SK686, COCKPIT VOICE RECORDER ANALYSIS

Summary

On Monday, October 8, 2001, a Scandinavian Airlines System MD87 collided with a Cessna Citation during take off from Linate airport, Milano, Italy. The aircraft's registration was SE-DMA and the flight number SK686. The Cessna was registered in Germany as D-IEVX.

The MD87 was equipped with a Cockpit Voice Recorder (CVR), which survived the crash without any damage to the recording.

With the assistance of the German Federal Bureau of Aircraft Accidents Investigation ("BFU" - Bundesstelle für Flugunfalluntersuchung) a copy was made from the CVR. This copy has been used when writing down all relevant information recorded on the four tracks of the CVR.

General

On Wednesday, November 8, a copy of the CVR recording was handed over to Magnic AB. The copy was made to a CD in .wav format.

It was found that the three CVR tracks recording information from the left pilot, right pilot and the service interphone audio channels, were clear and easily readable. The fourth track, recording information from the area microphone, was difficult to read due to the placement of the single microphone (on the overhead panel). Since the Area Mike track is by far the most important track, extra effort has been made to extract all relevant information from this track.

Technical information

The Cockpit Voice Recorder is an Allied Signal (Honeywell) model SSCVR, Part No 980-6020-001 and Serial No 2305. The CVR was located in the aft cargo compartment together with the Digital Flight Data Recorder (DFDR).

The CVR has an audio frequency response of 150-3500 Hz and a signal to noise ratio of 24 dB minimum (full bandwidth)

The audio is recorded digitally on a solid state recording media, storing 30 minutes of information. A total of four channels are recorded. The recorder automatically "erases" as it records so that only the last half hour of recording is retained.

The service interphone channel is recorded on track no 1. Track no 2 and 3 record the right and left pilot audio respectively. This means that information

passing through the pilot's audio selector panel is recorded according to the volume control settings. Track no 4 records information from the area microphone

The CVR operates whenever the right radio bus is powered.

Timing

The Air Traffic Control (ATC) at Linate used a Racal ICR64 recorder. A DAT (Digital Audio Tape) copy was made from the tracks recording Tower and Ground frequencies. A copy was also made from the track recording the emergency frequency (121.5 MHz). From ATC transcripts, the UTC time of the collision was taken and assigned to the same event on the CVR tracks. By interpolation approximate UTC time was then assigned to all information in the CVR transcript. A check has thereafter been made with the times for other messages heard both on the ATC copy and the CVR tracks.

The UTC (and "Rel") time in the CVR transcript should be accurate to within 2-3 seconds.

ATC Recording

The recordings from Tower, Ground and Emergency frequencies have been inserted in the same computer program as the CVR information.

On the Emergency frequency an ELT can be heard very clearly starting at the same time as on the CVR recording. The ELT can be heard for 18.6 seconds. The transmission is stable for the first 17.6 seconds, while during the last second, the signal is unstable and broken. – See appendix G.

CVR Contents

Only information from or to SK686 is written down, except when other traffic has some relevance for the sequence of events. This means that most of the radio traffic concerning other aircraft is omitted.

The cockpit voice recorder has registered a total of ca 30 minutes. On the CD copy the length of the different tracks are slightly different, the #1 track (Service Interphone) is 30 minutes and 51.094 seconds. The #3 and #4 tracks (Left Pilot and Area Mike respectively) are 30:48.207 and finally, the #2 track (Left Pilot) is 30:48.099 minutes and seconds.

The time from start of the takeoff roll to the crash is less than 1 minute Approximately 29 minutes is therefore spent on the ground with check list reading, preparations for the flight and taxiing as well as a few short periods of waiting.

All information generated within the cockpit, including checklist reading, has been included when possible.

The right pilot audio channel ("RP") has recorded all the radio traffic between SK686 and ATC, since the Captain was flying the aircraft and the First Officer was handling the radio.

The left pilot audio channel ("LP") has recorded most of the information that is recorded in the right channel, since the Captain also was listening to the radio traffic between the first officer and Air Traffic Control (ATC). This information is however assigned to the RP channel only.

The cabin crew's passenger announcement can only be heard on very low volume on the AM channel since the system is made so that passenger address is not recorded on the Service Interphone audio channel.

The Service Interphone audio channel ("SI") records audio from the Maintenance and Service interphone system. The captain's passenger address audio could also be heard on this channel, but not the cabin's passenger address audio. As can be seen in the transcript there are only a few messages recorded on this channel. No passenger address is made from cockpit during the time of the recording.

The Cockpit Area Microphone channel ("AM"). The microphone is situated in the CVR overhead monitor unit. It is supposed to pick up communication within the cockpit as well as aural warnings and other sounds.

Analysis

When extracting radio traffic, the Left and Right Pilot channels have been used. Only a few short messages are heard on the Service Interphone track. Most of the work has therefore been concentrated to derive information from the Area Mike track.

Since this recording is of a rather low quality and since the microphone is placed above the pilots heads, it is very difficult to hear what is being said. That is also the reason that it has not been possible to interpret all messages and that there is a degree of uncertainty to the interpretation of some other messages.

A transcript in original languages can be found in **Appendix A**. In **appendix B** all messages have been translated into English.

In the information it can be seen that SK 686 receives clearance for takeoff ca 06.09.24 UTC (29.29 minutes and seconds after CVR start) and that the collision occurs 57 seconds later (30:26 after start). From 7until 5.7 seconds before impact the callout Veee one is heard, indicating that the aircraft has reached V_1 – decision speed. V_1 is normally the highest speed at which a take off should be aborted. As can be heard a few seconds earlier the V_1 speed is probably 130 knots although this callout is very difficult to hear due to interference from other radio traffic during the take off roll.

4.8 seconds before impact the callout "Rotate" is heard and ca 3 seconds before impact a clicking sound from nose wheel lift off. At impact the aircraft have accelerated for about 6 seconds above V_1, which means the speed is several knots higher than V_1.

No indication of the pilots discovering the other aircraft can be heard until 0.5 seconds before impact, when a callout is heard. Of course the other pilot may have discovered the aircraft shortly before.

The sequence of events from "cleared for takeoff" until collision has been plotted in **Appendix C**. In this appendix, as well as Appendix d-F, time is displayed horizontally and sound amplitude or frequency on the vertical scale.

In **Appendix D** a graph of the last second of all four tracks have been made. On the vertical is sound amplitude and on the horizontal, time.

In this graph it can be seen on the AM track that the sound from impact starts ca 0.65 seconds before the recording (CVR recorder) stops.

The Left Pilot track is very similar to the Right Pilot track, which – as can be seen in the graph – is not perfectly synchronized with the other tracks. In the RP track, events are ca 0.1 second before the LP and SI tracks, which in turn are about 0.05 seconds before the AM track. According to BFU (Bundesstelle für Flugunfalluntersuchung) the time difference between the four channels is an effect of the copy process. Due to software limitations, the CVR content was played back and copied in an analogue format, then digitalized again into .wav files. It is of course easy to synchronize the tracks within milliseconds, using the last events on the tracks, and this was also made for the purpose of getting correct timing.

In **Appendix E** is a amplitude/time graph of the last second of the CVR recording, Area Mike track only. In the lower part is a "sonogram" i.e. a frequency versus time graph. The last 0.2 seconds are dominated by the ELT (Emergency Locator Transmitter) starting up. This means there are ca 0.4 seconds of sounds from the collision. Since the collision is a relatively lengthy event, with one large amplitude peak and a few smaller amplitude peaks, it cannot be ruled out that already the nose of the SK686 have contacted the other aircraft.

With a speed of e.g. 140 knots the aircraft moves with 72 meters per second. During 0.4 seconds the SK686 would therefore have travelled ca 30 meters. The MD87 is ca 40 meters from nose to tail.

Appendix F shows a graph show ca 0.7 of the last second of the Left Pilot track.

In this graph there is a heavy spike (disruption) starting 0.50 seconds before end of recording and about 0.17 seconds long, most likely emanating from the collision.

At the very end of the recording there is 0.21 seconds of sound from an ELT (Emergency Locator Transmitter), starting its first sweep.

Suggestions

The CVR is an extremely important and valuable instrument in accident investigation. To utilize it's capacity to the fullest extent, a few improvements should be considered;

On the SAS MD80 fleet, today only the area mike channel is used to its capacity. The other three channels are normally only recording information when a microphone button is pressed. This means that information is only recorded on these channels a fraction of available time.

1. It is therefore suggested that "hot" mikes should be considered. This means that all four channels should be continuously connected to "open" microphones. Preferably requiring the pilots to carry headset microphones should do this. Apart from considerably improving the recording of communication in the cockpit it would also help in locating the origin of different sounds such as position of switches being operated.

The service interphone channel could record information from the aft cabin attendant handset. An open microphone in the aft section would facilitate in analysing events in the aft part of the aircraft as well as engine sounds.

2. The quality of the recording on the area microphone channel is negatively influenced by a high noise level. It should be possible to improve the quality of the installation so that especially speech is recorded more legible.

3. Today the CVR receives its power from the right radio AC bus. In SE-DMA this caused the recording to stop during the collision. Supplying power from a battery source would minimize the risk of loosing information due to loss of electrical power. A suitable condition for stopping the CVR recording would also have to be implemented.

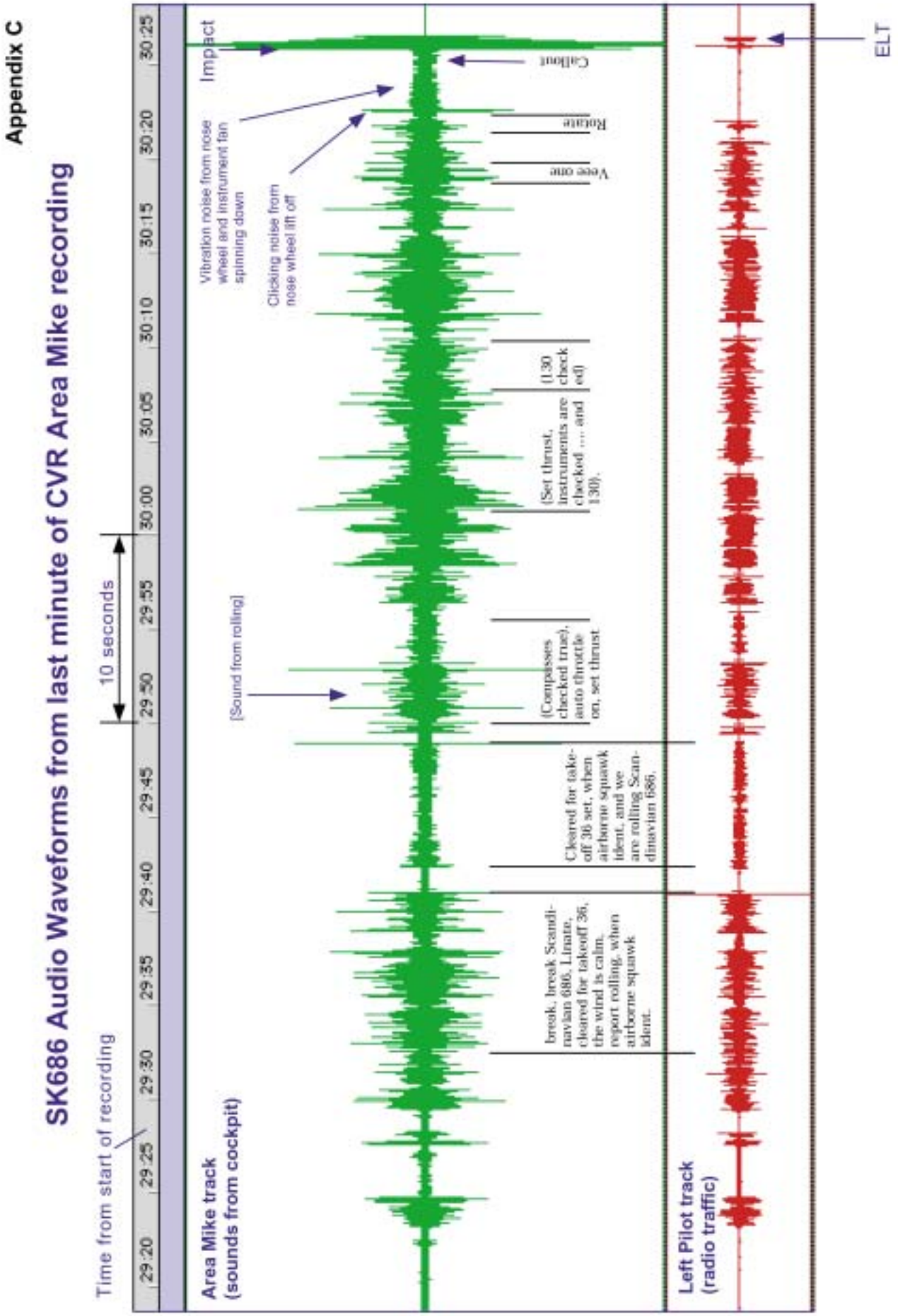
4. It should be considered to have the cabin's passenger address recorded on the service interphone channel.

Enclosures;

A. CVR transcript in original language.
B. CVR transcript, translated to English.
C. SK686, Audio Waveforms from last minute of CVR Area Mike recording. Audio amplitude is plotted vs. time with radio traffic inserted.
D. SK686, last second of CVR sound, all four tracks.

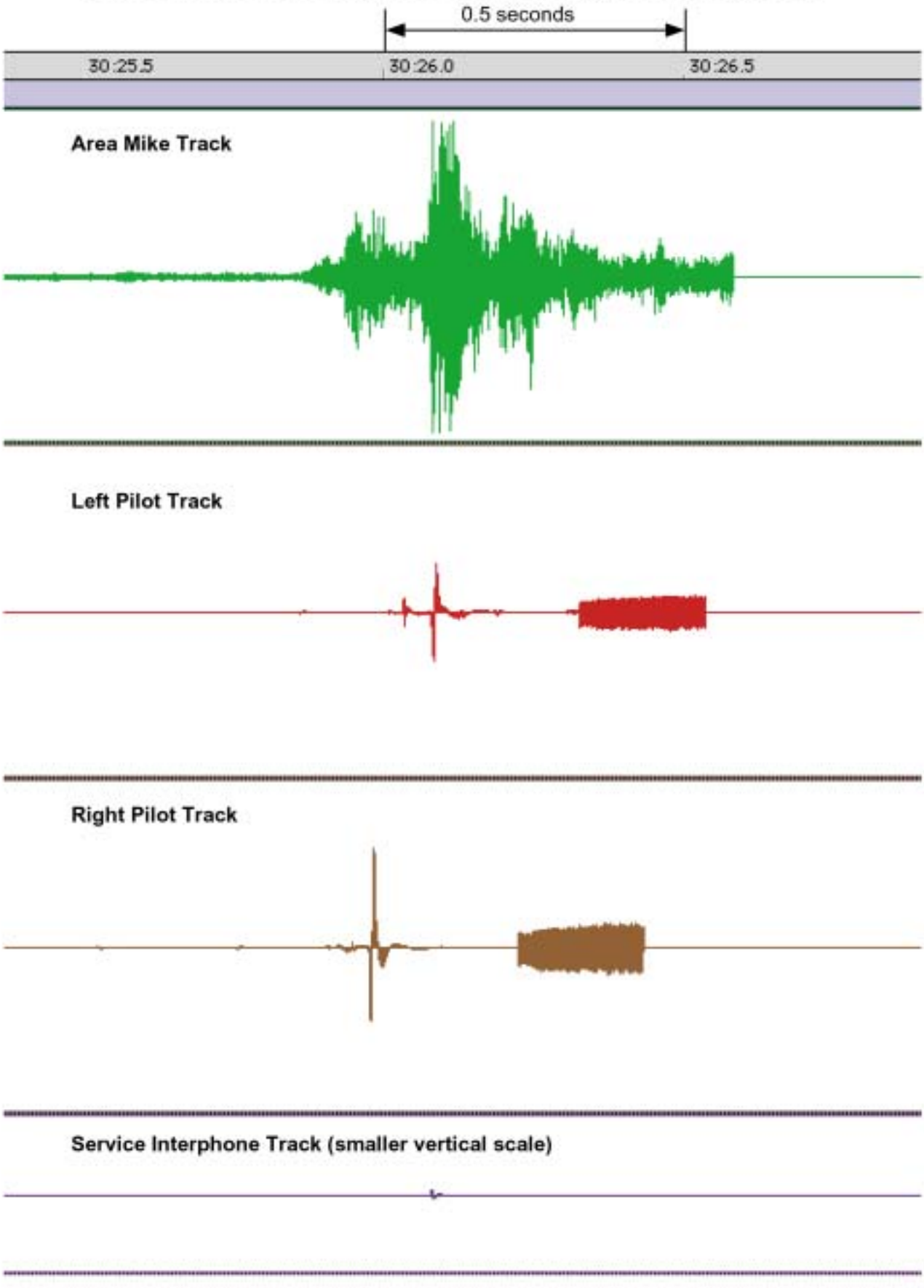
E. SK686, last seconds of CVR sound, Area Mike track.
F. SK686, last second of CVR sound, Left Pilot track.
G. Audio Waveforms from ELT transmission on 121.5 MHz.

Appendix C


SK686 Audio Waveforms from last minute of CVR Area Mike recording
Time from start of recording
29:20
29:25
29:30
29:35
29:40
29:45
29:50
29:55
30:00
30:05
30:10
30:15
30:20
30:25
10 seconds
Area Mike track
(sounds from cockpit)
Left Pilot track
(radio traffic)
Impact
Callout
Rotate
Vee one
Vibration noise from nose wheel and instrument fan spinning down
Clicking noise from nose wheel lift off
[Sound from rolling]
(Set thrust, instruments are checked ... and 130).
(130 check ed)
(Compasses checked true), auto throttle on, set thrust
Cleared for take-off 36 set, when airborne squawk ident, and we are rolling Scandinavian 686.
break, break Scandinavian 686, Linate, cleared for takeoff 36, the wind is calm, report rolling, when airborne squawk ident.
ELT

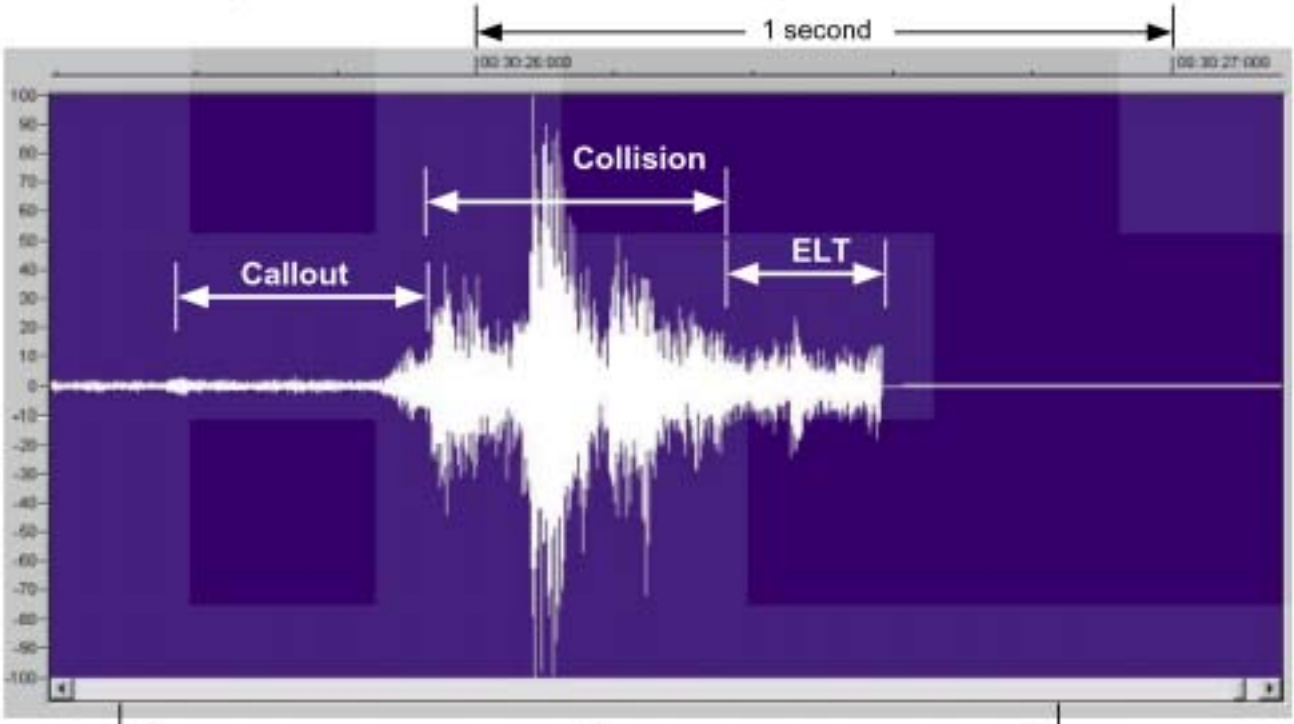
Appendix D

SK686, last second of CVR sound, all four tracks.



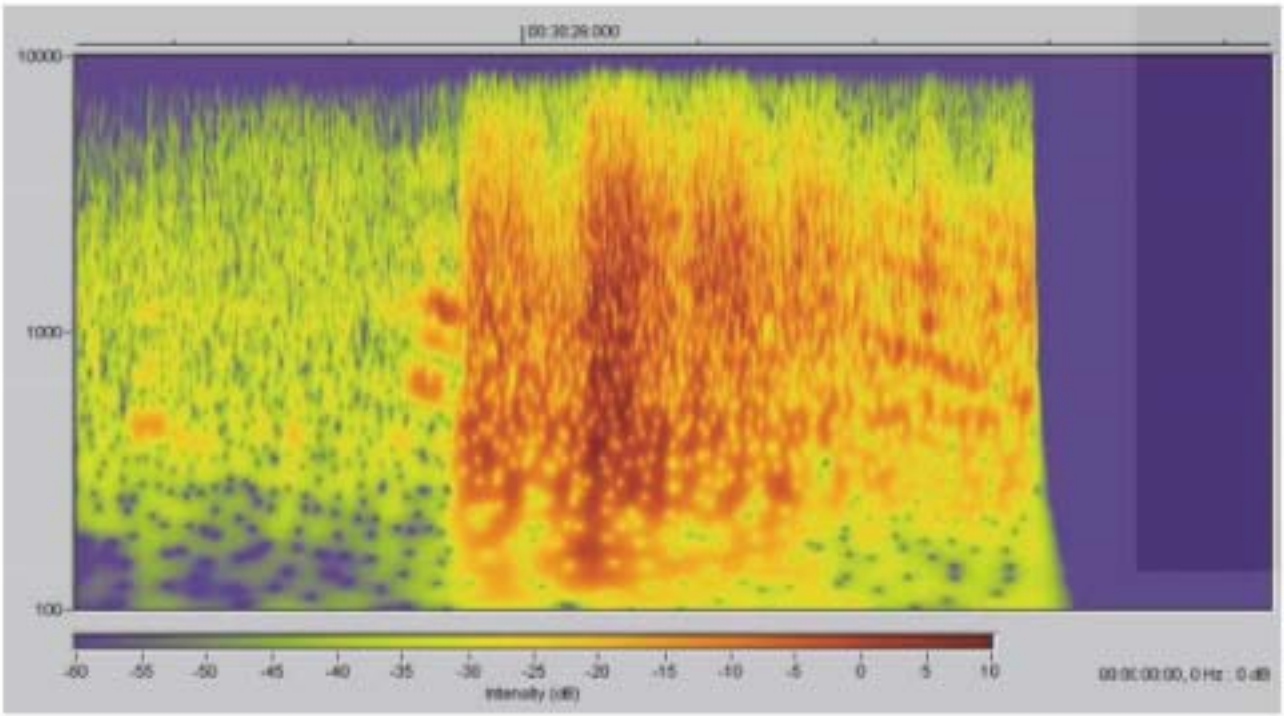
Appendix E

SK686, last seconds of CVR sound, Area Mike track.



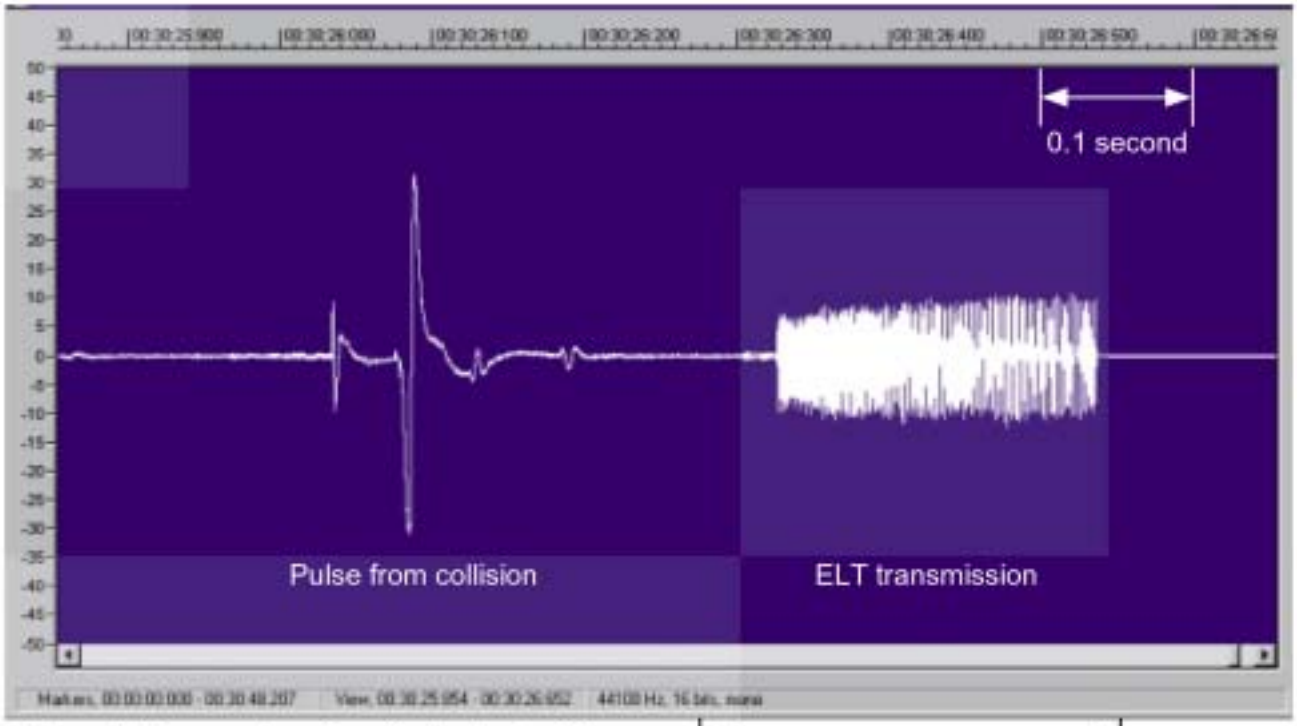
The upper picture is from is a wave-form (time on horizontal axis and amplitude on vertical axis) covering the last ca 2 seconds from the Area Mike track.

The picture below is a "wavelet", (sonogram) of the sound above. Instead of sound amplitude the vertical axis represents frequency on a log scale. As evident from the pictures the collision is a rather lengthy event. In the right part of the sonogram a downwards frequency sweep from the ELT (Emergency Locator Transmitter) can be seen.



Appendix F

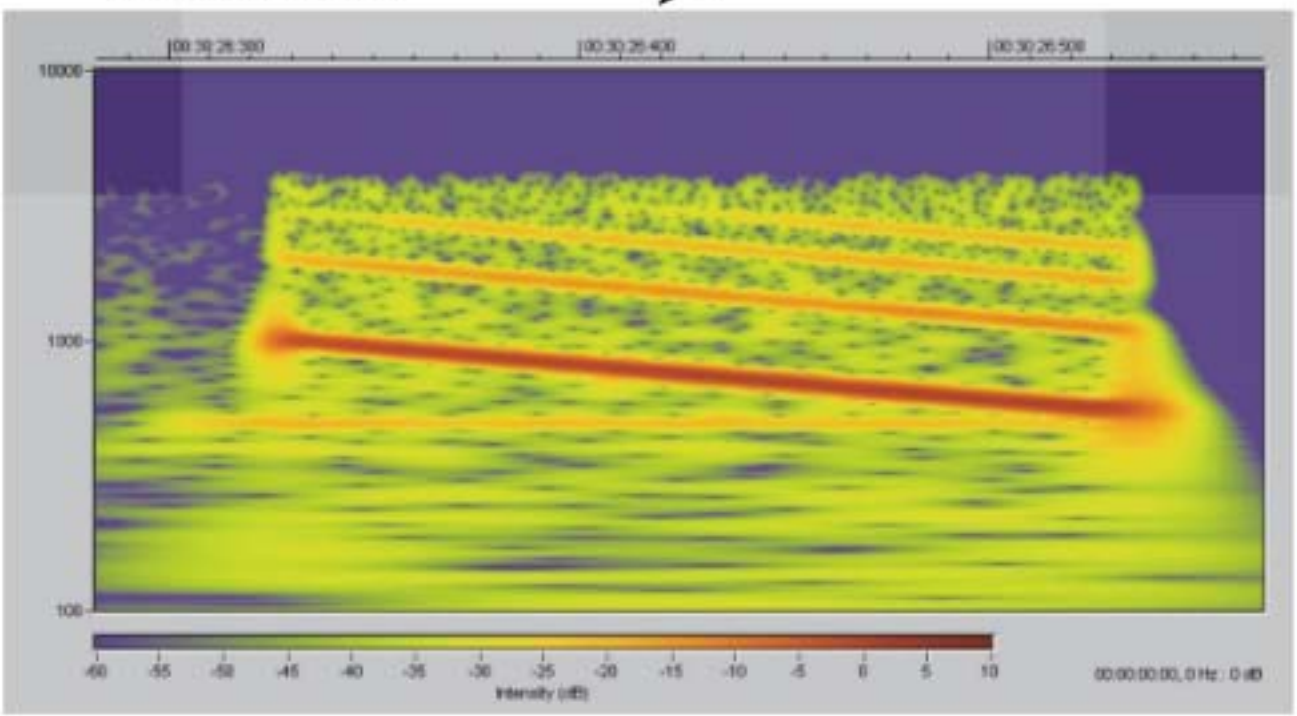
SK686, last second of CVR sound, Left Pilot track.

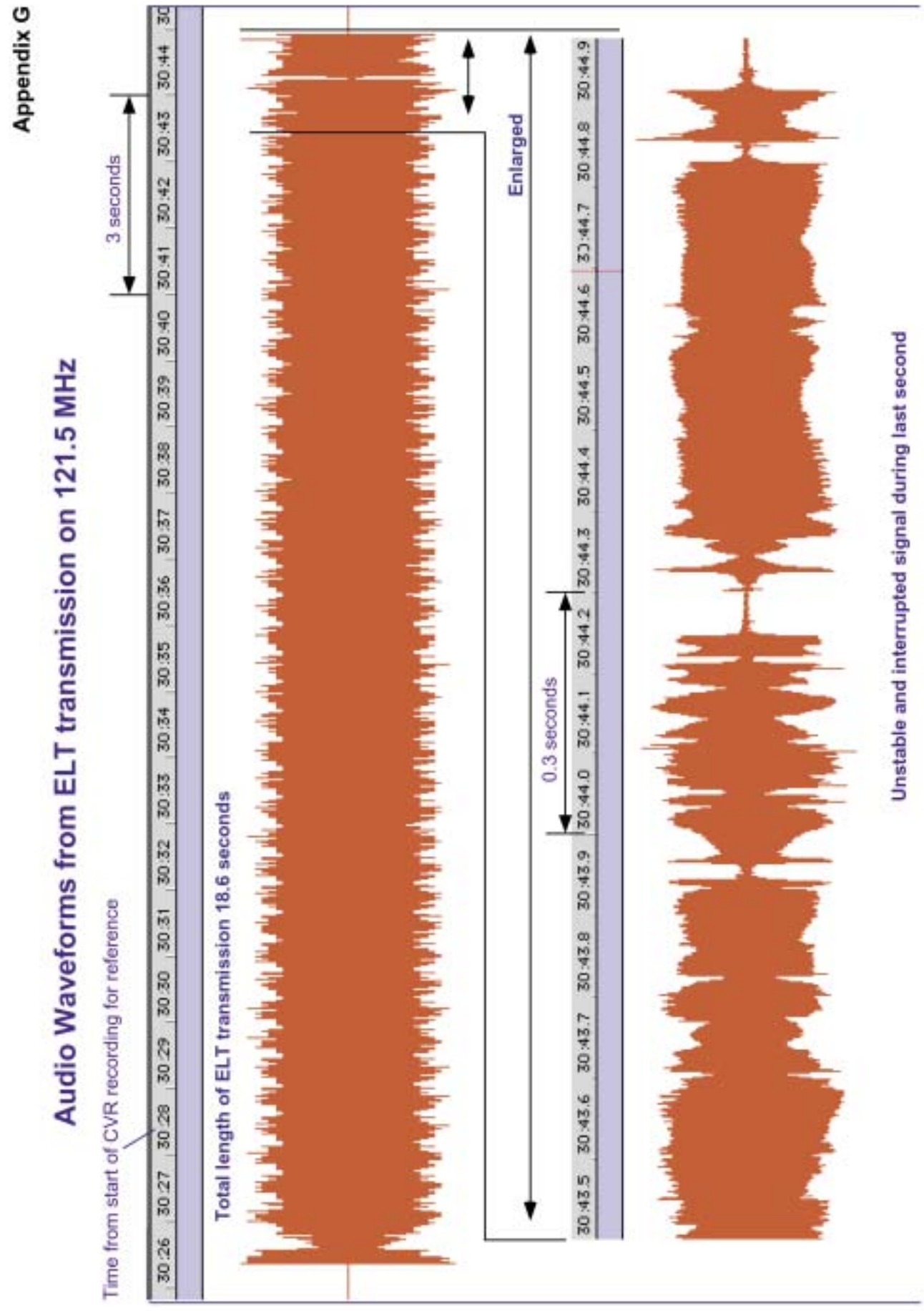


Above is the waveform from the last part of the CVR recording on the Left Pilot Track

Only this part in sonogram

Below is a sonogram from the LP track. The descending lines are from ELT transmission.




Appendix G
Audio Waveforms from ELT transmission on 121.5 MHz
Time from start of CVR recording for reference
3 seconds
Total length of ELT transmission 18.6 seconds
Enlarged
0.3 seconds
Unstable and interrupted signal during last second
30:26
30:27
30:28
30:29
30:30
30:31
30:32
30:33
30:34
30:35
30:36
30:37
30:38
30:39
30:40
30:41
30:42
30:43
30:44
30:43.5
30:43.6
30:43.7
30:43.8
30:43.9
30:44.0
30:44.1
30:44.2
30:44.3
30:44.4
30:44.5
30:44.6
30:44.7
30:44.8
30:44.9