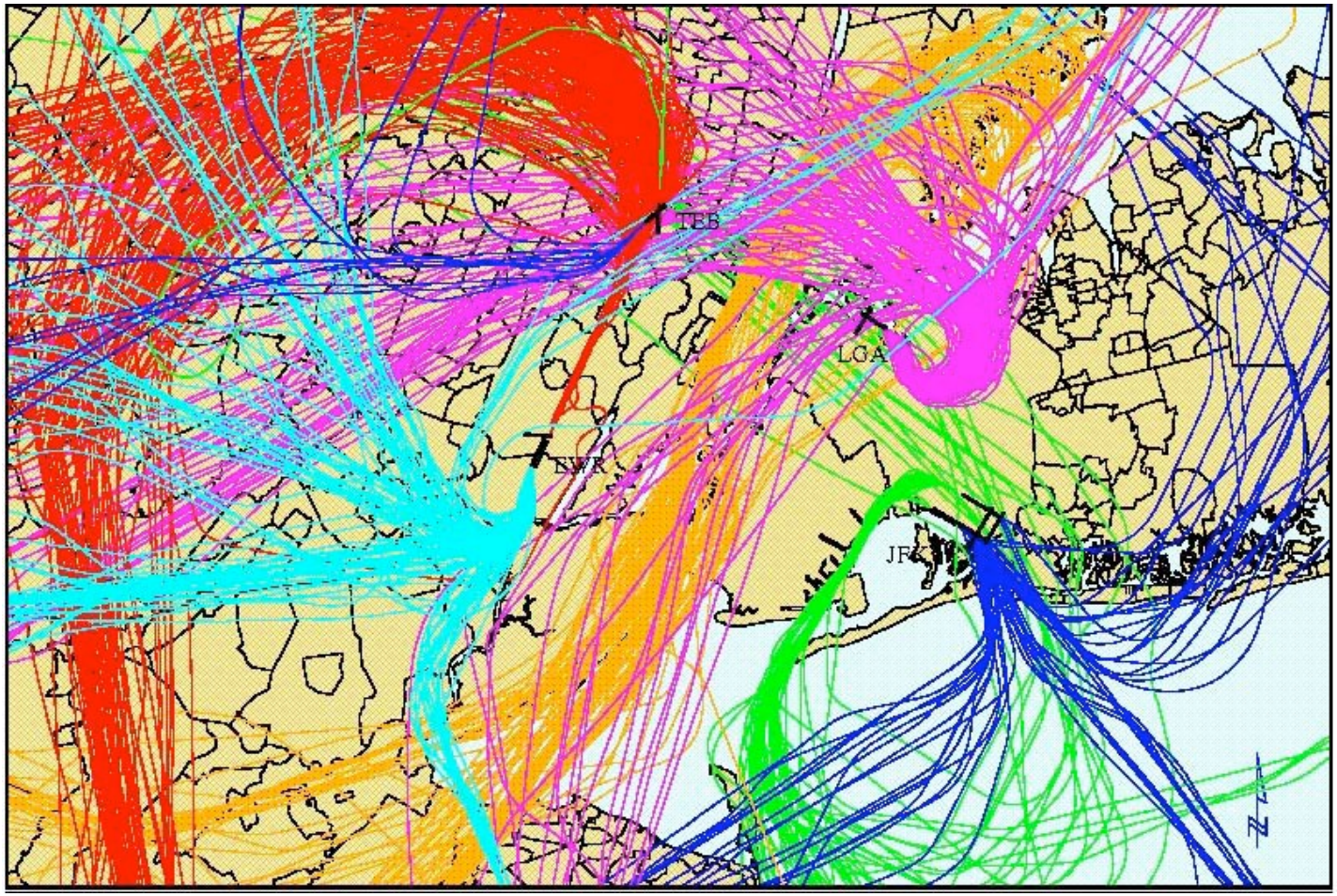
THE HONG KONG POLYTECHNIC UNIVERSITY
香港理工大學

AAE2001 – Introduction to Aircraft Design and Aviation Systems

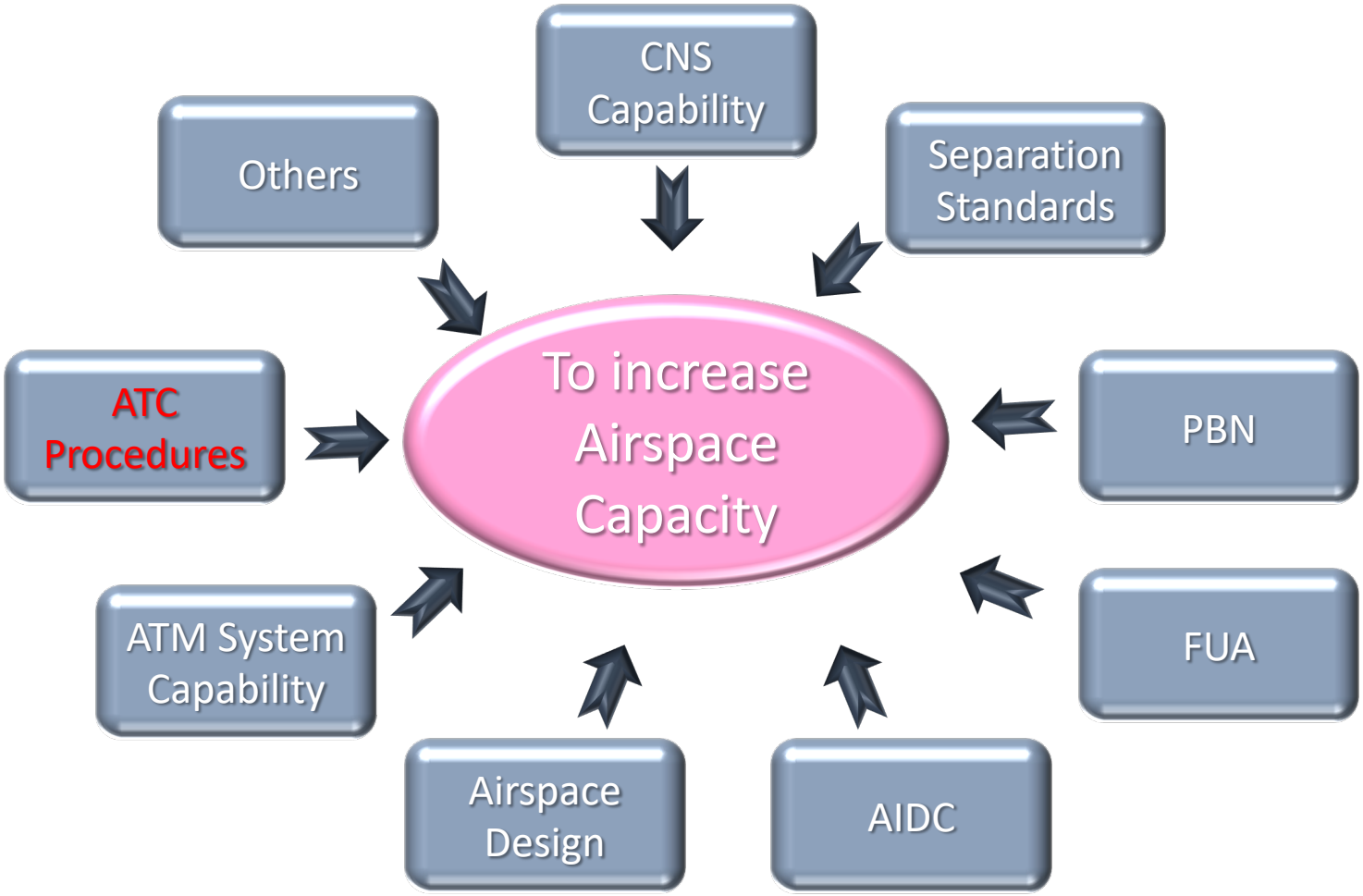
Air Traffic Control

Dr. Yiping Jiang

New York Arrival and Departure Tracks



Airspace Capacity



Air Traffic Control

- Air traffic control (ATC) is a service provided by ground based controllers who **direct the aircraft** on the ground and through *controlled air space* and can **provide advisory services** to aircraft in *non-controlled air space*.
- Air traffic control is used to separate aircraft safely – *in the sky* as they fly and *at the airports* where they land and take off again.

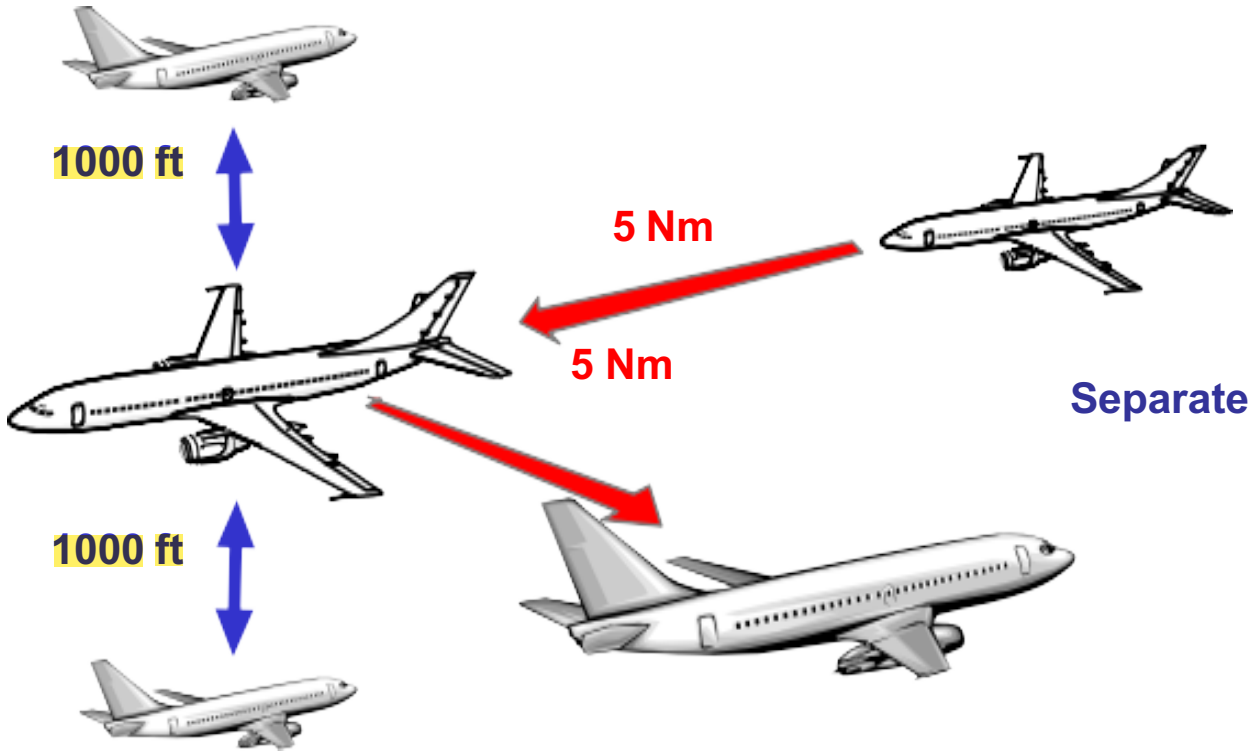
To prevent collisions ATC enforces *Traffic Separation Rules*, which ensure each aircraft maintains a minimum amount of empty space around it all times.

Separation Minimum

Be able to :

Detect an aircraft

How to make sure many aircrafts can fly at the same time in the airspace?

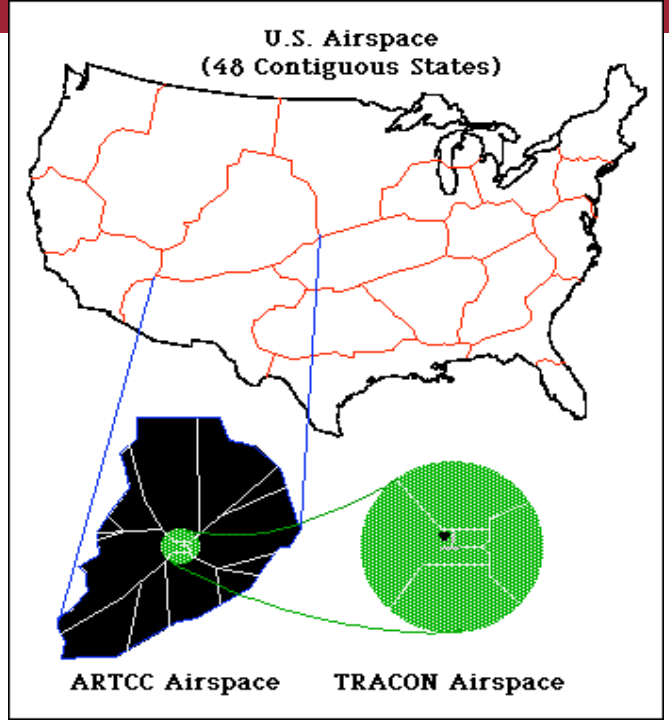


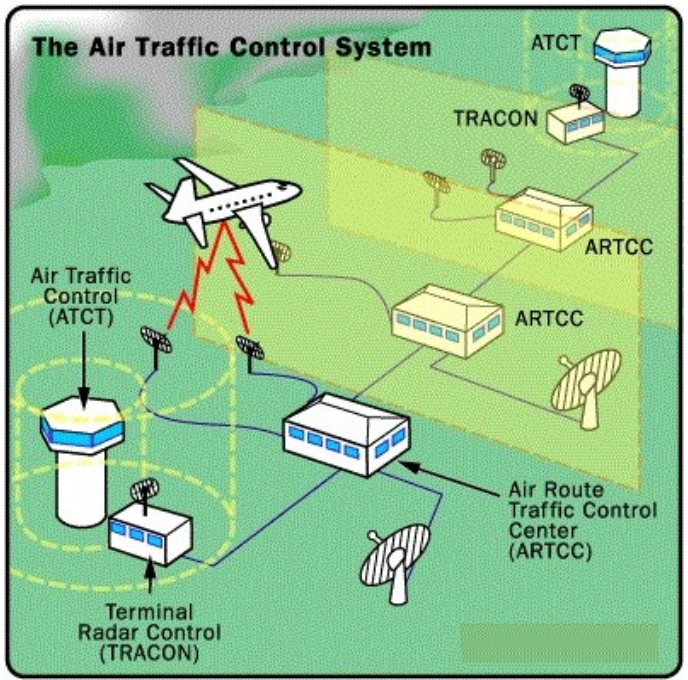
Separate the aircraft

Getting the parameters of the aircraft

Current Control Structure

- **Ground Control / Surface Control**
- **Local Control**
  - ❑ “Tower”
- **Terminal Area Control**
  - ❑ “Approach and “Departure”
  - ❑ Terminal Radar Appraoch Control Facilities (TRACON)
- **Enroute Control**
  - ❑ “Center”
  - ❑ Air Route Traffic Control Center (ARTCC)
- **Oceanic Control**
  - ❑ “Oceanic”
  - ❑ Flight Information Region (FIR)
- **Flow Control**
  - ❑ “Central Flow”
  - ❑ Air Traffic Control System Command Center (ATCSCC)





Duties of Air Traffic Controller

- Air traffic controllers give instructions, advice and information to pilots so that they can fly safely, efficiently and quickly. Controllers **keep track of flights** by using **radar** and the latest computer systems.
- Air traffic controllers need to be able to deal with *unexpected events* – **changes in weather**, unscheduled traffic, emergency situations.
- Air traffic controllers can work at airports – *in the airport tower* overlooking the runways or on approach as they stream aircraft to arrive – or at *en-route centres*.

Cross Winds affecting Take off and landing

https://www.youtube.com/watch?v=w4EQuM_t8Fo&ab_channel=Cargospotter

What can Air Traffic Controller do under such situations?

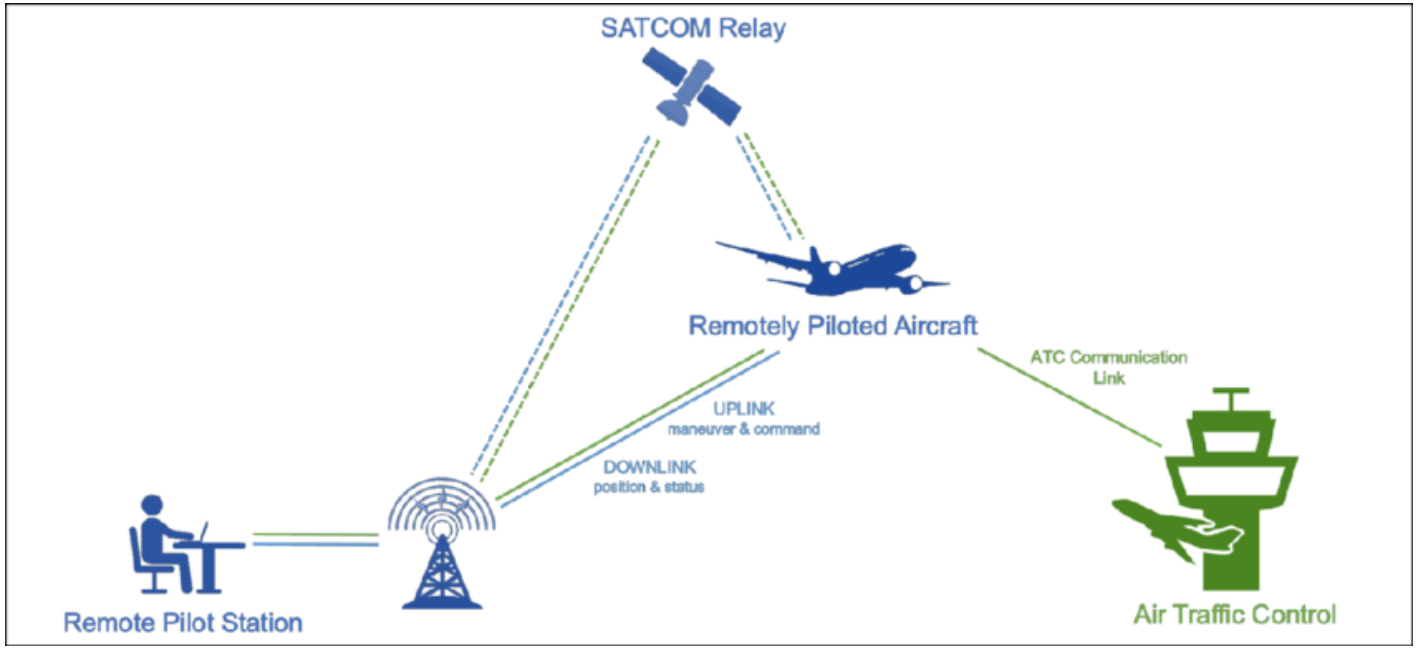
How to Track Flights?

- By a measurement

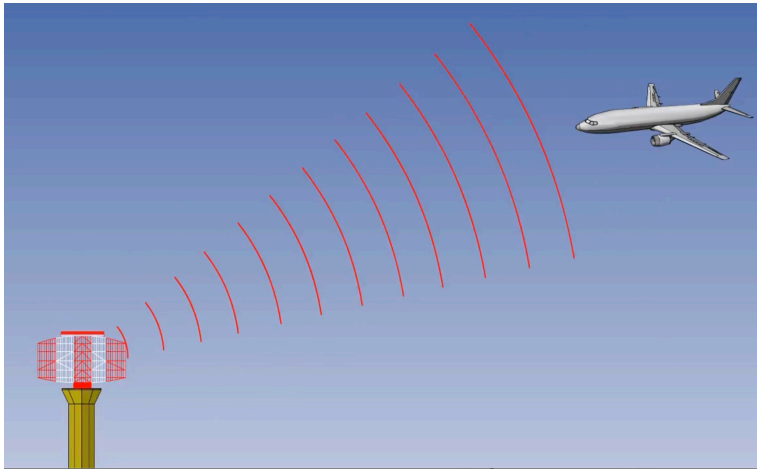
A ground equipment detects and localizes all the targets of interest for ATC

- By data communication

The aircraft are able to determine their position and transmit it using some data link



RADAR



- Radio Detection and Ranging: developed in 1930s as a military system to detect the location of hostile aircraft
- It refers to electronic equipment that **detects the presence of objects by using reflected electromagnetic energy**; measure the direction, height, distance, course, and speed of these objects.
- Two types of Radar

Primary Radar: same frequency emitted and reflected

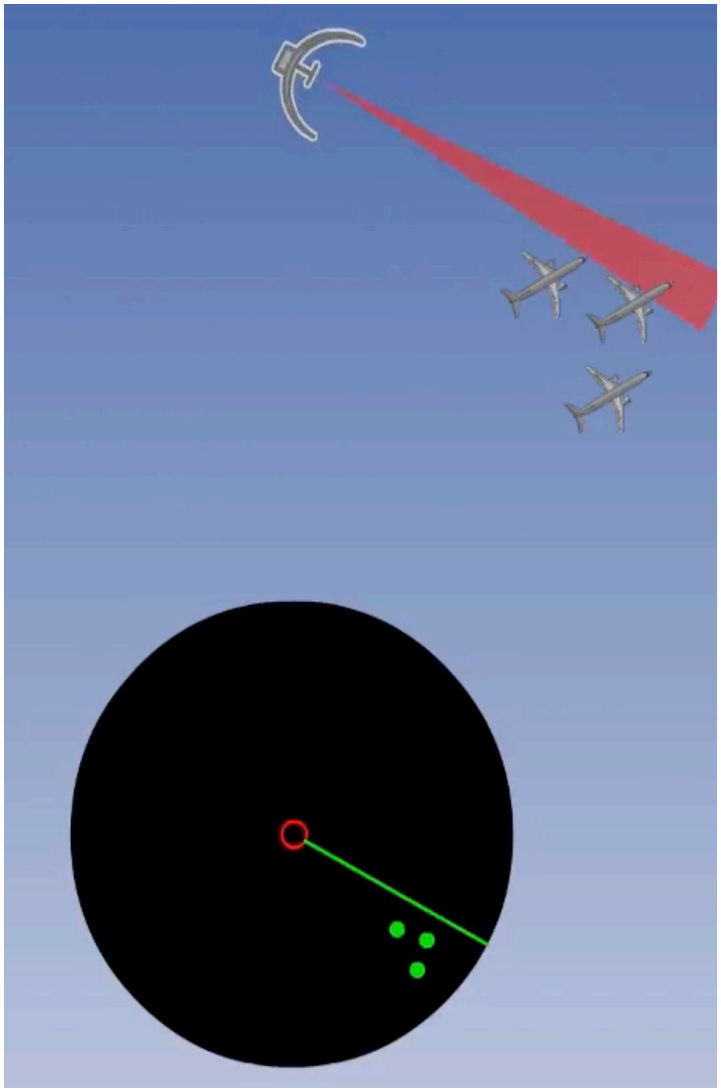
Secondary Radar: transmits interrogation on one frequency, and objective transponder responds on a different frequency

Echo Principles

- For determination of range:
- The electromagnetic waves are **reflected** if they meet an electrically leading surface. If these reflected waves are **received again** at the place of their origin, then that means an obstacle is in the propagation direction.
- The radio-frequency energy is transmitted to and reflected from the reflecting object. The returned energy is called an **ECHO**. Slant range is computed by the round trip time dividing by two and the speed of light.

Search Principles

- For determination of bearing by the antenna direction
- The antennas of most radar systems are designed to radiate energy in a one-directional lobe or beam that can be moved in bearing simply by moving the antenna.
- The shape of the beam is such that the echo signal strength varies in amplitude as the antenna beam moves across the target. The point of maximum echo, determined by the detection circuitry or visually by the operator, is when the beam points direct at the target.



Inside Amsterdam Aiport ATC

- Why are there six runways of different directions?
- Different roles of controllers at the control tower?
- After the control tower, where did Sam go?

https://www.youtube.com/watch?v=MjogCXKBx7Y

Airport Traffic Control Tower

- The primary method of controlling the immediate airport environment is *visual observation* from the airport control tower. The tower is a tall, windowed structure located on the airport grounds.
- Air traffic controllers are responsible for the *separation and efficient movement of aircraft and vehicles operating on the taxiways and runways of the airport itself*, and *aircraft in the air near the airport*, generally 5 to 10 nautical miles (9 to 18 km) depending on the airport procedures.

Run Way

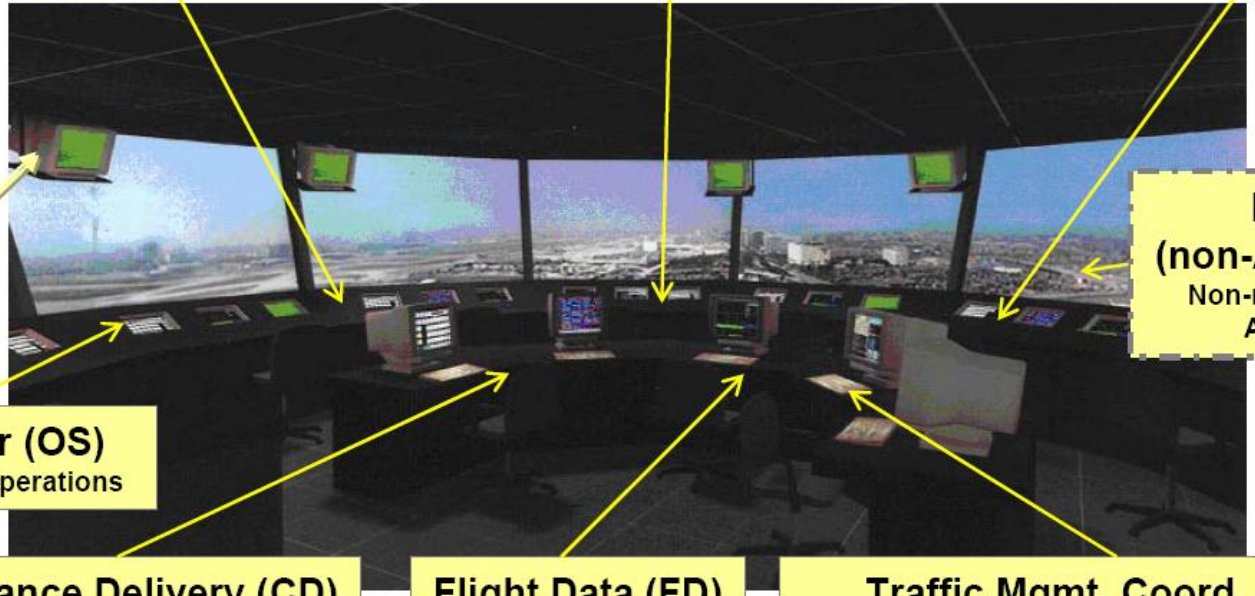
Taxi Way

Airport Traffic Control Tower

- *Surveillance displays* are also available to controllers at larger airports to assist with controlling air traffic.
- Controllers may use a **SSR radar system** for airborne traffic approaching and departing. These displays include a map of the area, the position of various aircraft, and data tags that include aircraft identification, speed, altitude, and other information described in local procedures.

In adverse weather conditions the tower controllers may also use **surface movement radar (SMR)**, surface movement guidance and control systems (SMGCS) or advanced SMGCS to control traffic on the maneuvering area (taxiways and runway).

Airport Traffic Control Tower (ATCT)
Positions and Equipment



Gate Hold (GH)
Gate management
in delay situations

Ground Control (GC)
Movement area- except active rwy.
Queue management

Local Control (LC)
Active runway
Airport airspace (Class D)

D-BRITE

Ramp Tower
(non-ATC in Gate area)
Non-movement area ramps
Aircraft push-back

Supervisor (OS)
Overall Tower operations

Clearance Delivery (CD)
Issues clearances

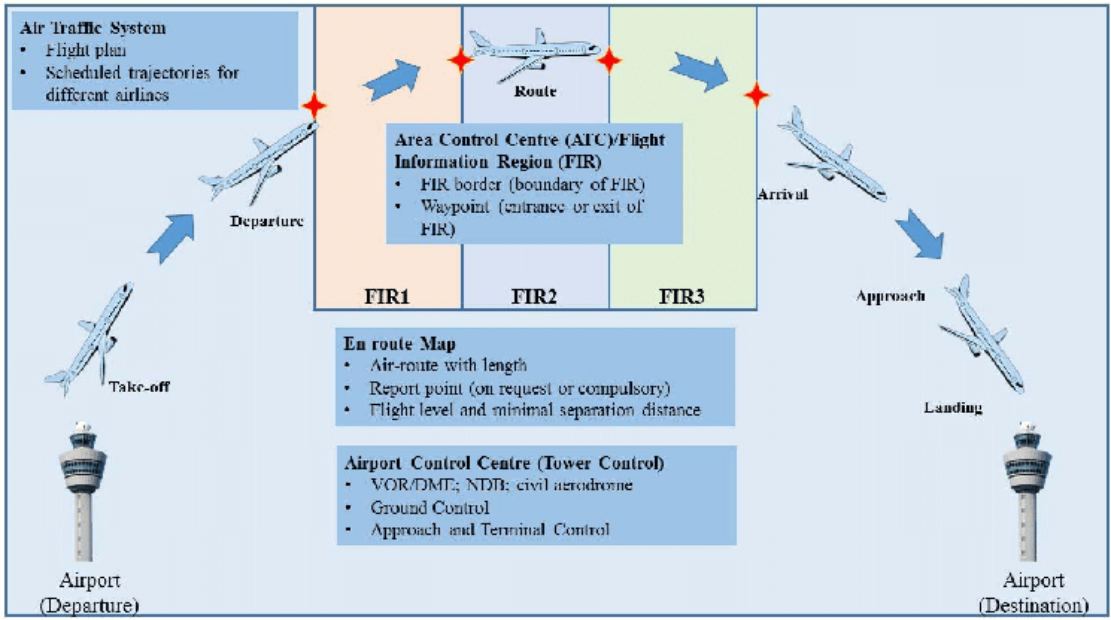
Flight Data (FD)
Prepares flight data
Prepares ATIS

Traffic Mgmt. Coord. (TMC)
Airport traffic management
Coordination with TRACON and Center TMUs

Airport Traffic Control Tower

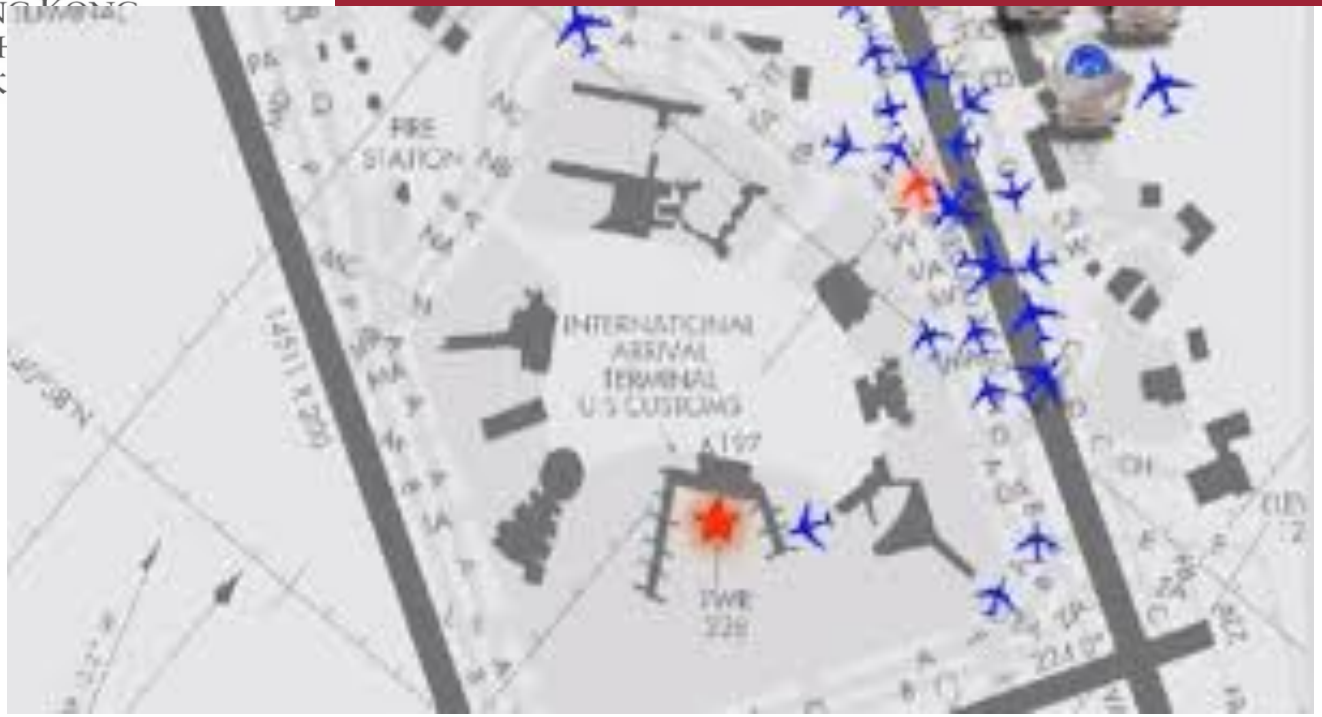
- The areas of responsibility for tower controllers fall into three general operational disciplines:
  - **ground control**
  - **local control**
  - **flight data / clearance delivery**
  - other categories, such as Apron control or ground movement planner, may exist at extremely busy airports.

Which parts belongs to the control of the airport traffic control tower?



Ground Control

- Ground control (sometimes known as ground movement control) is responsible for the airport "movement" areas. This generally includes all *taxiways*, *inactive runways*, *holding areas*, and some transitional aprons or intersections where aircraft arrive, having vacated the runway or departure gate.
- Any aircraft, vehicle, or person walking or working in these areas is required to have clearance from ground control. This is normally done via VHF/UHF radio.
- Ground control is vital to the smooth operation of the airport, because this position impacts the sequencing of departure aircraft, affecting the safety and efficiency of the airport's operation.


INTERNATIONAL ARRIVAL TERMINAL
U.S. CUSTOMS


Taxi way Markings - Yellow
Holding Position
Holding Position Sign
26
Centre Line
Taxiway
ROYAL AIR FORCE
air cadets
the next generation

Local Control

- Local control (tower control or air control) is responsible for the *active runway surfaces*.
- Local control clears aircraft for takeoff or landing, ensuring that prescribed *runway separation* will exist at all times.
- If the air controller detects any unsafe conditions, a landing aircraft may be instructed to "go-around" and be re-sequenced into the landing pattern.
- Local control must ensure that ground control is aware of any operations that will impact the taxiways, and work with the approach radar controllers to create "gaps" in the arrival traffic to allow taxiing traffic to cross runways and to allow departing aircraft to take off.
- Ground control need to keep the air controllers aware of the traffic flow towards their runways in order to maximise runway utilisation through effective approach spacing.

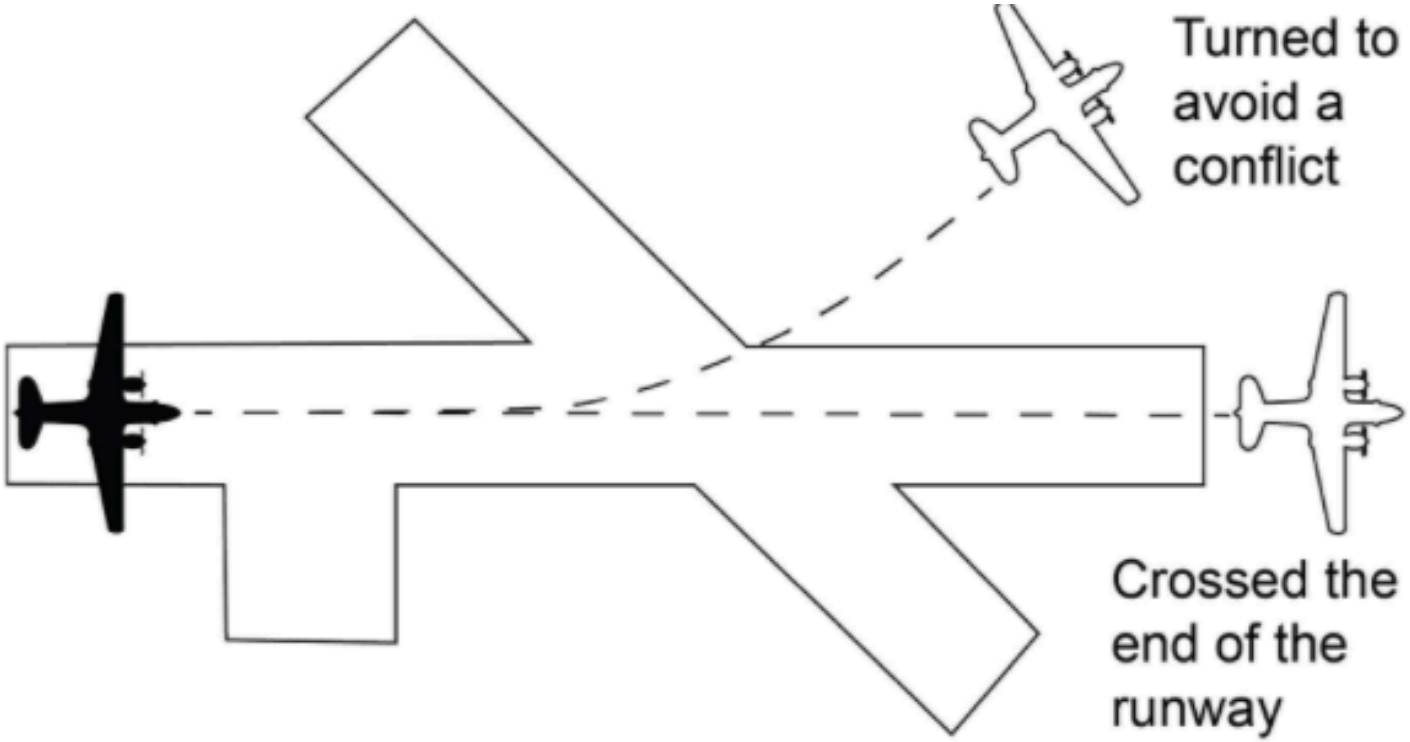
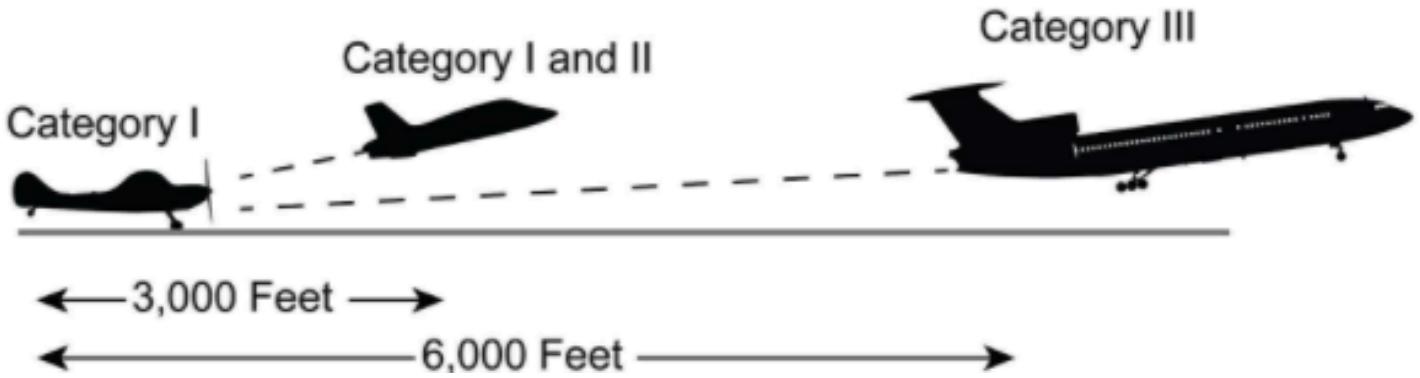


Figure 4-1. Departing aircraft separation



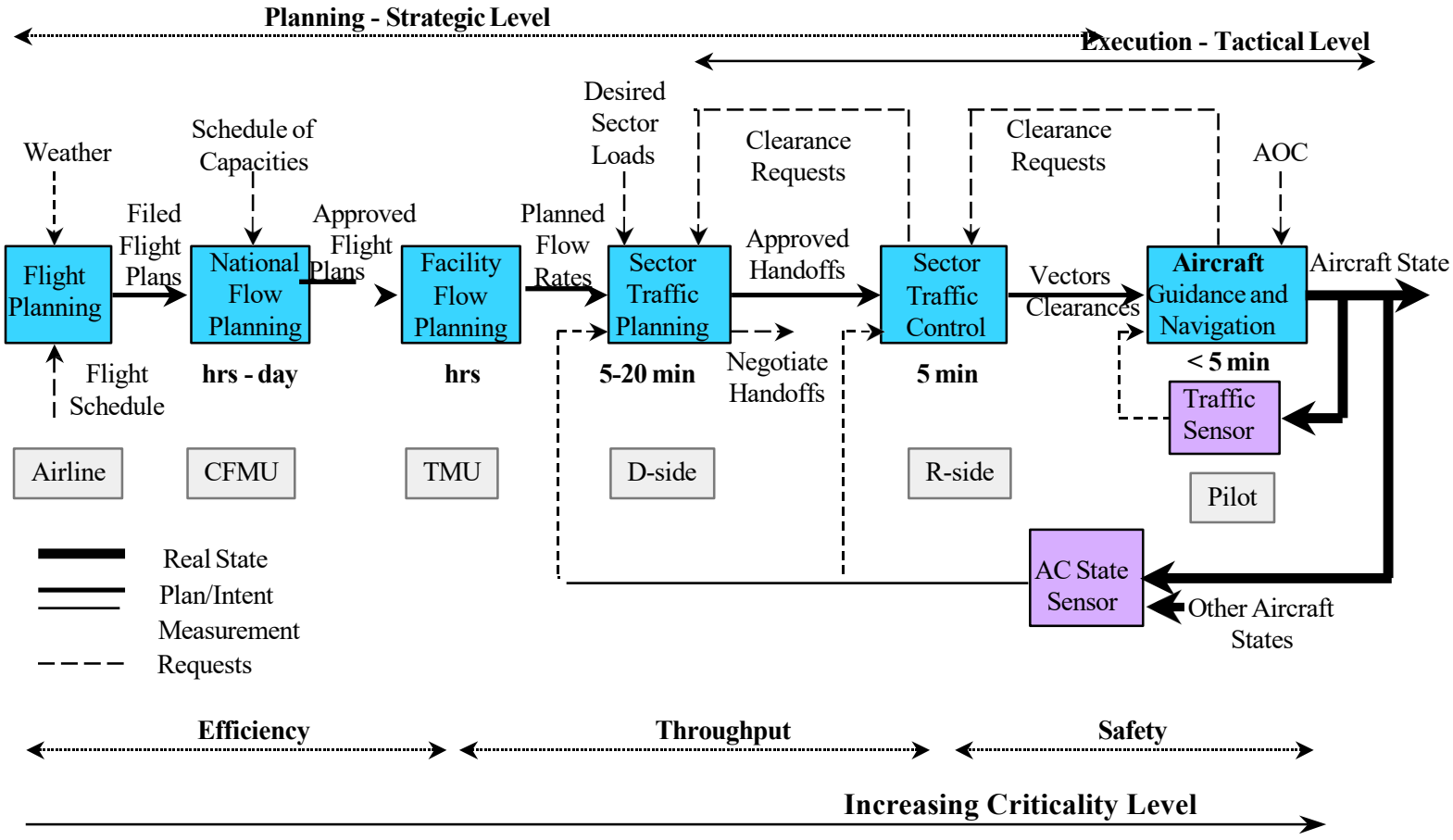
Flight Data and Clearance Delivery

- Clearance delivery is the position that issues *route clearances* to aircraft, typically *before they commence taxiing*. These clearances contain details of the route that the aircraft is expected to fly after departure.
- Clearance delivery (or, at busy airports, Ground Movement Planner (GMP) or Traffic Management Coordinator (TMC)) will coordinate with the relevant radar center or flow control unit to obtain releases for aircraft.
- At busy airports, these releases are often automatic and are controlled by local agreements allowing "free-flow" departures.

Flight Data and Clearance Delivery

- The primary responsibility of clearance delivery is to ensure that the aircraft have the correct aerodrome information, such as *weather and airport conditions*, the *correct route after departure and time restrictions relating to that flight*.
- This information is also coordinated with the relevant radar center or flow control unit and ground control in order to ensure that the *aircraft reaches the runway in time* to meet the time restriction provided by the relevant unit.

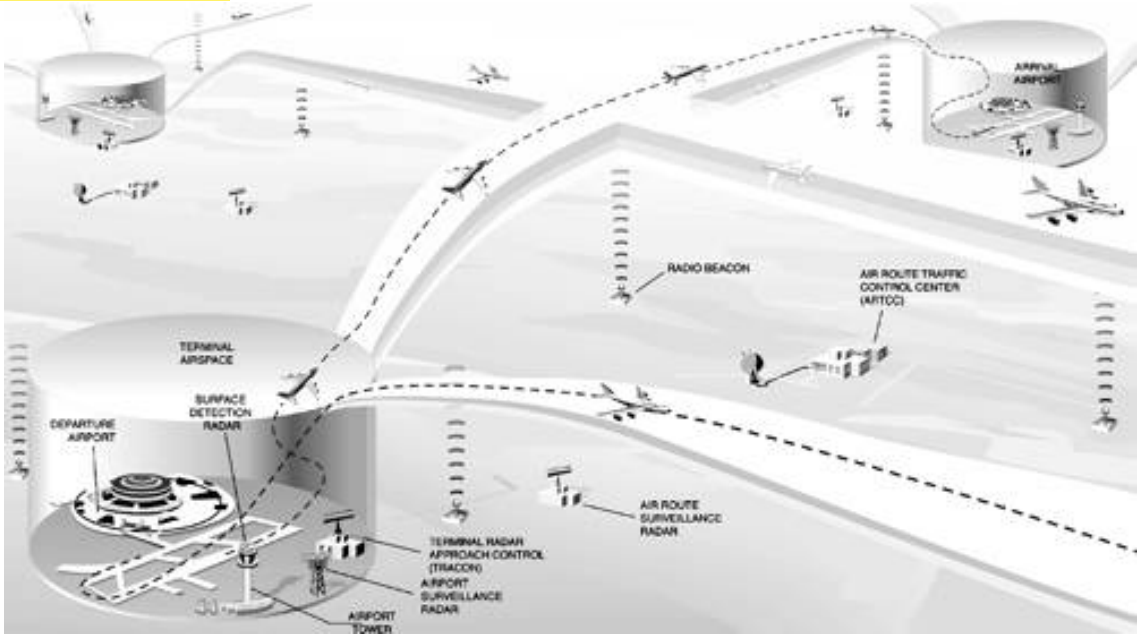
How is the clearance issued?



Source: A. Haraldsdottir Boeing

Approach and Terminal Control

- Many airports have a radar control facility that is associated with the airport. In most countries, this is referred to as *terminal control*
- While every airport varies, terminal controllers usually handle traffic in a *30-to-50-nautical-mile (56 to 93 km) radius* from the airport. Terminal controllers are responsible for providing all ATC services within their airspace. Traffic flow is broadly divided into *departures, arrivals, and overflights*.



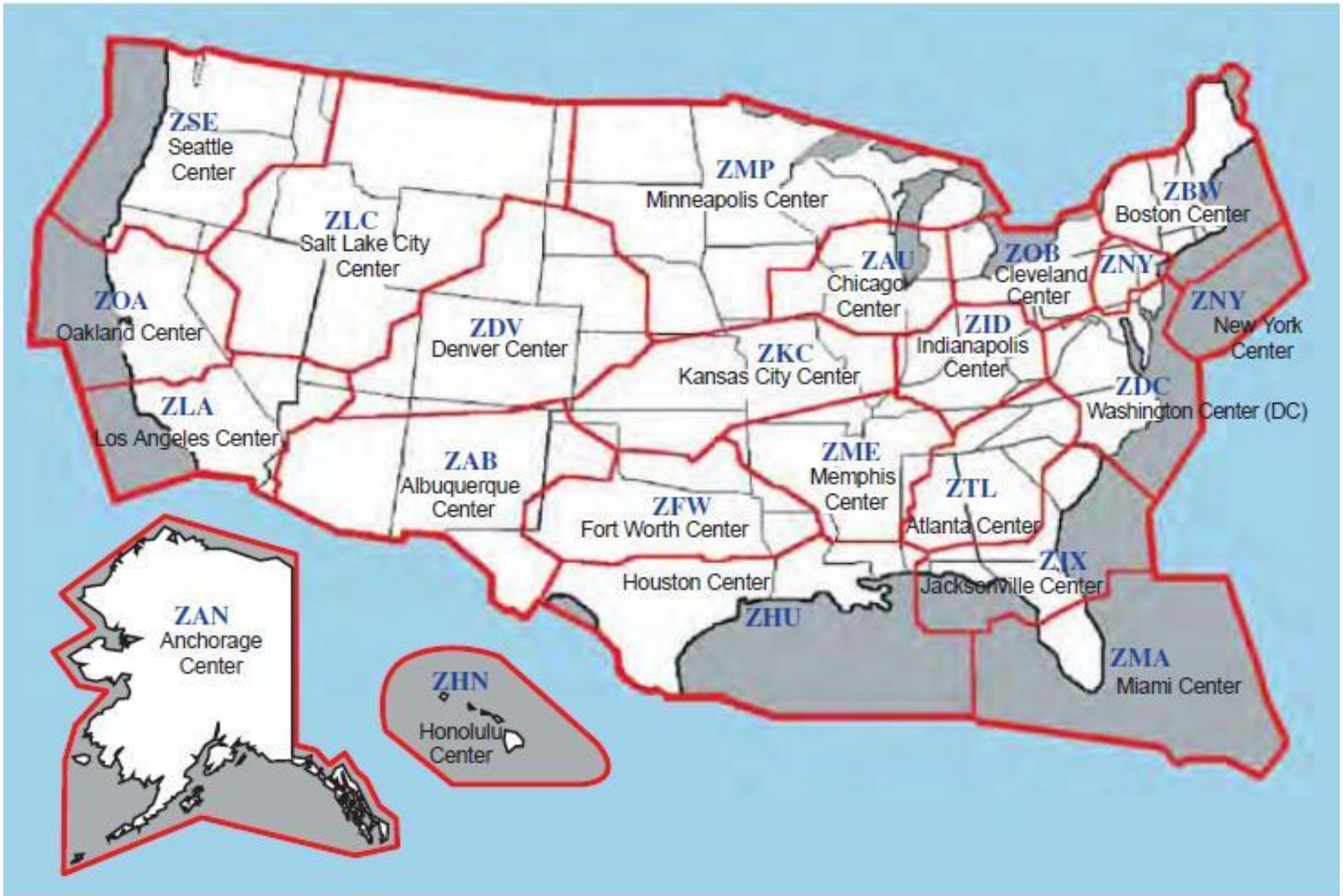
Approach and Terminal Control

- Terminal control is responsible for ensuring that aircraft are at *an appropriate altitude* when they are handed off, and that aircraft *arrive at a suitable rate for landing*.
- As aircraft move in and out of the terminal airspace, they are handed off to the next appropriate control facility (a control tower, an en-route control facility, or a bordering terminal or approach control).
- Not all airports have a radar approach or terminal control available. In this case, the en-route center or a neighboring terminal or approach control may co-ordinate directly with the tower on the airport and vector inbound aircraft to a position from where they can land visually.

En route, centre or area Control

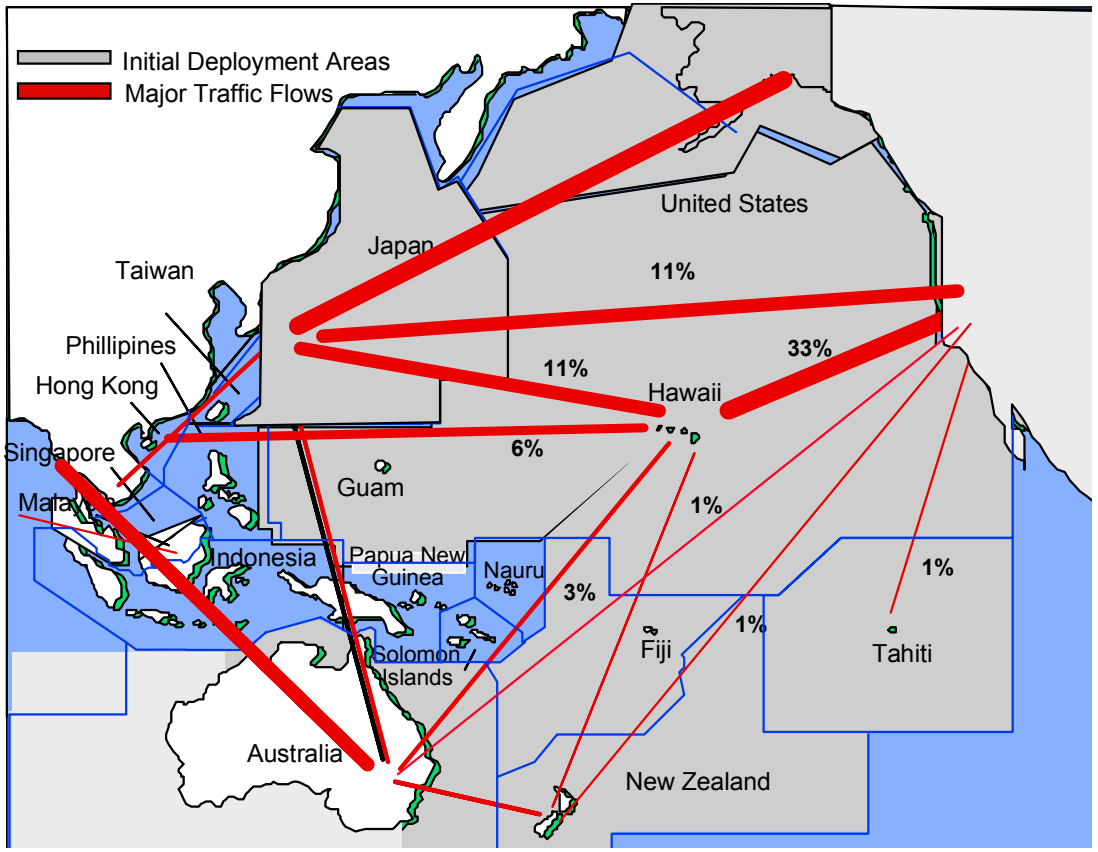
- ATC provides services to aircraft in flight between airports as well.
- Pilots fly under one of two sets of rules for separation: *visual flight rules (VFR)* or *instrument flight rules (IFR)*.
- Air traffic controllers have different responsibilities to aircraft operating under the different sets of rules. In the US and Canada VFR pilots can request traffic advisory services and may also provide assistance in avoiding areas of weather and flight restrictions.
- En-route air traffic controllers *issue clearances and instructions* for airborne aircraft, and pilots are required to comply with these instructions.

ARTCC in US


ZSE
Seattle Center
ZLC
Salt Lake City Center
ZMP
Minneapolis Center
ZBW
Boston Center
ZOA
Oakland Center
ZDV
Denver Center
ZAU
Chicago Center
ZOB
Cleveland Center
ZNY
ZNY
New York Center
ZKC
Kansas City Center
ZID
Indianapolis Center
ZDC
Washington Center (DC)
ZLA
Los Angeles Center
ZAB
Albuquerque Center
ZME
Memphis Center
ZTL
Atlanta Center
ZFW
Fort Worth Center
ZJX
Jacksonville Center
Houston Center
ZHU
ZMA
Miami Center
ZAN
Anchorage Center
ZHN
Honolulu Center

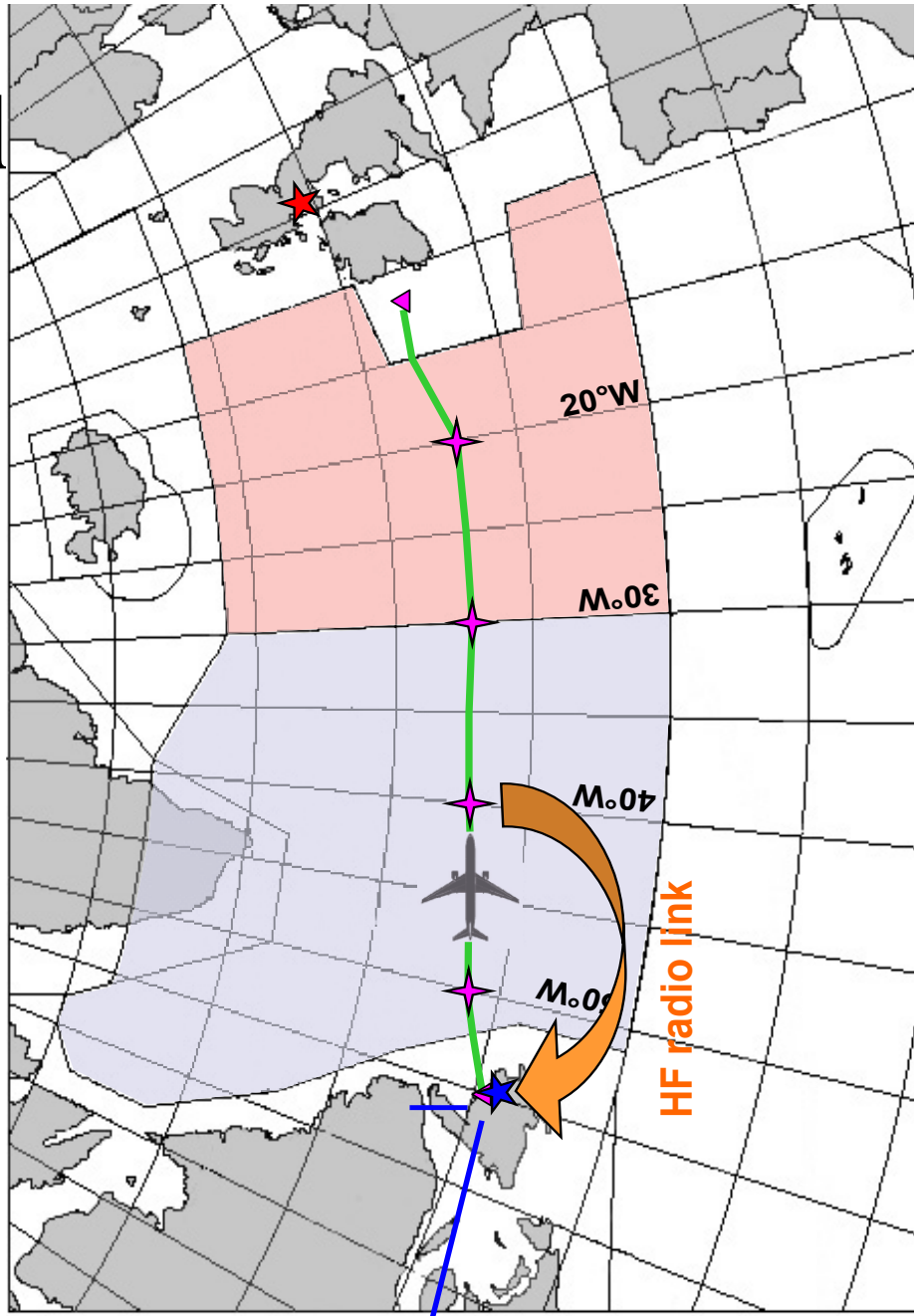
Oceanic Attributes

- International, ICAO oversight
- Low CNS Performance
- Generally low density
- Limited Diversion Opportunities
- Limited Weather Observations



Oceanic Area Control

- Because substantial volumes of oceanic airspace lie beyond the range of ground-based radars, oceanic airspace controllers have to estimate the position of an airplane from pilot reports and computer models, rather than observing the position directly (radar control).
- Pilots flying over an ocean can determine their own positions accurately using the GPS and can supply periodic updates to a center.
- Position report to Oceanic Area Control Centre every 10 degree via a HF Radio



Flow Control

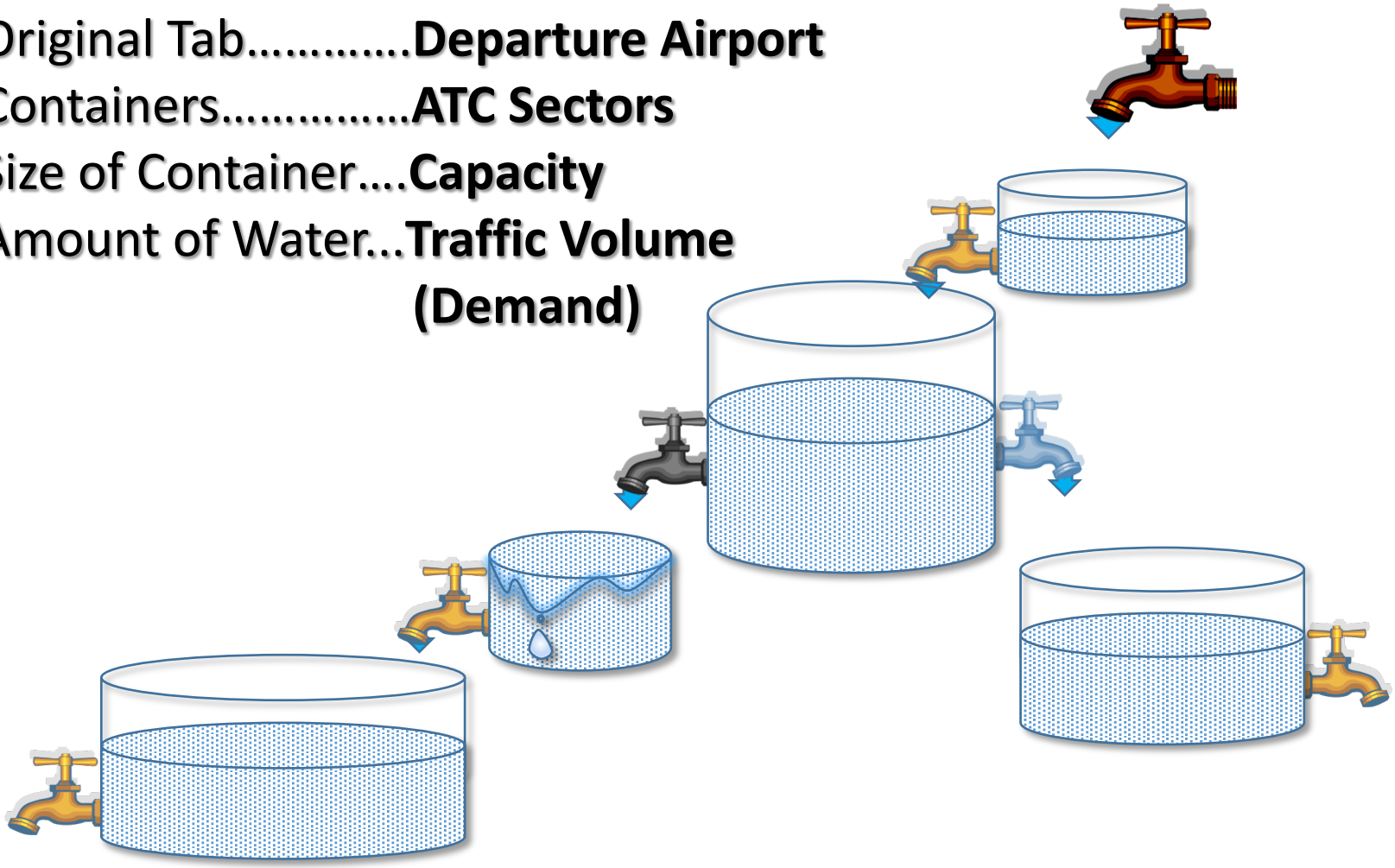
- Air traffic flow management (ATFM) is the regulation of air traffic *in order to avoid exceeding airport or air traffic control capacity* in handling traffic, and to ensure that available capacity is used efficiently
- *Airport Capacity*: Because only one aircraft can land or depart from a runway at a given time, and because aircraft must be separated by a certain distance or time to avoid collisions, every airport has a finite capacity; it can safely handle only so many aircraft per hour.
- This capacity depends on many factors, such as the number of *runways* available, *layout of taxi tracks*, *availability of air traffic control*, and current or anticipated *weather*.
- The weather can cause large variations in capacity; *strong winds* may limit the number of runways available, and *poor visibility* may necessitate increases in separation between aircraft.

ATFM

ATFM can optimize airspace capacity

However, ATFM is *NOT* a magic word to increase airspace capacity

Original Tab……**Departure Airport**
Containers……**ATC Sectors**
Size of Container….**Capacity**
Amount of Water…**Traffic Volume (Demand)**

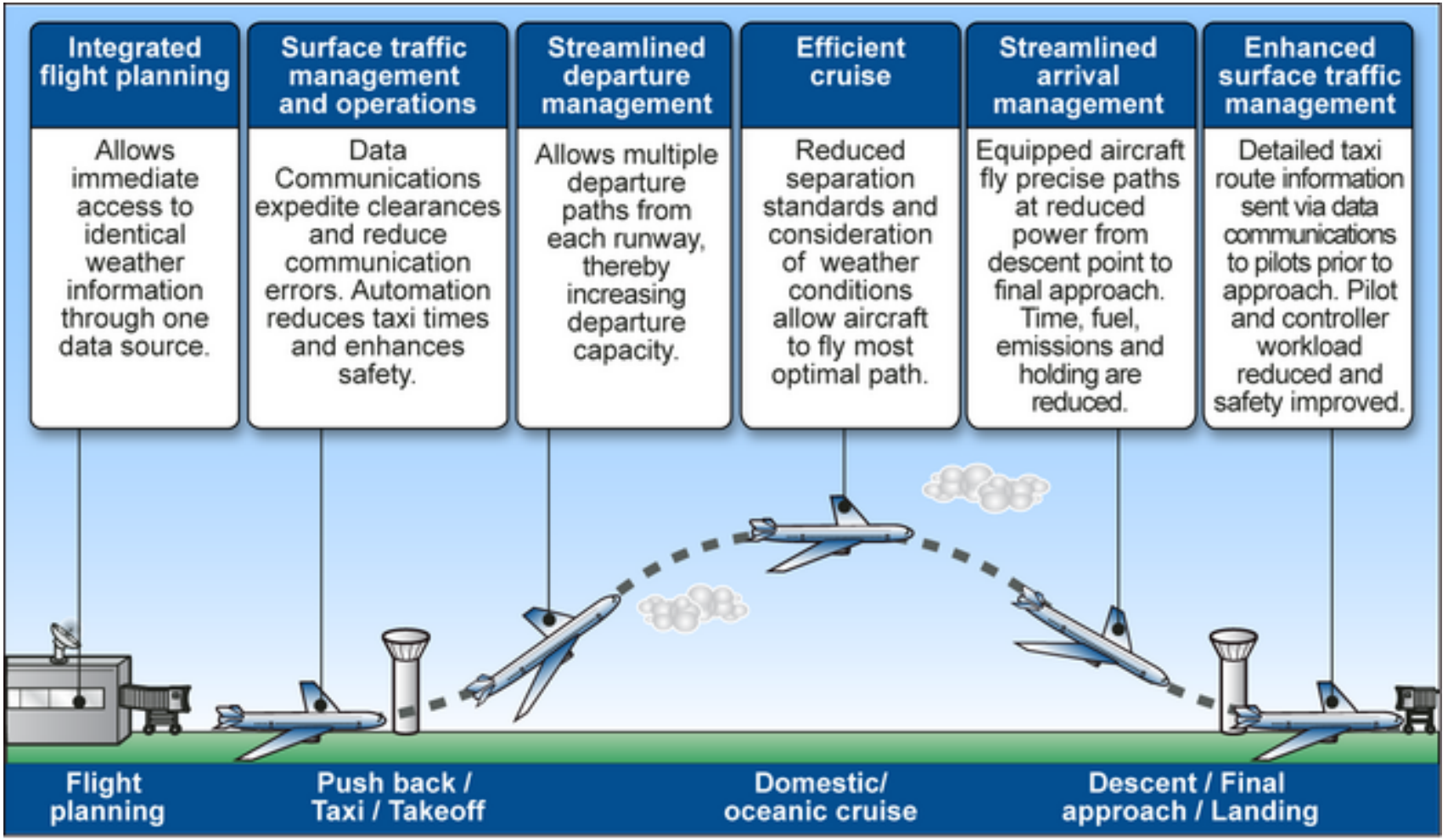


https://www.youtube.com/watch?v=C1f2GwWLB3k

How does ATC work in Europe?

- Identify the ground control, local control, terminal control and area control in the video
- How is the plane passed among different control centers?
- What is the role of Eurocontrol?
- What does British Airway send to the network management center in Eurocontrol?
- Ground control's responsibility stops until the aircraft reaches __?
- After tower control (local control), the plane passed to___, and then _____ within UK airspace?

New Generation ATC



Source: GAO analysis of FAA information. | GAO-17-450

New Generation ATC: ADS-B

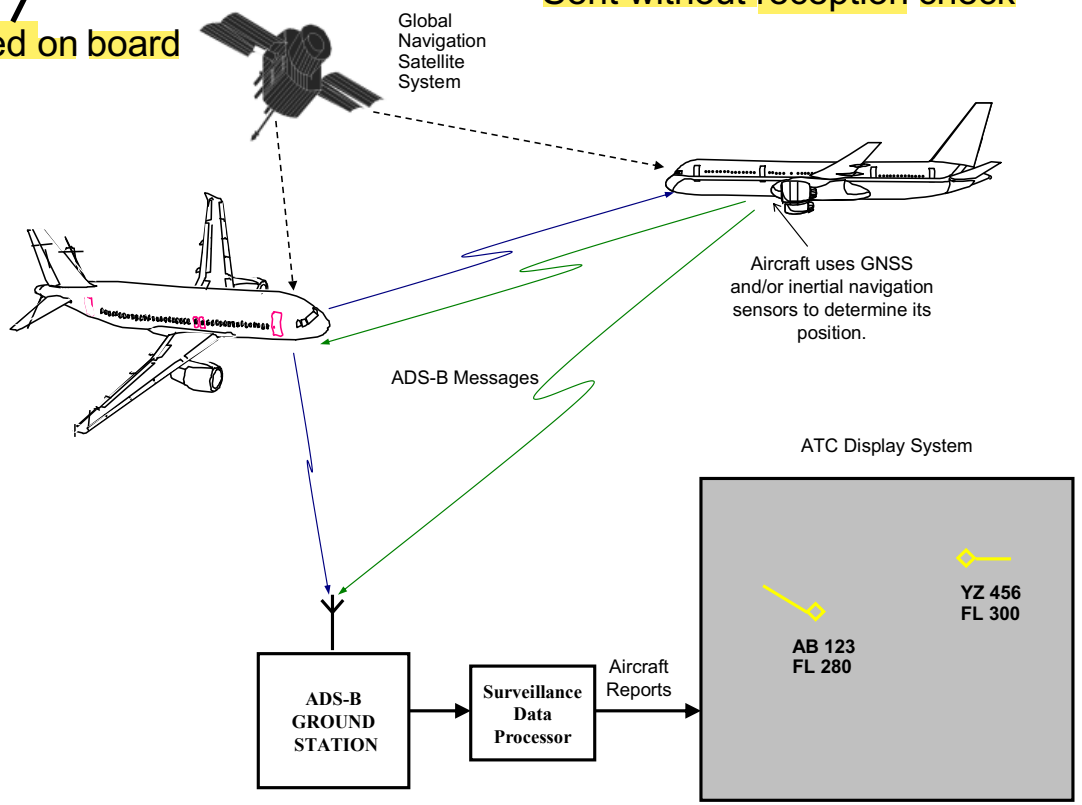
Automatic dependent surveillance - Broadcast

No interrogation from the ground

Position estimated on board

Surveillance data

Sent without reception check

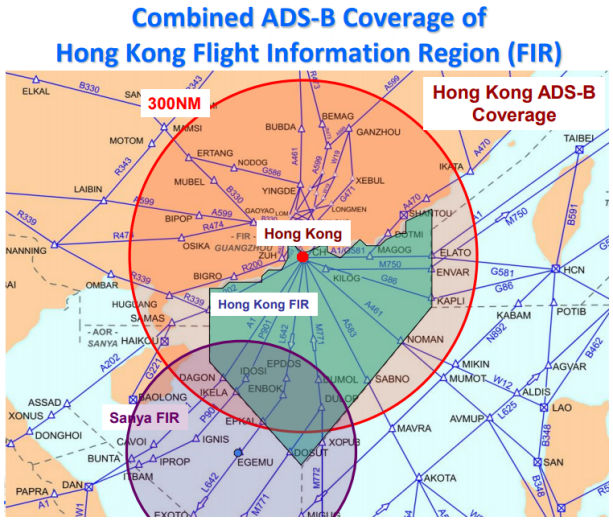


ADS-B

- Aircraft precise position broadcasted in space via a digital datalink with other data (airspeed, altitude..), and whether the aircraft is turning, climbing, or descending.
- ADS-B receivers provide users (Pilots/ATCs) with the same real-time information and accurate depiction of aviation traffic, both in the air and on the ground.
- ADS-B accuracy does not seriously degrade with range, atmospheric conditions, or target altitude
- ADS-B update intervals do not depend on the rotational speed or reliability of mechanical antennas.
- Is also effective in remote areas or in mountainous terrain where there is no radar coverage, or where radar coverage is limited.

ADS-B

- The aircraft will automatically reveal its location, flight path, and permissions to the nearby ATC.
- The controller can give instructions to a pilot without the need for active dialogue.
- ADS-B ground stations are significantly cheaper to install and operate compared to primary and secondary radar systems used by ATC for aircraft separation and control.



ADS-B vs. SSR

	ADS-B	**SSR**
Position Acquisition	Target longitude, latitude in WGS-84 coordinate system	Target range and azimuth from SSR station 方位角
	Unified coding of target address	Dynamic Allocation target secondary code
	Predict position and time of arrival of next waypoint	Only target detection information, no plan information
	Attitude information, such as turn, climb state etc.	No active attitude information report