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Application of Aircraft Navigation Sensors to Enhanced Vision Systems

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ABSTRACT

In this presentation, the applicability of various aircraft navigation sensors to enhanced vision system design is discussed. First, the accuracy requirements of the FAA for precision landing systems are presented, followed by the current navigation systems and their characteristics. These systems include Instrument Landing System (ILS), Microwave Landing System (MLS), Inertial Navigation, Altimetry, and Global Positioning System (GPS). Finally, the use of navigation system data to improve enhanced vision systems is discussed. These applications include radar image rectification, motion compensation, and image registration.

Application of Aircraft Navigation Sensors to Enhanced Vision Systems

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Outline

- Current Accuracy Requirements
- Current Precision Landing Systems
- Inertial Navigation
- Altimetry
- GPS
- Image Processing Applications

FAA Requirements for Navigational System Accuracy:

Non-Precision Approach:

Limited to 250 ft above surface

100 m 2 drms lateral position accuracy

Precision Approach:

Category I:	Category II:	Category III:
Vertical: +/- 1.4 m 2 sigma	Vertical: +/- 1.7 m 2 sigma	Vertical: +/- .6 m 2 sigma
Lateral: +/- 17.1 m 2 sigma	Lateral: +/- 5.2 m 2 sigma	Lateral: +/- 4.1 m 2 sigma
Decision Height 200 ft/61 m	Decision Height 100 ft/30 m	Decision Height 50 ft/15 m

drms = distance root mean square

Current Precision Approach Systems

Instrument Landing System

Come in three categories (I, II, III)

Straight-in Approach to Airport

Requires Glideslope & Localizer Transmitter for each runway threshold with an ILS approach

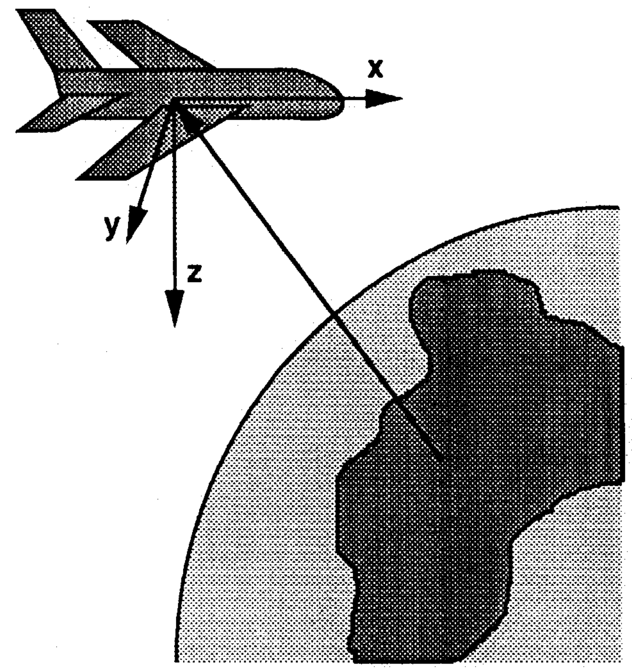
Microwave Landing System

Come in three categories (I, II, III)

Supports both Straight-in & Curved Approaches

Requires Glideslope & Localizer Transmitter for each runway threshold with an MLS approach

Inertial Navigation



Method:

Inertial Measurement Unit (IMU) measures accelerations and angular rates with respect to three orthogonal axes.

Coordinate transformations/integrations to determine position, attitude with respect to the earth.

Types:

Platform & Strapdown

Limitation:

Lateral positioning only. Vertical position not feasible.

Inertial Navigation

Accuracies output from the IMU:

Acceleration: 6 g to 14 bit plus sign resolution = .00037 g

Angular rates: 256 deg/sec to 14 bit plus sign resolution = .015 deg/sec

Groundspeed: 6 knots

Position: drift rate 1 nm/hr

Pitch, Roll attitude: .25 deg

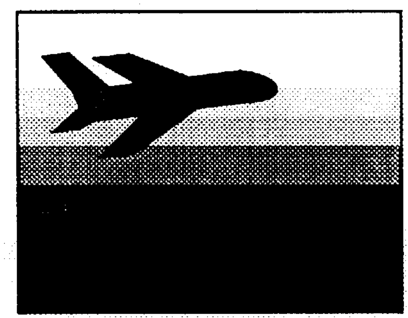
True Heading: 10 arc min

Track: function of groundspeed, nominally 3 degrees at approach

all accuracies 1 sigma

Altitude Measurement

Barometric Altimeter



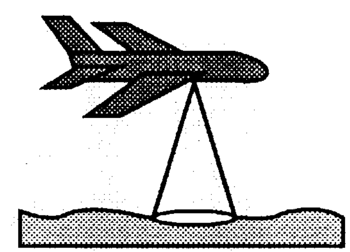
Indicates altitude based on standard atmosphere

Dependent on accurate altimeter setting

Error at surface: 50 ft (1 sigma)

Error at 40,000 ft: 200 ft (1 sigma)

Radio Altimeter



Calibrated to read zero when wheels touch at nominal landing attitude (3 degrees)

Gives elevation above terrain (directly below aircraft)

Operate from 0 to 3000 ft above ground

Accuracy: 2 ft below 40 ft, 2.5 % of height above 40 ft (1 sigma)

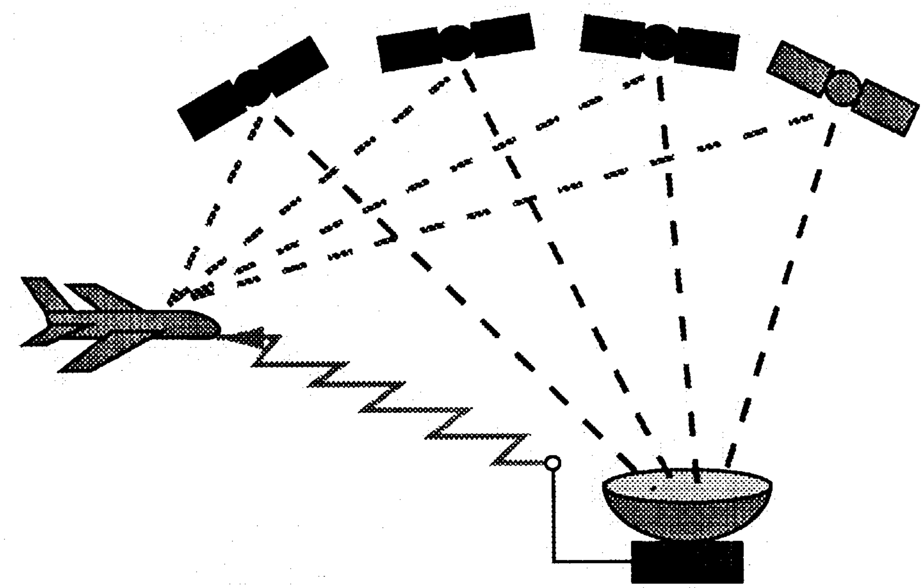
Global Positioning System (GPS)

- Satellite based system, no ground-based aids required
- Give range/range-rate to each satellite received
- Positioning in two levels of accuracy:

Precision Code (P-code) 17.8 m 2d rms lateral 27.7 m 2 sigma vertical	Available only to military users
Course Acquisition Code (C/A-code) 100 m 2d rms lateral 156 m 2 sigma vertical	Available to civil community

- Limitations due to masking of satellites can be encountered
- Typical update rates of 1 hz

Differential GPS



Ground-based receiver at surveyed location calculates ranges to all satellites in view

Range corrections broadcast to users

Demonstrated Accuracies:

P-code:
.91 m rms horizontal
2.7 m rms vertical

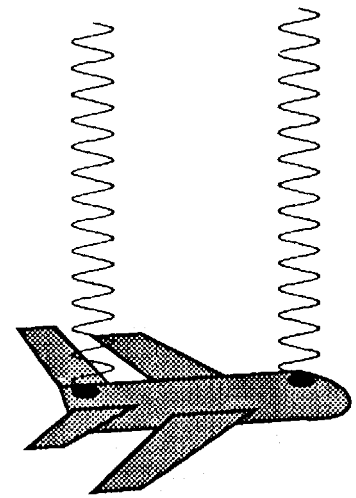
C/A-code:
7.6 m rms horizontal
8.5 m rms vertical

Pseudolite at differential station can improve vertical position

Carrier wave tracking shows promise for improving performance

Other GPS Applications

Carrier Wave Attitude Determination

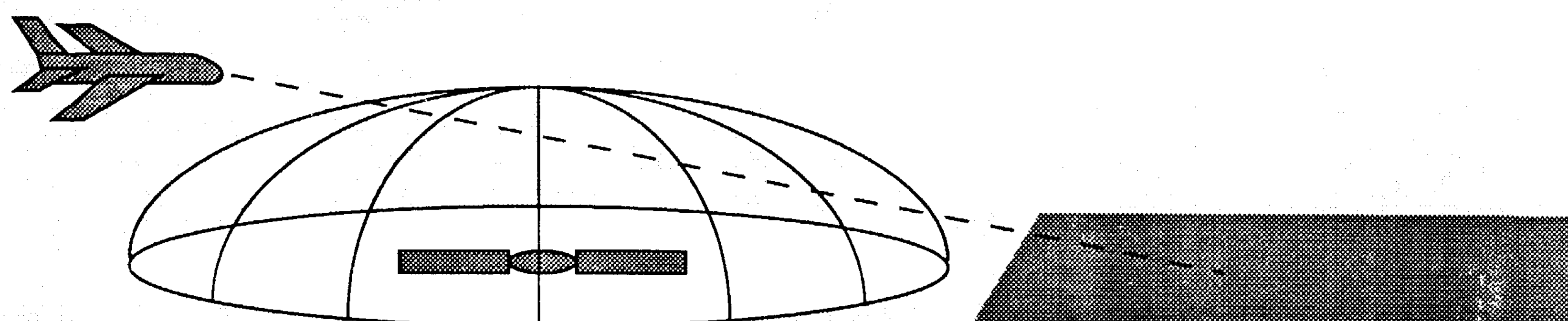


Multiple GPS antennaes on aircraft allows measurement of phase differential

Accurate to .05 deg 1-sigma

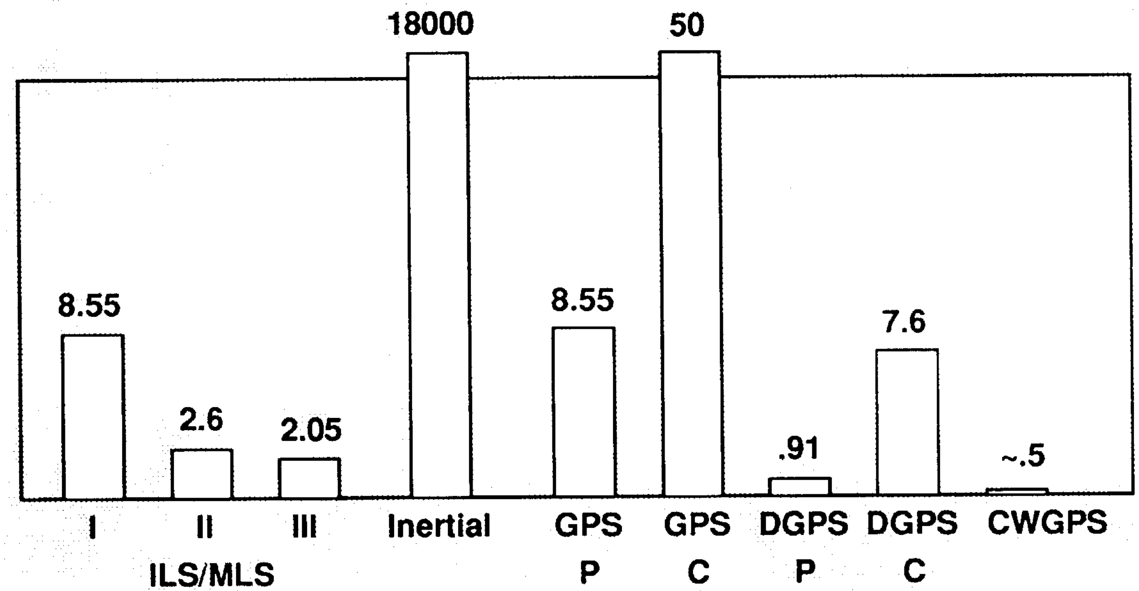
Carrier Wave/Pseudolite Navaid:

Demonstrated Accuracies in range of pseudolite of 5 cm

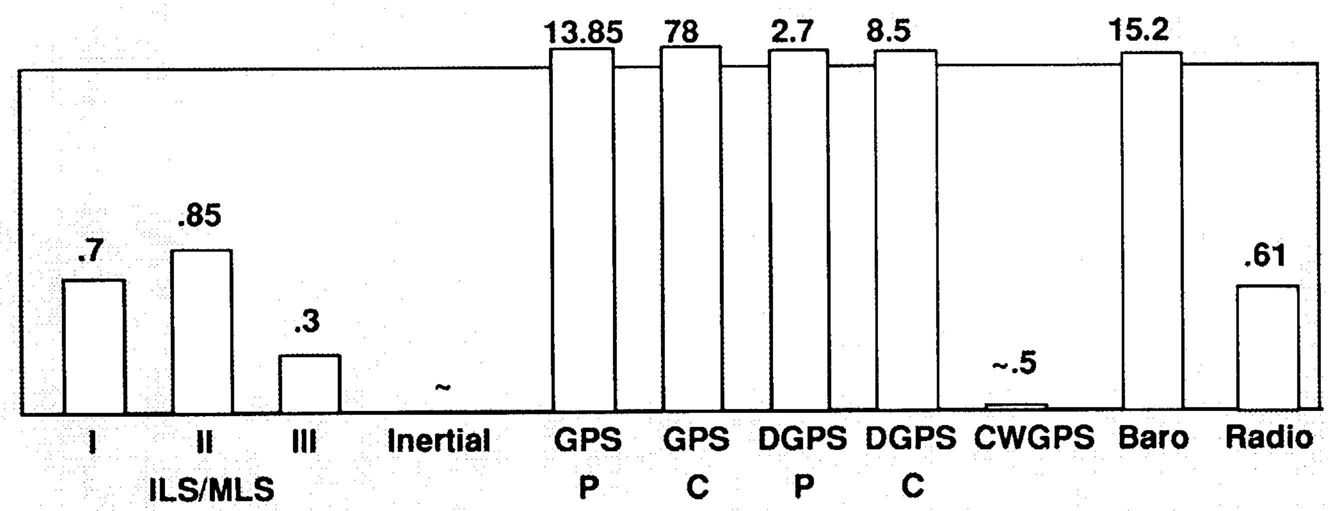


Summary of Navigational Accuracies

Lateral



Vertical



Applications to Enhanced Vision

- Radar Image Rectification
- Motion Compensation
- Image Registration

Radar Image Rectification

Issues

- Accurate altitude is key to producing rectified radar image
- Altitude is difficult to measure accurately
- Potential Energy vs Kinetic Energy

  mgh = potential
  mv^2 = kinetic
  → 50 ft potential energy is equivalent to 24 knots!

- Possible issue for certifying under current criteria

Motion Compensation

Issues

- Aircraft motion can cause blurring/distortion of radar image for slower scanning rates

- Improvement of image from motion compensation will be limited by accuracy of path measurement

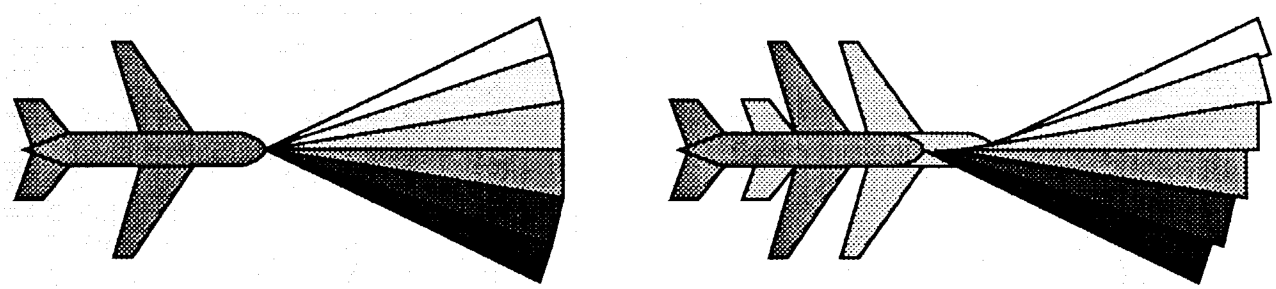


Image Registration

Issues

- Aircraft state information can affect registration times & registration accuracy
- In order to fuse images, registration is necessary
- Database image dependent upon position/attitude of aircraft
- Accuracy of position/attitude will affect feasibility of database fusion

Conclusions

- Accuracies of aircraft state measurements need to be accounted for in enhanced vision designs
- Techniques to extract state information from the image should be investigated

II. SENSOR MODELING

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