Goal-Based Fault Management

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Purpose of this Talk

Broaden our thinking about architectures for fault management

> "A mind once stretched by a new idea never regains its original dimensions."
>
> *Oliver Wendell Holmes Jr.*

Outline

- Objective
- Assessment criteria
- Overview of two FM architectural styles
  - Monitor-Response-Inhibit style
  - Goal-based style
- Example of goal-based FM
- Compare and contrast
- Summary

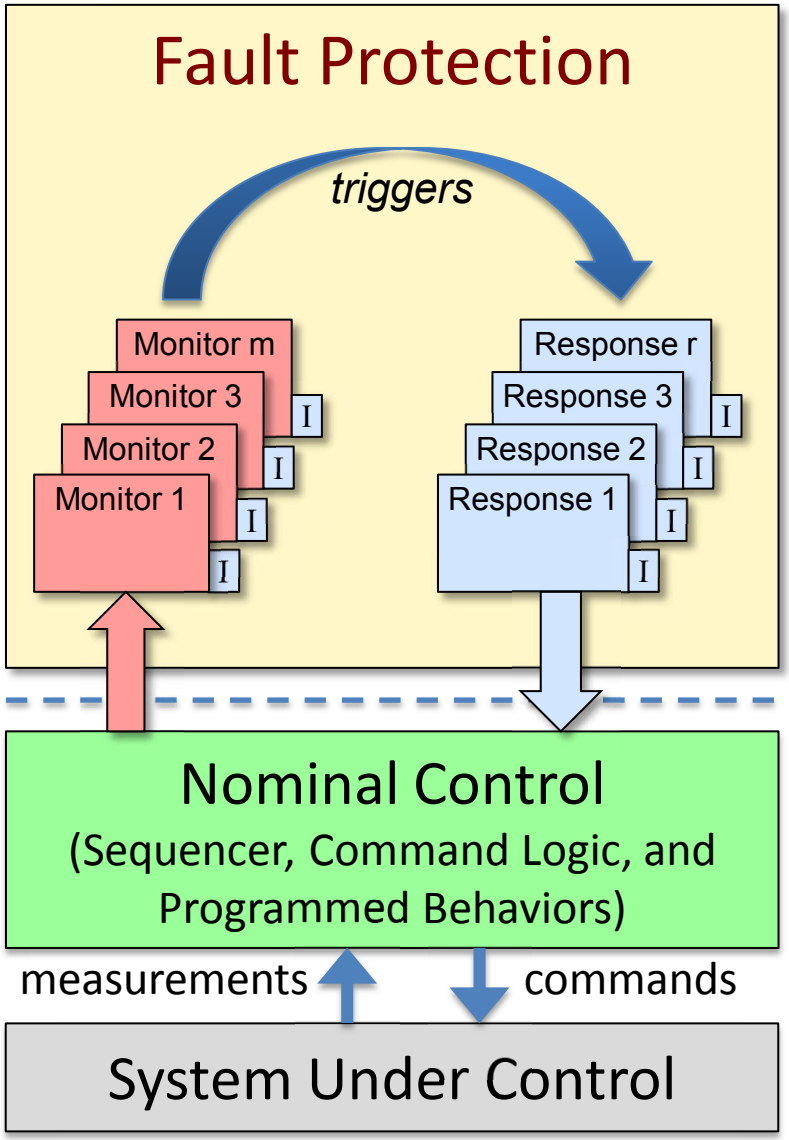
FM Architecture Assessment Criteria

1. Emphasize *failure* detection over *fault* detection
   - more important to respond to loss of function, no matter how it occurs, than to a set of anticipated faults
   - Lack of faults ≠ health
2. Upon failure detection …
   - allow unaffected activities to continue executing (graceful degradation)
   - decide responses based on context
3. Be compatible with flight software control architecture
   - Having different mechanisms for nominal control versus fault management creates an interface that is harder to engineer and validate

Monitor-Response-Inhibit (1 of 2)

Monitors

- Each monitor detects a specific problem
- Monitors have tunable thresholds, e.g., 'confidence', 'persistence' and 'decay'
- Thresholds are constant, not activity-specific
- A tripped monitor triggers a specific response (rule-like: "when x do y")



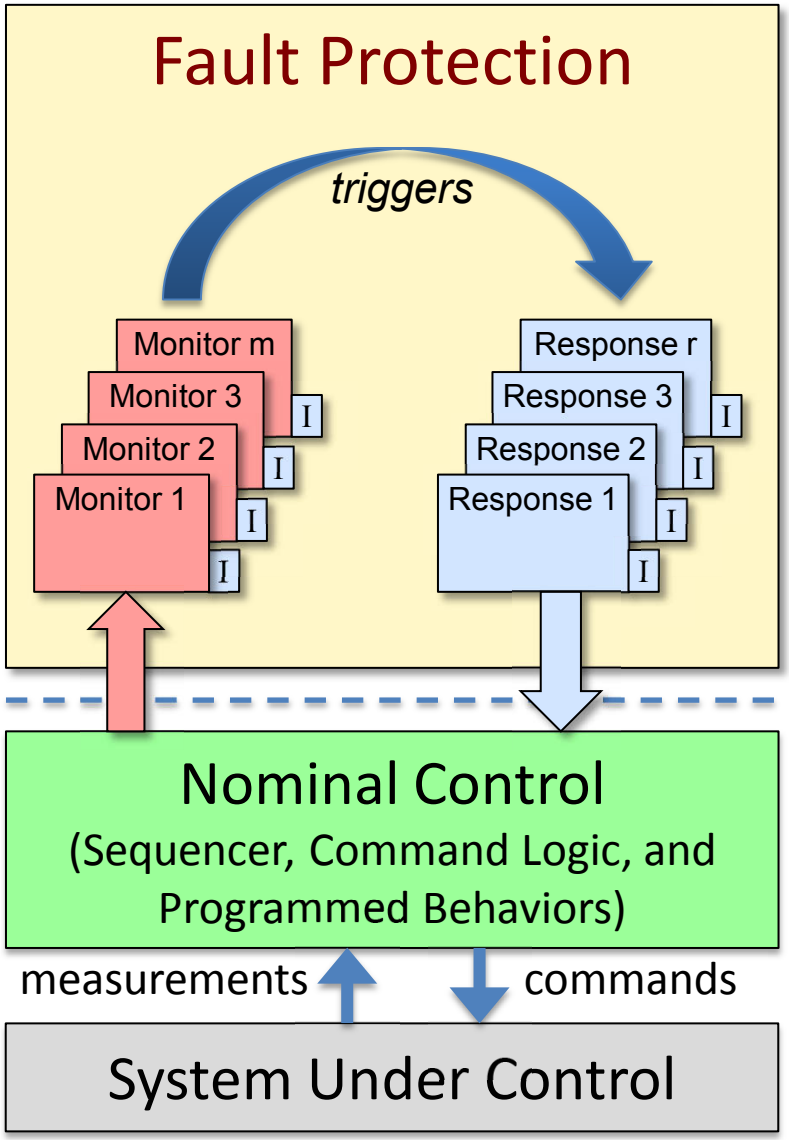
Monitor-Response-Inhibit (2 of 2)

Responses

- A response may kill a sequence and/or start a sequence
- Monitors & responses typically integrated after nominal control system working
- Often called "rule-based" or "autonomy"

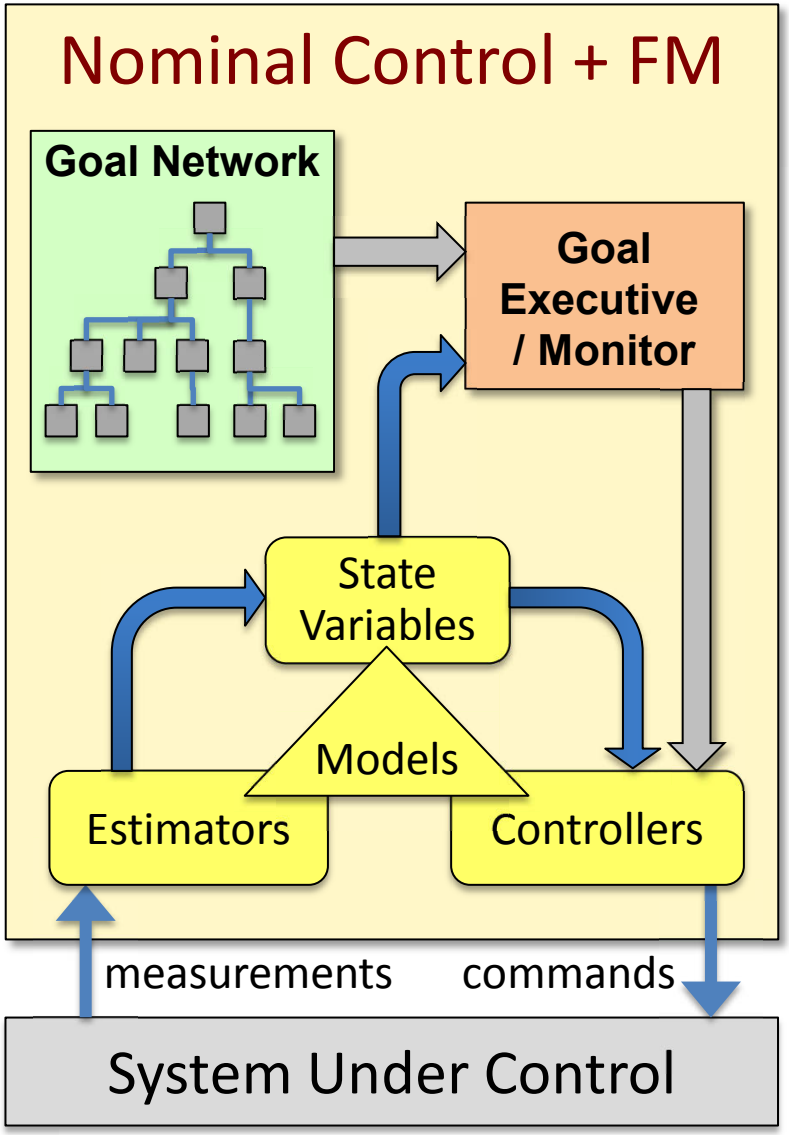
Inhibits

- Inhibit flag on monitors and responses can be set/reset by ground *and* by responses



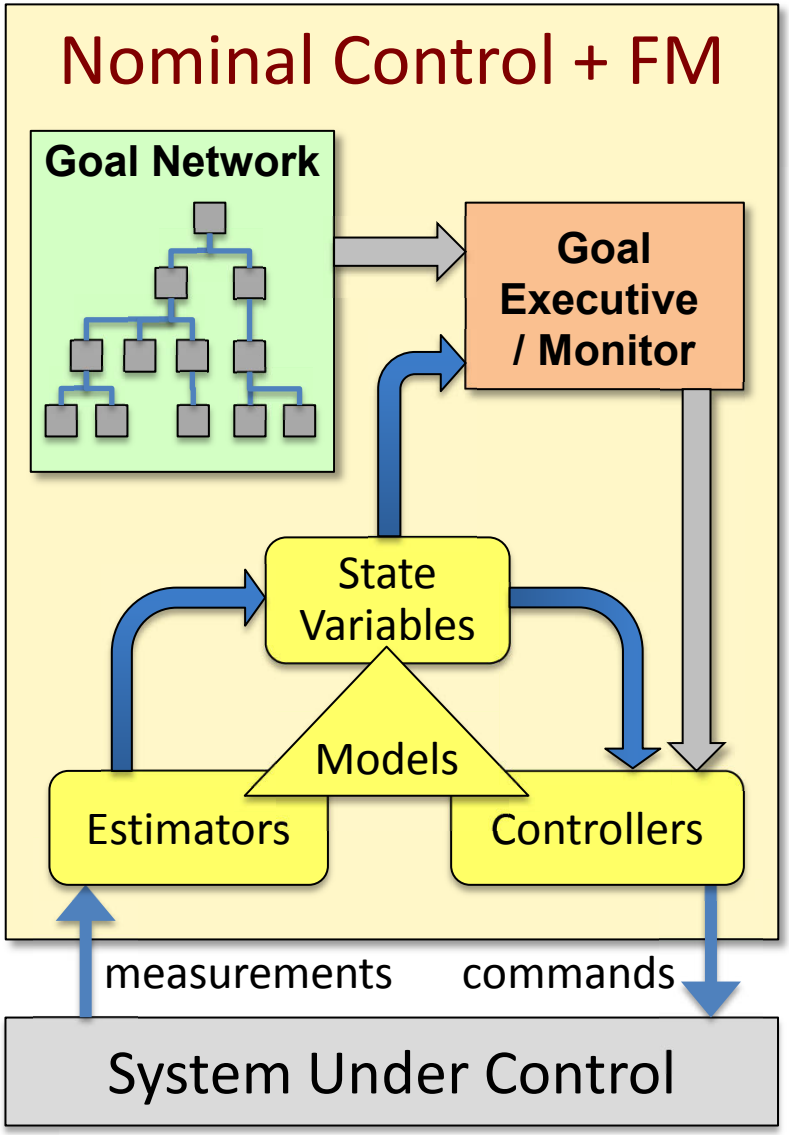
Goal-Based Control (1 of 2)

- State variables are explicit
  - corresponding to states of the system under control
- Each goal represents …
  - "a goal to be achieved"
  - acceptable behavior for a single state variable
  - a required condition
- Each goal has a success criterion that is…
  - specific to *that* activity
  - monitored for success/failure



Goal-Based Control (2 of 2)

- A goal may have supporting goals
  - To control *x*, must also control *y*
- Goals are the basis for operating the system
- Goal failure means that
  - a behavior is not acceptable
  - a required condition no longer holds
- How to respond to a goal failure is *informed* by the next higher goal

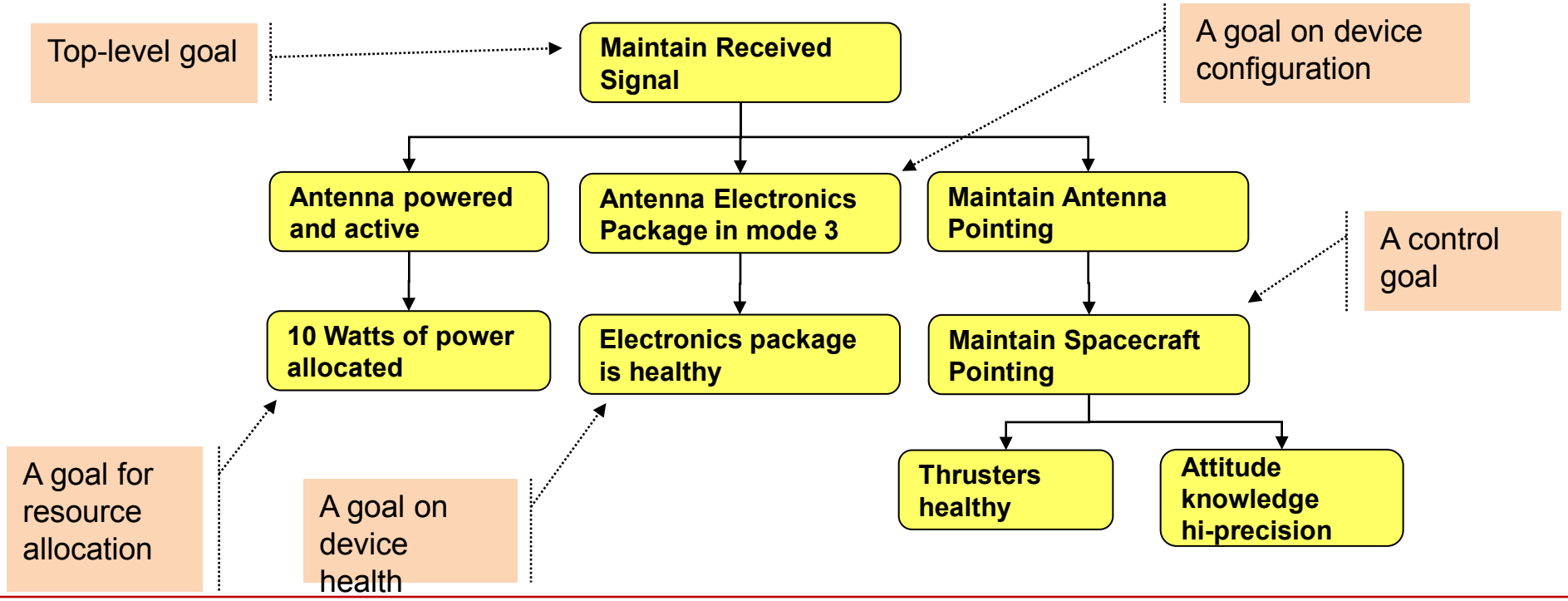


Context-Aware Failure Response

- A command sequence is just a sequence of commands; it does not represent intent
- When a failure occurs, the most appropriate response often depends on the context
  - i.e., on system state and on intent
- Goal-based operation enables cognizant control
  - Fault response decisions *are* based on context

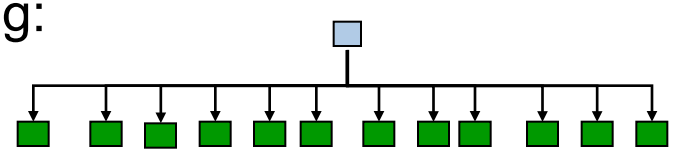
A Goal Elaboration Hierarchy

- A top-level goal is elaborated to add all of its supporting goals
- Looking upward explains <u>why</u> a goal exists
- Looking downward explains <u>how</u> it will be achieved and/or what it requires
- Goal failure response is *informed* by the next higher goal



Goal Failure Response Animations

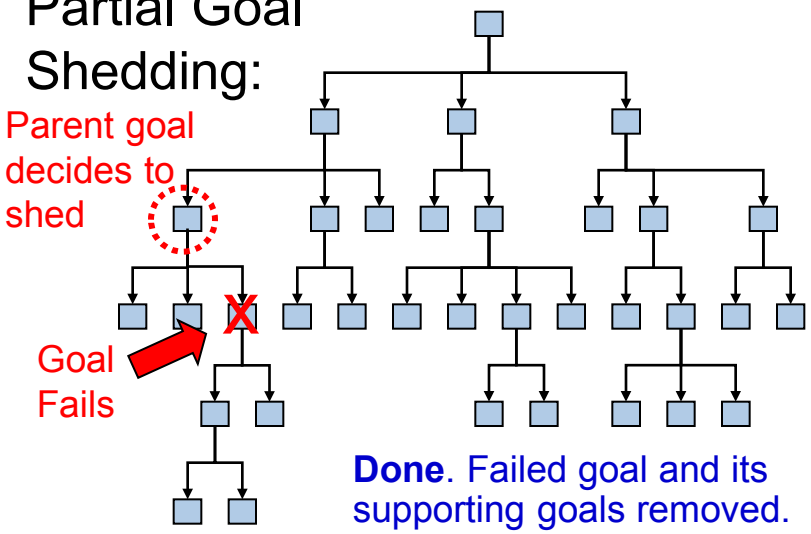
Safing:



Safe goal net

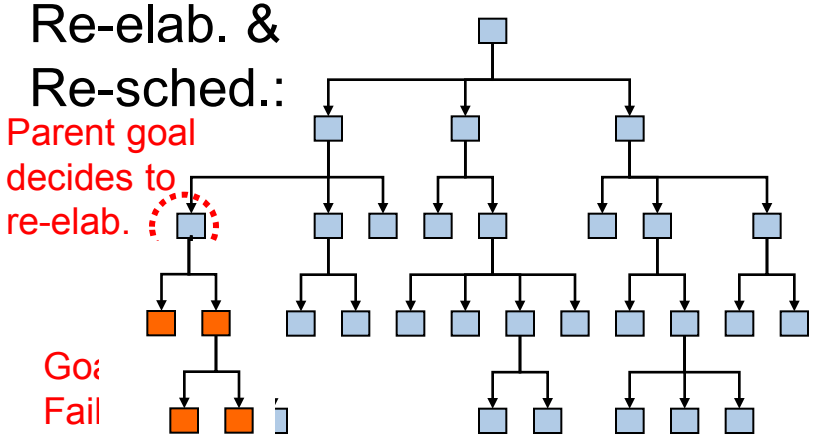
Done. Safe goal net installed, all previous goals removed

Partial Goal Shedding:



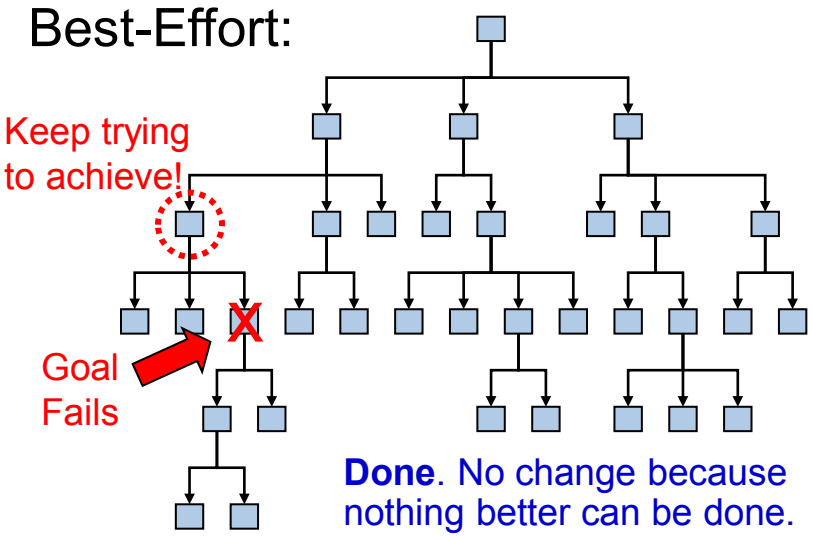
Done. Failed goal and its supporting goals removed.

Re-elab. & Re-sched.:



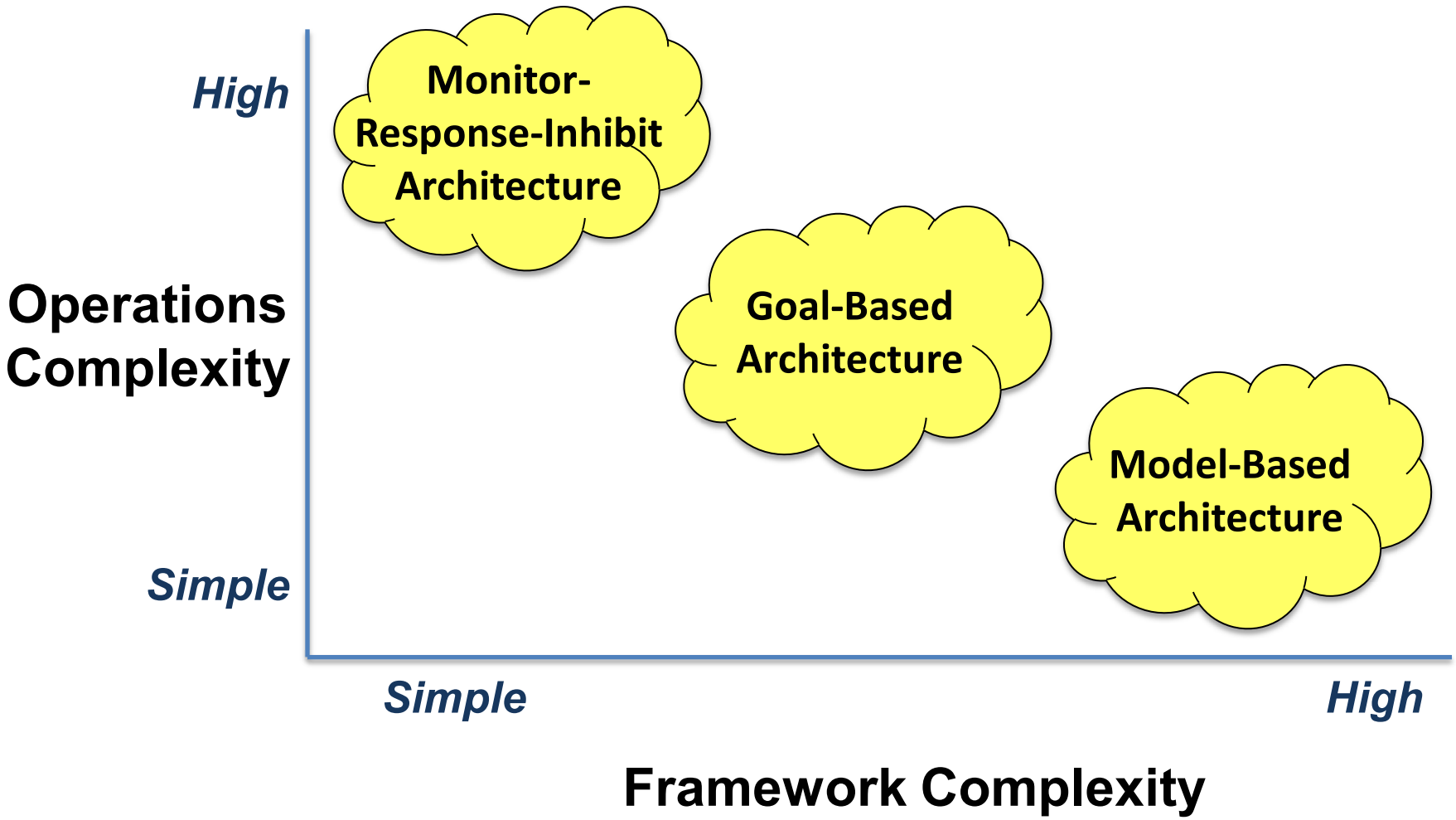
Done. Failed goal and its support removed and replaced by new goals.

Best-Effort:



Done. No change because nothing better can be done.

Framework vs. Application Complexity



Summary

- Single architecture for both nominal activities and fault tolerance
- All activities represented as goals on behavior of system under control
- Activity goals have supporting goals for every dependency (device modes, resources, necessary conditions, etc)
- All goals monitored during execution
- Goal failure, whether due to a hardware fault or environment, triggers response from goal elaborator