FROM EXTERNAL TO INTERNAL NOISE ON AIRBUS A350

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In the beginning of 2018 an important flight test campaign was launched on Airbus A350-1000. The project was to assess the noise for a double purpose: first concerning the noise in forward cabin linked to the engine fan at high rating, then in the aft cabin linked to the engine jet and fan noise.

From the external part of the aircraft to the internal noise perceived by the passenger, around 220 sensors were set up on the aircraft. It gathered several kinds of measurements. Thanks to the strong involvement of the flight test and the production teams, this big amount of microphones and accelerometers was set up in less than 7 days during a dedicated working party.

First 82 external microphones and 3 accelerometers were installed on the fuselage skin, then 21 accelerometers on the fuselage frames, 4 accelerometers on the cabin floor, 6 microphones between the fuselage and cabin lining, 30 accelerometers on the ceiling, the walls, the hatracks and finally 15 microphones on the seats. In addition the engine rotation speed tachymeter was recorded as well, thanks to a connection from the usual engine monitoring system. A noise localization device made of 60 microphones was installed as well in the forward part of the yankee class of the cabin.

In this set of sensors, a very special kind of external flush-mounted microphones were installed on the fuselage. This new prototype was a very thin one. It was able to perform measurements without altering the physical dynamic behaviour of the turbulent boundary layer.

The comparison of this sensor outcome with standard flush mounted microphones indicates that the low frequency noise has a lower level.

Keywords: noise, aircraft, microphones, accelerometers, flush

1. A specific and complete request

The goal of this project was to assess the noise in the Airbus A350-1000 cabin. In fact, a double purpose was motivating the flight test in order to assess:

- the forward cabin noise related to the engine fan rotation at high rating called “Buzz Saw Noise”. This noise affects the forward cabin especially during climb.
- the aft cabin noise related to the engine jet / fan noise disturbing the passengers in the backward area after the wings. This noise increases the background noise significantly.

The target was to gather around 220 sensors on the aircraft for a specific flight. This had to be done in a short time delay in order to have the flight test performed on time. The working party for this specific flight test instrumentation was 2 weeks after the starting point of the request. So a big amount of preparation and coordination started at that time.
The complete request identified the following measurements (see table 1 below):

### Table 1: Location of sensors on the aircraft

<table>
<thead>
<tr>
<th>Sensors</th>
<th>Fuselage</th>
<th>Behind lining</th>
<th>Cabin</th>
<th>Cargo</th>
<th>Engine</th>
</tr>
</thead>
<tbody>
<tr>
<td>External microphone</td>
<td>82</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Internal Microphones</td>
<td></td>
<td>6</td>
<td>17</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Accelerometers</td>
<td>3</td>
<td>11</td>
<td>32</td>
<td>10</td>
<td>1</td>
</tr>
<tr>
<td>Tachometer</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Localization device</td>
<td></td>
<td></td>
<td></td>
<td>60</td>
<td></td>
</tr>
</tbody>
</table>

This large amount of sensors was representing measurements from the engine to the inner cabin with several steps in between: on the fuselage skin, on the fuselage structure frames (see figure 1 below), behind the commercial lining, on the cabin furniture, in the cargo, on the cabin floor and finally at the level of the passengers’ seats.

![Figure 1: accelerometers and microphones locations between fuselage and lining](image)

Once the requested sensors were properly defined, a complete integrated team worked jointly in order to get ready for flight.
2. Getting ready together

The first step was about communication. Meaning making people be aware of the project and making sure everyone would work together in order to reach the goal in the schedule.

Then there was a big issue on gathering enough hardware to fulfil the requested flight test instrumentation. After a check on several internal stores, most of the sensors were found and provided in order to be set up. But some were missing, that’s why some help was asked abroad. Thanks to sensors and cables coming from Germany, we managed to gather the complete set of requested flight test instrumentation in Toulouse, France.

Once this hardware was available, a dry run on ground in our lab was performed in order to check that the complete recording system was operational.

This was an opportunity to see the autonomy of the fully autonomous battery powered system: the target for a 6 hours flight had to be reached thanks to 4 batteries of 81 A.h capacity.

You can find below illustrations of the flight test instrumentation that was set up on the aircraft in 7 working days:

Figure 2: accelerometers on the fuselage skin at the belly fairing level
Figure 3: external microphones on the forward fuselage skin

Figure 4: aft external microphones antenna for jet / fan noise assessment
Figure 5: external belly fairing accelerometers and internal localization microphones in cabin

Figure 6: accelerometers on lining and microphones on passengers seats in cabin

Once every sensor was set up, a global verification and validation of the measurements was done on ground thanks to usual calibrators. A real engine run up creating physical excitation of the aircraft was performed as well in order to check that each sensor out of the 220 channels was properly verified and checked. This was the official way to go for flight with a 100 % operating flight test instrumentation.
3. **Real time flight test monitoring**

On January the 16\textsuperscript{th} of January the flight test took place on A350 MSN 65 for a 5 hours flight. This lead us to perform several specific flight test conditions in order to assess the “Buzz Saw Noise” conditions in climb and to check the impact of the jet and fan noise engine impact in standard cruise conditions.

Thanks to the online monitoring system it was possible to make sure that the complete flight test instrumentation was working properly (see figure 7 below).

![Figure 7: real time monitoring of the 220 measurements in flight](image)

During the flight, some measurements pointed out some weird behaviour: it was for instance the very new kind of sensors that were set up on the fuselage skin with interesting technical specification.

These sensors were set up next to usual sensors for comparison. By chance, out of the 3 specific sensors, 2 of them worked properly most of the time during the flight test. Since they have a significant lower impact on the Turbulent Boundary Layer due to their lower width, the measurements should be checked and analysed with a serious attention.

On the next chapter you will find the comparison of these relevant and promising measurements.
4. Promising outcomes

After the flight test, several data were transmitted to the Acoustic Design Office. It gathered results for:

- Forward cabin noise Buzz Saw Noise general assessment,
- Forward cabin noise Buzz Saw Noise localization assessment,
- Aft cabin noise measurements in order to assess engine fan versus jet noise issues.

The comparison of the specific sensors that are pointed out on the figure 8 below indicates that with a thinner sensor (2 mm instead of 6), the measurements show a slightly different dynamic behaviour. The thinner sensors are shown in black on the picture.

![Figure 8: sensor comparison](image)

The figure 9 below indicates lower noise level in low frequencies and higher level in high frequencies for the thinner sensor showed in blue on the graph.

![Figure 9: comparison of flush mounted microphones in forward cabin in climb conditions](image)

In the aft part of the cabin, the spectral analysis indicates some wide band noise linked to the fan in the middle or high frequencies, some tonal responses are highlighted as well.

Jet noise can be observed with lower frequency impact with main contribution between 200 and 500 Hz.