HIL Simulator

Release 7.8.6/1.0

Embention Sistemas Inteligentes, S.A.

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Contents

Scope of Changes

- Version 1.0
  - Added:
    - First version issued

Introduction

HIL Simulator is the Veronte application to perform HIL (Hardware In the Loop) simulations. This kind of simulation runs Veronte software with a real autopilot (**1x** or **4x**), taking simulator input as real sensor data. The whole flight is controlled by the real autopilot in a virtual environment, making it the perfect tool for vehicle development and training operators in the use of Veronte autopilot, prior to conducting real flight operations.

HIL Simulator is designed for applications such as:

- Pilot training.
- Veronte configuration for unmanned platform control.
- PID setting.
- Mission configuration.
- Aircraft performance validation.

The operator can fly the system as a real flight, being compatible with main Veronte features: real-time mission edit, in-flight automatic to manual control, flight data recording, etc. Sometimes, during an edition saving, the simulation fails because the simulation link suffers a little interruption (this fact does not exist in real flights).

> ⊘ **Danger**
>
> When using **HIL Simulator**, real control actuators will move as a real flight. In order to avoid damaging people or equipment, make sure that motors are disconnected and there is no shock risk due to actuators movement.

HIL Simulator is employed along with:

- **Veronte Link** to connect the autopilot with a computer. To read the user manual click here.
- **Veronte Ops** to operate the autopilot during simulations. To read the user manual click here.

- **Simulators**:
  - **Microsoft Flight Simulator**, **X Plane 11** or **X Plane 12** to simulate flights.
  - **Bridge Command** can be chosen for ship simulations.
  - **Simulink** for a customizable environment.
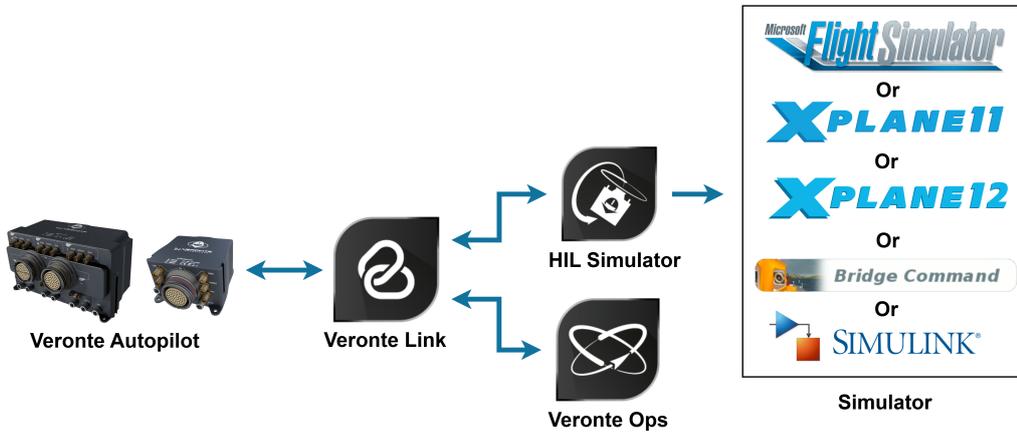
Quick Start

System Requirements

Before executing this software, users should check the following sections with the minimum and recommended PC hardware requirements.

Minimum requirements

- CPU: Intel Core i5-8365UE
- RAM: 8 GB DDR4
- STO: 256 GB SSD

Recommended requirements

- CPU: 12th Gen Intel(R) Core(TM) i7-12700H 14 cores up to 4,70 GHz
- RAM: 32,0 GB
- STO: 1TB SSD M.2 NVMe PCIe

Download and Installation

HIL Simulator software is available in the **Veronte Toolbox** platform. From there, users can download and install the application. For more information, please refer to the Veronte Toolbox user manual.

A **personal account** is required to access **Veronte Toolbox**; create a Ticket in the user's **Joint Collaboration Framework** and the support team will create it for you.
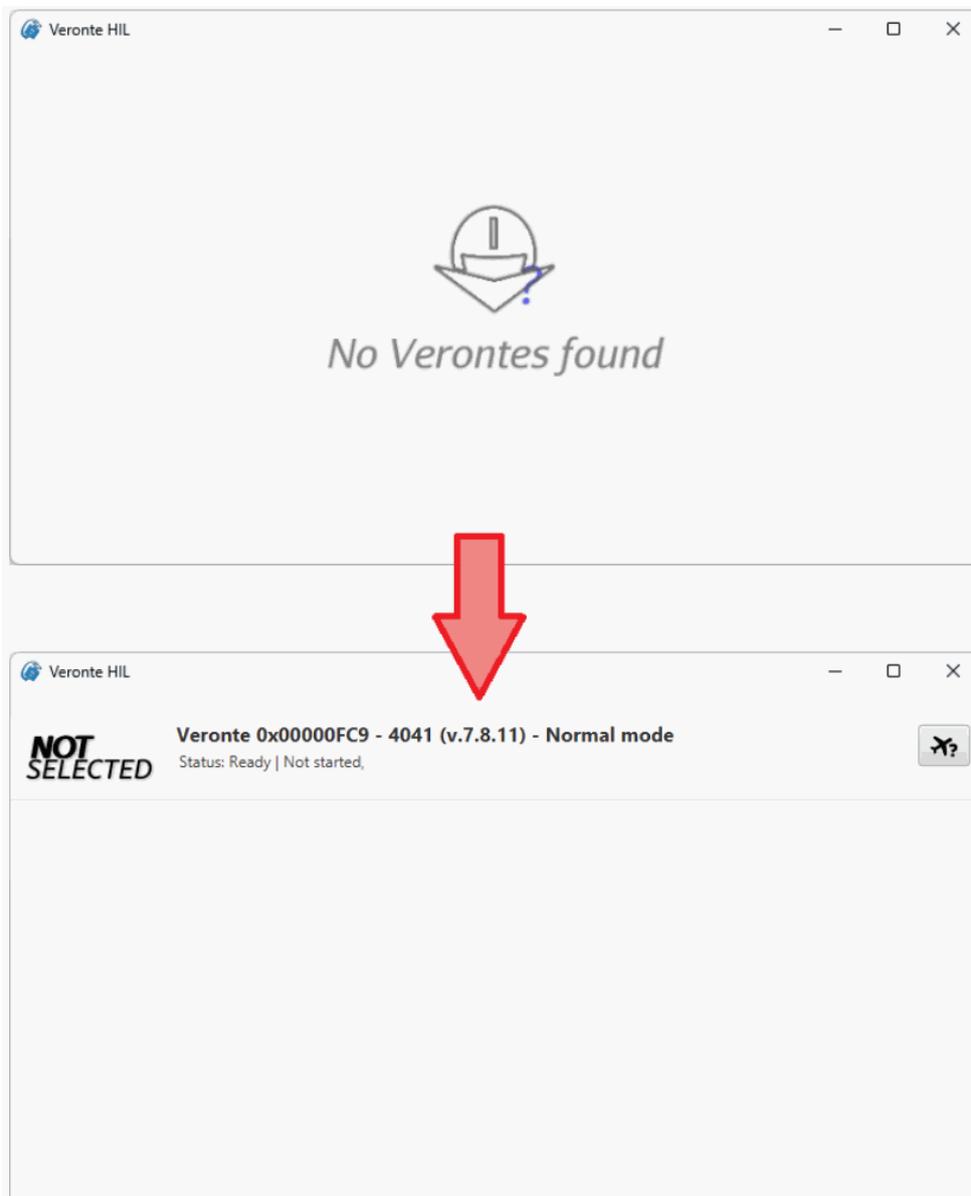
Operation

To start using **HIL Simulator**, follow the next steps:

1. **Connect the autopilot to a computer** and establish the connection through **Veronte Link**.

   > ⓘ **Note**
   >
   > Read the Veronte Link user manual for more information.

2. **Open HIL Simulator** and wait a few seconds for the connected autopilot to be detected.

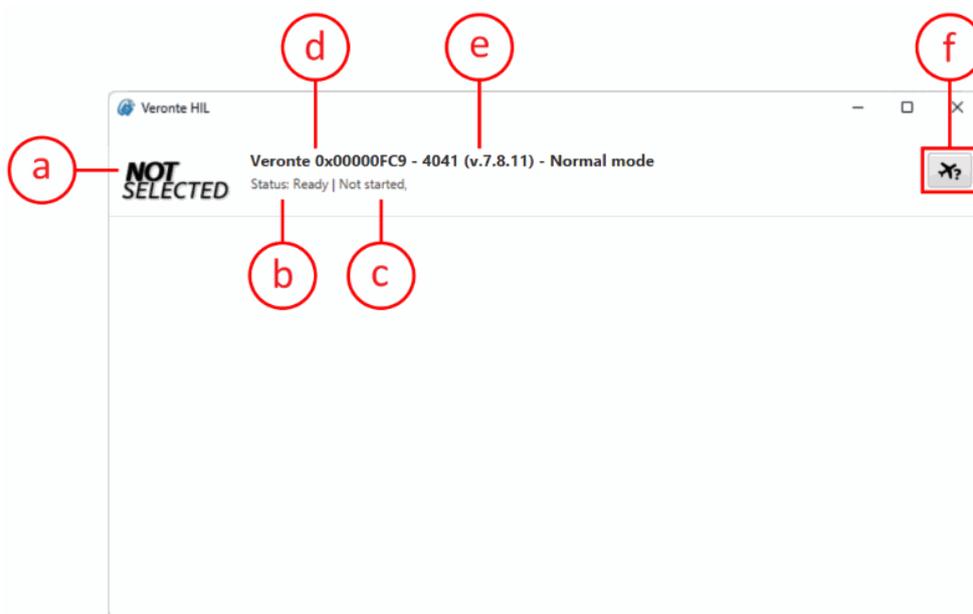**HIL detection of connected autopilot**

> ⓘ **Note**
>
> **HIL** will now run minimized in the System Tray:
>
>
>
> **Minimized running**

Once the autopilot has been detected, HIL Simulator will display the following menu:

HIL Simulator - Main menu

a. **Simulator icon**: The icon of the selected simulator is displayed.

b. **Status of the autopilot**: Ready, Running, Failed load conf, Maintenance mode or Offline.

c. **Status of the simulation**:

  ◦ Not started.
  ◦ Once started, simulation frequency parameters are displayed.
    ▪ To Simulator: Frequency of data transmission to the external simulator selected.
    ▪ To Platform: Frequency of data transmission to the autopilot.

d. **Autopilot ID and firmware version**

e. **Autopilot mode**

> ◈ **Important**
>
> The autopilot must be in **Normal Mode** to start the simulation. Refer to Unable to start HIL Simulation - Troubleshooting section of this manual for further details.

f. **Select simulator** button

This menu presents slightly different features when a **Veronte Autopilot 4x** is connected:

HIL Simulator - Main menu for 4x

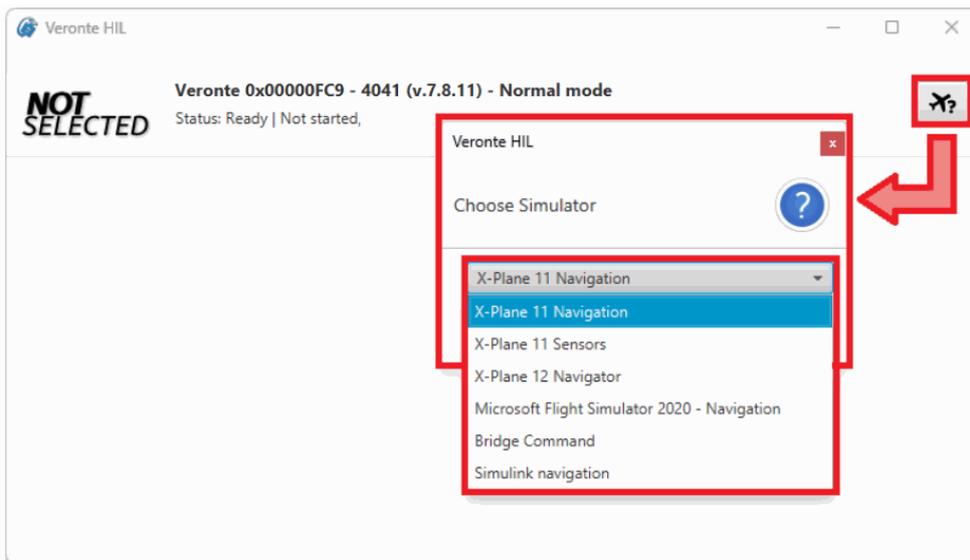g. **Autopilot 4x name**: 4x is labeled as "Veronte Group (4x)" and its ID.

h. **Selected UAV**: The index of the Autopilot 1x selected by the arbiter and its unit name are displayed.

> ⓘ **Note**
>
> The 'Status' displayed when connecting a **4x** corresponds to the status of **the selected UAV**.

3. **Choose a simulator**.

Click on [✈?] to choose a simulator to conduct HIL simulation.

4. **Configure HIL simulation parameters (optional)**.

   Default configuration parameters are recommended. To change them, click on ⚙️ .
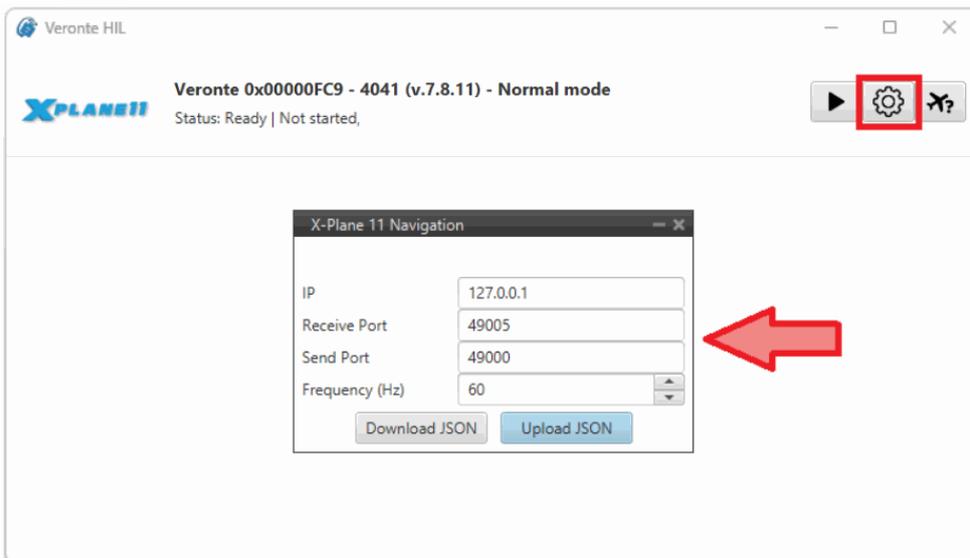
> ⓘ **Note**
>
> Some additional parameters may be configurable depending on the selected simulator.

5. **Configure the simulation parameters in the selected simulator software**.

   The selected simulator must be configured with the same **IP, port** and **frequency** as **HIL Simulator**.

> ⓘ **Note**
>
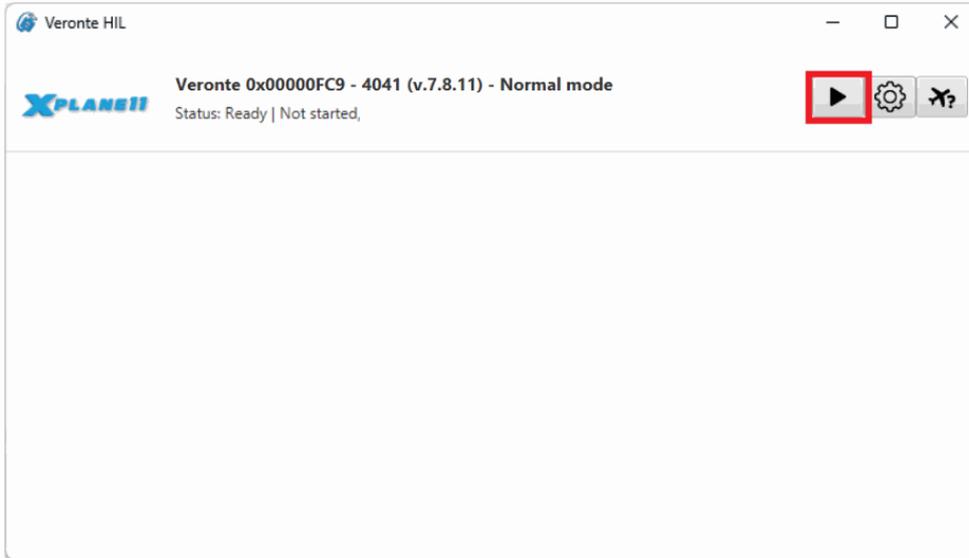> The procedure to configure these parameters vary depending on the simulator, consult the subsequent sections for more information.

6. **Run the selected simulator software**.
7. **Start HIL Simulator**.

Navigation variables

Variables of navigation must be shared between **external simulators** and **Autopilot 1x** for a functional simulation.

For this reason, with a proper configuration of HIL Simulator settings, the following variables are automatically sent to 1x:

> ⓘ **Note**
>
> For further information on these variables, please consult the Real variables list of the **1x Software Manual**.

Field	Description	Units
6	Yaw	rad
7	Pitch	rad

| Field	Description	Units
8	Roll	rad
12	p (Angular Velocity - X Body Axis)	rad/s
13	q (Angular Velocity - Y Body Axis)	rad/s
14	r (Angular Velocity - Z Body Axis)	rad/s
15	Forward Acceleration - X Body Axis	m/s^2
16	Right Acceleration - Y Body Axis	m/s^2
17	Bottom Acceleration - Z Body Axis	m/s^2
500	Longitude	rad
501	Latitude	rad
502	WGS84 Elevation (Height Over the Ellipsoid)	m
504	AGL (Above Ground Level) – Height	m
505	North Velocity	m/s
506	East Velocity	m/s
507	Down Velocity	m/s

X-Plane

> **◈ Important**
>
> The configuration and simulation steps described in this section are valid for both X-Plane 11 and X-Plane 12. The procedure is identical for both versions.

HIL Simulator presents two simulation modes emulated with the flight simulators **X-Plane 11**:

- **X-Plane 11 Navigation**
- **X-Plane 11 Sensors**

Both simulation modes are suitable for performing fast simulations where extreme precision is not required.
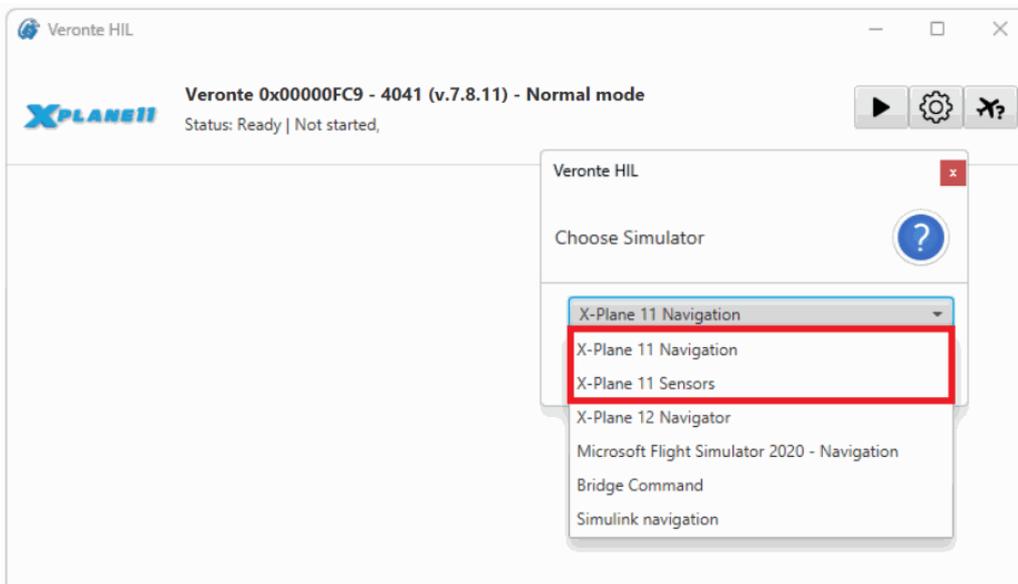
Select X-Plane 11 Navigation or X-Plane 11 Sensors

X-Plane Navigation and **X-Plane Sensors** perform the simulation with different approaches, so users can choose the one that best suits their requirements.

- **X-Plane Navigation**: With this mode, **Veronte Autopilot 1x** directly receives the clean attitude, altitude and rates of the aircraft from the X-

Plane simulation; this data is then processed by the autopilot as if it were the states output from the EKF. On its part, X-Plane 11 receives the control output signals of the autopilot and simulates the aircraft response.

X-Plane Navigation simulates an ideal environment in which sensor reading errors are not considered, thus focusing on testing the control performance.

- **X-Plane Sensors**: With this mode, HIL Simulator simulates the sensor data based on the state signals received from X-Plane 11 and then sends it to the **Veronte Autopilot 1x**. These calculated values are then used as inputs for the EKF algorithm, and the control response is sent back to X-Plane 11 Simulator.

  X-Plane Sensors simulates the processing of real sensors data, allowing to analyze the EFK behavior.

Configuration

X-Plane 11 communications settings shall be configured to link with Veronte systems.

> ◈ **Important**
>
> For low-performance computers, it may be needed to reduce the graphics quality on the simulator, as described below.

Follow the next steps to configure X-Plane 11 for conducting simulation through HIL.

> ⓘ **Note**
>
> **X-Plane 11 configuration** is the same for **X-Plane 11 Navigation** and **X-Plane 11 Sensors** simulation modes.

1. **Aircraft Model Installation**

   X-Plane 11 simulator is compatible with a wide variety of platforms: airplane, helicopter, multicopter, surface vehicle, etc. In order to create the platform model, Plane Maker tool provided by X-Plane 11 must be used.

Once the aircraft model has been created, it can be integrated on the X-Plane 11 simulator by following the next sub steps:

- 1.1: Copy the model folder to the "Aircraft" folder within the X-Plane 11 installation directory.
- 1.2: Copy the content in the "Airfoils" folder, available in the aircraft model folder, to the "Airfoils" directory within the X-Plane 11 installation directory.

2. **Custom airport**

   X-Plane flight starts from an airport; a custom airport must be defined for simulating in case of not having available airports. In addition, it is possible to create a new airport. In order to do that, the user should follow the X-Plane tutorial presented in the next link. Once the airport has been created, copy the model folder to the X-Plane 11 installation directory.

3. **X-Plane Settings**

   Data transmission settings of X-Plane must be edited on **Settings** ⇒ **Data Output**. This configuration must match with **HIL Simulator**. Select all the variables to sent through the UDP Network and set the UDP rate at maximum speed. The network configuration must be configured as shown in the following table and picture.

   > ⚠ **Important**
   >
   > Only selected variables will be simulated. If a value is not configured for simulation, **Veronte Autopilot 1x** will take the corresponding value from its internal sensors.

Parameter	Value
3 - Speeds	Mark ☑ in the **Network via UDP** column
4 - Mach, VVI, g-load	
16 - Angular velocities	
17 - Pitch, roll & headings	

Parameter	Value
18 - Angle of attack, sideslip & paths	
20 - Latitude, longitude & altitude	
21 - Location, velocity & distance traveled	
IP	127.0.0.1
Receive port	49005
Send port	49000
UDP rate (packets / second)	HIL Simulator frequency, with 99 as maximum value

Simulation

For running the simulation in X-Plane 11 software follow the steps below.

1. **X-Plane 11 Setup**

   Open X-Plane 11. In this **Main menu**, click on **New Flight** to start a simulation:

2. Select which **aircraft** to use, the starting **airport** and weather conditions to simulate. Then, click on **Start Flight** to start the simulation:

   X-Plane 11 Setup

3. **Start HIL simulation**

   Once X-Plane is configured and running, click on ▶ of **HIL Simulator** to enable the sending of commands. The frequency to the simulator should then be set to, approximately, the previously configured frequency:

HIL - Run simulation

4. **Check sending/receiving data**

   Go to **Settings** ⇒ **Network tab**. Check that the sending and receiving data to is correct:

   Check sending/receiving data

Once the hardware has been connected and the software has been configured, operation can start and the system can be operated as a real flight.

GPS will be simulated and the UAV should be visible on **Veronte Ops** in the selected airport, with a colored icon as follows:

Veronte Ops

> ⚠ **Warning**
>
> The simulation starts when the aircraft is in the initial phase (when it is powered). In this phase, X-Plane will simulate the GPS signal to locate the autopilot.

With GPS signal it is possible to pass the system to Standby phase and to start flight. Once the aircraft has taken off from the airport on X-Plane, the automatic control will start and the aircraft will fly, according to the defined mission on **Veronte Ops**.

> ⓘ **Note**
>
> For more information, read the Veronte Ops user manual.

Simulink Navigation

HIL Simulator enables simulation with **Simulink** software for a physical autopilot.
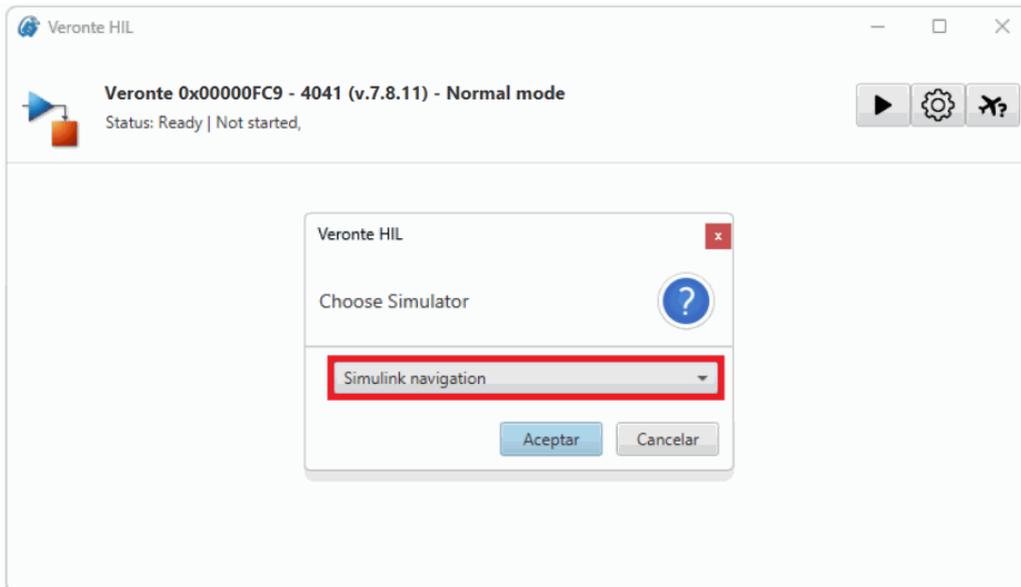
Select Simulink Navigation

With this simulation option, users can integrate the autopilot into their Simulink workspace, achieving a simulation as flexible and complex as they intend to design in this environment.

> ⬦ **Important**
>
> **HIL Simulator** is the tool to establish the connection between **Veronte Autopilot** and a **simulation Simulink model**. The design of the undertaken simulation in Simulink must be programmed by users according to their considerations.

This section summarizes the operation with **Simulink Navigation**.

Data blocks

The communication of Veronte Autopilot and the model of Simulink is done through customized Simulink blocks: Data Sender and Data Receiver. These

blocks must be added and configured in Simulink in order to establish this communication.
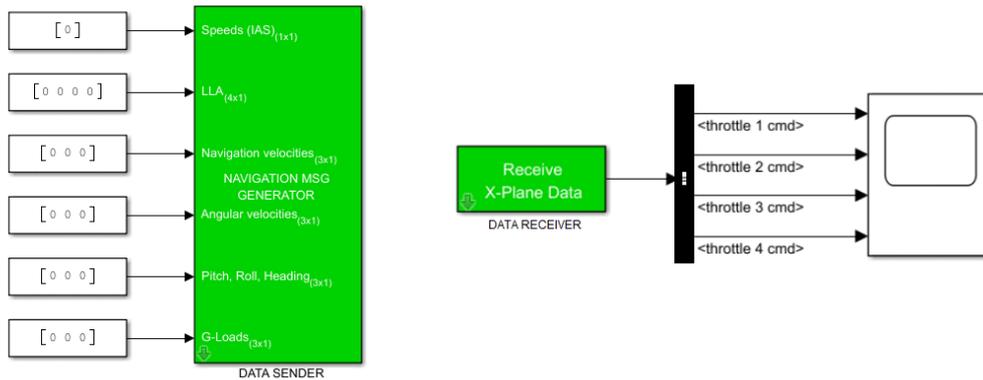
Data Sender & Data Receiver

> ⓘ **Note**
>
> Data blocks are provided as an asset of **HIL Simulator Release**. For additional details on accessing and downloading the software release, consult the Releases section of the **Joint Collaboration Framework** manual.

Data blocks are blocks of Simulink configured to send or receive certain parameters from the autopilot, allowing the analysis of an **Autopilot 1x** in the designed simulation. The following diagram summarizes how HIL Simulator operates with Simulink workspace:

Simulink Navigation diagram

Data Sender configuration

The Data Sender block has the following inputs:

Field	Input size	Required signal format
Speeds	1x1	IAS (knots)
LLA	4x1	

| Field	Input size	Required signal format
		Latitude (deg), Longitude (deg), Altitude MSL (ft.), Altitude AGL (ft.)
Navigation velocity	3x1	Velocities East, -Down, -North (m/s) **Important** Some of the fields are inverted (-)
Angular velocity	3x1	Pitch rate, Roll rate, Yaw rate (rad/s) **Note** All in body-axis
Pitch, Roll, Heading	3x1	Pitch, Roll, Yaw (deg) **Note** All in body-axis euler angles
G-Load	3x1	-gNormal, gAxial, gLateral (g) **Important** Some of the fields are inverted (-).

Steps to send these parameters to Veronte Autopilot:

In Simulink:

1. Ensure that the inputs have the required format and size detailed in the table above.
2. In the **Block Parameters** menu of the Data Sender block, configure the IP and Port entries according to HIL configuration.

> ⚠ **Warning**
>
> In the Data Sender block, the 'Port' corresponds to HIL 'Receive Port'.
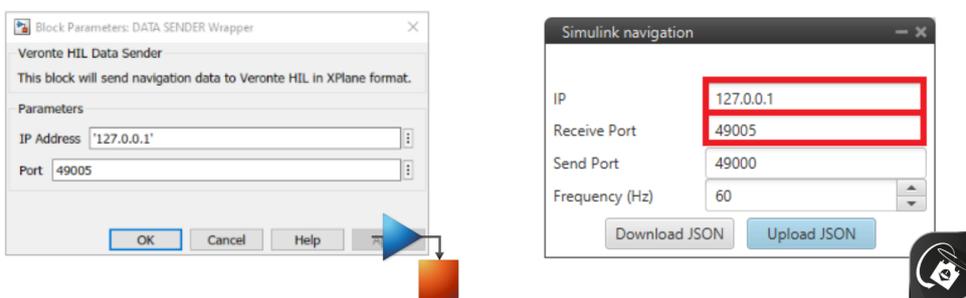
Simulink Navigation - Data Sender configuration

In 1x PDI Builder:

1. In **HIL** menu, configure the variables the Autopilot 1x must receive from Simulink simulation apart from the navigation variables.

> ◈ **Important**
>
> Navigation variables are automatically shared through HIL (received by 1x). Additional variables to receive will depend on the simulation design and purpose. This is an example.

1x PDI Builder - HIL configuration

For more information about this configuration, consult HIL - Configuration section of **1x PDI Builder** manual.

Data Receiver configuration

Steps to receive parameters from Veronte Autopilot:

In 1x PDI Builder:

1. In **HIL** menu, configure the variables the Autopilot 1x must send to Simulink simulation.

   > ⓘ **Note**
   >
   > The variables to send will depend on the simulation design and purpose. This is an example.
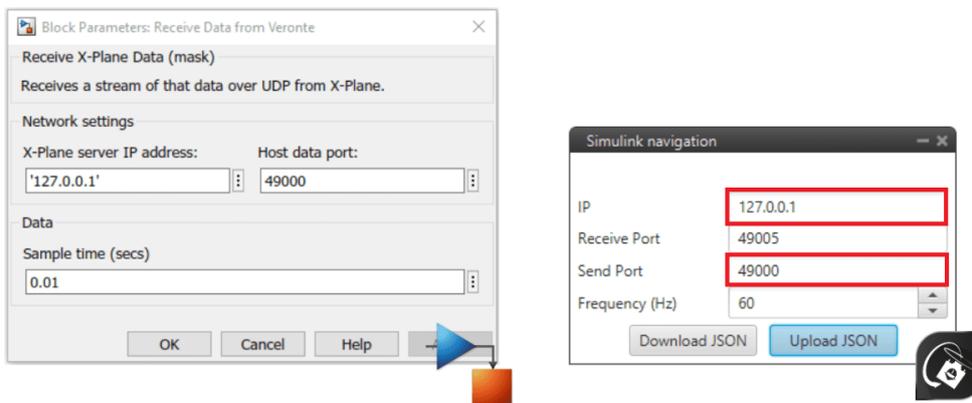
   1x PDI Builder - HIL configuration

In Simulink:

1. In the **Block Parameters** menu of the Data Receiver block, configure the IP and Port entries according to HIL configuration.

   > ⚠ **Warning**
   >
   > In the Data Receiver block, the 'Host data port' corresponds to HIL 'Send Port'.

   Simulink Navigation - Data Receiver configuration

2. To access the received variables independently, a **Bus Selector** block may be added to the Data Receiver block.

   This block outputs the selected elements separately, acting as a filter of the received values. In order to select the desired variables, open the **Block Parameters** menu of the Bus Selector. This is an example:

   Bus Selector block - Parameters

Simulation

For running the simulation in Simulink software:

1. **Run the designed Simulink model** by clickin on ▷ .

2. **Start HIL simulation**. Once Simulink is configured and running, click on ▶ of **HIL Simulator** to enable the sending of commands.

Integration examples

HIL with radiolink

If users want to do simulations via HIL with the 1x air unit and a PCS, they must setup the 1x air unit to a PC running X-Plane, and have a separate PC with the PCS connected acting as the ground station operating with Veronte Ops.

In this way, users have a **PC + 1x air** acting as the **aircraft, flight controller** and **environment**, and the **PC + PCS** as the **ground station**.

> ⓘ **Note**
>
> This example is described for a PCS as a ground control station, however, this could also be a LCS or an Autopilot 1x used as GND.

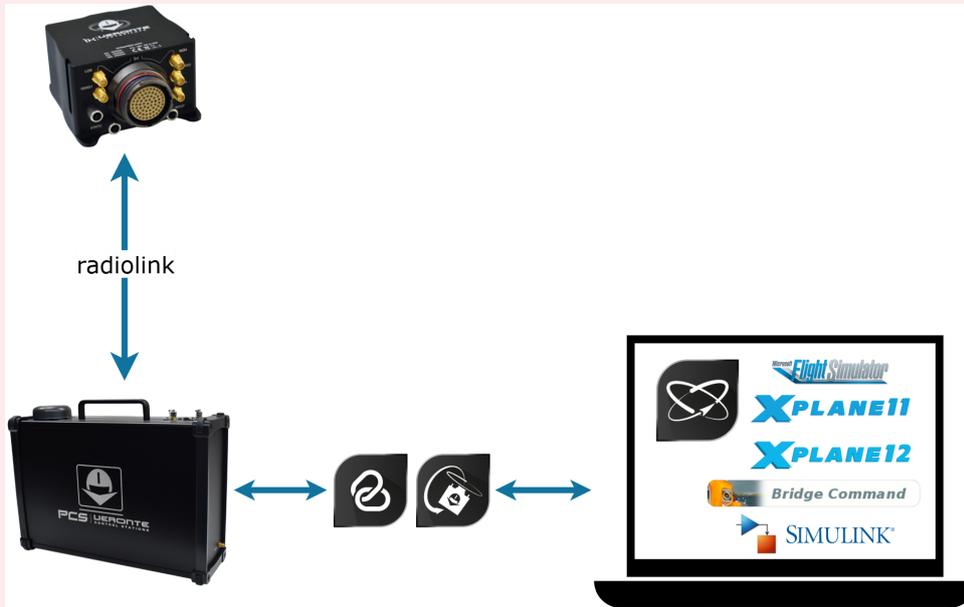The following diagram summarizes this connection:
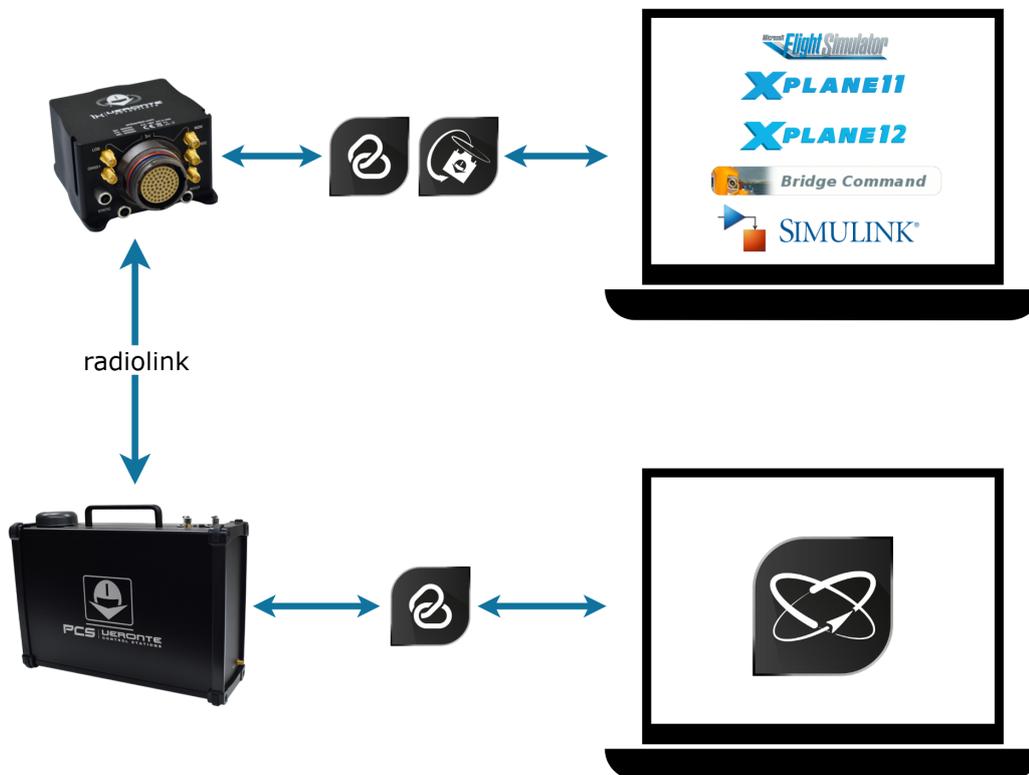
HIL with radiolink diagram

> ⚠ **Error**
>
> The following setup does not ensure a representative simulation of the real scenario, since transfering simulation data over radio may cause undesired behavior due to retarded processing.
>
>
>
> **HIL with radiolink wrong diagram**

Troubleshooting

Fixing inactive aircraft functions in X-Plane

If an X-Plane user experiences inactive aircraft functions or encounters issues, such as the JATO takeoff feature not activating, malfunctioning avionics, flight controls not responding, or other system glitches, they may be able to resolve these problems by **restarting the flight** and **reloading the aircraft**.

Restarting the flight resets the simulation environment, and reloading the aircraft refreshes its systems and configurations, potentially fixing glitches that occurred during the initial load.

To resolve these issues, follow these steps:

1. Restart the flight:
    - Go to the **Flight Configuration** menu.

    Flight configuration option

    - Choose the desired **location** and select **Start New Flight**:

    Flight configuration - Location

2. Reload the current aircraft:
    - Go to the **Developer** menu ⇒ Select **Reload the Current Aircraft (Skip Art Reload)**.

    Reload current aircraft - Developer

    - Alternatively, the user can create a **keyboard shortcut** to facilitate reloading the aircraft. To do this:

    Open the **Settings window**.

    Settings option

    Go to Keyboard ⇒ Operation ⇒ **Force reloading the current aircraft (skip art reload)**.

    Define a custom keyboard shortcut:

    Keyboard - Settings

> ⓘ **Note**
>
> In this example the letter "d" has been chosen for the keyboard shortcut, however the user can choose any letter.

Simulation with X-Plane does not start

The first time users run HIL Simulator with X-Plane 11, the simulation may not start. This is usually caused by a misconfiguration, please check the following settings in **X-Plane**:

- In **Setting** ⇒ **Network** ⇒ **UDP PORTS**:
  - Use UPnP for IPv4 port forwarding: **Disabled**
  - Port we receive on: **49010**
  - Port we receive on (legacy): **49000**
  - Port we send from (legacy): **49001**

  Network settings

- In **Setting** ⇒ **Data Output** ⇒ **NETWORK CONFIGURATION**:
  - Send network data output: **Enabled**
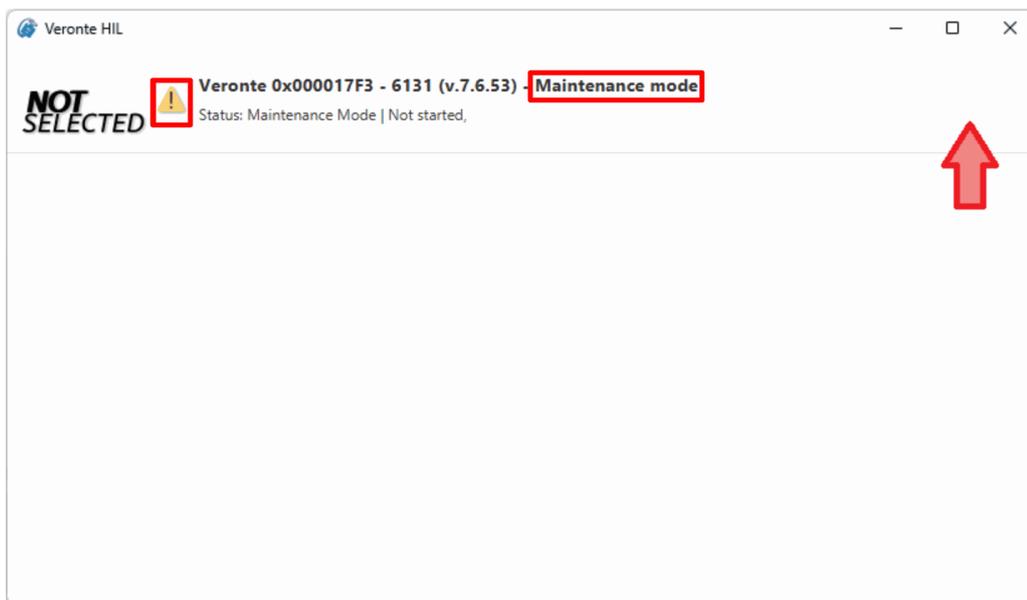 - IP Address: **127.0.0.1**
  - Port: **49005**

  Data Output settings

Unable to start HIL Simulation

HIL Simulation can only start if the autopilot is in **Normal mode**.

In the main page of **HIL Simulator**, the autopilot mode is indicated:

- Normal mode
- Maintenance mode
- Maintenance mode (loaded with errors)

Autopilot 1x mode

For further information on how to proceed to set the autopilot to Normal mode, please consult the Maintenance mode and Maintenance mode (loaded with errors) - Troubleshooting section of the **1x PDI Builder** user manual.

Software Changelog

This section presents the changes between the previous software version **v. 7.6.14** and the current one **v.7.8.6**.

Improved

- Updated the software to ensure full compatibility and proper functionality with all other products in the v.7.8 release.

Software Changelog