Air Transportation System Architecting

Formation Flight:

A possible approach to Commercial and Military Cargo Transport

Air Traffic Control and Avionics considerations

Richard Cléaz-Savoyen

Agenda

- Formation Flight in History
- Military procedures
- Operations optimization
- Avionics - GPS

Source: www.archives.gov

Berlin Airlift

June 25th 1948 -> August 1st 1949

- ✓ 2,223,000 tons of supplies
- ✓ 266,600 flights from West Germany
- ✓ 20 crashes among the British aircraft

Source: www.usafe.af.mil

Military procedures

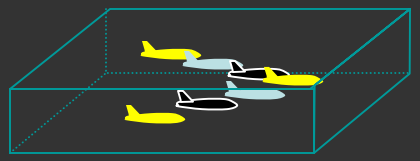
FAA – DOD Air Traffic Publications

Order 7610.4J
Special Military Operations
Section 12. FORMATION FLIGHT

Order 7110.65N
Air Traffic Control
Chapter 9: SPECIAL FLIGHTS

FF DEFINITION:
More than one aircraft which, by prior arrangement between the pilots, operate as a single aircraft with regard to navigation and position reporting. Separation between aircraft within the formation is the responsibility of the flight leader and the pilots of the other aircraft in the flight. This includes transition periods (join up and break away).

Standard Formation:
< 1 mile laterally or longitudinally
< 100 feet vertically



Nonstandard Formation:
under the provisions of a letter of agreement.

- Standard separation criteria are applied between the formation envelope and non-participating aircraft
- Formation join-up and breakaway are conducted in VFR weather conditions unless prior authorization has been obtained

Source: www2.faa.gov

Military procedures

General considerations in military FF

- The Leader aircraft is responsible for the communications with ATC
- Other aircraft fly relative to another one, and do not care of outside the cell
- The aircraft use mainly VFR, visual clues for positioning themselves in the vortex and keep the position
- The aircraft must be ready to communicate with ATC if FF breaks-away to get clearances to transition from formation to individual routes and altitudes
- ADS-B may be turned-off in commercial aircrafts flying in Formation

Source: Rob Holmes

Operations phases

Basically inefficient relative to the fuel savings

Takeoff

From same airport

From different airports

En-Route

Advantages

Break-away and Join-up

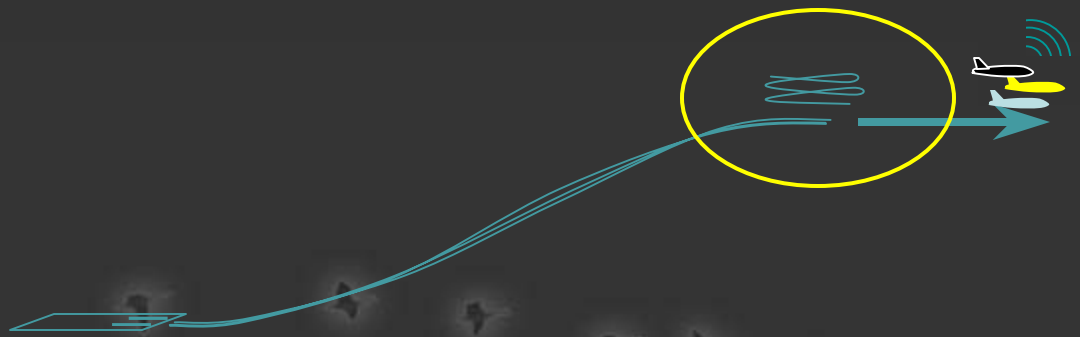
Landing

In same airport

In different airports

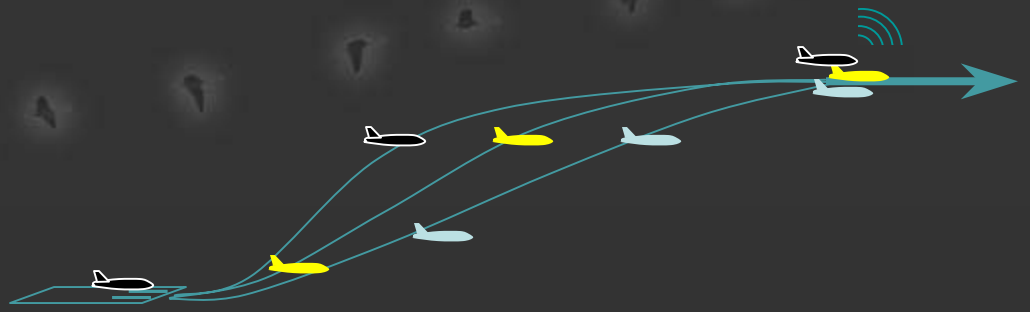
Operations

Takeoff from 1 airport



Drawbacks

- 2 minutes separation
- Airborne waiting
  -> wastes fuel savings



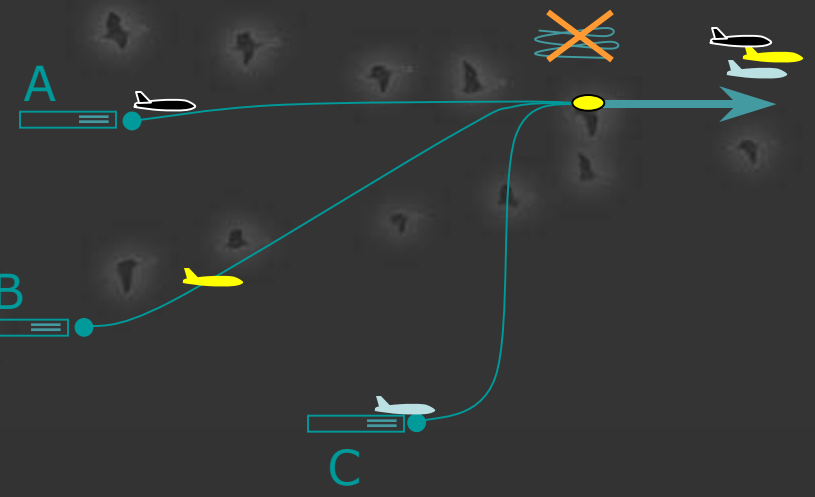
Potential solutions:

- Use // runways
- Wide runway (Bangor,ME = 90m = 300ft)
- Climb at different vertical speed to save fuel

Takeoff from n airports

Tasks:

- The aim is to avoid waiting at the rendezvous point -> wastes fuel
- Departures timing at the minute
- Rendezvous point optimized



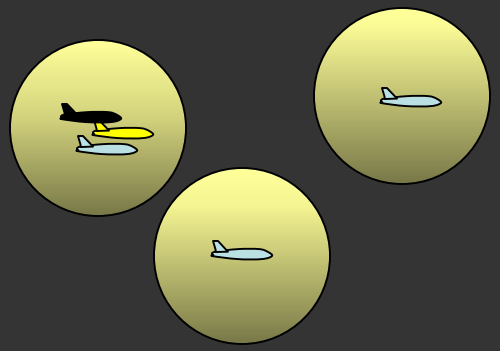
Problems:

- Airports congestion
- Weather

Needs real-time coordination (A/C-A/C; A/C-ATC; ATC-ATC)

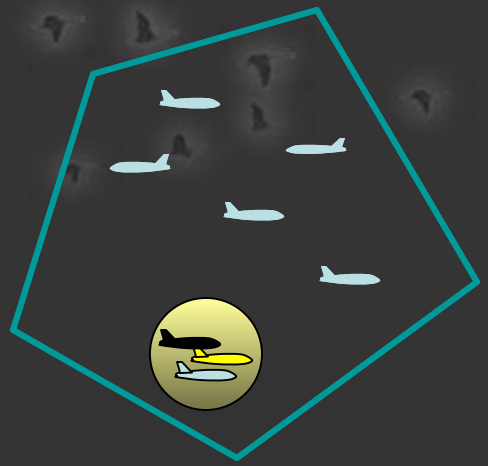
Operations

En-Route



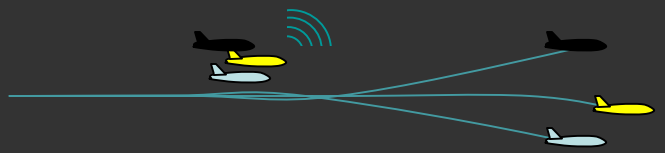
Advantages:

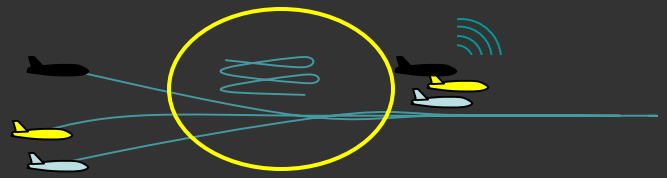
- Separation between the formation and the non-participating A/C remains the same
- Increases Airspace Capacity from p to p+n-1
  - Real Benefits



Drawbacks:

- Break-away and join-up -> to be avoided (Fuel & ATC)
- Airport break-away handling (workload increases)

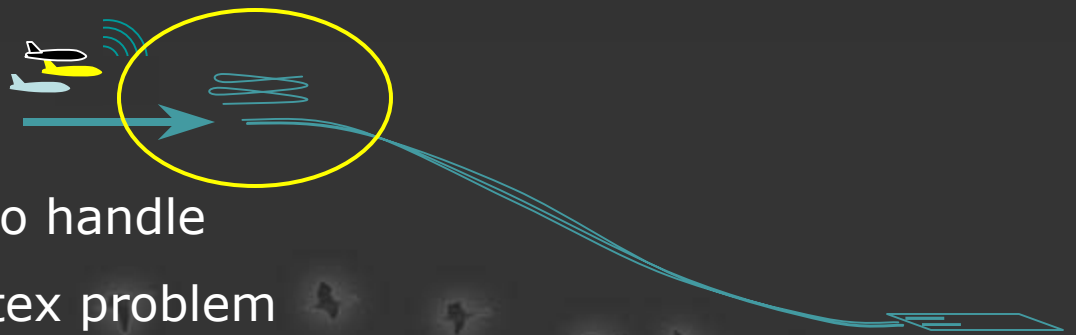




Operations

Landing

In one airport:

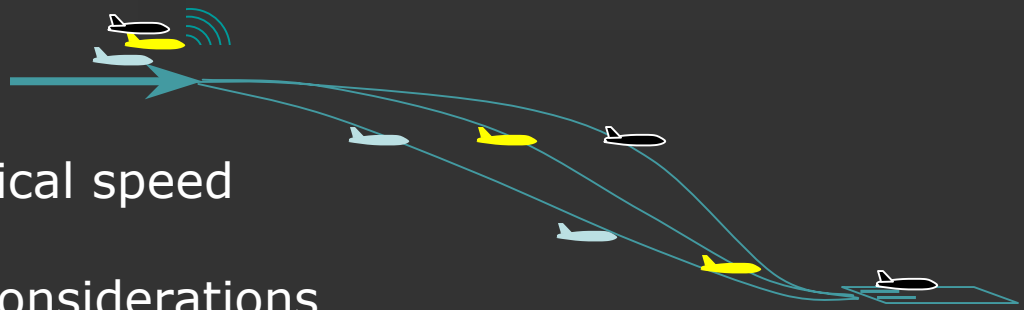


Drawbacks:

- Formation break-away to handle
- Separation to avoid vortex problem -> holding -> wastes fuel
- Airports congestion

Solutions:

- Optimum: landing in formation (wide runways)
- Use *//* runways
- Descend at different vertical speed

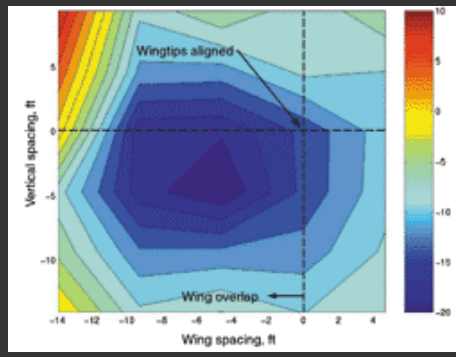


In different airports: No specific considerations

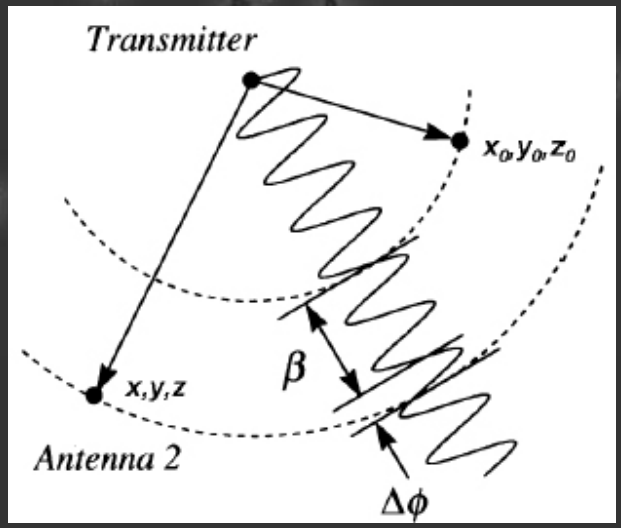
Avionics - GPS

State of the art: precision=2m

Requirements to optimize FF
- < 30 cm precision
- Real time, time accuracy
- Integrity and availability



Carrier Phase differential GPS (NASA)
- Based on the Doppler phenomenon
- Measurement of difference of phase ΔΦ
- Algorithms can compute the integer ß



Precision: about 5 cm

Sources: G. Larson, MIT 16.324, http://www.dfrc.nasa.gov

Avionics - GPS

- 3-D case: 4 satellites needed
  - 3-D vector of relative position
- Coupling with Inertial Measurement Unit

Attitude and relative position known with high precision

Possible redundancy using Galileo?

Source: Greg Larson

Conclusions

- Efficient to
  - ✓ reduce ATC workload
  - ✓ increase Airspace capacity
- But join-up and break-away phases will waste fuel
- Avionics: GPS for automated assistance

Acknowledgement: Robert Holmes, Technical Instructor, Naval science, MIT

Air Transportation System Architecting

Formation Flight:

A possible approach to Commercial and Military Cargo Transport

Air Traffic Control and Avionics considerations

Richard Cléaz-Savoyen

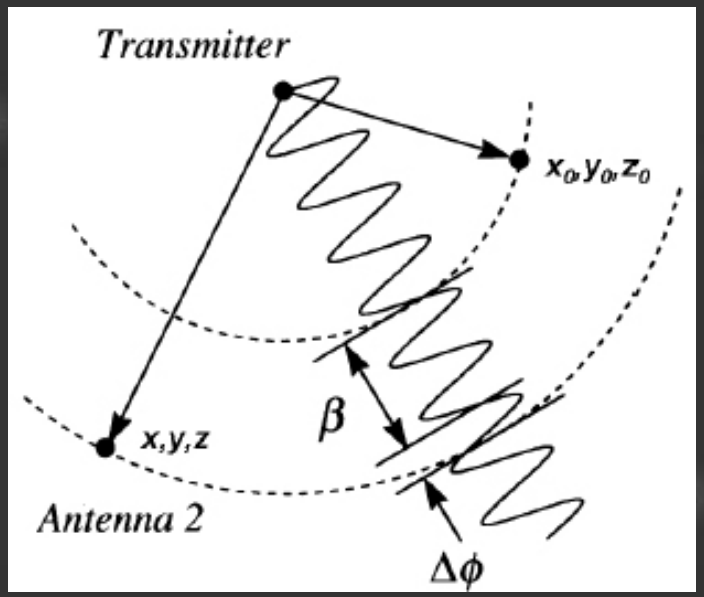
WWII Bombers

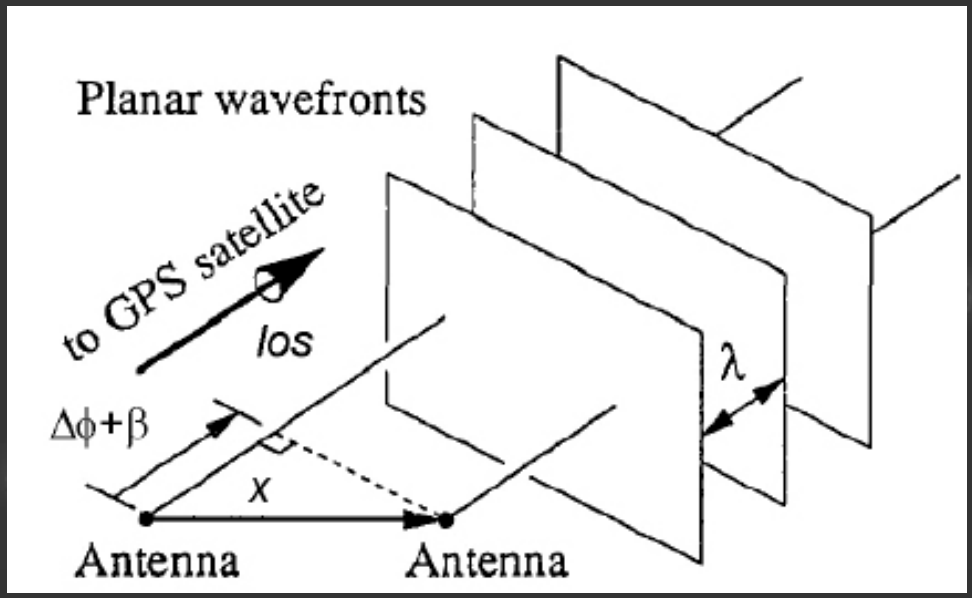
Diverse formation shapes

Source: www.archives.gov

Avionics - GPS

Carrier Phase differential GPS (NASA)





Source: Greg Larson & MIT 16.324