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

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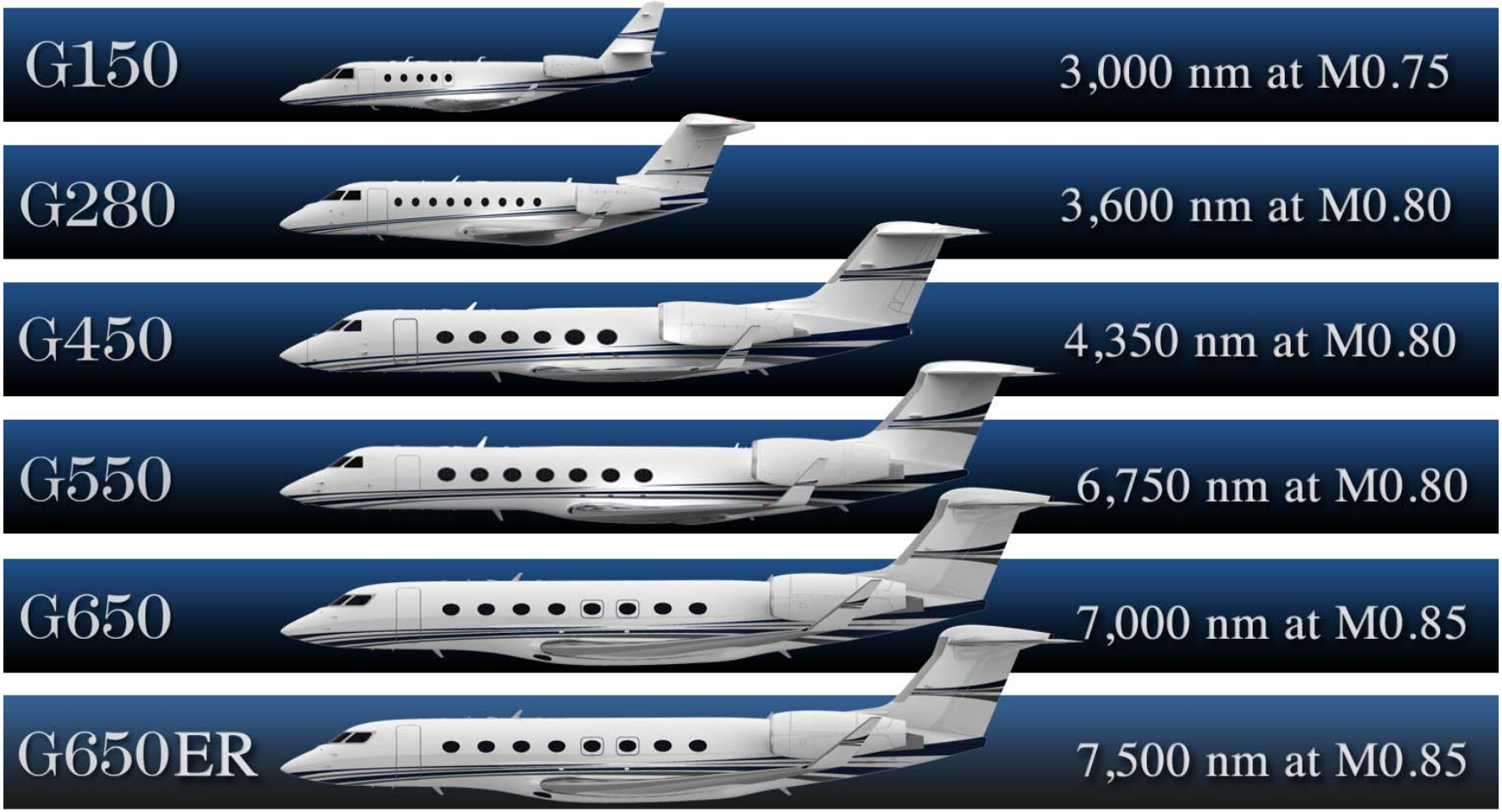
# Gulfstream Current Product Line



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# Gulfstream - The Need for Speed




**Increasing Speeds for Increased Productivity**



***Customers:***
***"It Saves Time – The Most Valuable Resource"***



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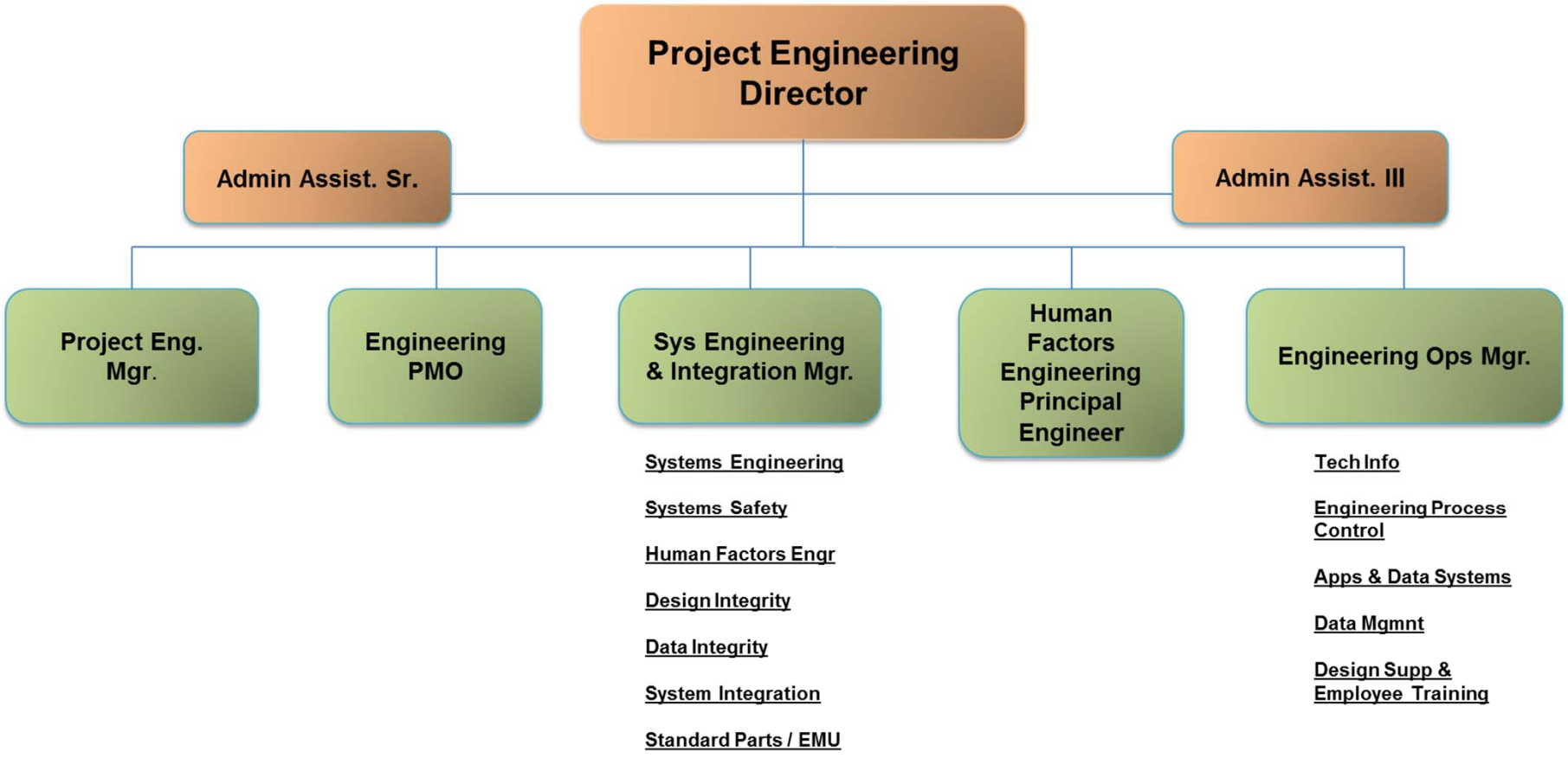
# Technology Driven by Safety, Customers

- 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



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# HFE Role in Gulfstream Engineering

- Generate Data Driven Requirements
- Develop and Apply Structured Test Methods




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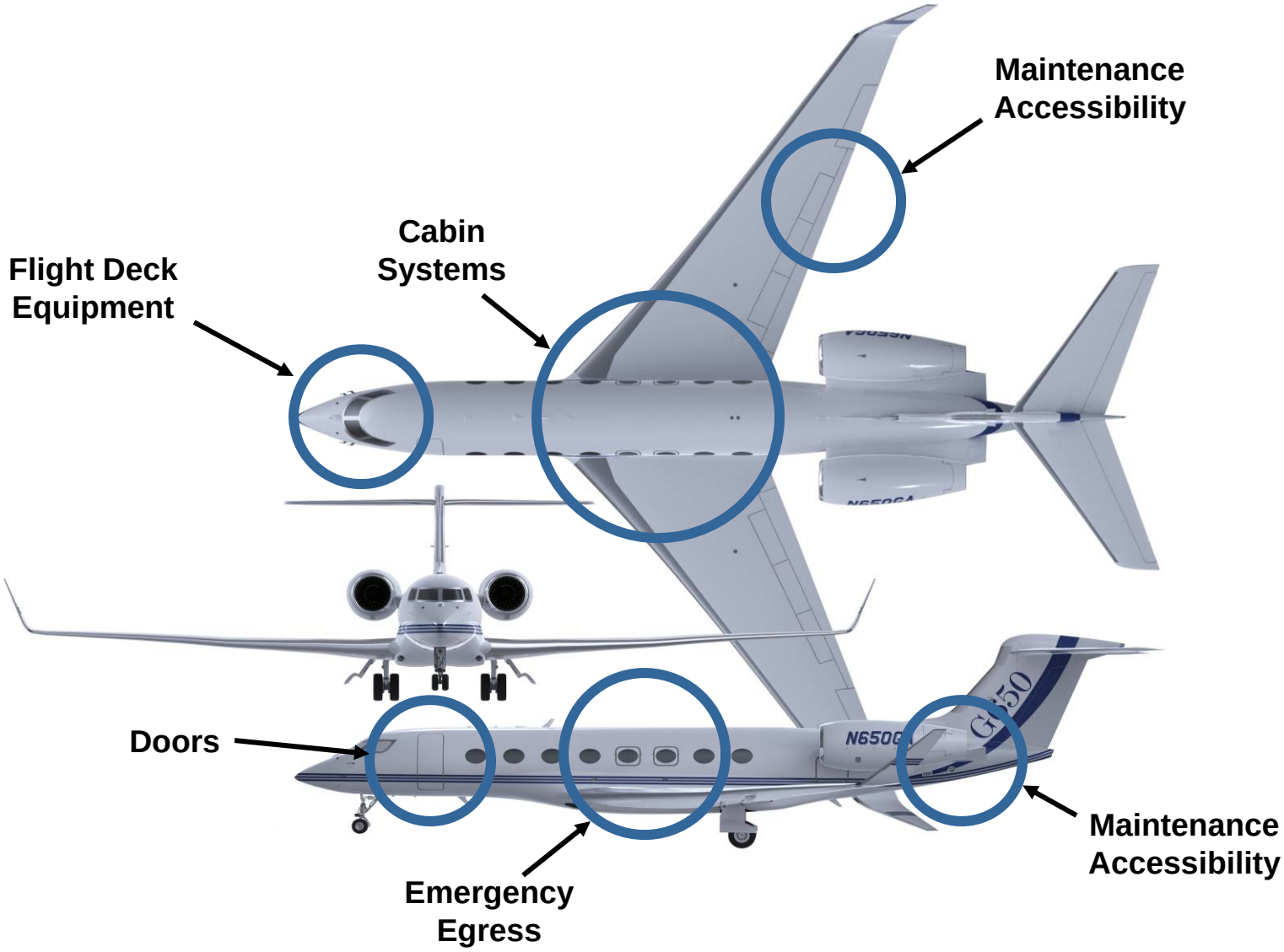
# Where Does HFE Get Applied?



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# HFE Process Applied to All New Programs

| Program Milestones | | HFE Process | HFE Deliverables |
|---|---|---|---|
| Mission Requirement Definition | | Program Objectives | |
| Operational Requirement Definition | | Flight Deck Design Guidelines | Color Philosophy Document, Flight Deck Philosophy Document |
| HFE Requirement Definition | PDR | Analysis, Prototyping | HFE Certification Plan, Function Allocation Matrices, Requirements Memos (SRD), FHA Validation, Human Error Analysis |
| Detailed Design Definition | CDR | Engineering Development Unit Test | Integrated Test Procedures (HFE scenario-based) |
| Final Requirement Verification | | Crew Workload and Human Factors Simulator and Flight Test | HFE Regulation Specific Flight Test Plans and Reports |
| | | Certification | |

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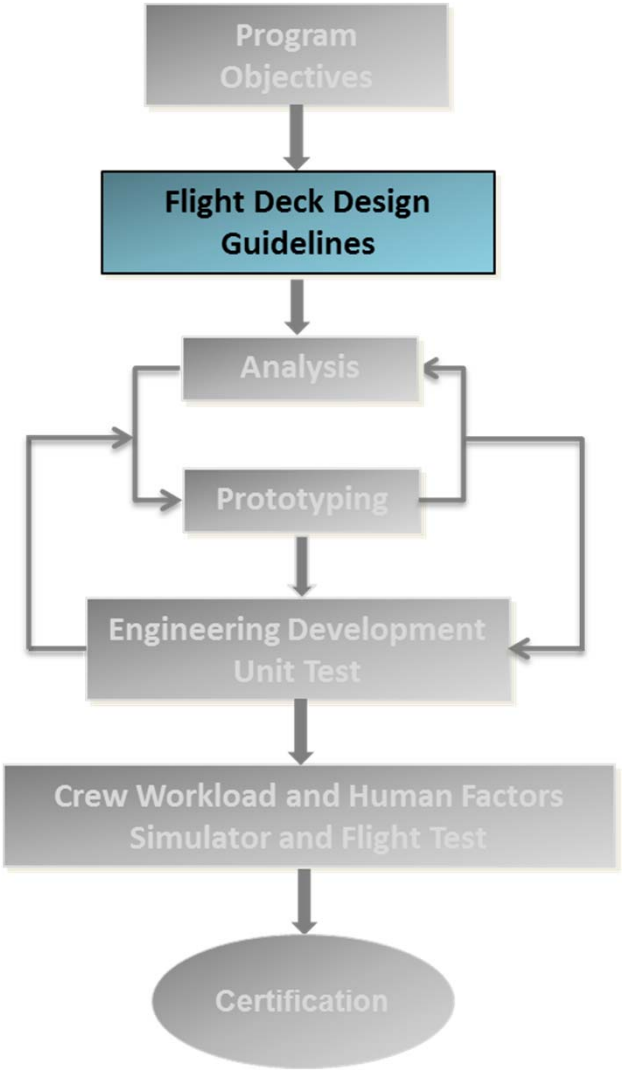
# Flight Deck Philosophy




- 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

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# 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

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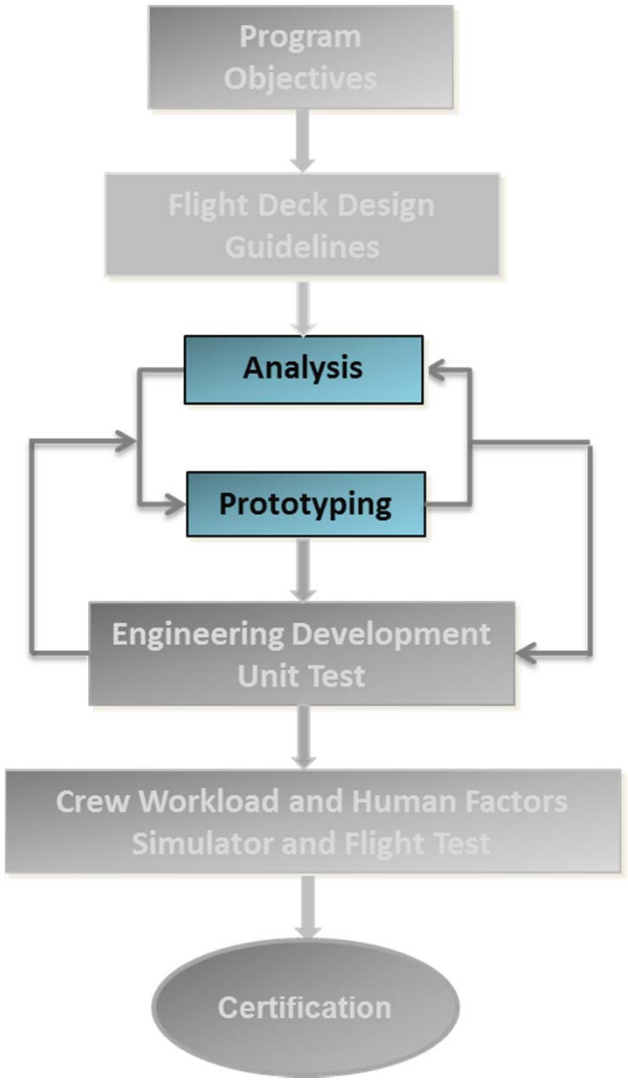
# New and Novel Development Testing

- 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
  - Lumicam
  - Process Simulation
  - Display Animation (iDATA tool)
- Physical Prototypes Used to Validate Early HFE Requirements
  - Operational Prototyping and Evaluation Lab (OPEL)
- System SRDs in DOORS

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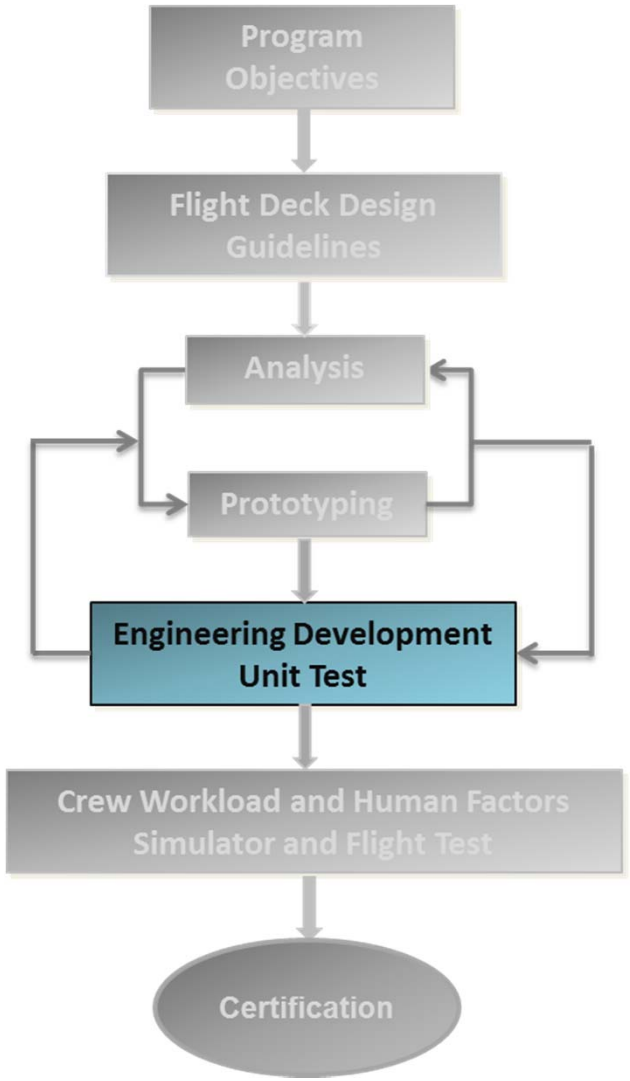
# Engineering Development Unit Test




- 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

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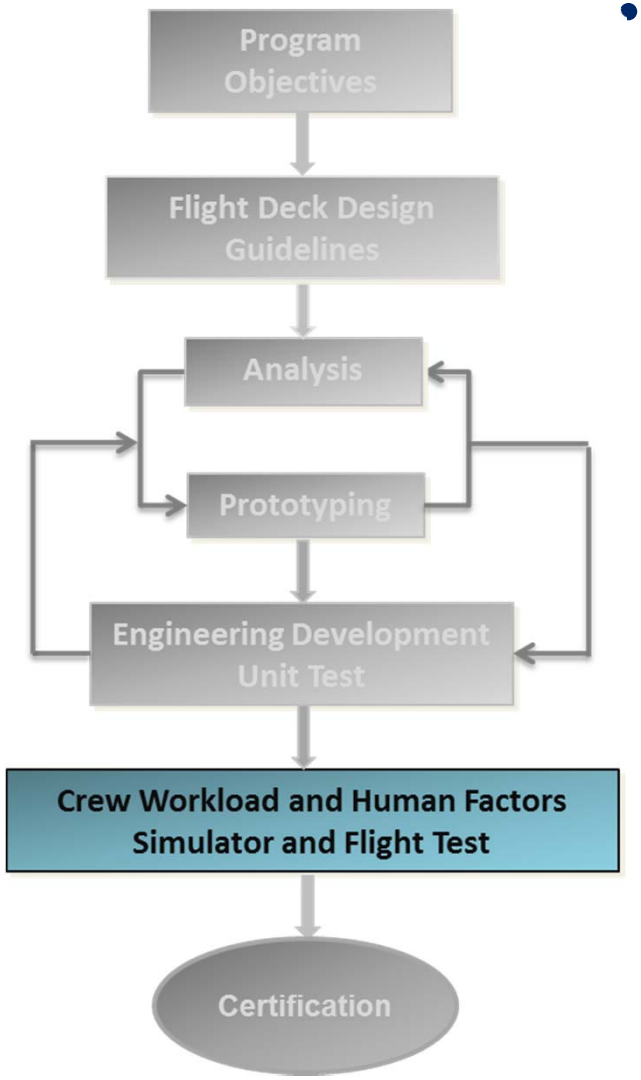
# Certification Simulator Test




- 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

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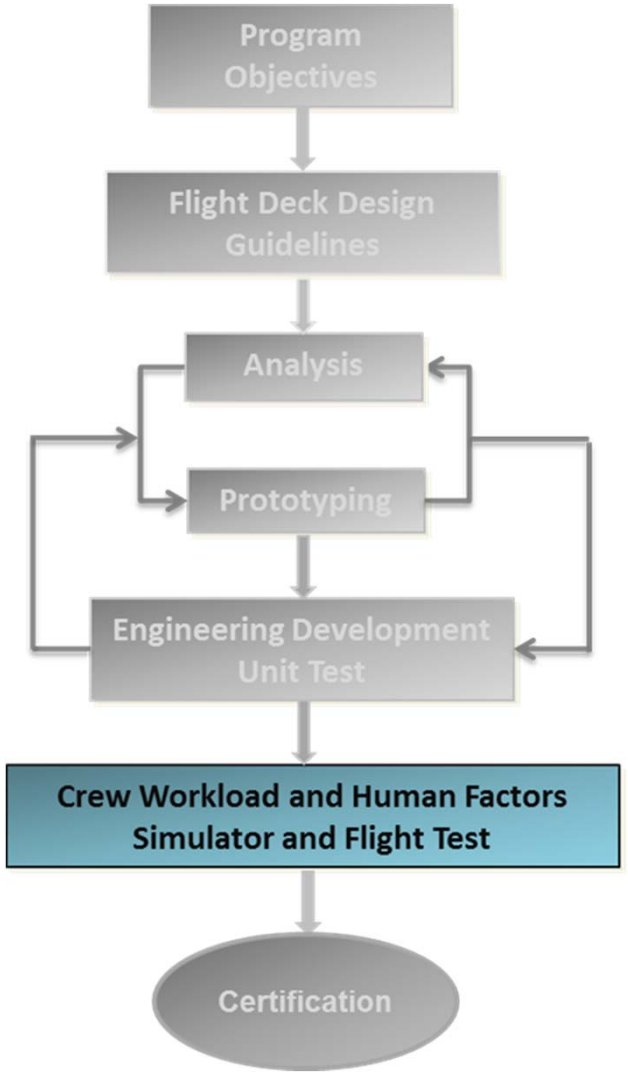
# Certification Flight Test




- 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

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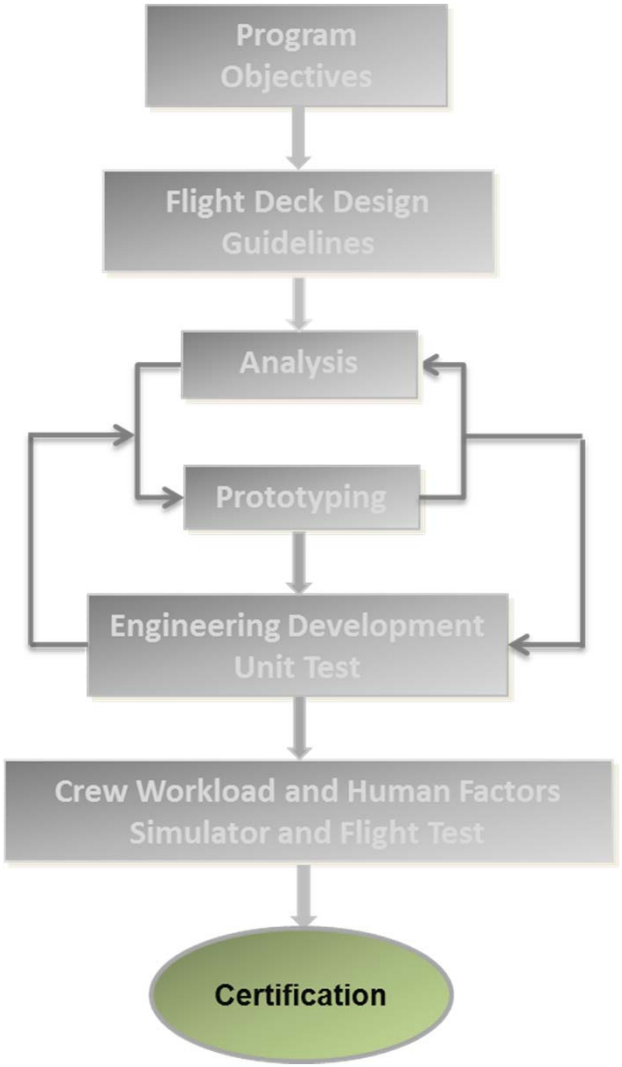
# Certification




- 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.)

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# Implementing An HFE Function in Engineering

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# 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