RNP In Daily Operations

Article **2**

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It was a dark and stormy night in the mountainous terrain of Kelowna, British Columbia. Suddenly, the noise of a jet airplane on final pierced the low cloud cover searching for the runway. Visual contact with the runway was not possible, so the flight crew initiated a missed approach, without any lateral track guidance. The aircraft started climbing, and suddenly experienced engine failure. The crew wondered if they had enough climb performance to safely extract the aircraft from the mountainous terrain. As scary as this scenario sounds, this occurs every day in some part of the world.

In the fall of 2001, WestJet, Canada's national low-fare carrier decided that this was no longer an acceptable manner of operating to provide the highest level of safe air service to 8 million annual guests. WestJet operates the Boeing 737NG aircraft, which has one of the more advanced navigational platforms in the world. Westjet knew there had to be a better way. WestJet determined that the ideal solution was a Required Navigation Performance (RNP) or RNP-based instrument approach procedure. RNP and Area Navigation (RNAV) instrument procedures provide vertical and lateral guidance down to the runway and during a missed approach. With the expertise of Naverus Inc., an RNP RNAV instrument procedure design company, the development of Canada's first RNP RNAV procedure began.

A few years later, Transport Canada, the regulating body for Civil Aviation in Canada, approved Naverus to design RNP RNAV 0.10 nm procedures in Canada. This was a significant achievement because it enabled Naverus to design and produce RNP RNAV procedures to every runway end in Canada without the complications of Transport Canada reviewing each procedure. The Canadian RNP RNAV design criteria is heavily based on the FAA AC 120-29A, Appendix 5. Transport Canada

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has approved WestJet to operate its fleet of Boeing 737NG aircraft using RNP RNAV instrument procedures. This approval allows WestJet to progress from RNP 0.30 nm to RNP 0.10 nm decision heights. A 0.1 nm RNP approach will allow the aircraft to descend to a minimum decision height of 250 ft. Four seasons of operational experience, flight data analysis, and aircraft software enhancements have paved the path to achieve full approval to use these RNP 0.10 nm decision heights.

Obviously, a significant amount of expertise is required to create each RNP RNAV procedure. A few of the requirements are: an initial airport evaluation, procedure design expertise, performance analysis, simulator checkout, flight demonstration, crew and dispatcher training and then revenue service can start. This article will attempt to address some of the challenges for the "Performance Engineer". Simply based on the fact that the procedures are called Required Navigational Performance implies the "Performance Engineer" will have some work to do.

Balked Landing Analysis

Traditional TERPs procedures do not provide obstacle protection for the aircraft during a balked landing (or rejected landing) initiated below the decision altitude or minimum descent altitude. Much like the FAA, Canadian Aviation Regulations specify the minimum Approach Climb and Landing Climb gradients. However, these gradients are generic and do not consider the specific aircraft or terrain environment and therefore do not ensure obstacle clearance during a balked landing.

RNP RNAV procedures, in compliance with RNP approach design criteria, specifically consider obstacle clearance when a balked landing is initiated below the decision height or minimum decision altitude. "A go-around safety assessment is intended to assist operators in assuring safe operations in the rare event of a low altitude go-around with certain failures. It is not intended to preclude or limit operations necessary at any particular location." (Reference AC120-29A) The go-around safety assessment provides new information to the operator that was not previously considered.

Go-Around Assessment Conditions (Reference 4.3.1.8c. – AC 120-29A)
Assessments may assume the following initial conditions:

a) A "balked landing" starts at the end of the Touchdown Zone (TDZ) (first 3000 ft of the designated landing runway).
b) An engine failure occurs at the initiation of the balked landing, from an all-engine configuration.
c) Balked landing initiation speed greater than or equal to VREF or VGA (as applicable).
d) Balked landing initiation height is equal to the specified elevation of the TDZ.
e) Balked landing initiation configuration is normal landing flaps, gear down.
f) At the initiation of the manoeuvre, all engines are at least in a spooled configuration.

A minimum obstacle clearance of 35 feet, within the lateral limits of the RNP RNAV containment, must be provided below the approach climb net flight profile (fig 1).

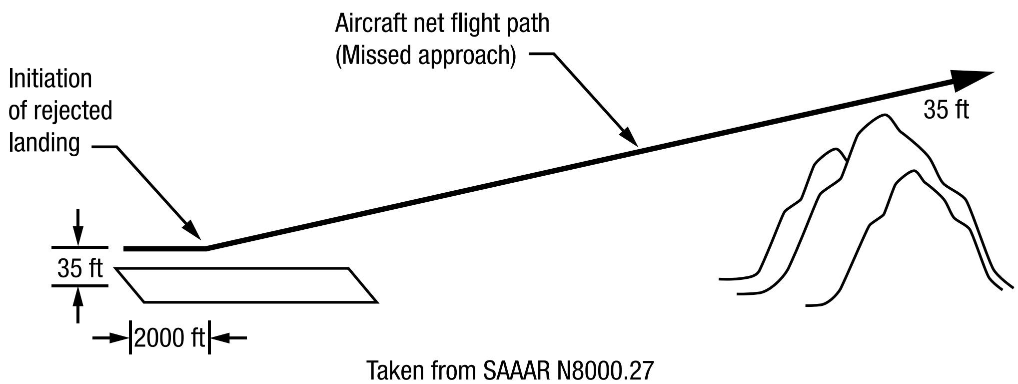

Figure 1. Minimum obstacle clearance

Performing the go-around safety analysis would have been very difficult without a tool like the Boeing Climb Out Program. The balked landing procedures were analyzed over the expected range of operational temperatures and up to the maximum certified landing weight.

Figure 2 shows the RNP RNAV Approach designed for approach to runway 28 in Calgary. The balked landing analysis starts at the end of the touchdown zone and the analysis ends at the hold instigated at YC127 with a requirement to attain an altitude of 5900 feet at this point.

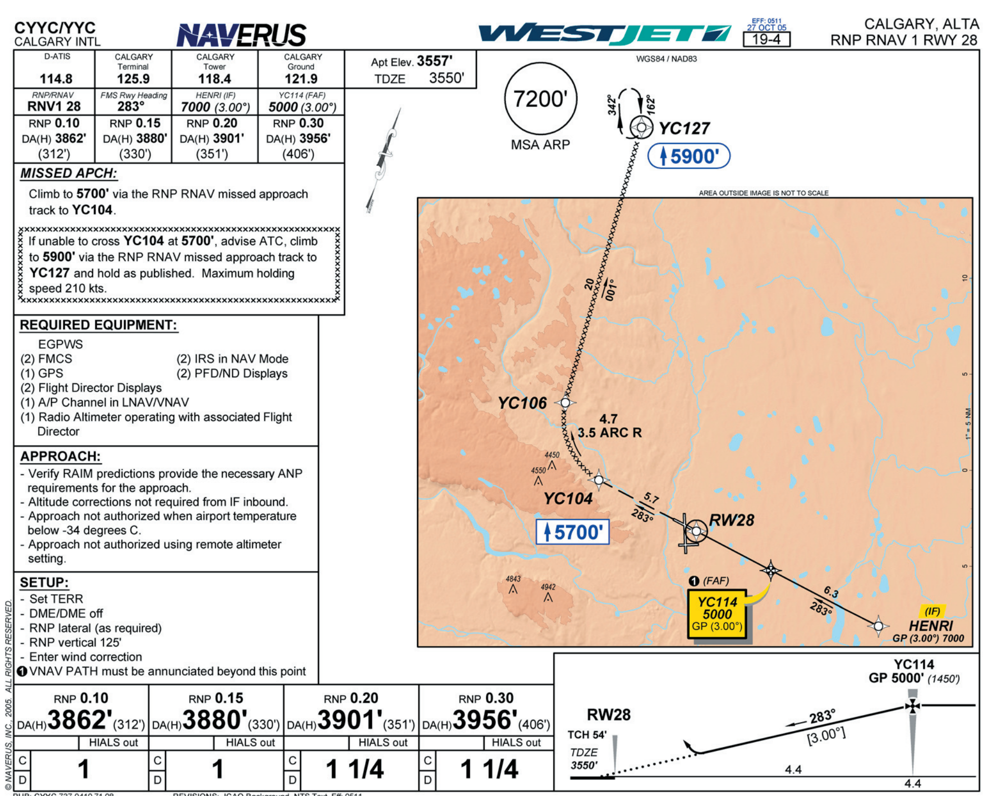

Figure 2. Sample of RNP RNAV procedure

Figure 3 displays the limit weight for a minimum obstacle clearance of 35 feet, net flight path. It is very clear that the maximum landing weight of 129,200 lb. cannot be extracted under these conditions for the entire range of temperatures. For this runway the controlling obstacle is less than 1 nm from the end of the touch down zone and is less than 50 feet above ground level occurring approximately 25 seconds after the initiation of the balked landing.

Performance Analysis by AeroData, Inc. for WetJet Airlines

15-Aug-05

Configuration:

Aircraft:	**737-700**
Engine:	**CFM56-7B22**
Engine status:	**One Engine Inop**
Air Cond:	**Auto (ON)**
Landing Flaps:	**40**
Go-Around Flaps:	**15**
Speed:	**Vref40 + 5**
Max Landing Wt:	**129,200**

Configuration:

Field Elevation:	**3557**
ISA °C:	**7.886**
Enroute Ice OAT °C:	**10**
Eng Anti-Ice OAT °C:	**10**
Enroute Ice Penalty:	**10,000**

ISA + °C	Airtport OAT °C	Min Flight Path OAT	Enroute Ice	Engine Anti-Ice	Weight
30	37.9	33.2	NO	OFF	**110,000**
25	32.9	28.2	NO	OFF	**115,400**
20	27.9	23.2	NO	OFF	**120,700**
15	22.9	18.2	NO	OFF	**126,200**
10	17.9	13.2	NO	OFF	**126,700**
5	12.9	8.2	NO	ON	**126,800**
0	7.9	3.2	YES	ON	**117,200**
-5	2.9	-1.8	YES	ON	**117,600**
-10	-2.1	-6.8	YES	ON	**117,900**
-15	-7.1	-11.8	YES	ON	**118,200**
-20	-12.1	-16.8	YES	ON	**118,600**

Figure 3. Results from Balked Landing Analysis CYYC –Runway 28

* *Enroute Ice penalty required when operating in icing conditions and the forecast landing temperature is below 10°C*

** *Engine Anti-Ice protection was applied where any temperature along the climb segment up to the final obstacle was below 10°C*

Other Items of Consideration

The Transport Canada approved Criteria for Required Navigation Performance (RNP) Instrument Approach Procedure Construction states that "No turns are initiated closer than the opposite end of the runway (DER) and until the point that the MAS is 400' or higher." Because of this requirement and the close in nature of this specific obstacle the RNP RNAV track, for rwy 28 Calgary, cannot be modified to avoid the controlling obstacle(s) by turning since the approved design criteria does not allow turns below 400'.

In this case, the RNP RNAV track over the controlling obstacle(s) follows the published missed approach path, for any instrument procedure. Therefore, it is not an RNP RNAV balked landing assessment but an assessment of any published instrument procedure for this missed approach.

The Go-Around Safety Assessment provides new additional information that has never been developed for traditional instrument approaches. The RNP RNAV procedures provide the safest extraction path for the aircraft during a balked landing with a known level of risk. In addition, RNP RNAV operations are compliant with all Canadian Aviation Regulations. The alternative to flying the RNP RNAV approach would be to fly the Instrument Landing System (ILS), which has not been analyzed and therefore does not provide protection during a balked or rejected landing at all conditions.

Multiple Aircraft Models

When RNP RNAV procedures were first considered WestJet's fleet consisted of 737-200's and newly delivered 737-700's. In 2005 WestJet took delivery of 737-800's and 737-600's which have replaced the 737-200's. However, the developed RNP RNAV procedures were specific to the 737-700 with 22K engines up the maximum certified weights or performance weight limitations for this configuration. It was an easy decision that multiple procedures based on different 737NG variants was not going to work. The philosophy of the company is that all three of the aircraft variants are the same for operational issues. The same crew will operate any of the three aircraft therefore is desirable to have the least number of differences possible. This includes balked/rejected landing procedures. The challenge is to have one RNP RNAV procedure that works for all three of the aircraft (Table 1). This would have to be a compromise because of the performance of the differences of the aircraft/engine combinations.

Aircraft Configurations

Aircraft	737-600	737-700	737-800
Engines	CFM-7B22	CFM-7B22	CFM-7B26
Maximum Landing Weight	120500 lb (54660 kg)	129200 lb (58600 kg)	146300 lb (66360 kg)

Table 1. Multiple configurations

One of the main considerations is the climb gradient capability of the airplanes. AFM-DPI was used to determine the Approach Climb (AC) gradients and Landing Climb (LC) gradients for the each engine/airframe combination at the maximum landing weight. These gradients were determined over a range of temperatures and pressure altitudes. Table 2 shows the set of conditions was used in AFM-DPI:

Analysis Type	Landing Performance
Output Report	Landing Limit Weights
Flaps App/Landing	15/30 and 15/40
Air Cond Bleed	Auto
Anti-Ice Bleed	Off above 10 °C Engine + Wing below 10 °C
C of G	Forward
Pressure Altitude (ft)	0, 1000, 2000, 2500 to 5000 by 500
Temperature (°C)	-40 to +40 by 2
Inflight Icing	Yes below 10 °C

Table 2. Test conditions

Note: The 737-600 was always better than the 737-700 and 737-800 and therefore is not shown in the graphics below.

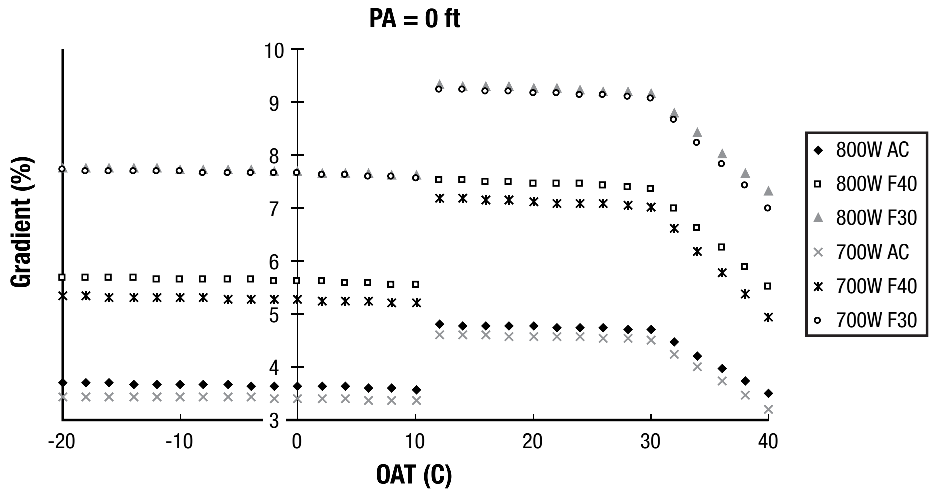

Figure 4. Climb gradient capabilities for sea level pressure altitude

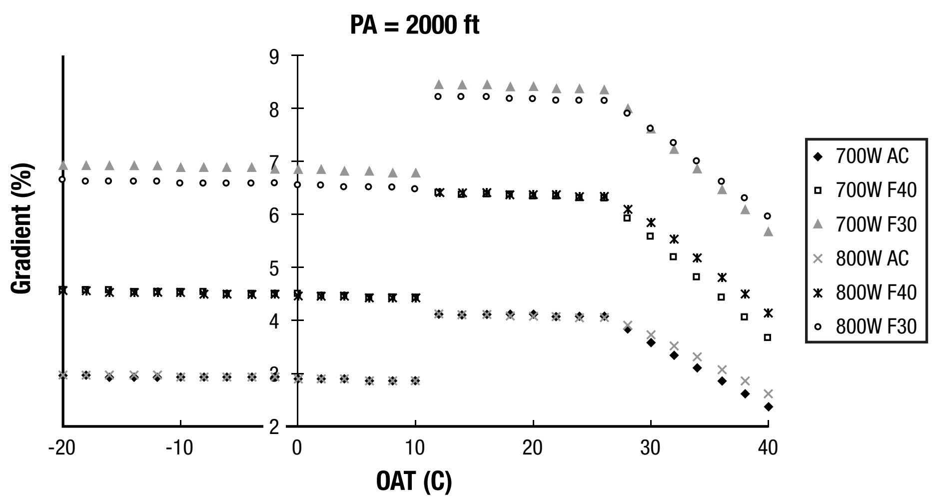

Figure 5. Climb gradient capabilities for 2000 ft pressure altitude

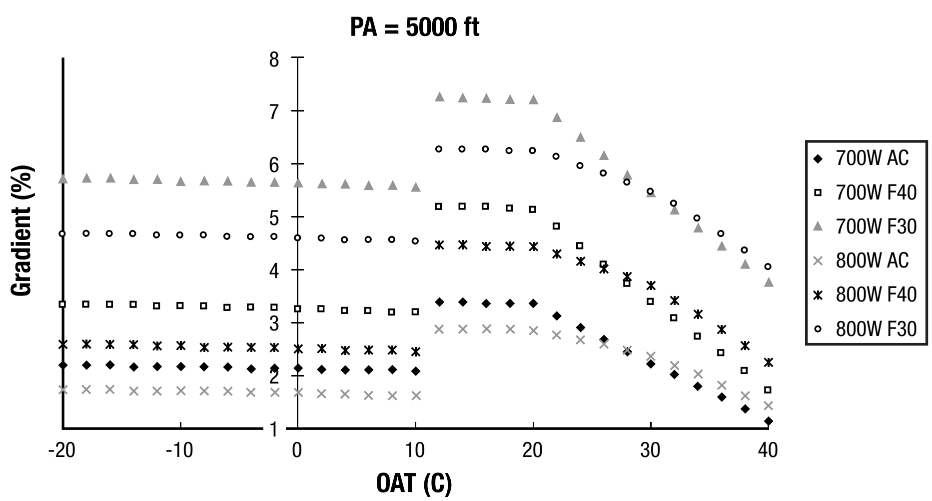

Figure 6. Climb gradient capabilities for 5000 ft pressure altitude

At sea level the 737-700 is limiting when compared to the 737-800 (fig. 4). However at approximately 2500 ft pressure altitude the climb gradient capability of the two aircraft are very similar (fig. 5). When the climb gradients over 2500 ft were analyzed the 737-800 is limiting at cold temperatures, however at warmer temperatures the 737-700 was still limiting (fig. 6).

Pressure Altitude	Temperature	Limiting Engine Airframe		
		737-600	737-700	737-800
0 ft	All	-	Limiting	-
1000 ft	All	-	Limiting	-
2000 ft	All	-	Limiting	-
Above 2500 ft	Above 36 C	-	Limiting	-

Table 3. Summary of the results

If the required RNP RNAV gradients at pressure altitudes above 2500 feet use a design temperature of 36 C then the 737-700/ CFM-7B22 will be the poorest performer of our fleet and therefore the procedures designed for this configuration will be conservative for the 737-600 and 737-800 in our fleets. For pressure altitudes below 2500 feet the 737-700 is always limiting.

An additional consideration that needs to be addressed is the 737-800 aircraft has a higher landing weight than the other models so the associated Vref speeds will be higher. This point still needs to be considered for significance to the RNP RNAV procedures. The momentary descent height after the initiation of a go-around will increase with the higher approach speeds.

Determining a single aircraft that is the poorest performer in the fleet was the initial approach for designing RNP RNAV procedures. However, the Boeing Climbout program allows the analysis of each engine/aircraft combination for each RNP RNAV procedure with very little effort. Therefore it has been decided that each engine/airframe combination will be analyzed with the Boeing Climbout program to ensure the correct performance (fig. 7).

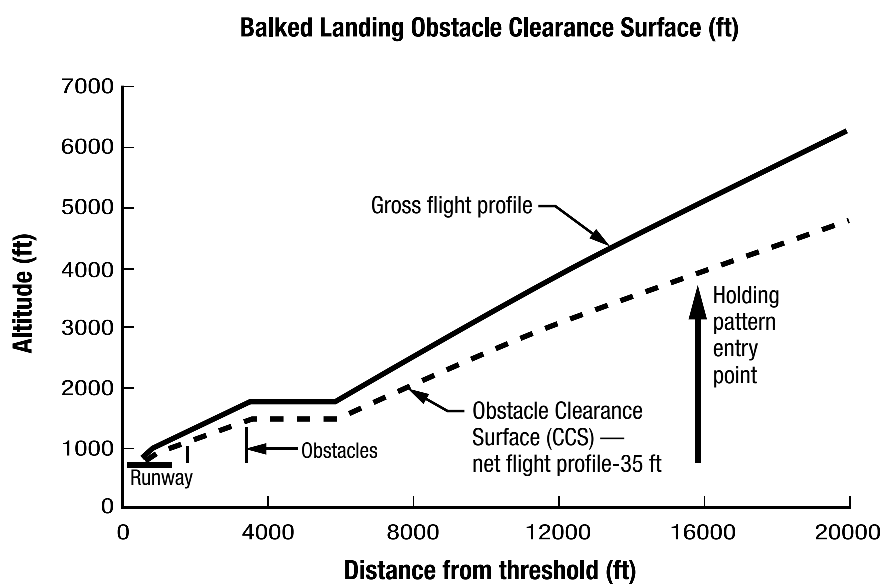

Figure 7. Vertical profile of balked landing analysis from the Boeing climbout program

Balked Landing Obstacle Clearance Surface (ft)

It was decided that operationally it is acceptable to design the RNP RNAV procedures to the lowest performing airframe/engine combination. This method does not fully take advantage of the performance available from each engine/airframe combination, however it does allow one RNP RNAV procedure for all engine/airframe combinations currently in WestJet's fleet.

Benefits

Three out of four runways ends at seventy percent of WestJet's Canadian destinations are non-precision approaches. This is because of the limited resources of Canada's not for profit navigation service provider. The Flight Safety Foundation reports that sixty percent of controlled flight into terrain accidents occurred when aircraft were flying a non-precision approach. WestJet's aircraft will be able to fly a RNP approach to almost every runway end in Canada, with vertical and lateral guidance, eliminating the need for non-precision approaches. RNP and ILS approaches are the only 2 approaches that will have to be trained so flight crew training costs will be reduced.

In addition to the safety benefits more direct routes are permitted with the RNP procedures. Between Calgary AB and Kelowna BC, a one hour flight, approximately 16 track miles are saved with the RNP approach. With five daily flights this adds up to 29,200 track miles per year saved for this one procedure.

RNP procedures also permit lower decision altitudes which of course is beneficial for the airline. Reduced decision altitudes equate to fewer diversions, delays, flight cancellations and ultimately economic savings. For example the NDB approach for runway 33 in Saskatoon has a decision altitude of 574 feet compared to the 0.1nm RNP approach that has a decision altitude of 403 feet.

The NDB approach in Regina for runway 08 has a decision altitude of 467 feet compared to the 0.1nm RNP approach with a 298 foot decision altitude. A third example is the NDB approach for runway 07 in Thunder Bay with a 527 foot decision altitude compared to a decision altitude of 410 feet for the 0.1nm RNP approach.

A significant benefit for airport operators is that RNP procedures do not require any costly ground based infrastructure. Airline operators may be able to achieve decision heights as low as 250 feet without any help from the ground. This would allow smaller communities to enjoy the benefits and convenience of scheduled air service.

Summary

WestJet is committed to implementing RNP RNAV procedures at nearly every airport in its route structure. The increased safety and efficiency provided by the RNP RNAV procedures will allow WestJet to continue to provide the highest level of safe air service to 8 million annual guests.