FACTORS ASSOCIATED WITH ALTITUDE OVERSHOOTS, EXCURSIONS AND UNDERSHOOTS

Introduction

A preliminary examination of keywords in the ASRS database indicated that deviations from assigned altitude were among the most common classes of events in the substantial group of deviations from ATC clearances. Because of the potential impact of such deviations on system safety, this group of events was selected for further study.

Definitions

An *altitude overshoot* is an occurrence in which an aircraft either climbs above, or descends below, an altitude to which it has been cleared.

An *altitude excursion* is a deviation of greater than 300 ft above or below an altitude at which an aircraft has been cleared and which it was maintaining prior to the excursion.

An *altitude undershoot* exists when an aircraft terminates a climb at an altitude below that to which it has been cleared, or terminates a descent at an altitude above that to which it has been cleared.

Altitude deviation is a generic term incorporating all of the above.

Approach

As of January 15, 1977, the ASRS database contained 61 reports coded as containing altitude overshoots (AO), excursions (AE), undershoots (AU), or deviations (AD). Manual records maintained by ASRS analysts identified 29 additional reports which the analysts believed might be pertinent to this study. The 80 records so identified were screened, to determine which of them met the study criteria, by reevaluating either the synopses or portions of the free text. The results of this reevaluation are given in table 14. The final sample of unique events was distributed as shown in table 15.

Results

Of the aircraft involved in these occurrences, over half were air carriers and one-fifth were military – either single or formation flights (table 16).

Potential conflicts between aircraft were reported in 23 (35 percent) of these occurrences. Near midair collisions were reported in 7 cases; less than standard separation was noted in 16 reports.

TABLE 14.– DATA CONSIDERED FOR ALTITUDE DEVIATION STUDY

	Screening of candidate reports	
	Identified as other than AO,AE,AU	Identified as AO,AE,AU
Reports coded in computer as containing AO,AE,AU,AD	1	60
Possibly pertinent but not coded as AO,AE,AU,AD	18	11
Reports that met study criteria		71
Duplicate reports of single occurrences		6
Unique occurrences		65

TABLE 15.– ALTITUDE DEVIATIONS

Type of event	Number	Percent
Altitude overshoots	54	83
Altitude excursions	9	14
Altitude undershoots	2	3

TABLE 16.– AIRCRAFT INVOLVED IN ALTITUDE DEVIATIONS

Type of operation	Number	Percent
Air carrier	38	58
General aviation	8	12
Military	13	20
Unknown	6	9

The reports were then studied in an effort to determine what factors were involved in those occurrences. In each case, an attempt was made to select one primary enabling factor and any secondary factors that were pertinent. The results are summarized in table 17.

Discussion

The type of occurrence under consideration here involves – virtually by definition – human error. The errors involved in these events may occur in the cockpit, on the ground, or in both places. It is hardly surprising, therefore, that about three-fourths of the enabling factors (33 of 46) involve human factors. It is not the purpose of this study to place blame, however, but rather to attempt to illuminate those factors, whether internal or external to the person involved, that make an error on his part more likely, or make it less likely that the system will compensate for and recover from an error. This study provides some helpful insights into both types of factors.

It is conceded that this classification scheme is at once arbitrary and to some extent subjective. Further, except in cases where multiple reports were available, it rests entirely upon unverified information supplied by the reporter. Its sole purpose is to assist in a systematic exploration of why such occurrences as these exist despite all of the redundancy and safeguards designed into the national aviation system.

TABLE 17.– ALTITUDE DEVIATIONS: ENABLING AND ASSOCIATED FACTORS

Occurrences in data bank	65
Insufficient data to permit analysis of factors[a]	19
Reports analyzed in detail	46

Factor category[b]	Enabling factor	Associated factor
Man		
Cognition, decision-making	1	4
Monitoring behavior	4	4
Subsystem operation	5	1
Flight control	1	1
Communications:		
Misunderstood clearance	9	1
Other communication problems	4	1
Distraction, high workload	10	6
Software		
Operating procedures, checklists	0	5
Navigation information, charts	2	0
Similar identifiers or trip numbers	2	0
Hardware		
Altitude alert system design	1	3
Autopilot malfunction	4	0
Other aircraft subsystem problem	1	1
Radar not available or OTS	0	2
Environment		
Turbulence, updrafts	2	0
High cockpit noise levels	0	2
Cockpit/instrument lighting levels	0	2

[a]Of these reports, 16 were descriptions of overshoots by controllers who had not been made aware of any reason for the occurrence. Eight involved military aircraft.

[b]Enabling and associated factors are classified in accord with the taxonomy described in NASA TM X-62,472, pp. 9 ff.

An examination of table 17 indicates that 10 deviations involved misunderstood clearances. In at least three cases, the misunderstood clearances were read back and acknowledged without correction by ATC. In another 10 reports, distractions (often other traffic) or high cockpit workloads were cited. Eleven cases involved errors in cognition and decision-making, monitoring, system operation, and flight control.

In 12 cases (26 percent), the primary enabling factor cited was related to the airplane, the software, or the environment. System factors were listed as pertinent in 13 other cases. The problem most often cited was an insidious failure of the autopilot altitude capture or altitude hold. In these cases, of course, there was an associated failure in human monitoring; in one case the absence of an altitude alerting system may have been an additional problem for a pilot who was accustomed to flying with such a system.

It is instructive to examine briefly, with the aid of some examples, certain of the human and system factors associated with altitude overshoots, excursions and undershoots.

The problem of misunderstood clearances is a particularly vexing one, especially when there is an error both in the air and on the ground. This latter situation involves a breakdown of the redundancy purposely designed into the system to compensate for possible misunderstandings. In some of these cases, such as the following, both flight crew and controller workload may have been factors:

> Airline aircraft flight planned and cleared to 24,000 ft. Center later changed clearance to 17,000 ft because of other traffic. At approximately 16,000 ft Center pointed out traffic and issued what pilot thought was clearance to 18,000 ft. Pilot acknowledged and Center did not correct readback. Factors: (1) I misread his transmission of traffic; (2) He misunderstood my clearance readback or failed to correct it.

Phraseology, either in the clearance or in subsequent communications, can also promote misunderstanding. There is a case in point:

> Original clearance was unrestricted to 23,000 ft. Shortly after takeoff an amendment was understood by the crew as "Expedite through 5000 ft." We did that and at 6300 were questioned as to our altitude. We were then informed that the clearance was "Expedite *to* 5000 ft." No reason for advisory was given.

Crew workload can be very high during climbs and descents in high-performance aircraft, particularly in terminal areas. Several reports indicated vividly the problems that can result:

> Flight plan . . . San Jose, Sunol 6 (SID) to Portland, OR . . . Cleared as filed Sunol 6 maintain FL 230. Taxi, takeoff normal. At approximately 500 ft we were advised to contact Departure Control. Contact was made with Bay Departure and we were cleared to "Fly the SID" and were also issued numerous traffic advisories. We observed several aircraft at various altitudes and courses in our field of view. First officer was flying aircraft from right seat and I was acting as copilot from left seat. Standard company, FAA mandated, noise abatement departure profile was flown. At approx. 3000 ft AGL first officer initiated aircraft cleanup and after takeoff checklist. While this was being accomplished we received a Departure Control frequency change. New controller issued clearance "Fly SID altitudes." After acknowledgment second officer and I continued after takeoff checklists while trying to maintain a proper lookout for traffic as there were many uncontrolled aircraft in our area. I then observed that the aircraft was passing through 5500 ft. I took action to return the aircraft to level flight at 5000 per the SID. First officer advised that he understood the SID but was preoccupied with heavy traffic.

(Company) procedures call for altitude alert system to be set on clearance limit altitude which in this case was 23,000 ft. Therefore, no alert was sounded passing 5000 ft.

Airline aircraft cleared by Denver Departure to climb to 8000. Passing through 6500 Departure advised of VFR traffic 3 miles at 12 o'clock. Crew sighted traffic in their flight path at approximately 7000 ft. At same time, crew was distracted by extremely loud aircraft transmitter that drowned out Departure Control. In the confusion, our aircraft climbed to 8500 ft before crew noticed altitude excursion and descended to 8000. Our aircraft was cleared through the other airplane's altitude, even though VFR; the situation was close.

Flight (airline aircraft, two-man crew) departed runway 8R to maintain 10,000 ft. Captain left ATC frequency to make company contact in accordance with standard operating procedures. Purpose: to relay departure times to station. While captain was preoccupied the first officer was required to handle radio contacts with ATC. In doing so he allowed the aircraft to climb out of our assigned altitude. We were immediately assigned another, higher altitude . . . Factors: Requiring company radio contacts of doubtful importance. Making these contacts too quickly after takeoff in heavy traffic areas. This is in part due to pressure from station personnel. First officer in this case was new on type and had not flown it for about 6 weeks. He was also using a hand microphone . . .

The high climb and descent rates of jet aircraft, together with the distractions commonly encountered in normal operations, were often factors in these occurrences:

Our aircraft was cleared to descent to 12,000 ft, to reach 12,000 25 miles east of Key Biscayne VOR. While descending through 13,500 Center advised we were following an aircraft at 11,000 ft in our 9 o'clock position. Efforts to see the other aircraft initially were negative, then we picked him up 4-5 miles away at our 9:30 position. As I started to report that I had the traffic I noticed we were passing through 12,000 with a fairly high sink rate. Because I had a seriously ill heart patient aboard and because it was VFR and I had our traffic I allowed the aircraft to scoop out at about 11,500 rather than pull excessive G's. I went ahead with my sighting report and added that I had busted my altitude but was returning to 12,000 ft from 11,500. The controller asked me to confirm that my clearance limit was 12,000. I replied in the affirmative; that was the reason for my reporting my descent below it.

Airline flight was cleared from flight level 240 to 16,000 ft. Shortly thereafter the crew piloted the aircraft to 14,000 ft. The problem was discovered by the pilot in command at 14,700 ft. He immediately stated to Center that we were leveling at 14,000 and requested further instructions. There were several contributing factors . . . the aircraft had just come through a clouded area where light icing conditions existed. Airspeed was 250 knots and rate of descent 1000 ft/min while in the clouds. We broke out in the clear at approx. FL 200 and immediately lowered the nose and accelerated to about 370 knots. Our rate of descent increased to 3000-4000 ft/min . . . to make an expected crossing restriction of 9000 ft at the 25-mile DME fix . . . the expected clearance is a standard one usually received, however, we had only received a clearance to 16,000 . . . as we broke out in the clear we secured the engine anti-ice. The number 2 anti-ice light did not extinguish and the crew began to troubleshoot the light. Furthermore, at 370 knots in this aircraft the cockpit noise level is very high; we did not hear the altitude warning bell. The warning lights are also difficult to see in the daylight. Also, the pilot flying was cycling the anti-ice switches because of their location. The pilot not flying did not make the required altitude callout "1000 ft above leveloff."

The principal reason the incident occurred is because the flight crew became preoccupied with an engine anti-ice malfunction. This, coupled with a high rate of descent and high cockpit noise level. . . .

Recommendations: (1) When an abnormal situation arises one pilot should be assigned to fly the airplane; (2) Cockpit noise levels should be reduced. I have measured levels . . . at 96 decibels . . . below FL 180 the noise level is so high you can hardly hear anything generated in the cockpit, i.e., warning bells, etc.; (3) The aural altitude warning feature of the altitude alert system should be piped into crew headsets . . .; (4) The altitude alert light should have its cover changed or the location changed to make it easier to see; and (5) Reemphasize callouts by crew member not flying.

The present design of the altitude alert system, which provides an identical aural warning signal when approaching and when departing a preset altitude, was cited as a factor by several reporters. The FAA has proposed to allow this system to be modified so that an aural warning tone will be heard only if the aircraft departs from its assigned altitude. This change should alleviate the altitude overshoot problem somewhat, though the comments of some reporters suggested that they have come to rely on the aural warning approaching altitude as well. Those who complained most bitterly about the duplicate signals were those flying high-density routes with frequent step climbs and descents. Long-haul crews seemed less bothered by the warning approaching altitude. It would appear that pilots will have to exercise considerable caution during the period of the changeover, if the FAA-proposed change is implemented, to avoid problems of the sort described in these reports.

Another area in which pilot aids may be associated with decreased alertness to primary instrument indications is that of flight on autopilot. Malfunction of the "altitude capture" or "altitude hold" mode was reported in four instances. One report was particularly interesting:

This was an Air Force Reserve scheduled flight of over 8 hr duration with four stops . . . about 1530 hours, Houston Center asked us to verify altitude. We were assigned FL 180. Upon cross-checking altimeters, we were at 17,000 ft and descending at about 150 ft/min. The autopilot had been engaged since leveloff and the altitude hold was supposed to be still engaged. Autopilot was disconnected and immediate climb started . . . without verifying that the altitude hold was engaged. However, I distinctly remember engaging altitude hold following autopilot engagement. There is no altitude warning system in these airplanes. . . .

After several hours of flying with the autopilot performing perfectly there is a tendency to omit altitude from your scan unless something abnormal happens . . . I also fly for an air carrier and have discussed the need for an altitude alerting system like those we have in the airlines with . . . Air Force personnel . . .

No estimate of the frequency of altitude deviations can be inferred from these data, since the Aviation Safety Reporting System is a voluntary one. It is significant, however, that system problems as well as human factors were cited as enabling or associated factors in 25 of 46 occurrences (54 percent). While this in no way detracts from the importance of human reliability in the prevention of such occurrences as these, it does emphasize that man's role in the aviation system cannot be considered in isolation. In 12 of these occurrences, a system problem was felt to be the primary enabling factor.

Summary

Forty-six examples of altitude deviations by aircraft on IFR flight plans were analyzed. One-quarter involved human error in the operation of the aircraft or its subsystems, one-quarter involved misunderstood clearances, nearly one-quarter involved distraction or high cockpit workloads. In the remainder (26 percent), system problems were thought to be the primary enabling factor.