



Multi-LRAUV simulation environment

Milestone #1

March 2020

Main goal and milestone #1 tasks

Develop a multi-LRAUV simulation environment

1. Basic 3D LRAUV vehicle model
2. Basic water column environment
3. Vehicle plugins
4. API and LRAUV software stack integration

Basic 3D LRAUV vehicle model

- Based on the MBARI Tethys CAD file -> Simplified mesh
- Create SDF file describing the kinematics and dynamics

```
<joint name="propeller_joint" type="revolute">
  <pose>0 0 0 0 0 0</pose>
  <parent>base_link</parent>
  <child>propeller</child>
  <axis>
    <xyz>1 0 0</xyz>
    <limit>
      <lower>-1e+12</lower>
      <upper>1e+12</upper>
      <effort>-1</effort>
      <velocity>-1</velocity>
    </limit>
  </axis>
</joint>
</model>
</sdf>
```

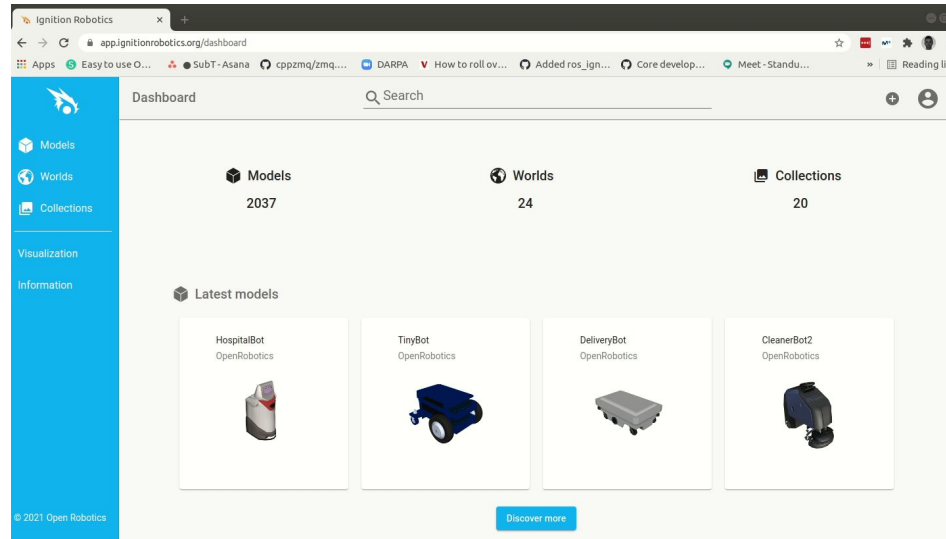
Basic 3D LRAUV vehicle model

- Split the original mesh: main vehicle, horizontal fin, vertical fin and propeller
- Associate a mesh and texture to each link
- Modified tail cone version



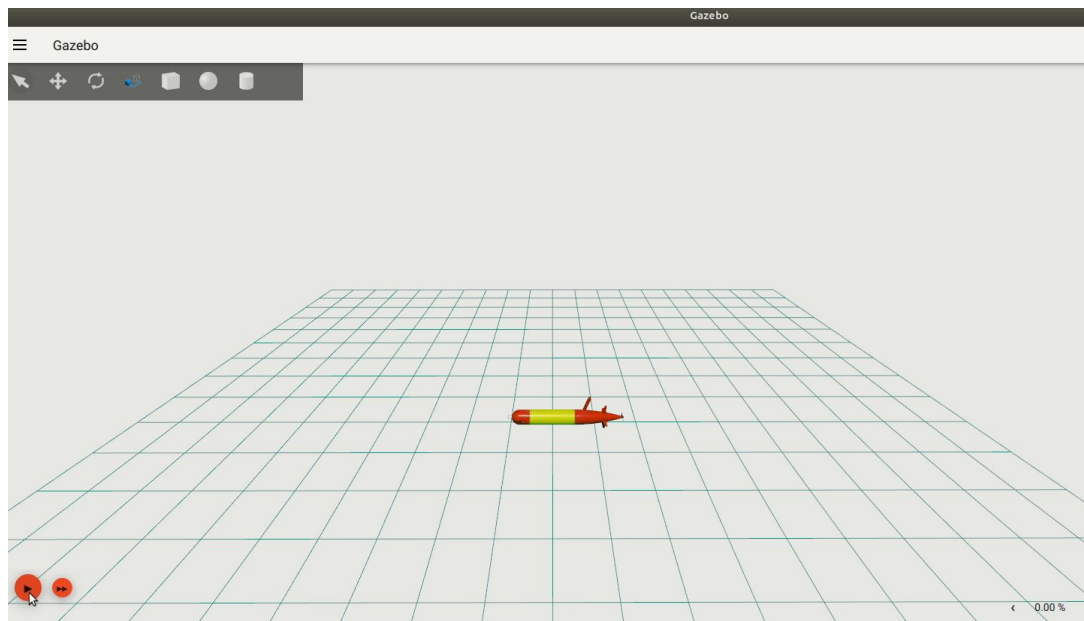
Basic 3D LRAUV vehicle model

- Tethys is available at [Fuel](#)



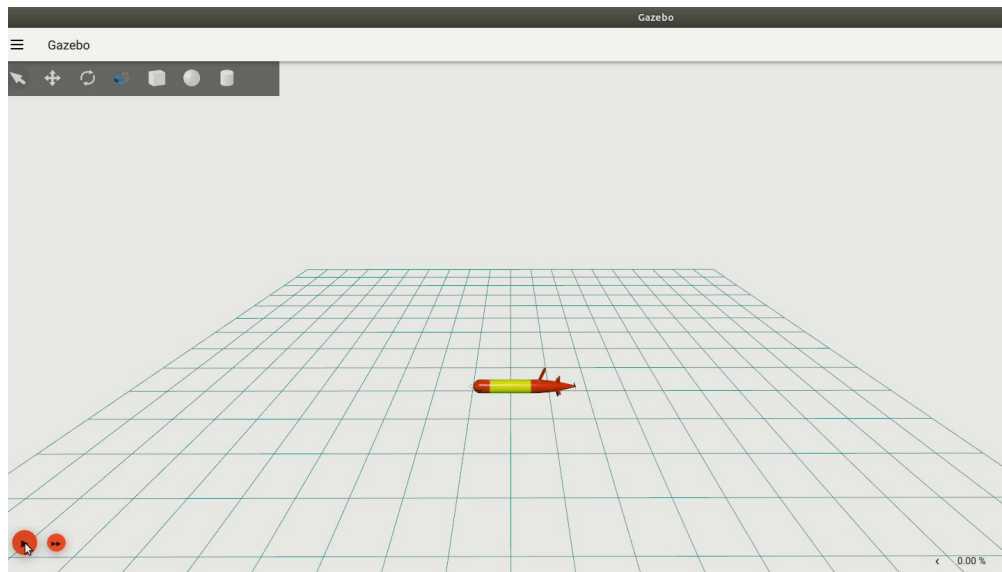
Basic water column environment

- Environment without buoyancy

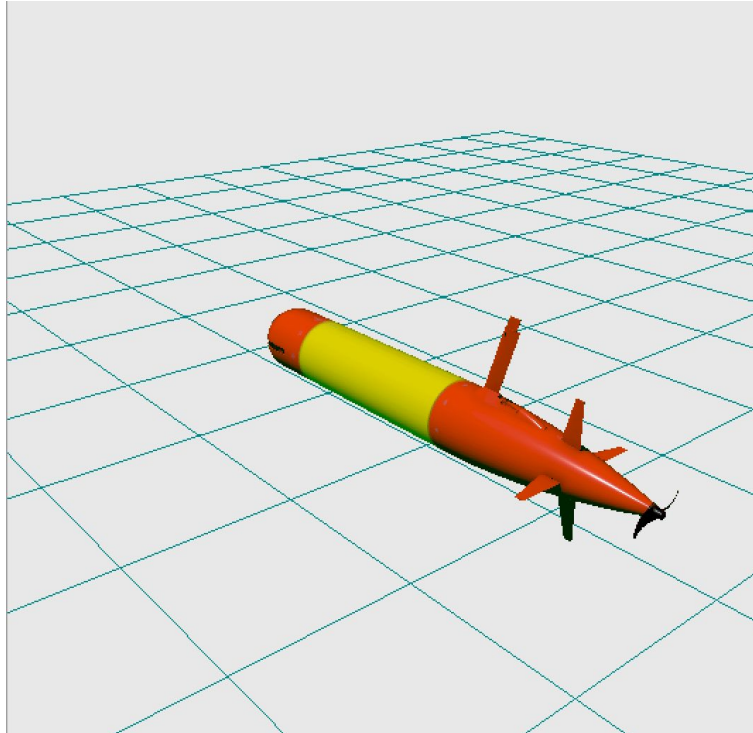


Basic water column environment 🐟

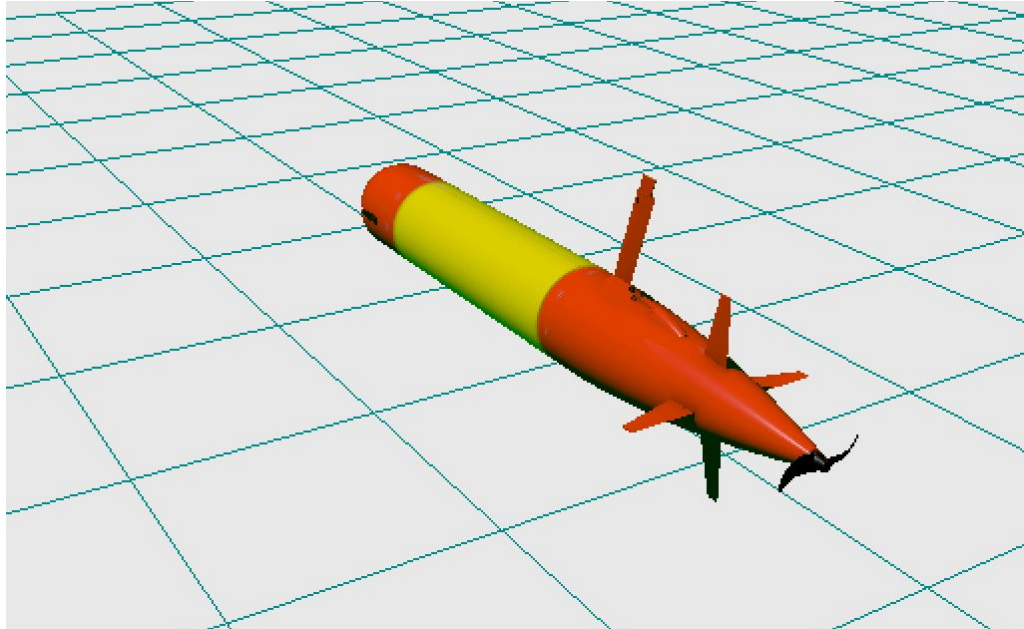
-  Buoyancy plugin
- Set fluid density (1000 kg/m^3)
- Set density of the object placed in the water
- $\approx$ Volume of the object
- $\approx$ Object collision mesh



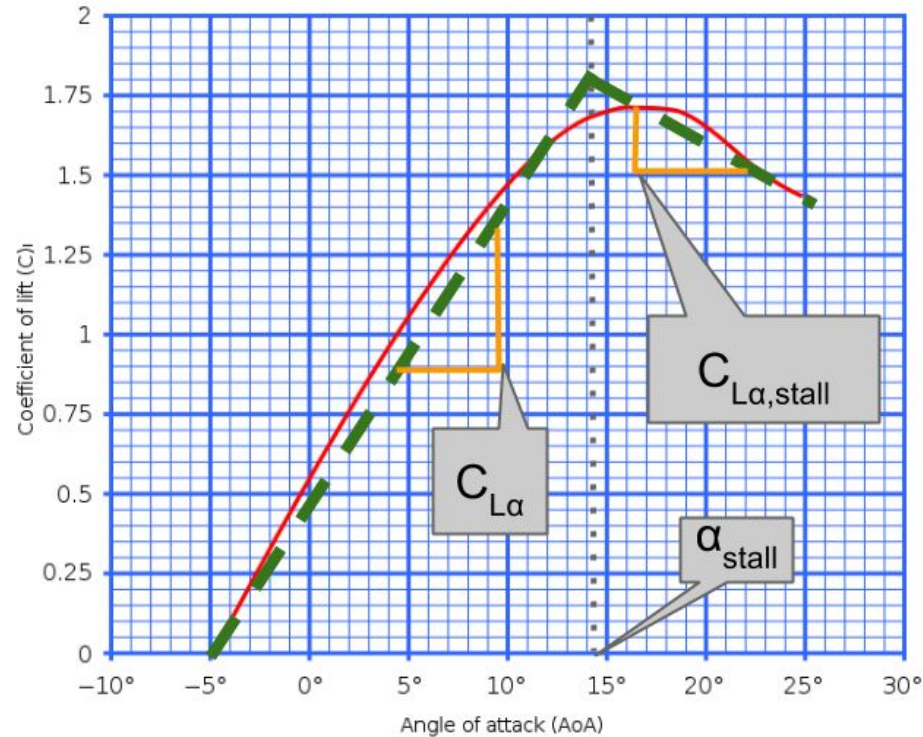
Vehicle plugins - Thruster



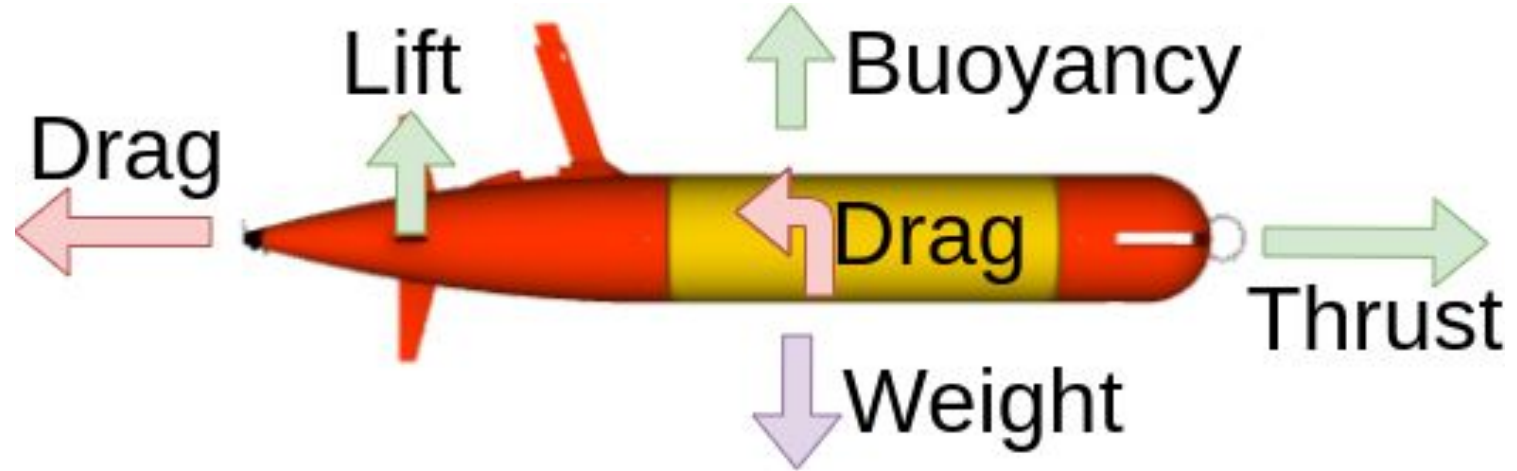
Vehicle plugins - Rudder / Elevator



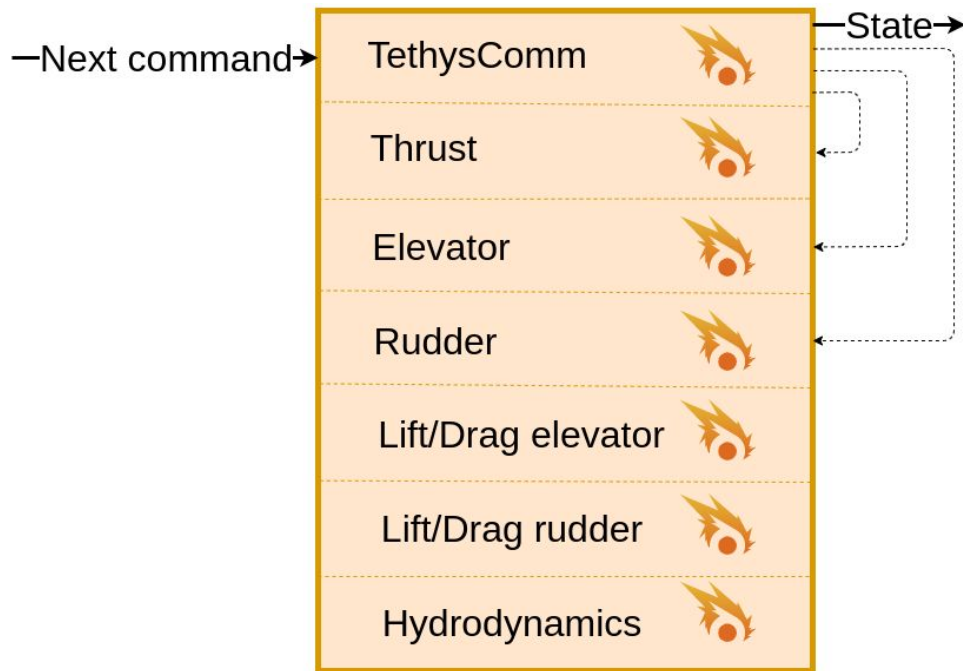
Vehicle plugins - Lift/Drag



Vehicle plugins - Hydrodynamics

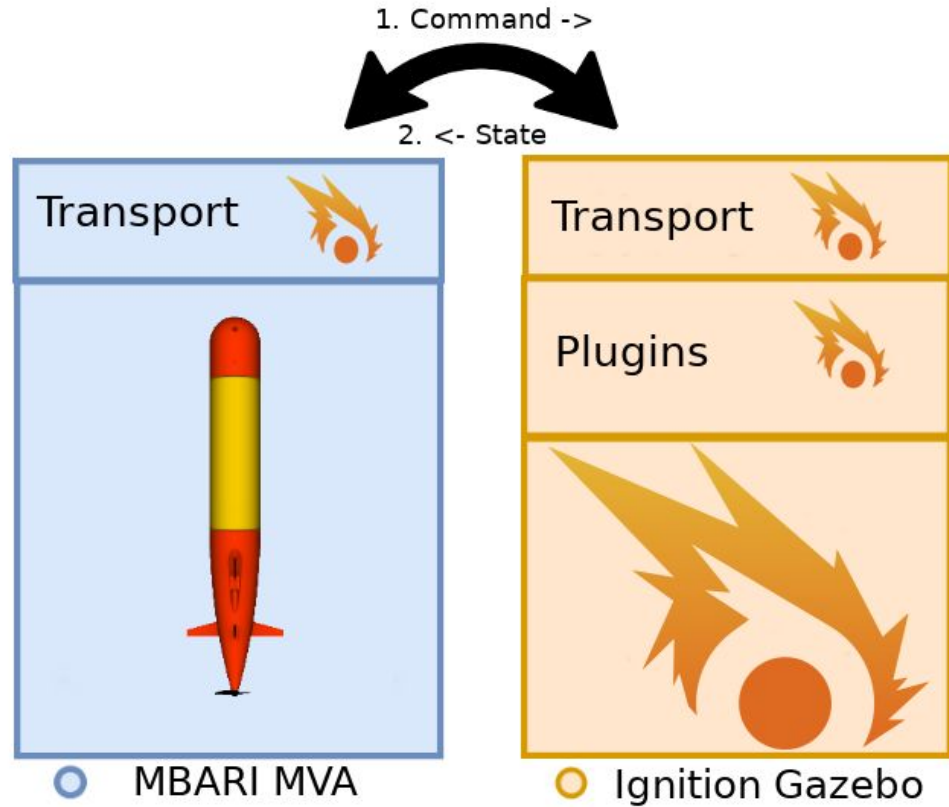


Vehicle plugins - TethysComm



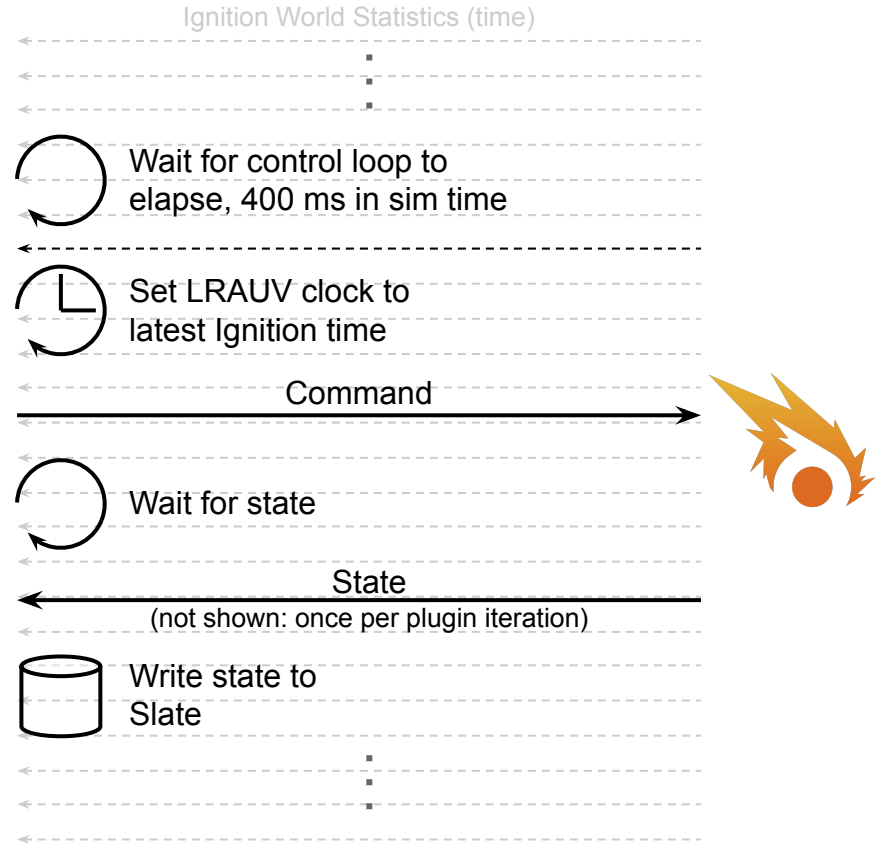
Simulation API

- Message passing interface
- Propeller, rudder, elevator
- Command message
- State message



LRAUV integration

- Ignition time is published every simulation iteration - “heartbeat”
- SimDaemon: `ExternalSim`
Ignition: `ExternalSimIgnition`
- One control iteration:



Integrated simulation in real time

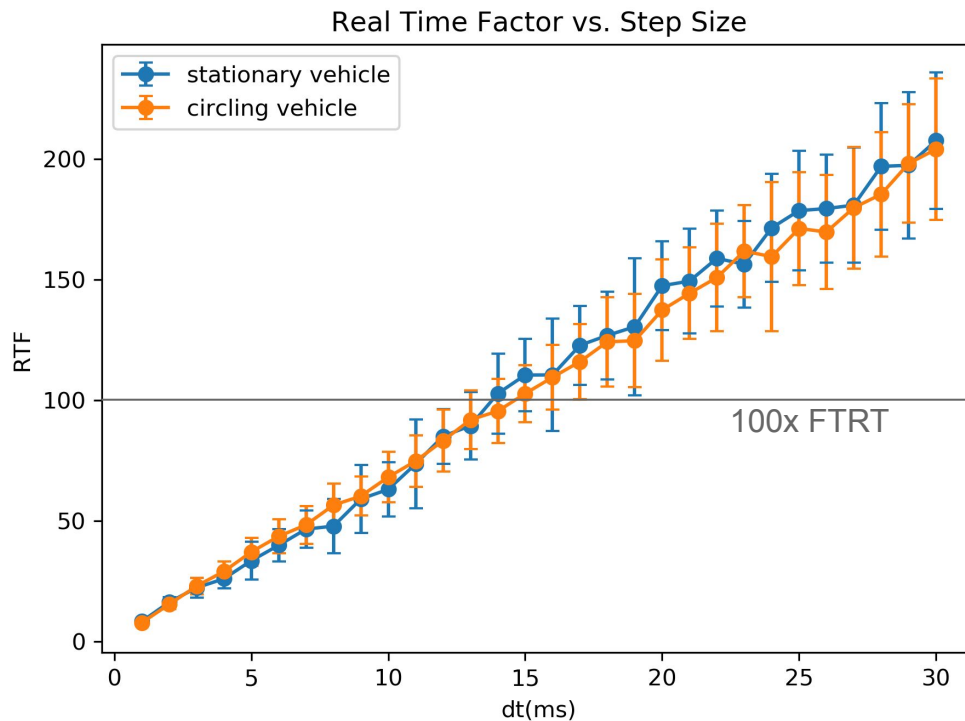
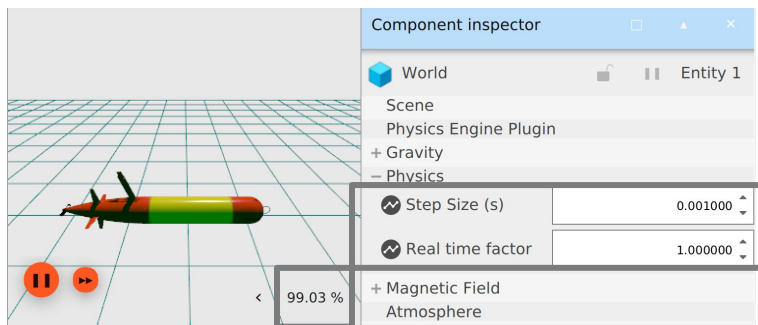
```
File Edit View Search Terminal Tabs Help
colcon build [2/2 done] [0 ongoing]
developer@876719e06cad: ~
Terminal
developer@06112518b9f2: ~
developer@876719e06cad: ~/mbari

st = 3.225000 s, runParams.dt_ = 0.400050 s)
2021-04-15T00:19:41.535Z,1618445981.535 [ExternalSim](INFO): Calling SetNow() on initTime_ + latestSimT_ (3.228000 s) = 1
618445981.534687 s
2021-04-15T00:19:41.535Z,1618445981.535 [ExternalSim](INFO): Timestamp: Now() - initTime_: 3.228008 s
2021-04-15T00:19:41.535Z,1618445981.535 [ExternalSim](INFO): Waiting for a state from Ignition...
2021-04-15T00:19:41.939Z,1618445981.939 [ExternalSim](INFO): Waiting as needed until Ignition sim time 3.628000 s... (late
st = 3.618000 s, runParams.dt_ = 0.400085 s)
2021-04-15T00:19:41.935Z,1618445981.935 [ExternalSim](INFO): Calling SetNow() on initTime_ + latestSimT_ (3.628000 s) = 1
618445981.934687 s
2021-04-15T00:19:41.935Z,1618445981.935 [ExternalSim](INFO): Timestamp: Now() - initTime_: 3.628012 s
2021-04-15T00:19:41.935Z,1618445981.935 [ExternalSim](INFO): Published command to Ignition (printed only once in a while):
2021-04-15T00:19:41.935Z,1618445981.935 [ExternalSim](INFO): propOmegaAction: 0.000000
2021-04-15T00:19:41.935Z,1618445981.935 [ExternalSim](INFO): rudderAngleAction: 0.000000
2021-04-15T00:19:41.935Z,1618445981.935 [ExternalSim](INFO): elevatorAngleAction: 0.000000
2021-04-15T00:19:41.935Z,1618445981.935 [ExternalSim](INFO): dt: 0.400034
2021-04-15T00:19:41.935Z,1618445981.935 [ExternalSim](INFO): time: 3.628011
2021-04-15T00:19:41.935Z,1618445981.935 [ExternalSim](INFO): (some fields omitted in printout)
2021-04-15T00:19:41.935Z,1618445981.935 [ExternalSim](INFO): Waiting for a state from Ignition...
2021-04-15T00:19:42.313Z,1618445982.313 [ExternalSim](INFO): Received state from Ignition (printed only once in a while):
2021-04-15T00:19:42.313Z,1618445982.313 [ExternalSim](INFO): header.stamp.sec: 4
2021-04-15T00:19:42.313Z,1618445982.313 [ExternalSim](INFO): header.stamp.nsec: 0
2021-04-15T00:19:42.313Z,1618445982.313 [ExternalSim](INFO): propOmega: 0.000000
2021-04-15T00:19:42.313Z,1618445982.313 [ExternalSim](INFO): rudderAngle: -0.000000
2021-04-15T00:19:42.313Z,1618445982.313 [ExternalSim](INFO): elevatorAngle: -0.000000
2021-04-15T00:19:42.313Z,1618445982.313 [ExternalSim](INFO): depth: -1.000000
2021-04-15T00:19:42.313Z,1618445982.313 [ExternalSim](INFO): roll: 0.000000
2021-04-15T00:19:42.313Z,1618445982.313 [ExternalSim](INFO): pitch: 0.000000
2021-04-15T00:19:42.313Z,1618445982.313 [ExternalSim](INFO): heading: 1.570000
2021-04-15T00:19:42.313Z,1618445982.313 [ExternalSim](INFO): speed: 0.000000
2021-04-15T00:19:42.313Z,1618445982.313 [ExternalSim](INFO): (some fields omitted in printout)
876719e06cad>
```

maintain control HorizontalControl.rudderAngleAction -0.2 radian
maintain control SpeedControl.propOmegaAction 300 rpm

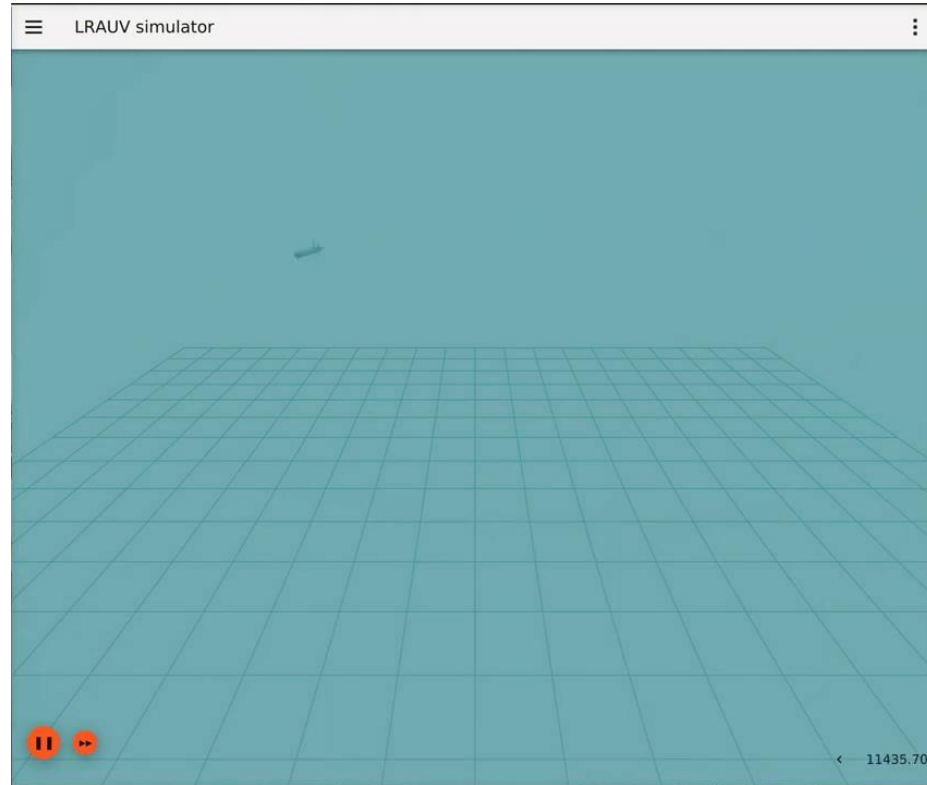
Faster-than-real-time Ignition performance

- Set in Ignition or SDF
 - Real time factor: 0 (AFAP)
 - Step size (duration per iteration)
- No change in LRAUV setup from RTF 1



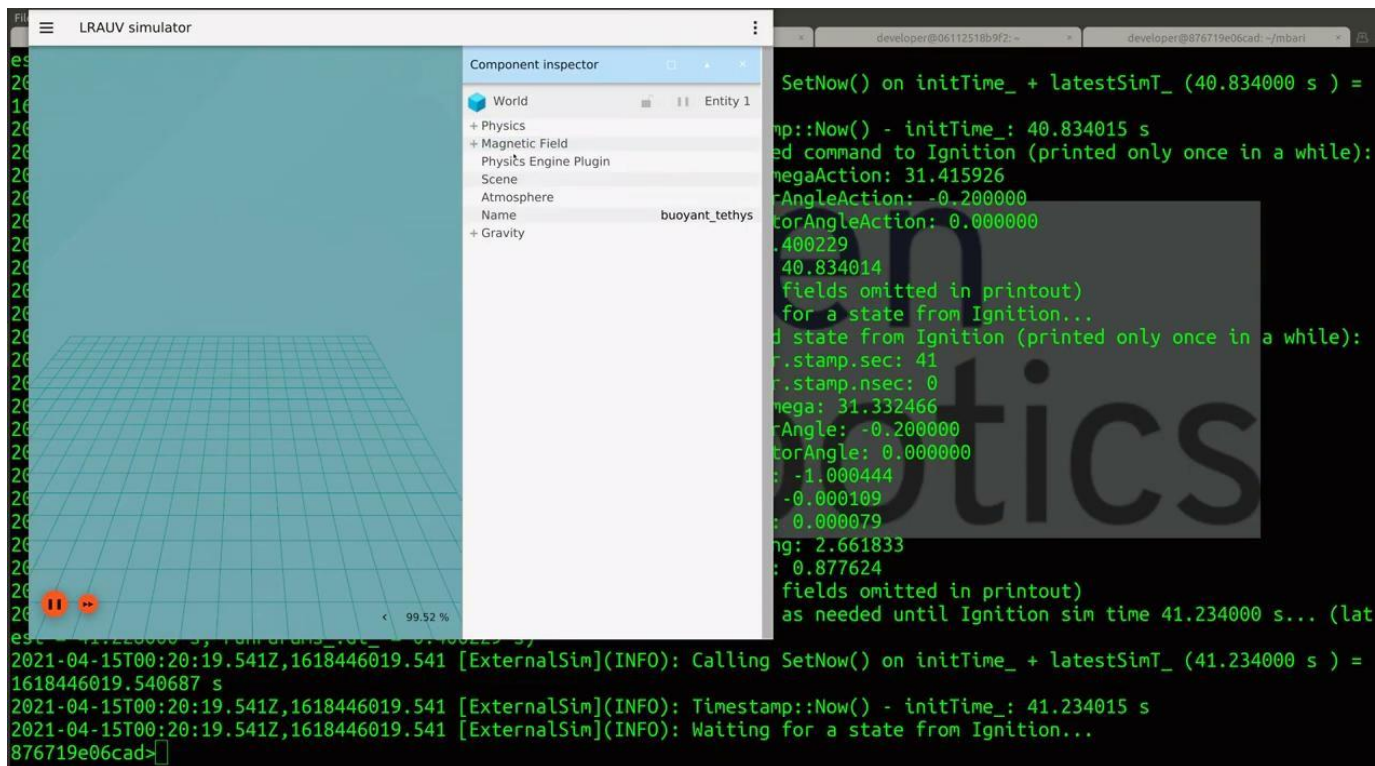
100 times faster than real time, Ignition only

Set in SDF:
RTF: 0 (AFAP)
Step: 0.02 ms



... or, not so fast,
look out?

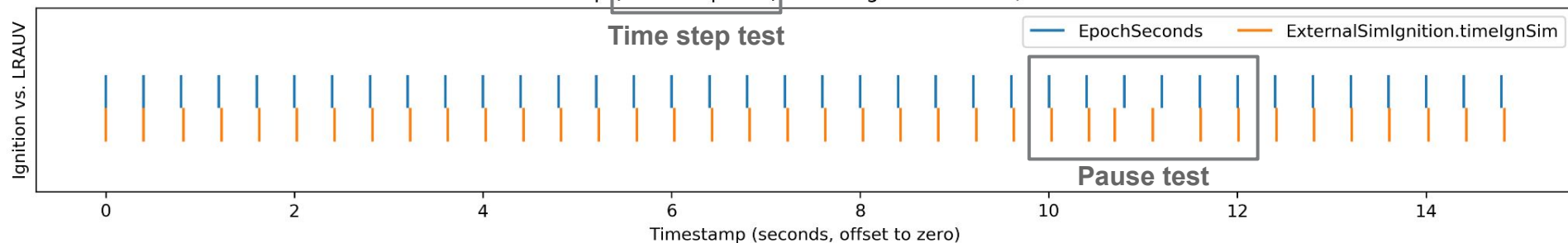
100 times faster than real time, integrated



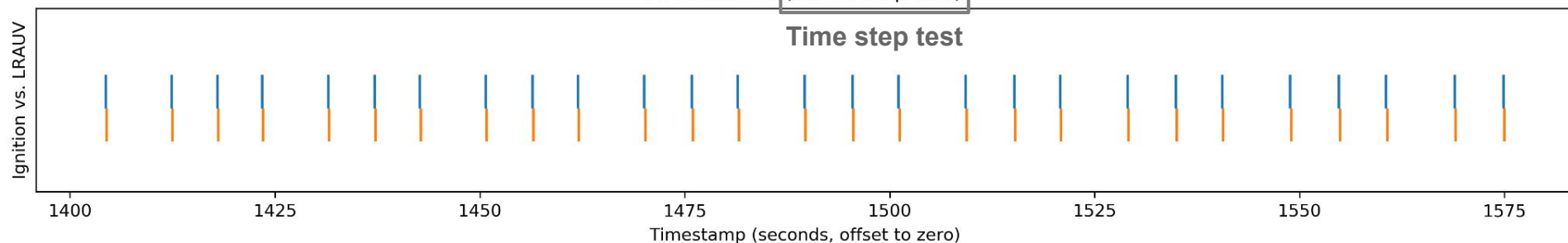
A 1500-second run with various step sizes

Time Step Synchronization between Ignition and LRAUV

At startup (1 ms step size) Pause Ignition at 10 s, resume



At shutdown (20 ms step size)





Thanks!

Time Synchronization between Ignition and LRAUV

