Bi-Directional DGPS for Range Safety Applications

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Outline

- Background
  - DGPS
- Remote Positioning
- Bi-Directional DGPS System
- Instantaneous Impact Point
  - Overflight Exclusion Zone
  - Flight Corridor
- Conclusion

Differential GPS

DGPS requires a Reference Station (surveyed location) that processes the GPS signals, derives the pseudo-range corrections with respect to its known location and transmits them to the mobile users in the area.

- Common error sources are either corrected or eliminated
- Accuracy can range from sub-meter to 10 meters

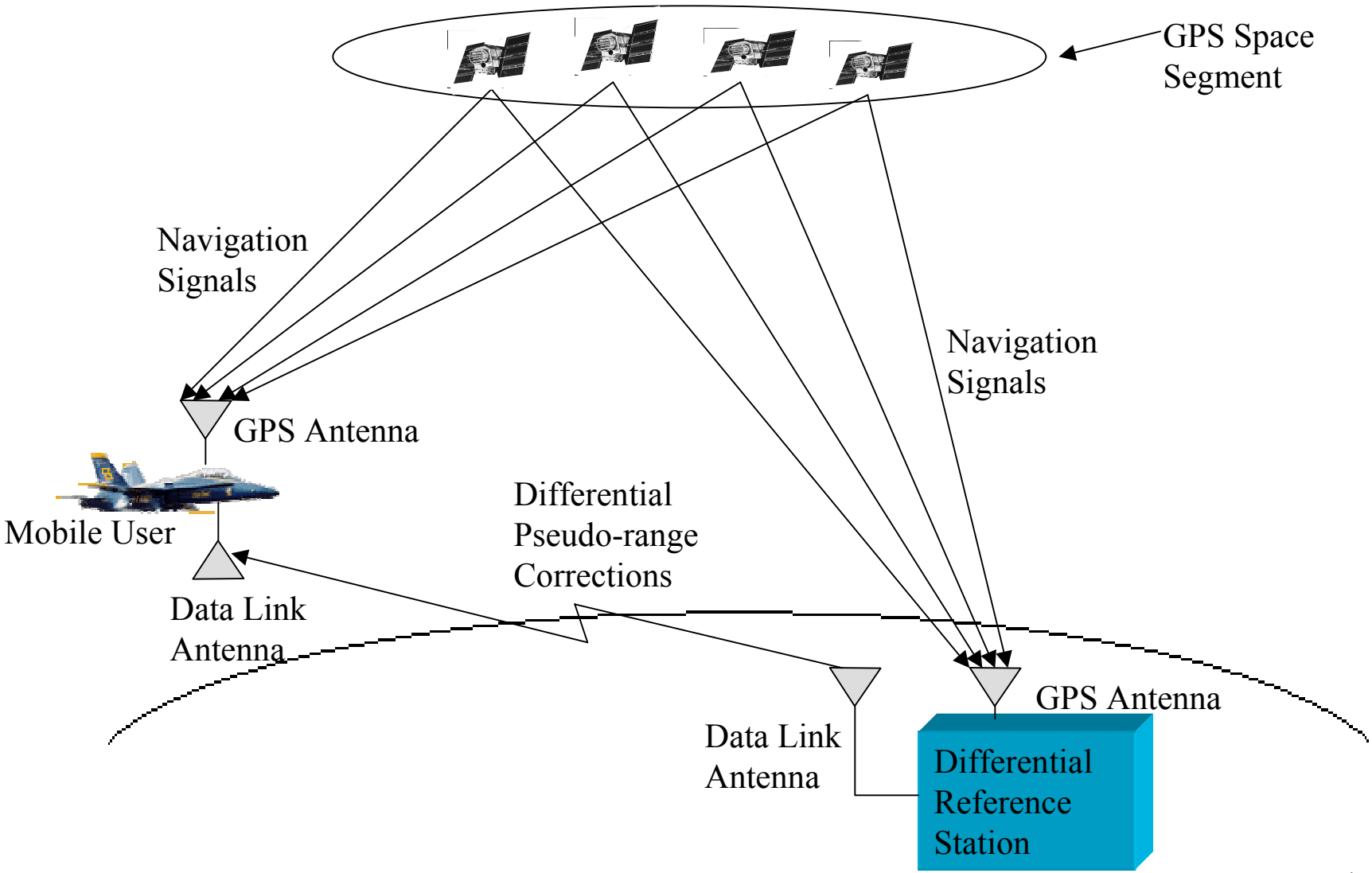
Errors Eliminated by DGPS

- Ionospheric Delay: 20 - 30 m during the afternoon and 1 – 6 m at night. Dependent on latitude and time of day, solar cycle.
- Tropospheric Delay: Up to 30 m for a low elevation satellite. Dependent on Elevation Angle.
- Ephemeris Errors: Typically 1 – 3 m
- Satellite Clock Error

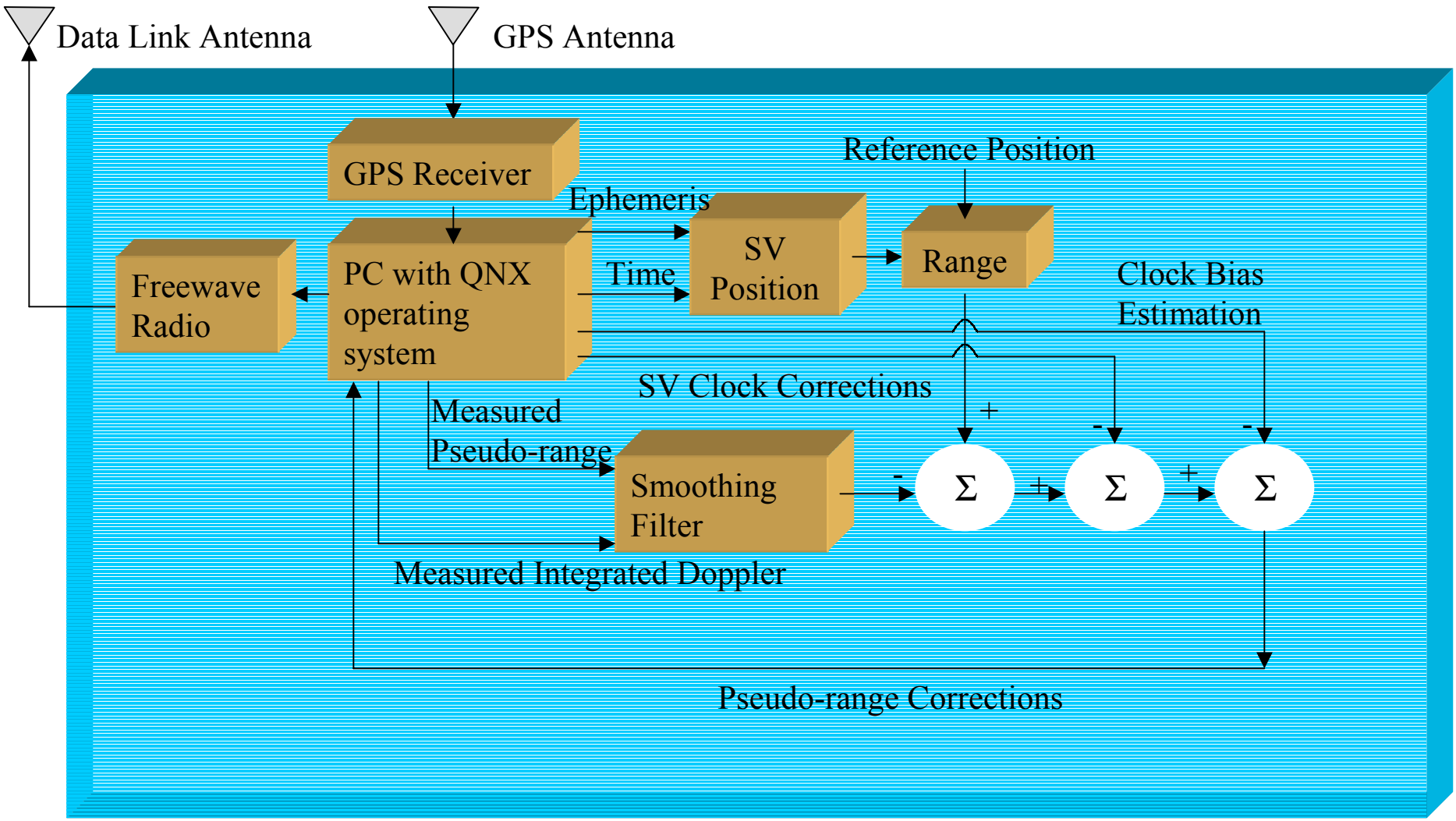
Errors not eliminated by DGPS

- Receiver Noise
- Uncorrelated Multipath
- Spatial Decorrelation : Changes with distance in Ionosphere and Troposphere
- Temporal Decorrelation : Changes with time

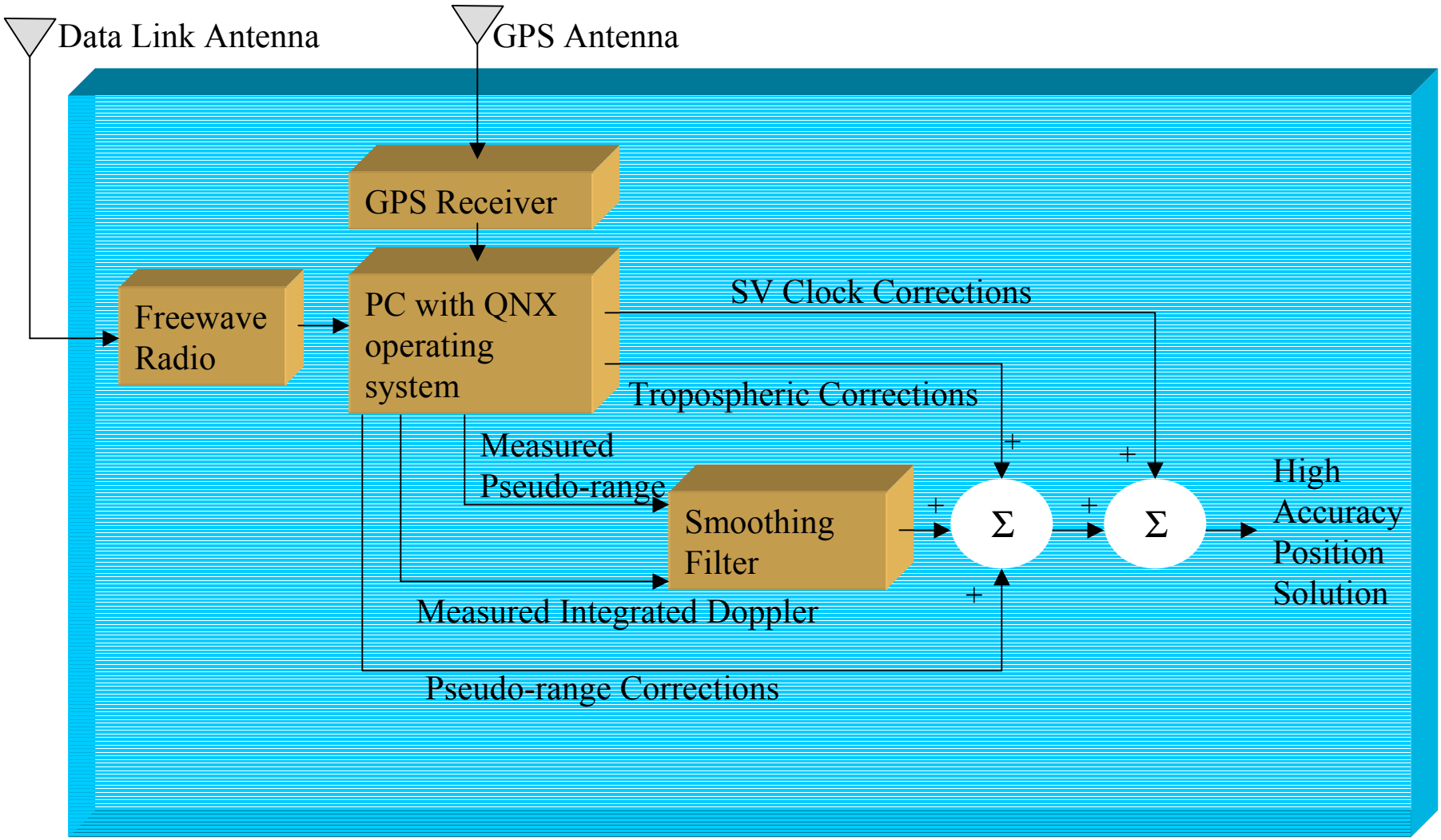
DGPS Illustration



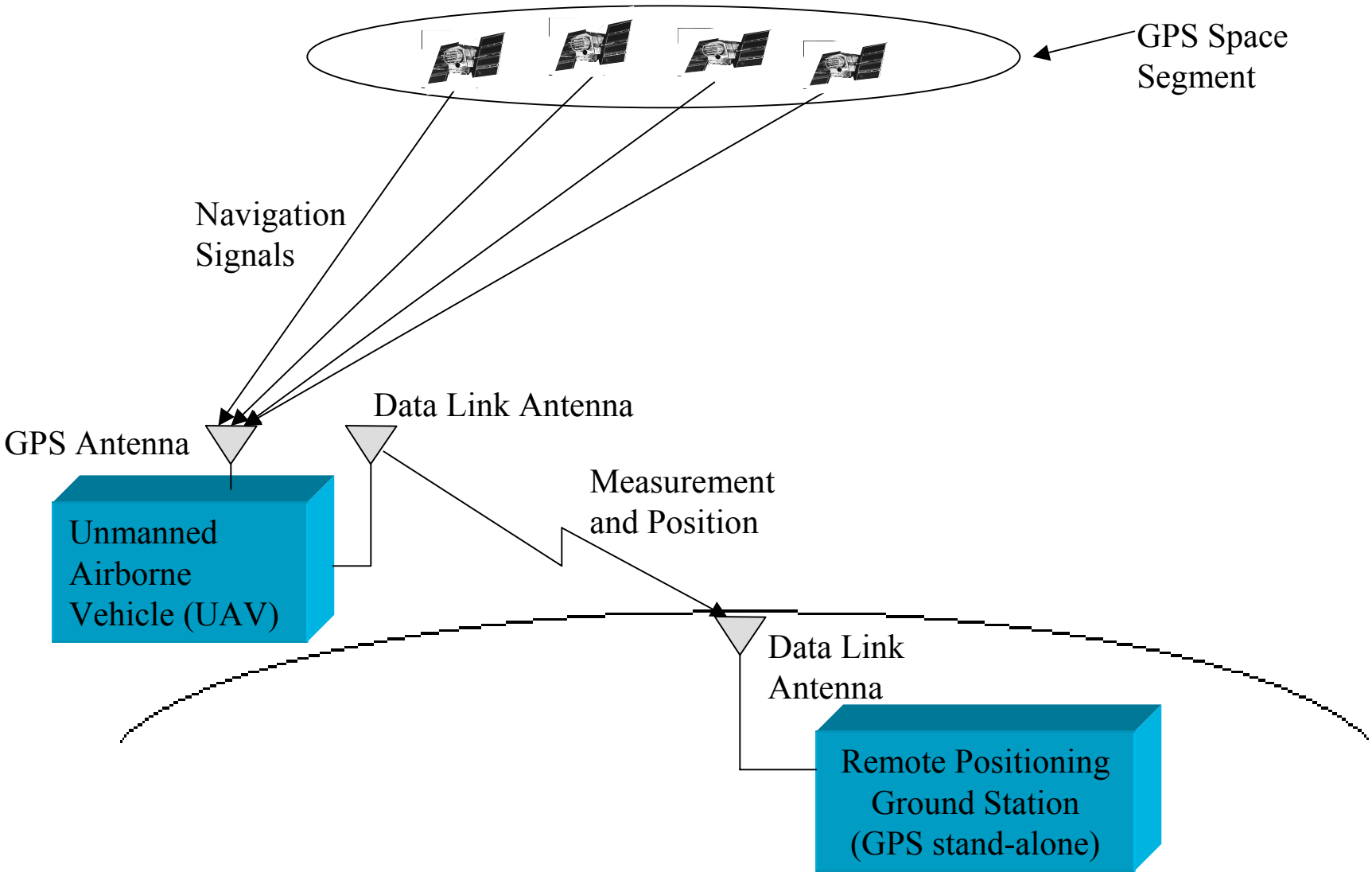
DGPS at Ground Station



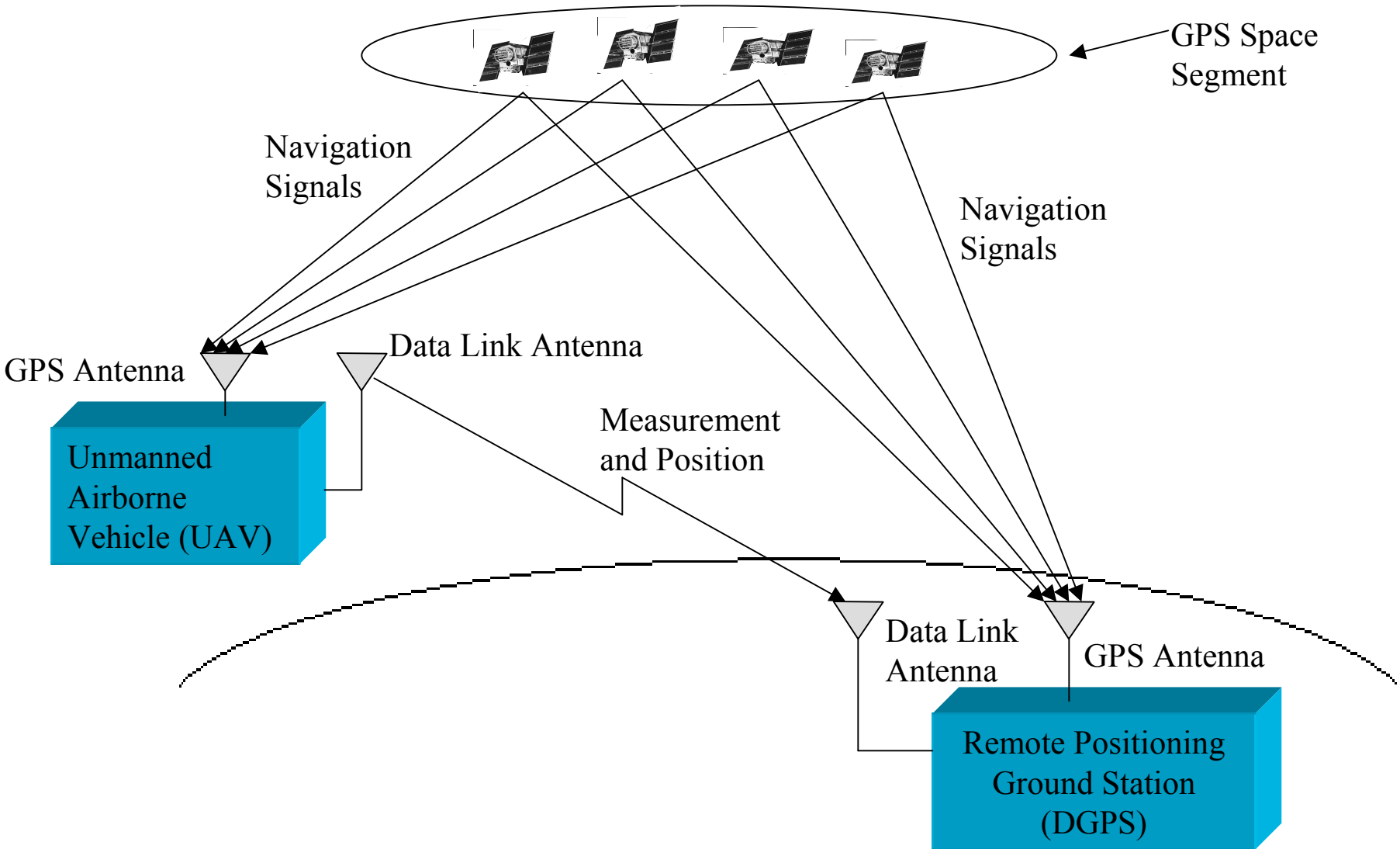
DGPS at Mobile User



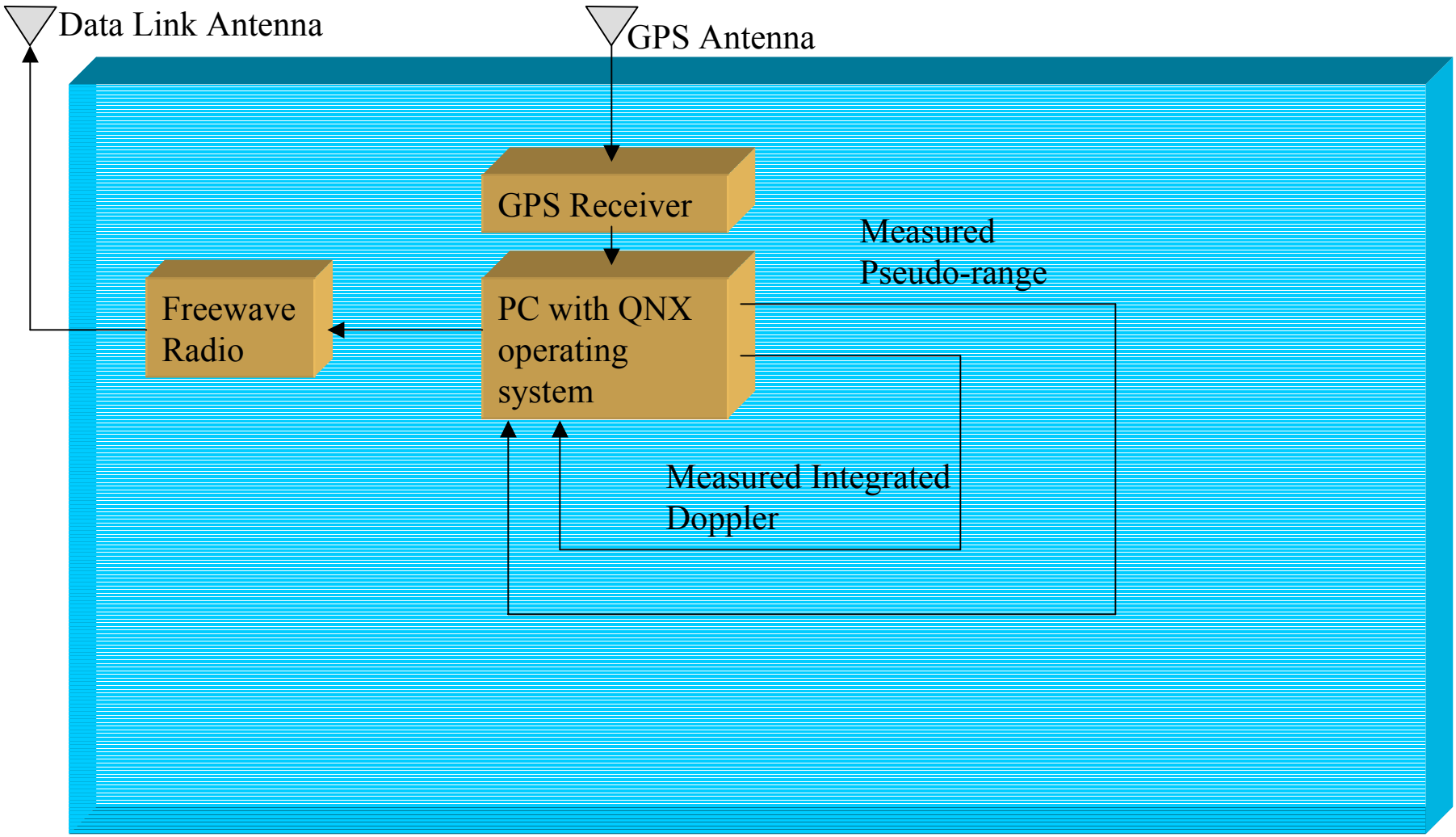
Remote-Positioning (stand-alone) System



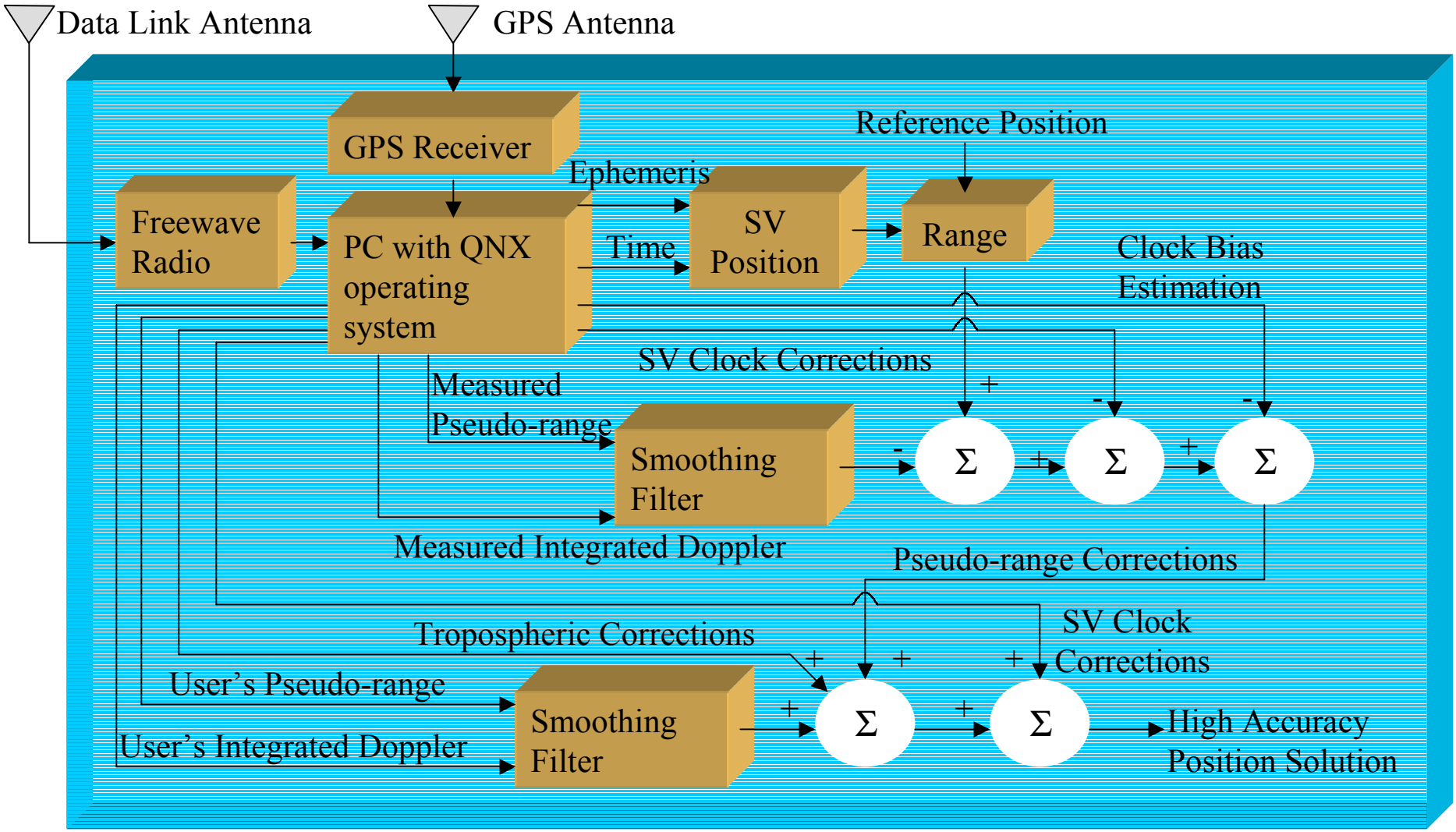
Remote-Positioning DGPS System



Remote-Positioning DGPS at Mobile User



Remote-Positioning at Ground Station



Positioning Requirements

Uplink

Differential Pseudo-range Corrections

- Enables high accuracy position solution at the user end
- Enables auto pilot, precision landing, etc

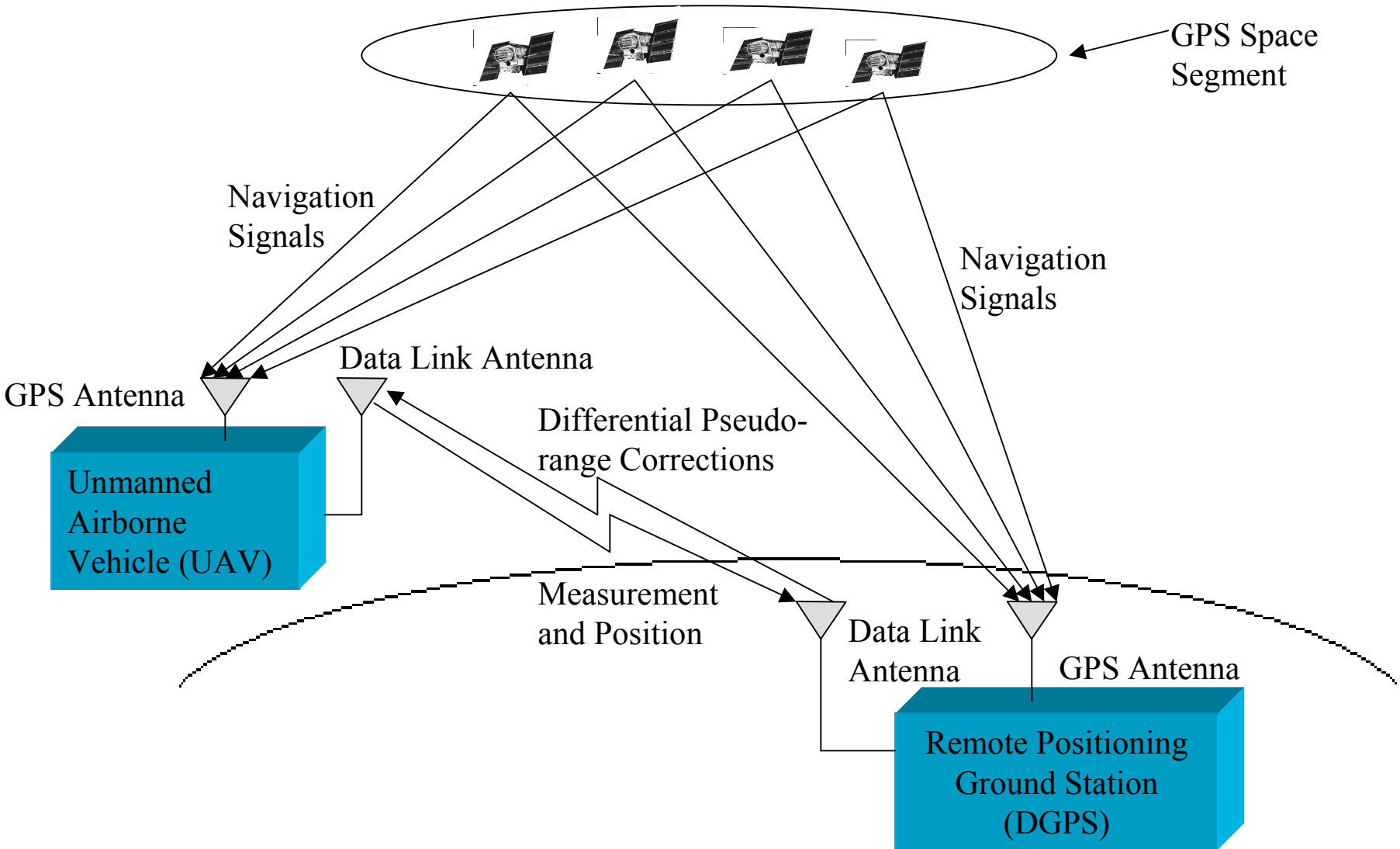
Downlink

Measurement and Position

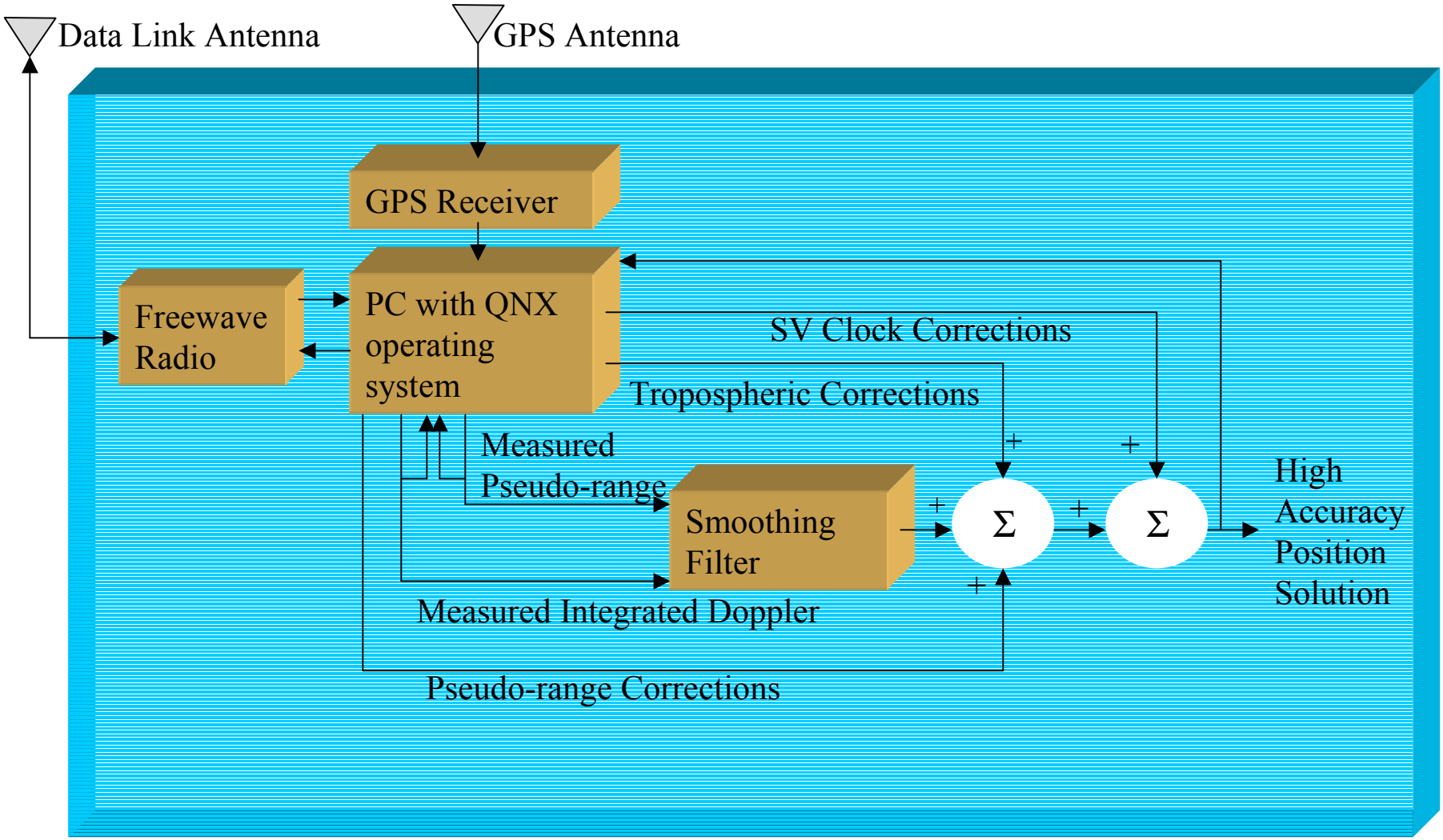
- Enables high accuracy position solution of the remote user at the ground station
- Can track the UAV from a remote position

We want both - Simultaneously

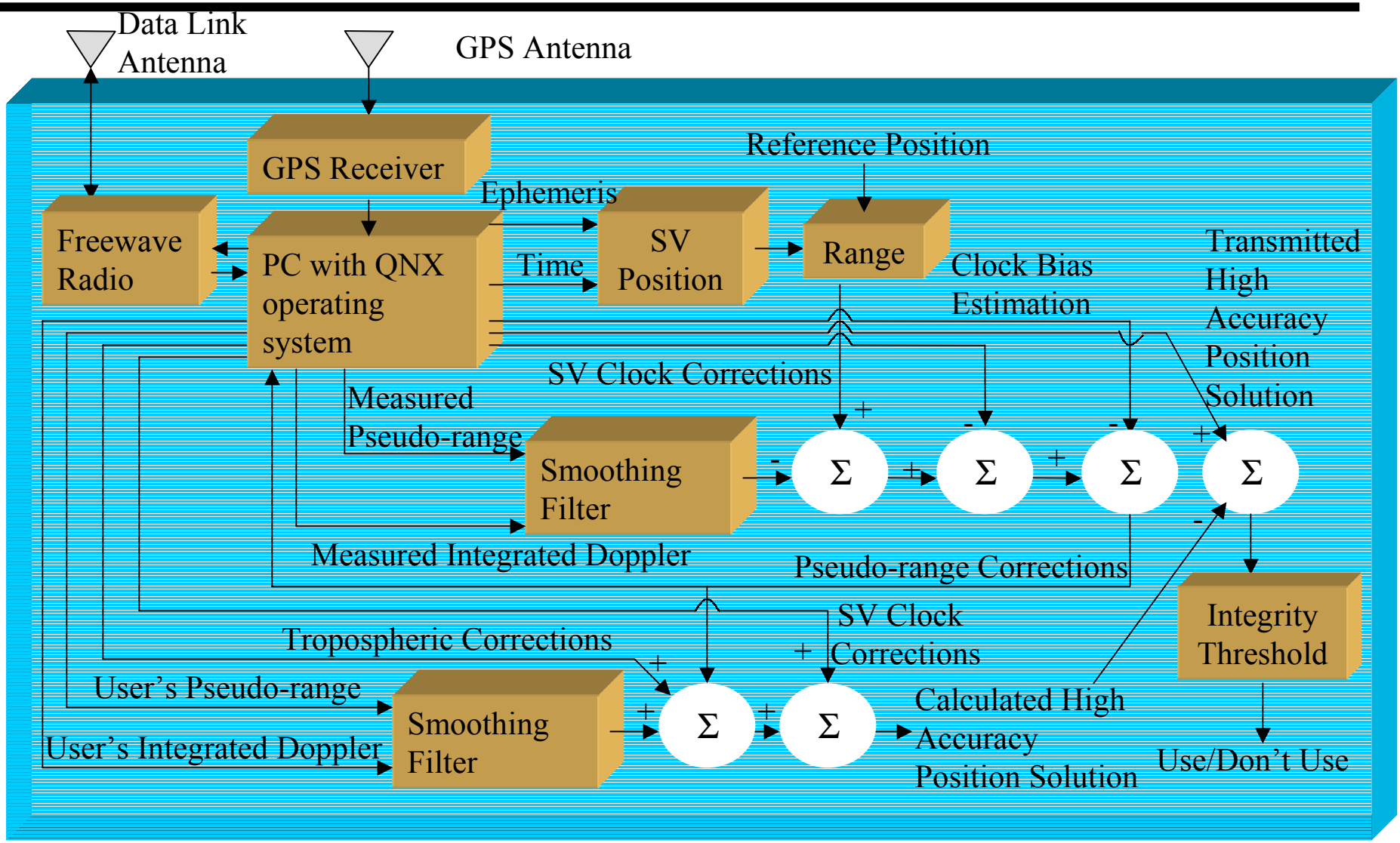
Bi-directional DGPS System



Bi-directional DGPS Mobile User



Bi-Directional DGPS Ground Station



Instantaneous Impact Point

Instantaneous Impact Point (IIP) - Continuous plot on the ground of where the vehicle would impact.

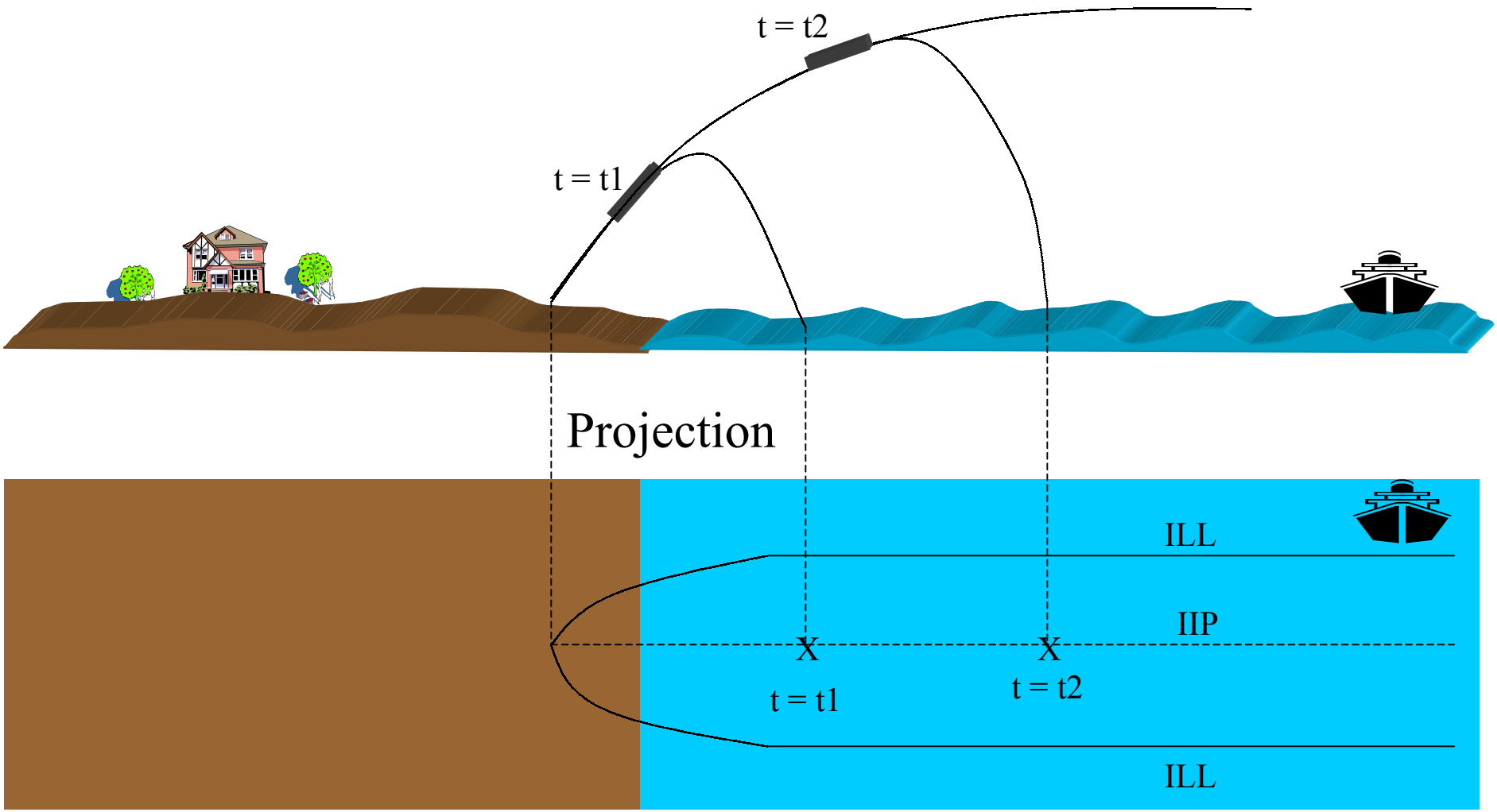
- Computed from the vehicles instantaneous velocity, current position and time to impact
- Displayed in real time during the flight

IIP uncertainties

- Less than 100 ft for the Eastern Range
- Less than 1000 ft for the Western Range

Impact Limit Lines (ILL) - Defined boundaries beyond which significant pieces of debris should not penetrate.

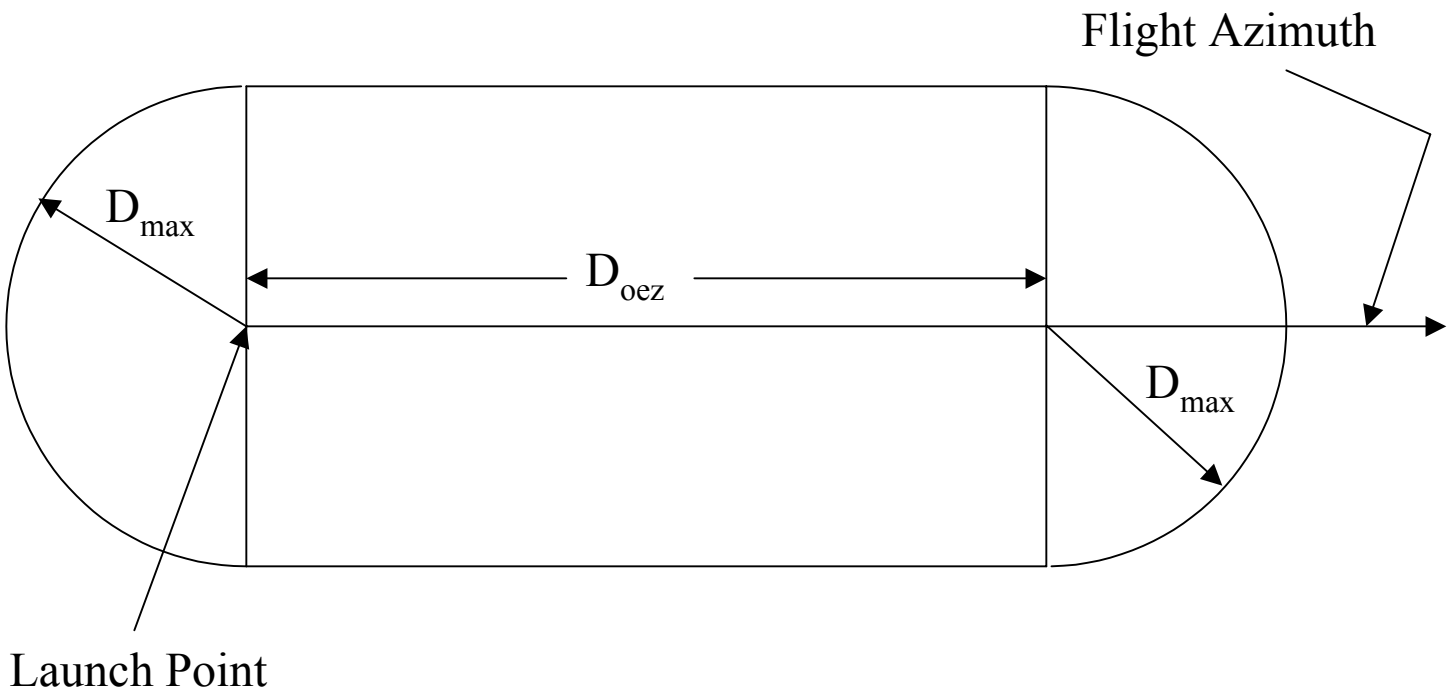
IIP Illustration



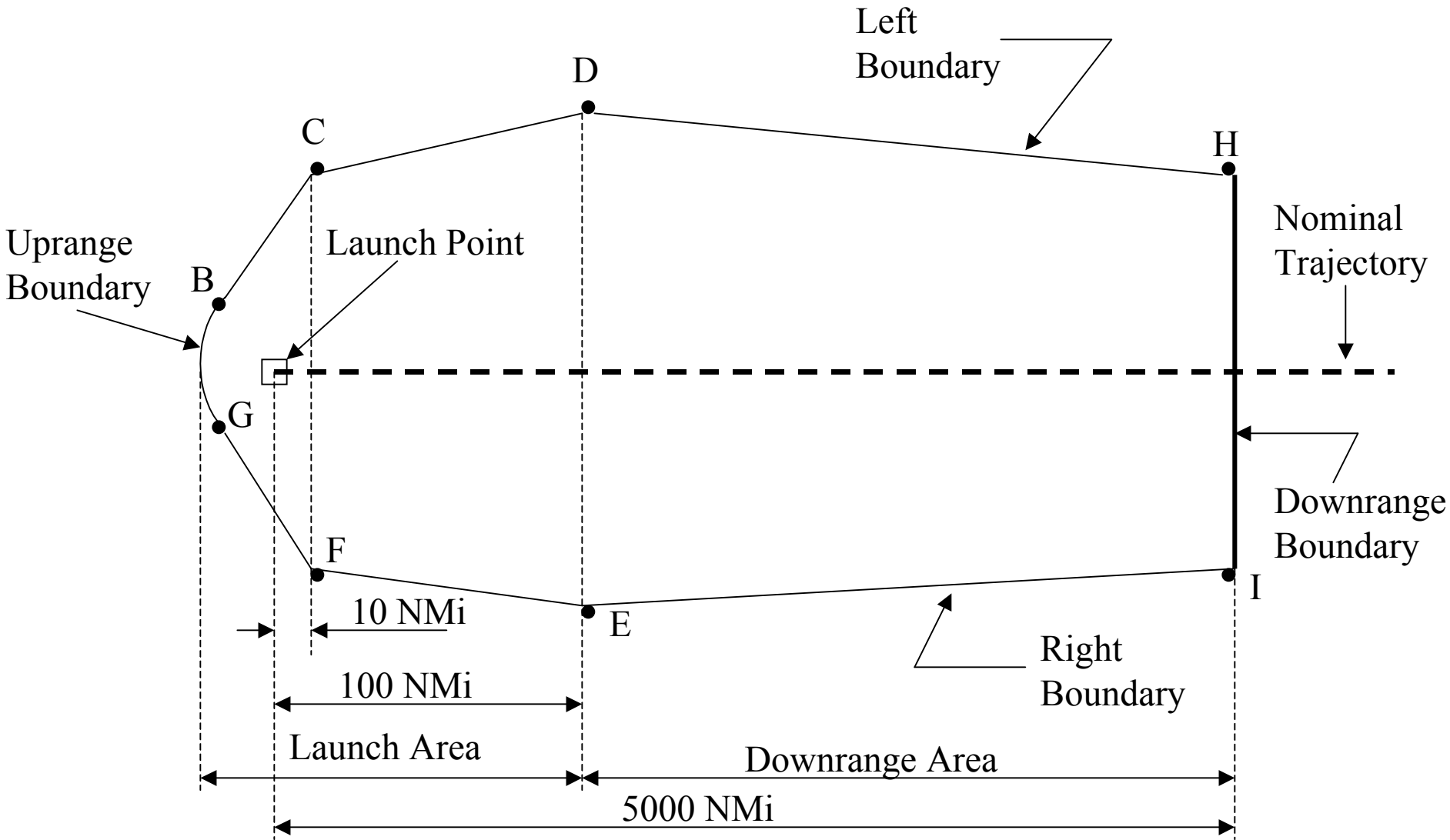
Launch Parameters

- Debris Dispersion Radius(D_{max}): Radius of a circular area indicating limits for flight control and explosive containment.
- Overflight Exclusion Zone: Area in close priximity to a launch point where mission risk is high. Should be clear of public.
- Flight Corridor: Area on the earth's surface estimate to contain majority of the hazardous debris from nominal flight.

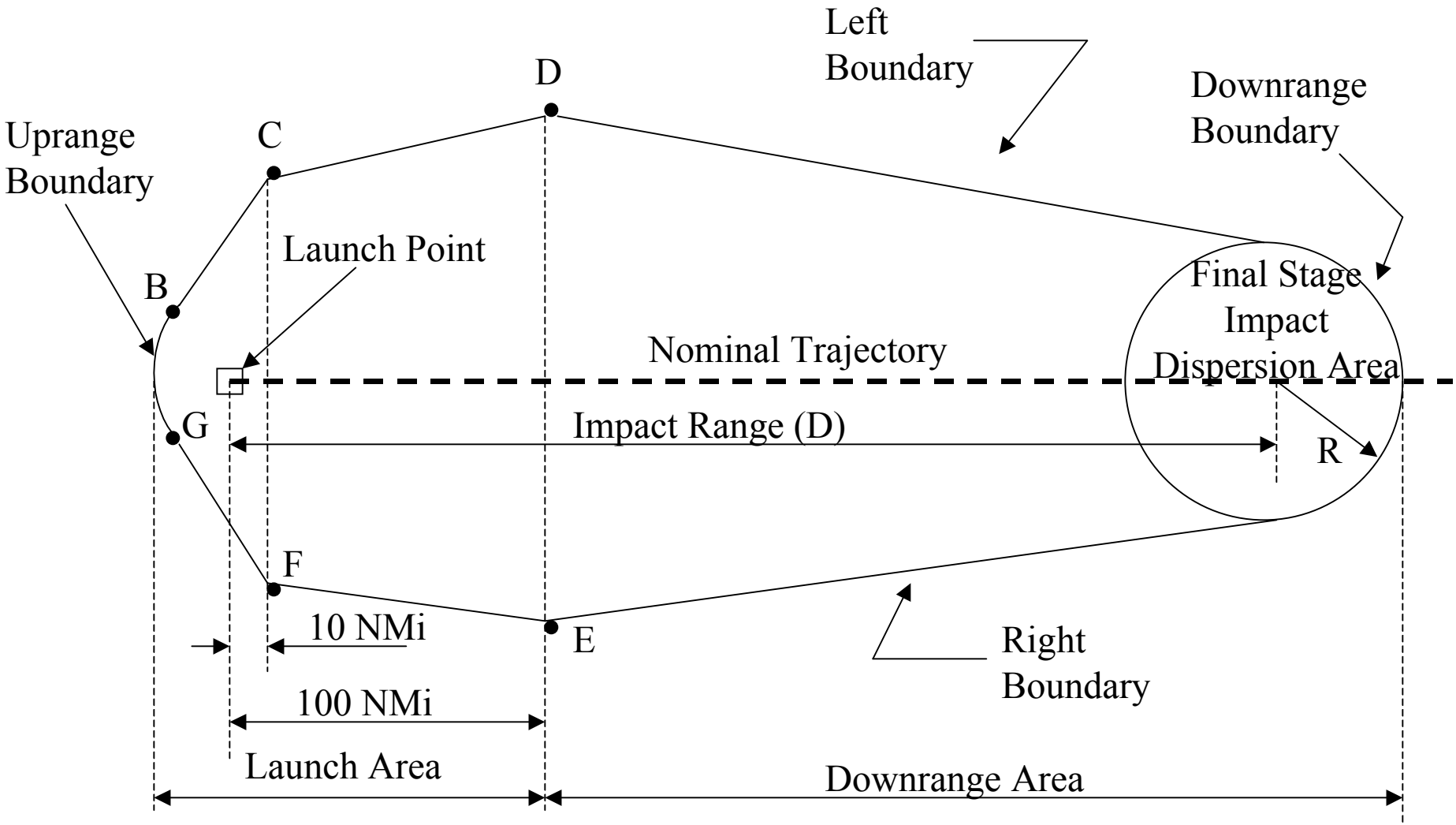
Overflight Exclusion Zone



Flight Corridor



Flight Corridor - Guided Launch Vehicles



Conclusion

- DGPS historically used to provide high accuracy position solution at mobile user for their use.
- DGPS Remote Positioning is applied to autonomous determination of a vehicle position at a remote location.
- Application of DGPS for IIP application is new.
- Bi-Directional DGPS System will provide high accuracy position solution at the mobile user as well as autonomous determination of vehicle position at a remote location for IIP applications.