# Electrical Diagnostic Tool Kit (ESDT)

BY DAWN VERLANDER

# About the Presenter

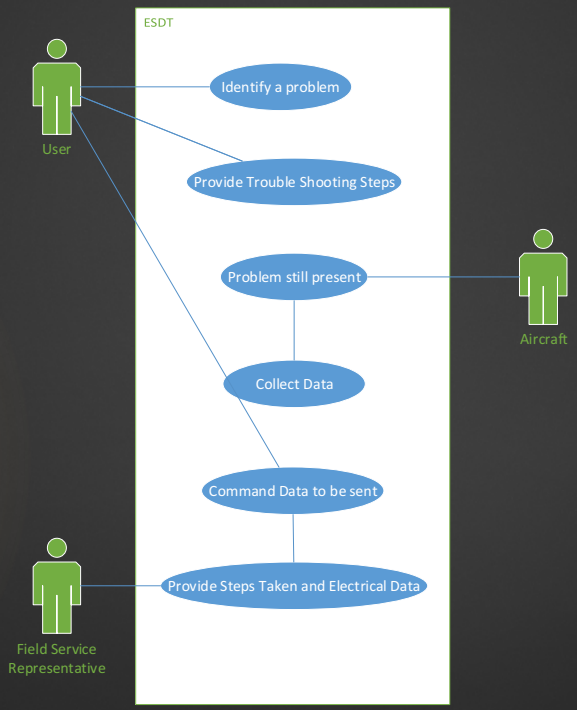
- Undergrad Info: Graduated from Messiah College with a Bachelor of Science in Engineering with Electrical and Computer Concentrations
- Current Employment
  - Works for Boeing in Philadelphia
  - Current US Army Block II Requirements Lead for the Chinook Program
  - Formerly Chinook Electrical System Designer
- Hobbies:
  - Traveling and Reading
  - New for 2019 – Knitting!

# Need for the Project

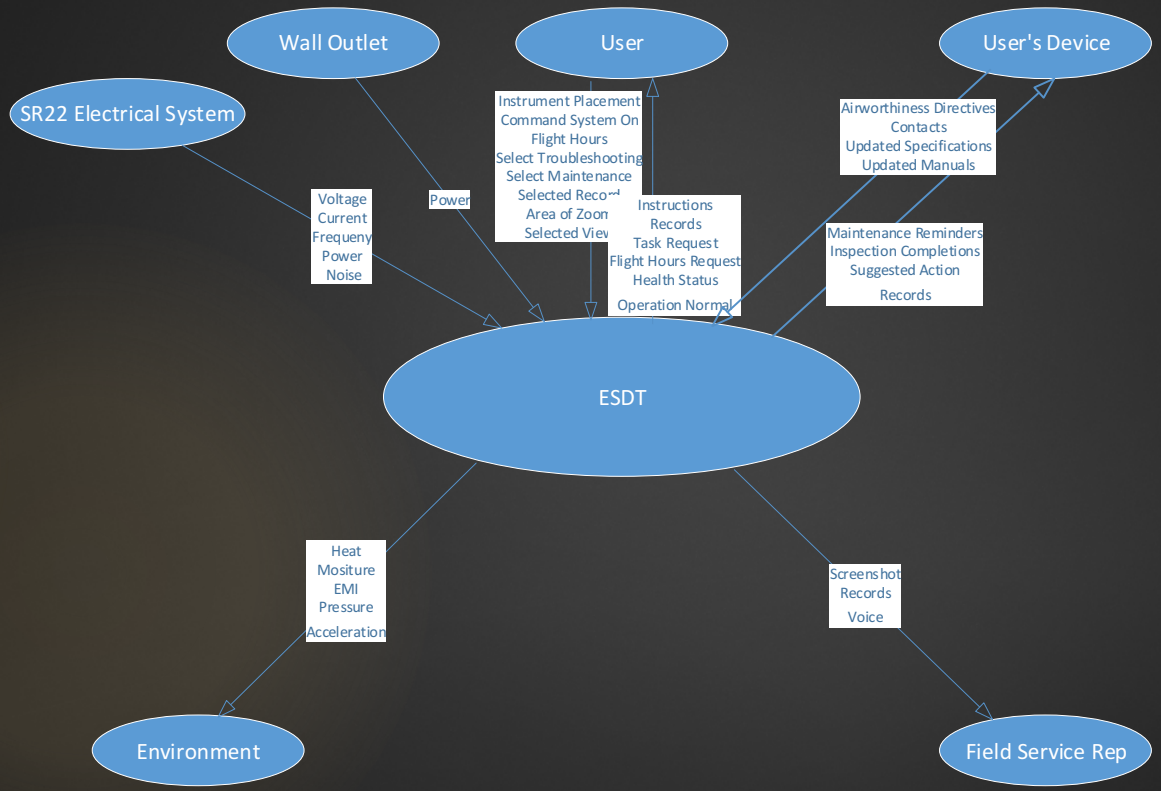
- Over 4,000 Cirrus SR22s have been delivered
- Current Practice is Remove/Replace and 'Hope'
- Can Run over $5000 for single issue
- Example of a possible troubleshooting scenario below

| Troubleshooting step | Labor hours (80$ per hour) | Parts Costs ($) | Total costs ($) |
|---|---|---|---|
| **Tighten corresponding connector.** | 0.5 | N/A | 40 |
| **Replace alternator.** | 1 | 1700 | 1780 |
| **Replace MCU.** | 3 | 3250 | 3490 |
| **Increase Engine RPM** | 0.5 | N/A | 40 |
| | | Total | 5350 |

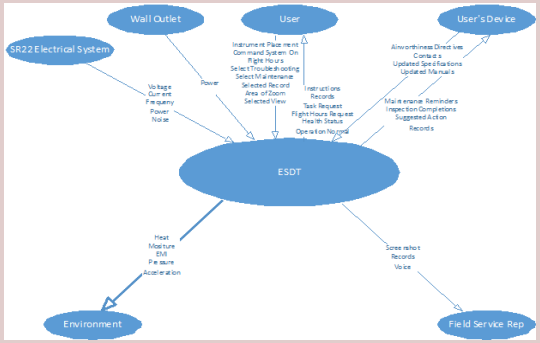
# CONOPS –Scenario 3



# Context Diagram



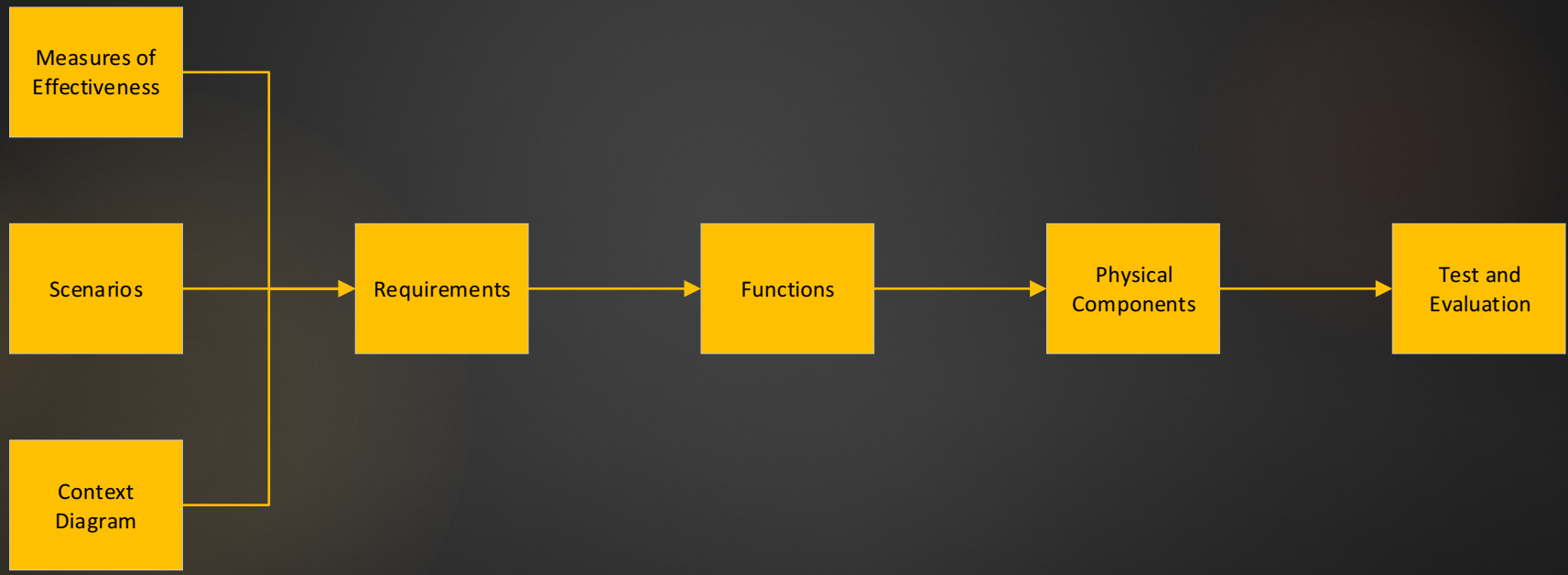
# Decomposition Example

| DOORS Identifier | Source | Requirements Analysis | Child Requirement |
|---|---|---|---|
| CTXT-DIA-10 |  | Section 4 Temperature and Altitude<br>RAR-59 captures the temperature requirement for the ESDT to operate between temperatures of -10F and 104F. Below -10 and the SR22 needs special winterizing kits. It is also believed the user will not want to be performing maintenance in conditions below -10 and would seek either a heated hangar or do it another day. | RAR-59: The ESDT shall operate in temperatures between -10F and 104F. |
| MOE-4 | System will complete 90% diagnostics within 2 hours. | RAR-102 captures the requirement for the time limit of the system to diagnose problem. Key condition include the user must first gather all equipment and the user must follow all the instructions provided by the system correctly. | RAR-102: The ESDT shall identify 90% of problems or the Cirrus SR22 electrical system within 2 hours from the time the user has gathered all the required equipment to identification of the problem when the user has followed all instructions. |

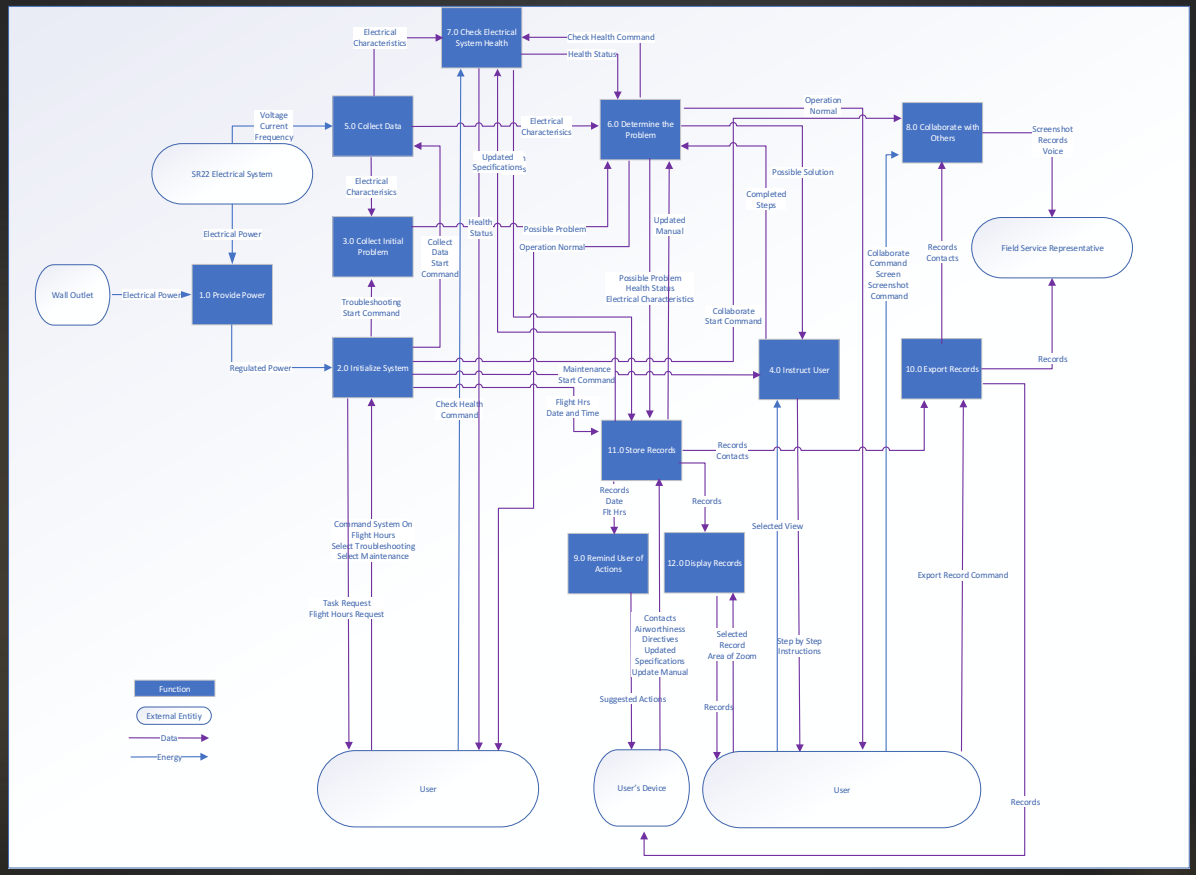
# Key Performance Parameters (KPPs)

- The ESDT shall update the airworthiness directive database for the aircraft within 24 hours upon receipt of the e-mail from the user.
  - **[RAR-8]**
- The ESDT shall diagnose 95% of all correctly identified problems of the Cirrus SR22 electrical system without inputs from mechanics or other equipment.
  - **[RAR-101]**
- The ESDT shall identify 90% of problems or the Cirrus SR22 electrical system within 2 hours from the time the user has gathered all the required equipment to identification of the problem when the user has followed all instructions.
  - **[RAR-102]**
- The ESDT shall maintain 90% of battery life with display and measurement systems off for 3 months when stored in dry conditions from 65F to 75F.
  - **[RAR-103]**
- The ESDT shall diagnose correctly 95% of all malfunctions.
  - **[RAR-104]**
- The ESDT shall keep an action log of up 40 years of airworthiness and maintenance actions and up to 3 year of future airworthiness actions required by the FAA.
  - **[RAR-10]**

# Requirements Architecture



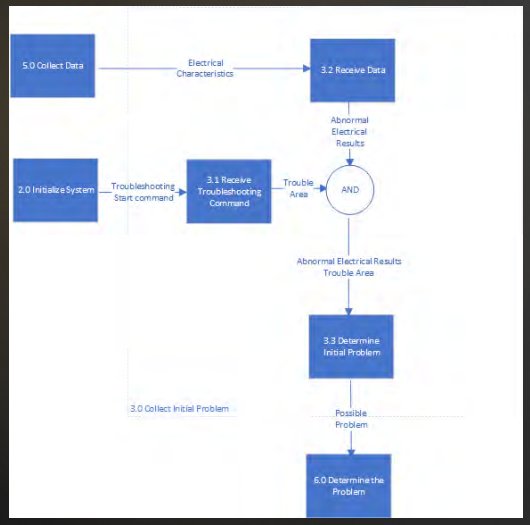
# Functional Block Diagram



# Functional Decomposition Example

| Function | Requirement ID |
|---|---|
| **3 Collect Initial Problem** | |
| **3.1 Receive Troubleshooting Command** | RAR-29<br>RAR-101<br>RAR-102<br>RAR-104 |

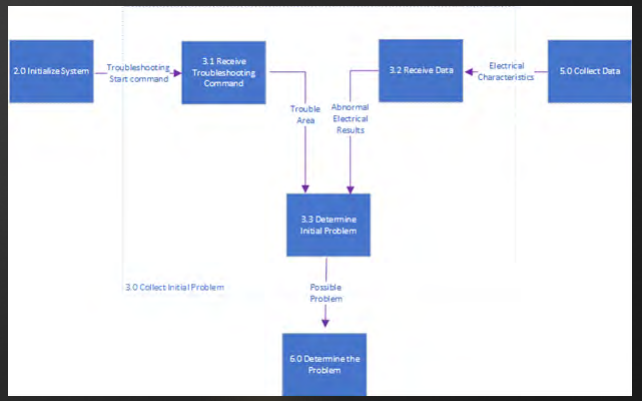
## Functional Flow Diagram



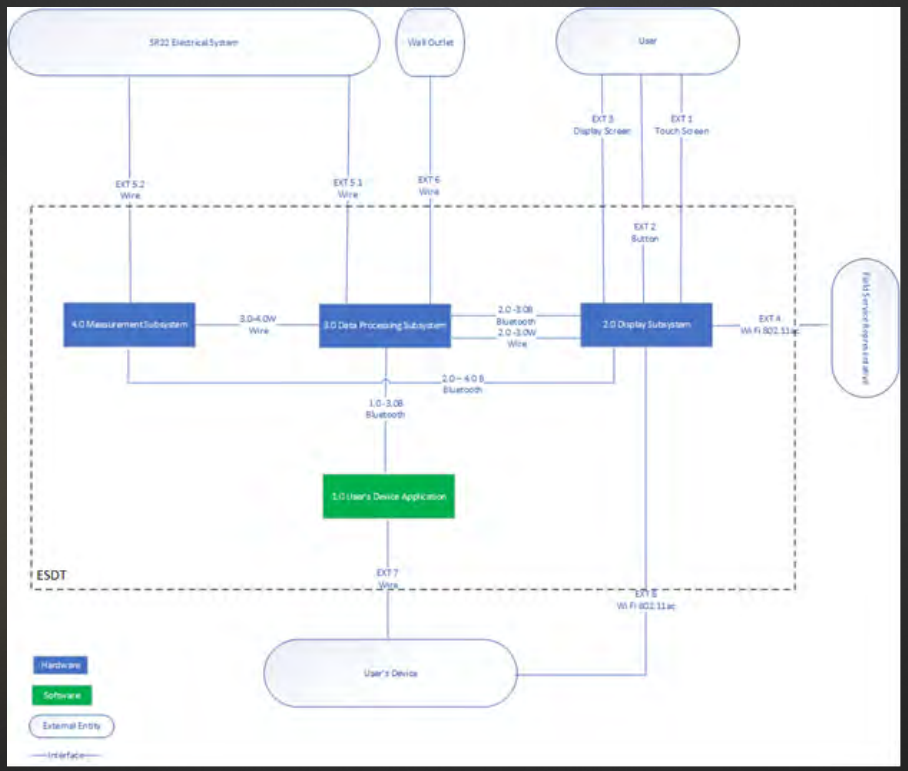

## N2 Diagram

| Functions | 1.0 Provide Power | 2.0 Initialize System | 3.0 Collect Initial Problem |
|---|---|---|---|
| **1.0 Provide Power** | 1.0 Provide Power | Regulated Power | |
| **2.0 Initialize System** | | 2.0 Initialize System | Trouble-shooting Start Command |
| **3.0 Collect Initial Problem** | | | 3.0 Collect Initial Problem |
| **5.0 Collect Data** | | | Electrical Characteristics |

## Functional Block Diagram



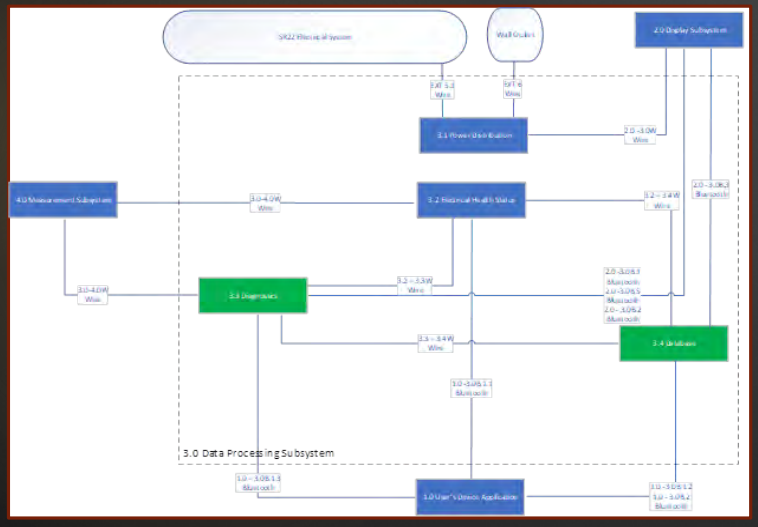
# Physical Design



# Physical Decomposition Example 1

| Requirement ID | Function | Subsystem | Subsystem Interface | Component | Component Interfaces |
|---|---|---|---|---|---|
| RAR-28<br>RAR-101<br>RAR-102<br>RAR-104 | 3.1 Receive Troubleshooting Command | 3.0 Data Processing Subsystem | 2.0 - 3.0B | 3.3 Diagnostics | 2.0 - 3.0B.1 |

## Physical Block Diagram

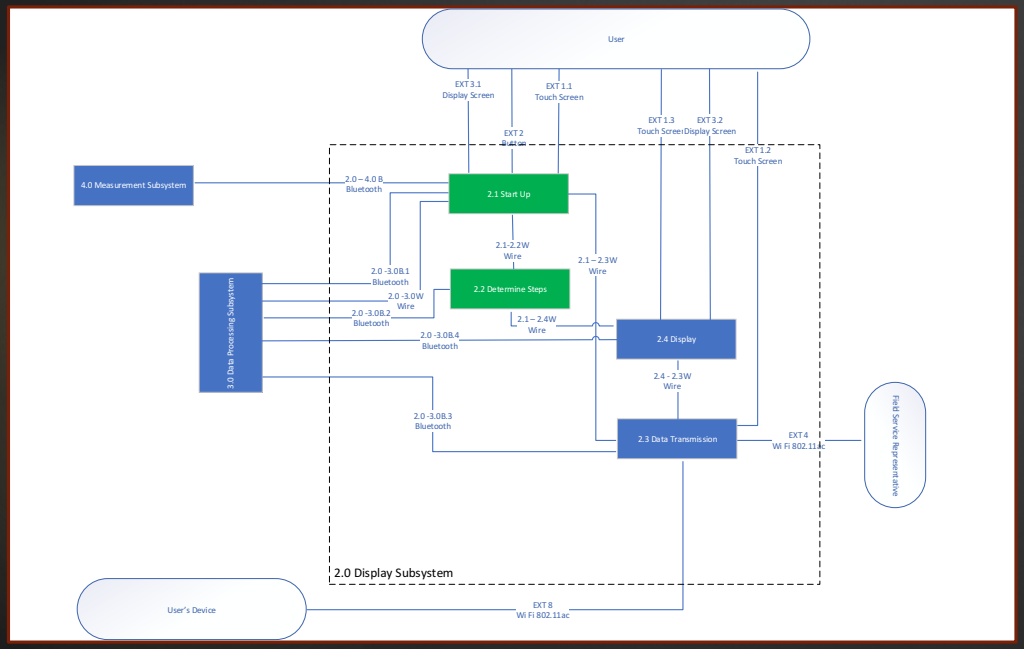



| Interface Number | Type | Data |
|---|---|---|
| 1.0 - 3.0B | Bluetooth | Contacts<br>Airworthiness Directives<br>Updated Specifications<br>Updated Manuals<br>Flight Hours<br>Date<br>Records |
| 1.0 - 3.0B.1.3 | Bluetooth | Updated Manuals |
| 2.0 - 3.0B | Bluetooth | Troubleshooting Start Command<br>Maintenance Start Command<br>Trouble Area<br>Flt Hrs<br>Possible Solutions<br>Operation Normal<br>Records<br>Contacts<br>Completed Steps<br>Export Records Command |
| 2.0 - 3.0B.1 | Bluetooth | Troubleshooting Start Command<br>Maintenance Start Command<br>Flight Hours<br>Date and Time |
| 2.0 - 3.0B.2 | Bluetooth | Possible Solutions |
| 2.0 - 3.0B.5 | Bluetooth | Completed Steps |
| 3.0 - 4.0W | Wire | Electrical Characteristics |
| 3.2 - 3.3W | Wire | Health Status<br>Check Health Command |
| 3.3 - 3.4W | Wire | Health Status<br>Electrical Data<br>Possible Problem<br>Abnormal Condition |

# Physical Decomposition Example 2

| Requirement ID | Function | Subsystem | Subsystem Interface | Component | Component Interfaces |
|---|---|---|---|---|---|
| RAR-59 | | 2.0 Display Subsystem | | | |

Physical Block Diagram

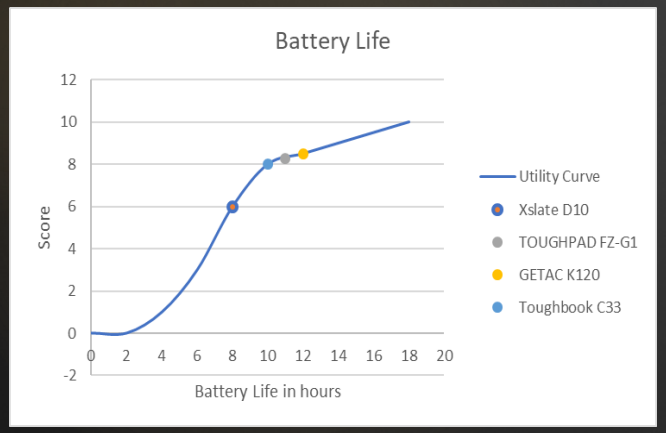


# Trade Study Analytical Hierarchy Process (AHP) Example

- Battery Life Criteria Supports RAR-102 and was listed as the most important criteria by the stakeholder

| Overall Criterion Pair Wise Matrix | Battery Life | Screen Brightness | Screen Size | Screen Resolution |
|---|---|---|---|---|
| **Battery Life** | 1.00 | 3.00 | 4.00 | 7.00 |
| **Screen Brightness** | 0.33 | 1.00 | 2.00 | 6.00 |
| **Screen Size** | 0.25 | 0.50 | 1.00 | 4.00 |
| **Screen Resolution** | 0.14 | 0.17 | 0.25 | 1.00 |

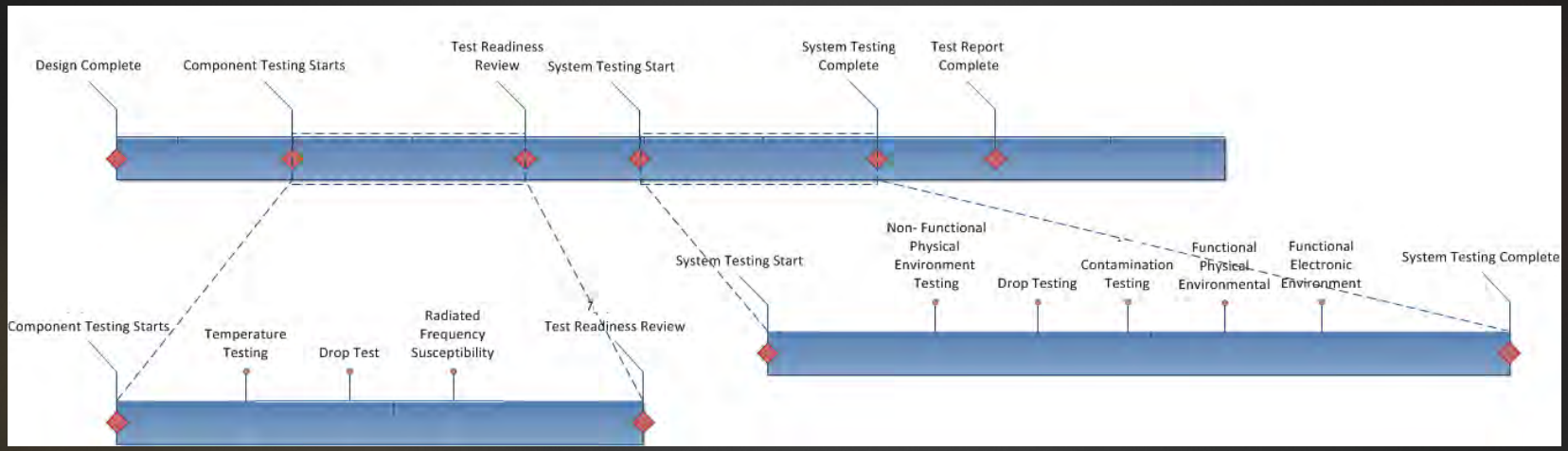
Utility Curve



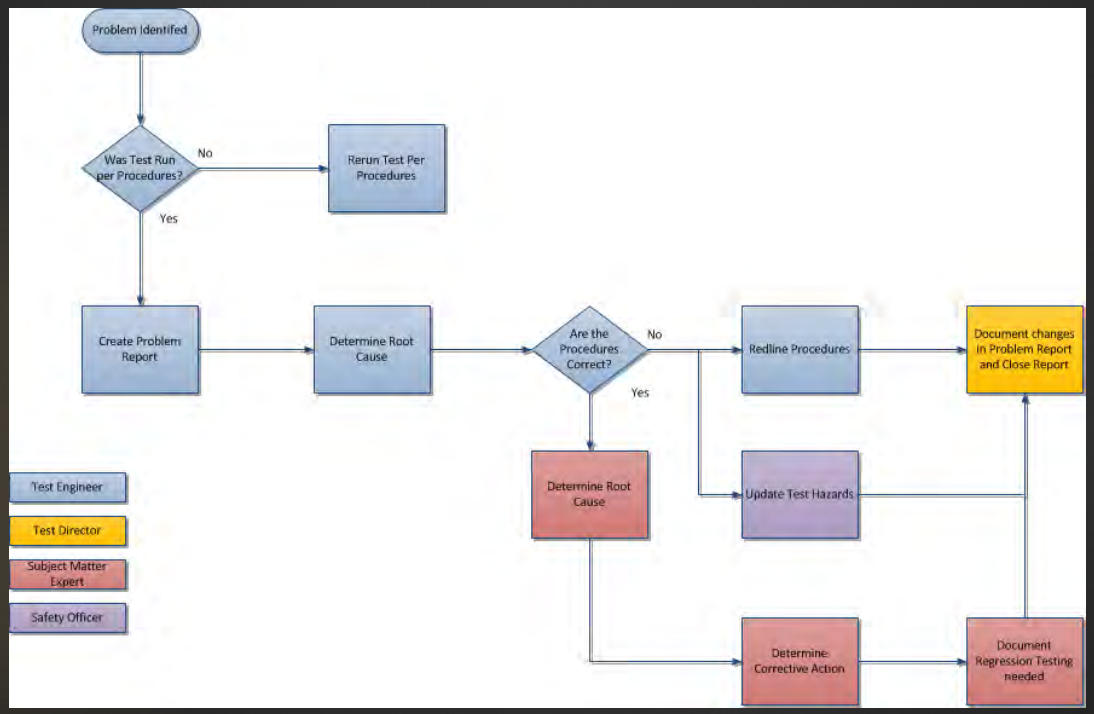
# AHP Results

| Criteria | Wt. | Xslate D10 | | | TOUGHPAD FZ-G1 | | | GETAC K120 | | | Toughbook C33 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Raw Score | Utility Value | Weighted Utility Value | Raw Score | Utility Value | Weighted Utility Value | Raw Score | Utility Value | Weighted Utility Value | Raw Score | Utility Value | Weighted Utility Value |
| **Battery Life** | 0.55 | 0.20 | 6.00 | 3.32 | 0.27 | 8.25 | 4.56 | 0.29 | 8.50 | 4.70 | 0.24 | 8.00 | 4.42 |
| **Screen Brightness** | 0.25 | 0.14 | 3.00 | 0.76 | 0.22 | 8.20 | 2.07 | 0.32 | 9.90 | 2.50 | 0.32 | 9.90 | 2.50 |
| **Screen Size** | 0.15 | 0.23 | 3.60 | 0.53 | 0.23 | 3.60 | 0.53 | 0.28 | 8.00 | 1.17 | 0.27 | 7.00 | 1.03 |
| **Screen Resolution** | 0.05 | 0.20 | 7.05 | 0.34 | 0.29 | 9.10 | 0.44 | 0.23 | 7.60 | 0.37 | 0.27 | 8.40 | 0.40 |
| **Operational Utility Function (Weighted Sum)** | | | 4.94 | | | 7.60 | | | **8.74** | | | 8.35 | |

# Test and Evaluation Plan

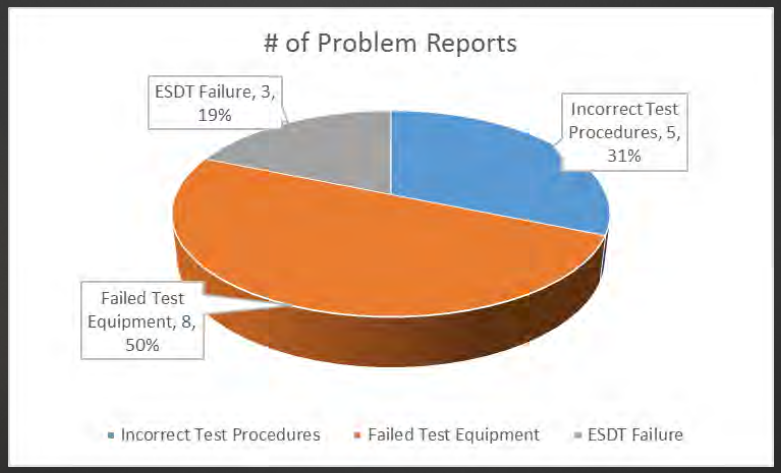


# Test Problem Reporting



# Test Metrics

- Test Hazards by category



# Test and Evaluation Example

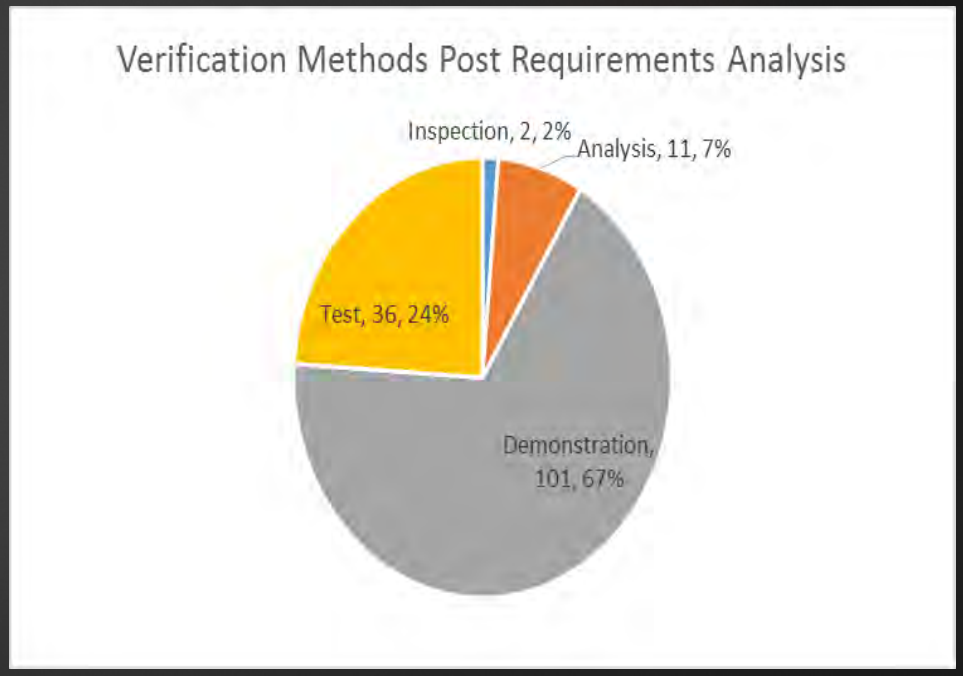
| Requirement ID | Requirement Text | Physical Components | Test Category | Test Event |
|---|---|---|---|---|
| RAR-59 | The ESDT shall operate in temperatures between -10F and 104F. | 2.0 Display Subsystem<br>3.0 Data Processing Subsystem<br>4.0 Measurement Subsystem | Functional Physical Environment Testing | Temperature |

Temperature Test Event under Functional Physical Environment Testing

- Test Guidance from RTCA DO-160G Section 4
- Subsystem must pass component or system Acceptance Test Procedure
- Test Equipment Required
  - Temperature Chamber
  - Temperature Probes

# Requirements Metrics After Requirements Analysis

| Requirement Type | Number of Requirements |
|---|---|
| **Quantitative** | 80 |
| **Qualitative** | 70 |
| **Total** | 150 |

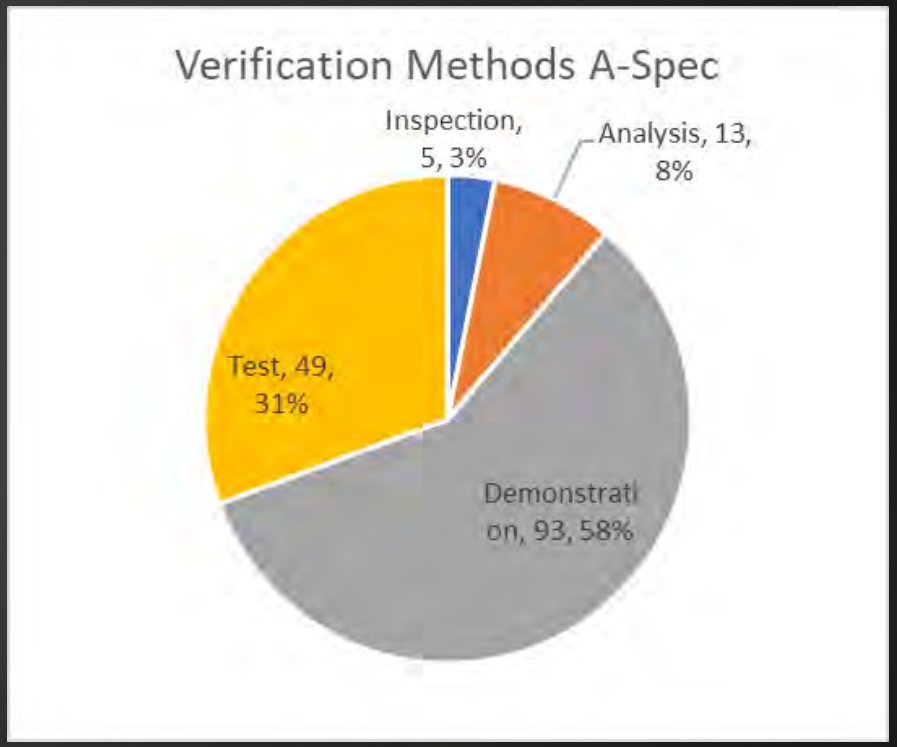


# Sources of Change

| Change Driver | Number of Requirements |
|---|---|
| **Functional Analysis** | 9 |
| **Trade Study** | 5 |
| **Conceptual Design** | 8 |
| **A-Spec** | 29 |
| **Total** | 51 |

# Requirement Metrics After A-Spec

| Requirement Type | Number of Requirements |
|---|---|
| Quantitative | 121 |
| Qualitative | 39 |
| Total | 160 |



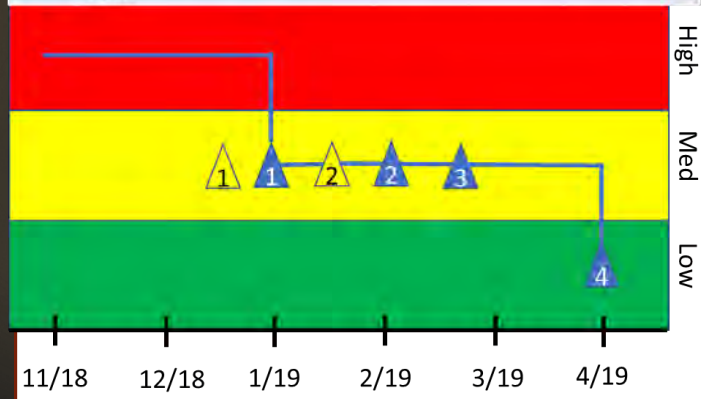
# Schedule Management

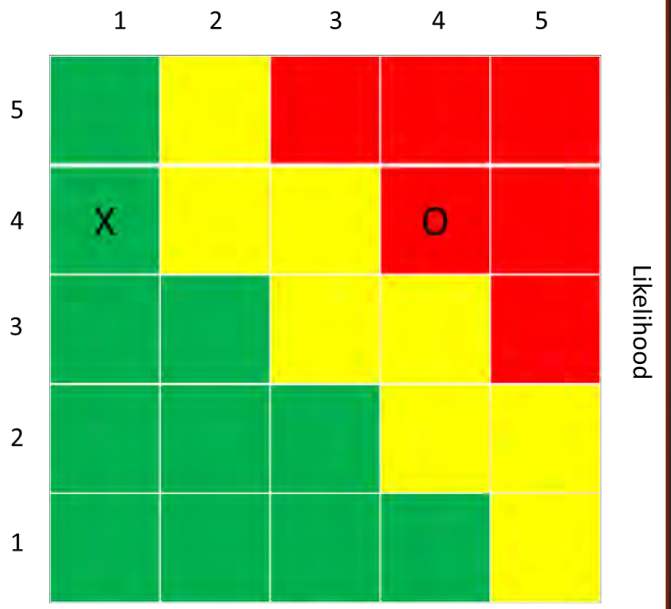
| Task Name | Finish | Work | Actual Finish | BCWP | ACWP | Total BWCS by Task Actual Finish Date | Task CPI | Total CPI | Total SPI |
|---|---|---|---|---|---|---|---|---|---|
| 1.0 Project Start Date | Mon 1/28/19 | 0 hrs | | | | | | | |
| Requirements Analysis Report | Mon 2/11/19 | 30 hrs | 1/31/2019 | 30 | 24 | 22 | 1.25 | 1.25 | 1.09 |
| Functional Analysis Report | Mon 2/25/19 | 23 hrs | 3/1/2019 | 23 | 33 | 51 | 0.70 | 0.93 | 1.04 |
| Trade Study Report | Mon 3/4/19 | 10 hrs | 3/14/2019 | 10 | 10 | 84 | 1.00 | 0.94 | 0.75 |
| Conceptual Design Report | Mon 3/18/19 | 21 hrs | 3/20/2019 | 21 | 20 | 86 | 1.05 | 0.97 | 0.98 |
| Test Plan Report | Mon 4/1/19 | 13 hrs | 4/13/2019 | 13 | 13 | 116 | 1.00 | 0.97 | 0.84 |
| A-Spec | Mon 4/8/19 | 19 hrs | 4/5/2019 | 19 | 12 | 116 | 1.58 | 1.04 | 1.00 |
| Final Report | Mon 4/15/19 | 19 hrs | 4/28/2019 | 19 | 11 | 143 | 1.73 | 1.10 | 0.94 |
| Presentation | Mon 5/6/19 | 7.7 hrs | 5/3/2019 | 7.7 | 6 | 150.7 | 1.28 | 1.16 | 1.00 |

# Risk Example

| Risk ID: | R001 |
|---|---|
| Risk Statement | If the deliverables take more work then anticipate then the project will extend past the spring semester. |

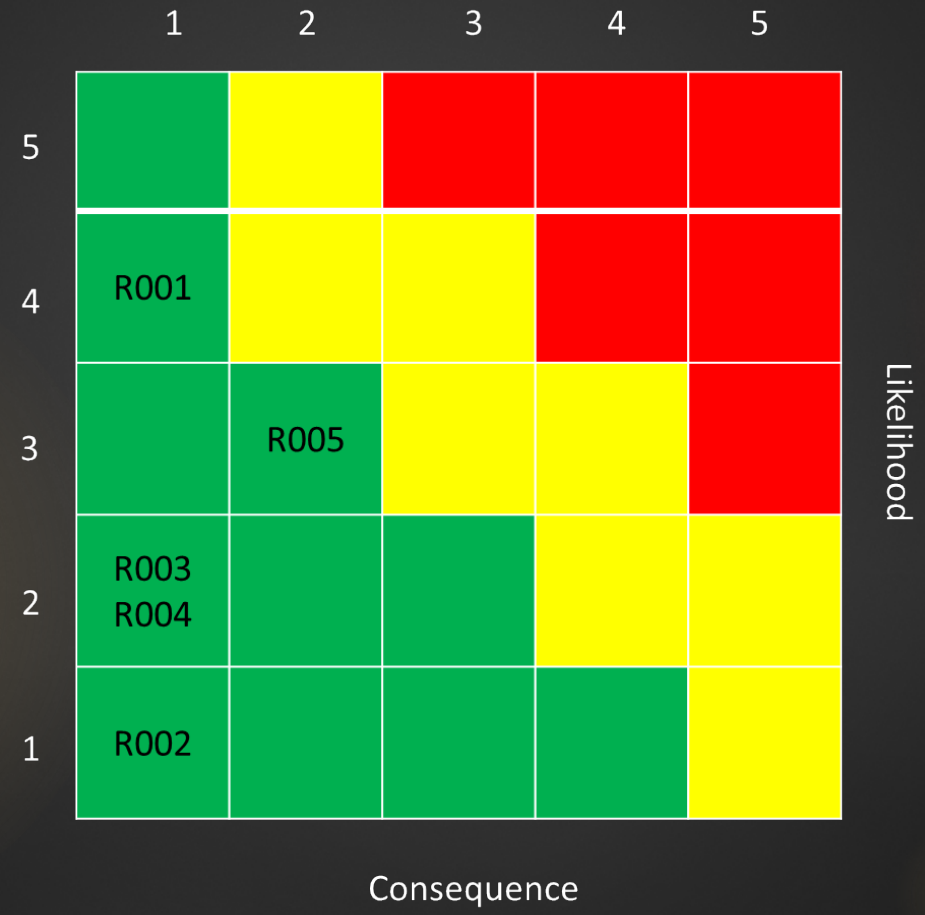
| Step # | Description | ECD | Actuals | Lik. | Con. |
|---|---|---|---|---|---|
| 1 | Complete Requirements Analysis Early | 12/25/18 | 1/29/19 | 3 | 4 |
| 2 | Complete Functional Analysis before start | 1/25/19 | 2/25/19 | 3 | 4 |
| 3 | Utilize time off to complete Trade Study and Conceptual Design | 3/20/19 | 3/20/19 | 2 | 4 |
| 4 | Utilize schedule float after final report | 4/15/19 | 4/15/19 | 1 | 4 |




O – Original risk Assessment
X – Post Risk Mitigation
1 - Planned Date
1 - Actual Date

# Risk Management



# Project Next Steps

- **Human Factors Design and Evaluation**
  - **Project heavily depends on guiding a wide range**
  - **The display subsystem will need extensive human factors testing and evaluations**
- **Cost Analysis**
  - **Project will need to 'pay for itself'**
  - **Needs a product cost within the 'budget' for owners**

# Lessons Learned

- **The Planning Fallacy is Real**
  - **Even an 'experienced planner' can run into issues**
  - **The availability of time, availability of mental energy, and calendar time must all align**
- **Functional Analysis is Highly Iterative**
  - **Must work across products as well as down the functional tree**
- **Gain Stakeholder Feedback Early and Often**
  - **Stakeholders will shift the focus of a project**
  - **Feedback is necessary for good CONOPS**

# Recommendations

- Systems Engineering Project
  - Provide an Option for a Technology Pull Project
  - Provide Grades with Sample Projects
- Systems Engineering Program Recommendations
  - Incorporate Design Reviews into Courses
  - Incorporate Mock Customer Interactions

# Q&A