S A F I R E

Service des Avions Français Instrumentés

pour la Recherche et l'Environnement

(Department of French instrumented aircraft for research and environment)

Centre National d'Etudes Spatiales

Centre National de Recherches Scientifiques
(Institut National des Sciences de l'Univers /Division Technique)

METEO-FRANCE

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SAFIRE

operates 3 aircraft

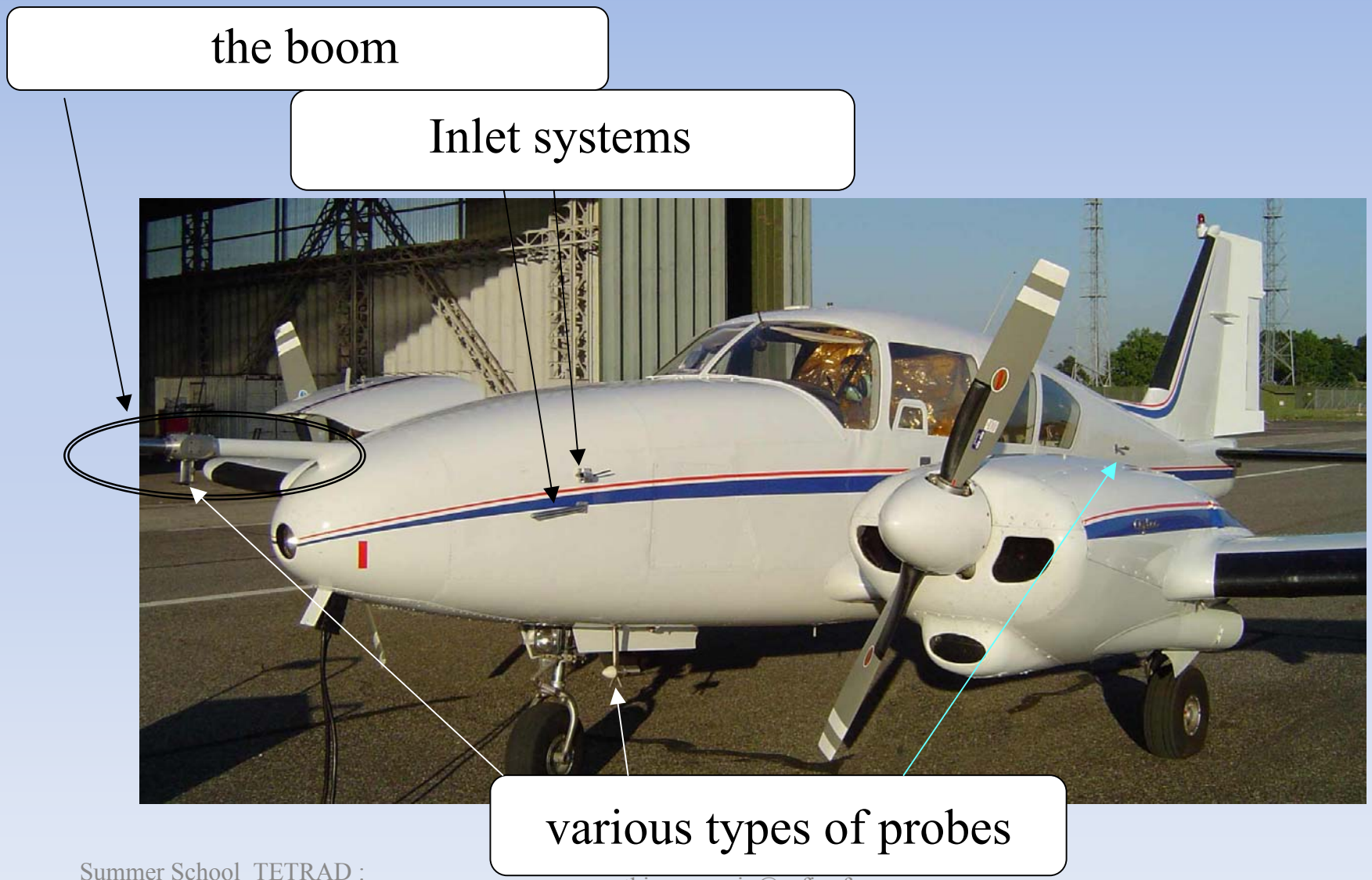
PA23 (Piper Aztec)

Compared technical data of the 3 aircraft

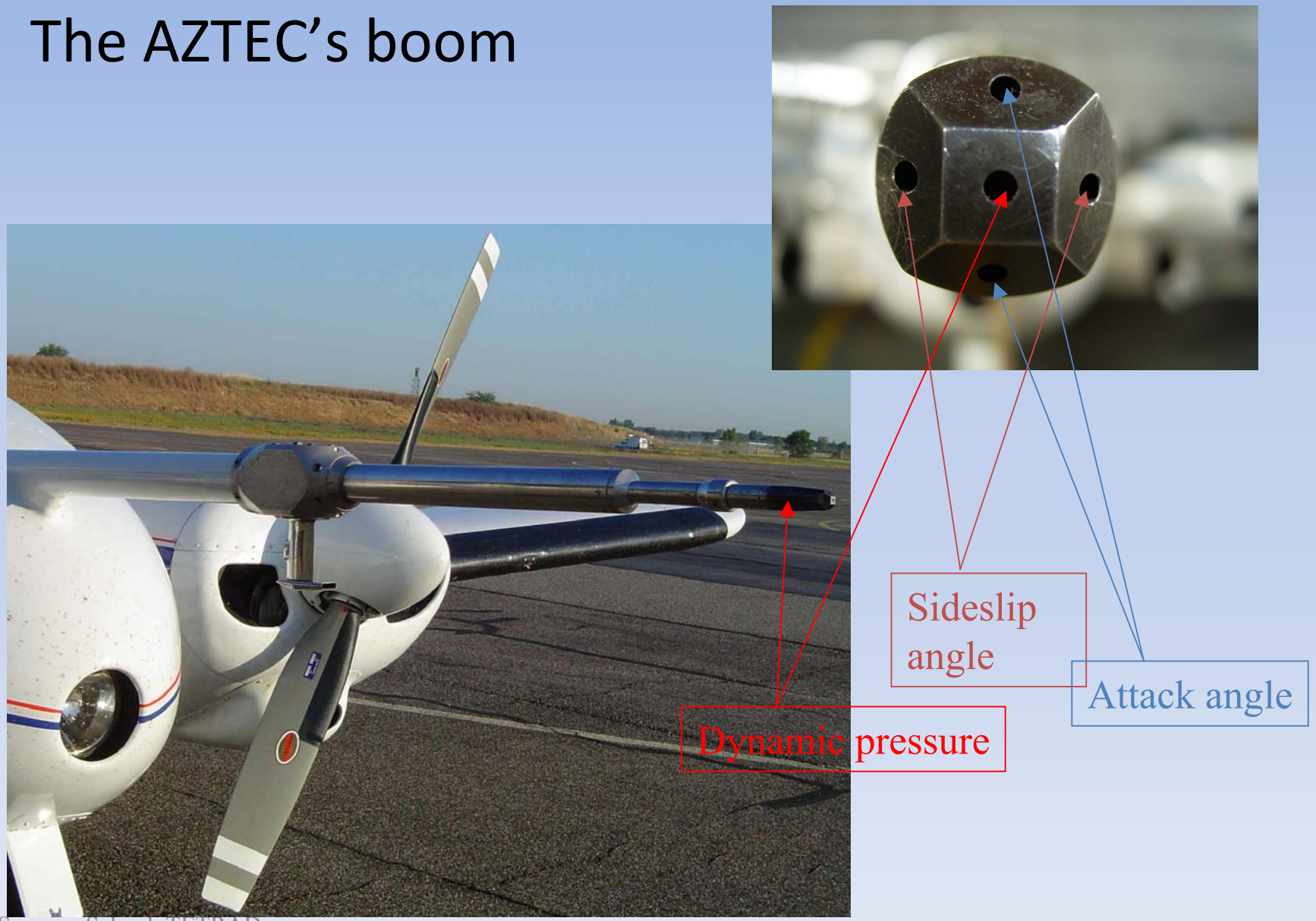
Everything is on the SAFIRE's website « www.safire.fr »

	PIPER	ATR42	FALCON 20
Length	9	23	17
wingspan	11	25	16
speed (m/s)	70	100	200
speed (knots)	136	194	389
max payload (Kg)		4600	1200
max altitude(ceiling) (m)	3962	7620	12802
ceiling (feet)	13000	25000	42000
max endurance (h)	5	6	5

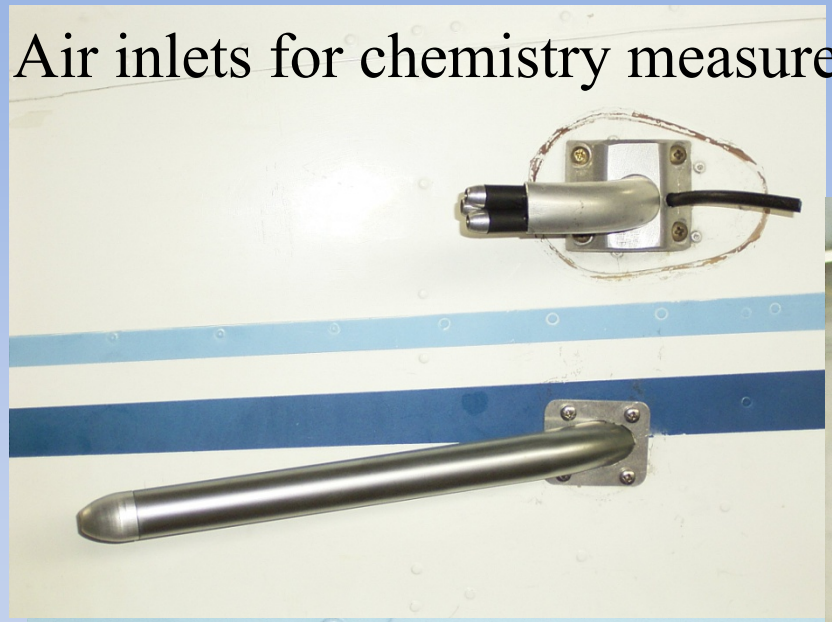
The PIPER AZTEC

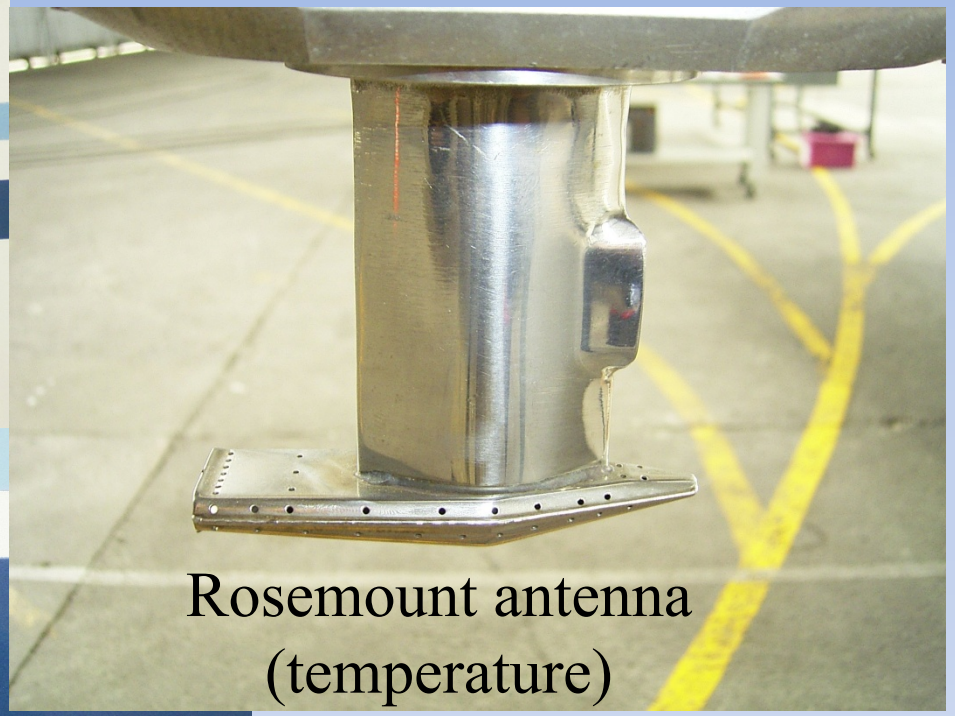


The AZTEC's boom



Air inlets for chemistry measurements

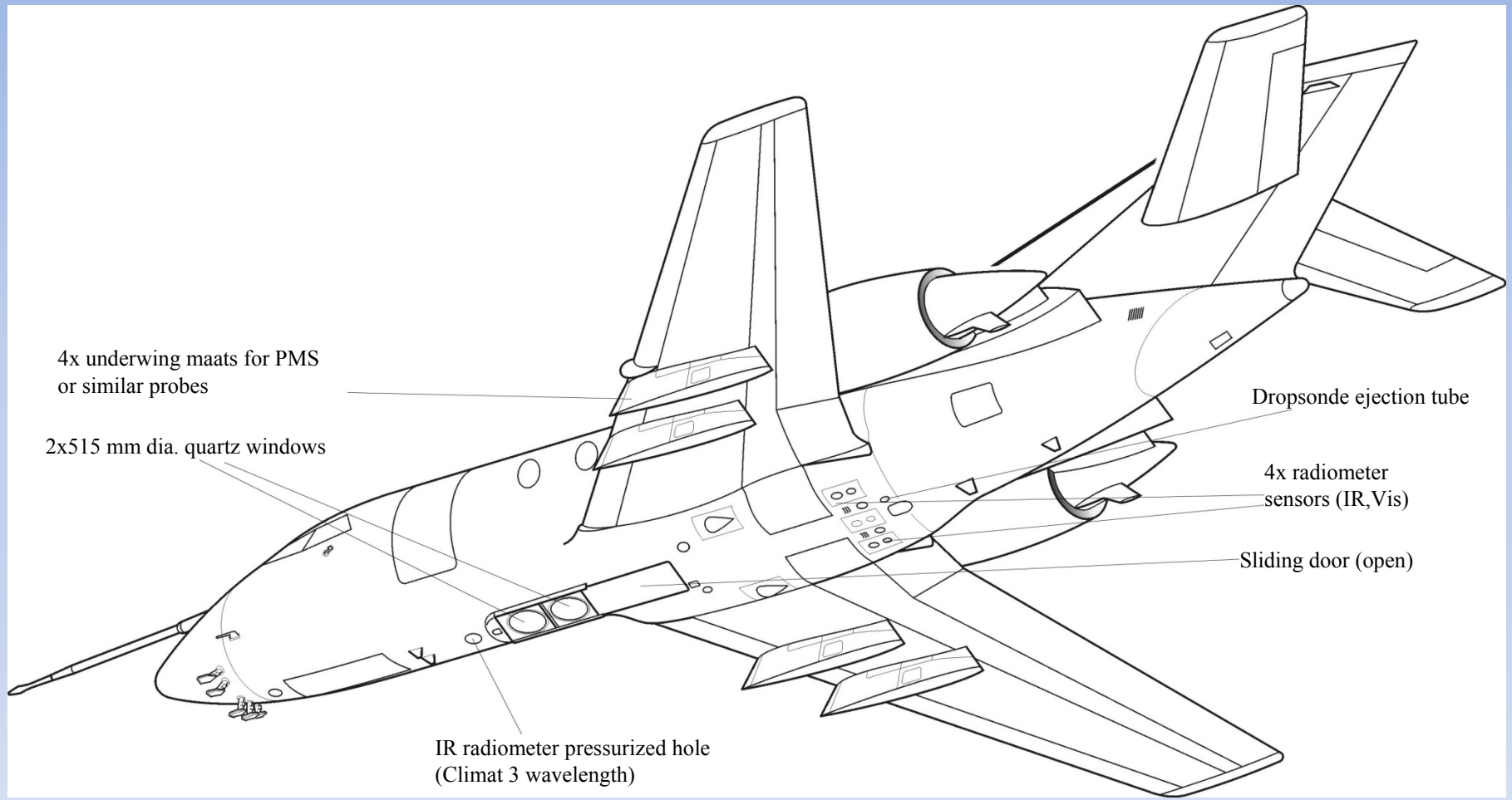




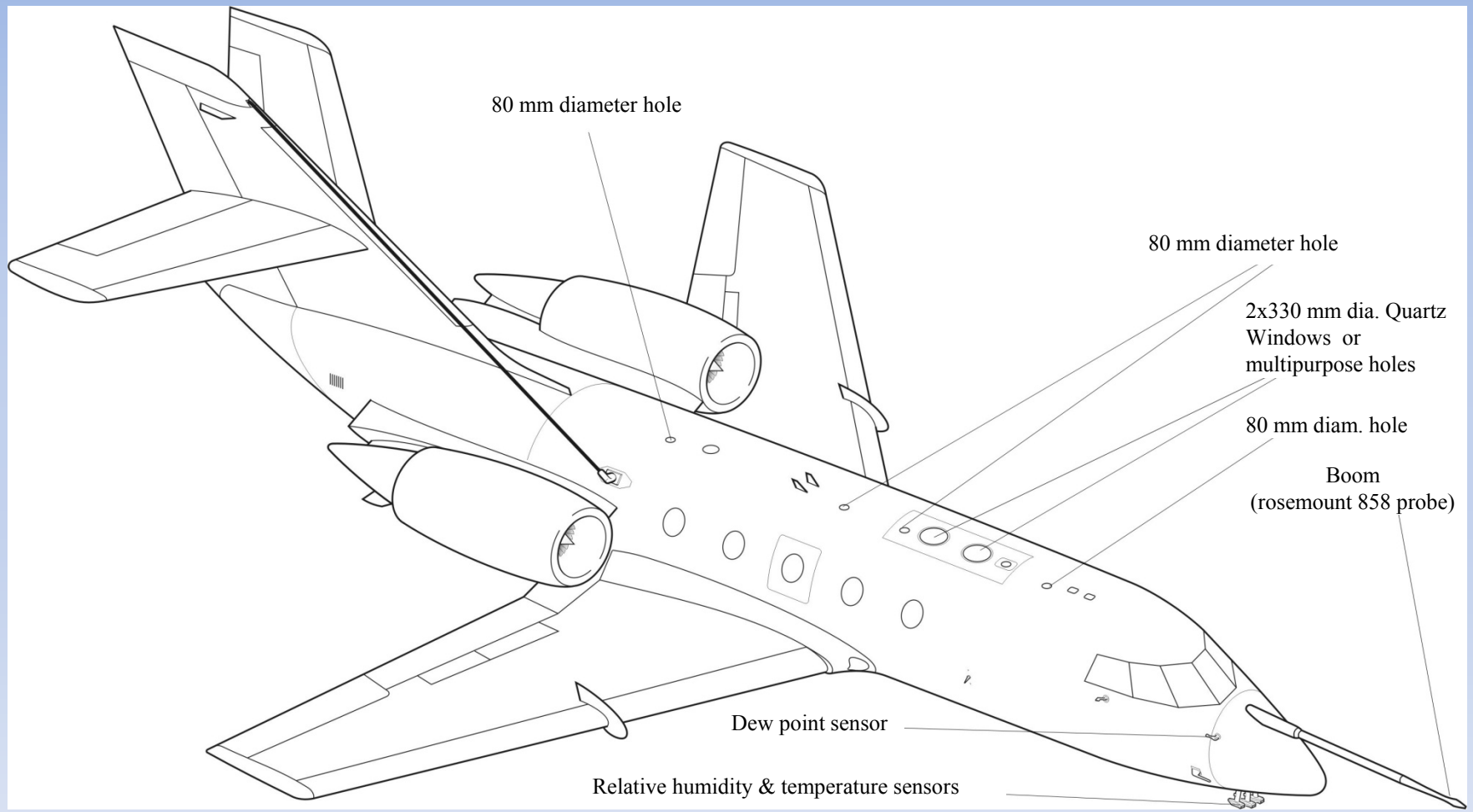
Rosemount antenna (temperature)

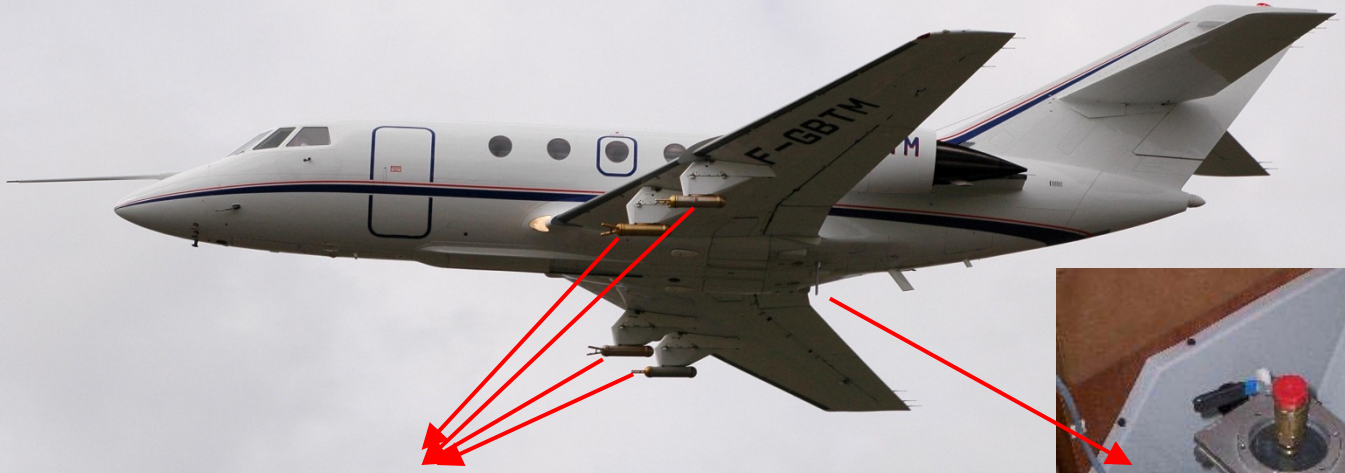
Sensing unit for aircraft hygrometer (1011B Buck Research)

Main modifications on Falcon 20GF (1/2 bottom view)



Main modifications on Falcon 20GF (2/2 top view)



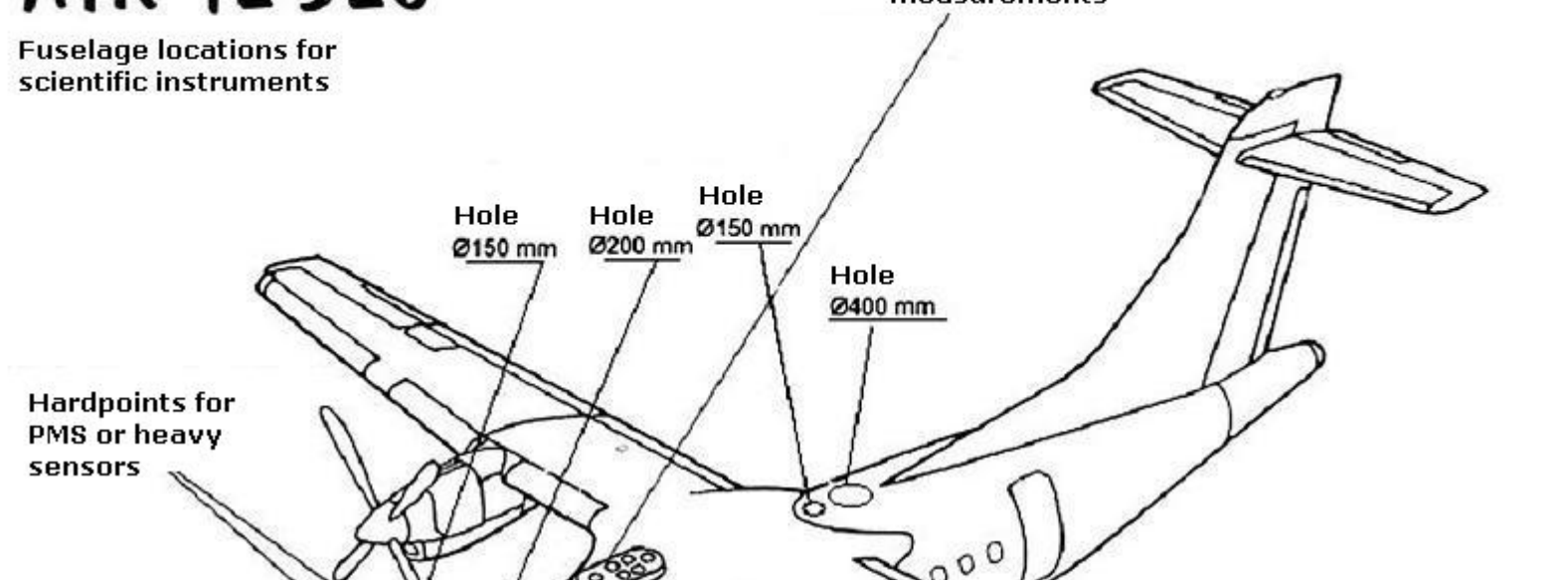


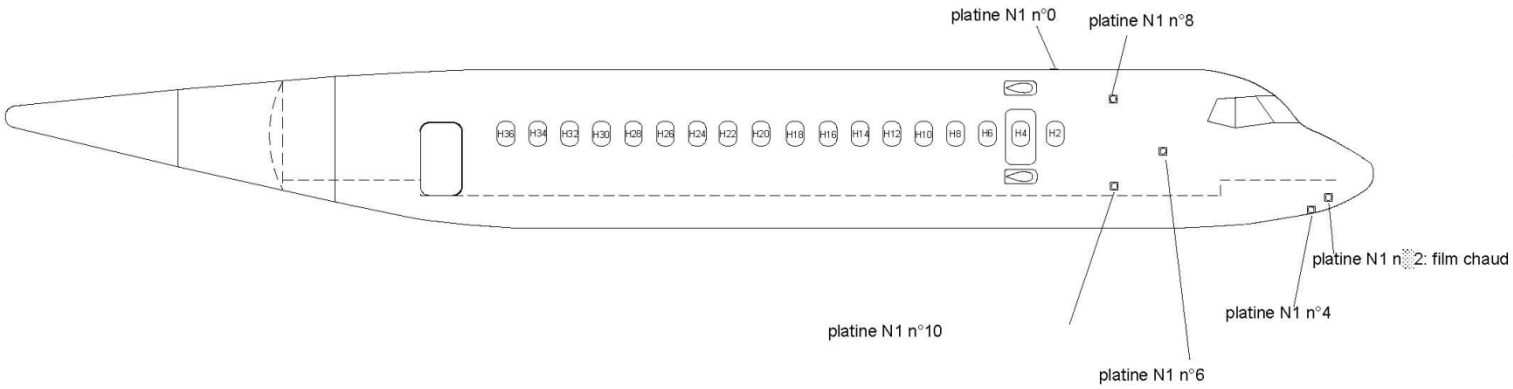
4 microphysical probes under the wings

The dropsonde launching system is a Vaisala AVAPS GPS system for RD94 dropsondes.

ATR 42-320

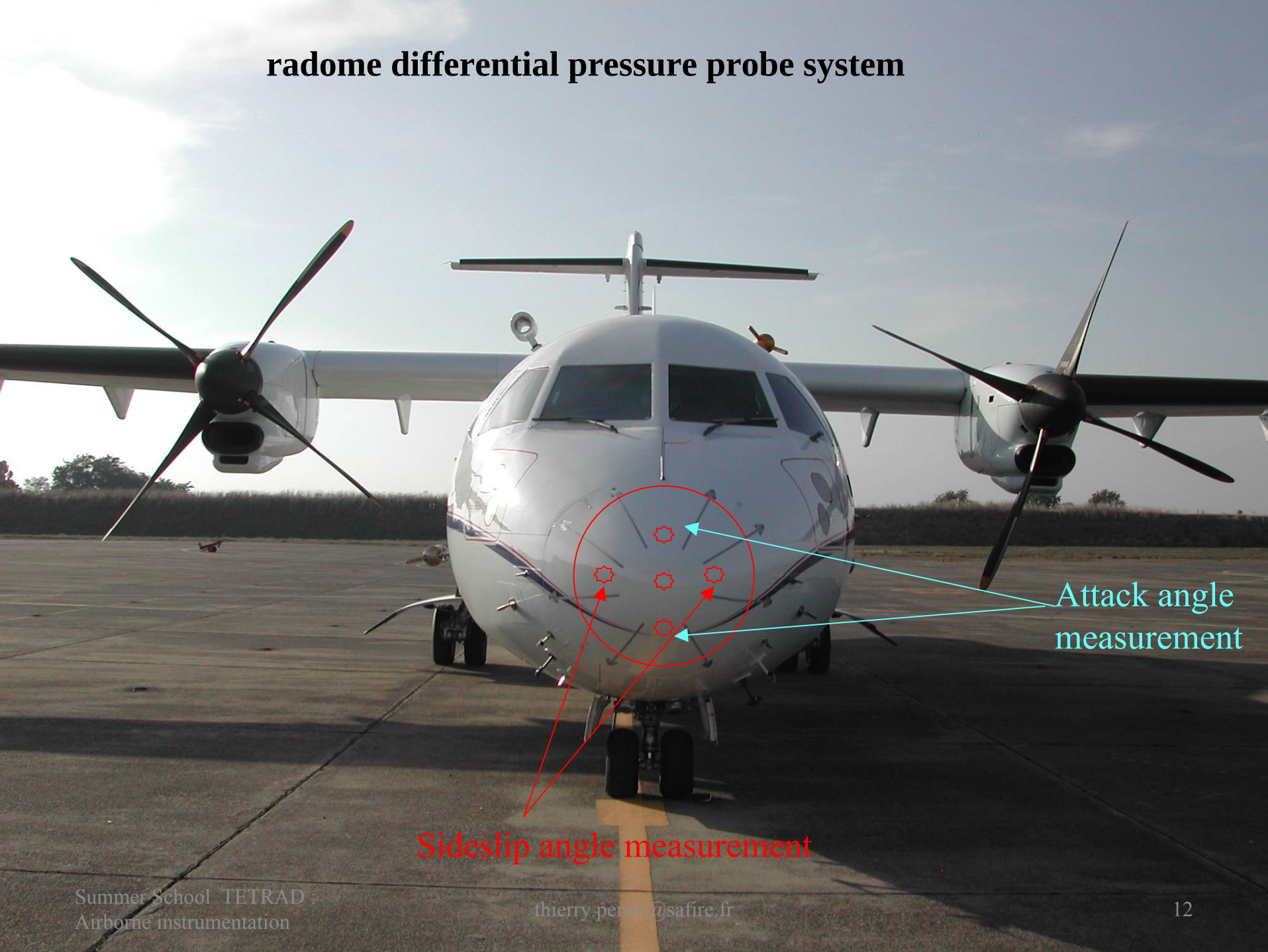
Fuselage locations for scientific instruments

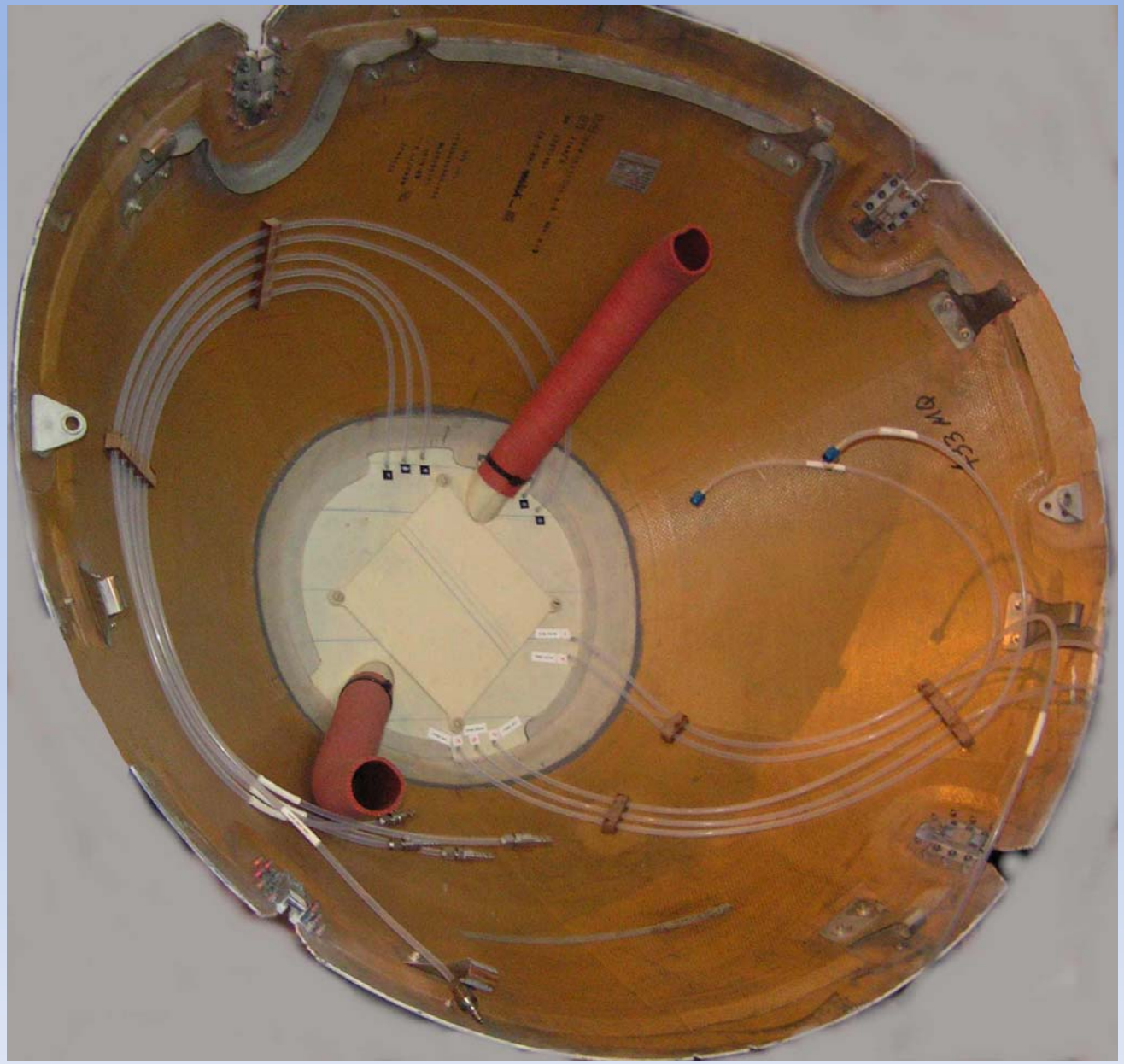




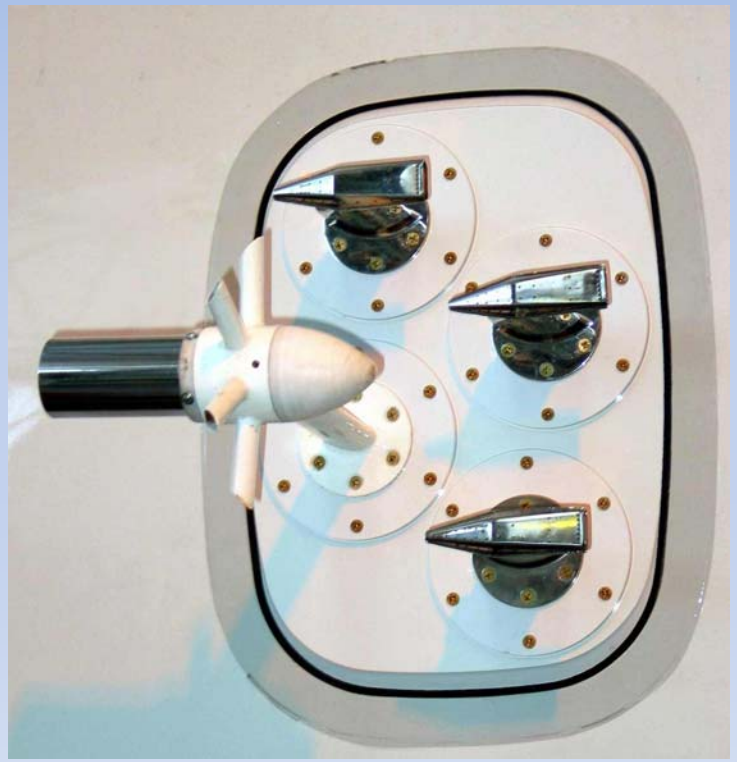
Global localisation of the probes on 4 hard points

radome differential pressure probe system

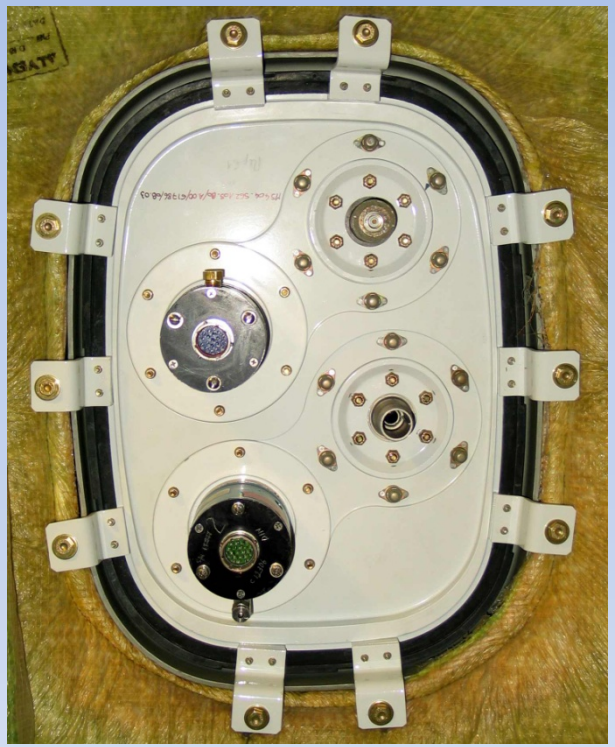



T53 MQ

Equiped window



View from outside



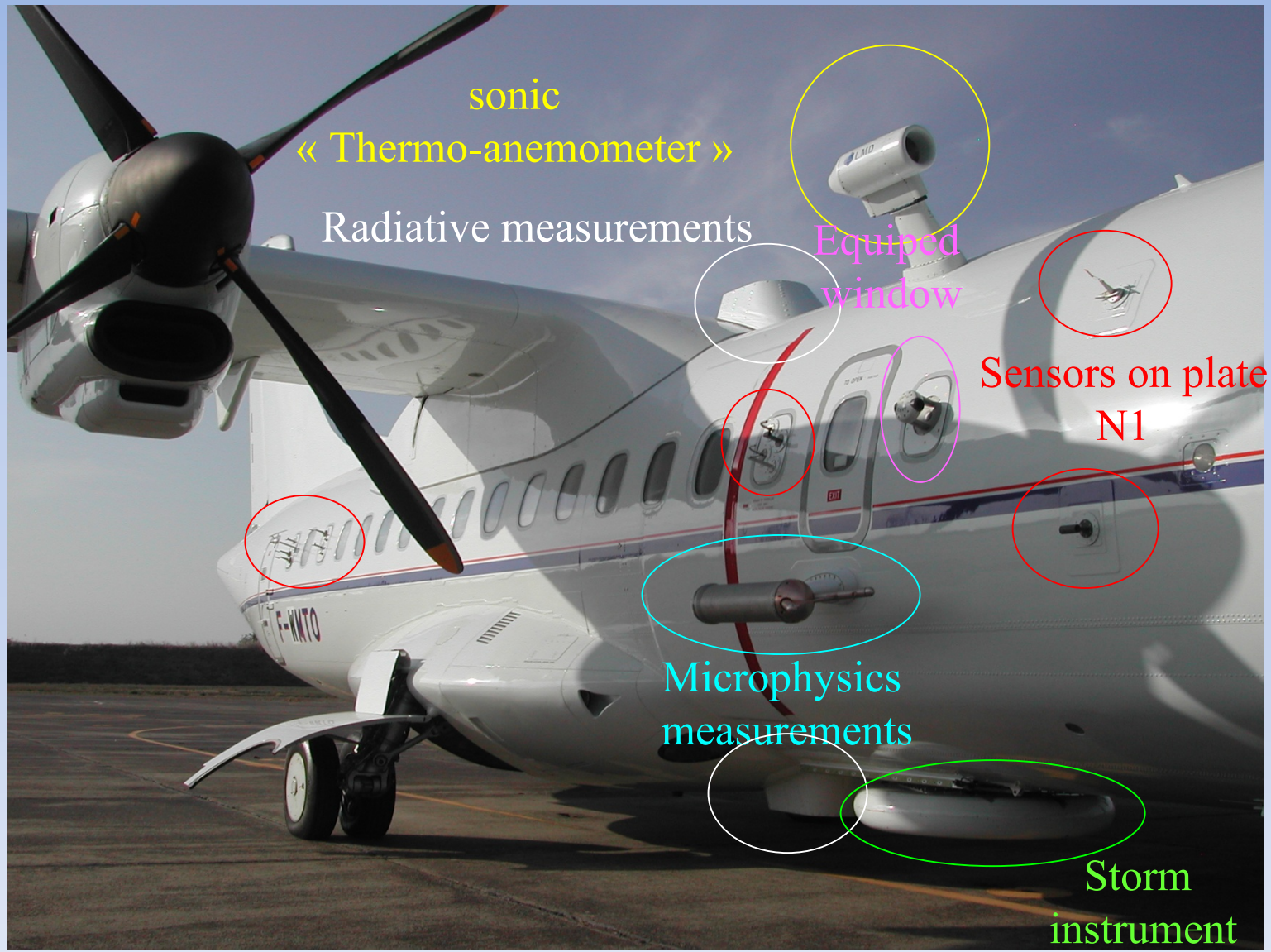
view from inside

« big » instruments

« RASTA » Radar

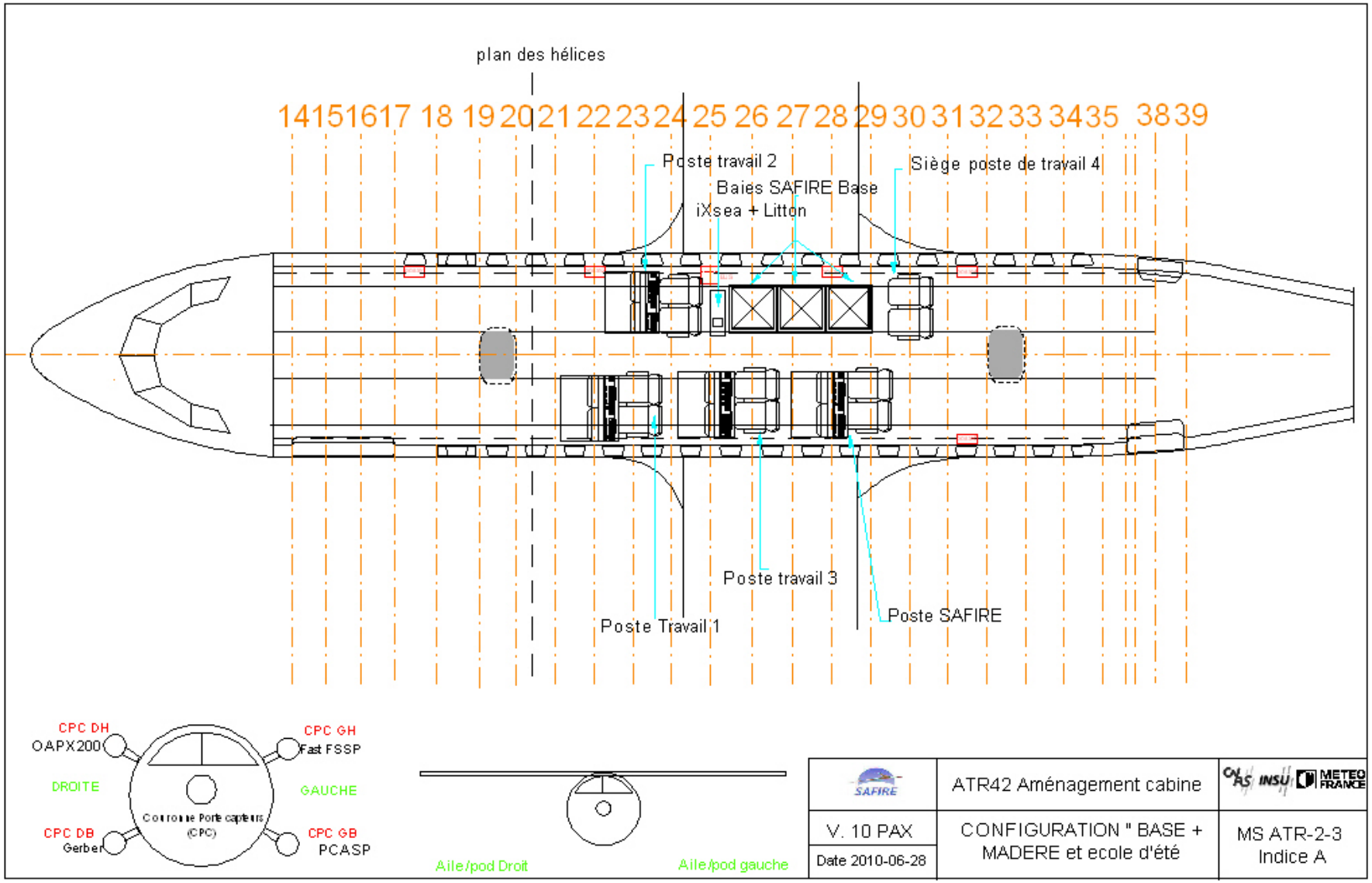
« STORM » Radar

Configuration example



Communautary aerosol inlet


SAFIRE
CNES CNRS-INSU METEO-FRANCE


plan des hélices
14151617 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 38 39
Poste travail 2
Baies SAFIRE Base
iXsea + Litton
Siège poste de travail 4
Poste travail 3
Poste Travail 1
Poste SAFIRE
CPC DH
OAPX200
CPC GH
Fast FSSP
DROITE
GAUCHE
Couronne Porte capteurs
(CPC)
CPC DB
Gerber
CPC GB
PCASP
Aile/pod Droit
Aile/pod gauche
SAFIRE
ATR42 Aménagement cabine
V. 10 PAX
Date 2010-06-28
CONFIGURATION " BASE + MADERE et ecole d'été
MS ATR-2-3
Indice A
INSU
METEO FRANCE

Measurements performed onboard the ATR42

Chemistry

Nitrogen Oxyde (*Nox*), *Carbon monoxyde (CO) and Ozone(O3)*

Physical *Pressure*, *Temperature*, *Humidity*

Dynamics *speed*, *position*, *attack*, *sideslip…*

Microphysics

Cloud Particle Measurements

Aerosols measurements

Cloud Liquid (and solid) Water Content Measurements

Radiative measurements (*visible and infra-red…)*

In addition to these various measurements, one can add any other instrument provided by external laboratory

Basic chemistry measurements at SAFIRE

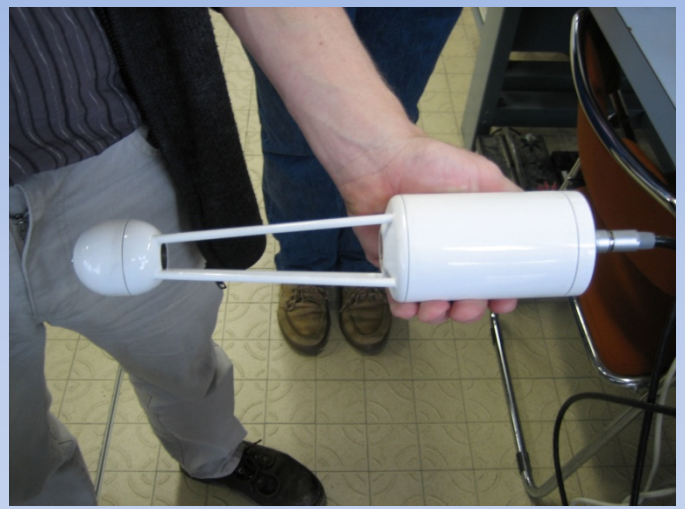
Component	Mark/Model	Principe	threshold/response time
Ozone ?	Environnement SA / O341M	UV Absorption	2 ppbv / 7s
Ozone	Thermo Environment Inc. / Mod 49	UV Absorption	2 ppbv / 4s
Nitrogen Oxides	Thermo Environment Inc. / Mod 42C	Chemiluminescence $NO + O_3 \rightarrow NO_2 + O_2 + h\nu$	0,5 ppbv / 300s
Nitrogen Oxides ?	Thermo Environment Inc. / Mod 42S	Chemiluminescence	0,15 ppbv / 300s
Carbon monoxide ?	Thermo Environment Inc. / Mod 48CTL modified	IR correlation	10 ppbv / 30s
Ozone & CO	MOZART (TEI49C+TEI48ctl)	UV Absorption & IR correlation	4s (O3)- 1s(CO)

Physical measurements at SAFIRE

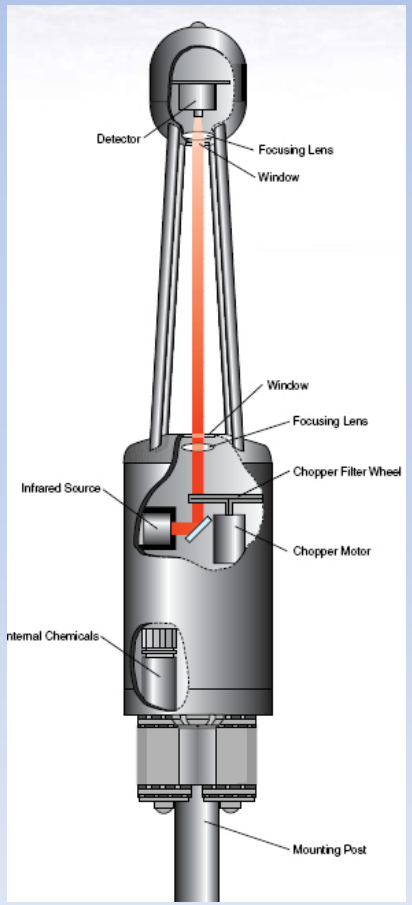
- Pressure measurements
  - Total
  - Static
  - dynamic
- Temperature measurements
  - Standard (platinum wire 25µm)
  - Reverse flow
  - fast (platinum wire 5µm)
- Humidity measurements
  - Dew point (chilled miror)
  - Lyman α (soon replaced by a licor) (absorption of light)
  - Capacitive (variation of electrical property of a capacitive component)


LINEX SUPER 50 M PAT. DENMARK

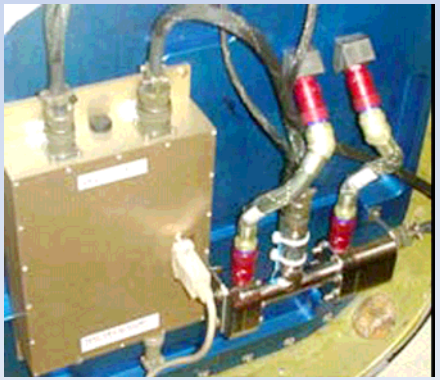
The licor 7500



Un rayon lumineux va être émis à partir de la base et fera plusieurs aller/retour afin d'augmenter le trajet optique et de mieux mesurer l'absorption de la lumière par la portion d'air traversée.



The WWSSII sensor



Corrections due to the speed of the aircraft

- It is necessary to apply corrections to pressure and temperature measurements.

These corrections will also depend on the value of the speed ; one will differentiate subsonic speeds from supersonic speeds

For example, the correction which must be applied on the temperature measurement will be the following formula :

$$Ts = \frac{Tm}{1 + rf \times \left(\left(1 + \frac{\Delta P}{Ps} \right)^{\frac{R}{Cp}} - 1 \right)}$$

Ts	static temperature
Tm	measured temperature
Ps	static pressure
ΔP	differential pressure
rf	probe recovery factor
R	perfect gas constant (R = 287.05 J.Kg-1.K-1)
Cp	specific heat at constant pressure for dry air (Cp= 7/2*Ra)

Dynamics Measurements

The attitude of the aircraft is measured using the radome and the associated pressure sensors.
The true air speed (TAS) is also computed from the dynamic pressure and the sideslip and attack angles measurements .
These data are obtained in the aircraft referential system

With the inertial navigation system we get real time measurements
in an earth coordinate system :
- position
- ground speed
- acceleration
- attitude angles (yaw, roll, pitch)

The wind components are computed from the difference between TAS and ground speed of the aircraft.

A third equipment :
The aircraft is of course equipped with a **GPS** receiver for the position and the ground speed
The problem of standard GPS are their refresh frequency (1Hz) and the bad precision for the altitude.

Position measurements

- Novatel DLV3 GPS receiver
- IxSea AIRINS (100Hz INS IMU)
- ULISS 45 Sagem (25Hz)

Cloud Microphysics

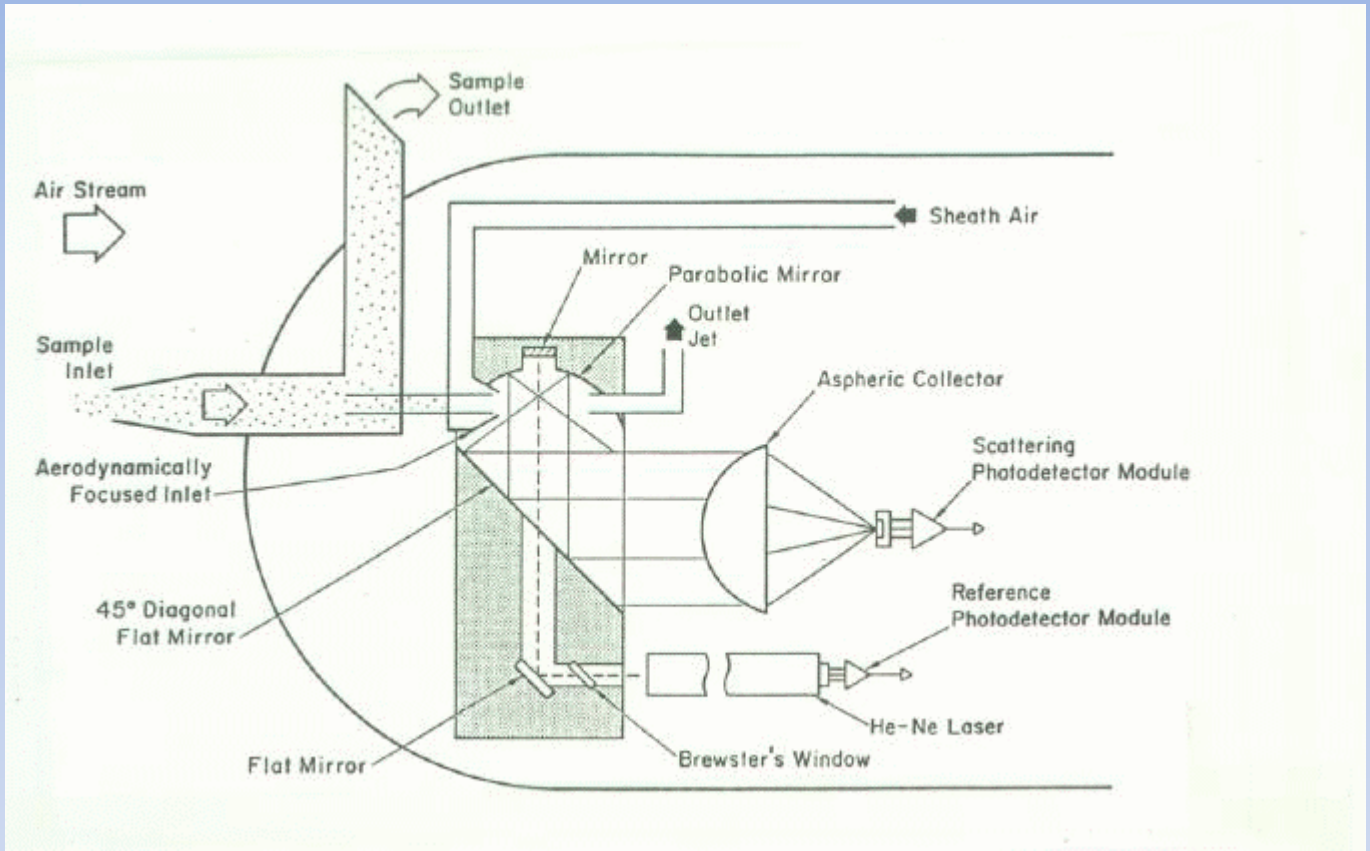
SAFIRE has several cloud particles measurement probes making it possible to cover a broad spectrum of the hydrometeors met in the atmosphere.

If all instruments are taken into account, the covered range extends from 300nm to 6mm.

These probes give the number of particle per class of size. One can then compute the lwc for example.

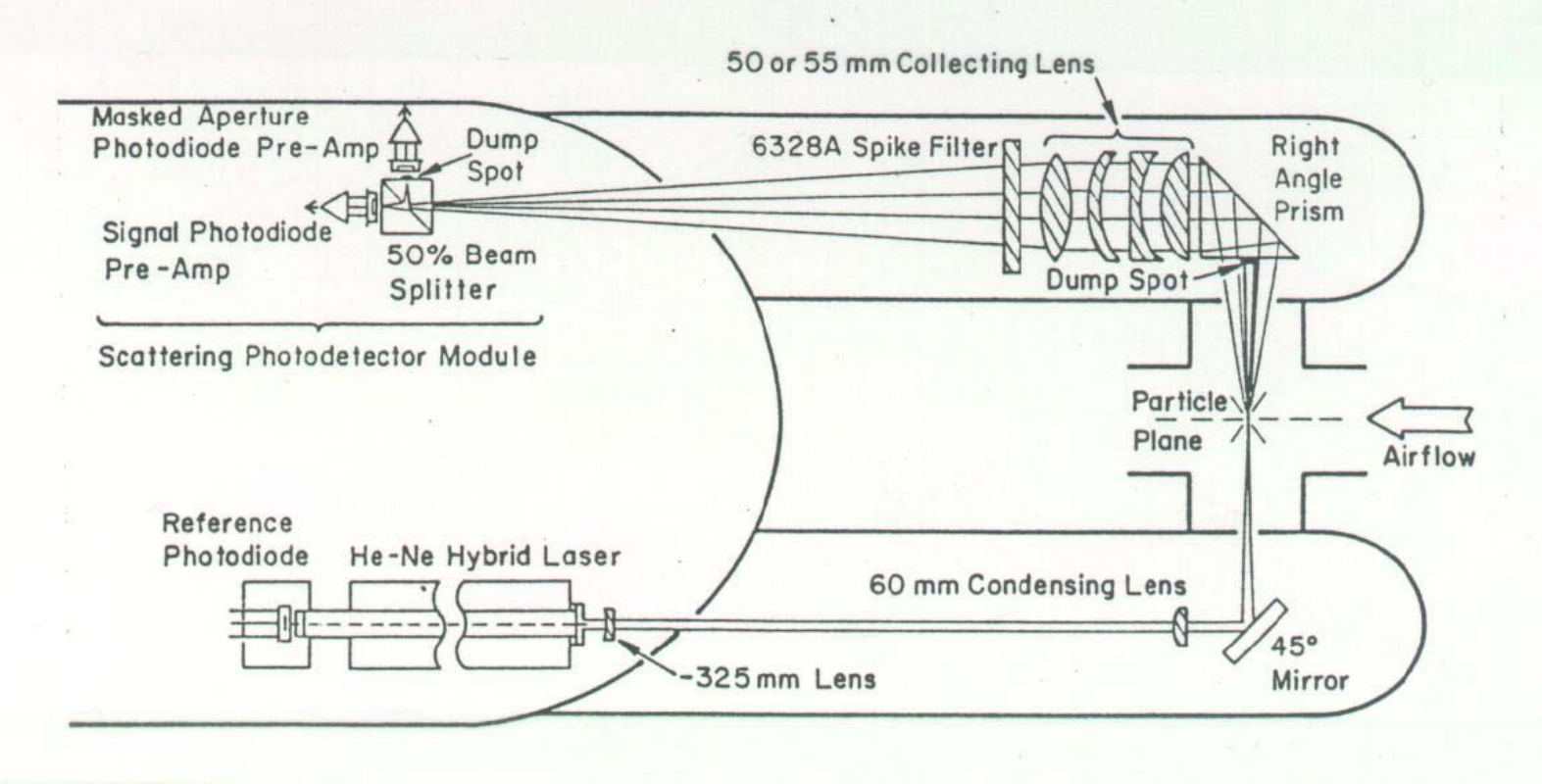
These probes are :

GERBER PVM100 *	0 - 10 g/cm³ 5 - 10 000cm²/m³
PMS PCASP 100 *	.12 - 3 µm (15ch)
DMT FSSP 300	0.3 – 20µm (31 ch)
PMS FSSP 100 *	.5 - 47 µm (4 ranges/15ch)
PMS OAP 200X	20 - 300 µm (15ch)
DMT CIP (2D&1D)	25-1600 µm (64 ch -25µm)
PMS OAP2D-C *	25 - 800 µm (32*1024)
PMS Optical Array Probe 230Y	200 - 6000 µm (30ch)



PCASP

Passive Cavity Aerosol Spectrometer Probe



FSSP

Forward Scattering Spectrometer Probe

Spectrometers probes use the Mie theory which can be summarized by this sketch

```
1 REAL,IMAG INDEX OF REFRACTION:    1.33000  0.00000
  BEGIN,END+1,STEP COLLECT ANGLE(DEGS):    4 15 1.0
  RADIATION WAVELENGTH(UM):        0.6328

2 REAL,IMAG INDEX OF REFRACTION:    1.51000  0.00000
  BEGIN,END+1,STEP COLLECT ANGLE(DEGS):    4 15 1.0
  RADIATION WAVELENGTH(UM):        0.6328

3 REAL,IMAG INDEX OF REFRACTION:    1.58000  0.00000
  BEGIN,END+1,STEP COLLECT ANGLE(DEGS):    4 15 1.0
  RADIATION WAVELENGTH(UM):        0.6328
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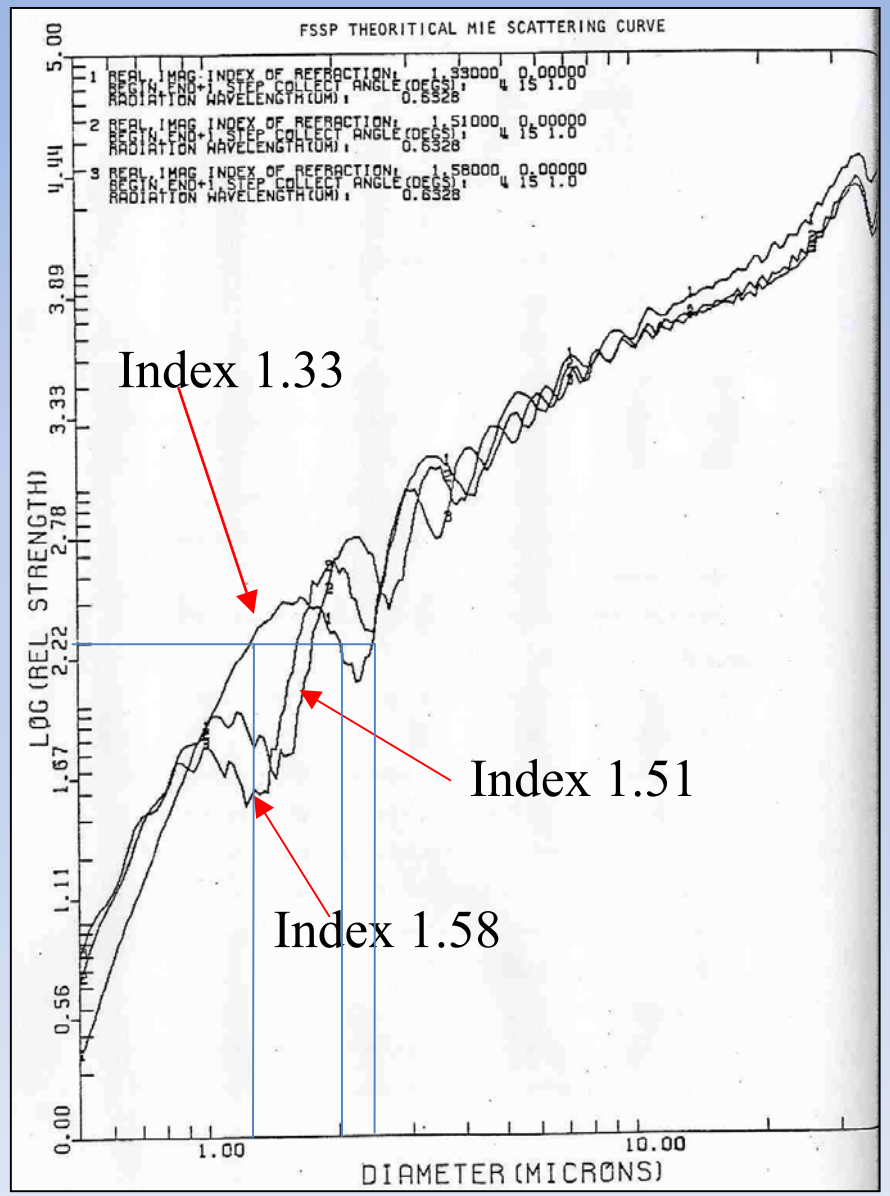
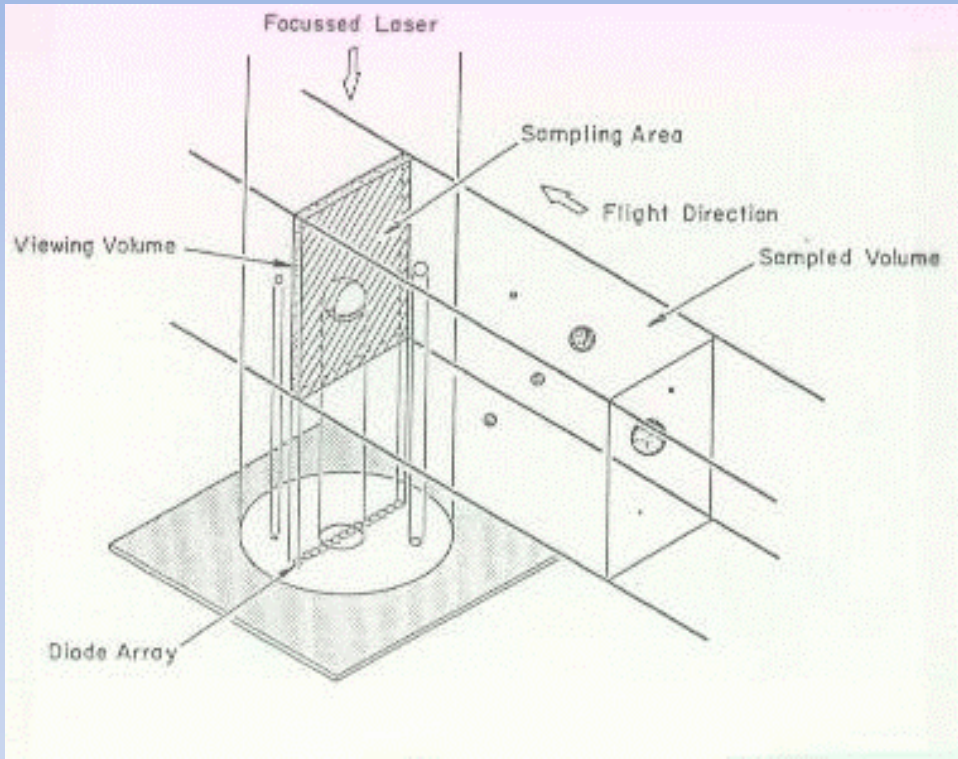
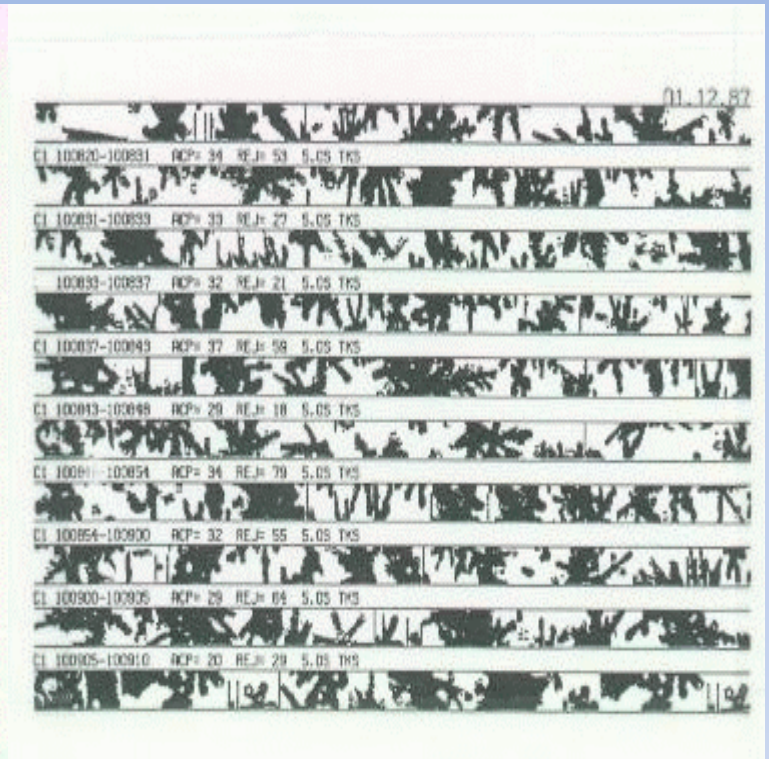


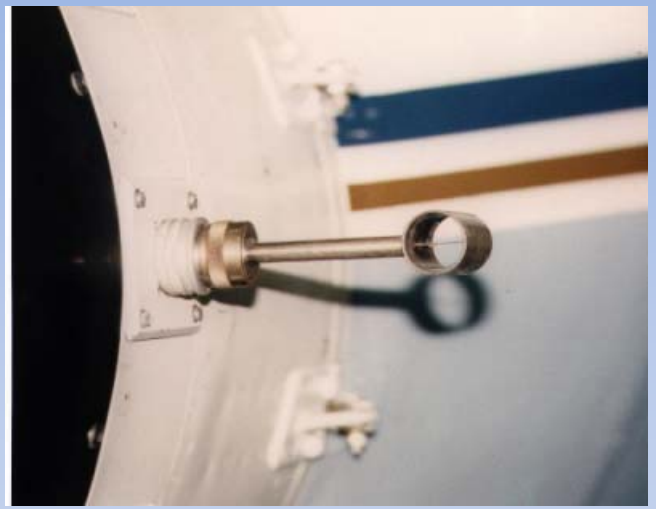

Focussed Laser
Sampling Area
Flight Direction
Viewing Volume
Sampled Volume
Diode Array


01.12.87

PMS 2D

King Probe

The King probe operates under the principle that liquid water can be calculated from measurements of the amount of heat released when vaporized. A heated cylinder is exposed to the airstream and intercepts on coming droplets. The electronics maintain this sensor at a constant temperature (approximately 130o C) and monitor the power required to regulate the temperature as droplets vaporize. This power is directly related to the amount of heat taken away by convection plus the heat of vaporization. The convective heat losses are known empirically and vary with airspeed, temperature and pressure. The liquid water content is calculated from power loss found from the difference between total and convective power losses.

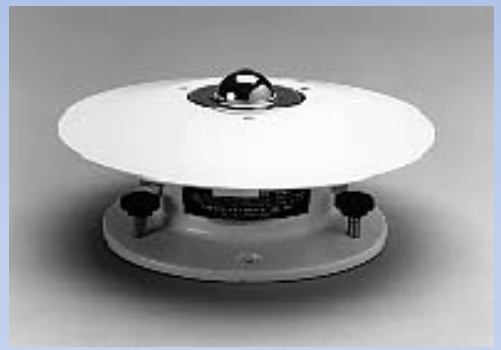


Johnson Williams

Under particularly severe conditions (LWC greater than 1.0 g/M^3 and T< -15C), the heaters in the JW sensing head are not sufficient to melt quickly enough any ice that has accumulated on the probe shield. Subsequently, ice builds up on the compensation wire, and erroneous data are obtained.

Radiative measurements

Eppley soon replaced by Kipp & Zonen : 2 types of radiometers are installed on the roof and under the aircraft.



We make measurements in the visible and infra-red ranges along the 2 directions (downward flux on the roof, upward flux ,under the fuselage.

Another radiometer is the CLIMAT (Conveyable Low-Noise Infrared radiometer for Measurement of Atmosphere and ground surface Targets)

Infrared radiometer 3 ranges
-8,7 µm
-10,8 µm
-12,0 µm

Radiative measurements

Type	Wavelength	range
Eppley Pyranometer	0.285 to 2.8 µm	0 to 1400 W/m^2
Eppley Pyrgeometer	3.5 to 50 µm	0 to 700 W/m^2
CIMEL Climat	300 to 380 nm	radiative temperature

Conclusion

Measurements are only part of the work….
The signals coming from our probes must be sampled, recorded, processed and often filtered in order to remove the bad measurements…
Immediately after a flight, a first process is made in order to check the basic operation of the instruments. These verifications enable us to repair very quickly the sensors if needed (and if possible!!!).
In parallel a first set of data is provided to scientists.
We call this set of data "Quick-Look".
The certified data are generally supplied one month later.
These data are provided by another team from Meteo-France : that is TRAMM ; The head of TRAMM is Bruno Piguet who is here and who will work with you after your flights.

End!……

Don’t forget that
a visit of the aircraft
is planned, not today, but Monday
morning

Radar RASTA is dedicated to the study of the properties dynamic, microphysics and radiative of the tropospheric clouds slightly precipitants .
It is an impulse radar monostatic functioning at a frequency of 95,04 GHz.

Parameters furnished by RASTA are :
the vertical distribution of the coefficient of retrodiffusion (or reflectivity) and its space variation ; this measurement is very sensitive to the cloud droplet dimension. (because of the speed of these particles)

The radial velocity :
In the case of a vertical aiming, this measurement is the sum of the sedimentation speed of the cloudy particles plus the vertical speed of the air.

•Définition de Oxyde d'azote (NOx) :

The analyzed compounds by the networks are NO and NO2 of which the sum being gathered under the term of nitrogen oxides (Nox).

Odorous gas, very toxic since the content of volume exceeds 0,0013% (beginning of the irritation of the mucous membranes). Is the product of the oxidation of nitrogen of the air or the fuel with oxygen in air or the fuel under conditions of high temperature.

The nitric oxyde NO and the nitrogen dioxide NO2 are emitted at the time of the phenomena of combustion. The NO2 results from the oxidation of NO the principal sources are the vehicles (nearly 60%) and the installations of combustion (power station, heatings…). The catalytic pot allowed, since 1993, a reduction in the emissions of the vehicles with gasoline, but the effect remains still not very perceptible taking into account the strong increase in the traffic and the duration of renewal of the automobile park. the NO2 also meets inside the buildings where function of the apparatuses to gas such as gazinières, water-heater,….

-Effect on the environment: intervention in the process of formation of ozone (effect of greenhouse), contribution to the phenomenon of the acid rains.

-- Effect on health: penetration in the finest respiratory ramifications being able to involve a degradation of breathing, a hyperreactivity of the bronchi at the asthmatic ones, an increase in the sensitivity of the bronchi to the microbial infections in the children.

-- acceptable maximum Threshold for WHO: 400 µm/m3 per hour, 150 µm/m3 per 24 hours.

•Chemiluminescence is the emission of light (luminescence) without emission of heat as the result of a chemical reaction. Given reactants A and B, with an excited intermediate ◊, we have:

[A] + [B] → [◊] → [Products] + light

Here the reactants are OZONE and NOx and we get :

$$2(NO) + 2(O_3) \rightarrow 2(NO_2) + 2(O_2) + 2h\nu$$

One places the sample to be studied in the presence of ozone in excess. There is then emission of light; this emission is proportional to the nitric oxide concentration. This light emission is then measured to determine [NO]. If the sample contains carbon dioxide it is possible to deduce [NO2] by difference. First a measurement of NO is made then the NO2 is transformed to NO then a second measuremnt is made. The difference of the 2 measurement gives the amount of NO2.

Définition de Monoxyde de carbone (CO) :

Gaz inodore, incolore et inflammable, le monoxyde de carbone CO se forme lors de la combustion incomplète de matières organiques (gaz, charbon, fioul ou bois, carburants).
La source principale est le trafic automobile. Des taux importants de CO peuvent être rencontrés quand un moteur tourne au ralenti dans un espace clos ou en cas d'embouteillages dans des espaces couverts, ainsi qu'en cas de mauvais fonctionnement d'un appareil de chauffage domestique.
Le CO participe aux mécanismes de formation de l'ozone troposphérique. Dans l'atmosphère, il se transforme en dioxyde de carbone CO2 et contribue à l'effet de serre.
- Effets sur la santé humaine : le monoxyde de carbone a un effet toxique à partir d'une concentration en volume inférieure à 0.1%, en exposition prolongée. Le CO se fixe sur l'hémoglobine pour former une molécule stable, la carboxyhémoglobine. L'hémoglobine s'associe préférentiellement avec le CO plutôt qu'avec l'oxygène, et cette fixation est irréversible. Pour une concentration de 800 ppm de CO dans l'air, 50% de l'hémoglobine se bloque sous forme de carboxyhémoglobine. Il en résulte une diminution de l'oxygénation cellulaire, nocive en particulier pour le système nerveux central. Le CO est responsable de 300 à 400 décès par an en France, en milieux clos, et de plus de 5000 hospitalisations.
Les causes en sont :
- le manque d'aération dans des locaux chauffés par une combustion,
- le mauvais réglage des appareils entretenant une combustion,
- l'obstruction du conduit de cheminée, provoquant le refoulement des gaz brûlés,
- la mauvaise conception de certaines cheminées, empêchant l'évacuation des gaz brûlés.
La région de Dehli (Inde) est l'exemple parfait de teneurs excessives en CO. Seuil maximal admissible pour l'OMS : 10 milligrammes/m3 de moyenne horaire sur 8 heures, 30 milligrammes/m3 sur 1 heure.

Le monoxyde de carbone absorbe le rayonnement infra-rouge et la méthode européenne de référence repose sur la mesure de son absorption, ainsi que sur le principe de la corrélation par filtre gazeux. Un rayonnement infra-rouge, émis par un filament chauffé, traverse une roue de corrélation, un banc optique, puis un filtre, pour être mesuré par le détecteur infrarouge.

Definition of Ozone (O3): It is an allotropic gas variety of oxygen O2, heavier than the air.

Stratospheric ozone is found with rather high concentration in terrestrial stratosphere, primarily at an altitude ranging between 15 and 20 km. This ozone strongly absorbing the ultraviolet rays, protects the living organisms from radiations U.V. It is destroyed by compounds, in particular resulting from the human activity, among which CFC, thus involving a “hole” in the layer of ozone.

Tropospheric ozone is generated by pollution close to the surface of the ground. The ozone of the low layers of the atmosphere is a gas extremely irritant and colourless. Tropospheric ozone is formed by a chemical reaction implying nitrogen dioxide with oxygen in air. However, to form nitrogen dioxide (NO2), one needs nitric oxyde (NO) directly rejected by the cars, compound with volatile organic compounds (COV) coming mainly from industries. One thus calls it secondary pollutant because it is produced when two primary education pollutants react to the sun and the stagnant air.

Tropospheric ozone contributes to the effect of greenhouse and the acid rains (deterioration of the plants and the forests). It is a factor of degradation of the materials of which rubber (frequent problem on the level of the tires). In the man or the animal, it is at the origin of irritation of the ocular and respiratory mucous membranes, of attacks of asthma at the significant subjects.

The ozone peaks always occur in the course of afternoon, according to the same diurnal cycle as that of the temperature: minimum towards 8h and maximum towards 17h.

Pollution by ozone increases regularly since the beginning of the century in the atmosphere of the northern hemisphere, and our areas are usually subjected in summer to points of pollution by ozone, in urban environment and rural.

-**Effects on health**: deterioration of the respiratory function

-Acute effects: reduction in the respiratory function observed in children and adults, colds, possible headaches, irritation of the eyes, release of attacks of asthma and symptoms respiratory. The strongest reaction occurs at the end of 2 days of episode. After 4 or 5 days of exposure, the reaction is not perceived any more (the organization reacted to protect itself).

-**Effects on the plants**: the great physiological processes of the plant (photosynthesis, breathing) are deteriorated by ozone and the production of the agricultural cultures can be significantly reduced.

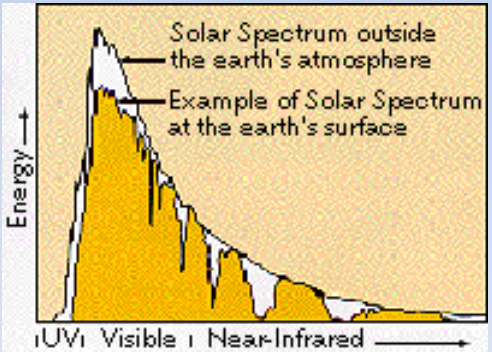
-**- Effects on materials**: ozone deteriorates rubbers and unquestionable polymeric.

-ozone is a gas for purpose of greenhouse, just like the carbon dioxide.

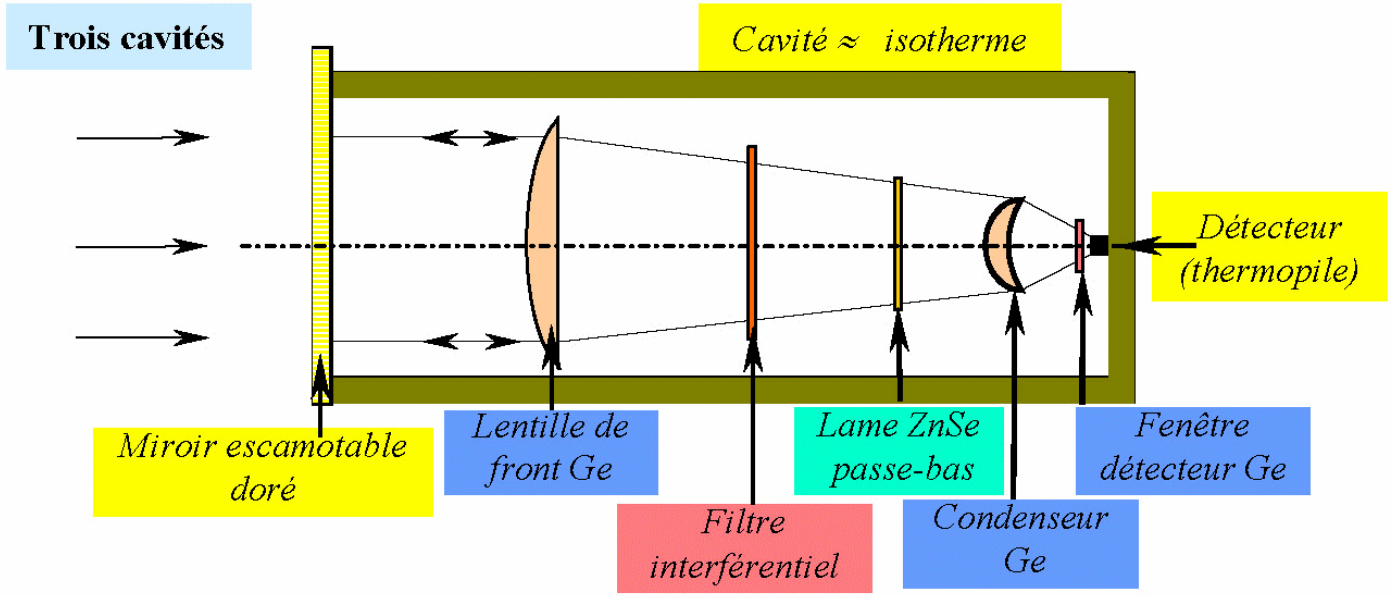
-Ozone is measured by absorption of ultraviolet light

Radiative Measurements

On distingue emission solaire (s'étend de l'UV au proche IR : 0.2 à 4 µm)et émission terrestre (IR).
Pour rappel on peut ranger les différentes gammes de radiations selon la liste suivante :
Ultraviolet: 0.20 - 0.39 µm
Visible: 0.39 - 0.78 µm
Proche IR: 0.78 - 4.00 µm
Infrarouges: 4.00 - 100.00 µm
Approximativement 99% des radiations solaires (ou courte l) à la surface de la terre sont contenues dans la gamme de 0.3 to 3.0 µm tandis que la majeure partie de l'émission terrestre (grandes l) sont contenues dans la gamme de 3.5 to 50 µm.
A l'extérieur de l'atmosphère la constante solaire est de l'ordre de 1370 watts/m2. A la surface de la Terre par beau temps à midi cette valeur sera de l'ordre de 1000 watts/m2.



CARACTÉRISTIQUES DE L'OPTIQUE ET DU DÉTECTEUR



	Distances focales (mm)	Diamètres effectifs (mm)
Objectif	50,80	11,80
Condenseur	3,23	4,35

Montage de Köhler (Condenseur dans le plan focal de l'objectif)

→ Homogénéisation de l'éclairement reçu par le détecteur ∀ le contraste de la cible (évite l'apparition de points chauds sur la surface du détecteur)

→ Permet d'exploiter un champ de pleine lumière en utilisant toute la surface utile de l'objectif et de supprimer totalement l'effet des sources extérieures à ce champ.

Dimensions de la surface sensible	S = 0,6 mm × 0,6 mm
Détectivité D^*	$D^* = 2,3\ 10^8\ cmW^{-1}Hz^{-1/2}$
Réponse	$R = 200\ VW^{-1}$
Coefficient de réponse avec la température	$\alpha = -0,15\ 10^{-2}\ K^{-1}$
Temps de réponse	$\tau = 12$ ms
Impédance	$Z = 100\ k\Omega$
Bruit en puissance	$NEP = 0,26\ nW\ Hz^{1/2}$

Détecteurs thermiques ***(thermopiles)***

→D* indépendante de la longueur d'onde

→Fonctionnement à température ambiante

→Très peu de dépendance de la sensibilité avec la température