“Harness Shake Down”
CKT Testing Flight Bus Harness

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Agenda

- Introduction
- CKT Machine
- Test Flow
- Requirements
- System Engineering process
- Trade Studies
  - Manual VS Using the CKT Machine
- Interface Diagram
  - How it is done now VS How it should be done.
- Requirements verification
- Adding Value
  - Implementing Lean Enablers
- Risk Management
- Documentation
- Deliverables
- Conclusion
Introduction

- Boeing Satellite Development Center is one of the largest Satellite manufacturers in the world.
- Thousands of man hours are budgeted for testing a satellite.
- "Harness Shake Down" is conducted to make sure that all the harness wiring in the bus module is correct.
- The current way the test is performed is manually using break out boxes, cables, multimeter, DC power supply.
- The goal is to run the flight harness validation automatically.
- The Special Test equipment organization uses a cable checker that was purchased from a company named CK Technologies. Need to incorporate this CKT rack for running this test.
- Systems engineering can help in this test by using the systems engineering process mil-std-499B. This will be used to ensure that the requirements are good and can be fulfilled.
- Lean systems engineering will play a large role in finding waste in the test and how to eliminate this non-value added waste.
- Understanding risk that can occur and ways to manage that risk will help this test be successful.
- Performing trade studies on how to do this test will help in making the proper engineering decision for the best way of doing the test while again, focusing on added value to the program.
CKT Machine

- "The main function of this machine is for cable / harness testing for the aerospace industry. These systems cover the entire spectrum of wired assembly testing - from the harness shop to the completed assembly, such as an entire aircraft."

(www.ckt.com)
System Engineering Process

Process Input:
- Customer Needs/Objectives/Requirements
  - Missions
  - Measures of Effectiveness
  - Environments
  - Constraints
- Technology Base
- Output Requirements from Prior Development Effort
- Program Decision Requirements
- Requirements Applied Through Specifications and Standards

Requirements Analysis
- Analyze Missions and Environments
- Identify Functional Requirements
- Define/Refine Performance and Design Constraint Requirements

System Analysis and Control (Balance)
- Trade-Off Studies
- Effectiveness Analyses
- Risk Management
- Configuration Management
- Interface Management
- Data Management
- Performance Measurement
  - SEMS
  - TPM
  - Technical Reviews

Functional Analysis/Allocation
- Decompose to Lower-Level Functions
- Allocate Performance and Other Limiting Requirements to All Functional Levels
- Define/Refine Functional Interfaces (Internal/External)
- Define/Refine/Integrate Functional Architecture

Requirements Loop

Design Loop

Synthesis
- Transform Architectures (Functional to Physical)
- Define Alternative System Concepts, Configuration Items and System Elements
- Select Preferred Product and Process Solutions
- Define/Refine Physical Interfaces (Internal/External)

Verification

Process Output
- Development Level Dependent
  - Decision Database
  - System/Configuration Item Architecture
  - Specifications and Baselines

Related Terms:
- Customer = Organizations responsible for Primary Functions
- Primary Functions = Development, Production/Construction, Verification, Deployment, Operations, Support, Training, Disposal
- Systems Elements = Hardware, Software, Personnel, Facilities, Data, Material, Services, Techniques
Requirements flow down

- Harness Shakedown is a series of harness continuity, isolation, resistance, and voltage checks designed to identify harness miss wirings that might damage flight.
- A volts/no-volts check will be conducted on each pin in a flight connector to check for any shorts that can damage flight hardware.
- The Harness shakedown verifies any connection made during installation of the harness on the spacecraft.
- The test procedure that the systems test organization will run for this harness shakedown test is TPxxxxx-hxx-654. The "x" values in the procedure name will be replaced with the spacecraft number, however the TP-654 is the number for the harness shakedown.
Requirements list

- TP-654 shall verify pin-to-pin continuity, isolation, and wire integrity after the integration splices for components on the bus have been completed.
- TP-654 shall determine harness resistances of bus wiring.
- TP-654 shall verify harness continuity of bus signal ground points.
- TP-654 shall determine power harness resistances.
- TP-654 shall verify proper power distribution from the IPC and the BPDUs for the bus.
- TP-654 shall determine harness resistances of flight and GSE pyro test harness used in pyro installation, electrical verification, and Squib Driver Unit testing.
- TP-654 shall determine harness resistances of pyro flight harness.
- TP-654 shall reference Payload Interface mates.
- TP-654 shall verify proper location of temp sensors.
- TP-654 shall determine harness resistances of heaters.
- TP-654 shall determine harness resistances of antenna module wiring, and temperature sensors.
## Trade Study

<table>
<thead>
<tr>
<th>Organization</th>
<th># of heads</th>
<th># of hours/shift</th>
<th># of shifts</th>
<th>$ for the test</th>
<th># of heads</th>
<th># of hours/shift</th>
<th># of shifts</th>
<th>$ for the test</th>
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<tbody>
<tr>
<td>STE</td>
<td>3</td>
<td>8</td>
<td>5</td>
<td>$24,000</td>
<td>3</td>
<td>8</td>
<td>5</td>
<td>$24,000</td>
</tr>
<tr>
<td>System Test</td>
<td>3</td>
<td>8</td>
<td>15</td>
<td>$72,000</td>
<td>2</td>
<td>8</td>
<td>3</td>
<td>$9,600</td>
</tr>
<tr>
<td>System Engineering</td>
<td>1</td>
<td>1</td>
<td>15</td>
<td>$3,000</td>
<td>1</td>
<td>1</td>
<td>3</td>
<td>$600</td>
</tr>
<tr>
<td>Harness Tech</td>
<td>2</td>
<td>8</td>
<td>3</td>
<td>$9,600</td>
<td>2</td>
<td>2</td>
<td>1.5</td>
<td>$1,200</td>
</tr>
<tr>
<td>Quality</td>
<td>1</td>
<td>8</td>
<td>2</td>
<td>$3,200</td>
<td>1</td>
<td>8</td>
<td>2</td>
<td>$3,200</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>10</strong></td>
<td><strong>33</strong></td>
<td><strong>40</strong></td>
<td><strong>$111,800</strong></td>
<td><strong>9</strong></td>
<td><strong>27</strong></td>
<td><strong>14.5</strong></td>
<td><strong>$38,600</strong></td>
</tr>
</tbody>
</table>

**Cost per hour of employee**

- Manual Test: $200
- CKT test: $200

**Total cost savings**

$73,200
CKT calibration

- BUSINESS PROCESS INSTRUCTION BPI-5195
- Metrology Lab Primary Standards North America certifies the Calibration box. It is measured with a calibrated reference to ensure that the components internal to the box meet the drawing specifications.
- Calibration CKT test program is written per the drawing of the calibration box.
- PSNA runs the test program per the calibration procedure (CP88000-STE-002).
- The test output data is reviewed for accuracy.
- If accurate, the machine is labeled as calibrated and can be used to take flight data.
- If inaccurate, the machine will be fixed by the vendor specialist and the test program will be run again.
How it is done now.
Roles

- **STE Department**: Responsible for set up, calibration, certification, validation, verification, STE data sell off to customer based on requirements.
- **System Test**: Responsible for using the STE to test the flight hardware. Sell data from testing to systems engineers.
- **Quality**: Quality is responsible for ensuring that all mates to the spacecraft meet our quality standards for connecting to flight hardware.
- **Harness Techs**: They are responsible for conducting the actual mates to the spacecraft.
- **Systems Engineering**: They are responsible for making sure that the data collected from System Test meets the requirement for the test.
How it should be done.
## Requirements V & V

<table>
<thead>
<tr>
<th>Requirement</th>
<th>Verification</th>
</tr>
</thead>
<tbody>
<tr>
<td>TP-654 shall verify pin-to-pin continuity, isolation, and wire integrity after the integration splices for components on the bus have been completed.</td>
<td>Test</td>
</tr>
<tr>
<td>TP-654 shall determine harness resistances of bus wiring.</td>
<td>Test</td>
</tr>
<tr>
<td>TP-654 shall verify harness continuity of bus signal ground points.</td>
<td>Test</td>
</tr>
<tr>
<td>TP-654 shall determine power harness resistances (power terminal board to terminal board).</td>
<td>Test</td>
</tr>
<tr>
<td>TP-654 shall verify proper power distribution from the IPC and the BPDUs for the bus.</td>
<td>Test</td>
</tr>
<tr>
<td>TP-654 shall determine harness resistances of flight and GSE pyro test harness used in pyro installation, electrical verification, and Squib Driver Unit testing.</td>
<td>Test</td>
</tr>
<tr>
<td>TP-654 shall determine harness resistances of pyro flight harness</td>
<td>Test</td>
</tr>
<tr>
<td>TP-654 shall reference Payload Interface mates.</td>
<td>Test</td>
</tr>
<tr>
<td>TP-654 shall verify proper location of temp sensors.</td>
<td>Test</td>
</tr>
<tr>
<td>TP-654 shall determine harness resistances of heaters.</td>
<td>Test</td>
</tr>
<tr>
<td>TP-654 shall determine harness resistances of antenna module wiring, and temperature sensors</td>
<td>Test</td>
</tr>
</tbody>
</table>
Adding Value

- **Kitting** – Cable roll around cart is used to deliver all required cables. Lean enabler 5.6.2.

- **Waste:**
  - **Waiting** – The waiting for harness to mate the cables when each connector is to be tested is removed by Lean enabler 3.5.2.
  - **Inefficiency** – Cost of harness support and QA is reduced by Lean enablers 3.5.2 and 6.2.4.
  - **Schedule** – Schedule is pulled to the left by Lean enablers 3.5.2 and 6.2.4.
Lean Principle/Enabler/Sub-enabler – 3.5.2

<table>
<thead>
<tr>
<th>Lean Principle</th>
<th>3. Flow</th>
</tr>
</thead>
<tbody>
<tr>
<td>Enabler</td>
<td>5. Use efficient and effective communication and coordination.</td>
</tr>
<tr>
<td>Sub-enabler</td>
<td>2. Maximize coordination of effort and flow (one of the main responsibilities of lean SE).</td>
</tr>
</tbody>
</table>
| Implementation | • For the flow of work to proceed robustly, predictably, right the first time, the effort of each task in the flow should be predictable, well planned, and coordinated with other tasks.  
  • Load should be leveled as much as possible, STE needs to be present during this test to help out with CKT hook up.  
  • Critical path effort should be clearly identified. Cables for the test need to be available when its time to run the test.  
  • SE is to monitor the state of the project to ensure continuous and predictable flow of the value added effort. He will be present during the execution of the test to review data accuracy. |
| Consequences   | • Lack of coordination can cause rework, delays, and frustrations that are not needed for the program. |
### Lean Principle/Enabler/Sub-enabler – 5.6.1-3

<table>
<thead>
<tr>
<th>Lean Principle</th>
<th>5. Perfection</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Enabler</strong></td>
<td>6. Drive out Waste through Design Standardization, Process Standardization, and Skill-Set Standardization.</td>
</tr>
<tr>
<td><strong>Sub-enabler</strong></td>
<td></td>
</tr>
<tr>
<td>1.</td>
<td>Promote Design Standardization with engineering checklists, standard architecture, modularization, busses, and platform.</td>
</tr>
<tr>
<td>2.</td>
<td>Promote process standardization in development, management, and manufacturing.</td>
</tr>
<tr>
<td>3.</td>
<td>Promote standardization skill sets with careful training and mentoring, rotations, strategic assignments, and assessments of competencies.</td>
</tr>
</tbody>
</table>

**Implementation**

- Make it easy to assign employees to tasks with flexibility, use work cells, and organize a lean flow.
- Create a checklist for the CKT machine.
- Create Cable Kit for the harness shake down.

**Consequence**

- Lack of standardization causes variation and a non-repeatable test.
- Lack of flow causes waiting waste.
- Increase cost to program.
# CKT checklist

<table>
<thead>
<tr>
<th>Task#</th>
<th>Status</th>
<th>Tasks list</th>
<th>Comments</th>
<th>Value?</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>complete</td>
<td>Review the Service request that was submitted with the Test director, STE Project Manager, STE support, Quality, Harness lead, System Engineer.</td>
<td></td>
<td>RNVA</td>
</tr>
<tr>
<td>2</td>
<td>in-work</td>
<td>Create a layout with the Test director for best work cell flow of work.</td>
<td></td>
<td>VA</td>
</tr>
<tr>
<td>3</td>
<td>in-work</td>
<td>Gather bob cables for the harness shake down test.</td>
<td></td>
<td>VA</td>
</tr>
<tr>
<td>4</td>
<td>open</td>
<td>Test all break out box cables and break out boxes on CKT machine.</td>
<td></td>
<td>VA</td>
</tr>
<tr>
<td>5</td>
<td>open</td>
<td>Place cables and Bob boxes in the proper labeled location in the roll around cabinet to be delivered to the test area as a kit.</td>
<td></td>
<td>VA</td>
</tr>
<tr>
<td>6</td>
<td>open</td>
<td>Prep the CKT machine to be moved to the work cell.</td>
<td></td>
<td>RNVA</td>
</tr>
<tr>
<td>7</td>
<td>open</td>
<td>Have rigging department move roll around to the work cell.</td>
<td></td>
<td>RNVA</td>
</tr>
<tr>
<td>8</td>
<td>open</td>
<td>Inform the test director that the cables are in the work cell.</td>
<td></td>
<td>RNVA</td>
</tr>
<tr>
<td>9</td>
<td>open</td>
<td>Assist Harness and Quality in mating all break out cables onto the spacecraft.</td>
<td></td>
<td>VA</td>
</tr>
<tr>
<td>10</td>
<td>open</td>
<td>Power and Ground CKT machine in the work cell per the layout.</td>
<td></td>
<td>VA</td>
</tr>
<tr>
<td>11</td>
<td>open</td>
<td>Load CKT program for harness shake down test.</td>
<td></td>
<td>VA</td>
</tr>
<tr>
<td>12</td>
<td>open</td>
<td>Follow prompts on connecting bob cables to the CKT machine.</td>
<td></td>
<td>VA</td>
</tr>
<tr>
<td>13</td>
<td>open</td>
<td>Run the CKT program and save the file to the computer.</td>
<td></td>
<td>VA</td>
</tr>
<tr>
<td>14</td>
<td>open</td>
<td>Attached the test results to the STE Service request that was submitted for the test phase.</td>
<td></td>
<td>RNVA</td>
</tr>
<tr>
<td>15</td>
<td>open</td>
<td>Review test results with STEPM, TD, SE and get consent to proceed.</td>
<td></td>
<td>VA</td>
</tr>
</tbody>
</table>
### Lean Principle/Enabler/Sub-enabler – 6.2.5

<table>
<thead>
<tr>
<th>Lean Principle</th>
<th>6. Respect for People</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Enabler</strong></td>
<td>2. Build an Organization Based on Respect for People.</td>
</tr>
<tr>
<td><strong>Sub-enabler</strong></td>
<td>4. Promote direct human communication.</td>
</tr>
<tr>
<td><strong>Implementation</strong></td>
<td>- Do not throw information OVER THE WALL.</td>
</tr>
<tr>
<td></td>
<td>- Collocation is better for communication. All members required for the test should be down on the floor when the test is run. No Waiting!</td>
</tr>
<tr>
<td></td>
<td>- Be clear and direct as possible.</td>
</tr>
<tr>
<td></td>
<td>- Minimize intermediate handoffs.</td>
</tr>
<tr>
<td><strong>Consequences</strong></td>
<td>- Waste created by waiting.</td>
</tr>
<tr>
<td></td>
<td>- Information is loss through handoffs.</td>
</tr>
<tr>
<td></td>
<td>- Miscommunication causes rework.</td>
</tr>
</tbody>
</table>
Risk Management

What are the risks?

1. If there is a short present in the flight harness, due to wires not being properly routed, then units on the spacecraft can be damaged under testing conditions.

2. If the proper distribution from the Power controller to the Bus Distribution Units are not correct, due to wrong wire layout, then lower powered units may be damaged when higher voltage is applied.

3. If the CKT data is bad, due to no calibration, then the data collected will be unusable.
1. If there is a short present in the flight harness, then units on the spacecraft can be damaged under testing conditions.
2. Create a CKT program by inputting the wire list and BOM into the test software.
3. Run the Test and verify continuity and isolation is present in the desired location.
1. If the proper distribution from the Power controller to the Bus Distribution Units are not correct, then lower powered units may be damaged when higher voltage is applied.
2. Create a CKT program by inputting the wire list and BOM into the test software.
3. Run the Test and verify continuity and isolation is present in the desired location.
1. If the CKT data is bad, due to no calibration, then the data collected will be unusable.
2. Create a CKT program that will measure the internals of the calibration box.
3. Run the Test and verify the required measurements met the calibration specs per the released drawing.
Documentation

- CKT calibration procedure (CP88000-STE-002)
- CKT test program.
- TPxxxxxx-hxx-654 redlines to include CKT use.
- CKT checklist.
Releasing a document

- When a procedure is created, it will need to be reviewed and signed off by a set of individuals before it can be officially released into our configuration management database and used on the floor.
- The procedure will need the following signatures on the cover sheet.
This is the cover page of the calibration document that was created for the CKT machine.
Changing a Document:

- Engineering Change Request (ECR) is a document that is used for changes in components, assemblies, hardware, or documents such as processes and work instructions.
OV-1 for ECR

- Test Department
- Equipment website database
- Change Correction Board
- STE Department
Roles

- **STE Department**: Responsible for set up, calibration, certification, validation, verification, STE data sell off to customer based on requirements.

- **Test Department**: Responsible for using the STE to test the flight hardware. Sell off data from testing to systems engineers.

- **Change Correction Board**: Responsible for reviewing all ECRs that are submitted.

- **Equipment Website Database**: Main link between all parties. Database that stores history of request. Form of knowledge management.
Conclusion

- The current way the Harness Shakedown test is currently run is an inefficient way of doing the test. Systems engineering can help Lean out the test and have a better way for doing this it to being value to the customer.

- This will require coordination between the following teams: STE Support, STE Project Management, Systems Test, Systems Engineering, Harness Technicians, and Program Quality Assurance.

- Risk Management helped show that using the CKT machine can reduce the risk so that the test can be a success.

- Requirement verification shows that all the requirements will be met.

- Showing this cost savings from using the current method versus using the CKT machine shows that there is a cost saving to the program man power, and schedule that will benefit the program and company.
References

- [WWW.CKT.com](http://WWW.CKT.com)