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Aircraft On-Board Navigation Data Integrity

A Serious Problem

Transport Canada Database Working Group Paper

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Canada

Executive Summary

Aircraft equipped with Flight Management Systems (FMS) and Global Positioning System (GPS[1]) receivers currently use these devices as a supplementary means of navigation. Data used in these systems lacks a regulatory oversight through the last critical stages of its use.

Quality checked data from published instrument procedures is provided by National authorities such as NAVCAN or Transport Canada to commercial companies such as Jeppesen and Racal. These companies manipulate the data according to loosely applied industry standards, and sell the data to FMS and GPS receiver manufacturers. This data is supplied to aircraft operators on a regular update cycle.

In the near future FMS and GPS will be the only means of navigation. While this will change the certification requirements for the software, there is no regulatory oversight of the data. Of greater concern is the lack of an identified quality control or other mandated, regulated process on the data once it leaves the National authority.

Transport Canada Aircraft Certification Flight Test Branch's experience with a wide variety of FMS and GPS receivers has shown significant problems with the integrity of the data presented to the pilot. FMS procedures do not conform to published procedures, data is missing, potentially misleading or extraneous data is added, and procedures are modified without reference to approved instrument safety criteria. Data is also presented in a different fashion from one manufacturer to the next.

The data used in these devices comes from several commercial sources, and is used differently by each FMS and GPS receiver manufacturer. It is not our task to determine <u>how</u> this data should be verified as being the same as that provided, merely that it is the same, within some appropriate statistical criteria.

Regular updates to this data can affect the previously approved software and hence function of FMS and GPS equipment. There is no process which ensures that the data changes do not compromise either the initial certification or continuing airworthiness.

Transport Canada Continuing Airworthiness does not track FMS/GPS equipment installations, as they are TSO'd equipment. Consequently it would be difficult for Transport Canada to issue an AD against an identified problem. Since it is not possible to identify all the problems that may occur, TC must rely on the manufacturers to issue some sort of recall or other non regulatory notice.

There is no TC representation on the ARINC or RTCA database working groups which set the industry standards. The presence of TC personnel on these groups is critical to ongoing safe integration of GPS navigation in Canada. Representation by NAVCAN is not sufficient as they have no regulatory input.

AARDC has been the identifier of the problems in individual FMS and GPS receivers, because of our participation in all new equipment installations and software upgrades. The

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[1] Throughout this document the term FMS will include GPS equipment. Both use databases.

resource drain is significant and cannot continue at the present pace in view of the demands of domestic airframe manufacturers.

The FAA needs to be advised of our concerns for data integrity and lack of regulatory relationship with the data suppliers and FMS manufacturers. We have been keeping the FAA informed of work through attendance at working group meetings such as Satellite Operations Implementation Team (SOIT), however co-ordination at a headquarters level is warranted. Other airworthiness authorities and safety agencies should also be contacted for support.

There is a more immediate safety issue. We are proposing that an Airworthiness Notice be sent out to warn the aviation community of the problem, and a draft of this AN is attached. It points out the errors found to date and highlights the actions necessary for increased vigilance by operators.

TC needs to co-ordinate internal processes and resources for interfacing with data suppliers, FMS/ GPS manufacturers and foreign regulatory authorities.

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Introduction

Published Procedures

In the not-too-distant past, the only method of conducting instrument enroute terminal and approach procedures was by following printed documents. In most countries, a National source provides this information, which has a quality control process indirectly associated to ensure safe flight.

While some paper instrument flight material is published by private companies, it is not subject to any formal regulatory approval or certification process, and quality control is entirely in the hands of the producers.

Flight Management Systems

Flight Management Systems (FMS) enable complex instrument procedures to be flown automatically (ostensibly reducing pilot workload). Until very recently, these FMS have been used only at high altitude, or in the terminal area, only for lateral navigation, and most importantly were considered from a certification point of view to be a 'supplementary' means of navigation. Any problems with these devices were not considered critical, due to the phase of flight and were often attributed to operator unfamiliarity.

An additional complicating factor in the safety implications is that nearly all of the FMS and GPS receivers are manufactured and approved in the USA, where the Air Traffic Control (ATC) system has nearly universal radar coverage. This helps in detecting errors, whether caused by the crew or FMS.

FMS were typically found only in large jets operated by major air carriers, which have detailed and comprehensive training programs for their highly experienced crews, as well as operating on set routes.

With the advent of approach-capable GPS receivers, this capability is now available in small, inexpensive boxes. Many regional carriers, corporate flight departments and private owners have installed the equivalent to an FMS. These smaller operators typically do not have training programs for FMSs, have greater variety in their operation and relatively inexperienced crews.

It must be stressed that this problem is not only with GPS-related data. It affects all data used in FMSs. Since GPS receivers draw their data from a database, these are also affected.

Implication of "Supplementary Means"

The term 'Supplementary Means' is important to this discussion. It means that these FMS were not, from a certification point of view, the primary means of navigation information. The crew could (and were expected to) revert to or at least cross check against 'raw' navigation information. When navigation aids consisted only of VOR, DME, ADF and ILS, this was not a problem, as even electromechanical instruments provided a visual display of relative navaid position. The flight crew had the final responsibility, but it was easy to cross check the FMS against the raw data.

It should be noted that:

1. software used in the FMS was developed for use as the 'supplementary means of navigation' only (typically DO-178 'essential' level) and not to the higher standard needed for primary means of navigation.
2. no data standards exist for the data used by the FMS.

Present and Near-Future Status of FMS

FMSs are now carrying out vertical navigation and approach procedures as well as GPS procedures. It is now possible to program a 'seamless takeoff to touchdown' flight on an FMS using a data from various sources such as GPS, VOR, DME and so on, as well as aircraft based altimeters.

If the present navigation system were to continue, the present situation might be acceptable, however within 15 years (under the present plans) only GPS will be used for navigation. We already have instrument approach procedures which are based solely on GPS, which means that GPS must be considered, in some cases, as a primary means of navigation. The implications of this are quite profound for FMS certification, discussed below.

Implications of GPS Only Navigation

With GPS only approaches, the pilot has no way to cross check the GPS data presented. In other words, he cannot cross check against a 'raw data' VOR or DME. All the data comes only from the FMS. The FMS thus becomes the primary means of navigation.

Adding to the problem is the lack of a requirement for the FMS or GPS receiver to have a graphic display of waypoints. Many only have a digital display of information such as latitude and longitude.

An error in the software or data from an FMS is thus less likely to be noticed by the crew, as there is no easy, intuitive way to cross check the situation, particularly in a rapidly changing dynamic situation.

All of these points indicate that:

1. any software used in the FMS or GPS receiver must conform to a suitable standard for primary means of navigation
2. any data must be subject to a rigorous quality process or regulatory check

FMS Data Quality Process

Having stated that there is a semi-official (if not official) quality control process associated with the National source paper instrument procedures, it is now appropriate to discuss what happens to the data between being issued by the National source, and it's arrival at the display page of an FMS.

Data is supplied by the National authority (i.e. NavCan or Transport Canada AIS) and provided to a data supplier, possible in an encoded format. There are several data suppliers, as listed below (the list may not be comprehensive)

Jeppesen
Aerad (British Airways)
Swissair
Racal Avionics
GTE Government Services

These data suppliers encode the provided data to their own format, which apparently follows ARINC 424 standards. ARINC 424 is an industry standard which has no official regulatory input or approval. The encoded data is then sold to FMS manufacturers who may apply their own software routines to the data. What the pilot sees on his screen is thus the result of one or two unregulated processes

It will be noted that there has been no mention of a quality assurance process once the data leaves the National source. None is required, nor appears to be followed.

ICAO mandates an update cycle for instrument approach procedures, which is typically 28 days. Thus, as frequently as every 28 days a new set of unregulated data is loaded into an FMS.

Operator Controlled Databases

Several operators of fleets of aircraft have indicated a desire to have a locally modified database. For example, one operator indicated that a means of flight path guidance for engine failure profiles was needed for takeoff flight paths at some airports, and the only way to do this was with a 'canned' routing.

Development of procedures such as this should be encouraged as it will prevent errors due to data entry (a not insignificant source of errors), but only if the process is properly controlled and subject to some sort of quality control process. This process can be overseen within the TC Commercial and Business Aircraft Branch's operations inspection procedures.

It is not known if any FMS manufacturers have features where databases can be set up locally by individual operators, however given enough commercial pressure, this feature will eventually appear, and should be subject to some regulatory approval process.

Implications of Errors in Software or Data

Incorrect data or corrupt software has the potential for significantly contributing to a catastrophic failure, as implicated in the Cali crash. Thus the data and software should be treated the same as any other aircraft component, that is, traceable to their source in order to ensure the other aircraft with the same component can have corrective action taken. Assuming an accident or incident occurs which is caused by a data or software error, it may be impossible to discover the cause of the accident, violating one of the principles of aviation safety and certification.

RTCA Database Working Group (SC181)

The Radio Technical Commission for Aeronautics is a non-profit organization set up to provide a forum for government and industry to address technical aviation issues and recommend minimum operational performance or technical standards. There is representation from the FAA on this group.

RTCA has set up a database working group (Special Committee 181). Their mandate is to develop a data integrity process for GPS data prior to the introduction of the Wide Area Augmentation System (WAAS) GPS system in 1999. A draft of this standard (RTCA DO-200A) was published for industry comment in July 1996. It is not known when the final version will be published. It is not clear if DO-200A would apply to all data, nor is it clear if it would have any legal status as a regulatory document.

Even if it is given legal status, it is focused solely on maintaining integrity during data handling. not ensuring that the data correctly reflects the published procedures.

Reports from this working group indicate that progress is very slow, and does nothing to alleviate the problems outlined in this paper.

It should also be stressed that the RTCA working group will only be interested in GPS-related data, when we know that a great number of the airliners using FMS do not have GPS equipment installed, but rely on databases nonetheless.

It is feasible that the process which RTCA eventually develops for WAAS GPS data could be used for a quality control process for other navigation databases.

ARINC 424 Data Coding Standards

ARINC is a joint industry / users group founded to ensure interoperability of equipment, and as such has very limited input from regulatory bodies such as the FAA and TC. They publish standards such as ARINC 424 for use between manufacturers.

ARINC 424 dictates the format for navigation data used by FMS and GPS receivers. Detailed review of ARINC 424 reveals that it adds criteria for convenience of handling, sometimes ignoring instrument criteria such as obstacle clearance. The intent of the National authority procedure designers have no insight into the workings of ARINC 424, and use of this standard does not guarantee the published procedure will be duplicated. An example of the hidden coding is shown in Example 8, ILS Transitions.

Transport Canada Aircraft Certification Branch, Flight Test Section, Experience

Our experience with FMSs and GPS receivers and their data has not been good. We used a methodical approach but, as the problems are random and different from FMS to FMS, problems are often found more by good luck than management. This only serves to highlight the nature of the problem.

We have tested a variety of FMSs and found problems of one sort or another with every box. In some boxes the problem appeared to be with the data supplier's data, in others with the software routines used by the FMS manufacturer.

In many cases, Transport Canada were first to find the problem and report them to the manufacturer, as well as the FAA.

Detailed examples are given in the attached Appendix A, but in general :

- Published procedures do not appear in the database
- Unpublished procedures may appear in the database
- Incorrect waypoint identification
- Waypoints are added to or deleted from published procedures
- Courses and bearings are different than published procedures
- Vertical Navigation information has many discrepancies
- Localizer intercepts may fall outside the published and safe areas of the approach
- Duplicate Identifiers are not all displayed
- Instrument approach procedures are not displayed in the same manner as appears on the published material
- Some navaids are not in the database (The GPS receiver TSO C-129 requires all material that appears in print to be in the database, and by inference, only that material and no other should be there)
- 'Hard' Altitudes cause violation of obstruction clearance criteria.

One FMS tested recently had problems on 24 of 28 approaches sampled.

In short, published procedures are not duplicated faithfully

Operator Experience

Many operators of FMSs have found problems with data (and software). These problems are often not recognized fully due to inadequate knowledge on the part of the operator, and if recognized, not reported beyond company level. Efforts by Transport Canada to have more information collected are part of this paper.

Database Updates Affecting Existing Equipment

Database updates can have adverse effects on previously satisfactory equipment. In one example, including GPS approaches on the database made the equipment dump all the existing navaids whenever a GPS approach was selected. In this case, the database update did not just affect the data, it affected the entire operation of the equipment.

Airworthiness Issue - TSO and Initial Installation Certification

The software used in each FMS is required to meet a TSO level of validation. The current TSO C115b standards do not address the software level required for a primary means of navigation system. It appears that it would not be feasible to ask that existing installed software in existing, certified FMS and GPS receivers meet the criteria for primary means of navigation, although it may be possible to re-write re-validate and re-install new software in these equipments.

Furthermore, while it is necessary to ensure that the physical parts of the aircraft function correctly in all areas of the world by means of hot and cold weather tests, etc., there is no requirement to ensure that the FMS equipment performs its intended function in all areas. Currently testing of FMS and GPS receivers for approval appears to be only a limited check of some procedures in the immediate area the certifying authority or agency.

The function of the FMS must be certified for all the areas of intended operation, not just the area where the certification takes place.

Transport Canada Aircraft Certification is in the position of having to certify equipment which has been granted approval in the USA, yet clearly does not meet the requirements of para 1301 of FAR's 23, 25, 27 and 29, namely "performing it's intended function".

Airworthiness Issue - TC Continuing Airworthiness

At present Continuing Airworthiness does not track navigation equipment and is thus not capable of easily addressing safety problems.

The real problem is a long term one. After the initial certification, the responsibility for continuing airworthiness means that every update cycle (for some boxes this is 28 days), the data should undergo a quality check and the intended function of the box should be confirmed to be unaffected.. Given the seriousness of the problem, this should be corrected within one year.

An additional problem is that there appears to be no regulatory method to ensure that the FMS manufacturers ensure that their data packages work with all existing software versions of their FMSs. For example, there is a GPS receiver which is currently undergoing a major software upgrade due to serious problems encountered in field operations. There is no guarantee (nor regulatory requirement) for the manufacturer to recall all the boxes in use to ensure they work correctly.

A method to track all navigation equipment using a database is needed in order to ensure that Transport Canada can address airworthiness issues when they arise.

Viruses

Although no instances have been reported of viruses affecting this data, it is conceivable that a virus could be introduced. Manufacturers might need to demonstrate suitable protection against this event. This is not an easy subject to address, and to date has been ignored by the manufacturers of FMS and GPS equipment.

Training

Earlier it was mentioned that the problems we have encountered were almost random in nature, and no pattern had been established. This characteristic means that training the operators to overcome the problems is not feasible, as it is only possible to train for known problems.

Self Regulation by FMS Manufacturers

We do not currently permit airframe and engine manufacturers to be self-regulating. Given the serious effects of the software and data on operations, we should not permit the manufacturers of FMS and GPS equipment any less scrutiny.

If we permit self-regulation (which is what a lack of a regulatory process would be) we would have difficulty compelling the manufacturers to communicate any problems on database updates which do not meet necessary standards.

Once a satisfactory process is set up, it would be in line with normal procedures to delegate approvals.

Magnitude of Problem

The problem is not small, and is going to be made more difficult by a rapid increase in the number of GPS based procedures. Canada has about 500 approach procedures, and this is expected to increase to about 700 within the next 10 years. The real compounding difficulty is the number of different manufacturers of FMSs (there are nearly 20) and the number of different models they produce. Every model will need demonstrate some type of quality control process.

Each model treats the data in a different way and will have to be tested separately. For example, some manufacturers package data for Eastern North America, others just for Canada.

If operators are permitted to set up their own databases, the problem becomes that much more complex.

It must be stressed that for reasons mostly related to litigation, we do not wish to certify the data. There are some strong legal implications for not doing this. What we want is a guarantee that the pilot using an FMS will be given the same exact information as that shown on the published procedures. There may be other ways to accomplish this, but we consider verifying a process for quality control of the data would be a satisfactory method.

Is an Audit Required?

We are operating in an area of less than perfect understanding, as ARINC 424 has set standards and database suppliers have loosely applied these. What we can identify is that the data coming out on the screen of an FMS or GPS is not always correct. It may be appropriate for an end-to-end audit of the process to be carried out to identify the areas where errors can be introduced, or assumptions are made which are not universally understood in the aviation community.

Experience of Others

The United States Air Force has recently decided that the problem is so serious that they have set up their own database for use in their navigation equipment. They use a number of commercial, off-the-shelf hardware in some of their transport aircraft, and as a result of the Dubrovnik, Croatia accident, they have also reverted to using US NOAA (National

Oceanographic and Aviation Administration) charts only. Those produced by third parties, such as Jeppesen, have been banned.

Suggested Action

Transport Canada is not in a position to oversee this problem in it's entirety. The majority of the FMSs and GPS receivers come from the USA, the largest supplier of data is from the USA and the largest user base is in the USA. It would be reasonable to expect the FAA to take the lead on this problem.

Our position should be that we have clearly and unmistakably identified serious problems, that we are willing to help the FAA with solutions and that we want this problem solved to safely and quickly.

By issuing an Airworthiness Notice in Canada, we will accomplish the following:

a) the operators will be aware of the problem in simple and clear terms

b) suggested action to ensure flight using this equipment is safe is highlighted

c) those operators who have equipment we have withheld approval for will be able to use the equipment, relieving pressure on regional offices and Aircraft Certification Branch for approval.

Testing by Manufacturers and Certification Agencies

Initial Testing

At present, the testing carried out by the FMS and GPS manufacturers appears to concentrate only on the immediate geographic areas adjacent to their facility. There is no requirement for the manufacturer to demonstrate that they have tested the equipment or data for all intended areas of operation. A parallel in airframe certification would be that only testing in mild, sunny weather would be deemed acceptable for cold and tropical weather, night and IFR conditions.

At a minimum, the manufacturer should be required to demonstrate that the equipment works for all areas of intended operation, and the certification authority should then verify or spot check different areas.

Database Updates

In the fullness of time, it would normal to expect that this process would be automated to ensure that enough of the data is subject to scrutiny during a database update.

Bottom Line - What do We Want?

We want the information the pilot gets from a database to have a quality control process so that the information the pilot gets is as close to identical to the published data as possible within a statistically safe limit.

It will be necessary to determine exactly what those statistically safe limits would be.

Reporting Problems

We know from discussions with operators such as major airlines that they are aware that these problems exist, but they have not been reported in a systematic fashion. We propose that the existing Service Difficulty Reporting (SDR) system be used to report navigation data problems. This is outlined in the draft Airworthiness Notice.

It should be noted that in order to keep the process simple, it is decided only to report discrepancies between published navigation data and that shown by the FMS. No attempt will be made to address the wider issues of FMS software.

We are suggesting that the SDR system be used as it exists, has the capability to collate data, and is accessible by the US and Australian authorities.

The data collected will be used to highlight the problem to the FAA and industry bodies.

Conclusions

The current certification and continuing airworthiness procedures do not adequately address the data used in FMSs. We have experienced many different problems with these systems and are concerned about the lack of a quality control process after the National data is provided. We are also concerned about the level of software used in these FMS, however there may be methods available to ensure this is improved.

Recommendations

Immediate

An Airworthiness Notice (AN) should be issued to ensure the widest possible dissemination of the problem. A draft of this AN is attached as Appendix B.

Co-ordination should be made at the headquarters level with other airworthiness authorities, most critically the FAA.

FMS and GPS receivers testing should include all areas of the world.

An immediate requirement is to educate the operators that the problem exists and to more accurately record the problem.

Continuing Airworthiness should:

- include IFR approved navigation equipment which uses a database in the list of equipment they track. This will permit Airworthiness Directives to be issued in the event a problem is identified with a particular type of equipment or database supplier.
- collect Service Difficulty Reports (SDRs) on problems related to data discrepancies between published and FMS / GPS data

A means of approving operator-developed databases should be implemented. This might be under the auspices of Commercial and Business Aircraft, Air Carrier inspectors.

As a result of setting up of NavCan, Transport Canada should commit to consistent regulatory representation on the ARINC 424 committee and on the RTCA database working group SC 181.

Long Term

If required, Transport Canada is in a position to restrict use of FMSs on Canadian registered aircraft. As nearly all of FMSs are manufactured in the USA, we are not in a position to legislate requirements at the most appropriate level for either initial or continuing airworthiness. In consideration of harmonization, it would not be advisable to put into place regulatory requirements that differ from those of the FAA. Consequently, it is recommended that the Transport Canada concerns be communicated to the FAA, at the appropriate headquarters executive level. with the intent of encouraging the FAA to initiate higher priority in addressing the issues.

Appendix A Examples

Example 1

FMS Procedure Different from Published Procedure

North Bay Ontario (CYYB) Runway 26

The published procedure and the procedure from an FMS are shown in Figures 1 and 2 respectively.

The FMS procedure does not duplicate the published procedure. Following the FMS guidance would have resulted in the aircraft climbing during the course reversal, as well as descending below the MDA shown.

Following is the sequence for an approach using the YYB beacon as the Initial Approach Fix (IAF). Altitudes are AMSL.

Expected		**FMS Solution**		**Comment**
Position	**Altitude**	**Position**	**Altitude**	
YYB	2900	YYB	2700	
DARRI	2700	DARRI	2700	
Procedure Turn	2700	Procedure Turn	2700	
		CF	3500	Not normal to climb during procedure turn
DARRI	2400	DARRI	2532	a) Unusual for altitude to be quoted to nearest foot b) Does not agree with published data
Missed Approach Point	1660 (MDA)	Missed Approach	1265	a) Does not stop descent at MDA b) Unusual for altitude to be quoted to nearest foot c) 50' threshold crossing height

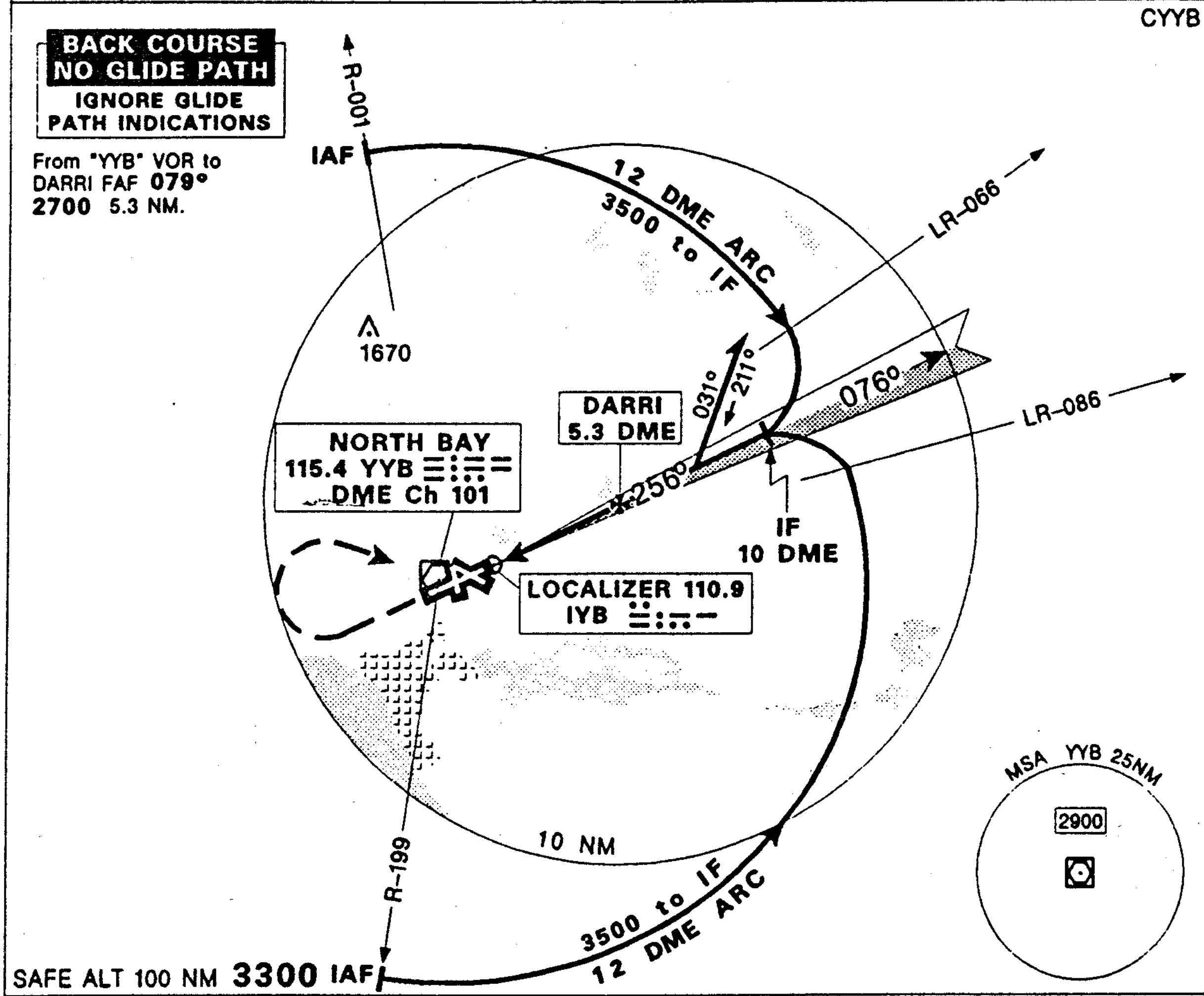
LOC(BC)/DME RWY 26

Geomatics Canada

NORTH BAY
NORTH BAY ONTARIO

ATIS	ARR/DEP TORONTO CENTRE	TWR 118.3 257.2 O/T RADIO	GND	ELEV 1215
124.9 228.2	127.250 132.375 233.4 356.3	118.3 257.2 (MF 7 NM)	121.9 275.8	TZDE 26 1215

CYYB



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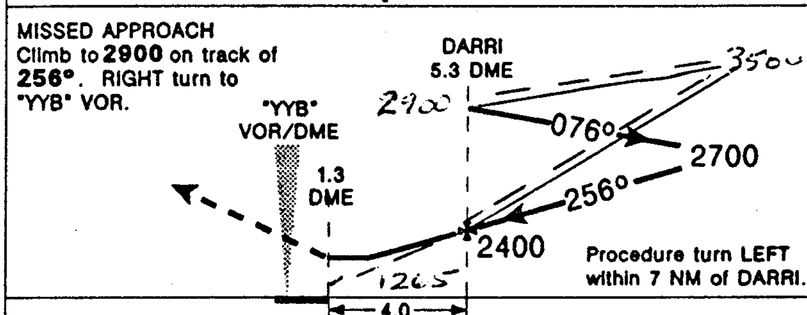
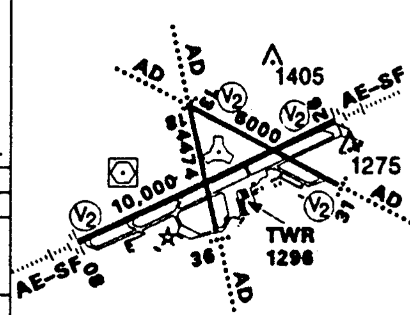


Right hand circuits Rwys 18, 26 & 31
Rwys 13-31 and 18-36 150' wide



CATEGORY	A	B	C	D
LOC(BC)/DME	1660 (445) 1			
CIRCLING	1720 (505) 1½		1760 (545) 2	1820 (605) 2

FAF to threshold 4.0 NM

Knots	70	90	110	130	150
Min:Sec	3:26	2:40	2:11	1:51	1:36

Example 2
Altitude Restriction in Published Data Different in FMS

Quebec City (CYQB) VOR/DME runway 26

The published procedure incorporates an altitude restriction on the final approach leg. This is shown in Figure 3. This is not unusual, and presents no problems when flown manually. The FMS presents two scenarios, shown in Figure 4.

1) Climb after procedure turn

If the pilot follows the vertical guidance, he would be required to climb following the procedure turn in order to reach the 3214' altitude the FMS calculates.

2) Maintain published altitudes

If the pilot prefers to maintain the procedure turn altitude of 2500 feet, and then engage VNAV mode following station passage of the YQB VOR, the pilot would be expecting the FMS to command a descent, however it would maintain level flight until a pseudo glidepath of 3° (which passes through the 920' altitude restriction) is intercepted. Then the FMS would commence a descent. This would take about 2 to 3 miles and cause concern that the FMS is not following the published procedure.

FMS Glidepath

The FMS calculated glidepath does not incorporate a level-off at Minimum Descent Altitude but continues to a 50' Threshold Crossing height. Following this guidance alone would mean that the aircraft would descend below Minimum Descent Altitude.

Threshold Crossing Height

The published approach indicates a Minimum Descent Altitude of 649' Above Sea Level. The FMS approach continues this descent to achieve a Threshold Crossing Height of 50' Above Ground Level (349 feet Above Sea Level). This continued descent by the FMS violates the clearances set for this approach.

Quebec City (CYQB) VOR/DME 06

YQB as the IAF and PT transition.

Expected		**FMS Solution**		**Comment**
Position	**Altitude**	**Position**	**Altitude**	
YQB	2900	YQB	2900	
Procedure Turn	2500	Procedure Turn	2500	
YQB	2500	YQB	3214	a) Have to climb from procedure turn b) Unusual to have intermediate altitudes quote to nearest foot c) No indication why altitude is higher than published figure
8 DME	920			No altitude restriction shown on FMS approach
Missed Approach	649 (MDA)	Missed Approach (1)	349	a) No idea what this altitude relates to (not 50' TCH, not published MDA, not normal DH for precision approach, etc.)

QUEBEC/JEAN LESAGE INT

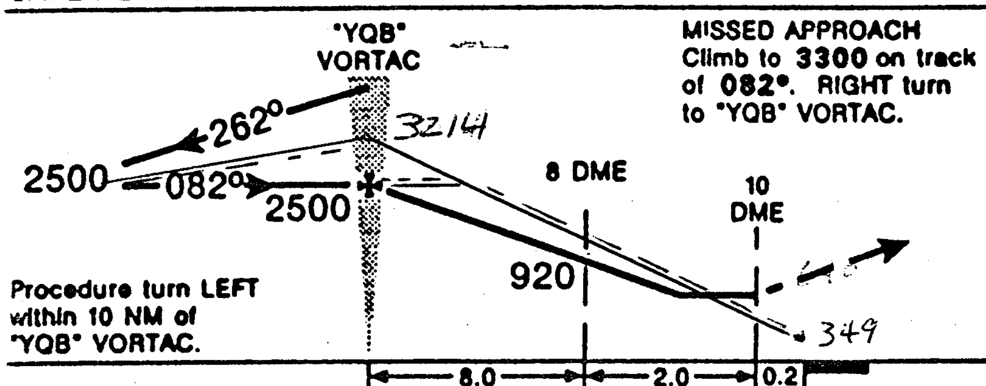
VOR/DME RWY 06

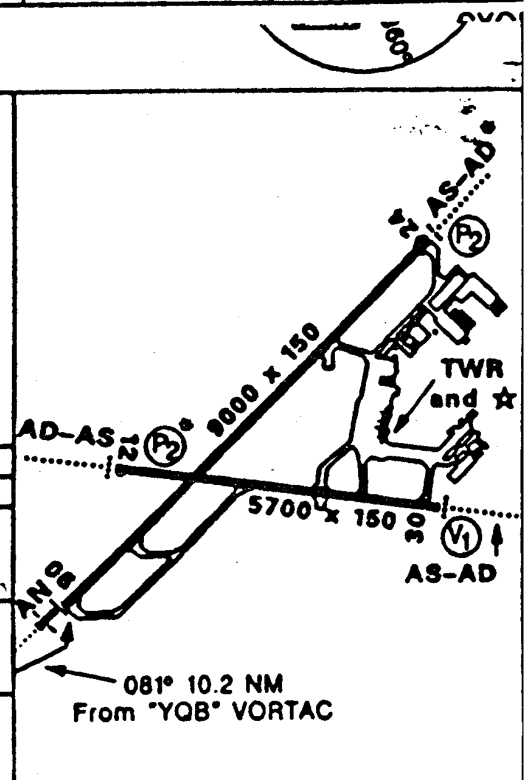
Geomatics Canada

QUÉBEC QUEBE

ATIS	ARR	TWR	GND	DEP	ELEV 244
119.8 (Eng) 128.3 (Fr)	127.85 124.0 322.8	120.3 236.6	121.9	127.85 124.0 322.8	TDZE 06 244

SAFE ALT 100 NM **6000**





CATEGORY	A	B	C	D
VOR/DME	640 (396) 1			
CIRCLING	760 (516) 1½		760 (516) 2	880 (636) 2

Knots	70	90	110	130	150
Min·Sec					

'OR/DME RWY 06

N46 47 36 W71 23 29 VAR 18° W QUÉBEC QUEBEC

QUÉBEC/JEAN LESAGE INTL

-F 29 FEB 96 CHANGE: Comm box

169

NAD83

Example 3
FMS Procedures Do Not Agree with Published Data

St. John NFLD (CYYT) ILS 29

The published data shows three possible transitions, namely:

1) 327° radial at 17 nm from YYT VOR (normal FMS coding would be D327Q)
2) 130° radial at 16 nm from YYT VOT (normal FMS coding would be D130P)
3) 'S' NDB

The FMS codings are respectively:

1) D327Q (agrees with normal FMS convention)
2) YY130 (does not conform to normal convention, and appears to be meaningless- there is no navaid with a YY identifier on the published data
3) YY065 (the 'S' NDB is on the 065° radial from the YYT VOR, but this is not a normal convention for naming a navaid which already has it's own identifier.

As if this were not enough, the procedures for each of these approaches add to the confusion.

D327Q Transition

The following shows the procedure as it would be expected to be shown from an FMS, and compared to the actual FMS procedure

Expected		**FMS Solution**		**Comment**
Position	**Altitude**	**Position**	**Altitude**	
D327Q		D327		
YYT		TESOX		Any information about where the arc approach is anchored is missing
D110				
TESOX				
etc.				

Expected		**FMS Solution**		**Comment**
Position	**Altitude**	**Position**	**Altitude**	
D327Q		D327		
YYT		TESOX		Any information about where the arc approach is anchored is missing
D137Q				
TESOX				

D130P Transition (called YY130 in FMS)

Expected		FMS Solution		Comment
Position	**Altitude**	**Position**	**Altitude**	
D130P		YYT		This infers that the FMS wants the aircraft to go to the YYT VOR.
YYT		D130P		
D110		TESOX		Expect to have YYT shown here as the arc anchor point.
TESOX				

ST. JOHN'S NEWFOUNDLAND

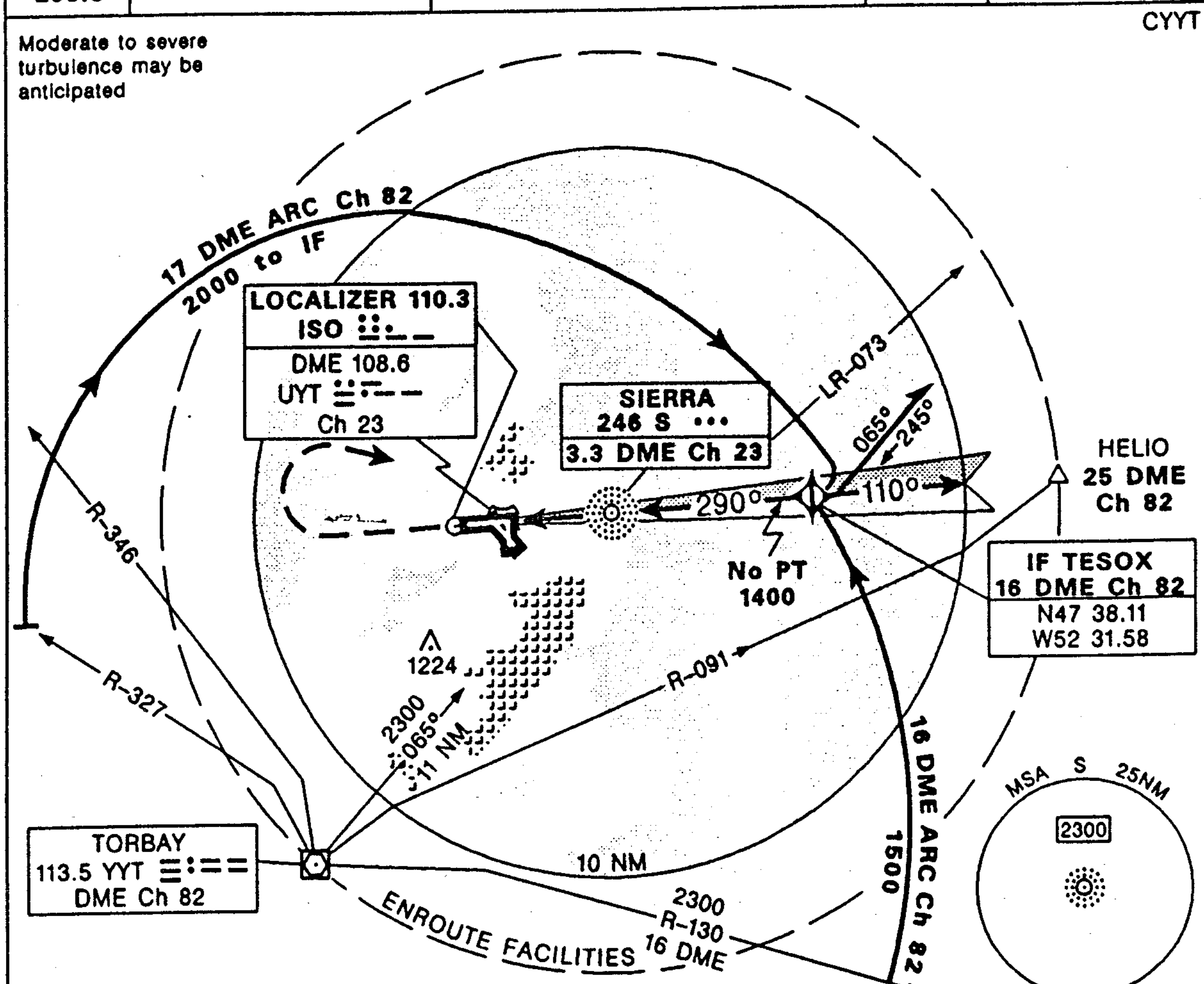
ILS or NDB RWY 29

Geomatics Canada

ST. JOHN'S NEWFOUNDLAND

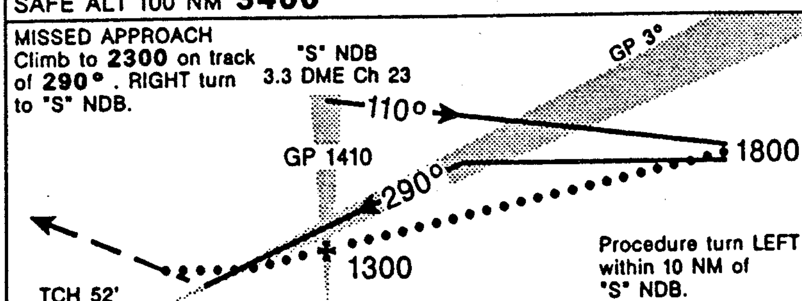
ATIS	ARR/DEP	TWR	GND	ELEV 461
128.0 293.8	GANDER CENTRE 133.15 227.3	120.6 236.6 O/T RDO 120.6 (MF 7 NM)	121.9 275.8	TDZE 29 449

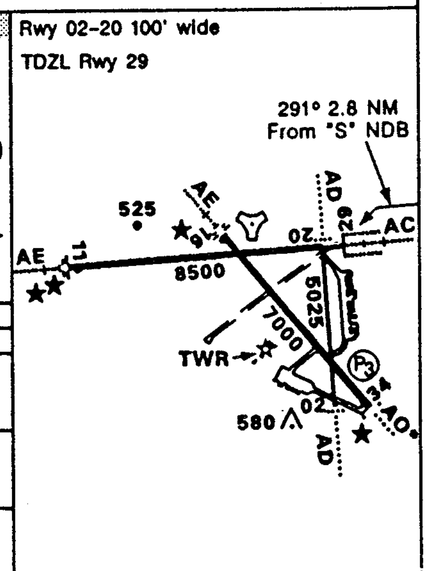
CYYT



SAFE ALT 100 NM **3400**

MISSED APPROACH
Climb to **2300** on track of **290°**. RIGHT turn to "S" NDB.





CATEGORY	A	B	C	D
ILS ILS/DME	**649** (200) ½ RVR 26			
LOC LOC/DME	**800** (351) 1 RVR 50			
NDB	**940** (491) 1 RVR 50			
CIRCLING	**1100** (639) 2		**1160** (699) 2¼	

"S" NDB to threshold 2.8 NM

Knots	70	90	110	130	150
Min:Sec	2:24	1:52	1:32	1:18	1:07

ILS or NDB RWY 29

N47 37 07 W52 45 07 VAR 24° W

ST. JOHN'S NEWFOUNDLAND

EFF 15 AUG 96 CHANGE: Plan view

ST. JOHN'S NEWFOUNDLAND

NAD83

Example 4

Incorrect Identification of Published Data

Ottawa Ontario (CYOW) Runway 25 ADF Approach GPS Overlay

The published procedure uses the OW NDB. One FMS manufacturer calls this BM07 (possibly shorthand for Back Marker 07?) however, Canada has not had marker beacons for at least three years. Other FMS manufacturers do not provide all different transitions to this approach.

Example 5

Changes in Database Coding Affecting Operation

In a more unsettling example, a change was made by Jeppesen in the way that single letter identifiers were coded. Prior to this change, several of the FMS had correct information for instrument approaches with single letter identifiers. It appears that the FMS manufacturers were not made aware fully of the implications of this coding change, and suddenly previously acceptable FMSs had incorrect instrument approaches where a single letter identifier navaid was used.

Fortunately, this occurred just prior to a review of a major manufacturers new equipment, and TC, working with the FMS manufacturer was able to identify the cause of the problem. Other FMS manufacturers did not appear to be aware of the problem.

If this had not been found on a routine check, it is uncertain how long the problem would have persisted.

Example 5
Hard-wired Altitudes

Transport Canada Air Navigation Section identified a problem with Final Approach Course Fix altitudes. Two examples were provided highlighting the problem. The problem was that altitudes used for Final Approach Course fixes were, in two instances, lower than the quadrantal altitudes permitted in that area.

The crews of several aircraft discovered the FMS dropped the "hard" altitude and airspeed published for the FACF on the STAR and continued descent to an altitude 1400 feet lower. Investigation has revealed that the database supplier was, in keeping with ARINC 424 coding standards, coding altitudes selected from the published instrument approach procedure for the FACFs and database defined centreline fixes. We were advised the FACF is coded as a hard altitude and the general criteria was to select the LOWEST altitude applicable at the location of the fix; this could either be the lowest transition altitude, the procedure turn altitude or FAF crossing altitude. There appears to be no consistency in what altitude is coded and in contradiction to the ARINC standards we have found cases where no altitude has been coded.

This causes a great deal of concern for several reasons:

i) The coded altitude is unknown to the procedure developers and aircraft operators until the approach is selected from the database.

ii) If utilised in the wrong context, the coded altitudes could place an aircraft in a situation where it would not have the required obstacle clearance. (ie. The coded altitude may not be suitable for the direction the aircraft is approaching from.)

iii) When linking an approach to a STAR, the FMS will drop the altitude and airspeed coded for the STAR and select the lower hard altitude coded for the approach. Aircraft flying the STAR will descend below the procedurally required altitude, and as well may descend below their required obstacle clearance.

Example

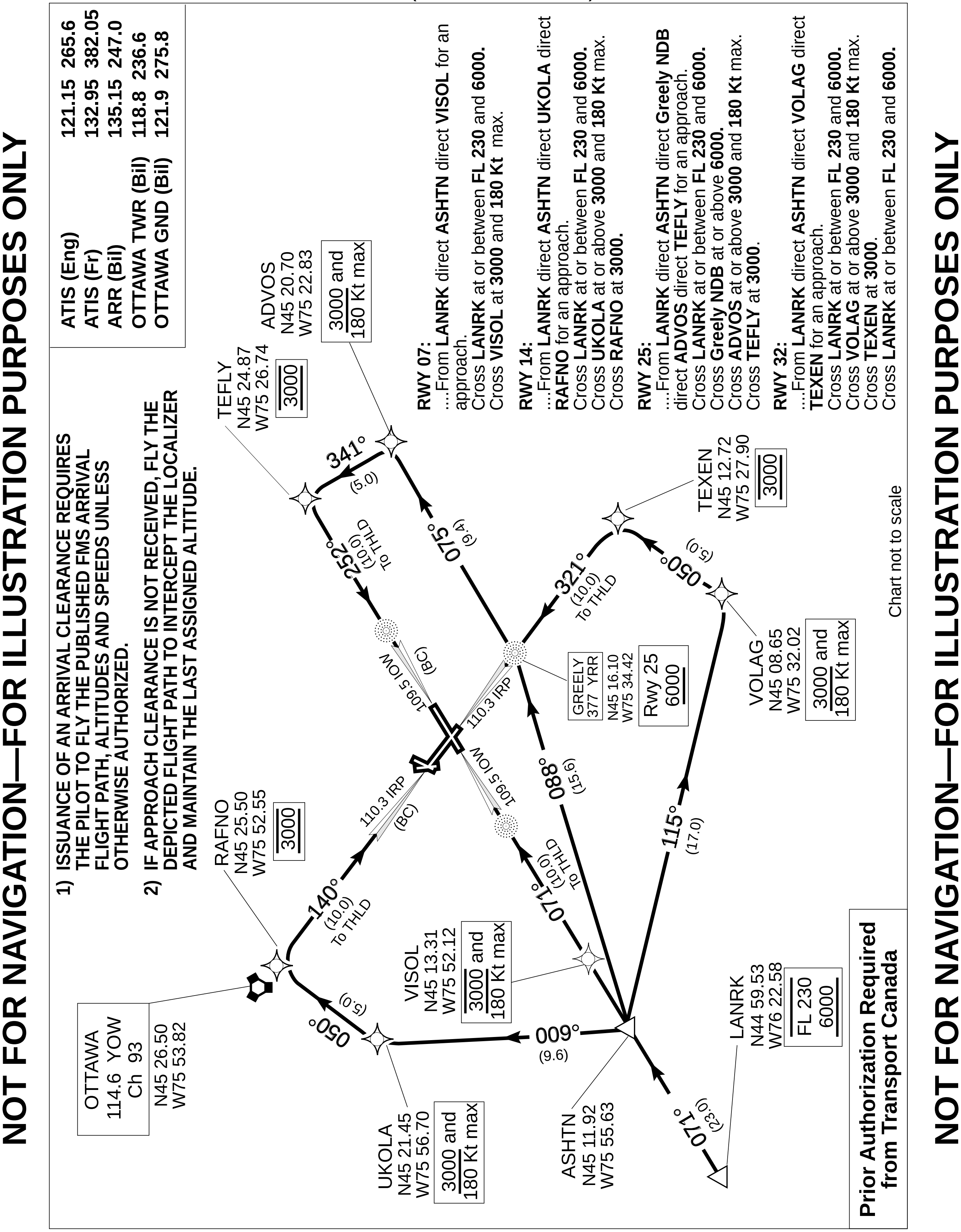
LOC(BC) RWY 25 via the FMS CAPITAL TWO ARRIVAL

The lowest transition altitude on the IAP is 1600 ft. The MSA is 2600 ft in the northeast quadrant and 2000 ft in the southeast quadrant.

The STAR requires the aircraft to cross TEFLY at 3000 ft. and a maximum airspeed of 180 kts.

The database supplier in keeping with the ARINC 424 format has coded TEFLY at 1600 ft in the approach portion of the database and 3000 ft and a maximum airspeed of 180 kts in the STAR portion of the database. Because two different altitudes are coded for the same FACF, when linking the approach to the arrival the FMS will automatically drop the higher altitude and airspeed of the STAR for the lower altitude of the approach. Unless the crew intercedes and manually changes the FACF crossing altitude to 3000 ft, when cleared for this arrival the aircraft will descend to 1600 ft rather than remain at 3000 ft till by the TEFLY fix.

FMS CAPITAL TWO ARR (LANRK .CAPTL 2)



Example 6
FMS Procedure Ignores Obstacle Avoidance Criteria

The ARINC 424 convention has incorporated a feature which is intended to correct for a shortcoming in the performance of some autopilots. It appears that some autopilots cannot safely perform an intercept onto a localizer if the intercept angle is greater than 30°. Many published transitions to localizers are greater than 30°, and ARINC 424 codes these transitions with intermediate waypoints. The following diagram shows a typical implementation of this feature.

It should be noted that the ARINC 424 localizer intercept implementation feature has the following characteristics:

The airspace inside the corner cutting may be outside the protected airspace for obstacle clearance for the approach. It is conjecture, but this may have been a contributing factor in Controlled Flight Into Terrain (CFIT) accidents and incidents.

The aircraft will not intercept the localizer until closer to the airfield. It is not permitted to start descending from transition altitudes to intercept the glidepath until the localizer signal is showing movement. This will put the aircraft higher closer to the field, and will result in higher rates of descent than the approach was planned for. It may preclude safe capture of the glideslope.

Example 7
No ‘Anchor’ for Procedure Turn

CYXU Runway 27 approach

When approaching from the North, following the published procedure, it is necessary to carry out a course reversal procedure turn. This turn is anchored on the published procedure on the EVELYN Intersection. The procedure called up by the FMS may not carry out a procedure turn. On reaching the EVELYN intersection, the FMS will turn the aircraft directly to the runway, and the aircraft will be too high to make the approach satisfactorily.

Example 8

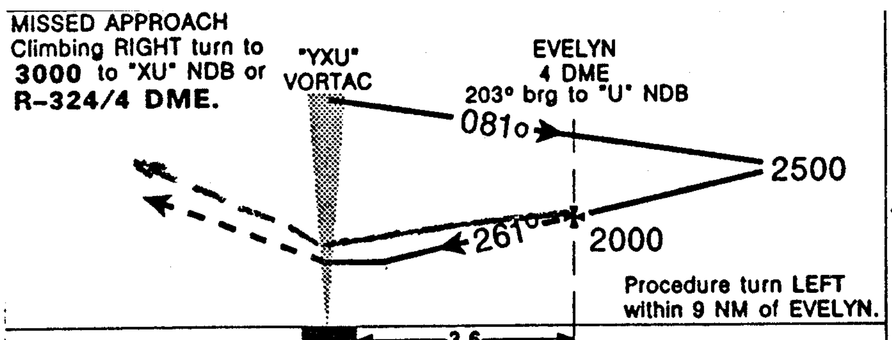
Vertical Navigation 'Pseudo' Glide Path Termination Point.

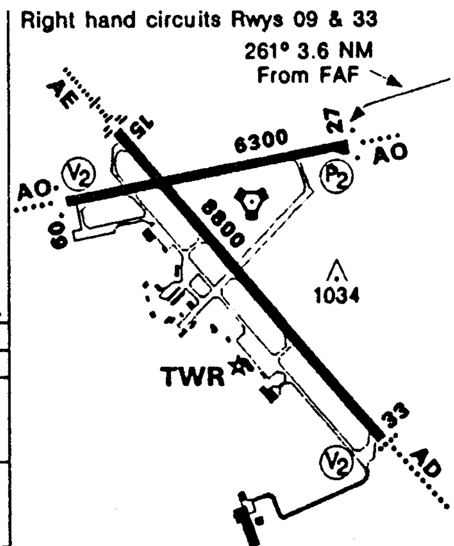
CYXU Runway 27 Approach

If flown using the VNAV guidance provided by the FMS, it will not result in a successful approach. The VNAV provides a 'pseudo' glide path which uses the published minimum descent altitude of 1300' MSL, however the guidance given differs significantly from the published approach.

The published approach calls for a descent from the 2000' height at EVELYN FAF to 1300 prior to the runway. This is a typical non-precision approach with an MDA. It is expected that the aircraft would be leveled at 1300' well before the runway, and be in a position to land if the runway was sighted. If the runway was not sighted the aircraft would continue at that altitude until the YXU VOR was crossed at which point the missed approach procedure would be carried out.

The FMS approach calls for the 'pseudo' glide path to terminate at 1300', but only when the aircraft is over the middle of the airfield. The missed approach point is taken as the YXU VOR, resulting in a very shallow glidepath. The aircraft would not be at 1300' until the middle of the airfield, which is too high to permit a safe landing to be made on Runway 27 without circling. (The circling approach minima is 1420'). Instead of being at an appropriate altitude prior to the runway, the FMS procedure keeps the aircraft high until well past the approach end of the runway.





CATEGORY	A	B	C	D
VOR/NDB VOR/DME	1300 (398) 1			
CIRCLING	1420 (508) 1½		1420 (508) 2	1520 (608) 2

Appendix B Draft Text for Distribution to Aircrew

Background

Recent experience of Flight Management Systems (FMS) and Global Positioning System (GPS) receivers has highlighted a problem with the data used by these devices. This experience has shown that aircraft using instrument procedures derived from these devices may not meet TERPS criteria.

It must be stressed that the problems are not restricted to GPS procedures or equipment.

Problem

FMS and GPS receivers are used to carry out instrument procedures, both terminal area operations and approaches. These devices use data from an on-board database which is updated on a regular basis. The intent of these devices is to duplicate published instrument approach procedures.

Numerous examples have been noted of instrument procedures being produced from these devices which do not duplicate the published procedures. Problems encountered include, but may not be limited to:

Approaches not in Database

Not all approved approaches may be in the database.

Non Published Approaches in Database

Approaches may appear in the database which are not published.

Incorrect Waypoint Identification

Waypoint names may not match those used on the published procedures.

Waypoints Added

Non-published waypoints may be added to procedures, particularly procedure turns, arcs and holds.

Waypoints Deleted

Waypoints in the published procedure may not be in the database.

Course and Bearings Different from Published

The course and bearings shown may be different from published data due to differences between the magnetic variation model used in the database and that used for the published approach survey.

VNAV

VNAV approaches may incorporate altitude restrictions which may be incorrect, or the VNAV guidance may produce a flight path which is different than the pilot would fly manually.

VNAV guidance may produce a VNAV path which may:

- go lower than the published MDA or
- move the glidepath termination point to the normal missed approach point, which may be at a navaid in the middle of the airfield.

VNAV approaches may use a nominal (50’) Threshold Crossing Height for the end of the pseudo-glidepath. This is below any authorized height or altitude for the published approach.

Some VNAV guidance may indicate a climb during procedure turns.

Intercept of Localizers

If the lateral intercept angle from a transition is greater than 30°, the database may create an intermediate waypoint to produce an intercept angle less than 30°. This new flightpath is outside protected airspace and does not meet obstacle clearance criteria.

The localizer will be intercepted closer to the airfield. Since transition altitude must be maintained until localizer intercept, glidepath capture may not be possible or will require a high rate of descent.

Duplicate Identifiers

Duplicate identifiers can be single letter NDBs or multi-letter navaids or intersections. Duplicate identifiers are not unique to Canada.

Not all duplicate identifiers may be in the database.

Approaches with single letter identifier NDBs may use the incorrect navaid for the procedure, particularly for missed approaches.

When a duplicate identifier is identified by the database, the latitude / longitude must be verified.

Changes in Data Formats Affecting Operation of FMS

From time to time, there are changes made to the basic formatting of the database. While these formatting changes are not obvious to the pilot, they may have unexpected effects on the operation of the equipment.

Combining Procedures - Duplicate Legs

When combining procedures, such as a Standard Terminal Arrival Route (STAR) and an approach, duplicate waypoints and legs may be created.

Procedure Turns added

A procedure turn may be added to an database generated instrument procedure where none is warranted or required.

Solution

Long Term

A regulated quality control process needs to be instituted to ensure the data used in the FMS and GPS receivers conforms to the published procedures. This will take some time. For the foreseeable future, operators should exercise prudence.

Immediate

Note

In all cases, and especially in the event of a discrepancy, the pilot is expected to fly the procedures as published in the Canada Air Pilot or other approved procedures.

Pre-Flight

After each database update, prior to using a procedure derived from a database in IFR, each waypoint in each procedure to be used should be manually verified for latitude and longitude and (if appropriate) altitude. Other ‘reasonableness’ checks such as range and bearing may be used.

In-flight

Be vigilant for the navigation equipment to not carry out the procedure as published.

Pay particular attention to:

- procedure turns
- missed approach procedures.

- VNAV altitudes and paths
- duplicate identifiers, especially in missed approaches

Although the Localizer intercept problem in Canada exists, it is not as significant as in the USA and other parts of the world.

Be prepared to uncouple the autopilot if it is coupled to the FMS or GPS.

Reporting Discrepancies

Discrepancies should be reported to:

To Be Detailed

by the normal Service Difficulty Reporting SDR system

As much detail as possible in describing the problem (make and model of equipment, database date, software version, navaid or approach, etc.) would be helpful. There is no need to report discrepancies of less than 2° in courses or bearings.