# A skill fault model for autonomous systems

Gabriela Catalán Medina [1,2] Jérémie Guiochet [1]
Charles Lesire [2] Augustin Manecy [2]

[1]LAAS CNRS, University of Toulouse, France

[2]ONERA/DTIS, University of Toulouse, France

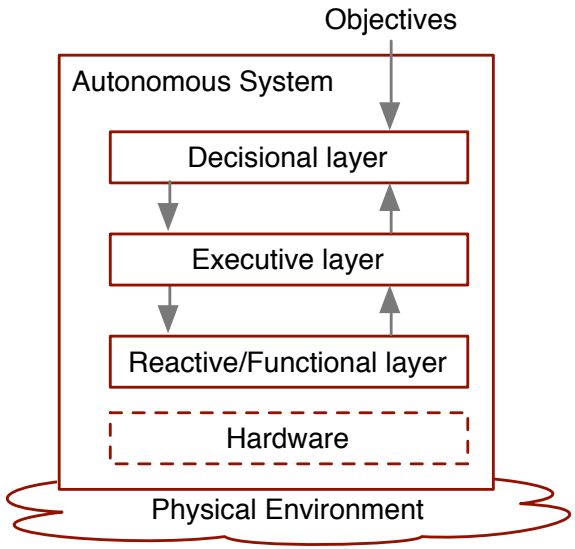
4th International Workshop on Robotics Software Engineering, ROSE@ICSE

May 9th, 2022



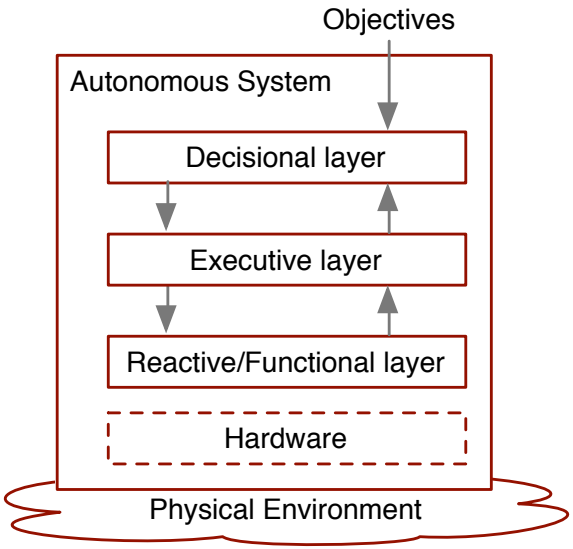
# Introduction

- Context
  - Autonomous systems and architecture : 3 layers
- Problematic
  - Faults in autonomous architectures may occur at all layers, usually managed with local treatment
  - How to specify consistent fault detection and recovery mechanisms in such architecture ?

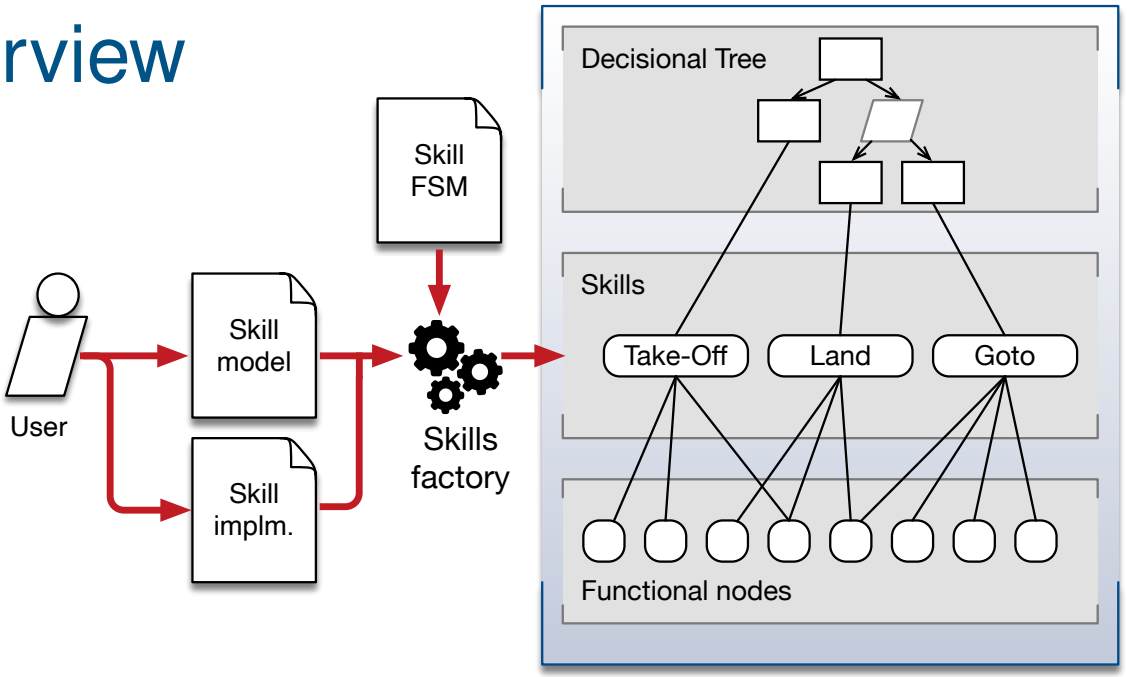


# Introduction (2)

- Our approach
  - Use a systematic approach for fault analysis (model-based), and to specific recovery mechanisms
  - Study how this detection and recovery mechanisms can be implemented at the executive layer (skill layer)
- Our case study
  - Autonomous drone (DJI M600), Infrastructure inspection Beyond Visual Line Of Sight (BVLOS)

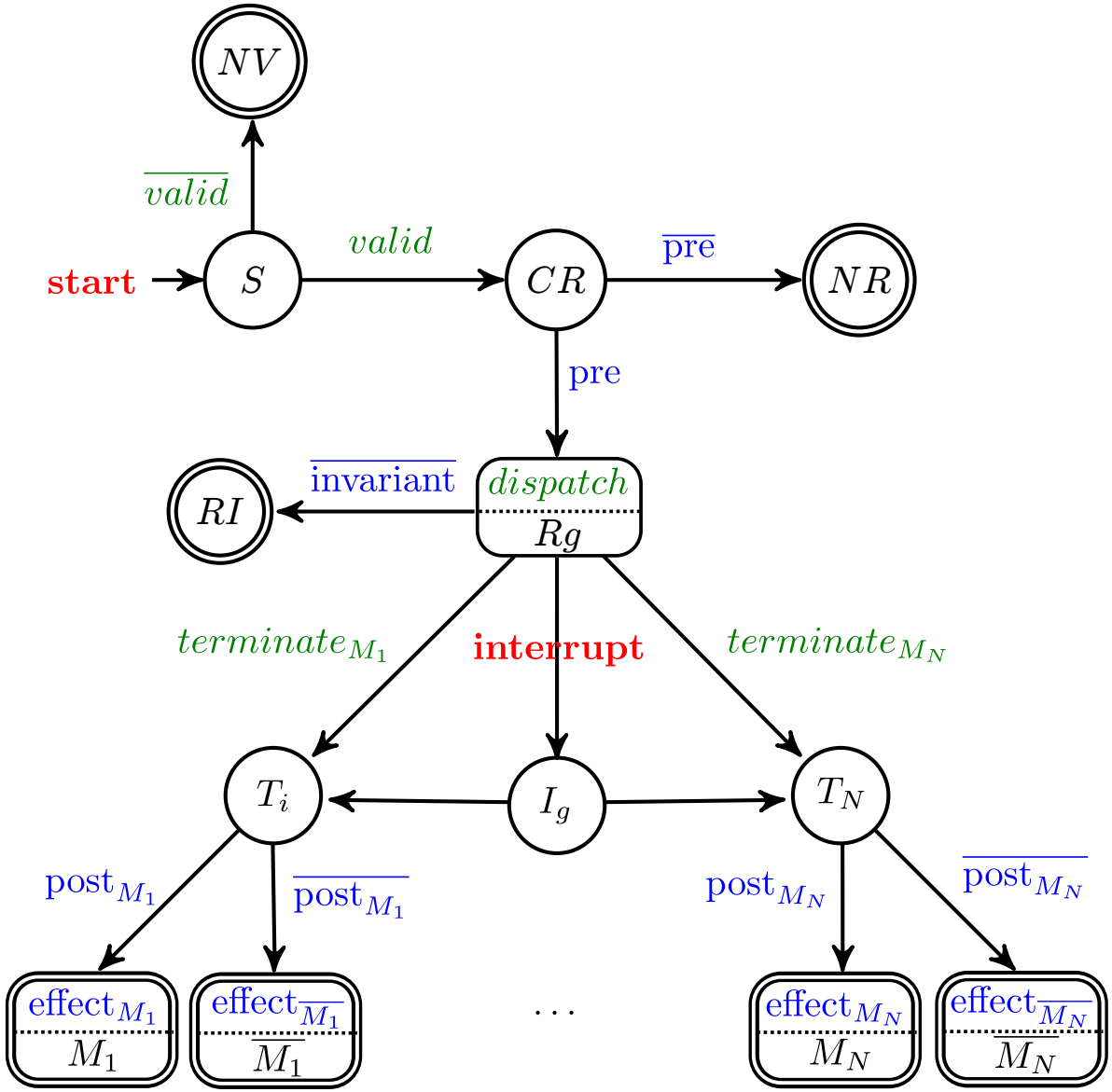



# Skills > Overview




- Skill layer converts plans sent by the decisional layer into primitive services (skills) realized by the functional under layer
- Skills are primitive services described by a skill model and a skill implementation
- Skill model and skill implementation are used to generate skill managers for the skill layer
- All skills share a same finite state machine (FSM), see next slide

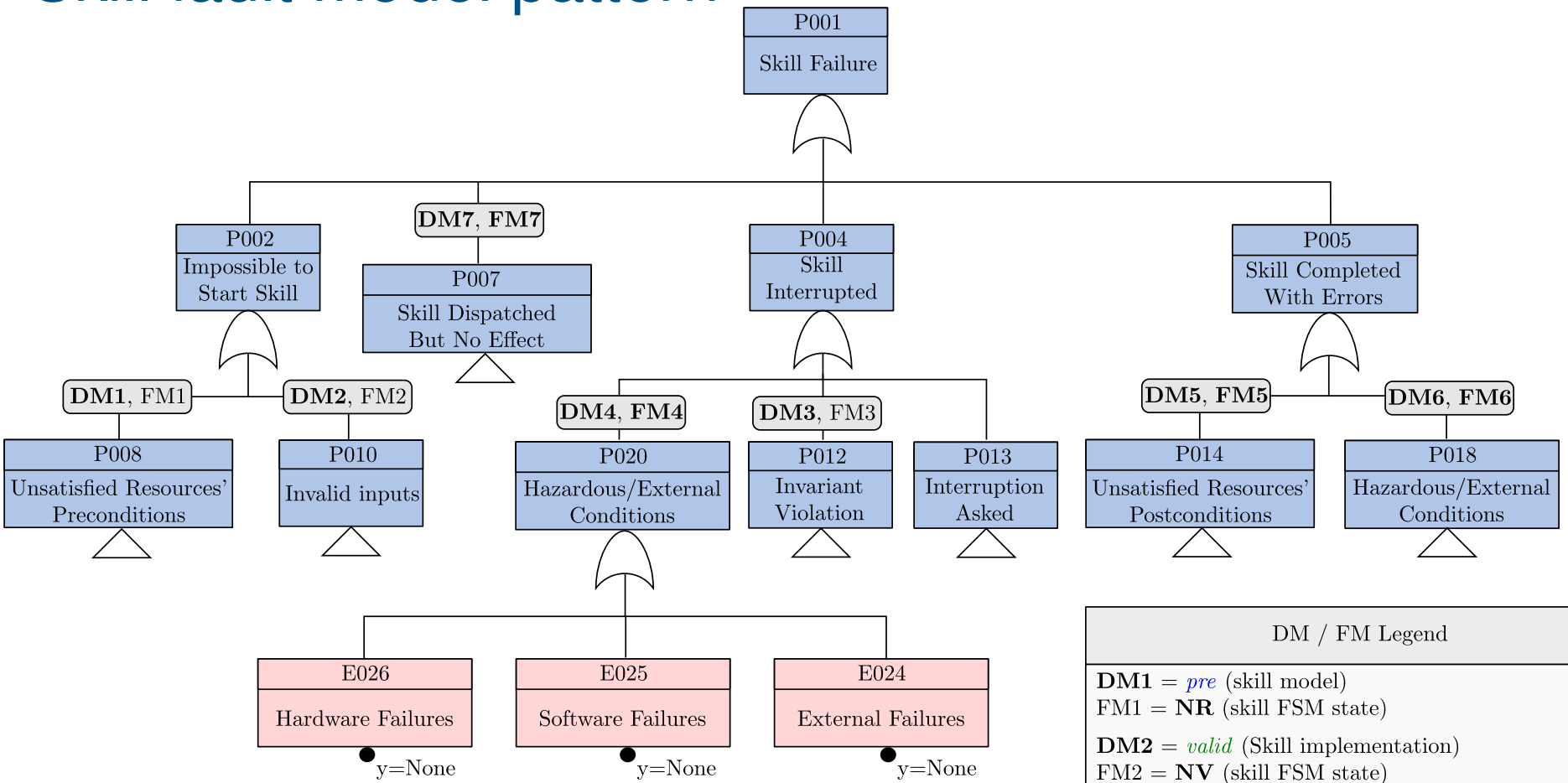
# Skills > Skill FSM



# Skills > Skill model example

```
skill takeoff {
    input {
        height: float64 // validate can fail if h>h_geo_fence
        speed:  float64 // maximum ascending speed
    }
    effect {
        take_control: axes_authority -> USED
        release_control: axes_authority -> AVAILABLE
    }
    precondition {
        sdk_authority: resource=(SDK_authority==AVAILABLE)
        not_moving: resource=(axes_authority==AVAILABLE)
        on_ground: resource=(flight_status==ON_GROUND)
        home_valid: resource=(homepoint_status==VALID)
        success take_control
    }
    invariant {
        keep_sdk_authority: resource=(SDK_authority==AVAILABLE)
        ↪  violation=release_control
        in_control: resource=(axes_authority==USED)
    }
    result {
        AT_ALTITUDE: apply=release_control
        BLOCKED: apply=release_control
        ABORTED: apply=release_control
    }
}
```

# Skill fault model pattern

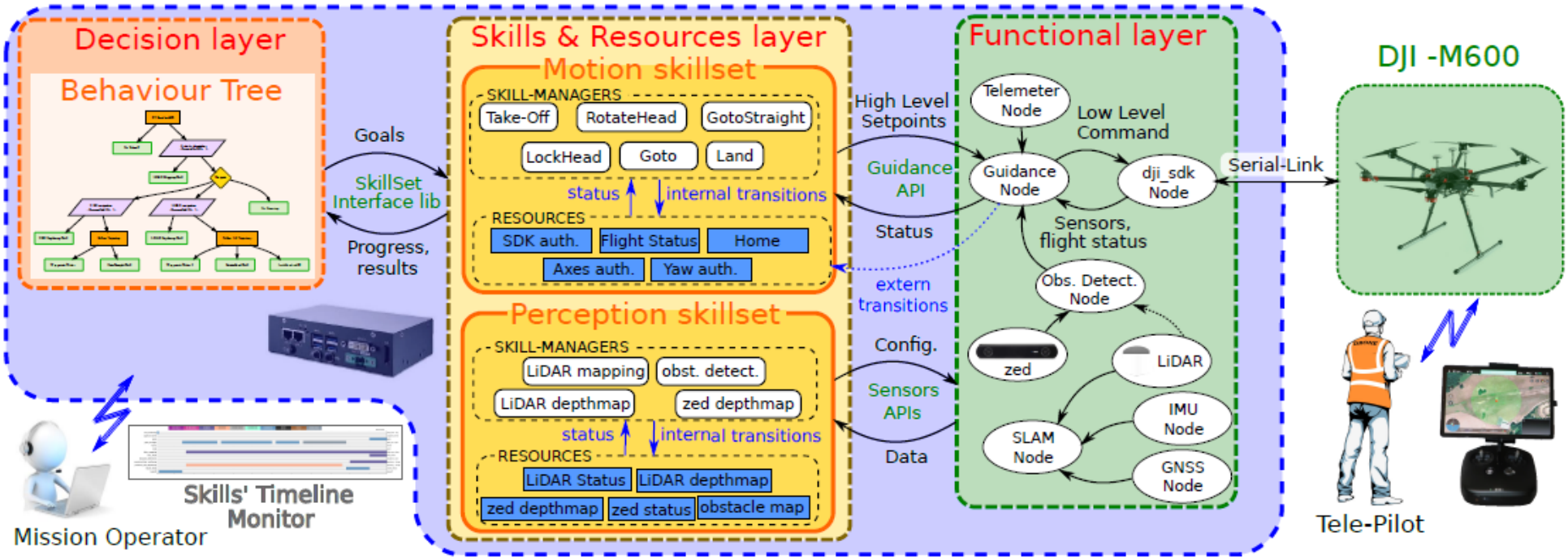



| DM / FM Legend |
|---|
| **DM1** = *pre* (skill model)<br>FM1 = **NR** (skill FSM state) |
| **DM2** = *valid* (Skill implementation)<br>FM2 = **NV** (skill FSM state) |
| **DM3** = *invariant* (Skill model)<br>FM3 = **RI** (skill FSM state) |
| **DM4** = `callback function` (Skill implementation)<br>**FM4** = $M_i$ or $\overline{M_i}$ (skill model) |
| **DM5** = *post* (skill model)<br>**FM5** = $\overline{M_i}$ (skill model) |
| **DM6** = `callback function` (skill implementation)<br>**FM6** = $M_i$ or $\overline{M_i}$ (skill model) |

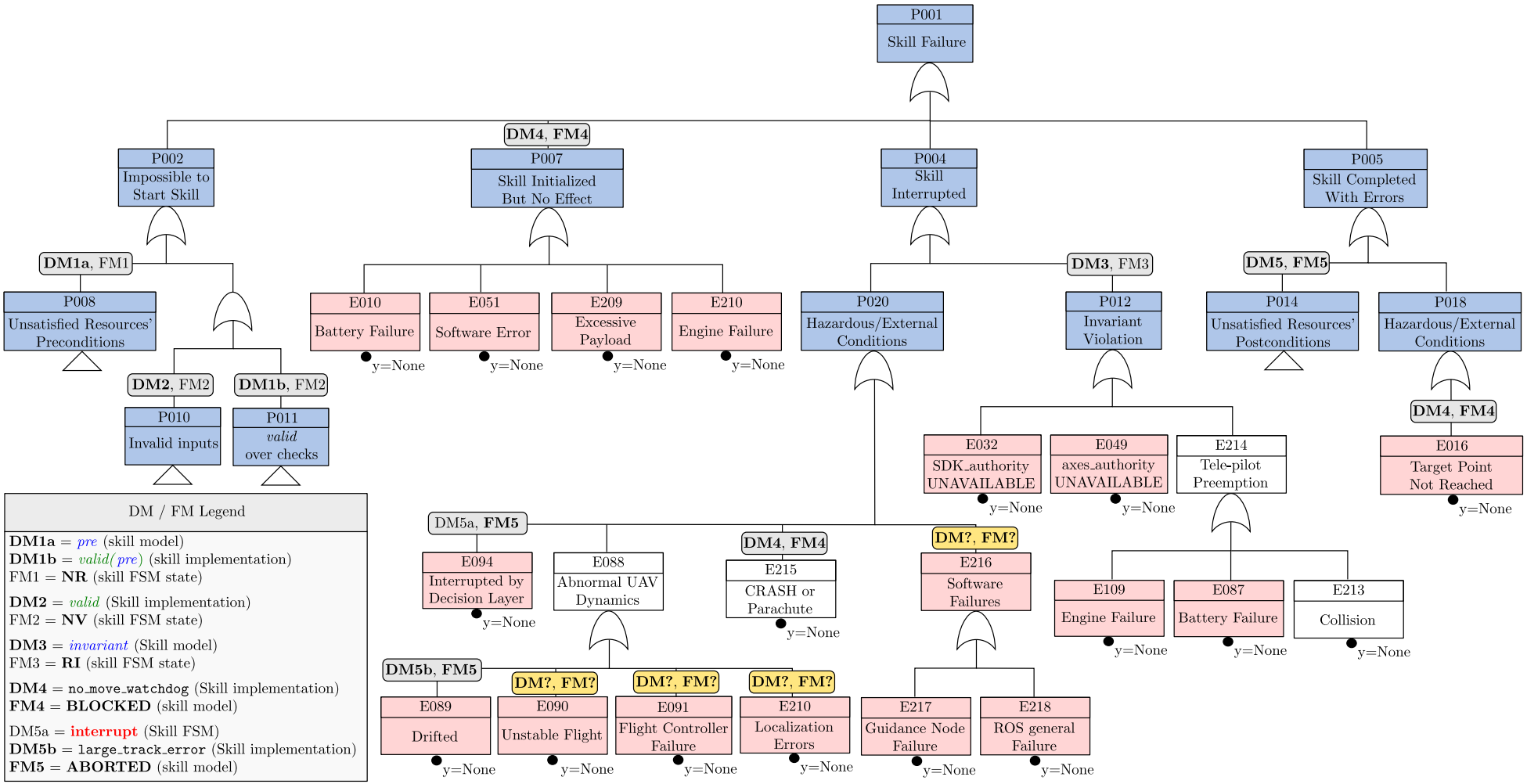
# Skill Fault Analysis Process

1. Error analysis : list all the events (errors) that may impact correct skill execution
2. Fault tree analysis : design **skill fault tree** based on the **skill fault model pattern**. Connection of each event listed in (1) with each **skill fault tree**,
3. Detection and recovery : determination of potential detection mechanisms ($DM_i$) and skill failure modes ($FM_i$) for each branch of the fault tree ;
4. Design/Verification : Design / Verify the skill model or implementation to add or correct a missing or incomplete $DM_i$ or $FM_i$.

# Case study > Architecture overview



# Case study > Fault tree for Take-off skill



# Case study > Fault tree for Take-off skill

Next step is then to identify inconsistencies or unmanaged events in the fault tree and to modify the skill model or skill implementation :

- Identify errors can propagate up to top of the fault tree, i.e. lead to a skill failure without being handled by a DM/FM mechanism (e.g. modification of the skill model, see paper).
- Errors of different nature could lead to the same failure modes of the skill, but with different detection mechanisms.
- Find redundant checks (DM) and optimize them

# Conclusion

- Support for skill design and analysis to deal with detection and recovery mechanisms
- Generic and model-based (skill model + fault trees)

- But only validated so far on drone applications and no we need to evaluate how this really improve safety and availability at system level

- Current development : study how the fault tree can also be used to generate test cases (to validate the detection and recovery mechanisms)