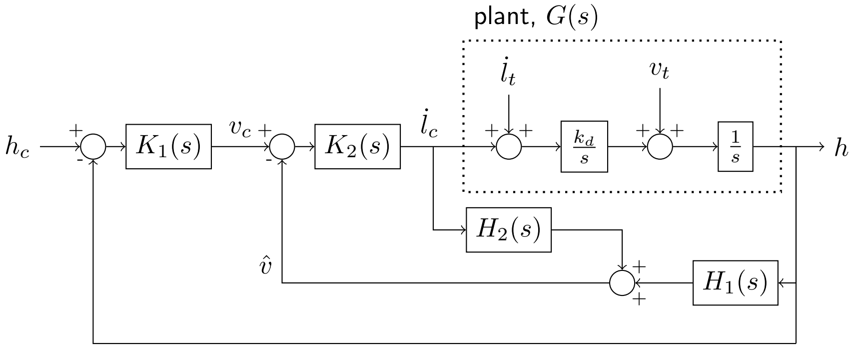
Lowpass filtered velocity estimate that fuses information on actions from the controller.



$$\mathcal{L}\{\hat{v}\} = H_1(s)\mathcal{L}\{h\} + H_2(s)\mathcal{L}\{\dot{l}_c\}$$

$H_1(s)$ is differentiation and 2nd order lowpass filter
$H_2(s)$ is integration with decay (estimate of effect of actions, decays to 0 over time)

Lasagna Block Diagram



$K_1(s)$: Position loop compensator
$K_2(s)$: Velocity loop compensator
$H_1(s), H_2(s)$: Velocity estimator

Lasanga Nonlinearities

Deadband: