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DEVELOPMENT OF THE GLOBAL EXPRESS: A SUCCESS OF INTERNATIONAL PARTNERSHIP

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First let me say how very pleased and proud I am to accept the International Council of the Aeronautical Sciences' Von Karman Medal on behalf of Bombardier Aerospace and our principal partners in the Bombardier Global Express business jet program:

- BMW Rolls-Royce;
- Mitsubishi Heavy Industries;
- Sextant Avionique;
- Liebherr-Aerospace-Toulouse SA;
- Lucas Aerospace;
- Messier-Dowty International (now Messier-Bugatti);
- Parker Aerospace;
- Honeywell Inc.; and,
- AlliedSignal Aerospace.

The ultra long-range Global Express will soon enter daily service with many of the world's leading corporate, government and individual customers. That milestone will be achieved less than eight years after the first designs were considered and less than five years after formal program launch.

The airplane is on time, on-weight and on budget, with its performance exceeding the initial specification.

I think that this is a significant accomplishment for any design and manufacturing team, and perhaps an even greater accomplishment for an all-new design and all-new way of designing, developing and building aircraft. However, before I get ahead of myself, perhaps I should begin at the beginning.

The Bombardier Global Express aircraft is a carefully considered response to the increasing globalization of business and international affairs.

While modern electronic systems such as telephones and the Internet carry much of the business and government communications burden today, there remains an important role for the long-range business aircraft. There is simply no effective substitute for bringing high value personnel together face-to-face.

Our early market research disclosed four important points in considering future business aircraft:

1. There has been significant growth in long-range missions, particularly those of 5,000 nautical miles and up. This is a direct reflection of globalization and the increasing role of Asian nations in the new world economy;
2. While mission length has been growing, so has overall reliance on corporate aircraft. In large measure, this is a result in changes to scheduled airline service;
3. More than 70 per cent of business leaders prefer the convenience of non-stop flights; and,
4. There was substantial demand for ultra long-range aircraft.

Clearly there was a market that was not being addressed, either by scheduled airline service, or by the then-current generation of business aircraft.

Today, many business and government leaders need to be in New York today, Tokyo tomorrow; or Paris today and Singapore tomorrow; or even Johannesburg today, and Hong Kong tomorrow. At first, this looks like a simple extension of the role of the inter-continental business aircraft, such as our Challenger 604.

On closer examination, however, the range and speed requirements — coupled with new standards in safety, productivity, comfort and reliability — called for a new approach, a clean sheet of paper. We subsequently estimated the total marketplace for such a product at between 550 and 800 aircraft, by the year 2010.

The all-new approach is necessarily more costly and entails a longer time-to-market than a derivative. To be completely fair, however, it must be said that in aircraft design, as in so many fields of endeavor, there is often more than one way to achieve a desired result.

But it should also be said that it is this same choice of different paths that permits the application of new technologies and which permits superior products to emerge.

Our analysis of the market's needs and the technologies available strongly indicated that a new design would serve our customers better over the long term.

Our understanding of the market led us to four specific criteria:

1. Superior long-range, high-speed, flexible operational capability;
2. The largest, most comfortable and productive cabin;
3. The very highest standards of reliability, maintainability and system redundancy; and,
4. Excellent value and product support.

These have been the four cornerstones of the Bombardier Global Express program, from the earliest days, beginning with the Preliminary Design Phase in 1991 and 1992, through to certification this year.

Let me turn now to some of the design philosophies that guided the development of the Global Express and which now permit it to fly farther and faster than any other corporate jet, current or planned.

The most significant design feature of the Global Express is its new wing, designed from the outset for the mission requirements of a truly global aircraft — not just longer range, but for higher long-range cruise speeds as well, without compromising the requirement for superior low-speed characteristics.

This is not a growth version of an older wing but a new design, which has been optimized for fuel efficiency at high cruise speeds and high altitudes, without compromising runway performance.

To maximize fuel efficiency, we developed a highly loaded wing to avoid the drag penalties, which grow with wing area. A highly loaded wing is also less sensitive to turbulence and delivers a smoother ride — and this is an important issue for passengers on a 14-hour flight.

High lift devices — for both leading and trailing edges — preserve superior runway performance and enable the Global Express to fly long-range missions while operating from comparatively smaller, general aviation airfields.

However, there is more to designing a superior wing than just wing loading and high lift devices.

Wing sweep, airfoil cross-section and trailing edge geometry all affect handling and all should be designed to deliver on mission objectives. The following techniques are employed on the Global Express wing to achieve the optimum configuration:

An advanced technology transonic airfoil with a 35-degree-swept leading edge — delays the formation and reduces the magnitude of the shock wave that develops over the wing at transonic speeds.

Large thickness-to-chord ratio — achieves the best compromise between maximizing fuel volume and minimizing drag and structural weight.

High aspect ratio — helps reduce wingtip vortices and span-wise migration of the airflow, thereby reducing induced drag.

Winglets — also help reduce wingtip vortices and thereby minimize induced drag.

Three-segment Fowler flaps — the wing's double-cranked trailing edge mandates use of three flap segments per wing and the Fowler flaps used are very effective high lift devices.

Four-segment leading edge slats — improve runway performance by allowing the wing to be flown at higher angles of attack. This results in slower, safer landing speeds and shorter runway requirements. In fact, Global Express will fly in at speeds as low as 104 knots.

Multiple spoiler panels — control descent more efficiently. Use of multiple panels also increases system reliability and availability. On the ground, all panels deploy to increase weight-on-wheels and thereby increase braking effectiveness.

A further major advantage of multiple panel spoilers is that they reduce the flight criticality of primary controls. Multi-function spoilers enhance the manoeuvrability of the aircraft in the event of jammed ailerons or rudder.

Buffet boundary — airliner manufacturers recommend a buffet boundary margin of 1.3g — the Global Express meets and exceeds this margin.

As a final word on the Global Express wing, it's worth noting that many modern airliner wings are designed to travel at Mach 0.85 to Mach 0.87.

To be fuel efficient, they have wing loading higher than business jets, current or planned. They also employ electrically driven high lift devices, as well as multiple spoiler panels, to improve altitude control and to enhance braking effectiveness — these are all reflected in Global Express.

Our engineering team made extensive use of computational fluid dynamics methods to design and optimize the wing and to tailor the nacelle-pylon-fuselage area for minimum drag.

With CFD methods, many configurations can be studied and optimized, before selecting the best candidates for wind tunnel testing.

CFD was employed earlier at Bombardier Aerospace in optimizing the wing for the 50-passenger Canadair Regional Jet airliner and, in total, the company has invested more than 80,000 direct hours in CFD methods development.

Our successes with this technology have been based on four factors:

- A specialized team of CFD engineers;
- Use of supercomputers, with powerful graphics;
- The latest CFD software and codes; and,
- Wind tunnel and flight test data to validate CFD solutions.

In designing the fuselage, our Flight Sciences group spent some extra time integrating the BMW Rolls-Royce powerplants and the airframe. Their efforts resulted in an area-ruled aft fuselage that almost eliminates shock wave formation in the pylon area, greatly reducing overall drag.

CFD was also employed to develop and optimize the high lift system for the Global Express wing.

Turning to the cabin of the Global Express, we relied heavily on the experience of our Challenger business jet, which introduced the widebody concept to corporate aviation in 1980 and, with a fleet of some 425 aircraft now in service, is the most popular aircraft in its class.

Our design goal is very simply stated — to provide a bigger, more comfortable cabin than any direct competitor, and here, we have also been successful, offering a total cabin volume of 2,140 cubic feet.

At 48 feet in length and six feet, three inches in height, the Global Express delivers 17 per cent more cabin volume and 26 per cent more floor space than our direct competitor.
More to the point, however, we have taken care to ensure that the cabin will be comfortable and productive. The fresh air availability is at least five times the minimum requirement and we have included an integrated humidity control system to enhance passenger comfort on long flights.

Selectable air recirculation also enables prompt pull-up and pull-down of cabin temperatures and the cabin itself is divided into three separate temperature control zones.

Cabin altitude — At the aircraft's maximum operating altitude of 51,000 feet, the cabin altitude is just 7,200 feet. At 45,000 feet, which many flight departments use as their maximum, the Global Express pressurization system maintains a cabin altitude of 6,000 feet; this drops to 5,000 feet at a cruising altitude of 41,000 feet.

Since most missions will be flown at these lower altitudes, the Global Express range guarantees do not rely on cruising at 51,000 feet.

Cabin noise — is just as important in assuring passenger comfort. Cabin noise is minimized through fuselage-mounted engines and auxiliary power unit located far aft of the pressure bulkhead. The air conditioning ducts are sized to reduce flow velocity; the use of a plug-type door with double seals further reduces noise.

As a result, interior noise levels are below the 50dB speech interference level.

Improved passenger view — The combination of larger windows and a lower floor greatly improves passenger viewing angles compared to those offered by the Challenger.

In addition, the entire pressurized area is outside the engine rotor burst zone. This enhances the safety of the passengers and the aircraft.

Completion — The 6,000-pound interior completion allowance was developed through defining a real-world completion, not scaling up an established design.

In addition, the Global Express completion allowance is highly realistic, as the basic "green" aircraft includes standard equipment — a third Inertial Reference System and a Traffic and Collision Avoidance System — which is optional on other aircraft and which therefore must be added to their completion weights.

A high standard of dispatch and mission reliability were also among our criteria for the Global Express. We met that requirement with extensive redundancy in major systems, including:

- Four independent electrical systems and five AC power sources, plus the ram air turbine;
- Three independent hydraulic systems, with a total of seven power sources; and,
- Triple hydraulically controlled flight control systems, plus dual motors for each flap or slat segment.

We are asking our customers for a significant investment to purchase a Global Express. With our investment in strong systems, Bombardier has assured operators that their aircraft will be available for dispatch and fully capable of completing its assigned missions safely.

Across the board, Bombardier has consistently followed a design philosophy, which has delivered the aircraft best suited to meet the needs of business and governments — not just today, but well into the next century.

As I noted earlier, this approach has cost more and resulted in us taking a bit more time to reach market than our competitors. But the result is an airplane, which has consistently exceeded our expectations. At each stage of the aircraft's development process more customers have become convinced of the merits of our approach.

Our marketing group has recorded significant increases in customer interest and order intake as we have passed major milestones in this program — including, first flight, in October 1996, and more recently, when the aircraft traveled to the NBAA and Dubai air shows.

Our order book stood at 75 aircraft shortly before certification last summer, and these aircraft are split evenly between U.S. and international customers. In 1997 we outsold the competition. With receipt of Transport Canada certification, which will soon be followed by FAA and JAA approvals, we are experiencing another surge of interest.

While developing and designing the Global Express to set a new standard in ultra-long range corporate aviation was one major challenge, building the airplane and getting it into service has been quite another.

The technical and business risks associated with developing a new aircraft or a new powerplant as a solo performance have long been recognized as being beyond the reach of all but the very largest manufacturers.

Although since entering the aerospace industry in 1986 Bombardier has become the world's third-largest civil airframe manufacturer, and the company has certificated and brought to market eight aircraft — with two more under development — the prudent course was to complete the design and manufacturing through an innovative risk sharing partnership.

In this structure, Bombardier invited the participation of a number of world-class suppliers, on a risk-sharing basis.

On the Global Express program, our partners include nine companies in six countries:

- BMW Rolls-Royce, of Germany, on the powerplants;
- Mitsubishi Heavy Industries, of Japan, wings and centre fuselage;
- Sextant Avionique, of France, flight control systems;
- Liebherr-Aerospace-Toulouse SA, also of France, for the environmental controls;
- Lucas Aerospace, of the United Kingdom, for the electrical system;
- Parker Aerospace, of the United States, for the fuel and hydraulic systems;
- Honeywell Inc., U.S., avionics;
- AlliedSignal Aerospace, U.S., for the APU; and,
- Messier-Dowty International, of Canada, for the landing gear system.

Of course, all of our Bombardier Aerospace units in Canada, the United States and Northern Ireland are also involved:

- Canadair provides overall program leadership in conceptual and aerodynamic design, work package interfaces, certification, marketing, sales and customer support;
- Canadair also designed and produces the nose fuselage and shares responsibilities for the vertical stabilizer, rear fuselage and pylons with de Havilland;

- Shorts in Belfast, Northern Ireland, provides the forward fuselage, horizontal stabilizer, body fairings and other composite structures;
- Final Assembly is conducted at the de Havilland plant in Toronto; and,
- Learjet in Wichita directs the flight test program, through the Bombardier Flight Test Center.

Through this business structure, Bombardier capitalizes on leading technologies inside and outside its organization. The company is also able to diversify risk and promote efficiencies by distributing work across a broader base. Finally, the aircraft program is able to develop a favorable schedule to capitalize on the strengths of all participants.

The business structure Bombardier selected for the design, development, construction and support of this aircraft was unique at the time but has since been applied to more recent programs. These include the 70-passenger Dash 8Q Series 400 turboprop and the Canadair Regional Jet Series 700 airliners.

The same partnership structure was successfully implemented on a somewhat smaller and narrower scale — on a purely internal basis — beginning with the design and construction of the Canadair Regional Jet airliner, which was certificated in 1992.

More recently, the new Learjet 45 was developed using this approach. In this case, de Havilland designes and builds the wings Shorts the fuselage, while Learjet retains overall program direction, design authority and responsibility for certification.

I think it's worth pointing out that although Bombardier's business structure does have some risk-sharing attributes in common with the Airbus type of partnership, the two are otherwise dissimilar.

In our structure, Bombardier remains the leading partner, with overall program responsibility. All program partners are obliged to Bombardier under contract for the complete discharge of their responsibilities.

This will be particularly important to customers for the continuing support of their aircraft over the coming 20 or more years.

In many regards, Bombardier's partnership structure for the development, production and continuing support of the Global Express resembles that of a company whose major players have been brought together specifically for a single project, such as a major motion picture. This may be the forerunner of the so-called virtual corporation.

This risk-sharing partnership works well for us and for this industry. As I noted a moment ago, this structure is being employed in the Dash 8Q Series 400 — now in test flight — and the Canadair Regional Jet Series 700 — which is scheduled to fly next year.

The same approach will also certainly be applied to any new development programs Bombardier undertakes, and this would include the proposed new-generation Super Mid-Size Business Jet.

Following the formal program launch in late 1993, the activity advanced to the joint definition phase, based in Montreal. The Global Express workforce grew substantially, as new partners and suppliers joined the team, ultimately reaching 30 companies, and more than 500 engineers and specialists from Bombardier and our partners, working together on-site.

The engineers were supported by more than 300 computerized workstations for technical analysis and the latest in CATIA 3-D model designs.

Looking at all the functions represented, the Global Express development program required the resources of more than 2,700 engineers, several super computers, hundreds of state-of-the-art, Unix-based engineering workstations, a pilot-in-the-loop re-configurable engineering simulator, and comprehensive flight test, structural and systems test facilities.

During this joint definition period all the structural and system configurations were defined and work package interfaces were developed.

The joint definition phase concluded with an extensive series of in-depth exit reviews to ensure that the aircraft could be built as intended, and to ensure that all systems on the aircraft would work together properly.

Detail design and early fabrication began in 1995. It focused on four major structural design and manufacturing centres:

- Montreal, for the flight deck;
- Nagoya, for the wing and centre fuselage;
- Belfast, for the forward fuselage and horizontal stabilizer; and,

- Toronto, for the rear fuselage and vertical stabilizer.

At the same time our systems partners were completing their own development programs and proving their products with test rigs. Bombardier also continued to manage the integration team with its partners, continued aircraft development and configuration control.
Final assembly began in 1996, and at this time our integration team and all partners sent representatives to Toronto to support the process there.

Our own team included more than 100 engineers and our partners contributed a further 35, which subsequently grew to 50 as first flight approached. During this period functional testing of all aircraft systems progressed as well.

The Global Express was rolled out in August 1996, and took to the air for the first time in Toronto on October 13, 1996 in a two hour and 46-minute flight that I'm pleased to say was completely routine. The aircraft paid a surprise visit to the Bombardier Aerospace head office in Montreal at the conclusion of its second flight, on October 25.

Following some initial test and shakedown flights, the first Global Express aircraft was ferried to the Bombardier Flight Test Center at Wichita, Kansas where it promptly began the flight test program.

In all, we have employed four aircraft in the flight test program and built up about 2,000 total hours prior to certification. Following a fairly standard flight test protocol, Aircraft 9001 was used to evaluate performance and stability; Aircraft 9002 for systems and powerplants; Aircraft 9003 for avionics; and, Aircraft 9004, which has a completed interior, for further performance evaluations, as well as final function and reliability testing.

In fact, Aircraft 9001 is the only unit which will remain as a test vehicle, as the others will be refurbished and sold.

Within the first 80 hours of flight testing it was apparent that — due to fuel volume availability, the engines' specific fuel consumption, aircraft empty weight and aircraft drag, that the Global Express would exceed our original range performance estimates.

Accordingly, we were pleased to announce a range increase of just over three per cent, from 6,500 nautical miles, to 6,700 nautical miles, at the long range cruise speed of Mach 0.80. At the design cruise speed of Mach 0.85, range increased from 6,330 nautical miles, to 6,500 nautical miles. This increased range opened up even more non-stop cities pairs to the Global Express, including: New York - Capetown; Paris - Santiago; and, Hong Kong - Chicago.

The flight test program was unexceptional, and confirmed the simulations and wind tunnel findings. In-flight handling is excellent and low-speed and ground handling is extremely pilot friendly — this is an aircraft pilots love.

The flight test program also confirmed that the Global Express is a very quiet aircraft from the outside, as well as on the inside. In all, the aircraft completed the three components of the community noise test with a cumulative margin of 19.8 dB over FAR 36, Chapter 3 limits. The aircraft proved to have the biggest noise margin on the approach, where it was 8.9 dB quieter than the current regulations.

The first Global Express aircraft — a company demonstrator — will enter service very shortly, to be followed almost immediately by the first customer aircraft.

The challenge we now face is to ensure a smooth entry into regular corporate service. I'm sure you'll appreciate that introducing two, all-new business aircraft within a period of about six months is a major undertaking for any organization.

On the maintenance and spares side for the Global Express, we have already received approval for the maintenance program and the Maintenance Review Board report was submitted to Transport Canada.

The aircraft technical manuals are complete and will be delivered with the aircraft, and the initial spares inventories have been ordered and are being positioned at strategic locations around the world.

The company has also expanded its technical support facilities for the aircraft. Bombardier Aviation Services in the United States and our joint venture, Lufthansa Bombardier Aviation Services in Europe, are factory-standard service centres for the aircraft. We are actively scouting additional support centres to look after customer aircraft in other parts of the world.

A Global Express flight simulator has been operational at our training centre in Montreal since early summer and this is now certified to Level C. Flight instructors have received training at Wichita and the first customer pilot training courses began in mid-summer. The initial maintenance training sessions began even earlier.

Across the company, Bombardier has been placing heavy emphasis on ensuring that our customers are able to obtain the very highest degree of availability and productivity from their aircraft, virtually from the moment of delivery. We have made it a corporate policy not to impose our ramping-up time or other typical new program shortcomings on our customers.

With a successful certification and flight test program behind us, we can be sure that the Global Express will deliver the performance, the reliability and the value that we have been claiming since the beginning of this program, more than five years ago.

We have proved that it is possible to design and build a large and modern aircraft at a variety of different points — literally around the globe — and separated by thousands of miles, hours of time zone differences and many different cultures.

And we have proved that it is not only possible, but desirable, to harness the creative talents and expertise of a diverse team and bring them together to create a superior product to serve customers' needs well into the next century.

Our partners have been there with us every step of the way over the past five years and they have shared fully in every success and every setback.

It has been rewarding to participate in a project that has involved so many specialists working together on a common objective, across both national boundaries and cultural differences, to achieve what many people said was impossible.

May I say again, on behalf of Bombardier Aerospace and all our partners in the Global Express program, thank you for this recognition and for rewarding our efforts.

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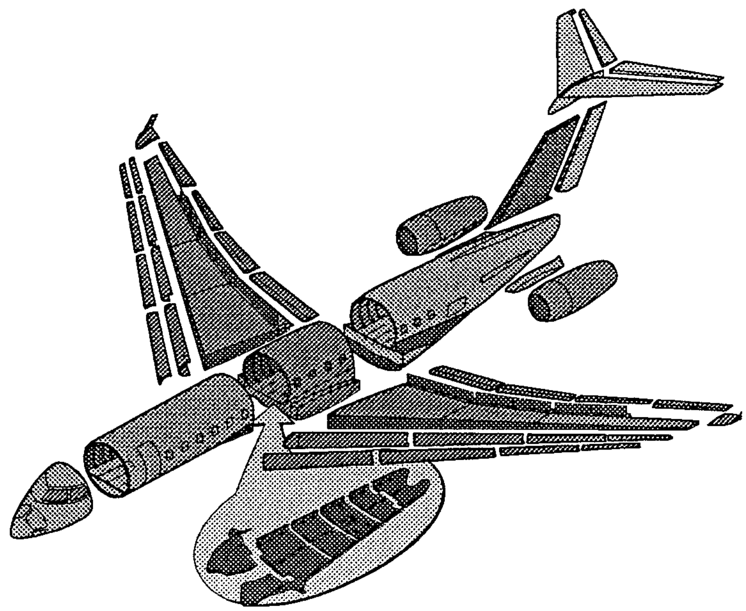
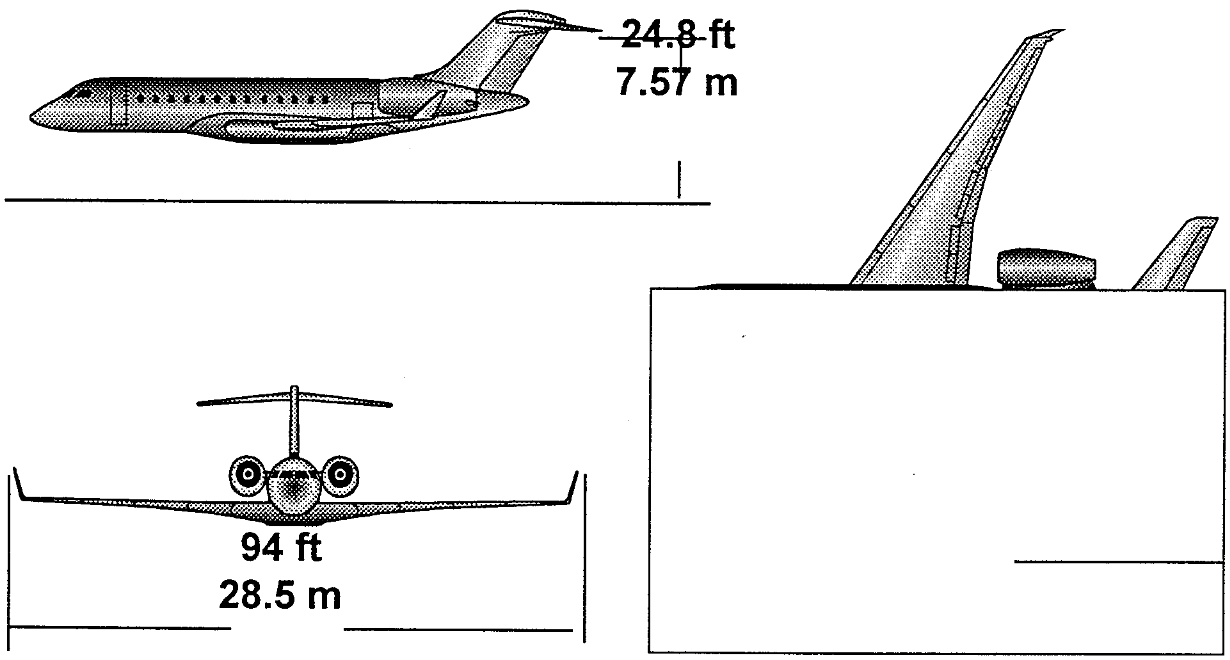
Design Certification Authority	Bombardier

1. Nose Fuselage	Bombardier
2. Forward Fuselage	Bombardier
3. Wing / Center Fuse	Mitsubishi
4. Rear Fuse and Pylons	Bombardier
5. Power Plant	BMW Rolls-Royce
6. Horizontal Stabilizer	Bombardier
7. Vertical Stabilizer	Bombardier
8. Body Fairing & other composite (excl. wing)	Bombardier
9. Landing Gear System	Messier - Dowty
10. Flight Control System	Sextant Avionique
11. Fuel System	Parker Aerospace
12. Avionics	Honeywell
13. Electrical	Lucas Aerospace
14. APU	AlliedSignal Aerospace
15. Air Management	Liebherr Aerospace
16. Hydraulic	Parker Aerospace
17. Pitch Feel	E-Systems
18. Lighting	Hella KG

19. ISTR	Bombardier
20. Static / Fatigue Tests	Bombardier
21. Flight Test Program	Bombardier
22. Final Line	Bombardier





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