System structure

The launch and recovery system (LARS) consist of two main subsystems, i.e., the A-Frame and the winch, as shown in Fig. 1. Figure 2 depicts the modeling sketch of the LARS. The LARS model of interest has two degree of freedom (DoF) enabled by the tilting cylinder and the winch drum through the sheave connected to the A-Frame beam.

Figure. 1. The LARS on Gunnerus vessel in operation launching the ROV (Photo credit. NTNU)

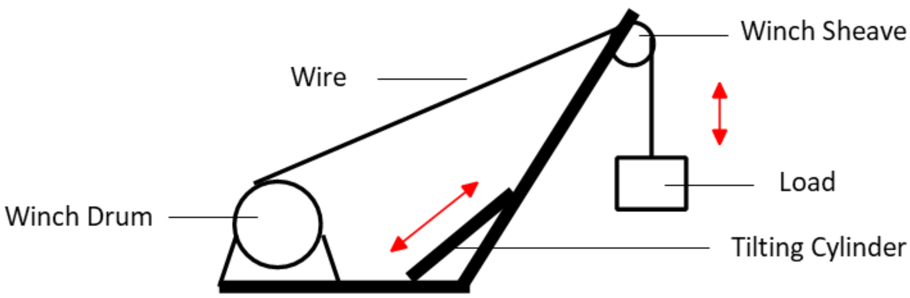


Figure. 2. Modelling sketch of the LARS

Subsystems, sub-models and FMUs

The reference system model is divided into eight sub-models and FMUs as shown in Fig. 3.

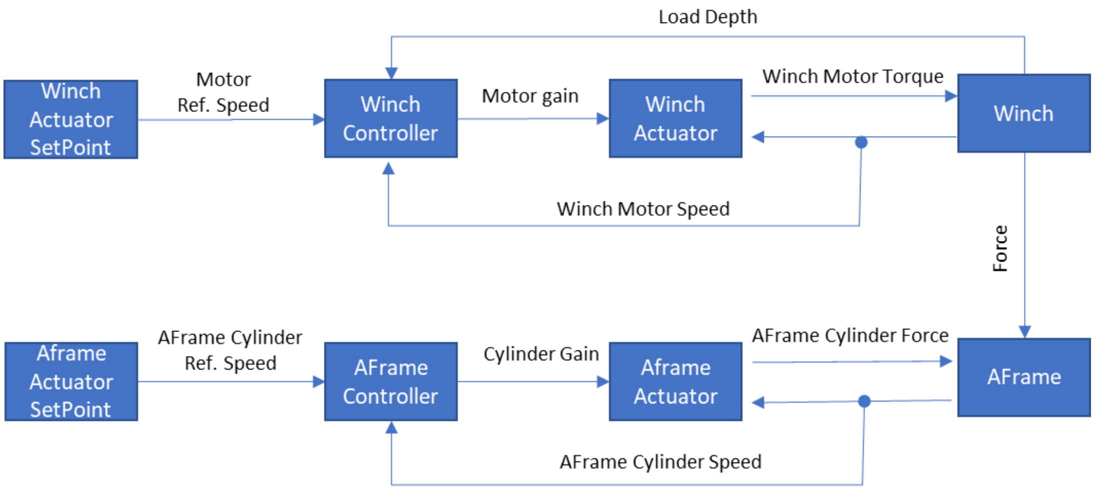


Figure 3. Model structure diagram of the LARS

For each sub-model (FMU) the interfaces and default parameters are defined.

FMU	input	output	Default parameters
Winch Actuator SetPoint		winchSetpoint	
Winch Controller	winchSetpoint loadSpeed	motorGain	Proportional gain K = 10 Derivative time constant Td = 0.1 Derivative gain limitation N = 10 Integral time constant Ti = 0.1 loadDepth_ min/max/init length 1/1000/200m
Winch Actuator	motorGain motorSpeed	motorTorque	Max motor output torque T = 10kNm
Winch	motorTorque1 motorTorque2 motorTorque3	motorSpeed loadSpeed winchForce	Gear ratio r = 141 Gear efficiency e = 0.925 Drum inertia i = 1600kgm^2 Drum diameter d = 1.36m Drum width B = 1.1 m Max wire length wireLmax = 1000m

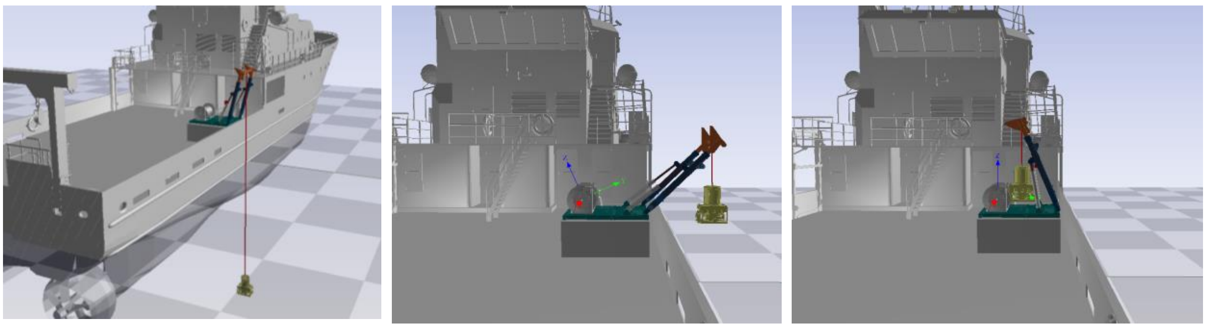
			Load mass m = 500kg Wire diameter D= 0.02m Wire Young's Modulus E = 85e9 Wire damping critical coefficient c= 0.5 Total friction coefficient r = 1
Aframe Actuator SetPoint		aFrameSetpoint	
Aframe Controller	aFrameSetpoint cylinderSpeed	cylinderGain	Proportional gain K = 2 Derivative time constant Td = 0.01 Derivative gain limitation N = 10 Integral time constant Ti = 0.01 Cylinder min/max/init length 1.2/1.7/1.7m
Aframe Actuator	cylinderGain cylinderSpeed	cylinderForce	Max cylinder output force F = 5000kN
AFrame	cylinderForce winchForce	cylinderSpeed	tilting leg length l=2m cylinder positions a = 0.46m, b = 1.3572m

Default scenario setup

The simulated scenario presents the retrieving of the ROV, as shown in Fig.4. Specifically,

From 5s to 95s, retrieving the ROV by spooling in the winch drum.

From 95s to 100s, by retracing the tilting cylinder the A-Frame operates from overboard position to the onboard position.



Position 1. ROV retrieving   Position 2. ROV overboard   Position 3. ROV onboard

Figure 4. Simulation scenario retrieving the ROV

Simulation results

Given the setpoint by the default scenario, the tilting angle of the A-Frame and the position of the load are shown in Fig. 6. Time step 0.001s.

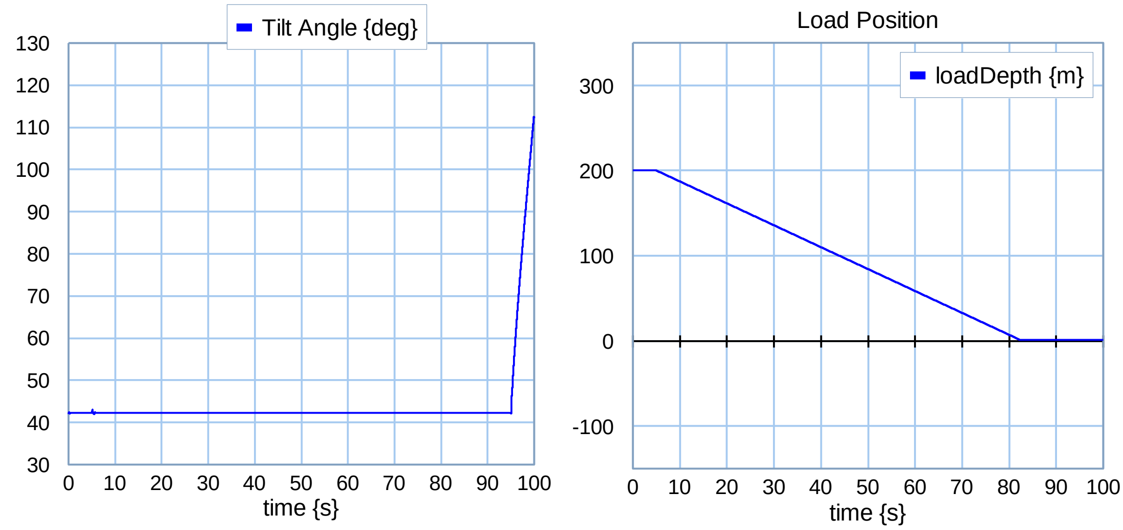


Figure 6. Tilting angle and the load position

For comparison, we replaced the winch FMU developed in a different tool (SimulationX), Fig.7. The co-simulation results are shown in Fig. 8 and 9, respectively, handled by 20-sim and cse.

Micro-time step is 0.001s for the 20-sim fmus, and 1e-8s for the SimulationX FMU, Macro-time step 0.001s.

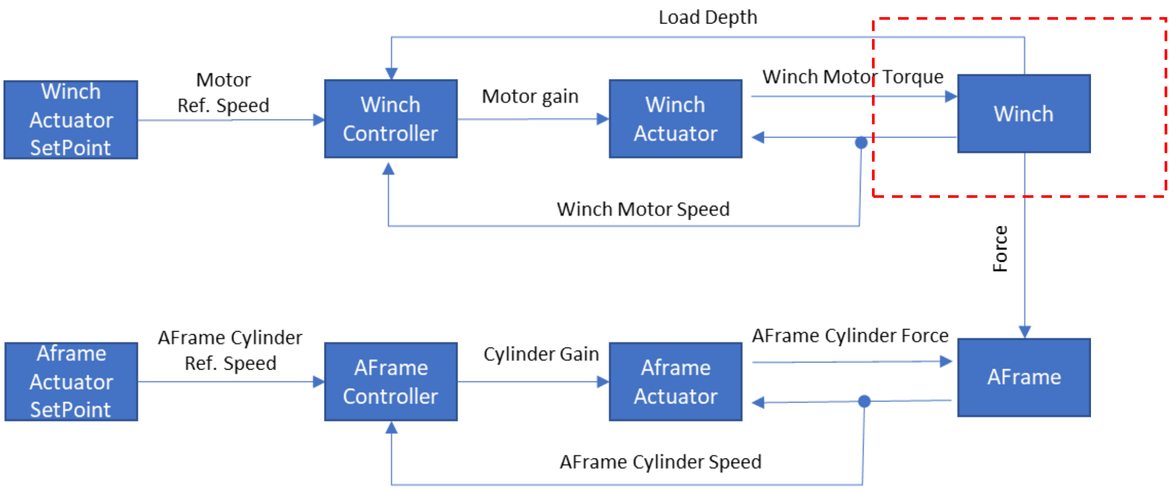


Fig. 7 Model structure diagram of the LARS – Co-sim

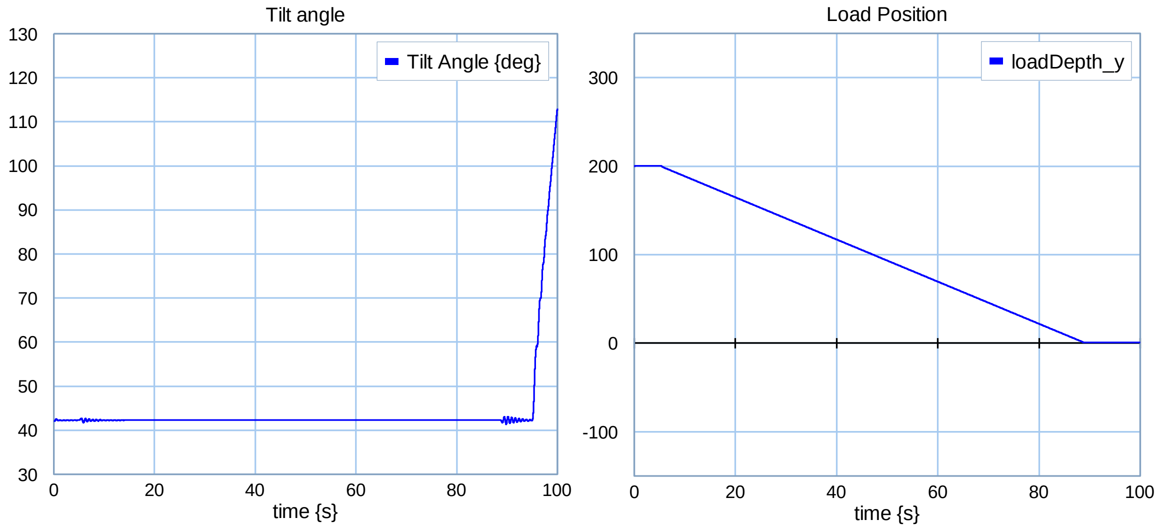


Figure 8. Tilting angle and the load position – Co-sim handled by 20-sim

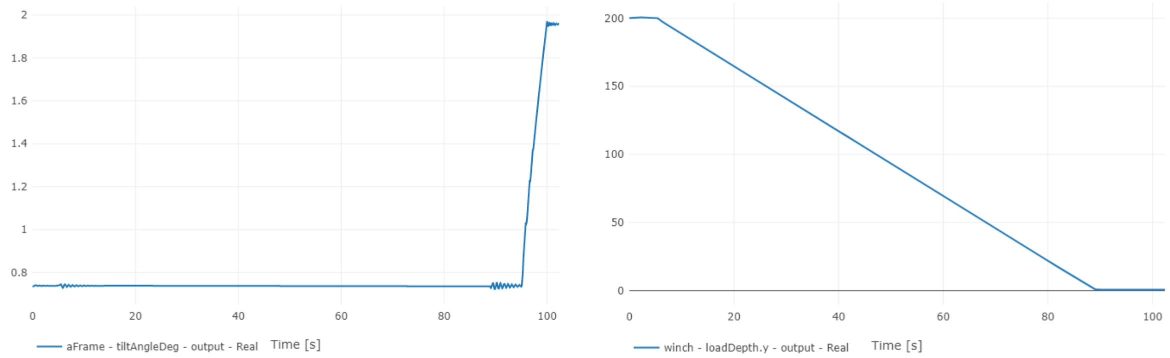


Figure 9. Tilting angle and the load position – Co-sim handled by cse client (windows)