Hochschule Bremen
City University of Applied Sciences

MATLAB® SIMULINK® Exercise - Parachutist

Modelling and Simulation 2022/2023 | MEAM 19

Bremen, 21.12.2022

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Problem Definition

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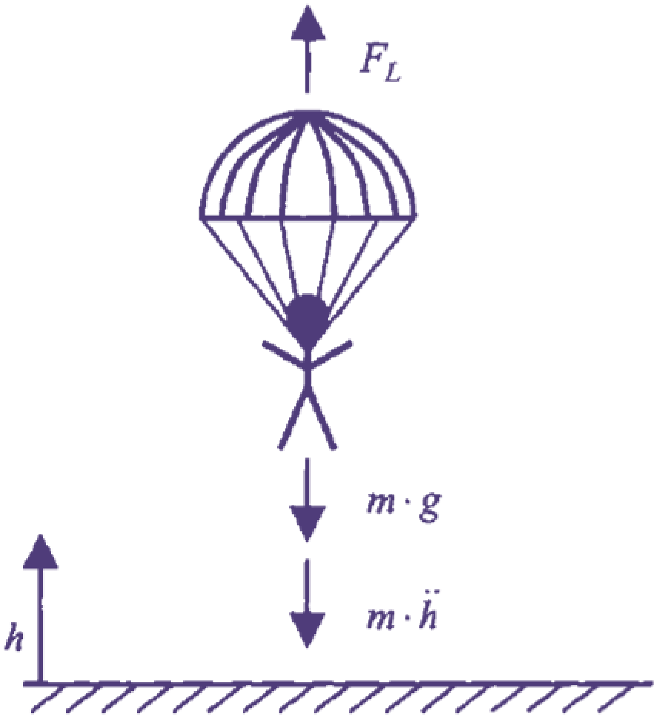
A parachutist (Mass m, Area A_S) falls down on earth. He gains speed as long as the weight is equal to the aerodynamic drag (absolute value). When he reaches a defined height h_1 he opens his parachute (Area A_O). The drag increases rapidly and he slows down.

1. Calculate the maximum speed of the parachutist on two ways:
   I. Analytical
   II. Computational (SIMULINK)

2. Display the height and the speed over time (computational/Simulation)!

3. **Task List**



<u>Given:</u>

$h_0 = 3000m$ (starting height), $h_1 = 1500m$

$A_s = 0{,}5m^2$, $A_O = 30m^2$, $m = 85kg$

$c_D = 1{,}3\ (const.\ for\ both\ cases)$, $\varrho = 1{,}2\frac{kg}{m^3}$

0. Prerequisite Equation of Motion

D'Alembert's principle: $m \cdot \ddot{h} = F_L - m \cdot g$

Aerodynamic drag: $\mathrm{F_L} = c_D \cdot A \cdot \frac{\varrho}{2} \cdot v^2$ $\mathrm{v} = \dot{h}$

Solution

1. Analytical Solution

1. Analytical Solution

Closed parachute:

Stationary (maximum speed): $\ddot{h} = 0$

$$\mathrm{m} \cdot g = \mathrm{c_D} \cdot A \cdot \frac{\varrho}{2} \cdot v^2$$

-> $$\mathrm{v} = \sqrt{\frac{2 \cdot m \cdot g}{c_D \cdot A \cdot \varrho}}$$

-> $$\mathrm{v} = -46{,}2\,\frac{m}{s} = -166{,}5\,\frac{km}{h}$$

Solution

1. Computational Solution

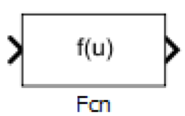
1. Computational Solution | Function Block

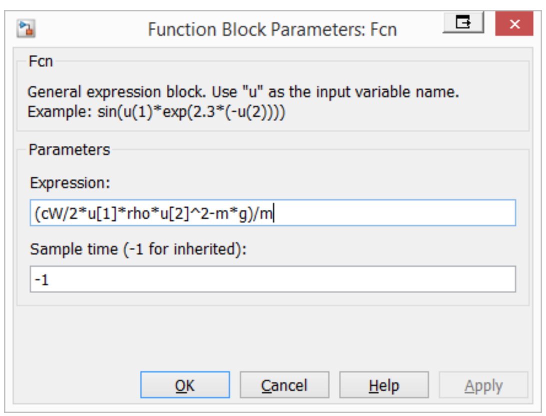
Stationary (maximum speed): $m \cdot \ddot{h} = F_L - m \cdot g$

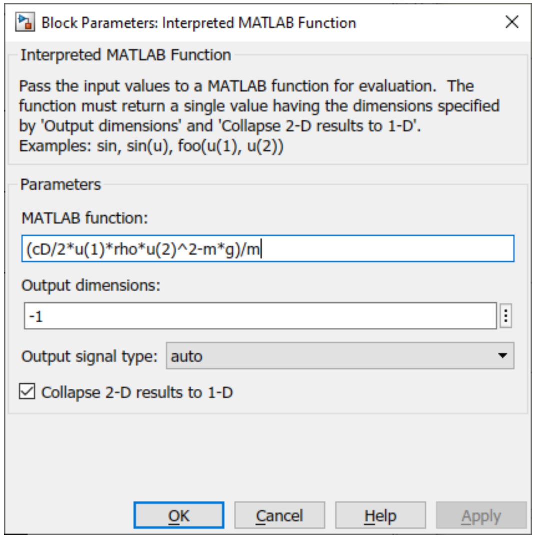
-> $\ddot{h} = \frac{c_D \cdot A \cdot \varrho \cdot v^2}{2 \cdot m} - g$ or

-> $\ddot{h} = \frac{\frac{c_D}{2} \cdot A \cdot \varrho \cdot v^2 - m \cdot g}{m}$

This differential equation can be expressed via a *function* block (older Matlab versions), where u[1] (new: u(1)) is the surface and u[2] (new: u(2)) is the velocity (*mux*-combined). The newer versions offer an *interpreted MATLAB function* block:

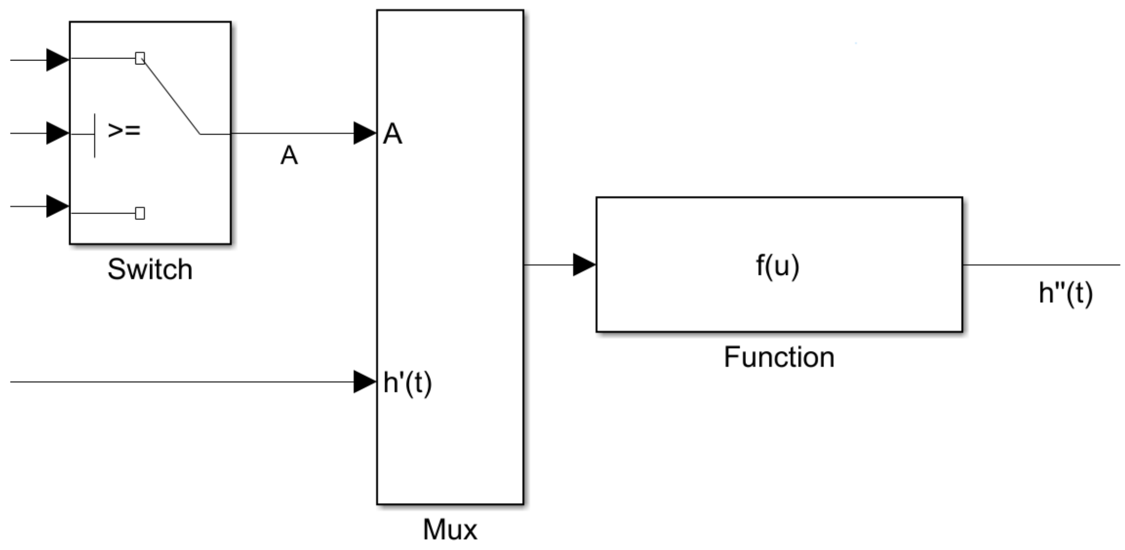






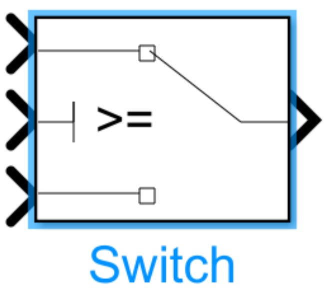
1. Computational Solution | Mux Block

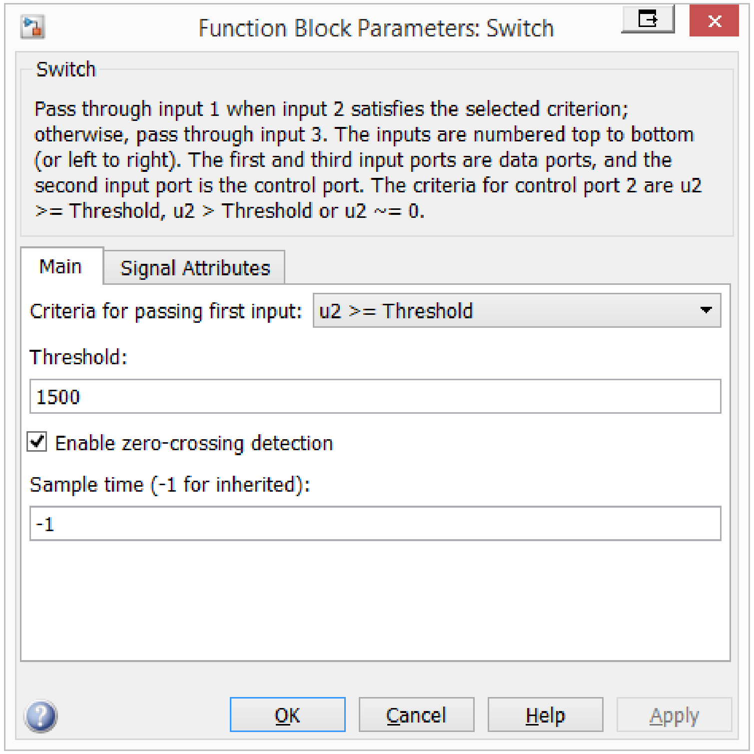
To get a multiplex scalar where u(1) is the surface and u(2) is the velocity a mux has to be implemented and the inputs have to be routed accordingly.



1. Computational Solution | Switch Block

The height acts as an threshold for a switch block, where the Area is defined:

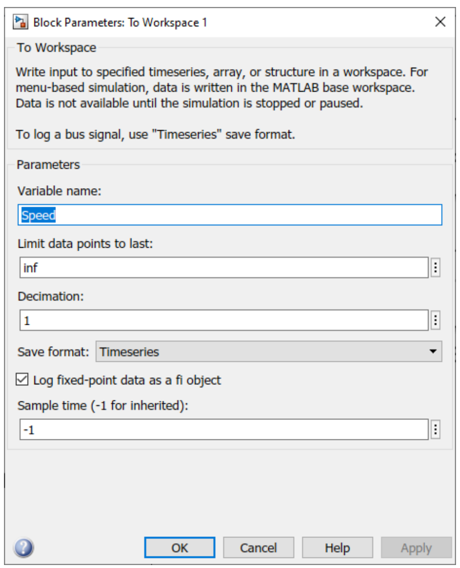


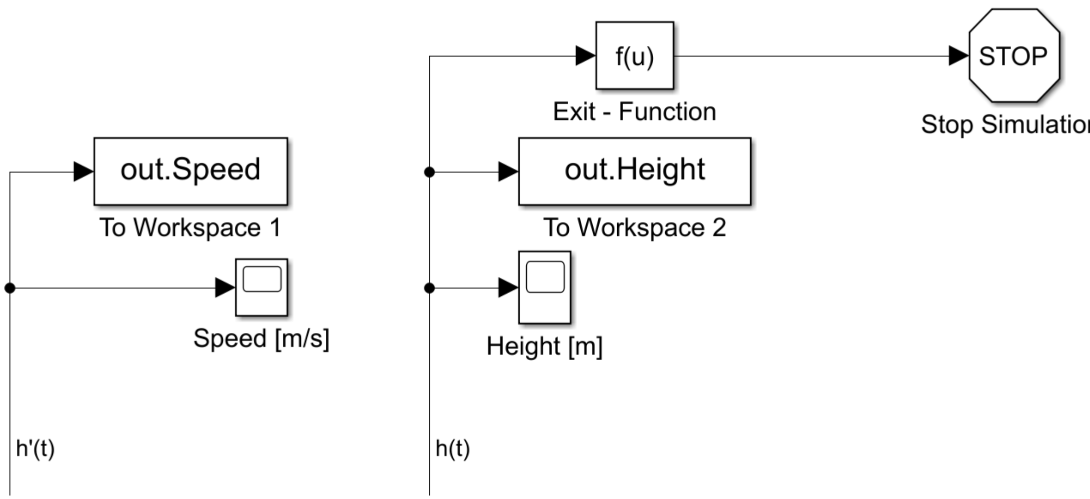


1. Computational Solution | Integrators, Scopes and To-Workspace

Two integrators create the height $h(t)$; and the velocity $h'(t)$ and the height $h(t)$ can be visually displayed by two scopes. The initial height h_0 must be inserted as initial condition for integrator 2!

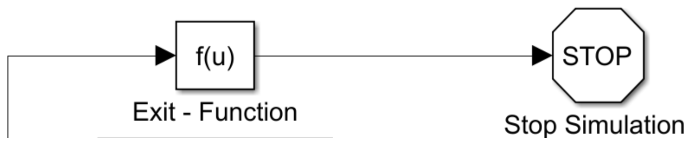
Two “To Workspace”-Blocks will route the calculated signals to the Matlab-Workspace.

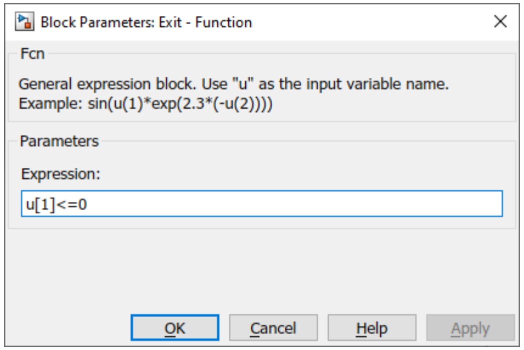


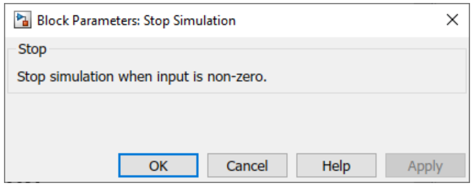


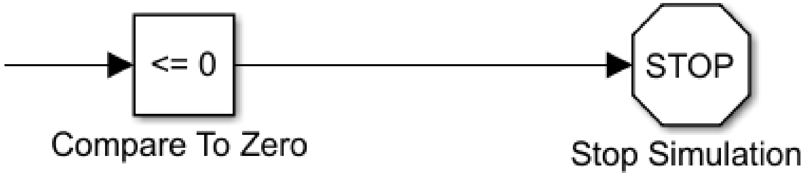
1. Computational Solution | Simulation Stop

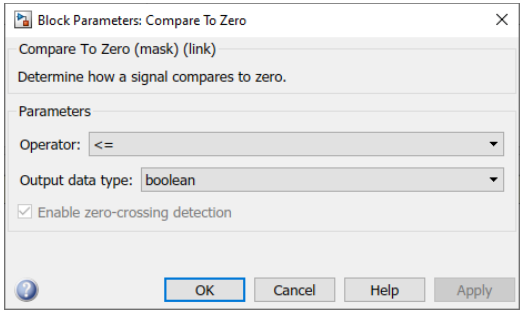
An additional function and the sinks block stop terminates the simulation when the parachutist reaches the ground. Because of the Boolean-required input, it is necessary to implement another function. This can be a *Exit fcn* or a *Compare To Zero* block.











1. Computational Solution

After adding the variables to the workspace the simulation can be made. The maximum speed can be obtained via the min/max command:

```
>> min(v(1:end,2))

ans =

  -46.2393
```

or

```
>> min(out.Speed)

ans =

  -45.9687
```

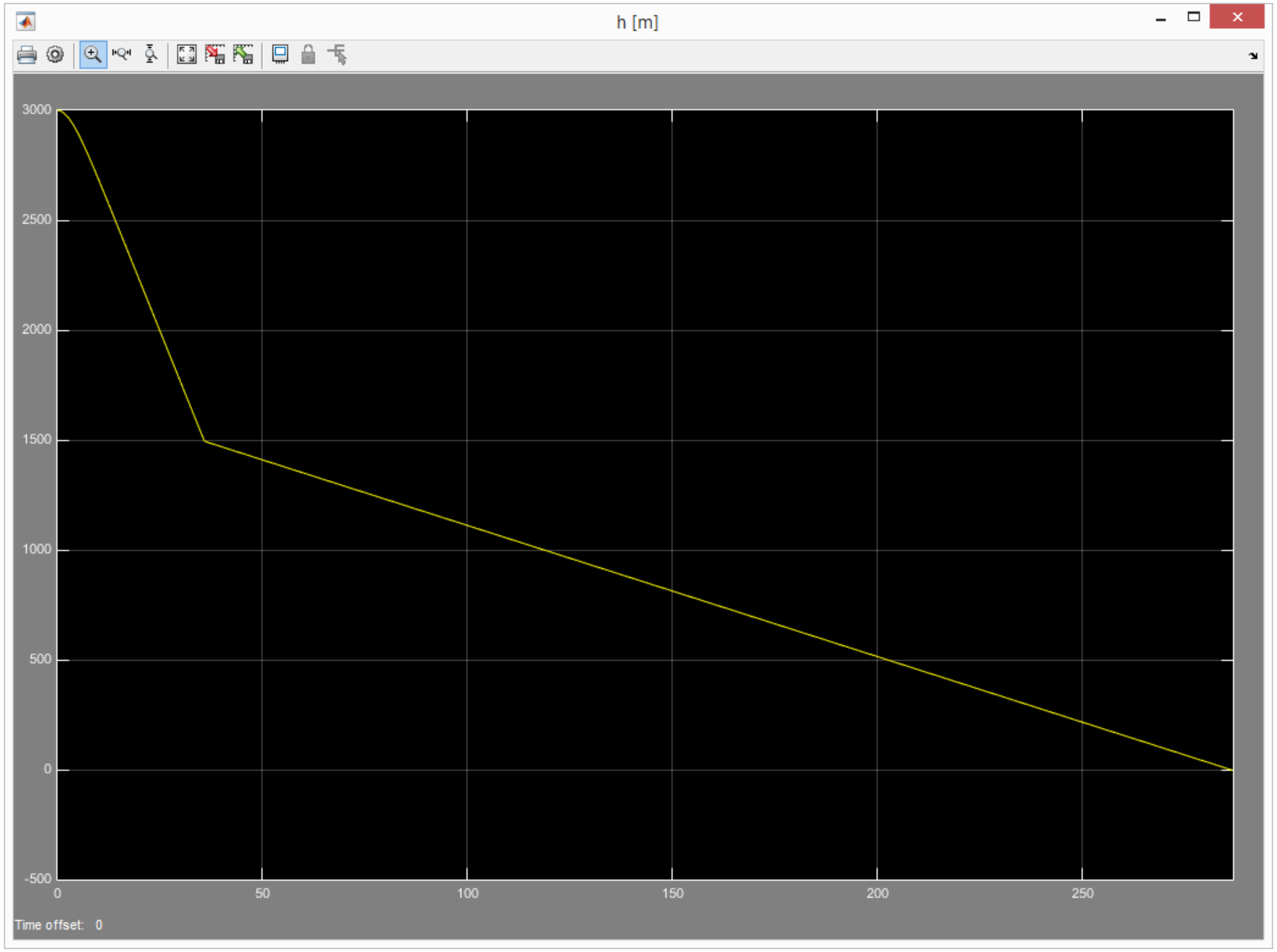
The result is equal to the analytical one.

Solution

2. SIMULINK Scope Screenshots

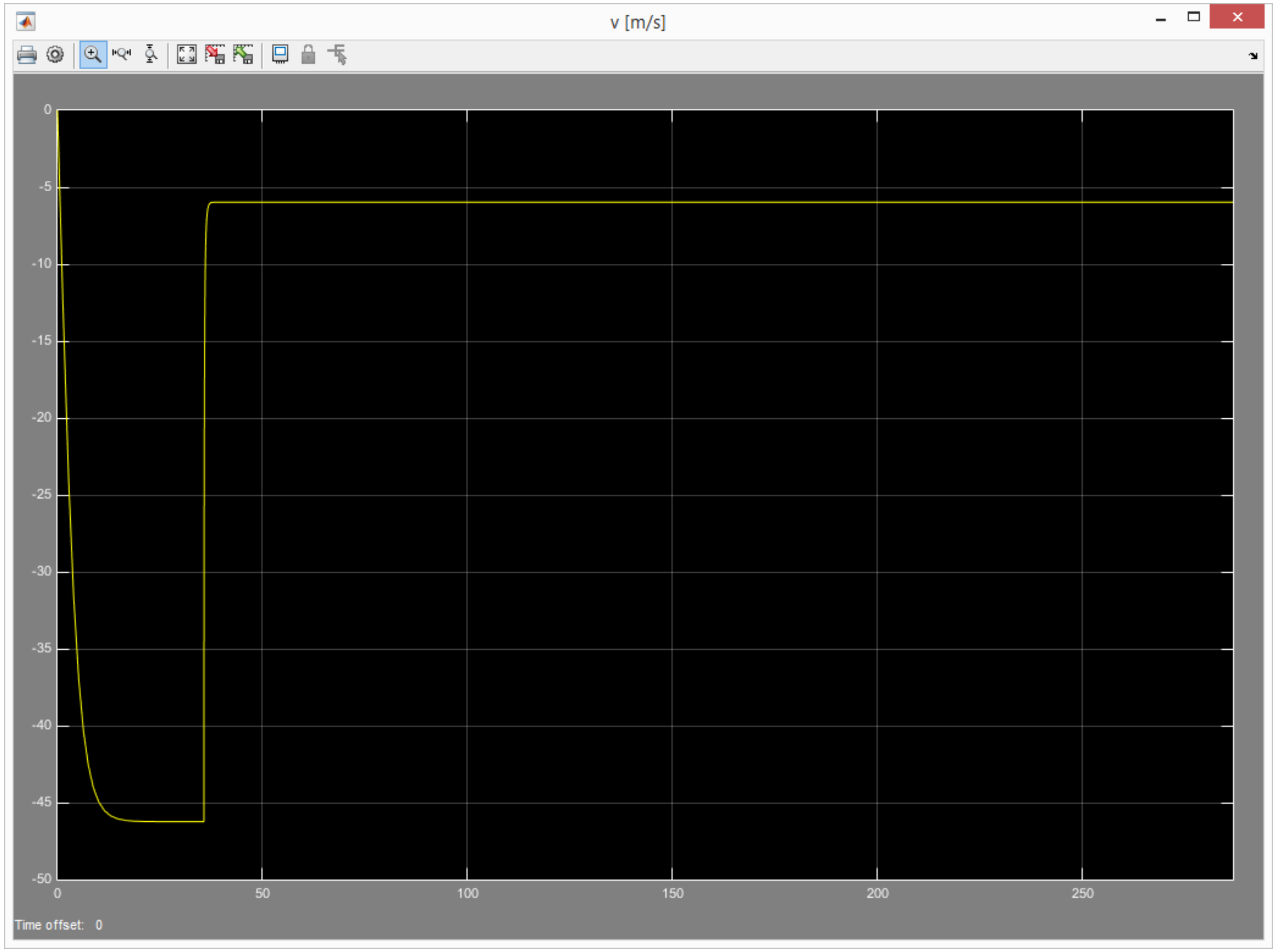
2. Computational Solution/ Simulation

Height over time:



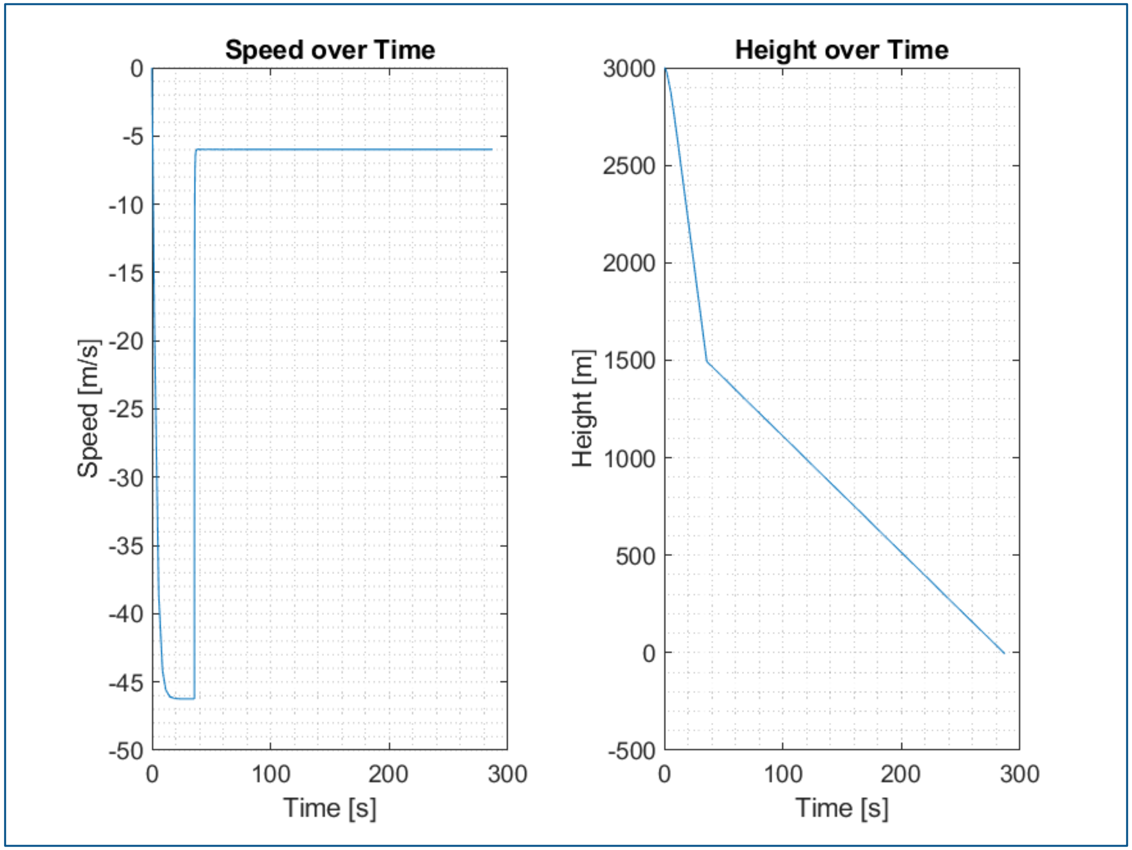
2. Computational Solution/ Simulation

Speed over time:



2. Computational Solution/ Simulation

Extract from the m-File:



Task list

3. To be delivered prior to 06.02.2023

3. Task list

- Create a Simulink model with the name “*P03_S_Parachute_”+YourLastName+”.slx*” with all necessary blocks and signals to achieve the presented results. The stop time should be changeable via the variable *tstop.*
  - Please add an Initialization Function (InitFcn) Callback to load all your variables in the Simulink model

- Create a m-File with the name “*P03_M_Parachute_”+YourLastName+”.m*”. This file should contain:
  - An Init part
  - A part to load all necessary variables
  - A part to run or sim your Model
  - A part that saves your results of the height and the speed over the time in one plot with the name “*P03_Parachute_Results_”+YourLastName+”.png*”. This should also implement a proper title, proper labels and of course the correct results (see p.17).

- Just send the .m and the .slx files (not the .pngs!) to denis.zimmer@lba.hs-bremen.de

- An example m-File is uploaded in the current folder

Hochschule Bremen
City University of Applied Sciences

HSB

Thank you for your Attention!

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