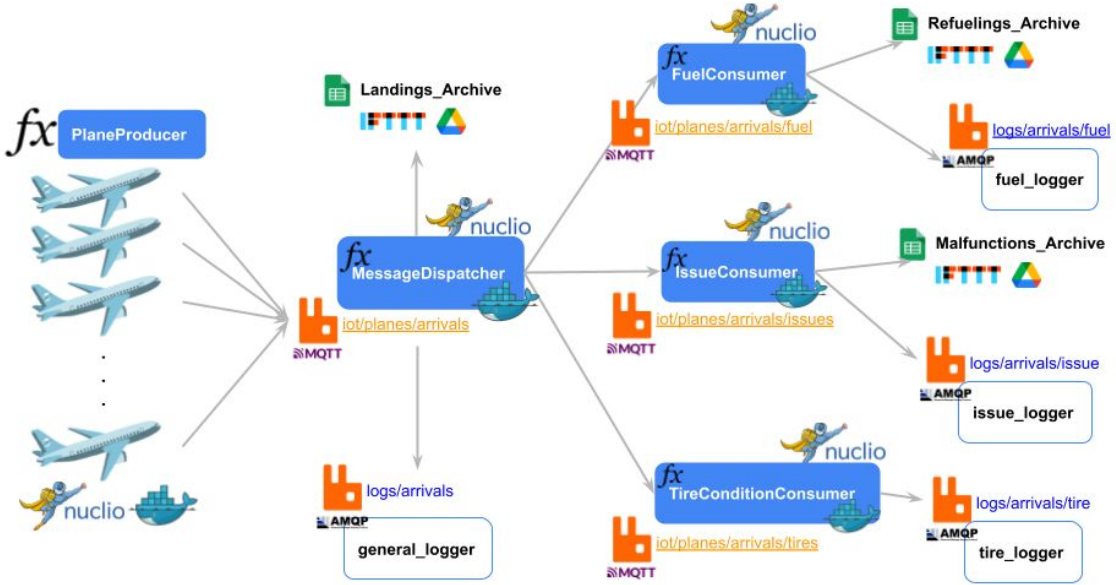
Serverless Computing for IoT 2019/2020

Plane-System

Airplanes Predictive Maintenance Architecture



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Vittorio Scarano
Carmine Spagnuolo
Matteo D'Auria

Student:
Antonio Glulio 0522500732

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Contents

Introduction

The **IoT** industry is revolutionizing the **Aerospace & Defence** sector.

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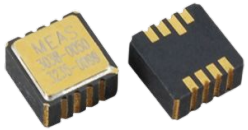
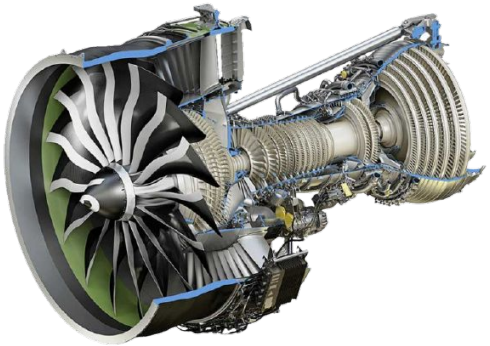
Last year were invested over **91.5 billion dollars.**

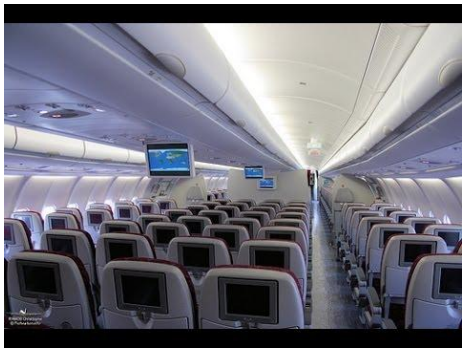
A multitude of small **sensors** and **actuators** are used in aviation, in order to detect:

- pressure
- force
- position
- temperature
- vibration





These sensors are applied in different parts of the aircraft, offering a **constant data provisioning** that aims to improve **efficiency**, **safety**, **control** and **costs**!



INTRODUCTION

The critical aspect is that these flight data can be analyzed in **real-time**, the engineers and **ground-crews** can diagnose any malfunction and arrange maintenance in order to

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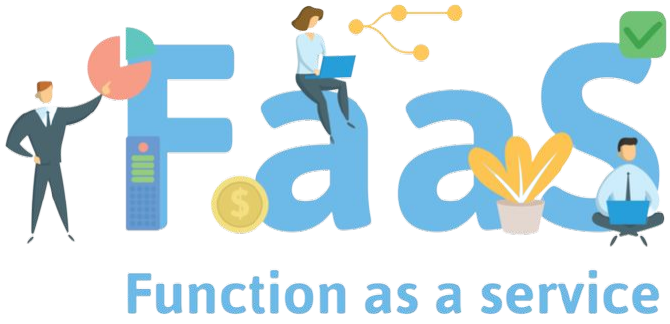
=

more



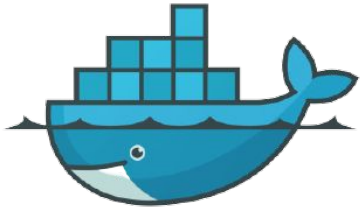
This project focuses on the processing of these data on **ground-control** in order to perform predictive maintenance.

It consist in a computing architecture based on open-source software that exploits the **Function as a Service** model in the context of **IoT.**

Tools

TOOLS

- Application containers engine **Docker** and **Docker Compose.**



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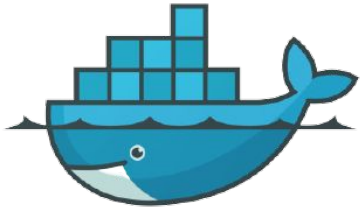
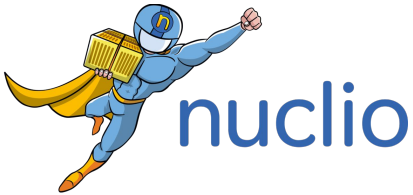


- Serverless computing provider **Nuclio**.



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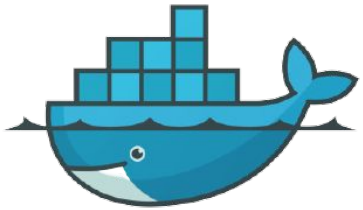

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AMQP
Advanced Message Queuing Protocol

MQTT

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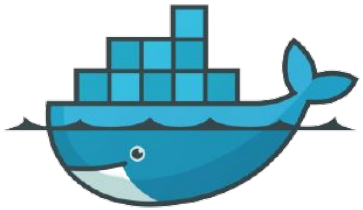

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- JavaScript Application runtime **Node.js**

node
JS

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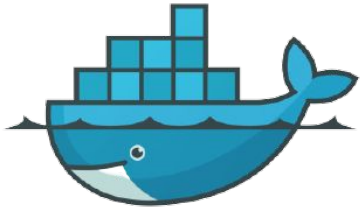

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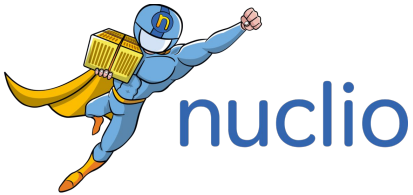

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- JavaScript Application runtime **Node.js**

- Applets creation and management service **IFTTT.**

Scenario

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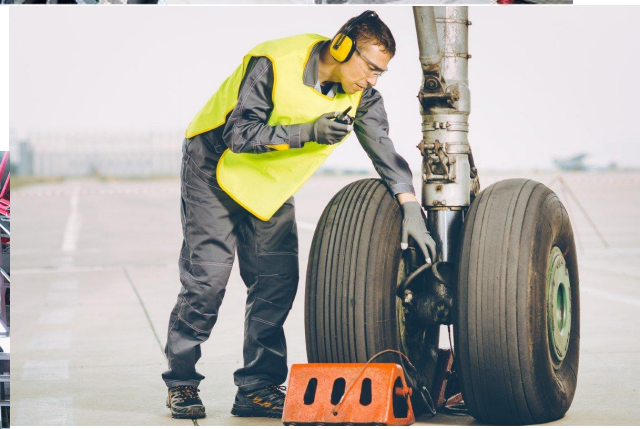
- Each airplane has sensors that produce information regarding the **fuel level**, the **condition of tires** and various **malfunctions.**

- An approaching airplane sends these data using the MQTT protocol, which are processed by different functions in a **serverless** way, and subsequently logged and stored.

SCENARIO

In this way the Ground Crew can prepare the exact amount of the necessary fuel, it already knows what are the tires that need maintenance and any damage that the aircraft suffered.



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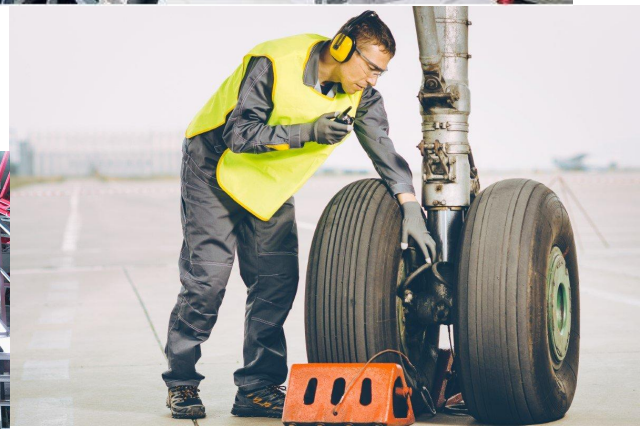
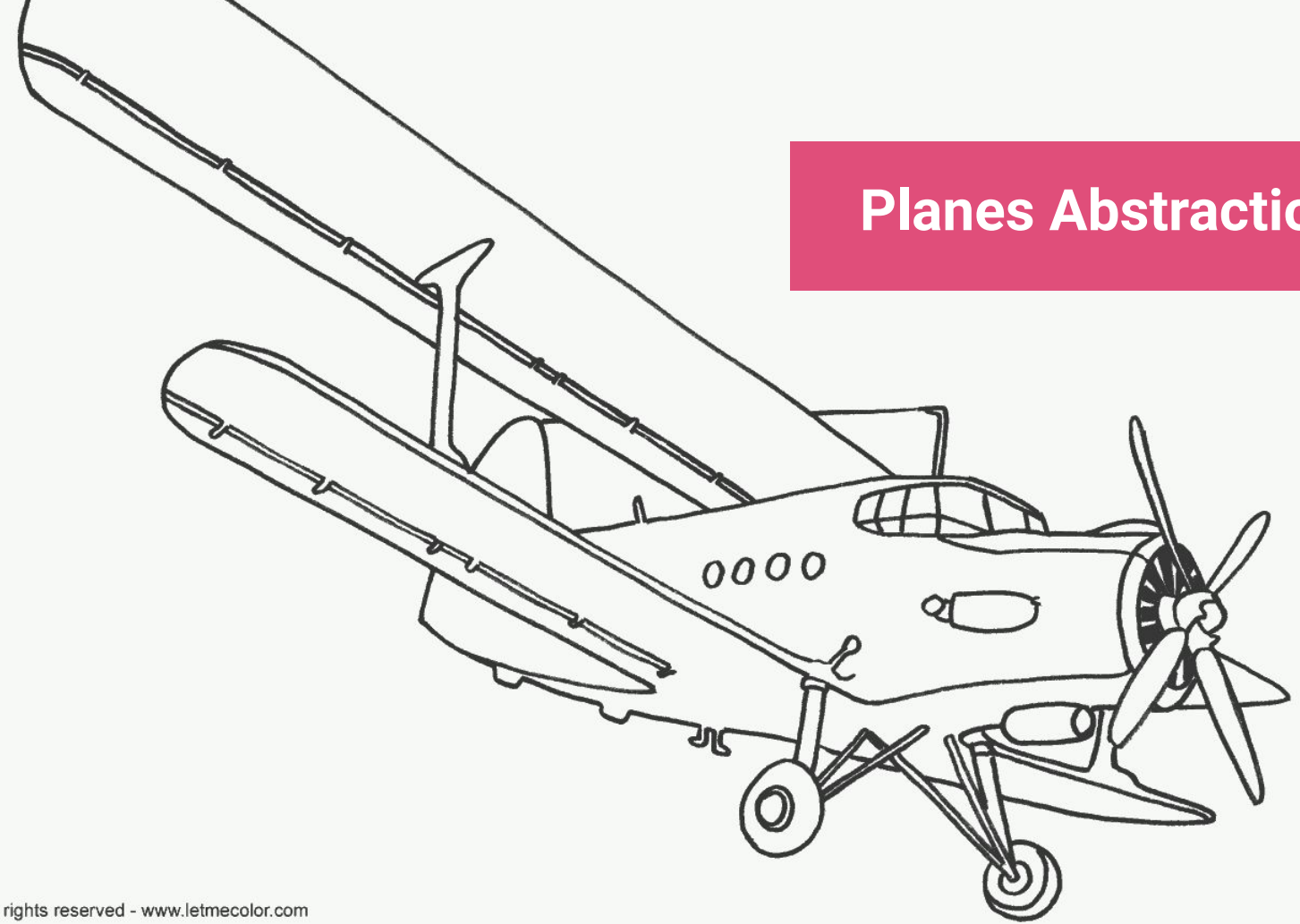
Through the use of these systems it has been shown that the **downtime is reduced by around 15-20%**.



Planes Abstraction



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- **model:** randomly chosen from a set of models, precisely among the 7 most produced model in the world!

Boeing-747

AirBus-A320

Douglas-DC-9

AirBus-A330

Boeing-777

AirBus-A300

Boeing-757

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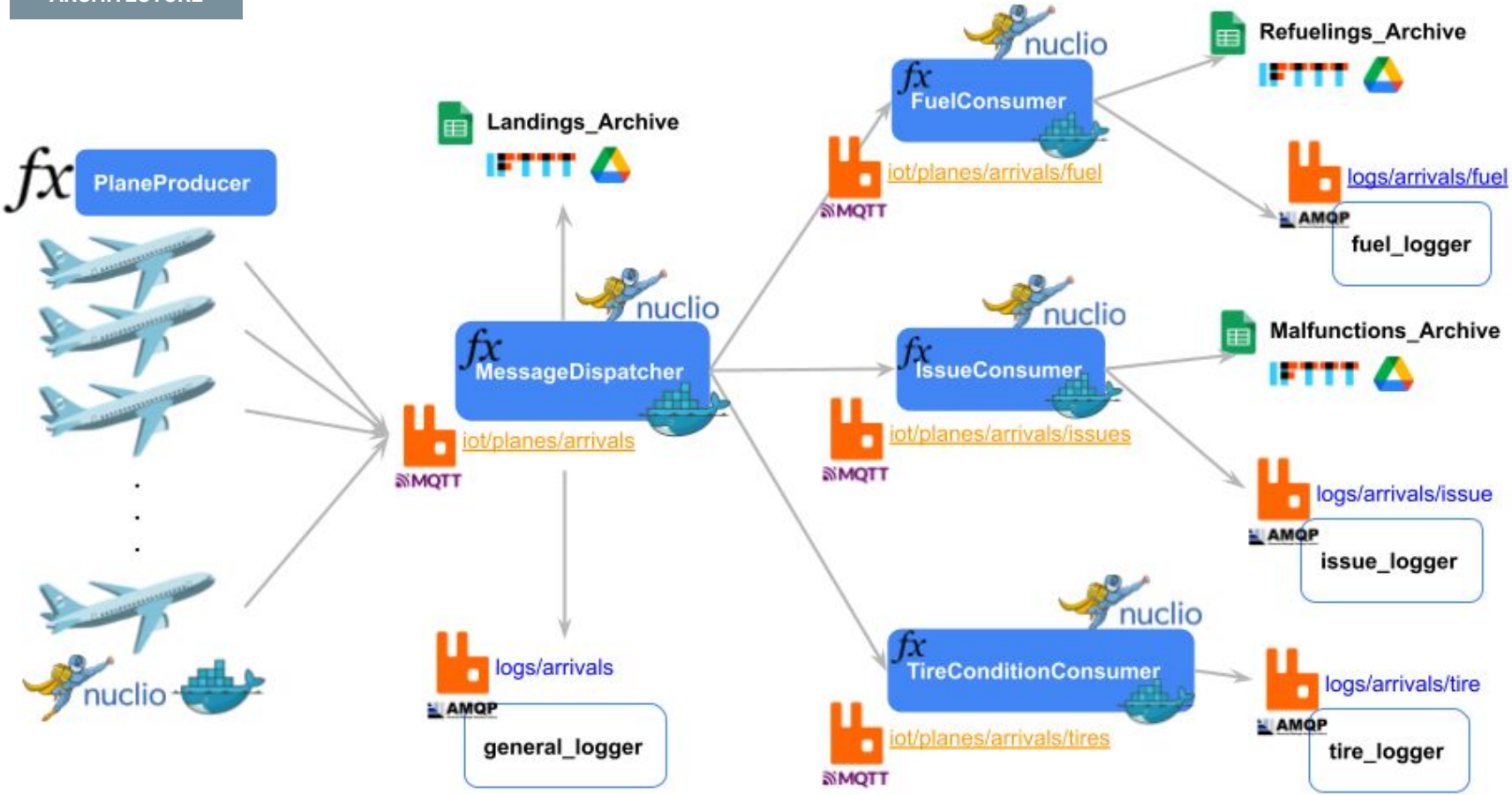
In this way anyone who uses Node.js can easily exploit the code by simply installing it by writing:

```
npm i planes-generator
```

Here the NPM page: [planes-generator]

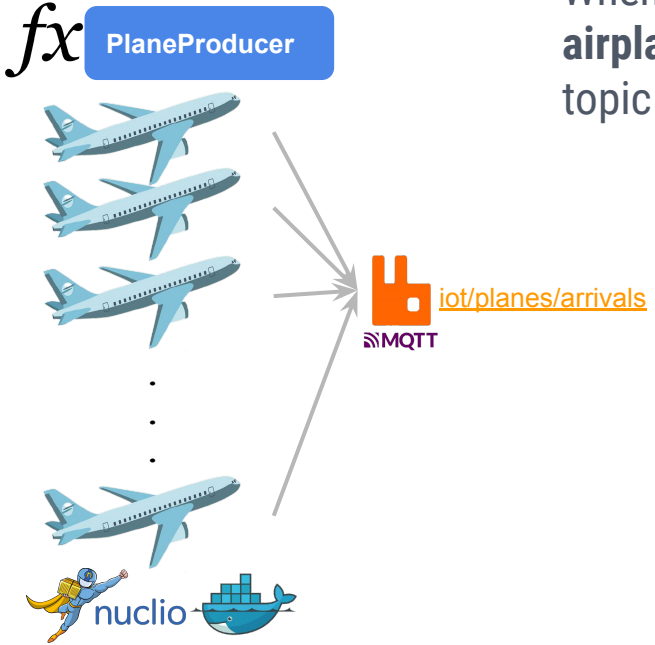
Architecture

ARCHITECTURE



ARCHITECTURE

Plane Producer



Whenever this function is invoked, it creates a **new airplane instance** and then sends the data on the MQTT topic **iot/planes/arrivals**.

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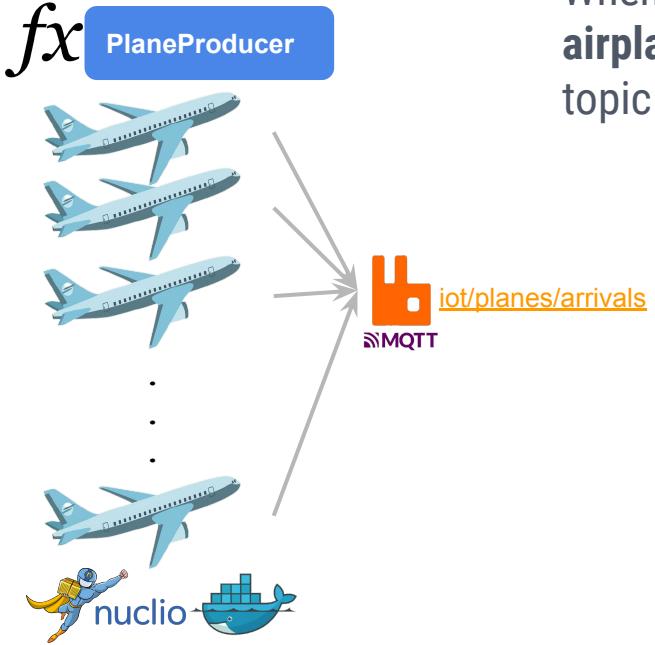

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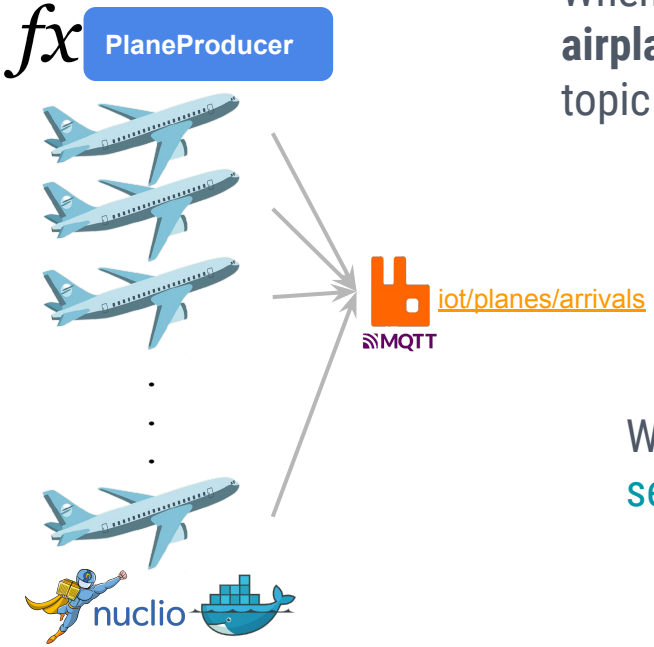

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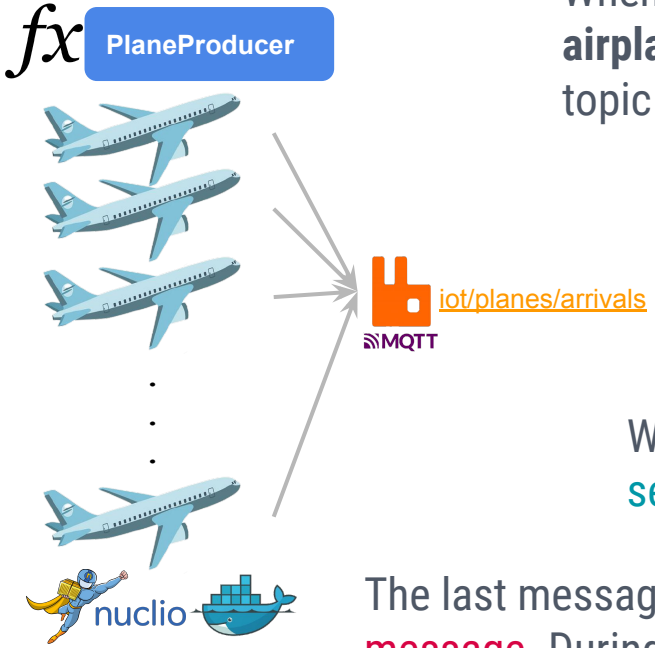

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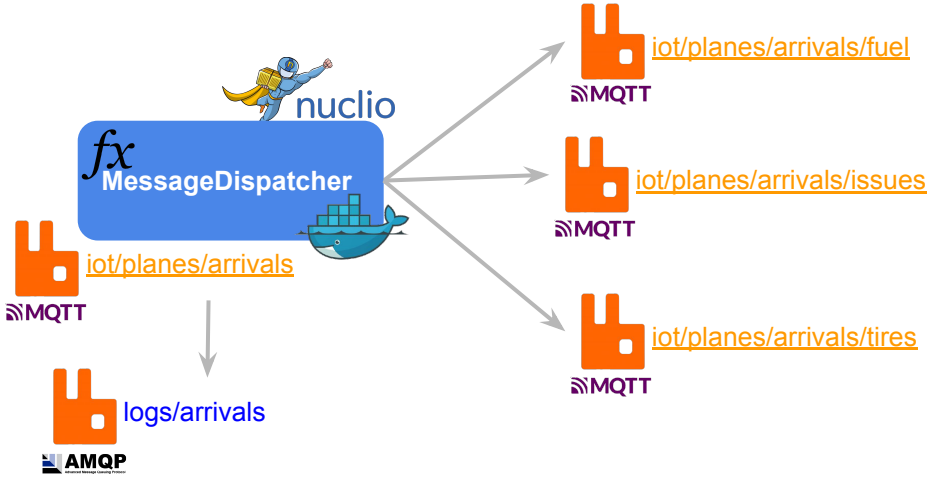
The last message published for each execution is the landing message. During the landing procedure, tire issues and othe casual issues are generated.

Message Dispatcher

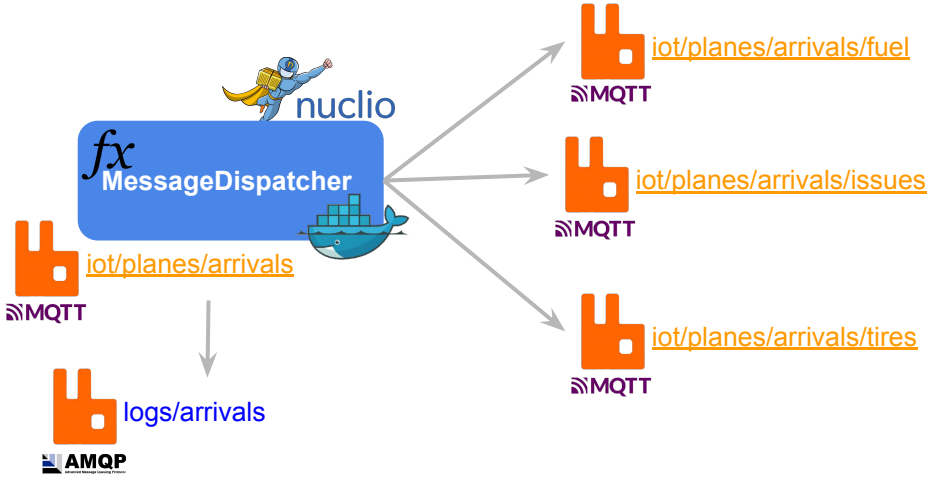
This function is triggered by a new MQTT message on the topic **iot/planes/arrivals** containing the plane information produced by Plane Producer.



Message Dispatcher

This function is triggered by a new MQTT message on the topic **iot/planes/arrivals** containing the plane information produced by Plane Producer.

For each message received sends a feedback on the AMQP channel **logs/arrivals** with the plane name, model and current fuel_level.



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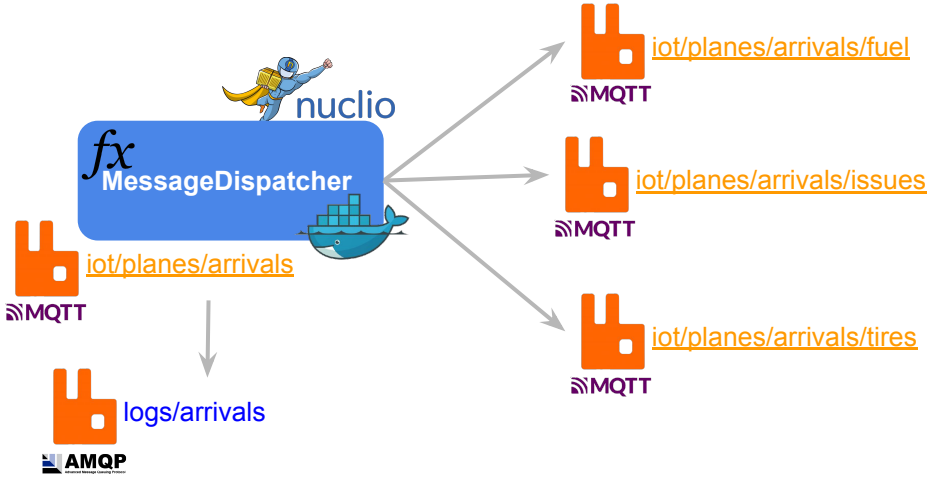
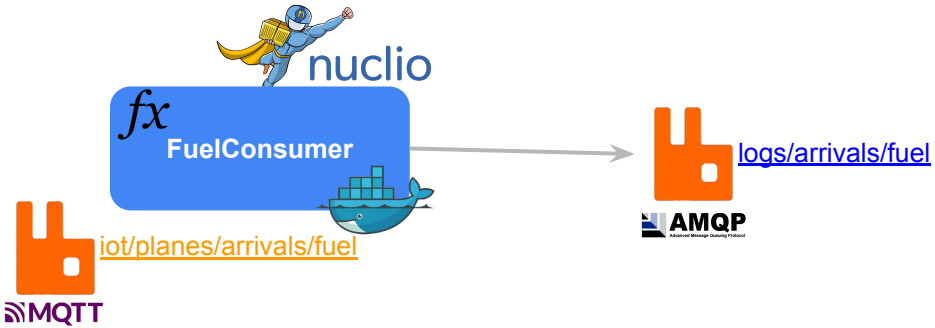


Only when the plane **lands** the Message Dispatcher publishes his data on 3 different MQTT topics, a sort of **forwarding**:

- **iot/planes/arrivals/fuel**
- **iot/planes/arrivals/issues**
- **iot/planes/arrivals/tires**

Fuel Consumer

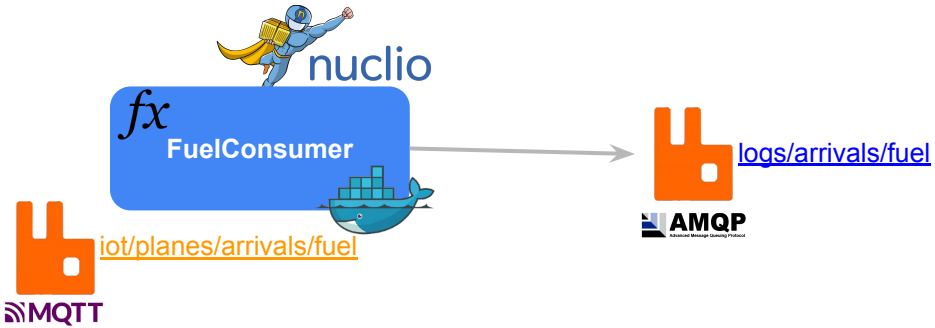
This function is triggered by a new MQTT message on the topic **iot/planes/arrivals/fuel** containing the plane information forwarded by the Message Dispatcher function.



Fuel Consumer

This function is triggered by a new MQTT message on the topic **iot/planes/arrivals/fuel** containing the plane information forwarded by the Message Dispatcher function.

The Fuel Consumer deals with **calculating the exact amount of fuel needed to refuel the aircraft**, then publish this information on the AMQ channel **logs/arrivals/fuel**.



Issue Consumer

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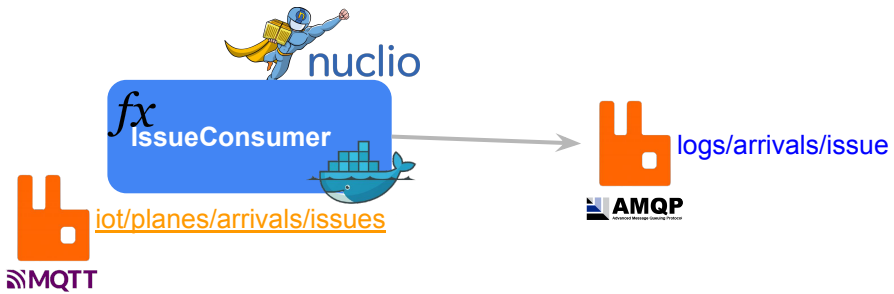
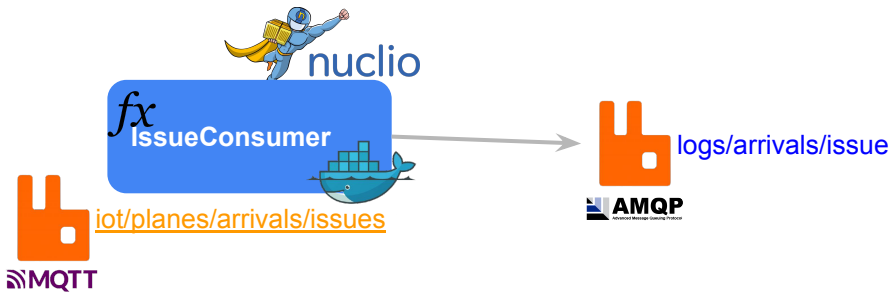


Issue Consumer

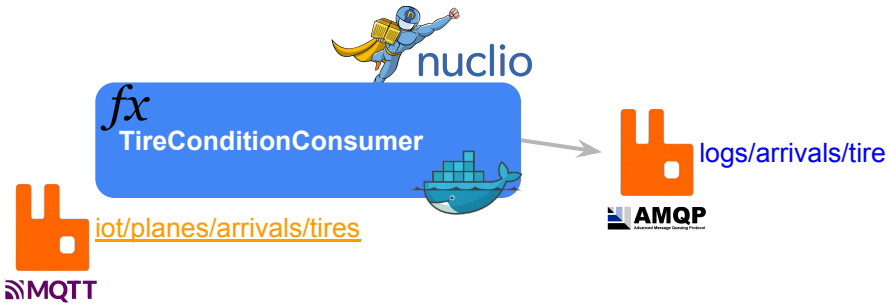
This function is triggered by a new MQTT message on the topic **iot/planes/arrivals/issues** containing the plane information forwarded by the Message Dispatcher function.

The Issue Consumer deals with updating the AMQP channel **logs/arrivals/issue** with information concerning the possible **malfunctions** detected during the previous flight.



Tire Condition Consumer

This function is triggered by a new MQTT message on the topic **iot/planes/arrivals/tires** containing the plane information forwarded by the Message Dispatcher function.



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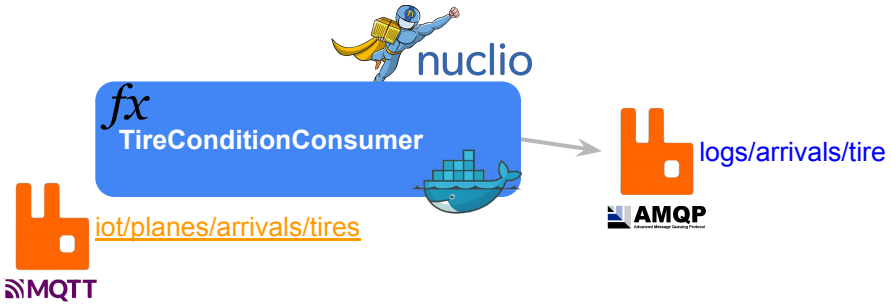
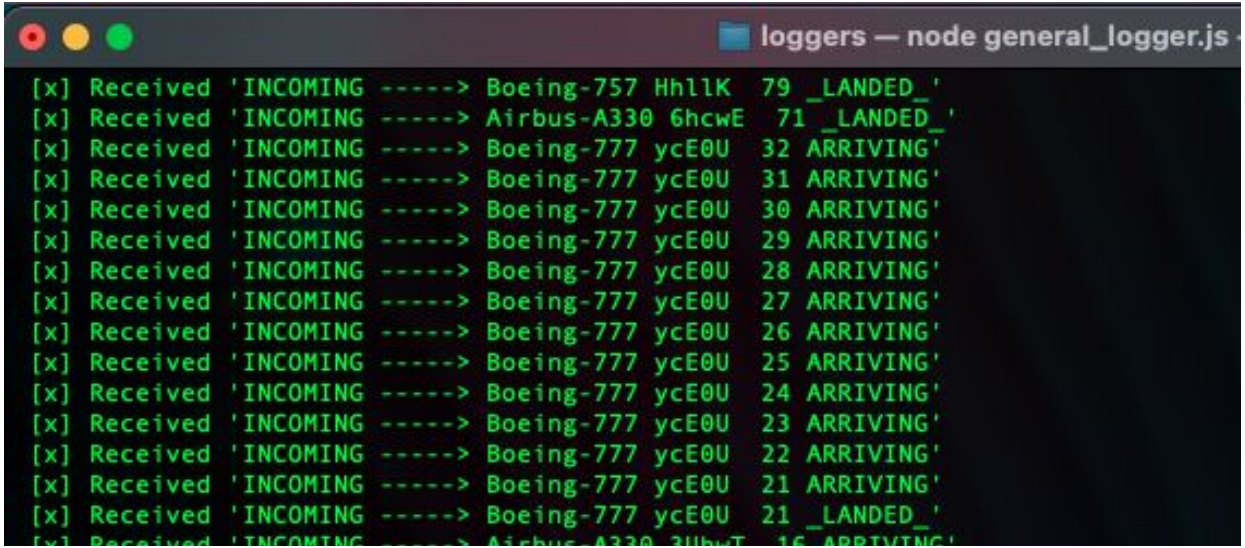
The Tire Condition Consumer deals with updating the AMQP channel **logs/arrivals/tires** with information concerning **which tires** and **which undercarriage** need immediate maintenance

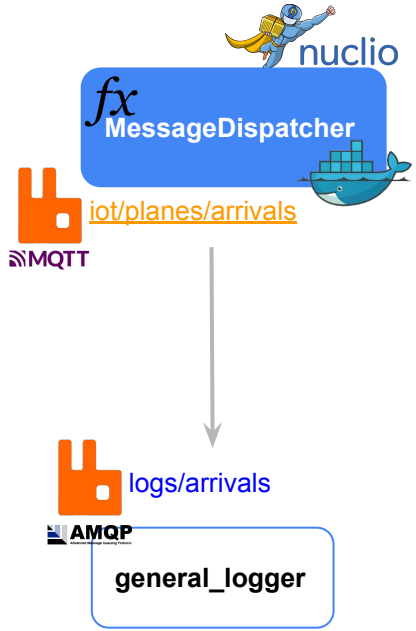


Loggers

4 loggers, each associated with a consumer function and listening on a AMQP dedicated channel.

General_logger listening on **logs/arrivals**

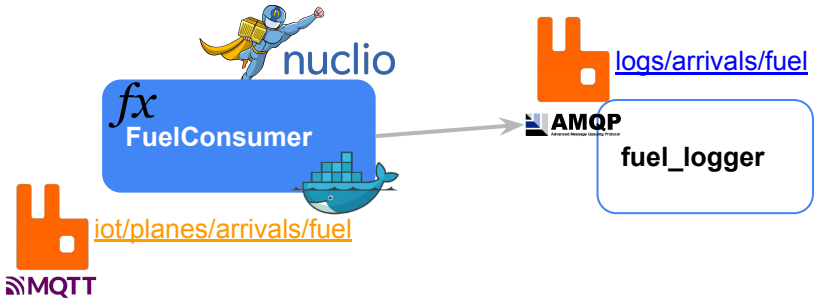




ARCHITECTURE

Loggers

Fuel_logger listening on **logs/arrivals/fuel**

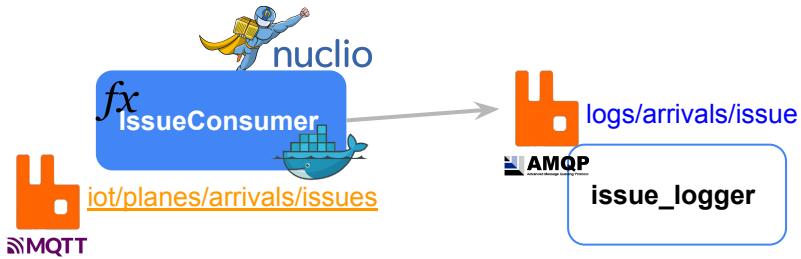



```
loggers — node fuel_logger.js — 134×35
[x] Received 'Airbus-A300 Wg3tJ is _LANDED_ with   40% of fuel. Fuel needing computed: 40896 liters!'
[x] Received 'Boeing-777 r6JKZ is _LANDED_ with   42% of fuel. Fuel needing computed: 105144.14 liters!'
[x] Received 'Boeing-757 sPM04 is _LANDED_ with   28% of fuel. Fuel needing computed: 30729.6 liters!'
[x] Received 'Boeing-747 wVB49 is _LANDED_ with   81% of fuel. Fuel needing computed: 41196.56 liters!'
[x] Received 'Airbus-A320 QqqG6 is _LANDED_ with   11% of fuel. Fuel needing computed: 21234.510000000002 liters!'
[x] Received 'Airbus-A330 ukQE9 is _LANDED_ with   87% of fuel. Fuel needing computed: 18081.7 liters!'
[x] Received 'Airbus-A300 1xF0d is _LANDED_ with   52% of fuel. Fuel needing computed: 32716.8 liters!'
[x] Received 'Douglas-DC-9 PHM3K is _LANDED_ with   45% of fuel. Fuel needing computed: 7659.3 liters!'
[x] Received 'Boeing-777 gA1WR is _LANDED_ with   15% of fuel. Fuel needing computed: 154090.55 liters!'
```

ARCHITECTURE

Loggers

Issue_logger listening on **logs/arrivals/issues**

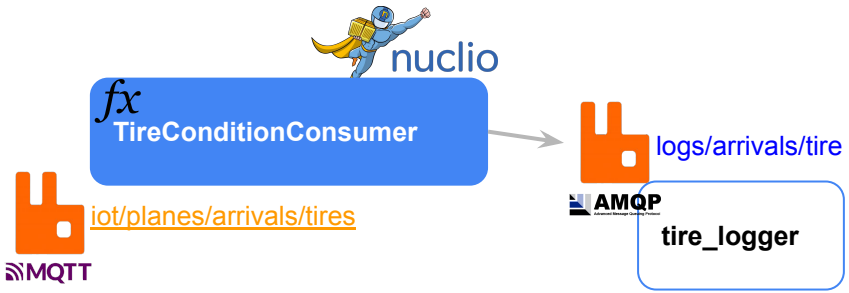


loggers — node issue_logger.js — 134×35

```
[x] Received 'Airbus-A300 Wg3tJ is _LANDED_! The sensors encountered a  Possible left engine malfunction'
[x] Received 'Boeing-777 r6JKZ is _LANDED_! The sensors encountered a  Possible damage to the tail'
[x] Received 'Boeing-757 sPM04 is _LANDED_! The sensors encountered a  Possible depressurization of the hold'
[x] Received 'Boeing-747 wVB49 is _LANDED_! The sensors encountered a  Possible damage to the left flaps'
[x] Received 'Airbus-A320 QqqG6 is _LANDED_! The sensors encountered a  Possible refrigerant leak'
[x] Received 'Airbus-A330 ukQE9 is _LANDED_! The sensors encountered a  Possible damage to the fuselage'
[x] Received 'Airbus-A300 1xF0d is _LANDED_! The sensors encountered a  Possible damage to the left wing'
[x] Received 'Douglas-DC-9 PHM3K is _LANDED_! The sensors encountered a  Possible damage to the right flaps'
[x] Received 'Boeing-777 gA1WR is _LANDED_! The sensors encountered a  Possible damage to the right flaps'
[x] Received 'Douglas-DC-9 mU7EM is _LANDED_! The sensors encountered a  Possible damage to the right flaps'
[x] Received 'Airbus-A300 7AlSk is _LANDED_! The sensors encountered a  Possible damage to the left flaps'
[x] Received 'Airbus-A330 mhnoQ is _LANDED_! The sensors encountered a  Possible depressurization of the hold'
```

Loggers

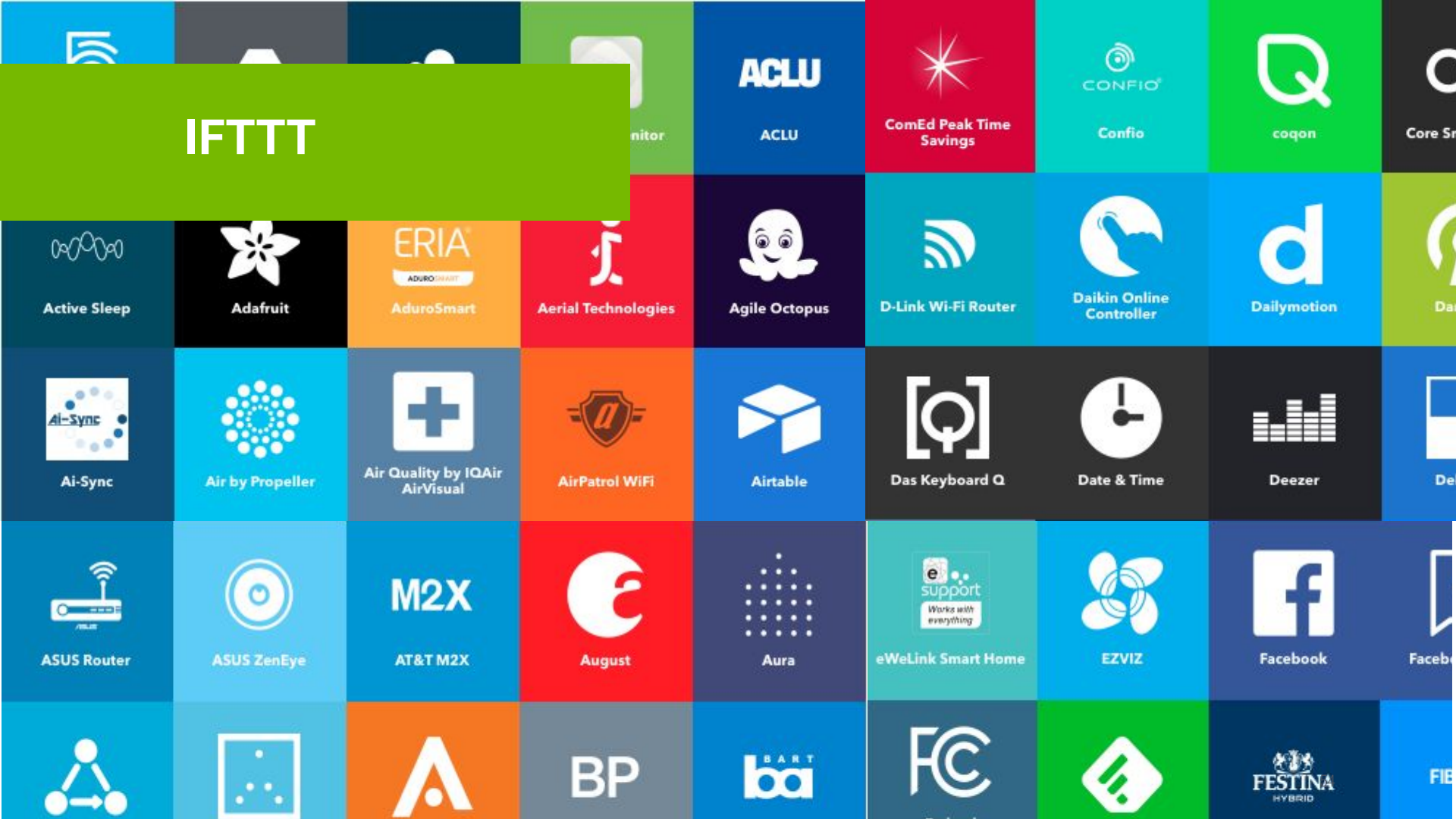
Tire_logger listening on **logs/arrivals/tires**



loggers — node tire_logger.js — 134×33

```
[x] Received 'Boeing-757 sPM04 is _LANDED_! Manteinance undercarriage n: 3! Pressure drop detected at tire n: 6 '
[x] Received 'Boeing-747 wVB49 is _LANDED_! Manteinance undercarriage n: 4! Pressure drop detected at tire n: 2 '
[x] Received 'Airbus-A320 QqqG6 is _LANDED_! Manteinance undercarriage n: 1! Pressure drop detected at tire n: 2 '
[x] Received 'Airbus-A330 ukQE9 is _LANDED_! Manteinance undercarriage n: 2! Pressure drop detected at tire n: 5 '
[x] Received 'Airbus-A300 1xF0d is _LANDED_! Manteinance undercarriage n: 3! Pressure drop detected at tire n: 9 '
[x] Received 'Douglas-DC-9 PHM3K is _LANDED_! Manteinance undercarriage n: 1! Pressure drop detected at tire n: 3 '
[x] Received 'Boeing-777 gA1WR is _LANDED_! Manteinance undercarriage n: 2! Pressure drop detected at tire n: 8 '
[x] Received 'Douglas-DC-9 mU7EM is _LANDED_! Manteinance undercarriage n: 3! Pressure drop detected at tire n: 3 '
[x] Received 'Airbus-A300 7AlSk is _LANDED_! Manteinance undercarriage n: 3! Pressure drop detected at tire n: 1 '
[x] Received 'Airbus-A330 mhnoQ is _LANDED_! Manteinance undercarriage n: 1! Pressure drop detected at tire n: 2 '
[x] Received 'Airbus-A300 PNkOP is _LANDED_! Manteinance undercarriage n: 1! Pressure drop detected at tire n: 1 '
[x] Received 'Airbus-A320 4aseA is _LANDED_! Manteinance undercarriage n: 1! Pressure drop detected at tire n: 3 '
[x] Received 'Douglas-DC-9 aTRWP is _LANDED_! Manteinance undercarriage n: 3! Pressure drop detected at tire n: 2 '
[x] Received 'Airbus-A330 kUuzO is _LANDED_! Manteinance undercarriage n: 3! Pressure drop detected at tire n: 3 '
```

IFTTT


ACLU
ACLU
ComEd Peak Time Savings
CONFIO
Confio
coqon
Active Sleep
Adafruit
ERIA
AduroSmart
Aerial Technologies
Agile Octopus
D-Link Wi-Fi Router
Daikin Online Controller
Dailymotion
Ai-Sync
Ai-Sync
Air by Propeller
Air Quality by IQAir AirVisual
AirPatrol WiFi
Airtable
Das Keyboard Q
Date & Time
Deezer
ASUS Router
ASUS ZenEye
M2X
AT&T M2X
August
Aura
eWeLink Smart Home
EZVIZ
Facebook
BP
BART
FESTINA
HYBRID

IFTTT

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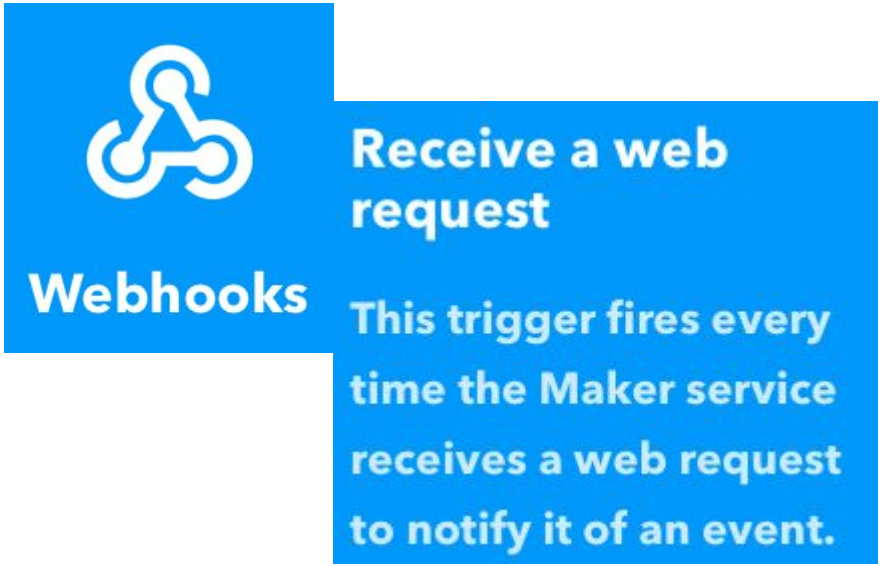
- **Triggers:** are the "**this**" part of an applet. They are the items that trigger the action.
- **Actions:** are the "**that**" part of an applet. They are the output that results from the input of the trigger.

IFTTT

For the Plane-System I created **three** applets using the following services offered by IFTTT:



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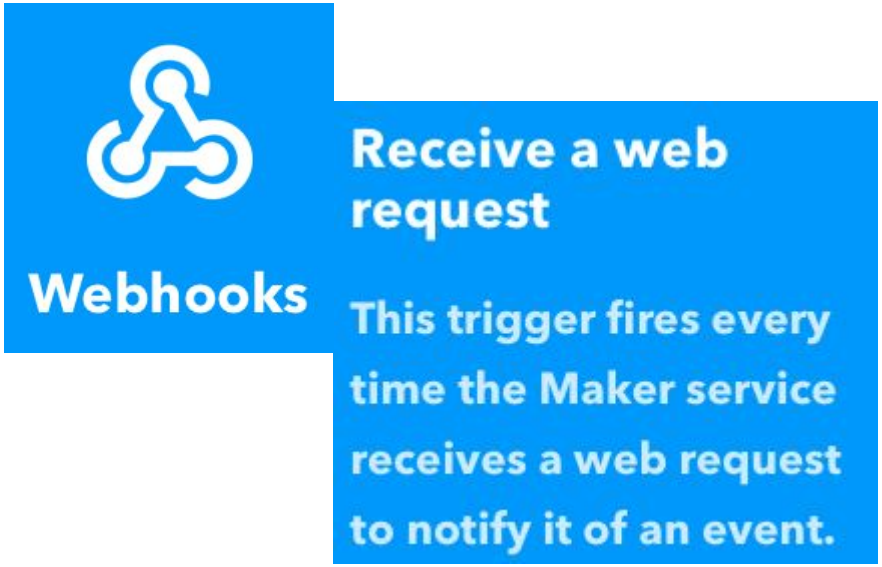
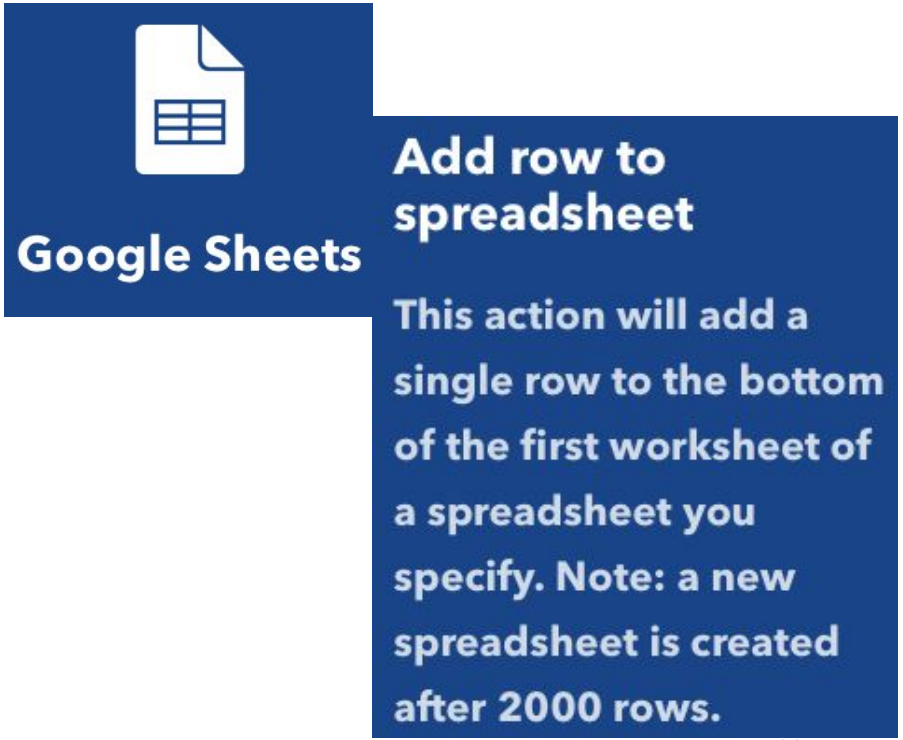


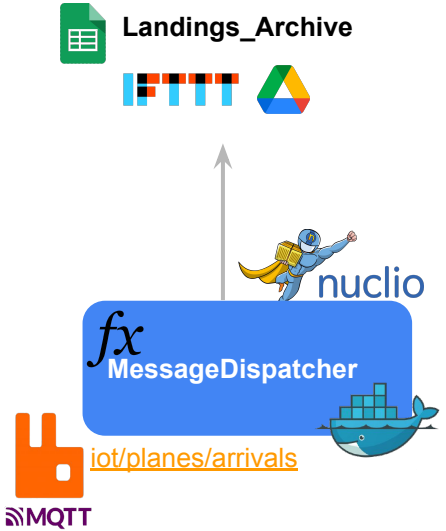


IFTTT

The first applet is called “**plane_landed**”.

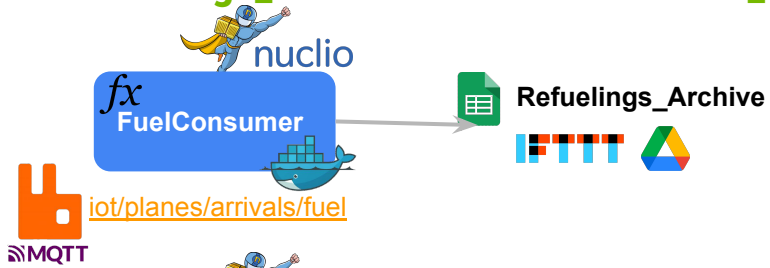
It is connected to Message Dispatcher, every time a plane lands, the applet is invoked and updates an excel file on my **Google Drive** which acts as a **Landing_Archive.**

46	plane_landed	Airbus-A320 - 64wX9	1/2/2021	10:59
47	plane_landed	Douglas-DC-9 - c8Dgx	1/2/2021	11:0
48	plane_landed	Boeing-757 - O6uVO	1/2/2021	11:0
49	plane_landed	Airbus-A320 - kgoxl	1/2/2021	11:0
50	plane_landed	Douglas-DC-9 - pKWX7	1/2/2021	11:0
51	plane_landed	Airbus-A320 - JUpF6	8/3/2021	12:27
52	plane_landed	Airbus-A300 - 8n6lo	8/3/2021	12:27
53	plane_landed	Boeing-747 - 4yp3L	8/3/2021	12:27
54	plane_landed	Airbus-A330 - X5Gvu	8/3/2021	12:27

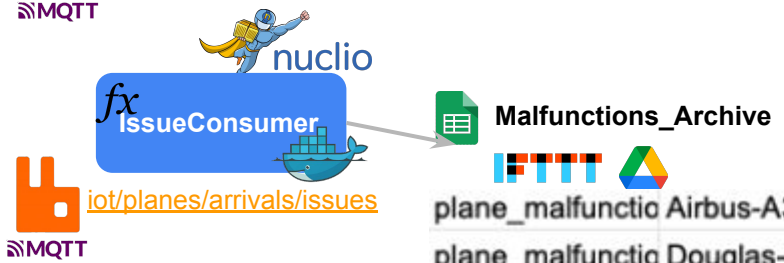


IFTTT

In the same way the other two applets (**plane_refueling** and **plane_malfunction**) are connected one with Fuel Consumer function, and the other with Issue Consumer function, in order to create **Refuelings_Archive** and a **Malfunction_Archive.**



plane_refueling	Airbus-A330 - 6hcwE	2/2/2021 - 15:33	40336.1 liters
plane_refueling	Boeing-777 - ycE0U	2/2/2021 - 15:34	143213.57 liters
plane_refueling	Airbus-A330 - 3UhwT	2/2/2021 - 15:52	132135.5 liters
plane_refueling	Boeing-777 - 3BTB7	2/2/2021 - 15:52	106956.97 liters
plane_refueling	Airbus-A300 - ubnFM	2/2/2021 - 15:52	41577.6 liters
plane_refueling	Douglas-DC-9 - SHwNI	2/2/2021 - 15:52	6684.48 liters
plane_refueling	Airbus-A300 - 8n6lo	8/3/2021 - 12:27	28627.2 liters



plane_malfunctio	Airbus-A320 - kgoxl	1/2/2021 - 11:0	Possible damage to the tail
plane_malfunctio	Douglas-DC-9 - pKWX7	1/2/2021 - 11:0	Possible damage to the right wing
plane_malfunctio	Boeing-757 - O6uVO	1/2/2021 - 11:0	Possible damage to the fuselage
plane_malfunctio	Airbus-A300 - 8n6lo	8/3/2021 - 12:27	Possible depressurization of the hold
plane_malfunctio	Airbus-A320 - JUpF6	8/3/2021 - 12:27	Possible depressurization of the hold
plane_malfunctio	Boeing-747 - 4yp3L	8/3/2021 - 12:27	Possible damage to the fuselage
plane_malfunctio	Airbus-A330 - X5Gvu	8/3/2021 - 12:27	Possible damage to the left wing

To integrate these applet in my code I have exploited the **NPM** package **ifttt-webhooks-channel** (installable with npm i ifttt-webhooks-channel) that provide a simple post method to trigger the webhook as follow:

```
// invoke the webhook
ifttt.post('plane_landed', [currentPlane.model + " - " + currentPlane.name,
                            date.getDate() + "/" + (date.getMonth()+1) + "/" + date.getFullYear(),
                             (date.getHours()+1) + ":" + date.getMinutes()]);
```

How to Run

HOW TO RUN

1. Install Docker and Docker Compose
2. Start Nuclio through Docker: `$ docker run -p 8070:8070 -v /var/run/docker.sock:/var/run/docker.sock -v /tmp:/tmp nuclio/dashboard:stable-amd64`
   then browse to http://localhost:8070 to use Nuclio Dashboard.
3. Start RabbitMQ through Docker: `$ docker run -p 9000:15672 -p 1883:1883 -p 5672:5672 cyrilix/rabbitmq-mqtt`
   then browse to http://localhost:9000 and login using username:guest and password:guest, to access to RabbitMQ management, where is possible to visualize the message queues and the broker status
4. Replace all IP addresses in the code with your own, also in the .yaml files and in logger functions. Then updates the **functionSourceCode** field in all .yaml files with the base64 encoding of the functions.
5. Browse to Nuclio Dashboard and create a new project uploading producer and consumers functions, the deploy all.
6. Start all loggers with node logger_name.js in the terminal.
7. Test the **planeProducer** function and observe messages on loggers.
8. If you want, create your applets with IFTTT and update the fields in the code.


Thank you for listening