TNyCA

Grado Aeroespacial

Introduction

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Bibliography

- **Descubrir la navegación aérea**
  - F.J. Sáez Nieto, Y. Portillo Pérez
  - Servicio de publicaciones de Aena

Introduction

- **Introduction**
- **Functional approach**
- **Operational approach**
- **Legal and institutional approach**

Basic concepts

Basic concepts

- **Air navigation**: process of flying an aircraft from a well known initial location to a well known destination following a path defined by a set of intermediate positions known as **waypoints**.
  - *Navigating implies a **permanent knowledge of the aircraft position**.*
  - *In its origins, navigating didn't take into account the existence of other aircrafts in the airspace...*
- **Orderly flow of air traffic**: multiple aircraft simultaneously sharing the same airspace require establishing some **flight rules** and **procedures** to maintain a safe and orderly flow of air traffic. In some cases it also requires ground based services (**traffic control**) to accomplish coordination.
- **Air Traffic Management (ATM) System:** it is a complex system of *infrastructure*, *procedures*, and *human resources* which enable and manage **air navigation** and **air traffic control**.
  - *Required by the increasing air traffic and instrumental flight.*

Basic concepts

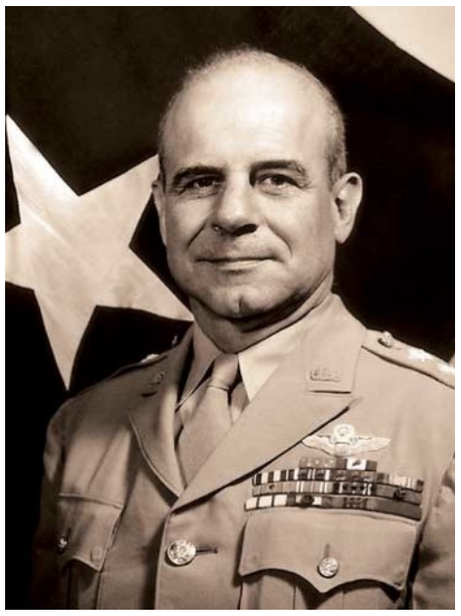
- **Goals of navigation techniques**

  Minimizing the probabilities of:

  - **Getting lost**.
  - **Collisions** with other aircrafts, ground or obstacles.
  - Being unable to complete a route or navigating it in an unsafe way due to **adverse weather conditions**.

    - ***Instrument Flying Techniques*** *allow to reduce the required visibility threshold.*

      - *Jimmy Doolittle,* 24/9/1929: first flight totally instrumental with zero visibility.



Basic concepts

Points of view of air navigation

- Air navigation comprises many components and can be dealt with from many points of view or approaches:

Final users
Pilots,
Controllers,
Airlines,…

Operational support
Service providers
Airports

Air Navigation

Business
Airlines
Service providers

Designers
Engineers
Technicians, ...

Regulators
Aviation authorities
Safety agencies
International conventions and organizations

Basic concepts

- **Approaches to air navigation**
  - **Functional**: it comprises the infrastructure and **technical facilities** which enable air navigation and air traffic management:
    - *On-board (embedded) systems.*
    - *Ground support equipment.*
  - **Operational**: it refers to an **organizational model** and **control units** that provide a set of aeronautical services which enable air navigation and air traffic control:
    - *Information services*
    - *ATC: Air Traffic Control Services*
  - **Legal and Institutional Framework:** air navigation requires international regulations and aeronautical authorities that make rules and enforce those rules.
    - *Personnel Licensing*
    - *Flight rules*
    - *Airworthiness requirements, etc...*

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Functional approach

Navigation process

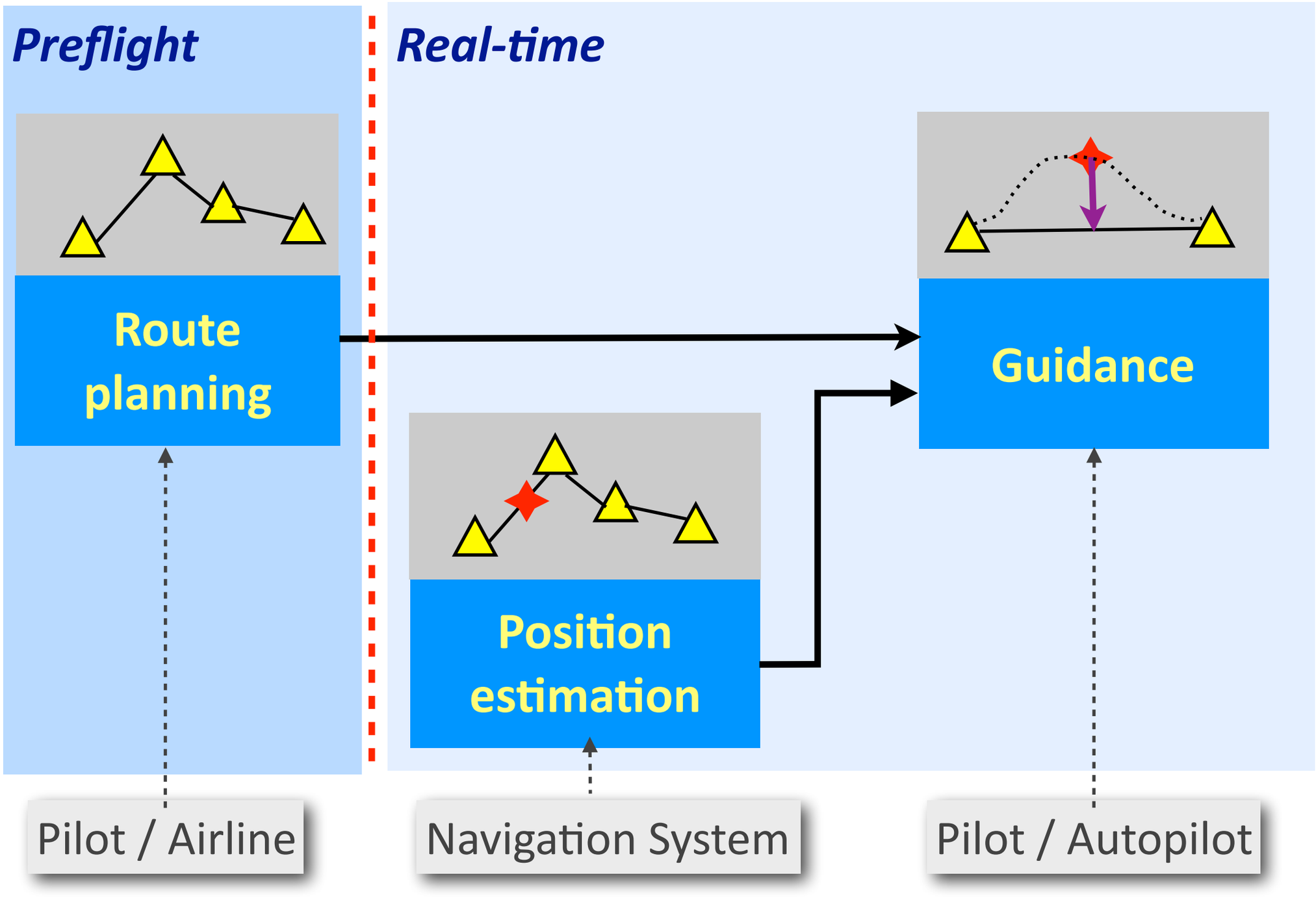
This approach focuses on the navigation process performed **on-board** by the pilot.

Navigation comprises three main processes:

- **Routing**: planning a route to fly from an origin to a destination.
  - *Performed by pilots or airlines in the pre-flight phase.*
  - *It produces a document called **flight plan**.*
- **Positioning**: process to estimate the position or coordinates of a body in some given *coordinate system*.
  - ***Position**: **longitude**, **latitude**, **altitude** in LLA coordinate system. in 4D navigation **time** is also considered as another coordinate.*
  - *It is performed in real-time by on-board equipment.*
- **Guidance**: process to drive a vehicle through a given route in an accurate way.
  - *Performed by a **pilot** or an **autopilot**.*
  - *Performed according to some predefined routes (**airways**) defined in charts, **flight rules** and **flight procedures**.*

Functional approach

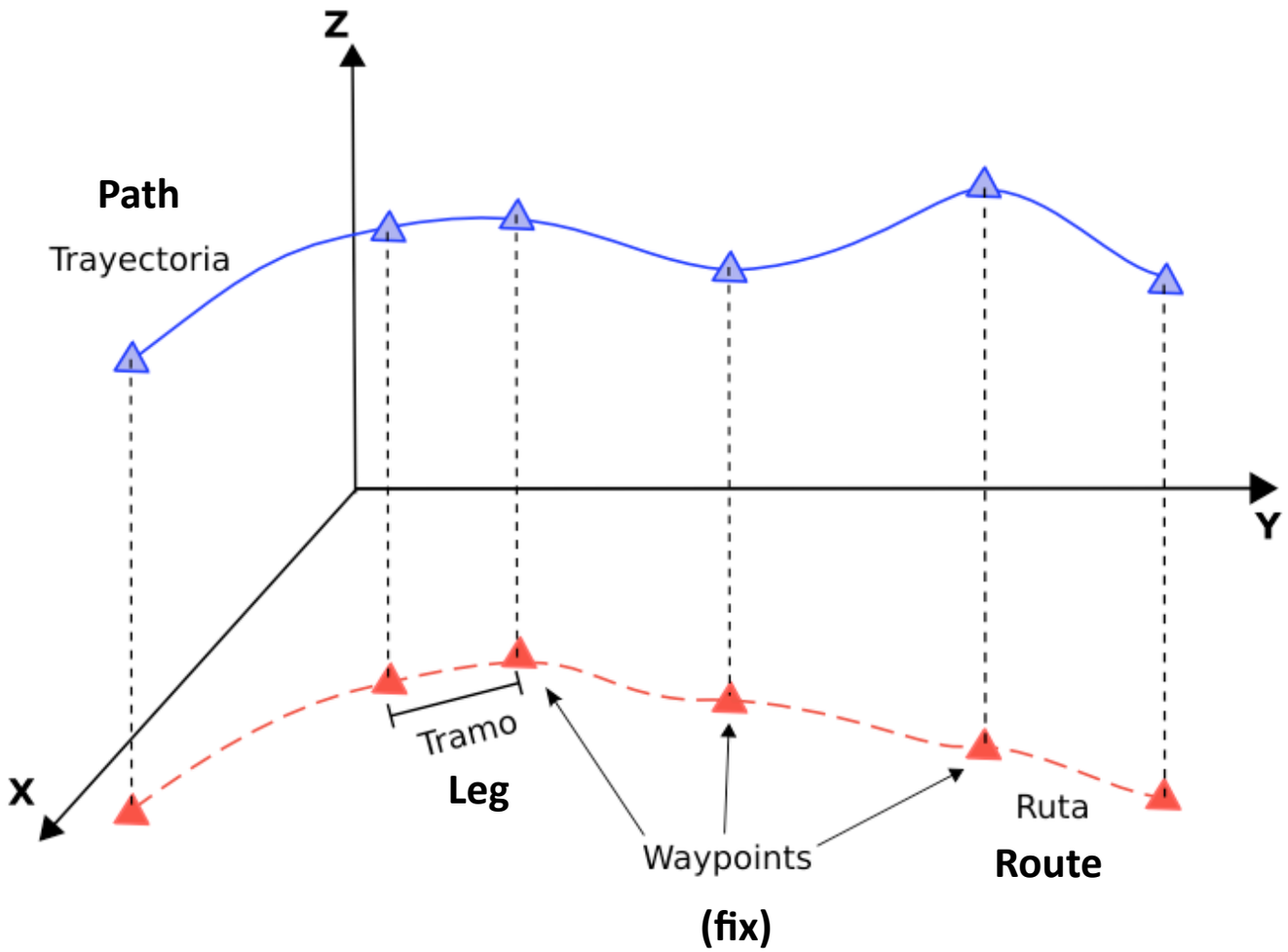
- **Navigation process**



Functional approach

Route definition

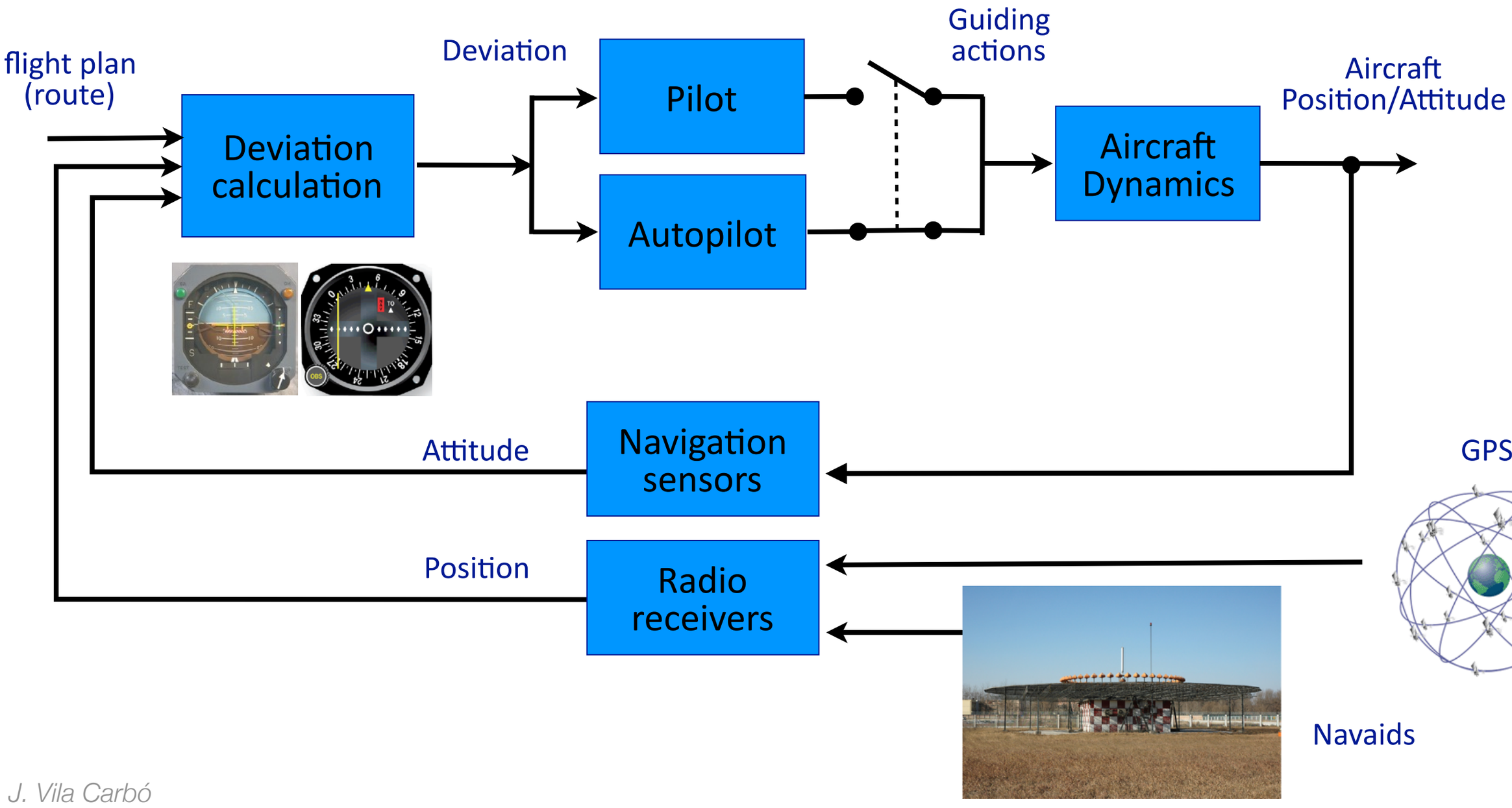
- **Path**: set of points that an aircraft passes through during flight.
- **Route**: projections of a route on the surface of the Earth.
- **Waypoints**: key points that define a route. They are special points with well known coordinates for some reason:
  - *airway intersections, puntos de **Fix**-Compulsory Position Report, etc.*
  - *In aeronautical charts they are also referred as **fixes**.*
- **Leg**: segment between two waypoints.



Functional approach

Guidance process

- It involves the following subsystems:

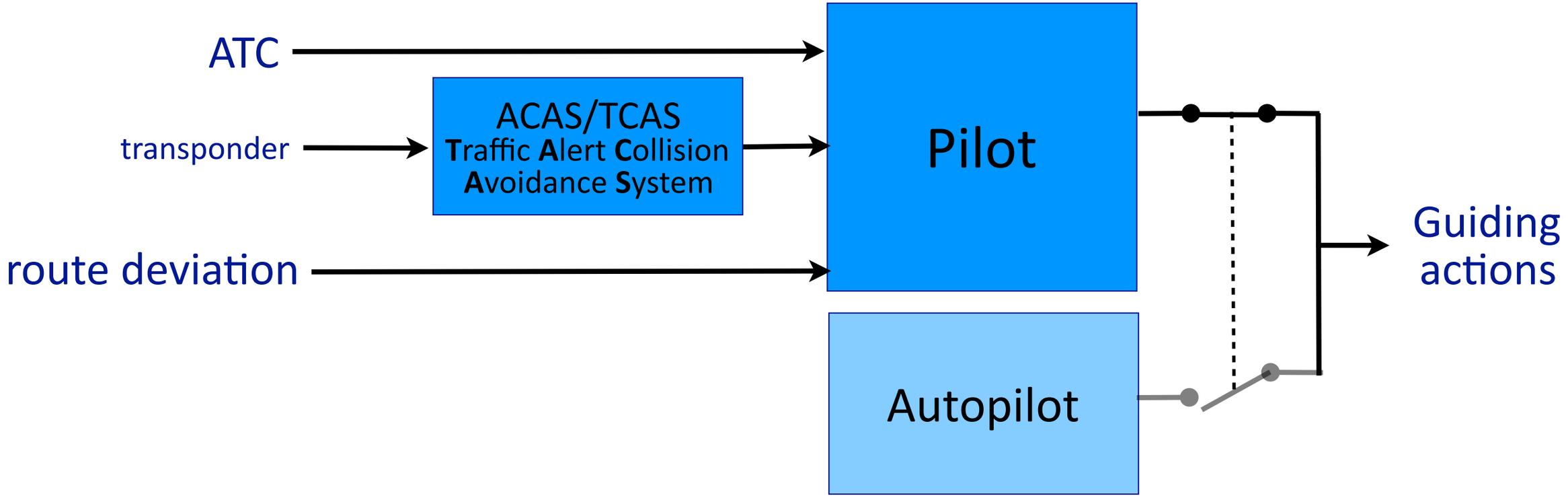


Functional approach

- **Position determination process**
  - There exist several techniques for determining the position according to the different types of navigation:
    - ***Visual navigation****: based on observation of the positions of some well known landforms or navigational stars.*
    - ***Dead reckoning****: (also "ded" for deduced reckoning or DR) process of calculating one's current position by using a previously determined position, or fix, and advancing that position based upon known or estimated* ***speeds*** *over elapsed* ***time****, and* ***course.*** *Constant speed motion formulas are assumed.*
    - ***Beacon navigation systems****: navigation based on measuring distances and/or angles to radio emmiters located in well known points and using trilateration (based on distances to three beacons) or triangulation (based on angles to three beacons).*
      - **Radionavigation**: radio emmiters located on Earth surface.
      - **Satellite navigation**: radio emmiters are satellites.

Functional approach

- **Orderly flow of air traffic**
  - ✦ Aircraft guidance is not only determined by a route definition, but also by the positions of the aircrafts which share the same airspace. To operate the aircraft, the pilot must also obey the **flight rules** and the **ATC** (Air Traffic Control).



Functional approach

- **Orderly flow of air traffic**

  - **Flight Rules:** they define what to do in case of conflicts between aircraft trajectories. See *"Reglamento de Circulación Aérea"* chap. 3. The origins of flight rules are:

    - ***Collision avoidance in visual flight****: this navigation technique is based on the rule of "seeing and being seen" and requires proper meteorological conditions. However, as traffic becomes more dense, there was a need to establish things like the right-of-way.*

    - ***Order of arrivals and departures from aerodromes****: an "aerodrome lookout" was set (by the RO 06/02/1928) to assign the operations order based on some criteria. Precursor of air-traffic controllers.*

  - **ATC - Air Traffic Control**: responsible for orderly flow of air traffic and collision avoidance. The origins of ATC are:

    - ***October 1929****: U.S. established a position reporting service for aircraft flying in "federal routes".*

    - ***April 1935****: first precursor of air traffic control center in the aerodrome of Newark, which provides information to pilots about the proximity of other aircraft in weather conditions with a visibility requiring "instrument flying".*

    - ***May 1958****: modification of the rule "seeing and been seen". The CAB (Civil Aeronautics Board) adopted special regulation 424, establishing "route segments with positive control", in which VFR (visual) flights were banned, allowing only IFR (instrument-based) operations.*

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Operational approach

- **Air traffic services**
  - The operational approach focuses on the **technical** and **operational ground based support** that enables navigation through a set of **air traffic services** before, during, and after flights.
  - Air traffic services rely on an **organization** that provides human resources, technical infrastructure and has a well defined *modus operandi*.
  - It provides:
    - ***Pre-flight information service****: weather information, airfield information, navigation charts.*
      - US: http://www.airnav.com/
      - España: Aena
    - ***Flight information service:*** *tactical support to pilots, changes in the operating state of the environment, collision risks, ...*
    - ***Radio installations*** *to aid navigation of aircraft.*

Operational approach

- **Air navigation infrastructure: CNS/ATM**
  - **CNS/ATM**: Communications, Navigation, Surveillance / Air Traffic Management. It is a compilation of technologies and organizations that provide air traffic services:
    - ***CNS*** *- It includes the infrastructure and support necessary for air navigation.*
      - C- Communication
      - N- Navigation
      - S- Surveillance
    - ***ATM*** *(Air Traffic Management) - It refers to the organization and operational procedures.*

Operational approach

- **CNS-ATM**

Navigation N

Airlines

Airline hubs
Crew

Air traffic services (ATS)

Information service

ATM

Communications C

Communications C
Surveillance S

Navaids

CNS

Operational approach

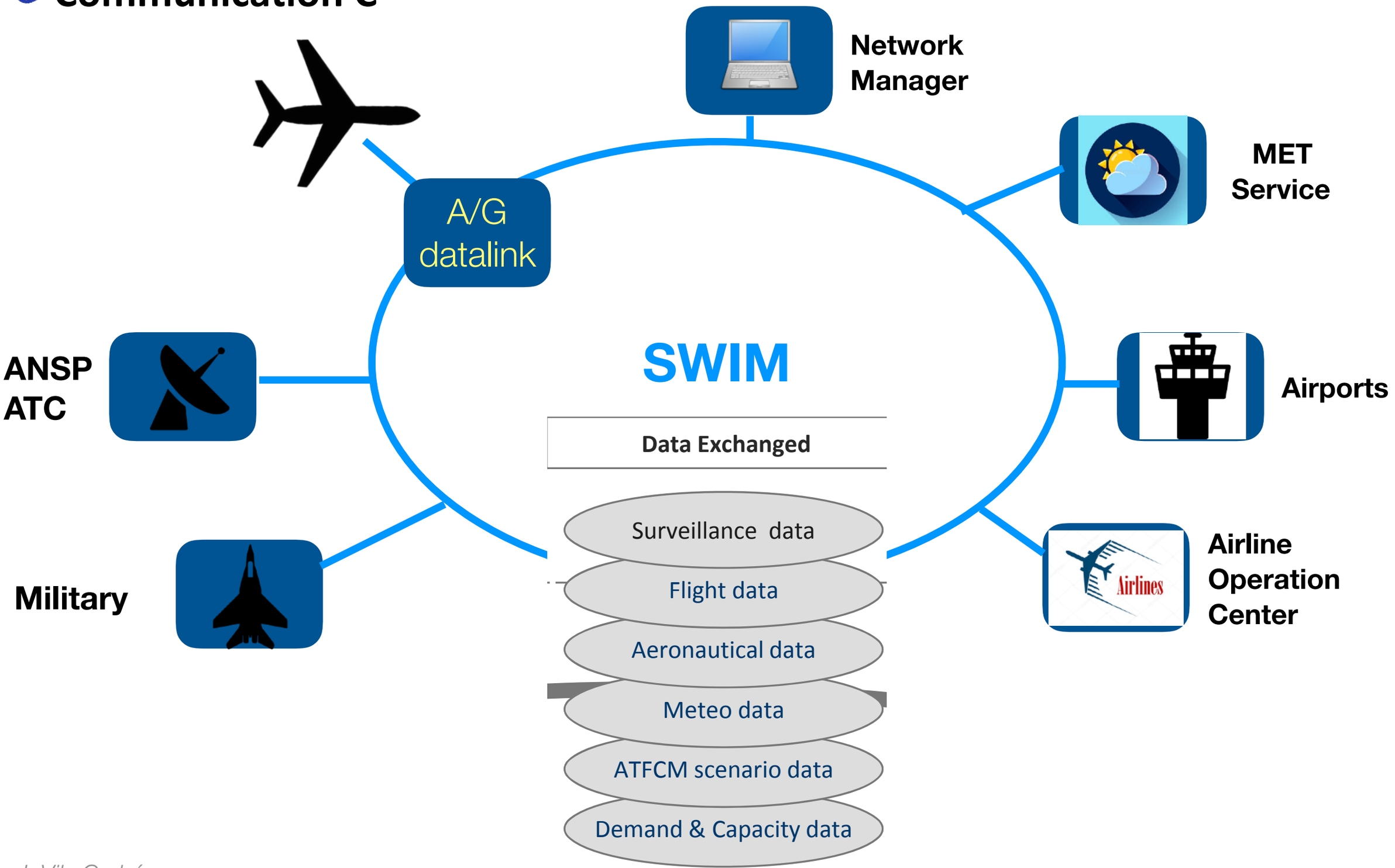
- **CNS system**
  - **✦Communication**
  - **✦ Navigation**
  - **✦ Surveillance**

Operational approach

- **Communication C**
  - ✦ It comprises the radio channels and stations used for:
    - *Broadcasting aeronautical information*
    - *The provision of **Air Traffic Services** (ATS). It is used to give instructions, advice, or report situations that may affect flights.*
  - ✦ The future of communications is the SWIM network.
    - ***SWIM**: System-Wide Information Management*
    - *A network that provides connectivity to all navigation stakeholders in a seamless way replacing old dedicated communication systems: A/G (Air to Ground) links, G/G links, A/A links.*
    - *Voice and analog services wil be replaced by digital services.*
    - *The core principles of SWIM consist of **standards**, **infrastructure** and **governance** enabling the management of ATM information and its exchange between qualified parties via **interoperable services**.*

Operational approach

- **Communication C**



Operational approach

- **Navigation N**
  - ✦ Ground infrastructure required for aircraft positioning and guidance through a given route.
    - *It mainly comprises a set of ground based navaids (radio beacons).*
    - *The aircraft must be equipped with the embedded equipment to use these aids.*
  - ✦ Ground infrastructure support for improving accuracy of satellite based systems (GNSS).

Operational approach

- **Surveillance S**
  - ✦ System that allows air traffic controllers to know the position of all aircraft overflying the airspace of responsibility.
  - ✦ This system can be provided by different types of **radars**:
    - ***PSR*** *and* ***SSR*** *- The* ***primary*** *and* ***secondary*** *surveillance radar. Ground based radars.*
    - ***ADS*** *- Automatic Dependent Surveillance. (under implementation). A technique that allows an aircraft to transmit their data from other aircraft equipment and ground systems. it will allow other aircraft to display the surrounding traffic.*

Operational approach

- **ATM - Air Traffic Management**
  - ✦ It provides the following services
  - ✦ **Air Traffic Services (ATS)**
    - ***Air Traffic Control (ATC):***
      - Orderly flow of traffic and collision avoidance in flight or on ground.
    - ***Flight Information Service (FIS):***
      - Providing useful information for aircraft that completes and updates the pre-flight information acquired by pilots before starting the flight.
    - ***Servicio de Alerta (ALS):***
      - Informing the competent authorities about aircrafts in trouble requiring help or search and rescue services and assisting such authorities.
  - ✦ **Information services** *(most of them now available in the web)*
    - *Aeronautical Information Service (AIS)*
    - *Meteorological services (MET)*
  - ✦ Other services

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Legal and institutional approach

- **Goal**
  - ✦ This framework must deal with the regulations related to:
    - *Training and licensing of aviation personnel*
    - *Communication systems and procedures*
    - *Rules about and aircrafts, flight procedures and traffic control.*
    - *Airworthiness requirements, registration and identification for aircraft in the international arena.*
    - *Aviation weather, navigation maps and charts.*
    - *Design requirements to be met by electronic navigation systems.*
    - *etc.*