Overview of Lightning Hazards to Aircraft

Pierre Laroche
Scientific Adviser
Physics and Instrumentation Department

Since its early age, civil and military aviation had to face atmospheric events of unexpected dangerousness. At that time, lightning was certainly the most unrecognized and misunderstood atmospheric hazard to aviation. How and where an aircraft is struck by lightning, what the expected consequences for flight safety are and what damages could be anticipated, were still open questions at the very beginning of the 1980s. Up until this period, lightning safety on aircraft was ensured by oversized metallic protection and by considering the greatest lightning threat known. At the edge of the modern age of aviation, for which performances and safety were about to become of paramount importance, this approach was no longer valid. Awareness of the need for an in-depth knowledge and understanding of the entire physical aspect of the interaction between lightning and aircraft arose at that time.

The twelve articles gathered in this special issue are aimed at addressing the entire aspect of the interaction between aircraft, launchers and lightning, from the state of the art on storm electrification and lightning phenomenology, up to the advance lightning zoning method on aircraft and the electromagnetic topology of the threat.

Understanding where an aircraft encounters lightning begins with knowing the electrical characteristics created by a storm cloud in its vicinity. A storm cloud acts as a giant electrostatic machine, generating a mean current of few amps in magnitude and developing an electrical potential of tens of megavolts from the ground up to the level of the tropopause. Lightning flashes generated by storm clouds need to be known and understood. An aircraft struck by a lightning flash is connected to kilometer long arc channels: a quantitative evaluation of the threat to aircraft is obtained through the knowledge of the characteristics of the flash.

The state of the art on storm electrical environments is given in [1] and is illustrated by an example of in situ measurement reported in [2], showing the relation between the microphysics and atmospheric electricity within a convective cloud. Natural lightning properties are derived from a remote detection and mapping system [3], which contributes to obtaining important macroscopic information on lightning flashes, such as their length, energy, speed and current.

To be authorized to fly, aircraft and helicopter need to be protected against the effect of a lightning flash. The certification against lightning is a complicated process, which is still today based on a semi-empirical approach consisting of standardization and testing. Standardization is the result of a pragmatic synthesis between the general knowledge on lightning and the in-flight experiences of airline companies. Aircraft certification relies also on testing, whose adequacy and representativeness are key issues of the process [11].

The behavior of natural lightning flashes is determined by precursor discharges, which cannot be easily observed since they involve low currents and low light emission. Some types of these discharges play a major role in the behavior of lightning interaction with aircraft [4]. Laboratory experiments involving short atmospheric discharges, whose length is limited to about 10 meters, had contributed a lot of information on the physics of these precursor discharges. The gap of knowledge between few-meter-long discharges and kilometer-long natural lightning channels is filled with experiments on artificially triggered flashes, which offer the opportunity of close-by observation of different types of precursors [5]. Triggered discharges and laboratory discharges were used to validate the physical modeling. Fundamental physical concepts were used to derive a simplified simulation of the attachment processes of lightning channels on aircraft [7] and to evaluate the surface distribution of different lightning hazards on an aircraft [8]. The design and the validation of the modeling depend on the in-flight observation of real events. From the mid-seventies up until the end of the eighties, three aircraft were instrumented to gather in-flight information on direct and indirect lightning strike events [6]. These validated simulations are used to design advance tools for a detailed description of the threat and the future advance approach in the Certification process at the aircraft design level [8].

The description and evaluation of the direct local effects of a lightning strike to the surface of the aircraft can be obtained by complex physical simulations [9]. Such a modeling approach is important for the design and the validation of the lightning protection for Carbon Fiber Composite aircraft.

A direct and nearby lightning strike induces strong electromagnetic coupling with the aircraft systems over a large frequency range, from a fraction of a kHz up to a few tens of MHz. 3D modeling of the coupling taking into account the actual waveform of the lightning signal is necessary to evaluate and mitigate this indirect threat [10].

In general, space launchers cannot be protected against the effect of a direct lightning strike. For that reason, special protection of the launching site and dedicated launching procedures are required to prevent any risk of a direct lightning strike [12]

References

[1] S. SOULA - *Electrical Environment in a Storm Cloud*. Aerospace Lab Issue 5, December 2012

[2] A. DELANNOY, P. GONDOT - *Airborne Measurements of the Charge of Precipitating Particles Related to Radar Reflectivity and Temperature within Two Different Convective Clouds*. Aerospace Lab Issue 5, December 2012

[3] Z. KAWASAKI - *Review of Location of VHF Pulses Associated with Lightning Discharge*. Aerospace Lab Issue 5, December 2012

[4] E. WILLIAMS, S. HECKMAN - *Polarity Asymmetry in Lightning Leaders: the Evolution of Ideas on Lightning Behavior from Strikes to Aircraft*. Aerospace Lab Issue 5, December 2012

[5] X. QIE, R. JIANG, P. LAROCHE - *Triggering Lightning Experiments: an Effective Approach to the Research of Lightning Physics.* Aerospace Lab Issue 5, December 2012

[6] P. LAROCHE, P. BLANCHET, A. DELANNOY, F. ISSAC - *Experimental Studies of Lightning Strikes to Aircraft*. Aerospace Lab Issue 5, December 2012

[7] P. LALANDE, V. MAZUR - *A Physical Model of Branching In Upward Leaders*. Aerospace Lab Issue 5, December 2012

[8] P. LALANDE, A. DELANNOY - *Numerical Methods for Zoning Computation.* Aerospace Lab Issue 5, December 2012

[9] L. CHEMARTIN, P. LALANDE, B. PEYROU, A. CHAZOTTES, P.Q. ELIAS - *Direct Effects of Lightning on Aircraft Structure ; Analysis of the Thermal, Electrical and Mechanical Constraints.* Aerospace Lab Issue 5, December 2012

[10] J.-P. PARMANTIER, F. ISSAC, V. GOBIN - *Indirect Effects of Lightning on Aircraft and Rotorcraft.* Aerospace Lab Issue 5, December 2012

[11] D. MORGAN, C. J. HARDWICK, S. J. HAIGH, A. J. MEAKINS - *The Interaction of Lightning with Aircraft and the Challenges of Lightning Testing*. Aerospace Lab Issue 5, December 2012

[12] F. ISSAC, E. BACHELIER, D. PROST, V. ENJALBERT, L. MOHEDANO - *Space Launching Site Protection against Lightning Hazards.* Aerospace Lab Issue 5, December 2012