Gulfstream V-SP

Up to 400 miles more range at high-speed cruise, increased usable cabin space, next-generation Primus Epic avionics and more standard features.

By Fred George

Photography courtesy of Gulfstream Aerospace

In late 2000, just when the competition thought Gulfstream was getting smug about celebrating the 100th sale of its ultra-long-range G-V, the firm surprised the market and upped the stakes. Gulfstream launched the G-VSP, an aircraft that, when compared to the G-V, would offer more range and speed, more usable cabin and baggage volume, shorter takeoff distances and lower direct operating costs.

Recently, we had an opportunity to fly the G-VSP prototype, serial number 632, on the 35th test flight. We also had time to discuss the program's progress with Gulfstream officials. The G-VSP, when it reaches customers in mid-2003, will have a maximum range of 6,750 nm at 0.80 Mach and a tanks-full payload of 1,600 pounds to 1,800 pounds. At this point in the program development, officials have high confidence the aircraft will meet this goal. Having these credentials gives the G-VSP the ability to fly eight passengers nonstop from New York to Tokyo. Gulfstream virtually guarantees this capability. (See "Qualifying Long-Range Claims" sidebar.)

The original G-V could fly from New York to Tokyo only subject to several conditions, and when those conditions were not met — about 40 to 50 percent of the time — the aircraft had to make a refueling stop.

In spite of this, the original G-V has a slight range advantage over the Bombardier Global Express, as well as the Boeing Business Jet and the Airbus Corporate Jetliner. It also beat the others to market by almost one year. Gulfstream, as a result, has logged more sales (for the G-V) than any other ultra-long-range competitor. At the end of 2001, there were 175 G-V orders and 100 aircraft were in service. This year, Gulfstream will build its 200th G-V. At the end of the year, G-V production will cease and G-VSP production will begin.

Why? One reason is that the "subject to" long-range mission limitations created a crack in Gulfstream's ironclad defenses against competitors. There are a dozen or so related aircraft in B/CA's May 2001 Purchase Planning Handbook, some of which are half the cost of the G-V, that can fly from New York to Tokyo with one refueling stop. Gulfstream didn't want its $43 million flagship to sink into that class.

So, the firm's engineers went back to their computers tasked with making the G-V a better aircraft, just as they did in 1994 when the G-IV was superseded by the enhanced-performance G-IVSP. Its aerodynamics are being fine-tuned in two dozen ways to increase range by 250 nm to 400 nm at 0.80 Mach and faster cruise speeds. Aircraft empty weight is going down, and MTOW is going up to boost tanks-full payload by 600 pounds. Rolls-Royce is dialing up engine thrust four percent to decrease TOFL. And most significantly, the G-VSP is getting PlaneView, Gulfstream's version of the new Honeywell Primus Epic avionics suite with one-third more display area, higher reliability, lower weight and less rack volume. (See "PlaneView" sidebar.)

Gulfstream will also bundle in more standard features, including a head-up display, infrared enhanced vision system, electronic navigation chart system, seven-channel satcom, air-to-ground radio telephone and an Airshow cabin entertainment system. No other business aircraft will boast more standard features than the G-VSP.

More Range and Speed Without More Fuel

The G-VSP will have the same 40,994-pound wing fuel capacity as the G-V and

also a 500-pound increase in MTOW. Absent other changes, this would be a classic recipe for performance loss. The G-VSP, however, is getting nose-to-tail drag-reducing modifications to squeeze more miles out of each pound of fuel. Surprisingly, this is being done without major surgery on the wing or fuselage.

Each small drag improvement item is almost insignificant. But, when the effect of all improvements is tallied, the result is 250 miles more range at 0.80 to 0.83 Mach, a range increase of 300 miles at 0.85 Mach and 400 miles at 0.87 Mach.

Gulfstream first installed aerodynamic tufts on a G-V and flew it at various cruise speeds to establish precise flow patterns. This identified several opportunities to reduce drag.

Chief among these is a new thrust recovery outflow valve (TROV). This is a significant improvement because the G-VSP (and G-V) has relatively more fresh, pressurized air flowing into the cabin than other long-range aircraft. Whereas on the G-V the fresh air largess is exhausted through the cabin outflow valve, more or less obliquely into the slipstream with little regard for aerodynamic effect, the TROV on the G-VSP, in contrast, redirects the outflow at an acute angle aft into the slipstream. This not only reduces drag, it also creates a slight forward-thrust vector.

Second, Gulfstream engineers discovered that the G-V's lift distribution wasn't perfectly elliptical. In lay terms, the inboard section wasn't developing quite the optimum proportion of lift. To compensate, the outboard wing sections carried more load, producing more total induced drag. The solution was to add small contour wedges to the bottom trailing edges of the inboard 30 percent of each wing, including the flap. The contour wedges, in effect, slightly increase the chord camber, thereby increasing the lift load of the inboard section. The result is a more elliptical lift distribution pattern that reduces overall induced drag.

Next, the engineers looked at every antenna, port and protuberance on the aircraft. Some objects are being reshaped. Others are being shortened. And many more are being fitted with aerodynamic fairings. The left and right ECS exhaust ports, for example, are getting new fairings. The engine pylons are being reshaped, and control surface gaps are being sealed. Fairings are being developed for the ADF antenna and bottom skeg. Some vent holes are being reduced in size.

All these small changes make the G-VSP slipperier at long-range cruise but have little effect on wave drag, the kind created by shock-wave-induced flow separation at 0.85 to 0.87 Mach high-speed cruise.

The thrust recovery outflow valve (TROV) redirects air exhausted from the cabin into the airstream, actually producing a slight forward-thrust vector.

Wave drag is not a new discovery. Aerodynamic engineers have been fighting shock-induced separation on the upper surfaces of wings for half a century. To counter the phenomenon, wings are often fitted with boundary layer energizers. This doesn't weaken the shock wave; however, it does boost the boundary layer's resistance to flow separation, which in turn reduces drag.

Wave drag becomes most significant at the highest cruise speeds because many shock wave "hot spots" form on the aircraft, but not just on the upper surfaces of the wings. Gulfstream identified "hot spots" on top of the nose cowl above the windshield, in the transition area between the wingtip and winglet and on the horizontal tail. Engineers are now adding vortex generators to boost boundary layer energy in those areas with the goal of reducing shock-induced separation and drag rise at the G-VSP's highest cruise speeds.

After baseline improvements are made to the G-VSP prototype, engineers conduct flow visualization tests to evaluate the results. In essence, they spray colored dye on the aircraft in flight. The dye streams back with the air flow and dries on the aircraft. After landing, the stains are studied to determine the effect of the aero modifications. This is done several times in an iterative, empirical process.


Trailing-edge contour wedges, on the inboard 30 percent of each wing, increase chord camber slightly, thereby creating a more elliptical lift distribution pattern.

The Rolls-Royce BR-710 engines are also doing their share to boost the G-VSP's range. Current production engines are delivering 1.5 to two percent better SFC than forecast. In addition, the engine nacelles are being fitted with thrust reverser gap seals to reduce drag. This results in about 90 miles more range, thereby improving the odds of the G-VSP meeting its range improvement goals.

The BR-710 engine, though, is not being fitted with Rolls-Royce's new 20-lobe mixer nozzle. During tests, Rolls-Royce discovered that the new nozzle, while effective, altered the relationship between thrust output and engine pressure ratio. Fitting the new mixer nozzle, as a result, would have required engine recertification work. If the nozzle is certified in the future, it could boost SFC by up to one-half percent.

Lower BOW and Higher MTOW Yields Greater Payload

If fitted in accordance with Gulfstream's product specification, the G-V weighs in at a svelte 48,000 pounds. Equipped with typical customer options, though, the G-V's BOW is close to 48,400 pounds, Gulfstream officials concede. Based on B/CA's experience, a G-V's actual weight is often higher. The aircraft we flew for our April 1999 Analysis (page 54), for example, had a 48,537-pound BOW.

Early G-V aircraft were even heavier. The aircraft in which B/CA flew around the world in April 1997 weighed 48,644 pounds. An ongoing weight reduction program has removed 100 to 200 pounds from production aircraft in the past four years.

Still, the tanks-full payload of the typically equipped G-V aircraft, as a result, seldom exceeds five to six passengers. The G-VSP, in contrast, will weigh 100 pounds less than the G-V, in spite of having considerably more standard equipment. The G-VSP's PlaneView cockpit saves 200 pounds, but 100 pounds is gained by adding two more cabin windows and more interior furnishings. Gulfstream predicts the G-VSP will have a 48,300-pound BOW, including considerably more standard equipment than the G-V.

The G-VSP is also getting a 500-pound increase in MTOW to 91,000 pounds, versus 90,500 pounds for the G-V. The resulting tanks-full payload is increased by 600 pounds, enabling the G-VSP to carry eight to nine passengers.

Takeoff field length distances also will be reduced by boosting engine takeoff thrust up to 15,385 pounds, flat-rated up to ISA+15°C. This is a FADEC "throttle push" increase that uses the BR-710's flat-rating margin. Currently, the engine is rated at 14,750 pounds thrust for takeoff up to ISA+20°C. In addition, Gulfstream is developing a bleed-off takeoff procedure for a two-percent thrust increase in hot-and-high airport conditions. Using the extra performance will not affect engine maintenance schedules or engine operating costs, Gulfstream officials told B/CA.

At the highest cruise speeds, sonic flow "hot spots" form at certain sections of the aircraft, creating shock-induced separation. Fin-shaped vortex generators energize the boundary layer, thus helping to prevent transonic airflow separation and the resulting drag.

For example, the G-VSP will be able to depart at its 91,000-pound MTOW from New York's Westchester County Airport on an ISA+16°C day with eight to nine passengers and fly nonstop to Tokyo-Narita, assuming 99 percent probability winter winds and ISA temperatures at cruise altitude. In contrast, the G-V, when flying between the same airport pair, is limited to ISA+11°C at its 90,500-pound MTOW.

At relatively low takeoff weights, the boost in engine thrust will make the G-VSP one of the most sporting performers in B/CA's May 2002 Purchase Planning Handbook. B/CA estimates the G-VSP will need only 3,100 feet of runway for trips up to 3,000 nm with eight passengers aboard.

Cabin and Baggage Compartment Enhancements

Passengers will immediately notice the G-VSP's cabin improvements. The cabin door is being moved forward two feet with no loss of cockpit volume. A seventh cabin window is being added to each side of the fuselage.

Inside, packaging efficiencies will add five to 10 feet to the usable cabin length. This will increase usable cabin volume by up to 20 percent, making possible a fourth

Qualifying Long-Range Claims

It's only 5,948 nm between New York and Tokyo as the crow flies, but very few birds can make this journey nonstop. About 85 percent of the year, there's a headwind of up to 34 knots that increases the equivalent still air distance to 6,424 nm, assuming a 0.80 Mach cruise speed.

Holding all other factors constant, a G-V, or any other aircraft having a maximum NBAA IFR range of 6,500 nm, can fly nonstop between these two cities.

But if the headwind increases to 51 knots, the 99-percent probability winter maximum, the equivalent still-air distance increases to 6,692 nm, leaving the G-V short of range. In contrast, the G-VSP, with its 6,750-nm maximum range, has just enough extra performance to make the mission with 99-percent probability headwinds.

Is this really enough to guarantee New York to Tokyo? Typically, the outside air temperatures above the tropopause in high latitudes exceed ISA. That decreases the range performance of any turbofan aircraft.

If OAT is 5°C warmer than standard, plan on losing 27 miles of range in the G-VSP. At ISA+10°C, the range drops another 27 nm. Under such conditions, the G-VSP still has a maximum range of 6,696 nm.

When the outside air temperature exceeds ISA+10°C, the range loss is more pronounced. At ISA+15°C, for example, the G-VSP's maximum range drops to 6,651 miles. At ISA+20°C, it drops to 6,532 miles.

If Russian ATC throws in the typical ATC reroute or cruise altitude descent, the New York to Tokyo guarantee becomes even more tenuous.

Virtually all ultra-long-range business aircraft, not just the G-VSP, are adversely affected by such factors. Therefore, it takes an aircraft with a maximum range of 7,000 miles or more to be capable of flying nonstop from New York to Tokyo year-round with 99-percent probability.

seating section. The G-VSP's usable cabin volume will be 1,204 cubic feet, versus 980 cubic feet for the G-V when fitted with a forward galley. With the aft galley configuration, usable cabin volume increases from 930 cubic feet to 1,129 cubic feet.

The increase in cabin volume will create weight control challenges during the completion process. The G-VSP will have a 7,100-pound completion allowance, versus the G-V's 6,700 pounds. Gulfstream's interior design team has been tasked with shaving 100 pounds from the G-VSP's fixtures and furnishings, even though it has more cabin volume, standard forward and aft vacuum lavatories, and a lengthy list of cabin entertainment equipment.

The aircraft can also be configured with three passenger seating areas and a forward crew rest area that will meet FAR Part 135 requirements for volume, darkness and sound levels.

Passengers will also appreciate the G-VSP's increased usable baggage compartment volume. The G-V boasted a 226 cubic foot baggage compartment, but 91 cubic feet were occupied by fresh water tanks, the vacuum lavatory system wastewater holding tank and miscellaneous items. On the G-VSP, the holding tank has been moved to the aft equipment bay and the fresh water tanks have been redesigned to conform to the baggage compartment contours. The result is 167 cubic feet of usable baggage compartment volume, an increase of more than 25 percent.

Most of the G-VSP's BOW reduction results from PlaneView's 200-pound lower weight, mainly in the front end of the aircraft. The G-VSP's aft holding tank and larger baggage compartment potentially add weight toward the rear of the aircraft. Gulfstream claims, however, the G-VSP will not have an aft c.g. problem.

Flying Impressions

When we strapped into the left seat of the G-VSP, we were immediately impressed with its Honeywell Primus Epic-based PlaneView avionics suite. Gulfstream and Honeywell have capitalized on 15 years of teamwork to create a next-generation cockpit in which experienced G-IV and G-V pilots will feel comfortable.

Aerodynamics is a black art as much as a science. V-shaped wave generators on the tail have been removed in favor of ultra-low-profile, fin-shaped vortex generators.

Most design, display and control conventions are carried over from the previous SPZ-8000, -8400 and -8500 cockpits. Controls have been modified only as needed for the enhanced capabilities of the PlaneView cockpit. The left- and right-side display controllers, for example, still control most of the functions of the four display screens and the head-up guidance system. Menus and soft key labels, though, have been updated to activate window management and map layer functions.

Accompanied by John O'Meara, the firm's senior experimental test pilot, we embarked upon Flight Test 35 in serial number 632, a standard G-V that's been configured with the G-VSP's PlaneView avionics suite and drag-reduction modifications for operational and performance evaluation. The purpose of the mission was to collect dye stream stain, flow visualization data in the landing configuration at low altitude and at 0.87 Mach high-speed cruise at FL 410.

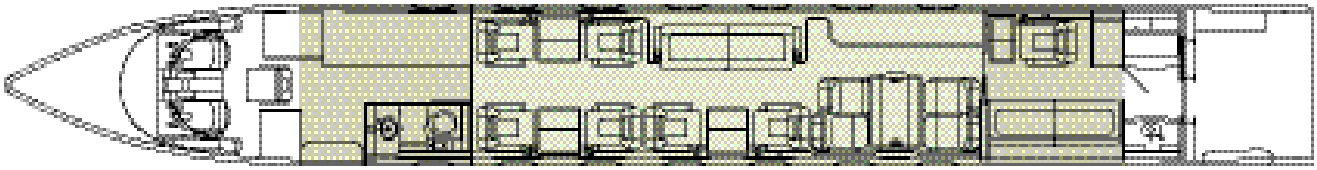
O'Meara pointed out the four new display reversion controls on the overhead panel, and the addition of integrated multi-function control display units with both FMS and radio tuning functions. The MCDUs also function as backup engine indicator displays.

Proficiency using the left- and right-side, sidewall-mounted cursor control devices (CCDs) will take some practice, in B/CA's opinion, but these units are easier to use than similar units in other business aircraft. The G-VSP retains dedicated controls for weather radar and airframe system controls. Gulfstream designed the CCD so that use by the pilot is optional.

Each CCD can control functions on the three closest screens, so the pilot flying can request the pilot not flying to make certain on-screen display choices on both the on-side and cross-side multifunction displays. Cursor controlled functions on the left- and right-side primary flight displays are very limited, enabling the crew to get a full screen of back-to-basics, flight-critical information with a couple of button pushes on the traditional Gulfstream display controller on the glareshield panel.

The G-VSP's checklists, procedures and handling characteristics are virtually the same as those of the G-V, so we won't rehash previous reports. It's worth noting, however, that the G-VSP and G-V are the nicest handling and lightest control-force Gulfstreams in two decades. The comparatively large wing and very effective wing flaps result in low V speeds and short runway requirements on all but the longest missions.

For flight test purposes, we used conservatively high V speeds, considering the



The G-VSP can be configured with three passenger seating areas and a forward crew rest area that will meet FAR Part 135 requirements for volume, darkness and sound levels.

aircraft's 67,000-pound takeoff weight, about three-fourths of its MTOW. O'Meara bugged V speeds of 119 KIAS for the V_1 decision and rotation speeds, 125 KIAS for the V_2 takeoff safety speed and 155 KIAS for flap retraction speed. The TOFL was 4,670 feet.

Flying with PlaneView is a pleasure. Gulfstream resisted the temptation to stuff excess data onto the 14.1-inch flat-panel screens. Instead, standard information occupies more space and, thus, it's easy to read. The full-screen PFD, with its edge-to-edge, attitude indicator sky and earth background, makes small pitch and roll changes immediately apparent. The altitude, airspeed and VSI tapes appear as windows with translucent backgrounds on the sky and earth.

We found it easy to switch back and forth between PFD full-screen and one-third/two-thirds display formats. At altitude, we flew a series of steep turns to expose the screens to direct sunlight. Our conclusion? Honeywell's CRT displays offer excellent sunlight viewability. The flat-panels are even better.

After the flight tests, we returned to Savannah and flew several ILS approaches in IMC. We encountered a few developmental quirks in the PlaneView system, but the basic design concepts were readily apparent. The size, brightness and contrast of the large displays, lack of screen clutter and quality of information put PlaneView in a new and superior class of avionics, as yet unmatched by any other avionics system we've flown.

PlaneView

Gulfstream's version of the next-generation Honeywell Primus Epic avionics suite has the best human engineering of any advanced avionics system we've flown to date. Experienced pilots, not lab technicians, are the ultimate decision makers in the system design. Gulfstream's goal is to preserve a common type rating for the G-V and G-VSP. Pilots already qualified in the G-V should have little trouble making the transition, based upon our observations.

PlaneView has the requisite large-format displays, four of which in landscape configuration fully span the width of the instrument panel. The system retains traditional controls, such as triple multifunction control display units, dual glareshield-mounted display controllers, a central flight guidance system control panel, and left- and right-side weather radar control panels. As a result, under high workload conditions, each crewmember can reach familiar, hard knobs, switches and buttons that provide tactile feedback and excellent hand-eye coordination. For example, we found it easy to use the MCDUs for both FMS programming and radio tuning functions. Triple MCDUs eliminate the need for stand-alone radio management units with no loss of situational awareness.

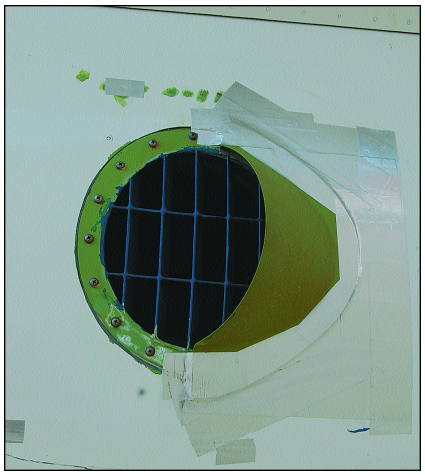
The sidewall mounted cursor control devices (CCDs) provide functions that are redundant with more traditional controls. These devices provide graphic flight planning, graphic radio tuning and selection of various display options — "window management" in designers' terms. The CCDs also have press-to-talk switches, individual buttons for moving the cursor between each of the three closest displays, an illuminated cursor movement control button and a thumb-operated display range selector wheel.

PlaneView offers more functional redundancy than the G-V's SPZ-8500 avionics suite. The system features triple Modular Avionics Units (MAUs), a computer chassis containing the function boards, and three IRSes, three micro ADCs, three FMS boards — all operating in synch — three display symbol generators, three audio control panels and three MCDUs. With the exception of the dual power source MAUs, the goal will be to still dispatch. Fail any one item in each category and the G-VSP can still dispatch. The MAUs also contain EGPWS boards, 24-channel GPS sensors, communication management function cards and HUD processing hardware.

The system features Honeywell's new Primus Epic digital, software-programmable radios housed in modular radio cabinets, similar in form and function to the MAUs. A third, software-programmable standby radio functions as a comm or nav radio. Notably, both the comm and nav radios have datalink functions.

Dual radio altimeters, a Primus 880 weather radar, TCAS II and seven-channel satcom round out the package. The flat-panel displays, statistically the most critical reliability items, should offer at least twice the mean time between failure of CRTs.

Best of all for passengers, the PlaneView package weighs 200 pounds less than the G-V's SPZ-8500 and occupies 58 cubic feet less cabin space in the forward equipment racks behind the cockpit.



Gulfstream is even reshaping the ECS exhaust fairings to prevent airflow separation, and the resulting drag, on the tail cone.

Is It Worth $2 Million More Than the G-V?

At about $42.6 million, the G-VSP will be one of the most expensive business aircraft in the May 2002 Purchase Planning Handbook. But it also offers the most range, the best fuel efficiency and the highest cruise altitudes in the ultra-long-range business aircraft class. Notably, G-VSP operators will have little trouble sprinting between popular North American and European destinations at 500 KTAS, if the aircraft meets Gulfstream's performance expectations.

The G-VSP will have shorter takeoff distances, considerably longer range at high-speed cruise, more usable cabin and baggage volume, an unsurpassed list of standard features and slightly lower direct operating costs because of drag-reduction modifications.

When delivered to customers in 2003, it will be priced at $46,550,000. Apples-to-apples, that's $2 million more than a G-V equipped with the Premium Package of options. In exchange for the price boost, though, the G-VSP will have four versus three cabin seating areas, Gulfstream's infrared enhanced vision system, 600 pounds more tanks-full payload and forward and aft vacuum lavatories.

Peruse the product specification and you'll find almost everything a customer could want in an ultra-long-range aircraft, including china, crystal, carpet runners and crew umbrellas. Standard equipment even includes triple videocams outside the aircraft.

The G-VSP has more substantive improvements versus the G-V than the G-IVSP offered in comparison to the G-IV. If the G-VSP meets all Gulfstream's performance projections, quite clearly it will be a better aircraft than the G-V. **B/CA**