Lightning: a constraining environment for aviation

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Résumé

Lightning is known as being a major hazard for any flying vehicle having to operate in all-weather conditions with no limitation: a hazard to flight safety, fully managed today by the aviation community, and a significant risk to operations with potentially penalizing consequences on the airline economics.
It is common to say that a passenger aircraft is exposed to an event about once a year despite the rules to avoid flying close to any thunderstorm cell. However, this rough statistics hide different realities experienced by the operators worldwide and regards their mode of operation. If the standards used by manufacturers and authorities are mature regarding safety because based on extreme scenarios, significant efforts are done to get more robust statistics to better anticipate effective operational impact. This is even more important in light of the dream mobilizing a lot of energy in industry today to bring urban mobility and short haul electrical flight to reality.

The feared consequences of a direct strike on an aircraft are multiple. The most visible one is the mechanical and thermal damage created at the arc root or by the transfer of intense currents of several tens of kA in structural joints or system components. The most dangerous one with no possible recovery by the crew would be the ignition of fuel vapor inside the structural fuel tanks due to sparks or "glows". The most insidious one is the induction of spurious transient into the aircraft wiring potentially source of computer upset or data misinterpretation.

The massive use of carbon fiber for the last generation of airliner put the lightning protection back on the critical path of the development. A regulation change pushed from the TWA800 accident in the 90s brought together with unexpected mechanisms of ignition obliged to go much deeper into the understanding of the disruptive phenomena in CFRP laminates. The challenge is to ensure that each potential ignition source cannot develop more than 200 uJ of energy when the strike hitting the fuel tank can be as intense as 100 kA. In addition, the protection performance must be robust against hidden failures and detrimental aging conditions or mistakes potentially made during maintenance operations.

Foreseen disruptive phenomena are clustered regarding their nature and associated protection means: corona effects, hot spots, surface discharges on anisotropic laminates, voltage breakdown and thermal sparks between parts, outgassing from uncontained plasma, and the recently identified edge glow. The last two ones are topics for intense research and technology development because the most constraining in term of design and quality control in production. One of the challenge is to move from a binary analysis (pass or fail, presence of light emission or nothing) to test procedures offering a real quantification of the phenomena,

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offering a notion of protection margin much easily. The accurate quantification of the spark energy was one item crucial for new composite with augmented bulk conductivity which provide excellent performances but can become the source of tiny "lights".

If the indirect effects of lightning are today optimally addressed with simulation integrated to engineering processes, it is not yet the case for effects involving disruptive phenomena, plasma, sparks or glows. Their versatility obliges manufacturers to run extensive test campaigns to verify that new materials or jointing techniques do not carry new risks, and to empirically characterize the performance domain and develop the design rules. This is where efforts to develop analysis tools are key to prepare the future composite aircraft generation.