The background of the slide is a large, semi-transparent NASA logo. It features the word "NASA" in white, bold, sans-serif capital letters across the center. Above the letters is a white swoosh representing a spacecraft's path. The background is a light blue circle with white stars and a white crescent moon. A red diagonal line, representing a rocket's trajectory, crosses the logo from the bottom left to the top right.

Cockpit Activity as Hierarchical Activity Planning and Execution

J. Benton

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Evolving Nature of System Failures

Operational Use of Flight Path Management Systems (FAA PARC *Flt DAWG Report*, 2013):

- LOSA data: Malfunctions occur on 20% of all “normal” flights
- and about 55% of major incidents are due to system malfunctions

Malfunctions:

- Multiple sometimes difficult-to-diagnosis messages from disparate systems
- Lack of basic data, unclear procedures for malfunctions

Air France 447 (A330), 2009

- Airspeed sensors inconsistent
- Intermittent, seemingly spurious stall warnings
- Lack of understanding on procedures

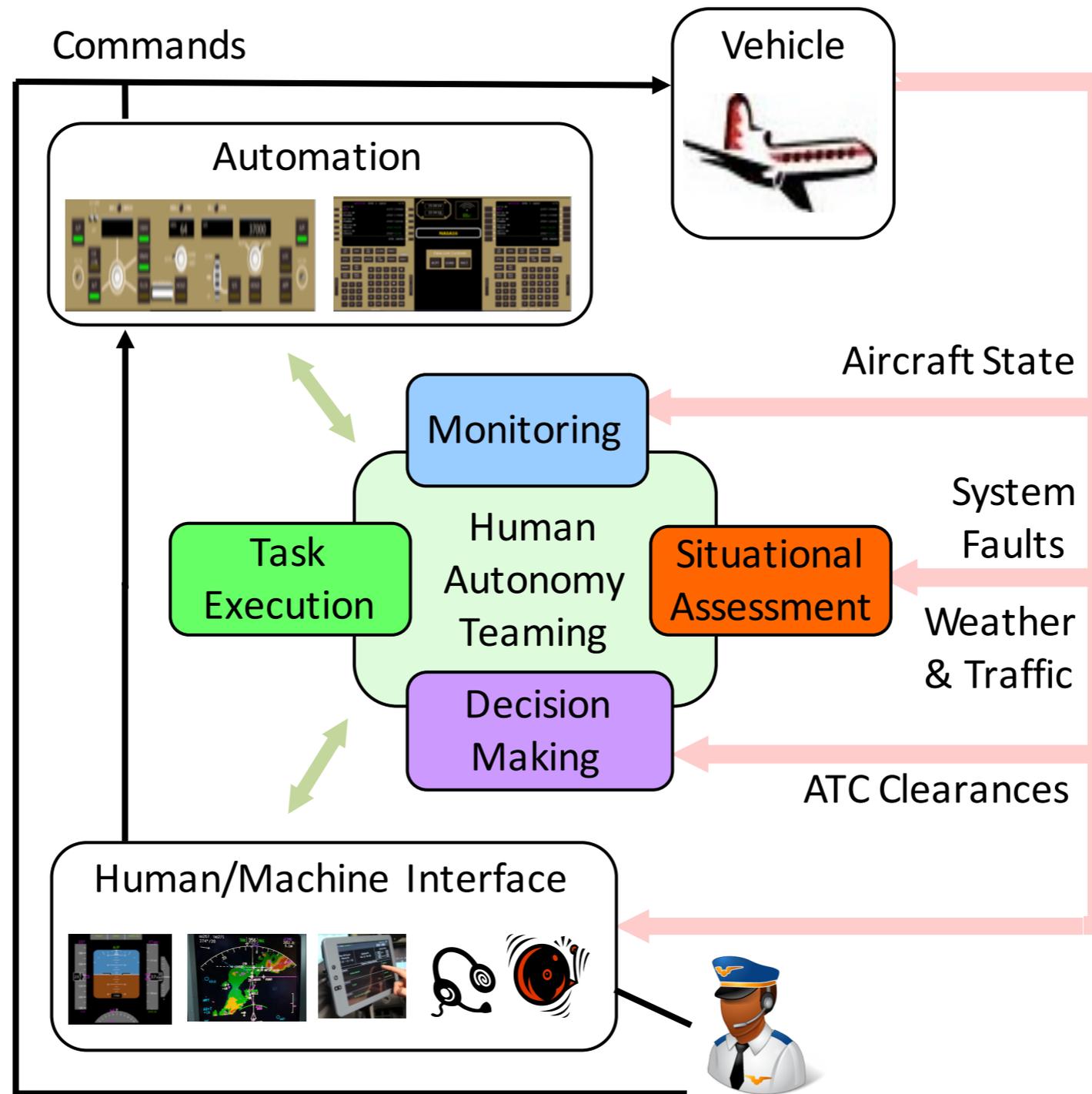
American Airlines 268 (B757), 2008

- Multiple warnings related to power
- Multiple possible procedures to follow
- Manual review of each procedure required to determine which to follow

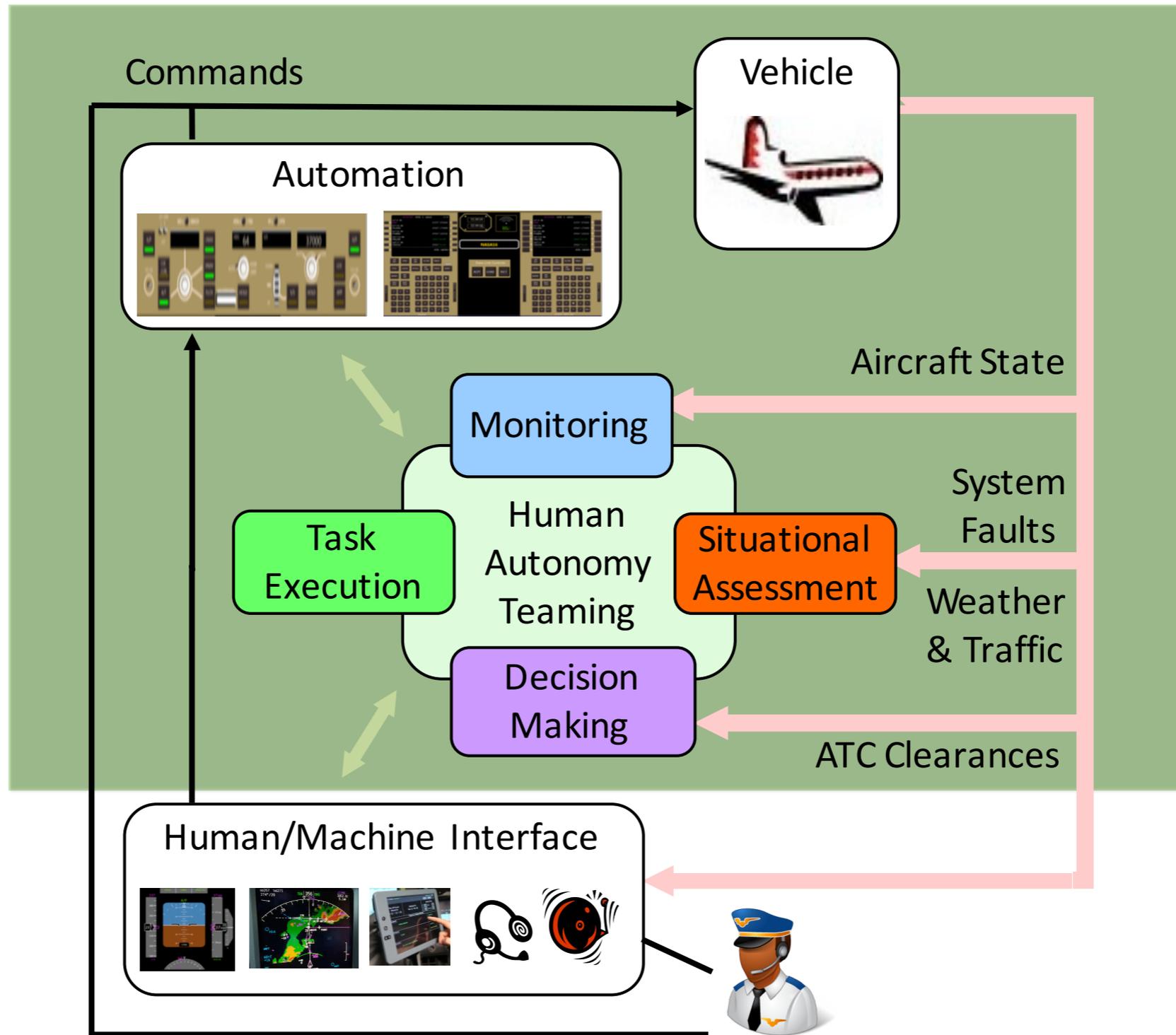
Turkish Airways 1951 (B737), 2009

- Altimeter readings inconsistent
- Multiple warnings
- Pilots attention divided, did not notice airspeed decay

Human-Autonomy Teaming in the Cockpit



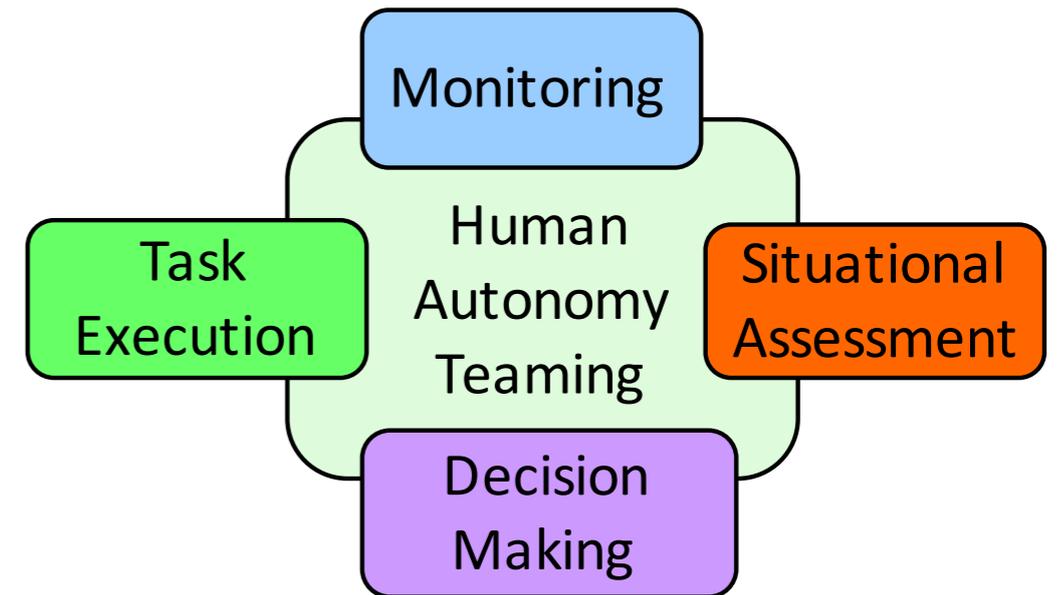
Human-Autonomy Teaming in the Cockpit



Under-the-hood of Big Picture View Automation Challenges

AUTOMATION CHALLENGES:

- Complex modern cockpits
- Difficult decision making
 - Assess risk
 - Request permission for decisions to ATC
 - Competing goals: dispatch, ATC, pilots
- Dynamically changing situations
 - Aircraft instrument monitoring
 - Weather monitoring
 - New airport status
 - ATC and dispatch directions



Hierarchical Planning

- Tasks

 - primitive

 - non-primitive

- Methods

 - Method T:

 - Parameters: x, y

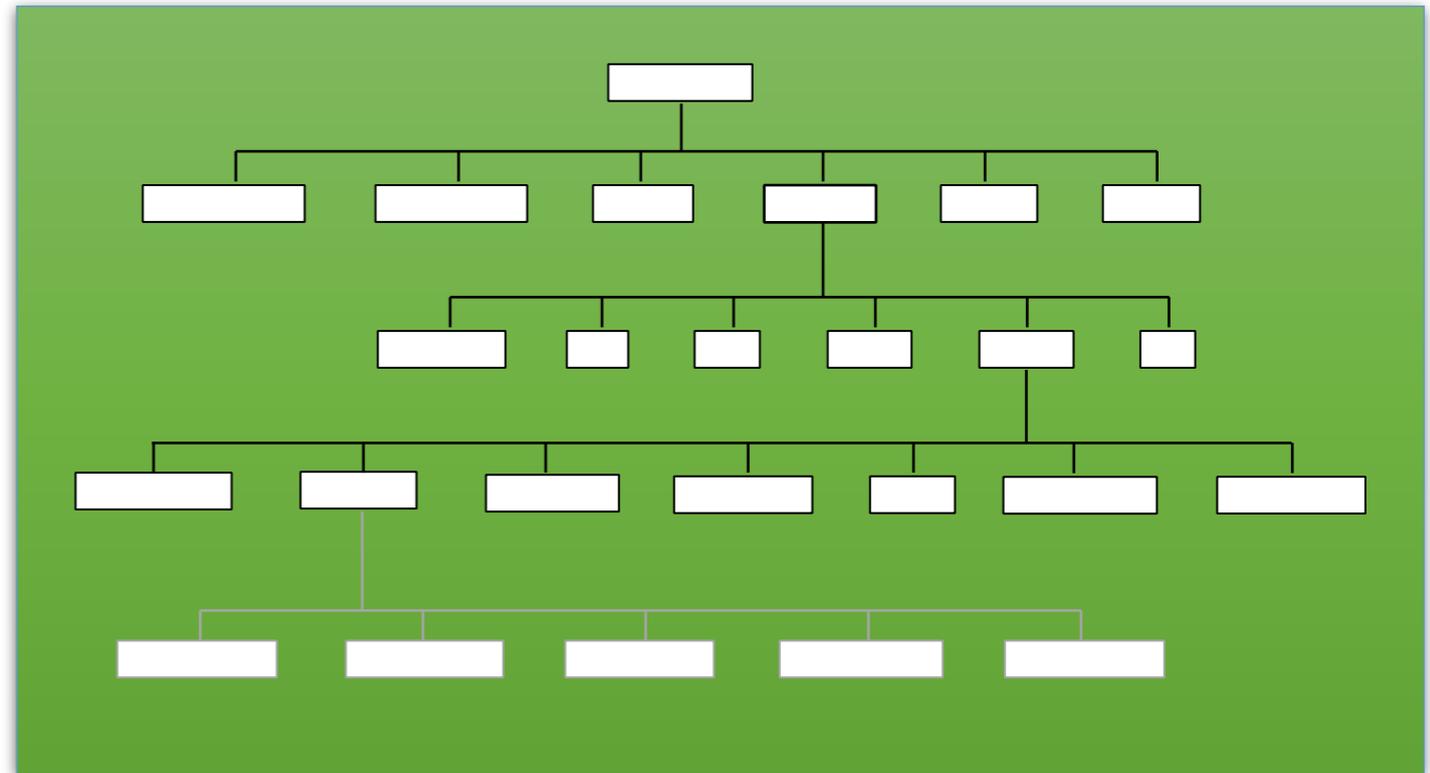
 - Subtasks: T1, T2, T3, T4

 - Constraints: T1 -> T3, C -> T3

- Planner

 - Expansion of tasks using methods

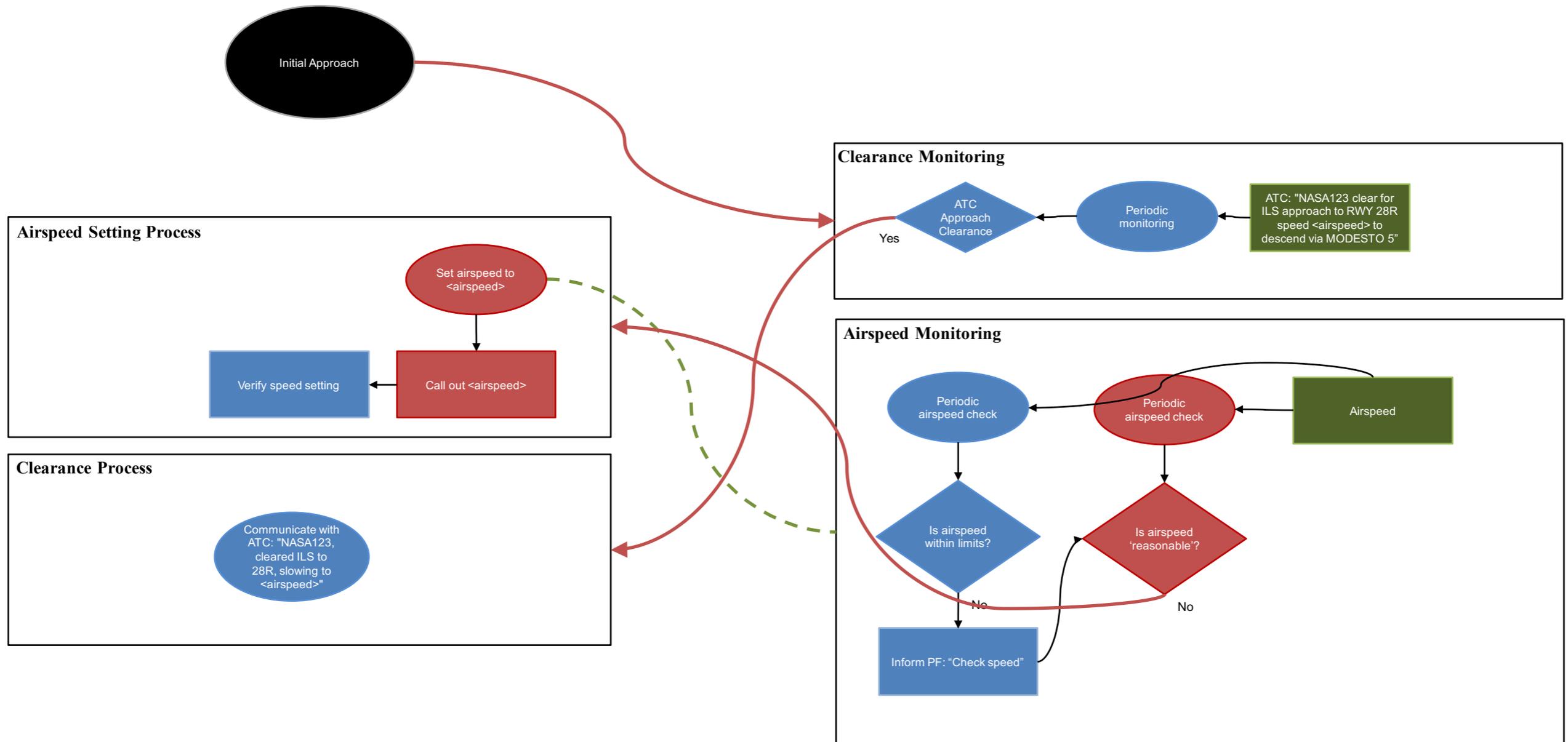
 - Satisfaction of constraints



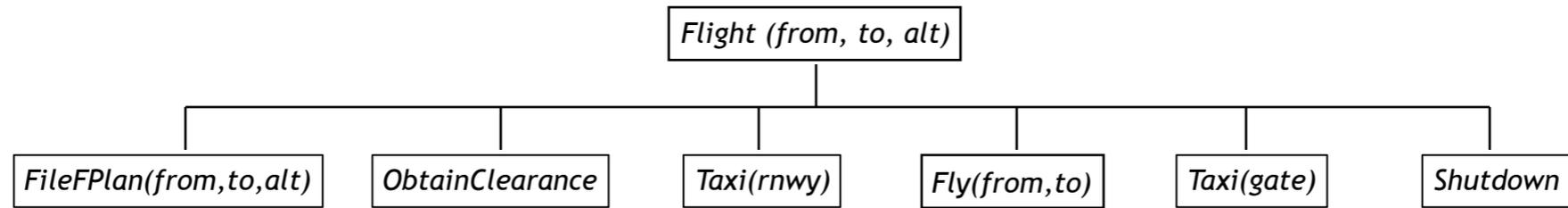
Capture Flight Tasks

Flight Processes

Periodic Monitoring / Triggers



Nominal Flight Plans



Nominal Flight Plans

Fly(from,to)

3. Cruise

3. Descend

2. Climb

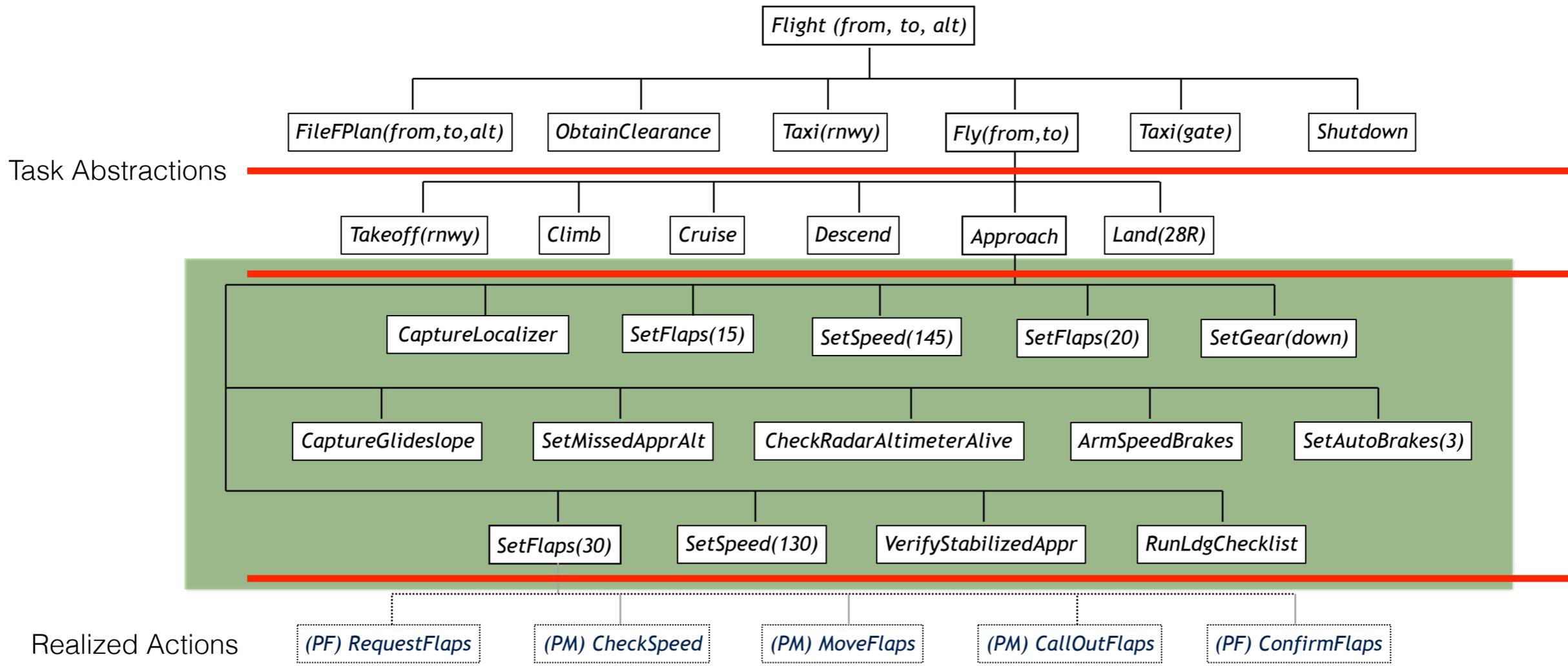
1. Takeoff

4. Approach

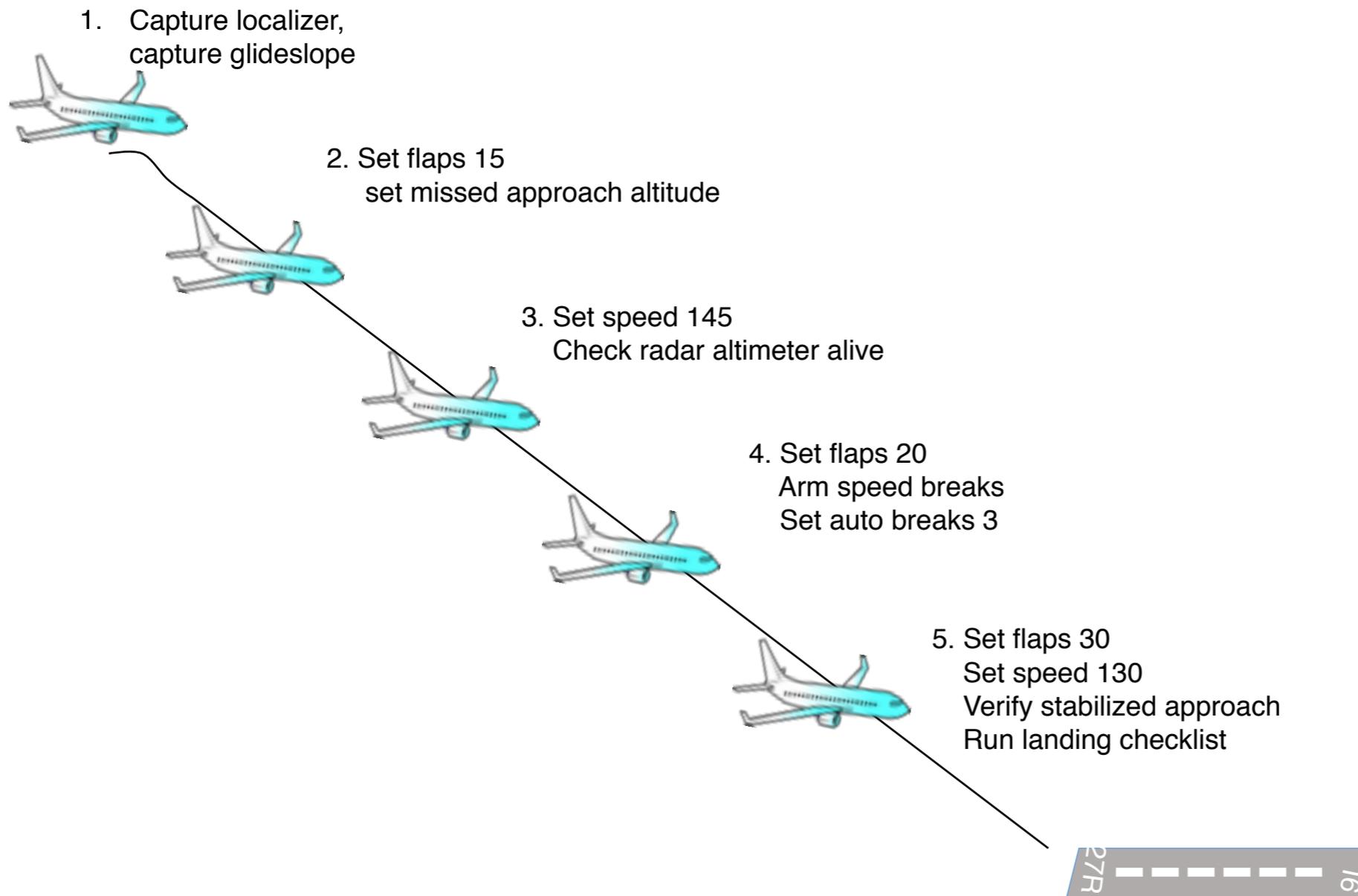
5. Land



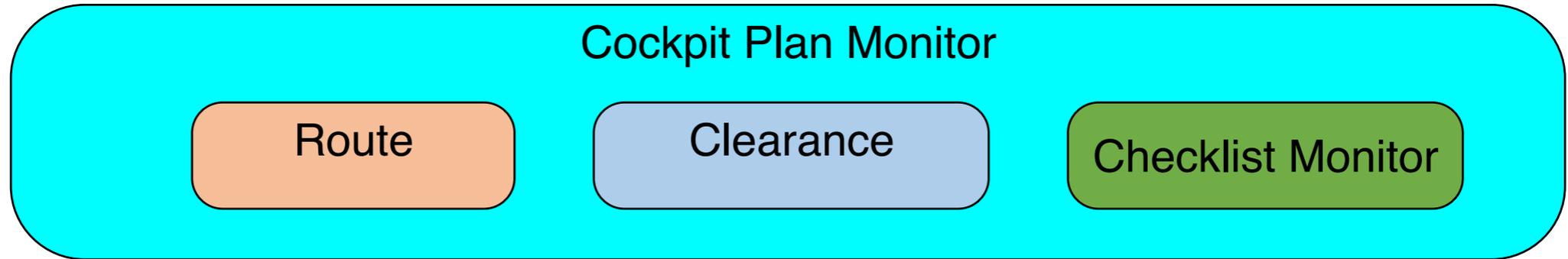
Nominal Flight Plans



Flight Plan Decisions



Monitors



Checks:

Aircraft Situation and Plan

Needed:

**Projection
Completion**

**Remedial
actions:**

**Reroute
Approach Change
Diversion
Corrective actions
Clearance revision**

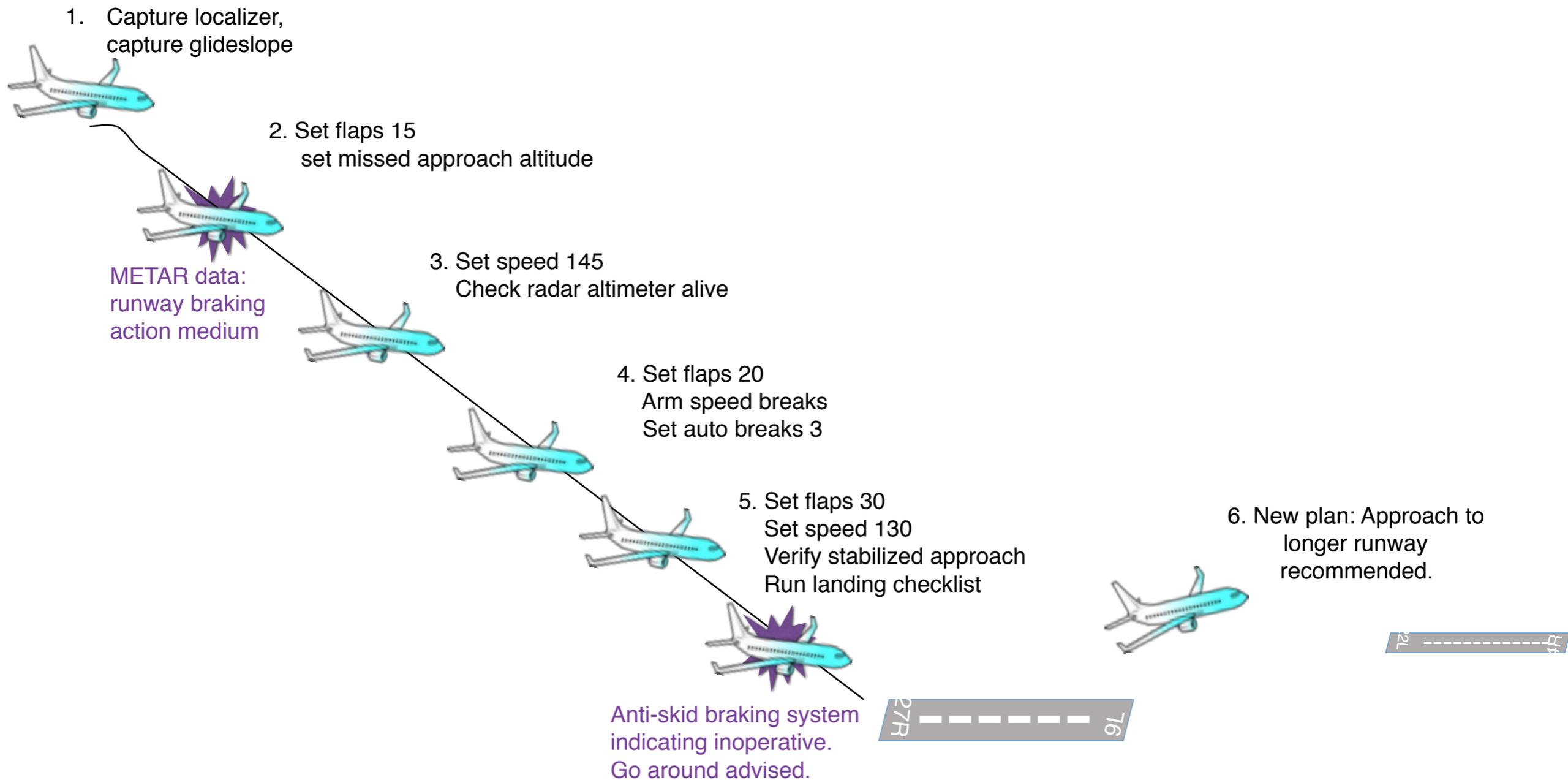
Execution Monitoring

EXAMPLE DATA SOURCES

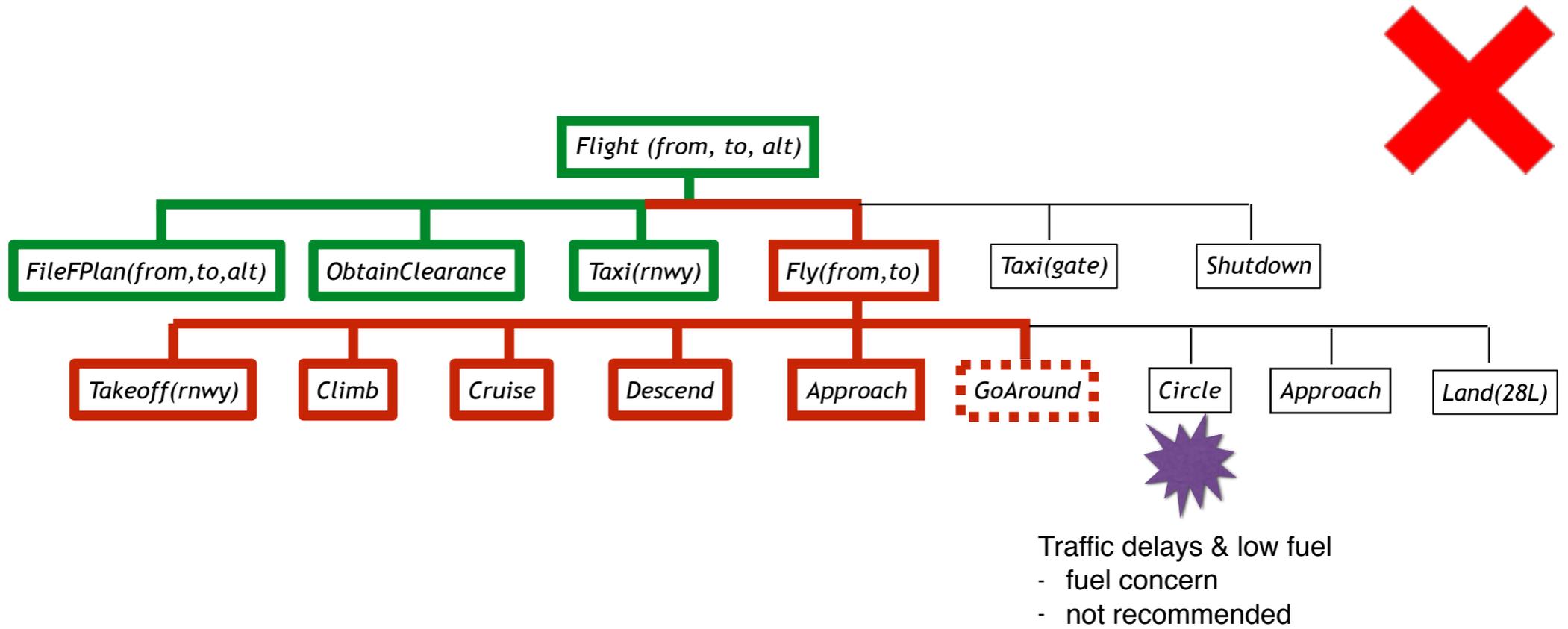
- Instruments
 - Altitude
 - Airspeed
 - Localizer/Glideslope Capture
 - Aircraft settings (flaps, gear)
 - Trajectory changes
 - Warnings
- Clearances
- Checklists
- Flight delay information
 - Airport weather observing systems (AWOS)
 - METAR messages



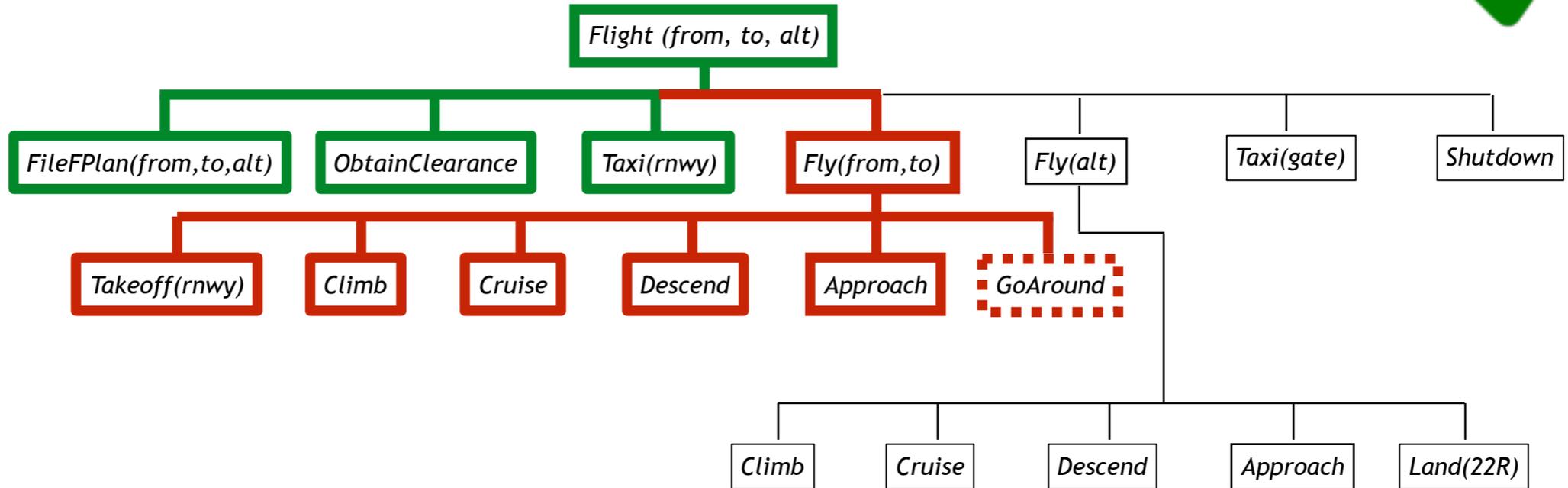
Flight Plan Decisions Monitoring



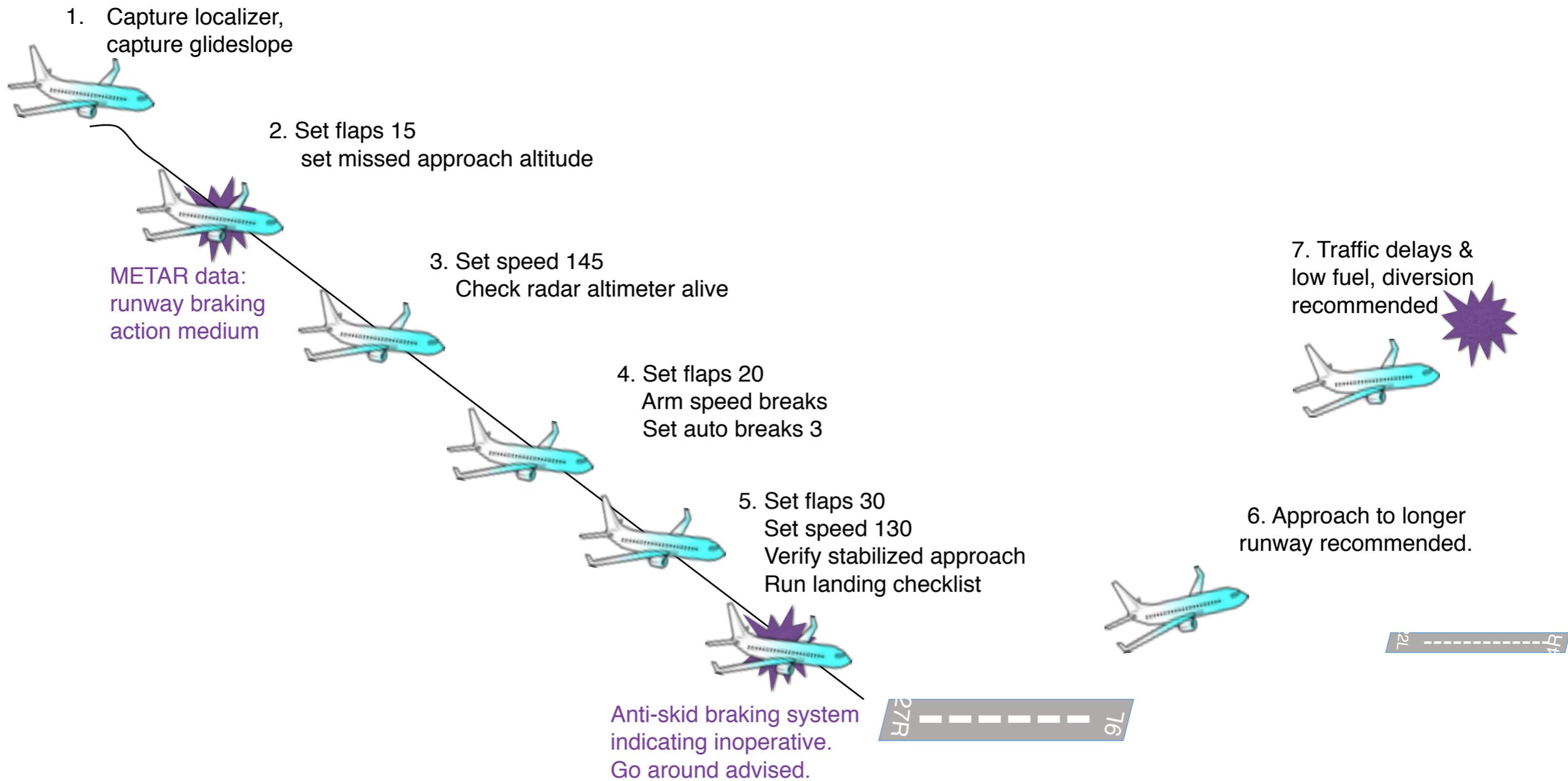
New Flight Plan Projection



New Flight Plan Projection



Flight Plan Decisions Projection



Summary

- Dynamic nature of flight makes cockpit automation difficult
- Cockpit Hierarchical Automation Planning and Execution framework provides
 - A structure to capture flight procedures
 - Projections over future tasks
 - Pilot recommendations
 - Constraints to monitor for off-nominal execution
- Work ongoing

