Abstract

The Maintainability Report estimates the Mean Time To Repair (MTTR) of the system and includes a list of suggested spare parts to reduce the MTTR.
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Executive Summary

Introduction
In any system, failures can and will occur. The likelihood of failures and the different types of failures in the LFEV-ESCM system are documented in the Reliability Memo. Once a system fails, it needs to be repaired. A well designed system will allow for a relatively short time to restore the system to its working condition. This is measured by the Mean Time To Repair (MTTR). The Statement of Work requires the LFEV-ESCM system to have a MTTR of less than one week. This document shows how the LFEV-ESCM system meets this requirement and includes a list of spare parts to help reduce the MTTR.

Note: This document only considers the maintainability of the safety system and the batter pack because these two subsystems are the most likely to be used in the vehicle.

Mean Time To Repair
The MTTR of the Pack/Safety System is 4 days. This comes from the largest MTTR of any part as a worst-case scenario. In order to maintain this MTTR a list of necessary spare parts is provided. The MTTR calculation includes the time it takes to order and receive any necessary new parts and the proper installation thereof. It does not include time taken to diagnose the problem, and any potential tests that need to be run after installation and before use. Additionally, the MTTR estimations are rounded up to a whole day.

For convenience, it is recommended that a spare pack and spare BMS boards are kept in addition to the list of spare parts below. This will allow continued operation while the reparations are being performed.
### List of Spare Parts

<table>
<thead>
<tr>
<th>Number of Spares Recommended</th>
<th>Description</th>
<th>Vendor</th>
<th>Part Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>PWR Lock NLDFT-2-BK-L-S120-M40A</td>
<td>Newark</td>
<td>44W4340</td>
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<td>PWR Lock NLDFT-N-BL-L-S120-M40A</td>
<td>Newark</td>
<td>44W4336</td>
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<td>1</td>
<td>PWR Lock Panel Source Contact</td>
<td>Newark</td>
<td>NPS-N-BL-T4</td>
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<td>1</td>
<td>PWR Lock NPDFT-3-BL-L-T6</td>
<td>Newark</td>
<td>28R9540</td>
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<td>1 of each</td>
<td>High Current Connectors: Pos. End Bar</td>
<td>Lafayette Machine Shop</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Neg. End Bar</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Standard Bar</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Necked Bar</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Pack End Caps</td>
<td>Lafayette Machine Shop</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Pack Walls</td>
<td>Lafayette Machine Shop</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Charging Fuse, 3AG 30-A fuses</td>
<td>Mouser</td>
<td>504-BK/AGC-30-R</td>
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<tr>
<td>5</td>
<td>Discharging Fuse, 200A Fast-acting Class T fuse</td>
<td>Zoro Tools</td>
<td>G3475534</td>
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<td>7</td>
<td>LiFePO4 prismatic cells</td>
<td>AA Portable Power Corp.</td>
<td>#6334</td>
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<td>7</td>
<td>BMS PCB</td>
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<td></td>
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<td>10</td>
<td>2A Cartridge Fuse</td>
<td>Digikey</td>
<td>F2437-ND</td>
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</tbody>
</table>
MTTR Analysis

The MTTR Analysis contains a list of parts in the Pack/Safety System that are either likely to fail or time consuming to replace. Any part analyzed that resulted in a MTTR greater than 1 week was placed on the spare parts list to reduce the MTTR to less than 1 week. The result is the longest MTTR of any part is 4 days.

Pack Analysis

PowerLock

- MTTF: 890 failures/million hours = 1 failure/47 days
- 2 weeks deliver time
- 1 day installation
- MTTR: 15 days (no spare parts)
- MTTR: 1 day (spare parts)

15 days is longer than the required 1 week. In order to reduce the MTTR, spare PowerLock parts should be kept on hand. If spare parts are kept, then the MTTR becomes 1 day. In order to keep the MTTR under 1 week, the next failure must not occur before new spare parts can be ordered and received. A failure will occur on average every 47 days. Since the rate of failure is longer than the time it takes to order a new part, only one spare part needs to be kept on hand.

Gigavac GX14CAB, 350+ Amp Isolation Relay

- MTTF: 0.44 failures/million hours ≃ 0 failures/week
- 2 weeks delivery time
- 1 day installation
- MTTR: 15 days (no spare parts)
- MTTR: 1 day (spare parts)

15 days is longer than the required 1 week. In order to reduce the MTTR, a spare Gigavac Isolation Relay should be kept as a spare. Only one spare part is needed because the likelihood that the next part will fail before a new part can be ordered is small.

High Current Machined Interconnects

- MTTF: unknown
- 2 weeks machine time
- 1 day installation
- MTTR: 15 days (no spare parts)
- MTTR: 1 day (spare parts)

It is assumed that the machine shop will take two weeks to machine any part. 15 days is longer than the required 1 week. In order to reduce the MTTR, a spare part for each of the high voltage connections should be kept on hand. It is assumed that the MTTF Gigavac GX14CAB, 350+ Amp
4-Pin MATE-N-LOK Connector

- MTTF: 1.6 failures/million hours \(\approx\) 0 failures/week
- 3 days delivery time
- 1 day installation
- **MTTR:** 4 days (no spare parts)

No spare parts are necessary for this part.

TE Sockets

- MTTF: 0.020 failures/million hours \(\approx\) 0 failures/week
- 3 days delivery time
- 1 day installation
- **MTTR:** 4 days (no spare parts)

No spare parts are necessary for this part.

Anderson Connector

- MTTF: 1.6 failures/million hours \(\approx\) 0 failures/week
- 3 days delivery time
- 1 day installation
- **MTTR:** 4 days (no spare parts)

No spare parts are necessary for this part.

Charging Fuses

- MTTF: 0.080 failures/million hours \(\approx\) 0 failures/week
- 3 day delivery time
- 1 day installation
- **MTTR:** 4 days (no spare parts)
- **MTTR:** 1 day (spare parts)

GPR05 requires that 5 extra fuses are kept on hand at all times.

Discharging Fuse

- MTTF: 0.080 failures/million hours \(\approx\) 0 failures/week
- 2 weeks delivery time
- 1 day installation
- **MTTR:** 15 days (no spare parts)
- **MTTR:** 1 day (spare parts)

GPR05 requires that 5 extra fuses are kept on hand at all times.

Discharging Fuse Holder

- MTTF: unknown
- 4 days delivery time
- 1 day installation
- **MTTR**: 5 days (no spare parts)

Since the MTTR is less than 1 week, no spare Discharging Fuse Holders are needed.

### Charging Fuse Holder

- MTTF: unknown
- 3 days delivery time
- 1 day installation
- **MTTR**: 4 days (no spare parts)

Since the MTTR is less than 1 week, no spare Charging Fuse Holders are needed.

### Cells

- MTTF: 300 failures/million hours = 0.05 failures/week = 1 failure/19 days
- 3 weeks delivery
- 1 day installation
- **MTTR**: 22 days (no spare parts)
- **MTTR**: 1 day (spare parts)

Since the MTTR is greater than 1 week, a spare cell for each cell should be kept on hold. If each cell is receiving the same usage, then they could fail close enough together that the next fails before a new one is ordered.

### Pack Walls

- MTTF: unknown
- 1 day delivery
- 2 weeks machine time
- 1 day installation
- **MTTR**: 16 days (no spare parts)
- **MTTR**: 1 day (spare parts)

Since the MTTR is greater than 1 week, a spare pack wall should be kept on hold.

### Pack End Caps

- MTTF: unknown
- 1 day delivery
- 2 weeks machine time
- 1 day installation
- **MTTR**: 16 days (no spare parts)
- **MTTR**: 1 day (spare parts)

Since the MTTR is greater than 1 week, a spare end cap should be kept on hold.

### BMS Analysis

**BMS PCB**
- MTTF: unknown
- 2 weeks delivery time
- 3 days installation
- **MTTR**: 17 days (no spare parts)
- **MTTR**: 3 days (spare parts)
- **MTTR**: 0 days (spare BMS board)

17 days is longer than the required 1 week. In order to reduce the MTTR, spare PCBs should be kept on hand to expedite building a new one. A spare PCB should be kept for each BMS in the pack. If one BMS failed, it is likely that whatever caused the first BMS to fail also caused its neighbors to fail as well. Additionally, if a spare completed BMS board is available, the MTTR is essentially zero.

**Capacitors**
- MTTF: 0.015 failures/million hours ≃ 0 failures/week (worst case)
- 3 days delivery time
- 1 day installation
- **MTTR**: 4 days (no spare parts)

No spare capacitors are required.

**Schottky Diode**
- 3 days deliver time
- 1 day installation
- **MTTR**: 4 days (no spare parts)

No spare Schottky Diodes are required.

**Chip LEDs**
- 3 days delivery time
- 1 day installation
- **MTTR**: 4 days (no spare parts)

No spare Chip LEDs are needed.

**Semi-shielded Power Inductor**
- MTTF: 0.936 failures/million hours ≃ 0 failures/week
- 3 days delivery time
- 1 day installation
- **MTTR**: 4 days (no spare parts)

No spare Power Inductors are needed.

**NPN Epitaxial Silicon Darlington Transistor**
- 3 days delivery time
- 1 day installation
- **MTTR**: 4 days (no spare parts)
No spare NPN Epitaxial Silicon Darlington Transistors are needed.

Resistors
- 3 days delivery time
- 1 day installation
- **MTTR**: 4 days (no spare parts)

No spare resistors are needed.

Push-Button SPST Switch
- 3 days delivery time
- 1 day installation
- **MTTR**: 4 days (no spare parts)

No spare push buttons are needed.

50µA, 550 kHz Rail-to-Rail Op Amp
- MTTF: 0.21 failures/million hours ≃ 0 failures/week
- 3 days delivery time
- 1 day installation
- **MTTR**: 4 days (no spare parts)

No spare Op Amp is needed.

600kHz PWM DC/DC Converter
- MTTF: 0.21 failures/million hours ≃ 0 failures/week
- 3 days delivery time
- 1 day installation
- **MTTR**: 4 days (no spare parts)

No spare DC/DC converters are needed.

Low-Power Linear Active Thermistor IC
- MTTF: 0.21 failures/million hours ≃ 0 failures/week
- 3 days delivery time
- 1 day installation
- **MTTR**: 4 days (no spare parts)

No spare Thermistor IC is needed.

PIC16(L)F1826/27 Microprocessor
- MTTF: 0.14 failures/million hours ≃ 0 failures/week
- 3 days delivery time
- 1 day installation
- **MTTR**: 4 days (no spare parts)
No spare PIC is needed.

**Dual I2C Isolator**

- MTTF: 0.21 failures/million hours ≈ 0 failures/week
- 3 days delivery time
- 1 days installation
- **MTTR**: 4 days (no spare parts)

No spare I2C isolator is needed.

**Safety Controller Analysis**

**Emergency Stop Switch**

- MTTF: 0.017 failures/million hours ≈ 0 failures/week
- 1 days delivery time
- 1 days installation
- **MTTR**: 2 days (no spare parts)

No spare Emergency Stop Switch is needed.

**Ring Terminal**

- MTTF: 0.017 failures/million hours ≈ 0 failures/week
- 1 days delivery time
- 1 days installation
- **MTTR**: 2 days (no spare parts)

No spare Ring Terminals are needed.

**Green Push Button Momentarily Normally Open**

- MTTF: 2.0 failures/million hours ≈ 0 failures/week
- 1 days delivery time
- 1 days installation
- **MTTR**: 2 days (no spare parts)

No spare Green Push Buttons are needed.

**Toggle Switch SPST, Off-On, 6A**

- MTTF: 1.4 failures/million hours ≈ 0 failures/week
- 1 days delivery time
- 1 days installation
- **MTTR**: 2 days (no spare parts)

No spare toggle switch is needed.

**2mm Panel Flush Push Button - Yellow**

- MTTF: 40 failures/million hours ≈ 0.01 failures/week
- 1 days delivery time
• 1 days installation
• **MTTR:** 2 days (no spare parts)

No spare Flush Push Button is needed.

**Sunlight-Visible and Waterproof LED - Green**

• MTTF: 1.1 failures/million hours ≈ 0 failures/week
• 1 days delivery time
• 1 days installation
• **MTTR:** 2 days (no spare parts)

No spare green waterproof LED is needed.

**Sunlight-Visible and Waterproof LED - Red**

• MTTF: 1.1 failures/million hours ≈ 0 failures/week
• 1 days delivery time
• 1 days installation
• **MTTR:** 2 days (no spare parts)

No spare red waterproof LED is needed.

**4-pin MATE-N-LOK Connector (Female)**

• MTTF: 1.6 failures/million hours ≈ 0 failures/week
• 3 days delivery time
• 1 days installation
• **MTTR:** 4 days (no spare parts)

No spare MATE-N-LOK connectors are needed.

**TE 3-Pin Connector (Female)**

• MTTF: 1.5 failures/million hours ≈ 0 failures/week
• 1 days delivery time
• 1 days installation
• **MTTR:** 2 days (no spare parts)

No spare green waterproof LED is needed.