Inter-IIT IdeaForge Doc

This is the main document for implementing the solutions for Inter-IIT IdeaForge PS.
This document includes:

- setting up the simulation environment on your local system
- implementing motor failure through custom PX4 based module
- generating the results for real time behaviour of drone on motor failure
- running the motor failure & motor detection modules based on PX4 architecture
  The detection module will automatically trigger the landing or hovering modules.

Pre-requisites :

- You system should have ubuntu-22.04 LTS Desktop installed (either dual booted with windows or completely ubuntu 22).
- In case you don't have ubuntu-22.04 dual boot, you can follow this tutorial dual boot ubuntu-22.04.

PX4 Environment setup with ROS2 & Gazebo

1. First update the debian packages on your system :

- Run these commands in your terminal

```
sudo apt update
sudo apt upgrade -y
```

2. Install ROS2-humble :

- Follow this tutorial -> install ros2-humble.

- Run this command to permanantly source your ros2 environment

```
echo "source /opt/ros/humble/setup.bash" >> ~/.bashrc
```

3. Install PX4 firmware :

```
cd ~
git clone https://github.com/PX4/PX4-Autopilot.git --recursive
bash ./PX4-Autopilot/Tools/setup/ubuntu.sh
sudo reboot
```

- Please make sure that there is no error while cloning the PX4-Autopilot repository as otherwise it will cause issues in further steps.

4. Install ROS2 dependencies :

```
pip install --user -U empy==3.3.4 pyros-genmsg setuptools
sudo apt install python3-colcon-common-extensions
sudo apt install ros-humble-desktop python3-argcomplete
sudo apt install ros-dev-tools
```

5. Install XRCE-DDS Agent :

```
cd ~
git clone https://github.com/eProsima/Micro-XRCE-DDS-Agent.git
cd Micro-XRCE-DDS-Agent
mkdir build
cd build
cmake ..
make
sudo make install
sudo ldconfig /usr/local/lib/
```

6. Installing QGroundControl (GCS) :

```
sudo usermod -a -G dialout $USER
sudo apt-get remove modemmanager -y
sudo apt install gstreamer1.0-plugins-bad gstreamer1.0-libav gstreamer1.0-gl -y
sudo apt install libfuse2 -y
sudo apt install libxcb-xinerama0 libxkbcommon-x11-0 libxcb-cursor-dev -y
cd ~
```

- Now download the app-image file from here in your **/home/username/** directory.
- Change the executable permissions for GCS & try to run it

```
cd ~
chmod +x ./QGroundControl.AppImage
./QGroundControl.AppImage
```

Close the terminal (by interrupting with **ctrl + c**) to close the QGroundControl.

7. Testing the PX4 setup :

- Build & launch the gazebo simulation with SITL

```
cd ~/PX4-Autopilot
make px4_sitl gz_x500
```

- Run the XRCE-DDS Agent

```
cd ~/Micro-XRCE-DDS-Agent/build
MicroXRCEAgent udp4 -p 8888
```

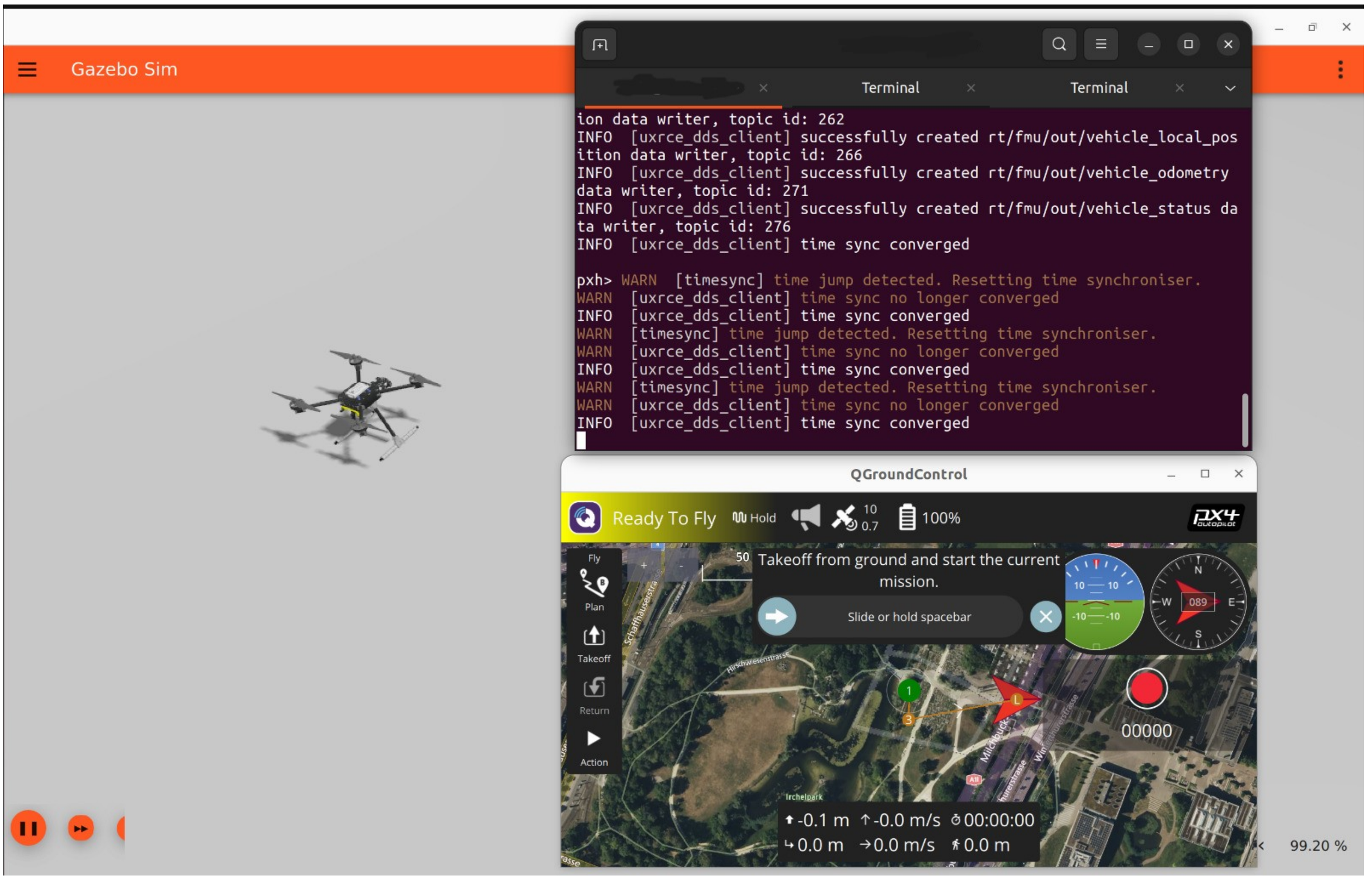
- Launch QGroundControl (GCS)

```
cd ~ && ./QGroundControl.AppImage
```

- In the SITL terminal (the one from where you launched gazebo), run the following command to arm & takeoff the drone

```
commander takeoff
```

If everything works fine, you should get something like this



- Use the command **commander land** to land the drone.

8. Increasing motor constant :

- To increase the thrust range of all the motors of the drone, we have increased the motor constant parameter by doubling it.

- Go to **~/PX4-Autopilot/Tools/simulation/gz/models/x500/** directory and open the ***model.sdf*** file and replace the motor constant value of all motors to this

```
<motorConstant>17.0916e-06</motorConstant>
```

Building custom px4 module

- For simulating single motor failure, we have created a custom module based on PX4 firmware architecture named single_motor_failure.
- In this module we've integrated injection of single motor failure, detection of motor failure and controlling the drone after detection of motor failure.
- We have used the predefined px4 based UORB topics to send commands to the drone in the modules.
- You can follow creating custom px4 module doc to know more about how to create a custom px4 module and compile it.

1. Building the module in PX4-firmware:

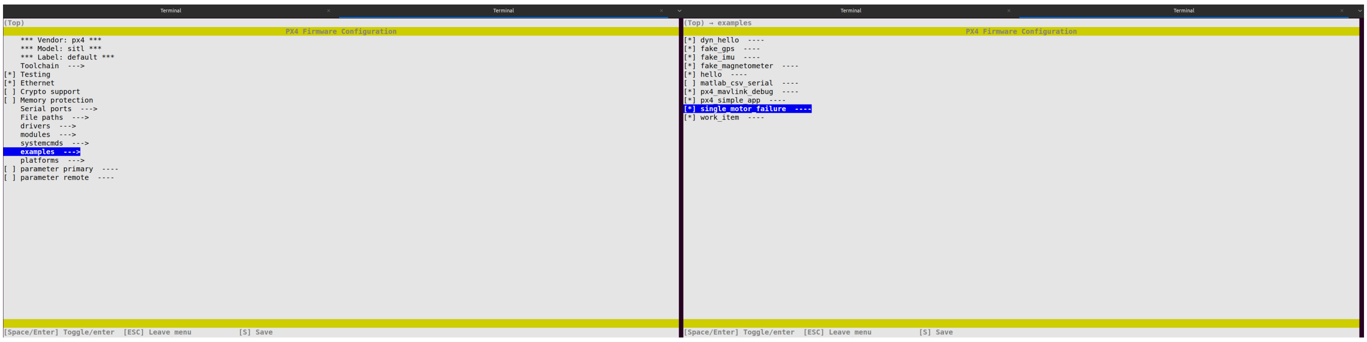
In order to run the **single_motor_failure** module you first need to make sure that it is built as part of PX4 Firmware.
Applications are added to the build/firmware in the appropriate board-level px4board file for your target:

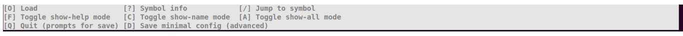
PX4-SITL (Simulator) : px4_sitl_default

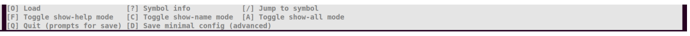
- To use this module, copy the **single_motor_failure** directory to **~/PX4-Autopilot/src/examples/** directory.

- To enable the compilation of the application/module into the firmware add the corresponding Kconfig key CONFIG_EXAMPLES_TEST_MODULE=y in the **px4_ofboard** file or run boardcofonfig make command a follows

```
cd ~/PX4-Autopilot/
make px4_sitl_default boardconfig
```







- Go to examples, you will file a new module named **single_motor_failure**, select that & press enter. Now save this module by pressing **Q** & then select **yes**.
- Now this module is ready to run as part of PX4 firmware in sitl.

NOTE:
For other boards, please select the specific board in the compiltion step.

Using the **single_motor_failure** module

1. running detection part first for motor failure:

- launch the px4 sitl & gazebo

```
cd ~/PX4-Autopilot
make px4_sitl gz_x500
```

- Run XRCE-DDS agent to convert px4 uorb topics to ros2 topics

```
cd ~/Micro-XRCE-DDS-Agent/build
MicroXRCEAgent udp4 -p 8888
```

- Launch QGroundControl (GCS)

```
cd ~ && ./QGroundControl.AppImage
```

- Takeoff your drone to default height (2.5m) by typing this command in your px4 sitl terminal

```
commander takeoff
```

- Run the detection file of the module to start checking for motor failure (if there is any) by running this command in px4 sitl terminal

```
smf detect
```

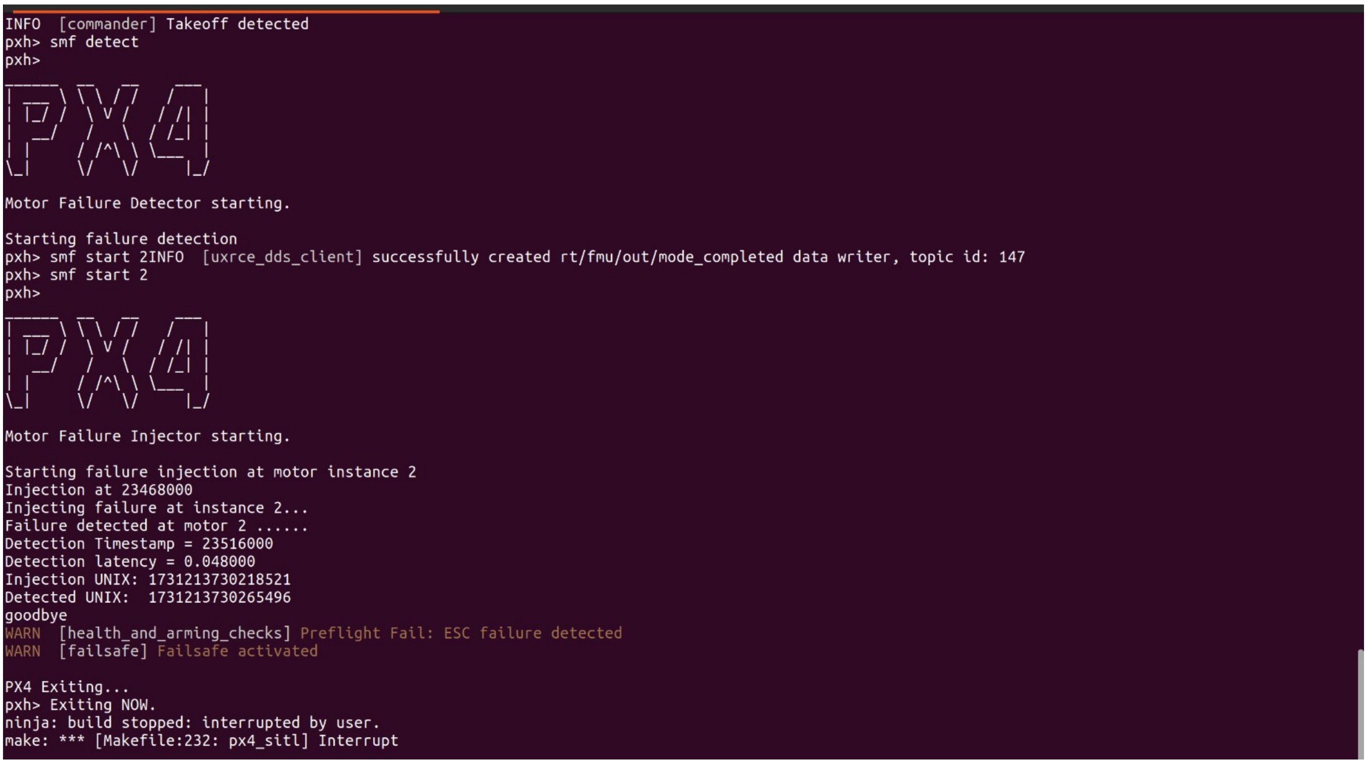
2. injecting the motor failure:

Before running this command, make sure everything in step 1 is already working.

- run this command in px4 sitl terminal to fail a motor with **motor_id=2**

```
smf start 2
```

The output would be something like this



```
INFO  [commander] Takeoff detected
pxh> smf detect
pxh>
 ______  __   __    ___
| ___ \ \ \ / /   /   |
| |_/ /  \ V /   / /| |
|  __/   /   \  / /_| |
| |     / /^\ \ \___  |
\_|     \/   \/     |_/

Motor Failure Detector starting.

Starting failure detection
pxh> smf start 2INFO  [uxrce_dds_client] successfully created rt/fmu/out/mode_completed data writer, topic id: 147
pxh> smf start 2
pxh>
 ______  __   __    ___
| ___ \ \ \ / /   /   |
| |_/ /  \ V /   / /| |
|  __/   /   \  / /_| |
| |     / /^\ \ \___  |
\_|     \/   \/     |_/

Motor Failure Injector starting.

Starting failure injection at motor instance 2
Injection at 23468000
Injecting failure at instance 2...
Failure detected at motor 2 ......
Detection Timestamp = 23516000
Detection latency = 0.048000
Injection UNIX: 1731213730218521
Detected UNIX:  1731213730265496
goodbye
WARN  [health_and_arming_checks] Preflight Fail: ESC failure detected
WARN  [failsafe] Failsafe activated

PX4 Exiting...
pxh> Exiting NOW.
ninja: build stopped: interrupted by user.
make: *** [Makefile:232: px4_sitl] Interrupt
```

The motor_id can be from **[0, 4]**.
0 means --> fail all motors at once.
1 means --> fail single motor with motor_id=0 and so on.

- After running this command, the **smf detect** will figure that a motor with motor_id=2 has been failed.

Generating flight data after failure injection

- The logic for motor failure detection has been implemented by visualizing the variations of avg_az(average angular acceleration of drone along z axis) and avg_rr(average rate of change of roll value) for multiple instances in different cases like hovering, takeoff & landing.
- The code for generating the flight data for different cases of drone flight (during and after failure injection) has been implemented in detection_tests/scripts/.
- Three different types of data are being generated by the scripts :

1. Odometry data of drone in detection_logs/csv/ directory.
2. Plots of odometry data wrt. time in detection_logs/plots/ directory.

1. Install the specific version of python libraries to run the code :

```
cd ~/inter-iit_Team62/detection_tests/scripts/
pip install -r requirements.txt
sudo apt install tmux
```

2. launch the python file to run xrce-dds agent alongside qground control :

```
cd ~/inter-iit_Team62/detection_tests/scripts/
python3 launch_drone_env.py
```

3. Generating the detection data for each of cases after failure injection :

- Those three cases are --> takeoff, hover, landing.

```
cd ~/inter-iit_Team62/detection_tests/scripts/automation/
bash demo.sh
```

- This bash file uses tmux to run different sessions of gazebo & px4 sitl.
- This will launch px4 sitl with gazebo and then fail the specific motor for each of those three cases and generate the **detection_logs**.

4. Plotting graphs for odometry data :

```
cd ~/inter-iit_Team62/detection_tests/scripts/
python3 plotting_automation.py
```