Aircraft Operational Reliability - A Model-based Approach

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Project: @Most

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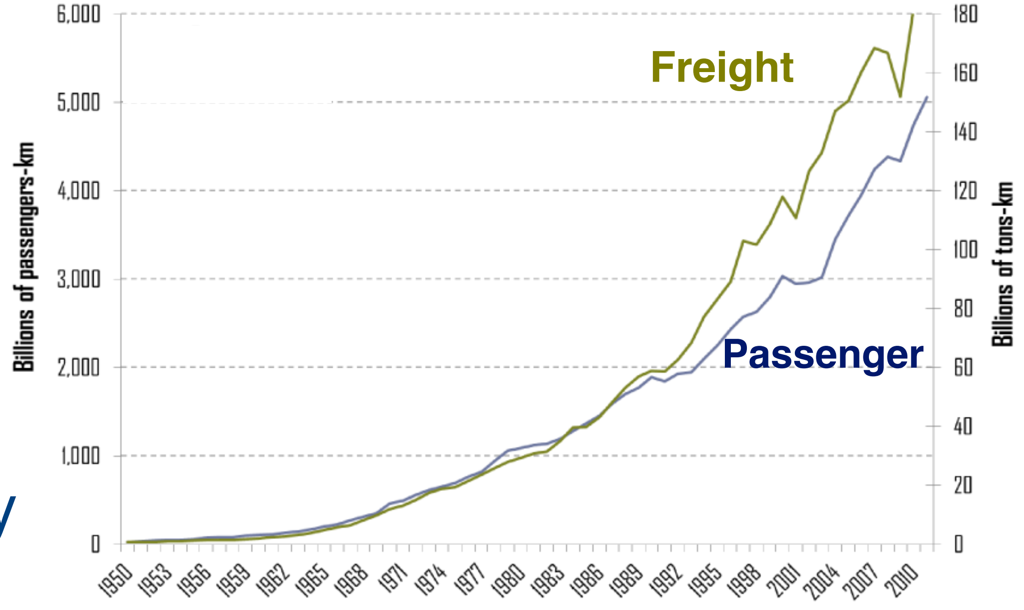
Context

☞ Growing interest in air transportation

☞ Competitiveness

☞ Enhance service delivery and minimize operation and maintenance costs



Contribution: Reinforce the role of dependability assessment in aircraft operation

Aircraft Dependability Modeling & Assessment

Common practice: during system design and development

Safety and availability oriented models $\Longrightarrow$ Support for System architecture definition

Long-term objectives

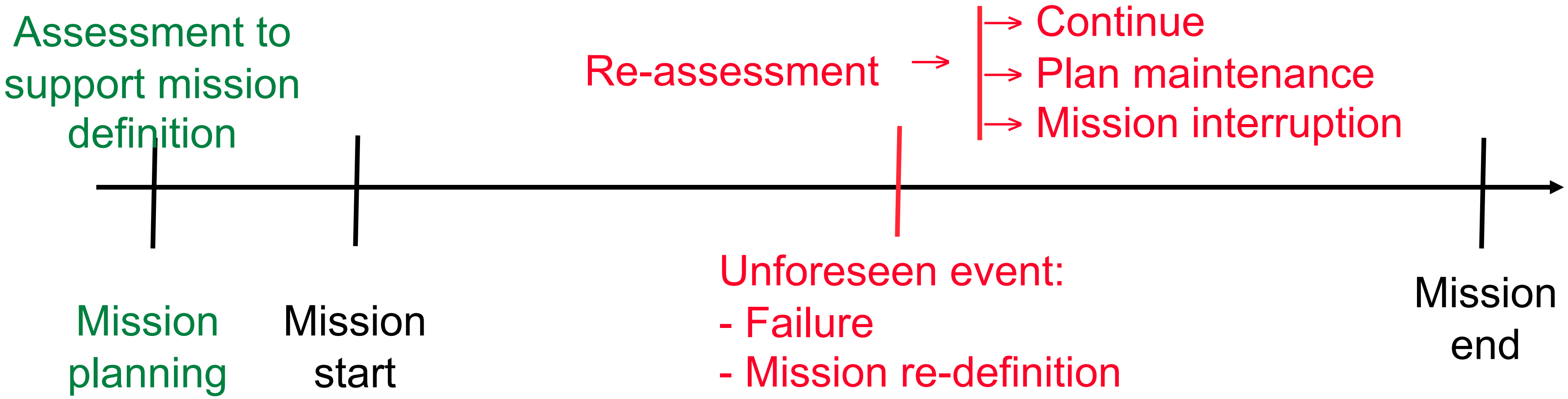
Future: usable during system operation - in addition -

Models for assessment in operation $\Longrightarrow$ Adjust aircraft operation according to the current operational conditions and changes

Short-term objectives

Objectives: Dependability Assessment in Operation

☞ Whenever necessary



☞ To avoid as much as possible disruptions/interruptions

Delay, Cancellation, In-flight turn back, Diversion

⇒ Evaluate the probability to operate without operational disruption/ interruption until a given time or location

Means

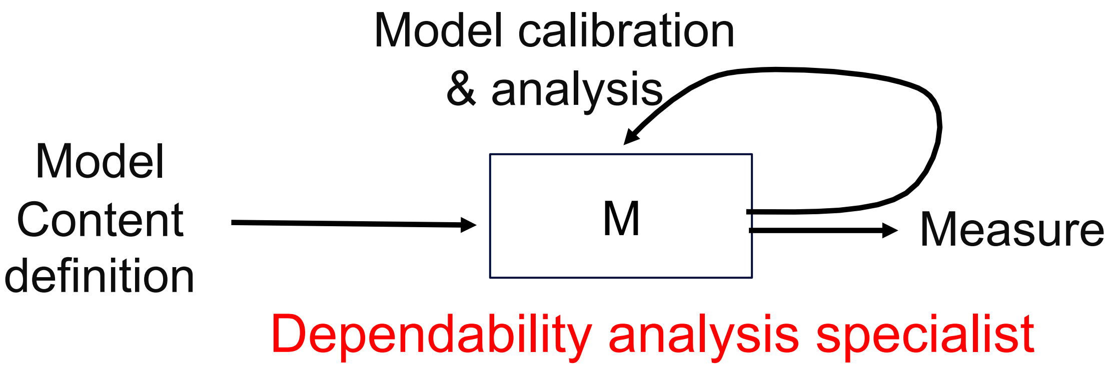
☞ Develop a model-based dependability assessment framework usable in operation

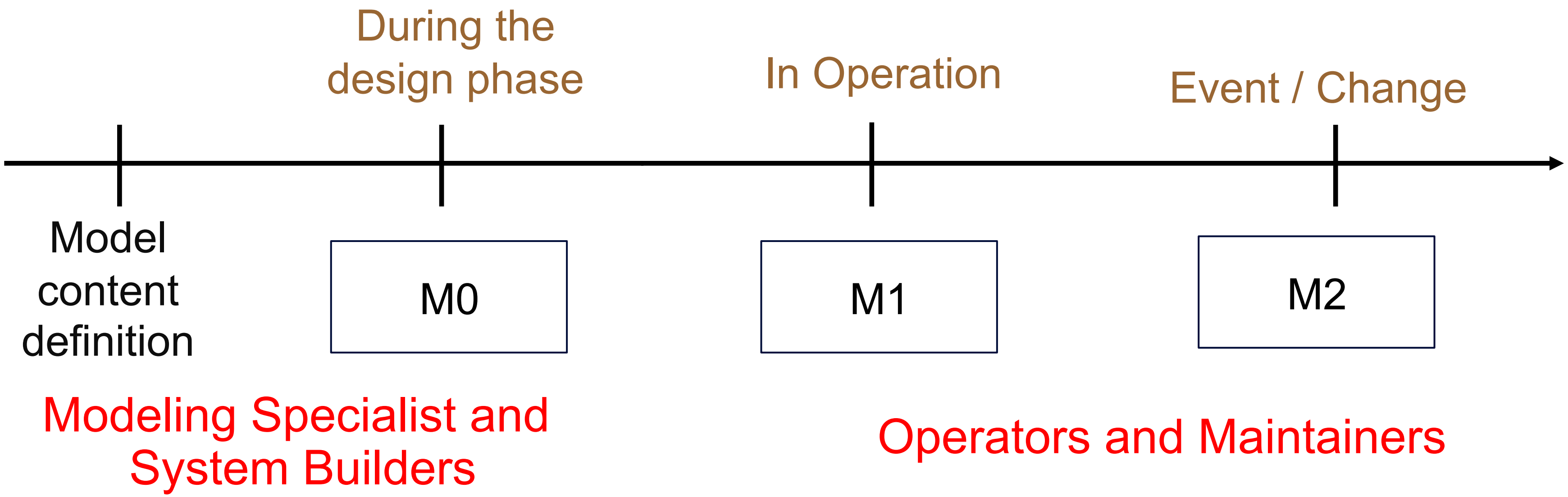
☞ Forecast operational reliability with regard to disruptions caused by failures and maintenance issues

Operational Dependability Measures

- System Reliability, SR(t): Probability to meet minimum requirements related to the system, during flight duration
- Mission Reliability, MR(t): Probability to achieve a specific mission without interruption

Dependability Modeling





To Achieve the Objectives

☞ Identification of relevant information for the model construction

☞ Modeling basis that facilitates:

- Model construction
- Model update in operation

☞ Validation on case studies

Outline

① Relevant Information Identification

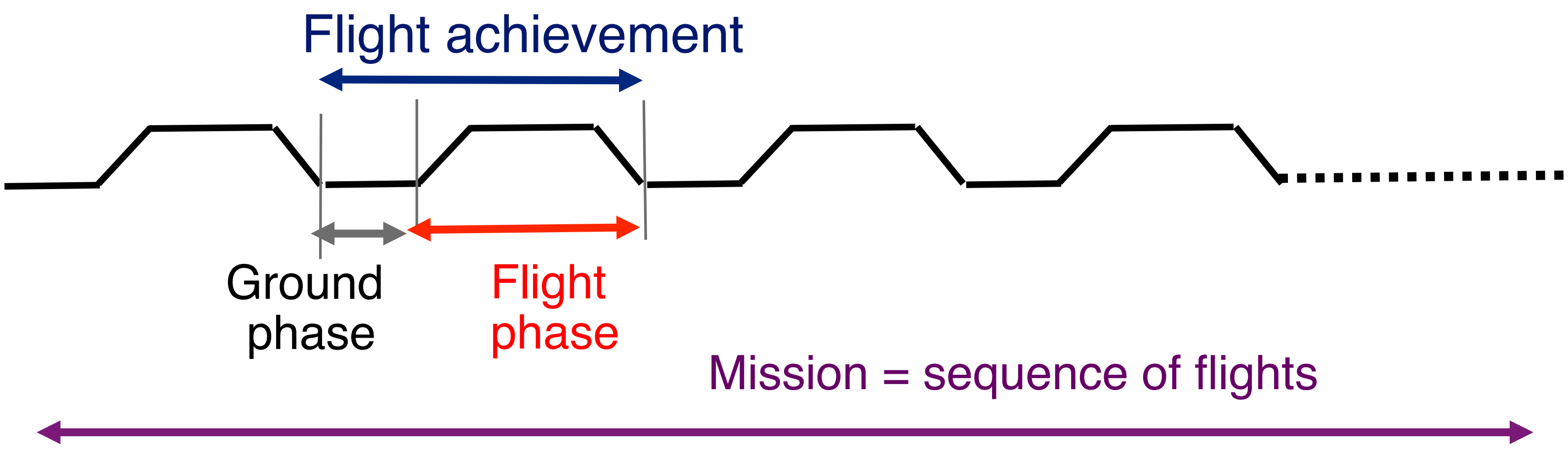
② Modeling Approach: Meta Model and Stochastic Model

③ Stochastic Modeling in the Context of @Most

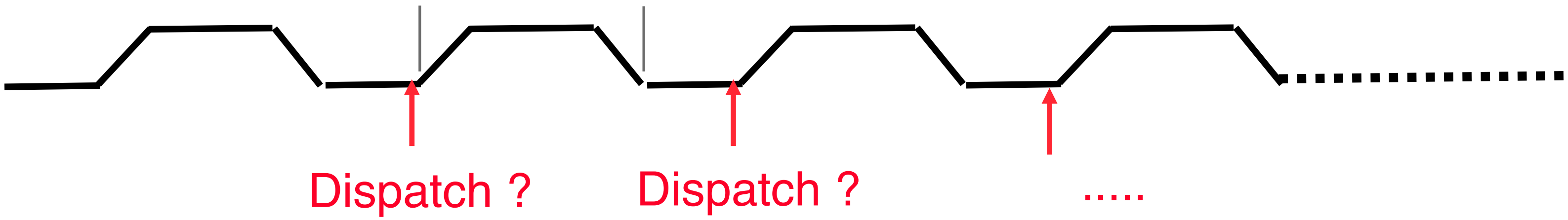
④ Case Study

- Stochastic Model
- Results

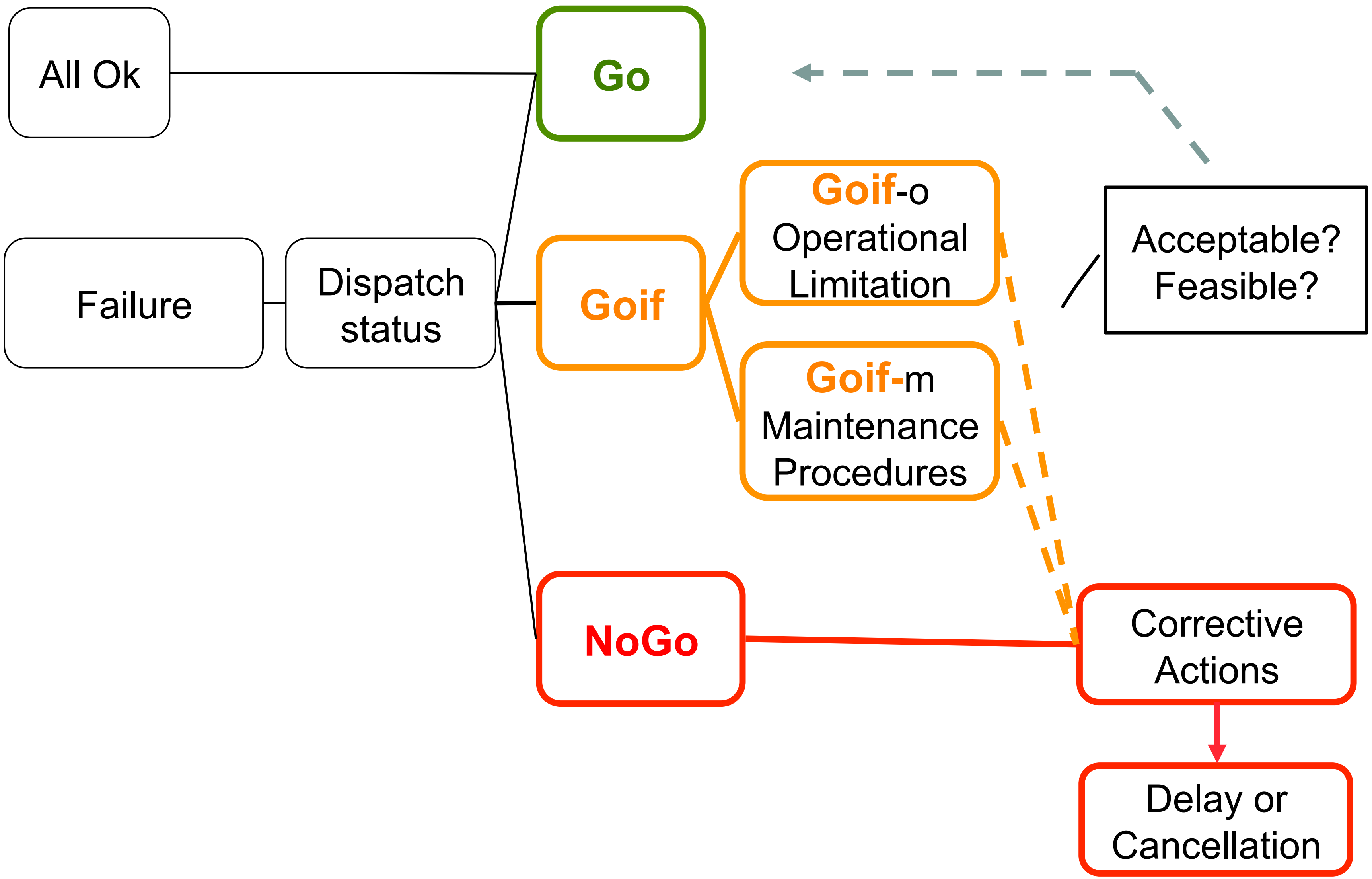
Mission & Mission Dispatch



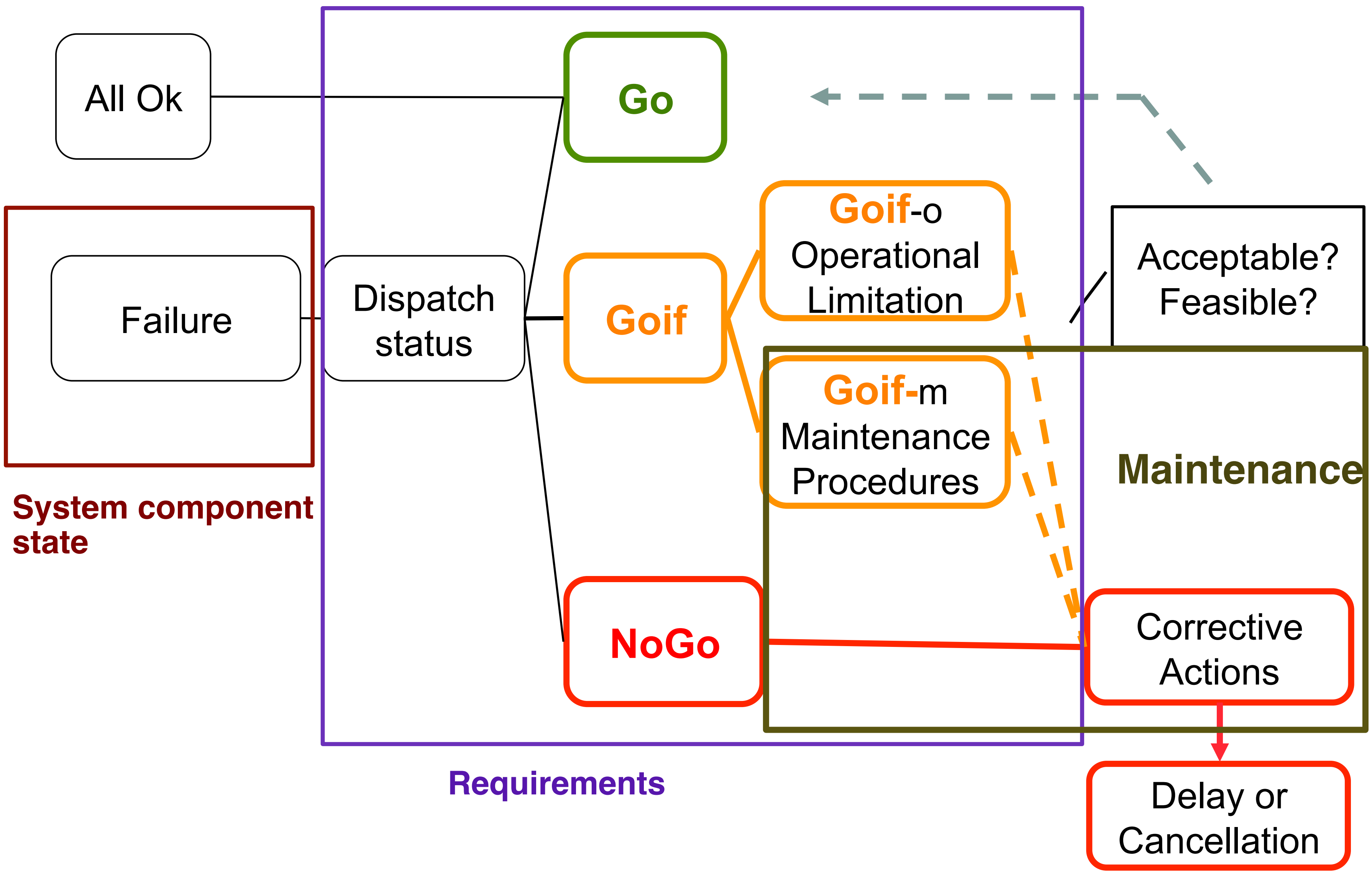
☞ Mission Dispatch Decision



Next Flight Dispatch Decision

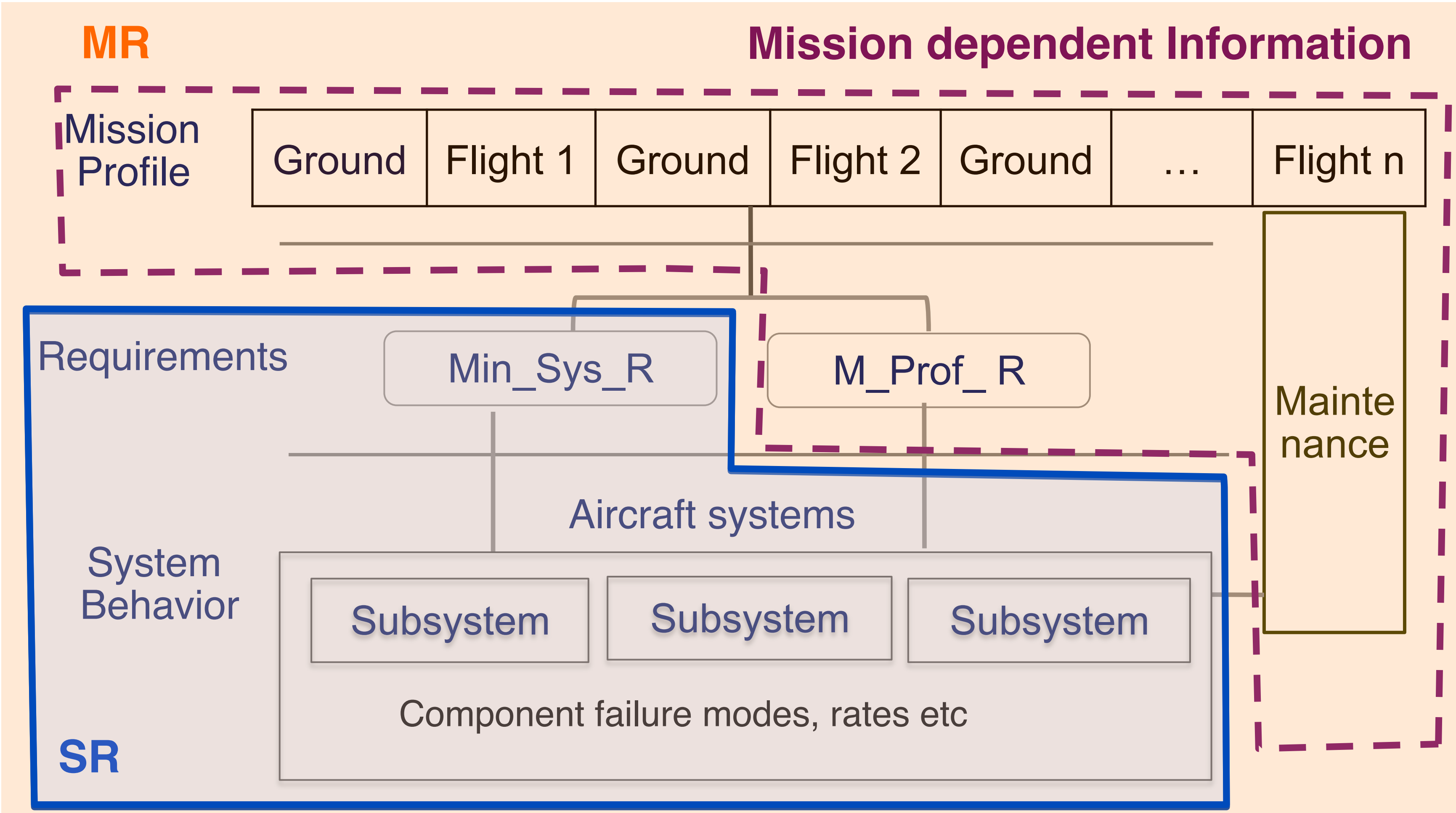


Relevant Information - 1



1 Relevant Information Identification

Relevant Information - 2



Core Information

Outline

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Changes and modeling constraints

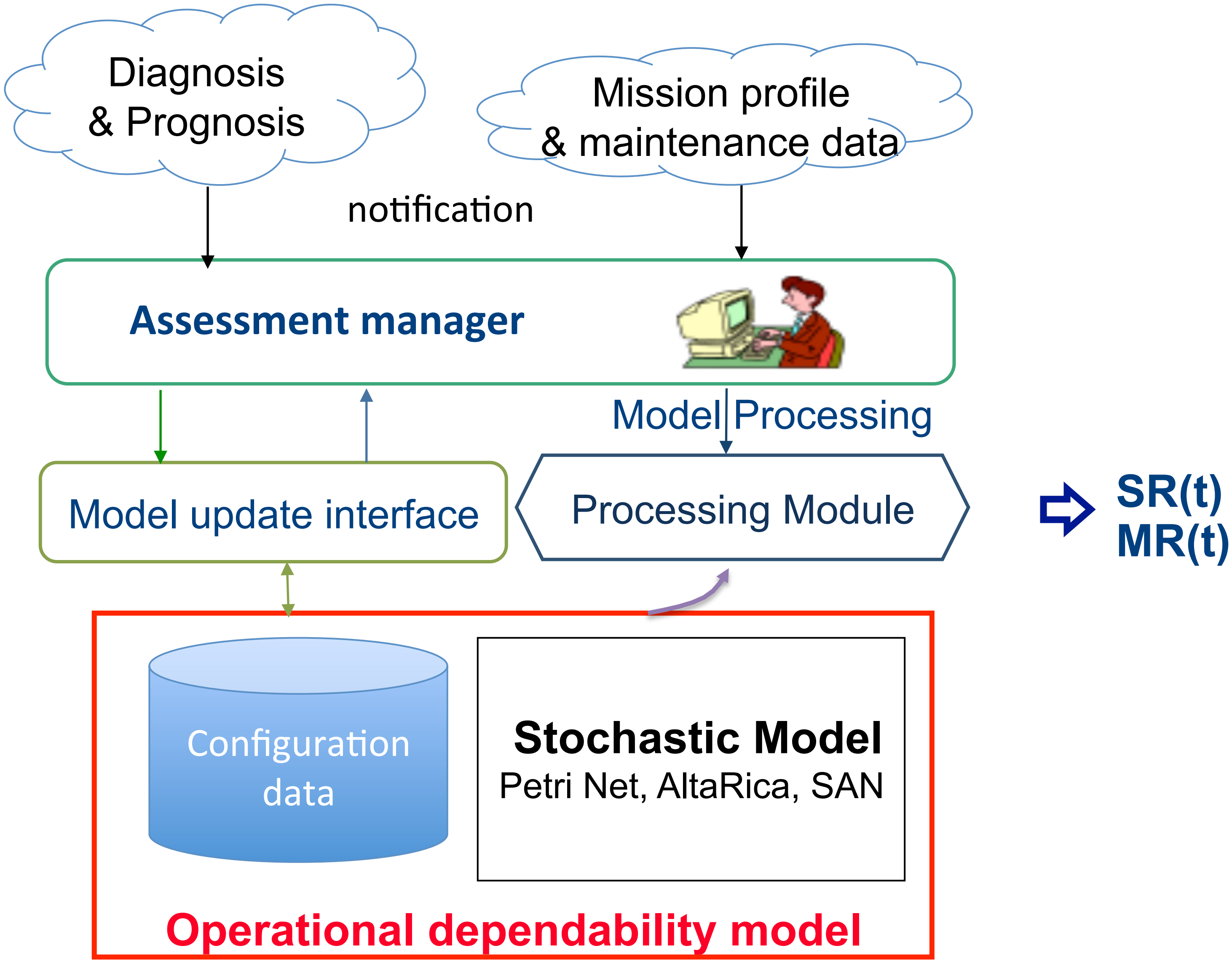
☞ **Changes to be Taken into Account**

- Changes in the states of the system components
  - Failure, Maintenance activities
- Failure distributions of the components
- Mission profile

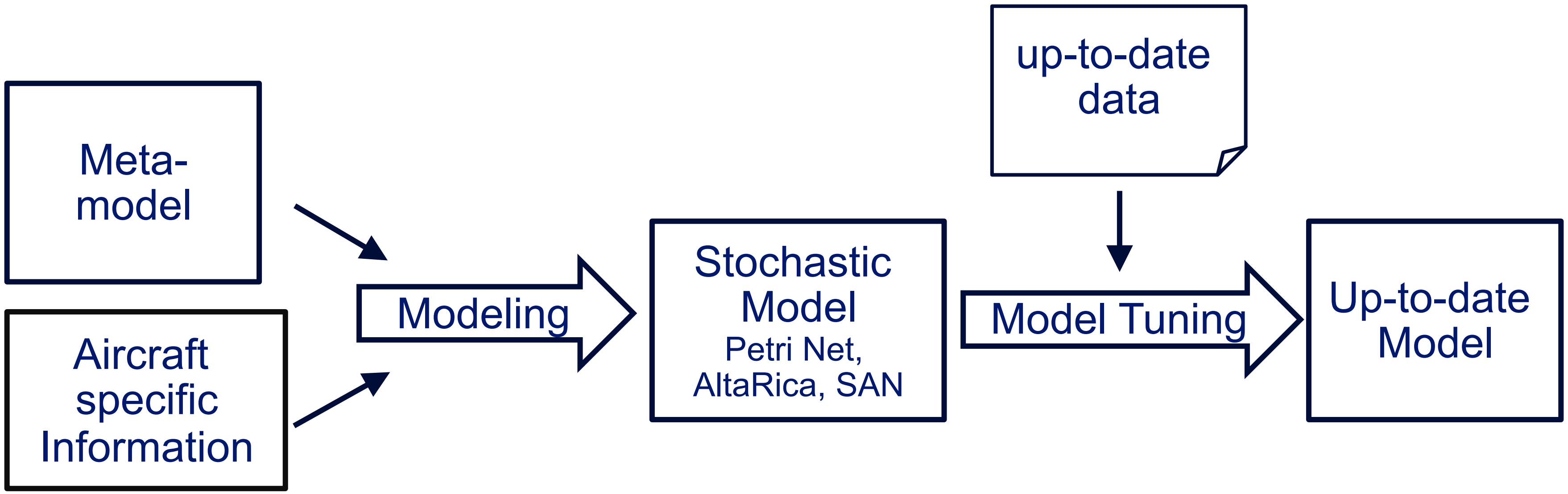
☞ Modeling constraints

- Model construction during the design and development phase
- Model update in operation by non-modeling specialist

Implementation

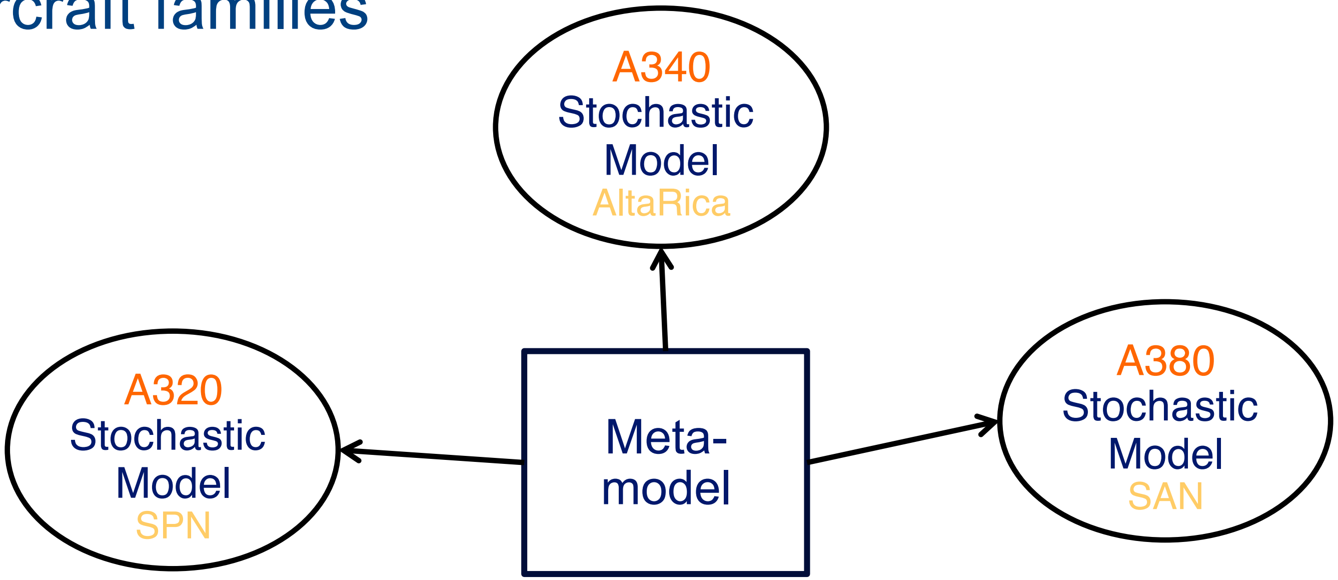


Model Construction and Update Process



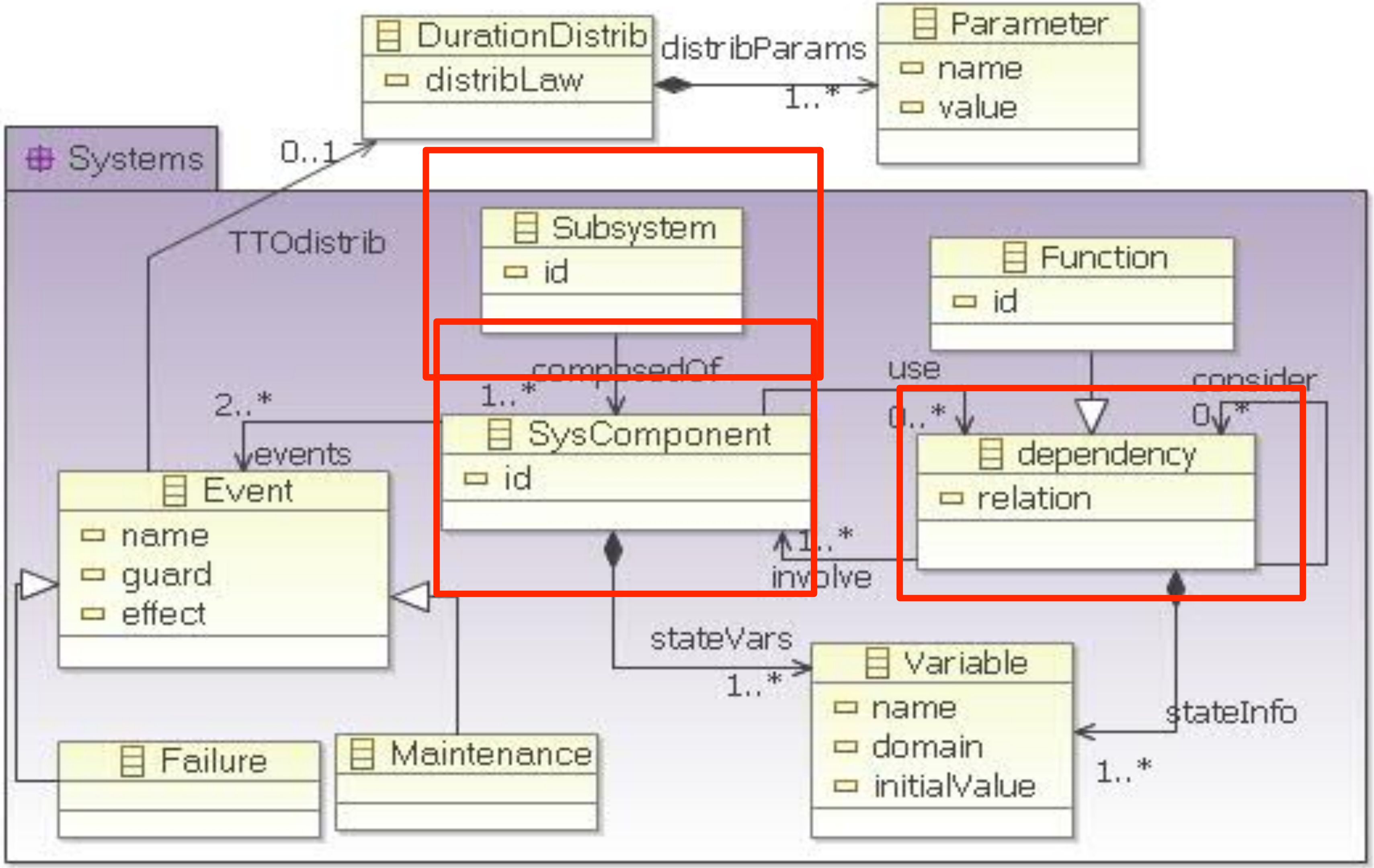
Benefits of the Meta-model

- Abstracts and structures model content
- Aircraft families



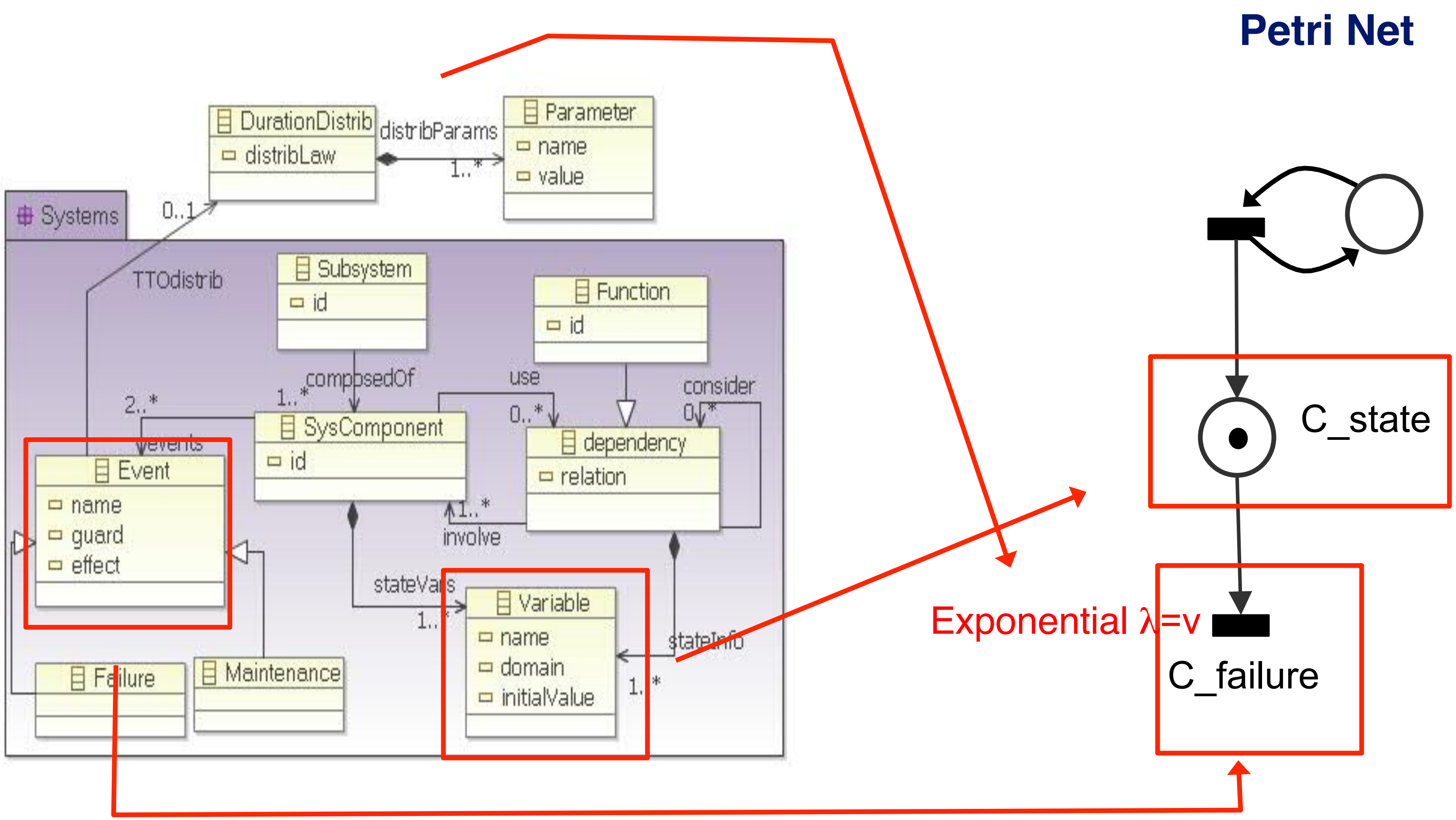
Model generation

Example of Meta-model: System Components



From Meta-model to Stochastic Model

☞ Dynamic models – state-based models



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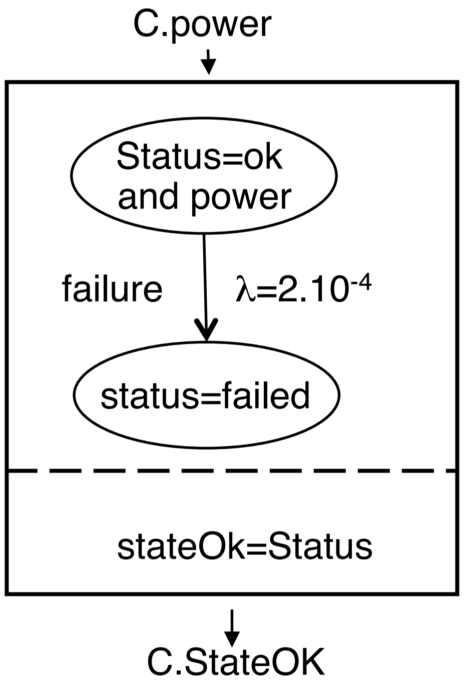
◎ Conclusion and Perspectives

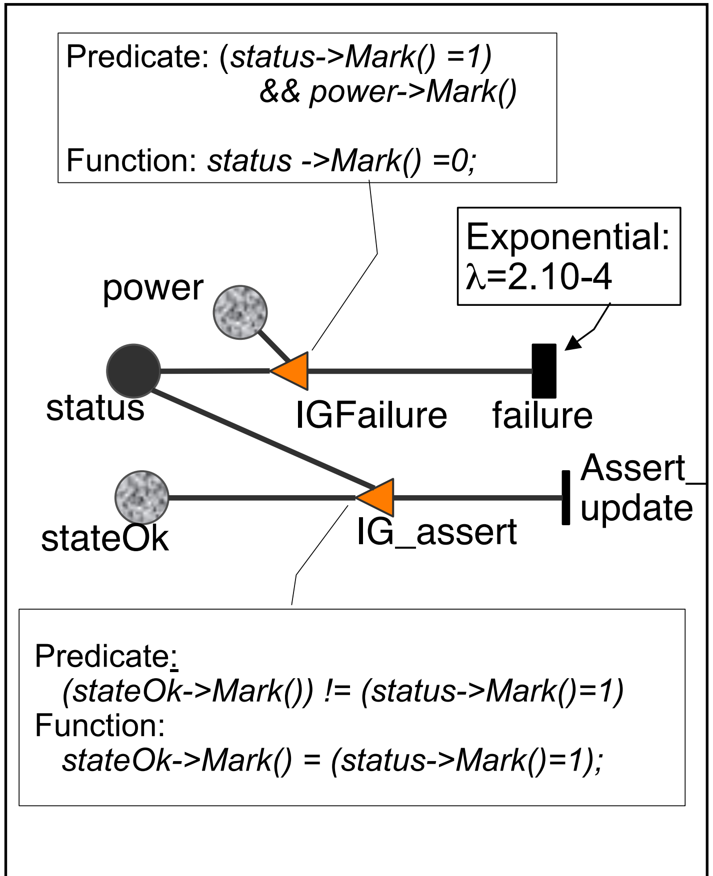
AltaRica and SAN

Basic Component

```
node Component
 flow
  stateOk : bool : out ;
  power: bool : in;
 state
  status : {ok,failed} ;
 event
  failure,
 init
   status := ok ;
trans
  status=ok and power |- failure
                    -> status:=failed;
assert
   stateOk=(status=ok);
extern
   law <event failure> =
                    exponential(2.0E-4);
edon
```

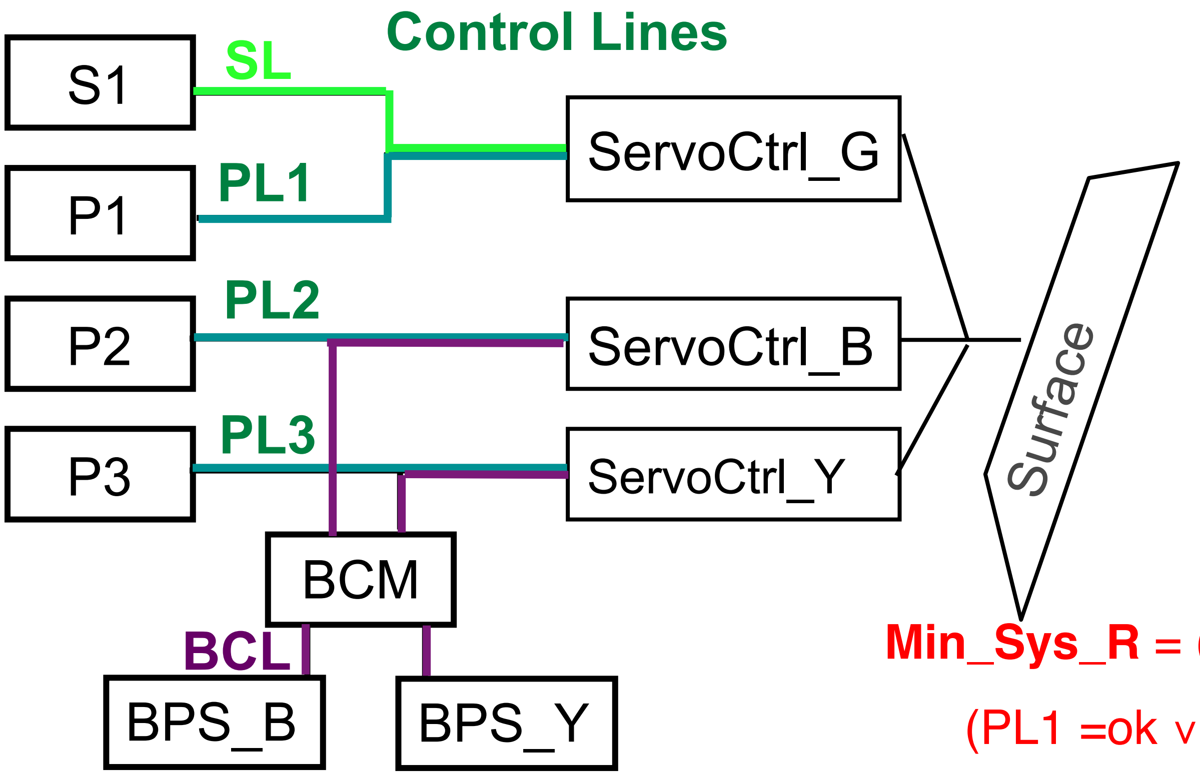
AltaRica model





SAN model

Case Study: The Rudder Control Subsystem



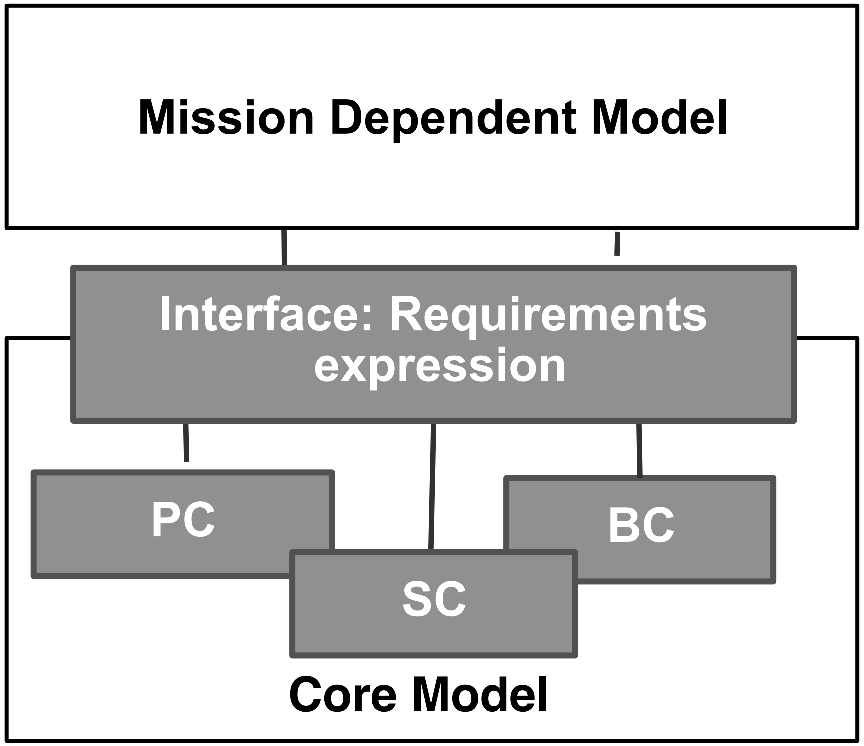
$$\textbf{Min\_Sys\_R} = (PL2 = ok \wedge BCL = ok \wedge (PL1 = ok \vee (PL3 = ok \wedge SL = ok)) \wedge (PL3 = ok \vee (PL1 = ok \wedge SL = ok)) \wedge (SL = ok \vee (PL1 = ok \wedge PL3 = ok))$$

Initially: PL1, PL2, PL3 activated

After failures of P1, P2 and P3: activation of S1

After failures of P1, P2, P3 and S1: activation of BCM, BPS_B, BPS_Y

Global Model Structure

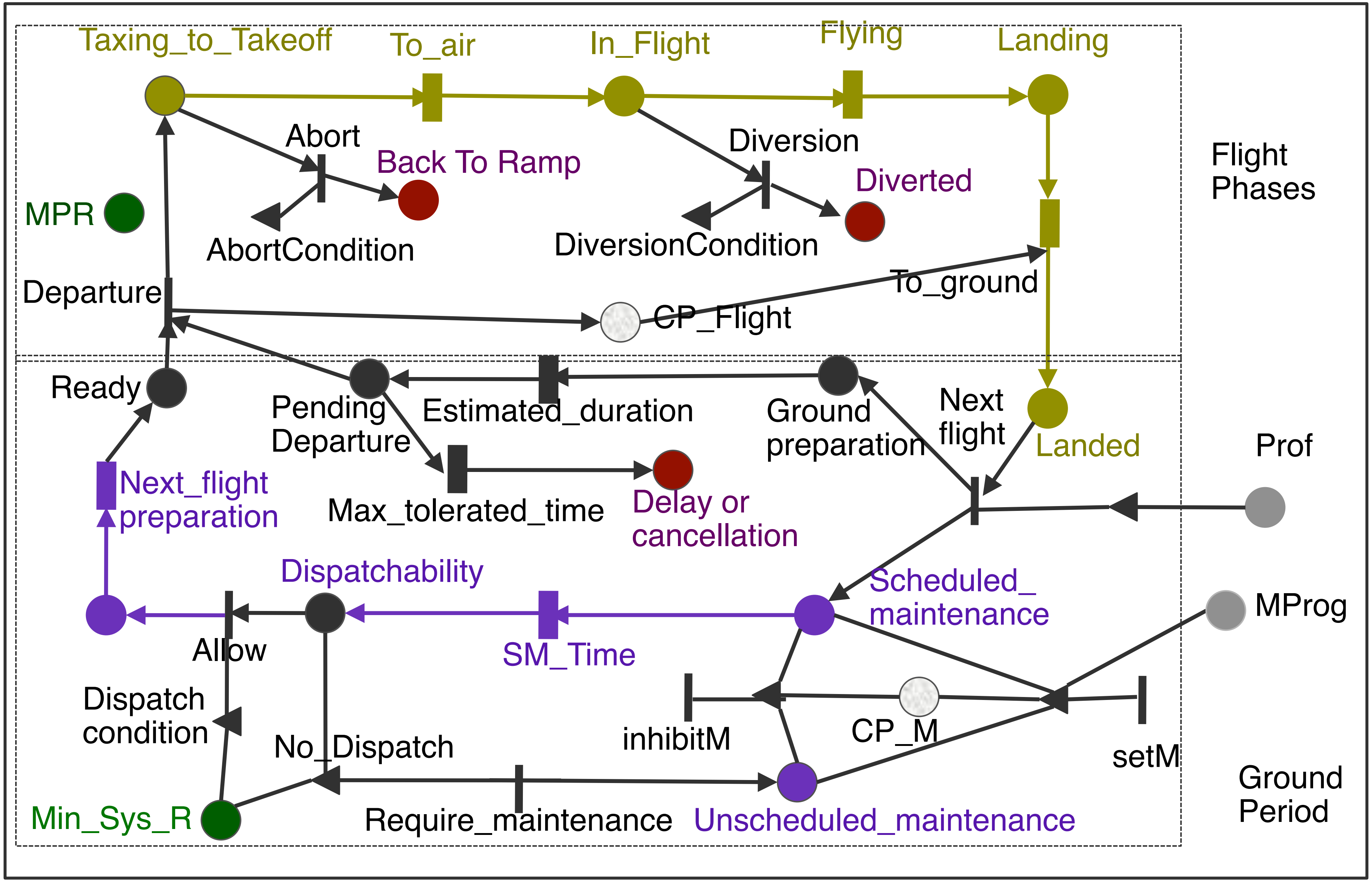


Min_Sys_R = (PL2 =ok ∧ BCL =ok ∧

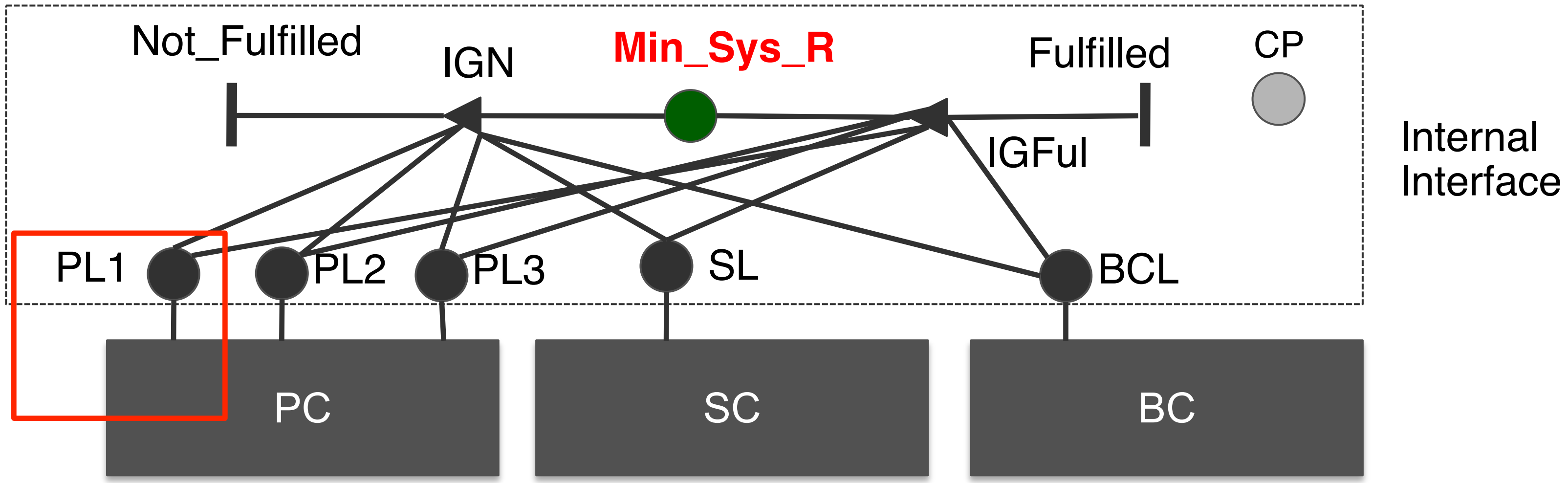
(PL1 =ok ∨ (PL3 =ok ∧ SL =ok)) ∧

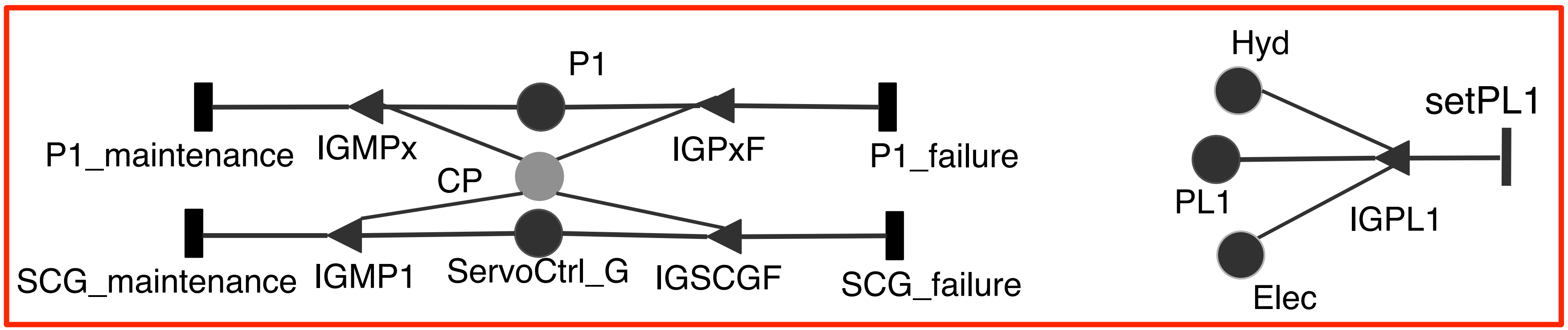
(PL3 =ok ∨ (PL1 =ok ∧ SL =ok)) ∧

(SL =ok ∨ (PL1 =ok ∧ PL3 =ok))


Taxing_to_Takeoff
To_air
In_Flight
Flying
Landing
Abort
Back To Ramp
Diversion
Diverted
MPR
AbortCondition
DiversionCondition
Flight
Phases
Departure
To_ground
CP_Flight
Ready
Pending
Departure
Estimated_duration
Ground
preparation
Next
flight
Landed
Prof
Next_flight
preparation
Max_tolerated_time
Delay or
cancellation
Dispatchability
Scheduled_
maintenance
MProg
Allow
SM_Time
Dispatch
condition
No_Dispatch
inhibitM
CP_M
setM
Ground
Period
Min_Sys_R
Require_maintenance
Unscheduled_maintenance

The Core Model





Control line PL1 sub-model

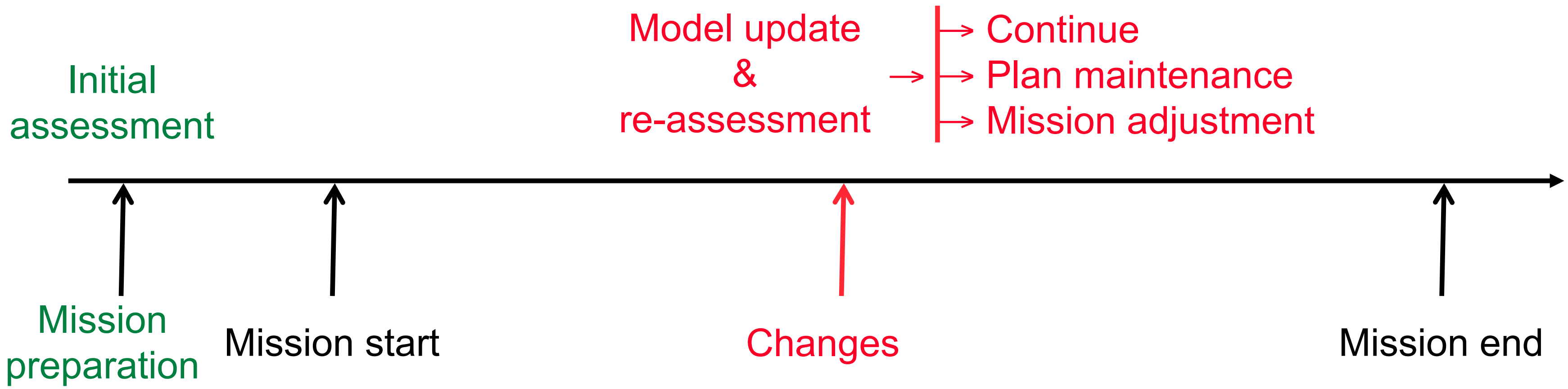
Assessment

- ☞ Parameter setting of model in operation
- ☞ All system components considered initially operational
- ☞ Exponential distribution for the failure events
    - Failure rates between 10^{-6}/FH and 10^{-4}/FH
- ☞ Deterministic durations for flight phases and ground activities

Re-assessment During Missions

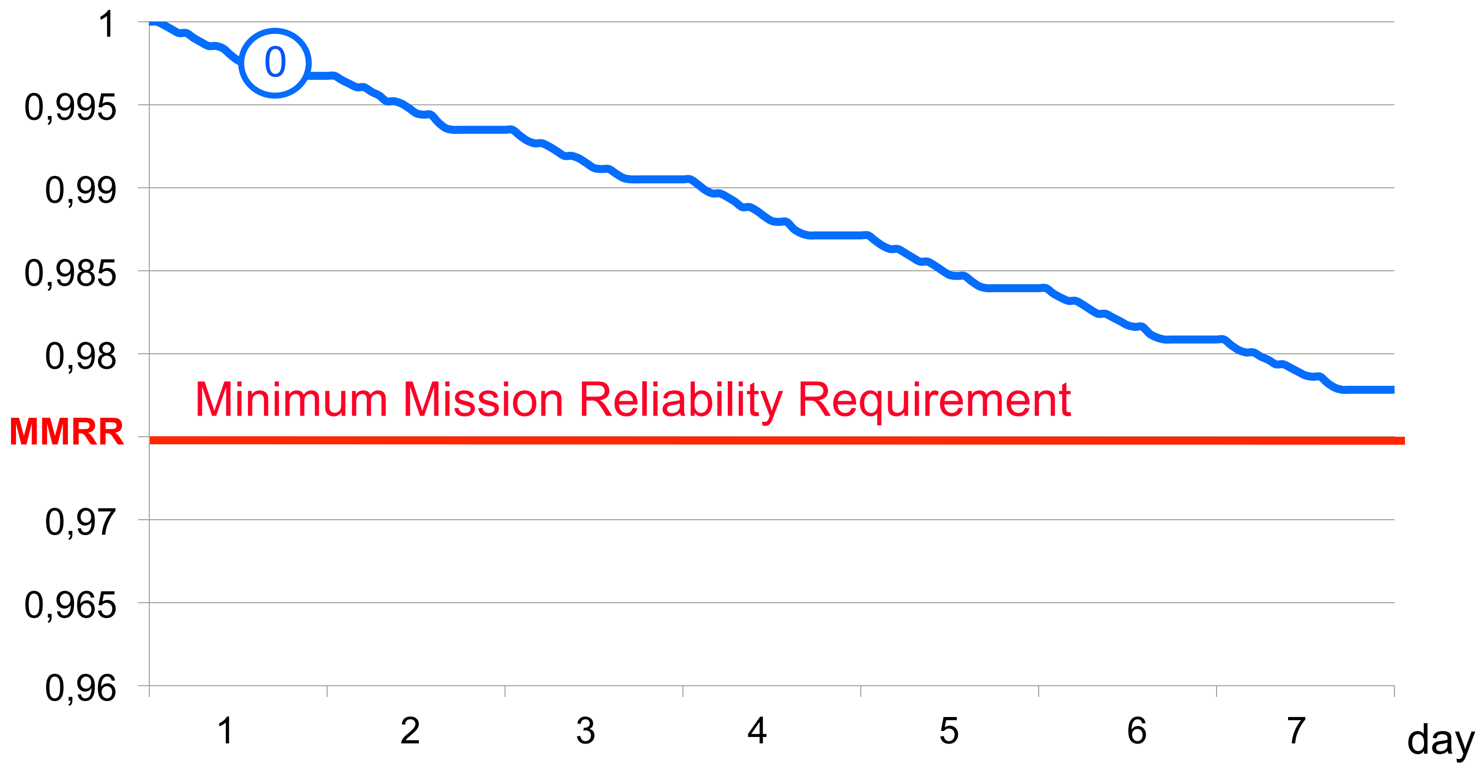
☞ Initial assessment & re-assessment after major changes

- Failure - Maintenance
- Distribution change
- Mission profile changes

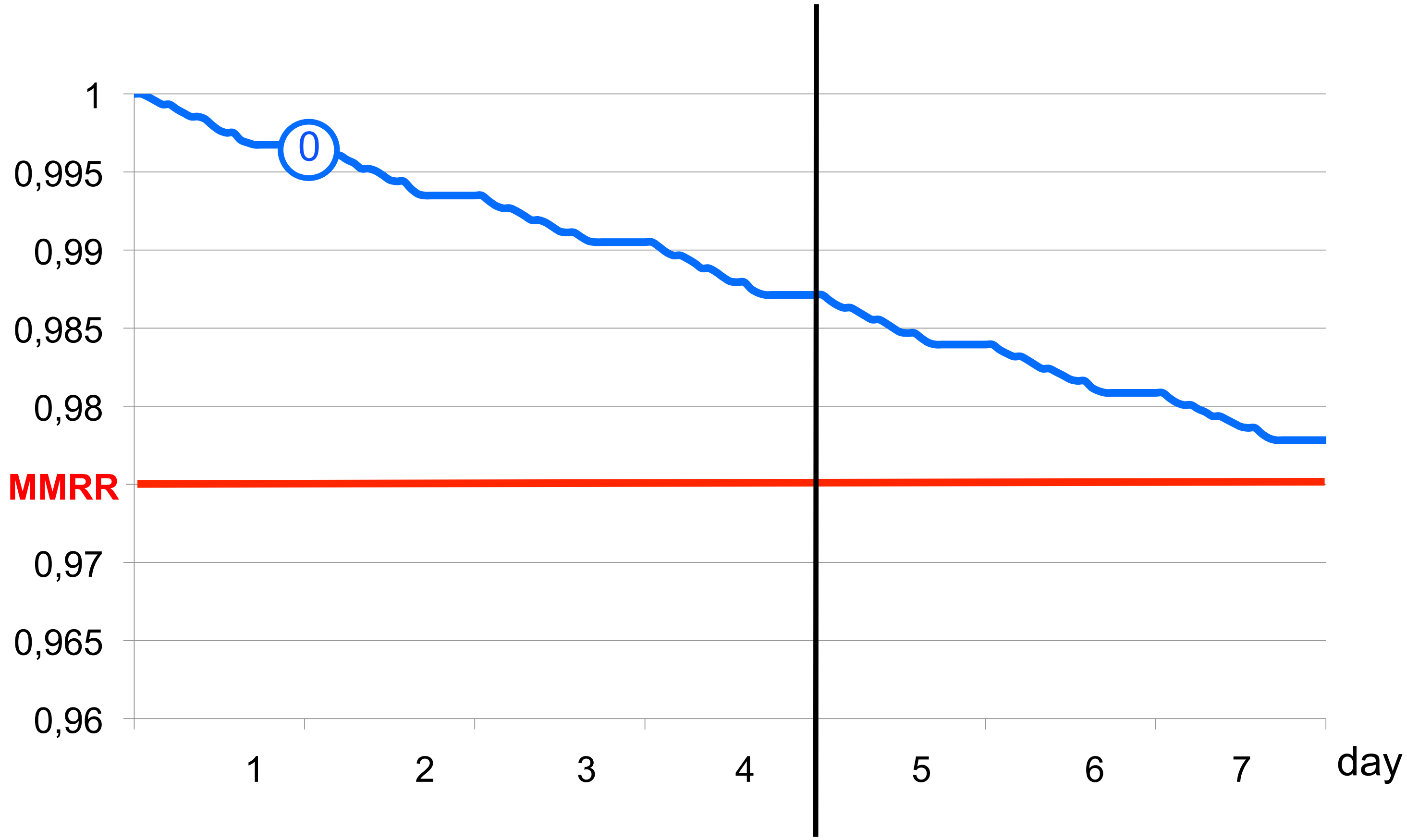


Initial Assessment

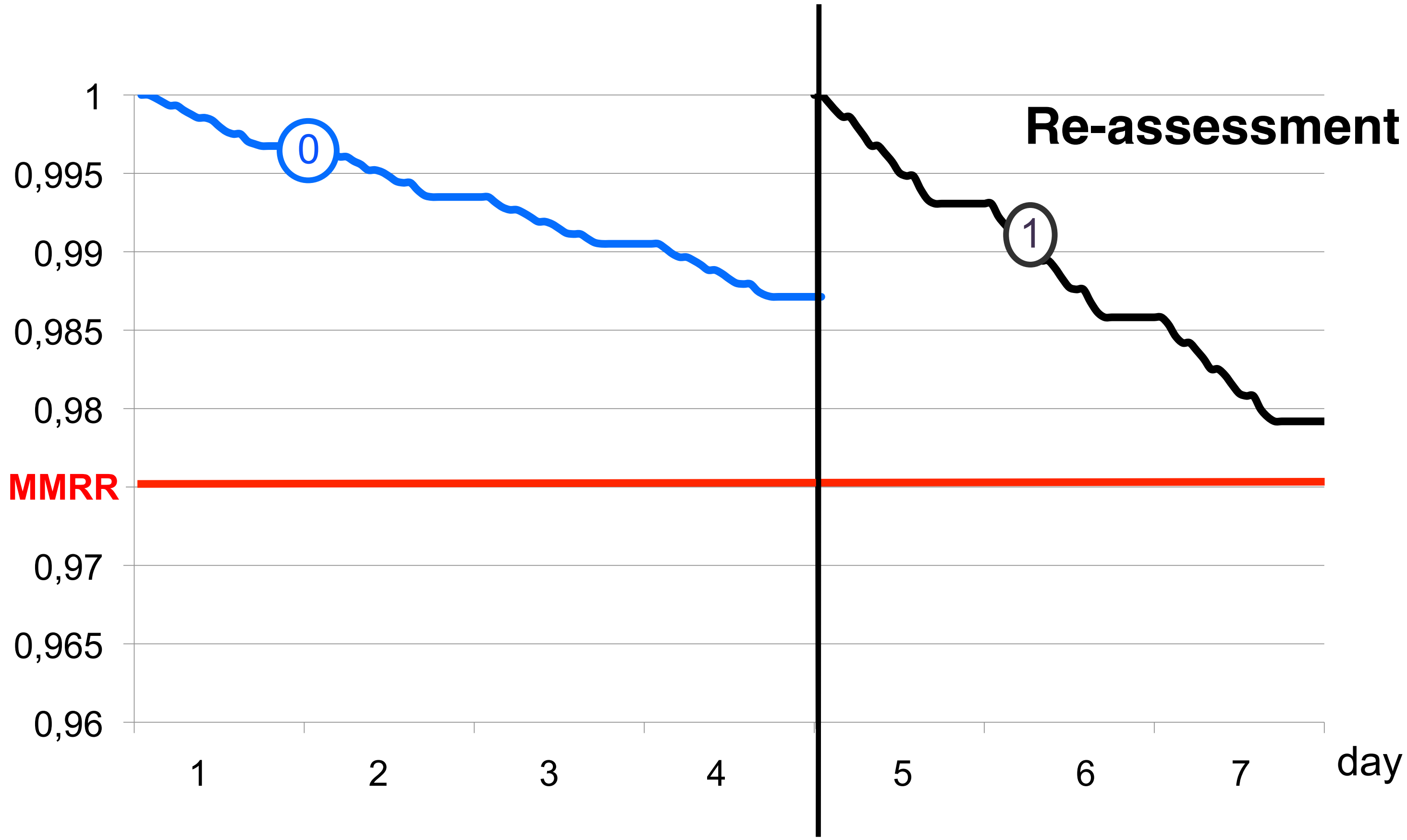
MR(t) evaluated before the start of the mission
Mission: 7 days, 4 flights/day, 3 hours each



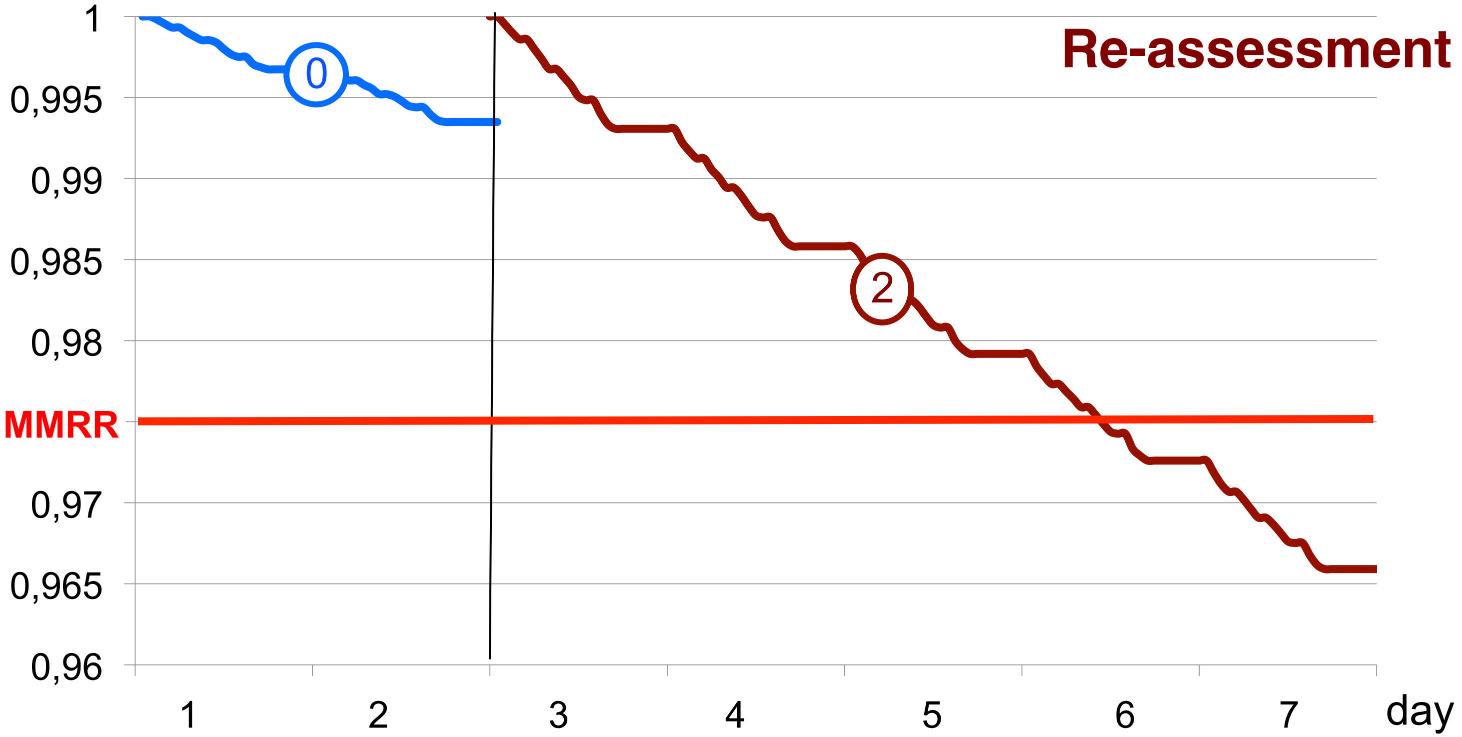
Failure of P1 after 4 days



Failure of P1 after 4 days

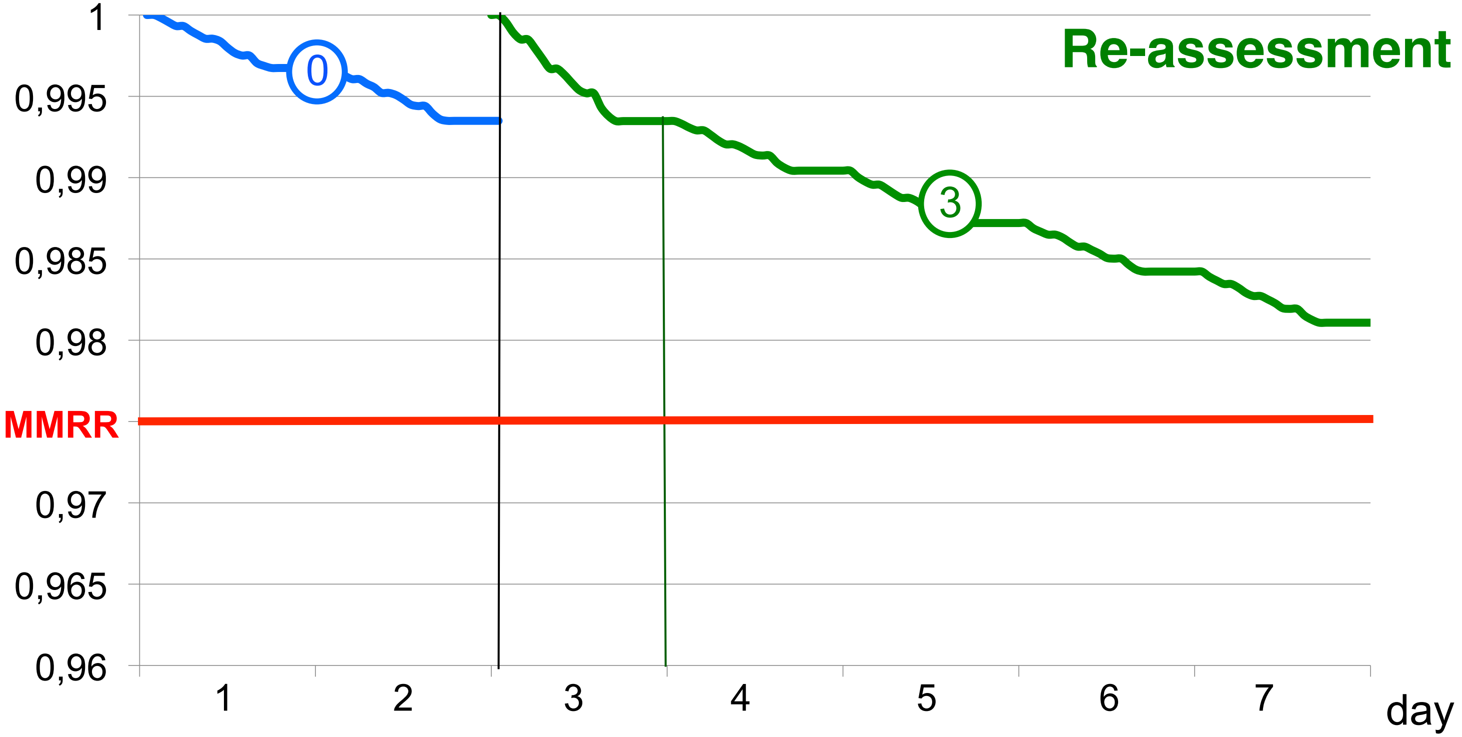


Failure of P1 after 2 days



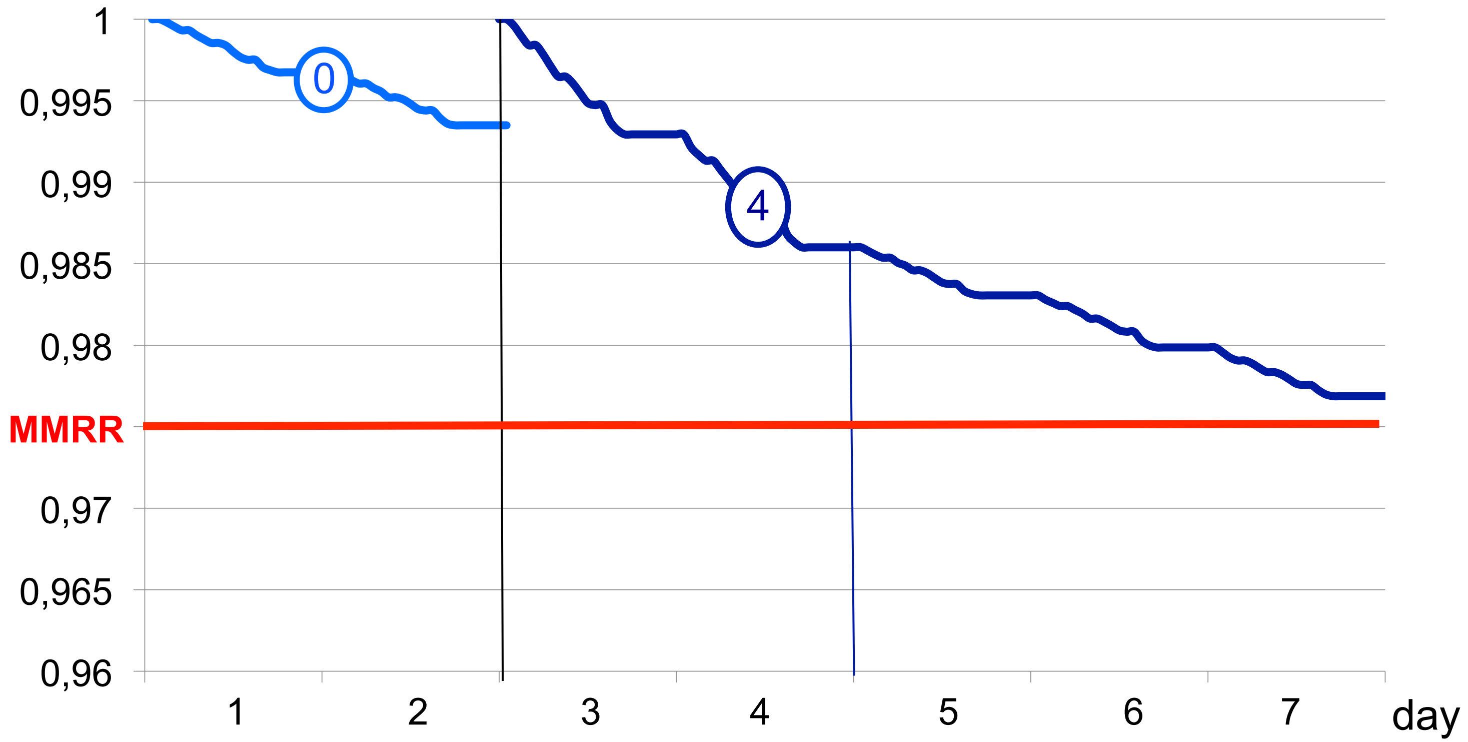
Maintenance Planning

Failure in day 2, repair end of day 3



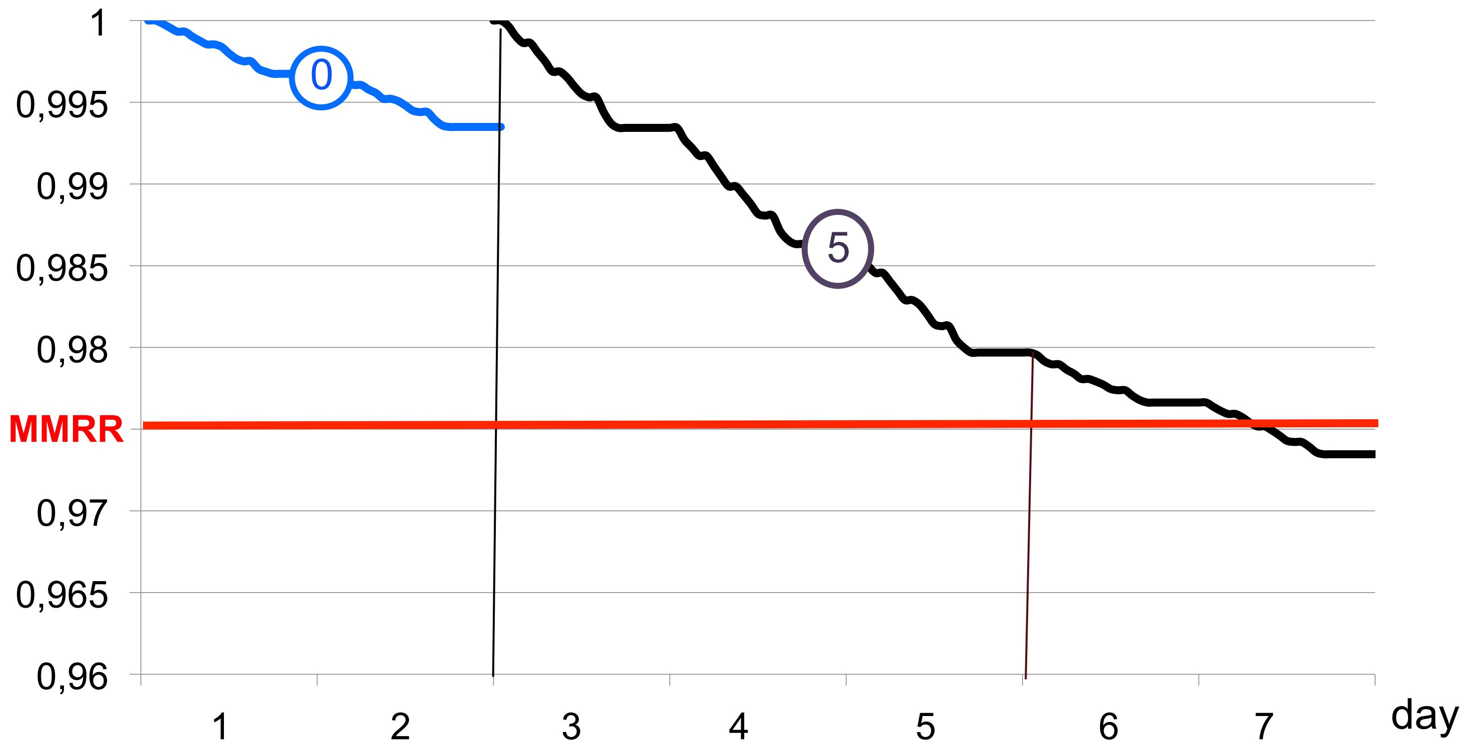
Maintenance Planning

Failure in day 2, repair end of day 4



Maintenance Planning

Failure in day 2, repair end of day 5



Conclusion

☞ Aircraft Operational dependability modeling for an assessment while in service:

- Feasible
- Relevant

☞ Modeling approach coherent with Airbus processes

☞ Probabilistic dispatch decision integrating multiple flights

☞ Optimization of maintenance cost