

Hochschule Bremen
City University of Applied Sciences



MATLAB[®] SIMULINK[®] Exercise - Parachutist

Modelling and Simulation 2022/2023 | MEAM 19

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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)!

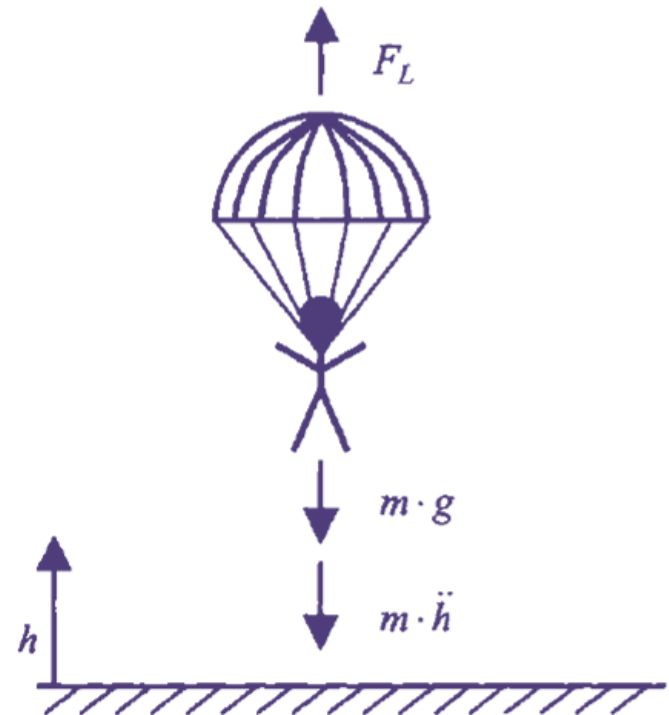
3. Task List

Given:

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

$A_S = 0,5m^2$, $A_O = 30m^2$, $m = 85kg$

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



0. Prerequisite Equation of Motion

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

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

Solution

1. Analytical Solution

1. Analytical Solution

Closed parachute:

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

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

$$\rightarrow v = \sqrt{\frac{2 \cdot m \cdot g}{c_D \cdot A \cdot \rho}}$$

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

Solution

1. Computational Solution

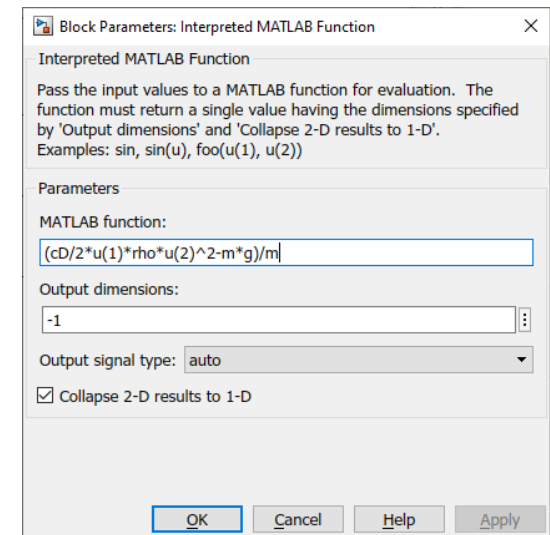
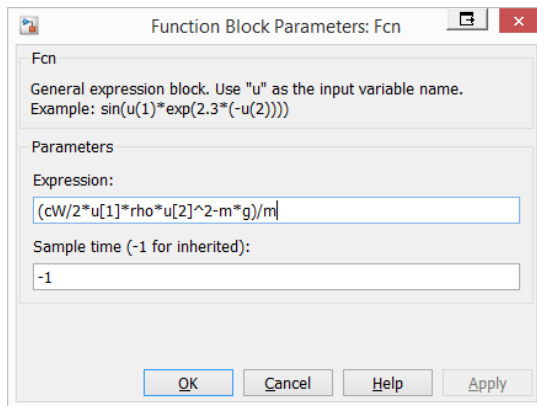
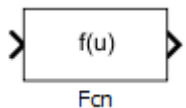
1. Computational Solution | Function Block

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

$$\rightarrow \ddot{h} = \frac{c_D \cdot A \cdot \rho \cdot v^2}{2 \cdot m} - g \quad \text{or}$$

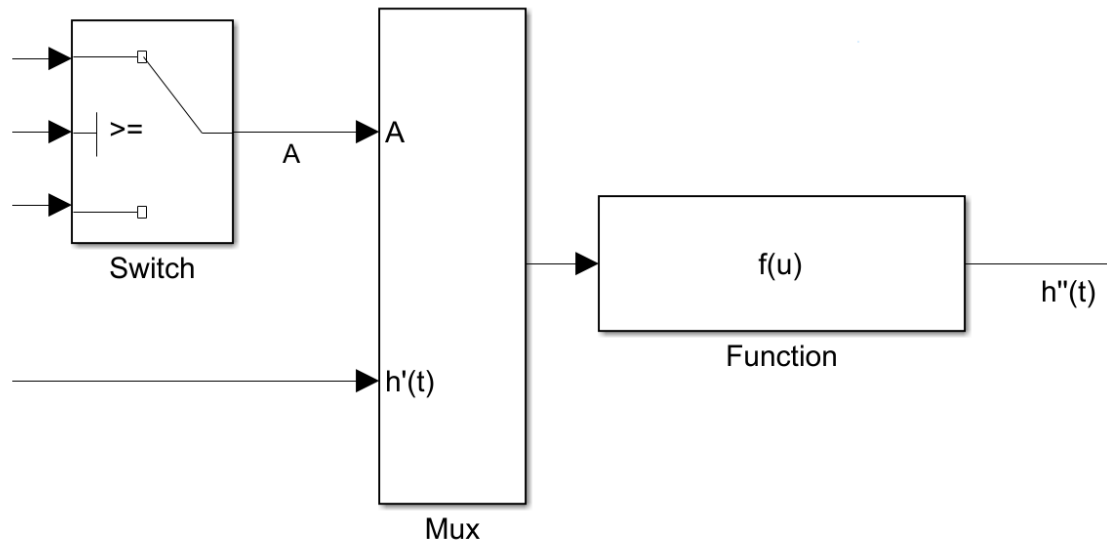
$$\rightarrow \ddot{h} = \frac{\frac{c_D}{2} \cdot A \cdot \rho \cdot v^2 - m \cdot g}{m}$$

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:



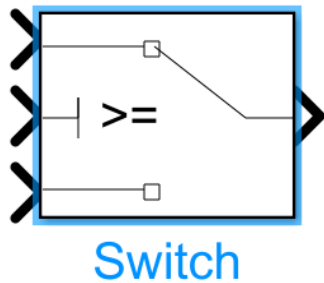
1. Computational Solution | Mux Block

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:



Function Block Parameters: Switch

Switch

Pass through input 1 when input 2 satisfies the selected criterion; otherwise, pass through input 3. The inputs are numbered top to bottom (or left to right). The first and third input ports are data ports, and the second input port is the control port. The criteria for control port 2 are $u2 \geq \text{Threshold}$, $u2 > \text{Threshold}$ or $u2 \sim 0$.

Main | Signal Attributes

Criteria for passing first input: $u2 \geq \text{Threshold}$

Threshold:
1500

Enable zero-crossing detection

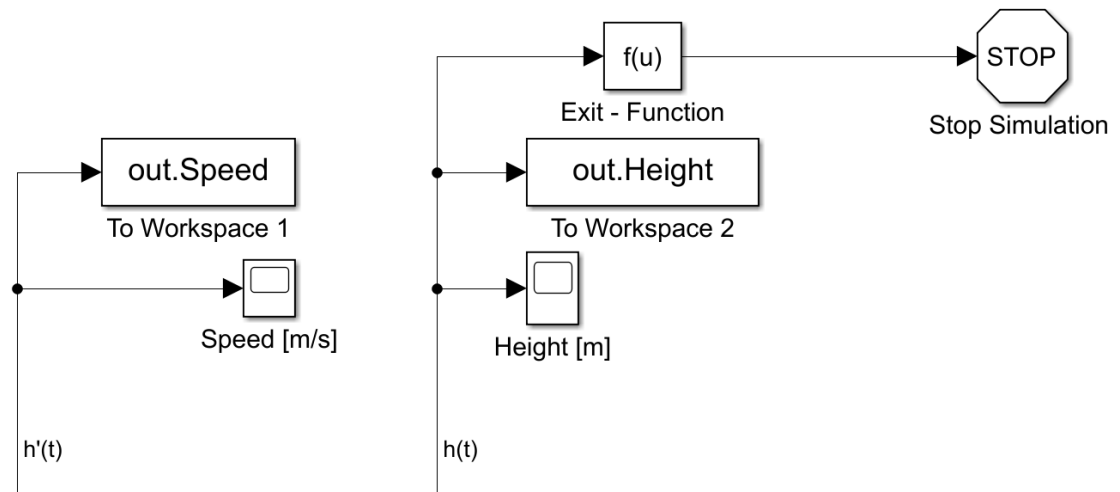
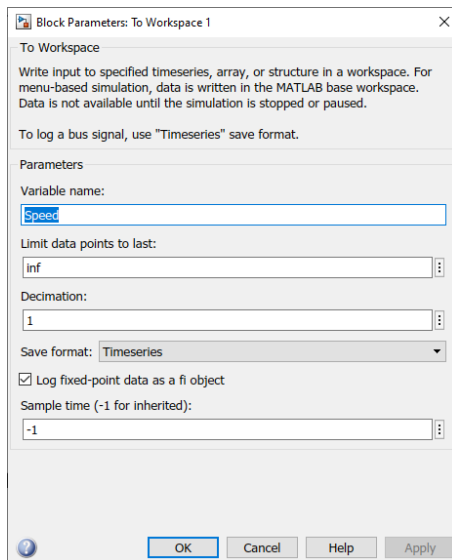
Sample time (-1 for inherited):
-1

OK Cancel Help Apply

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

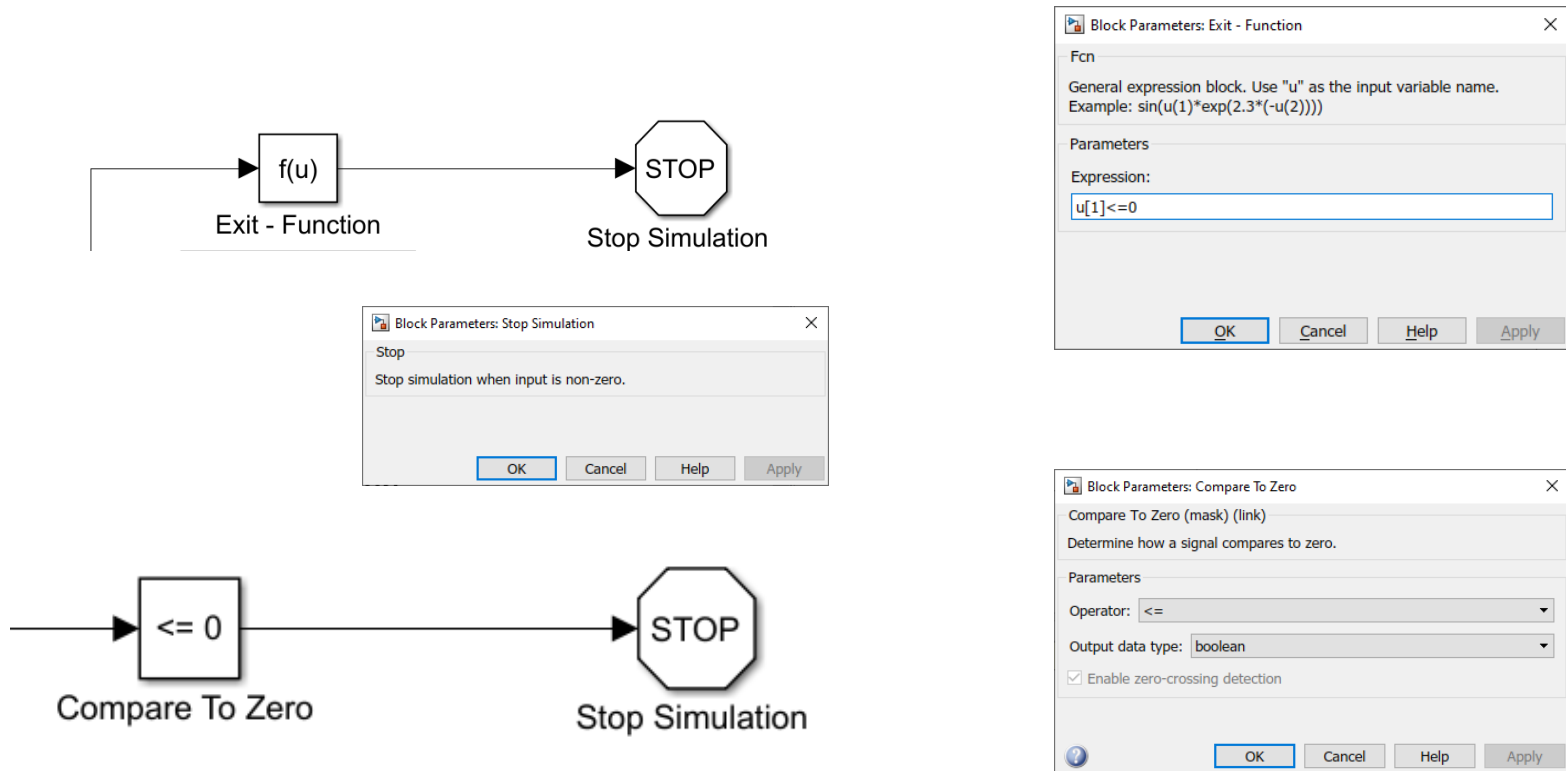
Two integrators create the height $h(t)$; and the velocity $h'(t)$ and the height $h(t)$ can be visually displayed by two scopes. The initial height h_0 must be inserted as initial condition for integrator 2!

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.



The diagram illustrates two methods to terminate a simulation when a parachutist reaches the ground. In the first method, an 'Exit - Function' block (containing the expression $f(u)$) is connected to a 'Stop Simulation' block. A second screenshot shows the 'Block Parameters: Stop Simulation' dialog, which is configured to 'Stop simulation when input is non-zero.' In the second method, a 'Compare To Zero' block (containing the expression ≤ 0) is connected to a 'Stop Simulation' block. A third screenshot shows the 'Block Parameters: Compare To Zero' dialog, where the 'Operator' is set to \leq , the 'Output data type' is 'boolean', and 'Enable zero-crossing detection' is checked.

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
```

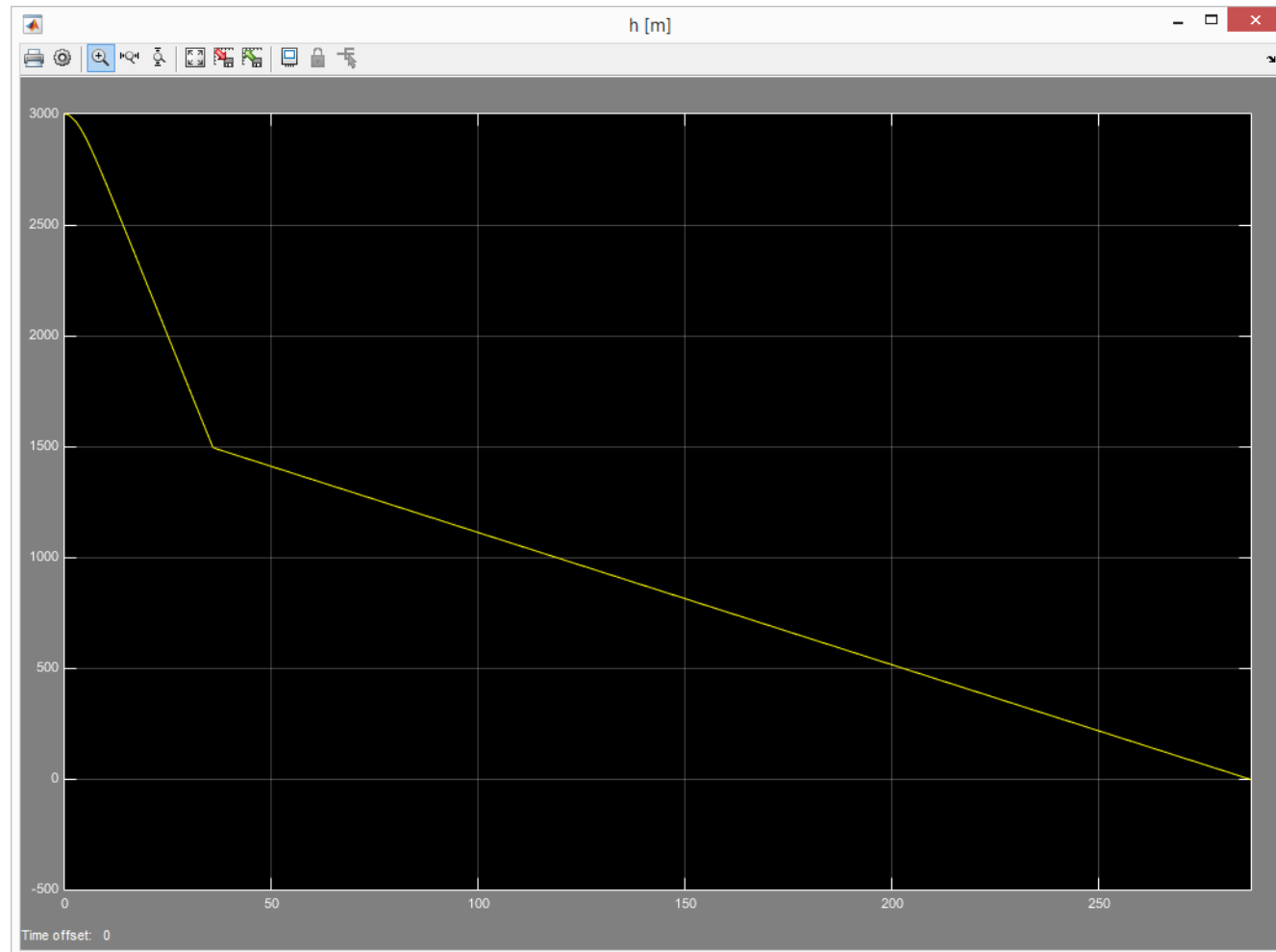
The result is equal to the analytical one.

Solution

2. SIMULINK Scope Screenshots

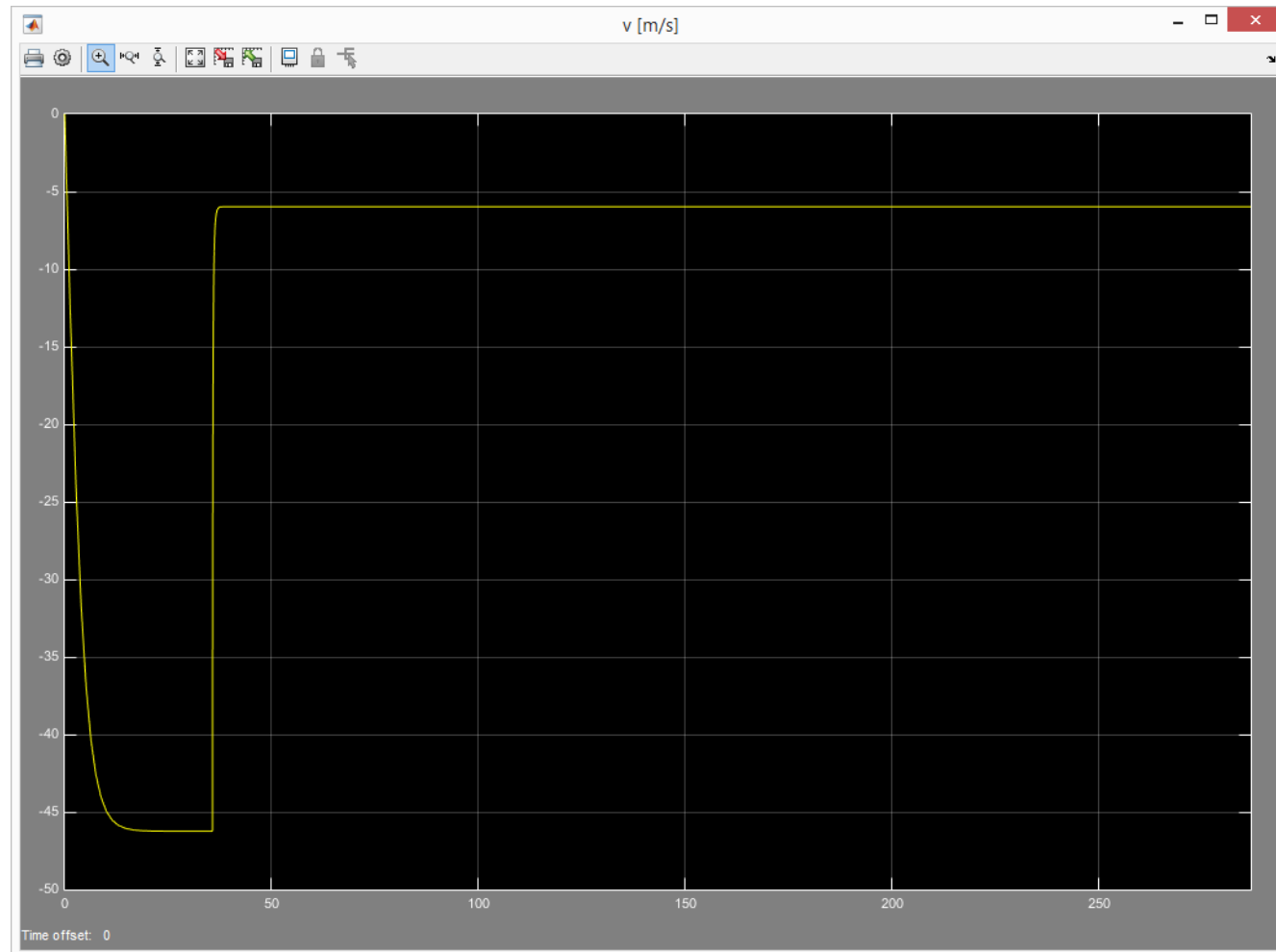
2. Computational Solution/ Simulation

Height over time:



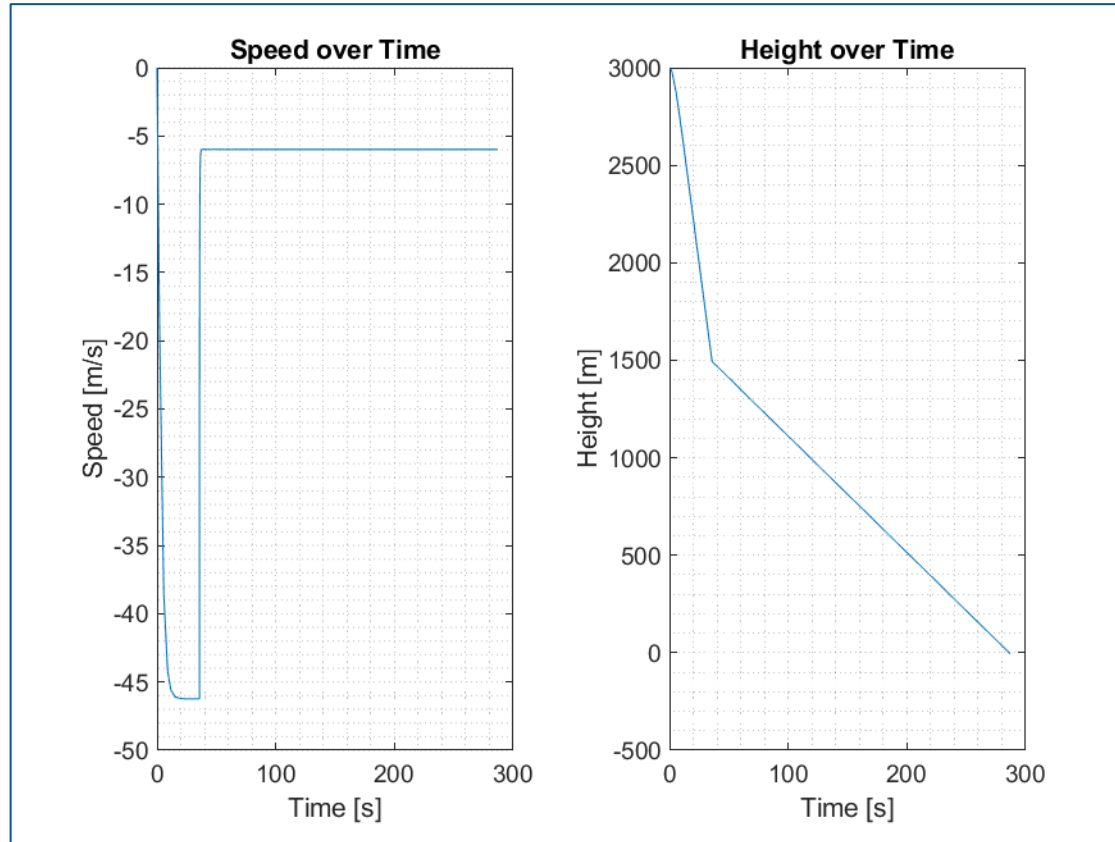
2. Computational Solution/ Simulation

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

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Thank you for your Attention!

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