Instructions for the installation of airborne scientific equipments on SAFIRE aircraft (F20, ATR42, Piper Aztec)

TABLE OF CONTENT

Please contact us as soon as possible for any information.

Director:
Aurélien Bourdon
aurelien.bourdon@safire.fr
Tel 00 33 5 34 57 23 01
Fax 00 33 5 34 57 23 00

Instrumentation Head:
Thierry Perrin
thierry.perrin@safire.fr
Tel 00 33 5 34 57 23 10
Fax 00 33 5 34 57 23 00

Aeronautics engineer:
Laurent GUIRAUD
laurent.guiraud@safire.fr
Tel 00 33 1 45 07 53 06
Fax 00 33 1 45 07 51 40

This note aims at reminding the regulation and procedures to be followed in the aeronautical context of scientific equipments design to be installed onboard the SAFIRE aircraft.
The decision to authorise or not the installation of any equipment is taken by SAFIRE but is subject to the approval of the competent authorities.

1. REGULATION INTRODUCTION

In aeronautics, any addition or change to an element must be approved by the aviation authority according to a precise regulation. The SAFIRE aircraft have to respect the CS23 or CS25 regulations for the design, and soon the JAR145 & JAR66 for the installation, maintenance and return to service. Most of the scientific instruments do not fully respect these regulations and it is impossible to substantiate all these proper aeronautics qualifications due to their specificities.

SAFIRE has obtained from the EASA (European Aviation Safety Agency) that its aircraft are managed by the French Civil Aviation Authority (DGAC : Direction Générale de l'Aviation Civile) and classed in CDN-S (Special Airworthiness Certificate). Airworthiness regulations related to this classification are specified in a document called CRI (Certification Review Items) which describes the design, production, installation and return to service process.
The SAFIRE aircraft CRI stipulate that everything related to the aircraft must be compliant with the existing regulation. For everything related to scientific instrumentations, the CRI give specific regulations and responsibilities.

1.1. DESIGN

For the scientific part, the CRI say that every modification must be proposed by a DOA holder applicant or equivalent.

SAFIRE is then authorised to apply for modification approval thanks to its European demonstration of capability EASA AP-DOA n°188 and is responsible for that.

This approval n° 188 establishes the rules, duties and responsibilities of SAFIRE:
- ✓ SAFIRE is able to design aircraft modifications classified as minor and major group 2, but not group 1.
- ✓ SAFIRE must submit the modification documents to EASA or DGAC.
- ✓ Modifications proposed by SAFIRE can be installed only on the aircraft of its own fleet.
- ✓ Any subcontractor willing to modify or add an element in an aircraft configuration designed by SAFIRE, must get a prior agreement from SAFIRE. Depending on the nature of the proposed change, SAFIRE accepts or rejects the amendment.

Thanks to its agreement for minor and major class 2 modifications, SAFIRE can design most of the instrumental modifications concerning the cabin interior and the equipment of external provisions already certified. For changes that exceed this level, it is necessary to require a DOA holder (allowing the design of major changes to group 1). At any time, the authority may call into question the classification proposed by SAFIRE.

Even if the design is initiated and carried out by a laboratory other than SAFIRE, SAFIRE must take the design on its own regulation and technical terms before proposing this amendment for certification. As a corollary, the lab becomes, in terms of aviation regulations, a "subcontractor" of SAFIRE. In practice, a representative of SAFIRE must be involved in the project from the start-up phase.

Any design must strictly comply to the ICAO Annex 8 (Organisation of International Civil Aviation) and other requirements which are the subject of the rest of this document.

1.2. PRODUCTION

There is no need to have aeronautical production agreement to manufacture the scientific instruments, except special requests.
According to the CRI, SAFIRE must ensure the following:

- ✓ When a scientific item is purchased "on catalogue" SAFIRE verifies that the product conforms to the technical notice provided by the seller and certifies compliance with the design requirements.
- ✓ When a scientific item is designed or amended by a subcontractor, SAFIRE requires the subcontrator to sign an agreement stating that the work complies with the specifications defined by SAFIRE. Upon receipt of this product, SAFIRE verifies the specification compliance and certifies it.

SAFIRE must certify that any production is compliant with the design requirements, and in practice, to certified design documents. On the production side, SAFIRE is responsible for the compliance to the design requirements of the airborne scientific instruments installed in its aircraft.
Therefore, SAFIRE asks the laboratory heads, managers and heads of technical projects to declare that their instruments are in compliance to the document description previously given to SAFIRE.

1.3. INSTALLATION AND RETURN TO SERVICE

The CRI distinguished two types of procedures: a "normal" procedure for the aircraft parts compliant with the aeronautical regulation and an "adapted" procedure, specific to the scientific parts.

For the "adapted" procedure, the CRI state that the details of installation operations and the return to service are provided in a specific annex of the maintenance program of each aircraft, filed and approved by the GSAC (Group for Civil Aviation Security).
In these annexes, the SAFIRE director lists the SAFIRE employees allowed to work on the aircraft and the tasks each of them is authorised to perform.
SAFIRE endorses responsibility for the installation of scientific instruments on board and for the approval of return to service.

1.4. MUTUAL COMMITMENT

Each laboratory organism, researcher, engineer who is developing or modifying an instrument to be installed on SAFIRE aircraft must take into account the regulatory constraints that the DGAC has set out to SAFIRE.

In this regulation context, SAFIRE will do its best to assist, to advise and support any person developing or modifying an instrument which has been accepted by SAFIRE.

2. STRUCTURAL OVERVIEW

All equipments which are installed in the 3 aircraft of the SAFIRE fleet must meet the criteria of structural stress analysis. This is worth the cabin crew security!

2.1. STATIC LOADS ANALYSIS

The criteria to apply are given by the aviation regulation of the aircraft according to the classification of the DGAC and by the flight loads given by the manufacturer.

Minimum acceleration rates to be withstood by all equipments in the cabin, relative to the longitudinal axis of the aircraft:

Direction	Upwards	Downwards	Forwards	Rearwards	Sideways
Value (g)	6.5	6	9	1.5	3

It is necessary to add a safety factor of 1.33 for all demountable structures (a box attached to the seat tracks for example). Thus, the future user should be able to justify, often by calculation, the maximum static load supported by its equipment. The stress analysis is needed for the interfaces between equipments and the aircraft (like screws), but also for the elements building. A final factor of safety of at least 1.5 compared to the tensile strength of the material is needed. The user must provide to SAFIRE a structural substantiation document depending on the type of equipment. These documents are used by SAFIRE in the certification process with the competent authorities.
Some of the equipments may require vibration substantiation (resonance with the propellers on the ATR, for example).

2.2. EXTERNAL PROBES

Each element to be installed outside the cabin must be designed to withstand both static loads (see paragraph 2.1.) and aerodynamic loads, which can be calculated from the following array:

Aircraft	ATR	F20
Calculation Speed of aerodynamic loads (m/s)	160	240

It is necessary to take into account the possible ice formation and its following consequences, like the modification of the airfoil and air flow downstream (ice projection hazard), the drag increase, the modification of weight balance and/or the dissymmetrical nature of the loads.

2.3. PRESSURISED AIRCRAFT (ATR42 & F20)

It is necessary to verify the withstanding to pressurisation loads during the design of the equipment (case of an instrumented plate on the skin of the aircraft, such as a radiometer for example).

Minimum pressure differential to be withstood:
Reminder: 1 PSI = 0.0689 bar

Aircraft	ATR 42	Falcon 20
ΔP (PSI)	13	17

2.4. STRUTURAL SEAT TRACKS STRESS ANALYSIS

Any equipment installed into the cabin is attached to the aircraft seat tracks (manufacturer rails, which include fixed seats). These tracks have a range of use to respect by weight and stress loads.

Maximum linear mass admissible for 2 tracks:

Aircraft	ATR 42	Falcon 20
M (kg/m)	232	210

Maximum admissible stress on tracks:

Aircraft	ATR 42	Falcon 20
F forwards (N)	12080	17280
F sideways (N)	6190	5760
F upwards (N)	14600	15600

2.5. SAFIRE RACKS

SAFIRE has designed specific racks (one for each aircraft) to install new equipments. It allows carrying 19 inches rackables materials.

Maximal admissible payload for a rack (gravity centre at half height) & height:

Aircraft	ATR 42	Falcon 20
Useful payload (kg)	120	97.5
Useful height (U)	29	16

2.6. MOUNTING AND DISMOUNTING INSTRUCTION

A mounting & disassembly instruction notice for each element not installed in a SAFIRE rack is necessary. It only deals with mechanical installation in the aircraft.

3. MASS

The user must design the equipment as light as possible because the weight is a major concern when installing airborne equipments. It is possible to reduce the weight of some structural elements if the stress analysis shows very high safety factors.
It is necessary to determine with precision the weight of each element, including cables, fasteners and other small hardware. The mass distribution (weight and balance) is important to determine the feasibility of a desired cabin lay out. A weighting of each element is done before each aircraft installation.

4. MATERIALS

4.1. METALS

In aviation, we mostly use aluminium for structure equipments. Its density is 3 times lower than steel. Recommended grades are 2017 (dural) and the 2024 (specific aeronautics dural), they provide high stress strength for a small mass. Steel can also be chosen for its mechanical properties. Other materials are generally not suited for structural pieces.
For structural assembly, it is recommended to use screwed assy or riveting (easier to substantiate). In the case of welding (elements too difficult to screw), it is important to take into account the quality of the weld for the stress analysis (a certificate of compliance may be requested).

4.2. NON METALLIC MATERIALS

The use of non-metallic materials is nevertheless accepted for applications other than structural. The user must ensure that these materials are non flammable and they do not release toxic fumes. It is generally electrical components, wiring and pipes between the equipments that must be compliant to this regulation. Small things such as cable clamps, keyboards, mice and so on, can be accepted under certain conditions (few items).

Non-exhaustive list of materials prohibited on board:

- Polyvinyl Chlorite (PVC)
- Polyethylene (PE)
- Polyester
- Nylon
- Polypropylene
- Polyurethane

Non-exhaustive list of materials allowed on board:

- Teflon (PTFE, TFE, PFA, FEP)
- Silicone
- Rubber (NR isoprene)
- Hypalon
- Neoprene

To use materials not included in this list, the user must show that materials meet the current standards of flammability and toxic smoke.

4.3. SCREWS

The screws used for structural assemblies as well as equipment/aircraft interfaces must be of aeronautics quality (NAS, NA or MS standards). The tapped holes must be adapted to these screws. Inserts may be necessary to improve the assembly holding. Every screw must be properly sized to meet the required structural criteria. The quality of the screws should not be disregarded for important masses. It often takes several months to have aeronautics screws delivered. A screw locking is expected (Nylstop, pins, lockwires, etc.).

5. HAZARDOUS EQUIPMENTS

Any potentially hazardous material must be reported to SAFIRE. The user must set up control measures limiting the hazard and also decreasing the occurrence of the involved risks. Here are some recommendations for some hazards in various elements (not exhaustive list).

5.1. CABIN LAY OUT

Installed equipments should not have sharp parts that may injure people on board. It is necessary to have all heavy objects attached in the cabin. The equipment space in the cabin and potential needs of access to instruments is to be taken into account. The elements which are fragile or not to be touched must be protected.

5.2. AIR CIRCUITS

Leaks in the air circuits must be avoided, from the inlet to outlet circuits and inside the scientific equipment. Particular attention is given in terms of fitting and sealing. The most important hazards are cabin depressurisation, pressurised gas in open circuit or the release of toxic gases in the cabin.
In addition, pipes and tubes must be designed to withstand at least 2 times the maximum working pressure of the circuit. For the air lets of large diameter (> ½ ") the presence of electro or manual valves must allow to isolate at any moment the cabin from the outside in case of problems on the debit or exhaust air line. With no power, electro valves must be in an insulating position of the circuit compared to the outside, in the closed position.

5.3. LASER

When laser sources are used it is necessary to take into account the eyesight hazard. It is mandatory that the probability of seeing the laser beam in the cabin is zero. This is possible with mechanical protection (use of sheath, etc.) and with a subordination of laser power. The nominal ocular hazard distance (NOHD, according to the European standard EN 60825-1) must be determined. It is the distance where eye hazard could occur. Eye protections appropriate to the source (goggles suitable to the laser wavelength) must be provided in case of maintenance or tests of the laser on the ground.

5.4. GAS / LIQUID

The presence of gas or liquid (bottled, imbibed in filters, or generated by instruments) must be reported to SAFIRE. It must be shown that the gas or liquid is not flammable, not toxic for people in the cabin and not corrosive to the aircraft structure. The user must minimise the danger and the occurrence of possible hazards. The gas or liquid volume used for the equipment operation should be minimised for the flight duration. The user must provide a system for controlling the concentration of gases (or liquid) created or used in the instrument if they are defined as flammable and/or toxic. The concentration of toxic gas detected in the cabin must always be below the level of dangerousness.

5.5. UNDER PRESSURE RECEPTACLES

The under pressure gas cylinders must meet the following criteria:

- Each cylinder is manufactured and certified as safe before use (tested by the manufacturer to 1.5 times the maximum working pressure).
- Cylinder tests must have been produced less than five years before flights to be mounted in the aircraft.

In addition to these criteria, there are precautions of use, such as checking the pressure gage before each flight.

5.6. HIGH TEMPERATURES

In the case of temperatures above 50° C, adequate protection is needed, both to protect people in the cabin (burns) and to reduce the hazard of fire starting. The insulation cover (with approved material), a temperature control as well as means of stopping immediately the source heating must be installed by the user.

6. ELECTRICITY

It is always preferable when designing devices to supply it with 28V DC power which is the basic supply of the aircraft.

6.1. CABLES & CONNECTORS

All the power cables must be compliant with the aeronautics standards. The dimension of each cable is to be determined according to its delivered power and the size of concerned connector contacts, while maintaining safety margin in overestimating the characteristics of used current. The standard AIR 7822 is to respect (available upon request from SAFIRE) to determine the wire gauge to be used.

The following table provides an overview of gauge sizing to be used:

Wire gauge dimension (AWG)	16	18	20	22
Max. admissible intensity (A)	22	16	11	7

The cable sheath are braiding and self extinguishing UL94V2 without halogens, respecting the aviation industry standards. The same goes for the connector used. Each one is adapted to its future use in terms of power and intensity. The connectors used are compliant with standards ASNE0052, ASNE0053 or MS. It is necessary to contact SAFIRE for connectors to be used for electrical supply of the equipment.

6.2. FUSE & CIRCUIT BREAKER

Each power line must be protected by a fuse or a circuit breaker compliant with aeronautics standards.

6.3. SWITCHES

It is important to be able to quickly switch off equipments. In case of any problem, it will be the first action. It is therefore necessary to equip each power line of switches. It is also a way to isolate equipment not operating with the rest of the experiment that can operate independently.

6.4. HIGH VOLTAGE

Some devices generate high voltage (> 1.5kV). It is important to make these supplies not accessible and shielded during normal operation to avoid electrisation of people on board or unshielded cables passing nearby.

6.5. ELECTROMAGNETIC COMPATIBILITY (EMC)

The Electromagnetic Interferences (EMI) generated by the equipment to be installed must be minimised. It can have dangerous effects on the avionics. The cable shielding reduces equipment radiations. In addition, effects on other scientific instruments are possible. Finally, the surrounding EMI can affect the new equipment itself. If it is sensitive to EMI, it has to be protected as much as possible in order to have an acceptable degree of EMC. EMI/EMC ground and in-flight control tests are performed after the first integration of the equipment in the aircraft.

7. DESIGN & INSTALLATION PROCESS

7.1. DESIGN

To design or modify any equipment, the user must take into account the information contained in this document. He/she must also contact SAFIRE so that the process of designing and manufacturing its equipment is optimised. All design information (mechanical and electrical sheets, masses, consumptions, etc.) must be supplied to SAFIRE at least 6 months prior to aircraft installation. SAFIRE has to submit every aircraft modification (the installation of new equipment is an aircraft modification) to the competent authorities. If this 6 months deadline is not met it can cause delay or cancellation of the project.

7.2. INSTALLATION

A review before installation is carried out by SAFIRE to have an overview of the equipment. A weighting is made to check the conformity. The new equipment should at least be provided one month before the first flight.

7.3. AIRCRAFT MODIFICATION

It is strongly recommended to use the aircraft existing modifications to install a new equipment. To modify a part of the aircraft is a solution that is both very expensive and time-consuming. The future user will have to take in charge all the costs incurred. Please contact SAFIRE as soon as possible for further information.

7.4. CONTROLS & TESTS FLIGHTS

One or more control flights may be necessary when installing new equipments. An EMC control flight is usually necessary. In the case of installation of external probes, flights tests can be expected, increasing the installation duration and costs incurred.