
Carousel INS

Delco Carousel IV-A Inertial Navigation System for *Microsoft Flight Simulator 2002*

Copyright © 2003-2007, Marco Ravello & Gianfranco Corrias, All Rights Reserved

Tutorial Flight

To explain all proper tasks, you have to accomplish for the INS correct use, we'll flight together from Boston Logan Int'l(KBOS) to Miami Int'l(KMIA). Our plane will be the default B737-400, the INS configuration will be triple and our Flight plan is the following:

#	WAYPOINTS	POSITIONS	HDG	ALT	SPD	DIS	FUEL	ETA/ATA
1	KBOS	112.70 N42°21.8 W71°00.3	000°	-----	---	----	28.5	___/___
2	PVD	115.60 N41°43.4 W71°25.7	222°	11000	290	42.6	26.5	09/___
3	TRAIT	N41°17.1 W71°55.1	235°	FL190	290	34.3	25.2	06/___
4	HTO	113.60 N40°55.1 W72°19.0	233°	240	290	28.0	24.1	05/___
	TOC		235°	280	M.780	9.5	23.6	03/___
5	HTO15	N40°43.7 W72°32.1	235°	280	.780	5.1	23.2	01/___
6	GEDIC	N40°08.8 W73°12.1	234°	280	.780	46.3	22.3	07/___
7	ZIZZI	N38°56.4 W74°31.7	233°	280	.780	94.9	20.8	14/___
8	SWL	112.40 N38°03.4 W75°27.8	231°	280	.780	68.9	19.6	11/___
9	SWL12	N37°53.1 W75°35.6	221°	280	.780	12.0	19.5	02/___
1	SAWED	N37°32.0 W75°51.4	220°	280	.780	24.5	19.4	03/___
2	ORF	116.90 N36°53.5 W76°12.0	213°	280	.780	41.8	18.6	07/___
3	WEAVR	N35°51.2 W77°08.0	225°	280	.780	76.9	16.9	12/___
4	ISO	109.60 N35°22.2 W77°33.5	224°	280	.780	35.6	16.0	06/___
5	JMACK	N33°59.3 W78°58.0	227°	280	.780	108.2	14.1	16/___
6	CHS	113.50 N32°53.7 W80°02.2	225°	280	.780	84.8	12.8	13/___
7	MILIE	N31°19.9 W81°10.3	217°	280	.780	110.0	10.9	17/___
8	CRG	114.50 N30°20.3 W81°30.6	200°	290	.780	62.0	10.0	09/___
9	BARBS	N29°18.4 W81°24.5	178°	290	.780	62.1	9.1	09/___
1	ORL	112.20 N28°32.5 W81°20.1	178°	290	.780	46.0	8.3	07/___
2	OHENU	N27°52.0 W81°05.2	165°	290	.780	42.6	7.4	06/___
	TOD		165°	290	.720	48.4	6.6	07/___
3	PHK	115.40 N26°47.0 W80°41.5	165°	240	IAS300	20.0	6.5	03/___
4	BRIKL	N26°08.2 W80°23.3	160°	10000	250	41.9	6.3	06/___
5	KMIA	113.90 N25°47.6 W80°17.4	177°	0	---	21.0	6.2	03/___

1 - PREFLIGHT CHECKS

Our plane is parked, with 29000 pounds of fuel on board with parking brake set, near the main apron at Logan airport.

Switching all three MSU selectors on STBY position we power the INSs and we are ready to start the INS preflight checks.

Setting the light dimming switch as required and selecting DSRTK/STS on all CDUs, we are able to check if there are any ACTION&MALFUNCTION codes, if they are present we can clear them by pushing the TEST switch.

The first digit of RH display should show 0, the last but one 9 and the last 5. Pushing HOLD on all three CDUs the ID program 11 17 appears on the LH displays; pushing again HOLD the ID program disappears.

Now we perform the INS test pushing and holding, one at time, all three INS TEST Switches. We'll should be able to see: all MSU&CDU lights on, all display digits showing 8 and NSEW illuminated and the related INS DME UPDATING green flag in view.(INS#3 does not have a green DME UPDATING flag associated).

Moving the CDU selectors to POS we are going to insert into the INSs the present position. The ramp position may be obtained both, from a parking chart or pushing SHIFT+Z on your computer keyboard. Our ramp position is:N42°21.8 W71°00.3. We will type, on each of the installed INS units:

N, 4, 2, 2, 1, 8, INSERT, W, 7, 1, 0, 0, 3, INSERT

After we have inserted the LAT&LONG ramp position, as present position, we turn back the CDU selectors to DSRTK/STS and we move all three MSU selectors to ALIGN. From now on the INS alignment will start and you can detect it by the accuracy index digit (last but one) decreasing.

The alignment will take about 15 minutes and no airplane movement is allowed. We will spend this time to insert the first nine flight plan waypoint coordinates and perform all other needed airplane checks.

We push/light, on all CDUs, the REMOTE keys. Then we move, on any CDU at our choice, the CDU data selector to WAYPT. We'll use this CDU for the waypoint's insertion.

Selected by the WAYPOINT/DME SEL the position#1 and inserted the ramp coordinates LAT&LONG as waypoint#1 (the same we have inserted as present position for the alignment) we move the WAYPOINT/DME SEL to position #2 and we insert the coordinates of the next flight plan waypoint (PVD). We have to repeat this insertion procedure for all first nine waypoints. According to our flight plan the waypoint n°9 should be SWL 12.We make a little check circle over the n° 9 just to remember that SWL 12 is the last inserted waypoint.

We push all REMOTE keys and check their lights turning off. Next step will be the leg distances check.

With the INS#1 CDU data sel on DIS/TIME we push/light the CDU#1 WPT CHG key. On the CDU#1, by its keyboard, we insert into the FROM-TO display all flight plan legs starting from 0-1. The second one (2-1) will be obtained by the key#2 pushing, the third one by the key#3 pushing etc...

As soon a leg appears on the FROM-TO display we check its distance, on the LH CDU display against the flight plan; naturally the distance of the first leg 0-1 will be = 0.

If the flight plan leg distances are matching with the INS calculated leg distances you can be sure that the waypoint coordinates insertion has been correct.

We push the CLEAR key and we check also that the WPT CHG light goes off. We move the CDU data sel #1 to DSRTK/STS to watch at its alignment and we repeat the same distance check on the INS#2 and#3.

We have now to carry out all other airplane checks. First thing is to listen KBOS ATIS on the freq.135.0. We are receiving "Information sierra":
wind 290°/10ktsG13 visibility more than 10 miles,light rain, 4500scattered 9000overcast
temp 50°F/ 10°C QNH 29.72 arrival Rwy 27 departure Rwy 33L.

Now, from KBOS Clearance Delivery, let's suppose that we receive the following departure

clearance:

Maintain RWY HDG until 3000ft then turn left to HDG 190° to intercept and maintain radial 222° of BOS VOR/DME to PVD as filed, climb at 17000ft.

We have to set our flight parameters in the following manner:

COURSE=222° HDG=331 IAS=250 ALT=17000 VERT SPEED=1500

HDG and ALT switches pushed and related Lts on

Freq NAV#1 112.7(BOS)

Freq NAV#2 115.6 (PVD)

If, in the meantime, 15 mins are passed, we should have on the CDUs the accuracy performance indexes (API) at value 5 or less and all MSUs READY NAV lights on. If they aren't yet, we can accelerate the alignment progress by the hidden FAST ALIGN button below any MSU right upper screw (left mouse click on the screw).

2 - BEFORE START CK LIST

Obtained the engine start clearance we perform the BEFORE START CHECK LIST and being all READY NAV LTS on, all MSU selectors should be set to NAV. Simultaneously the first digits of RH displays turns from 0 to 1 and all last digits from 5 to 4. In the mode index (MI) 4 the INSs are commanded in triple mixing.

The CDUs selectors now should be set in the following way:

INS#1	POS
INS#2	DIS/TIME
INS#3	WIND

We can now close, for the moment, the INS window by the related INS icon. After the engine start, obtained the taxi clearance to RWY 33L, as soon as we leave the ramp we notice the block time: 17:20 zulu. Once arrived at the 33L holding point we receive the clearance to enter the runway and take off.

3 - TAKE OFF

After T.O., with gear up, we maintain the RWY HDG up to 3000 ft, then we turn left on HDG 190° retracting flaps to up position on scheduled speeds.

After flaps retraction, we set the autopilot in command and the IAS on HOLD position checking the related Lt on.

Now the plane is climbing and passing about 8000 ft, the IAS is 250 kts, the HDG 190° and the radial 222° of BOS VOR/DME is almost intercepted.

When on track on HDG 222° to PVD VOR/DME we reopen, by its icon, the INS window and we choose which INS should be coupled with the autopilot. Our choice is INS#2 and for that reason we move the INS NAV MODE SEL #2 to ON.

In this condition the plane will be driven by the INS#2 displayed position calculated by triple mixing.

4 - CLIMB

When 10000ft are reached we can accelerate to the climbing speed 290kts.

Few miles before PVD VOR/DME we set on VHF NAV 2 HTO VOR/DME freq.113.6 and PVD freq. 115.6 on VHF NAV1.

Overflying PVD we set the COURSE 235° to TRAIT intx. The plane should automatically turn from HDG 222° to HDG 235°,the FROM-TO display indication should change from 1-2 to 2-3 and after that you'll be able to see the plane flying on radial 235° from PVD/VORDME to TRAIT intx.

Passing 15500ft we receive now further climbing clearance to FL280 and when near to 18000ft we set on the altimeter the QNE 29.92.

When TRAIT has been reached we select HTO freq.on the VHF NAV1 and on the autopilot panel the course 233° as filed on our flight plan.

Few miles after HTO we reach and maintain FL280 our scheduled cruising level accelerating at cruising mach 0.78.

That's the meaning of the correct use of the INS: to fly automatically by INS, coupled with autopilot, and check what the INS do by the flight instruments.

5 - CRUISE

We want now ascertain if the triple mixing is operative and if the displayed positions have been generated in all three INSs To do that, one at time, we position the CDU data selector to POS and we push the related HOLD key. The HOLD key illuminates and the CDU display should be frozen.

Moving the INS CDU data selector, from POS to WAYPT we can notice the difference between the DISPLAYED POSITION, generated by triple mixing, and the INERTIAL POSITION calculated by the single INS. Repeat the same procedure for all INSs. The differences between DISPLAYED and INERTIAL positions in all INSs are the prove that the triple mixing is working properly.

Going to waypoint 7 ZIZZI we decide, having more than 10 mins of time, to insert further waypoints into the INS. All INS units FROM-TO indicators show 6-7 so we can insert, in this condition, the next five flight plan waypoints. But pushing the WPT CHG key and commanding all three INSs from present position (0) to waypoint 7 we'll make the waypoint 6 available for a new waypoint insertion. We decide for this second opportunity.

In all CDUs, we push in sequence the following keys: WPTCHG; 0, 7 (checking that 0-7 appears on the FROM-TO display) and then INSERT. The INS and automatically the plane are now commanded to proceed from present position to waypoint 7 (ZIZZI).

Six waypoints now may be loaded in all INSs: we push and light all REMOTE keys, we choose an INS for the insertion and we set also its CDU data sel on WAYPT.

Selecting by the WAYPOINT/DME SEL the position #1 we insert the coordinates of the next waypoint SAWED: N37°32.0 W75°51.4.

The same should be carried out for the following flight plan waypoints.The actual insertion will be completed at waypoint 6 CHS VOR/DME.

Put a little check circle over the n° 6 CHS to remember that CHS is the last inserted waypoint.

To be sure that the entered coordinates are correct we have to perform the distance check

in the same way we did on ground at first waypoints insertion. On each INS at time, we move the CDU data selector to DIS/TIME and we push WPT CHG key. After that pushing the keys 9-1 on the related FROM-TO display will appear: 9-1. The DIS shown on the left CDU display should be the same of the scheduled flight plan distance between waypoint #9 SWL12 and waypoint #1 SAWED.

Push now the key 2 and notice that the FROM-TO indication changes showing now 2-1. The new distance indication should match with the flight plan distance between waypoint #1 SAWED and waypoint #2 ORF, we push now the key 3 etc...
We continue in the same manner for all inserted legs.

When all leg distances have been checked we push the CLEAR key to come back to normal operations.

6 - SINGLE DME UPDATING

Left ZIZZI and approaching SWL VOR/DME we move any CDU data selector to DSRTK/STS and we notice that the ACCURACY PERFORMANCE INDEX (API) is arrived at value 9 (the worst accuracy index). It's time to find an off track DME to carry out DME UPDATING.

On the chart we find, on the RH of our track, SBY (Salisbury) VOR/DME freq.111.20.

When SBY VORDME is received by our VHFNAV2 we read its position on the navigation chart: LAT N38°20.7 LONG W75°30.6 we are able to perform a single DME updating.

We choose by the WAYPOINT/DME selector of CDU#2 the position where we want insert the SBY DME coordinates. Our choice is position#1. Moving the CDU data selector to WAYPT and pushing simultaneously on the INS keyboard the keys 7&9 (right mouse click first on key 7 and then on key 9) we enter the DME UPDATE mode and on the FROM-TO display we see a flashing 0.

We insert now the SBY coordinates in the same way we did before for the waypoints.

After that we push now simultaneously the keys 3&9 (right mouse click first on key 3 and then on key 9). With this new pushing we entered the DME elevation mode. SBY elevation is very low (10ft) so we can accept as DME elevation zero. Now by the key 2 pushing we give the signal at INS that the next insertion will be the DME elevation, after that we push 0 and INSERT. By this last manouver we exit the DME elevation mode.

Moving the CDU data selector to DIS/TIME we can also check the distance received by our DME receiver and the distance calculated by the INS. They should be quite same except a little difference consisting the INS accumulated error. If they are matching the coordinates insertion has been correct and we can proceed to command the DME updating by pushing in sequence WPT CHG, then the key 1 and if 1 appears on FROM-TO display INSERT. After few seconds the DME UPDATING GREEN FLAG#2 will be in view and from now on the single DME updating is effective. To exit the DME UPDATE mode (not DME UPDATING) we have to move the CDU data selector in all position but WAYPT and DIS/TIME.

During the Single DME updating we can ensure, selecting DSRTK/STS on the CDU data selector, that the DME updating is operative watching at the accuracy performance index (API) decreasing. The INS 3 accuracy performance index should start to decrease and follow the others, one index late, being the DME updating acquired first by the INSs 1 and 2 and then transmitted to INS 3. The best reachable accuracy index in flight is 1.

When SBY is no longer receivable the DME UPDATING automatically should be terminated

and the relative DME UPDATING GREEN FLAG#2 goes out of view.

Now at our RH we have HRC (Harcum) VOR/DME freq.108.80, position: LAT N37°26.9 LONG W76°42.6. In the same way we did before we can repeat the SINGLE DME UPDATING and maintain the INS accuracy indexes low to perform a better navigation.

7 - DUAL DME UPDATING

We continue our cruise and, left ISO and then JMACK, proceeding to CHS we have 11 mins for a new waypoint insertion starting from waypoint 7 MILIE to waypoint 4 BRIKL.

We accomplish the insertion and the distance check in same way we did before. After this new waypoint insertion we make a little check circle over the n°4 (BRIKL) to remember that BRIKL is the last inserted waypoint.

The accuracy indexes are growing again and in order to have the INSs updated during the last part of our flight we find KENNEDY SPACE DME (TTS) on LH of our track and we set its frequency 112.25 on VHFNAV2.

KENNEDY SPACE isn't yet receivable and we continue our navigation by the VHFNAV1 passing through CHS, MILIE.

After the climb to FL 290 few miles before CRG, as filed on our flight plan, going to ORLANDO (ORL) 112.2 now we receive also KENNEDY SPACE DME so we can perform a DUAL DME UPDATING using, off track at our LH, KENNEDY SPACE DME, and, on track, ORLANDO DME.

We have to accomplish the same maneuvers with the same method we did before for the SINGLE DME UPDATING, first in the INS 2 with TTS DME and then on the INS 1 with ORL DME. As final result we'll be able to see both DME UPDATING GREEN FLAGS in view and the decreasing of accuracy performance indexes will be faster.

We load now the final waypoint KMIA on position 5 and checked its distance from waypoint 4 BRIKL we put a little check circle on N°5 to remember that, with KMIA, the waypoint loading has been completed.

8 - DESCENT

20 miles before PHK (115.4) the ATC calls us for descent clearance and we are instructed to descend to 13000 ft.

Tuning the KMIA ATIS on freq.119.15 we receive the information MIKE: wind 280° 5kts,cavok,temp 75°F/24°C altimeter 3006 departure rwys 27R and 30 landing rwys 27L and 30.

Passing trough FL 180 we set the QNH 3006 on the altimeter and we continue the descent.

9 - APPROACH & LANDING

We receive now further descent clearance to 9000ft. We reduce the vertical speed and we extend the speed brakes to decelerate below 250kts at 10000ft. When the speed of 230kts has been obtained we can retract the speed brakes.

Miami Approach when we are leaving 10000ft, at 40NM from DHP VORDME, asks us to follow HDG130° and to descend to 6000ft.

At this point we have to disconnect the INS from the autopilot and to do that we switch the INS NAV MODE SEL #2 in OFF position. Closed the INS window we are ready to follow the radar vectors for the approach.

We receive: at 30 NM from DHP VOR/DME, HDG 150°; at 25NM, flying at 6000ft, we are instructed to fly HDG 180° and descend to 3000ft; at 20 nm from DHP VOR/DME we start to extend the flaps on scheduled speeds and we set it, step by step, to 15 reducing the speed to 170kts.

Setting on VHFNAV1 the 27L ils freq.109.5, on the course selector the rwy QFU 271°, on VHFNAV2 still DPH VOR/DME and on ADF receiver the LOM (MI freq.248.0) we're sure now that we are ready for the approach and landing.

Finally at 18NM from DHPVOR/DME, the ATC gives us the clearance to fly HDG 250°.

In the meantime we have monitored all these instructions by the 27L LOM (MI freq.248.0) QDMs and we can ascertain that the radar is closing our path on intercepting HDG 250° at 3000ft to permit us to perform an ILS procedure on the rwy 27L of Miami airport.

Set the flaps to 25, on intercepting HDG 250°, reduced the speed to 160kts when we are aligned on ILS localizer and one dot down the glide path, we lower the landing gear checking the related LTs coming green.

Received the landing clearance, intercepting the glide path we set the flaps to full position, maintaining a speed of 140kts and completed the BEFORE LANDING CK LIST we land on the rwy 27L.

After a short taxi we arrive at our gate on central Miami airport apron and with the parking brake set we can shut the engines noticing the block time:20.23 zulu.

10 - POST-FLIGHT PROCEDURE

The post-flight procedure purpose is to verify how much the INS errors both of INERTIAL POSITION and of RESIDUAL GROUND SPEED are grown.

First we have to perform the ERADICATION procedure in order to cancel all updatings and return to the pure inertial INS data.

To do that, on all CDUs:

- 1 - we position the CDU data selector to DSRTK/STS
- 2 - we push the key 1
- 3 - we push INSERT

From now on all INS data are referred to INERTIAL POSITION.

We select by the INSs WAYPOINT/DME selectors the position where we want insert the ramp position as waypoint. We choose position 8. We can have the ramp coordinates both, on a MIAMI parking map or pushing SHIFT+Z on our computer keyboard, and positioned the CDUs data selector on WAYPT we insert it, one at time as waypoint 8: N25°47.6 W80° 17.4.

We move the CDUs data selectors to DIS/TIME and, one at time, we push in sequence the keys: WPT CHG, then 0-8, checking if 0-8 appears on the FROM-TO displays, and then INSERT.

The distances shown on the LH displays:

INS 1= 7NM
INS 2= 4NM
INS 3= 3NM

are the distance INS errors.

Being the DIS errors less than 10 NM the distance check is over. When the distance error becomes 10NMs or more, the hourly drift should be calculated dividing the distance error by the block time. Satisfactory hourly drifts are equal or less than 3 NM/Hour.

Now we move the CDU data selectors to TK/GS and on the RH displays we read the residual GS:

INS 1= 4kts
INS 2= 2kts
INS 3= 3kts

Being those values less than the tolerance of 15kts we can consider the GS check and our tutorial flight over.

END OF TUTORIAL FLIGHT
