Automated Ballast Control System for an Autonomous Underwater Vehicle

6th Biannual NRC-IOT Workshop on Underwater Vehicle Technology
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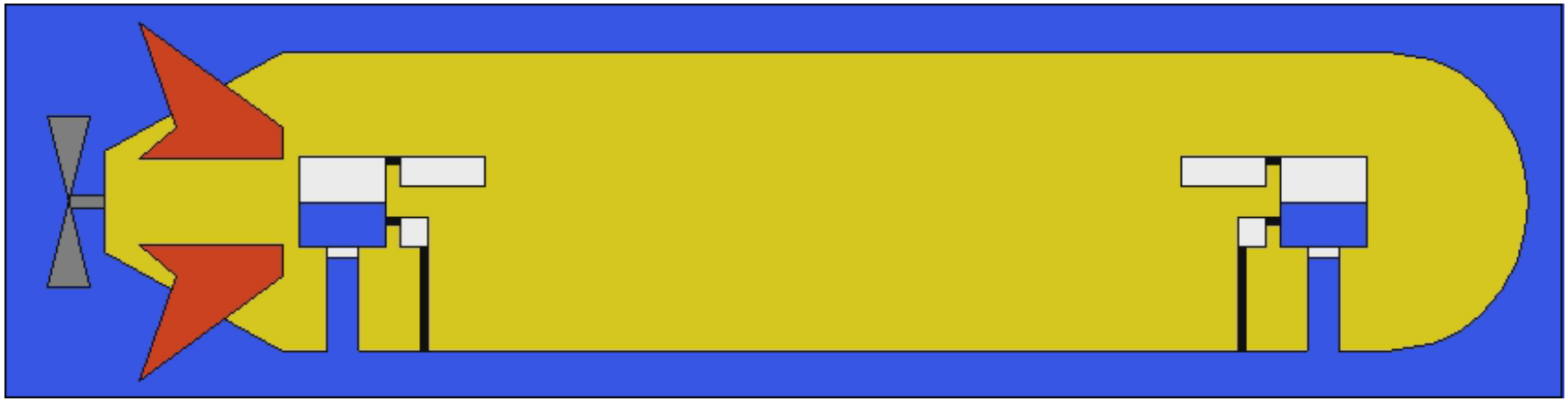

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INTRODUCTION

Motivation

Deep-water Ocean Applications

- Surveying
- Cable-laying

Purpose

- Accurate control of depth and trim
- Runs parallel with existing control systems

Challenges

- Manipulating controller aspects
- Emulating human operator behaviour and experience
- Complicated logistics
- Multiple sensors and actuators

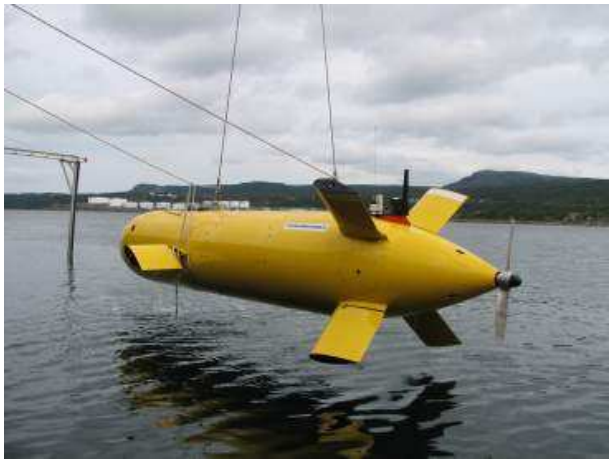
Goal

Variable Ballast Control System

- Develop
- Implement

Simulations

- 2D MATLAB/Simulink computer simulator



Support

•Funded by Defence Research and Development Canada (DRDC) Atlantic

Requirements

With Current AUV

- Work with the current AUV control system
- Coordination between fins and variable ballast tanks
- Assist driving during rise and descent

Methodology and Approach

Implemented Features

- 2D dynamics model (based on 2D equations of motion for an AUV)
- Dual ballast tank model
- Ballast depth controller
- MATLAB/Simulink computer simulator

Future Features

- Hydrodynamic forces
- Pitch control about the y-axis (ballast pitch controller)
- Translational motion about the y-axis
- Improved venting control
- Improved free-fill / free-empty rate approximations
- Ballast tank water angle
- Valve losses and improved valve dynamics
- Improve accuracy of AUV parameters

BALLAST
DEPTH CONTROLLER

Ballast Tank

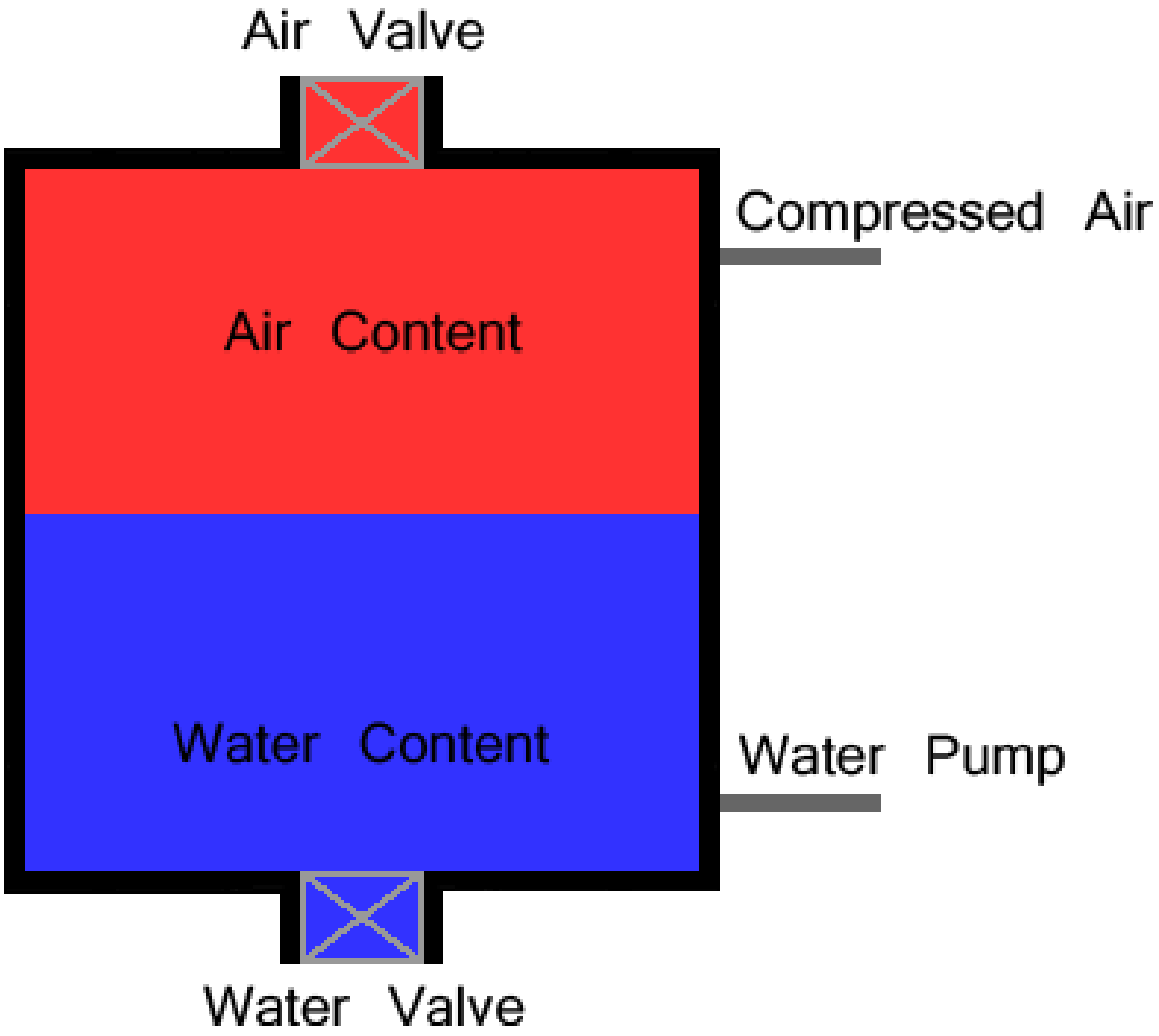
Assist Controlling

- Center of gravity
- Center of buoyancy
- Position
- Velocity
- Acceleration
- Pitch

Content Change

- Free –filling
- Free-emptying
- Water pump
- Air compressor

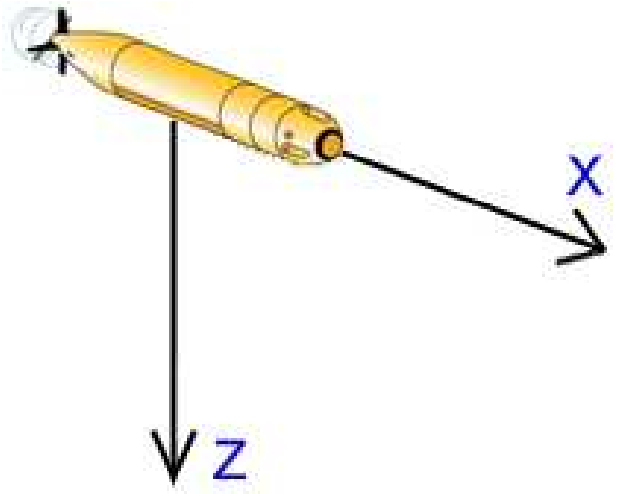
Ballast Tank Schematic



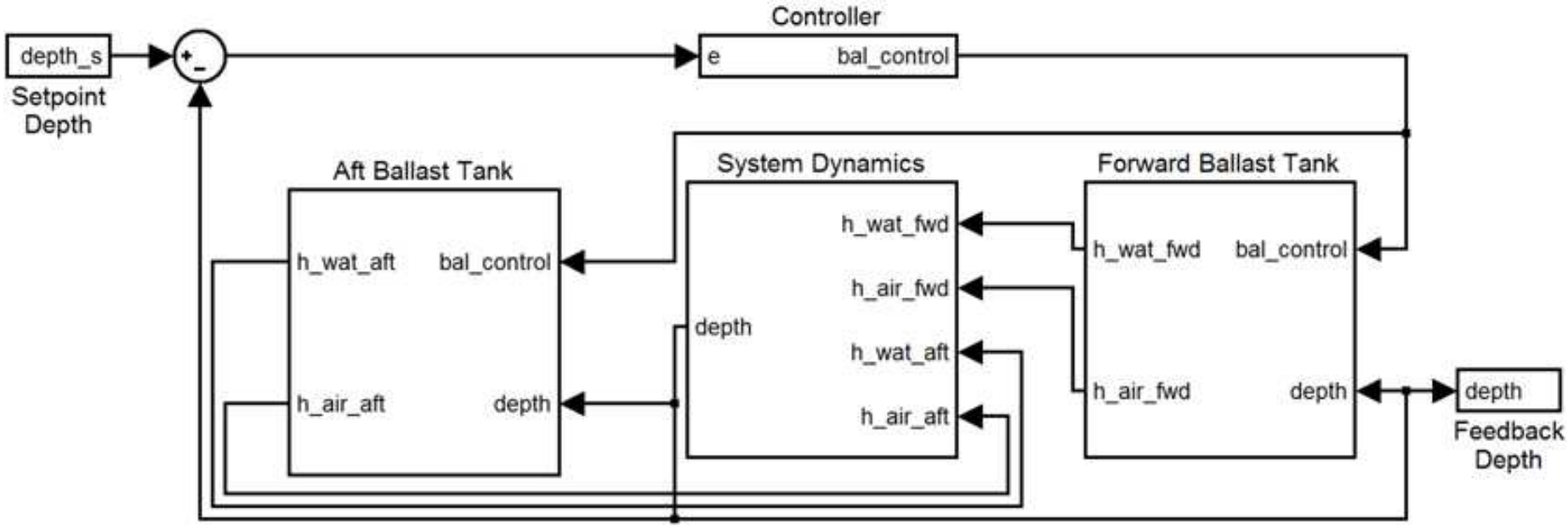
Simulator Assumptions

- **AUV Dynamics**
  - 2D dynamics
  - No pitch, roll, or yaw
  - Translational motion along the z-axis only
- **Ballast Tank**
  - Specified air compressor and water pump rate functions
  - Specified free-fill / free-empty rate approximation
  - Viscous damping used in place of hydrodynamic forces
- **Controller**
  - Depth control only
  - Specified damped (exponential) velocity range
- **Water and Air Valves**
  - Air vents to non-variable air mass
  - Constant valve opening/closing velocity
  - Instantaneous air venting
  - No valve losses

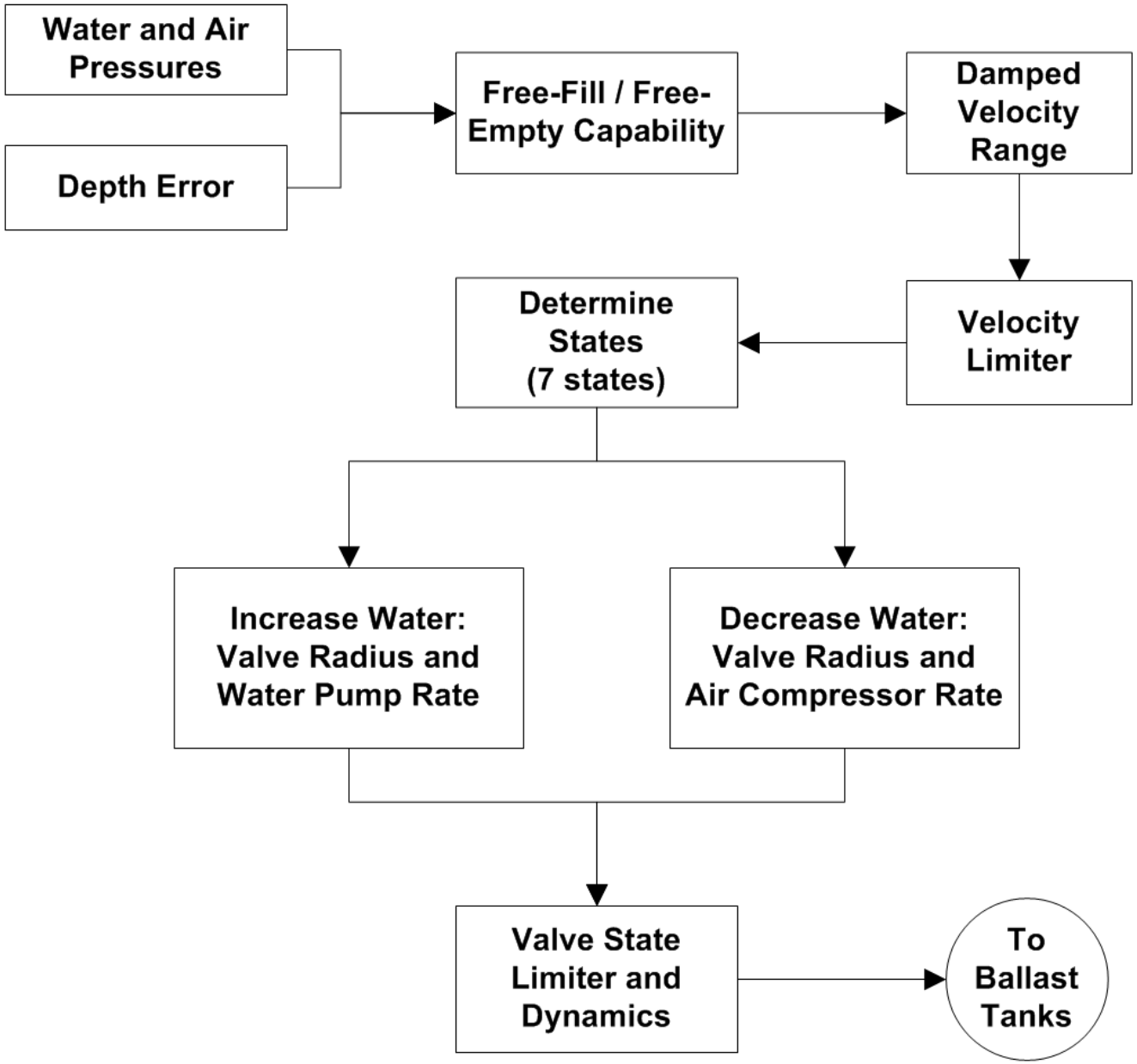
AUV Axes of Motion



MATLAB/Simulink Computer Simulator

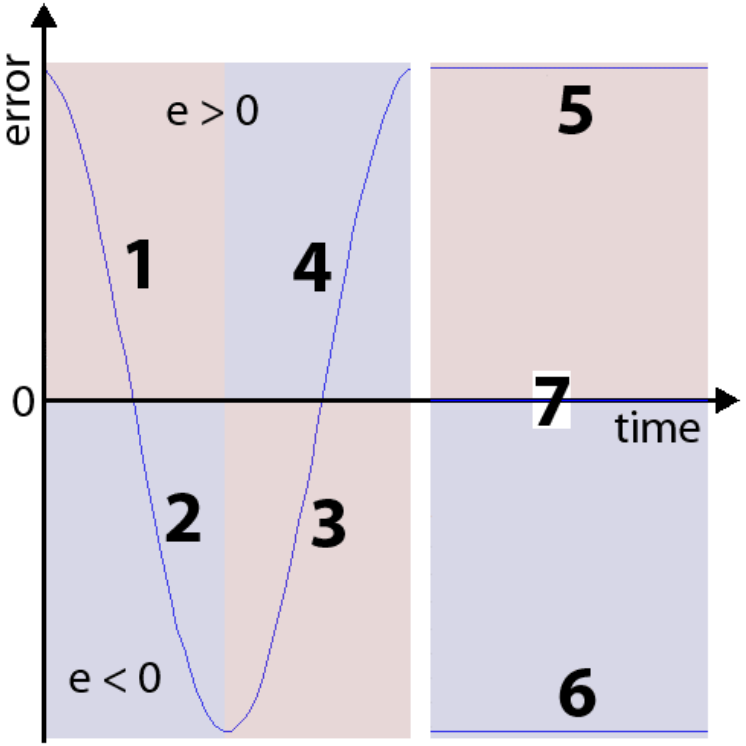


Controller Layout

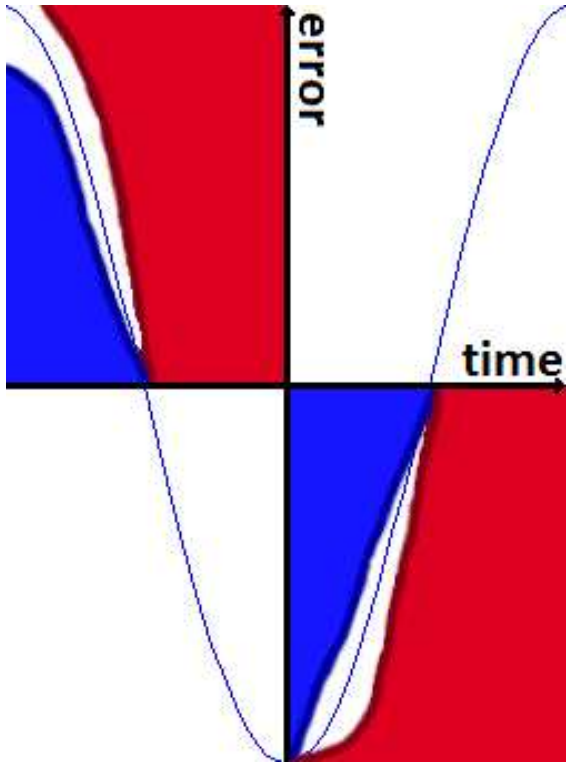


States and Damped Velocity Range

Seven Logistic States of an AUV



Damped Velocity Range (right)



2D DEPTH CONTROL
SIMULATION RESULTS

Controllable Variables

- Air Compressor Rate
- Water Pump Rate

- Desired Ballast Velocities
- Desired AUV z-axis Velocities

- Damped Velocity Limit
- Damped Velocity Range Constant
- Minimum Damped Velocity Ratio

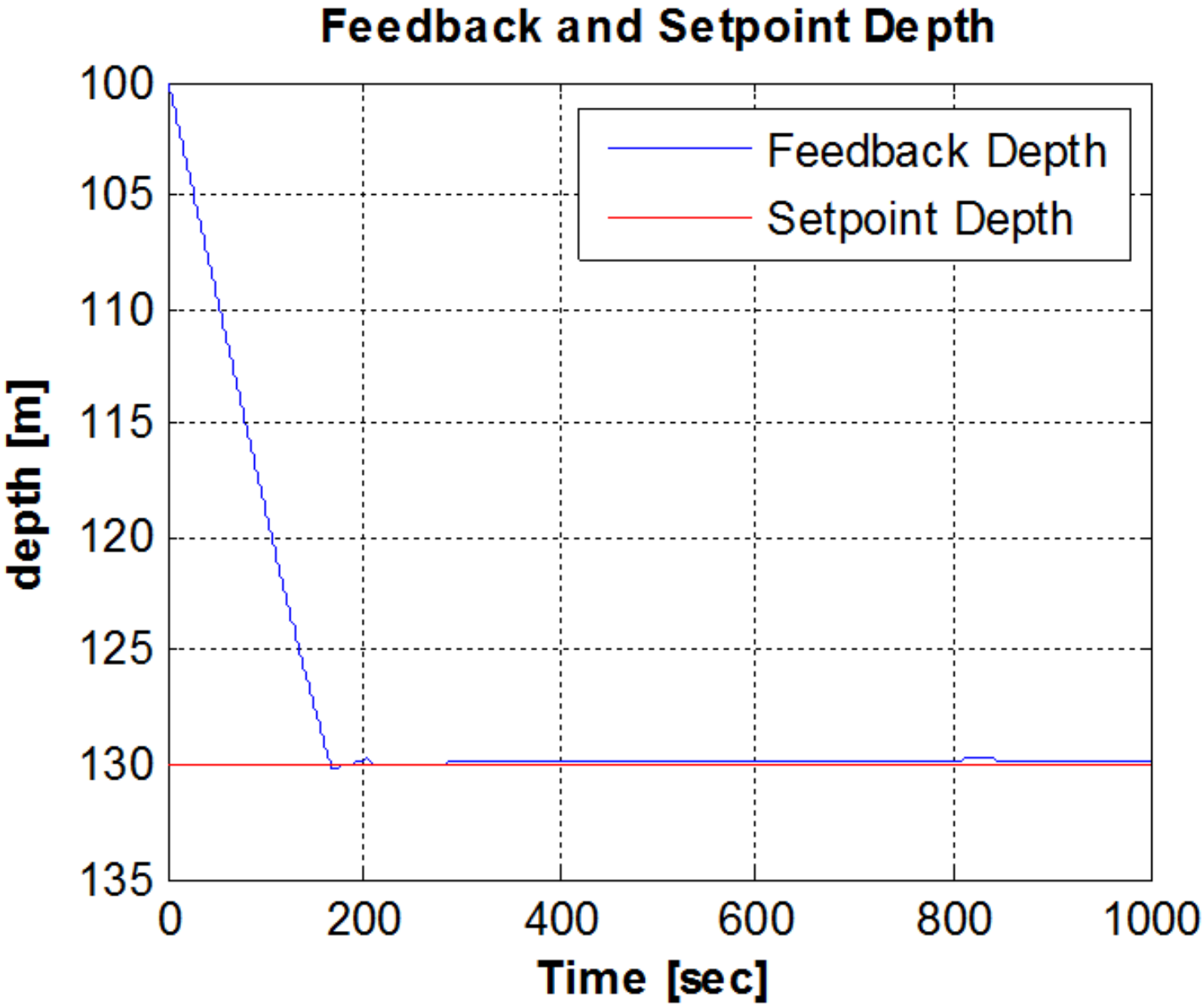
- Maximum Pressures

- Error Limit

- Pressure Difference Constant

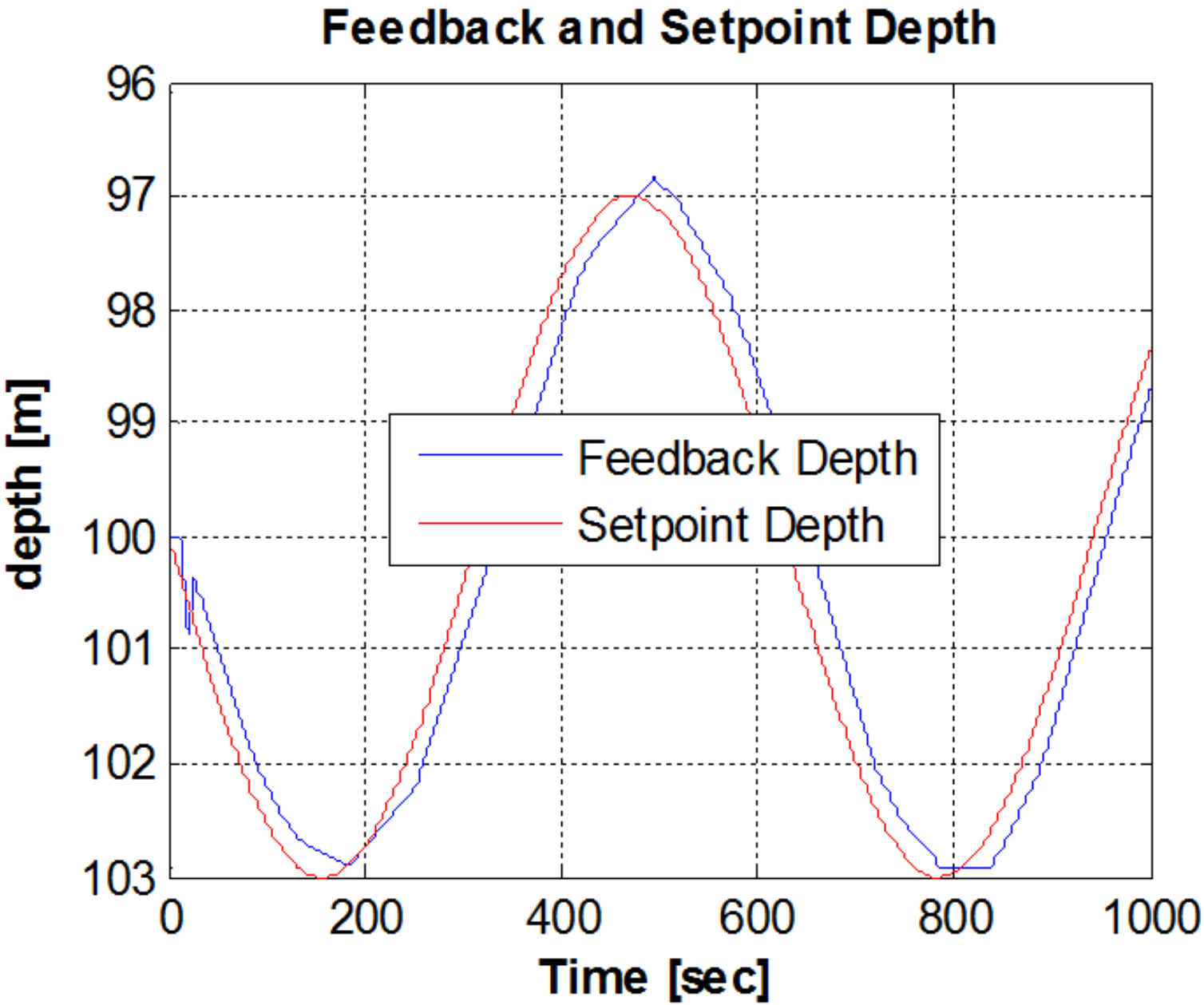
Simulation Results (no pitch or translational motion)

Step Setpoint Depth – 100 [m] → 130 [m]



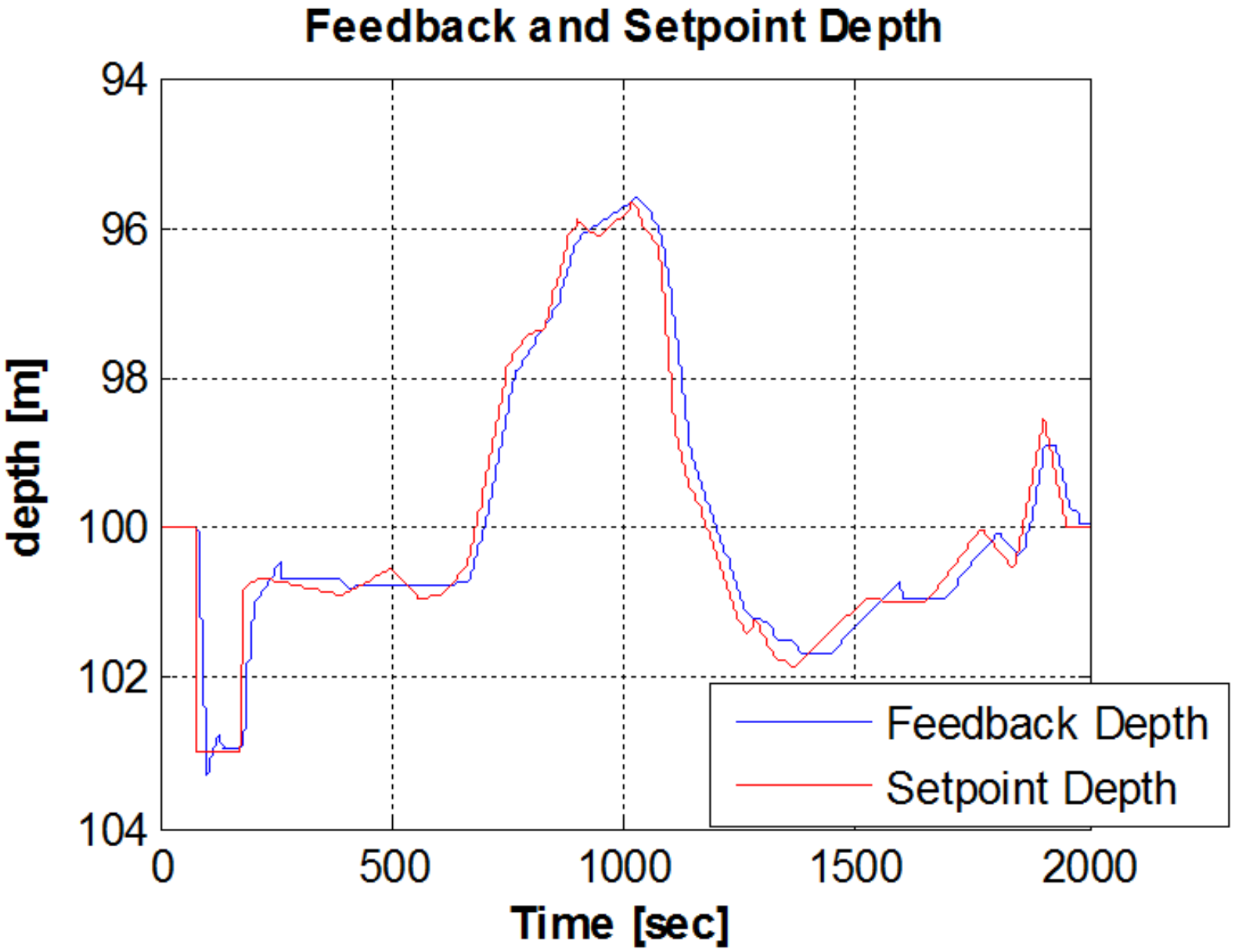
Simulation Results (no pitch or translational motion)

Sinusoidal Setpoint Depth – 600 [sec] period / 3 [m] amplitude



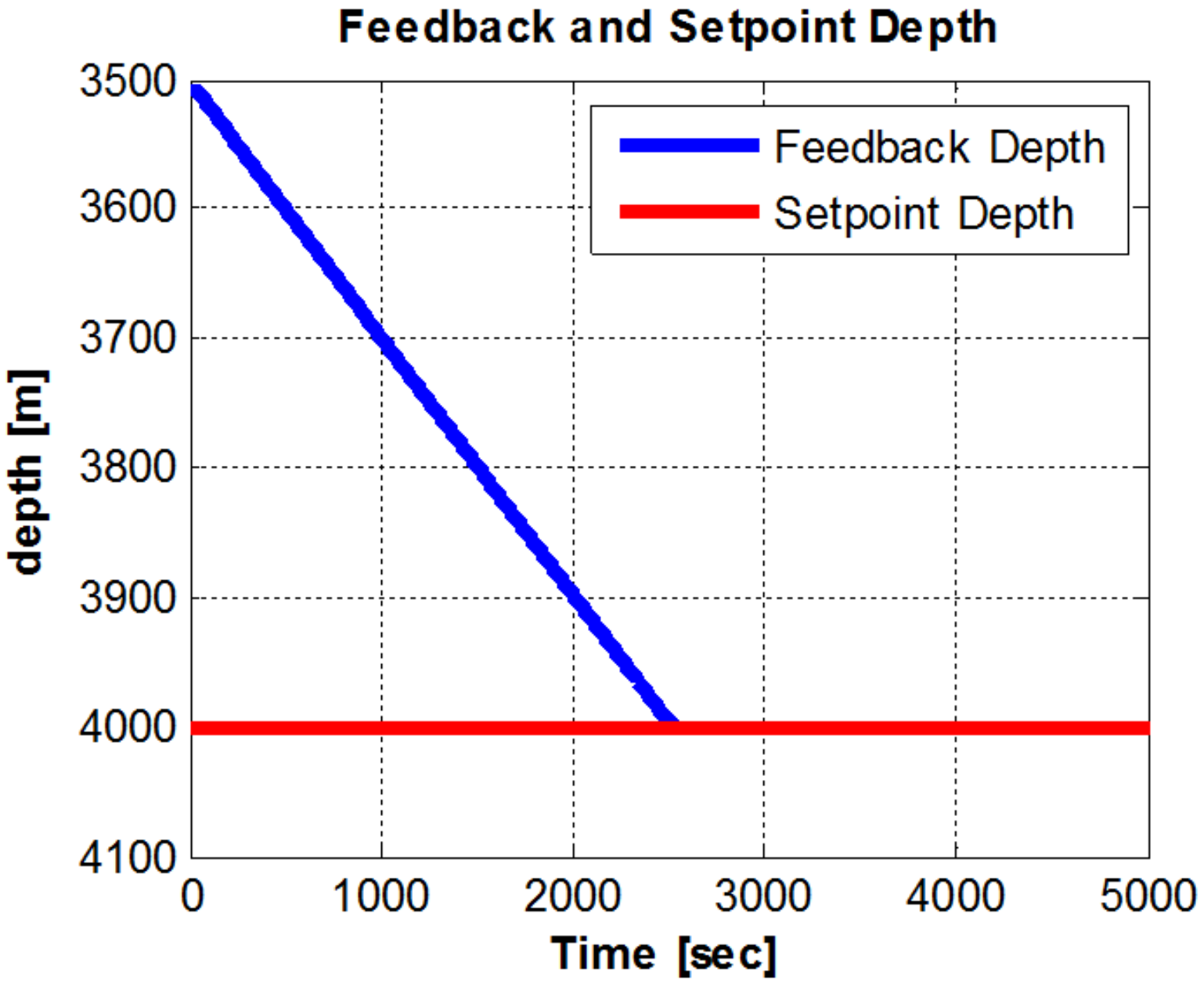
Simulation Results (no pitch or translational motion)

Custom Setpoint Depth



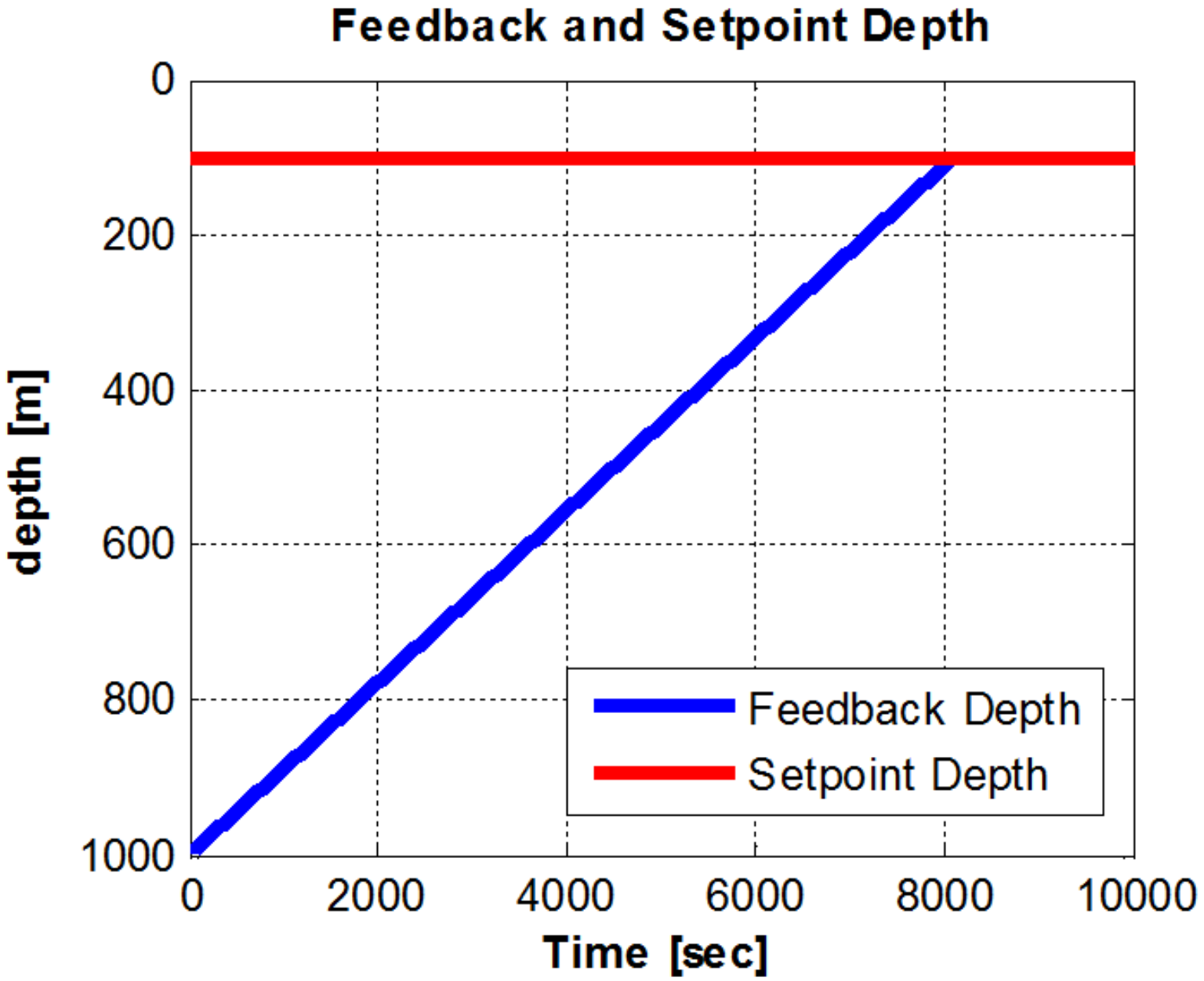
Simulation Results (no pitch or translational motion)

Step Setpoint Depth – 3,500 [m] → 4,000 [m]



Simulation Results (no pitch or translational motion)

Step Setpoint Depth – 1,000 [m] → 100 [m]

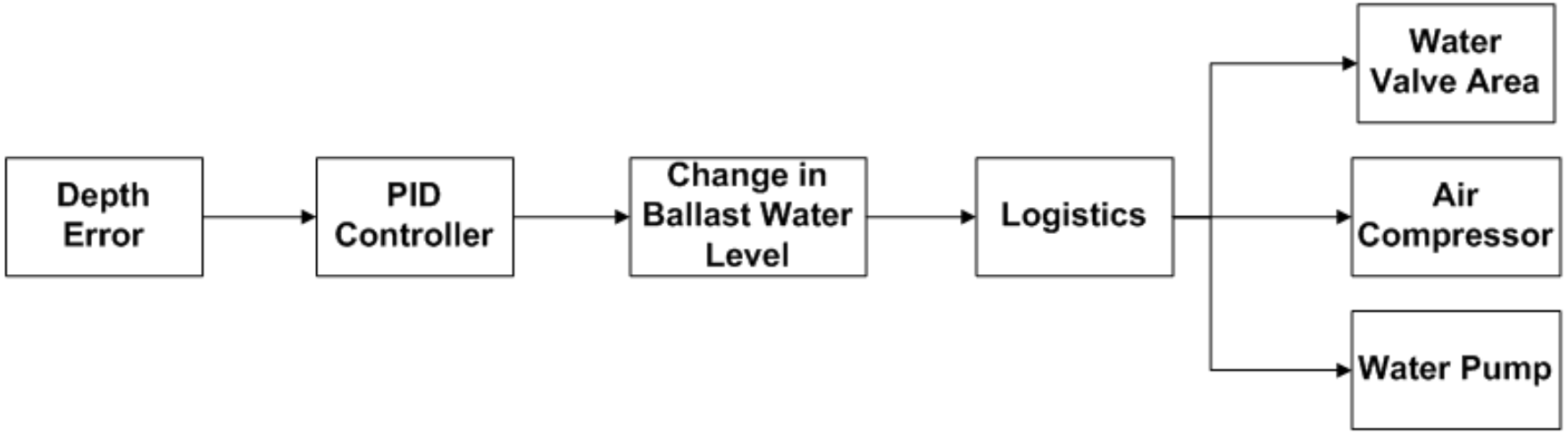


PID
DEPTH CONTROLLER

Controller Layout (work in progress)

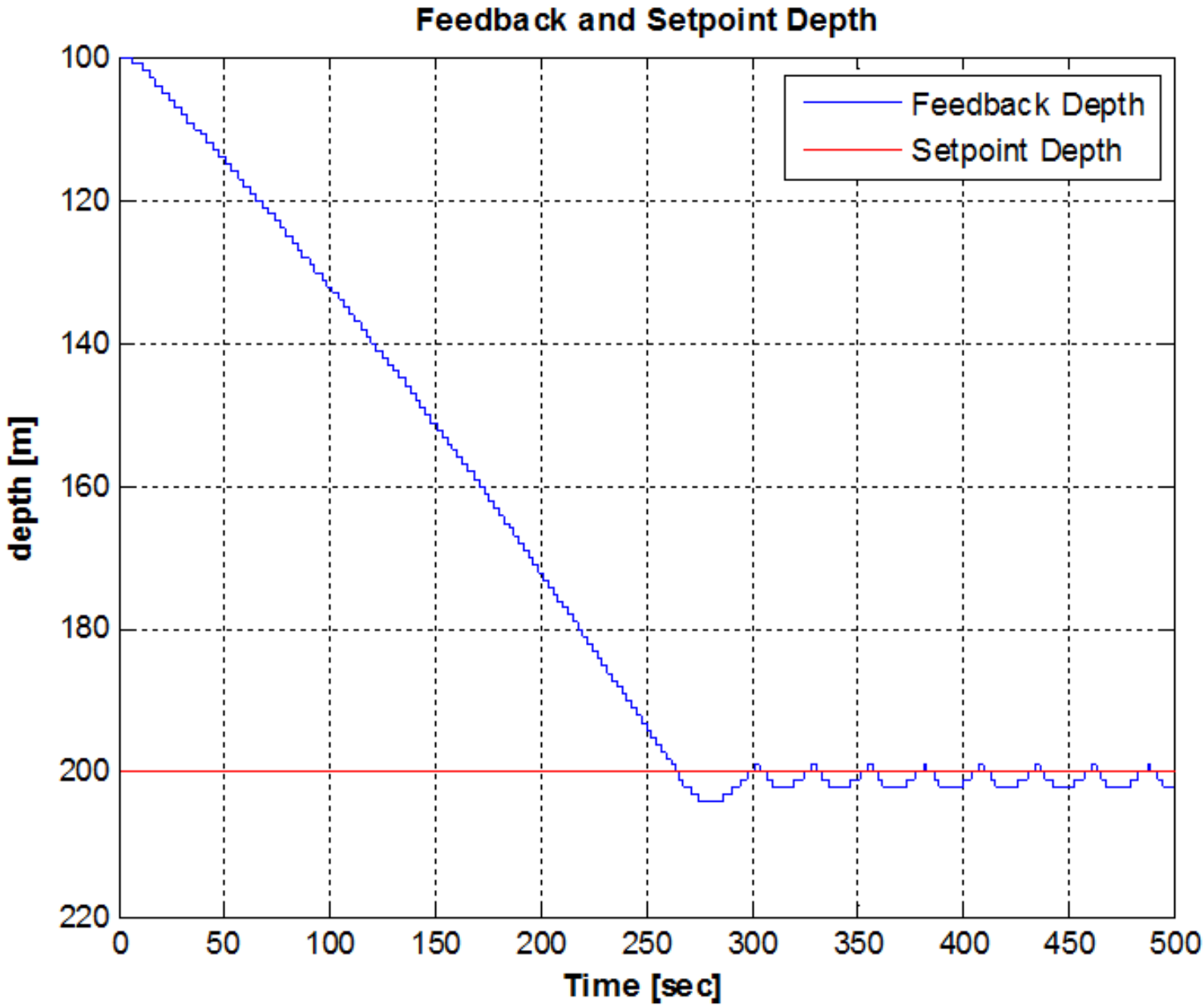
Purpose

- For direct comparison with current ballast depth controller



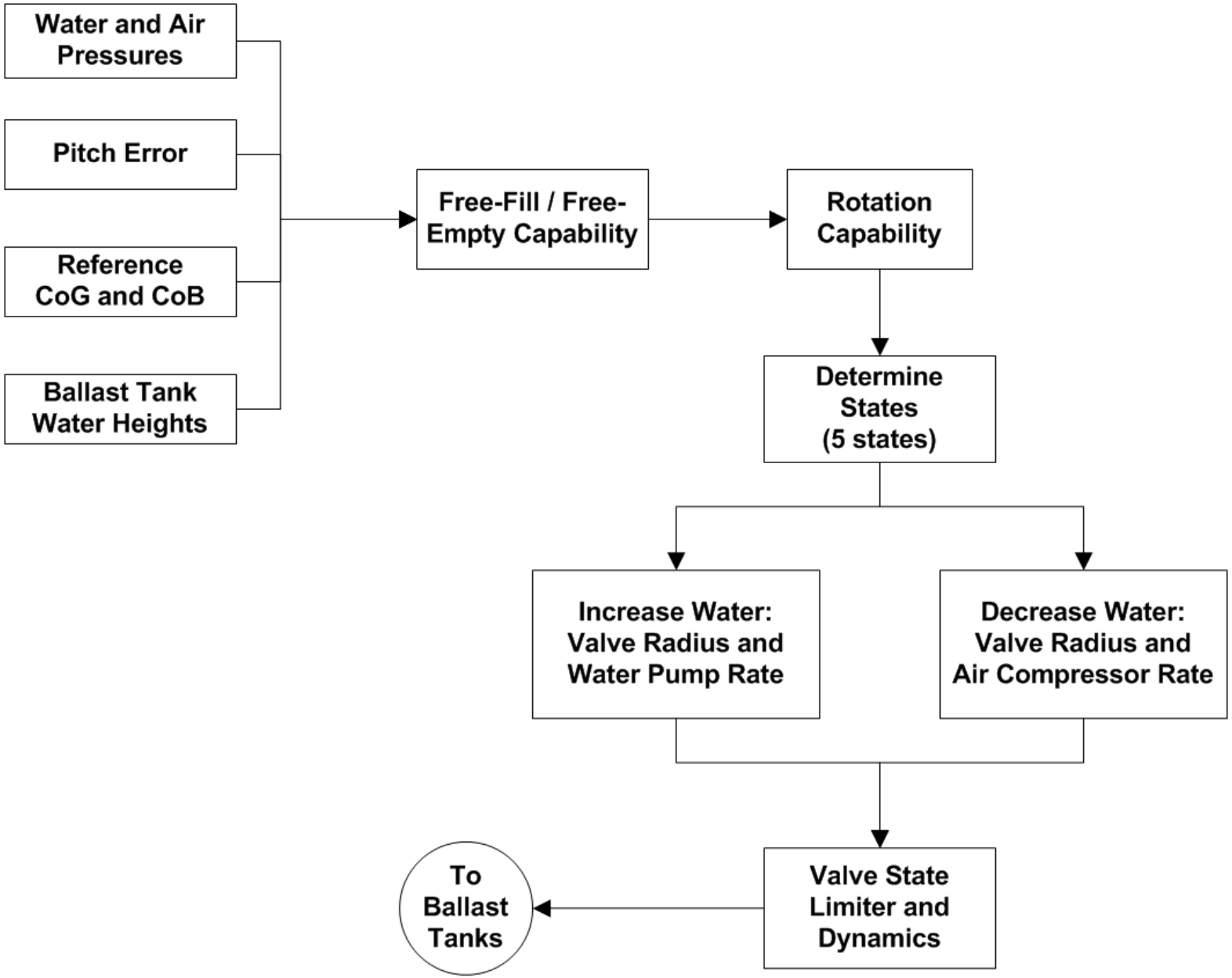
Simulation Results (no pitch or translational motion)

Step Setpoint Depth – 100 [m] → 200 [m]



BALLAST
PITCH CONTROLLER

Controller Layout (work in progress)



SUMMARY

Conclusion

Thank you for your time!

Any questions?

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