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WSP72 Systems Architecture

Air Traffic Control System Tutorial III

Alternative Behaviour &
System Architecture Analysis

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Lecture 15

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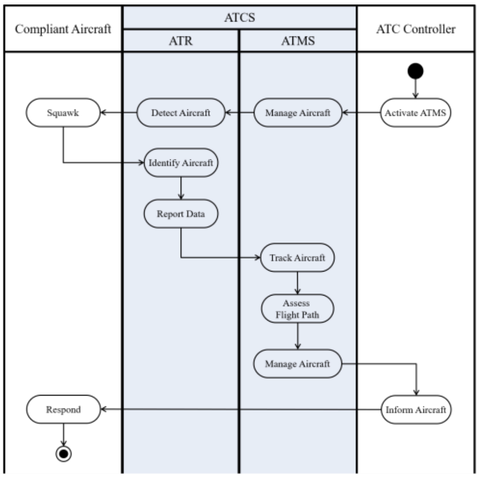
ATCS System Activity Diagram:
Case 1: Compliant Aircraft



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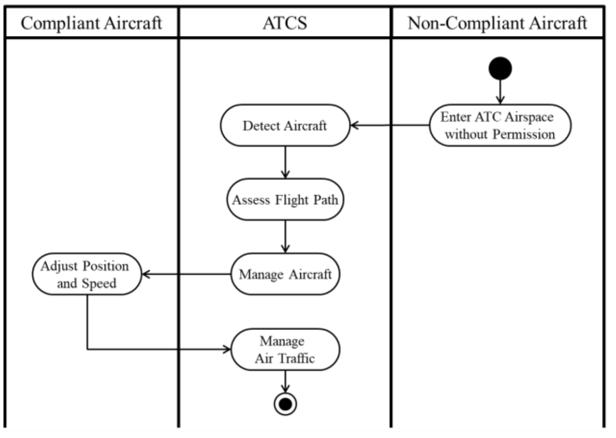
ATCS Activity Diagram:
Case 2: Non-Compliant Aircraft



Narrative (1 of 2):
Occasionally there are unintended aircraft in the airspace of the ATCS.

Narrative (2 of 2):
... manage ... positions (iii) assess ... risk of air-to-air collisions

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'Management' of Non-Compliant Aircraft

- ATCS does not have prior knowledge on who is compliant and who is not. The 'classification' of aircraft needs to be '***identified***'.*
- ATCS cannot manage non-compliant aircraft because they will not be compliant
- ATCS instead needs to manage compliant aircraft(s) to avoid air collision
- Non-compliant aircraft entering ATC airspace is expected as part of the requirement (baseline scenarios)
- The integration of system behaviour for compliant and non-compliant cases is NOT a simple linear flow
- We need additional control structure to appropriately capture the integrated scenario (basic flow + alternative flow(s))

** Tutorial I&II neglected the outcomes of the 'identification' step as a simplifying assumption*

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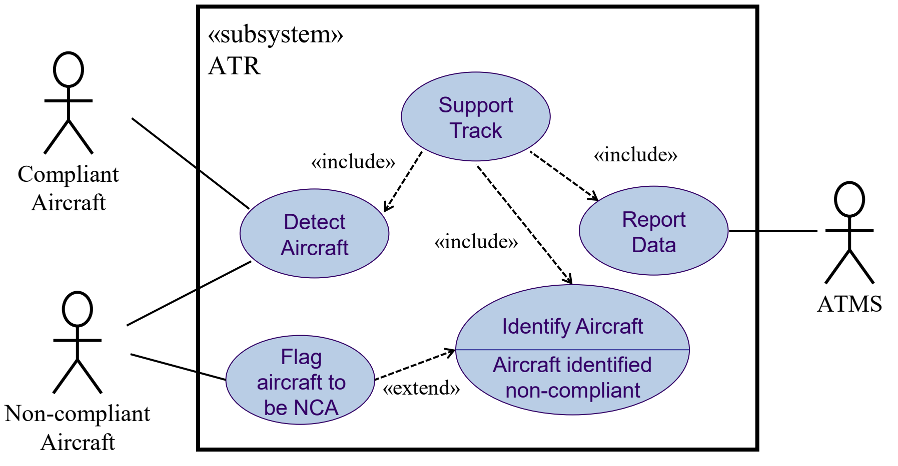
Revised ATR Use Case Diagram:
model alternative behaviour with <<extend>>



Allocate the 'outcome' of the identification to ATR (an architectural design decision to be agreed with stakeholders)

NCA: Non-compliant Aircraft

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Use Case Description:
Manage Air Traffic (Case 1 + Case 2)

Use Case Name	**Manage Air Traffic (Case 1 + Case 2)**
Description	Manage aircrafts
Actors	Non-Compliant Aircraft and Compliant aircraft, ATCC
Pre-conditions	Manage aircrafts that enters ATC airspace. Aircrafts can be compliant and non-compliant.
Post-conditions	None
Extension points	An aircraft is identified non-compliant (ATR reports non-identifiable aircraft)
List of Action for Basic Flow	1. ATMS manage aircraft 2. ATR detect aircraft 3. ATR identify aircraft to be compliant 4. ATR report data to ATMS 5. ATMS track aircraft **… (ATCS continues to manage this aircraft, details are neglected)**
Alternative Flow	3. ATR identify aircraft to be non-compliant 4. ATR report data to ATMS 5. ATMS track aircraft **… (ATCS does not do anything more to this aircraft, but continues to manage other aircraft)**

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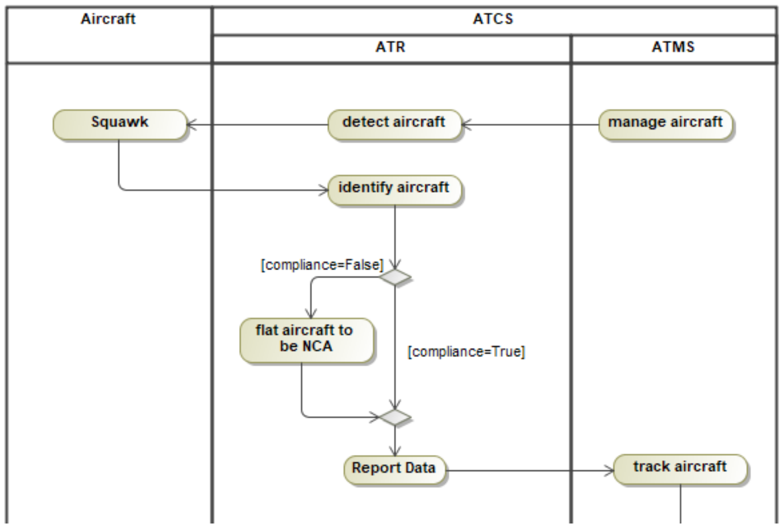
Revised Behavioural Model:
model alternative flow with decision/merge



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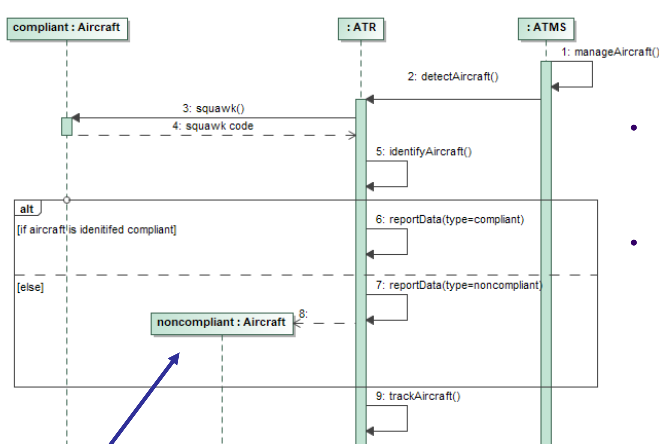
Integrated Sequence Diagram
(with *alt* structure and *object creation*)



A new object is created, but does not interact with ATMS nor ATCC

- NCA flagging is ‘implemented’ as creation of new object
- The part involves ATCC and that continues after track remains the same with previous sequence diagram (compliant aircraft)

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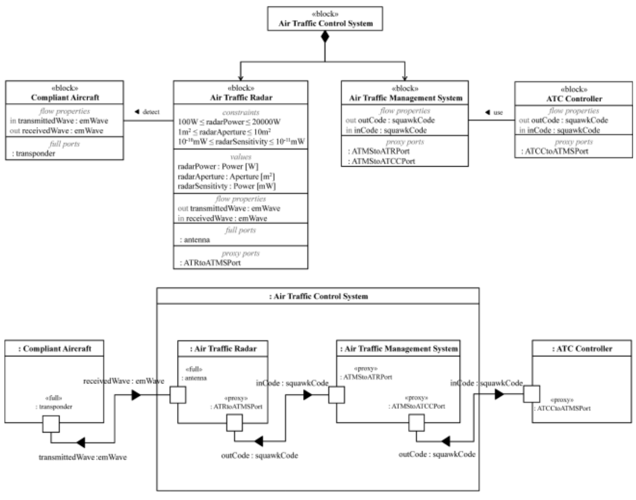
ATCS Interfaces Specification with SysML IBD and BDD



IBD:
- Ports (part or proxy) are used to specify interfaces.
- Flow properties specify what flows through the interfaces (ports)

BDD:
- Details of flow between ports
- Consistently specified against IBD

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Analysis of Aircraft Critical Flow Density

- Assume the following:
  - Runway maximum landing / take-off rate at **1 aircraft per min**

    Safety Rule: an aircraft cannot touch down whilst another is on the runway
  - Aircrafts approaching ATC airspace uniformly at max speed of **240nmi/h**
- Calculated critical spacing for compliant aircraft:

$$s = \frac{240\ nmi/h}{1\ aircraft/min} = \mathbf{4nmi/aircraft}$$

- The safety spacing of **500ft** with will always be met with compliant aircraft; but must be managed for non-compliant aircraft in ATC airspace
- Critical density = inverse of critical spacing:

$$k_c = 1/s = \mathbf{0.25\ aircraft/nmi}$$

- Safety issues: when current density, $k > k_c$
  - How does ATCS control approaching aircrafts and non-compliant aircrafts?
  - Note: critical density k_c corresponds to the maximum flow rate of aircraft

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Basic Traffic Modelling

- Density (k), Flow Rate (r), and Mean Speed (v) relationship:

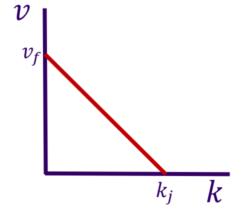
$$r = k * v$$

- A simple traffic model (Greenshield 1934) suggests that the relationship between mean speed and density can be linearized, such that

$$v = -\frac{v_f}{k_j}k + v_f$$

where v_f is the free flow speed and k_j is the jam density

- The critical density is the point on this linear relationship that gives the maximum flow rate



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Possible solutions when k is near k_c

Based on the given formulae, to lower the density below k_c, the controller could:

- Slow down approaching aircraft when they enter the ATC airspace. This reduces mean speed in the airspace and increases the aircraft spacing; hence reduces the density.
- Divert approaching aircraft to other airport to reduce arrival rate, and hence reduces the density
- Delay scheduled take-offs to temporally increase critical density to accept high arrival (flow) rate

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Summary and System Specifcation

- Fully **integrated interaction model** (Sequence Diagram) for managing air traffic involving both **complaint and non-complaint aircrafts**.
- Proposed ideas for the development of software for **ATMS**:
  - When non-complaint aircraft is detected, a **new 'object' should be created** that does not interact with ATMS. This would allow flexible tagging of aircrafts, e.g., non-complaint ↔ complaint, potentially easy for ATC Controller to manage and hardware memory friendly.
  - Three candidate management strategies proposed: **slow complaint aircrafts, divert approaching aircrafts or delay scheduled take-offs**. We propose **all three** strategies to be designed into the logical architecture/algorithms.
- Proposed strategies are based on engineering judgement supported by linear traffic modelling (Greenshield 1934). Higher fidelity model is required for assurance, before implementation takes place.
- Interfaces are identified and specified based on the interaction model:
  - Radar Interface (between ATR and aircrafts, Antenna – domain knowledge)
- Next step: shift focus to **ATR** redesign as current ATR may not be suitable for the need of ATMS.

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Questions?

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