Modeling and Execution of Coordinated Missions in Reconfigurable Robot Ensembles

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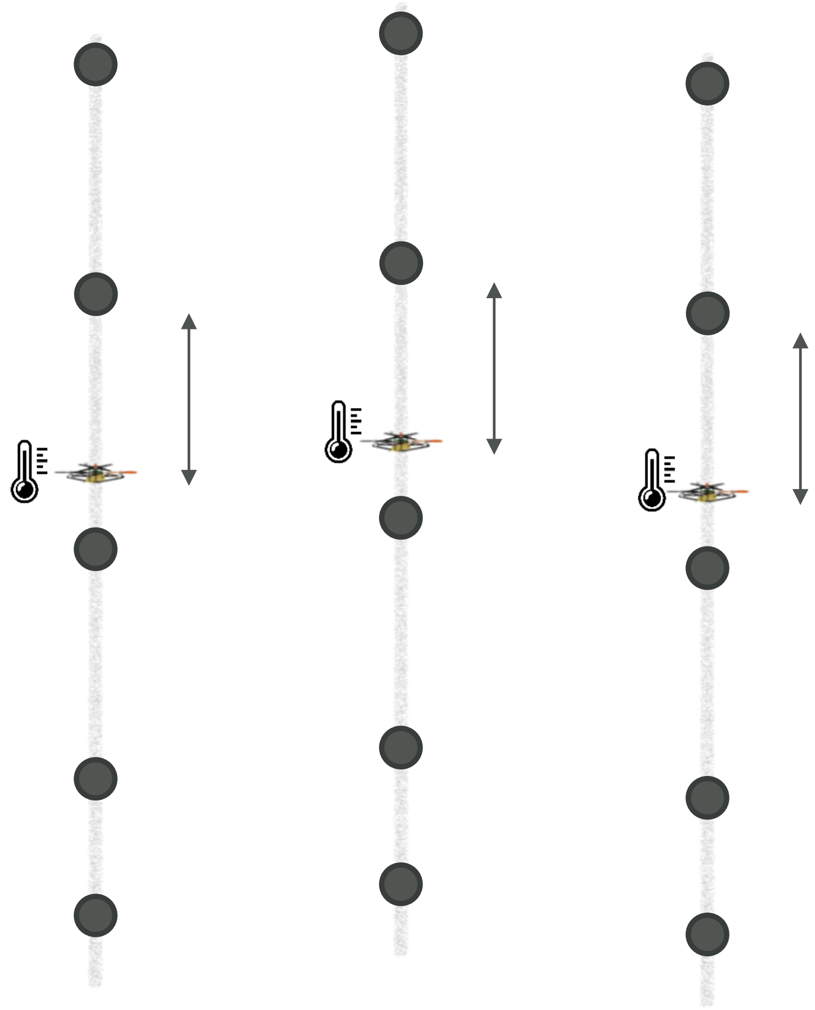
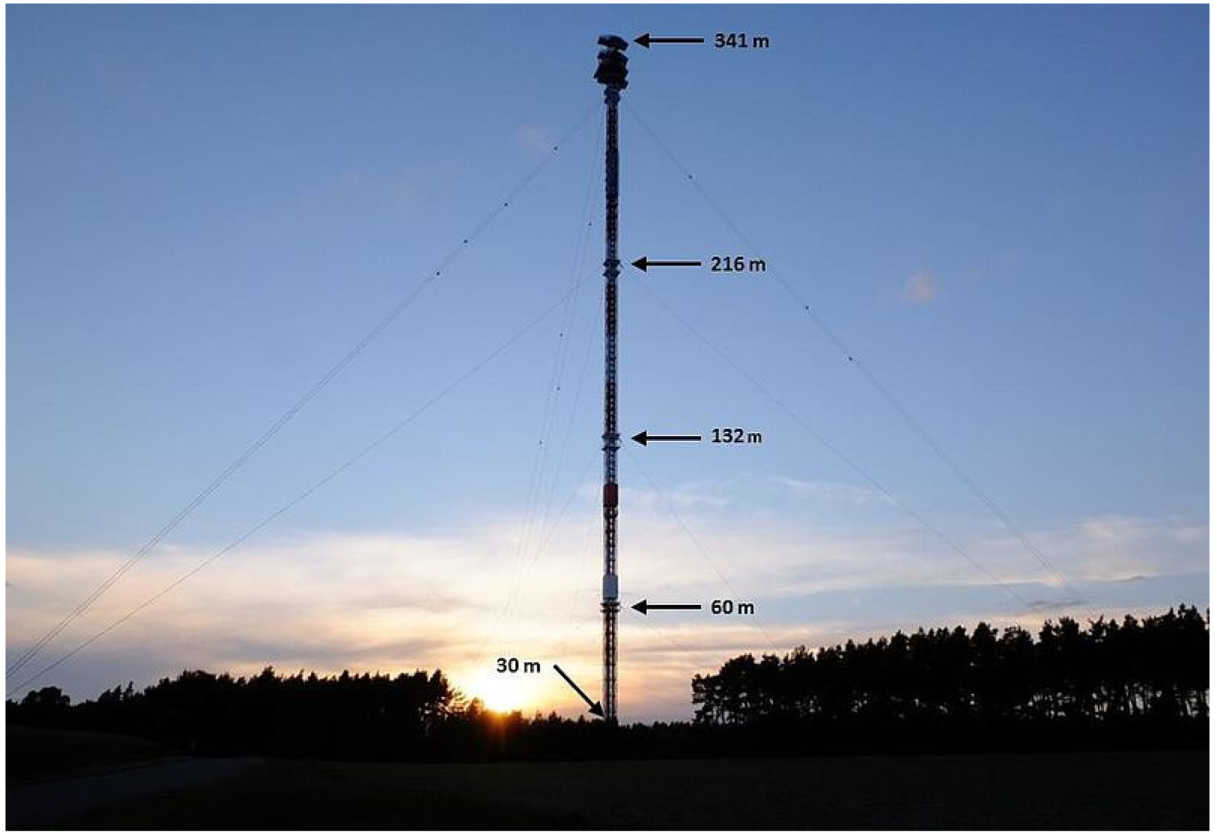
Motivation: ScaleX 2015 2.0





Mission Planning: Static missions

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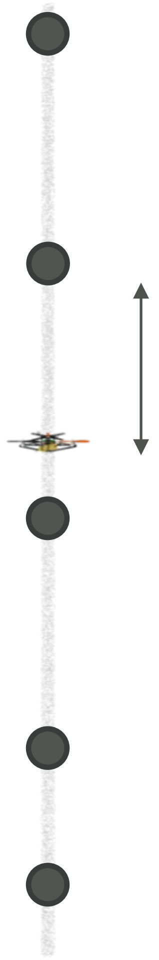
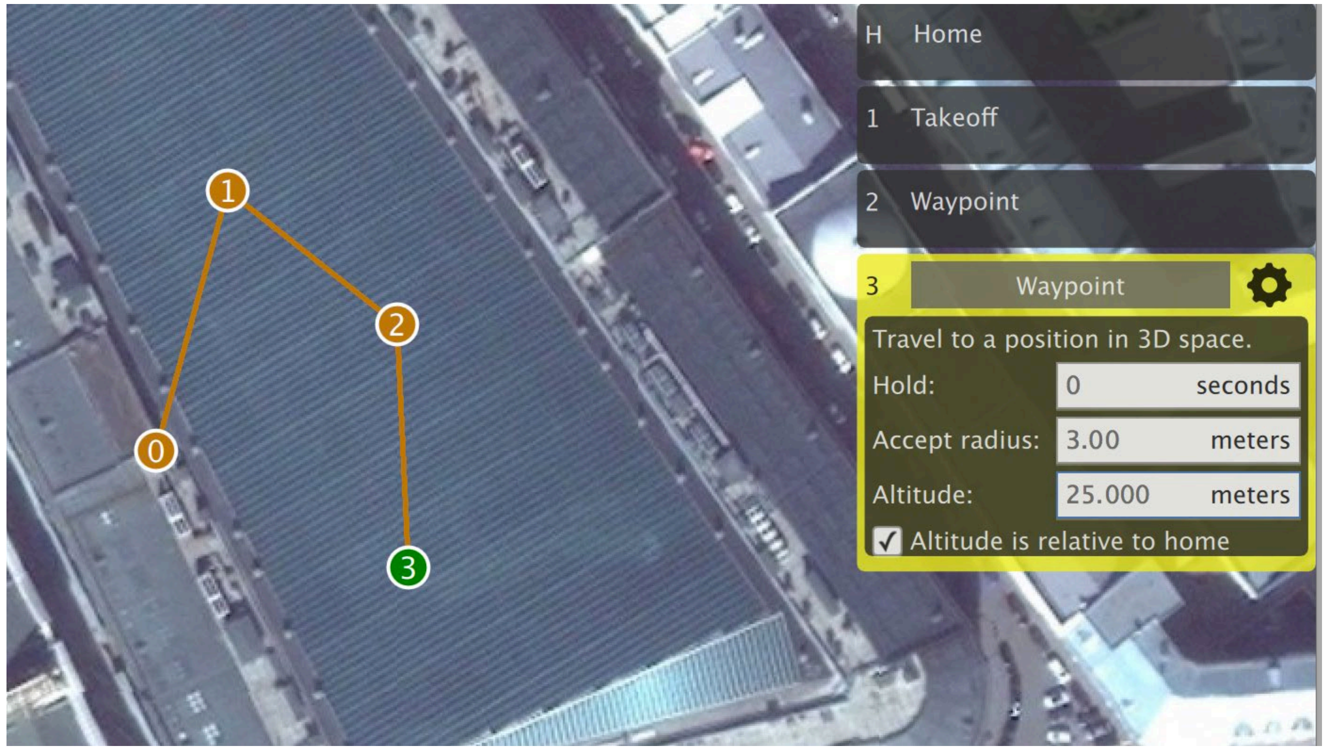
Functionality of missions limited to the feathures that the Flight Controller and the Ground Control Station (GCS) offer (Simple Waypoint Missions)

No support logging of sensor data





Travel to a position in 3D space.

Hold: 0 seconds

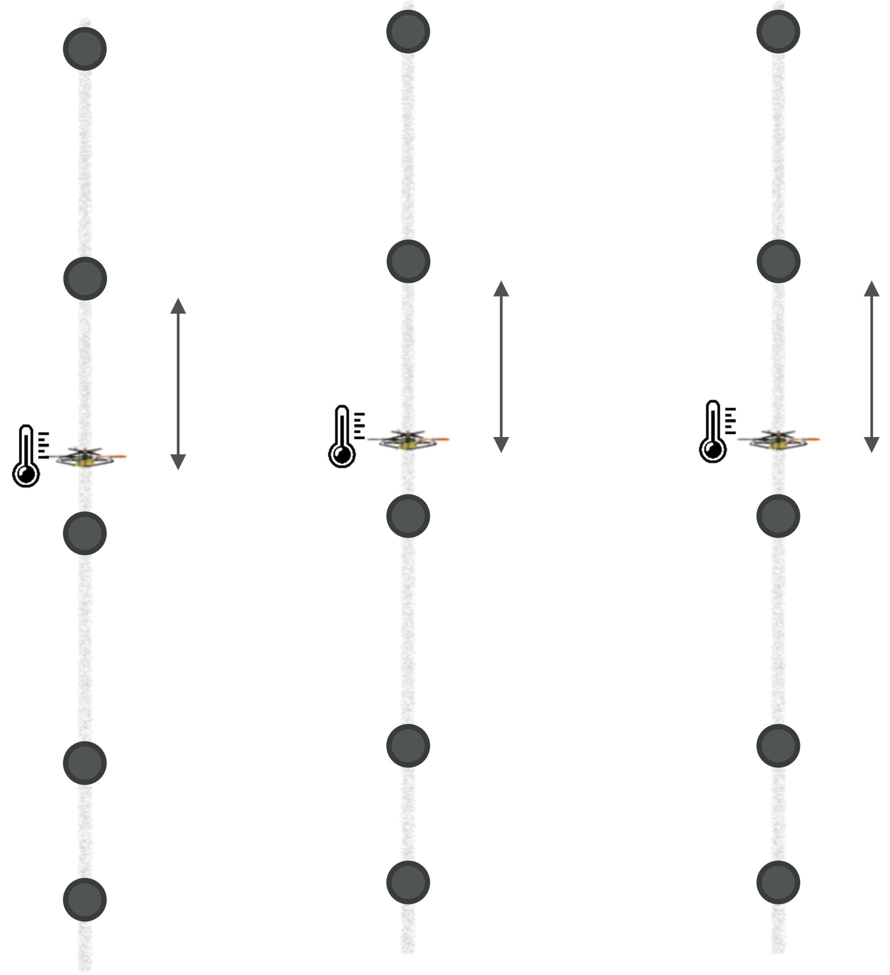
Accept radius: 3.00 meters

Altitude: 25.000 meters

✓ Altitude is relative to home

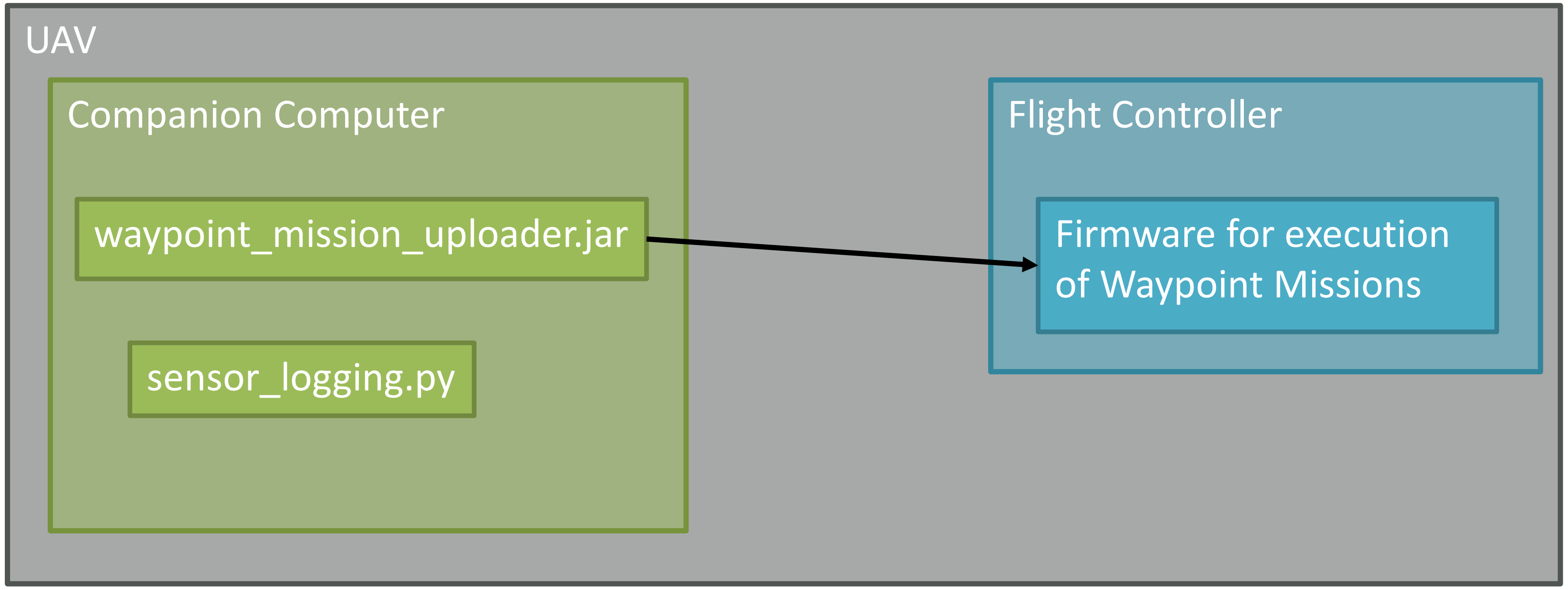
Missionsplanung: No automatic synchronization

„Synchronziation“ realized by manually starting all three missions at the same time and hoping for the best



Mission Planning: Poor extensibility of GCS

- Two seperate hardcoded programs for
  - Downloading and executing mission on flight controller
  - Aggregation of sensor values
- This separation complicates assignment of sensor data and copter / sensor position


UAV
Companion Computer
waypoint_mission_uploader.jar
sensor_logging.py
Flight Controller
Firmware for execution of Waypoint Missions

Scalex 2015: Problems

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Scalex 2015 Problems

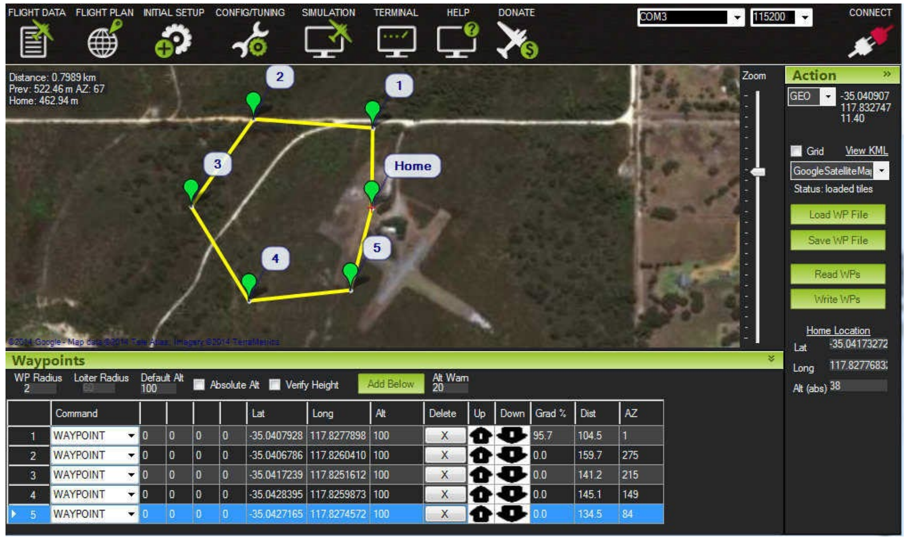
Missions not flexible enough

No synchronization

Hardcoded sensor logging

Mission Planning: State of the Art

- Mission planning is usually done via a ground control software (gcs)
  - Generic GCS: Qgroundcontrol, APM Planner, UgCS
  - Definition of waypoints that need to be reached in a certain sequence
  - Waiting on waypoints
  - Only limited possibilities for other actions (Logging, take pictures, activate sensors)
  - No or minimal swarm / ensemble support



Distance: 0.7989 km
Prev: 522.46 m AZ: 67
Home: 462.94 m

-35.040907
117.832747
11.40

Status: loaded tiles

Home Location
Lat -35.04173272
Long 117.8277683
Alt (abs) 38

Waypoints

WP Radius 2 | Loiter Radius | Default Alt 100 | Absolute Alt | Verify Height | Alt Warn 20

	Command					Lat	Long	Alt	Delete	Up	Down	Grad %	Dist	AZ
1	WAYPOINT	0	0	0	0	-35.0407928	117.8277898	100	X			95.7	104.5	1
2	WAYPOINT	0	0	0	0	-35.0406786	117.8260410	100	X			0.0	159.7	275
3	WAYPOINT	0	0	0	0	-35.0417239	117.8251612	100	X			0.0	141.2	215
4	WAYPOINT	0	0	0	0	-35.0428395	117.8259873	100	X			0.0	145.1	149
5	WAYPOINT	0	0	0	0	-35.0427165	117.8274572	100	X			0.0	134.5	84

Scalex 2015: Requirements for possible solution

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Modular mission planning framework

- Set of existing blocks to easily build simple missions
- Synchronize several UAVs with each other
- Possibility to log telemetry and sensor data
- Functionality easily expandable

Mission Planning with Block definition language (BDL)

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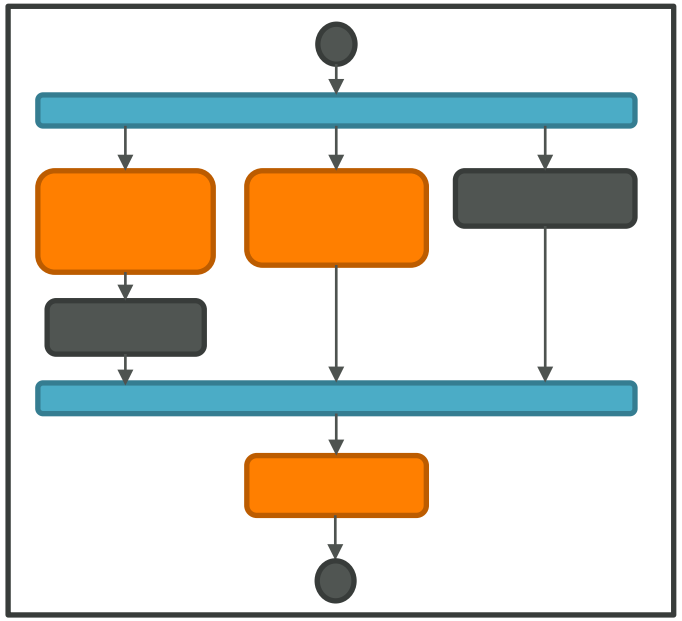
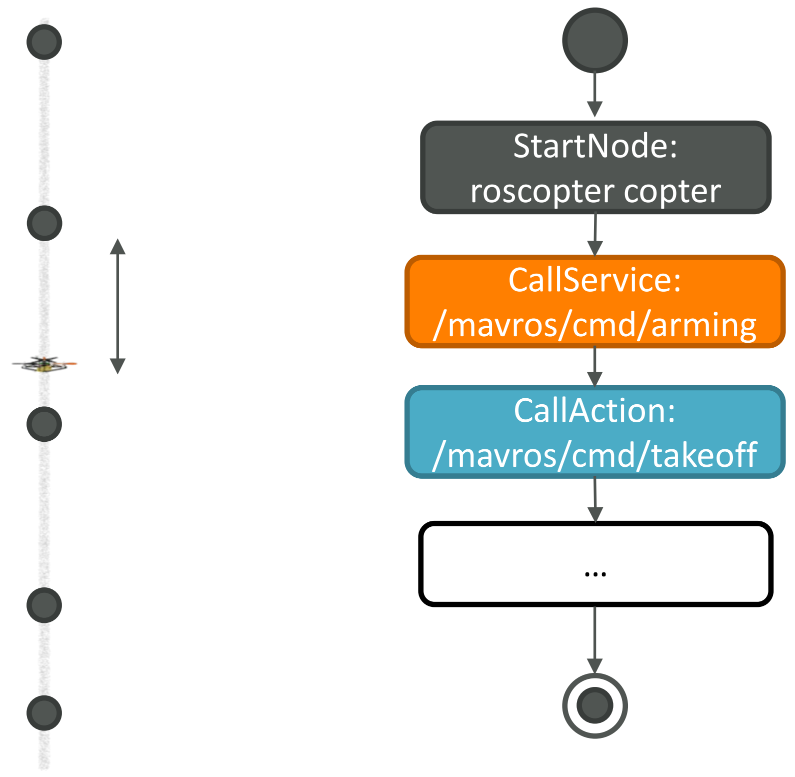
- Definition of a mission via json files
- Addition of new functionalities using Python modules
- Token semantics based on activity diagram
- Parallelism
- Decisions
- Reaction to errors

- Plugins for…
  - … interfacing with ROS2
  - … synchronizing multiple systems



Mission Planning: Modeling a mission

Modeling of missions in ROS2

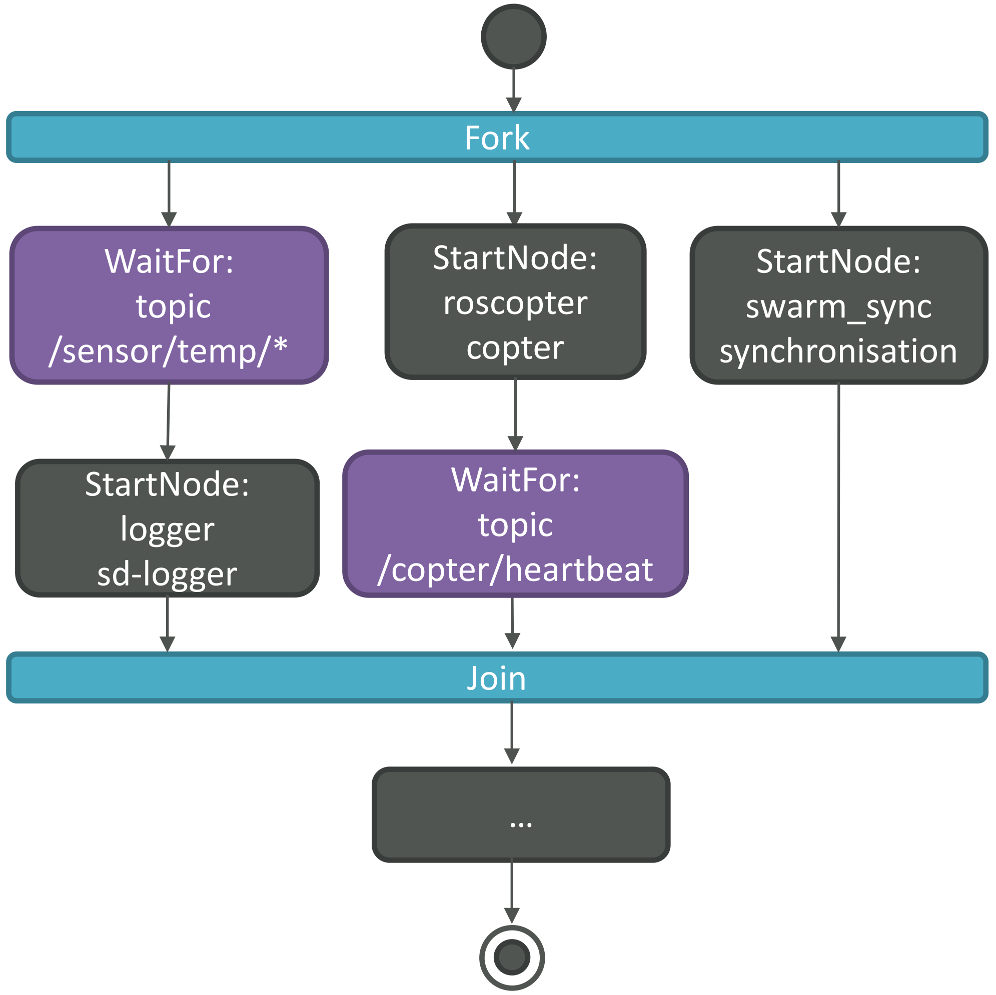


```
"b0": {
   "type": "Start",
   "next": "b1"
 },

 "b1":{
   "type": "StartNode",
   "package": "roscopter",
   "node": "copter",
   "nodename": "copternode1",
   "next": "b2"
 },

 "b2":{
   "type": "CallService",
   "name": "/mavros/cmd/arming",
   "args": "true",
   "next": "b3"
 },
…
```

Mission Planning: Parallel program flows


Fork
WaitFor: topic /sensor/temp/*
StartNode: roscopter copter
StartNode: swarm_sync synchronisation
StartNode: logger sd-logger
WaitFor: topic /copter/heartbeat
Join
…

Mission Planning: synchronization

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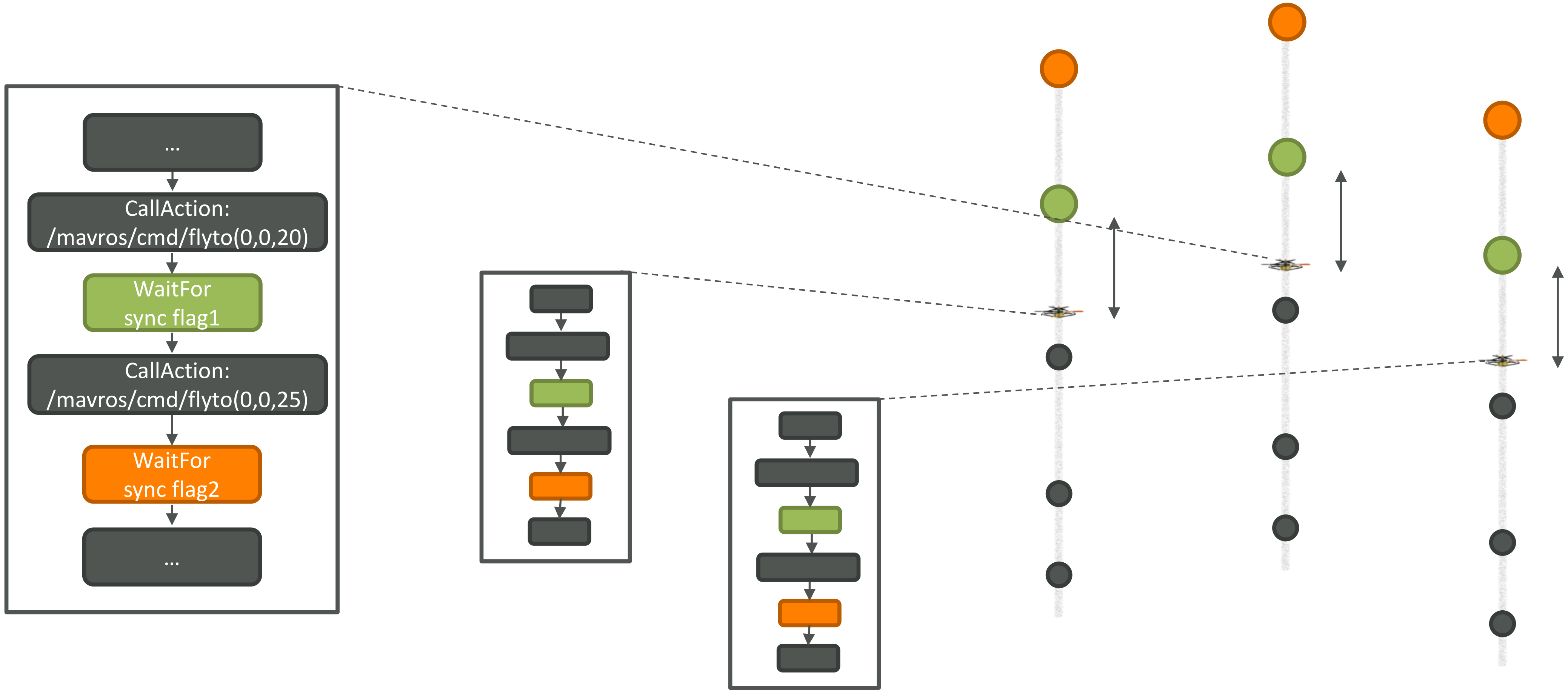
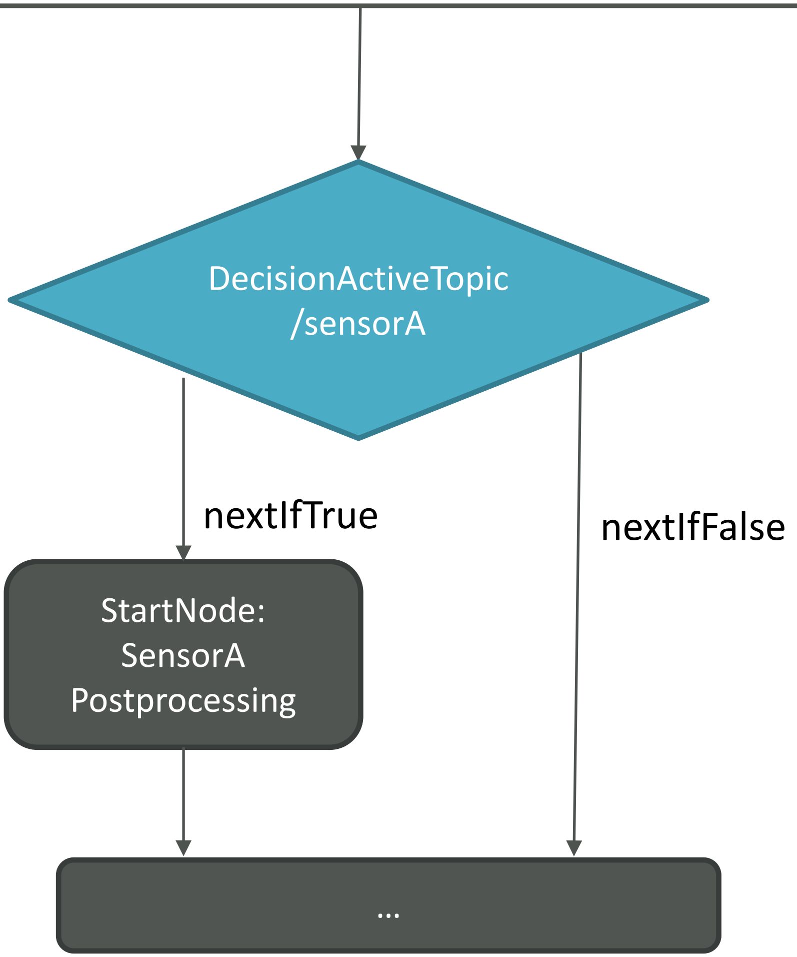

…
CallAction: /mavros/cmd/flyto(0,0,20)
WaitFor sync flag1
CallAction: /mavros/cmd/flyto(0,0,25)
WaitFor sync flag2
…

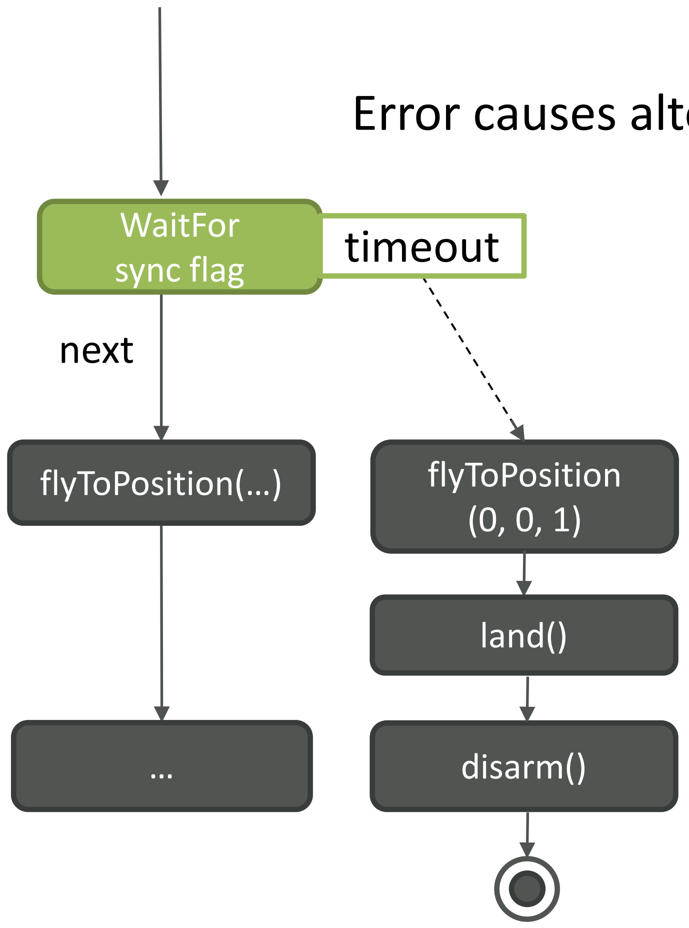
Mission Planning: Decision nodes



```
"b2": {
      "type": "DecisionRandom",
      "chanceForTrue": ".3",
      "nextIfTrue": "b5",
      "nextIfFalse": "b3"
},
```

Mission Planning: Error handling

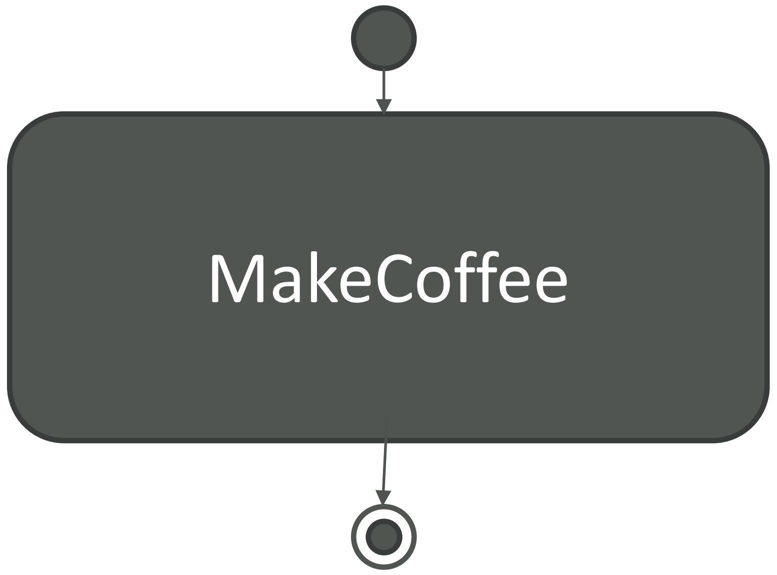
Error causes alternative program flow



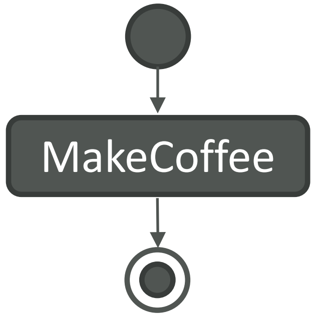
```
"b2": {
        "type": "WaitForSyncFlag",
        "id": "s13",
        "timeout": "15",
        "next": "b7",
        "nextTimeout": "b16"
},
```

Mission Planning: Extensibility

- That‘s nice and all, but i don‘t have a Drone ☹
- Can it make me some Coffee?



Mission Planning: Extensibility



coffee.json

```
"b0": {
     "type": "Start",
     "next": "b1"
  },

"b1": {
   "type": "MakeCoffe",
   "url": "iotcoffemaker.local",
   "type": "strong",
   "next": "b2"
},

"b2": {
     "type": „End",
}
```

coffee.py

```
import mission_player as mp
import coffee_maker as cm

# Define Functionality
def make_coffee(args):
  my_coffeemaker = cm(args["url"])
  my_coffeemaker.make(args["type"])
  return args["next"]

# Add Functionality
mp.add_block("MakeCoffee",make_coffee
)

# Play Mission
mp.play_mission("./coffee.json")
```

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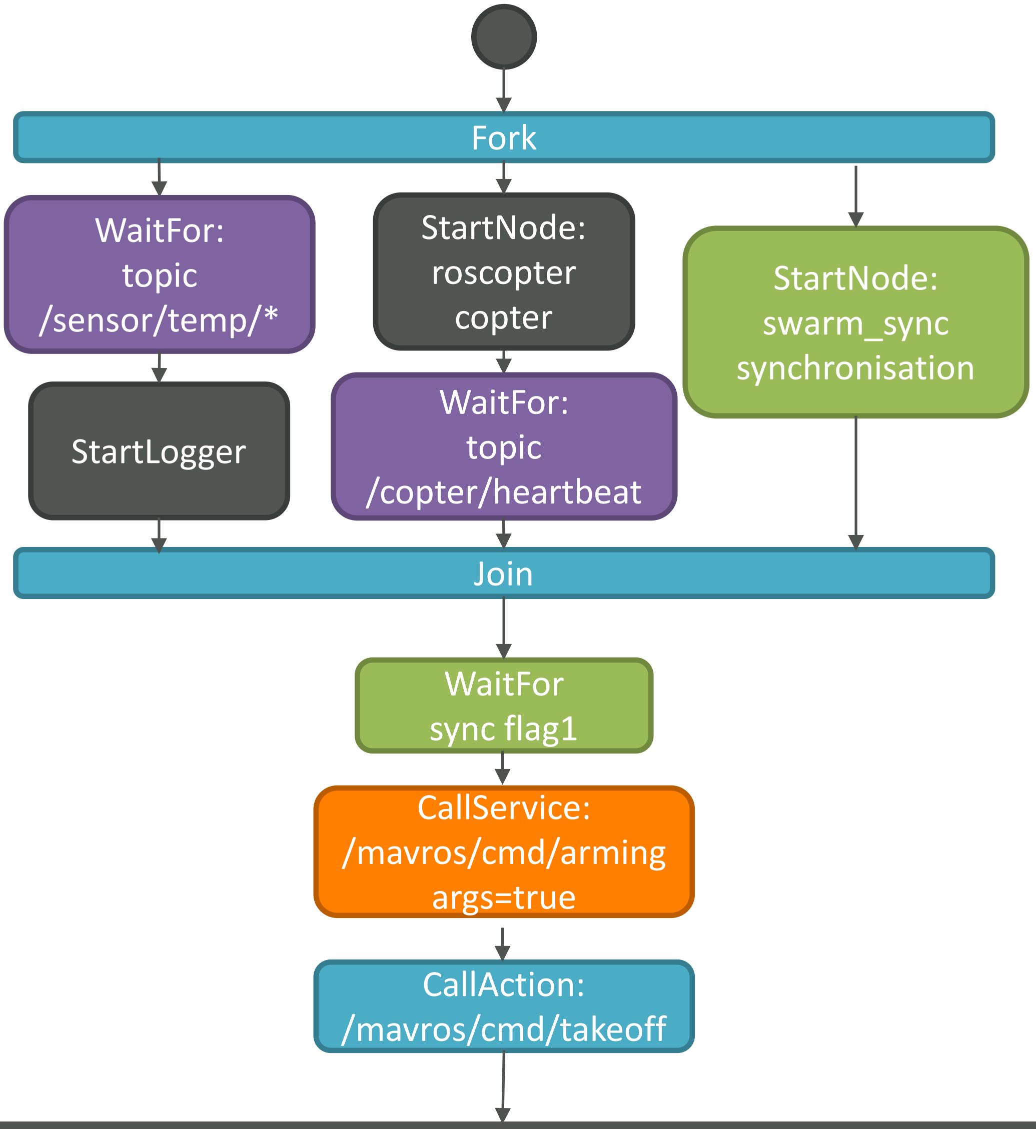
Mission Planning: ScaleX Remastered


Fork
WaitFor: topic /sensor/temp/*
StartNode: roscopter copter
StartNode: swarm_sync synchronisation
StartLogger
WaitFor: topic /copter/heartbeat
Join
WaitFor sync flag1
CallService: /mavros/cmd/arming args=true
CallAction: /mavros/cmd/takeoff

Mission Planning: ScaleX Remastered

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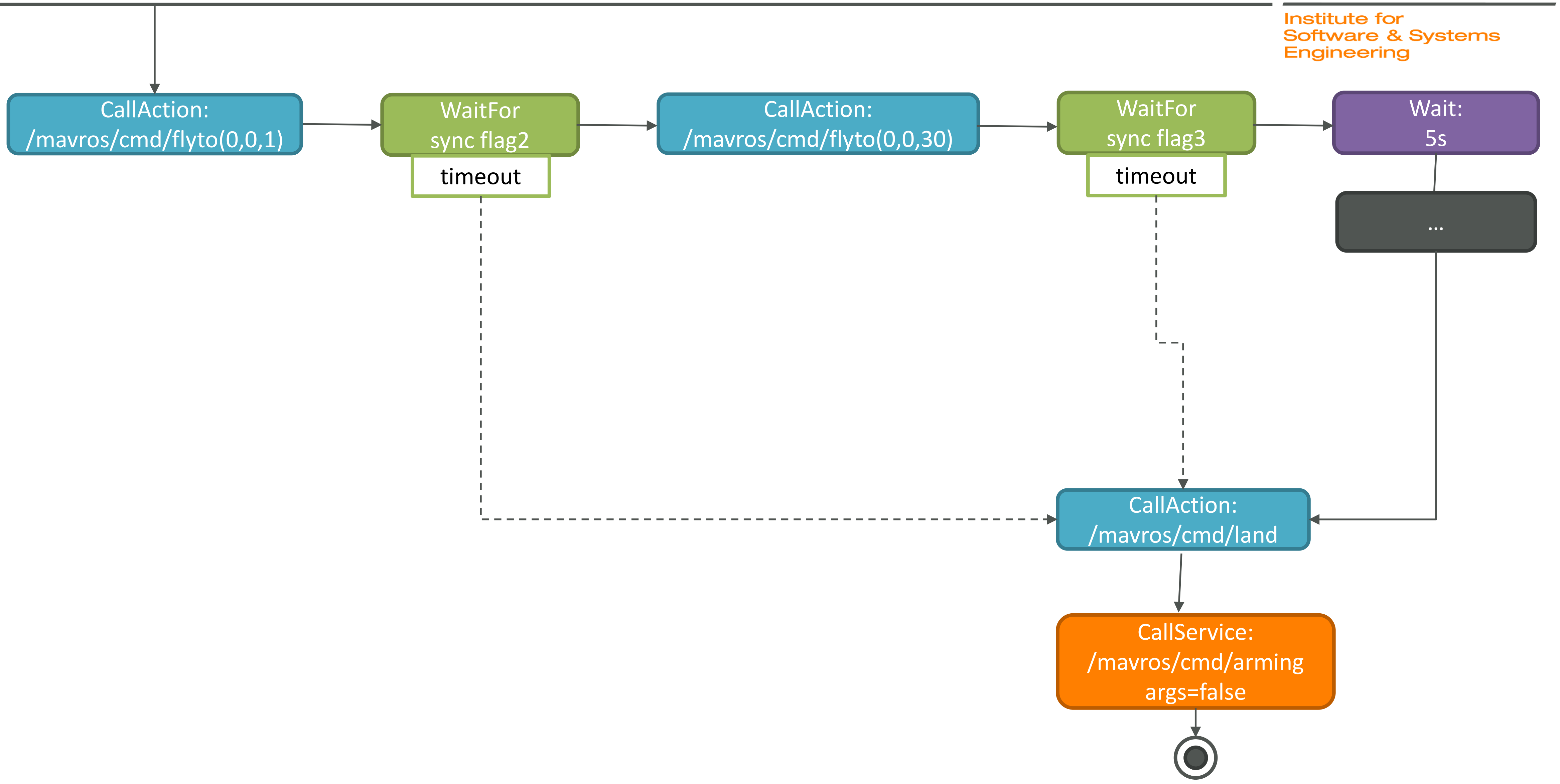
CallAction: /mavros/cmd/flyto(0,0,1)
WaitFor sync flag2
timeout
CallAction: /mavros/cmd/flyto(0,0,30)
WaitFor sync flag3
timeout
Wait: 5s
...
CallAction: /mavros/cmd/land
CallService: /mavros/cmd/arming args=false

Mission Planning : State of the Art

- ROS1 Launchfiles
  - XML
  - Allow to start multiple Programs / Nodes at once
  - No chronological order
  - No possiblities for cotrolling the program flow
- ROS2 Launchfiles
  - Python Script
  - Nodes have lifecycles
  - Launch file can react to changes in the lifecycle