

Saab Aerosystems AB: Per Våtz

**Title: Exterior noise measurements of  
Gripen NG demonstrator****SUMMARY**

To investigate the Gripen NG exterior noise emissions, a back-to-back noise test has been performed, comprising measurements on both the Gripen NG demonstrator and Gripen C. The measurements of the two aircraft versions back-to-back has allowed for the difference in measured A-weighted sound pressure levels to be deduced. Knowing the delta is very valuable information, since application of this delta on the comprehensive NPD database for the current Gripen versions A-D is possible.

Noise has been recorded on ground at Saab airfield in Linköping, Sweden, during take off with military thrust and flyover with thrust for level flight. The measurements were performed in less than 40 minutes under excellent comparable conditions.

The main conclusion of this back-to-back test is that the noise levels are the same at Military Power and slightly lower for the Gripen NG demonstrator when the power is reduced. Actual measured noise levels appear in Table 1. The presented levels have been corrected to 1000ft above ground to allow for a descent comparison.

Table 1 A-weighted noise levels of Gripen C and Gripen NG demonstrator.

<b>Fligth condition</b>	<b>Aircraft</b>	<b>L<sub>Amax</sub></b>	<b>Difference in dB Gripen C – Gripen NG</b>
Flyover*	A/C 39-227, Gripen C	80.1	0.9
	A/C 39-7, Gripen NG demonstrator	79.2	
T/O MIL**	A/C 39-227, Gripen C	108.1	0.1
	A/C 39-7, Gripen NG demonstrator	108.0	

\* Flyover with thrust for level flight at 1000ft and approximately 300kts.

\*\* Take off with military thrust at 1000ft and approximately 240kts.

Another important conclusion is that a slight noise level increase was measured at Military Power compared to the NPD database for both aircraft versions. Earlier recommendation of adding 1 dB to the NPD database for the Gripen NG is therefore still judged to be a good assumption, but required only for Military Power. This recommendation is then also applicable to the current Gripen A-D.

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## **1 INTRODUCTION**

This report comprises the documentation of a back-to-back noise test where the Gripen NG demonstrator is compared to Gripen C. The measurements of the two aircraft versions back-to-back allow for the difference in measured A-weighted sound pressure levels to be deduced. The delta can then be added to the current comprehensive Noise Power Distance (NPD) database available for the Gripen A-D aircraft, ref. [1].

## **2 BACKGROUND**

The new Gripen NG is equipped with the more powerful GE F414G engine compared to the current GE F404/RM12 engine. Estimations on the impact on the new engine noise emissions as compared to the current engine has been done based on static noise data from the engine manufacturer, ref. [2]. The estimated noise increase with the new engine was calculated to 0.6 dB.

On the request from Saab Aerosystems AB, measurements of actual noise emissions during flight with the demonstrator aircraft for Gripen NG has been accomplished. The assignment has been performed under purchase order number 1390076551 based on A2Zound quotation, ref. [3].

## **3 TEST PROGRAMME**

### **3.1 General**

Noise measurements were performed 2008-11-17 on Saab Airfield in Linköping, Sweden. Recordings were taken for flyovers at TFLF<sup>i</sup> and simulated take offs at military thrust both for JAS 39 Gripen C and the Gripen NG demonstrator. Take off tests using the afterburner were not included. The demonstrator aircraft was representative for the offered Gripen NG.

All measurements were completed as back-to-back test within less than 40 minutes under stable weather conditions. This is an important fact since minimizing potential causes of dispersion between the repeated measurements of the two aircraft versions gives more precise results.

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<sup>i</sup> Thrust For Level Flight

### 3.2 Test aircraft

Noise measurements were performed on:

- Gripen no. 39-227, C-version.
- Gripen NG demonstrator no. 39-7.

### 3.3 Flight conditions

Noise measurements were performed under the following flight conditions:

- Flyover at TFLF. Height approximately 1000 ft above microphones and speed approximately 300 kts.
- Simulated take-off at military thrust (MIL). Height approximately 1000 ft above microphones and resulting speed appr. 240 kts.

A third flight condition, simulated landings, were planned but had to be abandoned.

For both aircraft three flyovers and two simulated take-offs were captured. One complete take off from brake release was also measured for the NG demonstrator.

Details on aircraft data, including height, speed and PLA<sup>ii</sup>, are given in Table 2 below.

### 3.4 Test site

The measurements were performed at the beginning of runway 29 at Saab Airfield in Linköping according to Figure 1.

Microphones were located at the locations marked A, B and C. Microphones A and B were positioned on tripods 1.2 m above ground. The tripods were located on grass which was approximately 10 cm long. The grass was a little wet/frozen.

Microphone C was located on the asphalt, which was almost dry.

All microphones were equipped with 90 mm windscreens. For microphone C this implied that the membrane of the microphone was approximately 45 mm above the asphalt surface.

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<sup>ii</sup> Power Lever Angle

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Figure 1 Test site.

A photo from the test site is shown in Figure 2 with microphone A close to the camera position. Of particular interest to notice might be the surface conditions and the nice and stable weather.



Figure 2 Photo from test site.

### **3.5 Measurement equipment**

The following instrumentation was used for the noise tests:

- Three Norsonic ½" 1220/1201 IEC type 0 microphones
- Two Norsonic type 324 2-channel microphone front-ends
- One Brüel and Kjær 4230 microphone calibrator
- One 8 channel LMS Scadas Mobile front-end

Electric power supply was arranged at the test site primarily in order to make it possible to have the pre-heat turned on for the microphones. This implied that condensation on the microphone membranes could for sure be avoided in the rather cold weather.

The polarization voltage on the microphone amplifiers was set to 200 V for microphones A and C and to 28 V for microphone B. This implied a lower sensitivity of microphone B allowing for recording of higher noise levels

compared to microphones A and C. The difference in sensitivity due to the lower polarization voltage was 18.2 dB.

The input range of the measurement system was adjusted to maximum range, 12 V, for all measurement runs. Given that the microphone nominal sensitivity was 50 mV/Pa and that the output voltage of the microphone preamplifier was 35 V, the maximum peak sound pressure level possible to record without overload on the measurement system was approximately 141 dB for microphones A and C and approximately 159 dB for microphone B.

### **3.6 Calibration**

Calibration was performed prior and after measurements showing very small differences; in the order of 1%.

## **4 DATA ACQUISITION AND SIGNAL PROCESSING**

Data acquisition was done with an LMS Scadas Mobile front-end equipped with one V8 input module, providing 8 simultaneously sampled 24-bit analog input channels. All data were saved to disk on the controlling computer using the LMS Test.Lab Signature Acquisition software, revision 8B. The data was acquired with a sample rate of 51 200 Hz. This allowed for an effective bandwidth of 20 480 Hz, taking into account that the anti-aliasing filters were applied at 80% of the total bandwidth.

One-third octave bands and overall A-weighted sound pressure levels, LA, were calculated in-line with the measurements using the LMS Test.Lab Signature Throughput Processing software, version 8B. The one-third octave bands were calculated with time domain filters according to ANSI S1.11-2004 class 1. A-weighting was also done in the time domain according to ANSI S1.42.

The overall sound pressure levels were calculated in the time domain, compliant to ANSI S1.4.

All analyses were performed using an integration time of one second.

The interval between successive sound pressure level samples was set to 0.5 seconds.

## 5 MEASUREMENT RESULTS

### 5.1 General

Based on the noise recordings, the delta between the aircraft versions in A-weighted sound pressure level, LAmax, has been deduced. Knowing the delta is very valuable information, since application of this delta on the comprehensive NPD database for the current Gripen versions A-D is possible. Representative figures from the NPD database are given in section 5.3.2 of the report.

Additional information is also given on the spectral contents of the two aircraft versions, based on the 1/3 octave band analyses. This information is valuable for e.g. sound propagation calculations.

It should also be mentioned that further analyses, including e.g. calculation of Sound Exposure Level (SEL), are possible on the acquired noise data.

### 5.2 Meteorological data

Meteorological data was taken at three occasions in conjunction with the noise measurements, see Table 2. The noise test period of a/c 39-227 was between 10:03-10:19 and the similar test period for a/c 39-7 was between 10:25-10:40.

Table 2 Meteorological data.

Time	Wind dir. Deg.	Wind speed kts	Temperature C	Rel. humidity %	Airpressure Pa
09:51	290	5	2	62	1018
10:18	290	6	2	63	1017
10:30	290	5	2	64	1017

All meteorological data, except wind speed and direction, was taken 2 m above ground, 600 m from the noise test site. The wind was measured 10 m above ground.

One additional meteorological measurement was also taken 10:40 at 1000 ft height. The wind direction and speed was 340 degrees and 15 kts respectively.

Temperature aloft at aircraft height varied between ISA<sup>iii</sup>-12 to ISA-15 C during noise measurements.

<sup>iii</sup> International Standard Atmosphere

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### 5.3 Noise data

#### 5.3.1 A-weighted sound pressure level

In Figure 3 and 4 the A-weighted sound pressure level, LA, variation with time is shown for the flyovers and the simulated take offs. An additional curve representing the complete take off for Gripen NG demonstrator is also shown in Figure 4. The curves include no corrections for diverging aircraft data between flights or aircraft.

The legend for test run number, “r”, in the figures can be found in Table 3 below.

It is noted in the figures that the noise level variation with time looks quite similar for the two aircraft. Note also that zero time is arbitrary chosen.

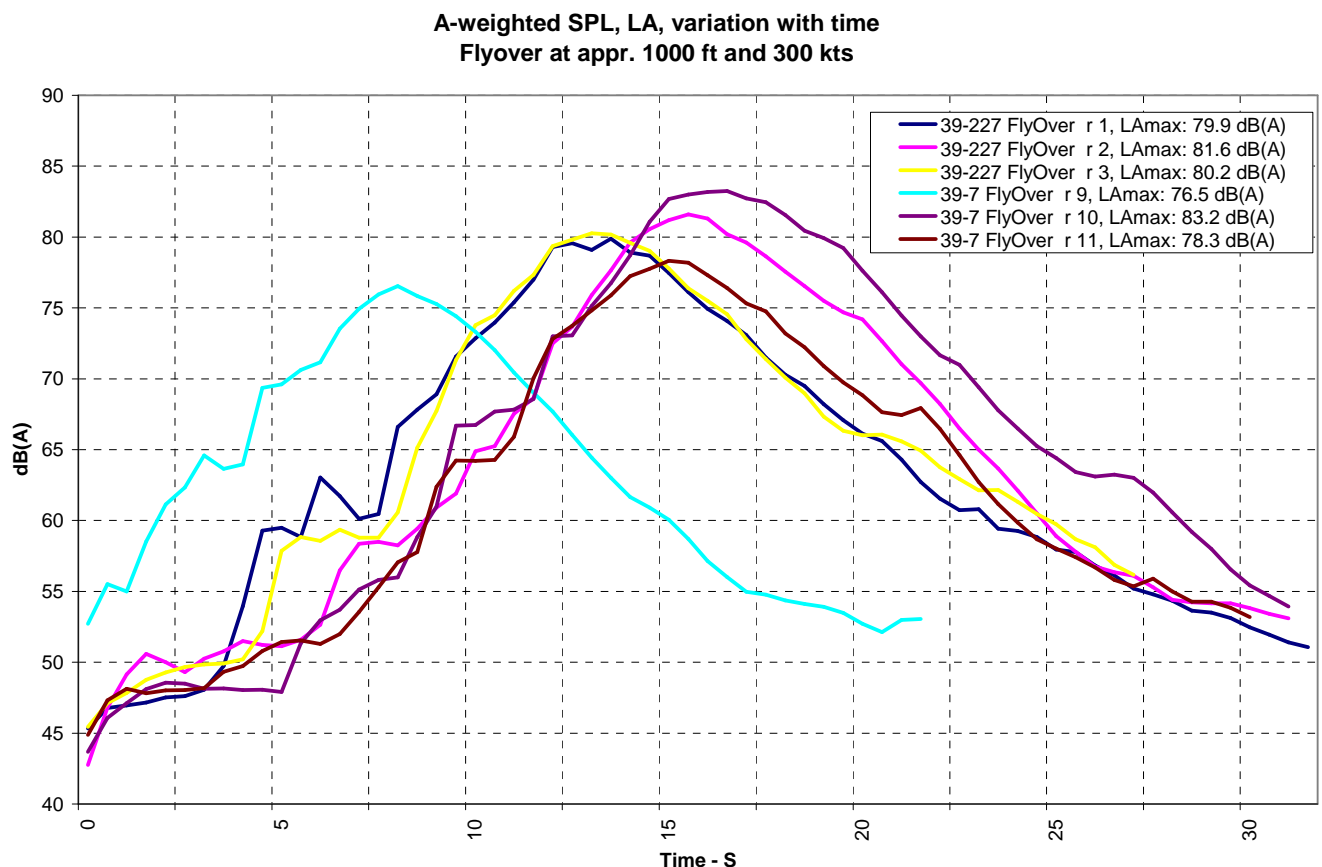


Figure 3 A-weighted sound pressure level during flyovers at TFLF for microphone A. Three flyovers with a/c 39-227 and three flyovers with a/c 39-7. Maximum levels are indicated in the legend of the graph.

**A-weighted SPL, LA, variation with time  
T/O MIL**

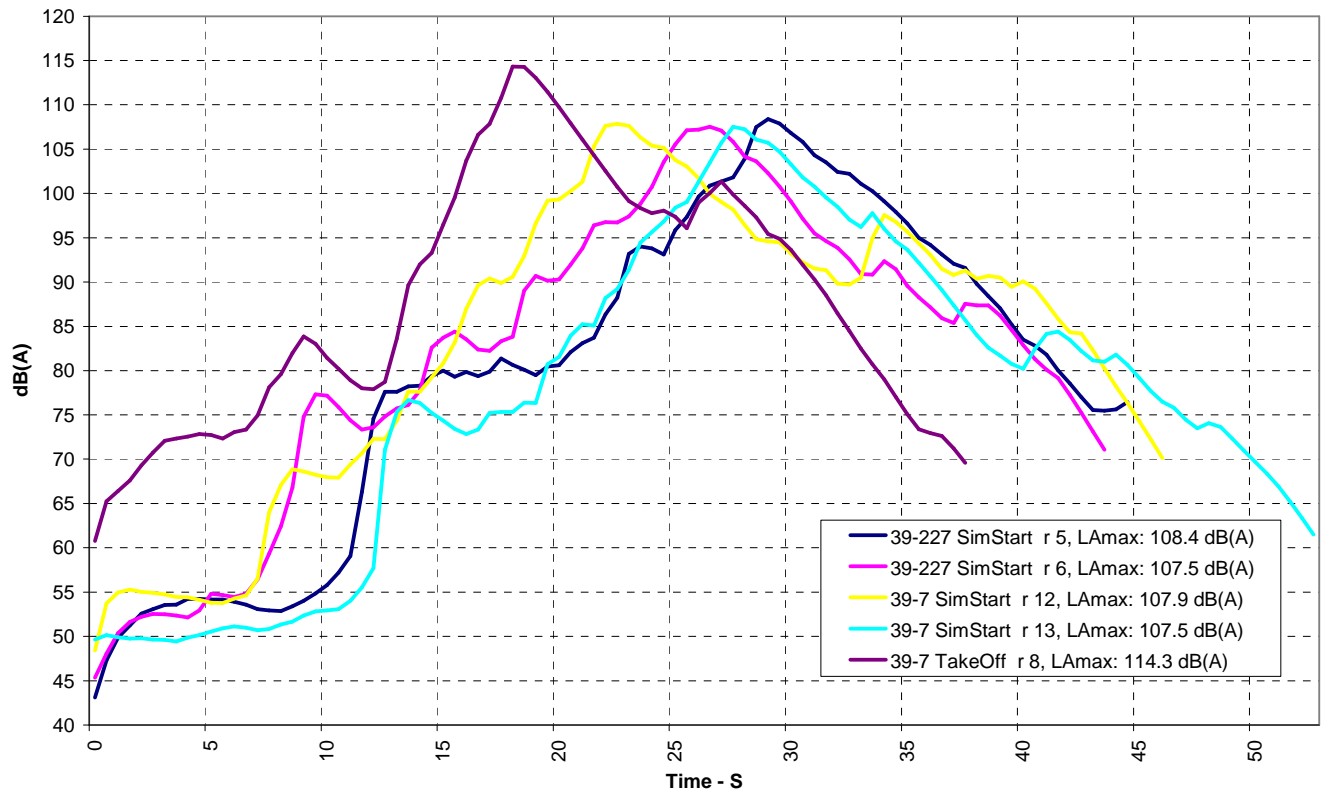


Figure 4 A-weighted sound pressure level during simulated take offs at military thrust (MIL) for microphone A. Two simulated take-offs at military thrust (MIL) with a/c 39-227 and two simulated take-offs (MIL) with a/c 39-7. Maximum levels are indicated in the legend of the graph.

The maximum A-weighted sound pressure levels, as noted in the figures above, were determined for each flyover and simulated take-off case. In conjunction with the noise measurements, the aircraft height and speed and engine power setting (PLA), when abeam the microphone site, were obtained via recorded data from the aircraft instrumentation system. In Table 3 the maximum noise levels, LAmax, of microphones A and B, the average number of the microphones A and B and the corresponding engine/aircraft data is given. The average LAmax is used for further analysis herein. It should be noted that for the presentation of the results, focus has been on microphones A and B and data on microphone C will not be shown.

A quick examination of the engine power data for the flyover cases reveals a difference in PLA between the two aircraft, both in level and in variation. This is not primarily due to difference in thrust required at 300 kts aircraft speed but due to different characteristics of the thrust vs. engine PLA relationship (same

thrust level requires a higher PLA in the NG demonstrator). The thrust level would have been the correct information on engine power but was not available when releasing this report. Note, however, that the measured LA<sub>max</sub> for the NG demonstrator correlates well with measured PLA.

According to Table 3, the height of aircraft when passing the microphone site for both flyovers and simulated take offs is about 1000ft. To get an apple-to-apple comparison of noise levels for the two aircraft versions, the maximum noise levels are adjusted to 1000ft by simply adding 20 times the logarithm of height divided by 1000. Averaging the numbers for flyovers and simulated take offs yield finally noise levels for comparison of the two aircraft. As can be seen the noise levels are almost identical at Military Power and slightly lower for the Gripen NG demonstrator during level flyovers at 300 kts aircraft speed.

Thus, the conclusions of this back-to-back test, performed under excellent comparable conditions, are that the noise levels are the same at Military Power and slightly lower for the Gripen NG when the power is reduced. This tendency could well mean that Gripen NG will have lower noise levels also at thrust levels required for landing.

These conclusions imply that the currently available NPD database for the Gripen A-D versions is directly applicable also to the Gripen NG.

Table 3 Noise levels, LAmax, and aircraft data for all flyovers and take offs. A/C's 39-227 and 39/7.

Run	Time	Test pos	MicA LA,max dB(A)	MicB LA,max dB(A)	Avg. (A,B) LA,max dB(A)	Aircraft/Engine Data when passing mic site				Correction to 1000ft			
						Mission Time	Engine Power	Height ft	Speed kts	Delta dB	Avg. (A,B) LA,max dB(A)	Avg. LA,max dB(A)	
		<b>A/C 39-227, Gripen C:</b>											
1	10:03	Flyover with TFLF	79.9	79.2	<b>79.6</b>	-	PLA 45	948	300	-0.46	<b>79.1</b>		
2	10:05	Flyover with TFLF	81.6	81.3	<b>81.5</b>	-	PLA 45	955	297	-0.40	<b>81.1</b>	<b>80.1</b>	<b>Flyover</b>
3	10:07	Flyover with TFLF	80.2	80.6	<b>80.4</b>	-	PLA 45	961	299	-0.35	<b>80.1</b>		
5	10:12	Simulated Takeoff, Mil. Power	108.4	108.5	<b>108.5</b>	1983.7	Mil. Power	1013	226	0.11	<b>108.6</b>		
6	10:17	Simulated Takeoff, Mil. Power	107.5	108.4	<b>108.0</b>	2201.3	Mil. Power	962	226	-0.34	<b>107.6</b>	<b>108.1</b>	<b>Mil. Pwr</b>
		<b>A/C 39-7, NG demonstrator:</b>											
8	10:25	Complete takeoff	114.3	115.2	<b>114.8</b>	33895	Mil. Power	491	228	-	-		
9	10:26	Flyover with TFLF	76.5	76.1	<b>76.3</b>	33992	PLA 50	918	288	-0.40	<b>75.9</b>		
10	10:28	Flyover with TFLF	83.2	83.8	<b>83.5</b>	34109	PLA 59	898	296	-0.35	<b>83.2</b>	<b>79.2</b>	<b>Flyover</b>
11	10:30	Flyover with TFLF	78.3	78.7	<b>78.5</b>	34237	PLA 52	932	302	0.16	<b>78.7</b>		
12	10:36	Simulated takeoff, Mil. Power	107.9	109.2	<b>108.6</b>	34529	Mil. Power	1044	244	0.11	<b>108.7</b>		
13	10:38	Simulated takeoff, Mil. Power	107.5	107.9	<b>107.7</b>	34693	Mil. Power	991	252	-0.34	<b>107.4</b>	<b>108.0</b>	<b>Mil. Pwr</b>

Note: Run 4, simulated take off was not analyzed. Pilot retarded the throttle too early.

### 5.3.2 Measurements compared to the NPD database

A comparison between the measured maximum noise levels, LAmax, for the Gripen NG demonstrator and the corresponding values as present in the NPD database (ref. [1]) for the Gripen A-D versions is made below, Figure 5 and 6.

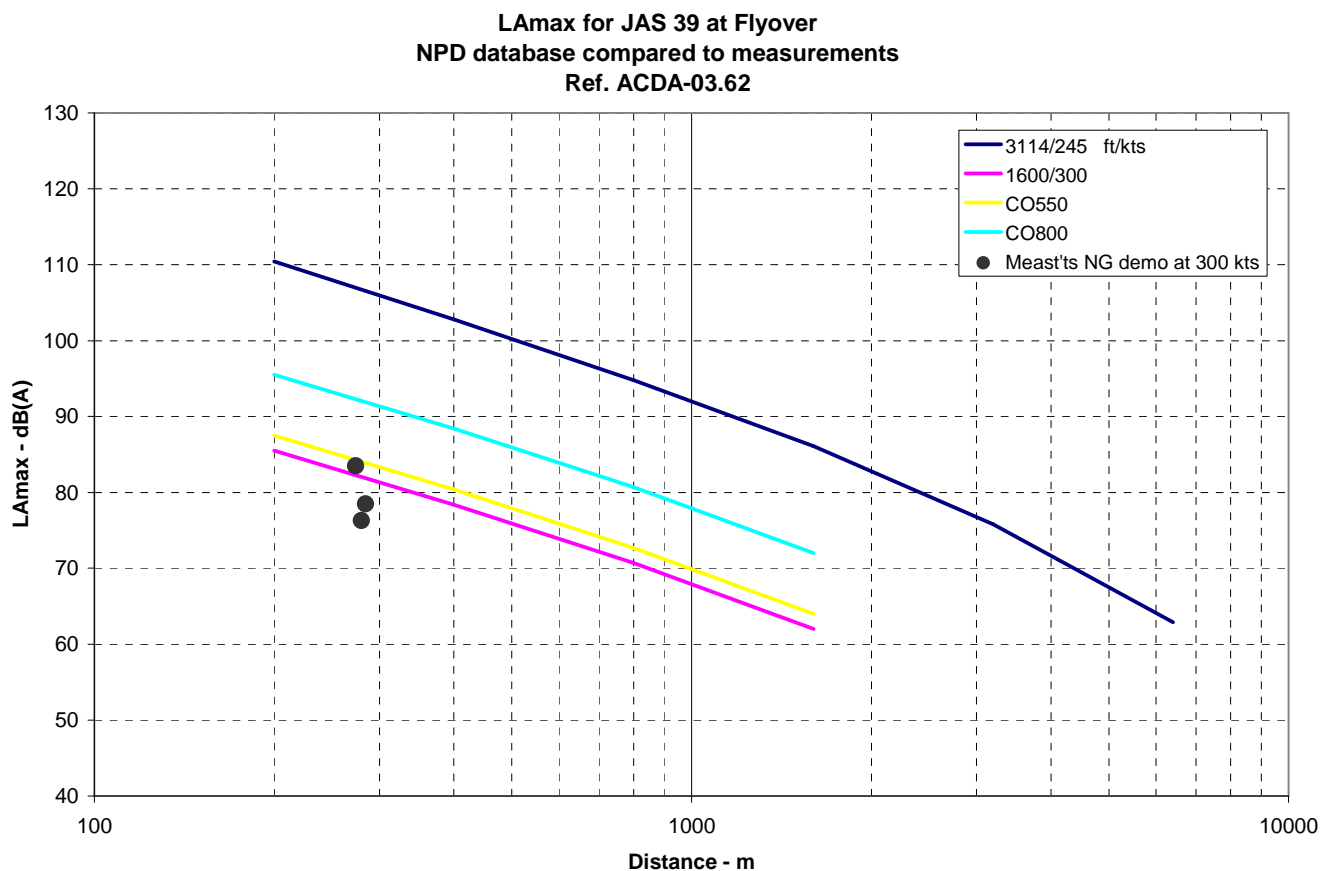


Figure 5 Noise level, LAmax, variation with distance to aircraft for flyover. Measured LAmax for Gripen NG demonstrator shown as black dots.

The upper and lower curves in Figure 5 show the span in noise levels to be expected between Military Power and power or thrust for level flight (TFLF). The yellow and cyan curves (the second and third curve from bottom) represent noise levels, LAmax, measured earlier with the Gripen A flying on different heights at 300 (CO550) and 430 kts (CO800), respectively. The NG demonstrator noise data can be compared to the yellow curve labeled CO550. It is noted that the NG demonstrator is giving slightly lower noise levels compared to the previous measurements with Gripen A.

Figure 6 below displays the predicted A-weighted noise versus distance database at Military Power. This database was confirmed by the earlier noise tests of Gripen A, ref. [1]. The upper curve represents static conditions and the lower curves increasing flight speeds. Note the marked effect on noise when leaving zero conditions. The measured maximum noise levels for simulated take-offs with the NG demonstrator, plotted at minimum distance to the flight path, appear slightly higher compared to the database. Remember this applies also to the result for the Gripen C, since the measured noise level at Military Power was almost identical (Table 3). The slightly higher noise level could well be an effect of ambient temperature. Zero temperature compared to 8-15 deg C in previous tests with the Gripen A means higher thrust and more generation of jet noise. But the effect of temperature, if any, has not been investigated further.

If the reason to the higher noise levels at Military Power is not due to temperature, it might be an indication to an actual difference to the NPD database. This implies that the current NPD database at Military Power might need to be updated to mirror actual noise emissions of Gripen A-D and NG.

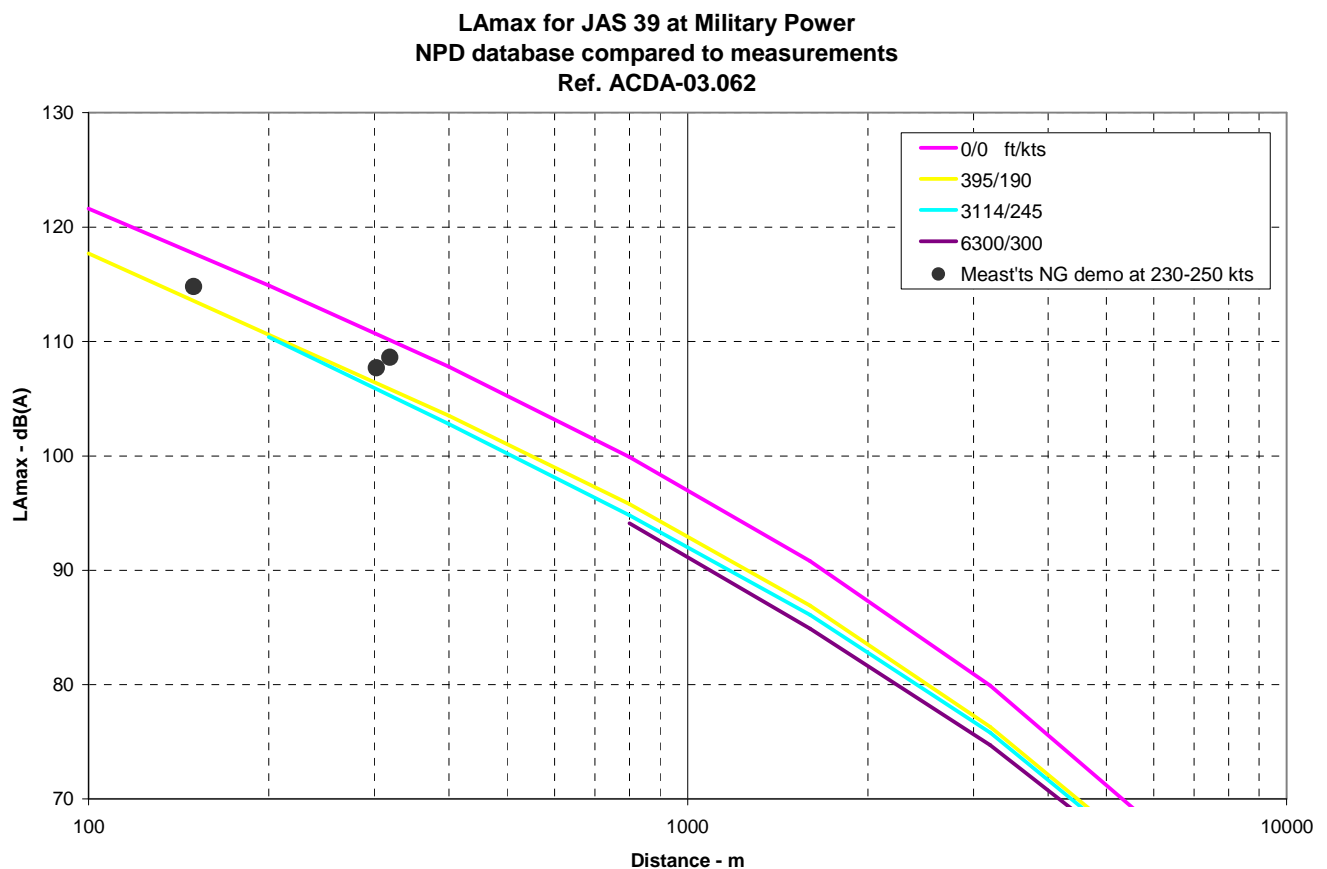


Figure 6 Noise level, L<sub>Amax</sub>, variation with distance to aircraft at military thrust. Measured L<sub>Amax</sub> for Gripen NG demonstrator shown as black dots.

**5.3.3 1/3 octave bands**

The 1/3 octave band sound pressure levels corresponding to the event of maximum achieved A-weighted sound pressure level, L<sub>Amax</sub>, was analyzed for all test cases. Figure 7 and 8 show the results for microphone A for the flyovers and simulated take-offs. It is noted that the spectral contents look very similar for both aircraft versions. Note, however, in Figure 8, that the 1/3 octave band spectrum at 1000 ft have lost some high frequency contents compared to the spectrum for the complete take off with peak noise occurring at lower height.

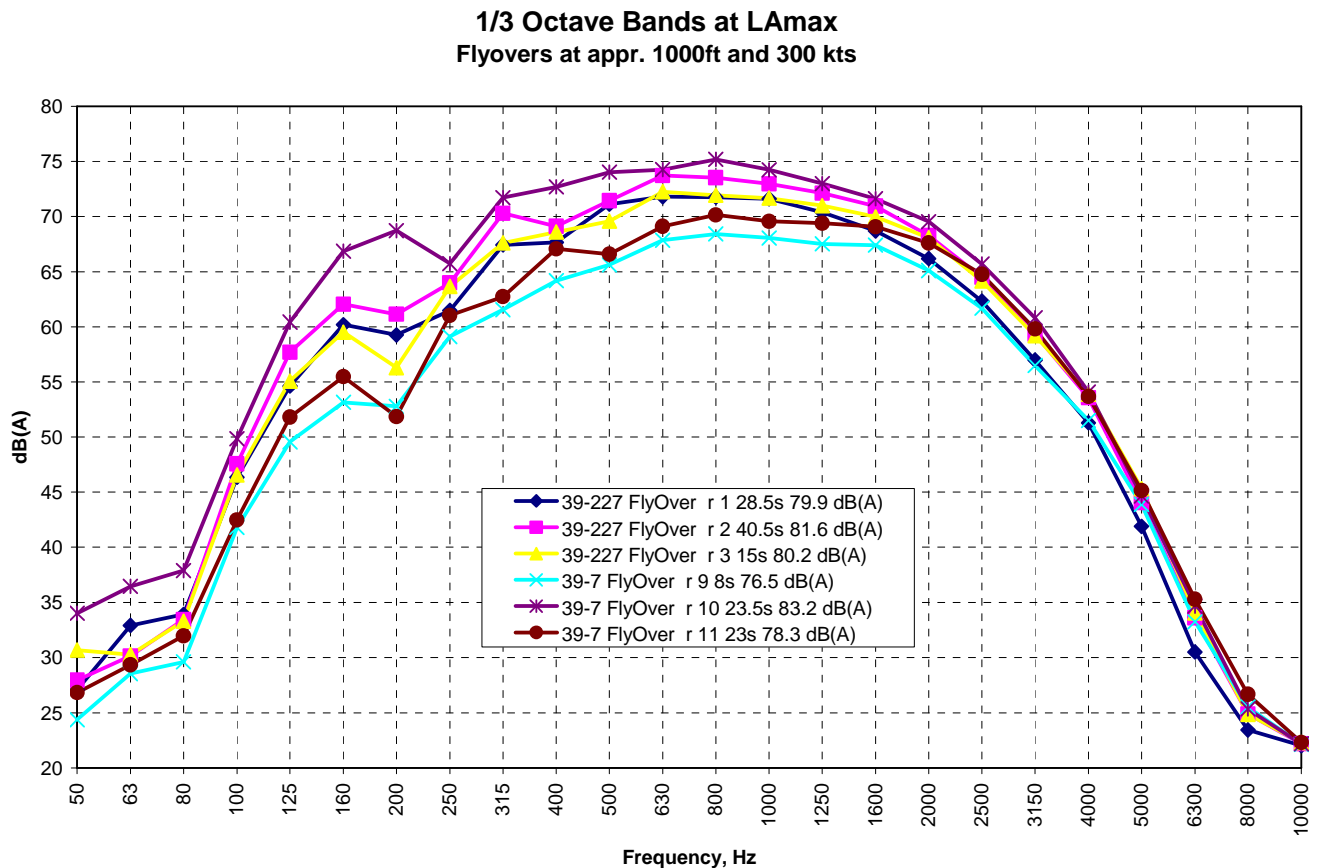


Figure 7 1/3 octave bands for repeated flyover runs with a/c 39-227 and 39-7 for microphone A. The actual time stamp in the recording for calculation of the 1/3 octave bands are shown in the legend together with the L<sub>Amax</sub> value.

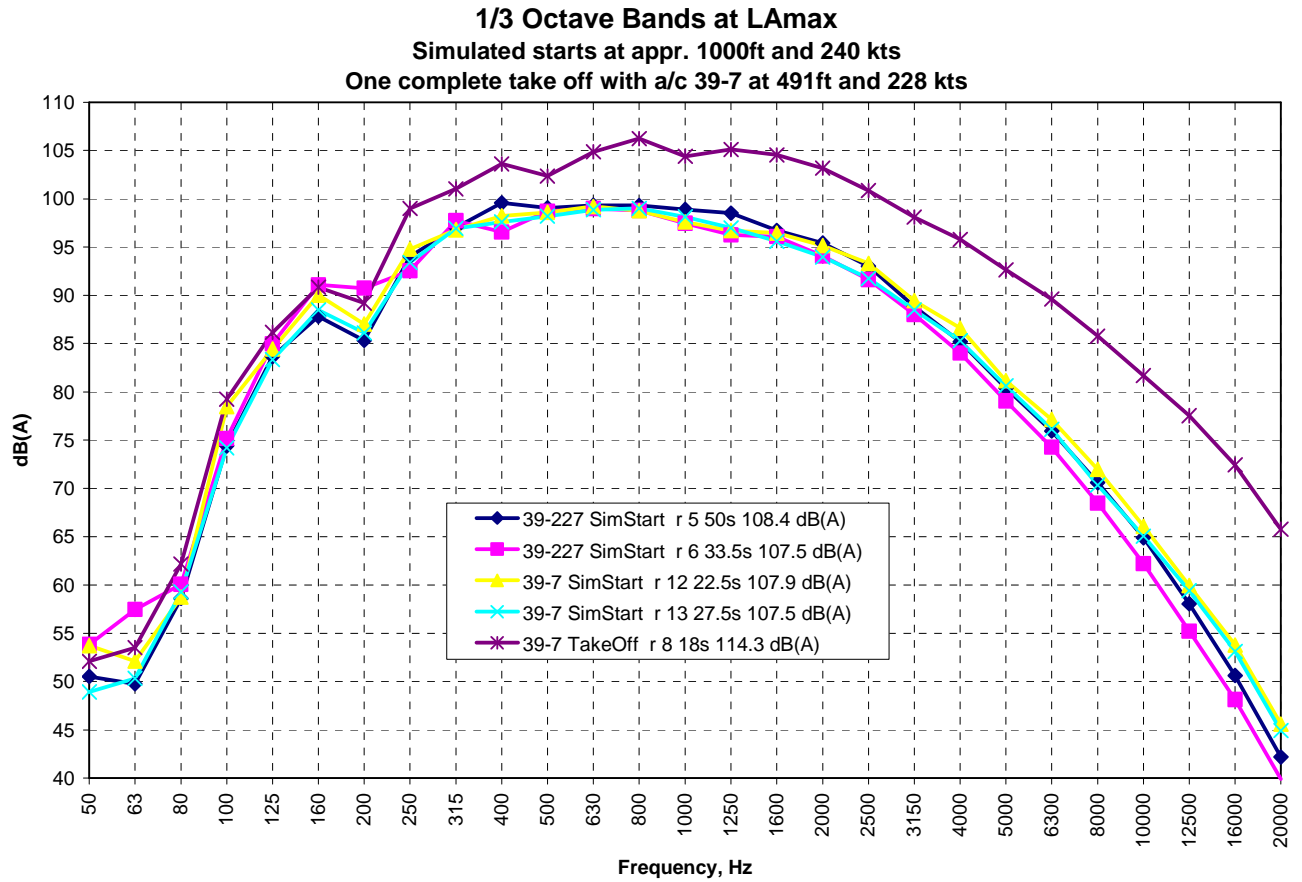


Figure 8 1/3 octave bands for repeated simulated starts with a/c 39-227 and 39-7. The 1/3 octave bands for one complete take off for a/c 39-7 is also shown. The actual time stamp in the recording for calculation of the 1/3 octave bands are shown in the legend together with the L<sub>Amax</sub> value.

## 6 CONCLUSIONS

The main conclusion from the performed noise measurements is that the difference in noise level between the Gripen NG demonstrator and Gripen C is minor. The difference was measured to 0.9 dB at flyover and 0.1 dB at take off, Gripen C giving the higher levels.

At Military Power a slight noise level increase was measured compared to the NPD database for both aircraft versions. Earlier recommendation of adding 1 dB to the NPD database for the Gripen NG is therefore still judged to be a good assumption, but required only for Military Power. This recommendation is then also applicable to the current Gripen A-D.

## 7 REFERENCES

- [1] Ericsson, L., ACDA-03.061, "Noise Database for the Saab JAS39 Gripen for Determining the Noise Exposure at and around Airfields.", including also "Appendix 1. Noise Database for the Saab JAS39 Gripen Aircraft", 2003-09-01.
- [2] Samuelsson, F., "A2Z-R-08-004, JAS39 Gripen. Assessment of the acoustic differences between the GE F404/RM12 and F414G engines.", 2008-02-08
- [3] Österström, N., "A2Z-Q-08-099, Exterior Noise Measurements of Gripen NG", 2008-11-11