What cost resilience?

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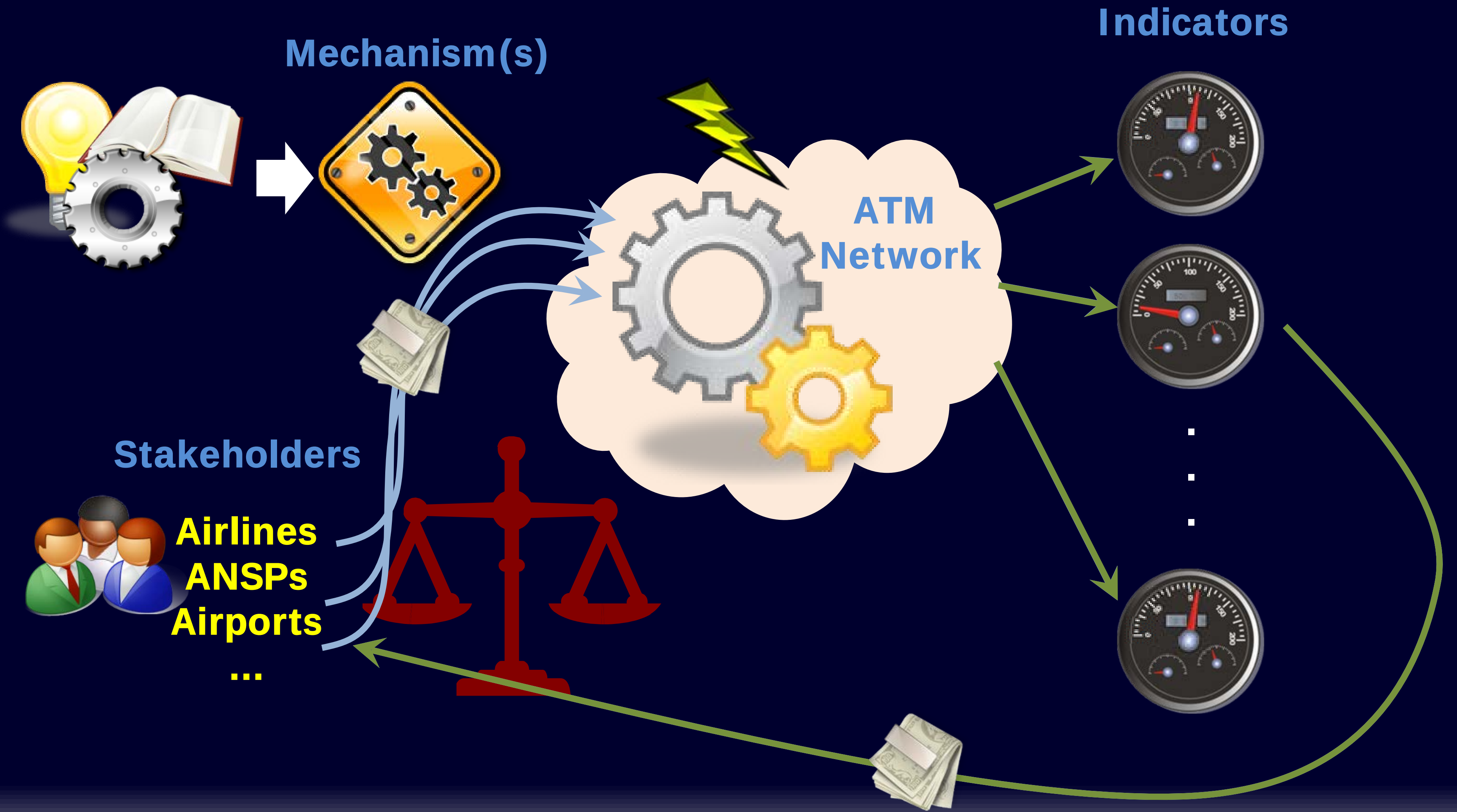
Overview

- Background and objectives
- ComplexityCosts model
  - Overview
  - Stakeholder uptake
  - Mechanisms
  - Disturbance
  - Cost allocation
- Resilience
  - Metric
  - Example
- Next steps

Background and objectives

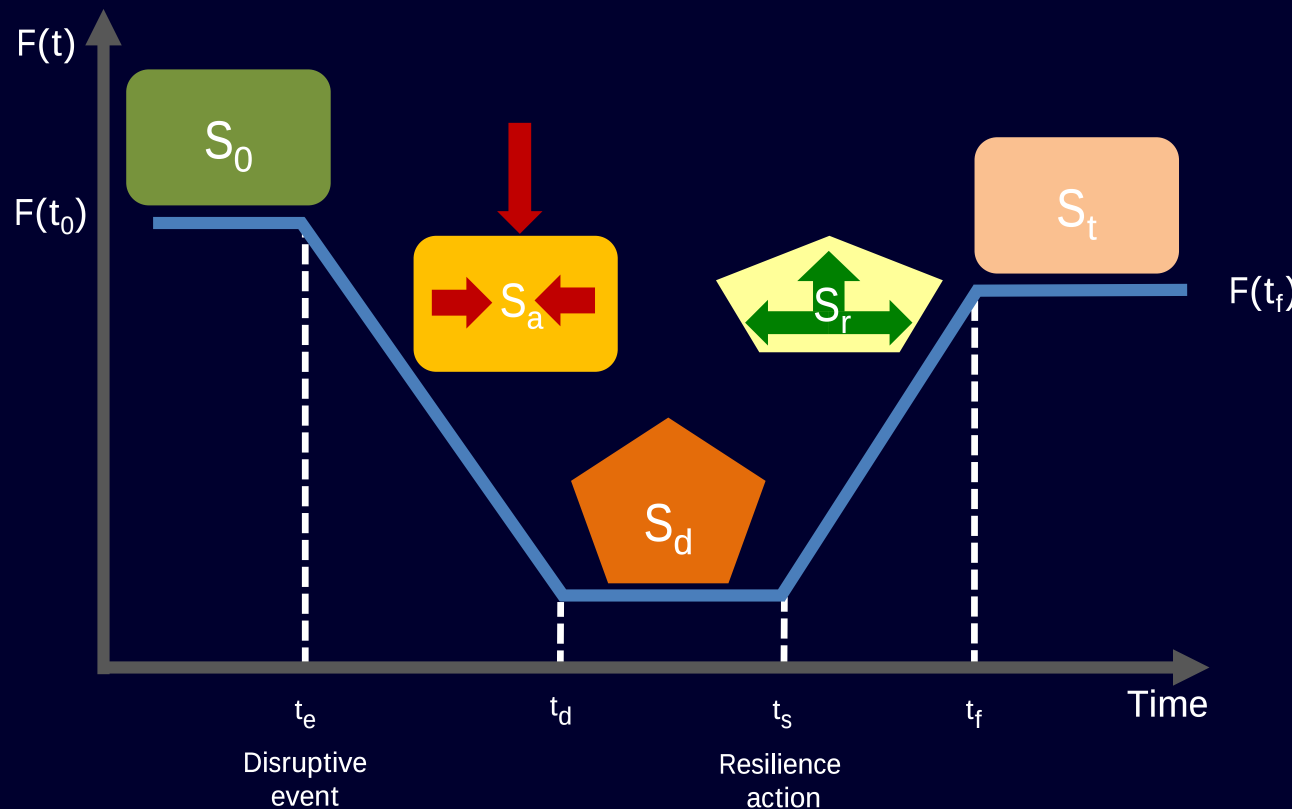
Background and objectives



Background and objectives

Mechanisms

Resilience



Background and objectives

- Reflect operational realities for investment mechanisms
- Consider disturbance as event capable of causing the system to change its specified state, as determined by one or more metrics

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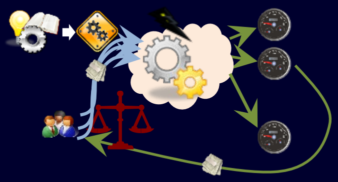
Complexity cost model

- Overwiev

Overview

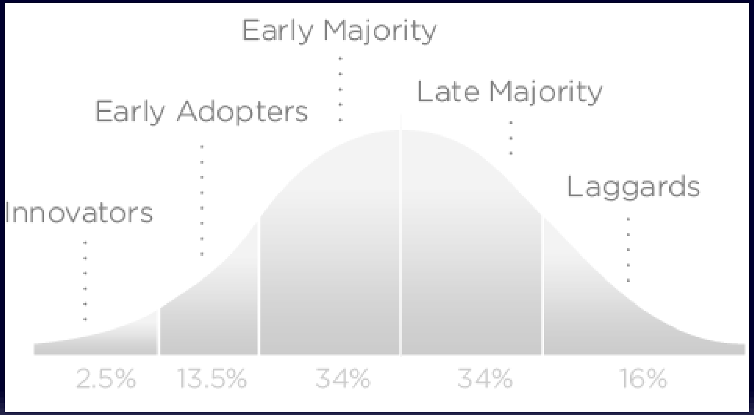


- Modelling
  - Stochastic, layered network with interacting elements and feedback loops
  - Stochastic elements will include systemic disturbance and specific modelled disturbance
  - Cost allocation for passengers and airlines
- Data
  - Traffic from busy (unexceptional) September 2014 traffic day as baseline
  - 200 airports in the ECAC area + 50 beyond
  - DDR2 for flight, capacity and airspace data
  - Passenger allocation algorithms based on previous work with IATA data (+ #pax) and GDS
  - Other data required has been identified

Complexity cost model
- Stakeholder uptake

Stakeholder uptake

- Differentiated degree of adoption of mechanism for user groups
- Based on stakeholder characteristics and mechanism characteristics
  - ANSPs: size, traffic density, regulatory
  - Airlines: business model
  - Airports: ownership, size, number of runways, slot coordination status, hub status



Complexity cost model

- Mechanisms

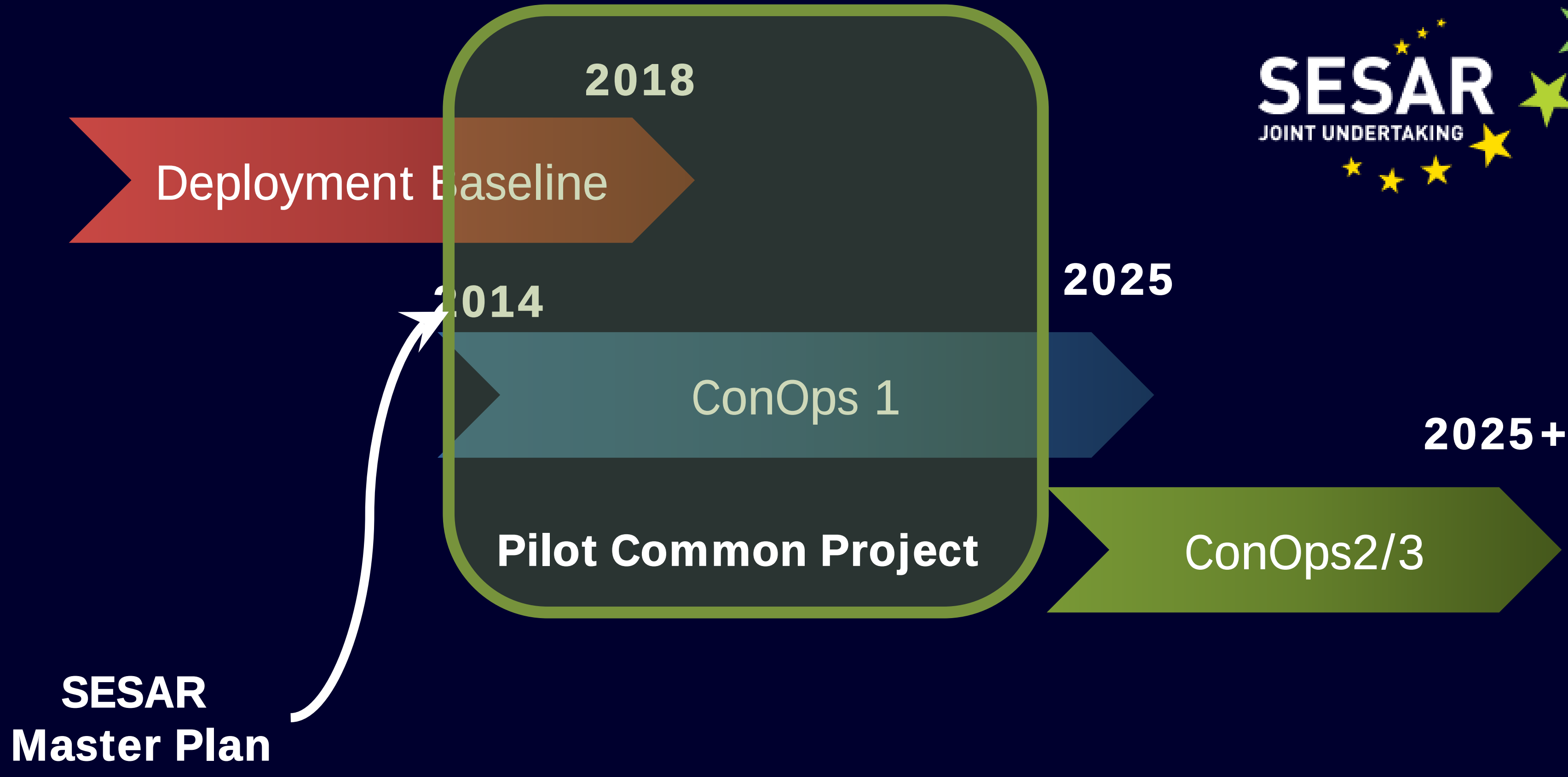
Mechanisms

- Basic criteria considered to select the investment mechanisms
  - Different types of mechanisms: basic, advanced
  - Cross-section of procedural, regulatory and technological types of change; addressing different flight phases
  - Well known costs or amenable to reasonable estimation for their implementation (strategic) and operational (tactical)
  - Modelled through different stakeholders uptake

Mechanisms

Mechanism		Summary description	Example
Type	Advanced	SESAR Essential Operational Changes and sub-components thereof	Airport collaborative decision making (A-CDM)
	Basic	Non-advanced, does not centrally involve implementing new technologies/tools.	Airline adding buffer to its schedule
Disturbance focus	Mitigation	Primarily aimed at mitigating the impacts of disturbance.	Spare aircraft crews with dynamic rostering.
	Nominal	Primarily aimed at improving the nominal functioning of the system	Additional runway capacity

Mechanisms


2018
Deployment Baseline
2014
2025
ConOps 1
2025+
Pilot Common Project
ConOps2/3
SESAR
Master Plan

Complexity cost model
- Disturbances

Disturbances

- Disturbances described by
  - Type
  - Frequency of occurrence
  - Localisation
  - Duration
  - Intensity

Scope

- Weather
- Ash plumes
- ATFM capacity restriction (non-weather)
- Strike actions
- Technical failures
- Passenger disruptions
- Military exercises

- CODA
- NOP
- METAR
- Other / Analysis

Complexity cost model

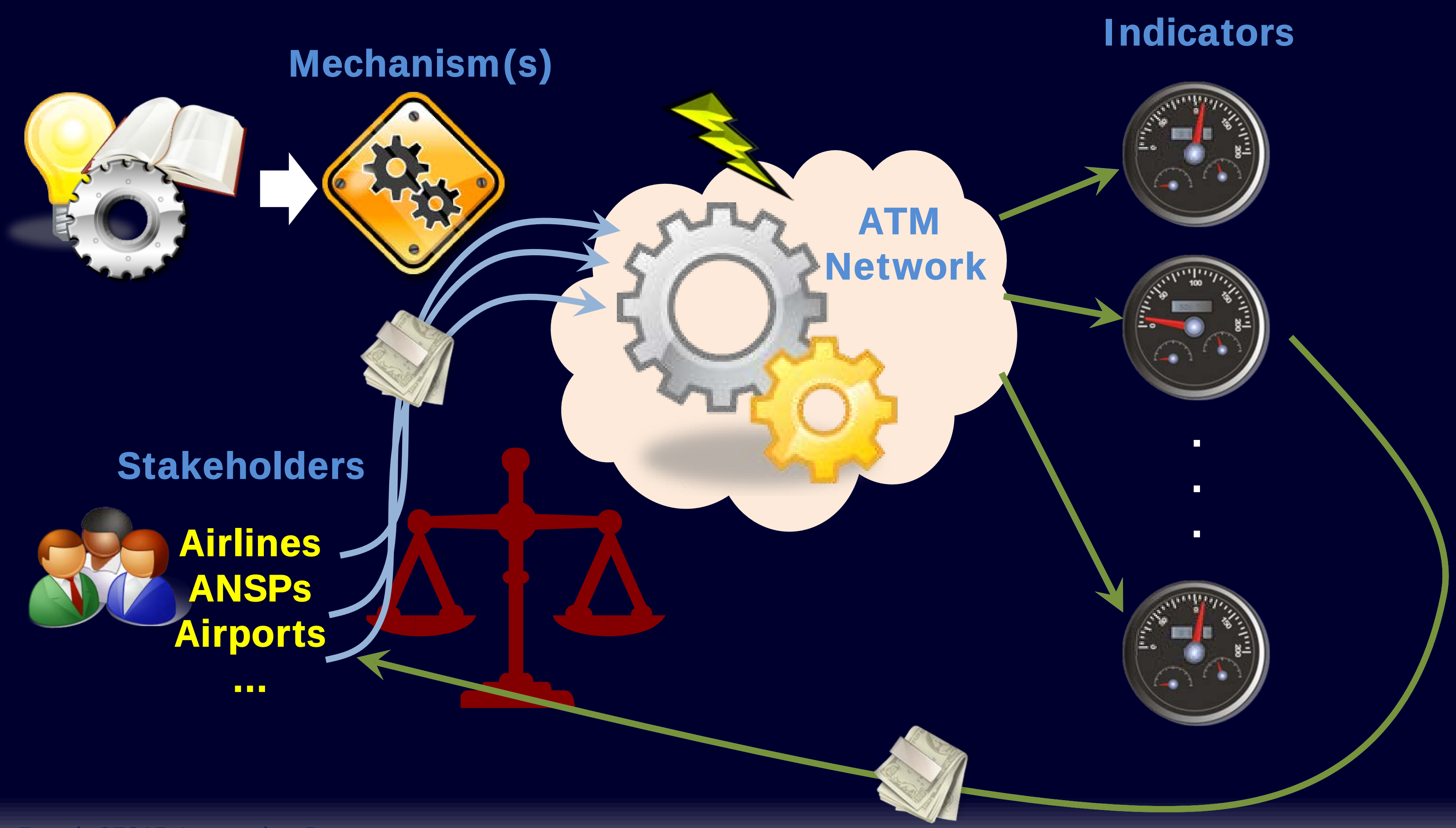
- Cost allocation

Cost allocation

- Airline costs for delay
  - Strategic (airline buffer)
  - Tactical (day of operations)
  - Reactionary delays will also be assessed
- Cost updated to 2014 values
- ‘High’, ‘base’ and ‘low’ costs scenarios considered

- Fleet
- Fuel (and carbon)
- Crew
- Maintenance
- Passenger costs

Background and objectives



Resilience

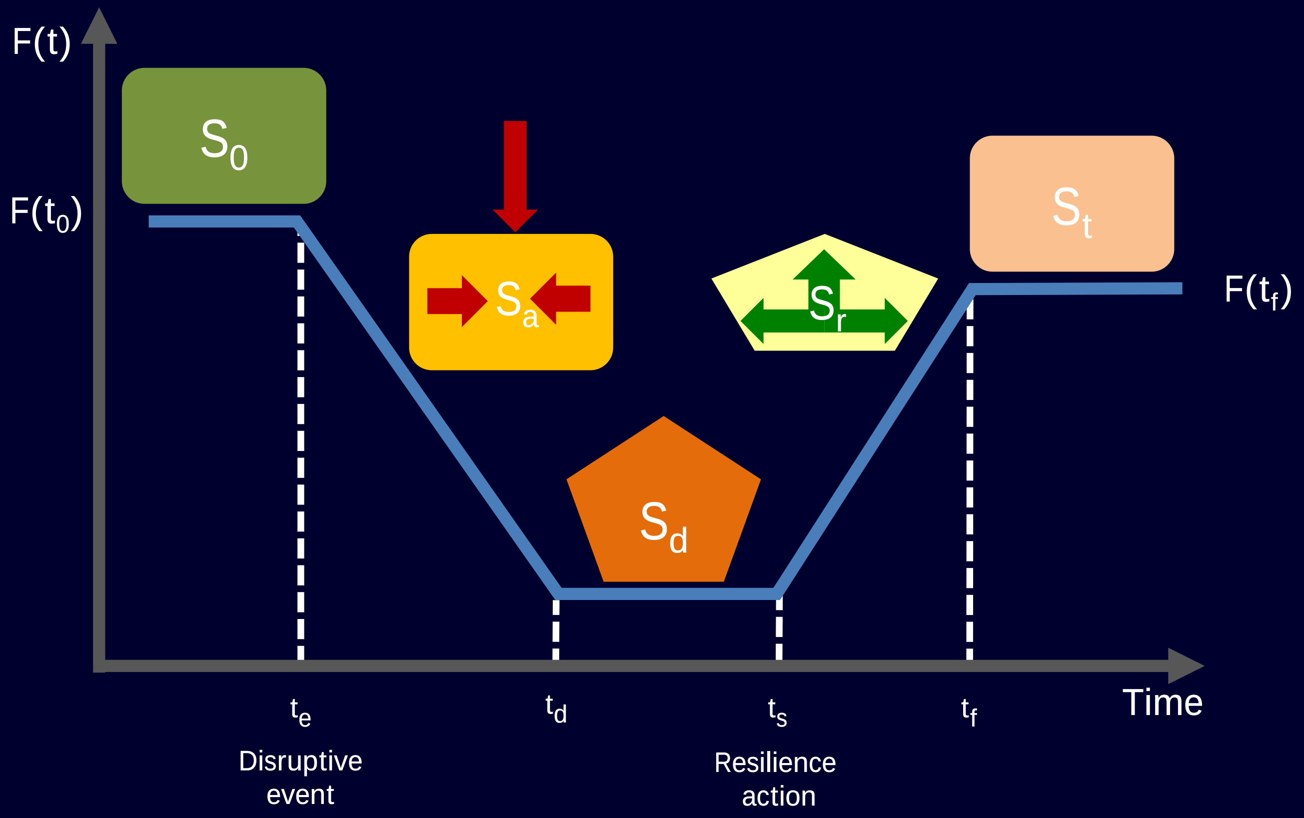
Resilience

- Major definitions

Terminology	Introduction	Field	State(s)	Key feature
Engineering resilience	Hoffman (1948)	material testing	one stable	inherent ability of the system to return to its original state
Ecological resilience	Holling (1973)	ecology	multiple	ability of the system to absorb disturbance
Resilience Engineering	Hollnagel (2006)	air transport	multiple	safety-based design of socio-technical systems

Resilience

- Major definitions



Resilience

- Capacities

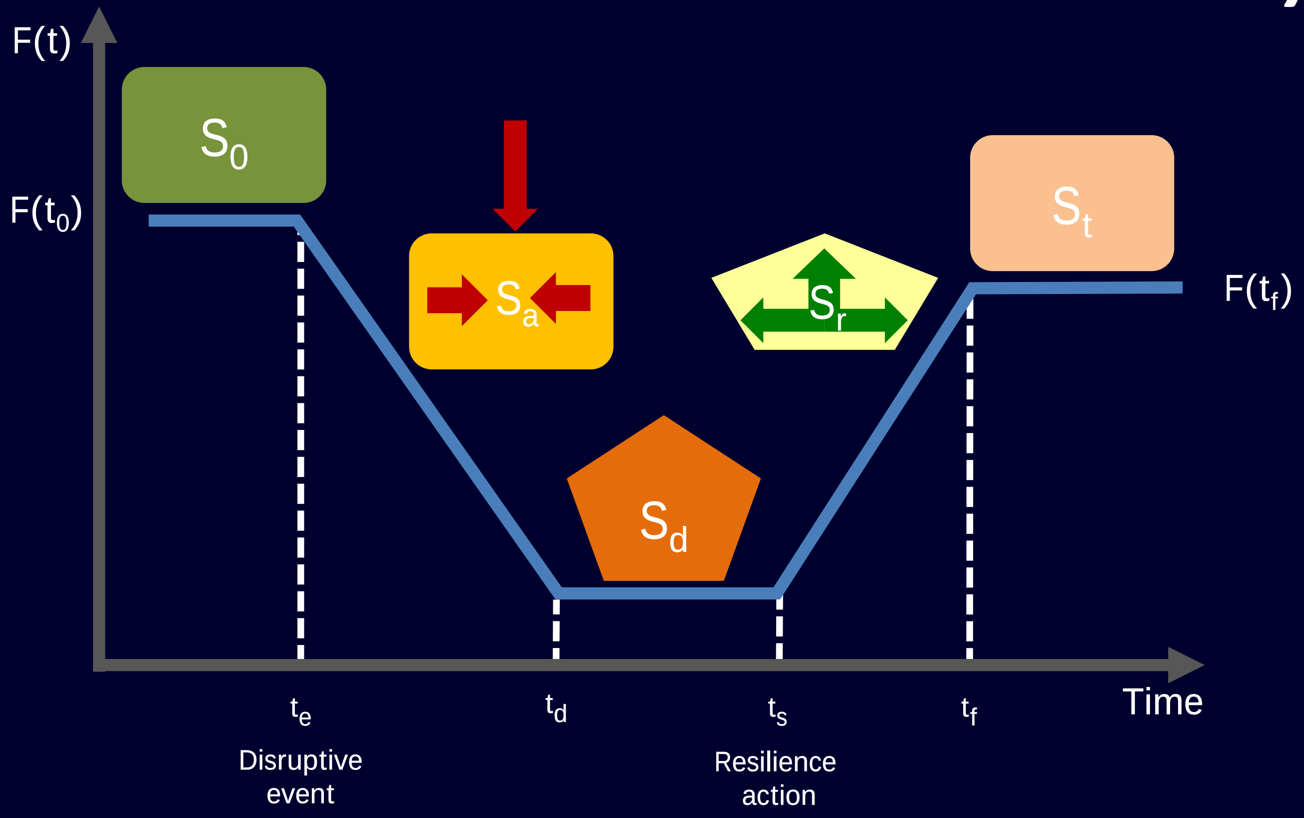
Capacity	Key feature	Key association(s)	ATM focus
Absorptive	network can withstand disruption	Robustness; little or no change may be apparent	strategic
Adaptive	flows through the network can be accommodated	change is apparent; often incorporates learning	strategic and/or tactical
Restorative	Recovery enabled within time and cost constraints	May focus on dynamics/targets; amenable to analytical treatments	tactical

Resilience

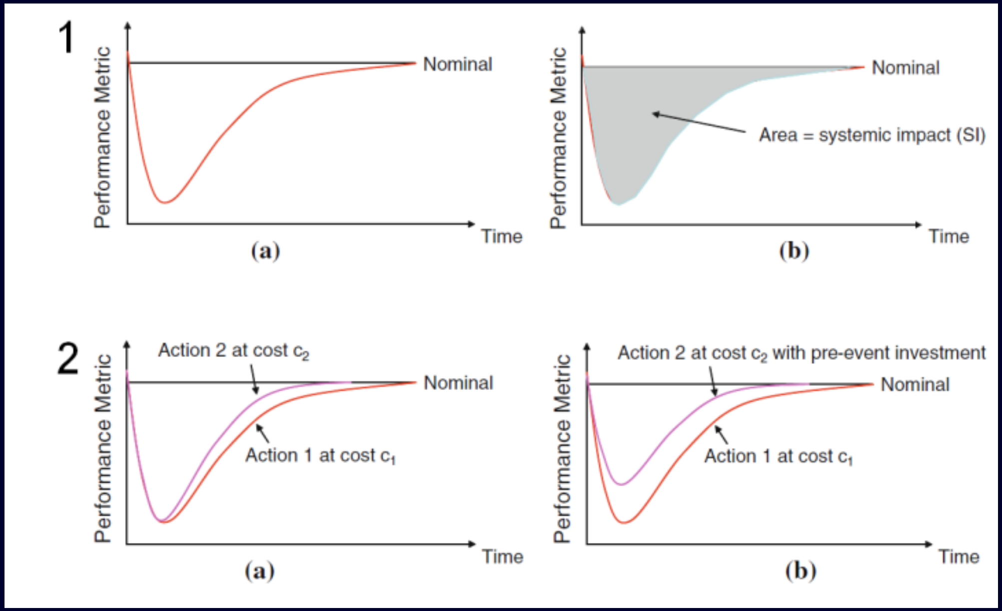
- Metric

Metric

$$Я(t) = \frac{Recovery(t)}{Loss\ (t_d)}$$



Metric



$$R = \frac{\int_{t_0}^{t_0+t_h} Q(t)dt}{t_h}$$

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Metric

- ATM context
  - Metric characteristics
    - Intelligible
    - Pertinent
    - Stable
  - Difficulty to establish the time over which a recovery occurs
    - Use one operational day in European airspace as the boundary conditions
  - Cost based metric
  - Return investment value
    - Ratio and absolute value relevant
  - Tactical costs of running the mechanisms considered

$$Я = \frac{€50}{€100} = 0.5$$

$$Я = \frac{€50k}{€100k} = 0.5$$

$$n = \Sigma u$$

Metric

- ATM metric

$$R_C = \frac{\sum_u^d C_u(t) - \sum_u^d \sum_u^m C_u(t) - C_m(t)}{\sum_u^d C_u(t)}$$

- disruption cost
- cost of disruption with mechanism
- investment running cost

$$R_C \leq 1$$

Resilience

- Example – Applying a mechanism

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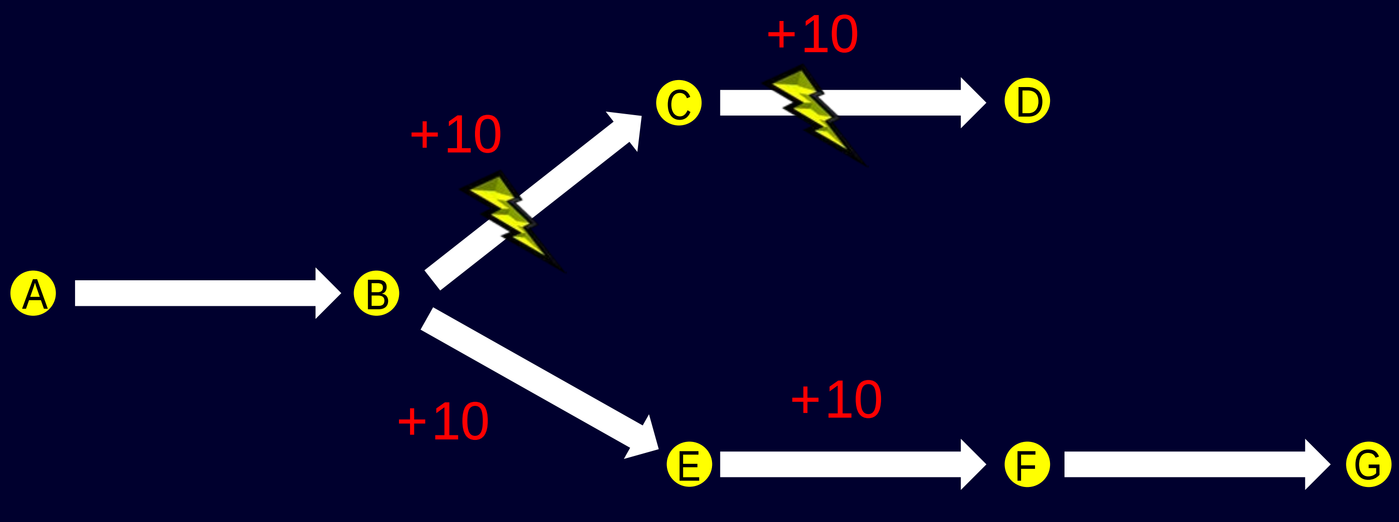
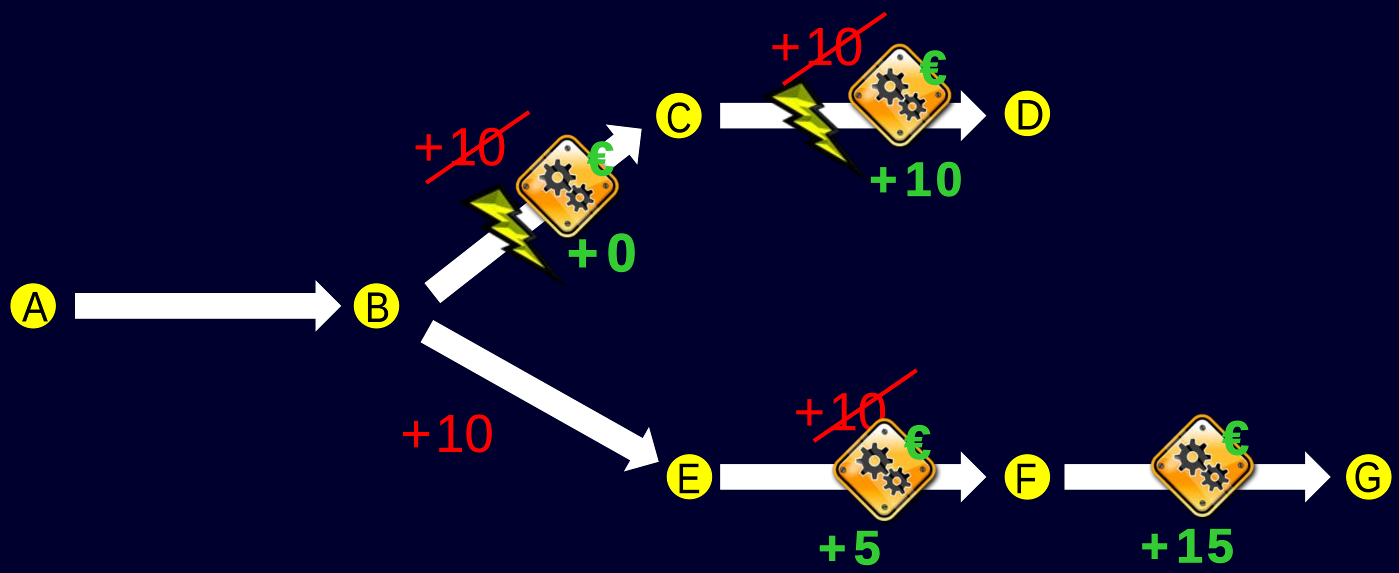
Applying a mechanism



Σ = +20 (at this planning stage)

Applying a mechanism



$+ \quad \Sigma = +30 \qquad \Sigma_u^d$

$\Sigma = +30 \qquad \Sigma_u^d \Sigma_u^m$

$R_C = 0$

Applying a mechanism

- Retrospective example
  - 199 ECAC airports + 50 beyond region (busy day in September 2010)
  - Passenger connectives and airline delay costs explicitly modelled
  - Airline decision-making mechanism applied to decide how long to wait (t>=0) for connecting passengers

Applying a mechanism

Scenario modelled	Total network delay cost		Cost resilience (R_c)
	without mechanism	with mechanism	
Nominal delays	**€ 16.11 m**	**€ 14.95 m***	**7.2%**
Increased delays	€ 17.08 m	€ 16.02 m*	6.2%

* $p<0.01$ for cost reduction relative to no mechanism

n=29 555

- Average saving for a nominal day is 39 € per flight
- € 1.16 m can be invested (benefit of mechanism in nominal day) and ensure a positive resilience in both scenarios
- A monthly cost of up to € 1.5m would be worthwhile for top ten carriers

Next steps

Next steps

- Model the different monetised mechanisms
  - Mechanisms focus between SESAR Deployment Baseline and ConOps Step 1
- Define passenger and flight centric metrics to compare mechanisms
- Further develop event-driven model to assess disruptions and their impact
- Improve the understanding of complex interdependencies
- Further define a framework to compare advanced and basic investment mechanisms to develop new cost-benefit analysis

Thank you