Polaris GEM e2 & Simulator

Center of Autonomy at University of Illinois at Urbana-Champaign

User Manual

Version 1.0

07/01/2020

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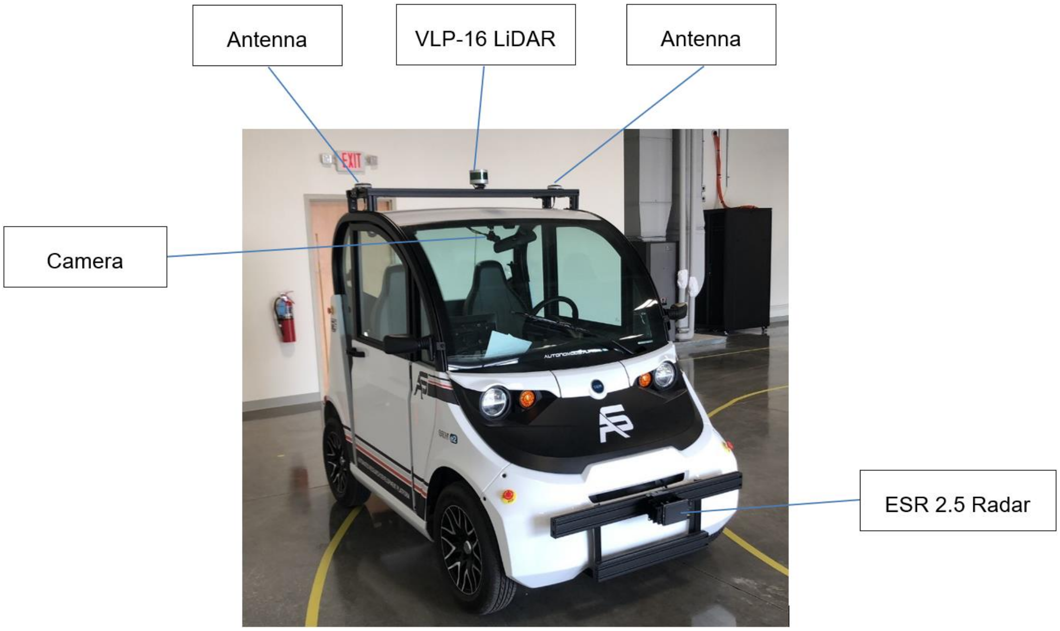
1. Polaris GEM e2 Hardware

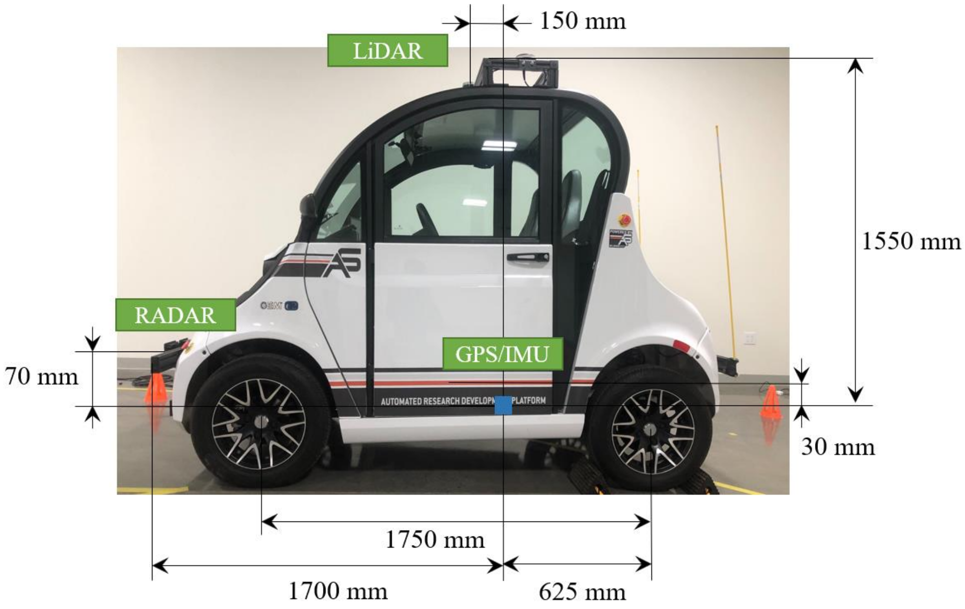
1.1 Polaris GEM e2 Vehicle



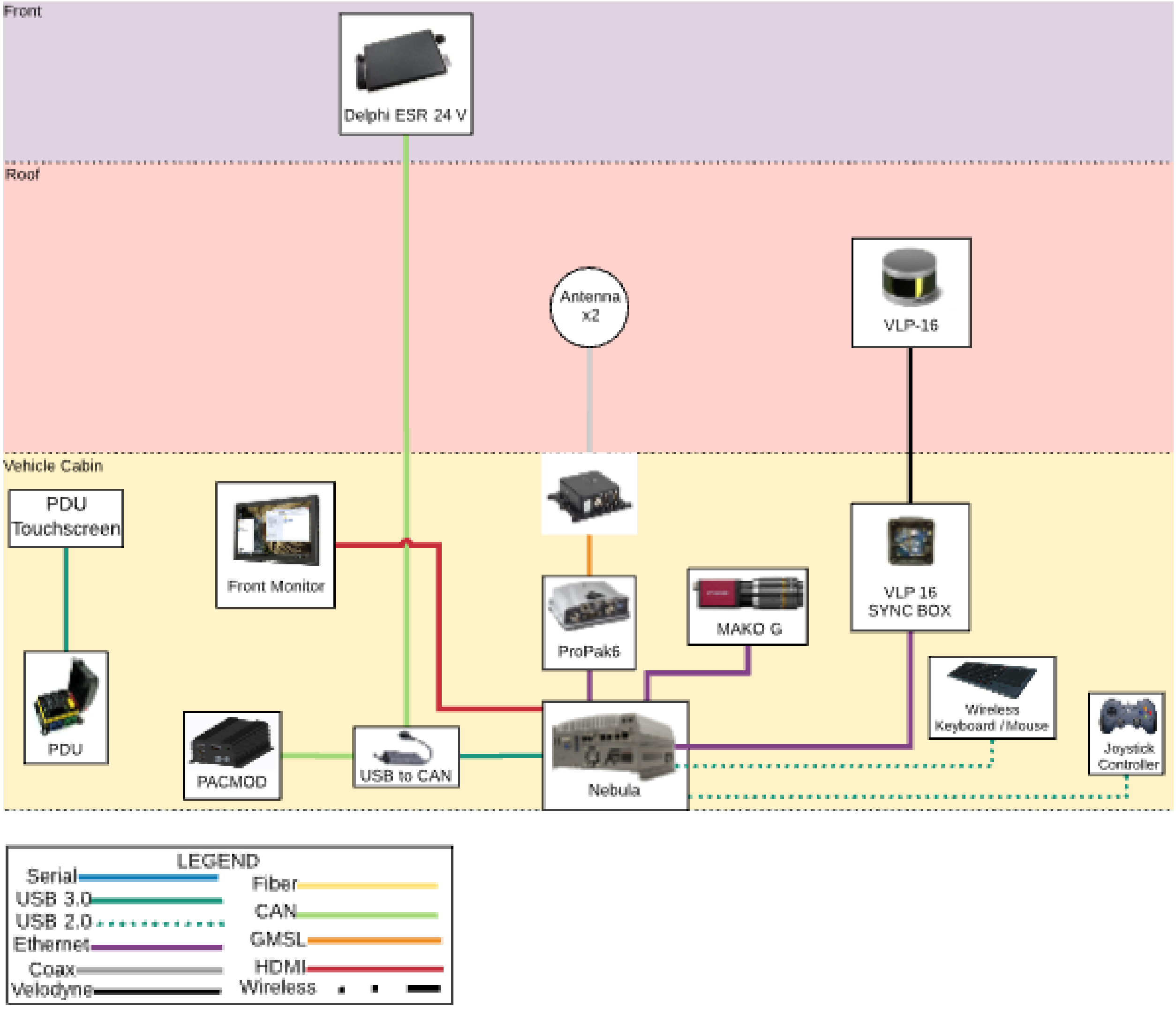
Software interfaces to the controls: steering, braking, acceleration

Software access: left and right blinkers, reverse and drive gear selection, speed feedback

Convenience features: Dash mounted display screen, Power distribution terminals



1.2 Hardware Overview



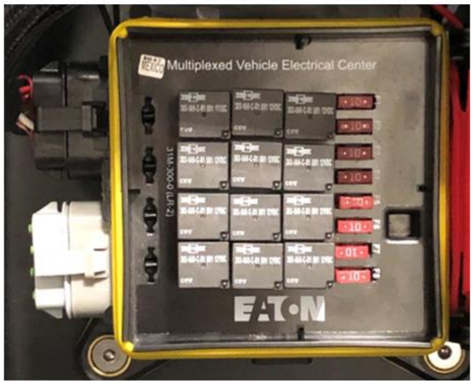
1.3 Master Power Switch

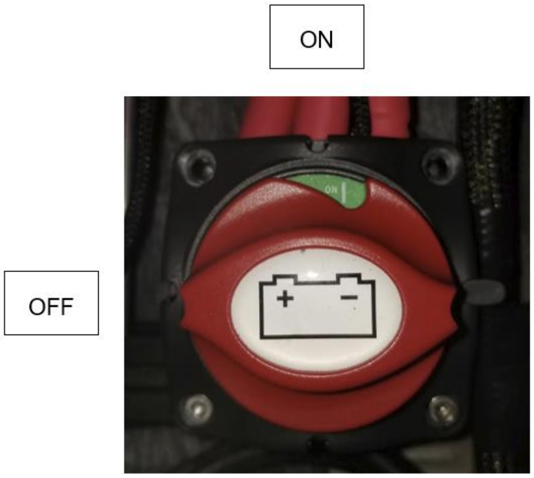
Switch will allow operator to cut power to power distribution system

ON will supply power to power distribution system from vehicle battery

OFF will remove power to the power distribution system

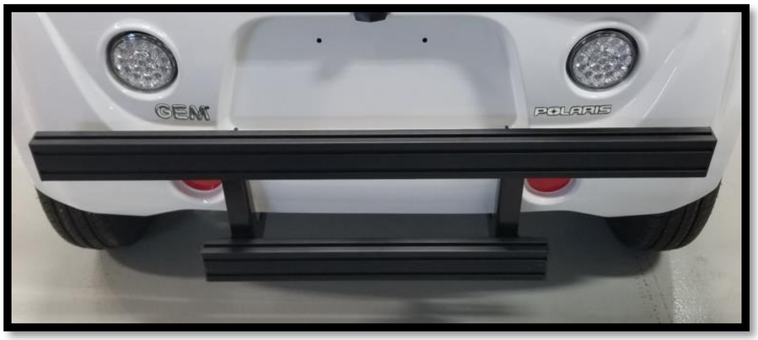
Located under the driver’s seat



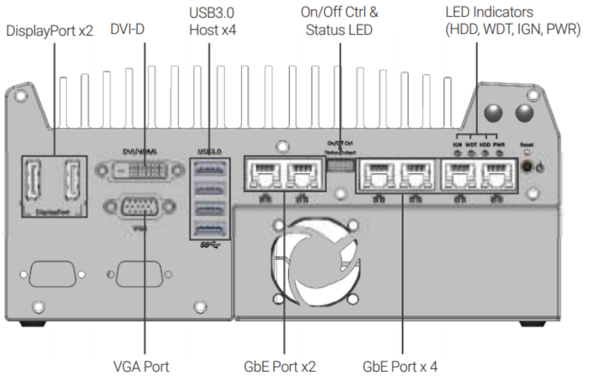


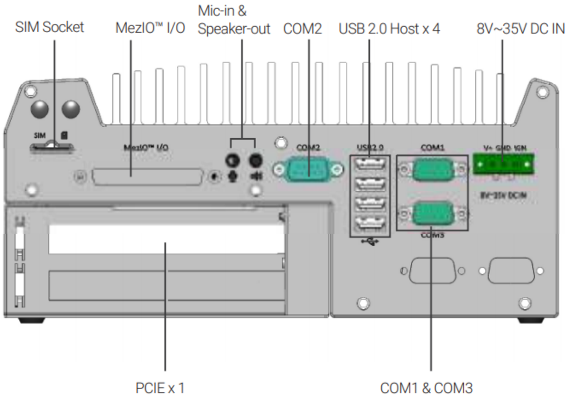
1.4 Automated Research Development Platform

All front and rear racks are made with 3 inch x 1.5 inch 15 series 80/20

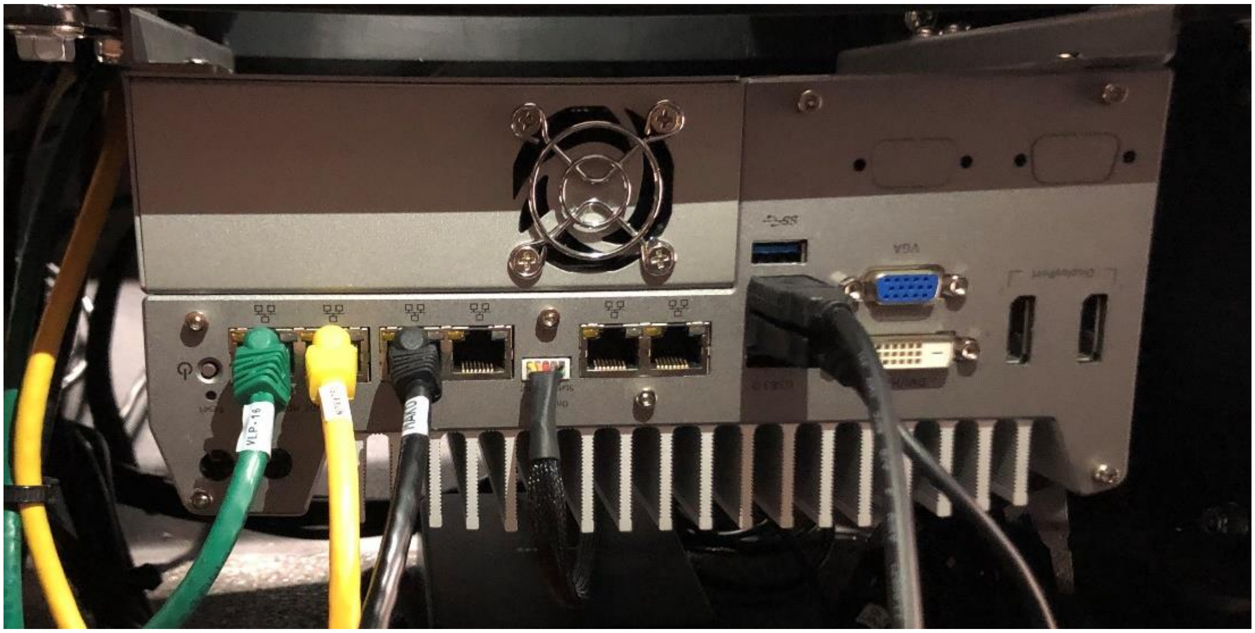


1.5 AStuff Nebula Station

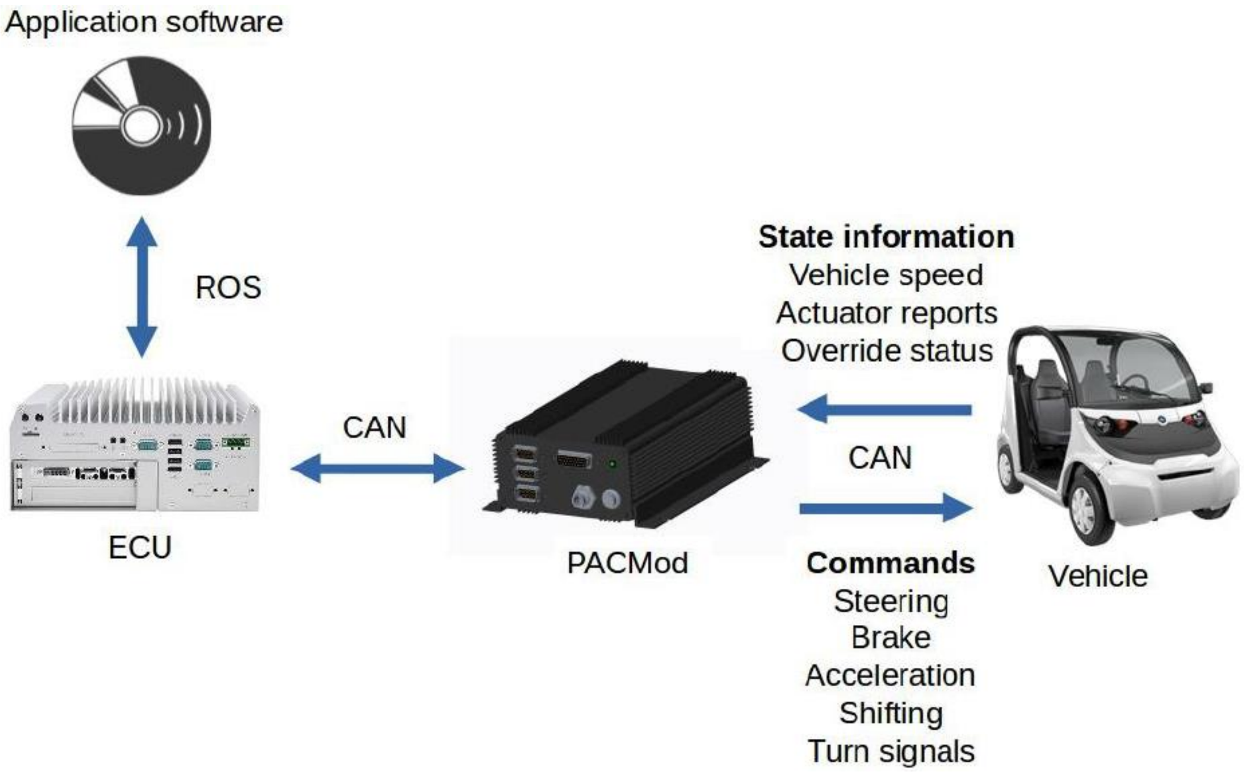




- Supports NVIDIA® GeForce® GTX 950 and GTX 1050 GPU
- 6th Generation Intel® Core™ i7-6700 quad-core processor 4.0 GHz max
- Six GigE ports, supporting 9.5 KB jumbo frame
- Comes standard with 16 GB RAM (32 GB max optional)
- 240 mm x 225 mm x 111 mm compact footprint
- MezIO™ 16-channel isolated digital I/O
- Preconfigured w/ Linux Ubuntu 16.04 LTS
- 128 GB, wide temperature range SSD w/ thermal sensor
- Accommodates two 2.5″ SATA HDD/SSD with RAID 0/1 support
- Patented thermal design of ventilation holes for the graphics card to allow -25 to 60°C wide temperature system operation



1.6 PACMod Vehicle Interface



PACMod Override

Steering

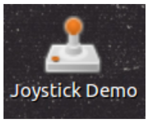
Brake / Throttle

1.7 Joystick Controller

Launching the Demo

There are two methods to launch the demonstration on a typical vehicle. First, an ECU configured by AutonomouStuff for use on a PACMod enabled vehicle will have a desktop icon named "Joystick Demo" for launching the demo graphically. Second, the launch through the terminal.

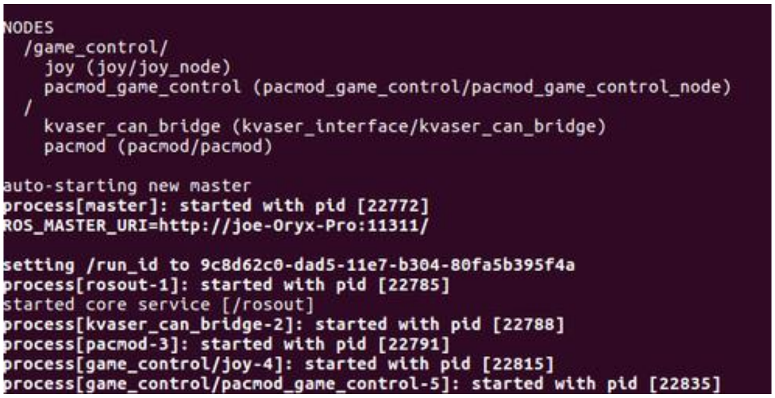
(1) On the Ubuntu Desktop, locate the icon shaped like a joystick with the name "Joystick Demo"



Set **LED OFF** using Mode button

Set **X mode** on the back of the controller

(2) Double click the icon and the demonstration will start

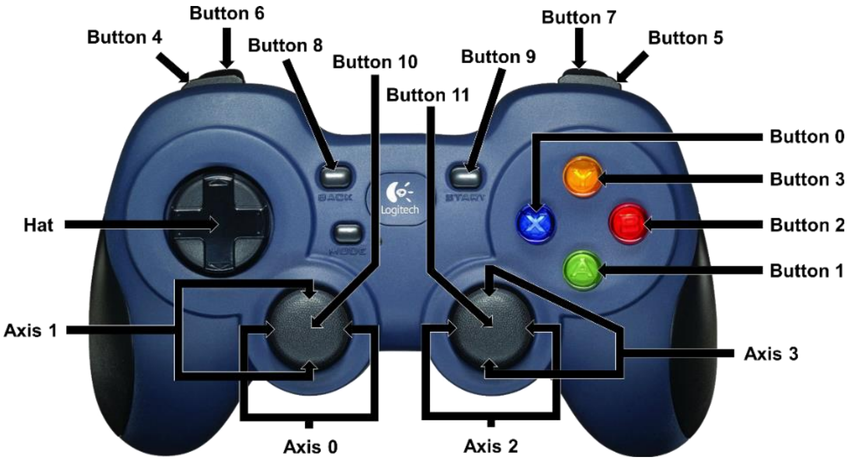


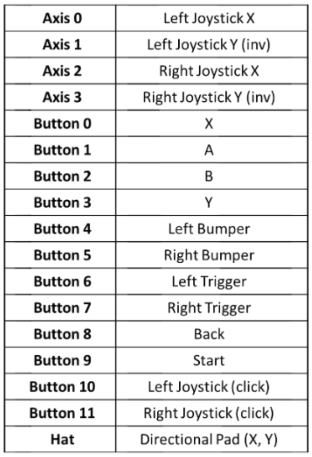
```
NODES
  /game_control/
    joy (joy/joy_node)
    pacmod_game_control (pacmod_game_control/pacmod_game_control_node)
  /
    kvaser_can_bridge (kvaser_interface/kvaser_can_bridge)
    pacmod (pacmod/pacmod)

auto-starting new master
process[master]: started with pid [22772]
ROS_MASTER_URI=http://joe-Oryx-Pro:11311/

setting /run_id to 9c8d62c0-dad5-11e7-b304-80fa5b395f4a
process[rosout-1]: started with pid [22785]
started core service [/rosout]
process[kvaser_can_bridge-2]: started with pid [22788]
process[pacmod-3]: started with pid [22791]
process[game_control/joy-4]: started with pid [22815]
process[game_control/pacmod_game_control-5]: started with pid [22835]
```

(3) At this point the demonstration has started and you can control the vehicle with the game controller





Axis 0	Left Joystick X
Axis 1	Left Joystick Y (inv)
Axis 2	Right Joystick X
Axis 3	Right Joystick Y (inv)
Button 0	X
Button 1	A
Button 2	B
Button 3	Y
Button 4	Left Bumper
Button 5	Right Bumper
Button 6	Left Trigger
Button 7	Right Trigger
Button 8	Back
Button 9	Start
Button 10	Left Joystick (click)
Button 11	Right Joystick (click)
Hat	Directional Pad (X, Y)

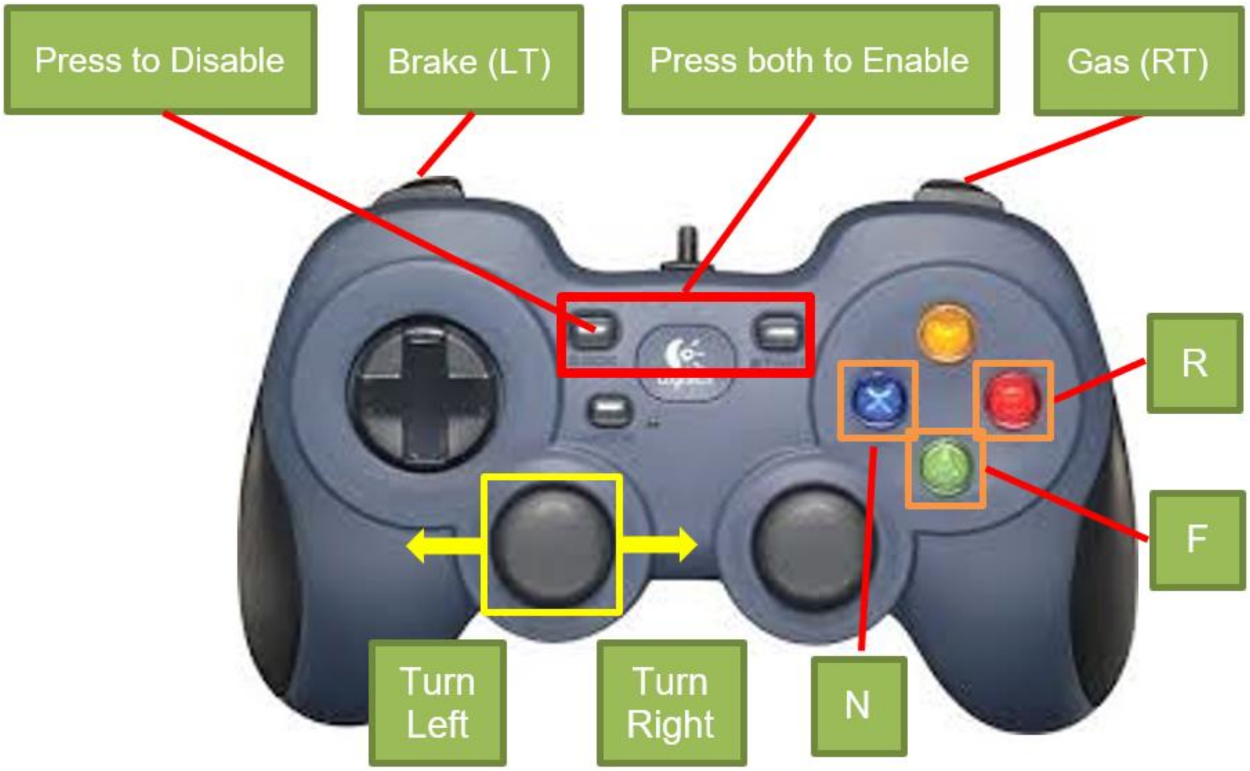
(4) **Joystick Demo**

basic_launch/launch/dbw_joystick.launch

$ **roslaunch basic_launch dbw_joystick.launch**

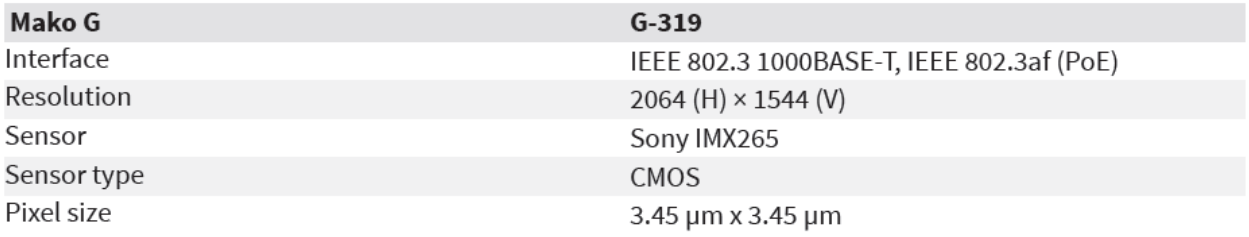
```
<launch>
  <include file="$(find pacmod_game_control)/launch/pacmod_game_control.launch">
    <arg name="launch_pacmod" value="false" />
    <arg name="is_pacmod_3" value="false" />
    <arg name="pacmod_vehicle_type" value="POLARIS_GEM" />
  </include>

  <include file="$(find platform_launch)/launch/$(env platform_name)/platform.launch">
    <arg name="use_dbw" value="true" />
  </include>
</launch>
```

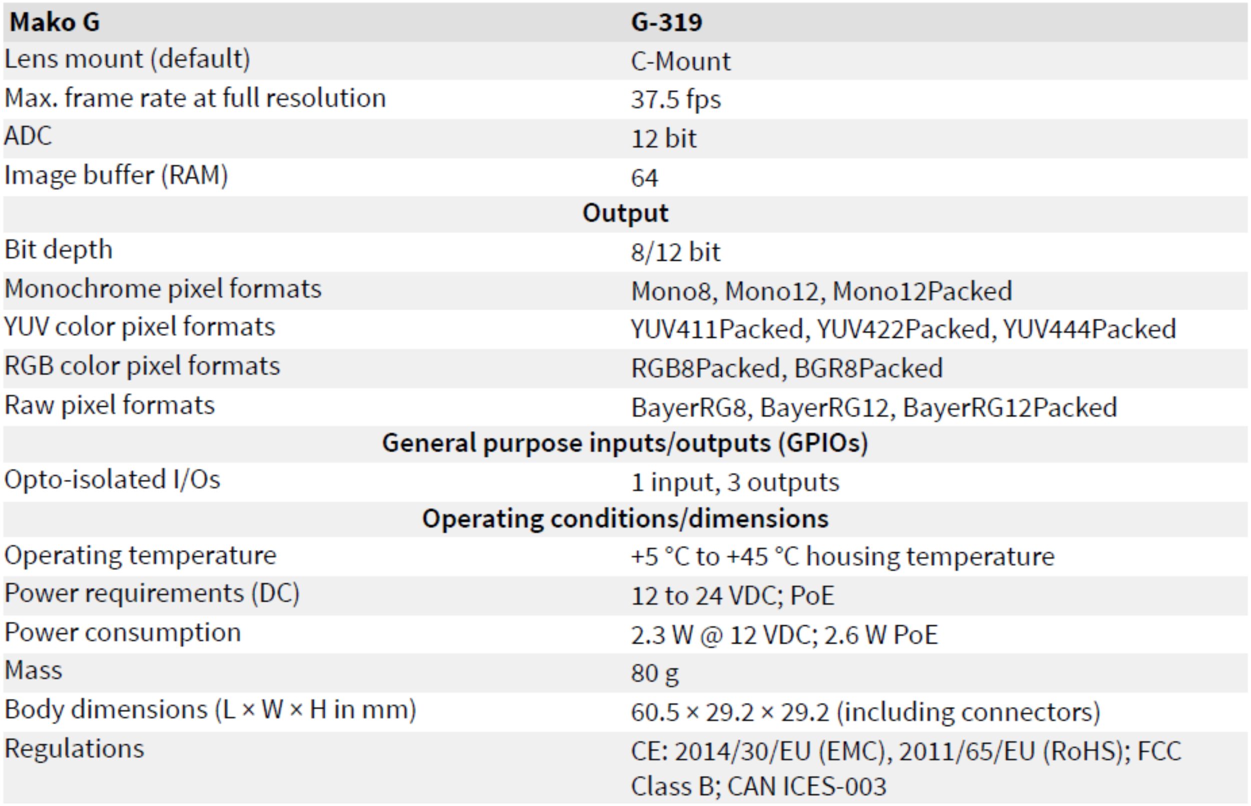


1.8 Mako G-319C Camera

- Sony IMX265 sensor
- Power over Ethernet
- Ultra-compact design
- Affordable



Mako G	G-319
Interface	IEEE 802.3 1000BASE-T, IEEE 802.3af (PoE)
Resolution	2064 (H) × 1544 (V)
Sensor	Sony IMX265
Sensor type	CMOS
Pixel size	3.45 µm x 3.45 µm



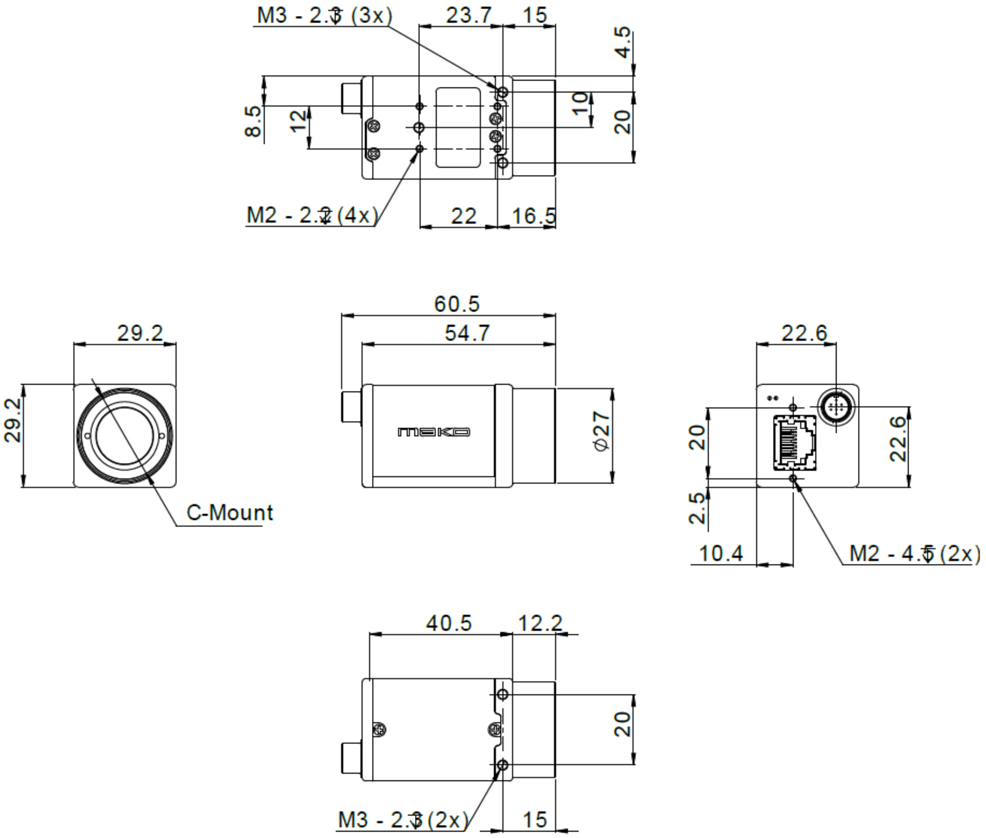
Mako G	G-319
Lens mount (default)	C-Mount
Max. frame rate at full resolution	37.5 fps
ADC	12 bit
Image buffer (RAM)	64
Output	
Bit depth	8/12 bit
Monochrome pixel formats	Mono8, Mono12, Mono12Packed
YUV color pixel formats	YUV411Packed, YUV422Packed, YUV444Packed
RGB color pixel formats	RGB8Packed, BGR8Packed
Raw pixel formats	BayerRG8, BayerRG12, BayerRG12Packed
General purpose inputs/outputs (GPIOs)	
Opto-isolated I/Os	1 input, 3 outputs
Operating conditions/dimensions	
Operating temperature	+5 °C to +45 °C housing temperature
Power requirements (DC)	12 to 24 VDC; PoE
Power consumption	2.3 W @ 12 VDC; 2.6 W PoE
Mass	80 g
Body dimensions (L × W × H in mm)	60.5 × 29.2 × 29.2 (including connectors)
Regulations	CE: 2014/30/EU (EMC), 2011/65/EU (RoHS); FCC Class B; CAN ICES-003

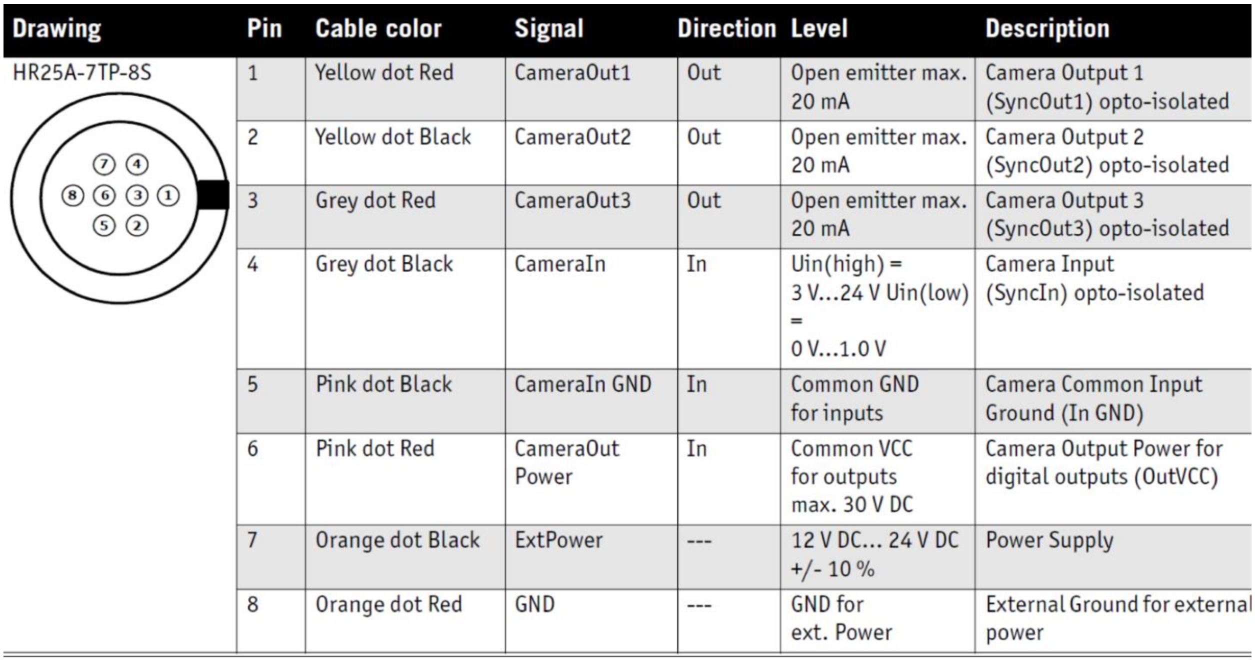
Image optimization features:

- Auto gain (manual gain control: 0 to 40 dB; 0.1 dB increments)
- Auto exposure (exposure time control varies by pixel format)
- Auto white balance (G-319C only)
- Binning
- Color correction, hue, saturation (G-319C only)
- Decimation
- Gamma correction
- One look-up table (LUT)
- Region of interest (ROI), separate ROI for auto features

Camera control features:

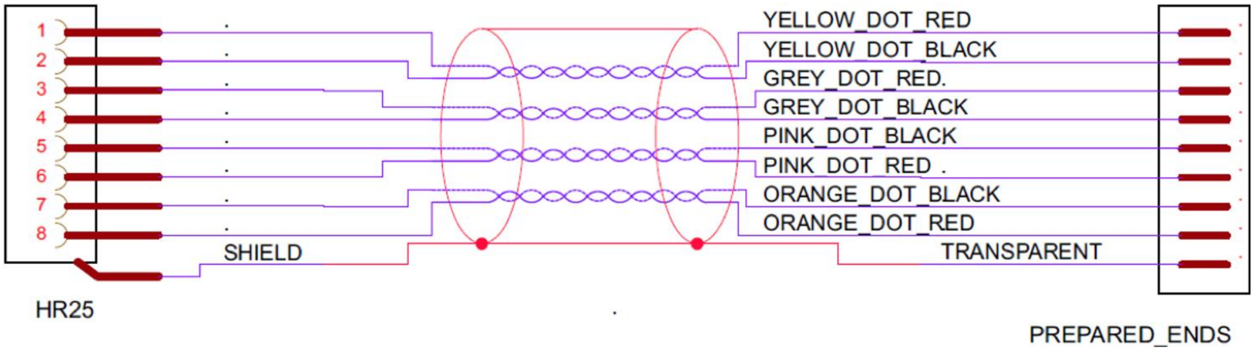
- Event channel
- Image chunk data
- Global shutter mode
- Storable user sets
- StreamBytesPerSecond (bandwidth control)
- Stream hold
- Sync out modes: Trigger ready, input, exposing, readout, imaging, strobe, GPO
- Temperature monitoring (main board only)





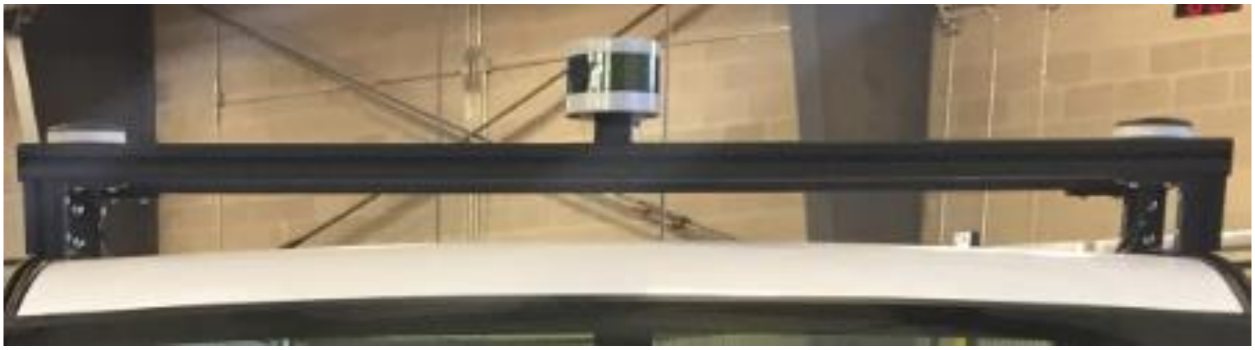
Drawing	Pin	Cable color	Signal	Direction	Level	Description
HR25A-7TP-8S	1	Yellow dot Red	CameraOut1	Out	Open emitter max. 20 mA	Camera Output 1 (SyncOut1) opto-isolated
	2	Yellow dot Black	CameraOut2	Out	Open emitter max. 20 mA	Camera Output 2 (SyncOut2) opto-isolated
	3	Grey dot Red	CameraOut3	Out	Open emitter max. 20 mA	Camera Output 3 (SyncOut3) opto-isolated
	4	Grey dot Black	CameraIn	In	Uin(high) = 3 V…24 V Uin(low) = 0 V…1.0 V	Camera Input (SyncIn) opto-isolated
	5	Pink dot Black	CameraIn GND	In	Common GND for inputs	Camera Common Input Ground (In GND)
	6	Pink dot Red	CameraOut Power	In	Common VCC for outputs max. 30 V DC	Camera Output Power for digital outputs (OutVCC)
	7	Orange dot Black	ExtPower	---	12 V DC… 24 V DC +/- 10 %	Power Supply
	8	Orange dot Red	GND	---	GND for ext. Power	External Ground for external power

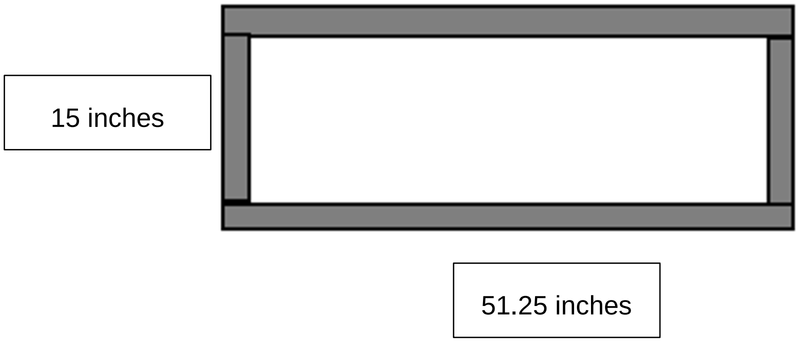
Table 5: Mako-GI/O definition



1.9 Velodyne VLP-16 LiDAR

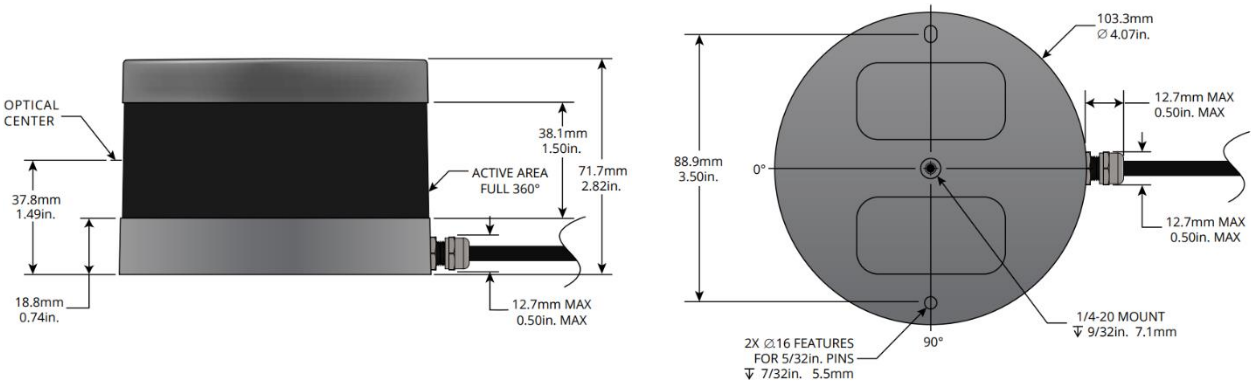
Roof Rack

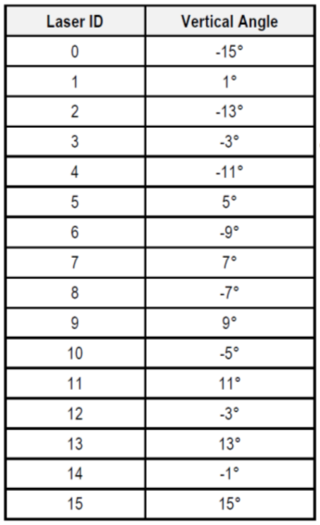




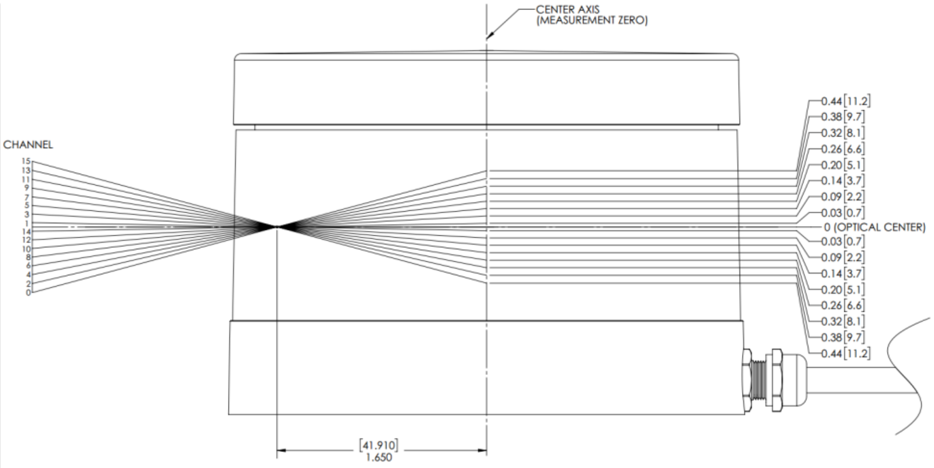
All roof racks are made with 1.5 by 1.5 inches 15 series 80/20

Dimensions

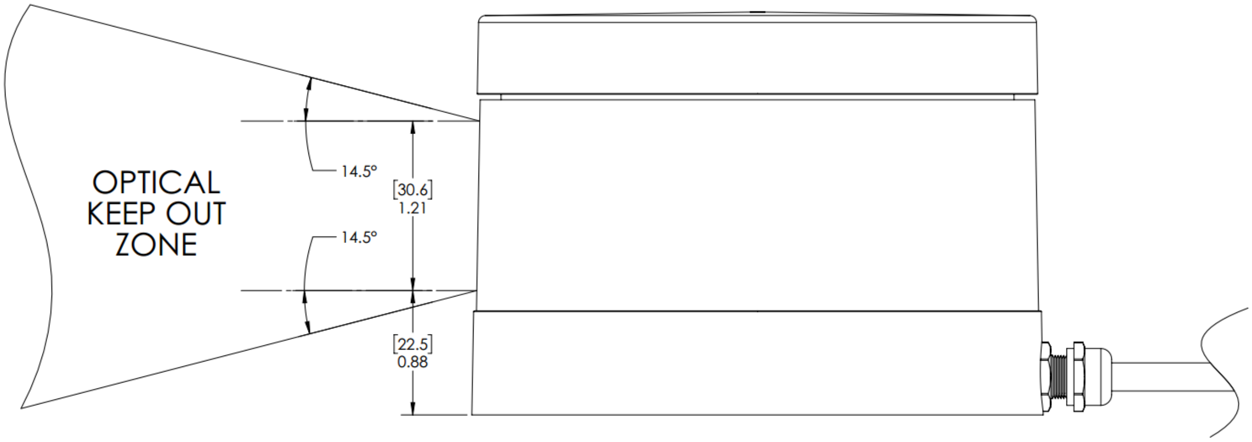




Laser ID	Vertical Angle
0	-15°
1	1°
2	-13°
3	-3°
4	-11°
5	5°
6	-9°
7	7°
8	-7°
9	9°
10	-5°
11	11°
12	-3°
13	13°
14	-1°
15	15°



APPROXIMATE BEAM CENTERS
DOES NOT REPRESENT BEAM WIDTHS
BEAMS ARE APPROXIMATELY 0.75 TALL AT FOCAL POINT
BEAM DIVERGENCE IS APPROXIMATELY 3 MILLIRADIANS HORIZONTALLY AND 1.5 MILLIRADIANS VERTICALLY
APPLY VERTICAL CORRECTION FOR GREATEST ACCURACY



Sensor

- 16 Channels
- Measurement Range: 100 m – 120 m
- Range Accuracy: Up to ±3 cm (Typical)1
- Field of View (Vertical): +15.0° to -15.0° (30°)
- Angular Resolution (Vertical): 2.0°
- Field of View (Horizontal): 360°
- Angular Resolution (Horizontal/Azimuth): 0.1° – 0.4°
- Rotation Rate: 5 Hz – 20 Hz
- Integrated Web Server for Easy Monitoring and Configuration

Mechanical / Electrical / Operational

- Power Consumption: 8 W (Typical)2
- Operating Voltage: 9 V – 18 V (with Interface Box and Regulated Power Supply)
- Weight: ~590 g (without Cabling and Interface Box)
- Dimensions: See diagram on previous page
- Environmental Protection: IP67
- Operating Temperature: -10°C to +60°C3
- Storage Temperature: -40°C to +105°C

Outputs

- 3D LiDAR Data Points Generated:

  Single Return Mode: ~300,000 points per second

  Dual Return Mode: ~600,000 points per second
- 100 Mbps Ethernet Connection
- UDP Packets Contain:

  Time of Flight Distance Measurement

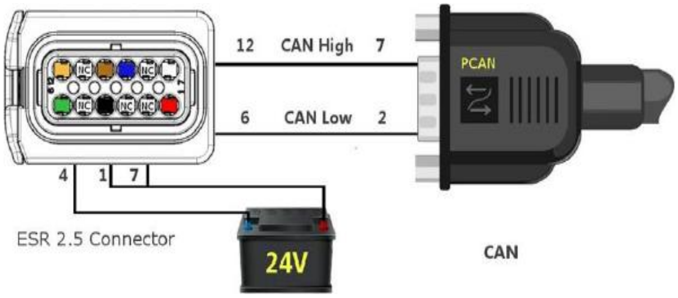
  Calibrated Reflectivity Measurement

  Rotation Angles

  Synchronized Time Stamps (µs resolution)
- GPS: $GPRMC and $GPGGA NMEA Sentences from GPS Receiver (GPS not included)

1.10 Delphi ESR 2.5 Radar (24V)

CAN / USB Connection Wiring



Pin #	Signal	Color
1	Battery (+24V)	Red
2	USB D+ (green wire)	Green (USB)
3	USB D- (white wire)	White (USB)
4	Ground	Black
5	USB Ground (black wire)	Black (USB)
6	PRVCANL	Green
7	Ignition (+24V)	White
8	USB +5V (red wire)	Red (USB)
9	VEHCANL	Blue
10	VEHCANH	Brown
11	VEHCAN Shield	▨
12	PRVCANH	Orange

USB-to-CAN (Kvaser Hybrid 2xCAN/LIN)

1.11 ProPak 6 & SPAN-IGM-S1

ProPak-6D1

Dual Antenna Support

Cellular

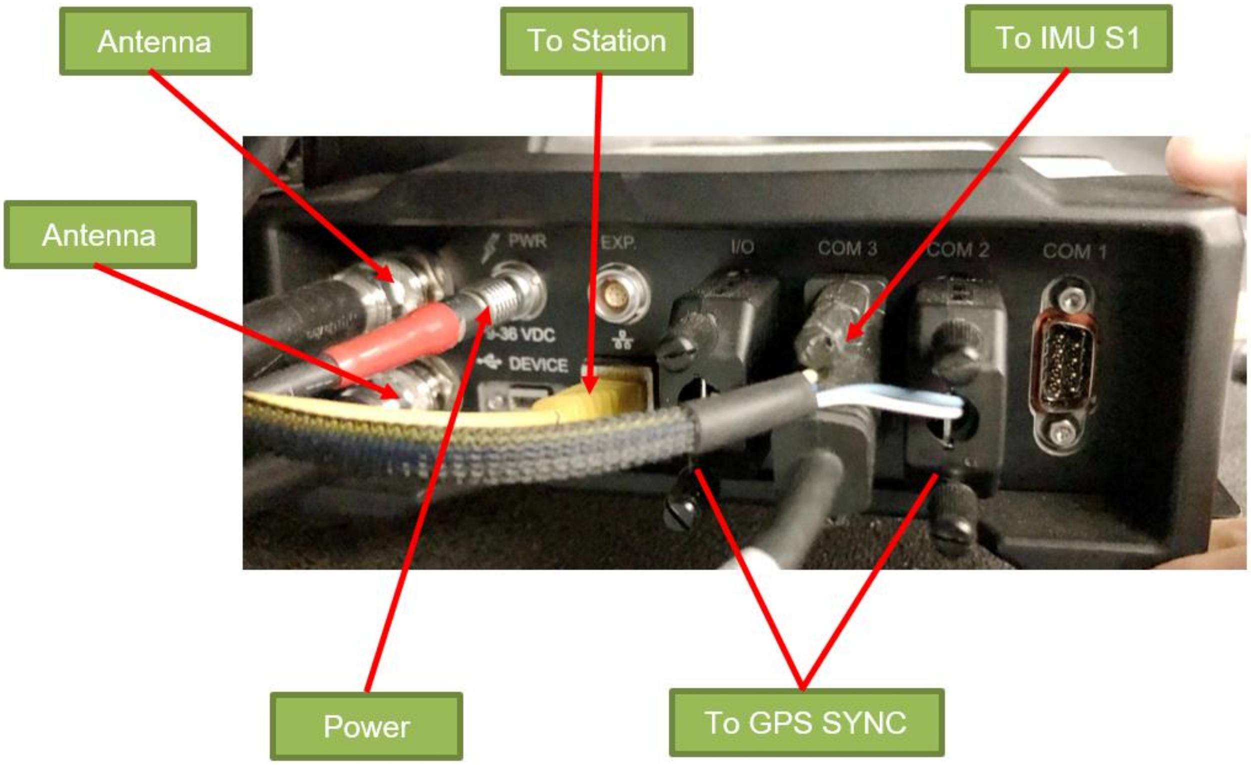
L1/L2 GPS+GLONASS

L-Band TerraStar-C PPP Corrections

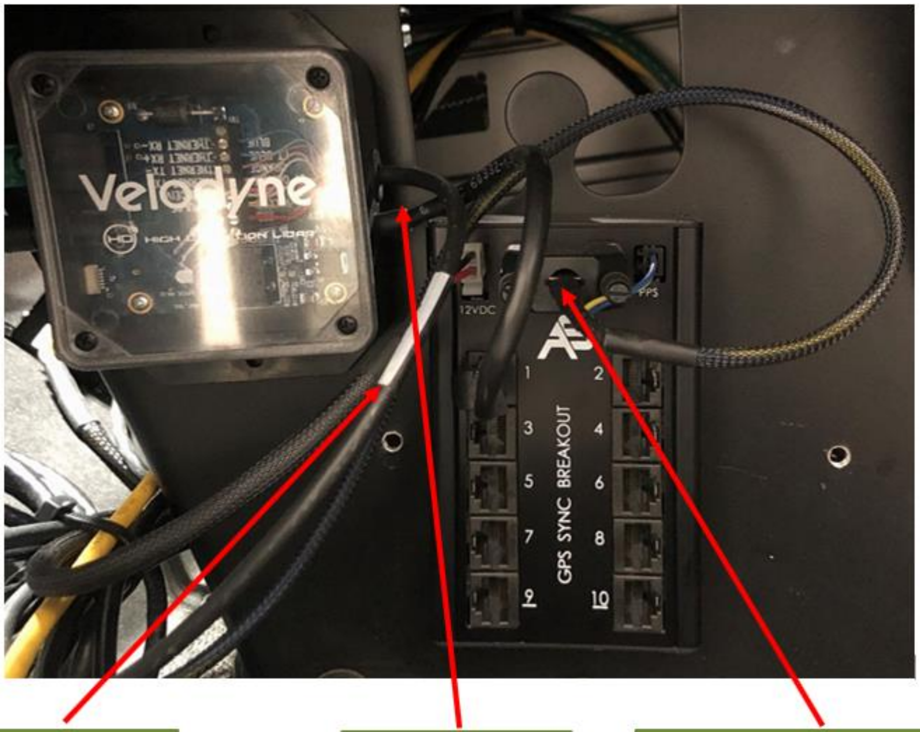
-3 Grade IMUs

20 Hz Positions and Measurements

4GB Internal Memory



Connector Type	Connector Label	Description
GNSS Antenna External Oscillator	ANT 1 ANT 2 or ANT1 OSC	GNSS GPS1 and GPS2 antennas (TNC) (model dependant) or GNSS GPS1 antenna (TNC) and external oscillator (BNC) (model dependant)
Power	PWR	4-pin LEMO power connector
Expansion	EXP.	9-pin LEMO expansion port for CAN1 and CAN2
USB	DEVICE	USB Device (Type micro B) connector (high speed only) 480 Mbps
Ethernet		Ethernet RJ45 connector
I/O	I/O	4 Event Input/3 Event Output (DB9 female connector) I/O port is configurable
Serial Communication Ports	COM1 COM2 COM3/IMU	COM1, COM2, COM3/IMU DB9 male communications port RS-232 (RS-422 selectable via software)



VLP-16

To GPS SYNC

ProPak-6D - I/O & COM2

SPAN-IGM-S1

200Hz/125 Hz Inertial Measurements

Direct Wheel Sensor Support

Commercially Exportable

Small and lightweight design

G5Ant-3AMT4

Matte black finish without branding

Various mounting options and connectors

Size: 89 mm dia. x 25 mm hgt

Weight: 368 g

2. Polaris GEM e2 ROS Software

2.1 Software Setup

Setup .bashrc

```
export PLM_LICENSE=~/licenses
export platform_name=white_e2

source /opt/ros/kinetic/setup.bash
source /home/dev/standard_ws/devel/setup.bash --extend
```

Setup AutonomouStuff drivers

```
$ sudo apt update && sudo apt install apt-transport-https
```

```
$ sudo sh -c 'echo "deb [trusted=yes] https://s3.amazonaws.com/autonomoustuff-repo/
$(lsb_release -sc) main" > /etc/apt/sources.list.d/autonomoustuff-public.list'
```

Install Kvaser linuxcan SDK:

https://autonomoustuff.atlassian.net/wiki/spaces/RW/pages/17475947/Driver+Pack+Installation+or+Upgrade+Instructions

https://www.kvaser.com/download/

```
$ sudo apt install ros-$ROS_DISTRO-kvaser-interface ros-$ROS_DISTRO-delphi-esr ros-
$ROS_DISTRO-delphi-srr ros-$ROS_DISTRO-kartech-linear-actuator ros-$ROS_DISTRO-
mobileye-560-660 ros-$ROS_DISTRO-neobotix-usboard ros-$ROS_DISTRO-ibeo-lux ros-
$ROS_DISTRO-astuff-sensor-msgs ros-$ROS_DISTRO-pacmod ros-$ROS_DISTRO-pacmod3
ros-$ROS_DISTRO-pacmod-game-control
```

```
$ sudo apt install ros-$ROS_DISTRO-wfov-camera-msgs ros-$ROS_DISTRO-web-video-server
ros-$ROS_DISTRO-automotive-navigation-msgs ros-$ROS_DISTRO-automotive-platform-
msgs ros-$ROS_DISTRO-tf2-web-republisher ros-$ROS_DISTRO-unique-id ros-
$ROS_DISTRO-rosbridge-library ros-$ROS_DISTRO-rosbridge-server ros-$ROS_DISTRO-
statistics-msgs ros-$ROS_DISTRO-geodesy ros-$ROS_DISTRO-image-exposure-msgs ros-
$ROS_DISTRO-marti-nav-msgs ros-$ROS_DISTRO-marti-sensor-msgs ros-$ROS_DISTRO-
novatel-msgs ros-$ROS_DISTRO-novatel-span-driver ros-$ROS_DISTRO-swri-* ros-
$ROS_DISTRO-qt-build
```

Extra Software

```
$ sudo apt install solaar
$ sudo apt install preload
$ sudo apt install meld
$ sudo apt-get install indicator-multiload
```

2.2 Frame Setup

platform_launch/launch/white_e2/platform.launch

platform_launch/launch/core/all_supported_drivers.launch

veh_frame (default=base_link)

front_radar_frame (default=front_radar)

lidar1_frame (default=lidar1)

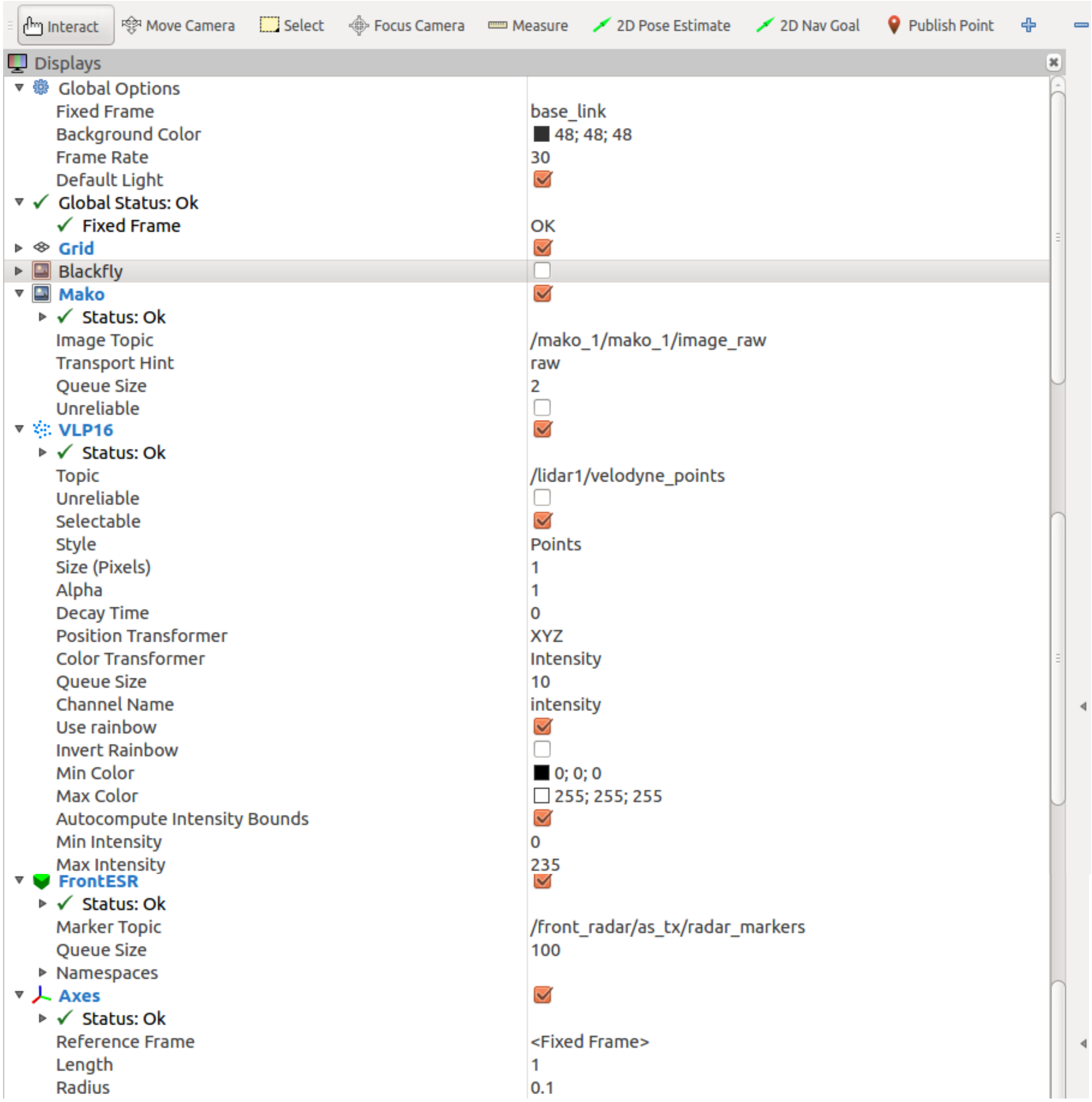
novatel_frame (default=novatel)

novatel_imu_frame (default=imu)

mako_1_frame (default="")

Usage: static_transform_publisher x y z yaw pitch roll frame_id child_frame_id period (milliseconds)

2.3 AStuff Nebula Station (Rviz)



Global Options	
Fixed Frame	base_link
Background Color	■ 48; 48; 48
Frame Rate	30
Default Light	☑
✓ Global Status: Ok	
✓ Fixed Frame	OK
Grid	☑
Blackfly	□
Mako	☑
✓ Status: Ok	
Image Topic	/mako_1/mako_1/image_raw
Transport Hint	raw
Queue Size	2
Unreliable	□
VLP16	☑
✓ Status: Ok	
Topic	/lidar1/velodyne_points
Unreliable	□
Selectable	☑
Style	Points
Size (Pixels)	1
Alpha	1
Decay Time	0
Position Transformer	XYZ
Color Transformer	Intensity
Queue Size	10
Channel Name	intensity
Use rainbow	☑
Invert Rainbow	□
Min Color	■ 0; 0; 0
Max Color	□ 255; 255; 255
Autocompute Intensity Bounds	☑
Min Intensity	0
Max Intensity	235
FrontESR	☑
✓ Status: Ok	
Marker Topic	/front_radar/as_tx/radar_markers
Queue Size	100
Namespaces	
Axes	☑
✓ Status: Ok	
Reference Frame	<Fixed Frame>
Length	1
Radius	0.1

2.4 PACMod Software Vehicle Interface

ROS wiki: http://wiki.ros.org/pacmod

Source: https://github.com/astuff/pacmod.git (branch: release)

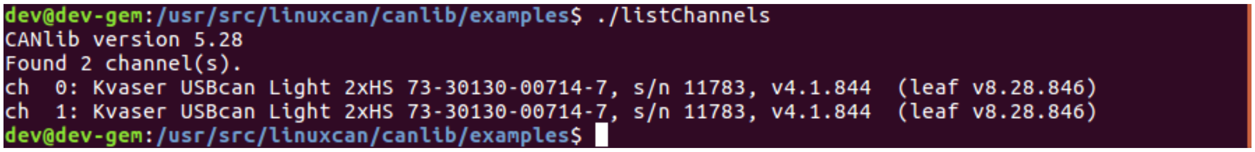
Supported Hardware

- Polaris GEM Series (e2/e4/e6/eLXD)
- Polaris Ranger X900
- International Prostar+ 122
- Lexus RX-450h

can_msgs/Frame.msg

Header header
uint32 id
bool is_rtr
bool is_extended
bool is_error
uint8 dlc
uint8[8] data

CAN Device List



```
dev@dev-gem:/usr/src/linuxcan/canlib/examples$ ./listChannels
CANlib version 5.28
Found 2 channel(s).
ch  0: Kvaser USBcan Light 2xHS 73-30130-00714-7, s/n 11783, v4.1.844  (leaf v8.28.846)
ch  1: Kvaser USBcan Light 2xHS 73-30130-00714-7, s/n 11783, v4.1.844  (leaf v8.28.846)
dev@dev-gem:/usr/src/linuxcan/canlib/examples$
```

Published Topics

Topic	Message Type	Description
can_rx	can_msgs/Frame	All data published on this topic is intended to be sent to the PACMod system via a CAN interface.
parsed_tx/global_rpt	pacmod_msgs/GlobalRpt	High-level data about the entire PACMod system.
parsed_tx/accel_rpt	pacmod_msgs/SystemRptFloat	Status and parsed values [pct] of the throttle subsystem.
parsed_tx/brake_rpt	pacmod_msgs/SystemRptFloat	Status and parsed values [pct] of the steering susbsystem.
parsed_tx/steer_rpt	pacmod_msgs/SystemRptFloat	Status and parsed values [rad] of the steering susbsystem.
parsed_tx/turn_rpt	pacmod_msgs/SystemRptInt	Status and parsed values [enum] of the turn signal subsystem.
parsed_tx/shift_rpt	pacmod_msgs/SystemRptInt	Status and parsed values [enum] of the gear/transmission subsystem.
parsed_tx/vehicle_speed_rpt	pacmod_msgs/VehicleSpeedRpt	The vehicle's current speed [mph], the validity of the speed message [bool], and the raw CAN message from the vehicle CAN.
parsed_tx/vin_rpt	pacmod_msgs/VinRpt	The configured vehicle's VIN, make, model, manufacturer, and model year.
as_tx/vehicle_speed	std_msgs/Float64	The vehicle's current speed [m/s].
as_tx/enable	std_msgs/Bool	The current status of the PACMod's control of the vehicle. If the PACMod is enabled, this value will be true. If it is disabled or overridden, this value will be false.

Subscribed Topics

Topic	Message Type	Description
can_tx	can_msgs/Frame	All data published to this topic will be parsed by the PACMod driver. This should be connected to a CAN interface.
as_rx/accel_cmd	pacmod_msgs/PacmodCmd	Commands the throttle subsystem to seek a specific pedal position [pct - 0.0 to 1.0].
as_rx/brake_cmd	pacmod_msgs/PacmodCmd	Commands the brake subsystem to seek a specific pedal position [pct - 0.0 to 1.0].
as_rx/shift_cmd	pacmod_msgs/PacmodCmd	Commands the gear/transmission subsystem to shift to a different gear [enum].
as_rx/turn_cmd	pacmod_msgs/PacmodCmd	Commands the turn signal subsystem to transition to a given state [enum].
as_rx/steer_cmd	pacmod_msgs/PositionWIthSpeed	Commands the steering subsystem to seek a specific steering wheel angle [rad] at a given rotation velocity [rad/s].
as_rx/enable	std_msgs/Bool	Enables [true] or disables [false] PACMod's control of the vehicle.

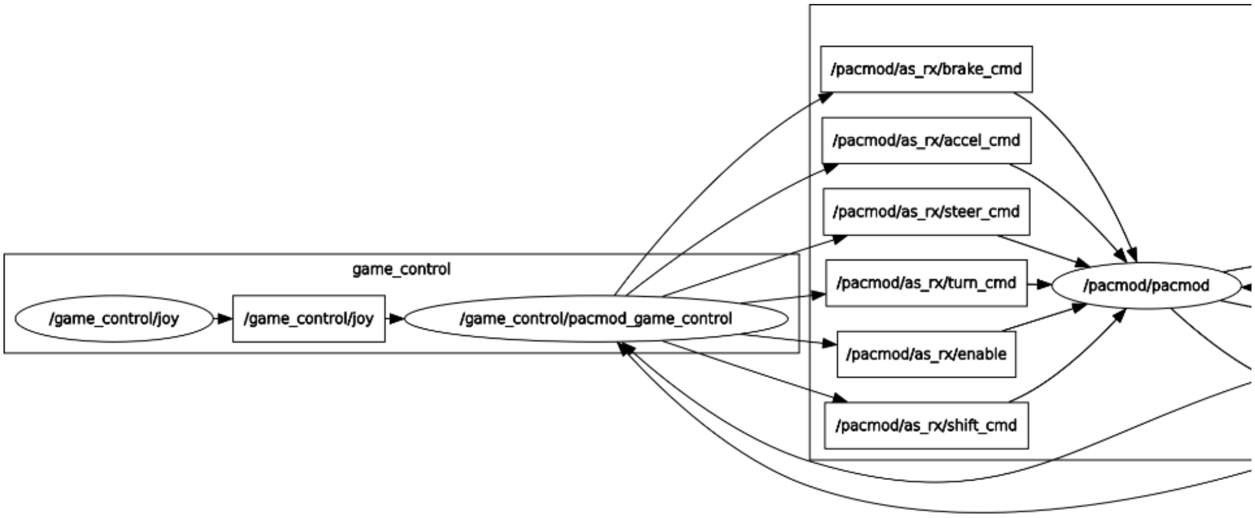
Parameters

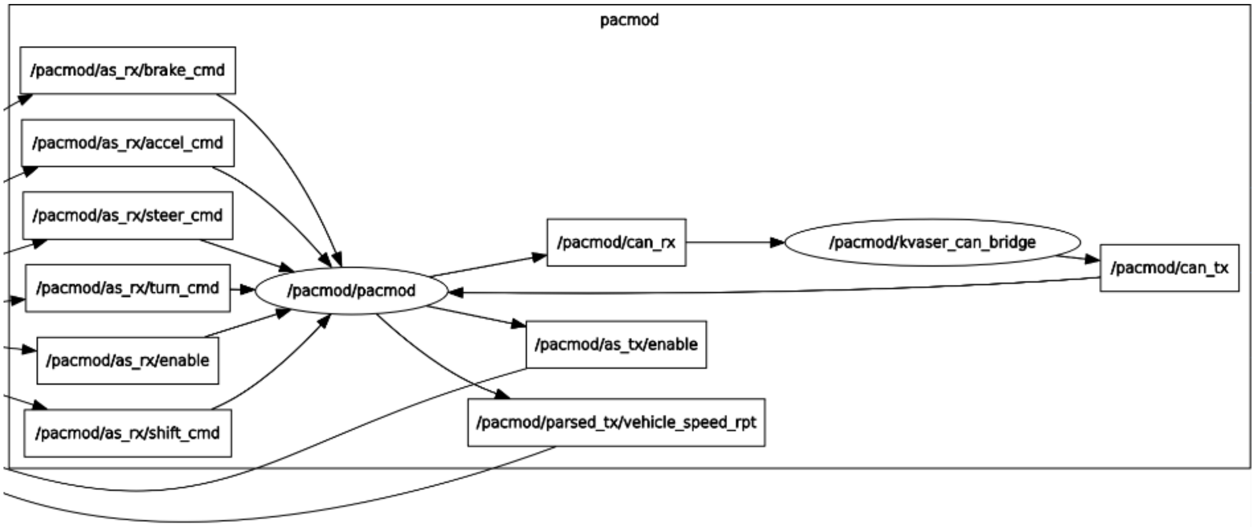
~vehicle_type: a string value indicating the type of vehicle to which the PACMod is connected.

Valid values are:

- POLARIS_GEM
- POLARIS_RANGER
- INTERNATIONAL_PROSTAR_122
- LEXUS_RX_450H

PACMod Graph





/pacmod/as_rx/accel_cmd

/pacmod/as_rx/brake_cmd

/pacmod/as_rx/enable

/pacmod/as_rx/shift_cmd

/pacmod/as_rx/steer_cmd

/pacmod/as_rx/turn_cmd

2.5 Joystick Controller

ROS wiki: http://wiki.ros.org/pacmod_game_control

Source: https://github.com/astuff/pacmod_game_control.git (branch: release)

ROS wiki: http://wiki.ros.org/joy

Source: https://github.com/ros-drivers/joystick_drivers.git (branch: master)

Parameters

~steering_stick: sets whether the steering command should be controlled by the left or right joystick on a two-stick controller. Valid values are LEFT or RIGHT.

~pacmod_vehicle_type: sets the type of vehicle which is being controlled. This manages vehicle-specific values like the available features and maximum steering angle. Valid values are:

- POLARIS_GEM
- POLARIS_RANGER
- LEXUS_RX_450H
- INTERNATIONAL_PROSTAR_122
- VEHICLE_4
- VEHICLE_5
- VEHICLE_6

~controller_type: sets type of controller being used and associated button mappings. Valid values are:

- LOGITECH_F310
- HRI_SAFE_REMOTE
- LOGITECH_G29
- NINTENDO_SWITCH_WIRED_PLUS
- XBOX_ONE

~steering_max_speed: the maximum rotational speed for the steering wheel in rad/s.

~max_veh_speed: the vehicle speed is used to scale the rotation rate of the steering wheel. This value is the speed, in m/s, at which the most restriction is placed on rotation rate. This helps controllability as speed increases.

~accel_scale_val: a scaling value (0.0 - 1.0) for the accelerator. 1.0 = full throttle range. 0.0 = no throttle control.

~brake_scale_val: a scaling value (0.0 - 1.0) for the brake. 1.0 = full braking range. 0.0 = no brake control.

2.6 ROS Topics of Polaris GEM e2

To get the message definition:

$ **rostopic type </rostopic_name>**

Joystick:

/game_control/joy
/game_control/joy/set_feedback

Front RADAR:

/front_radar/as_rx/vehicle_motion
/front_radar/as_tx/objects
/front_radar/as_tx/radar_error_status
/front_radar/as_tx/radar_markers
/front_radar/as_tx/radar_markers_array
/front_radar/as_tx/radar_status
/front_radar/as_tx/radar_tracks
/front_radar/can_rx
/front_radar/can_tx
/front_radar/parsed_rx/vehicle1_msgs
/front_radar/parsed_rx/vehicle2_msgs
/front_radar/parsed_rx/vehicle3_msgs
/front_radar/parsed_rx/vehicle4_msgs
/front_radar/parsed_rx/vehicle5_msgs
/front_radar/parsed_tx/radarstatus1
/front_radar/parsed_tx/radarstatus2
/front_radar/parsed_tx/radarstatus3
/front_radar/parsed_tx/radarstatus4
/front_radar/parsed_tx/radarstatus5
/front_radar/parsed_tx/radarstatus6
/front_radar/parsed_tx/radarstatus7
/front_radar/parsed_tx/radarstatus8
/front_radar/parsed_tx/radarstatus9
/front_radar/parsed_tx/radartrack
/front_radar/parsed_tx/radarvalid1
/front_radar/parsed_tx/radarvalid2
/front_radar/parsed_tx/trackmotionpower

LiDAR:

/lidar1/lidar1_nodelet_manager/bond
/lidar1/lidar1_nodelet_manager_cloud/parameter_descriptions
/lidar1/lidar1_nodelet_manager_cloud/parameter_updates
/lidar1/lidar1_nodelet_manager_driver/parameter_descriptions
/lidar1/lidar1_nodelet_manager_driver/parameter_updates
/lidar1/lidar1_nodelet_manager_laserscan/parameter_descriptions
/lidar1/lidar1_nodelet_manager_laserscan/parameter_updates
/lidar1/scan
/lidar1/velodyne_packets
/lidar1/velodyne_points

Front Camera:

/mako_1/mako_1/camera_info
/mako_1/mako_1/image_raw
/mako_1/mako_1/image_raw/compressed
/mako_1/mako_1/image_raw/compressed/parameter_descriptions
/mako_1/mako_1/image_raw/compressed/parameter_updates
/mako_1/mako_1/image_raw/compressedDepth
/mako_1/mako_1/image_raw/compressedDepth/parameter_descriptions
/mako_1/mako_1/image_raw/compressedDepth/parameter_updates
/mako_1/mako_1/image_raw/theora
/mako_1/mako_1/image_raw/theora/parameter_descriptions
/mako_1/mako_1/image_raw/theora/parameter_updates
/mako_1/mako_1/parameter_descriptions
/mako_1/mako_1/parameter_updates

GNSS & INS:

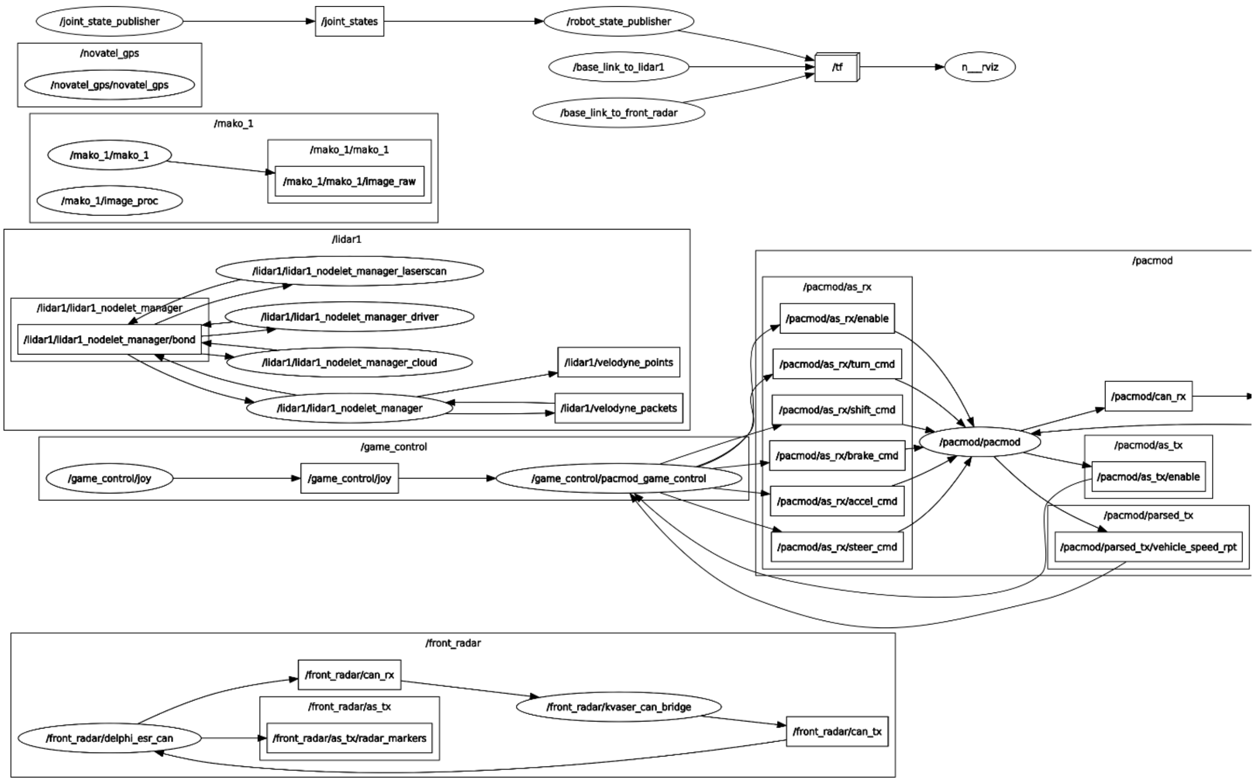
/novatel_gps/bestpos
/novatel_gps/corrimudata
/novatel_gps/fix
/novatel_gps/gpgga
/novatel_gps/gprmc
/novatel_gps/gps
/novatel_gps/gps_sync
/novatel_gps/imu
/novatel_gps/inscov
/novatel_gps/inspva

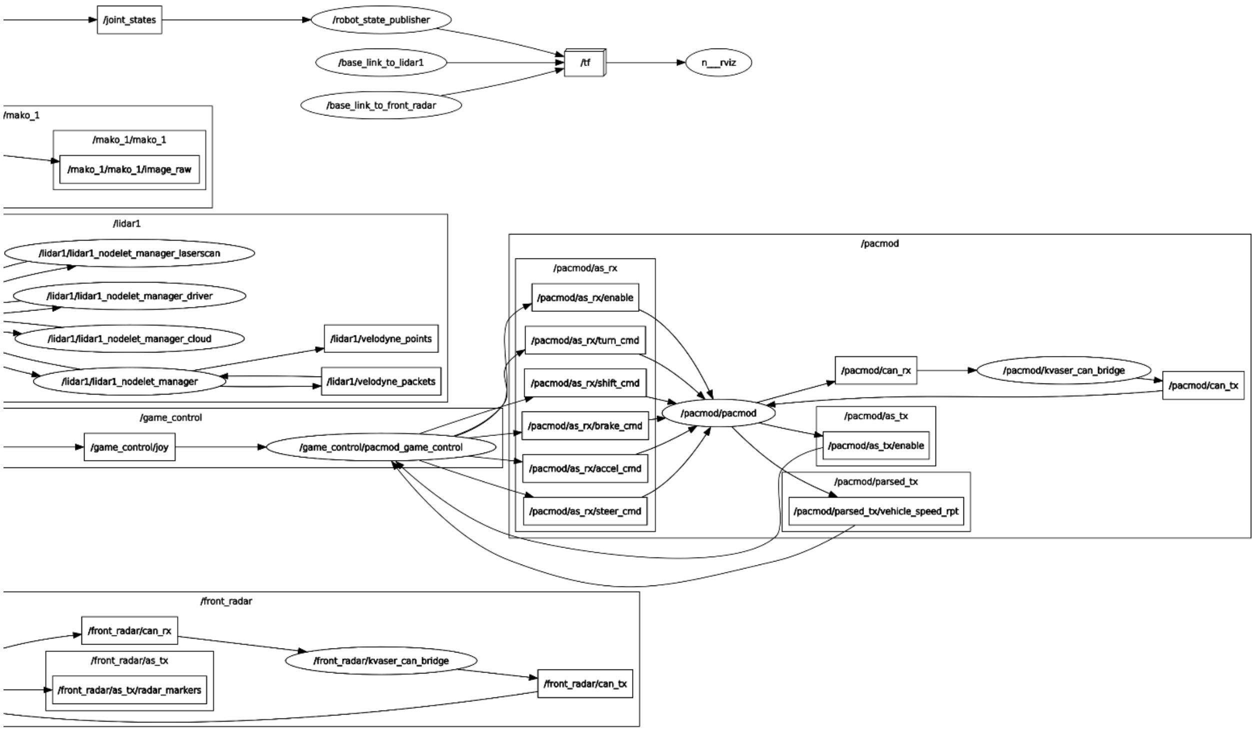
/novatel_gps/inspvax
/novatel_gps/insstdev

PACMOD:

/pacmod/as_rx/accel_cmd
/pacmod/as_rx/brake_cmd
/pacmod/as_rx/enable
/pacmod/as_rx/shift_cmd
/pacmod/as_rx/steer_cmd
/pacmod/as_rx/headlight_cmd
/pacmod/as_rx/horn_cmd
/pacmod/as_rx/turn_cmd
/pacmod/as_rx/wiper_cmd
/pacmod/as_tx/enable
/pacmod/as_tx/vehicle_speed
/pacmod/can_rx
/pacmod/can_tx
/pacmod/parsed_tx/accel_rpt
/pacmod/parsed_tx/brake_rpt
/pacmod/parsed_tx/brake_rpt_detail_1
/pacmod/parsed_tx/brake_rpt_detail_2
/pacmod/parsed_tx/brake_rpt_detail_3
/pacmod/parsed_tx/global_rpt
/pacmod/parsed_tx/shift_rpt
/pacmod/parsed_tx/steer_rpt
/pacmod/parsed_tx/steer_rpt_detail_1
/pacmod/parsed_tx/steer_rpt_detail_2
/pacmod/parsed_tx/steer_rpt_detail_3
/pacmod/parsed_tx/turn_rpt
/pacmod/parsed_tx/vehicle_speed_rpt
/pacmod/parsed_tx/vin_rpt

ROS rqt_graph



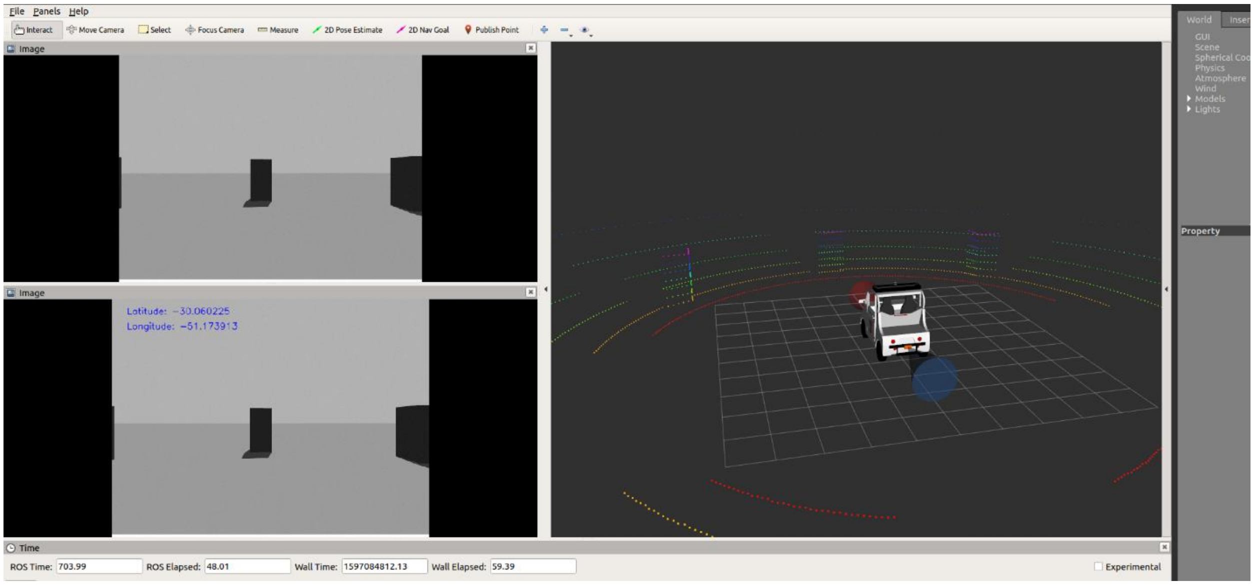


2.7 Coming more

3. Polaris GEM e2 ROS Simulator

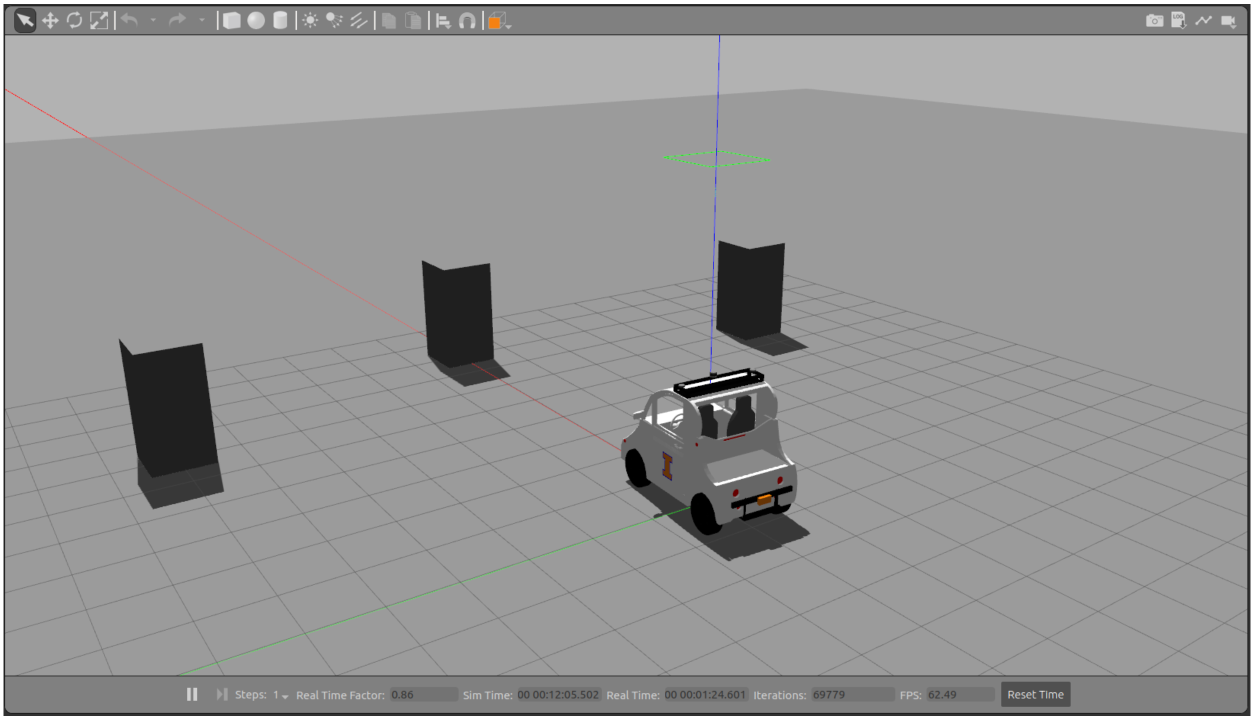
3.1 Launch the Simulator

```
$ cd ~/gem_ws
$ source devel/setup.bash
$ roslaunch gem_gazebo gem_vehicle.launch
```



Latitude: -30.060225
Longitude: -51.173913

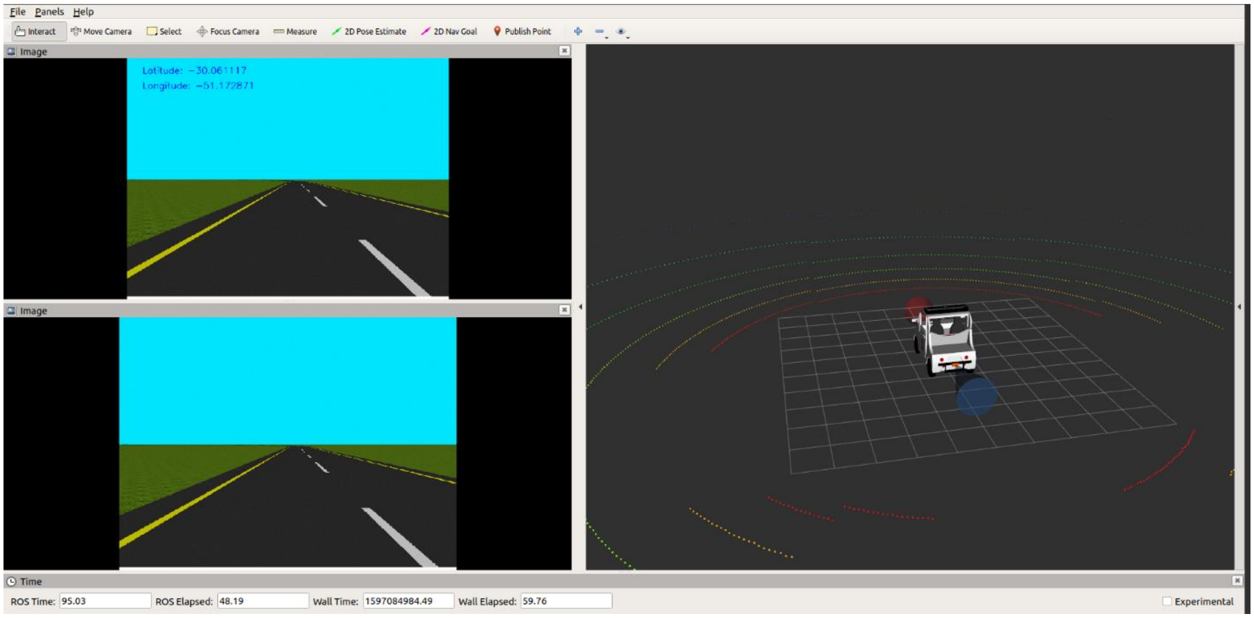
ROS Time: 703.99 ROS Elapsed: 48.01 Wall Time: 1597084812.13 Wall Elapsed: 59.39



Steps: 1 Real Time Factor: 0.86 Sim Time: 00 00:12:05.502 Real Time: 00 00:01:24.601 Iterations: 69779 FPS: 62.49

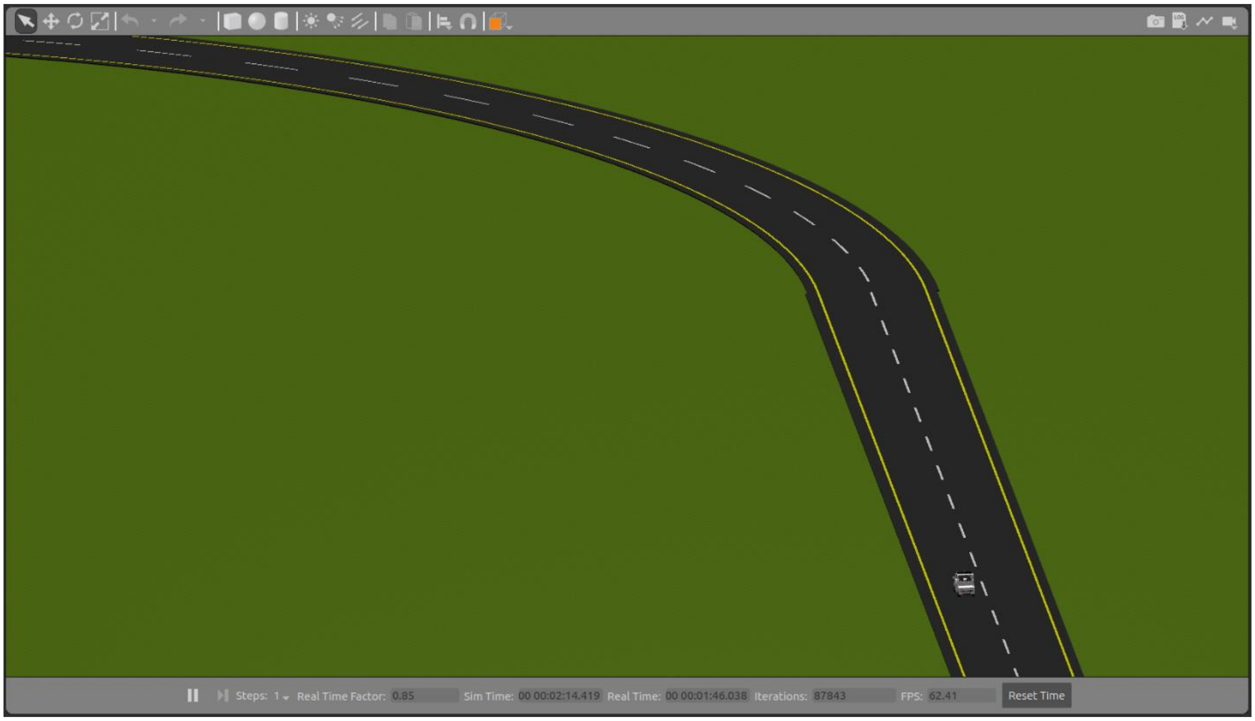
Race track

```
$ roslaunch gem_gazebo gem_vehicle.launch world_name:=race_track.world x:=100 y:=-99 z:=0.03
```



Latitude: −30.061117
Longitude: −51.172871

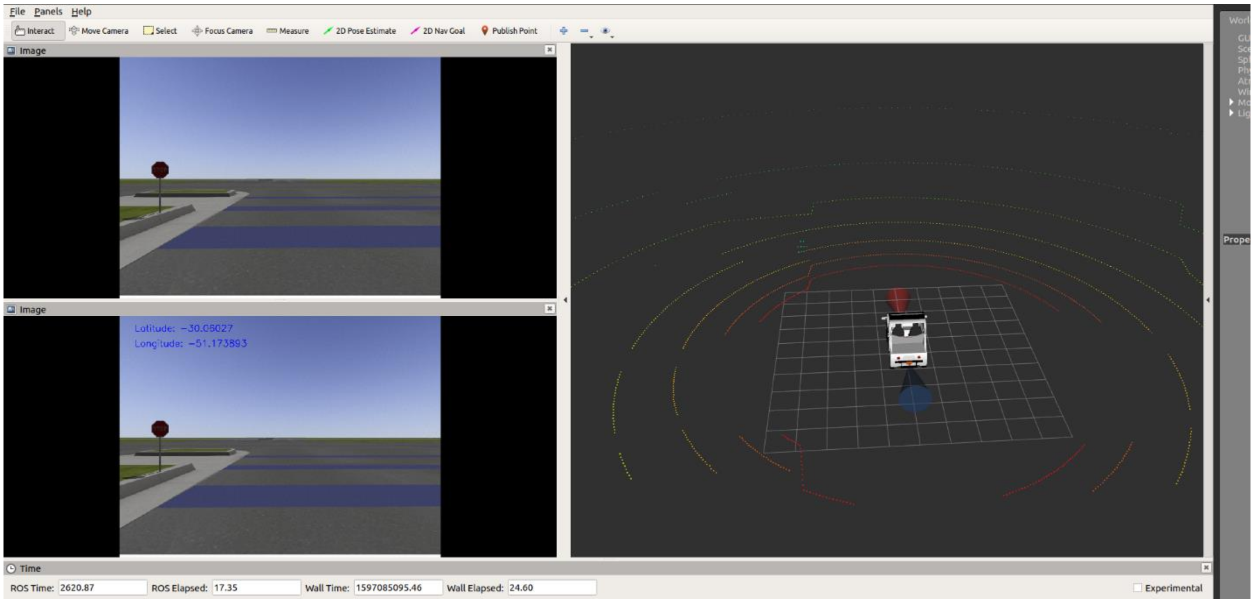
ROS Time: 95.03 ROS Elapsed: 48.19 Wall Time: 1597084984.49 Wall Elapsed: 59.76 □ Experimental



Steps: 1 Real Time Factor: 0.85 Sim Time: 00 00:02:14.419 Real Time: 00 00:01:46.038 Iterations: 87843 FPS: 62.41

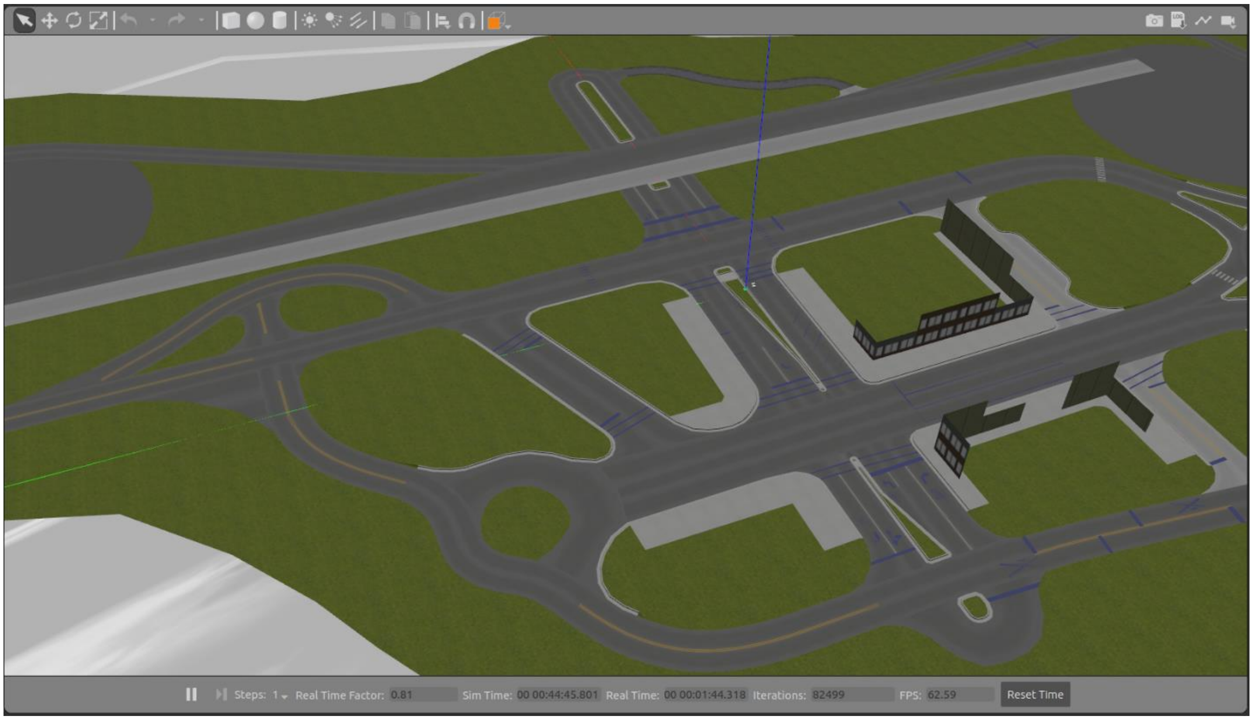
mcity

```
$ roslaunch gem_gazebo gem_vehicle.launch world_name:=mcity_clean.world x:=2 y:=-5
```

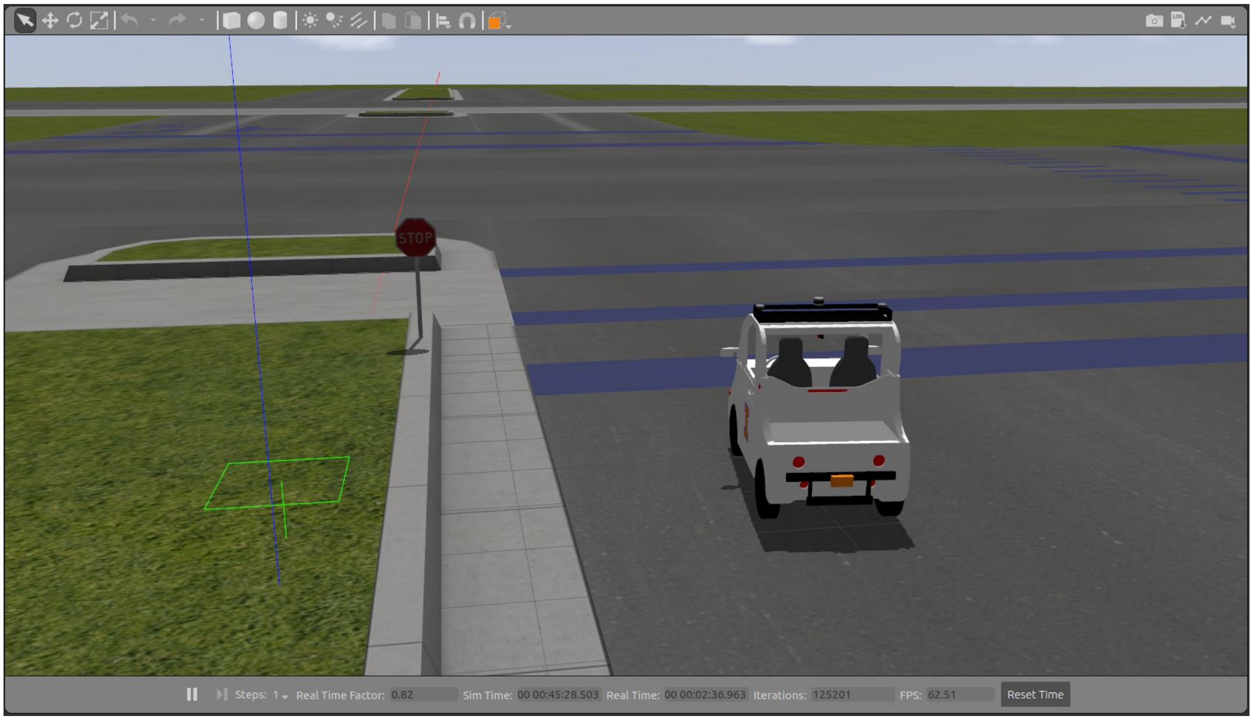


Latitude: −30.06027
Longitude: −51.173893

ROS Time: 2620.87 ROS Elapsed: 17.35 Wall Time: 1597085095.46 Wall Elapsed: 24.60



Steps: 1 Real Time Factor: 0.81 Sim Time: 00 00:44:45.801 Real Time: 00 00:01:44.318 Iterations: 82499 FPS: 62.59



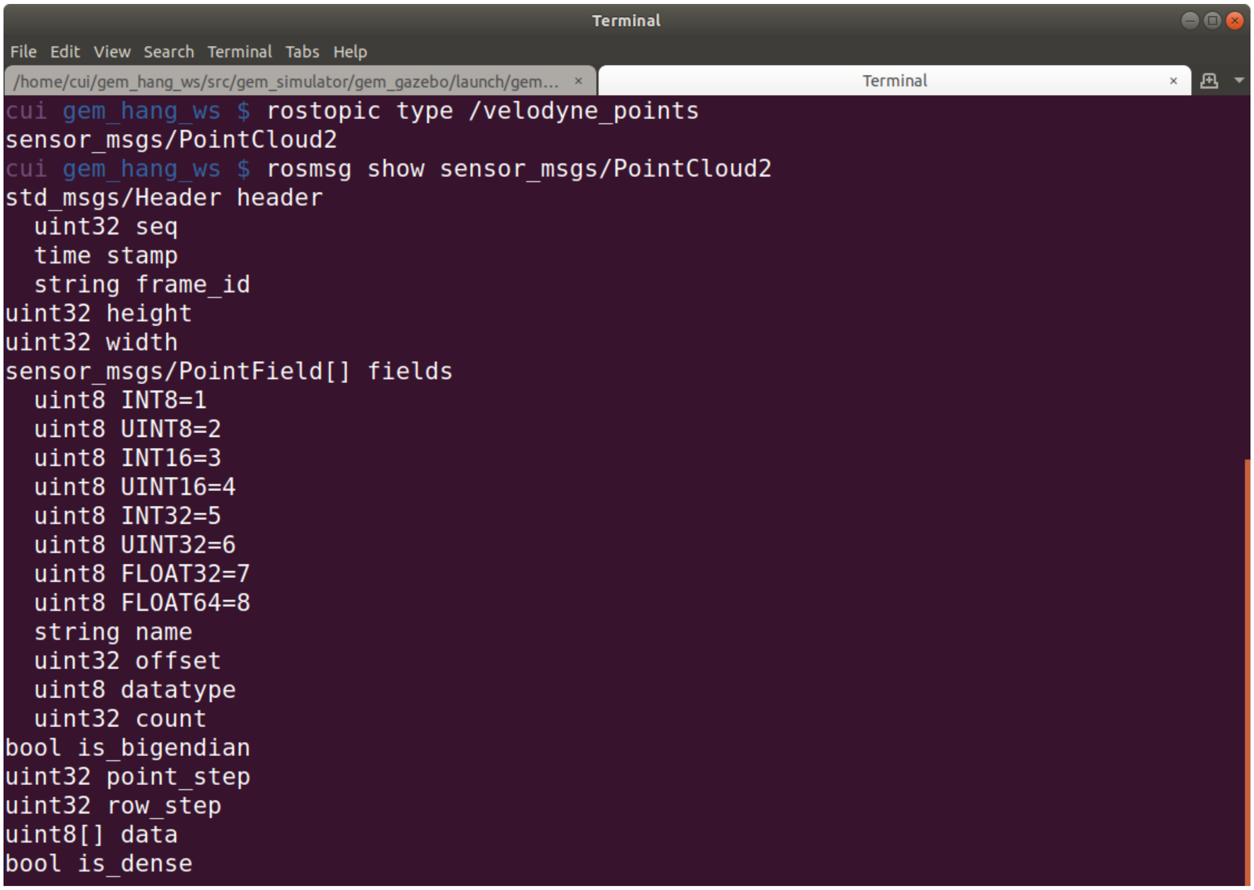
Steps: 1 Real Time Factor: 0.82 Sim Time: 00 00:45:28.503 Real Time: 00 00:02:36.963 Iterations: 125201 FPS: 62.51

Demo link: https://youtu.be/ngRfzJguGD8

3.2 LiDAR Sensor

$ rostopic type /velodyne_points

$ rosmsg show sensor_msgs/PointCloud2



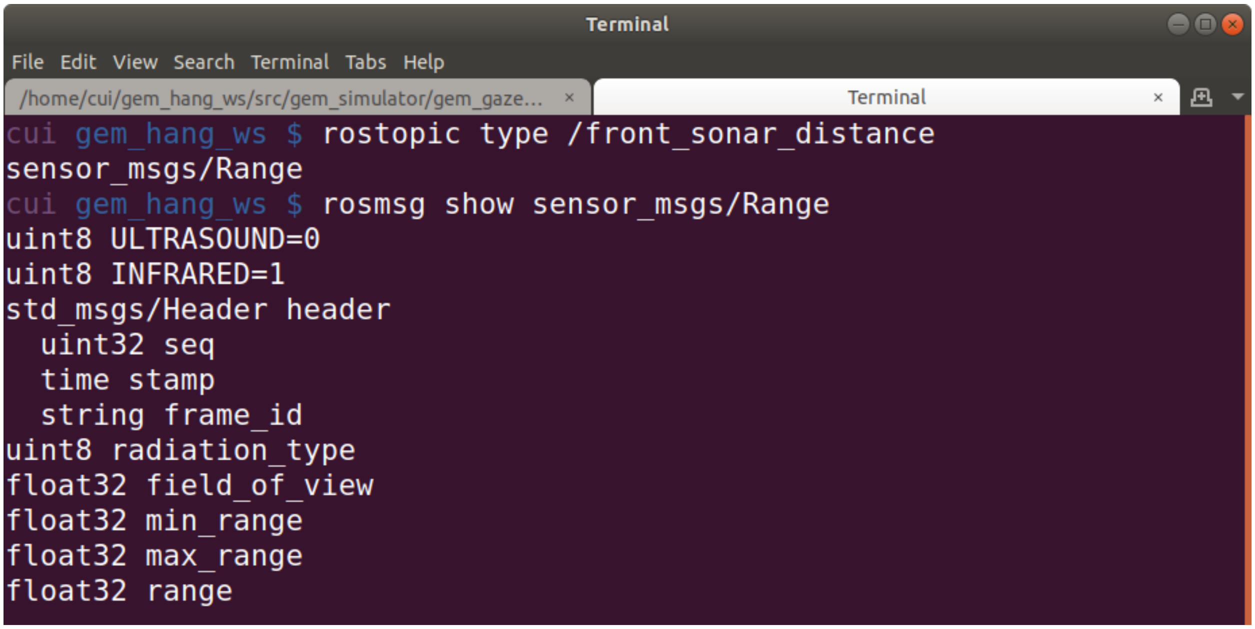
Terminal
File Edit View Search Terminal Tabs Help
/home/cui/gem_hang_ws/src/gem_simulator/gem_gazebo/launch/gem...
Terminal

```
cui gem_hang_ws $ rostopic type /velodyne_points
sensor_msgs/PointCloud2
cui gem_hang_ws $ rosmsg show sensor_msgs/PointCloud2
std_msgs/Header header
  uint32 seq
  time stamp
  string frame_id
uint32 height
uint32 width
sensor_msgs/PointField[] fields
  uint8 INT8=1
  uint8 UINT8=2
  uint8 INT16=3
  uint8 UINT16=4
  uint8 INT32=5
  uint8 UINT32=6
  uint8 FLOAT32=7
  uint8 FLOAT64=8
  string name
  uint32 offset
  uint8 datatype
  uint32 count
bool is_bigendian
uint32 point_step
uint32 row_step
uint8[] data
bool is_dense
```

3.3 Sonar Sensor

$ rostopic type /front_sonar_distance

$ rosmsg show sensor_msgs/Range



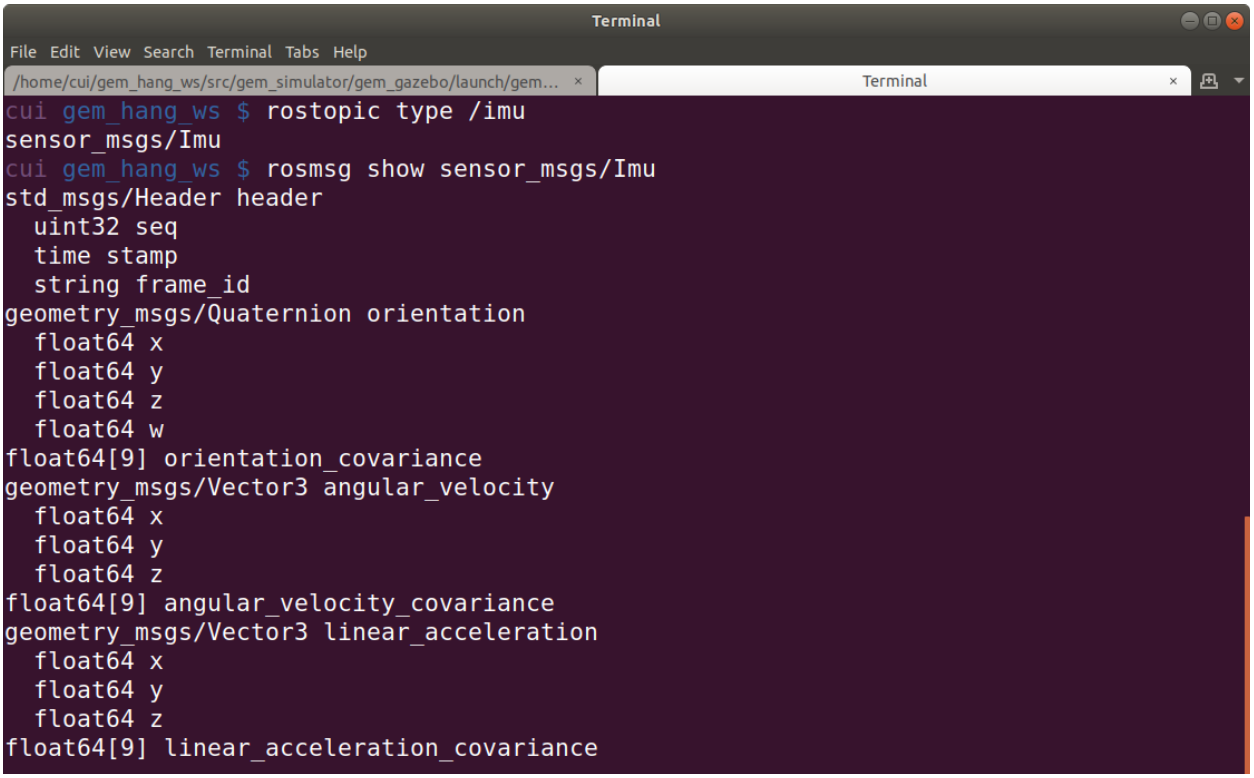
Terminal
File Edit View Search Terminal Tabs Help
/home/cui/gem_hang_ws/src/gem_simulator/gem_gaze...
Terminal

```
cui gem_hang_ws $ rostopic type /front_sonar_distance
sensor_msgs/Range
cui gem_hang_ws $ rosmsg show sensor_msgs/Range
uint8 ULTRASOUND=0
uint8 INFRARED=1
std_msgs/Header header
  uint32 seq
  time stamp
  string frame_id
uint8 radiation_type
float32 field_of_view
float32 min_range
float32 max_range
float32 range
```

3.4 IMU Sensor

$ rostopic type /imu

$ rosmsg show sensor_msgs/Imu

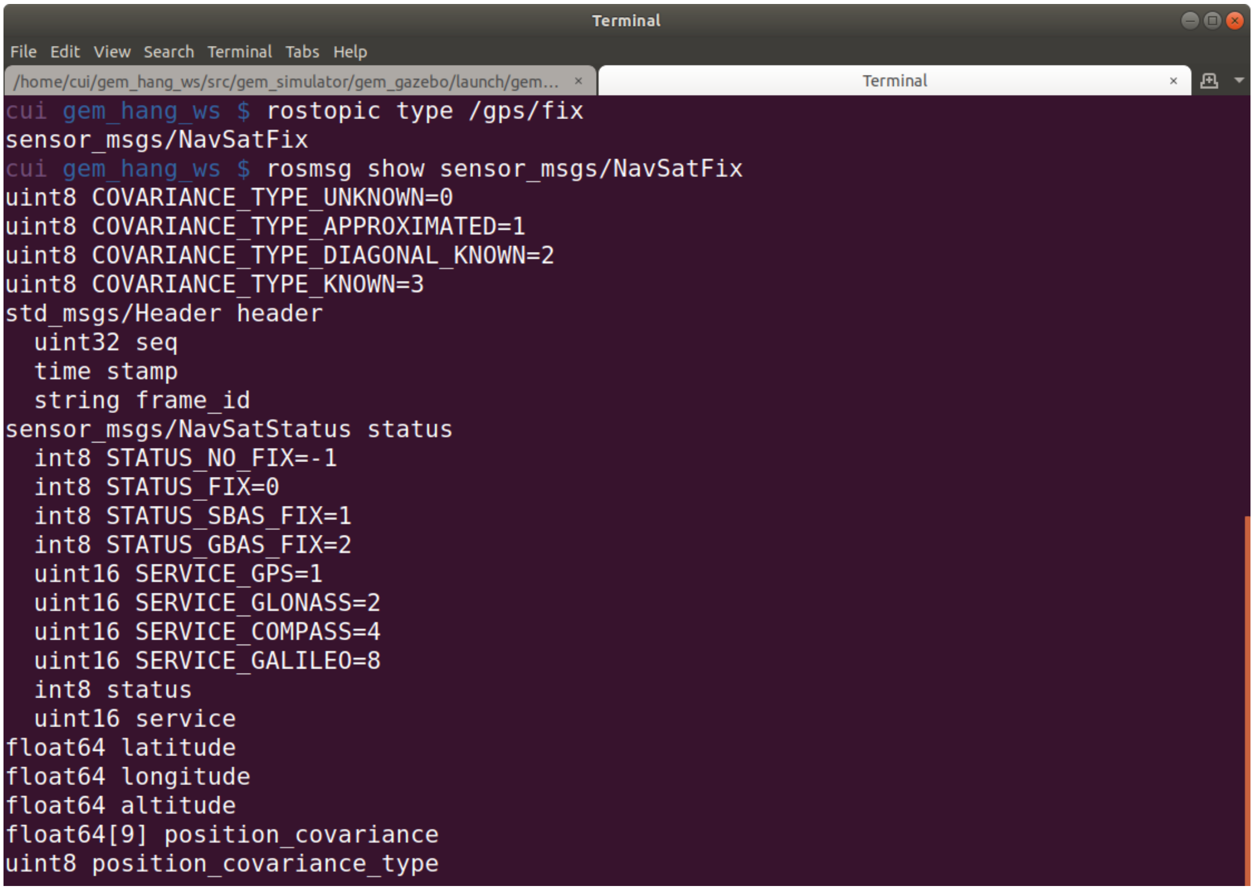

Terminal
File Edit View Search Terminal Tabs Help
/home/cui/gem_hang_ws/src/gem_simulator/gem_gazebo/launch/gem... ×
Terminal ×

```
cui gem_hang_ws $ rostopic type /imu
sensor_msgs/Imu
cui gem_hang_ws $ rosmsg show sensor_msgs/Imu
std_msgs/Header header
  uint32 seq
  time stamp
  string frame_id
geometry_msgs/Quaternion orientation
  float64 x
  float64 y
  float64 z
  float64 w
float64[9] orientation_covariance
geometry_msgs/Vector3 angular_velocity
  float64 x
  float64 y
  float64 z
float64[9] angular_velocity_covariance
geometry_msgs/Vector3 linear_acceleration
  float64 x
  float64 y
  float64 z
float64[9] linear_acceleration_covariance
```

3.5 GPS Sensor

$ rostopic type /gps/fix

$ rosmsg show sensor_msgs/NavSatFix

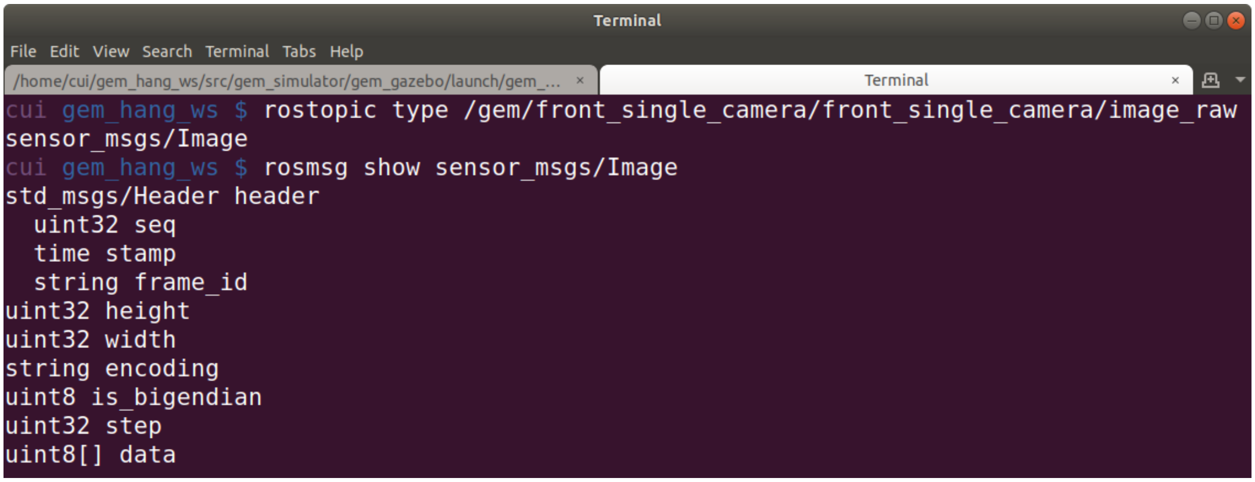

Terminal
File Edit View Search Terminal Tabs Help
/home/cui/gem_hang_ws/src/gem_simulator/gem_gazebo/launch/gem...
Terminal

```
cui gem_hang_ws $ rostopic type /gps/fix
sensor_msgs/NavSatFix
cui gem_hang_ws $ rosmsg show sensor_msgs/NavSatFix
uint8 COVARIANCE_TYPE_UNKNOWN=0
uint8 COVARIANCE_TYPE_APPROXIMATED=1
uint8 COVARIANCE_TYPE_DIAGONAL_KNOWN=2
uint8 COVARIANCE_TYPE_KNOWN=3
std_msgs/Header header
  uint32 seq
  time stamp
  string frame_id
sensor_msgs/NavSatStatus status
  int8 STATUS_NO_FIX=-1
  int8 STATUS_FIX=0
  int8 STATUS_SBAS_FIX=1
  int8 STATUS_GBAS_FIX=2
  uint16 SERVICE_GPS=1
  uint16 SERVICE_GLONASS=2
  uint16 SERVICE_COMPASS=4
  uint16 SERVICE_GALILEO=8
  int8 status
  uint16 service
float64 latitude
float64 longitude
float64 altitude
float64[9] position_covariance
uint8 position_covariance_type
```

3.6 Camera Sensor

$ rostopic type /gem/front_single_camera/front_single_camera/image_raw

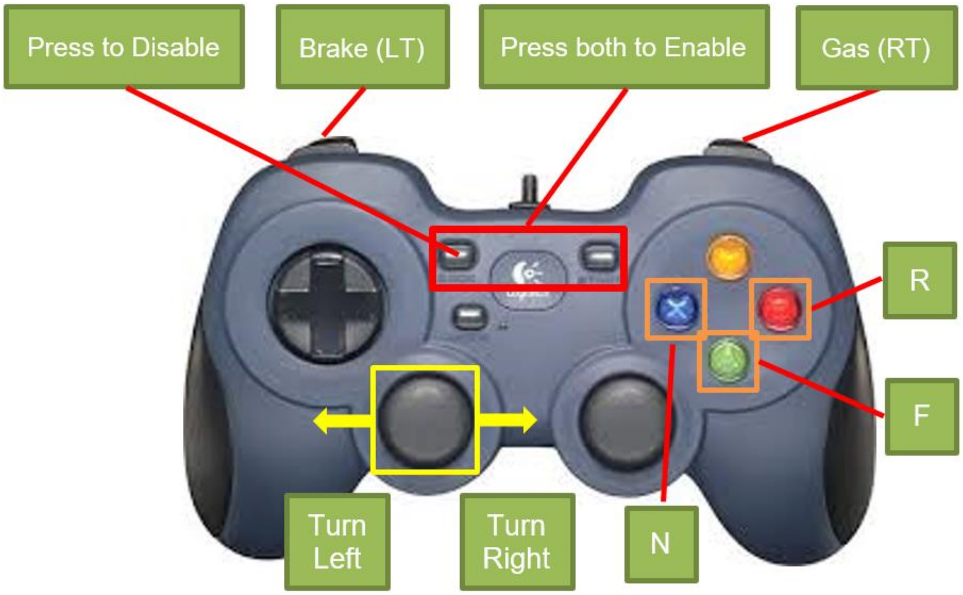
$ rosmsg show sensor_msgs/Image


Terminal
File Edit View Search Terminal Tabs Help
/home/cui/gem_hang_ws/src/gem_simulator/gem_gazebo/launch/gem_...
Terminal

```
cui gem_hang_ws $ rostopic type /gem/front_single_camera/front_single_camera/image_raw
sensor_msgs/Image
cui gem_hang_ws $ rosmsg show sensor_msgs/Image
std_msgs/Header header
  uint32 seq
  time stamp
  string frame_id
uint32 height
uint32 width
string encoding
uint8 is_bigendian
uint32 step
uint8[] data
```

3.7 Package gem_teleop

```
$ roslaunch gem_teleop teleop_joy.launch
```



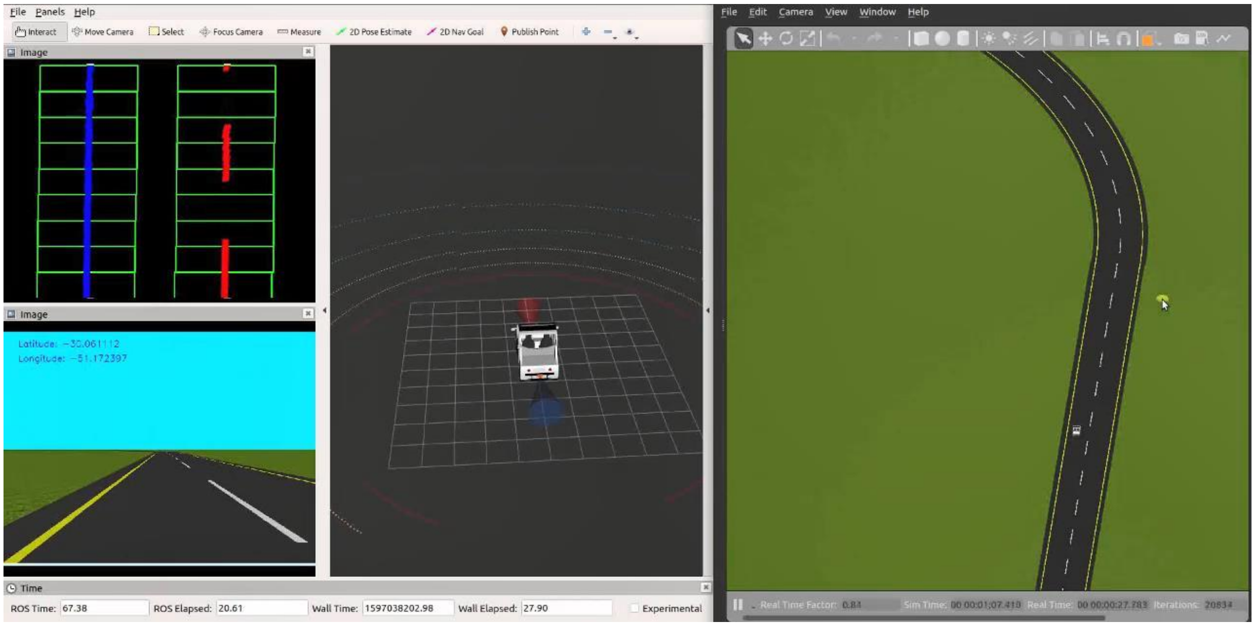
Demo link:

https://youtu.be/PcTgA5EessU

https://youtu.be/3hYSPpioVvo

3.8 Package gem_vision

```
$ roslaunch gem_gazebo gem_vehicle.launch world_name:=race_track.world x:=100 y:=-99 z:=0.03
$ roslaunch gem_vision gem_vision.launch
```



Latitude: −30.061112
Longitude: −51.172397

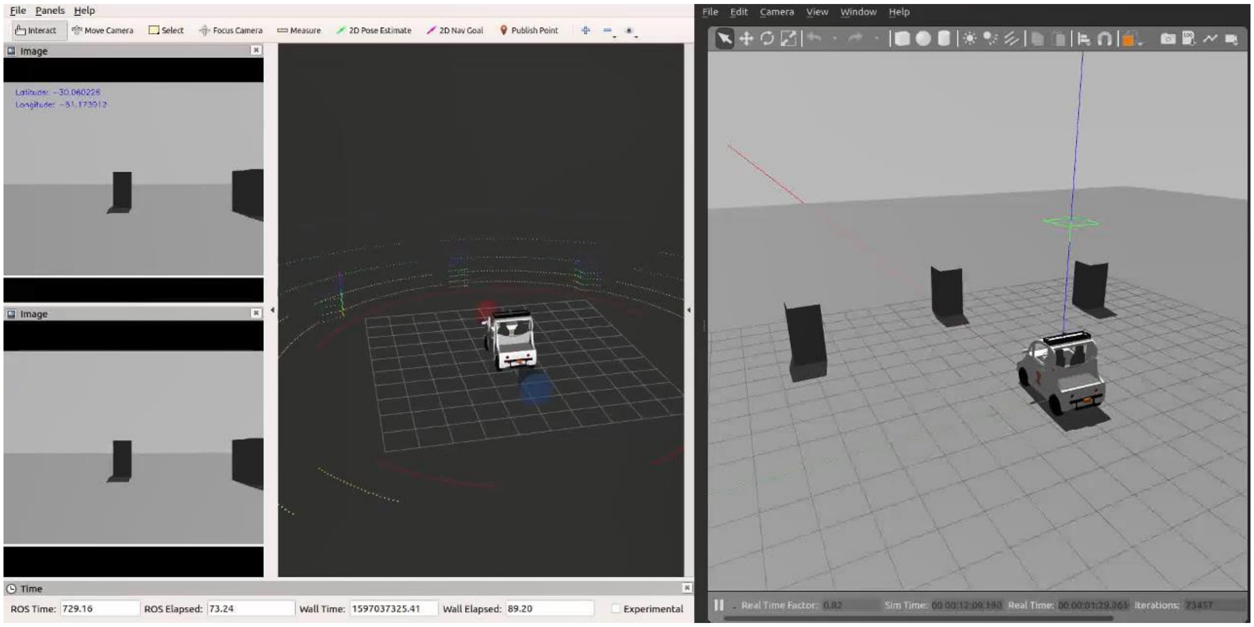
ROS Time: 67.38 ROS Elapsed: 20.61 Wall Time: 1597038202.98 Wall Elapsed: 27.90

Real Time Factor: 0.84 Sim Time: 00 00:01:07.410 Real Time: 00 00:00:27.783 Iterations: 20834

Demo link: https://youtu.be/gtiOVh_24bg

3.9 Package gem_pcl

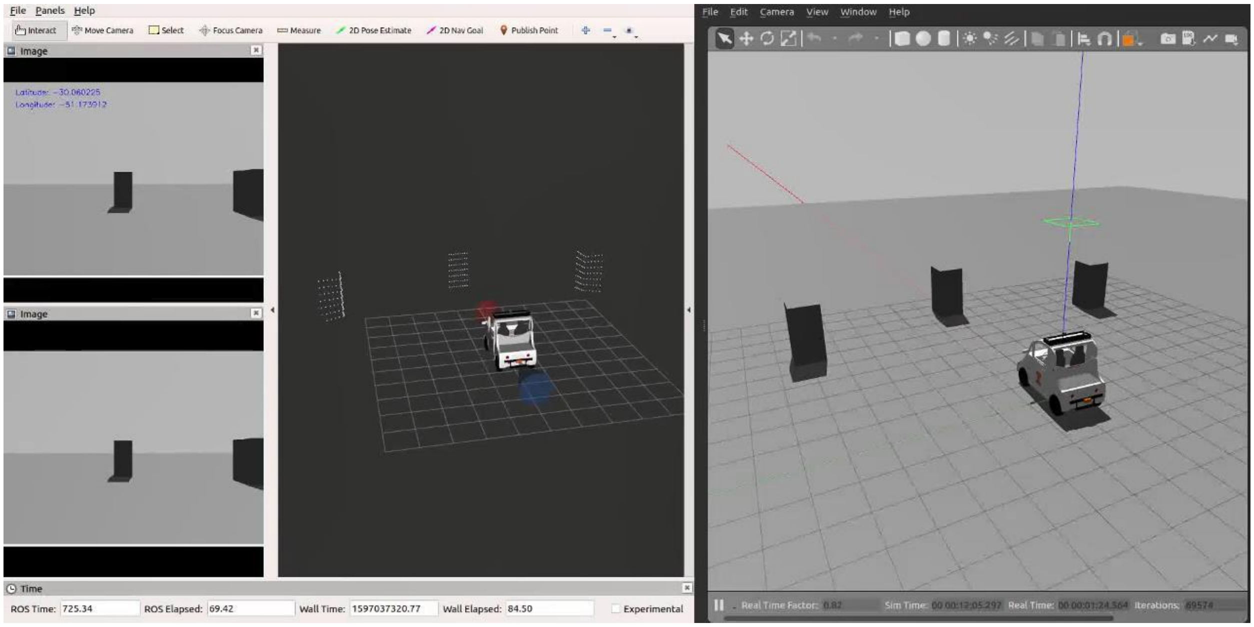
```
$ roslaunch gem_gazebo gem_vehicle.launch
$ roslaunch gem_pcl gem_pcl.launch
```



Latitude: −30.060226
Longitude: −51.173912

ROS Time: 729.16 ROS Elapsed: 73.24 Wall Time: 1597037325.41 Wall Elapsed: 89.20

Real Time Factor: 0.82 Sim Time: 00 00:12:09.190 Real Time: 00 00:01:29.361 Iterations: 73457



Latitude: −30.060226
Longitude: −51.173912

ROS Time: 725.34 ROS Elapsed: 69.42 Wall Time: 1597037320.77 Wall Elapsed: 84.50

Real Time Factor: 0.82 Sim Time: 00 00:12:05.297 Real Time: 00 00:01:24.564 Iterations: 69574

Demo link: https://youtu.be/cCxbKJZpNdM

3.10 Simulator on Virtual Machine

Windows & Linux: VMware Workstation15.x Pro

Mac: VMware Fusion 11.x Pro

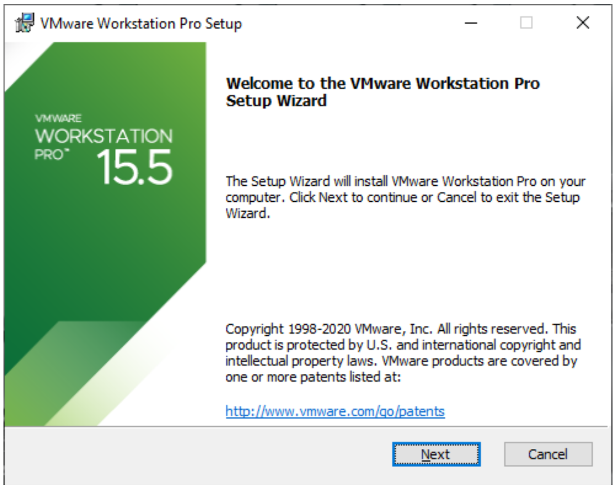
Virtual Machine Download: https://webstore.illinois.edu/shop/product.aspx?zpid=2585

Polaris GEM e2 Simulator Image: https://uofi.box.com/s/fvhymc7jtkj5ydgsi8vha6e5efwrnxw6

Polaris GEM e2 Simulator Source Code: https://github.com/hangcui1201/gem_simulator

Installation

Use campus email for Virtual Machine registration and get the license.



Welcome to the VMware Workstation Pro Setup Wizard

The Setup Wizard will install VMware Workstation Pro on your computer. Click Next to continue or Cancel to exit the Setup Wizard.

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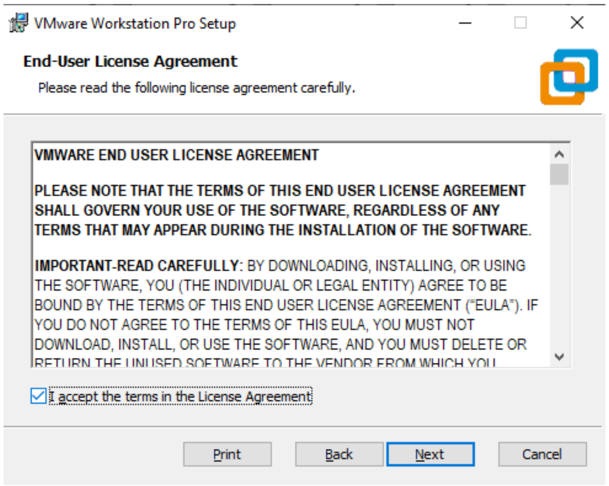
http://www.vmware.com/go/patents



End-User License Agreement

Please read the following license agreement carefully.

VMWARE END USER LICENSE AGREEMENT

PLEASE NOTE THAT THE TERMS OF THIS END USER LICENSE AGREEMENT SHALL GOVERN YOUR USE OF THE SOFTWARE, REGARDLESS OF ANY TERMS THAT MAY APPEAR DURING THE INSTALLATION OF THE SOFTWARE.

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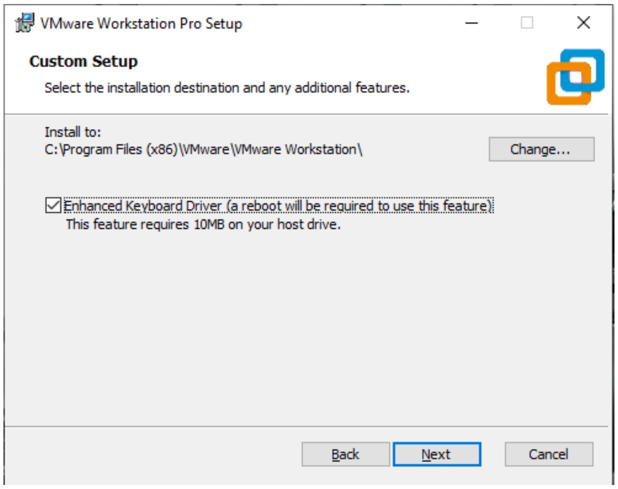
☑ I accept the terms in the License Agreement

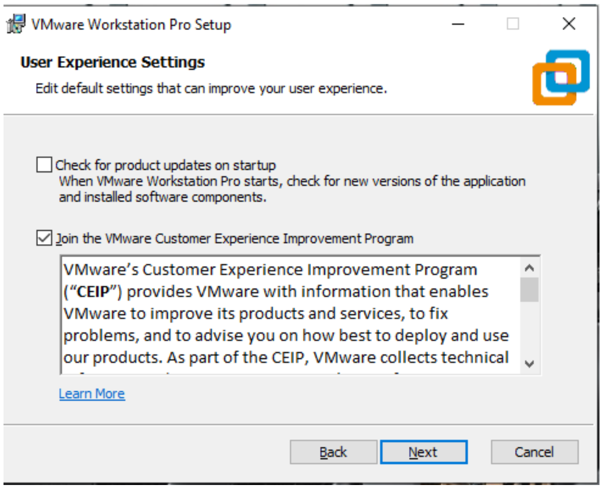


Custom Setup

Select the installation destination and any additional features.

Install to:
C:\Program Files (x86)\VMware\VMware Workstation\

☑ Enhanced Keyboard Driver (a reboot will be required to use this feature)
This feature requires 10MB on your host drive.



User Experience Settings

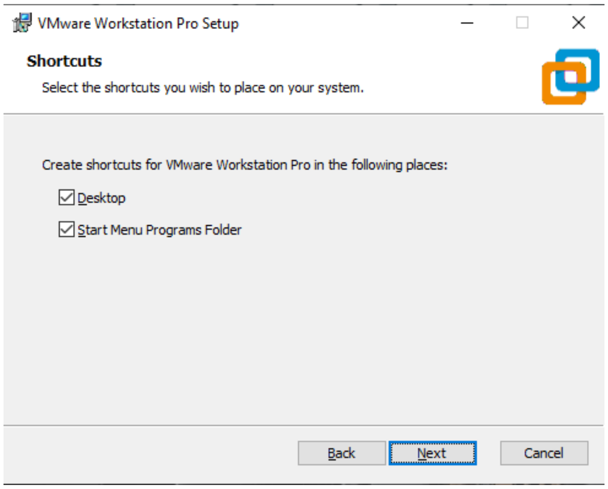
Edit default settings that can improve your user experience.

□ Check for product updates on startup
When VMware Workstation Pro starts, check for new versions of the application and installed software components.

☑ Join the VMware Customer Experience Improvement Program

VMware's Customer Experience Improvement Program ("**CEIP**") provides VMware with information that enables VMware to improve its products and services, to fix problems, and to advise you on how best to deploy and use our products. As part of the CEIP, VMware collects technical

Learn More


VMware Workstation Pro Setup

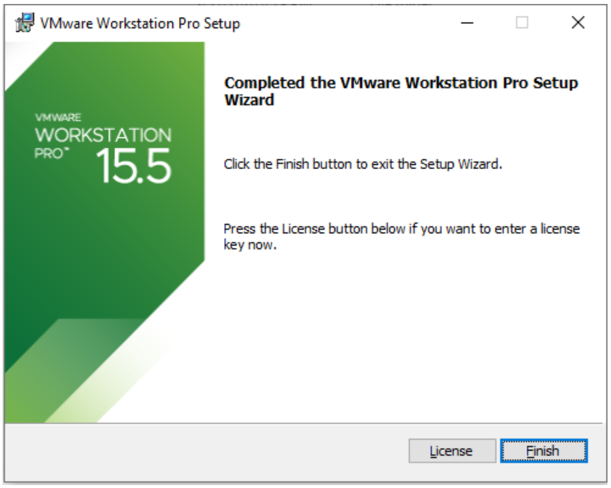
Shortcuts

Select the shortcuts you wish to place on your system.

Create shortcuts for VMware Workstation Pro in the following places:

☑ Desktop

☑ Start Menu Programs Folder


VMware Workstation Pro Setup

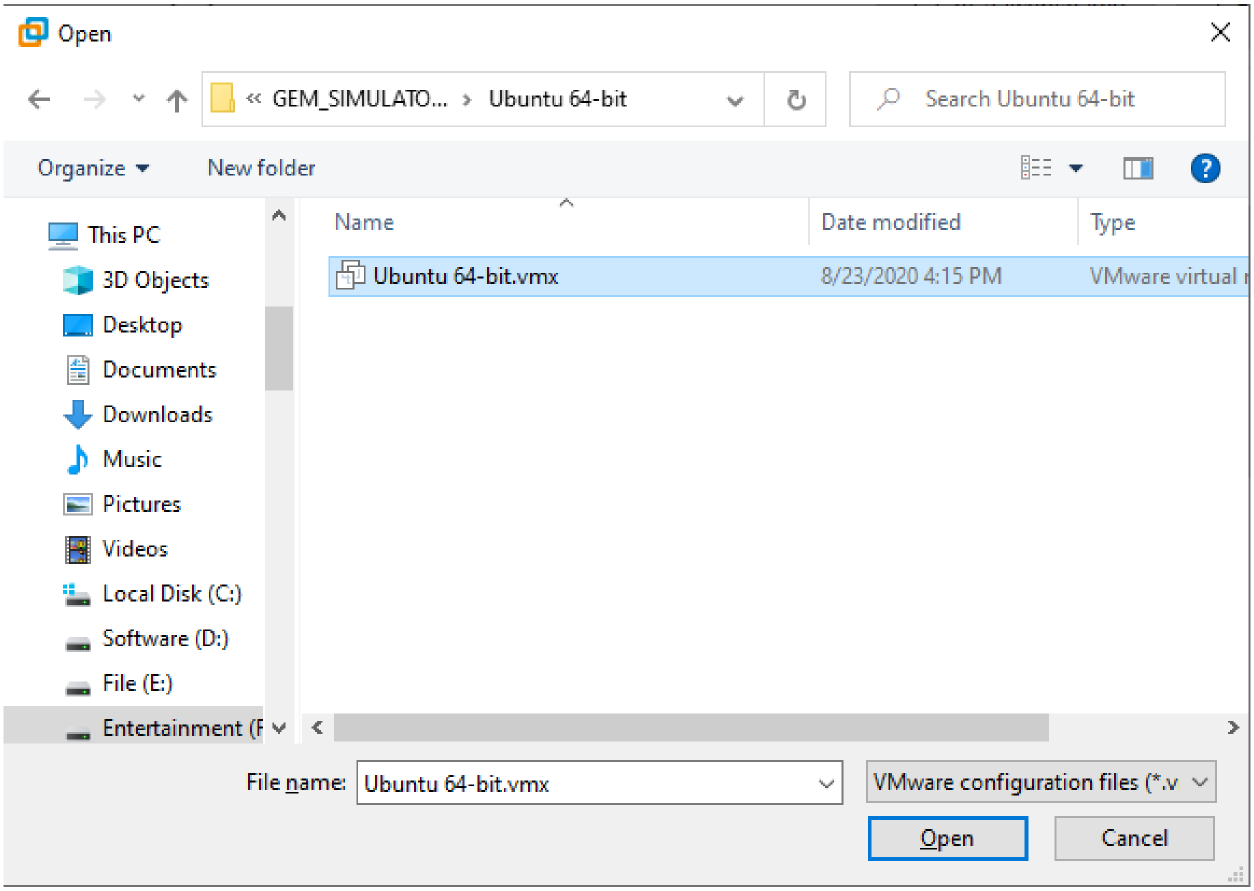
Completed the VMware Workstation Pro Setup Wizard

Click the Finish button to exit the Setup Wizard.

Press the License button below if you want to enter a license key now.

Import Polaris GEM e2 Simulator Image

First, extract the downloaded Polaris GEM e2 image. Start the program, from file->open


Open

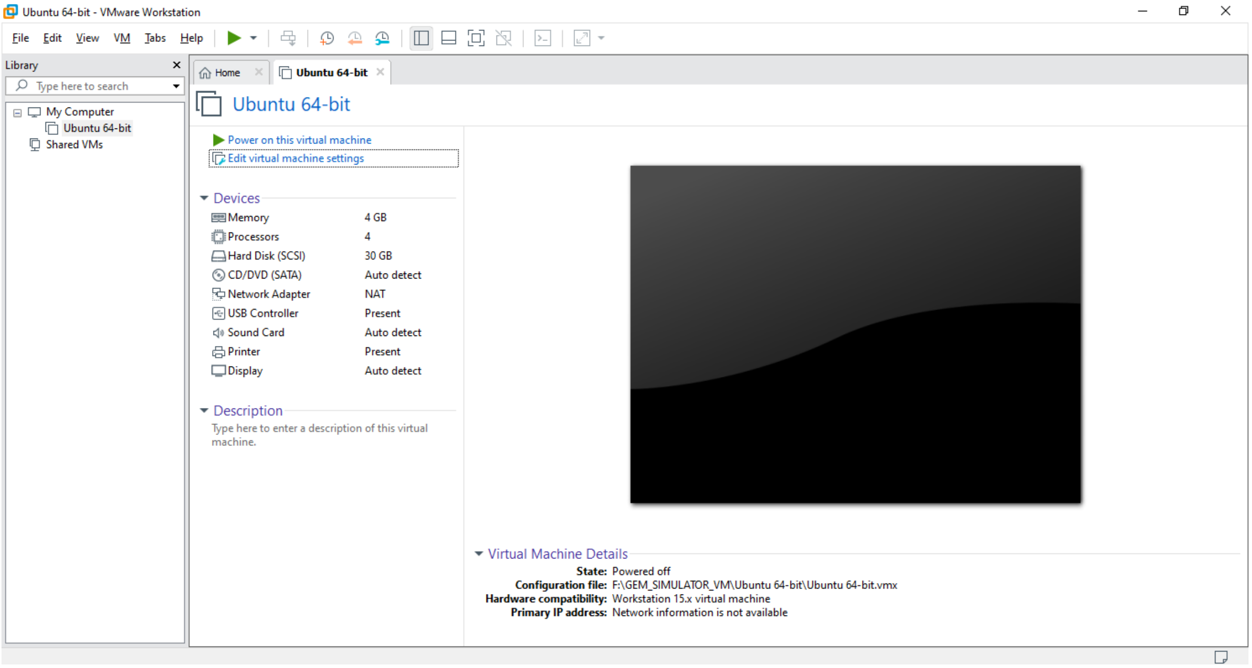
« GEM_SIMULATO... › Ubuntu 64-bit

Name	Date modified	Type
Ubuntu 64-bit.vmx	8/23/2020 4:15 PM	VMware virtual r

File name: Ubuntu 64-bit.vmx

VMware configuration files (*.v

Run the simulator image by click the play button on the top.



Devices

Memory	4 GB
Processors	4
Hard Disk (SCSI)	30 GB
CD/DVD (SATA)	Auto detect
Network Adapter	NAT
USB Controller	Present
Sound Card	Auto detect
Printer	Present
Display	Auto detect

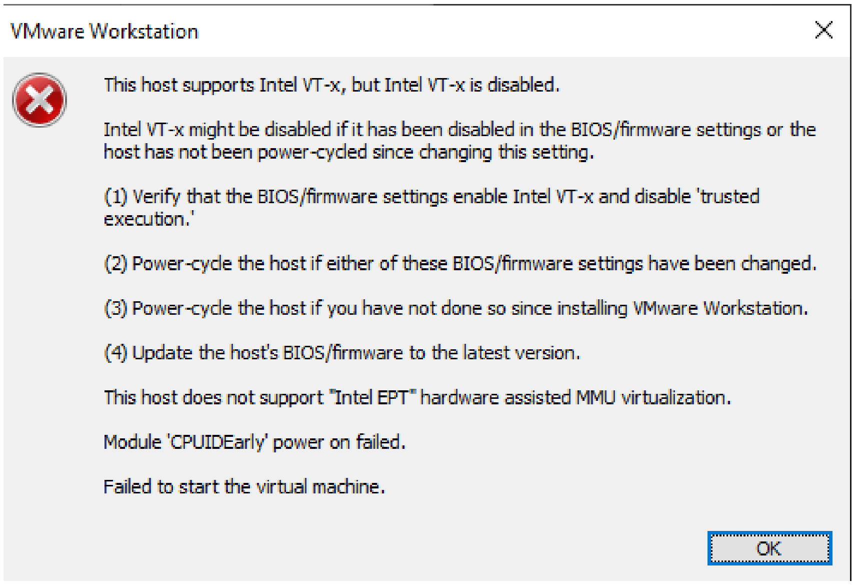
Description

Type here to enter a description of this virtual machine.

Virtual Machine Details

State:	Powered off
Configuration file:	F:\GEM_SIMULATOR_VM\Ubuntu 64-bit\Ubuntu 64-bit.vmx
Hardware compatibility:	Workstation 15.x virtual machine
Primary IP address:	Network information is not available

If you have the warning below, enable the VT-x in BIOS.



This host supports Intel VT-x, but Intel VT-x is disabled.

Intel VT-x might be disabled if it has been disabled in the BIOS/firmware settings or the host has not been power-cycled since changing this setting.

(1) Verify that the BIOS/firmware settings enable Intel VT-x and disable 'trusted execution.'

(2) Power-cycle the host if either of these BIOS/firmware settings have been changed.

(3) Power-cycle the host if you have not done so since installing VMware Workstation.

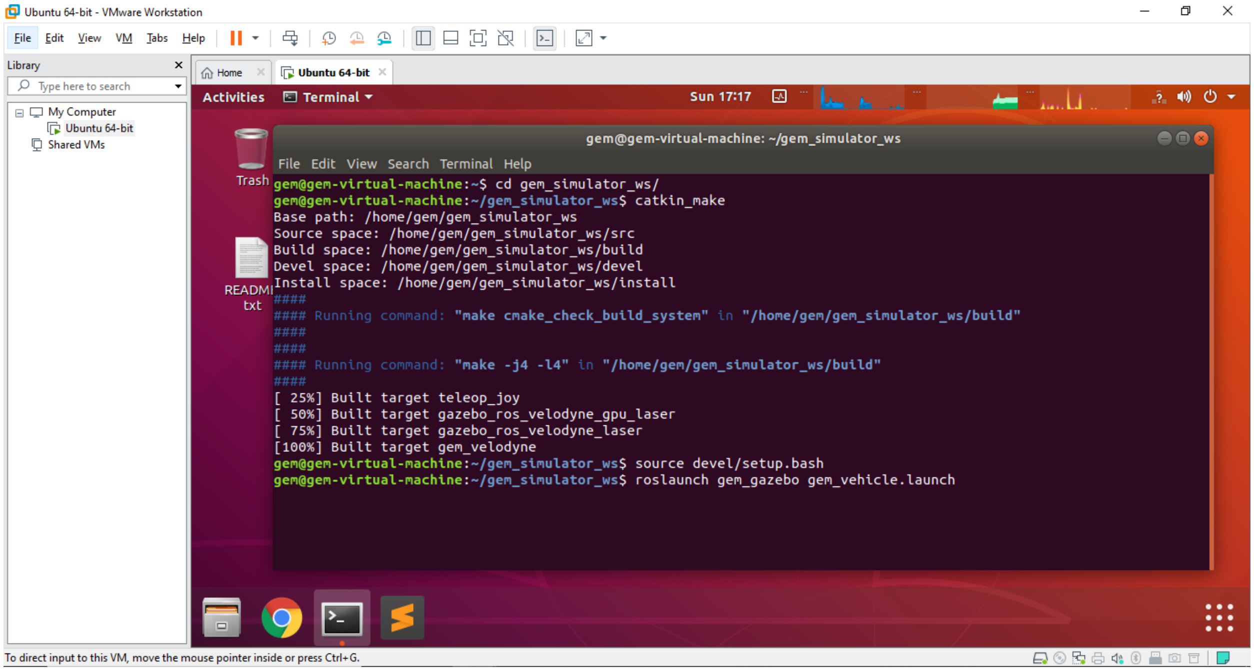
(4) Update the host's BIOS/firmware to the latest version.

This host does not support "Intel EPT" hardware assisted MMU virtualization.

Module 'CPUIDEarly' power on failed.

Failed to start the virtual machine.

Compile the simulator and run.


Ubuntu 64-bit - VMware Workstation
File Edit View VM Tabs Help
Library
Type here to search
My Computer
Ubuntu 64-bit
Shared VMs
Home
Ubuntu 64-bit
Activities
Terminal
Sun 17:17
Trash
README
txt
gem@gem-virtual-machine: ~/gem_simulator_ws
File Edit View Search Terminal Help
To direct input to this VM, move the mouse pointer inside or press Ctrl+G.

```
gem@gem-virtual-machine:~$ cd gem_simulator_ws/
gem@gem-virtual-machine:~/gem_simulator_ws$ catkin_make
Base path: /home/gem/gem_simulator_ws
Source space: /home/gem/gem_simulator_ws/src
Build space: /home/gem/gem_simulator_ws/build
Devel space: /home/gem/gem_simulator_ws/devel
Install space: /home/gem/gem_simulator_ws/install
####
#### Running command: "make cmake_check_build_system" in "/home/gem/gem_simulator_ws/build"
####
####
#### Running command: "make -j4 -l4" in "/home/gem/gem_simulator_ws/build"
####
[ 25%] Built target teleop_joy
[ 50%] Built target gazebo_ros_velodyne_gpu_laser
[ 75%] Built target gazebo_ros_velodyne_laser
[100%] Built target gem_velodyne
gem@gem-virtual-machine:~/gem_simulator_ws$ source devel/setup.bash
gem@gem-virtual-machine:~/gem_simulator_ws$ roslaunch gem_gazebo gem_vehicle.launch
```

3.11 Coming more