Nationaal Lucht- en Ruimtevaartlaboratorium

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In-flight lightning damage assessment system (ILDAS): Further in-flight verification, with multi-sensor configuration

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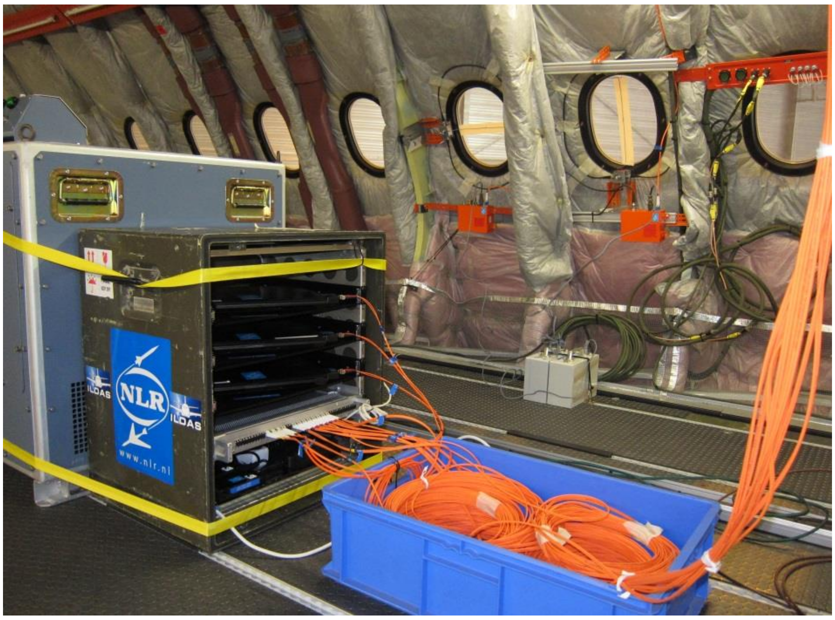
Executive summary

In-flight lightning damage assessment system (ILDAS): Further in-flight verification, with multi-sensor configuration



Problem area
On average, lightning strikes an individual commercial aircraft about once a year. Although nowadays not a safety hazard, the strikes may cause aircraft damage, resulting in inspection and maintenance costs and flight delays or cancellations. With long-term goals of improving scientific knowledge of aircraft-lightning interaction and of improving aircraft post-strike maintenance, the ILDAS programme objective is to develop a configuration for in-flight measurement of lightning strikes.

Description of work
In the ILDAS-2 project the measurement system is matured for operation on board Airbus test aircraft. A flight campaign was held on board an A380 to verify the system's performance using a multi-sensor configuration, capable of real-time detection of lightning strikes on the aircraft and automatic high-rate synchronous measurement and subsequent recording of sensor data from eight magnetic and one electric-field sensors.

Results and conclusions
The system worked well, apart from frequent false triggers which need further study. 17 strikes were recorded. The next stage will be deployment on an Airbus A350XWB during its icing trials, planned for end 2013.

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IN-FLIGHT LIGHTNING DAMAGE ASSESSMENT SYSTEM (ILDAS): FURTHER IN-FLIGHT VERIFICATION, WITH MULTI-SENSOR CONFIGURATION

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ABSTRACT

The goal of the ILDAS programme is to develop an operational system for determining the current waveform and attachment points of lightning striking aircraft in-flight. During a flight campaign, the system's performance was verified using a multi-sensor configuration, capable of real-time detection of lightning strikes on the aircraft and automatic high-rate synchronous measurement and subsequent recording of sensor data from eight magnetic and one electric-field sensors. The measurement setup is presented, calibration is addressed and the first results from the flight test are presented.

ACRONYMS AND SYMBOLS

ILDAS	in-flight lightning damage assessment system
SAE	sensor assembly electronics [unit]
DADS	data accumulation and data storage [unit]

INTRODUCTION

The ILDAS programme

On average, lightning strikes an individual commercial aircraft about once per year. The desire to know more about the lightning-aircraft interaction resulted in the ILDAS research programme: ILDAS-1 (2006-2009) and ILDAS-2 (2009-2014).

In the ILDAS-1 project, a European Union-supported FP6 research project, the principle of an in-flight lightning strike measurement system was validated. Results were presented at ICOLSE 2009 (reference [1]). A system called ILDAS was defined, developed and verified on a test rig and on an A320 aircraft on ground.

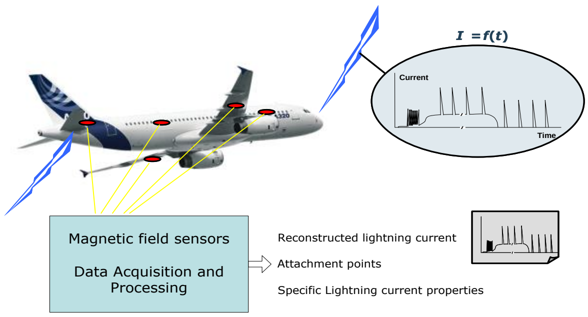

Figure 1 – Reconstruction of the lightning channel current

ILDAS can determine the electrical current waveform of the lightning channel and the points of attachment on the aircraft. Synchronous measurements of the magnetic field are performed on various parts of the aircraft (in particular the cabin, the wings and the tailplane) using a dedicated data acquisition system. The resulting data from multiple sensors are subsequently processed by a numerical toolkit called EM toolkit, which employs an inverse method based on a detailed aircraft electromagnetic model to determine the lightning attachment points and to reconstruct the lightning current waveform.

After the ILDAS-1 EU project, Airbus continued the programme with the ILDAS-2 project in 2010 with the final target to use the ILDAS system during the flight test campaign of the composite Airbus A350 XWB aircraft. This allowed validating the system's operational behaviour and performance in flight, increasing knowledge of lightning interaction and evaluating a possible future commercial adaptation for use in regular airline operations as a real-time lightning damage assessment system.

Roadmap

The maturity of the ILDAS technology is gradually increased from technology readiness level 3 ("analytical and experimental critical function and/or characteristic proof-of-concept"), at which the ILDAS-1 project ended, to level 6 ("system/sub-system model or prototype demonstration in a relevant environment") using test flights where it is known that the aircraft is hit by lightning. This consists almost exclusively of icing test campaigns for new aircraft or systems, which are infrequently held.

The following aircraft campaigns are held or planned:

1. A ground test on an Airbus A320 test aircraft with the concept prototype system with six sensor assemblies was performed in 2009 within the FP6 EU project, as described in reference [1]. The aircraft was parked on a conductive mesh and lightning test waveforms of 1-3 kA amplitude were directly injected into the aircraft fuselage using various attachment scenarios. The installed ILDAS sensors recorded the local magnetic field and reconstruction was applied using an aircraft EM model including the ground plane.
2. In-flight "engineering testing" with two sensor assemblies, one magnetic-field and one electric-field sensor, was performed on board an A340 test aircraft in March 2011, providing validation of hardware operation while in flight and while subjected to a true lightning environment. Data from both sensors were continuously recorded at a reduced sampling rate of 2.5 µs for the entire duration of each flight. The campaign led to the capturing of thirty lightning strikes to the aircraft in three flights. The results were described in reference [2].
3. With the results of the A340 campaign, ILDAS was configured and optimised for triggered data capture at a high sample frequency using a full set of sensor assemblies, eight magnetic-field and one electric-field sensor. System in-flight validation of the configuration was performed during an A380 flight test campaign held in May 2013. The results of the validation step are described in this paper.
4. Deployment of the validated lightning measurement system on an Airbus A350 XWB test aircraft during the icing test flights. At time of writing, the certification test campaign of the A350 XWB has started and the icing flights are planned for the end of 2013.

With the results of the A350 XWB in-flight test campaign, Airbus will then decide whether to further develop the ILDAS system or not.

MEASUREMENT SETUP

The focus of the ILDAS-2 project is on delivering an in-flight system with full in-flight measurement functionalities (reliable triggering, all sensors installed and data recording without missing strikes), and to post-process and analyse the data on the ground, after the flight. An implementation goal was set to make the system cabin-only, meaning a sensor configuration that does not require sensors outside the (pressure and temperature-controlled) cabin, such as on the wings or tail as defined in ILDAS-1. A cabin-only configuration greatly facilitates installation and relaxes environmental compatibility requirements, but reduces the obtained information, especially for scenarios including wings, engines or tailplane. A research goal was set to study how well waveforms could be reconstructed using such a configuration.

Architecture

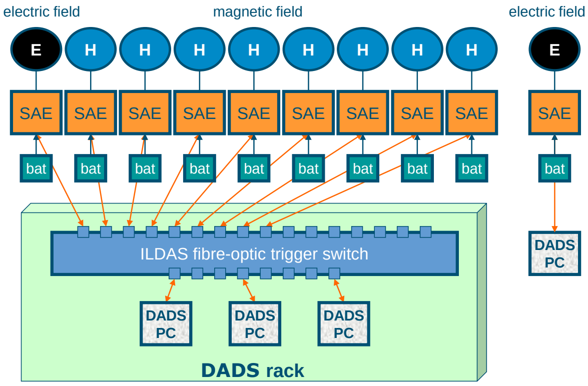

Figure 2 – ILDAS architecture

The ILDAS system is designed for triggered measurement of lightning-induced fields. Eight magnetic-field and one electric-field sensor assembly are placed at various locations in the cabin, with their sensors mounted on the inside of a cabin window, see Figure 2. Custom battery-powered sensor assembly electronics units (SAE) perform sensor data acquisition and local temporary recording in one of the two internal memory buffers inside each SAE. A fibre-optic Ethernet link connects each sensor assembly to a centrally mounted data accumulation and data storage component (DADS), consisting of a custom fibre-optic Ethernet switch and Linux-based laptop computers for system control and data recording onto hard disk. Three PCs are used to increase speed of download of strike data from the SAEs to the PCs.

Additionally, for this campaign a second electric-field sensor was installed, independent of the ILDAS system (see right-hand side of Figure 2). It performed continuous measurements at a reduced sample rate of 2.5 µs for the full duration of the flight. It was installed as a backup provision for evaluation of the electric-field trigger algorithm.

H field window sensor

The magnetic-field window sensor is based on the lightning current pattern around an aircraft cabin window; see [3]. The inner conductor of a coaxial cable crosses the window at mid-height. The flux due to the magnetic field penetrating through the window is captured by the wire across the window. The induced signal is proportional to the time derivative of K_0, the local current density unperturbed by the presence of the window.

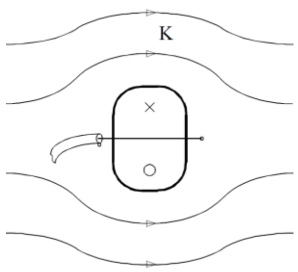

Figure 3 – Principle of window sensor, with lightning current density K through the aircraft fuselage. Magnetic field penetration of the window is indicated by × and ○.

With a vertical sense wire over the window replacing the horizontal wire in Figure 3, the vertical component of K_0 can be determined, be it with a different sensitivity. The sensor with horizontal sense wire is mainly intended for the current along the fuselage, such as a nose-to-tail attachment scenario. For scenarios that include a wing or engine, the vertical current is of interest at cabin positions near the wings.

E field window sensor

The electric-field sensor consists of two identical half capacitors, implemented with flexible printed circuit board technology. Calibration of the sensor, including compensation for field enhancement near the sensor's edges, was performed with finite-element modelling. The sensor is mounted on a cabin window. The electric-field signal is primarily used for system triggering and is not strictly needed for further data processing, but the measured data are recorded nonetheless for system performance evaluation and research purposes.

Sensor assembly electronics

The SAEs perform data acquisition and local storage of the *H* and *E* sensor signals. Each SAE contains two high-frequency acquisition channels with different gains. Automatic channel switching results in a wide dynamic range of about 96 dB. Each channel contains an analogue integrator, anti-alias filter and analogue-to-digital converter. The bandwidth of each channel is:

Magnetic-field:	HF1&2	100 Hz – 10 MHz
Electric-field:	E1:	10 Hz – 500 kHz
	E2:	100 kHz – 1 MHz

The bandwidth of the E1 sensor was extended down to 10 Hz instead of 100 Hz as a result of experience gained during the initial engineering flight test in 2011.

The SAE's low-frequency acquisition channel (160 mHz – 100 Hz, for connection to a dedicated LF sensor) was not used.

Data are sampled at 12 ns and locally stored in a ring buffer. When an SAE receives a trigger command, it stores 1.2 seconds of sensor data: 0.2 s before the trigger moment and 1.0 s afterwards. The SAE contains two buffers so it can capture a second strike if the first buffer is still full.

In addition to the high-rate triggered data storage, each SAE stores low-rate continuous data. In reporting intervals of 18 ms the minimum, maximum and average values of all high-rate samples within the reporting period are recorded. The purpose of this data stream is to ensure the availability of at least some high-level information for the complete duration of the flight, in case the system should fail to trigger or is suspected to have done so.

Triggering and synchronisation

Each SAE contains lightning strike detection (trigger) functionality. The ILDAS system's primary trigger method is based on electric-field signals during the strike attachment phase and the hypothesis was that all strikes are detected through this method. Due to uncertainties in the knowledge of in-flight field behaviour during each possible lightning attachment scenario, it was considered that a substantial risk remained that a strike would be missed when its attachment behaviour were to differ from expectations. Therefore it was decided to implement a backup trigger detection algorithm in the magnetic-field SAEs.

The trigger architecture was modified to allow multiple trigger sources. A fibre-optic switch was developed for multiple functionalities: routing of Ethernet traffic between DADS PCs and SAEs, trigger management and synchronisation timing source. When any SAE declares a trigger, it signals this to the trigger switch, which then broadcasts a trigger command synchronously to all SAEs.

Each SAE is independently clocked with a crystal oscillator, leading to frequency and phase differences in the time samples that are taken by the combined set of SAEs. The above triggering method, and additional regular distribution of synchronisation labels to the SAEs, allow measurement data from multiple SAEs to be synchronised accurately during post-processing. Testing showed that the uncertainty in the synchronisation timing is below two sampling periods of the SAEs.

Recording

Available data from SAEs, low-rate continuous data and high-rate triggered data, are downloaded from the sensor assemblies over a 100 Mb/s fibre-optic Ethernet link. The download process takes 18-20 s for each strike recording from each SAE. The SAEs are equipped with a second buffer to capture a second strike that occurs immediately or shortly after the first, but any third strike that occurs before data from the first strike are downloaded cannot be captured by the system. To reach an acceptable collection rate, three control PCs are employed that each cover three SAEs, keeping the data handling time to below a minute for one strike recording. With the double buffering in the SAEs the system's capturing rate limitation is therefore three strikes within a time period of one minute.

Installation in the aircraft

The system was installed on board an A380 flight test aircraft used as a flying test bed for the A350 XWB engine, see Figure 4. Part of the engine's certification was a flight test campaign under icing conditions. During such campaigns test aircraft are typically struck by lightning multiple times per flight. At the inboard left position the regular A380 engine is replaced by the A350 XWB engine under test.

Figure 4 – ILDAS equipment was installed on the A380 flying test bed for the A350 XWB engine during the engine's icing certification flight tests

ILDAS equipment was installed on the upper deck. The location of the sensors in the cabin is shown in Figure 5. The electric-field sensors, FLE and FRE, are placed in the front of the aircraft. The other sensors are magnetic-field sensors, generally measuring the *H* field component in the *z* axis direction for current flowing from nose to tail. The CLx and CRx sensors measure in the *x* axis direction, for current flowing from wing to wing.

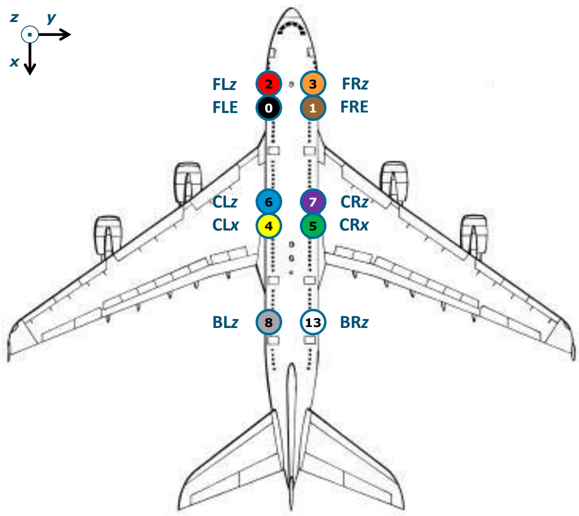

Figure 5 – ILDAS sensor configuration for A380 flight tests

Figure 6 shows the magnetic-field sensor installation in the flight test aircraft's cabin, in this case the FLz sensor. The magnetic field window sensor consists of two boxes mounted to either side of the window with two interconnecting cables going around the window top and bottom, and a horizontally mounted cross wire that was taped to the inner pane of the double-pane cabin window (in the test aircraft, the windows are not fitted with a third, thin window panel as in normal airline use). The orange unit is the SAE, with connections, from left to right, for the analogue sensor signal, (battery) power input, and fibre-optic digital communication network.

Figure 6 – Installation of the magnetic-field window sensor

Figure 7 shows one of the two electric-field sensor installations (FRE sensor). The sensor is taped to the window at a fixed distance from the bottom rim of the cabin window. Connections comprise the E1 and E2 channels and a test electrode.

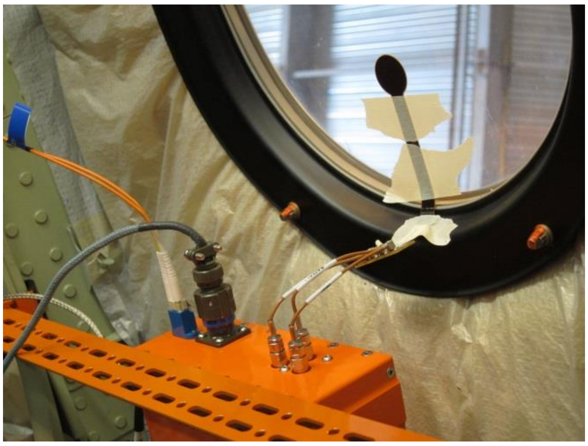

Figure 7 – Installation of the electric-field window sensor

Figure 8 shows the DADS equipment, three laptop PCs, fibre-optic switch and support equipment mounted in a vibration-damping cabinet, provisionally installed in the aircraft cabin. In the back the centre-right window sensor installations can be seen with their horizontal (CRz) and vertical (CRx) cross wire on the cabin window.

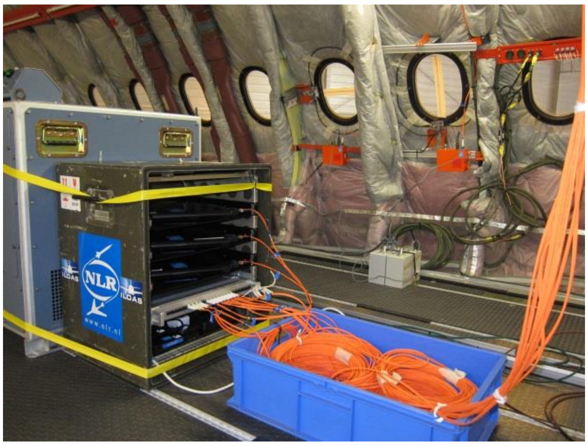

Figure 8 – Installation of the DADS equipment cabinet, and two window sensor installations (horizontal and vertical) in the background

CALIBRATION

During the ILDAS EU project, the magnetic-field sensors including the window sensor were verified with lightning laboratory tests and with a ground test on an A320 aircraft. Generated lightning-test current waveforms of 1-3 kA amplitude were injected into the aircraft fuselage. As described in [3], the windows sensor's effective capturing area was determined with a numerical method-of-moments calculation. The numerical method was checked by modelling a circular window and comparing with existing analytical expressions for its response (reference [4]); it was found to agree with 0.2 % error. Results from the ground test measurements were calibrated with the derived effective area and compared to magnetic field values determined by the EM model of aircraft plus ground plane when using a current waveform identical to the measured generator waveform. The results were found to agree very well, with an error of less than 5 %.

For the A380 window a new calculation of the effective area was performed, using the same method of calculation and verification with a circular window, reference [5]. Separate effective areas were calculated for horizontal and vertical orientations of the surface current and wire positions with respect to the window. It is noted that the difference between the orientations is 20 %, due to the different way in which the window modifies the path of the fuselage surface current.

Each sensor assembly was individually calibrated after manufacturing; calibration values are written into the measured data files during recording and the calibration is applied during post-flight processing.

Altogether, the calibration error is 10% or better, which is within the accuracy requirements of the ILDAS application. If the opportunity ever arises, a further check by current injection similar to the A320 ground tests will be carried out.

FLIGHT TEST MEASUREMENTS RESULTS

The A350 XWB engine icing certification flight campaign with the A380 consisted of multiple flights conducted during May 2013 from Toulouse, France. On six of the flights lightning activity was recorded by the ILDAS system and 28 strikes were recorded by the system. It was found that additionally many false triggers had been recorded, the reason for which will be discussed later in this paper. This led to capturing a large amount of nuisance data. Together with the limitation in the rate at which strikes can be captured and recorded by the ILDAS system, this resulted in 11 of the 28 strikes being only partly recorded, leaving 17 complete strike recordings.

All genuine strike recordings were triggered by electric-field sensors, in accordance with the hypothesis. However, electric-field triggering also led to false triggers, so the trigger concept currently allows complete coverage (no missed strikes) but it is too sensitive. Additional effort will be performed to improve the false trigger rate without sacrificing the completeness.

In this paper, the focus will be on one lightning flight on 26 May. This flight was the last in the campaign, was well covered, and included the largest stroke intensity measured during the campaign.

Flight overview

Figure 9 shows data from the continuous measurement channels, which provides low-rate statistical summary of *H* field data suitable for waveform inspection at large timescales. The *x* axis is time in seconds; the graph spans the complete flight recording duration, starting at *t* = 6900 s and lasting for 4 h 48 min. The *y* axis contains the recorded field extrema for all eight *H* sensors in A/m on a logarithmic scale. Three spikes denote the three lightning events during the flight. The period between 0 s and 6900 s covers a time when the trigger switch, which acts as the system's time reference, was switched on but the SAEs were not switched on yet.

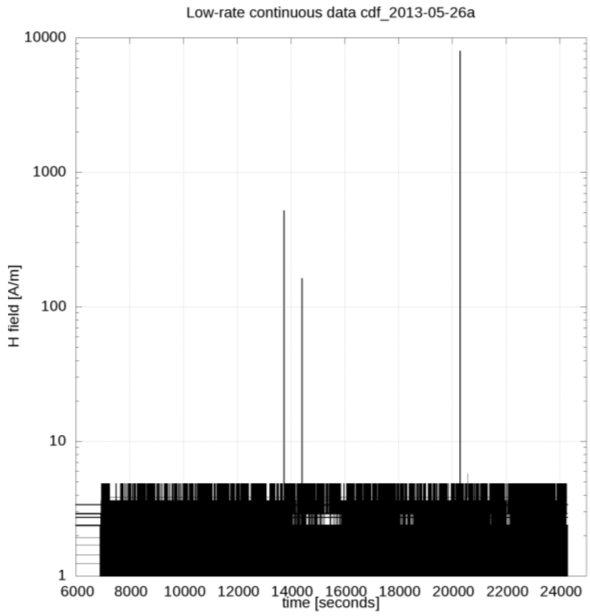

Figure 9 – H field levels recorded during the complete flight, displayed on a log scale

E-field data

The electric-field data for the three strikes (Figure 10) show the characteristic waveform that is used for trigger purposes. The electric field will rise to over 100 kV/m relatively slowly and then decay fast. This pattern is associated with positive leader development starting from the aircraft. The *x* axis is in seconds, with *t* = 0 being the moment that the ILDAS system was synchronously triggered. The E field bandwidth was extended at the low-frequency side from 100 Hz to 10 Hz as a result of the initial engineering flight tests in 2011. With the extended bandwidth, the *E* waveforms are in accordance with expectations, and are better suited to trigger on.

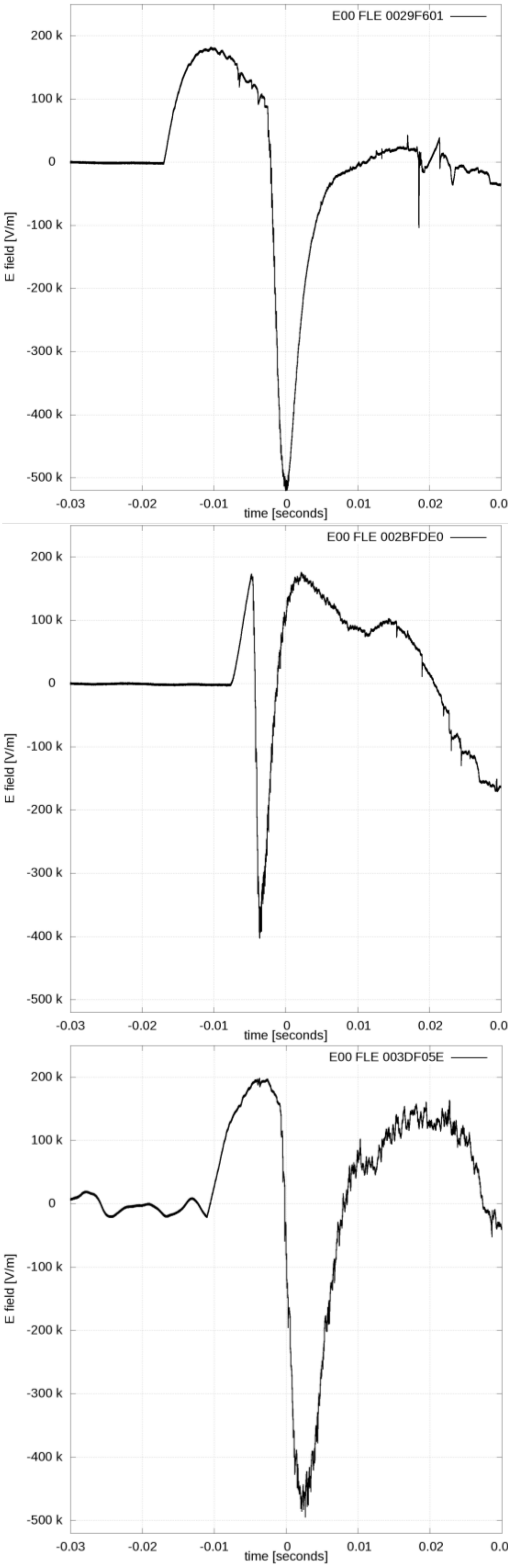

Figure 10 – E field waveforms for the three strikes on 26 May, showing a characteristic waveform

H-field data

The magnetic-field of the stroke with the largest amplitude that was recorded during the campaign is shown in Figure 11 and Figure 12. Waveform colours are matched with the sensor colours used in the aircraft installation diagram, Figure 5. The representation of the sensor signal polarities was chosen so that positive signals in the graph indicate fuselage current in the positive *x* axis direction, i.e. nose to tail. For the two sensors with alternative orientation, CLx and CRx, the signals are shown positive for currents in the positive *y* axis direction, i.e. from left to right wing in an aircraft top view.

The stroke occurred about 37 ms after standard triggering by electric-field. Between 0 and 37 ms (not shown in the figure) there are only some low-intensity excursions on the H signal; overall, the strike consisted of just the single large stroke shown. The measured peak intensity is 8800 A/m for the FLz sensor and 6900 A/m for the FRz sensor. The following analytical relation for fuselage current is used to determine a first estimate of the aircraft current:

$$I = 2\pi \cdot r \cdot H_0$$

Here *r* is the average radius of the A380 fuselage of 3.9 m and H_0 is the average of the FLz and FRz measured fields. The estimation results in a peak aircraft current of 190 kA, representing a severe strike.

Figure 13 shows the direction of the local fuselage currents for the strike. Based on simulation results with the aircraft EM model, this pattern is indicative of a nose to left wing scenario. At this time it cannot be determined in detail which part of the left wing was involved, e.g. the left wing tip or one of the engines.

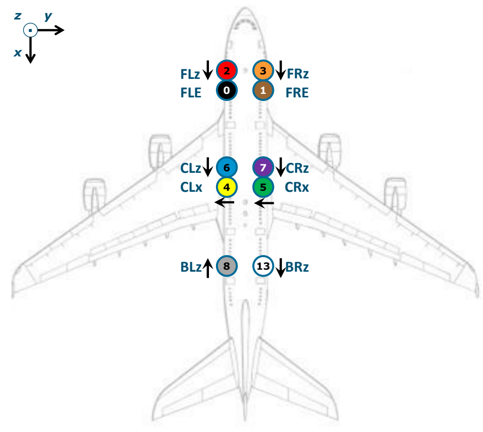

Figure 13 – Direction of surface currents at the sensor positions

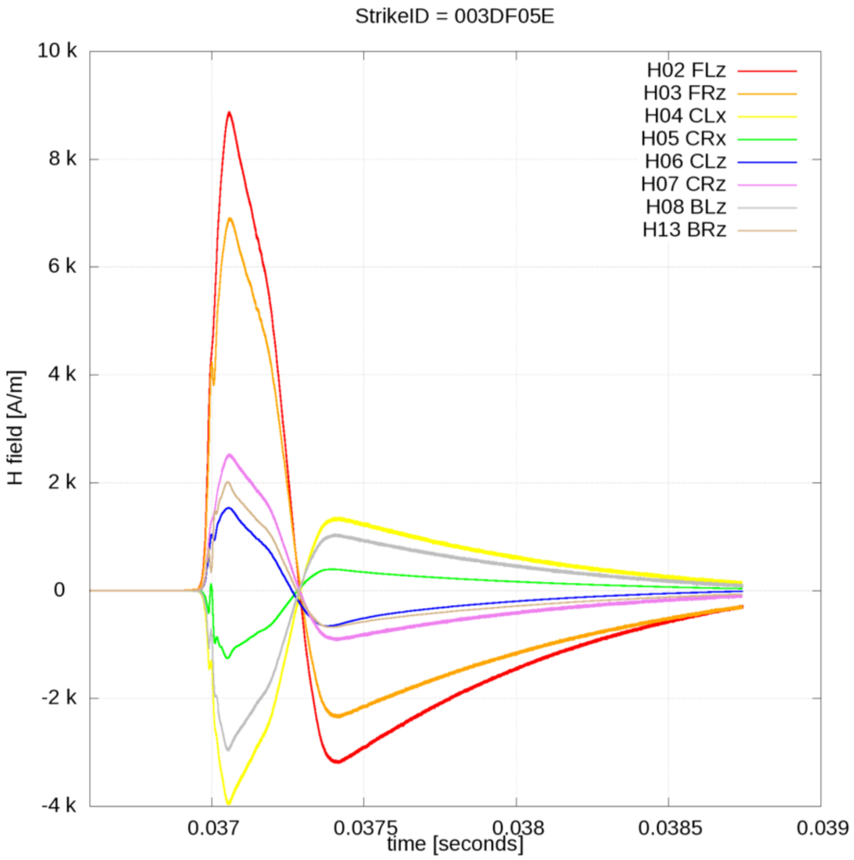

Figure 11
Magnetic-field data from a synchronous lightning recording performed by all eight sensors

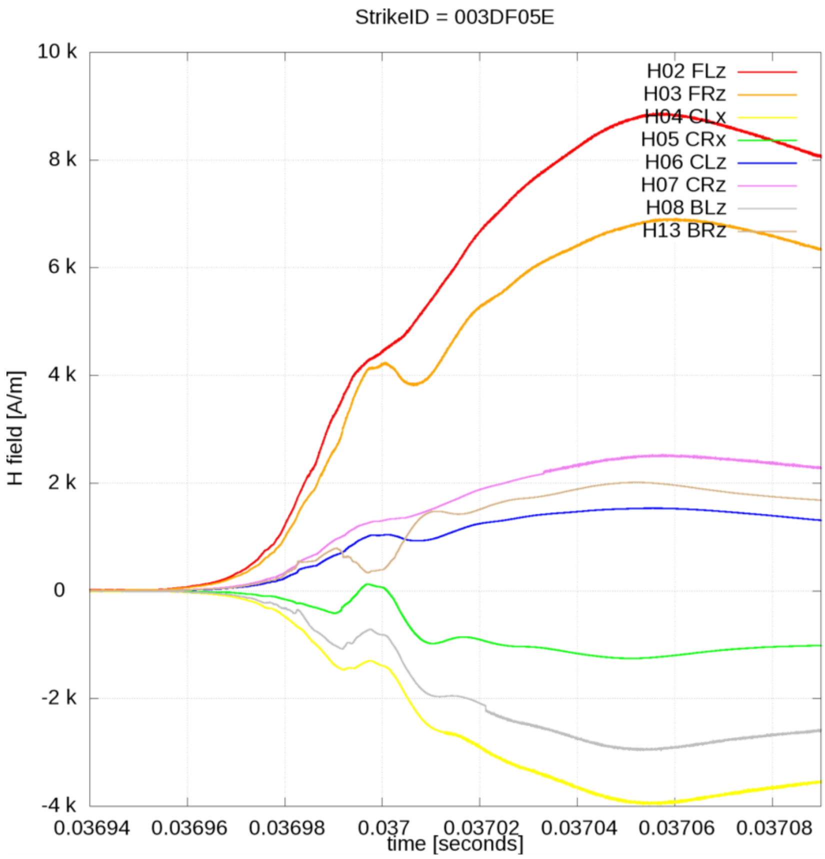

Figure 12
A zoomed-in version of the figure above, showing detail of the rising edge of the stroke

False E triggers

An important observation from the flight tests was that there were numerous false triggers, i.e. the system acted as if a lightning strike had occurred to the aircraft, but analysis after the flight showed that no surface current signals other than noise were recorded. Figure 14 shows the complete recording (1.2 s duration) of the electric-field for a genuine lightning detection. The characteristic electric-field waveform, which was shown in more detail in Figure 10, represents a significant signal. Figure 15 shows the electric-field of a false trigger using the same scaling. The waveforms for genuine and false triggers show remarkable differences, giving confidence that improvement of the trigger algorithm should be achievable; however this requires detailed analysis which was only in a very early stage at the time of writing.

Figure 16 shows a different recording with a remarkable coincidence. The system was falsely triggered, shown as $t = 0$ in the graph, but within the 1 s recording period after this trigger, a true lightning attachment occurs at $t = 0{,}52$ s and a strike takes place. The magnetic-field data (not shown) confirms this: there is only regular noise up to the true attachment point, followed by multiple strokes occurring between $t = 0{,}53$ s and $t = 0{,}76$ s.

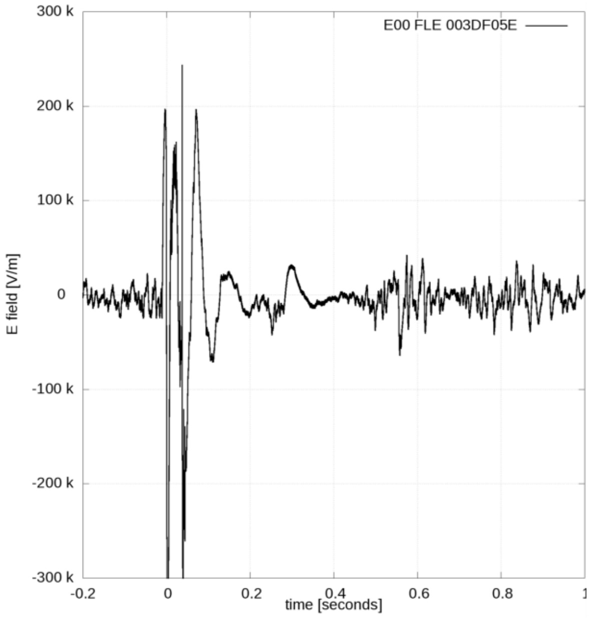

Figure 14 – Full-duration (1.2 s) recording of a genuine trigger

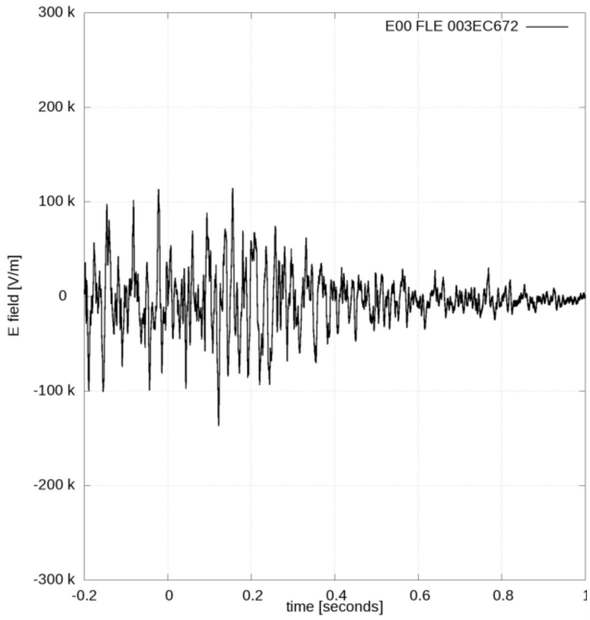

Figure 15 – Full-duration (1.2 s) recording of a false trigger

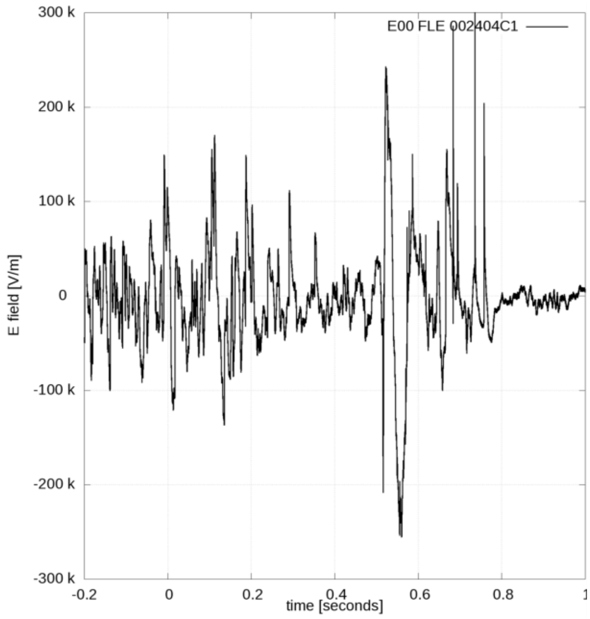

Figure 16 – Full-duration (1.2 s) recording of a false trigger which by coincidence captured a lightning strike later in the recording.

CURRENT RECONSTRUCTION

The measurement results presented in the paper are intended to be processed by ILDAS EM toolkit in order to retrieve lightning strike characteristics. The principle of the inverse method developed to identify the lightning scenario and reconstruct the injected current was presented in [2]. Unfortunately, the time schedule was too tight to perform and report A380 campaign lightning identification results in the present paper.

AIRCRAFT DAMAGE

A first aircraft inspection after the 26 May flight revealed relatively minor damage on the doors of the nose landing gear (see Figure 17 and Figure 18), right-wing inboard engine nacelle and on two right-wing flap track fairings. Lower-intensity strikes on other days seem to have led to larger damage spots after a first overview.

The relation between measured waveforms and aircraft damage requires further study, which is currently on-going and could not be included in this paper.

Figure 17 – The left nose landing gear door with minor damage in the '001' lettering

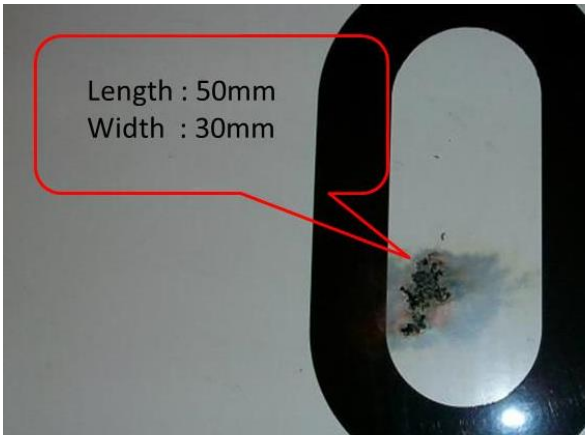

Figure 18 – Detailed view of nose landing gear damage

CONCLUSION

A further step was made towards the availability of an operational on-board integrated lightning system, capable of recording lightning strike events and identifying impact locations and strike intensity.

In-flight testing was performed with a full-configuration ILDAS system consisting of 8 magnetic and one electric-field sensor. The trigger algorithm based on electric-field activity during the leader attachment phase did not fail to detect any lightning strikes to the aircraft, but was too sensitive leading to frequent false triggering resulting in some data loss. Analysis and optimisation of the algorithm will be performed before the next campaign.

17 lightning strikes were recorded with all sensor assemblies, at the system's high sample rate, and with full time synchronisation information. The resulting data appear to be good quality from a measurement system perspective. Current reconstruction by numerical inversion methods, and correlation between measured waveforms and aircraft damage are on-going.

The next flight campaign is the icing certification test of the A350 XWB, planned for end of 2013.

CREDITS

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REFERENCES

[1] In-flight Lightning Damage Assessment System (ILDAS): Results of the Concept Prototype tests, R. Zwemmer e.a., ICOLSE 2009, Pittsfield, United States, September 15-17, 2009.

[2] In-flight Lightning Damage Assessment System (ILDAS): Initial in-flight lightning tests and improvement of the numerical methods, A I de Boer e.a., ICOLSE 2011, Oxford, United Kingdom, September 6-8, 2011.

[3] Inductive Sensor for Lightning Current Measurement, Fitted in Aircraft Windows – Part II: Measurements on an A320 Aircraft, A P J van Deursen, IEEE Sensors Journal, Vol. 11, No. 1, January 2011, p.205-209.

[4] Inductive Sensor for Lightning Current Measurement, Fitted in Aircraft Windows – Part I: Analysis for a Circular Window, A P J van Deursen e.a., IEEE Sensors Journal, Vol. 11, No. 1, January 2011, p.199-204.

[5] Window sensor for the A350 and A380 aircraft, A.P.J. van Deursen e.a., ICEAA 2013, Torino, Italy, September 9-13, 2013