Herschel and Planck satellites: challenges met with brio
### TÉLÉGRAMS

#### How to regenerate air under the sea...

DTA is renowned for its aeronautic activities, but it is less well known for its underwater experiments. In both cases, the Sassenage innovations allow military personnel to breathe. Recently, the shipbuilding company DCN ordered several products from DTA. The first will enable regeneration of the confined air in the next missile-launching nuclear submarine, the "Terrible", designed to come up to the surface only every three months, whose construction has just begun in Cherbourg. Relying on a molecular sieve, this system for regenerating air will eliminate accumulated carbon dioxide. The project, begun in May 2004, will last for over two years. Delivery of "factories" is envisaged for mid 2006.

A second apparatus under study could equip other submarines that will see the light of day in... 2012! These nuclear attack submarines, baptized "Barracuda", smaller and faster, will escort the aircraft carriers and missile-launching nuclear submarines of the "Terrible" type. The machine will also serve to regenerate the confined air, but it will be based on the innovative "pulse-tube" technology. By crystallizing the carbon dioxide by cryogenics, it will be less costly and will provide better quality air, since it will eliminate other pollutants besides CO₂. "The air in submarines must be purer than that in a few cities!" emphasizes Jean-Marie Gaillard, in charge of marine activity for DTA. Finally, DTA provides systems for storing oxygen for a third type of submarine: conventionally propelled (non-nuclear) models, equipped with AIP (Air Independent Propulsion), intended for DCN's export market. This oxygen serves as supply for the fuel cells equipping these submarines and for the crew to breathe. Such a system, of a more modest size, could also provide the "Barracuda" with a supply of breathable air.

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#### Pure Xenon at 99.9999% in satellite motors

Remember: on July 12, 2001, the Artémis telecommunications satellite was placed in orbit about 300 km lower than intended! Luckily, Artémis has the advantage of being equipped with plasma engines with Xenon gas, fed by solar energy. The result: the satellite was able to reach its orbit on its own, gaining 20 km in altitude every day. In this way, what had been considered a setback in 2001 turned out to be a world first. In fact, DTA manufactures units, equipped with a cryogenic compressor, that enable the tanks of these plasma engines to be refilled automatically with Xenon (see Cryoscope 12 p6-7). At present, Astrium requires even more transfer units. Whereas the Xenon used up till now for satellites contains 1 ppm impurities (principally water, oxygen, hydrogen and hydrocarbons), the company wants the gas to contain no more than 0.1 ppm (pure at 99.9999%).

With time, the slightest pollution of the Xenon can in fact oxidize the engine's cathode, stopping it from functioning. But it is not enough simply to provide this ultra-pure gas for Astrium; the refilling system must supply the satellite engine without adding the slightest trace of impurity. Astrium dreamed of this transfer unit; DTA made it real.

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#### First major export orders for Voxal

Progressively, Schering Plough has built its new factory in Singapore. Step by step, as the different workshops came into service, the pharmaceutical company installed systems for treating Volatile Organic Component (VOC) emissions. For its third workshop, and in order to respect the environment, Schering Plough contacted the Soxal company, a Singapore subsidiary of Air Liquide and BOC. For more than 25 years, Air Liquide and in particular DTA, has gained a reputation for its equipment for treating VOCs of the VOXAL range. In fact, more than sixty units have been installed in Europe, mainly within the production units of pharmaceutical groups. The client from Asia came to France to study the operation of DTA VOXALs, at Speichim (TREDI Group) at Saint-Vulbas (01) and at Orli near Le Havre (76).
Indian helicopters equipped with OBIGGS

The Indian aeronautics company of Hindustan Aeronautics Limited (HAL) has just signed a contract with DTA for the supply of OBIGGS inverting systems (On-Board Inert Gas Generating System) intended for helicopters. The on-board nitrogen generator allows the oxygen content of the helicopter fuel tank to be decreased. Without OBIGGS, if there is an impact or a fire, there is a risk that the tank might explode. DTA’s system has been proved to be reliable for a long time; it equips German army “Tiger” helicopters. This experience helped HAL to make the choice of Air Liquide OBIGGS.

DTA must design and qualify the OBIGGS for Indian Advanced Light Helicopters (ALH) within only a year. The Sasseenage engineers have finished the design phase and will have built the qualification prototypes by the end of 2004. The delivery of the system is thus expected in India for April 2005 and amounts to 200 units. Flight tests will begin in May 2005.

Indian helicopters will soon be equipped with Air Liquide OBIGGS.

“This is the first contract we have signed with an Indian company,” Olivier Vandroux explains. “In particular, we appreciated the serious approach and technical competence of our contacts at HAL. We are also working to supply them with on-board oxygen generators for hundreds of Indian airplanes.”

A lot of noise for space!

Imagine the noise and vibrations 1 000 ConcordeS would make taking off: 156 decibels! This is what a satellite has to withstand when it is launched into space. In order to be sure that the electronics resist these sonic vibrations, satellites are carefully tested in acoustic chambers. The properties of launchers for big satellites are developing, and therefore, to be able to conduct all relevant tests, Alcatel Space, the Cannes constructor, decided to build a new acoustic chamber: an enormous concrete cavity of 1 000 m³.

DTA and GIS are taking part in this adventure, precisely by generating the “noise”, in sirenS by means of a nitrogen flux at a pressure of 2 bar (+/- 0.035 bar). The gas generator designed by DTA is made up of a heat exchanger, transforming liquid nitrogen into gas, a thermalizer to stabilize the nitrogen at a temperature of 22°C, and a system for regulating the pressure and flow rate.

“This is a first for DTA” notes Jean-Christophe Courté, enthusiastically. “We have never made noise from gas before, and we have never built such a big exchanger. No less than 3.4 megawatts!”

Installation of the DTA system begins in December 2004 and reception will take place in April. The chamber must be operational in June 2005 according to the schedule, in order to be ready for the tests envisaged.

In Cannes, the Alcatel acoustic chamber has been under construction since July 2004.

Under cold (cryogenic storage at -196°C) conditions, the unit ordered by Schering-Plough – 8 meters high on a base of 9 sq.m. – enables recuperation of the solvents used in the manufacture of the active substances in medicine containing steroids.

This VOXAL is special because it is equipped with a remote-monitoring system, to allow remote connection to provide a diagnostic of its operation. “I can see what is happening in Singapore on my computer in Sasseenage”, explains Project Leader Jérome Beaupisage.

After a series of tests, the unit left DTA for Asia last May; it was installed in June and put into operation, and delivery was successfully completed in September.

The VOXAL, before departure for Singapore.
Try to do what has never been done before, multiply the "first" techniques, work in a climate of absolute incertitude and more. With their partners, the DTA engineers have lived through all this for the Herschel and Planck satellites, before the explosion of joy that followed the successful trials in May and July. Here we recap a rare industrial adventure...

Herschel and Planck satellites:

The success of the Planck project is particularly remarkable since it involved preparing an apparatus able to withstand being put into orbit and operating for three years in space, while this type of system starts leaking after a few weeks on Earth... "We worked from beginning to end with other experts, researchers from the CRTBT* and those from the Space Astrophysics Institute" explains Louis Sentis, DTA project chief. It made no difference... For years, the project was considered impossible because of a major contradiction.

The apparatus in question, "a dilution refrigerator", produces cold at 0.1 K, i.e. one tenth of a degree above absolute zero. At such temperatures, it needs ultra-thin supports to avoid any heat addition by conduction. But, to withstand take-off, with accelerations of 30 G, it needs the opposite: ultra-strong supports! "Talks between heat experts and engineers came to a complete standstill, until a brilliant idea saved the project".

What idea? Very simple... At take-off, when the refrigerator is at ambient temperature, it is inserted inside strong alloy claws with shape memory; once in orbit, the cold of space causes these claws to open, freeing the refrigerator and its ultra-light support. Easy to describe, but it took years to convince everybody that the idea was feasible.

Planck involved other challenges, in particular the almost total absence of leaks over several years. "The nominal flow rate of the refrigerator is equivalent to the leak flow rate tolerated on a classic system, but its own leak rate must be 1,000 times less: at the limit of spectrometer detection!" The result was incredible work on welds, critical parts of the device, and operational trials spaced out over a month. "It was April, everything was perfect and we had begun to believe in it".

But the hardest part remained: to torture the precious instrument, pampered and guaranteed without leaks, by inflicting vibrations and accelerations on it at the space center in Liège. "We were sorry to have had to do this to it, but it was essential to simulate take-off". After a week of this treatment, the refrigerator was taken back to Grenoble for another month of tests for leaks. "It was already incredible to have produced an apparatus so well sealed. But after having been treated like an assault tank, we could expect that anything could have happened, and not necessarily for the best".

You can imagine the thrill of the teams when they learned that the refrigerator had stood up to the shock perfectly well. Not the slightest suspicion of a leak! A large number of engineers from DTA, the CRTBT and the IAS celebrated this success with a splendid meal, but without counting their chickens before they hatched: the Planck "cold" part had been proved, but the IAS still had to test the detectors and their alignment...

The demands of the Herschel project also centered on the seal, with leak flow rates also at the limit of spectrometer detection. In answer,
challenges met with brio

very specific materials had to be used, and new welds qualified.

There was an additional problem, ultra-cleanliness: since the 2 400 liter fuel tank built by DTA contains superfluid helium at 1.6 K (-271.4°C), the slightest impurity, even molecular, turns into an ice-cube and can prevent the valve closing.

There was only one solution: to work in sterile class 100 rooms, as for micro-electronics... Even though it meant production on the cubic meter scale, and not an integrated circuit! Not to mention the multiple junctions, valves, flexible heat screens... "Everything had to be ultra-clean, both the interior and the exterior," explains Nicolas Balcer, Project Leader. We consulted an Air Liquide subsidiary (ALES) specialized in materials for micro-electronics. They were stupefied by the level of the test and validation we required, and for one very good reason: once in space, there is no after-sales service".

The trial, the all-important trial capable of deciding whether or not the near-impossible specifications had been met, lasted for several days, including only a few hours in superfluidity: the time needed to trace any leaks, by means of about twenty pick-ups connected to spectrometers. But before this critical moment, months were needed to build a test chamber entirely dedicated to this and without any parasitic leaks! At the beginning of July, thanks to the work of an unbeatable team**, the motor and the test means were finally ready. After the leak test, just as demanding as the one for Planck, the Herschel fuel tank was delivered to Astrium in Germany.

And just suppose that everything hadn't worked? And if a grain of sand had scratched these beautiful mechanics? "We would not have been ashamed because the technical problems were so severe", said Pierre Crespi, in charge of Launcher activity and orbital systems. "But it would have meant an enormous delay, at best, and more probably the abandonment of one or more projects." This risk explains the euphoria when the teams finished these tests: the pioneer spirit always creates excitement...

* Center for very low temperature research, a CNRS laboratory counted among the best in the world in this field
** In particular, Jérôme Guichard for the lines, Stéphane Duval for the test chamber and Étienne Stürm for the screens

The precious cooler designed at DTA for Planck was submitted to the worst tortures to guarantee absence of any leak.
DTA gas analyzers, used in Europe, China and soon in the United States, track impurities at extreme levels (1 ppb, or even 0.1 ppb) for micro-electronics companies.

Essential throughout the world
The secrets of the high

The last client to be equipped by DTA was Chinese: the ASMC founder, installed in an industrial zone in Shanghai, that equipped itself for an extension of its "fab" (micro-electronics factory). The next will be American: Sandia Lab, manufacturer of semiconductors for use by the American army, has just concluded an order. Before them, others acquired high purity analyzers in Europe, and particularly in France. ST Microelectronics in Grenoble even beat a world record for purity requirements for its Crolles 2 site, the most recent: 0.1 ppb maximum (0.1 parts per billion), that is, on a timescale, a capacity of isolating an event lasting one second over a period of 320 years! At these levels, even the most aseptic operating theatre would be considered an abominable nest of microbes - this is "artificial" purity owing everything to high technology.

The motivations of industries equipped in this way are well known: not to pollute their integrated circuits, in which the electrical connections are narrower than a ten thousandth of a millimeter, with impurities contained in the manufacturing gases (nitrogen, oxygen, hydrogen, helium, argon). Less known are the efforts employed by the analyzer manufacturers to keep up with the specifications. "An apparatus must be able to analyze several gases continuously and to detect water, oxygen, hydrocarbons, CO and CO2, hydrogen and solid particles" explains Domenico D'Andrea, gas engineering specialist at DTA. "It has to be operational 365 days per year, just like the factory it is watching, and must emit an alarm when really necessary: no unjustified alert, no impurity left undetected."

No manufacturer in the world can produce a piece of equipment like this alone: the major market players, including DTA, buy all or part of the analysis apparatus they need from various suppliers (spectrometers, chromatographs, electrolytic batteries, etc.). For example, Air Liquide integrates the APIX, a very high performance analyzer which it has developed, with equipment of external origin. Apparatus like this cannot be used as such. If an ordinary gas supply were to be connected, the gas would be "polluted" by the line upon arrival, since the detection threshold is so low. The work on design, integration and assembly is therefore determinant. It guarantees that the analyzed gas is not denatured between being debited on the principal flux of the factory and its arrival at the apparatus itself.

The basic principle: perpetual motion! The gases circulating in an analyzer are never immobile, in order to avoid any impurity deposit. If an analyzer scrutinizes two gases one by one, the gas whose analysis is interrupted is passed over to a purge circuit, but it is never in any case stopped. The boiler-work...
purity analyzer

The analyzer represents extreme reliability and precision: production quality can depend on purity.

equipment has no dead spaces nor dead-ends. The internal surfaces of the tubing are electro-polished, so as to avoid leaving any roughness that might “catch” an impurity. No bending of the tubes is allowed: too risky, since the internal surface could be scratched, cutting is surveyed closely and only under certain conditions...

As for the welds, major sources of risk, they are first tested on trial parts and validated by X-ray until the correct operational parameters are obtained. These parameters are then applied to the real parts, whose welds will not be checked: this would mean taking them out of the sterile room!

Despite these endless precautions, an analyzer will always detect a high level of impurities when it is put into operation. This is no surprise: new materials, stainless steel in particular, give out gases such as hydrogen. It suffices to know this, and to purge the apparatus for weeks (!) while checking the displays. Little by little, the impurity levels drop, until they are nil.

The analyzer thus represents reliability and precision pushed to the extreme, for a cost which – not surprisingly – can be counted in hundreds of thousands of euros. Industries make the investment, because the quality of their production depends on it. But strangely, when an impurity is detected, they first react by blaming the apparatus! "They always begin by telling us that it is out of order, and not that the gas is polluted", jokes Domenico D’Andrea.

After this, comes a tried and tested procedure for checking the apparatus and its components, and then measurement tests with a gas reference specimen. The common obsession is to be quick, to avoid prolonging a stop in production when the cost rises rapidly into millions of euros.

However, Domenico D’Andrea is even more afraid of a technical aspect, besides the stops, impurities or salting out of gases: computer technology! This is because the analyzer, with its central lookout role, is not self-sufficient in operation. It is linked with the factory's central system, receives information from this (results, rates, process stages, planning etc.) and regularly contributes its own analysis results for traceability purposes. Therefore its relays have to be connected within a network, it has to communicate with the site computer via protocols that are only "standard" in name, avoid contagious crashes and look for bugs for days on end... In short, avoid the traps that are less critical but still just as necessary as obtaining the all-important 0.1 ppb.

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Civil aviation
Fuel tank inerting: the United States announces a count-down

Why inert airplane fuel tanks?
Gradually, as they empty, these fuel tanks become filled with petrol fumes that can ignite under certain temperature, pressure, and energy supply conditions. This is what happened to the TWA 747: it took off with a central fuel tank almost empty, in very hot conditions, and an electric spark did the rest. But, if an inert gas such as nitrogen is injected this suppresses this ignition risk.

Was this phenomenon known before the accident?
Of course, and many military planes are equipped with an inerting device. But they risk being a target for snipers at any moment... For civil aviation, on the other hand, the risk was considered to be very low. The working group set up in 1999 on the initiative of the FAA also came to the same conclusions: an inerting device would be too heavy and too expensive taking into account the low probability of an accident.

Then why this announcement of a ruling proposal?
The FAA never abandoned its wish for legislation: in June 2001, it set out a directive (SFAR 88) which imposed "reduction of the spark risk linked to electric components of fuel tanks" for planes flying to or within the United States. In other words, the cables must be made to pass somewhere else. At the same time, it also began to test inerting systems that were less demanding than those studied to begin with, and therefore less costly: it was sufficient that the ignition risk did not persist for more than 3% flying time for a fleet of airplanes.

Was the message accepted by airplane manufacturers?
Aeronautics professionals are always carrying out work and have benefited from the test results from the FAA. We ourselves, at DTA, with our American colleagues from MEDAL, have taken part in working groups since 1998 and we have provided materials for certain American tests. This information sharing has produced its fruits: Boeing has announced that all its new planes must be equipped with OBIGGS from 2005, and Airbus says it is working on the intrinsic security of its fuel tanks.

The OBIGGS, or on-board nitrogen generator, is the option defended by DTA; why is this?
Compared to the bottles of nitrogen that have to be changed regularly, it is an expensive solution to begin with but it requires less maintenance; the plane produces its nitrogen independently, from its air circuits, without logistics. Imagine the headache for a company that has to check nitrogen bottles for a fleet of several hundred planes every day!

When will there be an inerting system for fuel tanks on all civil aviation planes?
After the ruling proposal is deposited, 12 to 24 months must pass before it becomes official, and then five to seven years for retrofitting older airplanes. These deadlines can slide a bit, of course. But the most important thing is that the principle of an obligatory inerting system already seems to have been accepted.

*Federal Aviation Authority
**The latest meeting was held in Grenoble in June.

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OBIllGS is intended to equip Boeings in 2005.

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