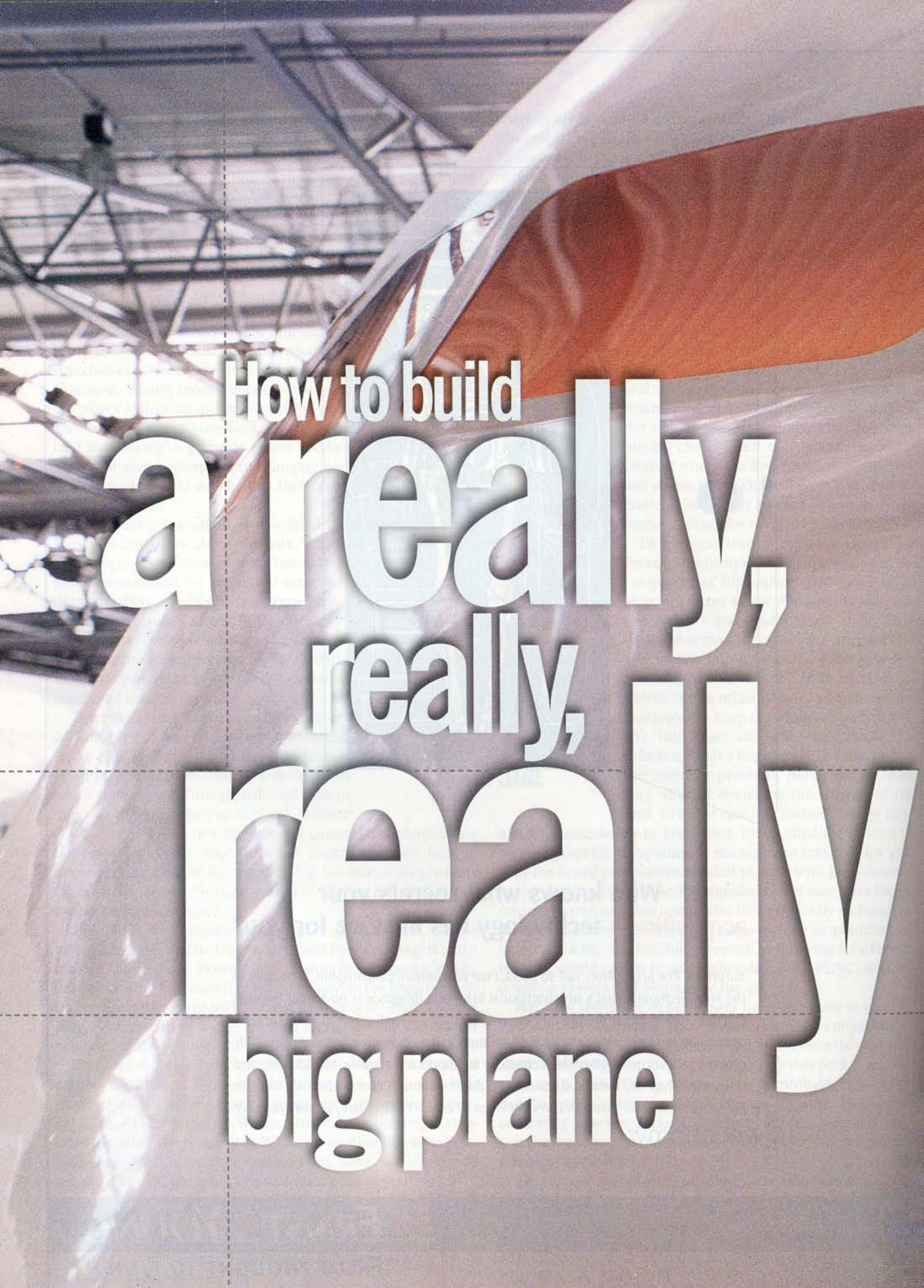
How to build a really, really, really big plane



PHOTOGRAPHS BY GERARD RANCINAN—CORBIS SYGMA

Airbus is betting that what the world needs is a 555-passenger megaliner. Boeing has an idea that's almost as big, and a lot cheaper.

by Stuart F. Brown

Through the window of Robert Lafontan's office in Toulouse, France, a porky Beluga aircraft can be seen lumbering skyward after disgorging a big chunk of a jetliner from its belly at the nearby Airbus Industrie assembly plant. On his laptop computer the soft-spoken engineer-pilot is running through a sequence of drawings that portray a stout-bodied, four-engine airplane—a really big double-decker. As one image morphs into the next, the fuselage thickens and thins a bit, the wings sweep fore and aft a degree or two, doors change location, and a host of other features shift slightly while he reviews the many layouts Airbus considered before settling on the design for its A380 megaliner. Lafontan is vice president of engineering and product development at the company's large-aircraft division, which is charged with designing and building the big bird, planned for entry into airline service in 2006. Calling up a chart showing the materials that will be used to build the major structures of the 555-passenger jetliner, Lafontan points to what he says was one of the most difficult decisions: to fabricate the ten-ton "wing box" from carbon composite, the same stuff the bat-shaped stealth bomber is made from. The most massive structural component of any airplane, the wing box runs through the lower fuselage, and ties the wings into the rest of

Looming large in a Toulouse hangar, a full-scale mockup of the Airbus A380 gives prospective buyers a taste of gigantism.

Two full-length decks will distinguish the Airbus A380 from everything else in the sky.

the craft. It bears huge loads during takeoffs and landings, and when flying though turbulence. Carbon composite has a very attractive strength-to-weight ratio compared with traditional metal alloys. But it's tricky stuff to laminate into a massive section of an airplane's skeleton while ensuring that there are no internal defects that could cause a loss of strength over time.

Team Airbus (left), led by Phillipe Jarry, Robert Lafontan, and Jurgen Thomas. Above, Boeing's John Roundhill, Walt Gillette, and David von Trotha, with a model of a 747X Stretch Freighter.

Think of Lafontan as a general preparing to fight one of history's all-time great battles between rival makers of people-carrying machines. The competition is also an exercise in probing the limits of gigantism, the elusive point beyond which more starts to become less. Lafontan is specifying advanced materials like carbon composite because he has no choice. "If I just try to copy the way the 747 is built," he says, "I will never achieve our goals, never." The A380 has the venerable 747 squarely in its sights and aims to carry more passengers farther, at an operating cost about 17% lower, than the Boeing flagship.

If Airbus had to worry only about beating the 747's operating costs while carrying one-third more people with its megaliner, the Europeans might be breathing easy right now. But Boeing has countered with its proposed 747X family of derivative planes, which could match the A380's service-entry date and carry as many as 522 passengers. The 747X will emphatically not be a full-length double-decker. "I'm on record that I don't want to be chief engineer on a double-decker airplane. Every time I went to bed I would worry about how many people might be injured or killed trying to get down the escape slides in an emergency," says Joe Sutter, who was chief engineer on the original 747. Now retired, Sutter consults at Boeing.

Hanging on a wall in Boeing's product-development and design department in Everett, Wash., are detailed models of possible successors to the mighty 747 that the company has studied over the years. Several of them have full-length double decks, like Airbus' A380, yet engineers like Sutter are eager to explain why Boeing still thinks a single main deck is the way to go for the 747X planes they're cooking up.

It's the job of these engineering teams on two continents to push and pull on airplane shapes and internal arrangements of components, weighing the costs and benefits of endless design "trades" affecting aerodynamics, fuel consumption, packaging of passengers and cargo, ground handling, and a multitude of other variables. Both teams are searching for the blueprint of a megaliner that can satisfy the needs of a majority of airlines while someday earning a profit for the company.

The airplanes that the designers have come up with look quite different, because when the forecasting people in Toulouse and Seattle read the tea leaves, they see different worlds. The two things they agree on about the evolving air-travel market over the next 20 years are that growth will average about 5% per year and that there certainly will be a market for some megaliners, bigger-than-ever jet planes carrying 500 and more passengers. But how many megaliners? About 1,500, Airbus thinks. No, Boeing says, the market's only about 500 planes deep.

Airbus estimates that it will need to spend $12 billion to develop the A380. So

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far six airlines, including elite Singapore Airlines, have signed up for 50 of the huge planes. Most recently, FedEx ordered ten freight-hauling versions. Singapore Airlines CEO Cheong Choong Kong heralded the big Airbus as the answer for the crowded airports his airline serves. "A larger aircraft will allow us to carry more passengers without having to get additional landing slots," he said. Boeing won't say exactly what the 747X program will cost, but it's rumored to be as little as one-quarter to one-third of the A380's budget, making profits possible on a much smaller number of sales.

Airbus set the megaliner competition in motion last summer by offering the 555-passenger plane, then dubbed the A3XX, to potential airline customers. Had Airbus not made the first move, Boeing probably would have been content to just keep on building its 747, which earns a handsome profit. That's because there's no pricing competition for the so-called queen of the skies, which has been in production for 30 years and in its current 747-400 version can carry 416 passengers.

Conceiving a significantly more efficient airliner today is no mean feat. Operating cost per passenger seat-mile, the airline industry's performance yardstick, improved by a whopping 25% when the late 1950s–era Douglas DC-8 and Boeing 707 were superseded by the wide-bodied 747, which more than doubled the number of passengers that could be carried. Technological progress was booming in those days. Among the big gains was a move away from the 707's primarily sheet-aluminum construction to lighter sandwich structures made with honeycomb-core material. Aerodynamicists were busy figuring out how to improve the efficiency of wings. (For comparison, a modern jetliner scores a lift-to-drag ratio of at least 20 to one; the stubby Space Shuttle is about four to one, and a slender-winged sailplane can get 60 to one or better.) Perhaps most important, jet engine designers were achieving giant strides in fuel efficiency (see box) by replacing noisy, gluttonous, cigar-shaped turbojets with quieter, fatter fanjets.

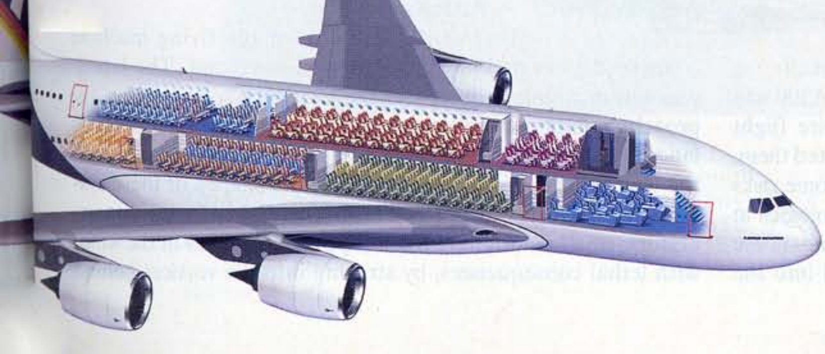
"When I first started working here you could count on an accumulated wealth of new technology every ten years that would let you replace your existing product with something irresistible," says David von Trotha, Boeing's chief engineer for 747 product development. "Now when we draw up paper airplanes, we can't assume those kinds of breakthroughs are available." To gain further operating efficiencies this time around, the megaliner engineers will have to make masterful use of the big planes' interior volume and extract the most sturdiness from the lightest possible structure. And they know they must keep the dimensions within the 80-meter-square box that major airports consider the maximum space an aircraft should occupy.

Because their development costs are so dauntingly high, new airplanes are conceived not as stand-alone products but as eventual families of related birds that will share many components. Airbus plans to initially roll out a 555-passenger A380 that could grow through a subsequent fuselage "stretch" into an A380-200 with 656 seats. Like ships, aircraft are built with a smooth, stressed skin wrapped around an internal skeleton. The European megaliner's structure will be a mosaic of trendy materials.

In addition to its massive carbon wing box, the A380 will have an upper fuselage skin formed with a recently developed lightweight material, called GLARE, that's made from glass-fiber tape bonded between thin layers of aluminum. Aluminum skin panels for the lower fuselage will be manufactured using a continuous laser-welding process to attach the longitudinal internal stringers that impart stiffness. (Riveting, the traditional method of fabricating such panels, would require the use of slightly thicker metal to avoid stress cracking around the rivet holes.)

STACKED UP

Airbus thinks it has overcome long-standing objections to double-decker planes —like inadequate emergency evacuation.



Fans spinning on a broomstick: how they make big birds fly

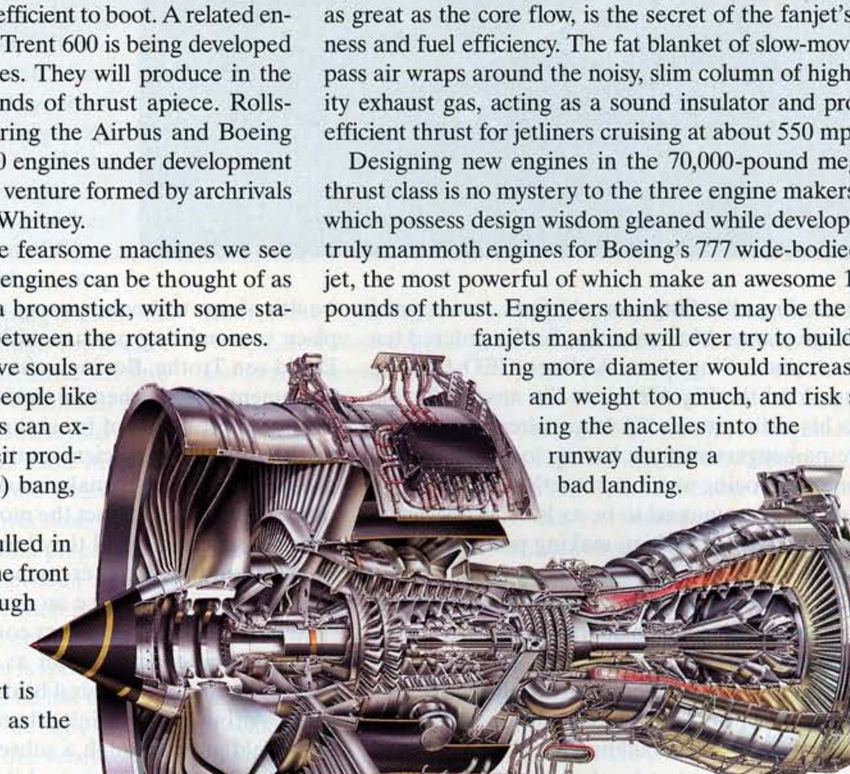
The magnificently complex device shown here with part of its exterior peeled away is a Rolls-Royce Trent 900 fanjet engine, the type that Singapore Airlines has selected to power its Airbus A380 megaliners. Designed to comply with Heathrow Airport's new noise standard, the world's strictest, it will be one of the quietest aircraft engines in history and extremely fuel-efficient to boot. A related engine called the Trent 600 is being developed to power Boeing's 747X planes. They will produce in the neighborhood of 70,000 pounds of thrust apiece. Rolls-Royce's competitor for powering the Airbus and Boeing megaliners will be the GP7000 engines under development by the Engine Alliance, a joint venture formed by archrivals General Electric and Pratt & Whitney.

What exactly is inside those fearsome machines we see hanging under the wings? Jet engines can be thought of as a bunch of fans spinning on a broomstick, with some stationary blades interspersed between the rotating ones. After making sure any sensitive souls are out of earshot, the jet-engine people like to explain that just four words can express what goes on inside their product: (1) suck, (2) squeeze, (3) bang, (4) blow.

In the suck phase, air is pulled in through the big inlet duct at the front and squished as it flows through the several stages of the engine's low-pressure compressor section. The squeeze part is really just more of the same, as the high-pressure compressor's multiple stages further increase the pressure of the air, to about 25 times what it was before entering the engine. After all this sucking and squeezing, the air has become quite—pardon the expression—hot. When it enters the combustor section and high-grade kerosene (a.k.a. jet fuel) is sprayed in, we get the metaphoric bang of combustion; actually it's more of a roar. Now the expanding hot exhaust gas needs somewhere to go, so it blows out the back of the engine. On its way out, the gas spins turbine wheels, which in turn power the compressor sections at the front of the engine. And because every action has a reaction, the engine reacts against the thrust of the escaping exhaust by moving forward, pushing the airplane along with it.

Today's fat fanjets have a very large-diameter fan section at the front end that pushes a large quantity of "bypass air" through a big duct wrapped around the turbine core. This bypass flow, which in the latest engines is about eight times as great as the core flow, is the secret of the fanjet's quietness and fuel efficiency. The fat blanket of slow-moving bypass air wraps around the noisy, slim column of high-velocity exhaust gas, acting as a sound insulator and providing efficient thrust for jetliners cruising at about 550 mph.

Designing new engines in the 70,000-pound megaliner thrust class is no mystery to the three engine makers, all of which possess design wisdom gleaned while developing the truly mammoth engines for Boeing's 777 wide-bodied twinjet, the most powerful of which make an awesome 115,000 pounds of thrust. Engineers think these may be the largest fanjets mankind will ever try to build. Adding more diameter would increase drag and weight too much, and risk smacking the nacelles into the runway during a bad landing.



All of this is in keeping with the European consortium's long-standing strategy of aggressively adopting new ideas and technology to differentiate itself from Boeing and McDonnell Douglas, which Boeing acquired in 1997. The Airbus A300 was the first twin-aisle, twin-engine jetliner, and fly-by-wire flight controls appeared on Airbus planes before Boeing adopted them. "When you are the challenger you are forced to take some risks and be innovative—but when we introduce new technologies in the A380, we are not starting from scratch," says Lafontan. He points out that most of the new stuff being designed into the megaliner has already been proved in other Airbus models.

Part of designing a salable flying machine these days is making sure it's a good citizen. The latest-generation engines are so quiet that the lion's share of an approaching jumbo's noise comes from the air roaring around its landing gear and extended wing flaps, so to minimize the din the wind-tunnel boffins are finessing the shapes of these systems. Wake-vortex turbulence is another worry for airport operators; small planes have been flipped like leaves in the wind, with lethal consequences, by straying into the vortices behind

The A380 lounge as fantasized by Airbus. Will any airline use priceless real estate this way? Virgin says it's considering the idea.

a big jet. Airbus researchers have been firing A380 scale models through a smoke-filled tunnel to see if subtle shape changes weaken the invisible but powerful horizontal tornadoes spiraling off the wings. Making the A380's wake no rowdier than a 747's is the goal.

Lafontan is a pilot, and one of his pet cockpit features for the A380 is a taxiing aid that shows the crew a map of the airport and where they are at the moment. "A teenager can fly an approach these days, but to find the taxiway and the gate in bad weather conditions can be very hard. It has happened to me. This is a commonsense safety improvement that we already have in our cars, so why not in the planes?" he asks. Such a feature might have helped prevent the recent nighttime tragedy in Taipei in which a Singapore 747 crashed while mistakenly trying to take off from a runway that was closed for repairs.

Dual rows of windows running the full length of the fuselage are what will make the A380 instantly recognizable, just as the 747's bulging forehead sets it apart from everything else in the sky. Probably the biggest design challenge in going from one deck to two involves an international certification requirement: Airplanes must permit the evacuation of all passengers within 90 seconds.

Engineers at Airbus have convinced themselves that a double-decker can pass the test. There's plenty to worry about. People evacuating the upper deck must arrive on the ground via inflatable slides at a slow enough speed to avoid serious injury. And when there's not an instant to spare, they have to be willing to hop on the long slides without hesitating. This concern has led to consideration of covered slides that would reduce evacuees' potential fear of heights. The slides also have to work properly in windy conditions without getting tangled up, or when the plane is cocked at an odd angle because of collapsed landing gear.

Which brings us to crashing. It seems as though everybody's first reaction to the idea of a megaliner is "What a lot of people to kill all at once!" And it would be. What isn't widely known is that in Japan and France, 550 and more passengers are routinely crammed aboard 747s fitted out with a grim, cattle-car seating configuration. Comfy this is not, but cost-conscious folks put up with it. Megaliners would take it a giant step farther. Configured all in cheap seats, a stretched A380 could carry 800 people, a number that just boggles the mind.

The people in charge of selling Airbus' megaliner have a whale of a sales tool in their recently completed full-sized fuselage mockup. Proud to show it off is marketing development vice president Phillipe Jarry, a jovial fellow who tools around Toulouse in a red Citroën Deux Chevaux with a customized rear deck reminiscent of a 1930s Ford coupe. With a flourish, M. Jarry escorts a visitor through the mockup's forward door and into the ocean-liner-esque entryway.

That's where the grand staircase—a conversation piece that outclasses the original 747's spiral stairs—beckons passengers assigned to the upper deck. Slightly aft of the escalier is a way stylish lounge with a cocktail bar and ultramoderne seating/eating/sleeping pods sculpted by the British design firm Priestman Goode, which specializes in vehicle interiors. But wait a minute. With airline decontrol sweeping the globe, and the bottom line at the top of every airline exec's agenda, can any customers actually be expected to use priceless cabin real estate in this way? Jarry knows what to say: "It is our job to show them the possibilities."

Many people remember bygone piano bars in 747s, but they may not recall that the operators of those aircraft were having trouble filling them at the time. When business got better, out went the pianos. "When you take out seats to put in amenities it becomes expensive, and you're putting weight in there as well. I don't see how that's going to fly," says Morgan Stanley airline analyst Kevin Murphy.

The cost of developing derivative versions of an aircraft is hugely less than that of an all-new one because a large number of components, and the factory tooling to make them, are recycled into the new model. On the 747X planes, for example, 105-inch-wide "wing-root inserts" are grafted between the fuselage and standard-issue 747-400 wings, adding span and the lift needed to carry greater weight with a minimum of unique hardware. The stretch version gets a 31-foot-longer fuselage via the addition of two cylindrical "plugs" spliced in fore and aft of the wing.

continued

Stretching a venerable design can deliver a payoff beyond the development and manufacturing savings. According to figures published by both "airframers," as their airline customers call them, the A380, in spite of the exotic materials used in its construction, will have an empty weight per passenger about 15% greater than the 747X Stretch. Thus while the Airbus will be able to carry more passengers across the oceans, it will burn appreciably more fuel per person in doing so. The reasons have to do with family values. When the first aircraft in a new family is designed, certain major components must be overbuilt to serve in the larger, heavier versions that will follow. In the case of the A380, its large wings and stout landing gear lend heft to the first model that would be better amortized in a subsequent stretched version. Engineering boss Lafontan sees it this way: "Tolerating some weight is a good investment if it permits derivative models. The 747 has been like this, too." The good news for Boeing is that in the process of being stretched out the 747 has become more structurally efficient, with benefits that show up in the fuel bill. Although the company has yet to book a single 747X order, you can bet that the sharp pencils at the airlines are studying that energy efficiency more closely than ever by now.

Boeing's engineers say that almost every 747 follow-on study they have conducted—except one exploring a really huge 800-passenger plane—has started out with a double-deck design, which then evolved into a single-decker as all the issues were hashed through. One reason is that two decks make the planes shorter, with less of the constant-section fuselage that provides an efficient package for everything. Worries about safe evacuation are another major reason.

Boeing can be aptly described as a technologically conservative company. Accordingly, the 747X would be built using far more aluminum-alloy structures than the big Airbus. "That's an area where Airbus has differentiated themselves," says von Trotha. "You can build a big sheet of bonded material like the GLARE Airbus is using in their upper fuselage, and if there are no production defects and it all goes together perfectly, it's a beautiful thing. But if you need to make a repair, you have to take a big chunk of skin off the fuselage rather than making a local patch."

There's a cautionary tale that everybody in the aircraft industry knows. It's the story of how Lockheed and McDonnell Douglas committed mutual fiscal suicide by launching very similar airplanes, the L-1011 Tristar and the DC-10, into a market that had room for only one profitable entry. Heeding this lesson of history, Boeing and Airbus together embarked in 1993 on a study of the prospects for what was called the Very Large Commercial Transport, which they considered producing jointly.

The Boeing-Airbus collaboration lasted two years, after which the pair concluded they weren't going to build anything together. Boeing went off and started work on a 747-500/600 design, which it then decided would have to be all new and therefore too expensive to justify. And in early 1996, Airbus embarked on the A3XX program. Some people in Toulouse felt that the joint study with Boeing had merely been a ploy to prolong the 747's dominance. Top Airbus salesman John Leahy, whose cell-phone dealmaking never quite ceases, recalls, "It would have made an interesting case study at Harvard, because it would have been the first time a monopolist took his biggest cash cow and entered into a joint venture with his No. 1 competitor—to compete with himself."

The contrast in world views between the two megaliner contenders is stark. Since the U.S. airline industry was decontrolled back in 1978, air traffic worldwide has boomed, loading up international hubs such as Paris, London, New York, Los Angeles, and Tokyo. At the same time, the development of twin-engine, long-range aircraft like the Boeing 767 and 777 and the Airbus A330 have made it viable for the airlines to offer nonstop service between new city pairings such as Dallas and Osaka.

Boeing's market forecast sees the world jet fleet as more than doubling by 2019, to almost 32,000 aircraft, most of them twins. During the same period, the company expects the 747-and-larger slice of the pie to actually decline, from 7% to 6%, although in dollar terms the big, expensive birds would of course account for a larger share. Boeing's bigger-than-747 megaliner market forecast sees about 330 passenger planes, plus an additional 170 freighters, bringing the total to just 500 aircraft. "Regardless of how you characterize the long-term market, there are not going to be 300 or 400 of these large airplanes sold in the first five years," says Michael Bair, VP of marketing management. "You can march down the list of airlines, but you just can't find who's going to buy them all."

Airbus doesn't care that Boeing's market forecasting is highly regarded. The people in Toulouse think it's far too pessimistic about megaliners. They believe about 1,200 passenger megaliners and 300 freighters can be sold. "The cake is getting bigger," says Jarry. "The airlines are requesting more productive airplanes with more volume and range. The only way to get lower operating cost is to aggregate the number of people and tons that you fly together on a bigger airplane."

Cathay Pacific Airways is one carrier mulling the megaliner option. "We are receptive to looking at the 747X and the A380; both are contenders for our future," says technical VP Peter Gardner. "Like most operators, we don't think any airline is likely to order more than 25 of these large airplanes from a particular supplier."

Are the new megaliners the end of the road in terms of airliner gigantism? Will there someday be even larger birds? Many engineers think that anyone trying to go much bigger would run afoul of a physical principle called the square-cube law, which states that when an object's volume is cubed, its surface area only squares. Elephants have immense ears because of the square-cube law. Their bodies have a relatively small surface area, considering how massive they are, and the critters would overheat without those blood-rich ears to serve as cooling radiators.

As with pachyderms, when an airplane's size and weight increase, the amount of surface area available for lifting devices such as wings gets proportionally smaller. What's known as the wing loading starts to increase, along with takeoff and landing speeds. At some point, the ultra-mega-super liner starts to turn into an overweight, fuel-gobbling, scary-to-land loser you'd be crazy to build. "We have laid out airplanes in size increments all the way up to 1,000 passengers," says John Roundhill, Boeing VP of product strategy and development. "As they get bigger you can see them getting heavier and less structurally efficient. I think 1,000 passengers is past the stupid point on that curve." It's as if the laws of physics were saying: Yo, genius. For that, you want *two* airplanes. F

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