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Gulfstream Flight Test Organization Abstract of Process and Procedures (April 2011)

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Gulfstream Flight Test Organization

Abstract of Process and Procedures as of April 2, 2011
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1.0 Schedule to Type Certificate

The first step taken to establish the overall flight test schedule is to allocate the various tests across the test fleet. This is done to both establish an optimum allocation and define the unique flight test configuration requirements for each test aircraft. After allocating the tests across the fleet, aircraft test schedules are established based on the estimated test requirements, proper sequencing of tests, previously demonstrated flight rates and expected improvements in the current flight test program over prior programs based on use of improved tools and processes.

The calendar span and total aircraft months used during a test program varies depending upon the complexity of the model changes, the maturity of the technologies being implemented, pre-program risk reduction tests and new regulatory requirements. Since the test program schedules are based on actual performance from prior programs, they have inherent allowances for some contingencies. However, the actual time required to complete a test program is dependent upon many factors not known beforehand, primarily the magnitude of the unplanned technical and compliance issues that occur during the development and company test phase of the program.

To monitor performance and track progress of the test program, metrics for flight hours and test points are established. Metrics in this instance refers to analytical measurements for planned and actual results used to track the state of progress in the flight test program.

In addition to the metrics used to track progress of the test fleet, detailed plans and metrics are also established for the desired analytical products, or "deliverables," that are produced within each area of flight test. These involve the release of design models, material, test plans, test reports and open aircraft work.

The schedule and all metrics are reviewed weekly in a meeting that includes Flight Test; Engineering; the Program Office; and the Senior Vice President, Programs, Engineering and Test. The schedule and related metrics are continuously reviewed along with the current status of issues facing the test program. Typical issues encountered during a test program include:

- Adjustments to delivery dates by suppliers
- Availability of the latest aircraft configuration from Engineering
- Availability of results and any issues from past tests
- Added test requirements

To mitigate delays in completing the overall test program, the test schedule is frequently adjusted. Aside from changing the timing for when tests will be conducted, tests may be re-allocated from one aircraft to another and resources prioritized (or added) to complete

time-sensitive tasks. Reallocating tests can be more complex and requires extra effort on the part of Flight Test since it involves reviewing the test article configuration and modifying them as required to insure the configuration and instrumentation are appropriate. Despite the extra effort, these changes are implemented to effect progress and mitigate delays to the overall program,

2.0 Flight Test Organizational Structure

Gulfstream's Flight Test Organization resides within the Engineering Organization. It is comprised of four functional areas which are Flight Test Engineering, Instrumentation Engineering, Maintenance Operations and Aircraft Coordination.

2.1 Flight Test Engineering

This department is responsible for a multi-disciplined staff of engineers and specialists responsible for the planning, conducting flight tests, processing data produced by those flight tests, analyzing the resulting data, and reporting the results of the flight tests and data analysis. Specific roles and responsibilities are divided amongst a couple of elements:

2.1.1 Flight Test Engineer (FTE)

The Flight Test Engineers are responsible for tests associated with flight sciences (aerodynamic performance, stability and control, loads and dynamics, acoustics), electrical, hydraulic and pneumatic systems systems, powerplant and propulsion, and avionics. Major responsibilities include:

- Establishing all test requirements and test plans
- Defining instrumentation requirements and submitting those to Flight Test Instrumentation Engineering (FTIE)
- Establishing analytical methods and data reduction[1] plans
- Performing risk assessments and flight test safety strategies
- Preparing detailed test cards[2], conducting mission briefings and providing real-time test support
- Issuing Flight Reports and maintaining test aircraft records
- Performing post-test data reduction, analysis, and generating reports of test results

2.1.2 Data System Specialist

The Data System Specialists are responsible for providing necessary tools, software databases, computer applications and storage methods to enable processing, delivering

[1] Data reduction refers to the process of taking the measured data and performing calculations and analysis to support further engineering analysis or determine results and conclusions.

[2] A test card contains instructions to participants regarding the targeted maneuvers for a particular flight or test series and the desired data to be collected along with any pertinent test limitations.

and storing all types of acquired data. While the majority of data center efforts are on-site, capability for remote-site support is also required. Major responsibilities include:

- Database design and development for processing and storing data
- Data reduction and analysis tools
- Data format conversion tools
- Data transfer, storage, back-up and archiving
- Interface with vendors and other organizations external to Flight Test to fulfill their requirements for Flight Test information
- Troubleshooting data system hardware and software

2.2 Flight Test Coordination

This department is responsible for coordinating the flight test activities with internal flight test personnel and external Gulfstream personnel, suppliers and regulatory agencies. This includes responsibilities for establishing test program plans along with short-term and long-term aircraft schedules.

2.3 Flight Test Instrumentation Engineering

These departments contain a multi-disciplined staff of engineers and specialists responsible for the definition, development, design, installation, and operation of instrumentation, data acquisition and specialized test equipment.

2.3.1 Instrumentation Operations Engineer

The Operations Engineers define instrumentation and data acquisition systems as well as other unique modifications to satisfy data collection requirements defined by Flight Test Engineering. Major responsibilities for these engineers include:

- Selecting sensors and performing accuracy and response analysis
- Establishing calibration methods and procedures
- Developing data systems and providing large-scale or miniature quick-response data systems based on program scope
- Maintaining all data system components to ensure proper operation and airworthiness
- Maintaining instrumentation calibrations, measurement lists and configuration control per internal and regulatory requirements
- Providing electrical designs to support instrumentation, data acquisition and special test installations
- Providing preflight and post-flight checks for flight test instrumentation and systems
- Supporting in-flight, ground test and remote operations as required

2.3.2 Instrumentation Mechanical Designer

Mechanical designers create engineering models, released through approved work methods, for installation of flight test instrumentation and equipment. This function includes:

- Providing designs that incorporate structural, aerodynamic, or systems modifications to test aircraft for the installation of transducers, data system components, and specialized test equipment
- Releasing designs that have been approved through cognizant Engineering groups to ensure airworthy and effective installations
- Providing support and technical guidance for part fabrication and installation of hardware on test aircraft.
- Resolving installation and fabrication problems due to design deficiencies or workmanship issues
- Addressing aircraft installation discrepancies and working with the Material Review Board (MRB) and Stress Engineering to obtain necessary repairs

2.3.3 Instrumentation Technicians

Instrumentation Technicians perform the build-up, integration, installation and maintenance for instrumentation, data systems and special flight test systems. This function includes:

- Off-aircraft fabrication and assembly of mechanical and electrical components and assemblies
- Maintaining a dedicated laboratory with proper equipment to calibrate a variety of sensor types
- On-aircraft installation, calibration and maintenance of the flight test instrumentation suites and any other special test installation
- Preflight and post-fight checks for the flight test instrumentation and systems

2.4 Flight Test Maintenance & Operations

This multi-department organization is responsible for the maintenance, modifications and repairs across a multi-aircraft-model test fleet. This includes:

- Scheduled and unscheduled maintenance
- Installation of production configuration changes
- Installation of prototype systems
- Installation of specialized flight test systems and equipment

Internal resources within the Flight Test Maintenance consist of mechanics, avionics and electrician technicians, and fabricators. Additionally, a Material Department is responsible for the planning, inventory and control of stock and non-stock parts.

2.5 Other Organizations

Other functions are required to properly operate the test fleet that exist organizationally outside of Flight Test. These functions provide the resources to support Flight Test in a matrix-type[3] environment, and consist of:

2.5.1 Quality

The Quality organization is responsible for ensuring that all modifications and maintenance activities comply with documented requirements, as well as completing daily inspections in preparation for and issuance of flight release of all Flight Test aircraft, whether managed under the repair station or the manufacturer's authority based on program (PSCP) guidelines.

In addition, Quality Assurance is responsible for preparing and presenting the aircraft to the (ODA) Inspection Airworthiness Representatives (IARs) for the issuance of conformity or airworthiness certificates. The ODA IAR's are also members of the Quality organization.

2.5.2 Materials

The Materials organization provides support to Flight Test by managing stock material (aircraft production parts). This includes planning; logistics and control support for the flight test inventory of production spares, parts borrowed from Production, and parts upgrades; maintaining a current list of parts shortages; expediting shipping and receiving; and maintaining inventory control.

2.5.3 Material Review Board

The MRB is a group of engineering representatives empowered to review all reported airplane discrepancies (DIs) and develop authoritative resolution instructions.

2.5.4 Flight Operations

Flight Operations is responsible for providing all the experimental test pilots for any Flight Test flight as well as any other necessary cockpit crew.

[3] A "matrix" relationship is one where personnel are temporarily assigned to another organization to provide the necessary cross-functional skill sets to support

3.0 Flight Test Staffing

The staffing requirements for the Flight Test Program centers around the manpower required from the departments listed above. The staffing for each department and skill set is based on the expected requirements to support the test program, the associated schedule and an overtime factor. These department estimates are reconciled against previous programs and the overall business plan to generate the staffing plan. As with test schedules, these resource plans are reviewed and adjusted as the program progresses based on the total hours being worked by each department (including overtime), current department and program performance status, and understanding of future requirements.

4.0 Flight Test Operations

Test missions are conducted in accordance with the test requirements outlined in the flight test plans approved through Flight Test Engineering, the Cognizant Design Engineer and Flight Operations. The FTE organization prepares the test cards for each flight, conducts preflight briefings with the entire test crew, executes the mission, conducts the post-flight briefings, then provides a flight summary report, analyzes and reduces the data and publishes the final test report when all tests are completed.

4.1 Flight Test Cards

The test cards contain the specific details associated with a test point(s) as defined within the flight test plan. Information on the test cards include the test conditions, configuration and test procedure. Test procedures are established from regulatory guidance material and tailored to the system functionality and operational envelope of the aircraft. Multiple test cards are assembled into a flight card package along with other pertinent mission information such as weight and balance, interim flight restrictions and Test Safety Hazard Analysis (TSHA). The completed flight card package is signed by the FTE and Coordinator at the end of the pre-flight to confirm that the aircraft has been configured for the planned tests.

4.2 Changes to Flight Test Procedures

During the course of a pre-flight briefing, only certain changes to the test procedures or conditions are allowable. These changes are those that provide further clarity to the test procedure, adding build-up maneuvers, or test points to gather additional data points to support more conclusive results. These changes are only authorized to enhance safety or efficiency of the test program without affecting the risk assessment or appreciably changing the scope of the test program. Once the preflight is concluded, only those tests briefed are authorized to be conducted during test flight..

4.3 Reporting of Discrepancies

Following the flight, the results of the tests are discussed at the post-flight briefing along with any maintenance or engineering issues that were observed during the flight. If issues were identified that do not pertain to maintenance, they are recorded as

engineering issues and communicated back to Engineering via the Problem Report (PR) system. These are classified by severity with Severity 1 items affecting the safety of flight. An open Severity 1 PR will ground the aircraft until the severity is downgraded through either implementation of a corrective action or an acceptable means of mitigation. The Problem Report system is a formally established engineering process that manages these issues from identification through determination of root cause, corrective action, implementation and validation. The PRs are managed by technical discipline with multi-disciplined review boards that determine when the item can be closed.

4.4 Flight Test Data Analysis

After a flight, data is processed and made available to the Flight Test Engineer for data reduction and release to Engineering specialists. The tools in use by Gulfstream to acquire and process the data enable data to be available almost immediately after completion of a flight. Since the FTE has the knowledge on how each measurement is defined and implemented, they typically review the data to insure the measurements are providing valid data and then provides requested data to Engineering. This data can be either measured data or parameters that have been calculated based on approved methods. For those situations where engineering needs immediate access to flight test data, provisions are provided to process and download data for cognizant engineers to access directly.

While data is shared with cognizant engineering specialists, the FTE is responsible for the data reduction and release of the final test report that provides the analysis, test results, conclusions and recommendations. These test reports are released through an approval process that involves Flight Test Engineering, Flight Operations and Engineering. For certification tests, these reports are approved by the Flight Analyst and Flight Test Pilot (ARs) along with the appropriate engineering ARs.

4.5 Flight Test Team

The minimum test crew on the aircraft typically consists of two pilots and one FTE. Additional crew members are included when their role is essential to the purpose of the test. The FTE is an essential part of the test crew and is responsible for directing and executing the tests with the pilots. The FTE monitors the data to insure the safety and quality of the maneuver and notes the real-time observations and results on the flight cards. The FTE also insures proper operation of the data acquisition systems and operates any specialized test equipment. The data monitoring responsibilities vary and include safety of flight and safety of test monitoring along with confirming the validity and quality of the data. The FTE also provides the performance numbers and any performance targets necessary to execute the testing.

For certain testing that is high risk or involves significant real-time engineering support, telemetry is utilized. The Gulfstream TM capability includes 8 computer workstations with significant capacity to display parameters on multiple screens using a variety of

formats. For offsite operations, a TM trailer can be utilized that provides 4 engineering workstations

5.0 Safety Management

The formal safety management process covering flight test operations is established through the Flight Test and Flight Operations process manuals outlined in Section 8 below.

As mentioned in Par 4.3 above, the Engineering Problem Report system is used during development programs to capture issues associated with design discrepancies. Any safety-related issues encountered during test missions are reported back as Severity 1 PRs. These may also come from Engineering as a result of the most recent off-aircraft test efforts or analysis. Regardless of the source, Severity 1 PRs will ground the test aircraft until properly addressed.

Manufacturing issues uncovered after production are communicated and managed by the flight test organization through the Quality Alert Process and Notice of Escape process by Suppliers. These systems describe the issue and provide necessary compliance times for any corrective action.

A key element to safe operations during a developmental test program is the frequent communication of test results, current aircraft activities, future plans and issues that need to be resolved to support the test schedule. This is accomplished through daily cross-functional coordination calls, daily aircraft status reports and flight reports that are distributed via email to a wide audience within Engineering, Flight Operations, the Program Office and Flight Test. This allows issues within the program to surface and for mangers to establish priorities and a response plan along with the appropriate allocation of resources.

6.0 Flight Test Safety

6.1 Risk Assessment

The Flight Test safety process starts during the development of the flight test plan by determining, for each desired test point[4], the associated hazards along with the causes and effects. Once the hazards are understood, a subjective judgment is made relative to probabilities to define the risk classification. Guidance for hazard assessments and tests typically considered hazardous are based on previous Gulfstream experience along with external resources such as Gulfstream's Flight Operations Manual Standard Operating Procedures for Production / Test (Section 2.3.0) and FAA Order 4040.26A.

[4] A test point might best be described as a combination of airspeed, altitude, angle of attack, and other parameters sought to be recorded on the test aircraft.

6.2 Test Safety Hazard Analysis

For those tests determined to have a medium or high risk, a Test Safety Hazard Analysis (TSHA) is prepared by the FTE that define the necessary preventative actions and risk mitigation or minimizing procedures. These list all reasonable steps that can be taken to avoid the hazardous condition or reduce its probability of occurrence and provide the pilot actions to recover from the hazard if encountered.

6.3 Flight Test Safety Review Board

For those tests that are determined to be either medium or high risk, a Flight Test Safety Review Board (FT SRB) is convened. The FT SRB is an inter-disciplinary group of Management, Engineering and Flight Operations personnel. The FT SRB is responsible for reviewing tests and test safety information and concurring that the subject tests can be conducted as planned, with the prescribed mitigation strategies, and that the resulting overall level of risk is acceptable.

The FT SRB is co-chaired by the VP of Flight Operations and Director of Flight Test. The board is also comprised of a senior Management Member, Chief Engineer, Chief Test Pilot, Project Pilot and senior FTE and Engineering personnel.

At the FT SRB, the FTE presents the relevant information to support the board's determination whether the risk level is acceptable. This typically consists of the information noted below. If there are any open questions, these are recorded as open actions and require closure before board approval is provided for the tests.

- Test background
- Test aircraft configuration
- Test conditions and procedures
- Safety of flight monitoring and abort limits and procedures
- Test sequence (build-up, pre-requisites)
- Data analysis requirements (pre-requisite analysis, interim data reviews)
- Risk levels
- TSHAs (hazards, probabilities, mitigation strategies)

6.4 Flight Test Manuals

Both Flight Test and Flight Operations have process manuals that govern test operations. These manuals establish standardized procedures for use in flight test operations for the purpose of maximizing safety and efficiency.

The Flight Operations Manual complies with ISBAO standards and incorporates elements of a Safety Management System (SMS). But the SMS program was not extended to cover experimental test flights.

The Flight Test procedures manual addressing processes to follow through the various stages of the test process (requirements definition through test conduct and final reports).

The procedures associated with paragraphs 6.1 – 6.3 are detailed in the Flight Test Process Manual. The processes outlined in the Risk Assessment section of the Flight Test Manual were reviewed and been accepted by the FAA in 1998 as establishing an adequate level of safety for FAA flight test programs.

These procedures, along with other internal Gulfstream procedures such as the Engineering Problem Reporting procedure and use of FAA Order 4040.26A were intended to incorporate Gulfstream and industry best-practices. They cover procedures spanning the entire test process, risk management, crew qualifications plus operational standards such as crew duty, crew rest and weather minimums.

6.5 Field Performance Testing

Company field performance testing is scheduled following completion of certain pre-requisite tests: air data calibrations, stall speeds, stall characteristics, Vmcg, Vmca, climb performance, and nose wheel steering (NWS) and brake system tuning. Once the pre-requisite tests are complete, the takeoff performance tests begin with Vmu's to determine the maximum pitch attitude and, minimum liftoff speeds to safely proceed with liftoff and climbout to out of ground effect. with sufficient margins to aerodynamic stall. Afterwards, a series of AEO and OEI takeoffs are completed to finalize the test procedure, and target speeds. Once established, the AEO and OEI takeoffs are conducted at the necessary flap settings and range of thrust / weight conditions required. The takeoff procedure and performance is established to accommodate the abused takeoff demonstrations required by the regulations. These early, rapid and mis-trimmed takeoffs are scheduled last in the test program.

Field performance tests are normally done at Roswell NM. There are a variety of considerations that make Roswell a favorable location (runway length, surface, low airport utilization, logistics support, etc). While operating offsite at Roswell, the test team consists of engineering support from both Flight Test and Flight Sciences. Telemetry is utilized to support the test flights and data is monitored by both FT and FS performance engineers. Real-time support is provided for additional data monitoring by engineers to correlate results to predictions, and insure the quality of the data on each test run. Also done near-real-time or following the flight is the data reduction for each test condition. However, there was no requirement to reduce all data from one day's test flights before proceeding to the next day's test flight.

6.6 Test Safety Margins

Flight tests are conducted to the design limits for performance, airspeed, mach number, altitude, load factor, temperatures, etc. Tests conducted at the design limits and extreme angles (AOA, Roll, Sideslip) are always approached in a gradual, build-up fashion. These tests, especially initial exposures, are typically considered to be high risk and the margins along with other pertinent test information are reviewed at the Flight Test SRB.