AIRCRAFT ENGINE ELECTRICAL WIRING

(Design / Features / Maintenance)

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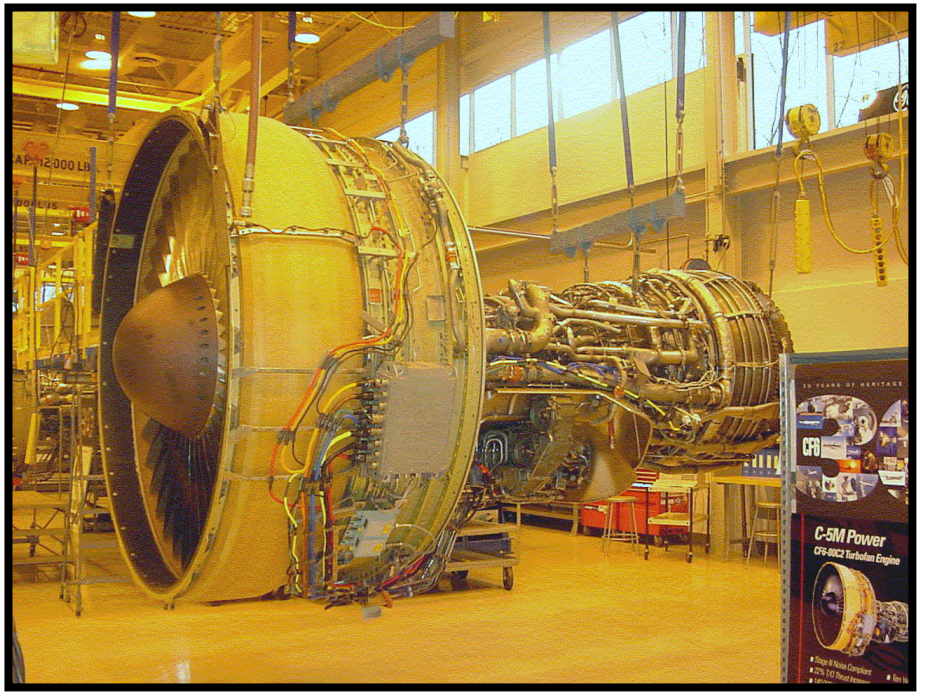
SCOPE:

- **This presentation is limited to GE Aircraft Engine's experience on commercial wide body aircraft**
- **GE's CF6 engine family has powered these aircraft since 1980, with 182 customers and over 200 million hours of operation**

Engine	Aircraft
CF6-6	DC10-10
CF6-50	DC10-15 DC10-30 A300 747-200/300
CF6-80A	767-200 A310-200
CF6-80C	A300-600 A310-200/300 747-200/300/400 767-200ER/300/400
CF6-80E1	A330



DESIGN REQUIREMENTS

- **Internal**
  - **Designs are controlled by internal design practices based on "Lessons Learned"**
  - **GE certifies a harness to FAR 33.91, similar to other control components**
  - **GE defined engineering tests are conducted to determine the design margin of a particular design**
  - **GE has incorporated many industry best practices (AS50881) for harness design and support on the engine**

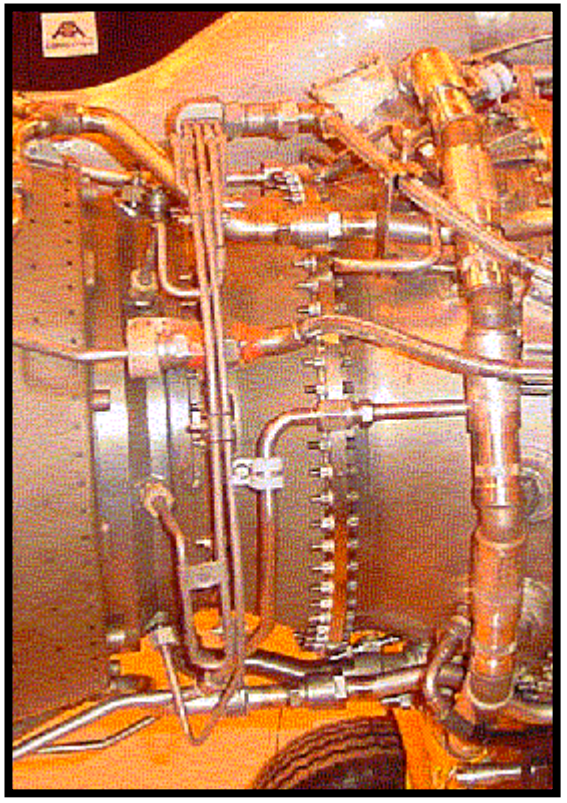
- **Airframer**
  - **Individual airframer reqts may dictate design features (fire resistance, repairability, maintainability-LRU)**

DESIGN BACKGROUND/HISTORY

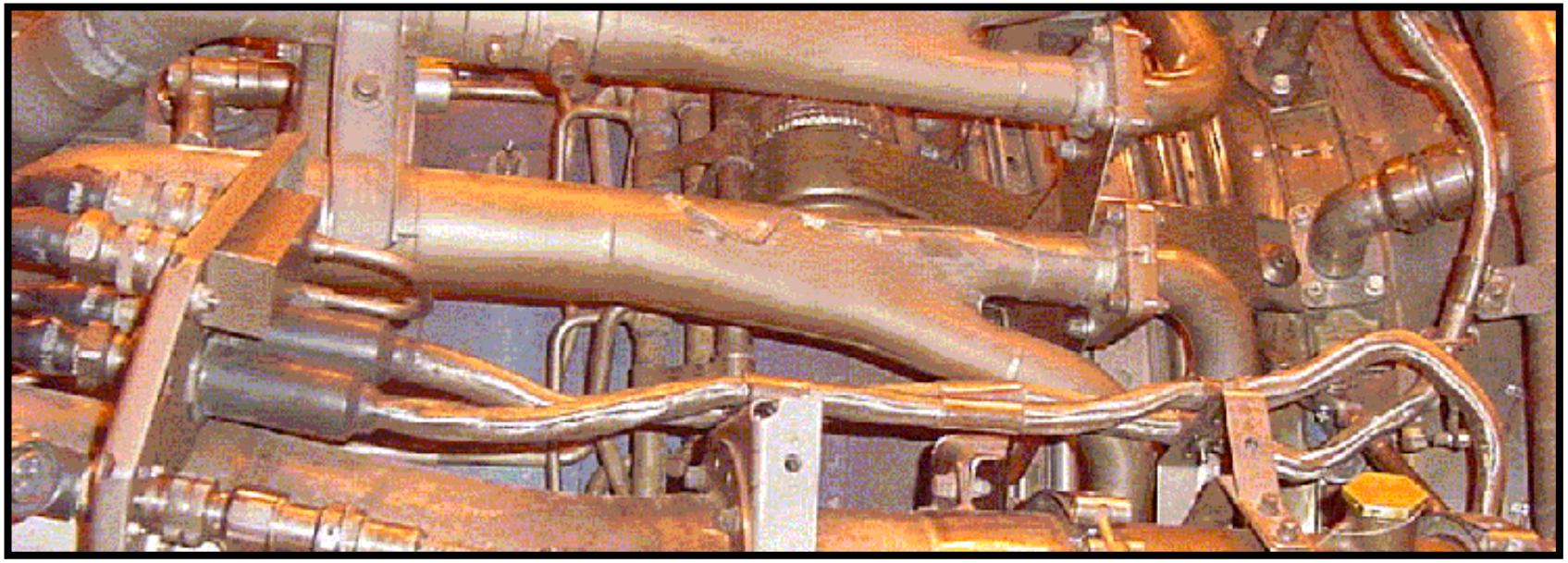
- **Basic design features (materials) are derivatives of designs originally qualified on military engines**
  - **Military engines have a total life of approx. 3,000-5000 hrs**
  - **Commercial engines may accumulate this many hours per year of operation**
- **Continued reliable operation of our electrical harnesses is dependent on the following criteria:**
  - **Correct selection of materials to survive the environment**
    - » **Temperature, Fluids, Vibration**
  - **Using proven design features**
    - » **Basic design features and materials that have proven their durability are rarely changed**
  - **Selective use of design upgrades based on improvements in materials / technology**

DESIGN TYPES

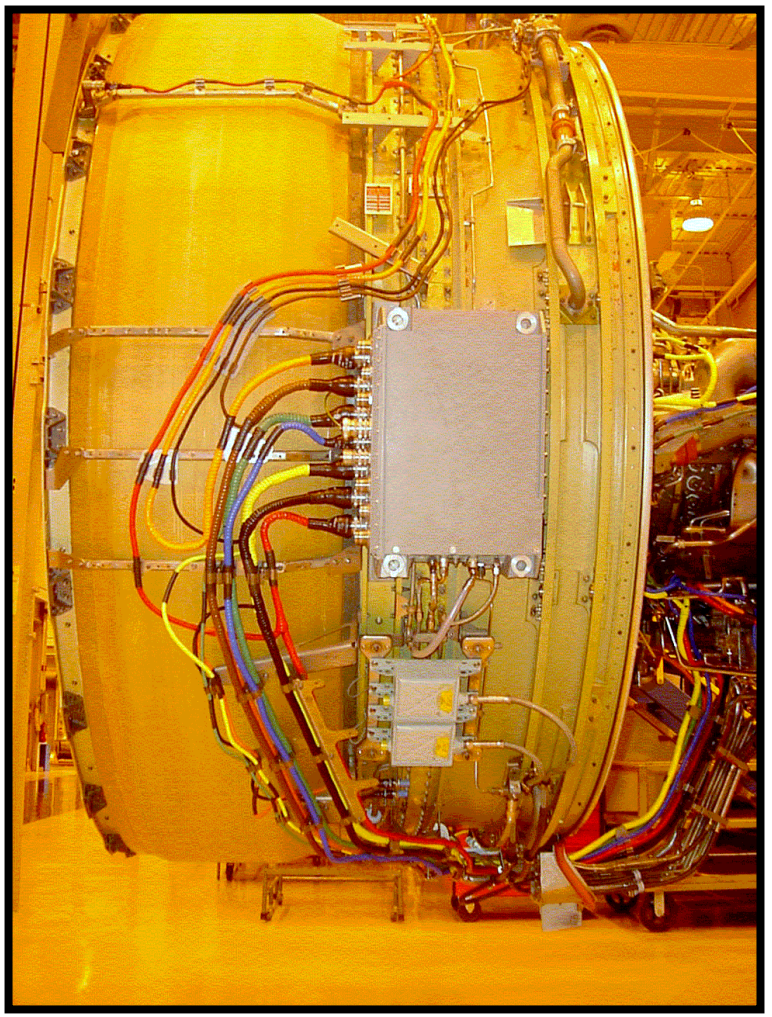
- **Three basic types of electrical harnesses are used:**
  - **1 High Temp (Rigid) > 800 F**



– 2 High Temperature (flexible) 500 F - 800 F

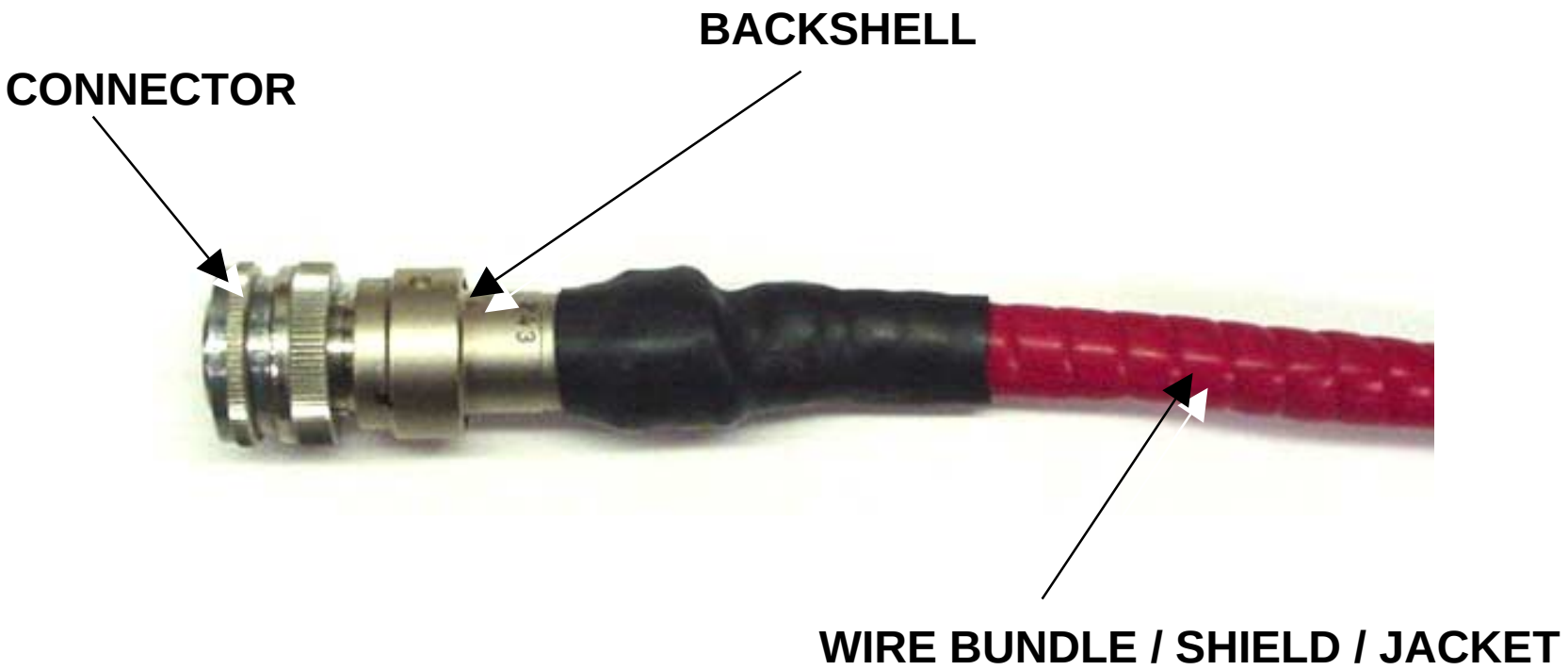


- 3 Emphasis of this presentation - Standard Construction < 500 F
  - » Most common (highest qty of connections)



Design Features

- **Typical “Standard” Harness Construction**



Design Features

- **Electrical Connectors (Stainless Steel Only)**
  - **Three main connector families are utilized**

Connector Type	Common Location	Advantages (+)	Disadvantages (-)
M83723	*Component & FADEC	GE developed design for robustness	# of pin patterns (inserts) are limited - Standard design not scoop proof
D38999	Component & *FADEC & *Major interfaces	High pin density – Scoop proof – Single turn to uncouple	Design can be vibration sensitive – Mating different suppliers plug/receptacle
M5015	Components	Interface to older components – no technical advantage	Not originally designed for the aircraft engine environment

* preferred application

Design Features

- **Electrical Connectors (continued)**
  - **GE specifies connectors to meet a GE connector specification and a GE source controlled drawing**
    - » **GE connector specifications exceed the performance requirements of standard military type specifications**
    - » **GE connector specifications control coupling and uncoupling torques to allow for hand tight installation**
    - » **Recently European connector specifications (i.e. EN2997) have been issued specifically to meet the requirements of the jet engine environment**
  - **Other special connector types used for specific applications have also been GE designed and specified**
    - » **Scoop proof M83723 connectors**
    - » **High Temperature M5015 connectors**

- **Backshell**
  - Provides mechanical support for the wire terminations
  - Attach point for internal and external shielding to provide a ground path from shielding to the electrical connector
    - » Interfaces with connector and shielding must have low resistance and remain tight to provide adequate shielding
  - Standard materials are nickel plated aluminum, stainless steel (SS) or nickel plated stainless steel
  - Backshell geometry can be straight/ 45 / 90 degrees based on cable routing and adjacent hardware
    - » Other backshell angles can be designed as required
  - Designs may be potted or unpotted
  - Unpotted backshells (SS) are oriented to prevent the collection of fluid or have drainage holes installed

- **Wire**
  - **Preferred wire uses a “hybrid” insulation**
    - » **Insulation known as T-K-T (Teflon-Kapton-Teflon)**
      - **Insulation offers optimum performance without the negative features of standard aerospace type wire, such as:**
      - **1 Pure Teflon (PTFE) insulation**
        - **Material has excellent temperature and fluid resistance - but will deform and “cold flow” if stressed at engine temperatures**
      - **2 Pure Kapton (Polyimide) insulation**
        - **Small conductor diameter and reduced weight are attractive characteristics. When exposed to engine vibration and temperature, material may degrade.**
    - » **Minimum recommended wire sizes are:**
      - **Copper : AWG 20 or AWG 22 - 19 strands**
      - **Thermocouple : AWG 20 - 7 or 19 strands**
    - » **Conductors may be grouped and twisted (2 = pair, 3=triplet, 4=quad) to meet electrical system reqts**
    - » **Grouped wires can be shielded or unshielded**
    - » **Shielded wires may be jacketed or unjacketed (outer layer of insulation**

- **Shielding**
  - Material is generally nickel-plated copper. Other material (nickel/stainless steel) may be specified depending on environment
  - Individual wire groups may be shielded
    - » As required to meet control system reqts
  - Overall cable bundle may be shielded (overbraid)
    - » Outer shielding is specified to meet EMI/Lightning reqts
  - Shielding usually terminates to the connector backshell (b/s) for electrical grounding
    - » Internal shielding provides end-to-end coverage (into b/s)
    - » Overbraid should provide a 360 termination @ the b/s
  - The shield termination resistance is controlled by the supplier to insure a reliable ground path

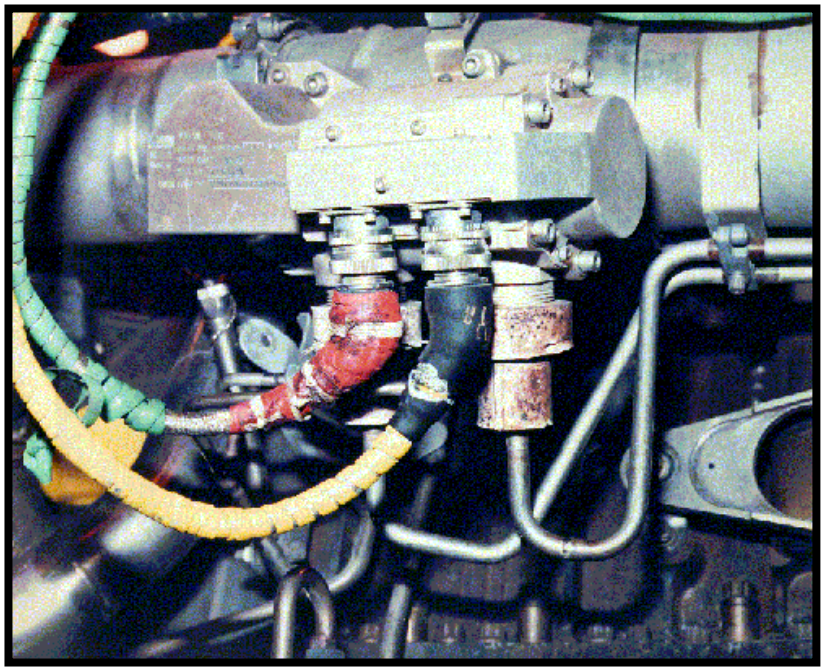
- **Chafe Protection**
  - Purpose is to protect the cable and adjacent hardware from contact damage (may be color coded to aid maintenance)

Material	Advantages (+)	Disadvantages (-)
Spiral Wrap (PTFE)	Material thickness / chafe properties	Weight, low cut resistance / shrinks at elevated tempertures / difficult to install
PEEK Overbraid	Light weight / easy to install / will not fray	Will chafe with heavy contact

FIELD PERFORMANCE / MAINTENANCE

- **Engine harness are maintained based on the engine's normal maintenance**
  - **Inspection interval varies based on airline customer (ex 1K, 5K, 10K hours)**
  - **Normal periodic maintenance includes a visual inspection (heat/vibration damage)**

EXAMPLE OF HEAT DAMAGE ON FADEC ELECTRICAL HARNESSES



FIELD PERFORMANCE / MAINTENANCE

- More thorough engine rebuilds include harness removal, inspection, cleaning and minor repairs
- Harnesses are electrically checked to the CMM (continuity, IR, Hi-Pot)
- Damaged harnesses are repaired at a service shop or returned to the OEM (repair / replacement or key components)

TYPICAL SERVICE SHOP SET UP TO INSPECT / REPAIR HARNESSES

FIELD PERFORMANCE / MAINTENANCE

- **Based on our field experience, “standard” engine harnesses have no life restrictions (max # hours)**
  - **Electrical harnesses are not considered to be life limited parts**
  - **GE does not track hours on individual harness assemblies (interchangeable between engines)**
    - » **Airlines may track hours/cycles on individual harnesses**
  - **Upper limit (max hours) for a standard harness in its’ designed environment has not been determined (open ended)**
  - **Failure rates of harnesses are closely tied to an individual engine’s characteristics (nacelle temperatures, vibration)**