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AIRBUS SPECIALISTS

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are expressed in good faith. Where the supporting grounds
for these statements are not shown the Company will be
pleased to explain the basis thereof.

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FUEL CONSERVATION

By a team of Airbus specialists from the Technical Department, the Flight Test Operations Department, the Support Division, the Technical Publications Department and Engine Manufacturers.
Having dealt with aerodynamic cleanliness, ground operations and engine maintenance, the Fuel Conservation series continues with an article on some aspects of flight operations. Flexible take-off and judicious choice of flight level are but two of the procedures that can be used to help save fuel; more will become apparent as you read this paper.
### Table 1

<table>
<thead>
<tr>
<th>Flight</th>
<th>Actual</th>
<th>Effective</th>
</tr>
</thead>
<tbody>
<tr>
<td>Take-off</td>
<td>12%</td>
<td>7.5%</td>
</tr>
<tr>
<td>Climb</td>
<td>8%</td>
<td>2.5%</td>
</tr>
<tr>
<td>Cruise</td>
<td>10%</td>
<td>1.0%</td>
</tr>
</tbody>
</table>

Effective derate total result: 11.0%

### THE FLIGHT ENVELOPE

**Engine Power Management**

Up to the present time Airbus Industrie has stressed the use of the “flexible thrust setting” concept at take-off. However, the benefit of derating at take-off may be amplified by a derating during the climb too, whenever this is possible and additionally, by the choice of an optimum cruise Mach number. According to the engine manufacturers an important factor when operating at reduced power is the effective derate achieved during the whole flight by managing derated thrust from the rated values at take-off, during the climb and at cruise. Since it is difficult to modulate the thrust in the climb as easily as at take-off or in cruise by adjusting the Mach number, Airbus Industrie recommends the use of max. cruise (CR) setting for the climb in most cases. Since the impact on time between standard take-off and climb and derated take-off and climb is negligible and “direct” fuel saving benefits are insignificant, the effective benefit rests in the reduced wear/increased life of the engines which indirectly results in fuel savings from derating. The effective results of derating are shown in Table 1 and below using information from Figures 1 & 2.

The severity factor for a one hour flight is 1.6 with no derate and 1.2 with 10% derate, which represents a 30% decrease therefore:

Shop visit rate (SVR) improvement = 0.9 x 30% = 0.27, decrease in material cost = $60 x 30% = $18 US per flt. hour, based on the following assumptions, 1 flight hour sector, 12% derate at take-off, 8% derate during climb (full climb performed at CR setting), 10% derate during cruise (at FL310 with mean weight of 135t), 0.9 shop visit rate $60 U.S. material cost per flt. hour.

Figure 3 shows, from G.E. information the comparison between reliability of all in-service CF6 engines and of those installed on Airbus A300’s. While the A300 is the only short-medium range aircraft with an average flight duration of about 90 min. equipped with CF6, the engines installed on it show the greatest reliability.

---

**Figure 1**

- Take-off
- Climb
- Cruise

**Figure 2**

- Severity factor

**Figure 3**

- CF6 engine reliability
  - All CF6 - 12 months to 30 June 1981
  - All CF6 - 12 months to 30 October 1981
  - A300 only - 12 months to 30 June 1981
  - A300 only - 12 months to 30 October 1981

Unscheduled Engine Removal (UER)
Shop Visit Rate (SVR)
In Flight Shut Down (IFSD)
It is significant to record that the rate of in-flight shut down on the Airbus is only half that of all the CF6 engines. A large part of this phenomenon is due to the method recommended by Airbus Industrie for derated thrust at take-off. As opposed to other methods, the Airbus procedure allows the operator to get the best possible derate, and also to conserve engine life as much as possible. Airbus Industrie is convinced that every bit of derating has to be considered, since the effect on engine life and maintenance cost is important.

**Climb Schedule**

The types of graph shown in Figure 4 enable determination of the optimum climb schedule as a function of take-off weight and cruise flight level. Up to a take-off weight of 140 tonnes, climb at 300 kt/M .78 is very close to the optimum. Above 140 tonnes TOW, speed should be linearly increased to reach 320kt for 165 tonnes TOW. Climbing at 320kt/M .78 instead of 300kt/M .78 after take-off at 165 tonnes saves 30 to 40 kg fuel. If the adjustment of climb speeds saves 10kg fuel per flight, an annual saving of 3000 US Gal per aircraft is achieved.
Optimum Altitude

Currently this term means optimum cruise altitude with wind. Cruise flight should be chosen as close as possible to it, except on very short stages or when wind speed is different from one flight level to another.

Figure 5 shows the increase in fuel consumption at M .78 on a stage of 1000 nm when not flying at the optimum flight level (FL 330 for a TOW of 140 tonnes and FL 370 for a TOW of 120 tonnes). A flight undertaken 4000ft too low increases fuel consumption by 3% i.e. about 150 US gal.

Optimum Altitude on Short Stages

On short stages, the cruise is too short to compensate for the increased fuel consumption due to climbing to optimum altitude for TOW. It is in fact better not to climb to the optimum altitude for TOW; optimization should be made for each stage, depending on the stage length.

The following fuel penalty has been computed when climbing to optimum altitude for TOW of 100 and 140 tonnes on stages of 250 and 400nm (climb 300kt/M .78 - cruise, long range - descent M .78/300kt) (PW engines). TOW 140 tonnes: optimum FL should be 300. However climbing to this FL requires 16kg more fuel than cruising at FL 310 for both 250 and 400nm.

TOW 100 tonnes: optimum FL should be 390 which however, cannot be reached on a stage length of 250nm and climbing to FL 390 requires 28kg more fuel than to FL 310.

For a stage length of 400nm, however, it is better to climb to FL 390.

Optimum Altitude with Different Wind Speeds Depending on Flight Level

In no-wind condition, specific range is maximum at the optimum altitude. However, when flying at the optimum altitude with a wind condition, it is obvious that if a tail wind is higher or head wind lower at different altitudes, it may be beneficial to fly at such a different cruise altitude. Figure 6 indicates the corresponding breakeven curves. Note: the "breakeven" wind is that required to give equal nm/tonne at both altitudes. If the actual wind difference is greater than the "breakeven" wind, greater range can be gained by going to the new altitude.

Example: weight at end of climb - 140 tonnes. Optimum flight level without wind FL310. With a head wind of 60kt at FL310 it is preferable to fly at FL270 if the actual wind difference is greater than the breakeven wind (20kt in this case) and if the head wind at FL 270 is 40kt or less.

Mach Optimum Function of Altitude

Optimum Mach number is given for optimum altitude, but if it is not possible to fly at this altitude, it is generally better to change the Mach.

Figure 7 shows, for an Airbus A300 fitted with P&W engines, the recommended Mach number as a function of weight and altitude. A similar graph is applicable to GE powered A300s.
The Fuel Conservation series will be continued in the next edition of FAST
The AIDS installed on South African Airways Airbus A300

South African Airways made the decision at an early stage to take advantage of the Airborne Integrated Data System offered as an option on Airbus A300 aircraft. It was decided that their whole A300 fleet would be equipped with the system from their first aircraft delivered (AVC No32), to the last to be accepted.

by Gerald West
Deputy Manager Atlantic Engineering
South African Airways
For those readers not too familiar with the Airborne Integrated Data System (AIDS) the following background may be useful.

It is mandatory for aircraft with a mass of greater than 5700 kg to be fitted with a Flight Data Recorder. On modern aircraft this is a digital system complying with ARINC specification 573 on analogue aircraft and 717 on digital aircraft. The Flight Recorder system is made up of 4 components (Figure 1):

- Control Panel
- Acquisition Unit
- Recorder
- Sensors

The primary use of the Digital Flight Data Recorder (DFDR) is for accident/incident analysis. This data is also extremely useful for trouble-shooting and determining maintenance requirements for aircraft, engines and systems. However, due to its design, which enables it to comply with extreme survival requirements, the data cannot be easily retrieved.

The problem of difficult access to data on the DFDR is resolved by extending the basic Flight Data Recorder system to add an AIDS system on to it. This is done so that the acquisition of the Flight Data Recorder parameters is not duplicated - the data is copied to the AIDS system on a digital bus. In its most simple form the AIDS consists of a Quick Access Recorder (QAR) which records the same data as the DFDR from the auxiliary output of the acquisition unit. As implied by its name, the data is easily retrieved from the QAR by means of a cassette change. In its most complex form the AIDS consists of additional acquisition units in order to acquire additional special interest parameters. These are a Data Management Unit, which is a computer providing intelligence to the system, an AIDS panel to provide the flight deck with a system communication link, an AIDS printer on the flight deck with a system for reporting purposes, and the AIDS recorder.

**SAA DESIGN OBJECTIVES ON THE A300**

In 1976 the major design objectives were

1. That the system should assist line maintenance in decision-making for both airframe and engines, where time is a critical factor;
2. That the system should provide sufficient information to enable in-depth analysis of engine and airframe at the maintenance base.

In order to accomplish this the system has the following features (Figure 2):

- **Engine exceedance reporting**
- **Airframe exceedance reporting**
- **Engine analysis reporting**
- **Engine start-up summary reporting**
- **Engine information reporting and display**
- **Fuel and oil reporting**
- **Flight control surface information reporting**
- **Recording of data on the QAR**
- **AIDS system BITE display**
- **AIDS system summary and BITE reporting**

**SYSTEM PERFORMANCE AND EXPERIENCE**

**Engine Exceedance Reporting**

Any N1, N2 or EGT exceedance results in an exceedance report. This is most useful, particularly where the time over limit is important.

**Airframe Exceedance Reporting**

Any vertical acceleration experienced by the airframe that exceeds the limit results in an exceedance report. This is very useful as it is virtually impossible for a human being to estimate G values. Flap extension versus airspeed limit exceedances also result in a cockpit printout.

**Engine Analysis Reporting**

Deterioration of an engine module beyond certain limits is flagged in this report which is issued when stable conditions are experienced. This has not been successful, mainly due to the unreliability and inaccuracy of the engine transducers, and limitations imposed by the capacity of the Data Management Unit.

**Engine Start-Up Summary Reporting**

After engine start-up a summary of the event is given in the form of maximum EGT and time to start. This is useful when starting problems are experienced.

---

**Figure 1**

![Flight Data Recorder System Diagram](image)
Engine Information Reporting and Display
An engine report listing current status of parameters of both engines can be requested at any time. Any engine parameter can be displayed real time in engineering units on the Flight Data Entry Panel (FDEP). This has proven most useful as the parameters are monitored from their source (at the engine), and the FDEP is thus a stand-by indicator for any engine indicator that may fail. We have flown aircraft home using the FDEP in this manner when an indicator has failed.

Fuel and Oil Reporting
A fuel consumed and oil quantity report can be requested at any time. Little use has been made of this feature.

Flight Control Surface Information Reporting
A flight control surface position report can be requested at any time. Little use has been made of this feature.

Recording of Data on the QAR
All parameters monitored by the system are recorded on the QAR. Data compression techniques based on aircraft flight mode and event detection are used to reduce volume of data. These data have proven most valuable as a trouble-shooting tool for incident analysis, particularly engines.

AIDS System Summary and BITE Reporting
A summary report is issued at the end of each flight, giving system performance. Featured are the number of BITE malfunction conditions monitored for each LRU and the number of spikes monitored for engine exceedance sensors.

Benefits Realised
It has not been possible to place a monetary value on the savings realised as a result of the system, but it can be stated that these are significant in terms of reduced engine removals, more accurate trouble-shooting, more effective decision making and fewer delays incurred.

NEW SYSTEMS
New systems are now becoming available which have the following improved features:

Engine Multiplexer Units
These provide a higher level of accuracy and reliability over traditional engine transducers.

The AIDS QAR
Until recently the data was recorded serially and had to be transcribed on a ground station, a process that is labour intensive and time consuming. New technology recorders record data in a format that can be processed immediately on a ground computer making the transcription process redundant.

Digital Aircraft
The system designed by airlines and manufacturers to ARINC specification 717 provides a simpler and more cost effective design with a much higher level of reliability.

On-Wing Gas Path Analysis (GPA)
With the advent of the engine multiplexer and the sophistication of ground-based software, the success of the concept of engine module performance analysis using AIDS aircraft data should be realised.

Data Link
Transmitting the AIDS engine data to the maintenance centre over the data link (ACARS/AIRCOM) will result in real-time engine monitoring.

CONCLUSION
AIDS has developed to the point where the benefits it provides make it an extremely attractive system which should gain in popularity as user airlines are able to demonstrate benefits actually realised.
It is fairly obvious that fuel quantity indication accuracy has a direct influence on surplus fuel load and on subsequent fuel conservation. So, 100% accuracy is the ideal in the FQI system operation. However, although complying perfectly with the specification, the response curve for the inner fuel tanks on A300 aircraft shows a fluctuation between positive and negative for a small increase in fuel quantity loaded. Furthermore, some operators have observed relatively large negative errors in the quantity readings in the 8 to 15 tonne range and large positive errors in the 20 to 30 tonne range. The respective errors have been observed with repeatable consistency. Figure 1 shows a typical inner tank probe response curve evolution and the effective range of the different probes. In the continuous process of product improvement Airbus Industrie, in conjunction with Intertechnique, has developed the so-called 'PROBE REPROFILING PROGRAM'. Reprofiled probes have been successfully evaluated in service with an A300 operator and are now offered as an optional alternative to existing probes. Airbus Service Information Letter 28-019 issued on May 11th, 1984 refers to these new probes and provides further details.

**Background - FQI Probe Function**

The tank probes are designed to measure the quantity of fuel in the different fuel tanks. Each FQI probe consists principally of two fixed, concentric tubes. These form the plates of a capacitor which registers a value according to the length of tube immersed in fuel. The dielectric of this capa-
The capacitance being provided by air and fuel and the fact that the dielectric constant of the fuels used is approximately twice that of air, the capacitance of a vertically installed probe varies with the fuel level. The measurement of the capacitance value thus gives an indication of fuel quantity in the tank.
The outer tube assembly consists of an insulating, laminated epoxy resin structure, coated on the inside with high grade silver.

The inner tube assembly is a similar arrangement but the silver coating is on the outside of the tube. In addition, the metallised surface of this tube is profiled so that the capacitance varies directly according to the quantity of fuel measured by the probe. Making allowances for the fuel tank shape, this enables the fuel quantity indicator dial to be graduated in evenly spaced increments. Figure 2 shows a typically profiled probe. Six probes are installed in each A300 wing tank and four in the center tank. They are connected in parallel and transmit the respective tank quantity through the FQI amplifier to the Fuel Control Panel indicators (Figures 3 & 4).
The Improvement Proposed
The improvement proposed consists, as mentioned earlier, of reprofiled inner tank probes. In order to compensate for the established, and largely consistent, inner tank response curve behaviour, extensive capacitance measurements of very small increments have been performed on production aircraft during refuelling operations. Analysis of the measurements resulted in a revised definition of the individual tank probe profiles (Figure 1). Observing that the nominal amplifier settings at empty and full loads for the sum of these six probes remain unchanged but that the previously exhibited error zones were significantly compensated, a set of reprofiled inner tank probes was tested on both an Airbus Industrie Flight Test aircraft and during an in-service evaluation. The results showed considerable improvement (Figure 5).

Figure 5
Improved measured FQI error curve
- Response curve band before probe reprofiling
- After probe reprofiling
- Of indications readings (combined inner tanks)

Tank content (tonnes) 10 20 30 40
7.33 tonnes 34.7 tonnes

Benefits
The conclusions drawn from the assessment carried out after the in-service evaluation were as follows.
1. Inner tank response curve fluctuation improvement:
   reduced from about 600kg to approximately 200kg over a 5 tonne content range;
   reduced from about 900kg to approximately 400kg over the total combined inner tank content range.
2. The corresponding accuracy improvement tends to reduce the amount of reserve fuel loaded by up to 500kg.

These clear benefits are made still more attractive since inexpensive retrofits can be undertaken on an "attrition basis". That is to say that failed probes can be modified during normal repair and both old and new types of probe may be intermixed if need be.

ERRATUM FAST 1/1984 ERRATUM
PAGE 21
SUPERIOR FIRE RESISTANCE
Please read on the two graphs
● Phenolic for Epoxy and vice versa
● Neoprene for Silicon and vice versa

FQI PROBES
minutes. With such a tight time constraint, you can hardly afford any unscheduled event if you want to preserve your reputation as an "on time" airline. During the turnaround, the cargo loading time, with some 15 to 20 minutes for both compartments, looks an obvious target for the "chasing of wasted minutes" exercise. The basic automatic loading system on the Airbus A300 is a considerable contribution to rapidity. Its automation, if properly managed, provides unmatched loading performances.
However, it may happen that an inexperienced operator disturbs the system's functions, by untimely interruption of the light beams, for example. Or it could be that one of the automatic components fails. An additional man must then be employed for a manual operation.

Quite a few airlines have chosen to take advantage of the possibilities offered by the sophisticated and highly efficient automatic Cargo Loading System (CLS). They have, where necessary, regularly upgraded it technically to its present optimum standard which they find wholly satisfactory.

Some other Airbus operators, for whom turnaround performance is not the primary target, do not derive a benefit from the automatic system, commensurate with the associated maintenance and qualified personnel requirements. For those customers Airbus Industrie has designed a retrofitable semi-automatic cargo loading system. The aim is to make available (and affordable as retrofit) a sturdy and efficient system. Consequently, throughout the design work, emphasis has been laid on the simplicity of the logic and the components as well as the reliability of the system while keeping in clear view the second main target - low cost retrofit.

**THE SEMI-AUTOMATIC PHILOSOPHY**

With minimum physical changes, the main features of the drive and latching control are considerably modified.

The Power Drive Units (PDU) are directly controlled via a joystick panel providing IN-OUT-FWD-AFT functions (Figures 1, 3 and 4).

The electrical supply to the PDU's of occupied positions is cut off by switches actuated by the relevant latches (Figure 1).

Unit Load Device (ULD) latching is manual. The "anti roll out" overrideable door sill latches are controlled directly by the operator via a spring loaded switch located on the operator's control panel (Figures 2 and 4).

**MINIMUM REPLACEMENT, LOW COST CHANGES**

Downgrading the automatic CLS to a purely
manual one is particularly easy and inexpensive. The conversion into semi-automatic, though obviously less simple, still represents quite a low investment in labour and material, a clear benefit, a design aimed deliberately at retrofit.

The automatic latches can be modified to manual latches by deleting the automatic actuation, and incorporating a power cut-off switch. The control box, control panel, circuit breaker panel and associated electrical wiring are replaced by existing A310 or A300-600 type components with proven reliability. Drawings are provided to operators for the local manufacture of many simple parts. Any unnecessary change has been avoided.

UNCHANGED ENVIRONMENT

In addition to the low material cost, extra investment has been minimized, and except for the change in philosophy of the CLS, the aircraft cargo capacity and capability in terms of ULD positions/max gross weights and cargo door operation remain unchanged. Further, in terms of ULD spec-

Figure 3
Drive unit control

- Changeover relay
- Drive unit relay

Figure 2
Conveyance and latching (simplified principle schematic)

Before modification

After modification
**SIMPLE OPERATION**

The users of the modified system will have no adaptation difficulties. The loading procedure is the same as that for A310 and A300-600 and is similar to that for some other wide body aircraft (Figure 4). The manpower required for loading an A300B2/B4 is unchanged, but the loading times are slightly affected:

<table>
<thead>
<tr>
<th></th>
<th>FWD compartment</th>
<th>AFT compartment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Automatic system</td>
<td>1 man 12 mn</td>
<td>1 man 8 mn</td>
</tr>
<tr>
<td>Semi-auto system</td>
<td>1 man 16 mn</td>
<td>1 man 12 mn</td>
</tr>
<tr>
<td>Manual operation</td>
<td>2 men 28 mn</td>
<td>2 men 14 mn</td>
</tr>
</tbody>
</table>

**VARIOUS ALTERNATIVES**

The system highlighted above is undoubtedly likely to be favoured by many Airbus A300 operators. Besides that, Airbus Industrie offers, as usual, maximum convenience with the most fully customised design, thus giving operators a real choice: the A310-type control panel (Figure 5), integrated in an external non-pressurized housing, provides additional convenience and simplification, and lowers the risk of damaging the panel, the A310-type container latches (Figure 6) are of the simplest possible design. Together with a significant weight reduction they also bring along easy handling, increased commonality with other Airbus aircraft and considerably reduced spare parts prices.

**HOW TO GET IT ON TO YOUR AIRCRAFT?**

The answer is simply by ordering the appropriate kit as described in Service Bulletin A300-25-398 which is planned for release by the end of 1984. The labour, hence the necessary grounding time for modification depend, of course, on the option selected.

However, Airbus Industrie has taken great care to make sure, in any case, that downtime is reduced to a minimum. Downtime is calculated as 2 - 3 days without the integrated control panel and 5 days including this panel.

The SB incorporation guarantees Airbus Industrie engineering, spares and documentation support. Should an airline require it, assistance can be provided for modification embodiment. Further information is available from the Airbus Support Division.

**AIRBUS INDUSTRIE WISHES YOU A GOOD TURNAROUND...**

...and without any reservation. The experience gained in service with the semi-automatic CLS on Airbus A300, A300-600 and A310 is associated with more than 100,000 trouble-free flying hours with exceptional reliability of the system.
To the majority of readers the word LASER (Light Amplification by Simulated Emission of Radiation) still conjures up a vision of science fiction death rays and diabolic inventions designed by mad professors intent on destroying the world. This image, however, is far from reality. Today, laser technology has been successfully developed and applied to numerous industrial processes and medical techniques. Laser cutting tools and laser surgery are now commonplace but other less visually spectacular uses have been found for lasers, including their application to aircraft navigational equipment.

Laser technology has now extended into the commercial aviation industry with the introduction of laser gyros into Inertial Reference Systems. The laser gyro is a "solid-state" angular rate sensor, which does not use the inertia of a spinning mass, but is based on the principle of constancy of light velocity in space, using an optical resonator, the laser.

by Marc Tran-Huu-Au
Aérospatiale Avionics Department

THE RING LASER GYRO
WHY A LASER GYRO?
A laser system eliminates the need for gimbals, torque motors and other moving parts, and therefore is particularly suited for strapdown systems. The rotating mass has been replaced by two counter-rotating light beams inside a fixed optical block. The output is no longer a gimbal angle as for conventional gyros, but takes the form of interference fringes between two light beams.

HOW CAN THE SAME PATH BE DIFFERENT?
The Ring Laser Gyro (RLG) uses the principle of the Sagnac interferometer, the two counter-rotating beams do not travel the same path when an angular rate is applied.

Duration of light travel in one revolution is:

\[ T = \frac{2\pi TR}{C} \]

Difference between left and right light beam travel is:

\[ \Delta L = 2\Omega TR \]
\[ \Delta L = \frac{4\pi TR^2}{C} \Omega \]
\[ \Delta L = \frac{4S}{C} \Omega \]

C is the speed of light
L is the perimeter of the cavity for the travelling wave
S is the area enclosed by the cavity
Ω is the input axis rate (inertial rate perpendicular to cavity plane)

DESCRIPTION
The laser gyro needs a gain medium to overcome radiation losses and obtain lasing action, and a resonant cavity to sustain oscillation. This gain medium is a mixture of helium and neon gases at low pressure, excited by an electrical charge. The gas is contained in a closed triangular or square cavity with mirrors mounted at each corner. A cathode and two anodes are mounted on the legs. A high voltage is applied across the anodes to the cathode, this ionizes the gas and produces a glow discharge. Mirrors mounted in the corners of the laser cavity reflect the photons of light in a closed path in opposite directions around the gyro, and augment the cascading effect along the closed path to create and sustain oscillation. Since the cavity length is many thousands of times longer than the optical wavelength, the cavity length is resonant in many frequencies. However most of these frequencies do not receive sufficient gain to oscillate, and the remaining light is filtered by appropriate coating of the mirrors to give a laser radiation at a single frequency (Figure 1).

The photo cells will detect the direction and the rate of rotation. Since the fringes are seen as pulses by the photo cells, the detected frequency difference appears at the output of the detector in digital form, ready for immediate processing by the system’s associated digital electronics. The pulse frequency is a direct measure of angular rate.
PRINCIPLE OF OPERATION

The basic operation of the RLG is to excite and sustain two directional waves travelling in opposite directions and oscillating at the same frequency at rest (Figure 2). A rotation perpendicular to the plane of the cavity results in a difference in the optical paths, the time taken by the two waves to travel round the cavity, and the frequency of the two waves which is a direct function of the inertial rate: \( L \) is an integer number of wavelength.

\[ L = N\lambda = N\frac{C}{F} \]

\( F \) is the frequency of the emitted radiation,

\[ \frac{\Delta L}{L} = - \frac{\Delta F}{F} \]

\[ \Delta F = - \frac{4S}{\lambda L} \frac{4S}{\lambda L} \]

since \( \lambda = \frac{C}{F} \), the frequency difference expression is given by:

\[ \Delta F = - \frac{4S}{\lambda L} \Omega \]

Figure 2

Read-out system
- Counter clock wise beam
- Clock wise beam
- Prism
- Photo cells
- Mirror substrate
- CW → \( \frac{\lambda}{\lambda^2} \)
- CCW ← \( \frac{\lambda}{\lambda^2} \)

Laser Gyro construction principle
- Gyro block
- Mirrors
- Anodes
- Cathode
- Detection coil
- Activation coil
- Connector
- Read-out system

Laser Gyro production installation
The change in laser beam path length has the effect of increasing the frequency of one beam while decreasing the frequency of the other. This frequency difference is measured optically via the interference pattern of the two light waves. Signal readout is accomplished by allowing a small portion of the light from each of the two beams to pass through one of the mirrors. The light from one beam is combined through a set of optics with the other beam in a nearly parallel fashion; the two beams will interfere with each other, forming a fringe pattern.

**THE LOCK-IN PHENOMENA**

As in any mechanical system that sustains two modes of oscillation, problems occur when the two frequencies tend to come together. This cross coupling is in fact caused by back-scattered radiation from imperfect mirrors and is known as "Lock-in".

Figure 3 shows the relationship of frequency difference versus input rotational rate, and shows the lock-in zone magnitude definition: current mirror technology produces lock-in magnitudes in the vicinity of 100°/h, which is very far from the 0.01°/h requirement for the 1 nm/h class system.

The principle chosen to eliminate the lock-in area consists of applying a sinusoidal dither movement through a stiff dither flexure suspension. This acts as a rotary spring built into the gyro assembly that makes it possible to pass rapidly through the lock-in area and linearize the response (Figure 4). For this purpose the mechanical rotation (\(\Omega_D\)) has to be greater than the lock-in threshold (\(\Omega_L\)).

**PATH LENGTH CONTROL**

The path length controller performs the function of cavity tuning and for that purpose, not all corner mirrors are identical. One mirror is servo-controlled so that it can make micro-adjustments to keep the physical path constant (through temperature and other environmental changes) since the optical cavity has a peak intensity for a length equal to a whole number of wavelengths.

**RLG OPERATIONAL BENEFITS**

The incorporation of laser gyros in a strapdown inertial reference system offers the functional benefits of digital solid state technology. RLG outputs are inherently digital and therefore interface directly with the processor for all computation.

An RLG requires no heaters and may be operated over the full temperature range from -55°C to +85°C.

The absence of friction and heat producing moving parts considerably increases the reliability of the laser gyro compared to the conventional gimbaled gyros.

It is hoped that in explaining what is a very interesting development for the Aircraft industry, this article has also laid to rest some of the ghosts of laser technology for those unfamiliar with the subject.
AIRBUS A300

OPERATIONS ON SHORT RUNWAYS

The general appearance of Congonhas Airport in Sao Paulo is that of an aircraft carrier anchored right in the middle of the city, a metropolis ranking amongst the biggest in the world. The runway is an elevated one surrounded by what appear as long waves of houses and high buildings. Being elevated, the ramps at each end of the runway, (16R and 34L), consist of an almost vertical red and white chequered wall. This is another of the characteristic features of the airport. To complete the picture the "strip" is only 1939 metres (6361 feet) long and at an elevation of 802 metres (2631 feet) above sea level.

Sao Paulo is, of course, situated in a tropical region and heavy cloud and thunderstorms make the sky overcast most of the year. One never knows when leaving the blocks in sunshine whether the take-off will be made minutes later into a blue sky or through a tropical shower.

These stormy, tropical conditions make both wind direction and force fluctuate almost continually, making the approach, particularly, more difficult here than at more conventionally sited airports. Despite the grooving of concrete runway surface, patches of residual rain water are often to be encountered after storms. Temperatures, however, remain moderate throughout the year, ranging from 21°C in winter to 26°C in summer.

Three airlines operate the A300 through Congonhas with an average of six rotations per day. These flights by Cruzeiro Do Sul, Varig and VASP represent only some of the somewhat heavy traffic using the single available runway.

About 34 take-offs and landings are performed hourly throughout a 17 hour operating day.
THE VIVID FEATURES OF CONGONHAS
SAO PAULO, BRASIL

by André Fort
Deputy Vice President
Flight Division

Figures, obviously, vary according to stage lengths flown, but the average aircraft weights at take-off are 130 tonnes ±7 tonnes, and at landing 114 tonnes ±6 tonnes. An operational advantage of these combinations of weights and temperatures is that they allow the use of the Flexible Take-Off concept as recommended by the Performance and Operations Engineering Group of Airbus Industrie’s Flight Division. In spite of the difficult conditions, an analysis of the operational performance of the A300 at Congonhas reveals the following details:

* lift-off is achieved at two-thirds runway length from the brake release point,
* manually conducted approaches are assisted by VASI bars at each end of the runway,
* the touchdown zone is shown to be consistently across the second VASI bar.

The autobrake is always used in the high mode and assisted by the use of the thrust reversers. It is, indeed, quite spectacular to see a wide-body aircraft slow to taxi speed within a shorter distance than that required by narrow-bodies such as the 727 and 737. When landing on 16R it is quite normal to see the A300 taxi in on the mid-runway taxiway. Brake fans are used to bring brake temperatures down after the short landing and when reaching the parking area the figures observed are around 170°C. Using the brake fans, turnaround times of 40 min. are achieved as normal practice.

The results of A300 operations observed at Congonhas show that the aircraft behaves consistently well under the difficult conditions encountered on the rather short runway of a crowded airport, where heavy rain and turbulence are a standard way of life. Congratulations to the pilots.

**Possible down-drafts near threshold runway 16R**

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**AIRBUS A300 OPERATIONS ON SHORT RUNWAYS**

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<thead>
<tr>
<th>AIRLINE</th>
<th>REPRESENTATIVE</th>
<th>ADDRESS</th>
</tr>
</thead>
<tbody>
<tr>
<td>ATLAS</td>
<td>Volker GELLER</td>
<td>c/o Deutsche Lufthansa, Building 116/452, D-2000 Hamburg 63, Postfach 300, Federal Republic of Germany</td>
</tr>
<tr>
<td>AIR AFRIQUE (RK)</td>
<td>Jean-Yves LE PAYEN</td>
<td>c/o Air Afrique, Centre Industriel de Dakar, BP 8165 Dakar Yoff, Sénégal</td>
</tr>
<tr>
<td>AIR ALGERIE (AH)</td>
<td>Alain VICENTE</td>
<td>c/o Direction Technique Air Algérie, Aéroport H. Boumediene, Dar El Beida, République Democratique Algérie</td>
</tr>
<tr>
<td>AIR FRANCE (AF)</td>
<td>Robert CISTAC</td>
<td>c/o Air France, Zone d’Entretien DM/QN, BP 10253, 95704 Roissy-Charles de Gaulle, France</td>
</tr>
<tr>
<td>AIR INDIA (AI)</td>
<td>Mario TAVERNA</td>
<td>c/o Air India, Engineering Dept., Technical Building, Old Airport, Bombay 400029, India</td>
</tr>
<tr>
<td>AIR INTER (IT)</td>
<td>Michel LEFEBVRE</td>
<td>c/o Air Inter DM/QO, BP 225, 94396 Orly-Aerogare, France</td>
</tr>
<tr>
<td>AIR JAMAICA (JM)</td>
<td>Dieter KINDERMANN</td>
<td>Post Office, Norman Manley Airport, Kingston, Jamaica WI</td>
</tr>
<tr>
<td>ALITALIA (AZ)</td>
<td>Michel BOYER</td>
<td>c/o Alitalia, Direzione del Materiale, Aeroporto Leonardo da Vinci, 00050 Roma Fiumicino, Italia</td>
</tr>
<tr>
<td>BRITISH CALEDONIAN AIRWAYS (BR)</td>
<td>Anthony JONES</td>
<td>c/o British Caledonian Airways, 3rd Floor, Hangar West, Caledonian House, Crawley, West Sussex RH10X1, United Kingdom</td>
</tr>
<tr>
<td>CHINA AIRLINES (CH)</td>
<td>André LAMOUR</td>
<td>c/o China Airlines, Maintenance Technical Area, PO Box 20, Chiang Kai Shek Intl. Airport, Taoyuan, Taiwan (ROC)</td>
</tr>
<tr>
<td>CYPRUS AIRWAYS (CY)</td>
<td>Jean-Pierre DO</td>
<td>c/o Poste Restante, Larnaca Airport, Cyprus</td>
</tr>
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<td>EASTERN AIRWAYS (EA)</td>
<td>Manfred THOMSEN</td>
<td>c/o Eastern Airlines, PO Box 660797, Miami Springs, Florida 33166, USA</td>
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<td>EGYPTAIR (MS)</td>
<td>Uwe KLANN</td>
<td>Box 2701, El Horreia, Heliopolis, Cairo, Egypt</td>
</tr>
<tr>
<td>GARUDA INDONESIAN AIRWAYS (GA)</td>
<td>Ajith FRANCIS-JOSEPH</td>
<td>Garuda Maintenance Center, Room 209, Kemayoran Airport, PO Box 3760, 10002 Jakarta, Indonesia</td>
</tr>
<tr>
<td>HAPAG-LLOYD FLUG (HF)</td>
<td>Günther STOLL</td>
<td>c/o Hapag-Lloyd Flug, D-2000 Hannover 42, Flughafen Strasse 10, Flughafen Postfach 420094, West Germany</td>
</tr>
<tr>
<td>IBERIA (IB)</td>
<td>Jean PUGINIER</td>
<td>c/o Iberia, Oficina de Correos, Aeropuerto de Barajas, 28042 Madrid, Spain</td>
</tr>
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<td>INDIAN AIRLINES (IC)</td>
<td>Peter REHFELD</td>
<td>c/o Indian Airlines, New Engineering Complex, Sahar, Bombay 400090, India</td>
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<td>IRAN AIR (IR)</td>
<td>Jean-Claude HUG</td>
<td>c/o Iran Air, Engineering and Maintenance Dept., Mehrabad Airport, Tehran, Iran</td>
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<td>KLM ROYAL DUTCH AIRLINES (KL)</td>
<td>Manfred MÜCKE</td>
<td>c/o KLM Royal Dutch Airlines, 1117 Schiphol Airport Oost, Building 404, Room 310, Amsterdam, Netherlands</td>
</tr>
<tr>
<td>KOREAN AIR (KE)</td>
<td>Eberhardt KUNBERGER</td>
<td>c/o Korean Air, Kimpo International Airport, Seoul, South Korea</td>
</tr>
<tr>
<td>KUWAIT AIRWAYS (KU)</td>
<td>Max EICHER</td>
<td>c/o Kuwait Airways Corporation, Engineering Dept, PO Box 928, Kuwait</td>
</tr>
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<td>LUFTHANSA (LH)</td>
<td>Christoph DORMANN</td>
<td>c/o Luftansa, Abteilung FRA-IFB, Flughafen, D-6000 Frankfurt/Main 75, Federal Republic of Germany</td>
</tr>
<tr>
<td>MALAYSIAN AIRLINE SYSTEM (MH)</td>
<td>Christian SENAT</td>
<td>c/o Malaysian Airlines System, International Airport of Kuala Lumpur, Subang, Selangor, Malaysia</td>
</tr>
<tr>
<td>MARTIN AIR (MP)</td>
<td>Manfred MUECKE</td>
<td>c/o KLM Royal Dutch Airlines, 1117 Schiphol Airport Oost, Building 404, Room 310, Amsterdam, Netherlands</td>
</tr>
<tr>
<td>NORTHEASTERN INT’L AIRWAYS (OS)</td>
<td>Alphonse SANTKIN</td>
<td>c/o Northeastern International Airways Inc., 1203, SW 40th Street, Forer Lauderdale, Florida 33315, USA</td>
</tr>
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<td>OLYMPIC AIRWAYS (OA)</td>
<td>Robert THIEBAUT</td>
<td>c/o Olympic Airways, Hellinikon Airport, Athens, Greece</td>
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<td>PAKISTAN INTERNATIONAL AIRLINES (PK)</td>
<td>Robert LIPSCOMBE</td>
<td>c/o Pakistan Airlines, Director Engineering and Maintenance, Karachi Airport, Pakistan</td>
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<td>PHILIPPINE AIRLINES (PR)</td>
<td>Michael RENKEN</td>
<td>CPO Box 8088, Paraanque, Philippines</td>
</tr>
<tr>
<td>SABENA (SN)</td>
<td>Paul MAS</td>
<td>c/o Sabena, T. Ent. Av., Hangar 41, 1930 Zaventem, Belgium</td>
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<td>SAUDI ARABIAN AIRLINES (SV)</td>
<td>Johannes CORDIER</td>
<td>c/o CC 933, PO Box 167, Jeddah, Saudi Arabia</td>
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<td>SCANDINAVIAN AIRLINES SYSTEM (SK)</td>
<td>Jean-Pierre GAYRAL</td>
<td>c/o Scandinavia Airlines System, Maintenance Base Arlanda, STO27, S 19045, StockholmArlanda, Sweden</td>
</tr>
<tr>
<td>SINGAPORE AIRLINE (SQ)</td>
<td>Anton GENSBICHLER</td>
<td>c/o Singapore Airlines, Engineering Division, PO Box 501, Changi Airport, Singapore</td>
</tr>
<tr>
<td>SOUTH AFRICAN AIRWAYS (SA)</td>
<td>Charles MAILLARD</td>
<td>c/o South African Airlines, PO Box Jan Smuts Airport 1627, Room 215/7 B707 Annex, Johannesburg, Republic of South Africa</td>
</tr>
<tr>
<td>SWISSAIR (SR)</td>
<td>Gerd BAHR</td>
<td>c/o Swissair Engineering, Dept. T1, CH 8058 Zurich Airport, Switzerland</td>
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<td>THAI AIRWAYS INTERNATIONAL (TG)</td>
<td>Jean-Marie VIVIES</td>
<td>c/o Thai Airways International, Technical Dept, Don Muang Airport, Bangkok, Thailand</td>
</tr>
<tr>
<td>TOA DOMESTIC AIRLINES (JD)</td>
<td>Bernd JUERGENS</td>
<td>c/o TOA Domestic Airlines, DA 1-2 Sogo Building, 7-1, 1 Chome Haneda-kukuro, Oita-Ku, Tokyo, Japan</td>
</tr>
<tr>
<td>TRANS AUSTRALIA AIRLINES (TN)</td>
<td>Mathias MARIASCHK</td>
<td>c/o Trans Australia Airlines, Melbourne Airport, 3045/VIC, Box N° 107, Melbourne, Australia</td>
</tr>
<tr>
<td>TRANS EUROPEAN AIRLINES (HE)</td>
<td>Paul MAS</td>
<td>c/o Sabena, T. Ent. Av., Hangar 41, 1930 Zaventem, Belgium</td>
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<td>c/o Tunis Air, Division Entretien, Departement Technique, Aeroport du Tunis-Carthage, Tunisie</td>
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<td>c/o Varg SA, Rua de Hangares 5/N Galeo, CEP 21941, Rio de Janeiro, Brazil</td>
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<td>VASP (VP)</td>
<td>Bernard BONNEFOY</td>
<td>Edificio VASP, Hangar 1, Aeroporto de Congonhas, Sao Paulo, SP 04695, Brazil</td>
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<td>MA 37276</td>
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<td>81 (3) 7476004</td>
<td>(7810) 2466274</td>
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<td>61 (3) 3382771</td>
<td>31320</td>
</tr>
<tr>
<td>BRUSSELS</td>
<td>32 (2) 7214315</td>
<td>23931</td>
</tr>
<tr>
<td>TUNIS</td>
<td>216 (1) 238000/Ext. 2054</td>
<td>13557</td>
</tr>
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<td>RIO DE JANEIRO (GIG)</td>
<td>55 (21) 3932525/Ext. 159</td>
<td>(021) 21765</td>
</tr>
<tr>
<td>SAO PAULO (CGH)</td>
<td>55 (1) 5337011/Ext. 361</td>
<td>-</td>
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Although the present state of technology has attained a highly complex level - via up to solid state LASER concepts of gyroscopic electronics and pneumatics driven gyroscopes - the basic principles have been in use since the mid-eighteenth century.

The behaviour of spinning rotors was studied around 1750 by the Swiss mathematician Leonard Euler who lectured at the university in Berlin, and then by the French scientist Leon Foucault (1819-1868).

The device was named a gyroscope, a combination of two Greek words, gyro, to turn, and skopein, to view or to see, thus a "turn-seer" or a device to indicate turns or angular rotation. The first experimental inventions of consequence began to appear in the early 1900's with the introduction of a gyrocompass patented by the German Dr. Kämpfe in 1908 and the American Dr. Elmer A. Sperry in 1911.

The first public demonstration of gyroscopes embodied in an aircraft with an automatic pilot took place in France at Bezons on the river Seine on the 18th of June 1914 during the "Concours par l’Union pour la Sécurité en Aéronautique". The aircraft in use was a Curtiss flying boat Model E, piloted "hands-off" by one of Elmer Sperry's sons, Lawrence Burst Sperry, and mechanic Emile Cachin who during the flight stood outboard between the right hand bi-plane wings to demonstrate in a graphic fashion the capabilities of gyro stabilization via compressed air servo actuators. Tragically, Lawrence B. Sperry was drowned 10 years later, in the English Channel in December 1923. He had not survived a ditching accident with his Sperry Messenger bi-plane while en-route from London to Amsterdam.
As far as operational utilization of gyros is concerned the Germans were the most advanced during World War One due to the fact that they operated numerous heavy bombers with up to six or eight engines, often during night operations. Only in these "Riesenflugzeuge" (Giant airplanes) was one able to carry the relatively heavy equipment of the gyro indicator and the associated electrical 3-phase power supply. The Telefunken generator was initially air driven but in 1917/1918 a two-cylinder Bosch APU was installed in the mid-fuselage to achieve better frequency/voltage stability, thus gyro rotor speeds of 18,000 RPM were attained.

In the main two kinds of gyro-devices were fitted in the center of both the open or closed "wide-body" cockpits and diameter size of the front dial often reached 20 cm.
The Drexler company in Berlin produced a “Steuerzeiger”, called in English terminology of the twenties a “Steering Gauge”, and in modern parlance a Turn Indicator. Sometimes a bubble bank indicator was added. The Anschütz company in Kiel and Gyrorrector in Berlin produced their “Kreiselneigungsmesser”.

Drexler “Steuerzeiger” first turn indicator (1915/1916)

This was an early version of the modern day artificial horizon but was limited to roll axis only. The pitch “athwartship” had to be monitored by a separate carpenter’s spirit level, which was acceleration sensitive. It is surprising that for more than a decade after World War One, all these safety related gyro devices to assist blind-flying disappeared from the cockpit navigational instrumentation entirely.

Anschütz “Kreiselneigungsmesser” first artificial horizon limited to roll axis only (1917)

The gyro invention could be said to have come of age again after the famous U.S. pilot Jimmy Doolittle performed his extraordinary “CAT III” take-offs and landings on 24th of September 1929 at Mitchel Field. The feat was accomplished by using a Sperry artificial horizon and a directional gyroscope. These were newly developed by Elmer Sperry Jr., another of Dr. Sperry’s sons, in conjunction with Doolittle’s experience gained during a year of simulator training. That first flight took place under actual zero-zero fog conditions using a Consolidated NY-2 Navy trainer, and the second one with a hood fitted to this tandem seater but accompanied by a lookout-pilot to avoid mid-air collisions. The IMC go-around was eye-

Staaken RIV

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