MODE S
Helping to reduce risk

Mode S has been around for many years but for various reasons its implementation as a surveillance technology and ATS support tool has been a long time coming – too long for many people in the ATC world. However we are now seeing the technology come on line in many European States and the benefits are beginning to be realised.

By Andy Edmunds, NATS, UK

There are two levels of Mode S, Elementary and Enhanced.

- Elementary Mode S (ELS) allows selective interrogation of aircraft providing the potential to eliminate Garbling and Fruiting. Additionally, ELS includes the aircraft identification Down-link Airborne Parameter (DAP).
- Enhanced Mode S (EHS) provides the functionality of ELS plus additional DAPs, including ground speed, indicated airspeed, heading and the Selected Altitude entered by the crew into the Mode Control Panel (MCP) or Flight Control Unit (FCU). Fig 1 shows a typical MCP unit.

Fig 1: Typical Mode Control Panel showing selected altitude of 23000

So as well as more robust surveillance data, Mode S DAPs now provide the ATS provider with much more information on what the aircraft is actually doing and, more pertinently, intent data.

What's the problem?

In the late 1990s, the UK CAA produced a report which captured the main underlying causes of level busts and its recommendations have since been progressed. Yet these events still occur and last year NATS experienced about 400 instances. Although not all level busts lead to losses of separation, their large number poses a potential

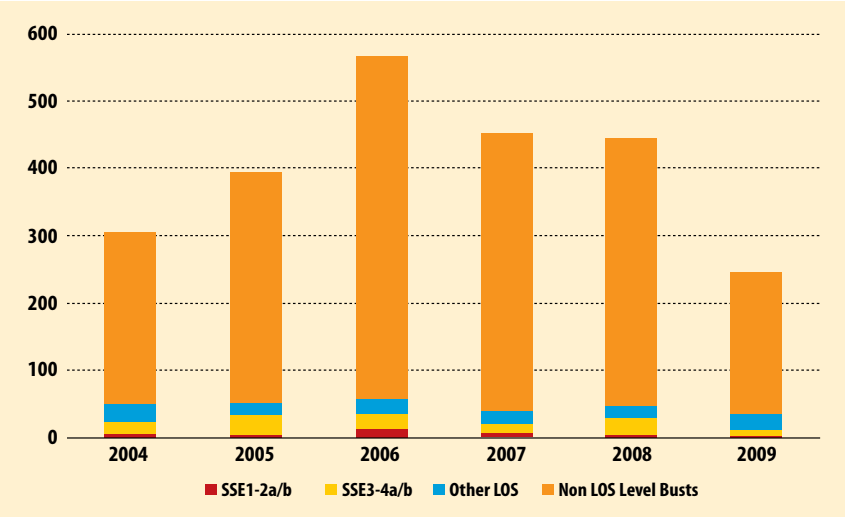

Fig 2: NATS UK Level Bust data from 2004 to date

risk to the ATC operation and so on the back of the CAA report, NATS started the Level Best campaign.

Through a mixed programme of live presentations to operators with radar recordings of real busts, a video training package, magazine articles, posters and a website, the programme aimed to raise awareness of this issue within the aviation community. As part of this in 2006 NATS conducted an internal Prevented Level Bust Trial which in a 10-day period recorded some 1454 level busts or potential level busts which were prevented by the intervention of the controller. Many of these involved the aircraft not stating its cleared level on first contact. The Level Best campaign was specifically intended to see:

- An **increase** in the proportion of level busts reported, to understand the scale of the problem
- A **decrease** in the number of events leading to a loss of separation

Awareness and education are often effective in changing behaviour so NATS sends level bust performance data out to 45 or so individual operators, highlighting the operator's individual performance compared to the average for the group. We also show the operator's position within a league table! For some operators we have sent out trend analysis of causal factors, type, level, position, etc. to help identify any peculiarities associated with particular fleets or bases. The data is very much appreciated by the airlines and is often used as a key performance indicator by them. Also as a result of such data analysis, the UK CAA has written to the National Supervisory Authority of two foreign operators highlighting poor level bust performance.

The number of reported level busts within UK airspace where NATS is the controlling authority is shown in Fig 2. The events for each year are broken down into differing levels of severity (SSE is a NATS severity classification) and it may be concluded that the peak in 2006 was the result of a steady increase in level busts in line with overall traffic growth. This may be the case but the trend could also be attributed to an increase in open reporting as a consequence of internal safety initiatives and the Level Best campaign.

With the same level of reporting and rising traffic levels, the drop in 2007 may be attributable to an increasing awareness of the issue and level busts being caught before they happen. The story for 2008 is largely similar although the downturn at the end of that year and in 2009 will also have a bearing.

Drilling down into each event identifies one or more causal factors and Fig 3 shows these for the level busts in 2008.

It is noticeable that correct pilot readback followed by incorrect action was by far the commonest causal factor ▸

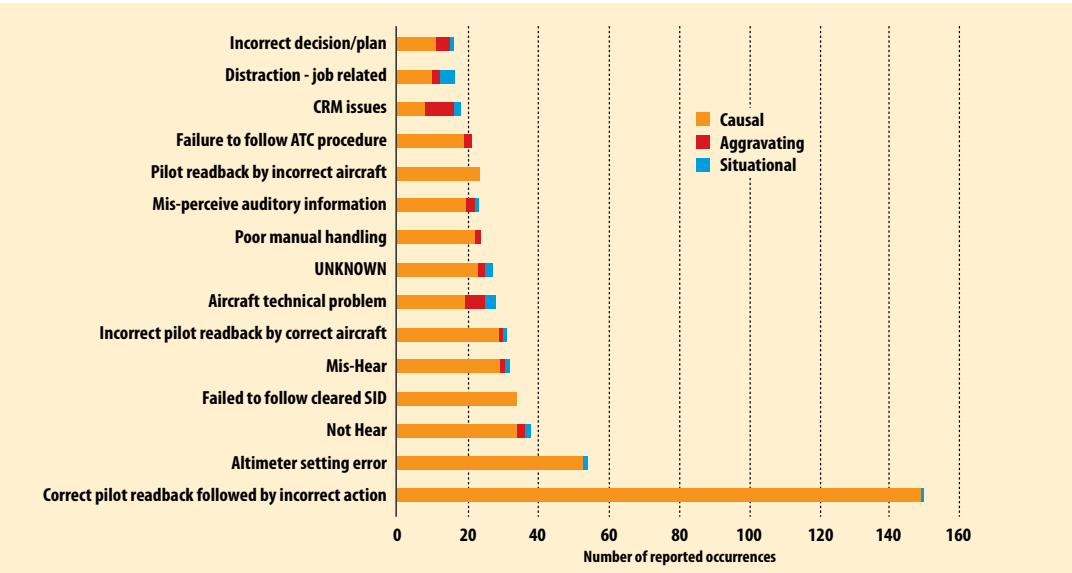

Fig 3: Causal factors for level busts in 2008

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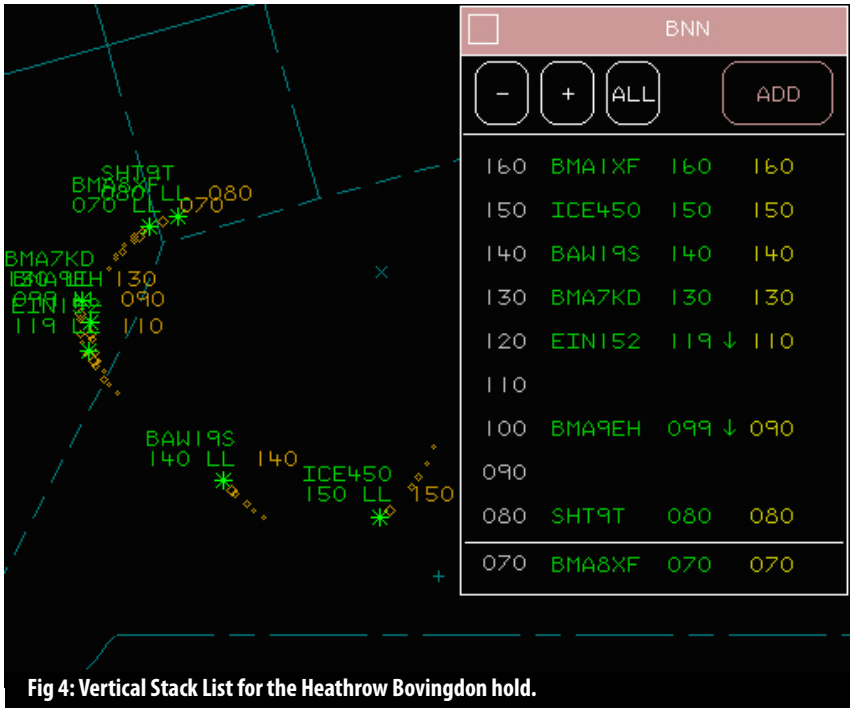

Fig 4: Vertical Stack List for the Heathrow Bovingdon hold.

Fig 5: EHS information in the aircraft Target Label

although it should be noted that in reality this set represents 'what happened' and not 'why it happened'. Assuming other factors may have contributed to the eventual outcome, nevertheless this group represents the biggest problem of a pilot saying one thing and doing another. This is where prevention of risk is problematic but Mode S functionality has proven most beneficial in this respect.

Mode S Selected Altitude DAP – How is it used?

In December 2005 NATS enabled the display of Mode S EHS data in the London Terminal Control (LTC) operation and introduced new support tools intended to provide positive safety and efficiency benefits. The introduction was supplemented by a UK CAA regulatory mandate for aircraft flying into London Terminal airspace to be Mode S EHS equipped.

The Vertical Stack List (VSL) tool provides a plan view of the London holding stacks. Fig 4 shows the Bovingdon hold and on the left is the normal surveillance picture of the hold with a lot of garbling. On the right is the VSL showing level occupancy, actual altitude and in orange the Selected Altitude DAP. The tool not only enhances controllers' vertical stack awareness but also provides a warning of a potential level bust.

Outside the inner holding areas, the Selected Altitude DAP can also be displayed for any aircraft within LTC airspace. Fig 5 shows the Target Label of BMA3XF. The altitude readout and destination code are shown in line 2, along with the MCP/FCU altitude selected by the pilot (dark orange to distinguish it from the actual altitude). BMA3XF has selected 15000 feet and is passing Flight Level 165. Other DAPs such as Ground Speed, Indicated Air Speed, and Magnetic Heading can also be displayed in line 3 of the Target Label and in this case the aircraft's magnetic heading has been selected.

All UK ACCs and TMAs will have the capability to display Mode S DAPs by the end of 2010 and this functionality is now also increasingly available at UK airports where Mode S EHS surveillance systems have been installed.

Human workload limitations and time delays incurred whilst flight crew input information into the MCP/FCU must be taken into account. Therefore, the requirement for aircrew to read back all clearances and for controllers to check the readback still applies and recognition of the Selected Altitude does not constitute confirmation of the clearance. However if the controller detects an anomaly, the UK has published specific phraseology to ask the pilot to check the cleared level but without stating the observed incorrect level:

"(Callsign), check selected level. Cleared level is (correct cleared level)".

Selected Altitude data is presented as either a flight level or an altitude, depending on local surveillance system settings. In the UK, for ATC and RTF phraseology purposes, the generic phase 'Selected Level' is used to mean data presented as either an altitude or a flight level.

Has it been worth it?

In justifying the implementation of EHS functionality within LTC airspace, it was predicted that in 2006 the system would provide a quantifiable safety benefit in the prevention of level busts, compared to 2005 data. Of the many 'causal factors' (see Fig 3), the following were chosen as being preventable by EHS:

- Correct pilot readback followed by incorrect action.
- Incorrect pilot readback by correct aircraft.
- Pilot readback by incorrect aircraft

The results? Well, we found that overall there had been a 63% reduction in the level of risk exposure associated with these causal factors, expressed as the severity of the consequent level bust. Statistical headlines never tell the whole story and other factors undoubtedly influenced events. However, set against rising traffic levels for the years in question and no other system support tools, this improvement is significant and we feel the project achieved what it set out to do.

Although not a scientific endorsement of the tool, LTC controllers have now had a number of years' experience using the Selected Altitude DAP and the view from the shop floor is that it's something they would not want to live without.

SELECTED ALTITUDE IN ACTION

The following are extracts from reports where EHS Selected Altitude has or might have prevented a level bust.

- ***A319 given descent to FL130, but crew selected FL110 which was showing on Mode S. ATC queried this with the crew, who stated it was a mistake. Standard separation maintained.***

- ***The controller intended to climb Aircraft A to FL170 and turn it left heading 315. However, he transposed the callsign and issued the instruction to a similar company callsign (Aircraft B). The controller saw the selected level on Aircraft B change to FL170 and the a/c turn slightly, at which point he recognised his mistake and took appropriate remedial avoiding action. Standard separation was maintained.***

The following incident occurred in London Area Control airspace where the Centre does not yet have Mode S capability. Callsign 1 was cleared to FL370 on top of Callsign 2 (the orange 31▽ symbol is an electronic inter-sector coordination function and is not related to the incident). Unfortunately the pilot read back FL310 as the cleared level and this incorrect readback was not picked up by the controller. The aircraft subsequently descended through FL360 and there was a loss of separation.

The same scenario recorded from the London TerminalControl radar display and it clearly shows the pilot of Callsign 1 has input FL310 as the Selected Altitude. This error could have been picked up by the area controller had the functionality been available.

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Concurrent with the introduction of Mode S EHS tools, NATS has seen a marked reduction in exposure to risk in a busy TMA environment.

Nothing is perfect

Whilst the display of Selected Altitude is an obvious safety enhancement, there are occasions where despite the flight crew complying with the ATC clearance, the displayed Selected Altitude is different:

- Along SIDs/STARs with vertical restrictions where pilots may select the final cleared level, and utilise the aircraft flight management system to achieve the vertical constraints.
- During final approach where pilots may pre-select the Missed Approach Point altitude. To avoid any confusion the EHS information is removed from the target label.
- When the aircraft is being flown manually.
- Where there is an incorrect barometric pressure setting.

A review of UK Mandatory Occurrence Reporting data from the introduction of EHS in LTC airspace in December 2005 to the present did not find any instances of data corruption between the altitude set by the pilot in the MCP/FCU and the DAP displayed to the controller. However, the review did identify 35 instances of autopilot failure to capture the Selected Altitude. Therefore regardless of the apparent accuracy of the Selected Altitude, controllers should always remain alert to the potential for non capture and subsequent level bust.

Of course, the full value of the tool is reduced where the Selected Altitude DAP is not available, either because there is a fault with the Mode S transponder or because the aircraft is not suitably equipped.

Looking ahead

Concurrent with the introduction of Mode S EHS tools, NATS has seen a marked reduction in exposure to risk in a busy TMA environment. The roll-out of the tools to other areas of UK airspace should see a similar improvement.

Further enhancements can be made because at the moment prevention requires the controller to manually observe the Selected Altitude and compare it to the cleared level. There is no guarantee that a controller can carry out such a task at all times and incorrect settings may still occur. With the introduction of electronic flight data in the near future, we can then provide system support in this area by automatically alerting the controller to a discrepancy, so reducing risk even further.

Mode S has been a long time coming, but now it's here, it's showing its worth. ■

Andy Edmunds

After serving in the RAF, he joined NATS in the early 1990's as an en-route ATCO at the London Centre. He has since had experience in Unit Operations departments and has managed Systems and ATCO Competency teams. Currently he is an ATM Policy expert at NATS Corporate & Technical Centre at Fareham, responsible for managing operational risk and providing NATS' Unit customer support and he still retains an operational validation at the Swanwick Centre.