# CASE STUDY IN INNOVATION DIFFUSION: AIRCRAFT ELECTRICAL SYSTEM

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## ABSTRACT

Civil aviation technology includes two tendencies. One tendency is to unify optimal, proven methods and techniques in construction, manufacturing and maintenance related to aircrafts and aviation in general. The other tendency is to broaden, virtually without limits imposed within the aviation industry, set of existing solutions exploited.

This paper presents an analysis of these two tendencies, and context within which they evolve.

We state a conjecture about the possible limits, i.e. the envelope of exploitation of diverse construction, manufacturing and maintenance methods and techniques.

## 1 INTRODUCTION

On the most general level, aviation enables people to conduct their tasks using air as a medium. That medium may serve as a transport route, place for collecting information, strategic position enabling some, usually larger groups of people to gather advantage in power in comparison to other groups, etc.

Such tasks have been successfully conducted during the last century. When projected onto the level of aircraft technology, they are transformed into the following guidelines, rather stringent and perpetually imposed onto all parts and systems utilised:

(i) minimize power consumption,
(ii) minimize mass,
(iii) maximize reliability.

These guideliens are not mutually independent, as e.g. lowering the mass of some part automatically lowers the power which the engines need to develop in order to keep the whole aircraft in the air. Furthermore, they are not mutually congruent, since e.g. reliability is augmented using multiplication of equipment and utilizing more than one working principle of some method. That, in turn, is contrary to other two guidelines.

Moreover, reliability enhancement, or preservation in otherwise modified aircraft, is further developed into several prescriptions: use modular architecture of aircraft systems, minimize number of moving parts, etc.

Listed guidelines, and consequently prescribed approaches, have brought about during the last century, which contains most of the aircraft flying, two solidly founded, spontaneously developed, constantly present tendencies. Let us call them convergind and diverging tendency.

Converging tendency means that aircraft's producers and users try to utilize some solutions which have been proven as contemporary optimal. Either by their own development, or by adopting otherwise existing solutions, that tendency is realized as diffusion of best practices. Overall, a consequence is that best practice gradually suppresses other practices, thus in some segment of equipment and systems, realized solutions converge toward the contemporary optimal one.

Diverging tendency means that some realization of a system or its parts, gradually develops in number of variants in order to become better aligned with specific requirements imposed on the aircraft systems and performances. Requirements are caused e.g. by customers, by efforts to mutually align different aircraft's systems as good as possible.

Listed notions, i.e. "best practices", "tendencies", as well as meny realizations which are consequences of the three guidelines, are simply innovations. Diverse processes related to them, such as introduction, adoption, etc. are covered by the notion of innovation diffusion.

Innovation diffusion is a process having rather generally unique dynamics.

In this article we set the foundation for analysis of capabilities of some system, aircraft in particular, regarding the different amount of realization of some innovations within hts systems. In particular, our goal is to observe the dynamics of aggregated quantities, generalized potentials like entropy and free energy, in the capabilities of aircraft. In that sense, this paper is continuation of previous work on that subject [1-3].

In the second section we briefly state main characteristics of innovation diffusion. In the third section aircraft electric system is considered in some details. Main steps in its development during the last century are listed, and are interpreted from the point of view of innovation diffusion. Last section concludes that case study and provides the readers with the projections of further work.

## 2 ELEMENTS OF INNOVATION DIFFUSION

Innovation diffusion is a process of adopting an innovation by entities of a some system [4]. It is rather sociological process, since the technical development of innovation must be in a considerable part finished in order that the innovation becomes interesting to the entities. These entities can be individuals in some social system, firms in a regional or global economy [5], etc. In this paper, by entities we consider aircraft producers.

According to E. Rogers, there are five main stages of entities' adoption of innovations:

(i) knowledge,
(ii) persuasion,
(iii) decision,
(iv) implementation and
(v) confirmation.

In particular, in the context of aviation technologies, **knowledge** implies a set of known methods, techniques, principles, experiments, testing. Some parts could have been known in scientific or other communities for decades before they become utilized within the aviation industry. An example of the former approach is the concept *Fly-by-wire*, while an example of the later are optical gyroscopes exploiting Sagnac's effect.

The **persuasion** means that facts within the knowledge ar actively collected and that entities are interested in a particular set of facts forming knowledge. Naturally, entities could initiate applied research & development processes in order to enlargen understanding of some principle, or in order to develop some method or technique. The example of such an approach is *Fly-by-Wire* concept.

It is interesting to note that in this case, persuasion precedes knowledge.

Stage of **decision** is the very stage in which an innovation is adopted or rejected. It is usually interrelated with analysis of previously formed knowledge. However, some decision stages may induce further collecting of knowledge, e.g. through comparison of innovation performance in diverse conditions, or through comparison of performances of several innovations in the same conditions.

**Implementation** is a stage in which an innovation becomes part of the entity's regular processes. The percentage in which that innovation is used may differ considerably among diverse systems. Similarly to previous stages, in this stage knowledge is broadened. However, that broadening occurs spontaneously, through observations of regular processes with adopted innovation.

Finally, innovation diffusion ends with the stage of **confirmation**. That, functionally marks the end of adopted innovation as an innovation, and transforms it into an established practice. It is expected then, that gradually that practice becomes more and more ubiquitous and that its further interference with innovations occurs only if its disadvantages arise.

Innovation diffusion by the aircraft producers are somewhat different than innovation diffusion by individuals. The reasons are that set of operations is more restricted in the aviation industry than in life of individuals, and furthermore that stages like persuasion and decision are conducted using different criteria.

If number of entities adopting some innovation are considered, than time dependence of that adoption follows the logistic curve. Thus in the early phase of innovation diffusion, rather small percentage of entities, the more innovative ones, adopt an innovation. That is followed with increase in percentage of innovation adopters. That forms the **diverging tendency**, as more and more adopters rise the number of variants of an innovation.

However, when most of the entities adopted an innovation, the percentage of its adoption by the rather small part of further possible adopters generally implies that knowledge about innovation collected in implementation and confirmation stages of early adopters contributed to further profiling of characteristics of related innovations. In that sense, spontaneously, the hierarchy of related innovations forms pointing to one or a small subset of related innovations which are further adopted. That contributes to **converging tendency**.

Overall, constantly there are innovations which contribute to diverging and converging tendencies, regarding different aircrafts' systems.

## 3 CASE STUDY: AIRCRAFT ELECTRICAL SYSTEMS

Modern aircrafts are similar to powerplants regarding their generation of electricity, and to villages regarding their use of electricity. However, during previous decades, intensity of utilization of electrical energy in aircrafts have been developing in many steps.

Historically, first aircrafts did not use electricity [6]. That was folloed with the aircrafts utilizing electricity in modest amount, e.g. for radio-navigation, lights, some instruments etc. An important step for the use of electricity in aircrafts was, in fact, start of using of hydraulics (for landing gear, flaps, etc.) as the hydraulics required well pressurized system. The commonest pumps for setting the hydraulic system became the electric motor driven pumps.

Thus, constantly the number of components, for which the electric energy was needed, arose [7]. Furthermore, the very electric network developed, both because of more and more components and because of the redundancy realized as multiplication of systems. The fundamental characteristic of the electric energy, the electromotive voltage and character of the current also developed, hence also broadened in number of realizations. While first aircrafts with electric power utilized direct current, later the aircrafts usually utilized several types of electric energy: direct current of low and higher voltage, single-phase alternating current and triple-phase alternating current of frequency 400 Hz and lower and higher voltages, etc.

It is, however, interesting to note that such diverting tendency stil persists with introduction, or at least experimenting with different voltages and frequencies of the electric energy utilized.

On the other hand, contemporary, most of the newly introduced aircrafts utilize completely new, and rather different electric current: the current of variable frequency. Since it has rather useful characteristics regarding the introductory stated tendencies, main aircraft producers have exploited that concept in their new products such as Airbus A 380 or Boeing 787.

Overal, importance of the electric energy for aircrafts have been formulated within the rather novel concept of the *More-Electric-Aircraft*, along with its limit, the *All-Electric-Aircraft*.

## 4 CONCLUSIONS AND PERSPECTIVES

This paper develops the approach to aircrafts as systems in which dynamics of innovation diffusion can be observed, and related to the overall aircraft capabilities.

This provides setting for application of previously defined system-level, i.e. aggregated, potentials as indicators of the overall aircraft capabilities.

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