



# GPS denied navigation for airborne vehicles

Aerospace Technology Congress 2019

---

Fredrik Andersson

Saab Aeronautics

Flight Data and Navigation Department

# Disposition

---

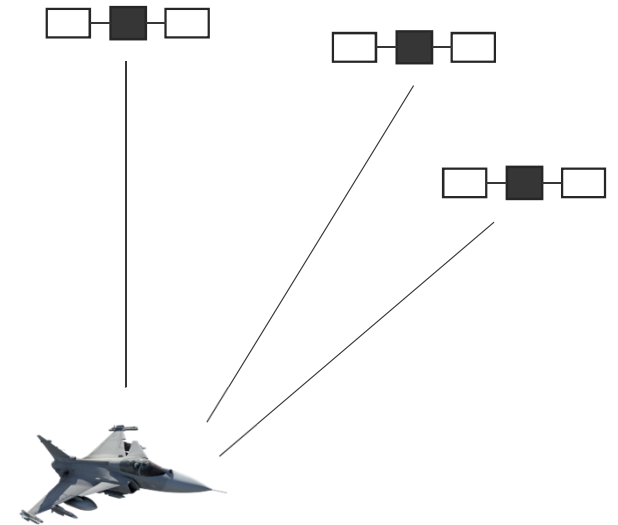
- Background
- Constraints & Limitations
- GPS denied navigation methods
- Integration method
- Time
- Summary

The content in this presentation does not represent any functionality in any variant of the Gripen aircraft system

# Satellite Navigation Systems

---

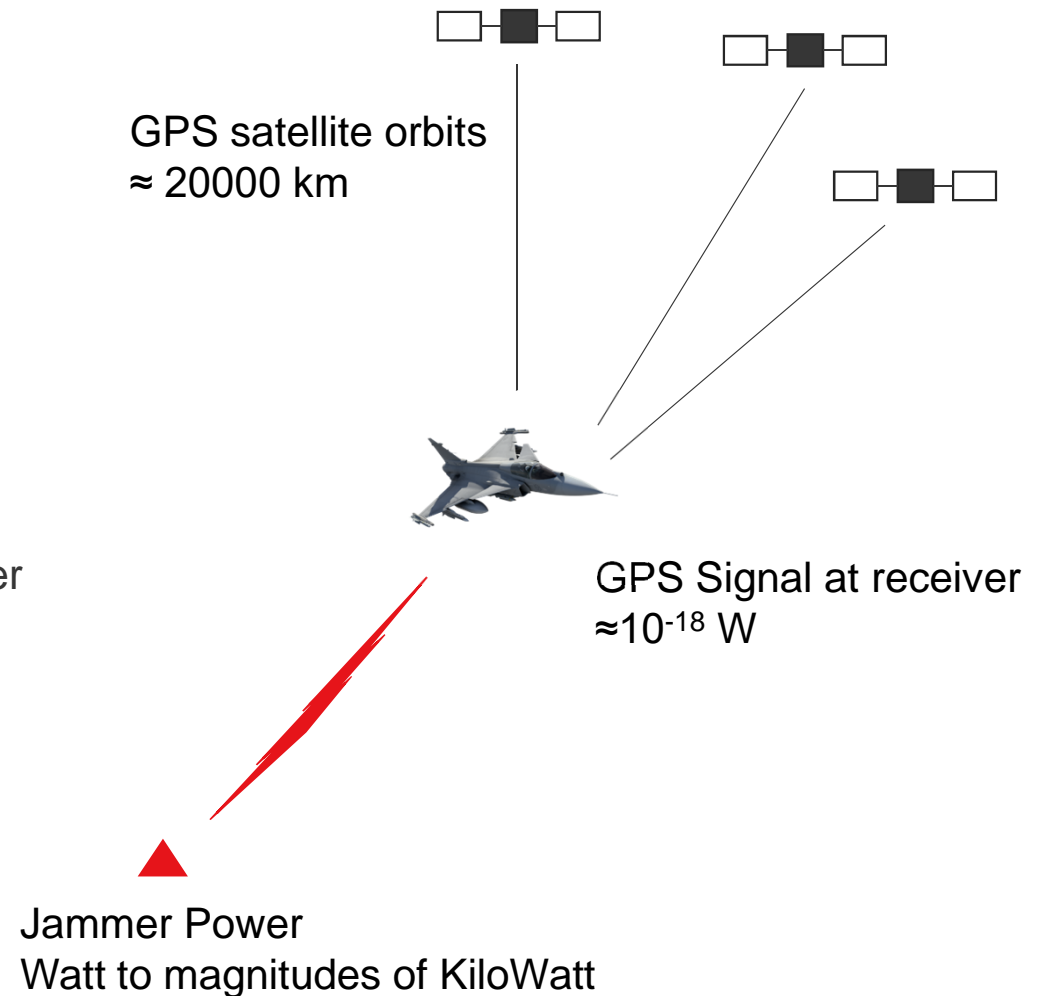
- Global Navigation Satellite System (GNSS)
  - GPS, Galileo, Glonass, Beidou, ...
- Extensive military and civilian use of GPS
- During nominal conditions
  - High navigation & timing accuracy



# GPS threats

---

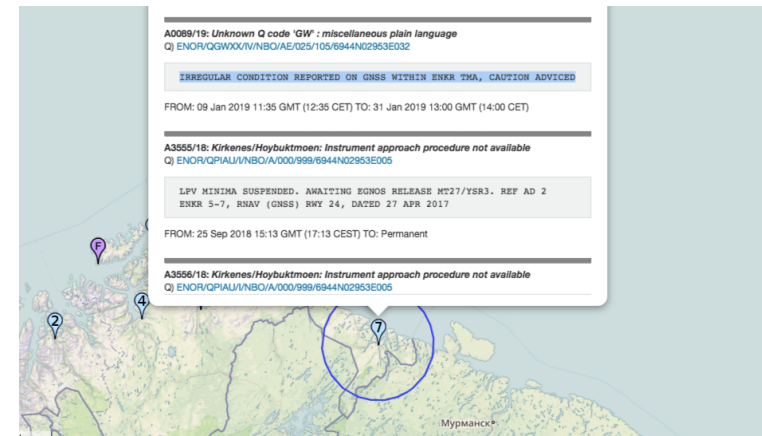
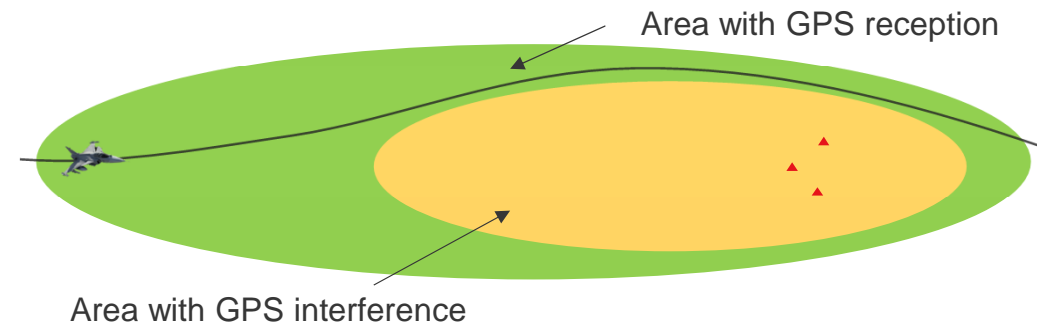
- GPS susceptible to signal interference
  - Jamming (suppression of GPS signal)
  - Spoofing (introducing of incorrect GPS signal)
- GPS interference
  - Natural causes, e.g. solar activity
  - GPS jamming intentional/unintentional
- Intentional jamming
  - Relatively easy to buy/construct a GPS jammer
  - Military grade high power GPS jammers
  - Ground based / Airborne GPS jammers
- Access to GPS jamming capability
  - Individuals
  - Organizations
  - Sovereign states



# Operational Scenario

## Avoid GPS interference

- Avoid or minimize time in GPS interference area
- Mission Planning based on
  - NOTAM (Notice to airmen) or other intelligence sources

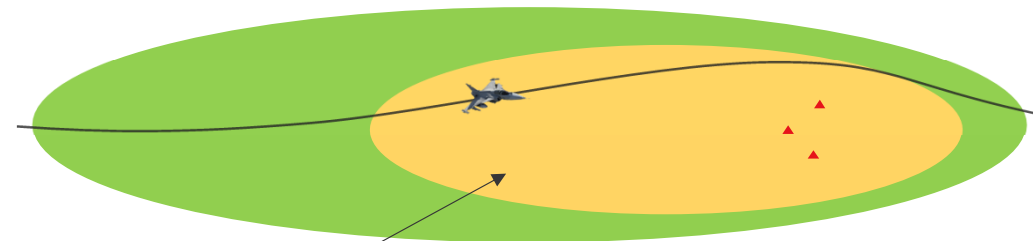


Example of NOTAM issued by the Norwegian Aviation Authority  
Reference: <https://thebarentsobserver.com>

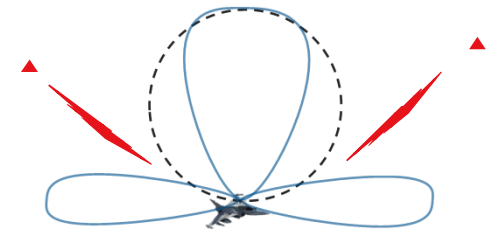
# Operation in GPS interference environments

## Protection of GPS reception

- GPS signal jamming/spoofing resistance methods
  - Encrypted GPS signals
  - GPS antijam system
    - Antenna Electronics
    - Controlled Reception Pattern Antenna
    - Adaptive Antenna Beam Forming
    - Suppression of multiple jammers
  - Inertial aiding of GPS signal tracking
  - Inertial GPS sensor coupling
    - Tight/Ultratight integration



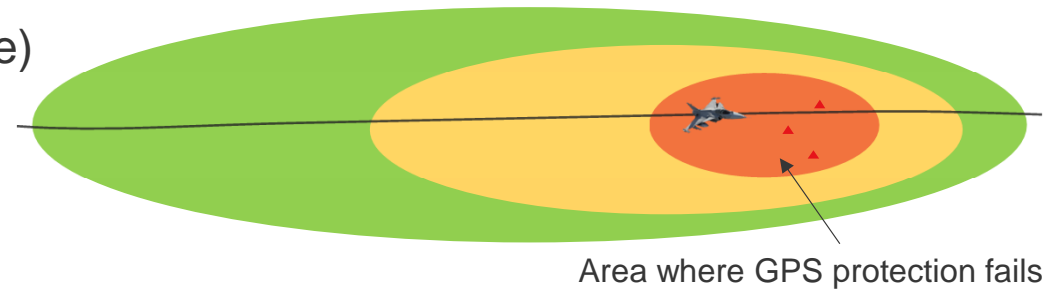
Area with GPS interference



# Operation in GPS denied environment

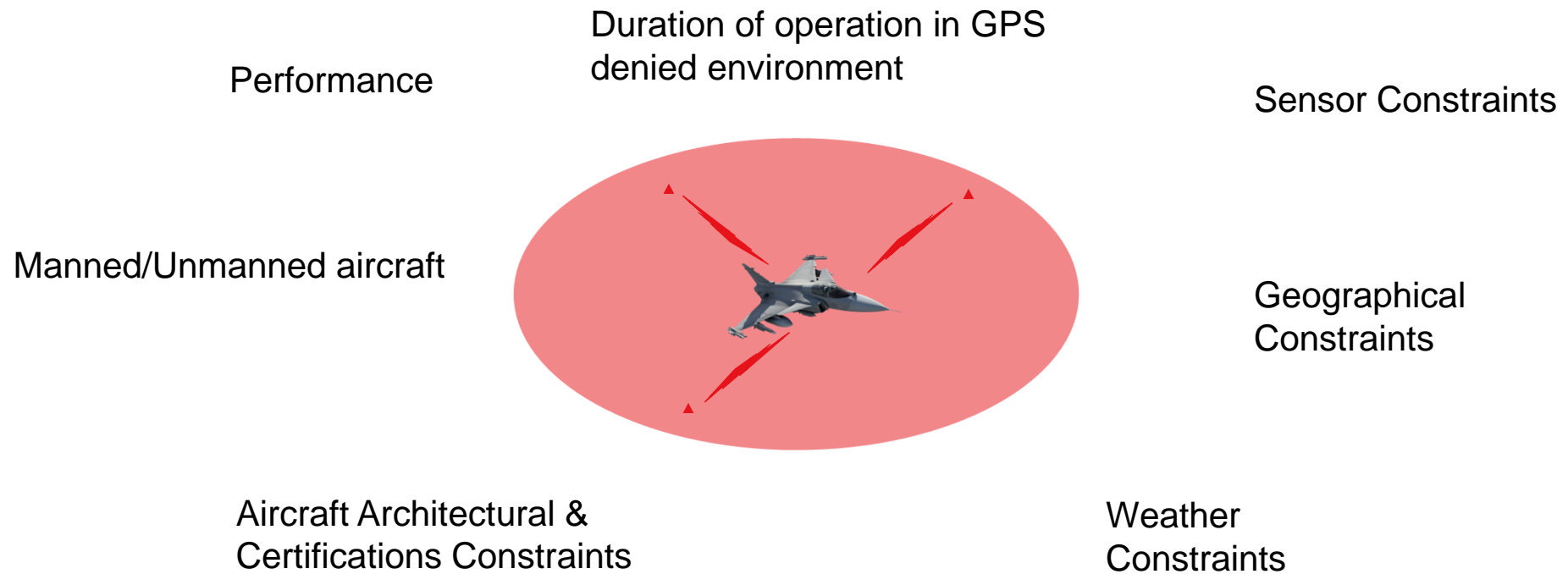
## GPS independent navigation

- GPS denied area (GPS signal protection failure)
  - Loss of or incorrect GPS signal
- Size of GPS denied area dependent on:
  - Platform's jammer resistance methods
  - Multiplicity of GPS jammers
  - GPS jammer power and type
- Other means of navigation are needed (dependent on operational scenario)



# Operation in GPS denied environment

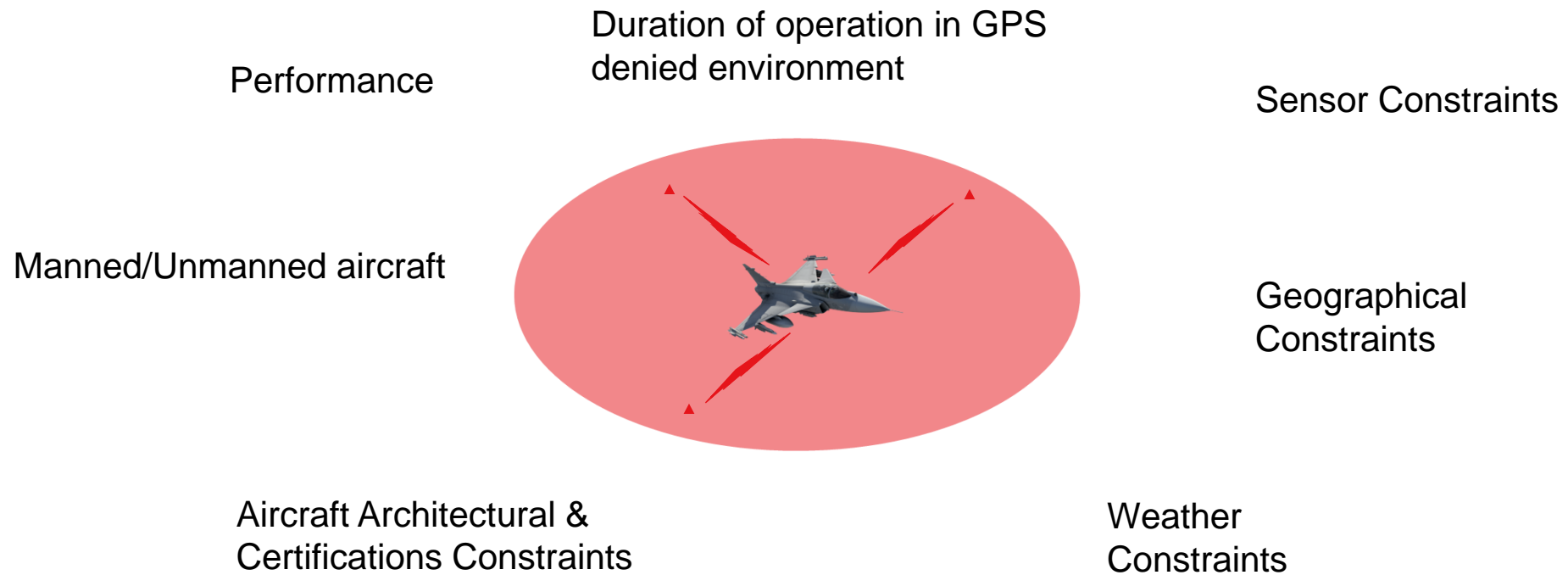
## Examples of design constraints





# Operation in GPS denied environment

## Examples of design constraints

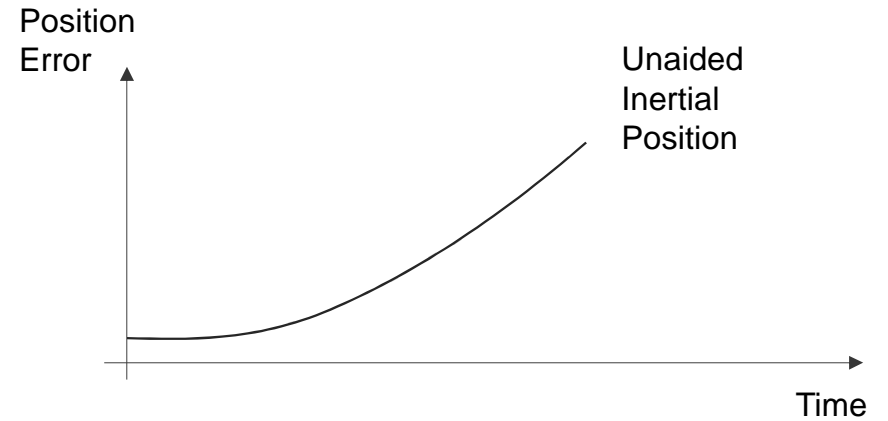


Challenging to satisfy all constraints all the time for all types of scenarios

# Inertial Navigation System (INS)

---

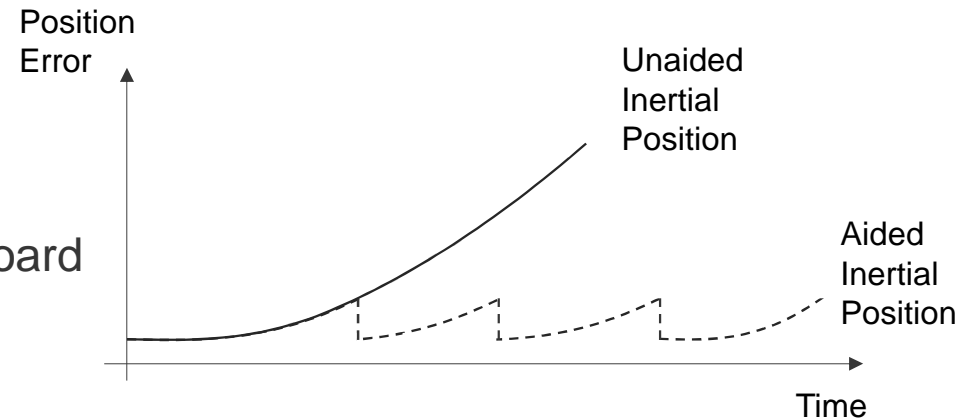
- Core sensor in navigation system
- Unaided navigation performance degrades with time
- Very often supported by a GPS system



# Inertial Navigation System Aiding

---

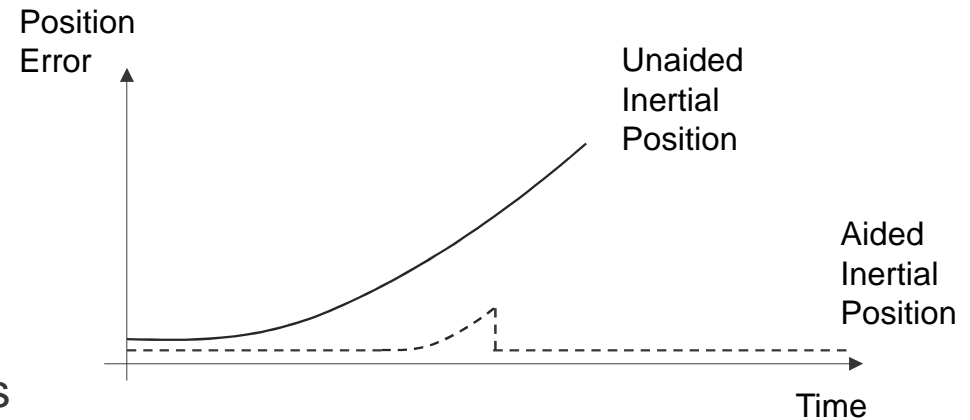
- Manual aiding (Manned vehicle)
  - Pilot visual fixes e.g. overfly fix
  - Measure known geographic points with onboard sensors
  - Performed at regular interval depending on inertial sensor performance
  - Pilot workload depending on mission scenario



# Inertial Navigation System Aiding

---

- Automatic aiding (Manned/Unmanned)
  - One aiding method does not fit all scenarios
  - Several aiding methods needed
  - Functions should complement each other
    - Work with dissimilar functional principles



# Examples of Automatic Aiding Systems

---

Terrain Navigation

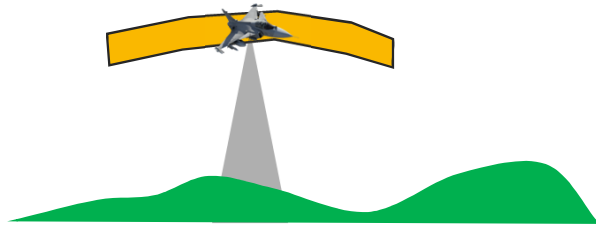
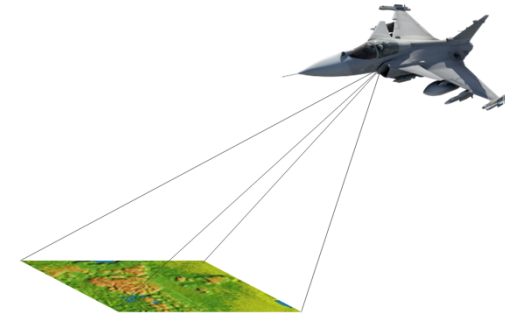
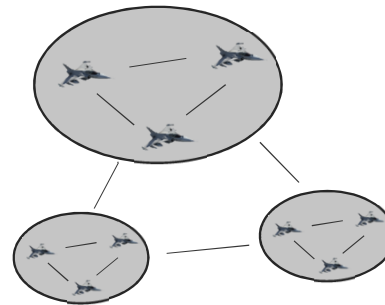


Image Based Navigation

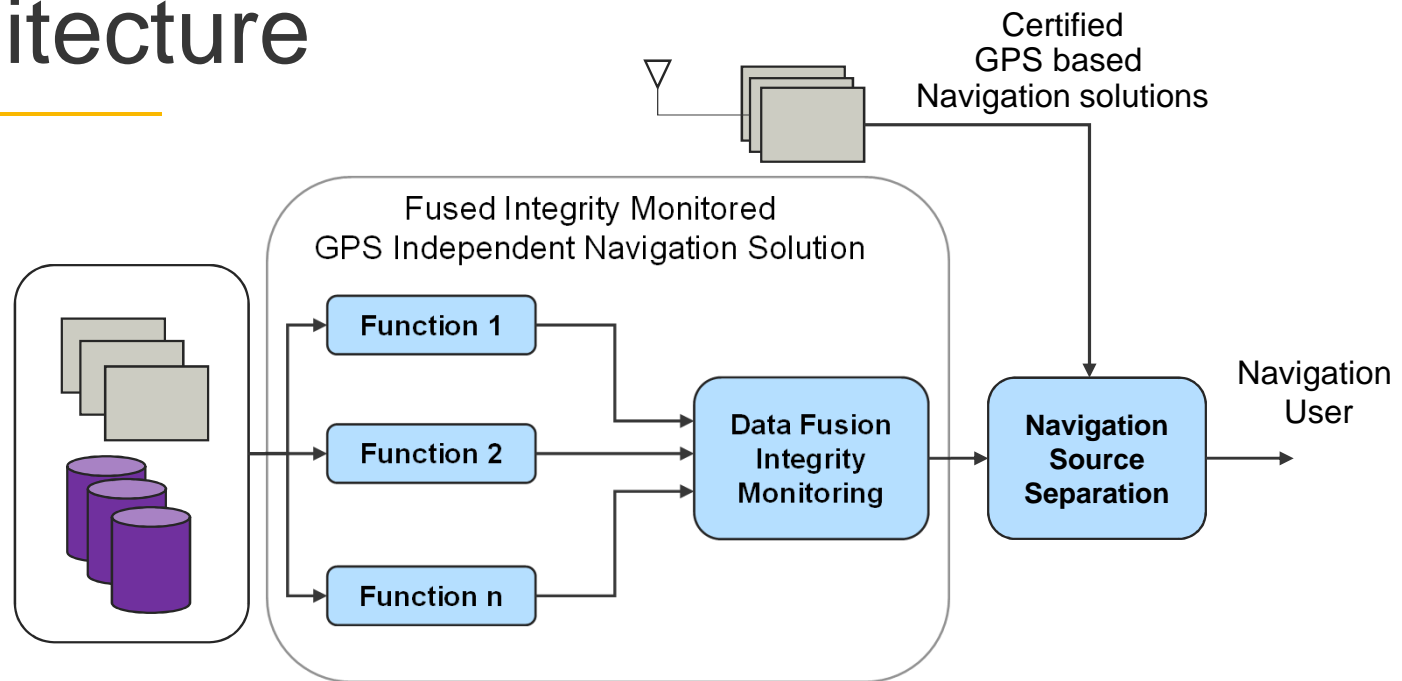


Network Based Navigation



# Integration architecture

- Complementary navigation functions
- Fused navigation state
- Graceful degradation
- Integrity Monitoring
- Separation of navigation solutions due to
  - Certification issues
  - Operation in civilian and military airspace
  - Eurocontrol
    - Enhanced Civil-Military CNS Communication-Navigation-Surveillance Interoperability



# Time

---

- GPS high accuracy time source
- Time can be crucial for aircraft system functionalities (dependent on the type of system)
- Typically avionic computers maintains time during loss of GPS timing info
  - Performance dependent on computer clock stability & drift
- Augmentation of timing functions with chip scale atomic clock
  - Redundancy (multiple high accuracy time sources)
  - Integrity monitoring (detection of GPS spoofed time signal)

# Summary

---

- Satellite navigation systems vulnerable to interference
- Avoid GPS interference areas
  - Mission planning
- Protect GPS reception
  - Encrypted GPS signals
  - GPS antijam antenna systems
- Augmentation of navigation system
  - Extend with multiple GPS independent navigation functions, preferable with dissimilar functional principles
  - Time augmentation with atomic clocks
  - Integrity monitoring for detection of navigation failure



Questions?

