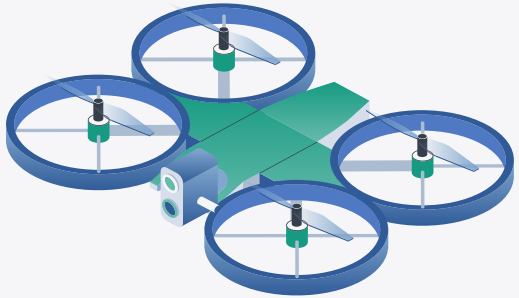


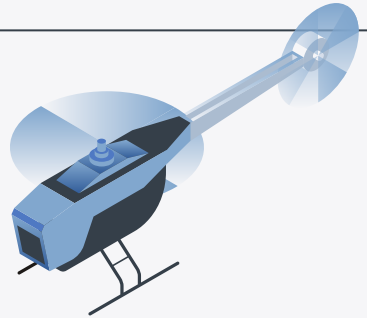
# State-Based Testing of Flight Controllers

Catarina Gamboa and Simon Chu

# Domain

Flight controller has been deployed to more life-critical use cases like search and rescue and medical supply delivery, and shifting towards more autonomy.

# Problem



Testing techniques in this space remains limited

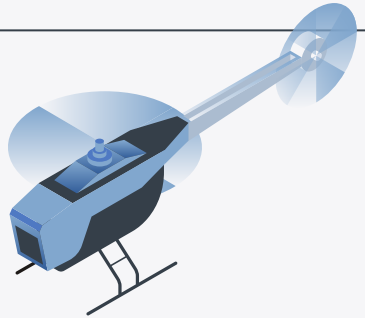
Flight Controller API Unit Test

Simulation-based Testing

Deploy on Real-world Hardware

Existing techniques do not consider the statefulness of the drone and overlook some of the bugs resulted from calling certain API from the wrong state.

# Problem

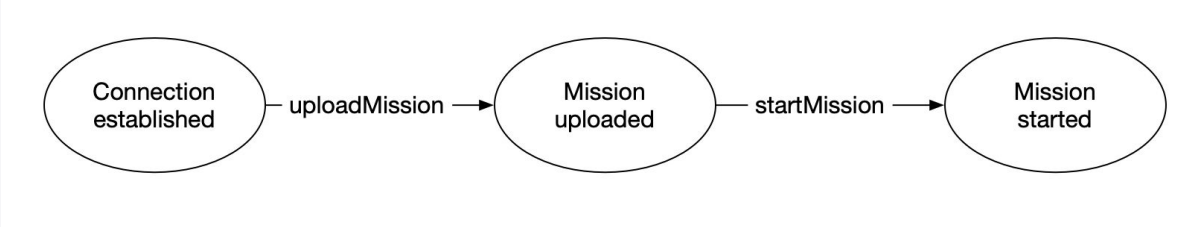


```
Mission mission = drone.getMission();
mission.startMission();
```

```
Mission mission = drone.getMission();
mission.uploadMission(...);
mission.startMission();
```

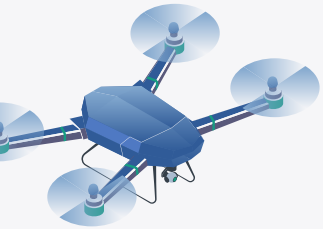
Mission has to be uploaded before started.

Otherwise the drone may remain on a holding pattern or execute previously cached mission causing crashes or under undefined behavior



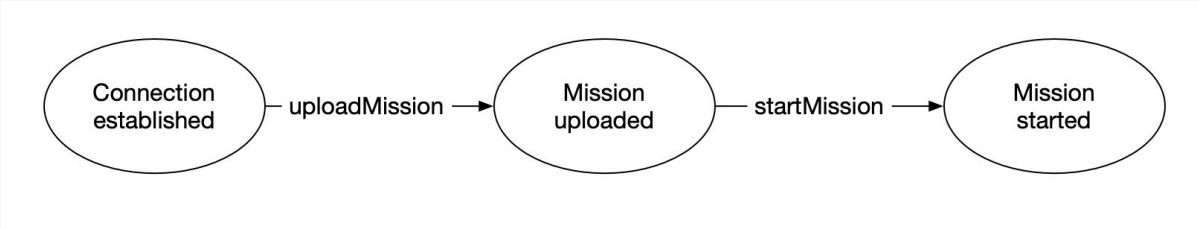
# Approach

Extract state machine from documentation → Annotate flight controller API with LiquidJava → Statically analyze controller code

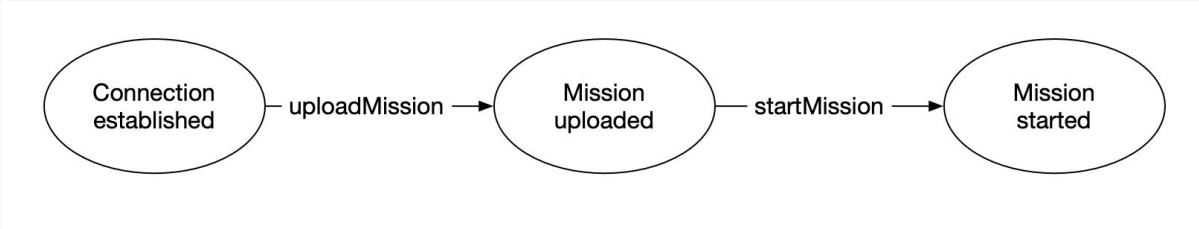


We chose to annotate **MAVSDK** because it is one of the two most popular open-source drone controller frameworks.

# Example


Connection established
uploadMission
Mission uploaded
startMission
Mission started

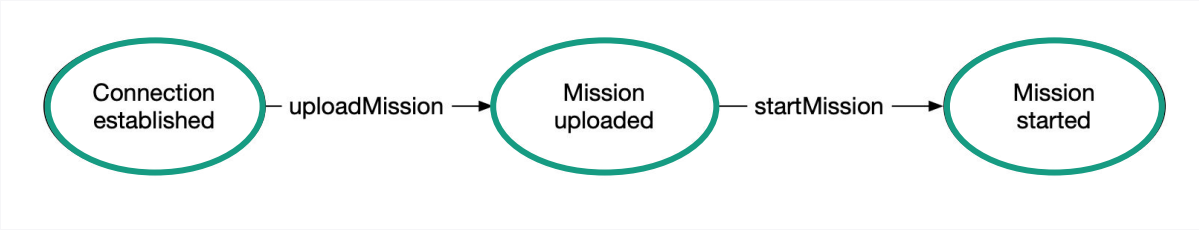
# Example




Mission

```
@ExternalRefinementsFor("io.mavsdk.mission.Mission")
```

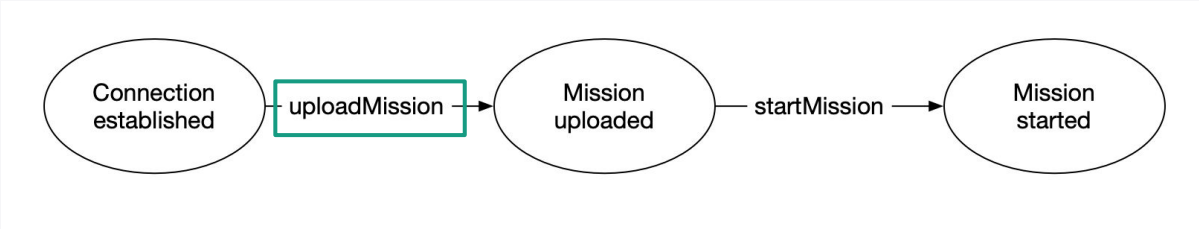
# Example




Mission

```
@ExternalRefinementsFor("io.mavsdk.mission.Mission")
@StateSet({...,"connectionEstablished", "missionUploaded", "missionStarted"})
```

# Example




Mission

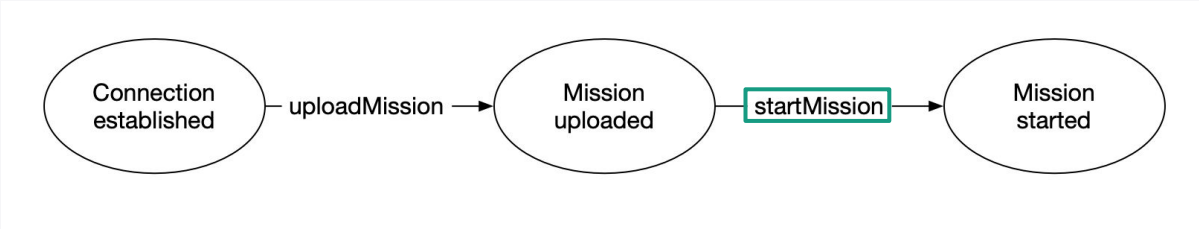
```
@ExternalRefinementsFor("io.mavsdk.mission.Mission")
@StateSet({...,"connectionEstablished", "missionUploaded", "missionStarted"})
public interface MissionControllerRefinements {

      @StateRefinement(from="connectionEstablished(this)",to="missionUploaded(thi
s)")
      public void uploadMission(MissionPlan missionPlan);




}
```

# Example




Mission

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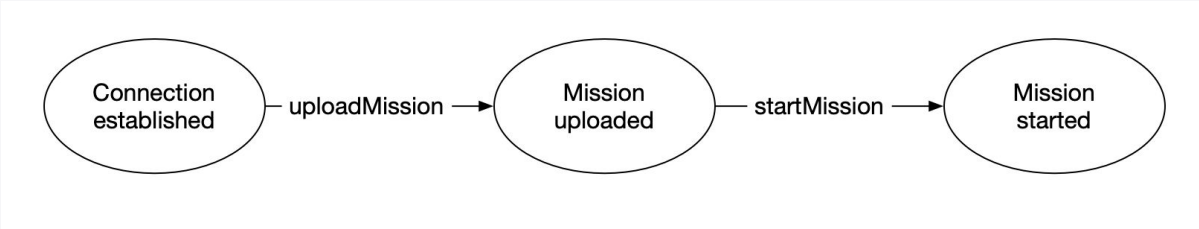
      @StateRefinement(from="connectionEstablished(this)",to="missionUploaded(thi
s)")
      public void uploadMission(MissionPlan missionPlan);

      @StateRefinement(from="missionUploaded(this)", to="missionStarted(this)")
      public void startMission();

      …
}
```

# Example




**Mission**

```
@ExternalRefinementsFor("io.mavsdk.mission.Mission")
@StateSet({...,"connectionEstablished", "missionUploaded", "missionStarted"})
public interface MissionControllerRefinements {

      @StateRefinement(from="connectionEstablished(this)",to="missionUploaded(thi
s)")
      public void uploadMission(MissionPlan missionPlan);

      @StateRefinement(from="missionUploaded(this)", to="missionStarted(this)")
      public void startMission();

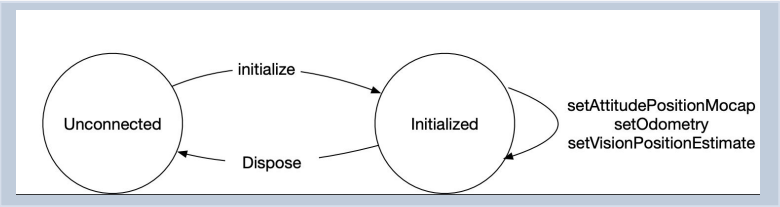
      …
}
```

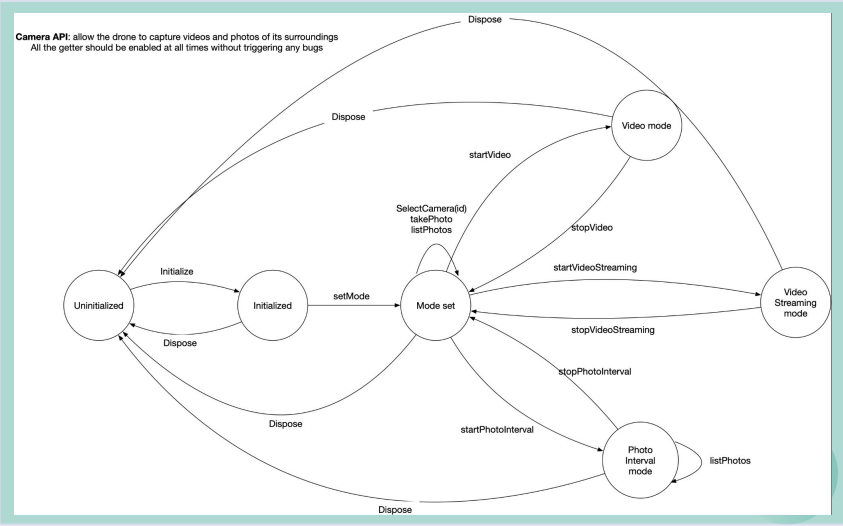
**Client**

```
Mission mission =
      drone.getMission();
//mission.uploadMission(...);
mission.startMission();
```

# 7 classes modelled

| | States | Transitions |
|---|---|---|
| **Mocap** | 2 | 6 |
| **Geofence** | 3 | 5 |
| **Mission** | 4 | 14 |
| **Offboard** | 4 | 17 |
| **Camera** | 6 | 15 |
| **FTP** | 5 | 19 |
| **FollowMe** | 6 | 20 |



# Evaluation

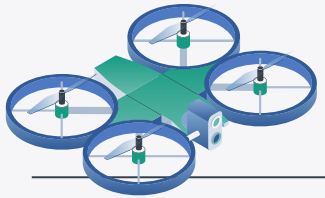
**01 Real Examples**

For each class we found 1-3 real code examples

**02 Change the examples**

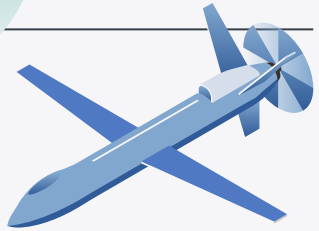
1. Asynchronous -> synchronous
2. Change to Java

**03 Verify with LiquidJava**



We have found 3 bugs where code does not follow the declared protocols:
2 in **Camera** and 1 in **Ftp**

# Insights



## LiquidJava

- Handling asynchronous code and aliasing
- State Transitions based on parameters

## Flight Controllers

- Modelling the protocols is helpful to find errors
- Other APIs, for example non-open source and used in industry, should take advantage of these verification techniques

# Thank you!