Human Factors Engineering (HFE) in Gulfstream Flight Deck Development and Certification

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September 17, 2014
# Gulfstream Current Product Line

<table>
<thead>
<tr>
<th>Model</th>
<th>Range</th>
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<tbody>
<tr>
<td>G150</td>
<td>3,000 nm at M0.75</td>
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<tr>
<td>G280</td>
<td>3,600 nm at M0.80</td>
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<tr>
<td>G450</td>
<td>4,350 nm at M0.80</td>
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<tr>
<td>G550</td>
<td>6,750 nm at M0.80</td>
</tr>
<tr>
<td>G650</td>
<td>7,000 nm at M0.85</td>
</tr>
<tr>
<td>G650ER</td>
<td>7,500 nm at M0.85</td>
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Gulfstream - The Need for Speed

Increasing Speeds for Increased Productivity

Customers:
“It Saves Time – The Most Valuable Resource”
Technology Driven by Safety, Customers

• Accident / incident data is continuously reviewed to assess new flight deck designs
  – Pilot input solicited at each stage of design

• Performance changes affect flight deck technology
  – Example: supersonic nose and fuselage size

• Ongoing investment in Flight Deck technology
  – Ability to go anywhere, anytime
  – More displays, simplification where needed
  – Synthetic Vision, Enhanced Vision, External Vision
HFE Integral Part of Flight Deck Design Process at Gulfstream
HFE Resides in Systems Engineering

- Project Engineering Director
  - Admin Assist. Sr.
  - Admin Assist. III
  - Project Eng. Mgr.
  - Engineering PMO
  - Sys Engineering & Integration Mgr.
  - Human Factors Engineering Principal Engineer
  - Engineering Ops Mgr.

- Systems Engineering
- Systems Safety
- Human Factors Engr
- Design Integrity
- Data Integrity
- System Integration
- Standard Parts / EMU

- Tech Info
  - Engineering Process Control
  - Apps & Data Systems
  - Data Mgmt
  - Design Supp & Employee Training
HFE Role in Gulfstream Engineering

- Generate Data Driven Requirements
- Develop and Apply Structured Test Methods
Where Does HFE Get Applied?

- Flight Deck Equipment
- Cabin Systems
- Doors
- Emergency Egress
- Maintenance Accessibility
HFE Process Applied to All New Programs

Program Milestones
- Mission Requirement Definition
- Operational Requirement Definition
- HFE Requirement Definition
- Detailed Design Definition
- Final Requirement Verification

HFE Process
- Program Objectives
- Flight Deck Design Guidelines
- Analysis
- Prototyping
- Engineering Development Unit Test
- Crew Workload and Human Factors Simulator and Flight Test
- Certification

HFE Deliverables
- Color Philosophy Document, Flight Deck Philosophy Document
- HFE Certification Plan, Function Allocation Matrices, Requirements Memos (SRD), FHA Validation, Human Error Analysis
- Integrated Test Procedures (HFE scenario-based)
- HFE Regulation Specific Flight Test Plans and Reports

Gulfstream
Flight Deck Philosophy

- Referenced from top level requirements, ARP4754 compliant

- Philosophy Elements
  - Pilot Characteristics / CRM Roles
  - Certification Requirements
  - Alerting Guidelines
  - Control Interface Guidelines
  - Crew Error Mitigation
  - New and Novel Criteria
  - Automation Guidelines

- Created in DOORS to Assign Top Level HFE Requirements for Traceability
New and Novel Classification Criteria

• New and Novel Defined as Not Previously Certified Implementation

• All New and Novel Identified in HFE Certification Plan

• Classifications per AC/AMC 25.1302 plus the following:
  – Complexity
    • Number of information elements used by the crew, display or control
  – Integration
    • Interactions or dependencies among systems (<2=low, 2-4=moderate, >4=high)

• New and Novel Intended Functions Clearly Described, Specifically Tested
New and Novel Development Testing

- New and Novel Continuously Scrutinized Throughout Process
  - New and Novel Items Area of Focus for Human Error Analyses
- Crew Error Emphasis in Developmental Testing (ITPs, FSI Simulator Test if required)
- Test Points Specifically Developed to Target Intended Function
  - Addressed in early scenario-based testing as part of ITPs, including failure cases
  - Tested during Crew Workload and Human Factors Certification Simulator and Flight Test
Analysis / Prototyping

- Simulation Models Used to Derive HFE Requirements
  - CATIA V5 Human Builder
  - 3DSSPP Strength Model
  - OPTIS SPEOS
  - Luminicam
  - Process Simulation
  - Display Animation (iDATA tool)

- Physical Prototypes Used to Validate Early HFE Requirements
  - Operational Prototyping and Evaluation Lab (OPEL)

- System SRDs in DOORS
Two Types of HFE Testing Performed During this Stage

- System-Specific
  - Flight Controls Aspects (e.g., Shaker Evaluation)
  - Displays (e.g., Standby Instrument, 3D AMM, etc.)

- Integrated Test Procedures (5)
  - Scenario-Based
  - Phase of Flight Specific
  - Requirements Based

Problem Reports (PRs) Generated from Both Types of Testing
Certification Simulator Test

• Simulator Test
  – Flight profiles (Day VMC, Night VMC, Day IMC, Night IMC)
  – Multiple crews
    • 5’2” to 6’3” pilot stature
    • Low time pilot, demo (line) pilots included
    • FAA/EASA test pilot participants
  – Failures assessed
  – New and novel intended function test points included
  – Real ATC simulated
  – FSI familiarization training week before
  – Simulator test familiarization session
Certification Flight Test

- Flight Test
  - Minimum four FAA/EASA pilots; with GAC safety pilot
  - Left/right seat combinations
  - Multiple approach types
  - Lighting Characteristics
  - Vibration effects
  - Validates simulator test results
  - Verifies any items that could not be tested during simulator test
  - Addresses PRs identified during simulator test
  - Includes high density airport
Certification

• All Deliverables per HFE Certification Plan submitted
  – Analyses
  – Test Plans and Reports
  – Supporting Analyses (e.g., Fan Blade Out, High/Low Temp Analysis, Emergency Egress, etc.)

• Summary Compliance Report Completed

• All PRs Disposed Of (e.g., AFM revisions, future software revisions, etc.)
Implementing An HFE Function in Engineering
Benefits of Standardizing HFE Methods

• Well Accepted Good Engineering Design Practices Address HFE As Early As Possible

• HFE Documentation Provides Rationale for Design Decisions (Natural Fit for ARP4754 Process)

• Early Simulation Modeling to Generate Requirements Reduces Problems with Physical Prototypes

• Multidiscipline Design Team Sensitizes Other Engineering Disciplines to HFE, Usability

• HFE Contributes Structured Approach to Interface Design vs. Ad Hoc or “Shoot From the Hip” Design
  – Considers full range of pilot sizes, types, experience
Challenges of Standardizing HFE in Engr

1. Industry Acceptance of HFE Role as Integral to Aircraft Development
   - Clearly Defined HFE Role in Certification Helps Reduce Confusion (e.g., AR role)
     • Ambiguity Between Groups (e.g., Flight Test; STC vs. Amended vs. TC – how much HFE support is required?)
   - Documented Methods Standardize Role

Recommendation: Establish HF AR in Flight Test; Support HFE Methods Standardization
Challenges of Standardizing HFE in Engr

2. 25.1302 Compliance, Human Error Analysis Difficult to Standardize

- Ambiguous language (HFE-ese)
  - Differences between authorities on how to operationalize, level of authority involvement required
  - Gulfstream uses combination of analysis, simulator, and flight test; typically situation-specific
- Human Error Analysis complements safety analysis, but safety looks for quantitative approach
  - HFE research data needed to provide hard numbers; difficult to justify cost for OEM

**Recommendation:** Provide Specific Methods for 25.1302, Including Human Error Analysis Methods
Challenges of Standardizing HFE in Engr

3. Simulation Methods Reduce Prototyping and Flight Test Time
   - Human Modeling Easy Benefit Because of Industry Transition to Electronic Design Tools
   - Strength Modeling Easy Benefit Because Quantitative Output
   - Interface Prototyping Tools Typically Require Dedicated Experts (and More Resources)
   - More simulation tools (lighting simulation, process, etc.) needed

**Recommendation:** Provide List of Approved Simulation Methods To Use for Certification
Challenges of Standardizing HFE in Engr

4. Crew workload testing
   – Situation-specific (e.g., display symbology vs. global)
   – Subjective instruments still best method for certification
     • Easy to administer in flight; easy for pilots to understand
     • Video recording supports pilot ratings / comments
     • Flight Technical Error, if applicable
   – Quantitative Methods very useful, situation specific
     • Airspeed, ATC communication lapses, etc.

**Recommendation:** Support Research on Secondary Task Measures for Crew Workload to Validate Subjective Data
Challenges of Standardizing HFE in Engr

5. Staffing Qualified HFEs
   - Hard to Fill Positions; Gulfstream Engineering Has Identified HFE as a Critical Need
     • Skill set unique combination of engineering/science and psychology: OJT required and breadth of system knowledge creates steep, and lengthy learning curve
     • BCPE attempted to standardize, but probably needs revision in light of recent FAA changes
       – 25.1302
       – More emphasis on HFE, HF AR qualifications

**Recommendation:** Partner with Universities to Develop Curricula that Ensures Qualified Human Factors Engineers
Future Directions

• Gulfstream continues research and evaluation of potential solutions or new technologies that:
  – Directly enhance operator safety and performance
  – Sustain (and improve) a very high dispatch reliability
  – Provide efficiencies to meet future performance requirements
  – Target flight deck solutions that support supersonic travel