Procedures and Guidelines

DIRECTIVE NO.	565-PG-8700.2.1B	**APPROVED BY Signature:**	Original signed by
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EXPIRATION DATE:	11/18/2010	**TITLE:**	Branch Head

COMPLIANCE IS MANDATORY

Responsible Office: 565 / Electrical Systems Branch

Title: Design and Development Guidelines For Spaceflight Electrical Harnesses

PREFACE

P.1 PURPOSE

This PG establishes guidelines for the Product Design Team (PDT) providing support for the design and development of spaceflight electrical harnesses.

P.2 APPLICABILITY

This procedure applies to the design and development of all flight electrical harnesses performed by members of, and contractors working for, the Electrical Systems Branch, as well as employees and contractors of other GSFC organizations providing support to the Electrical Systems Branch in the development of flight electrical harnesses, that fall within the scope of the GSFC Quality Management System.

P.3 AUTHORITY

GPR-8700.1 Design Planning and Interface Management
GPR-8700.2 Design Development

P.4 REFERENCES

GPR 1310.1, Customer Commitments and Review
GPR 1710.1, Corrective and Preventive Action
GPR 5330.1, Product Processing, Inspection, and Test
GPR 5340.2, Control of Non-conforming Product
GPR 8700.1, Design Planning and Interface Management
GPR 8700.2, Design Development
GPR 8700.3, Design Validation
GPR 8700.4, Integrated Independent Reviews
GPR 8700.6, Engineering Peer Reviews
GPR 8730.3, The GSFC Quality Manual
500-PG-1310.1.1, External Customer Agreements
500-PG-8700.2.3, Issue and Management of Engineering Drawing Numbers
500-PG-8700.2.5, Engineering Drawing Standards Manual

Design And Manufacturing Standard For Electrical Harnesses
NASA-STD-8739.3 Soldered Electrical Connections
NASA-STD-8739.4 Crimping, Interconnecting Cables, Harnesses, and Wiring

CANCELLATION

565-PG-8700.2.1 Electrical Harness Design and Manufacturing

P.5 SAFETY

None

P.6 TRAINING

Familiarization with, or Certification to, NASA-STD-8739.4, recommended.
Certification to NASA-STD_8739.3, and NASA-STD-8739.4 required for fabricators

P.7 RECORDS

Record Title	Record Custodian	Retention
Design Planning Documentation Reference: GPR-8700.1 Design Planning And Interface Management	Product Design Lead (PDL) Project Office CM when development activities completed	NASA Records Retention Schedule (NRRS) 1/22A. Permanent. Retire to a Federal Records Center (FRC) when 5 years old. Transfer to NARA when 10 years old.
Work Order Authorization (WOA) Reference: GPR-5330.1 GSFC Form 4-30	Product Design Lead (PDL) Project Office CM when development activities completed	NRRS 8/5A2 Project Test, Engineering, and Evaluation Files. Records may be retired to a Federal Records Center (FRC) when 2 years old. Destroy when 15 years old.
Engineering Peer Review (EPR) Report including RFA's, RFA Responses, RFA Originator Decisions, and Summary Status of RFA's	Product Design Lead (PDL) Project Office CM when development activities completed	NRRS 7/5B1

P.8 METRICS

None

P.9 DEFINITIONS

a. Product Design Lead (PDL) - The PDL is the manager or leader with overall responsibility for managing the design activity, managing the technical and organizational interfaces identified during design planning, and where required, forming and leading the Product Design Team (PDT). The term PDL may refer to flight project managers, mission managers, instrument managers, subsystem technical managers, integrated product development team leaders, lead engineers, or others who have the responsibility for managing a design activity. In the context of this document, PDL typically refers to the Electrical Systems Lead Engineer.

b. Customer - Any organization or person receiving electrical harness design and development support from the Electrical Systems Branch, or the Applied Engineering and Technology Directorate (AETD). In the context of this document, customer would typically refer to a project manager or instrument manager.

c. Design Plan - The documentation created as a result of executing GPR 8700.1, Design Planning and Interface Management. This documentation consists of schedules and budgets, a work breakdown structure (WBS), a validation plan and other information. It may be gathered together as a single document, consist of multiple documents, or be a portion of a more comprehensive document, such as a Project Plan, Implementation Plan, or equivalent.

PROCEDURES

In this document, a requirement is identified by “shall,” a good practice by “should,” permission by “may” or “can,” expectation by “will,” and descriptive material by “is.”

The PDL, hereafter referred to as the lead engineer, is responsible for the quality and timely completion of the electrical design and development activities as specified in the Customer Agreement and/or Statement of Work (SOW) (see GPR 1310.1, Customer Commitments and Review; and 500-PG-1310.1.1, External Customer Agreements). This includes providing the design output documentation, budgets, schedules, and review support to the customer. It is the responsibility of the lead engineer, in partnership with the customer, to determine and document in a design plan (per GPR 8700.1, Design Planning and Interface Management) which specific steps of the typical design and development process (as described herein) will be executed.

The following procedure describes a typical process for providing design and development support to a customer. The actual design and development process is, by nature, iterative and must maintain some degree of flexibility.

1. Compilation of Design Inputs

The lead engineer compiles and evaluates the design inputs which may include one or more of the following:
- Statement of Work (SOW)
- Customer imposed requirements
- Interface Control Drawings (ICD)
- Applicable specifications, standards, and statutory/regulatory requirements
- AETD imposed requirements

2. Initial Planning

2.1. The lead engineer develops the design plan, which contains a high level description of the electrical harness to be developed, key support personnel, a budget, and a schedule for review and approval by the customer. The plan should include adequate contingencies for completion of the design and development activity within the resources negotiated in the Customer Agreement and/or SOW (see GPR 1310.1, Customer Commitments and Review and/or 500-PG-1310.1, External Customer Agreements). A project or instrument manager may request this design plan information be documented in a formal Implementation Plan for the electrical subsystem. Other approaches may be to have the design planning documentation combined with other discipline inputs and consolidated into a Project Plan, or the design planning documentation may be a part of several individual project documents. Regardless of the approach, the design planning documentation is a quality record and shall be maintained per the applicable configuration management plan for this design and development activity.

2.2. The lead engineer, with assistance from line management, ensures that the PDT is composed of individuals, civil servants and/or contractors as necessary, with the required discipline skills.

3. Requirements Definition

The lead engineer supports the generation of a requirements document from the design inputs. It may be necessary for the PDT to perform various analyses in order to derive lower level design requirements from the top-level design inputs. These top level and derived requirements shall be documented, reviewed for adequacy and consistency with relevant NASA and GSFC standards, and signed off by the lead engineer and the customer. The requirements document shall be maintained per the applicable configuration management plan.

4. Design Practice

The design effort should be conducted according to GPR 8700.2, Design Development, and according to the following good design practices, as appropriate:

4.1. Multiple design concepts should be identified, and the best selected by a trade study process. The best design concept is that which fully meets all of the design requirements and considers cost, technical complexity, schedule risk, technology infusion, design heritage, and other factors as appropriate. It may be necessary to prototype one or more of the design options and to conduct various performance and/or environmental tests before the optimum design path is chosen. In any case, the customer shall be a key participant in this critical selection process. In addition, the results of the trade study process are typically "peer reviewed" (See GPR 8700.6,Engineering Peer Reviews).

4.2. Detailed designs should be as simple as possible, making maximum use of standardization, repeated elements, known processes, and readily available parts and materials.

4.3. Designs, as well as the specific parts and materials incorporated into designs should be robust and insensitive to typical and /or expected environmental conditions, and consider ease of fabrication, integration, and testability.

4.4. All appropriate functional discipline personnel (e.g., manufacturing, integration, testing, and other subsystems, such as thermal, mechanical, optical, etc.) having interfaces or particular concerns regarding harness design should be a part of the PDT, or, at a minimum, be consulted to review the design and make suggestions to improve manufacturability, testability, etc. and/or reduce the costs associated with such activities. The lead engineer, in conjunction with the project or responsible organization, shall decide whether to accept or reject these recommendations.

4.5. Harness assembly drawings, if required, shall be documented in accordance with 500-PG-8700.2.5, Engineering Drawing Standards Manual. Other product documentation sets typically include top-level block diagrams, grounding schemes, wiring diagrams, and parts lists. The wiring diagrams used for harness fabrication do not necessarily have to comply with formatting specified in the Drawing Standard, but the drawings shall be complete and unambiguous, containing all the necessary information to produce the desired cable or harness. Some or all of these drawing practices may also be applicable to pre-flight and pre-operational hardware (such as engineering model cables, non-flight test cables, and proof-of-concept hardware), but are not required. Applicability shall be determined by the lead engineer. All pertinent design drawings shall be placed under configuration control, and managed by the project's Configuration Management (CM). Instructions for obtaining official GSFC Drawing Numbers can be found in 500-PG-8700.2.3, Issue and Management of GSFC Engineering Drawing Numbers, if official GSFC Drawing Numbers are not provided by the project CM.

4.6. The lead engineer is responsible for assuring that all fabrication drawings for flight hardware, and ground support equipment hardware that interfaces with flight hardware are checked for accuracy and completeness and are approved.

4.7. The following checklist of design considerations is provided as an aid in developing the design:

- Application (spaceflight, ground, aircraft, balloon, sounding rocket, etc.)
- Environmental conditions (thermal, vibration, etc.)
- Shielding/Grounding
- Electro-magnetic interference (EMI), electro-magnetic compatibility (EMC)
- Signal types (single ended, differential, impedance controlled, etc.)
- Power interfaces (conductor sizing, protection, connector selection, etc.)
- RF/coaxial/triaxial interfaces (cable and connector selection)
- Conductor, connector, and fuse de-rating criteria
- Umbilical/test interfaces
- Deployables/pyros (safing and arming plugs, etc.)
- Physical attributes (cable lengths, bundle diameters, mass estimate, etc.)
- Routing (connector spacing, harness bundle diameter, bend radii, harness support. etc.)
- Mass constraints
- Thermal constraints
- Ease of installation/integration
- Ease of testing
- Parts classification
- Mock-up requirements (refer to section 9.2.6 of the Design, And Manufacturing Standard For Electrical Harnesses)

4.8. The lead engineer/PDT should query the NASA Lessons Learned Information System (LLIS), (http://llis.nasa.gov/llis/llis/llis.html). The NASA LLIS is an on-line, automated database system designed to collect, and make available for use, the NASA lessons learned from over forty years in the aeronautics and space business. The LLIS enables the knowledge gained from past experience to be applied to current and future projects. Its intent is to avoid the repetition of past failures and mishaps, as well as the ability to share observations and best practices. Through this resource, the Lead Engineer may facilitate the early incorporation of safety, reliability, maintainability, and quality into the design of flight and ground support hardware, software, facilities, and procedures.

4.9. The lead engineer/PDT should also consult the "Design And Manufacturing Standard For Electrical Harnesses" (http://eed.gsfc.nasa.gov/docs/harness/harness.html). This document, the result of a knowledge capture exercise by the Electrical Harness Working Group, provides valuable recommendations and "best practices" gleaned from decades of harness fabrication experience within the Electrical Systems Branch.

5. Design Changes

Design changes, as required by customer request, process improvement, errors in the original design, improper component selection, drawing error, product non-conformance, etc., shall be documented, approved, and implemented per the relevant configuration management plan. Lead engineers shall be familiar with the customer's configuration management process, such as how changes are requested, reviewed and approved, as well as forms, websites, or other media utilized in the process.

6. Design Reviews

At appropriate stages throughout the design and development process, reviews shall be scheduled and conducted.

6.1. Internal reviews are held during the design process and are truly at the grass roots level. Participants of these informal reviews are usually members of the PDT and other electrical engineers/technicians. Though not required, informal documentation and tracking of action items sometimes occurs at the discretion of the lead engineer.

6.2. Engineering Peer Reviews (See GPR 8700.6,Engineering Peer Reviews) are more formal reviews that evaluate a design's technical status using a team of appropriate specialists independent from the PDT. They are conducted as specified in the Engineering Peer Review Plan (See GPR 8700.6). Emphasis should be placed on selecting a well-rounded review team consisting of personnel cognizant of and experienced with the subject matter of the review. These reviews are conducted to ensure that the harness design fully meets the design requirements. It is the responsibility of the lead engineer and/or the PDT to respond to all Requests for Action (RFA's) generated at the reviews. Engineering Peer Reviews can be scheduled at any time during the design and development process. Some typical reasons for scheduling an Engineering Peer Review could be any one or more of the following:

- Required per the Engineering Peer Review Plan (See GPR 8700.6)
- Review of a new design
- Review results of trade studies
- Review modifications to an existing design or to existing design requirements
- Preparation for an Integrated Independent Review
- Preparation for a complex functional or environmental test

6.3. Integrated Independent Reviews (See GPR 8700.4, Integrated Independent Reviews) provide expert technical review of the end-to-end mission system and are conducted at the system-level at critical milestones in project formulation and implementation. They are conducted as specified in the project's Integrated Independent Review Plan (See GPR 8700.4). The Integrated Independent Review Team consists of two co-chairpersons and a team of technical and systems management experts independent of the program and project team. The status of the electrical harness design and development is presented at these reviews by the Electrical Systems lead engineer, or appointed member of the PDT. Other lead engineers/PDTs present the status of their respective subsystems at these reviews. These reviews are conducted to ensure that the system design fully meets the design requirements. Again, it is the responsibility of the lead engineer and/or PDT to respond to all Requests for Action (RFA's) generated at the reviews for their respective subsystem. Reviews typically conducted include a Systems Concept Review, Preliminary Design Review, Critical Design Review, Pre-Environmental Test Review, and a Pre-Ship Review.

7. Design Verification

During the engineering design and development process, design verification will be conducted as required to ensure that the design meets all of the customer's requirements. Verification can be accomplished by a combination of analysis, review, and test.

7.1 Depending upon the application, one or more of the following analyses may be appropriate:

- Various transmission line analyses (cable capacitance, inductance, line loss, etc.)
- Shielding effectiveness
- Review and comparison with similar systems/designs

7.2. In addition to internal reviews, Peer and Systems Reviews will be conducted as described in Section 6 of this procedure to verify that the design and test documentation meets the customer's requirements.

7.3. Development and testing of proof-of-concept designs, and engineering or qualification test assemblies may also be conducted as part of the design verification.

7.4. The Work Order Authorization (WOA) shall be utilized (per GPR 5330.1, Product Processing, Inspection, and Test) to plan and document the processing of a product as it progresses from the initial stages of manufacture through integration, inspection, and test events, including all functional and environmental tests, required for design verification.

8. Design Validation

The lead engineer/PDT shall validate the product in accordance with GPR 8700.3, Design Validation. Validation includes manufacture, integration to larger systems/assemblies, as well as environmental and functional tests. Note that due to the iterative nature of the design process, intermediate validation is frequently required.

8.1 The lead engineer shall determine the most appropriate and efficient method for fabrication of the hardware. Options include use of in-house manpower, task order contracts, or any other contracting medium that accesses a viable fabrication resource.

8.2. Assembly and integration of flight hardware should be performed in accordance with an assembly drawing and/or plan. Assembly, integration, inspection, and test events shall be documented via the Work Order Authorization process defined in GPR 5330.1, Product Processing, Inspection and Test. All assembly and integration activities shall be performed with the appropriate safety considerations addressed for personnel and/or hardware, and under the appropriate environmental conditions. Some items for consideration are:

- Cleanliness requirements
- Temperature/Humidity requirements

- Electro-static discharge (ESD) control
- Unique power and/or grounding requirements
- Adequacy of space
- Unique safety requirements particular to any subsystem, instrument, and/or spacecraft

8.2 Validation testing shall be conducted using approved (formally released) validation test plans and procedures. Validation testing shall consist of the following, as appropriate:

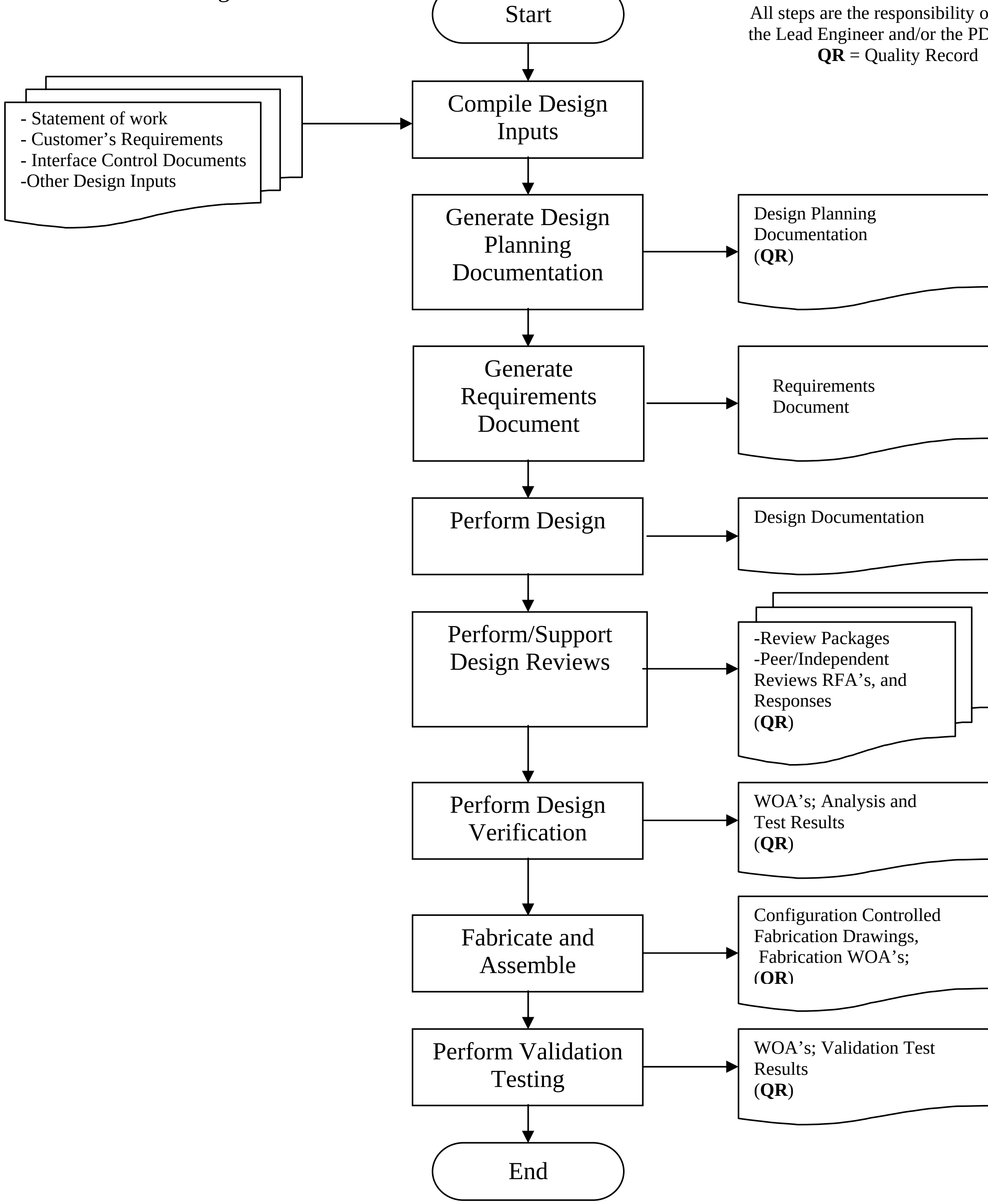
- Interface testing (mechanical and electrical)
- Functional testing
- Life testing
- Vibration testing
- Thermal/Vacuum testing
- Thermal Balance testing
- EMI/EMC testing
- Magnetics testing

8.3. The WOA shall be utilized (per GPR 5330.1, Product Processing, Inspection, and Test) to plan and document manufacturing, assembly, inspection, and test events, including all functional and environmental tests, required for product validation. Test results shall be analyzed and evaluated to ensure that all customer-imposed requirements have been validated. Anomalies found during the validation process shall be documented and resolved per GPR 5340.2, Control of Non-conforming Product, and GPR 1710.1, Corrective and Preventive Action.

9. Communicating Design Output to Customer and Configuration Management

The lead engineer/PDT shall assure that both the design output (e.g., engineering drawings, test plans, procedures, reports, review documentation, etc.) and the design progress (technical, budget, schedule) are communicated to the appropriate configuration management system per GPR 1410.2, Configuration Management and to the customer upon request.

10. Process Flow Diagram



11. Flight Harness Fabrication

All flight harness fabrication shall be done in accordance with NASA-STD-8739.4. As defined in Section 1.2 of NASA-STD-8739.4, the requirements of the Standard are applicable to interconnecting cable and wire harnesses for flight hardware, mission critical ground support equipment, and elements thereof, and wherever invoked contractually.

Section 4.2 of NASA-STD-8739.4 specifies requirements for approval of departures from the standard. In addition to approval by in-house project management, all departures from the standard shall be evaluated and approved by Code 565 prior to implementation.

All personnel involved in the fabrication, testing, inspection, and integration of flight electrical harnesses shall be certified to NASA-STD-8739.3, and NASA-STD-8739.4.

11.1 Ground Support Equipment

As stated above, any mission critical ground support cabling shall be fabricated and tested in accordance with NASA-STD-8739.4. All parts and materials used in the fabrication of any ground support cabling that will mate to, or be used on or around space flight hardware, shall be acceptable for space flight use.

CHANGE HISTORY LOG

Revision	Effective Date	Description of Changes
Baseline	09/23/1998	Initial Release
A	02/02/2005	Replaces 565-PG-8700.2.1 Electrical Harness Design and Manufacturing. Format modified to conform to GPR 1410.1A.
B	11/18/2005	Added references to NASA-STD-8739.3, and NASA-STD-8739.4 Added sections 11, and 11.1