

**Dowty
Rotol
landing gear**



experts by experience

Company capabilities

Dowty Rotol is the largest company in the Dowty Group Aerospace Division. Situated at Staverton Airport, Gloucester it employs 3 300 people and occupies 74 000 m² (800 000 ft²) of workshops and offices.

The company provides complete systems capability over a wide range of advanced aircraft with landing gear as its main product line.

Aircraft landing gear and associated hydraulics have been produced by Dowty for over 50 years and fitted to more than 200 different types of aircraft. Therefore the company offers its customers

- Proven experience gained over half a century
- Total responsibility from a team dedicated to aircraft landing gear
- In-house production workshops equipped with the latest machine tools
- In-house development test facilities.
- Ability to manage major landing gear projects
- Worldwide product support

The company's design office houses over 300 highly qualified personnel of which approximately one third are engaged on work with aircraft landing gear.

CAD/CAM techniques are employed to explore design alternatives then to supply optimum production configurations.

Design work on landing gear covers the following

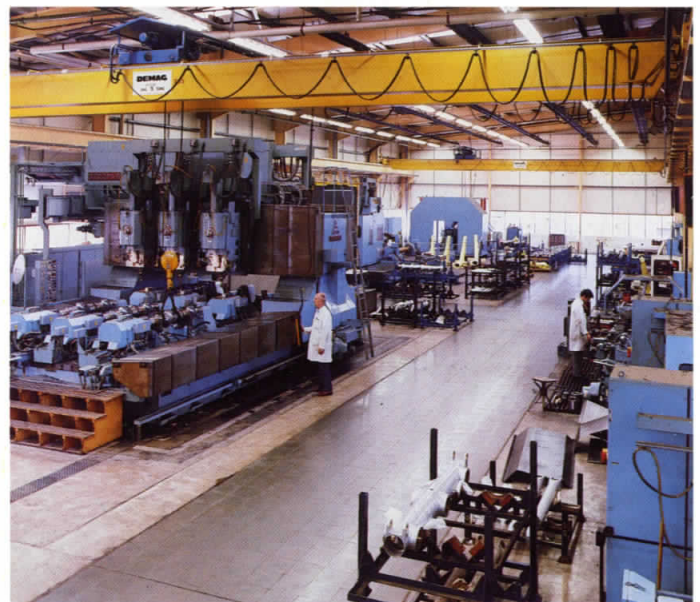
- Aircraft requirements
- Suspension options
- Shock absorption techniques
- Materials technology
- Steering controls
- Retraction mechanisms
- Associated hydraulics



Dowty Rotol at Staverton Airport



Computer aided design work stations



Landing gear production shop

In order to convert the latest design advances to precision manufactured hardware, the company has made a major investment in a production facility that is the most modern of its kind in Europe. The floor area of this purpose built shop is 3125 m² (33 600 ft²) and its eaves height is 7 m (23 ft). There are four overhead cranes, each with 5000 kg (5 ton) lift capability.

This landing gear production plant was constructed as a heavy duty machining cell with special attention paid to machine centre foundations, surface hardened gangways and the provision of ancillary process areas. It is also served by other machine shops of the company as well as heat treatment, plating and laboratories adjacent to it.

Dowty Rotal has comprehensive facilities for the assembly and testing of landing gear and associated hydraulics. The 1830 m² (19 700 ft²) assembly shop is staffed by experienced fitters and approved inspectors.

The engineering development department covers every aspect of landing gear qualification and is fully equipped for

- Drop testing
- Strength testing
- Fatigue testing
- Functional testing
- Vibration testing
- Experimental stress measurement
- Environmental testing

The landing gear development test department is fully computerised so that all data is available for analysis.

The Dowty Rotal Product Support Division provides worldwide back-up to all its customers. This includes service support, spares support, technical support, publications support, training support, repair and overhaul support.

The company also provides support for other manufacturers landing gear to keep operators flying.



Drop testing rig for landing gear up to 400 000 lb AUW



Landing gear assembly shop



Servicing Dowty Rotal gear on BAe 146

The Engineering Department of Dowty Rotol occupies 3700 m² (40 000 ft²) of technical offices together with 5600 m² (60 000 ft²) for research and development activities.

Collectively the company's landing gear specialists have acquired considerable experience and expertise. They are thus eminently capable of co-operating with aircraft designers from the earliest project stages so as to evaluate options suitable for any particular configuration.

Design approach

Landing gear design is dependent, not only on the type of aircraft, but also on the requirements for its usage and intended operational role. The choice of suspension and the shock absorber arrangement often result from the matching of runway conditions with those of aircraft structure leading to optimum passenger comfort.

Shock absorption

Shock absorber variants include

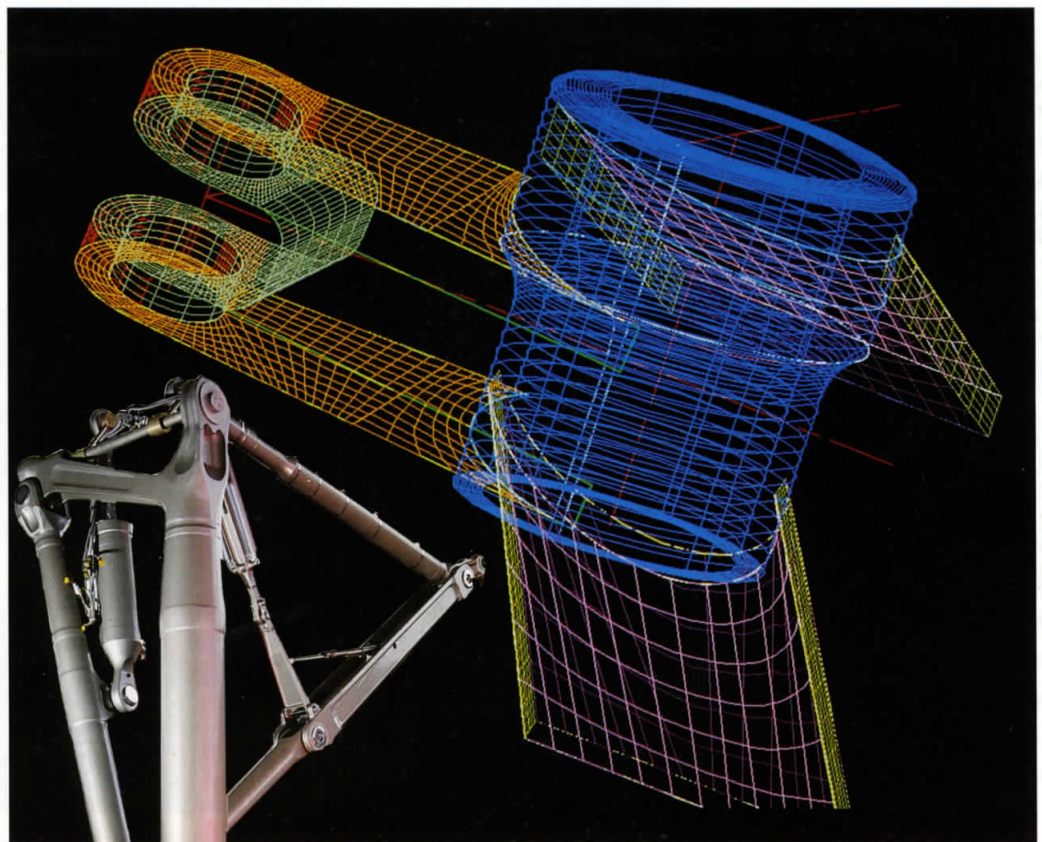
- Single or two-stage gas springs
- Basic liquid springs
- Nitrogen supplemented springs

Extensive design know-how exists within the company to provide optimised damping for special applications such as aircraft having to taxi over extremely rough ground, at the same time maintaining compatibility with all landing and take-off demands.

On-going research has developed passive devices, incorporated within shock absorbers, which have advantages in reducing fatigue loads, also semi-active damping devices controlled electronically by external sensors.



British Aerospace 146



CAE 'wire framing' of landing gear detail



Airbus A310 main landing gear



Fokker F.28 operating on rough runway in West Africa

Dynamic analysis

The design of aircraft landing gear equipment involves the application and dissipation of energy within the various mechanisms, not only for the main function—that of landing—but also for retraction, lowering, steering and other associated mechanisms.

Over the years Dowty Rotol has developed comprehensive analytical techniques to determine the performance of such mechanisms. These analyses take into account system, aerodynamic and environmental conditions thereby ensuring that loads generated are well within the strength and performance parameters.

Computerised design

The Graftek system at Dowty Rotol was selected specifically to embrace the requirements of landing gear design and is capable of

- 2D drawing
- Wire framing
- Solid modelling

Materials technology

Dowty Rotol landing gear designers have consistently kept abreast with the latest materials available, such as ultra high tensile steels, now extensively used to produce low weight components. The company has accumulated excellent service experience in such materials and has perfected suitable manufacturing techniques.

Further to this on-going programme of working in special steels, aluminium alloys and titanium, company technicians are engaged in research and development concerned with non-metallic and other materials for landing gear applications.



Computer aided engineering on bogie configuration



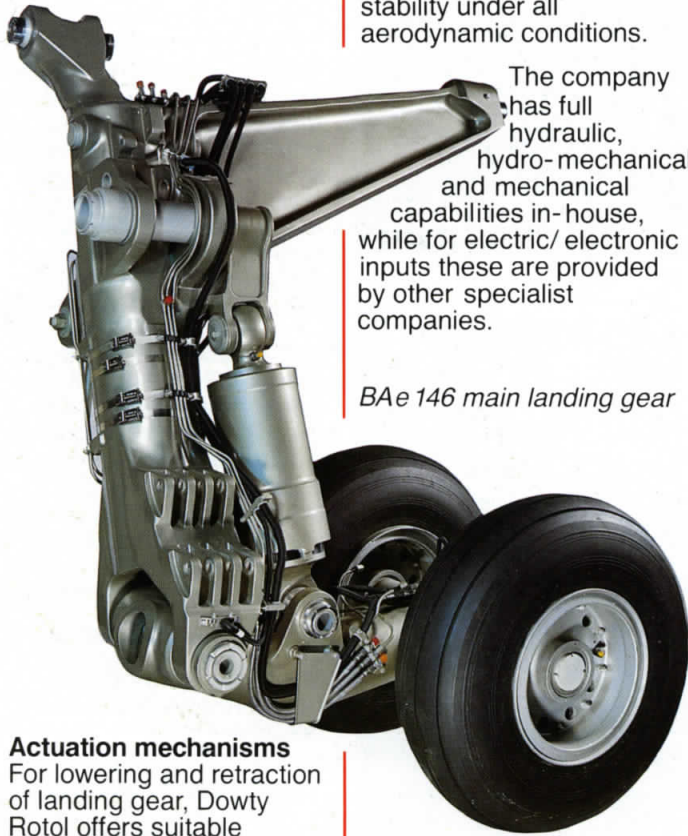
Airbus A320 main landing gear

Using computerised techniques, it is possible to pre-determine the motion of landing gear components relative to airframe structuring with the minimum of delay. This provides speedy evaluation of options available and constitutes an invaluable aid to the aircraft and landing gear design teams alike.

Steering mechanisms

Dowty Rotol nose landing gear units generally utilise hydro-mechanical steering mechanisms tailored to suit the particular application. These are in turn controlled, through either mechanical linkages or electronically, with the option of using flight data to modify steering characteristics and provide stability under all aerodynamic conditions.

The company has full hydraulic, hydro-mechanical and mechanical capabilities in-house, while for electric/ electronic inputs these are provided by other specialist companies.



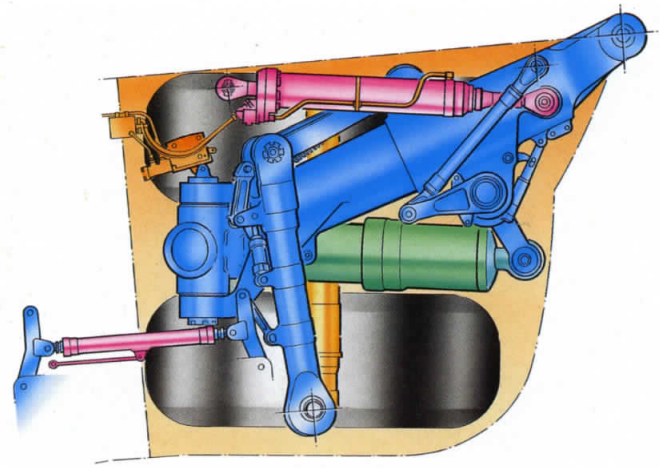
BAe 146 main landing gear

Actuation mechanisms

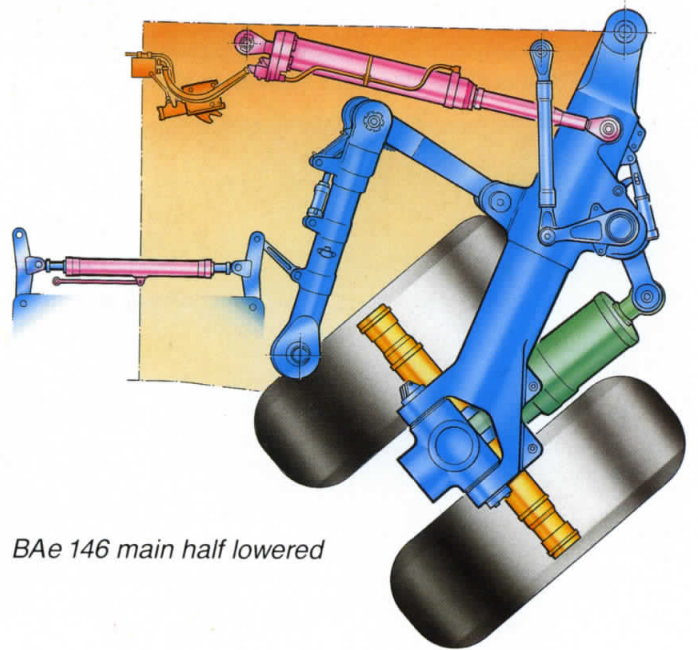
For lowering and retraction of landing gear, Dowty Rotol offers suitable equipment to provide a total system. Depending on the geometry, most Dowty Rotol landing gears are capable of emergency free fall lowering. Typical system components are

- Hydraulic actuators
- Folding stays
- Direction linkages
- Up/down locks
- Door locks

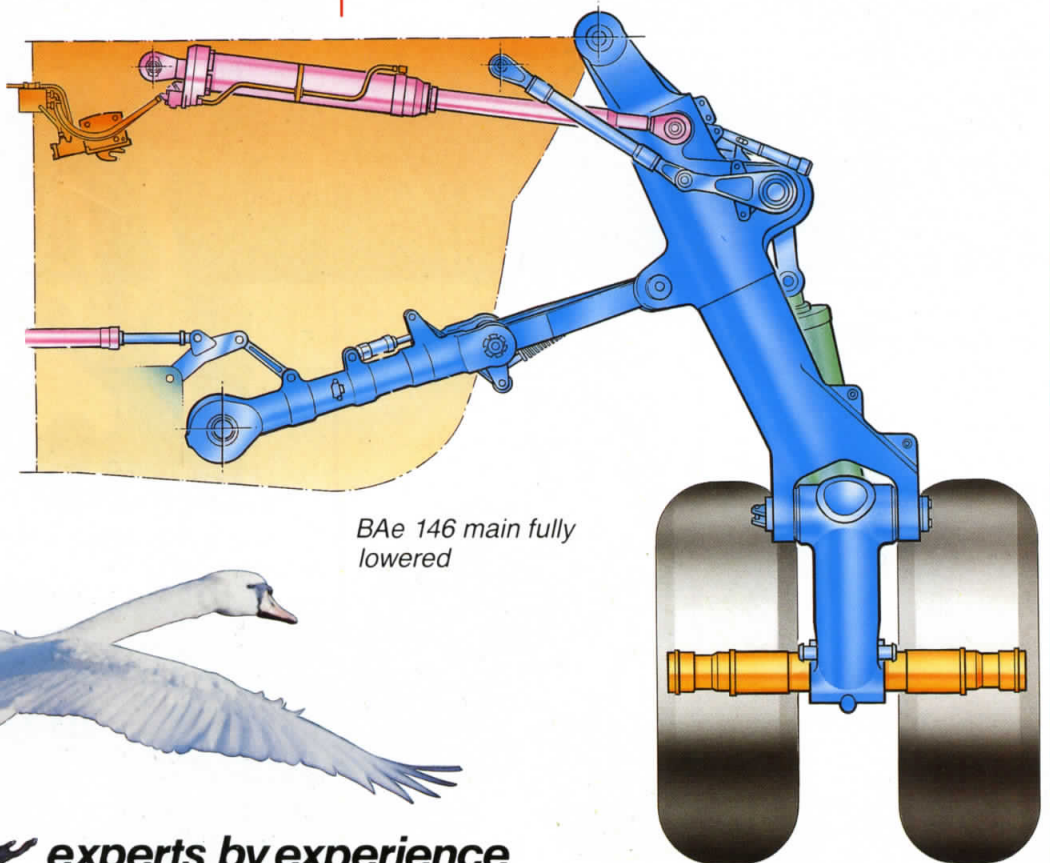
Hydraulics is a Dowty speciality and the company is ideally suited to produce hydraulic systems co-ordinated with the landing gear.



BAe 146 main retracted



BAe 146 main half lowered



BAe 146 main fully lowered



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Suspension development testing of model landing gear

Research and development

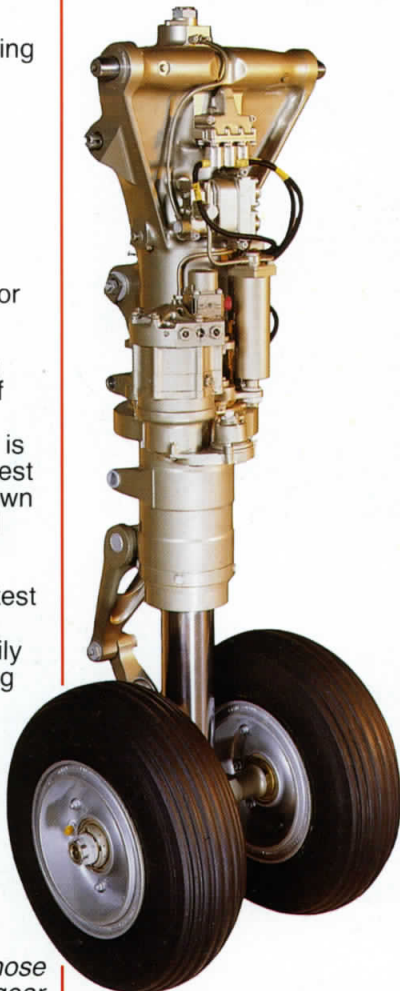
Dowty Rotol carries out all its own research and development on landing gear units and associated actuation systems. R&D includes work on materials, fluids and seals.

Tests applicable to landing gear include

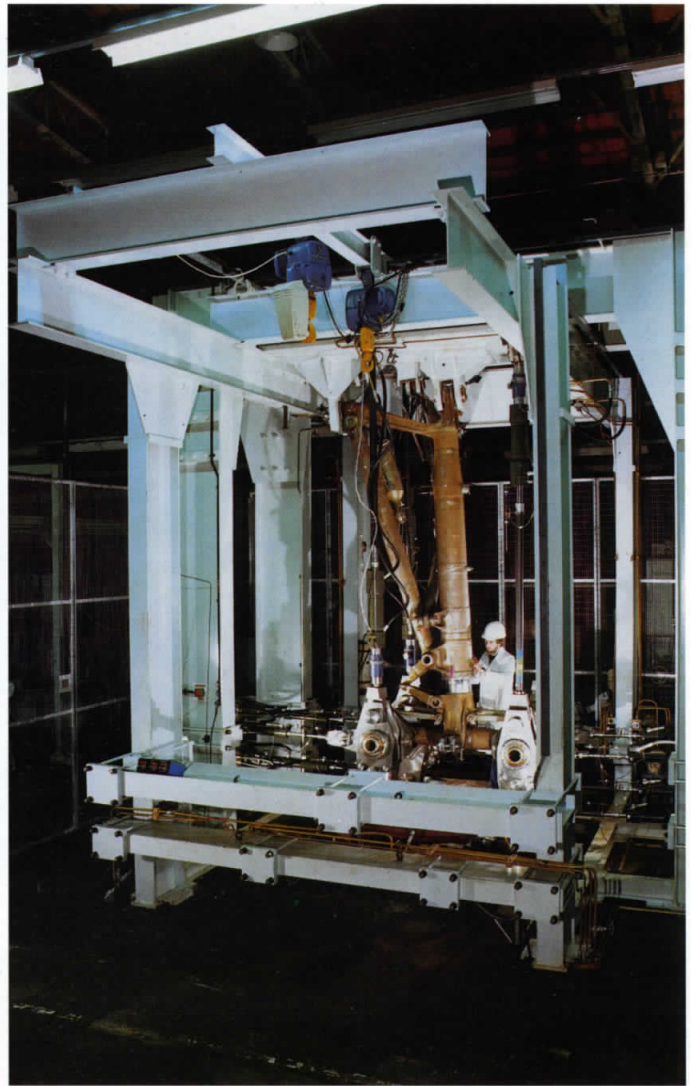
- Element testing of mechanisms
- Stress evaluation
- Dynamic testing of prototype units
- Qualification testing for certification

As a supplier of landing gear for a wide range of aircraft operating worldwide, Dowty Rotol is capable of meeting all test requirements as laid down by the relevant civil and military authorities.

The R&D landing gear test facility is computerised so that results are readily available for engineering assessment.



Panavia Tornado nose landing gear



Airbus A310 main leg on fatigue test rig



Computerised test house facility

Reliability and maintainability

It is the company's policy to design-in optimum reliability and maintainability at the earliest stage of all new landing gear. These considerations are reviewed throughout the development and manufacturing stages of the equipment. Reliability and maintainability

feedback from the equipment in service is applied both to the gear concerned in the form of modification improvements and particularly to new unit designs. This policy has resulted in Dowty Rotol landing gear systems providing high reliability, requiring the minimum of maintenance and resulting in low cost of ownership.

Dowty Rotal has maintained a consistent policy of major investment in new production plant and equipment for the manufacture of aircraft landing gear.

Company workshops are now equipped with over 420 machines, emphasis being on CNC models and automatic tool changing 4, 5, 6 and 7 axis machine centres.

Manufacturing capabilities of typical piece part sizes are

Boring

Up to 250 mm (10 in) dia × 3000 mm (9.75 ft) deep

Grinding

External up to 920 mm (36 in) dia × 1830 mm (6 ft) long

Internal up to 920 mm (36 in) dia × 2000 mm (6.5 ft) long

Honing

Up to 270 mm (10.25 in) dia × 3000 mm (9.75 ft) deep

Milling

Up to 1250 mm (49 in) wide × 3000 mm (9.75 ft) long

Turning

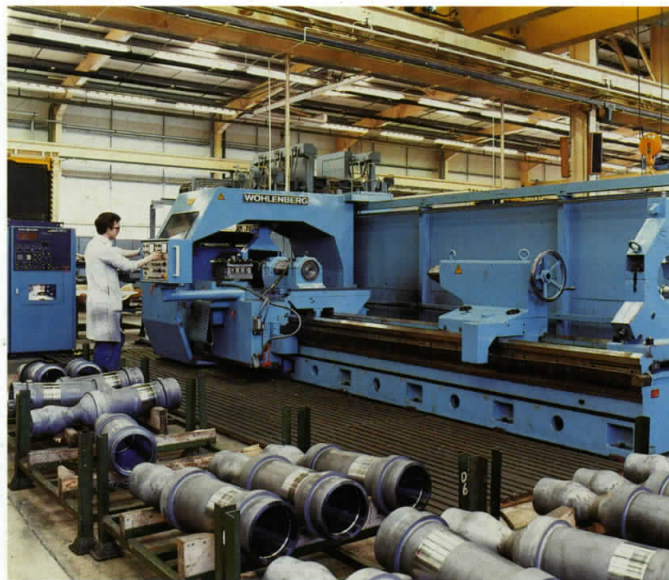
Up to 920 mm (36 in) dia × 5000 mm (16 ft) between centres

Up to 4000 mm (13 ft) swing × 7442 mm (24.25 ft) between centres

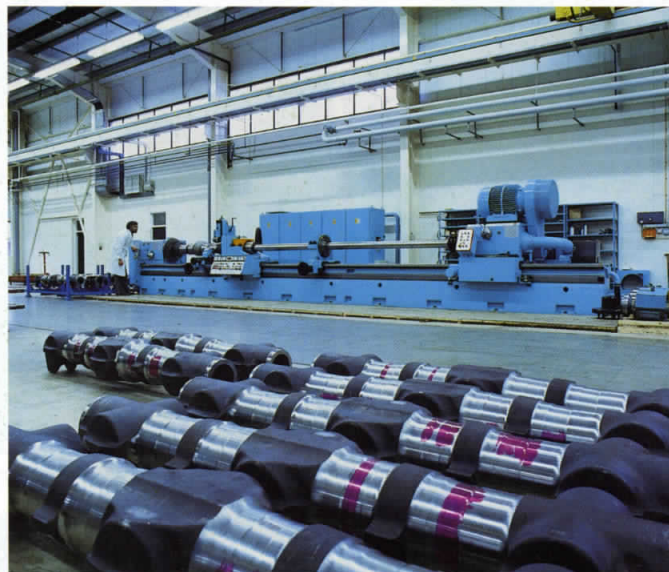
Machine work on components for large landing gear (e.g. Airbus A310 and A320) is carried out in the purpose-built shop previously described.

The largest machine tool in this shop is the Droop & Rein moving gantry, five spindle, profile mill unit with each spindle driven by a 30 hp motor at an infinitely variable speed range.

A seven axis single spindle Droop & Rein machining centre has been installed to cope with increased demand for large landing gear components.



CNC heavy duty turning A310 retraction jacks



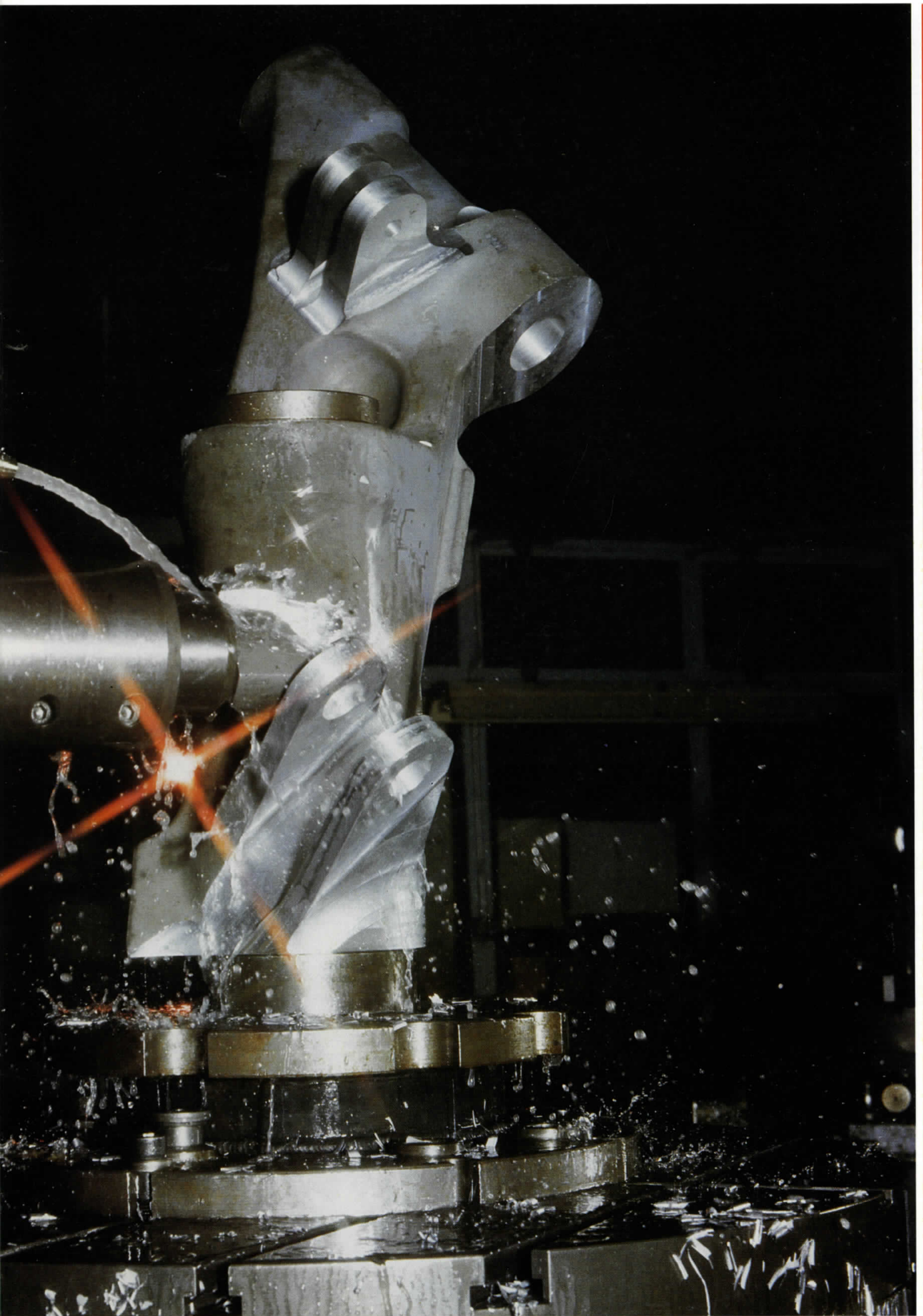
Deep hole boring A310 bogie beams



Assembling A310 bogie beam units



Machining Tornado main leg



Other examples of the latest machine tools used at Dowty Rotol include

- CNC heavy duty machining centres with 40 hp spindles, automatic tool changers, rotary tables and indexing heads
- CNC heavy duty turning with special tooling for chambered bores and wide swing/gap lathes for machining extra large components
- Deep hole boring with 45 hp main spindle for producing accurate bores at high penetration rates

Dowty Rotol has special expertise in the precision machining of high strength aluminium alloys and ultra high strength tensile steels.

Typical aluminium alloys include 2024, 7010 and 7075, while the steels cover 300M, 4330 and 4340, also 35NCD THQ.

Two major in-house facilities possessed by Dowty Rotol are heat treatment and plating. The heat treating department has a range of furnace sizes with compatible pre-heat and tempering units. The largest pit furnace provides a charge space of 1830 mm (6 ft) dia x 3660 mm (12 ft) deep with atmosphere control automatically regulated by infra-red gas analysis.

Other heat treatment facilities include smaller pit furnaces, sealed quench box furnaces, nitriding and gas carburising furnaces, also salt baths for tempering. The shop is served by a two-ton rapid response travelling crane with suitable furnace loading furniture.

The Dowty Rotol plating facility has been extended to provide special deep plating and allied pre-treatment vats for large landing gear components. The range of surface finishes, which are applied to MIL specifications or to special requirements, include anodising, chrome plating and low embrittlement cadmium plating. There is a range of ovens available for pre- and post-plating treatments.

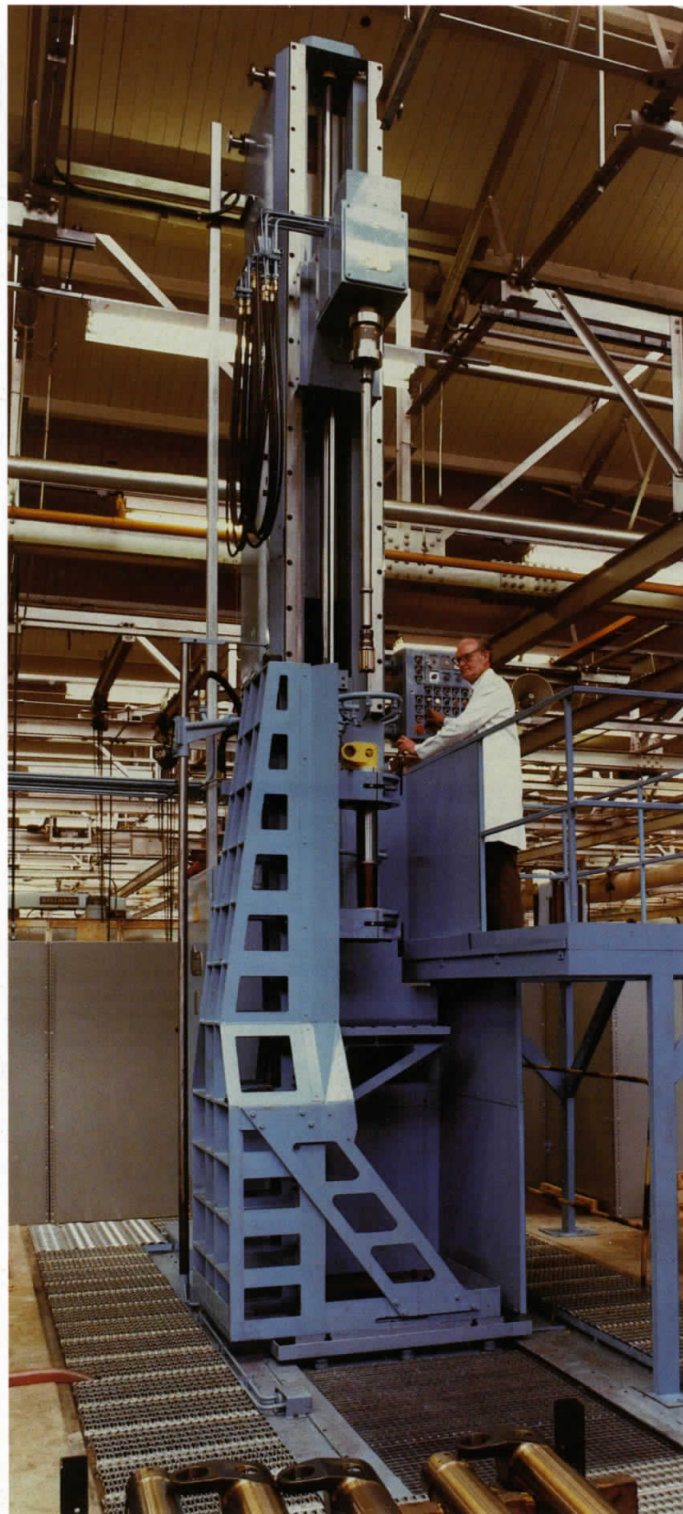
All heat treatment and plating work, which provides complete capability for processing on site, comes under close laboratory control. The company has two fully equipped and approved laboratories as follows

Metallurgical laboratory

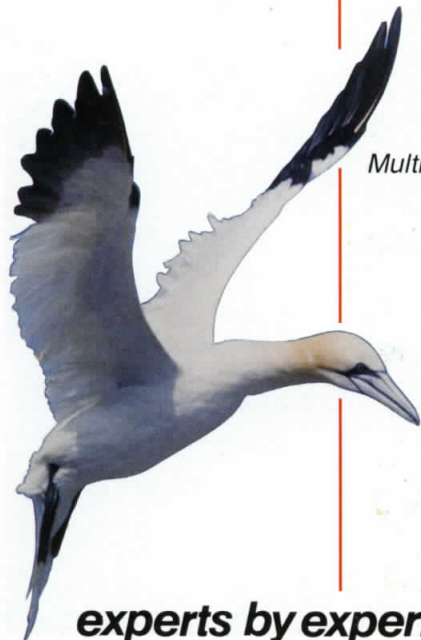
Covers mechanical testing, non-destructive testing and metallography.

Chemical laboratory

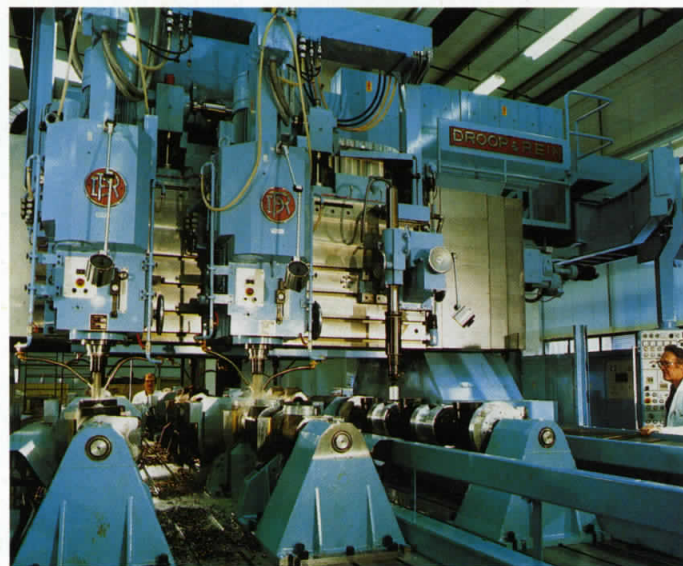
Covers metal analysis, testing of associated non-metallic materials, plating processes and control.



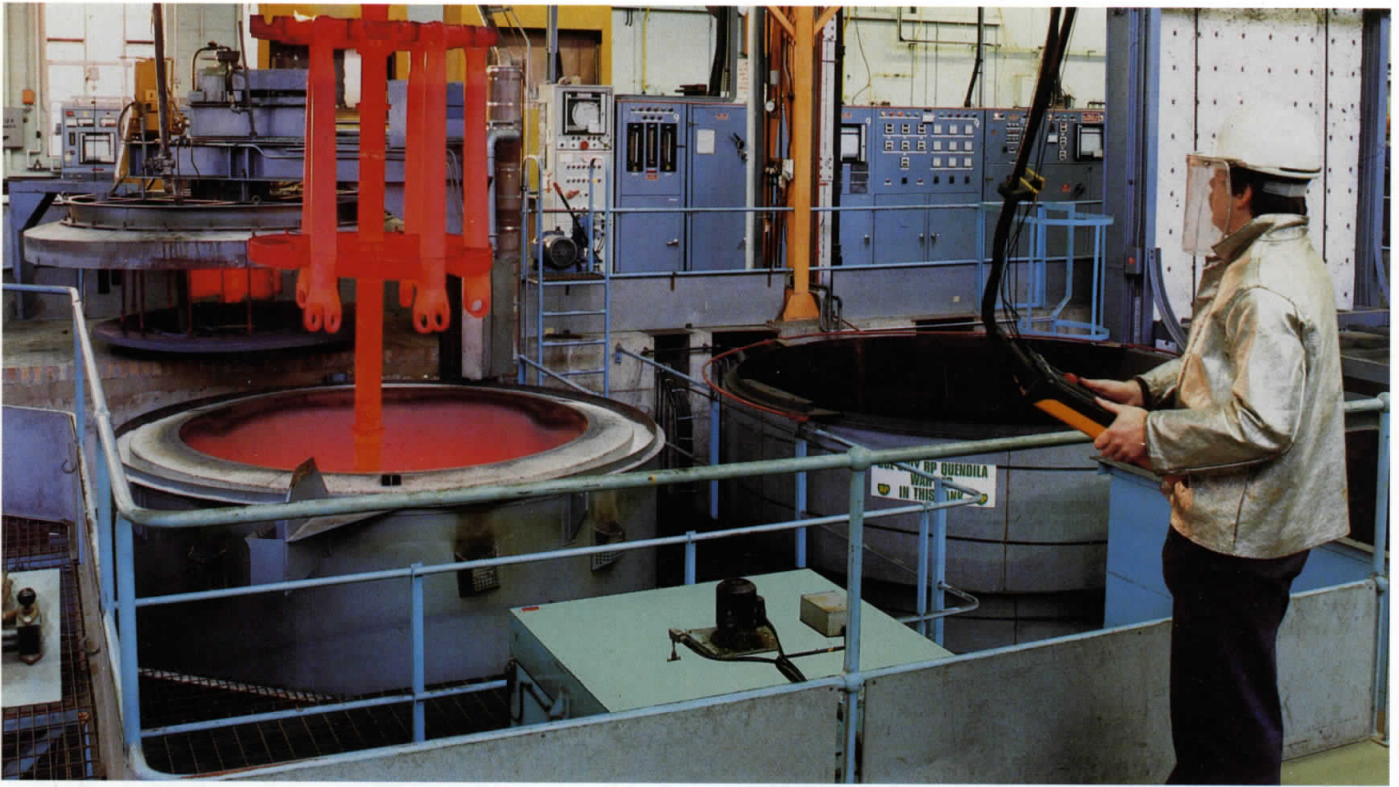
Vertical honing



Multi-spindle profile milling large landing gear components



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Heat treatment of landing gear reaction bar units



Plated shock absorber components



Metallurgical laboratory

Dowty Rotol operates a quality system which is both registered by the UK Civil Aviation Authority and the UK Ministry of Defence, also is recognised by major international airworthiness bodies. Written procedures exist to ensure that drawings, operation layouts and other formal instructions, are maintained at the required modification or issue level. All specifications, whether of internal, customer or government origin, are controlled and distributed by the Standards Department to the latest issue.

Quality system

Senior management are appointed with well-defined responsibility, authority and organisational freedom for the maintenance and development of the quality system thereby providing

- Departmental responsibility
- Reporting and documentation
- Corrective actioning
- Managing cost elements

Quality planning

The company's policy to design-in the quality of a product starts at the earliest project phases with the participation of senior engineers and is maintained to fulfil contract aims by

- Identifying characteristics
- Defining acceptance standards
- Testing, inspection and audit
- Meeting accuracy requirements

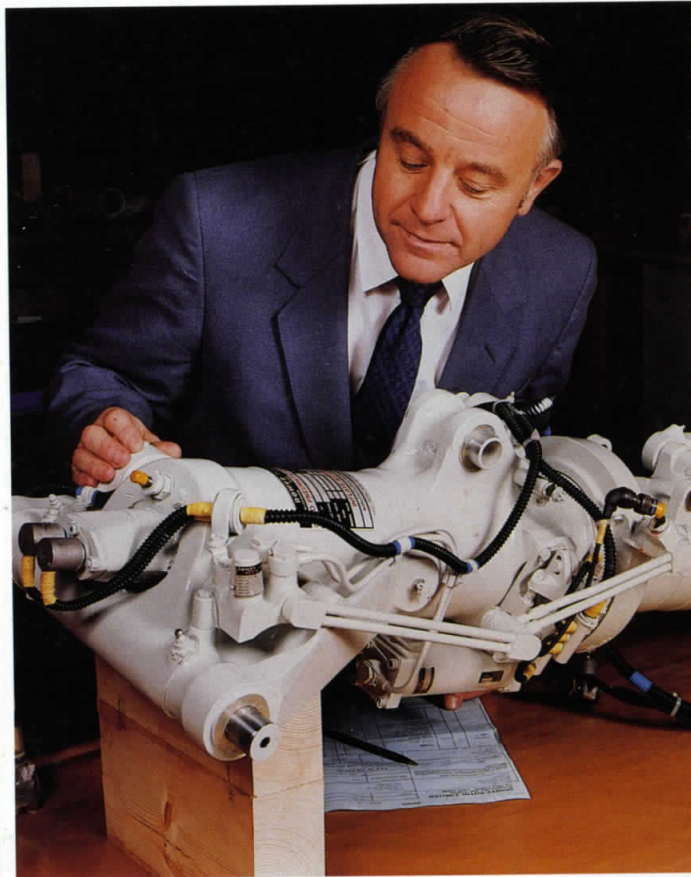
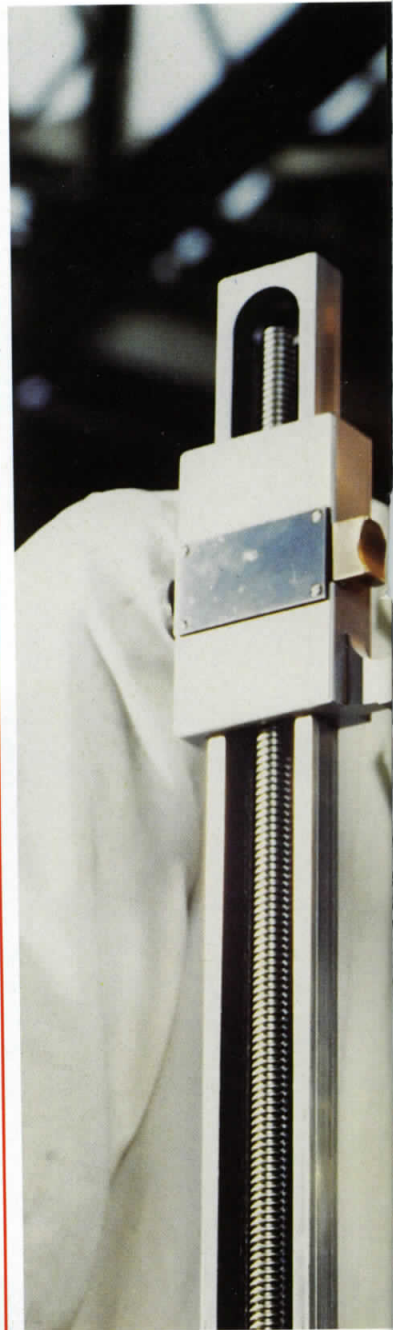
Quality control

The quality of the product during manufacture is assured by the timely provision of instructions, equipment and controls, also the programmed verification of operation completed to ensure

- Control of standard operations
- Control of special processes
- Control of inspection equipment
- Control of material and non-conforming products

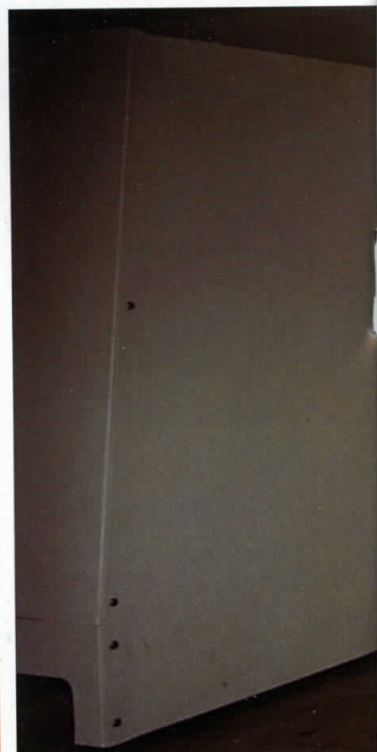
Dowty Rotol quality control personnel are highly trained and thoroughly experienced. They work to the latest design and production engineering techniques, also use the latest testing and inspection equipment. Thus the integrity of Dowty Rotol landing gear is ensured from conception, through manufacturing, installation and operation to total support by the company on a global basis.

Checking landing gear splines



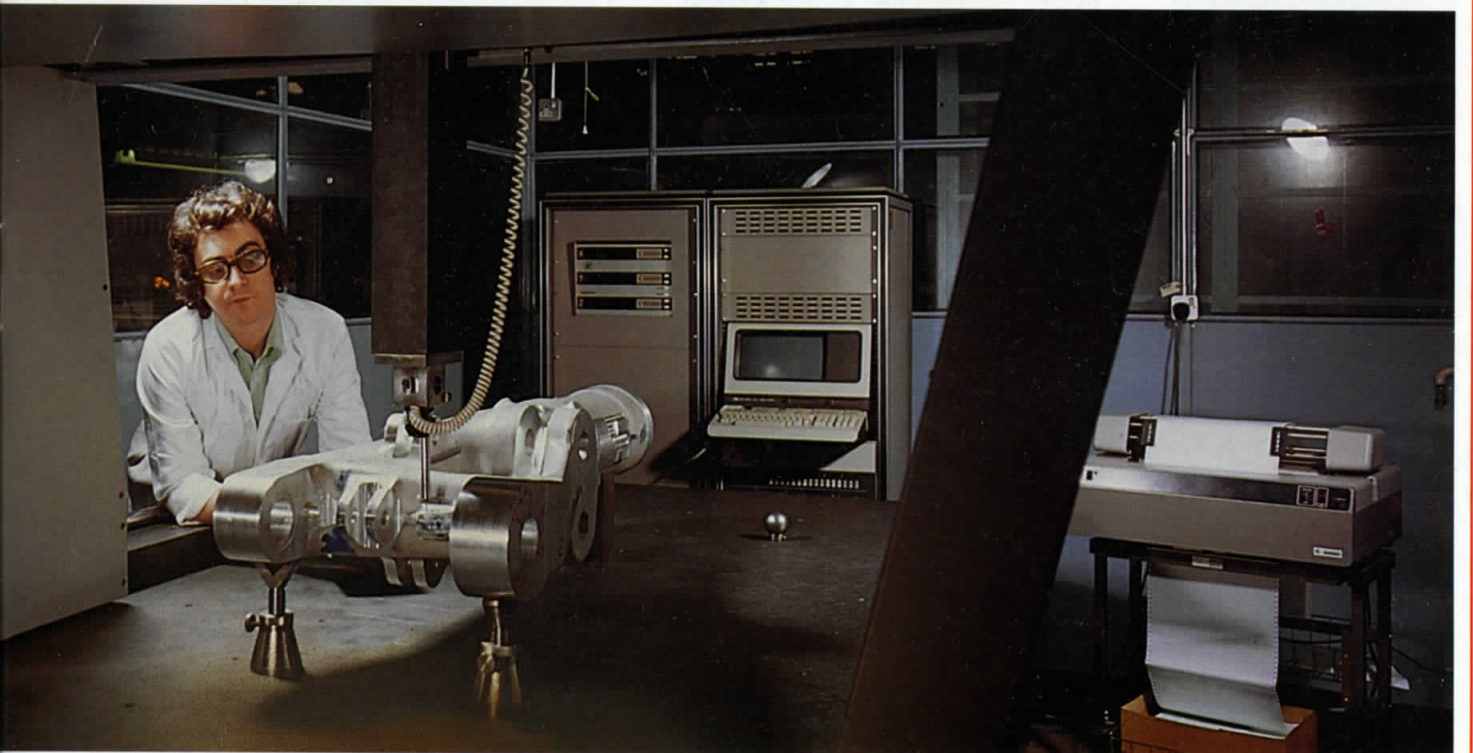
Final check on Tornado nose landing gear

Computerised inspection of landing gear





Quality assurance



Programme management

Since the founding of the Dowty Group in 1931, an organisation of clear-cut and responsible management has been maintained. This management organisation contains provision for every type of programme—from simple product/single customer orders to sophisticated system/multi-national projects. Thus every customer receives close management attention from before receipt of contract to after final delivery.

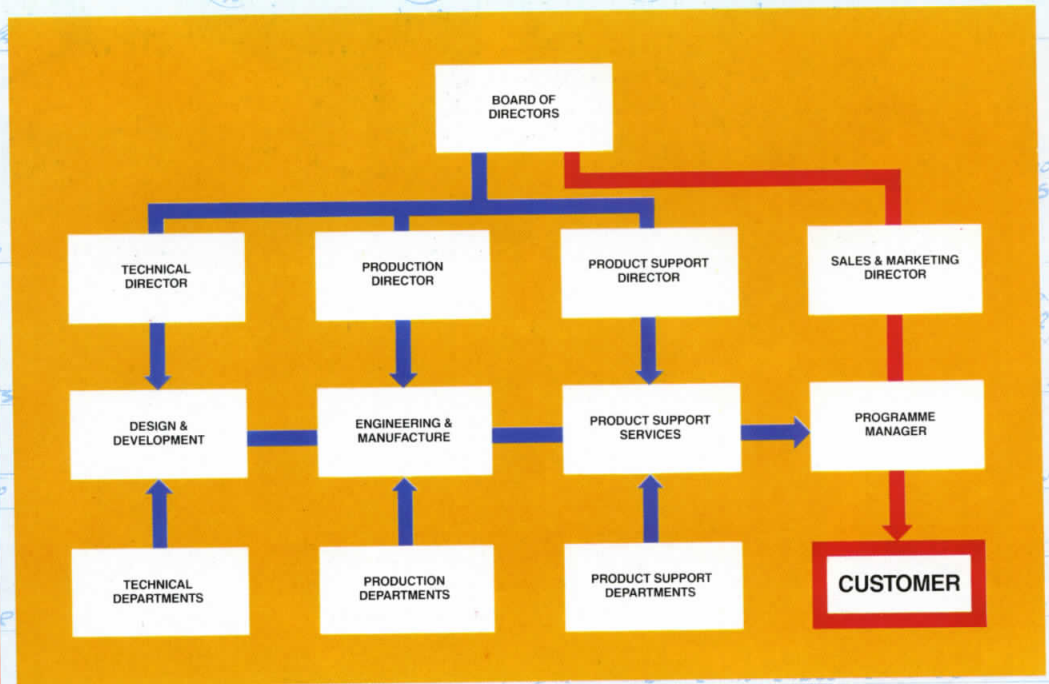
Shown opposite is a simplified management chart for a major landing gear programme. It will be seen that the Technical Production, Product Support, Sales & Marketing Departments all contribute to the project—first with obtaining the order, then following it through all its stages. The essential disciplines involved are as follows

- Defining programme requirements then producing a complete plan on how to meet them
- Informing all departments concerned and ensuring that they are fully responsive to the plan
- Monitoring plan progress in relation to contract schedules, product quality and cost targets
- Keeping the customer fully acquainted with all aspects of equipment design and manufacture

The inter-related processes of defining, informing and monitoring, also liaising with the customer, involve seven key areas to ensure success. These are

- 1 Financing
- 2 Purchasing
- 3 Pricing
- 4 Engineering
- 5 Manufacturing
- 6 Quality assurance
- 7 Product support

Management structure for major programme



The company maintains computerised facilities for all detailed programme planning, procurement, scheduling and control of manufacturing cycles and the system continues through despatch and installation of the landing gear to its maintenance in the field.



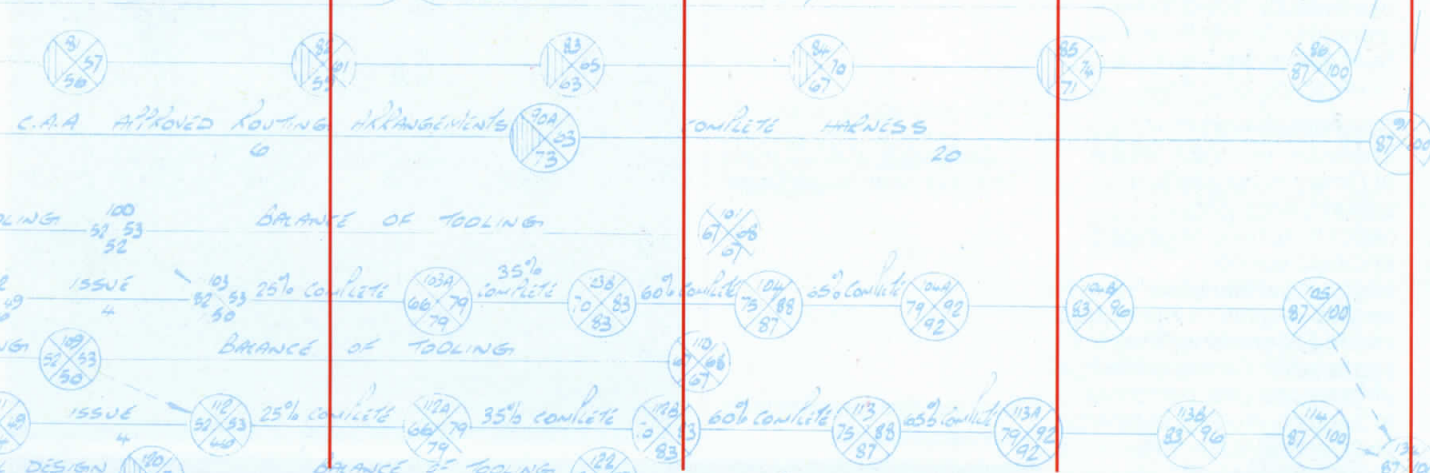
Technical discussions with customer



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DESCRIPTION	MONTH	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36					
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MACHINING																																										
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Typical landing gear component programme



All Dowty Rotal landing gear equipment, also gears not of the company's manufacture, are backed by product support resources that have operated for decades on a worldwide basis. Product support is carried out by a specific division of the company to ensure a positive and integrated service to customers.

The Product Support Division is controlled and co-ordinated from Dowty Rotal Limited at Staverton Airport, Gloucester, England. North American activities are met by Dowty Rotal Incorporated at Sterling, Virginia.

Where there is the need to support the company's equipment overseas, subsidiaries and stockists are created in customer territories or the required geographical areas. For example the latest to be created is Dowty Aviation Services at Singapore to cover south east Asia.

Service support

There are two main teams of Dowty Rotal product support engineers—resident service engineers and field service engineers. Resident service engineers are located at constructors plants while field service engineers assist operators. In addition product support engineering staff make regular visits to all customers.

Spares support

This department covers the world of airlines and air forces. Every year thousands of enquiries, orders and information items are processed, the average annual turnround is 10 000 customer orders and 200 000 customer postings. A seven day a week, round the clock AOG emergency service is also maintained.

Technical support

This is available under the following categories

Design support

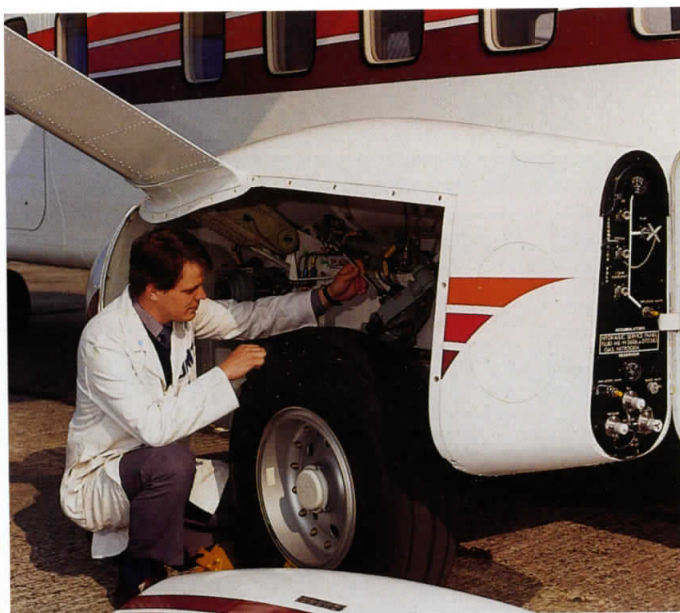
Laboratory support

Maintainability engineering

Workshop evaluation

The Product Support organisation can call on the design office for specialist

technical advice, also the Dowty Rotal metallurgical and chemical laboratories are available to investigate and solve customer problems. An important area of product support activities involves visiting customers' plants or sites, then making detailed proposals complete with working plans, throughputs and equipment needed.



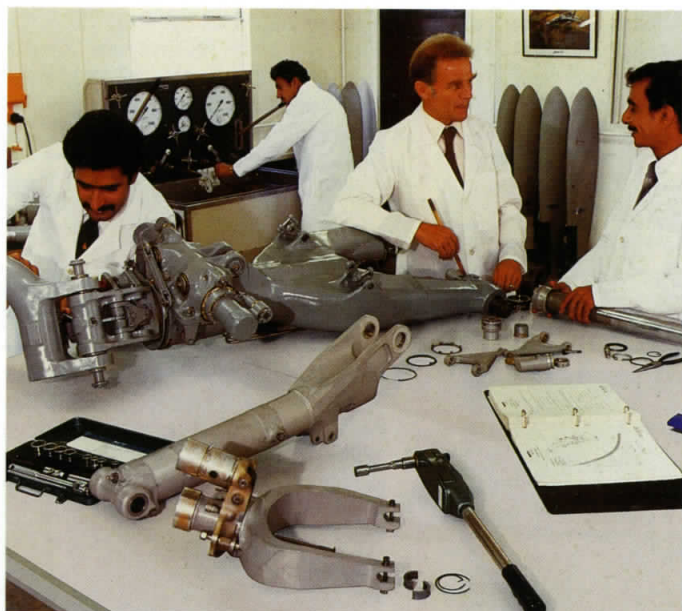
Servicing Shorts 360 main landing gear



Despatch of A310 main landing gear bogie beam

Servicing Panavia Tornado nose landing gear

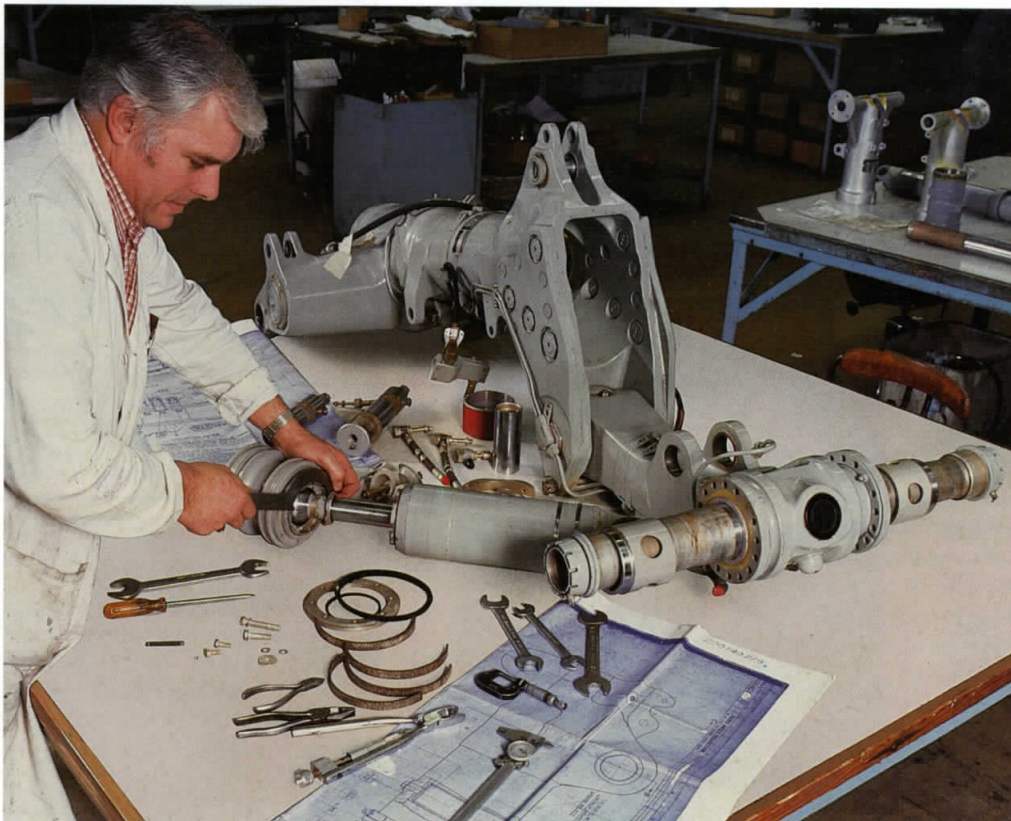




Customer training for landing gear maintenance



Technical illustrating for landing gear training courses and maintenance manuals



Assembling repaired landing gear

Publications support

Dowty Rotol maintains a Technical Publications Department within the design office staffed by technical authors and illustrators with many years experience in preparing complete sets of maintenance manuals. One set of publications is issued to each operator. Currently there are 1500 sets of manuals and over 50 000 copies in use by operators around the world.

Training support

It has been a long established Dowty Rotol custom to provide operators with courses of instruction on equipment they are utilising

- Use is made of all modern aids
- Manuals are provided for every trainee
- Concentrated courses are available for customer executives
- Full courses cover all equipment maintenance areas
- On-site instruction at the operator's facility is available

Repair and overhaul support

Dowty Rotol maintains workshops in the UK and USA staffed and fully equipped to deal with all aspects of repair and overhaul. Personnel from the Product Support Division regularly visit operator customers to ensure the optimum serviceability of landing gear equipment under all conditions.

Equipment exchange and leasing schemes are available. Such schemes are tailored to meet the needs and preferences of individual operators.

Another service of Dowty Rotol is to arrange repair and overhaul for landing gear equipment manufactured by other companies, including reverse engineering.

Panavia Tornado

The Tornado is fitted with Dowty Rotol main and nose landing gear, and associated hydraulics, also an emergency ram air turbine on the Air Defence Variant.



Airbus Industrie A310

The main landing gear is made in a collaborative arrangement between Messier-Hispano-Bugatti and Dowty Rotol. This gear has a bogie beam and axles carrying two tandem-mounted twin-wheel units.



Fokker F.27

For three decades over 750 F.27s have operated worldwide with Dowty Rotol main and nose landing gear, turbopropellers and accessory drive gearboxes all providing integrity and reliability.



British Aerospace 146

The 146 is fitted with Dowty Rotol complete landing gear and high lift systems. The main landing gear units shorten while retracting into fairings on the sides of the aircraft fuselage.



Fokker 50

The new Fokker 50 airliner incorporates Dowty Rotol landing gear, advanced technology turbopropellers, power drive unit for the flap system and the cabin door actuating system.



McDonnell Douglas AV-8B Harrier II

The AV-8B Harrier II utilises Dowty Rotol telescopic oleo-pneumatic main and outrigger gear, also a levered suspension nosewheel leg with nitrogen liquid spring mounted in tandem forward of the main leg.



Fokker F.28 Fellowship

The twin-jet F.28s rely on Dowty Rotol landing gear and associated hydraulics for operating from some of the world's most remote and rough airfields.

British Aerospace Harrier

Dowty Rotol landing gear, consisting of nose and main legs in tandem with two wing gears has been associated with the Harrier throughout its operating life and given exceptional service worldwide.

British Aerospace 748

The 748 uses Dowty Rotol landing gear, propellers and gearboxes. All landing gear units retract forward, the main wheel fitting into engine nacelles forward of the front wing spar.

Sepecat Jaguar

Design collaboration between Dowty Rotol and Messier-Hispano-Bugatti has resulted in DR manufacturing the single rearward retracting nose wheel and MHB making the twin wheel main units.

Shorts 360

The trailing arm type main landing gear, with stabilised locking and the steerable nose gear for the 360 are to Dowty Rotol design and manufacture.

British Aerospace ATP Advanced Turboprop

The Dowty Rotol nose and main landing gear for the ATP represent design advances on the well tried and proven units for the 748. The main gear is a new design and the nose gear incorporates a shortening mechanism for retraction and stowing.



British Aerospace EAP

The BAe Experimental Aircraft Programme (EAP) has Dowty Rotol landing gear, hydraulics, secondary power gearbox and leading edge flap system all configured for this advanced combat prototype.



Gates-Piaggio GP-180 Avanti

The Avanti landing gear is designed and built by Dowty Rotol to requirements in line with the overall concept to achieve the high speed capability of this revolutionary aircraft.



Casa C-101 Aviojet

Dowty Rotol designed both the nose and main landing gear, with nitrogen supplemented liquid springing, for the Aviojet trainer. The nose gear is made by DR while Casa manufactures the main gear under licence.



Fokker 100

The nose and main landing gear produced by Dowty Rotol for the new Fokker 100 follows F.28 production units with strengthening to meet the weight requirements of the new aircraft.



British Aerospace Sea Harrier

The Dowty Rotol landing gear variant for the Sea Harrier has special design refinements for carrier operations and in particular for ski-jump take-offs.



Airbus Industrie A320

The A320 will be fitted with Dowty Rotol designed main landing gear made in collaboration with Messier-Hispano-Bugatti. The leg is a simple, telescopic oleo-pneumatic unit with a side stay assembly folding during retraction.





DOWTY



THE QUEEN'S AWARD FOR
TECHNOLOGICAL ACHIEVEMENT

1984

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