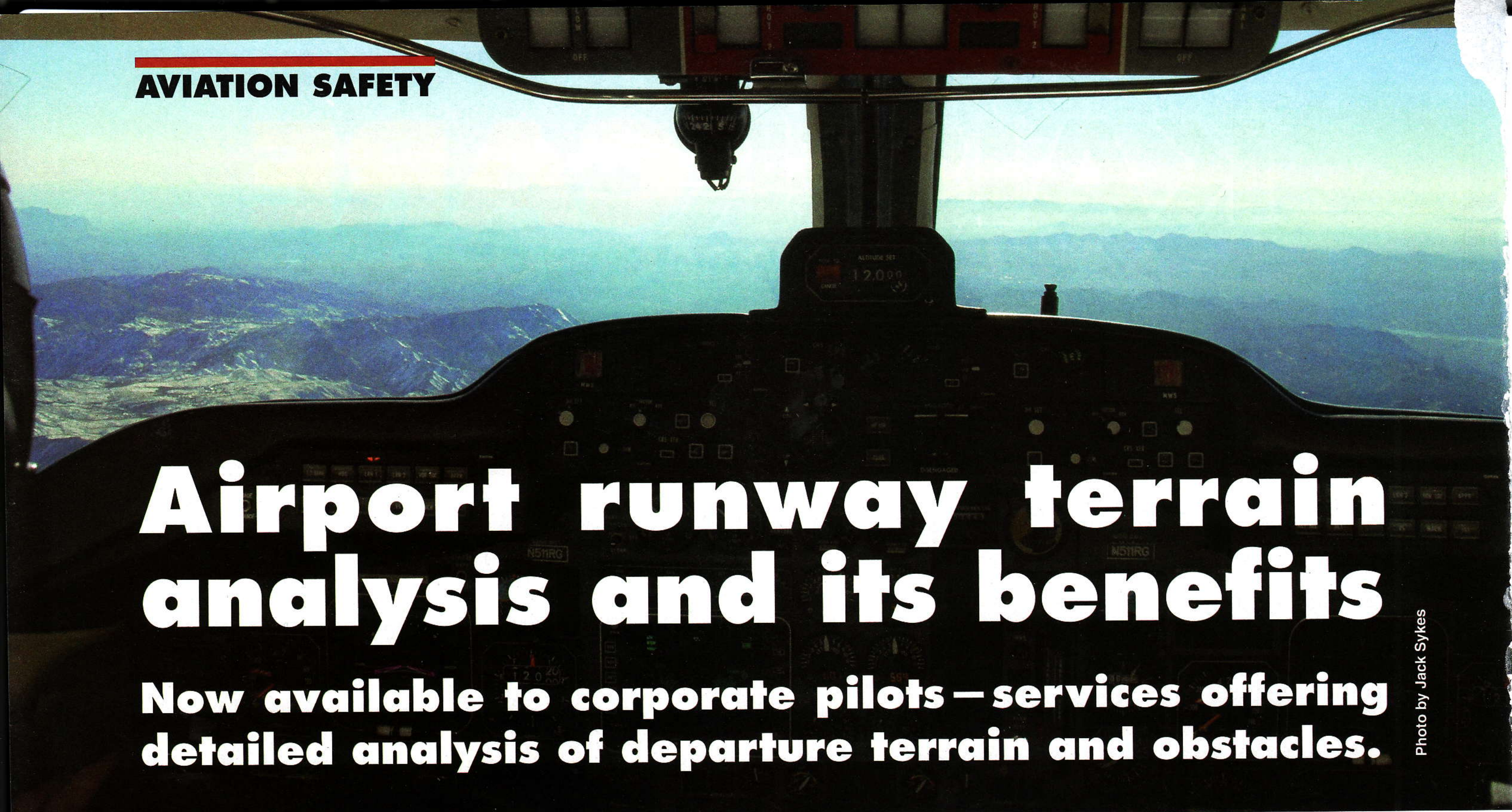


Airport runway terrain analysis and its benefits

Now available to corporate pilots—services offering detailed analysis of departure terrain and obstacles.

Photo by Jack Sykes

View from a Hawker Beechcraft Hawker 700A departing PHX (Sky Harbor, Phoenix AZ). Safe clearance of such rugged terrain is modeled by runway analysis services.

By Don Witt
ATP. Learjet series, Airbus A320, Boeing 737, Boeing 757/767

Imagine the following scenario. A Learjet 31A has just landed at ASE (Aspen CO) on a Part 135 charter flight. The pilot has dropped off some clients and is planning to pick up another couple and take them to APA (Centennial, Denver CO), but the outbound clients have not shown up yet.

Our pilot is nervous. The forecast for this July day was for scattered clouds all day long, but on the approach it looked more like broken than scattered. He reflects that he was lucky to have seen the runway when he did.

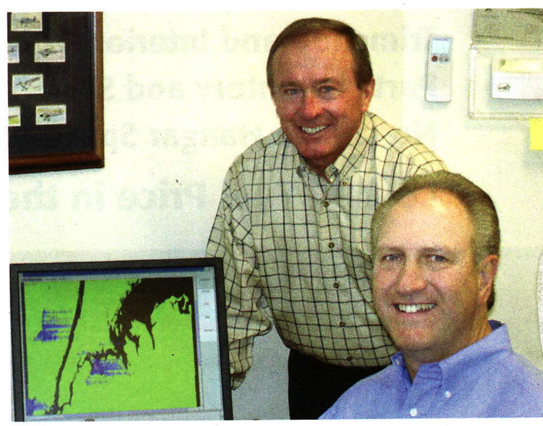
What if the reports start to call the cloud deck broken? He has already noted that the cloud bases are below 3100 ft agl—and he knows that with a ceiling below 3100 he cannot legally depart.

Our pilot knows that the required climb gradient on the LINDZ 4 SID out of Aspen is steep (460 ft per nm all the way up to 14,000 ft, which equates to 7.7%). Furthermore, he knows that the regulations require Part 135 operators to be able to make that climb gradient engine-out—FAA's Air Transportation Operations Inspector Handbook (Order 8400.10) was clear on that. On the LINDZ 4 Departure chart it says that this gradient applies if the weather is below 3100 ft or 3 miles. (See chart on p 97.) The pilot pulls the airplane flight manual (AFM) out of the closet behind the cockpit and leafs through it to the page headed "Second-Segment Net Climb Gradient."

It's currently 82° F (28° C). After much squinting, scrutinizing the chart and interpolating details, our pilot figures out that his Learjet 31A has to weigh 10,000–11,000 lbs to make good such a gradient engine-out. (And that's if he takes credit for cooler temperatures aloft using standard lapse rate. This is an interpolation nightmare.) The BOW is 11,000 lbs. Right now, with 2400 lbs of fuel in the tanks, the airplane weighs 13,400 lbs, and the clients haven't even shown up!

Looking around the ramp, our man sees that they're fueling up a Beechjet 400 next to him. The pilots over by that Challenger 601 look as if they're waiting to go too. Well, if he can't dispatch a Part 135 trip out of here, they certainly can't—after all, the little Lears outclimb just about anything.

So what's he to do? If the company our pilot works for subscribed to a performance-calculation service like UltraNav—which provides a handy gradient calculator—he wouldn't have driven himself crazy with interpolating. He wouldn't have even had to open the AFM. However, he'd still be in the same pickle, because the answer would be the same. The problem is the required single-engine gradient, which is impossible on a summer day like this.



Aircraft Performance Group (APG) Partners Rogers Hemphill (L) and Mark Thelen. APG provides runway analysis to corporate pilots, as does Jeppesen with its OpsData.

Solving the puzzle

There is a way out. For decades airline engineering departments have been analyzing terrain and obstacles at airports for their pilots. They provide the pilots with takeoff weights that permit obstacle clearance engine-out (and meet runway limits, brake energy limits etc).

These weights are often quite a bit heavier than what a pilot would come up with using the AFM and the charted (TERPs) required gradients. Why the difference? Because airline engineers actually exploit 2 different advantages.

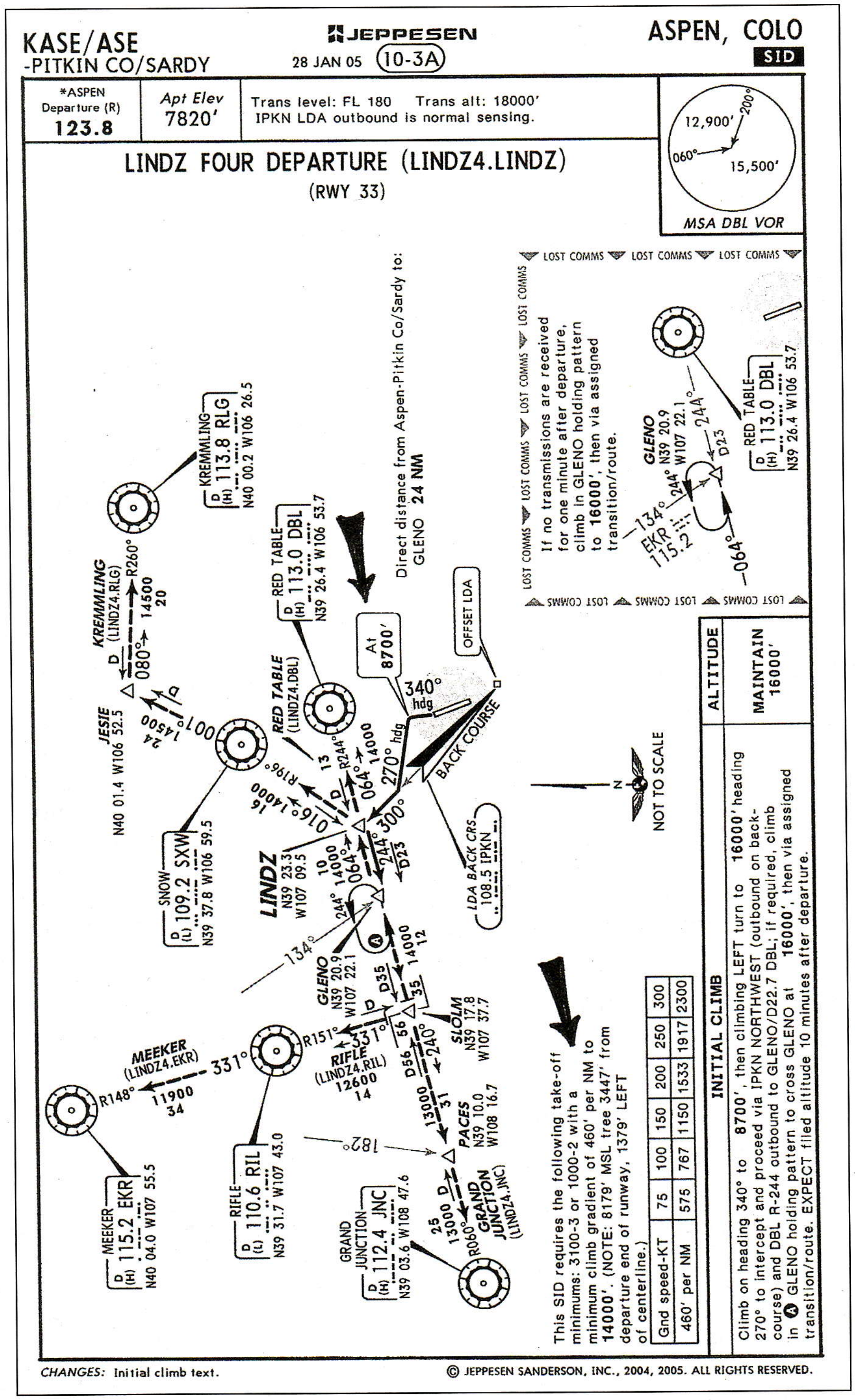
FAR takeoff flightpath versus TERPs

Airline engineers account for obstacles and terrain in the takeoff flightpath as defined by FAR Part 25. This area has a much narrower lateral extent than that which must be included in a TERPs analysis—300 ft to either side of centerline (ie, a 600-ft-wide corridor) outside the airport boundary.

In fact, AC 120-91 has recently enlarged the extent of the FAR 25 takeoff flightpath to provide more conservative obstacle clearance buffers. The AC 120-91 corridor splays out to 2000 ft each side of centerline (ie, to a width of 4000 ft) for a straight-out departure. Where turns are required, the splay opens to 3000 ft on either side (ie, to a width of 6000 ft).

However, the point is that even the enlarged protected area of AC 120-91 is still quite a bit narrower than that defined in TERPs. The TERPS corridor starts out as 500 ft to either side of centerline (and is thus 1000 ft wide) and then splays dramatically 15° to either side. (The upper diagram on p 98 shows a comparison of the two.)

Fewer obstacles or areas of high terrain may be encompassed by the FAR 25/AC 120-91 corridor. As a result, permissible engine-out weights are often greater using this "runway analysis" (RWA), because the calculated required gradients are less than the TERPs gradients for a departure from the same runway. The gist of this is that TERPs gradients are often overly conservative. A professional pilot should not wander anywhere near 15° off runway heading following an engine failure!



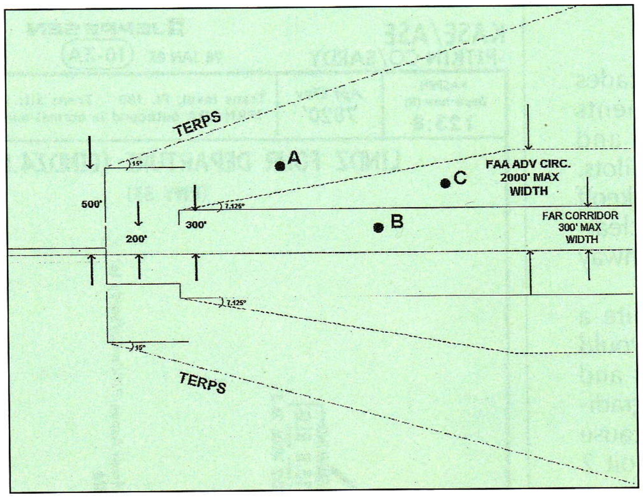
LINDZ 4 departure at ASE (Aspen CO). Note the climb requirement in the lower left. Also note that the turn to 270° begins as the aircraft reaches 8700 ft amsl.

Engine-out special departure procedures

Airline engineers also take advantage of a second powerful tool. They can create special engine-failure procedures optimized for terrain clearance. These are emergency procedures. They are not filed—they are flown only if an engine fails on takeoff. A pilot does not plan to fly them if the departure is normal—but, if an engine fails, he/she resorts to this special procedure under the emergency authority granted all PICs by FAR 91.3(b).

Some special departure procedures are quite original and creative—involving, say, 360° turns at a particular point before proceeding on course. Others are minor variations on published departures, with slightly different headings or turn points.

Since special procedures avoid the high terrain which a published SID may fly over or close to, required gradients can be dramatically less.



Comparison of FAR Part 25, AC 120-91 and TERPs obstacle clearance corridors.

GA airport terrain analysis

Airport terrain analysis and its advantages are available to the corporate pilot from a couple of sources. Aircraft Performance Group (APG) and Jeppesen both provide this kind of analysis, specific to an aircraft make and model (for a fee, of course). James Williamson of Jeppesen says that his company has been providing such analysis to airlines for 20 years, and markets the service to fractional, corporate and medical flight departments under the name Jeppesen OpsData.

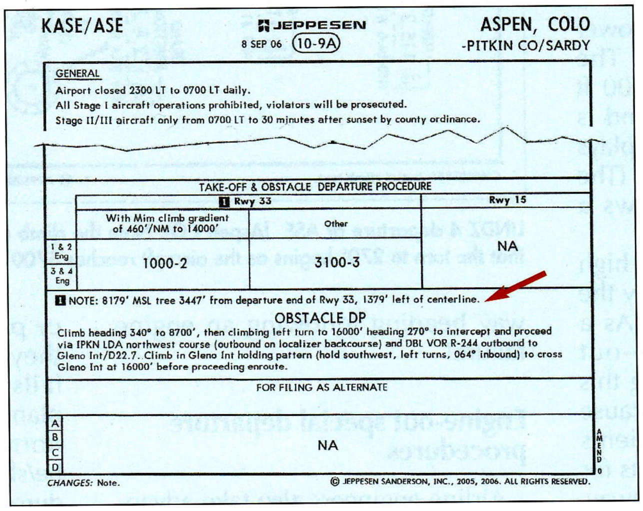
These vendors use AFM performance data and terrain/obstacle data from several sources, including FAA obstacle charts for a specific airport, the FAA digital obstacle files and digital terrain models. The terrain models are soon to be improved and "filled in" for more remote corners of the world by adding recently available NASA Space Shuttle terrain mapping data. Note that these services also provide landing data.

According to APG Partner Mark Thelen, his company's product offers advantages both in the higher operating weights allowable in many circumstances, and in safety. Obviously, the emergency special departure procedures devised by APG and Jeppesen enhance safety by providing flightpaths that will avoid high terrain and obstacles in an emergency—but there is another advantage.

TERPs required gradients for departure procedures are calculated for terrain and obstacles beyond 1 mile from the departure end of the runway (DER). As far as obstacles within 1 mile of the DER are concerned, FAA's Instrument Procedures Handbook notes that, "to eliminate publishing an excessive climb gradient," TERPs gradients ignore these completely!

Instead, information on the location and height of these "close-in obstacles" is published in the departure procedures section of a given FAA Terminal Procedures Publication (TPP) booklet. On Jeppesen charts, this information is found as a note under the Takeoff and Obstacle Departure Procedure section on the 10-9A page. (See diagram below.)

So this important information is not exactly ignored—it's presented to the pilot in tabular form, but then it's up to the pilot to figure out how to avoid the obstacles. The TERPS gradient does not consider them—the assumption is that, if you know where they are, you can turn to avoid them. If it's night or IFR, this is not a particularly conservative assumption.


KASE/ASE — JEPPESEN — 8 SEP 06 (10-9A) — ASPEN, COLO -PITKIN CO/SARDY

GENERAL
Airport closed 2300 LT to 0700 LT daily.
All Stage I aircraft operations prohibited, violators will be prosecuted.
Stage II/III aircraft only from 0700 LT to 30 minutes after sunset by county ordinance.

TAKE-OFF & OBSTACLE DEPARTURE PROCEDURE

	Rwy 33: With Mim climb gradient of 460'/NM to 14000'	Rwy 33: Other	Rwy 15
1 & 2 Eng / 3 & 4 Eng	1000-2	3100-3	NA

NOTE: 8179' MSL tree 3447' from departure end of Rwy 33, 1379' left of centerline.

OBSTACLE DP
Climb heading 340° to 8700', then climbing left turn to 16000' heading 270° to intercept and proceed via IPKN LDA northwest course (outbound on localizer backcourse) and DBL VOR R-244 outbound to Gleno Int/D22.7. Climb in Gleno Int holding pattern (hold southwest, left turns, 064° inbound) to cross Gleno Int at 16000' before proceeding enroute.

FOR FILING AS ALTERNATE
A B C D — NA — AMEND 0

CHANGES: Note. © JEPPESEN SANDERSON, INC., 2005, 2006. ALL RIGHTS RESERVED.

Jeppesen Aspen 10-9A page listing "close-in obstacles" in the Takeoff and Obstacle Departure Procedure section. These are obstacles closer than 1 mile from the departure end of the runway. TERPs gradients do not consider these obstacles.

Runway analyses like those provided by Jeppesen and APG account for all obstacles, including those within 1 mile of the DER. For that reason there are some cases where the runway analysis allowable weight may be lower than the weight one gets by calculating for a TERPs gradient. In those cases we lose some capability in operating weight, but that's the price of safety. In fact, it's seldom the case, but when it is we can see it as a safety bonus rather than a weight penalty. Perhaps we've been blind to this close-in obstacle hazard on past IFR departures.

Back to the ASE departure

So what about our Learjet captain at Aspen? Would a runway analysis actually help him? The upper chart on p 100 shows an excerpt from APG data for a Learjet 31A departure from ASE. The column headed "Runway 33DP" gives allowable weight either for terrain/obstacle clearance or for the runway limit. (Takeoff distance can be no more than available runway length.) It always shows the lesser of the 2 figures.

Note that the row for 28° C (82° F) shows 16,010 lbs. Note that the letters "FL" next to 16,010 lbs indicate that the more limiting of the 2 figures in this case is actually the runway limit. "O" would indicate that obstacles had required this number. The obstacle limit weight is even higher here because of the advantages of airport terrain analysis discussed previously. In all cases, the actual limit weight from the APG data is the lower of 2 weights—that listed for the runway's departure (in the column headed "33DP"—which in our case is 16,010 lbs) and the column to the far right headed "Climb Limit." This column is what the Learjet AFM or checklist calls "TO Weight Limit." This is the data that considers sec-

Reduced for illustrative purposes. Not to be used for navigational purposes

-- ASE -KASE -- TAKEOFF PERFORMANCE -- ASE -KASE --
LEARJET 31A ASPEN, CO
ELEVATION 7820 TFE731-2-3B ENG ASPEN-PITKIN CO/SARDY
AFM REVISION 28

* RUDDER BOOST ON * TAKEOFF FLAPS 8.0 DEGREES
STATIC T/O ** N1 DEEC **

NOTES: RWY 33DP REQUIRES USE OF MODIFIED LINDZ DEPARTURE PROCEDURE
** RWY33DP REQUIRES USE OF ATTACHED SPECIAL DEPARTURE PROCEDURE **

RUNWAY	33DP
TORA(FT)	7006
TODA(FT)	7006
ASDA(FT)	7006
SLOPE(%)	-2.00

TMP DEG C	N1 DEEC N1 A/I OFF / A/I FULL	RUNWAY/OBSTACLE LIMIT WEIGHT	CLIMB LIMIT
-20	95.7/ 92.7	17000 ST	17000.
-15	96.7/ 93.7	17000 ST	17000.
-10	97.6/ 94.6	17000 ST	17000.
-5	98.6/ 95.6	17000 ST	17000.
0	98.5/ 95.4	17000 ST	17000.
2	98.3/ 95.2	17000 ST	17000.
4	98.0/ 95.0	17000 ST	17000.
6	97.9/ 94.9	17000 ST	17000.
8	97.7/ 94.7	17000 ST	17000.
10	97.5/ 94.6	17000 ST	17000.
12	97.3	17000 ST	17000.
14	96.4	17000 ST	17000.
16	96.7	17000 ST	17000.
18	96.4	17000 ST	17000.
20	96.1	17000 ST	17000.
22	95.7	17000 ST	17000.
24	95.1	16847 FL	16596.
26	94.6	16415 FL	16164.
28	94.1	16010 FL	15743.
30	93.6	15618 FL	15327.
32	93.1	15226 FL	14913.
34	92.6	14841 FL	14531.

HW +LBS/KT	11	
TW -LBS/KT	129	
NACL A/I ON-LBS	0	0
FULL A/I ON-LBS	0	0
RUDDR BST OFF-LBS	120	MINV1=109
ASKD INOP/V1-LBS/KT	6730/19	MINV1=100
ROLLING T/O-LBS	60	
ACCEL HT (MSL)	10410	

*** OBSERVE STRUCTURAL LIMITS *** 30Nov07

Excerpt from APG takeoff data for ASE. The middle column, headed Runway/ Obstacle Limit Weight, shows the limit weight for structural (ST), runway limit or field length (FL), or obstacles (O). The right column, headed Climb Limit, gives the brake energy/second-segment climb (2.4%) limit weight, which is called "takeoff weight limit" in the Lear AFM.

SPECIAL DEPARTURE PROCEDURES

ASPEN, CO KASE
ASPEN-PITKIN CO/SARDY 30 Nov 07

Rwy 33DP TAKEOFF WEIGHTS FOR RWY 33DP REQUIRE USE OF THIS TAILORED DEPARTURE PROCEDURE:

TAKEOFF WEIGHTS FOR RWY 33DP REQUIRE USE OF THIS MODIFIED PUBLISHED LINDZ DEPARTURE PROCEDURE:

MAKE AN IMMEDIATE CLIMBING, 15 DEGREE BANK, -RIGHT- TURN TO A HEADING OF 340 DEGREES.

AT 10 DME SOUTH OF DBL VOR, TURN VIA 270 DEGREE HEADING TO INTERCEPT AND PROCEED VIA IPKN LDA NORTHWEST COURSE (OUTBOUND ON BACKCOURSE)

AT LINDZ INTXN, INTERCEPT THE DBL VOR R-244 OUTBOUND TO GLENO INTERSECTION/DBL D23.

IF REQUIRED, CLIMB IN GLENO INT HOLDING PATTERN TO CROSS GLENO INT AT 16000' THEN VIA ASSIGNED TRANSITION ROUTE.

These procedures describe the non-standard, one engine inoperative, departure flight path. The maximum allowable takeoff weights, presented in the attached analysis, are based upon the procedure(s) outlined above.

apg

APG special departure procedure for ASE. Note that the turn to 270° begins at 10 DME south of the DBL VOR, rather than 8700 ft msl.

ond-segment climb requirements (2.4% gross minimum, without regard to terrain) and brake energy limits. In our case the climb limit is 15,743 lbs. Being the lower of the 2 weights, it is the effective limit—in other words, our Learjet 31A pilot could depart at 15,743 lbs.

ASE emergency special departure procedure

Let's examine the special departure procedure on which APG bases this data. If we compare the text in the lower chart on this page with that for the LINDZ 4 departure on p 97, we can see a subtle difference. Everything in the 2 procedures is identical except the point at which the turn to a 270° heading is made. On the LINDZ 4, the turn is made when the aircraft reaches 8700 ft msl. Just where would that be depends on the climb rate.

On the other hand, on the APG emergency special departure procedure, the turn to 270° is made at 10 DME south of the DBL VOR. This is an exact point in space. When the turn is made at 10 DME, the 270° heading takes the crippled aircraft directly down the center of a river valley. If the aircraft were flying the LINDZ 4 as published, the turn could take it into terrain either south or north of that valley, depending on how fast the aircraft was climbing. This is one reason for the onerous climb gradient required by the LINDZ 4. And remember that the APG procedure is not filed—it is flown only if an engine fails.

Doesn't a Part 135 operator like our pilot at ASE have to meet TERPs gradient requirements engine-out anyway? If his principal operations inspector (POI) approves the use of an runway analysis product like APG's, an operator can plan to depart at weights provided in that data. Many Part 135 POIs have given this approval to operators who have requested it. There is no reason not to.

To make a long story short, if our Learjet captain had a subscription to APG data, he could be planning to depart ASE on this day at a gross takeoff weight of 15,743 lbs even if the ceiling came down.

Furthermore, if he actually suffered an engine failure at V1, he would have a safer and much less demanding procedure to follow. Together, more weight and more safety make this a win/win.

Don Witt is a former Airbus A320 and Boeing 757 captain with United. He has also worked as a meteorologist, CFI and charter/corporate pilot, and is currently an FSI Learjet instructor. He flew McDonnell F4s in Vietnam.