MAINTENANCE MANUAL

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Installation

Prerequisites

- EMLID Real-Time Linux Image (or Raspbian for testing purposes)
- MATLAB 2015 or later with Simulink

Installing SimuCopter

Step 1: Clone the repository onto the Raspberry Pi

```
/home/pi$ git clone https://github.com/icedraco/simucopter-bridge.git
```

Step 2: Run the installer script on the Raspberry Pi

```
/home/pi$ cd simucopter-bridge
/home/pi/simucopter-bridge$ bash install.sh
...
```

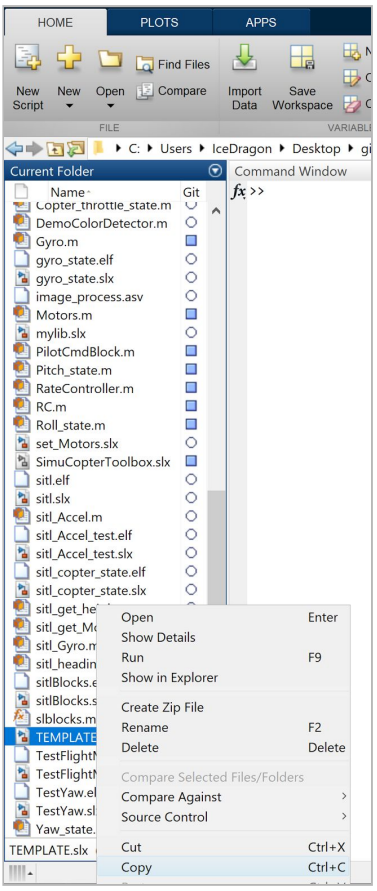
The installer script will automatically check for the presence of **ardupilot** and offer to download it if missing. The script will also augment said ardupilot installation to work with the SimuCopter system.

Step 3: Download simucopter-matlab onto the PC/control station

The directory is a part of the **simucopter-bridge** repository and can be safely extracted from within it onto the PC via an SCP file transfer. Be sure to do this **AFTER** you run the installer!

```
WINDOWS/Desktop$ scp pi@10.66.66.254:simucopter-bridge/simucopter-matlab ./
```

Creating a Flight Mode Diagram



Creating from a template (recommended)

1. Locate the **TEMPLATE.slx** file in the **simucopter-matlab** directory.
2. Copy the **TEMPLATE.slx** file, then Paste it into the same location.
3. Rename the **Copy of TEMPLATE.slx** file into a flight mode.
4. Double-click the renamed SLX file to open a Simulink window, and start designing your new flight mode diagram. The diagram should be preconfigured to work with SimuCopter on a Raspberry Pi.

NOTE:

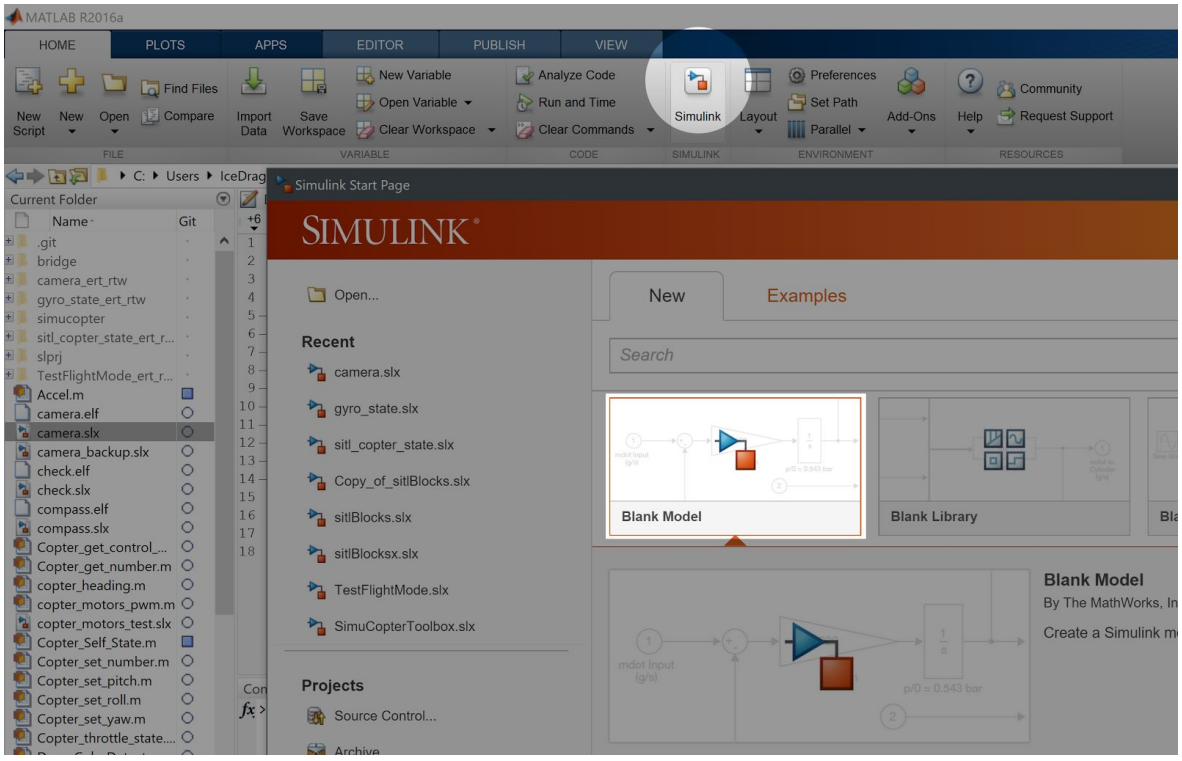
Be sure to check the **Board Parameters** in the **Tools** -> **Options** window:

- The correct IP and credentials should be set.
- The flight mode is deployed to SITL by default! If you need to use it on physical hardware (navio), be sure to follow the instructions in the NAVIO Mode section!

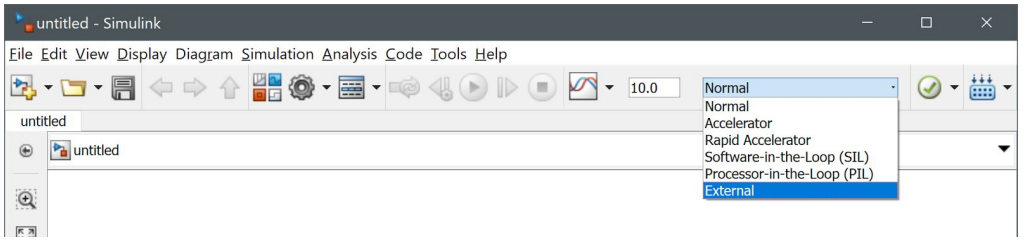
Creating from scratch

While it is much easier to use a template, in an event and the template file is damaged, or missing, the following instructions will help you to reconstruct the template model.

Step 1: Create a blank Simulink model

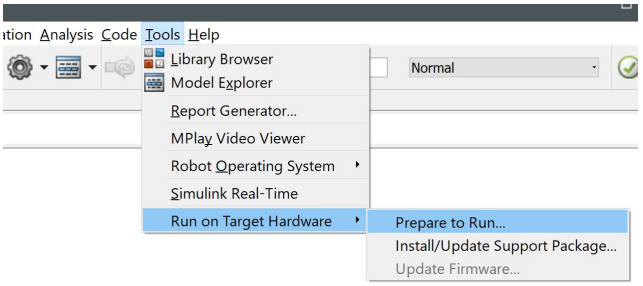


Step 2: Change execution mode to External



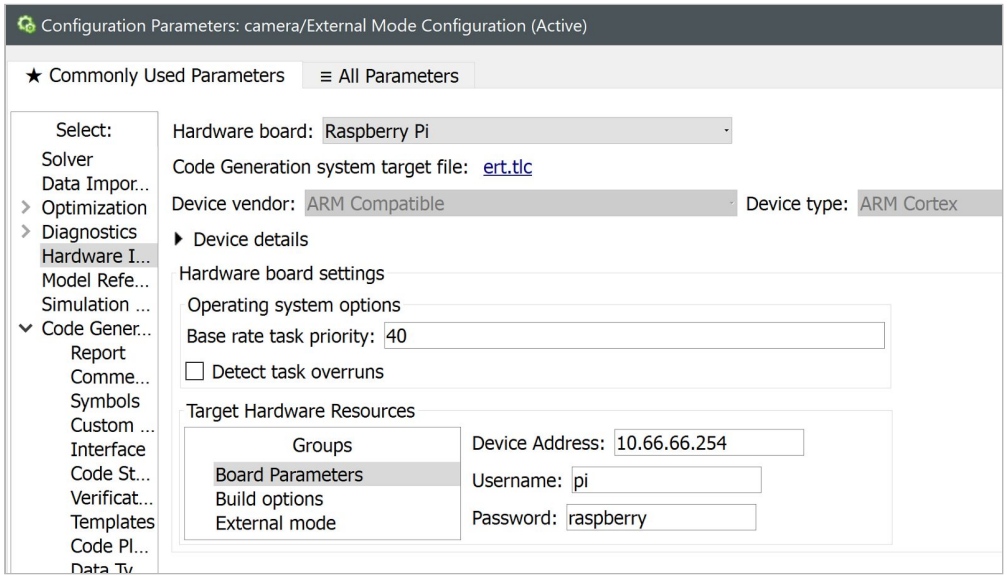
Step 3: Configure model

Click **Tools -> Run on Target Hardware -> Prepare to run** to prepare, and open the Configuration Parameters window.



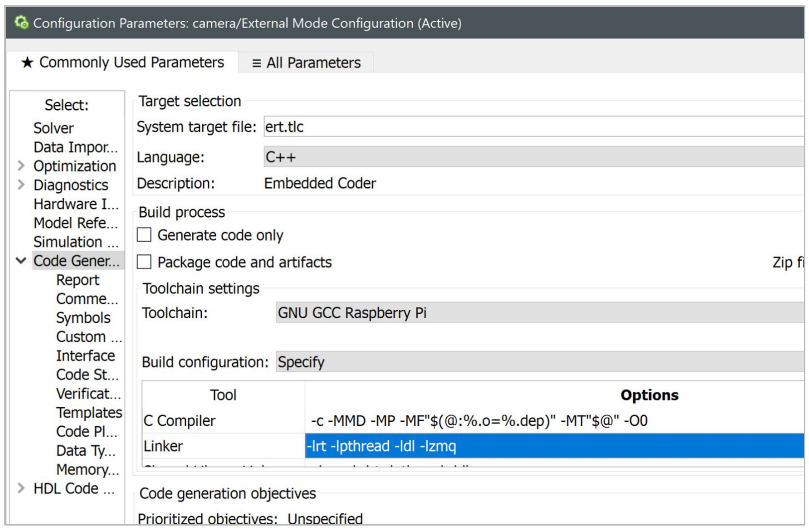
Modify only the sections/settings mentioned below and leave the rest as default, unless you have a reason not to...

Section: Hardware Implementation



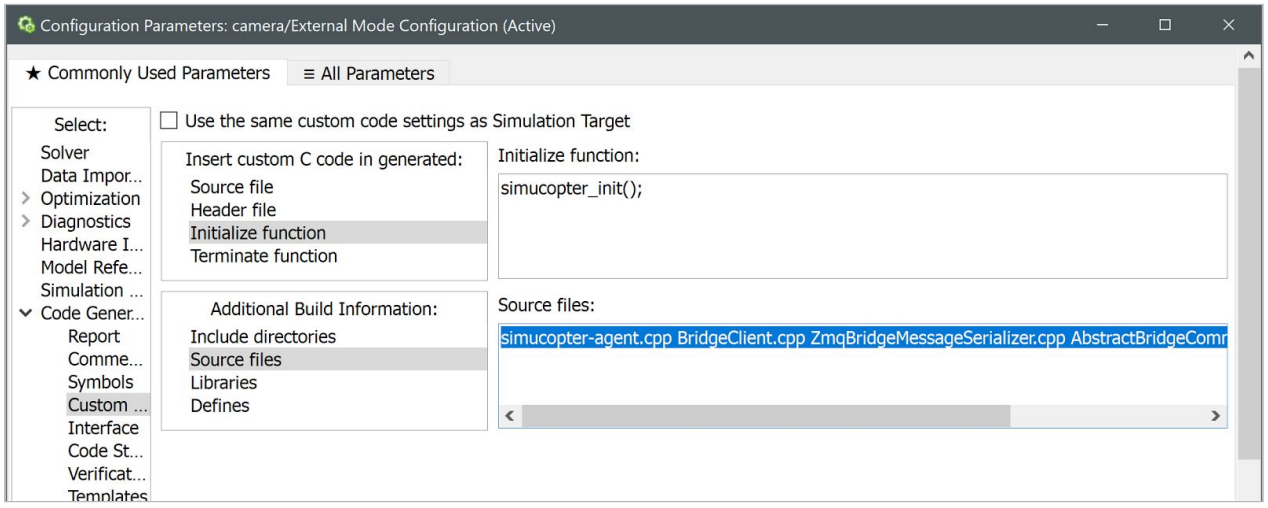
- Change **Hardware board** to be **Raspberry Pi**
- Configure **Target Hardware Resources** section below as follows:
    - **Board Parameters**:
        - Device Address: IP address of the Raspberry Pi (e.g.: **10.66.66.254**)
        - Username: username to log into (default: **pi**)
        - Password: password to log in with (default: **raspberry**)
    - **Build Options**:
        - Build Action: **Build and run**
        - Build directory: **/home/pi/simucopter**

Section: Code Generation



- Language: **C++**
- Build configuration: **Specify**
    - Linker: **-lrt -lpthread -ldl -lzmq**
    - C++ Linker: **-lrt -lpthread -ldl -lzmq**

Section: Code Generation / Custom Code



- Insert custom C code in generated:
    - Source file: *Nothing*
    - Header file: *Nothing*
    - Initialize function: **simucopter_init();**
    - Terminate function: **simucopter_stop();**
- Additional Build Information:
    - Include directories(space-separated):
      simucopter bridge
    - Source files (space-separated):
      simucopter-agent.cpp BridgeClient.cpp BridgeMessage.cpp ZmqBridgeMessageSerializer.cpp AbstractBridgeCommandHandler.cpp
    - Libraries: *Nothing*
    - Defines: **SIMULINK_AGENT**

Section: Code Generation / Interface

- Code interface packaging: **Nonreusable function**

Any configuration not mentioned here can be left as-is.

NOTE
Don't mistake the **Simulation Target** section with **Code Generation / Custom Code**! Both sections appear the same. However, the former is supposed to remain empty (unless you yourself have a reason to reconfigure it) while the latter is to be configured as mentioned above!

At this point, you should have re-created the model template from the "Creating from a template" step. You may proceed from there in creating your Flight Mode Diagram.

Switching ArduPilot Modes (SITL / NAVIO)

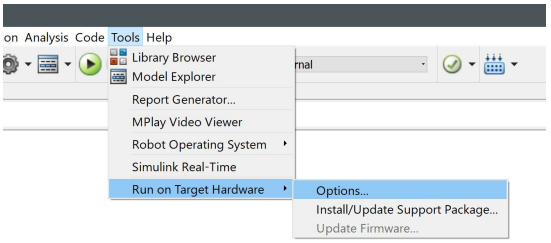
The system can be configured to work in SITL (software-in-the-loop / "simulation") mode or in NAVIO (hardware) mode.

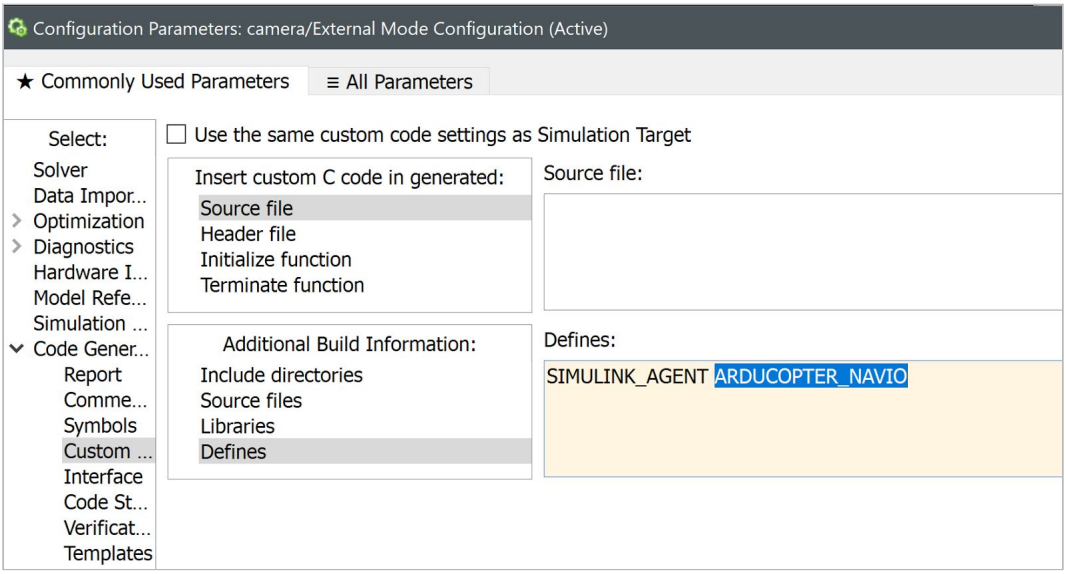
NAVIO Mode

In short: define **ARDUCOPTER_NAVIO** in the Simulink model configuration

Procedure:

1. Click **Tools** → **Run on Target Hardware** → **Options...**
2. Select **Code Generation** / **Custom Code**
3. In **Defines** section, add the string: **ARDUPILOT_NAVIO**





SITL Mode

This mode is used by default. In order to return to it, undo the instructions for NAVIO mode above.

TIP: See **simucopter-agent.cpp** to understand how the two modes are activated.

NOTE
Switching between SITL and NAVIO modes requires a lengthy recompilation process of the ArduPilot software! It may take several minutes for the first Simulink flight mode deployment to work!

You can monitor the progress of the compilation from the Raspberry Pi device by reading the log file of the flight mode (the name is usually the same as the SLX filename):

```
pi$ tail -f ~/FlightModeName.log
```

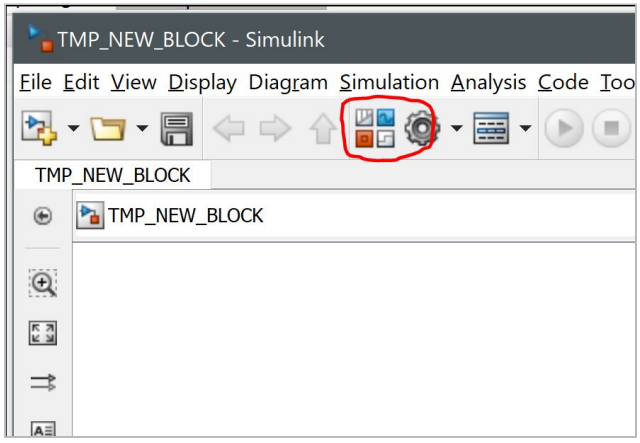
Adding Simulink Blocks (GETTER / SENSOR BLOCKS)

Getter (or Sensor) blocks read data from ArduPilot sensors on demand, and supply the readings back to Simulink. These blocks only have OUTPUT channels!

If you need to create a SETTER / ACTUATOR block, check the SETTER / ACTUATOR BLOCKS section!

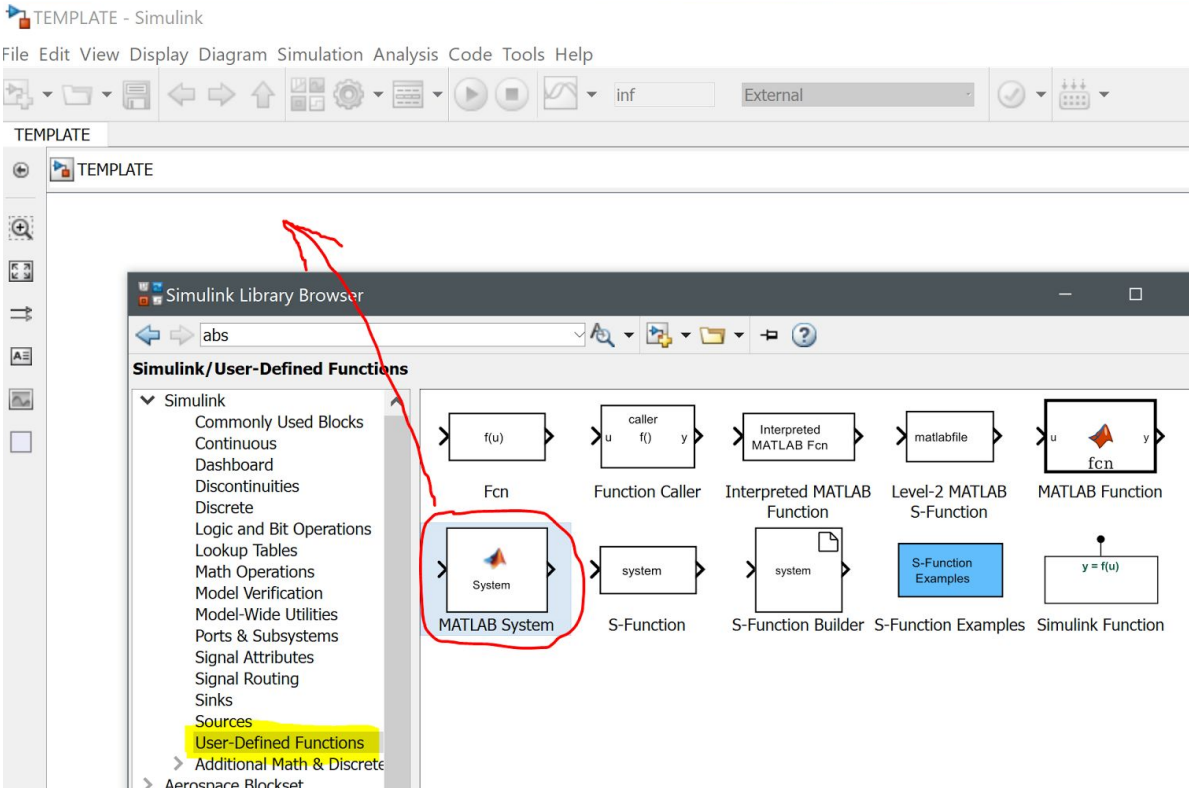
Simulink Side

Click the Block Library icon in a Simulink Model window

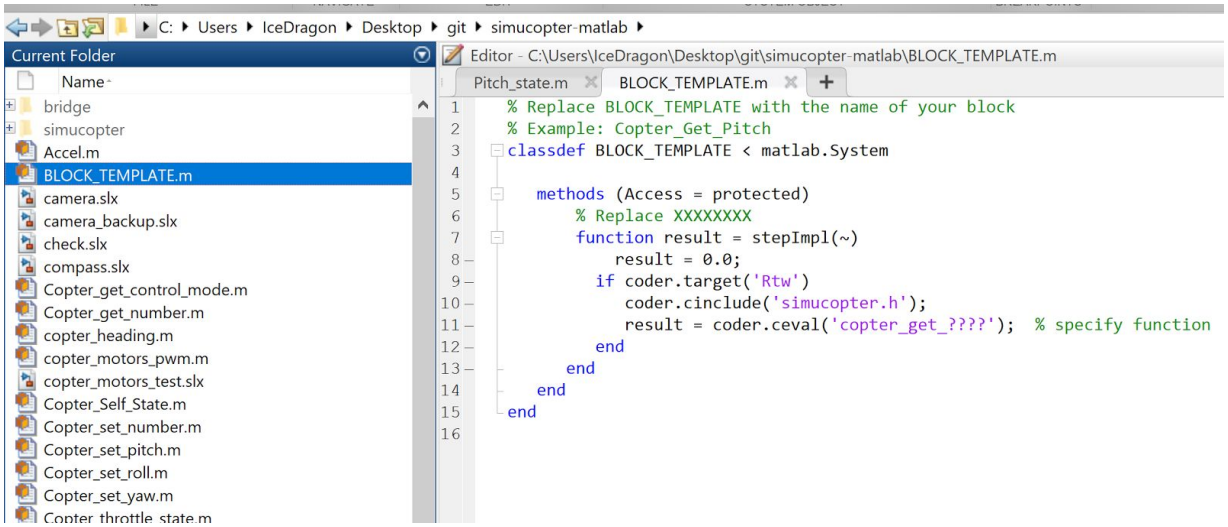


Add a user-defined function block to the model

Select the "User-Defined Functions" section in the Simulink Library Browser, and drag the **MATLAB System** block onto the model window:



Create a new .m file for the block



Use the **BLOCK_TEMPLATE.m** file to create the code that the new block is going to execute:

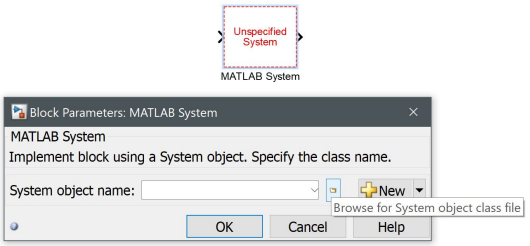
- Right-click the **BLOCK_TEMPLATE.m** file, select Copy, then paste into the same folder.
- Rename the new **Copy of BLOCK_TEMPLATE.m** file into the name of the block you are going to create. For example: **Copter_Get_Pitch.m** if your block name is going to be **Copter_Get_Pitch**.
- Double-click the .m file in order to edit it.
- Change the **classdef** string to match the name of your block (e.g., from **BLOCK_TEMPLATE** into **Copter_Get_Pitch**)
- Change the **copter_get_????** string to the name of the C function that this block will execute. In our case, we name it **copter_get_pitch**.

IMPORTANT
Code executed solely on the Raspberry Pi **MUST** be inside the "coder.target('Rtw')" if block! Failing to do so will result in Simulink trying to compile locally (i.e., on Windows) code that does not exist!

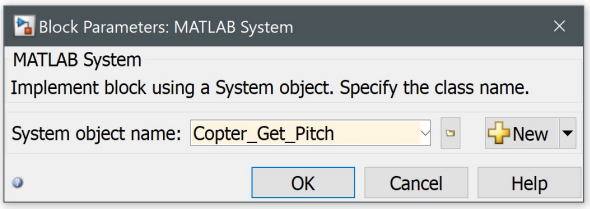
Example Code

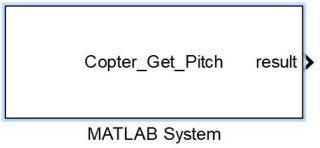
```
% Replace BLOCK_TEMPLATE with the name of your block
% Example: Copter_Get_Pitch
% NOTE:      This name must match the filename! (Copter_Get_Pitch.m)
classdef BLOCK_TEMPLATE < matlab.System
   methods (Access = protected)
       function result = stepImpl(~)
         result = 0.0;
         if coder.target('Rtw')
              coder.cinclude('simucopter.h');
              result = coder.ceval('copter_get_????');  % specify function
         end
       end
   end
end
```

Associate the block code file with the block itself

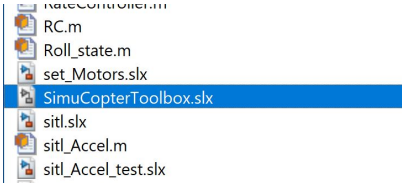


- Double-click the new (currently red) block you've created to get the Block Parameters dialog.
- Click the "Browse" (folder) button and select the newly created **Copter_Get_Pitch.m** file inside.
- Click OK to associate the code with the block.

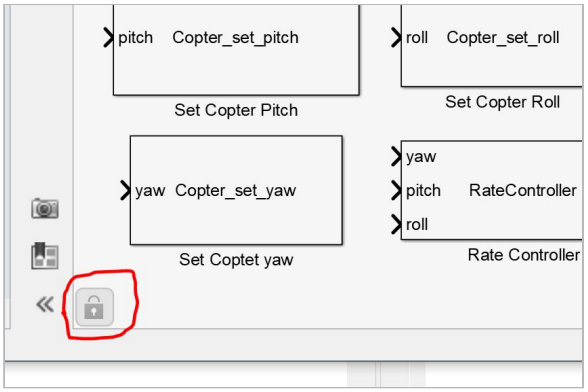


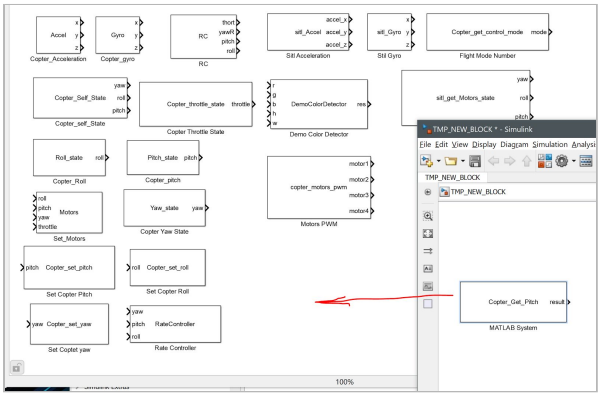


Add the newly created block to the SimuCopter Block Library



- Locate and double-click the **SimuCopterToolbox.slx** file in the left-hand file list; double-click it.
- Click the small "lock" icon in the bottom-left corner of the window.
- Drag the newly created block from the model window into the SimuCopterToolbox window.
- Re-activate the lock and save changes.





At this point, you have created a Simulink block. However, you still need to add support for it in the backend!

SimuCopter - Client Side

You are now going to edit the files/code used by the client side of the SimuCopter system: the side that is ran by the Simulink Agent executable. The files/code you are about to edit must be available to the Simulink software on your PC (i.e., the **simucopter-bridge/simucopter/** folder on Windows)!

simucopter.h

Add a declaration to the header file for the function you defined in the **.m** file. The name is the same as the name in the string:

```
double copter_get_pitch();
```

simucopter-agent.cpp

Add a definition of the **copter_get_pitch** function that calls a corresponding method of the ArduPilot Bridge Client:

```
double copter_get_pitch() {
    return G_ARDUPILOT->get_pitch();
}
```

SimuCopterMessage.h

Add a new SimuCopterMessage ID:

```
GET_PITCH = 0x6666;
```

IMPORTANT
Copy **SimuCopterMessage.h** to the other side!
This will make sure that both - Simulink Agent and ArduCopter understand this message ID!

SimulinkBridgeinterface.h

Add an inline method that requests a double from the SimuCopter server:

```
inline double get_pitch() { return m_client->request_double(SimuCopterMessage::GET_PITCH); };
```

SimuCopter - ArduPilot Side

Now it's time to edit the files/code used by the server side of the SimuCopter system: the side that is ran by ArduPilot. The files/code you are about to edit must be available to the ArduPilot software on the Raspberry Pi!

ArduCopterRequestHandler.cpp

- In the **register_self** method, add a line that shows that you can handle the new **GET_PITCH** message: **service.set_request_handler(SimuCopterMessage::GET_PITCH, this);**

```
void SIMUCOPTER::ArduCopterRequestHandler::register_self(BridgeService &service) {
   /**
    * NOTE: WE DO NOT PUT THE SET_* MESSAGES HERE, AS THEY ARE NOT
    *       CONSIDERED REQUESTS THAT MUST RETURN A VALUE!
    *       ADD THEM TO THE COMMAND HANDLER INSTEAD!
    */

   service.set_request_handler(SimuCopterMessage::GET_FLIGHT_MODE, this);
   ...
   service.set_request_handler(SimuCopterMessage::GET_PITCH, this);
}
```

- In the **handle** method add a case that handles the aforementioned request.
  See available code in that file for an example.

```
void SIMUCOPTER::ArduCopterRequestHandler::handle(const BridgeMessage &msg, ...) {
   assert(msg.type == BridgeMessageType::REQUEST);
   double result;
   float target_roll, target_pitch, target_yaw;  // desired angles (GET_DESIRED_*)

   switch ((SimuCopterMessage)msg.id) {
   ...
   case SimuCopterMessage::GET_PITCH:
       result = copter.ahrs.pitch;
       break;
   ...
   }
}
```

Recompile ArduPilot

```
cd ~/ardupilot
./waf build --target bin/arducopter -j 4
```

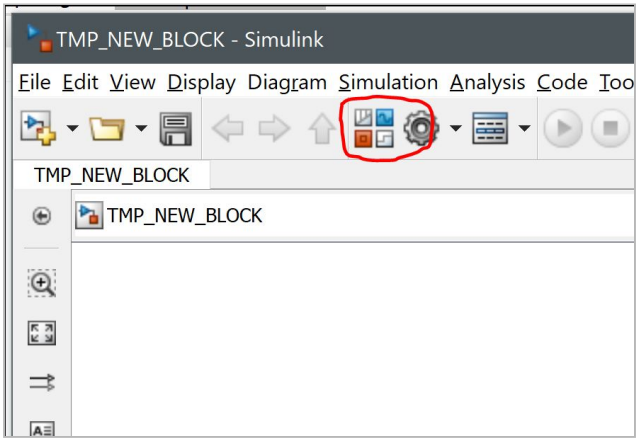
Adding Simulink Blocks (SETTER / ACTUATOR BLOCKS)

Setter (or Actuator) blocks write/send data to ArduPilot actuators on demand from Simulink. These blocks only have INPUT channels!

If you need to create a GETTER / SENSOR block, check the GETTER / SENSOR BLOCKS section!

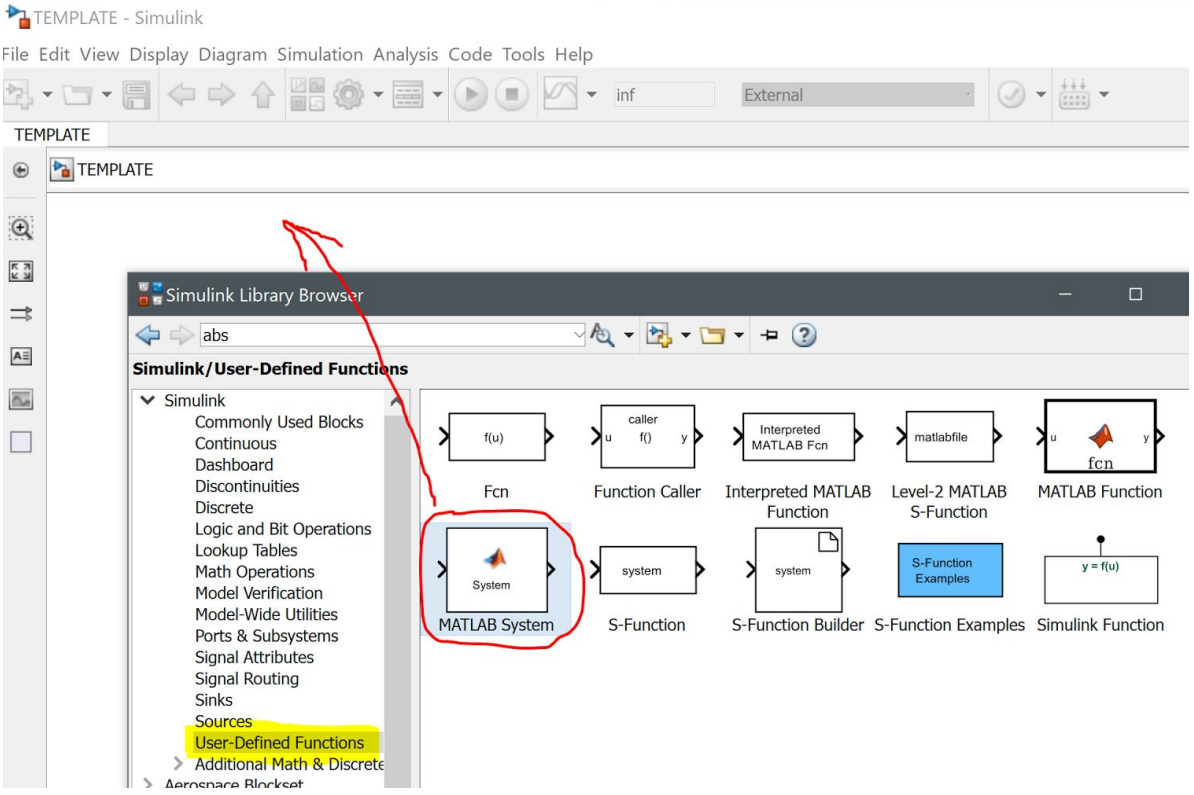
Simulink Side

Click the Block Library icon in a Simulink Model window

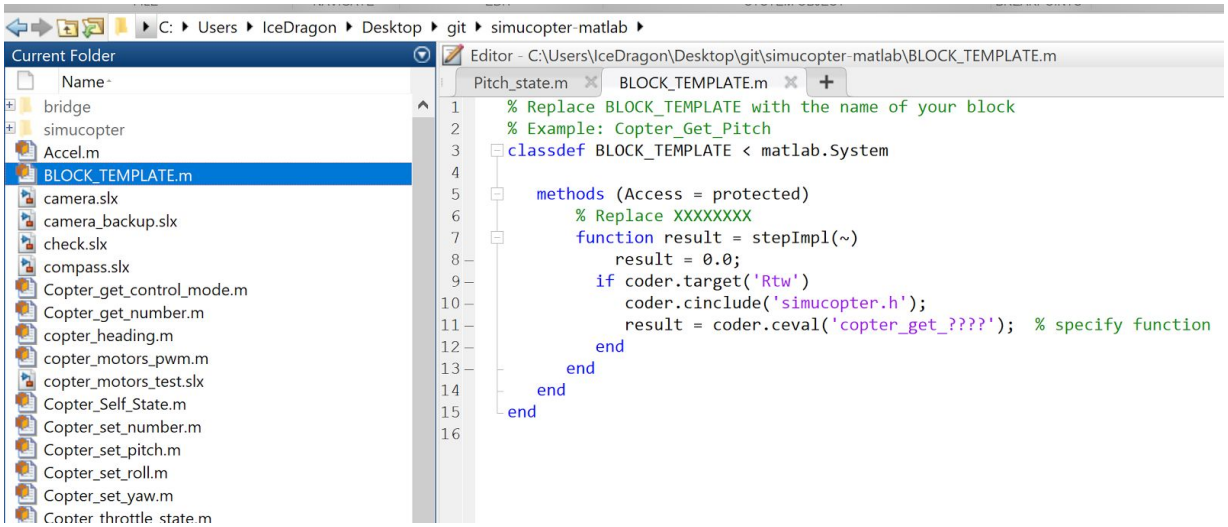


Add a user-defined function block to the model

Select the "User-Defined Functions" section in the Simulink Library Browser, and drag the **MATLAB System** block onto the model window:



Create a new .m file for the block



Use the **BLOCK_TEMPLATE.m** file to create the code that the new block is going to execute:

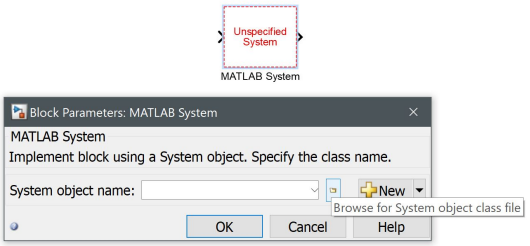
- Right-click the **BLOCK_TEMPLATE.m** file, select Copy, then paste into the same folder.
- Rename the new **Copy of BLOCK_TEMPLATE.m** file into the name of the block you are going to create. For example: **Copter_Set_Pitch.m** if your block name is going to be **Copter_Set_Pitch**.
- Double-click the .m file in order to edit it.
- Replace the code within with the example code below.
- Change hilighted areas to suit your needs, where **Copter_set_pitch** is the block name, and **copter_motors_set_pitch** is a C function with one argument of type **double** to pass data to.

IMPORTANT
Code executed solely on the Raspberry Pi **MUST** be inside the "coder.target('Rtw')" if block! Failing to do so will result in Simulink trying to compile locally (i.e., on Windows) code that does not exist!

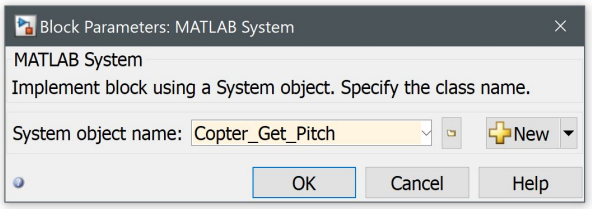
Example Code

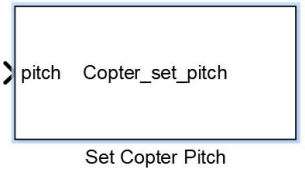
```
classdef Copter_set_pitch < matlab.System
    methods (Access = protected)
        function stepImpl(obj, pitch)
            if coder.target('Rtw')
                coder.cinclude('simucopter.h');
                coder.ceval('copter_motors_set_pitch', pitch);
            end
        end
    end
end
```

Associate the block code file with the block itself

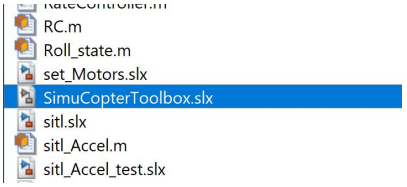


- Double-click the new (currently red) block you've created to get the Block Parameters dialog.
- Click the "Browse" (folder) button and select the newly created **Copter_Set_Pitch.m** file inside.
- Click OK to associate the code with the block.





Add the newly created block to the SimuCopter Block Library



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- Click the small "lock" icon in the bottom-left corner of the window.
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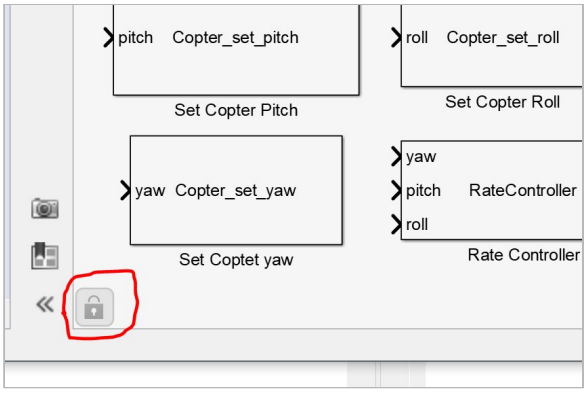
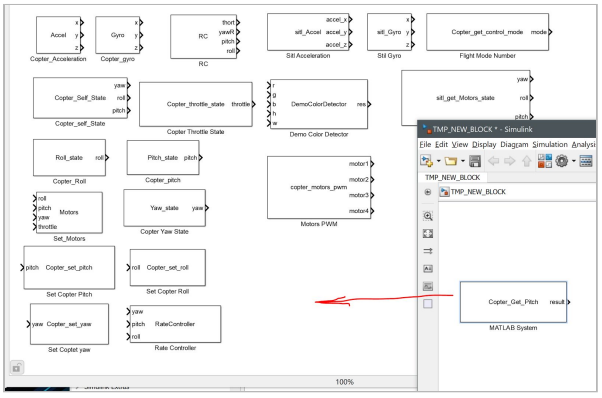




At this point, you have created a Simulink block. However, you still need to add support for it in the backend!

SimuCopter - Client Side

You are now going to edit the files/code used by the client side of the SimuCopter system: the side that is ran by the Simulink Agent executable. The files/code you are about to edit must be available to the Simulink software on your PC (i.e., the **simucopter-bridge/simucopter/** folder on Windows)!

simucopter.h

Add a declaration to the header file for the function you defined in the **.m** file. The name is the same as the name in the string:

```
void copter_motors_set_pitch(double pitch);
```

simucopter-agent.cpp

Add a definition of the **copter_set_pitch** function that calls a corresponding method of the ArduPilot Bridge Client:

```
double copter_motors_set_pitch() {
    G_ARDUPILOT->motors_set_pitch(pitch;
}
```

SimuCopterMessage.h

Add a new SimuCopterMessage ID:

```
SET_PITCH = 0x6667;
```

IMPORTANT
Copy **SimuCopterMessage.h** to the other side!
This will make sure that both - Simulink Agent and ArduCopter understand this message ID!

SimulinkBridgeinterface.h

Add an inline method that sends a command with the pitch argument to the SimuCopter service:

```
inline void motors_set_pitch(double pitch) {
    m_client->send_command(SimuCopterMessage::SET_PITCH, pitch);
};
```

SimuCopter - ArduPilot Side

Now it's time to edit the files/code used by the server side of the SimuCopter system: the side that is ran by ArduPilot. The files/code you are about to edit must be available to the ArduPilot software on the Raspberry Pi!

ArduCopterCommandHandler.cpp

- In the **do_handle** method, add a case that handles the new **SET_PITCH** command:

```
static void do_handle(int cmdid, double arg) {
   switch (cmdid) {
   ...
   case SIMUCOPTER::SimuCopterMessage::SET_PITCH:
       copter.motors->set_pitch(arg);
       break;
   ...
}
```

- In the **handle** method add a case that allows buffering (and later handling) of the command:

```
void SIMUCOPTER::ArduCopterCommandHandler::handle(const BridgeMessage &cmd) {
    ...
    switch ((SimuCopterMessage)cmd.id) {
    ...
    case SimuCopterMessage::SET_RATE_TARGET_YAW:
    case SimuCopterMessage::SET_RATE_TARGET_ROLL:
    case SimuCopterMessage::SET_RATE_TARGET_PITCH:
    case SimuCopterMessage::SET_PITCH:
        m_packer.unpack(cmd.data(), cmd.size(), &arg1);
        m_commandBuffer[cmd.id] = arg1;
        break;
    ...
}
```

Recompile ArduPilot

```
cd ~/ardupilot
./waf build --target bin/arducopter -j 4
```

Adding SITL Blocks (SITL-based Testing)

- SITL blocks are currently implemented in a REQUEST form only - there are no COMMANDs.
- Adding such blocks is a process almost identical to adding GETTER / SENSOR blocks except:
  - Simulink: Use **SitlBridgeInterface.h** instead of SimulinkBridgeInterface.h
  - ArduCopter: Use **SitlRequestHandler.cpp** instead of ArduCopterRequestHandler.cpp
  - Both: Use **sitl_** function name prefix instead of **copter_**
  - DO NOT add setter/actuator blocks - the system does not yet support SITL "commands"!
- See existing SITL blocks and code as an example.

Troubleshooting

Logs & progress

After the flight model is finished "Building" in Simulink, you can view the execution progress on the Raspberry Pi device itself by reading/tail-ing the log file. The log file is normally kept in the home folder (i.e., /home/pi) under the same name as the SLX file that's being activated.

Example

```
tail -f /home/pi/TestFlightMode.log
```

Agent shutdown / killall

If your Simulink is stuck, and you need to shut down the system in order to restart it, you need to kill all the relevant processes still running on the Raspberry Pi. In order to do it, you must perform a **kill** command as a **root** user, taking out both - the Simulink agent (if still running), and ArduPilot executable.

Use the following commands to do so:

```
sudo -i
ps -ef | grep "\.elf -port" | grep -v grep | awk '{print $2}' | xargs kill -9
ps -ef | grep copter | grep -v grep | awk '{print $2}' | xargs kill -9
```

You may want to put these commands in a script, as it isn't rare for such measures to be needed from time to time.

Problem: Segmentation fault on arducopter start (NAVIO mode)

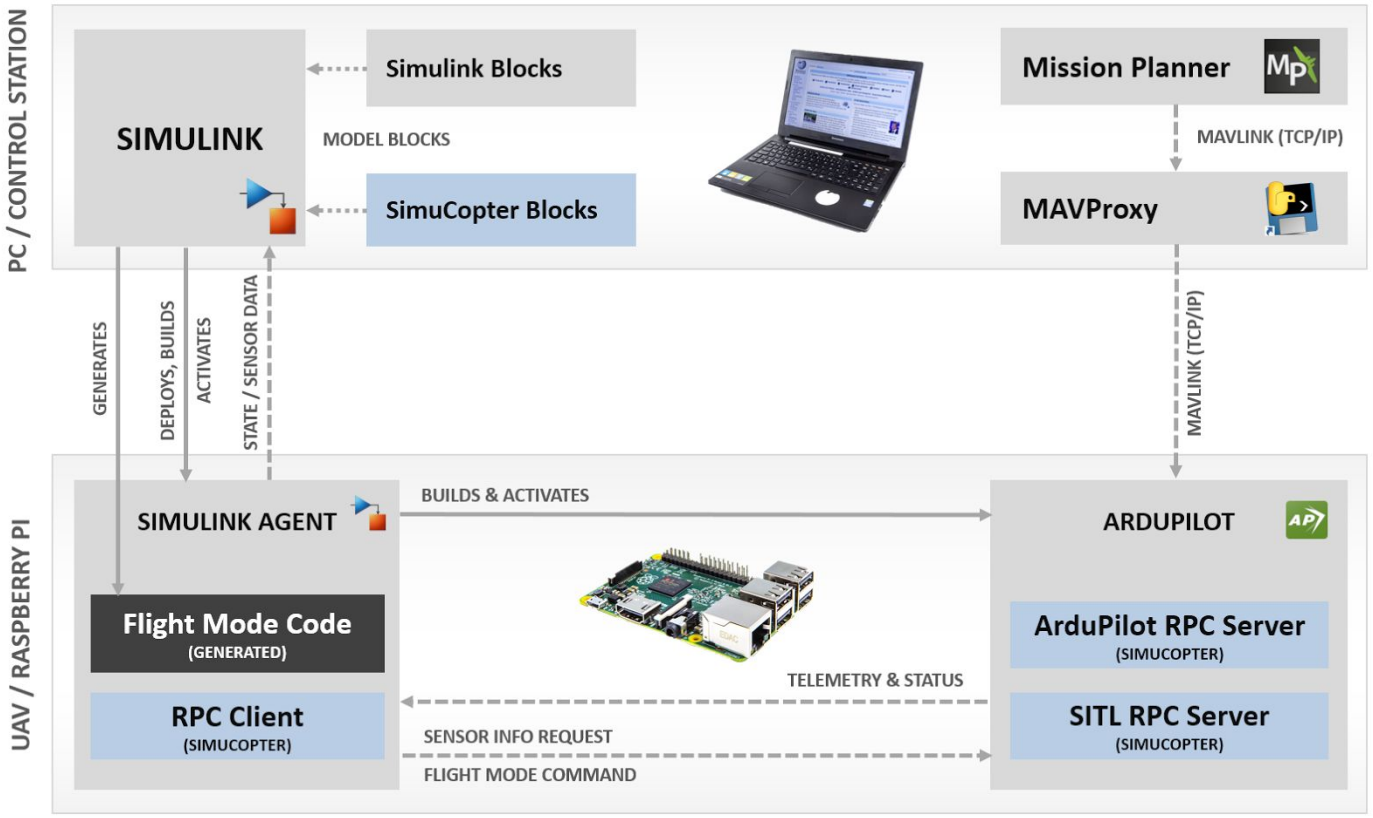
This usually happens if ArduCopter was not launched as root. Use **sudo** in order to launch ArduCopter instead: `sudo ~/ardupilot/build/navio/bin/arducopter -C /dev/ttyAMA0 -A tcp:0.0.0.0:5760`

> **THIS IS NOT THE PROBLEM WITH SPORADIC SEGMENTATION FAULTS AFTER THE STARTUP STAGE! SEE CAVEATS SECTION FOR THE MORE NASTY ISSUE.**

TECHNICAL MANUAL

System Architecture

General

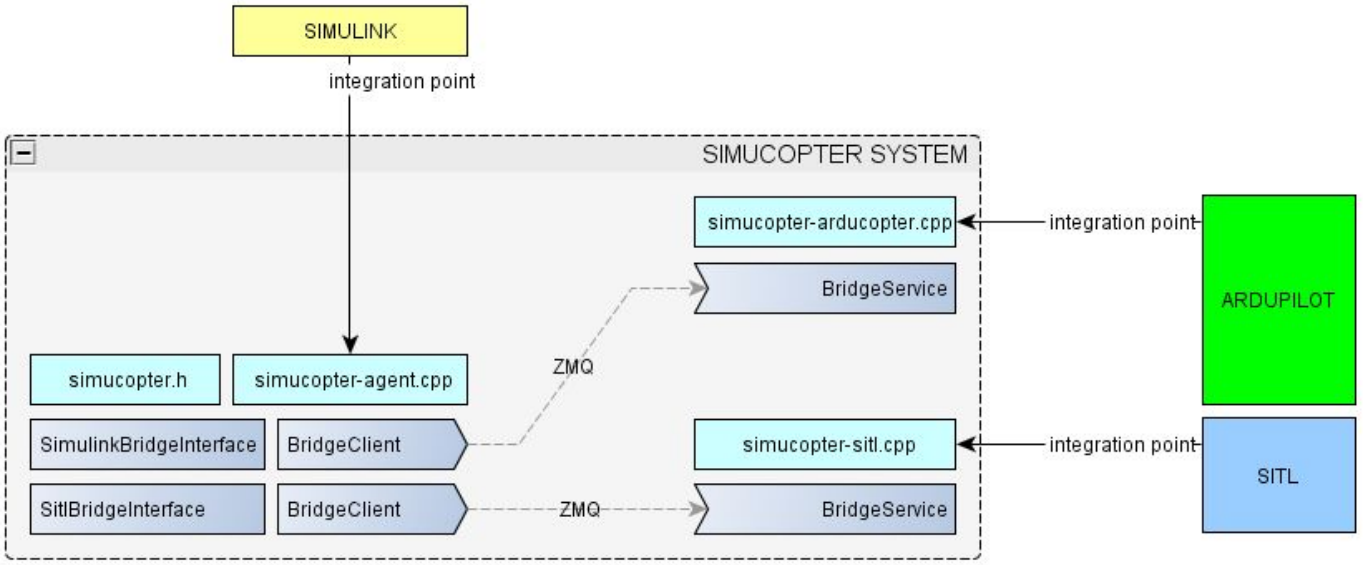


The entire system consists of two sides, both of which are extended by SimuCopter:

- **PC/CONTROL STATION**
  Runs the MATLAB/Simulink software; allows design and live monitoring of flight modes; optional.
  - The **Simulink** software is expanded with ArduPilot-specific "SimuCopter Blocks". Said blocks are used to access ArduPilot in various ways, whether to monitor its state, or even control it.

- **RASPBERRY PI**
  A device/board that sits on top of the UAV; responsible for controlling it. This area has two subcomponents: the **Simulink Agent** and **ArduPilot** itself.
  - **Simulink Agent** is an executable compiled by the **Simulink** software and deployed onto the Raspberry Pi (UAV). It runs on behalf of Simulink, keeps Simulink itself informed via the network, and executes commands on the device itself (including those that control **ArduPilot**).
    - Simulink Agent contains the **Flight Mode Code** that the user designed within it!
    - This component is expanded with RPC-like "bridge" client code that allows it to send messages to **ArduPilot**, as well as receive information about the UAV's current state.
  - **ArduPilot** is the autopilot software with its basic capabilities.
    - This component is expanded with RPC-like "bridge" server code that handles incoming requests/commands, and performs various procedures on demand.

SimuCopter Integration Points



The SimuCopter system extends both sides with communication-related code:

- **ARDUPILOT / SITL**
  Each of the two components is extended with a **Bridge Service** server-like module, whose purpose is to receive requests and commands, handle/execute them, and respond as necessary:
  - The **ARDUPILOT** component interacts with the code in **simucopter-arducopter.cpp**
    The initialization code is located in **ardupilot/ArduCopter/system.cpp**
  - The **SITL** component interacts with the code in **simucopter-sitl.cpp**
    The initialization code is located in **ardupilot/libraries/AP_HAL_SITL/HAL_SITL_Class.cpp**

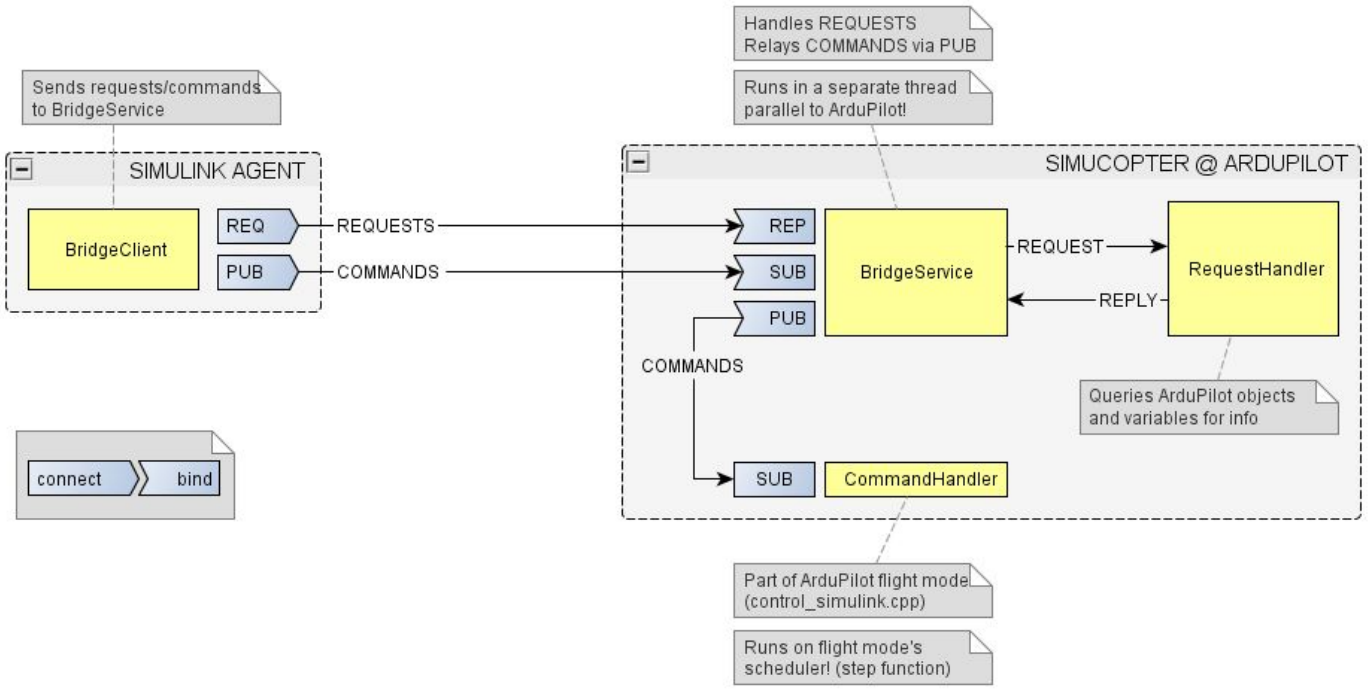
  The code at these integration points enable communication with **SIMULINK**.

- **SIMULINK**
  Extended with two **Bridge Client** modules, whose purpose are to send requests to the ARDUPILOT and SITL component respectively, and receive responses from them.

  The initialization code and the Simulink block functions are located in the provided **simucopter/simucopter-agent.cpp** file and included from the **simucopter.h** header file (see one of the Simulink block for an example)

Both of these sides share the same **bridge** library: a library that provides a transport of arbitrary messages over ZeroMQ protocol. This bridge library is (and should be) identical on both sides, whereas the code that uses it to send or process messages - is not.

Communication



The communication between Simulink and ArduPilot is done using ZeroMQ socket pairs. There are two types of pairs currently used in the bridge:

- **REQ-REP** (Request-Reply)
  A "request" is delivered to the remote component. A "reply" must be provided by the remote component before another request can be sent. **This pair is used to pass REQUEST messages from Simulink Agent to ArduPilot, and each request blocks execution until a response is received.**

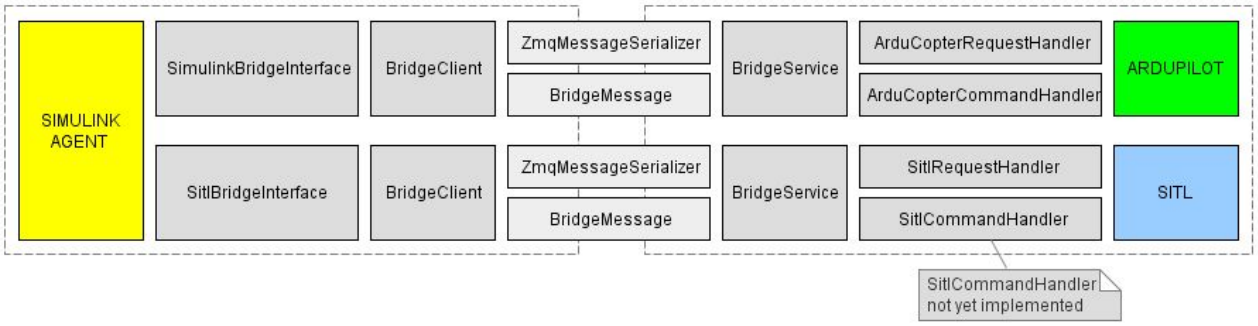
- **PUB-SUB** (Publish-Subscribe)
  A publisher dispatches messages en masse to all its subscribers. A subscriber may not yet be present, nor is it expected to keep up. If the subscriber cannot keep up, a message will be lost. **This pair is used to pass COMMAND messages from Simulink Agent to ArduPilot; I/O operations on either side don't block execution.**

Message Delivery Sequence

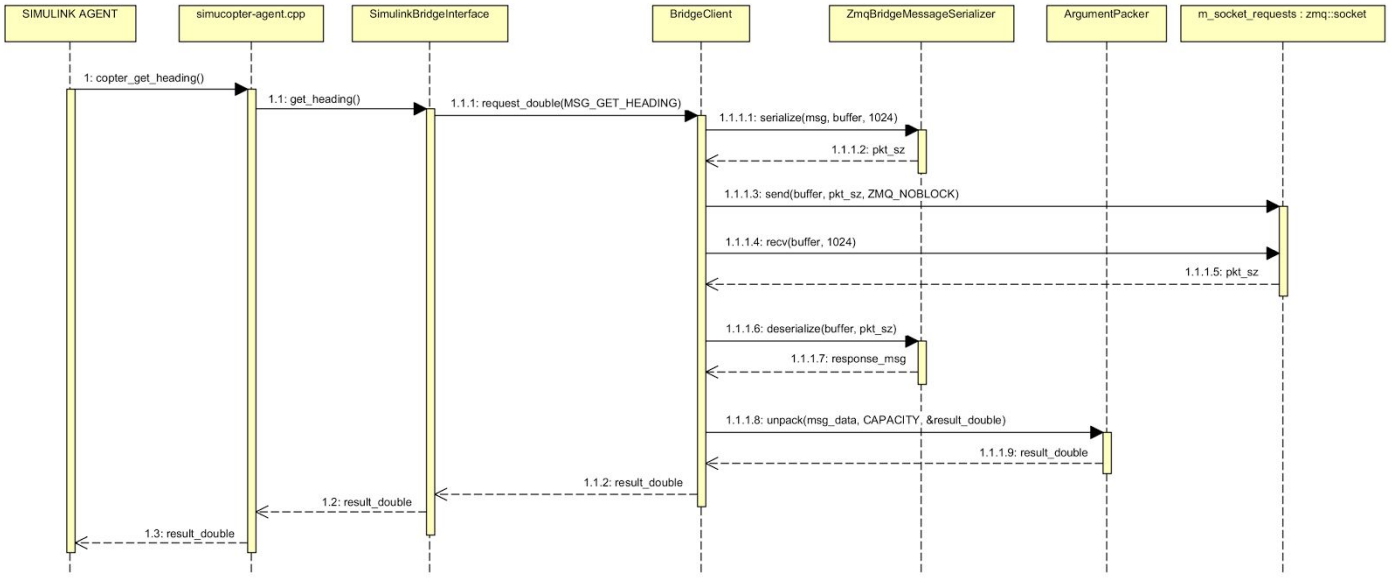
1. **Simulink Agent** executes **simulink.h** functions during its "step" function.
2. Each **simulink.h** function on the client side triggers an appropriate **SimulinkBridgeInterface** or **SitlBridgeInterface** method.
3. Each such method creates a REQUEST or COMMAND message (depending on the block).
4. **Simulink/SitlBridgeIntergace** passes the command to the **BridgeClient** for delivery.
5. **BridgeClient** sends the command through a ZeroMQ socket.
   (REQ/REP for REQUEST messages, PUB/SUB for COMMAND messages)
6. **BridgeService** receives the command through a ZeroMQ socket belonging to the same socket pair.
7. **BridgeSerivce** passes the message to a **RequestHandler** or a **CommandHandler**.
8. **Request/CommandHandler** extracts data from the message, and executes relevant commands on the **ArduPilot** or **SITL** side.
9. **RequestHandler** sends back a REPLY message with the resulting values (if applicable).

Message Delivery Sequence (cont'd)

The following image illustrates the connection between each sub-component responsible for creating and delivering messages:

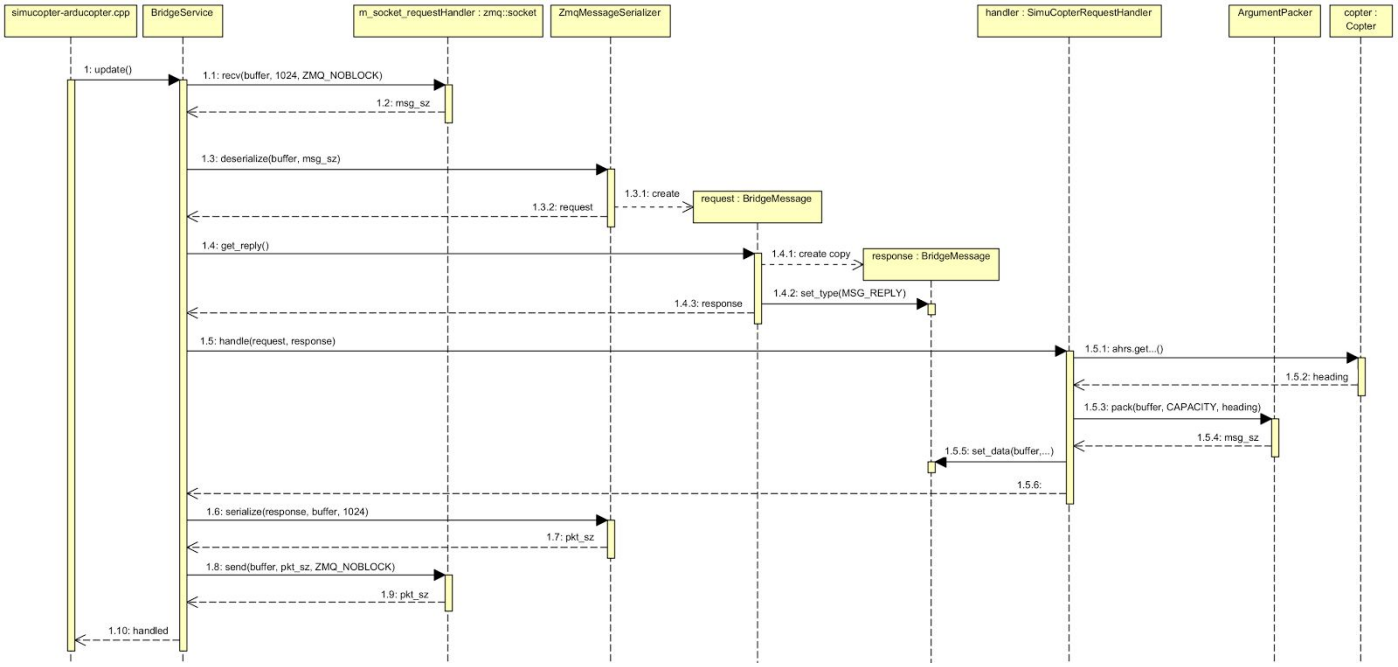


Client-Side Delivery Sequence (REQUEST message example)



Server-Side Delivery Sequence (REQUEST message example)

This is a continuation of the sequence above as the server sees it:



Caveats

Simulink shutdown quirks

- **DO NOT run models with SITL blocks in "navio" mode!**
  If we are running in "navio" mode with SITL getter blocks, the Simulink diagram will lock up and will be unable to shut down. This is because SITL BridgeService is **down** in "navio" mode - there is no SITL running, and a request from it is expected indefinitely...

- **DO NOT stop a model before aircraft is at rest!**
  Killing ArduPilot prematurely will keep the UAV in the state it was in when killed until ArduPilot is restarted!

- The shutdown works. However, if the Simulink Agent is "stuck" before ArduPilot is fully operational (T=0.000), or ArduPilot unexpectedly dies (i.e., "T=" value gets stuck), **the shutdown will not work**. The agent has to be killed through the shell **as root** in such cases!

- Obviously, if the agent executable crashes of unexpectedly shuts down for any reason, the ArduCopter process will also not be killed - you have to do this manually (see **kill-arducopter.sh**)!

Sporadic segmentation faults

WARNING: THIS PROBLEM IS STILL PRESENT!

At this point, ArduPilot appears to crash sporadically when using the SimuCopter infrastructure. The backtrace of the crashes is as follows:

```
Program received signal SIGSEGV, Segmentation fault.
[Switching to Thread 0x759bf450 (LWP 5383)]
0x000bb6e8 in Linux::RCInput_RPI::_timer_tick() ()
(gdb) bt
#0  0x000bb6e8 in Linux::RCInput_RPI::_timer_tick() ()
#1  0x000be388 in Linux::PeriodicThread::_run() ()
#2  0x000be500 in Linux::Thread::_run_trampoline(void*) ()
#3  0x76d8be90 in start_thread (arg=0x759bf450) at pthread_create.c:311
#4  0x76d15598 in ?? () at ../ports/sysdeps/unix/sysv/linux/arm/nptl/../clone.S:92
   from /lib/arm-linux-gnueabihf/libc.so.6
Backtrace stopped: previous frame identical to this frame (corrupt stack?)
```

The following is known about the crash:

- It does not seem to occur if all SimuCopter components are disabled.
- It never occurred in SITL mode.
- It does not occur immediately upon start.
  If you get SEGV on start, you need to run as root - it's not the same case as this!

- The system is **a lot more stable** with the ASLR system **DISABLED**.
  `su -c "echo 0 | tee /proc/sys/kernel/randomize_va_space"`
  NOTE THAT THIS DOES NOT PREVENT CRASHES ALL TOGETHER - JUST REDUCES THE CHANCES!

- This ArduPilot bug report may be relevant: https://github.com/ArduPilot/ardupilot/issues/4850
  It may be possible to upgrade ArduPilot to avoid these crashes all together… or not...

Missing C++ library files in certain Simulink models

Currently, we are required to add all the ".cpp" files we use into the model configuration:

1. **Tools → Run on Target Hardware → Options...**
2. Select **Code Generation** / **Custom Code**
3. Check the **Source Files** section

There may be models on GitHub that are still missing the **ArgumentPacker.cpp** file in that list - that file is relatively new! If your model does not compile due to ArgumentPacker-related issues, make sure that this file was added to the model!

This is a Simulink quirk and we cannot help it...

define private public

Currently, there is no better way to extract information from ArduPilot than through "#define private public". That said, this is the method used since before we took the project…

Message serialization - hardcoded buffers

The "message-to-bytes" serialization and deserialization code uses hardcoded 1024-byte buffers. This is no big deal per se: the messages are MUCH smaller than that. However, those are hardcoded magic numbers and likely need to be fixed in the long run (or changed to use a better method).

Search for "**buffer[1024]**" in the code - likely in the **BridgeService.cpp** or **BridgeClient.cpp** files.

No Simulink independence

While the model can be compiled and activated through MATLAB/Simulink, the agent itself may not yet be standalone, and may not function without the Simulink software running! Such autonomous behavior was not implemented during this year.