<u>Satellites Landing Systems</u>

- Discovery of satellites and its progressive development establishes an important means of navigation on earth.

- Today satellite based navigation system used for position update of ship, navigation of land vehicle, intense development for aircraft navigation system as landing system and space navigation .

- GPS based navigation system now exploring the huge applications of every day event of human being, this causes due to advancement of satellites in universe.

- Satellite navigation systems mostly comprised of a system of satellites that transmit radio signals.

- Appropriately equipped aircraft receiving these transmitted signals can derive the 3-D position, velocity and time.

Navigation Systems discussed here:-

1. NAVSTAR Global Positioning System(GPS) - (US)

2. Global Orbiting Navigation Satellite System(GLONASS)-(Russian)

3. Global Navigation Satellite System(GNSS) - (ICAO & RTCA, Inc)

4. Navy Navigation Satellite System(NNSS) - (US NAVY)

5. Tsikada -(Russia, similar as NNSS)

- Both GPS & GLONASS are ranging systems. They provide range and range-rate measurement.

All the above navigation systems have overall common system configuration as below:-

Three:-

1. A space segment
2. A control segment &
3. A user segment

- A space segment:- Comprised satellites constellation made up of multiple satellites.

provide:-

Navigation Frame of Reference

Transmit the Radio Signals-user collect info. For nav. Solu.

- A control segment:- Three Measures Elements:-

Monitor Stations-track satellite signals and collect measurement

Master Control- determine satellite's ephemeris and time history

subsequently upload parameter that satellite modulate

on transmited signals

Ground Antenna-perform upload & general control of satellite

- A user segment

Receiving Equipment and processors

Satellites Landing Systems

- Operation Approach called *Special Category I Precision Approach Operations* Using DGPS.
- The unique requirements of the approach and landing phase with regard to accuracy, integrity, and availability have led to the development of additional *GPS Augmented Method*.

Principle of DGPS:

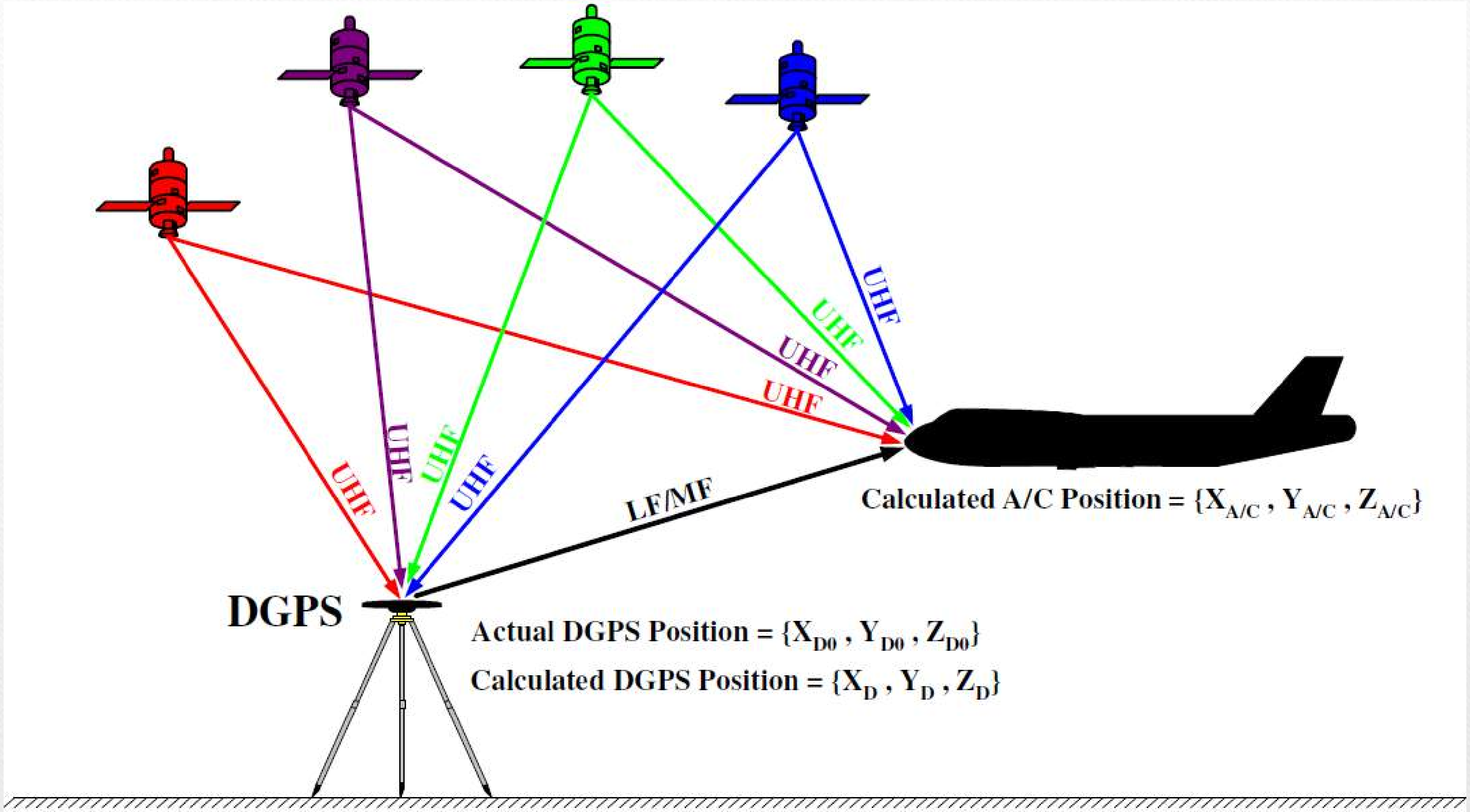
GND system used to increase GPS accuracy. In fact, DGPS is typically found in airports in order to bring a more precise A/C position fix during the A/L phases.

As for the A/C, it must be equipped with a GPS-Rx so that signals from both SAT and DGPS would be observed to correct position errors.

A/L-Approach Landing
A/C-Aircraft
SAT-Satellite
DGPS-Differential Global Positioning System

DGPS

Satellites Landing Systems



DGPS used to correct A/C position fix

Satellites Landing Systems

- **On the GND:**

1) *Rx-Tx:* *DGPS system.*

2) *Frequency:*

- *Rx:* UHF *[used to calculate DGPS position fix]*
- *Tx:* LF/MF *283.5 – 325 kHz [used to transmit correction signal to A/C]*

3) *The DGPS is stationary, therefore its actual {LATD0, LOND0, ALTD0} is well known. Then It can be transform to {XD0, YD0, ZD0}.*

4) *4-SATs to obtain a 3D position fix for the DGPS. This calculated position is identified as {XD, YD, ZD}.*

5) *The DGPS then takes the difference that exists between the actual known position and the calculated position obtained using GPS SATs.*

Satellites Landing Systems

- Even if DGPS is located on the GND, it still has a height for its antenna and therefore, we consider a *3D* = {*LAT, LON, ALT*} position rather than a *2D* = {*LAT, LON*} position.

$$\Delta = Calculated\ Position - Actual\ Position$$

$$\Delta = \underbrace{\begin{pmatrix} X_D \\ Y_D \\ Z_D \end{pmatrix}}_{\text{Calculated DGPS Position}} - \underbrace{\begin{pmatrix} X_{D0} \\ Y_{D0} \\ Z_{D0} \end{pmatrix}}_{\text{Actual DGPS Position}}$$

6) *Ideally, Δ should be roughly zero; however, most of the time this is not the case, and therefore the Δ information is transmitted to the airborne GPS-Rx in the form of a correction signal.*

Satellites Landing Systems

- **In the A/C**:

1) *Rx:* *GPS-Rx system.*
2) *Frequency:*
   - *Rx:* UHF *[used to calculate A/C position fix]*
   - *Rx:* LF/MF *[used to observe correction signal from DGPS]*
3) *Range of Operation* *370 km*
4) *Again, the A/C obtains its 3D position fix using the 4-SATs.*
5) *Then, the GPS-Rx detects the correction signal that contains the information and performs the following correction:*

$$Actual\ Position = Calculated\ Position - \Delta$$

$$Actual\ A/C\ Position = \overset{\substack{Calculated\ A/C \\ Position}}{\begin{pmatrix} X_{A/C} \\ Y_{A/C} \\ Z_{A/C} \end{pmatrix}} - \Delta$$

- *Range of Operation*- In other words, the maximum distance that separates the GND DGPS and the airborne GPS-Rx cannot exceed *370 km*.

Carrier Landing Systems

Advantages:

1) *GPS is quite accurate; however, using DGPS pushes its accuracy even further.*
2) *GPS/DGPS makes A/L guidance every precise as oppose to ILS and MLS.*

Disadvantages:

1) *Errors:*

Accuracy	Errors [m]
Horizontal (i.e. LAT & LON)	1.3
Vertical (i.e. ALT)	2

Typical DGPS errors

Global Positioning System – GPS

Principle:

- Provides A/C position fix (3D).
- This technology is without any doubt the most precise system used in NAV by CIV and MIL A/C.
- To understand why, we first need to realize that generally there exist a tradeoff between position fix accuracy and the coverage area in systems seen thus far.
- In other words, we cannot have the best of both worlds. However, we know for a fact that SATs operate at the UHF band (i.e. high Freq), and hence accurate position fix reading.
- As for ensuring a large and excellent coverage area we must place the GPS Transponder (i.e. SAT) faraway in outer space at roughly *20,000 km* form the earth surface, and not on the GND.
- As a result, GPS becomes an exceptional NAV tool ever invented due primarily to its accurate position fix and large coverage area.

Position Fix:

To obtain a **2D** position fix we need at least **3 SATs**. Whereas for a **3D** fix a minimum of **4 SATs** are required.

A least position fix calculation, the size of the dimension and SAT must be equal.

However, from a practical or cost effective approach we will always require an extra SAT.

1) *SAT operate at the UHF band > Signal is an LOS Wave > Wave travels at the speed of light*

6) *To measure the time the signal travels from SAT to Rx would mean that each of these HW must be equipped with an atomic clock. In fact, all GPS SAT have Cs and/or Rb clocks; however, most GPS-Rx have an ordinary quartz timer due to its low-cost w.r.t. an atomic clock. Hence, the measured signal time would not be as accurate as desired, which eventually maps to a vague position fix.*

i : Satellite Number.

c : Speed of light $\left[c=3\times10^{8}\,\text{m/s}\right]$.

T_i : Accurate time it take a signal to travel from SAT to the GPS-Rx [sec].

$\tilde{T}_i$: Inaccurate time it take a signal to travel from SAT to the GPS-Rx [sec].

ΔT : Time factor of inaccuracy [sec].

R_i : Accurate range between SAT and the GPS-Rx [m].

$\tilde{R}_i$: Inaccurate range between SAT and the GPS-Rx [m].

ΔR : Range factor of inaccuracy [m].

$X_{S\text{-}i}$: Satellite X-axis component $[\mathrm{m}]$.
$Y_{S\text{-}i}$: Satellite Y-axis component $[\mathrm{m}]$.
$Z_{S\text{-}i}$: Satellite Z-axis component $[\mathrm{m}]$.

$X_{A/C}$: A/C X-axis component $[\mathrm{m}]$.
$Y_{A/C}$: A/C Y-axis component $[\mathrm{m}]$.
$Z_{A/C}$: A/C Z-axis component $[\mathrm{m}]$.

1 :	$i = 1,2,3$	Logically speaking 3 SATs are required for a 3D position fix.
2 :	$\tilde{T}_i$	Measure the time that it takes for a signal to go from a SAT to a GPS-Rx. This measured time is obviously inaccurate since the Rx does not have an atomic clock.
3 :	$T_i < \tilde{T}_i$ $\therefore$ $T_i = \tilde{T}_i - \Delta T$	The measured inaccurate time is for sure greater than the actual time by a factor of say ΔT.

4 :	$R_i = cT_i = c\left(\tilde{T}_i - \Delta T\right) = c\tilde{T}_i - c\Delta T$ $\therefore$ $R_i = \tilde{R}_i - \Delta R$	The actual distance between the SAT and the observer is nothing else than the inaccurate range minus some factor ΔR.
5 :	$\left\Vert \begin{bmatrix} X_{S\text{-}i} \\ Y_{S\text{-}i} \\ Z_{S\text{-}i} \end{bmatrix} - \begin{bmatrix} X_{A/C} \\ Y_{A/C} \\ Z_{A/C} \end{bmatrix} \right\Vert = \left\Vert \begin{matrix} X_{S\text{-}i} - X_{A/C} \\ Y_{S\text{-}i} - Y_{A/C} \\ Z_{S\text{-}i} - Z_{A/C} \end{matrix} \right\Vert$ $=$ $\sqrt{\left(X_{S\text{-}i} - X_{A/C}\right)^2 + \left(Y_{S\text{-}i} - Y_{A/C}\right)^2 + \left(Z_{S\text{-}i} - Z_{A/C}\right)^2}$ $=$ $R_i = \tilde{R}_i - \Delta R = c\tilde{T}_i - \Delta R$ $\therefore$ $\sqrt{\left(X_{S\text{-}i} - X_{A/C}\right)^2 + \left(Y_{S\text{-}i} - Y_{A/C}\right)^2 + \left(Z_{S\text{-}i} - Z_{A/C}\right)^2} = c\tilde{T}_i - \Delta R$	We know the SAT position $\left(X_{S\text{-}i}, Y_{S\text{-}i}, Z_{S\text{-}i}\right)$, we also know the inaccurate time $\tilde{T}_i$ and the speed of light c. What we want at this moment is to get the A/C position, namely $\left(X_{A/C}, Y_{A/C}, Z_{A/C}\right)$. However, we have another unknown ΔR; this means that the number of unknowns is actually 4 and not 3. To solve for 4 unknowns, we must have 4 equations, i.e. we need data from 4 SATs and not 3. $\therefore \ i = 1, 2, 3, 4$

Satellite #1:	$\sqrt{(X_{S\text{-}1}-X_{A/C})^2+(Y_{S\text{-}1}-Y_{A/C})^2+(Z_{S\text{-}1}-Z_{A/C})^2}=c\tilde{T}_1-\Delta R$	
Satellite #2:	$\sqrt{(X_{S\text{-}2}-X_{A/C})^2+(Y_{S\text{-}2}-Y_{A/C})^2+(Z_{S\text{-}2}-Z_{A/C})^2}=c\tilde{T}_2-\Delta R$	(6.5)
Satellite #3:	$\sqrt{(X_{S\text{-}3}-X_{A/C})^2+(Y_{S\text{-}3}-Y_{A/C})^2+(Z_{S\text{-}3}-Z_{A/C})^2}=c\tilde{T}_3-\Delta R$	
Satellite #4:	$\sqrt{(X_{S\text{-}4}-X_{A/C})^2+(Y_{S\text{-}4}-Y_{A/C})^2+(Z_{S\text{-}4}-Z_{A/C})^2}=c\tilde{T}_4-\Delta R$	

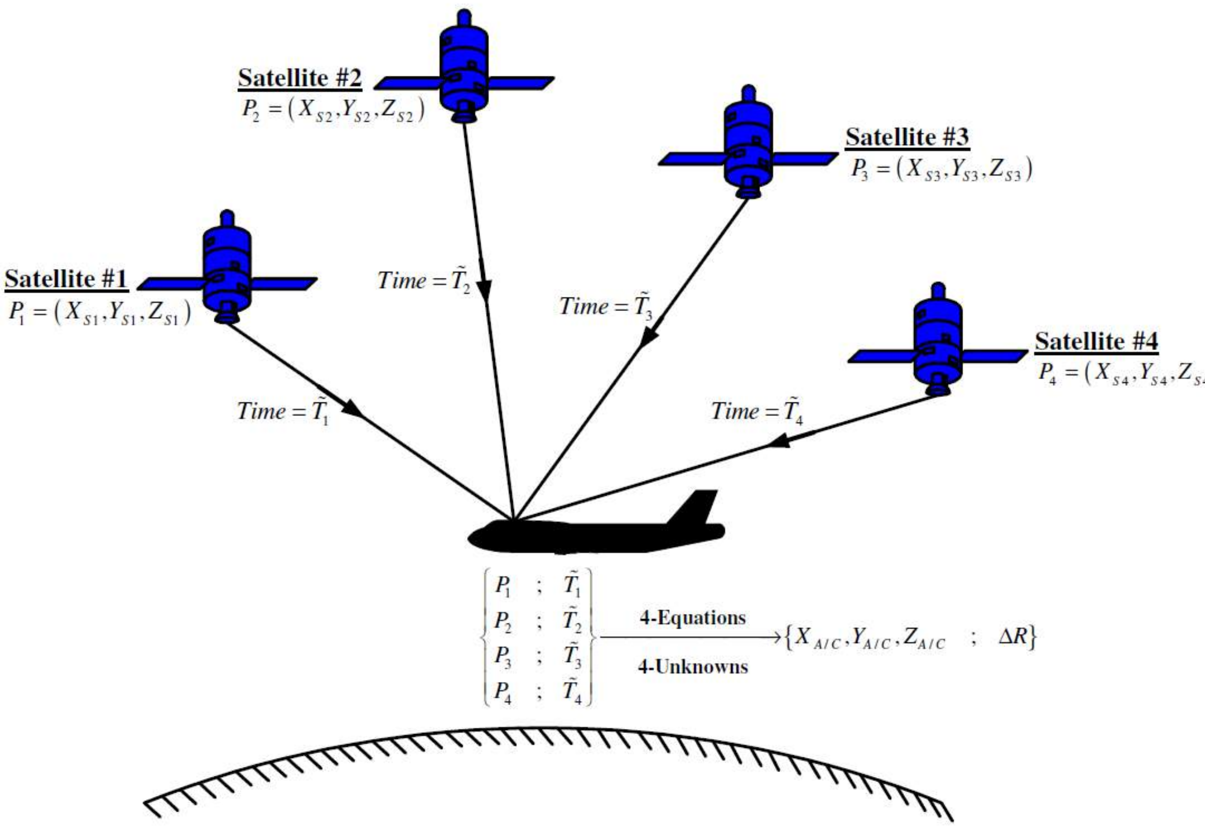


Figure-6.16 A/C position fix using GPS *[K6-21]*

Thanks
Questions