Automotive EMC Testing – The Challenges Of Testing Battery Systems For Electric And Hybrid Vehicles

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The focus of this presentation is to share the challenges and flexibility that a test facility needs to address in order to accommodate OEM approved Test Plans and development testing.

Part 1 - Defining the Test Methodology using System Engineering

Presented by: James Muccioli

Part 2 - Test Laboratory Practical Implementation

Presented by: Dale Sanders

Hybrid / Electric Vehicles

Toyota Prius

Ford Fusion Hybrid

Volkswagen Jetta

Chevrolet Volt

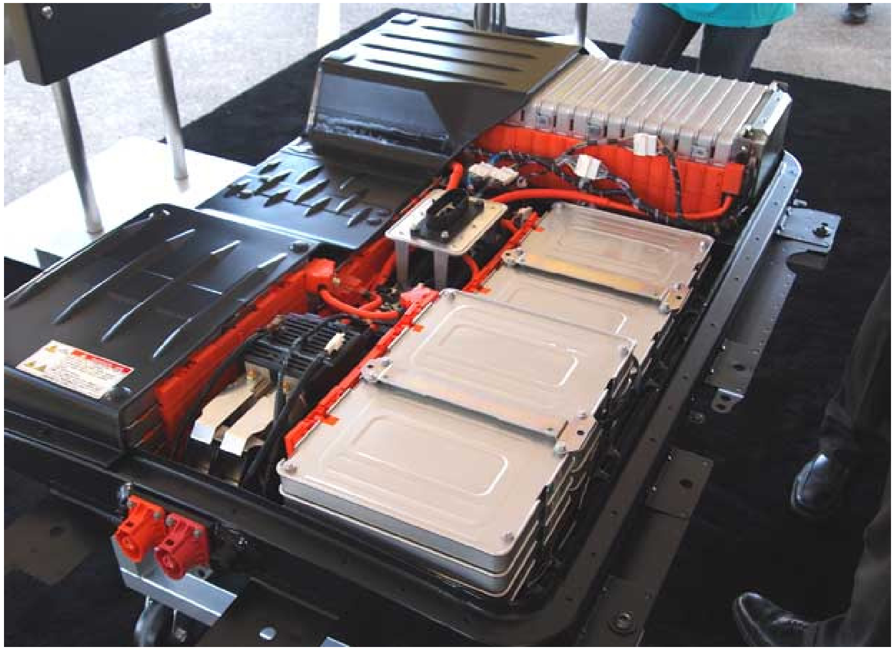
Coda Automotive

Nissan Leaf

Hybrid / Electric Engines

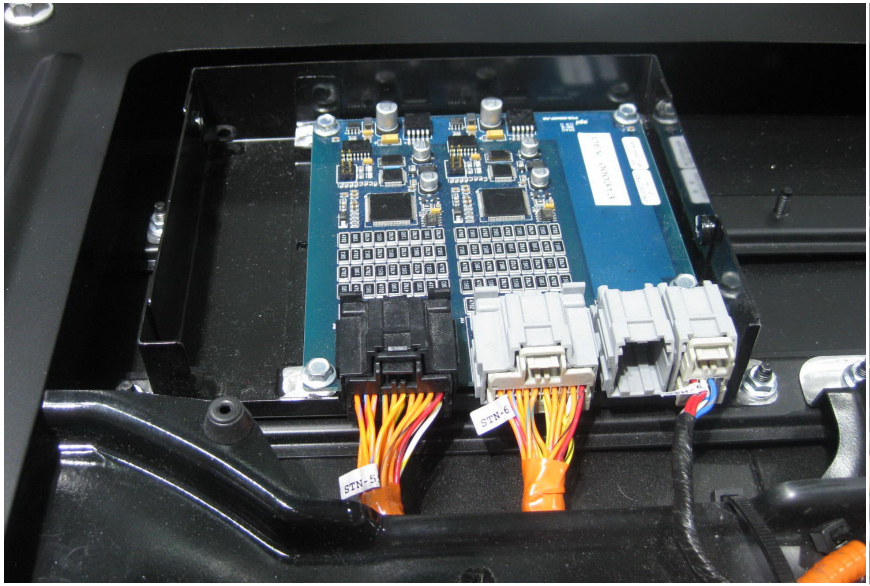
North American International Auto Show 2011
Pictures courtesy of Dale Sanders

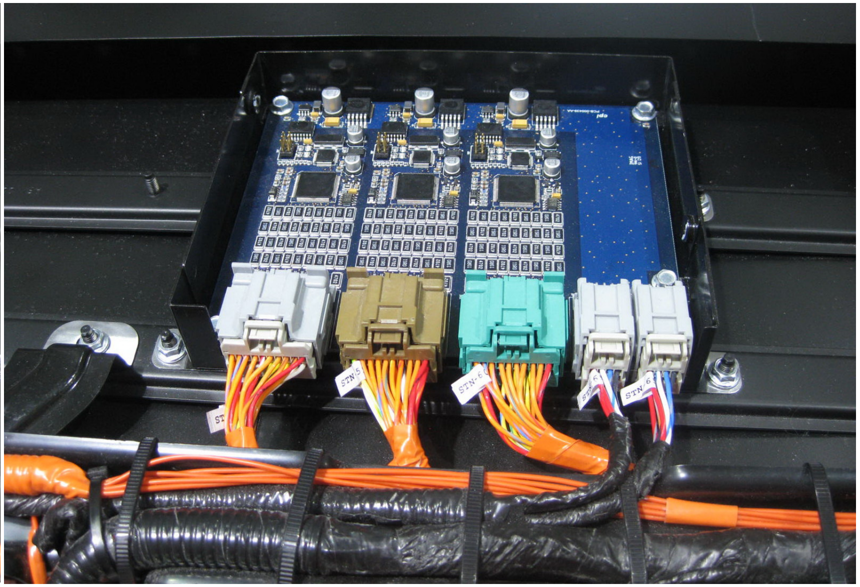
Nissan Leaf Battery Pack

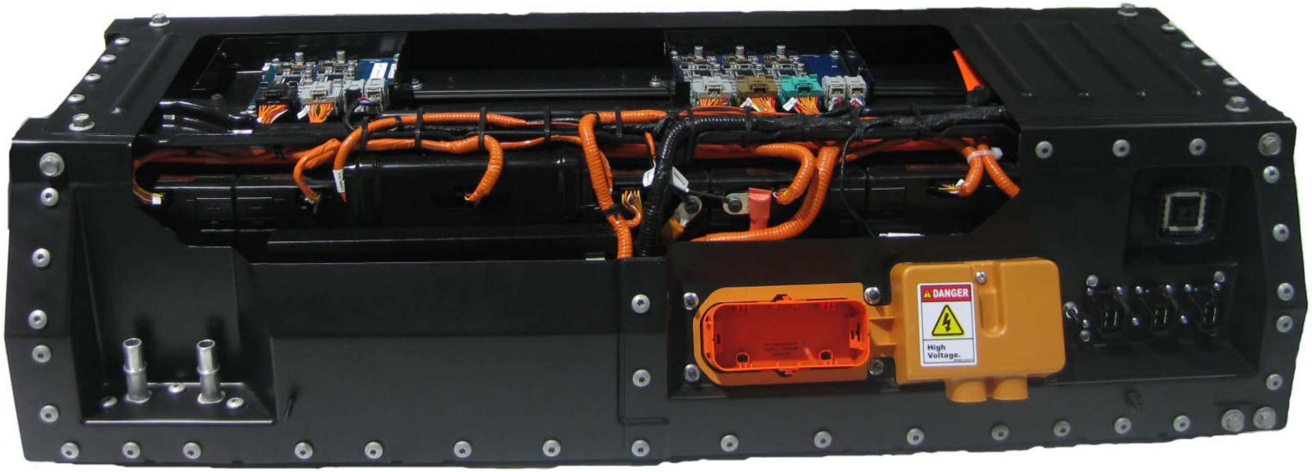


The Nissan Leaf battery pack consists of 48 modules.

Ford Battery Pack

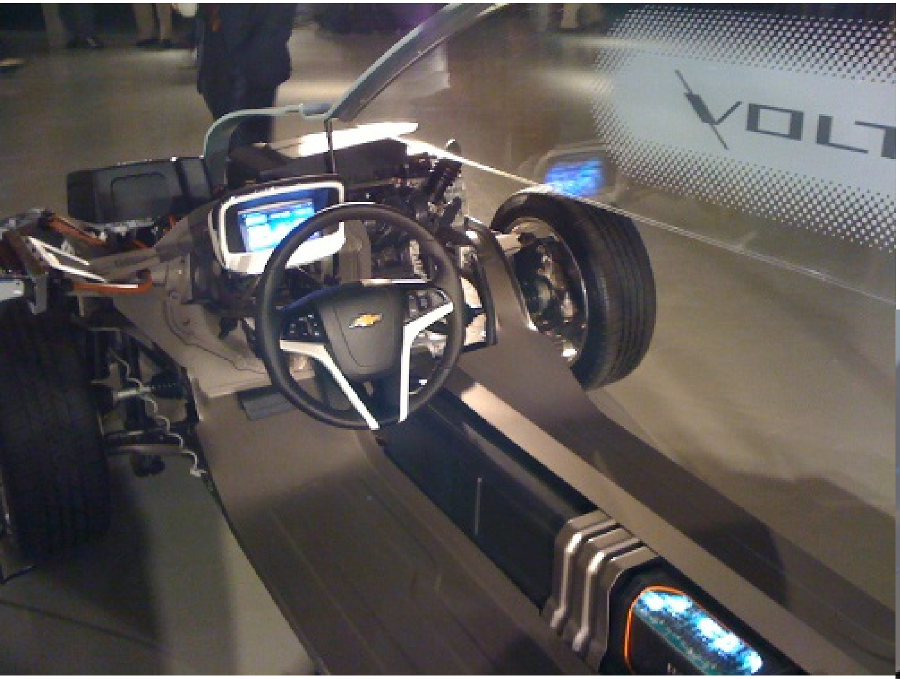






North American International Auto Show 2011
Pictures courtesy of Dale Sanders

GM Volt Battery Pack

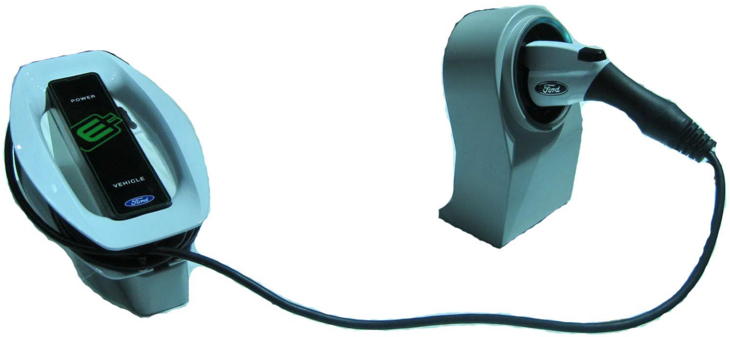


The battery pack is T-shaped, and runs the length of the car underneath the center of the car and then Ts underneath the rear seats.

Close-up of battery cells in the Chevy Volt battery pack.

GM Volt Battery Pack

Electric Charging Stations



North American International Auto Show 2011
Pictures courtesy of Dale Sanders

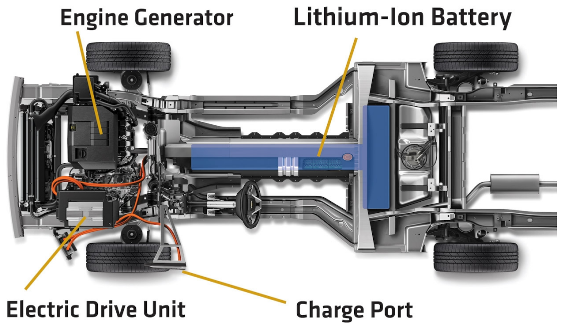
What is new to EMC testing?

We are not just testing a battery module, but an Energy Storage System.

The **paradigm shift** is moving to complete EMC system level testing from module or component level testing.

The Energy Storage System can be designed with the following modules:

1. Battery control module
2. DC to DC convertor module
3. Internal battery charger
4. Internal battery cooling module
5. Other modules



Writing an EMC Test Plan

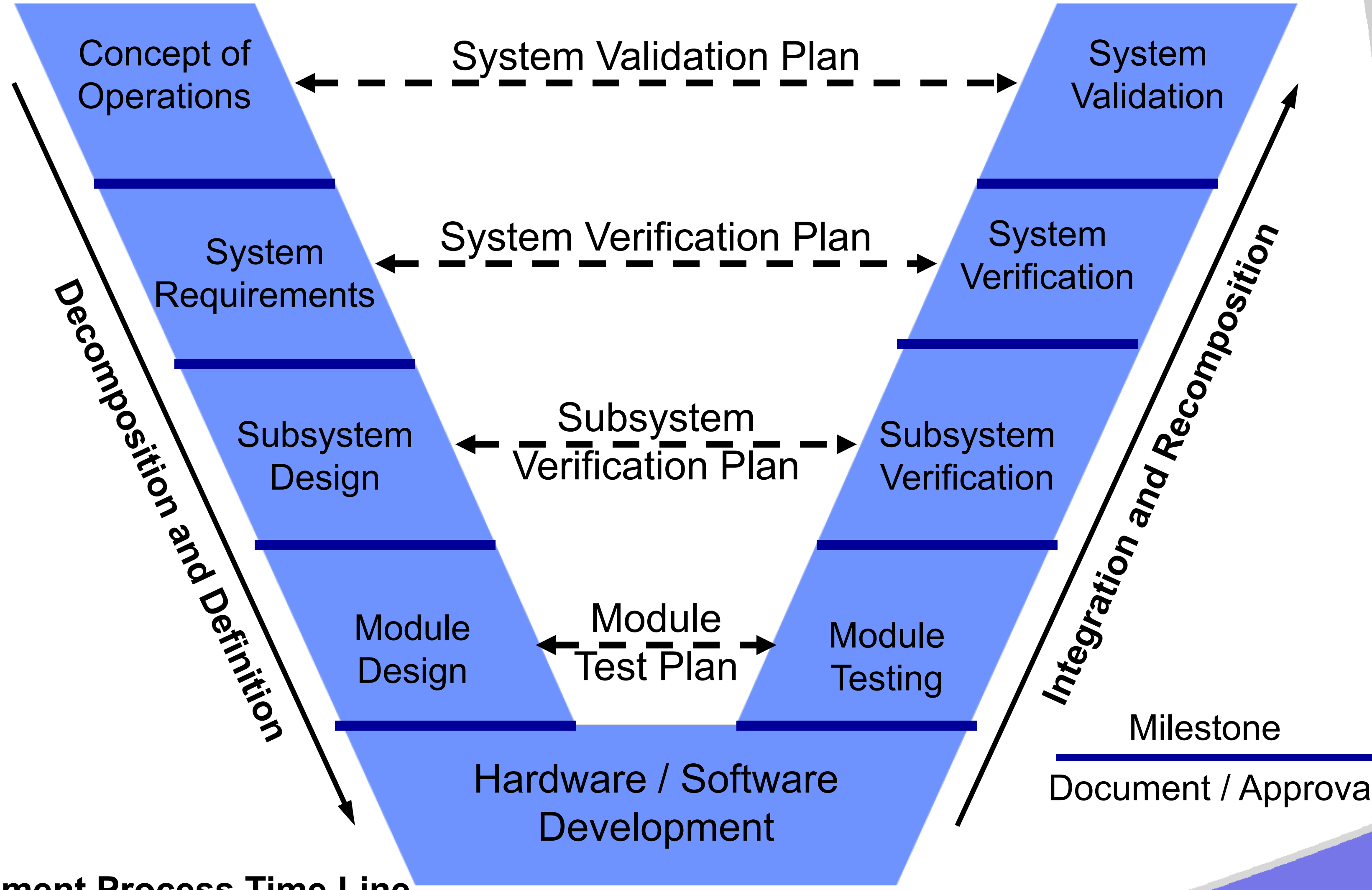
The person writing an EMC Test Plan must understand three things about the Device Under Test (DUT) or System Under Test (SUT).

1. What EMC standards should the SUT be tested to and how do they apply to the test setup?

2. What are the operating states of the SUT to be tested?

3. What are the conditions when an RF field is applied or measured that determines a pass or failure criteria for the SUT?

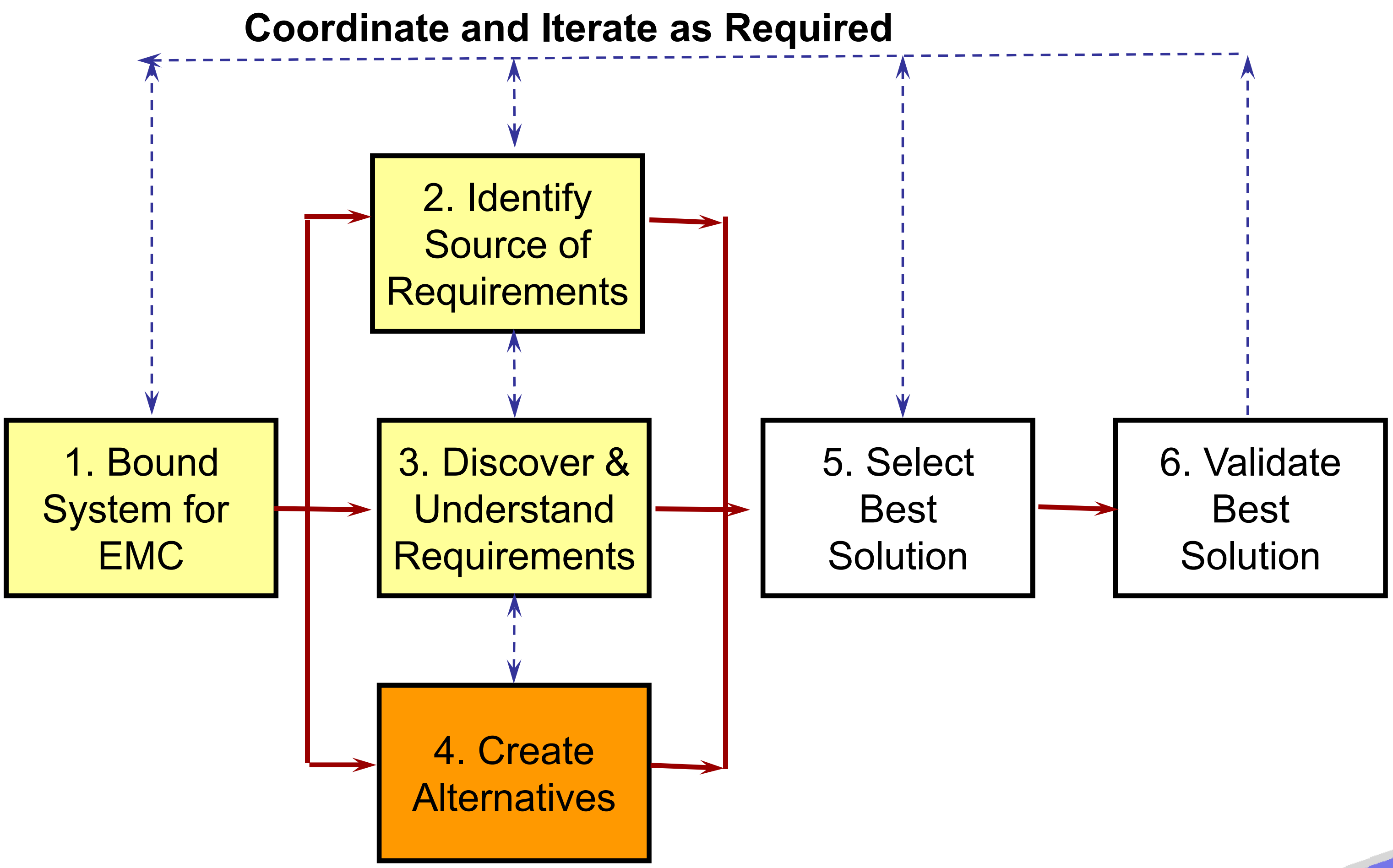
Big "V" System Engineering Model



Development Process Time Line

Validation is confirming that a product or service meets the requirements.
Verification is process for quantifying and accepting the requirements.

System Engineering Process



Systems Engineering Approach to EMC

Description

Before discussing the process for developing good requirements, some important definitions must be established:

System: a set of components acting together to achieve a set of common objectives via the accomplishment of a set of tasks.

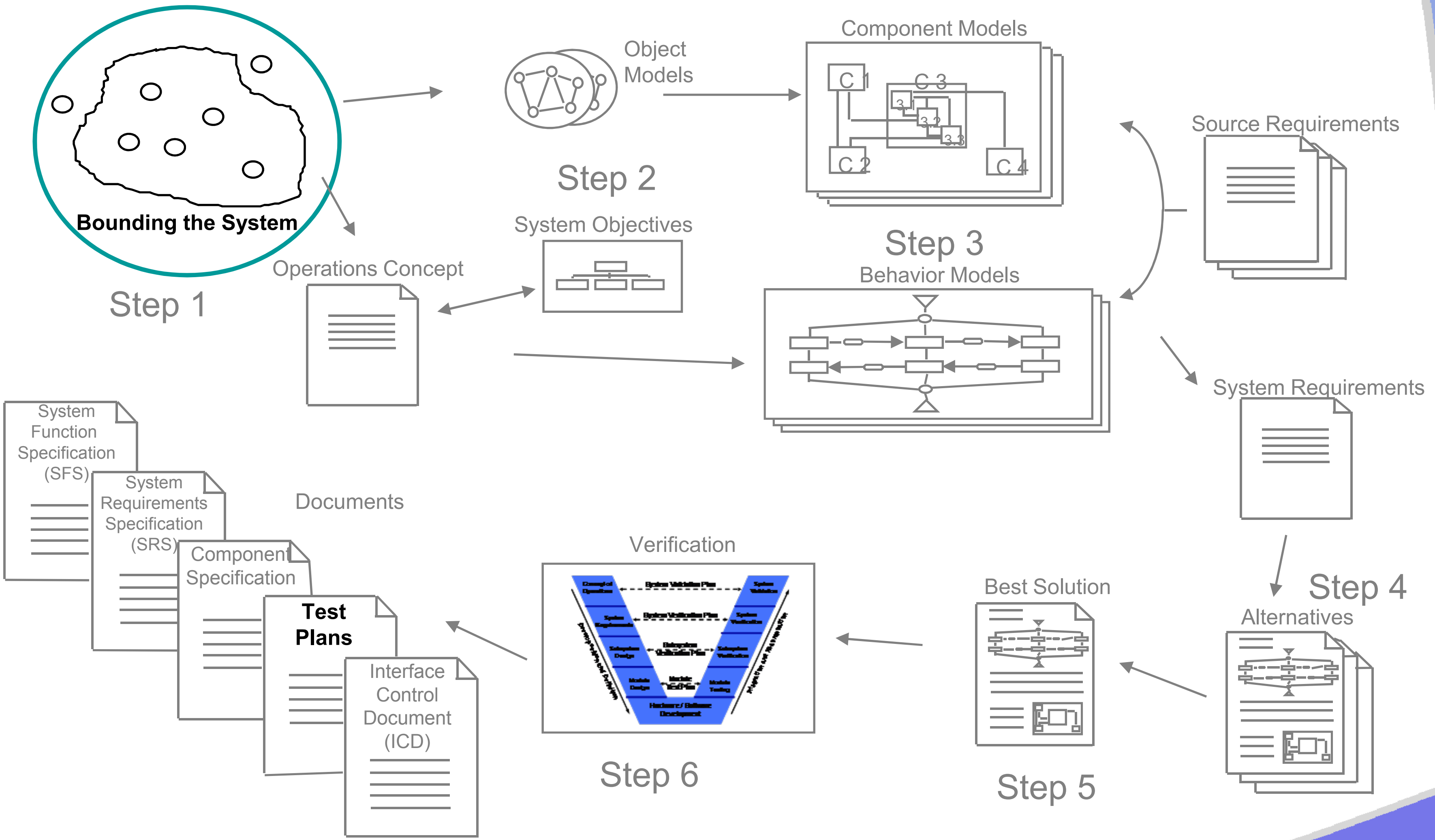
System Behavior: a sequence of functions or tasks, with inputs and outputs, that must be performed to achieve a specific objective.

Requirement: mandates that something must be accomplished, transformed, produced, or provided. The attributes of a good requirement are that it is unambiguous, understandable, traceable, correct, concise, unique and verifiable.

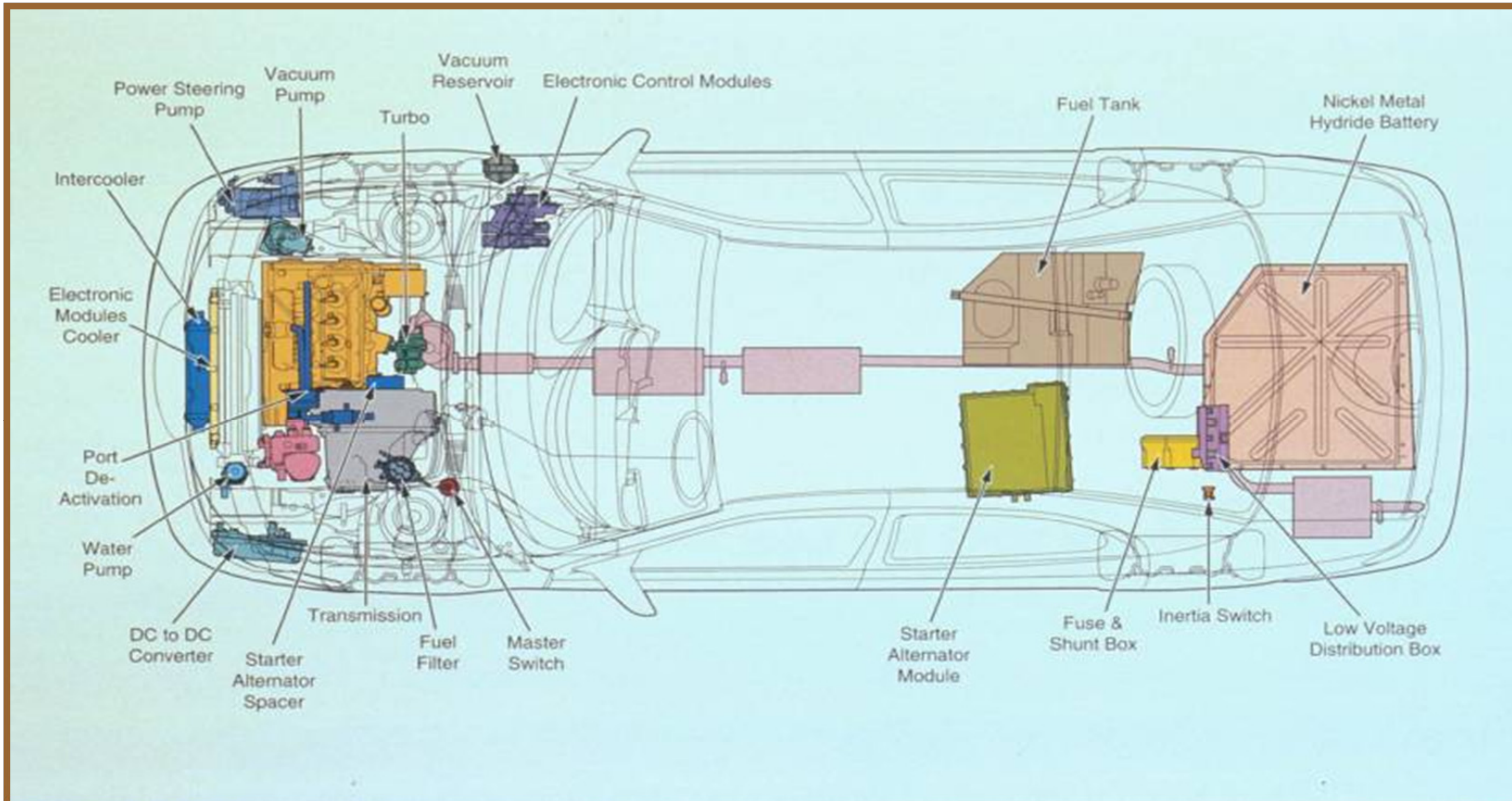
Traceable: in reference to requirements; a requirement is said to be traceable if one can identify its source. The source may be a higher level requirement or a source document defining its existence. An example would be if a component level requirement (weight, reliability) is traceable back to a vehicle level requirement.

Operational Concept: an operational concept is a shared vision from the perspective of the users and development participants of how the system will be developed, produced, deployed, trained, operated, maintained, refined and retired to meet the operational needs and objectives.

Bounding the System



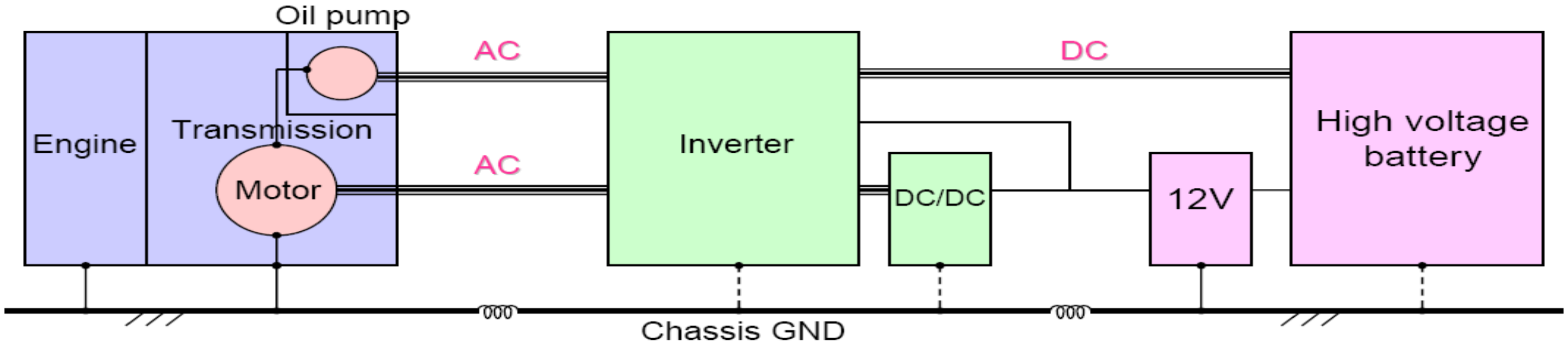
Step 1 - Bound System for EMC



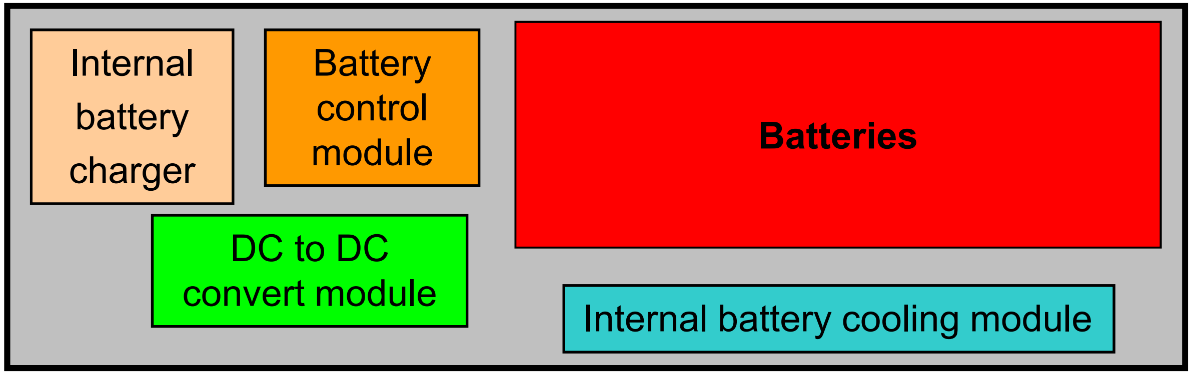
From: www.Hybrid.gov

Step 1 - Bound System for EMC

Typical Hybrid Electric Powertrain with Inverter

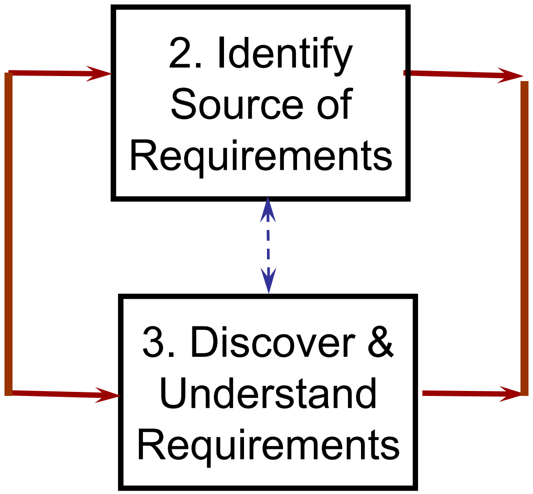


Energy Storage System



Note: EMC08 EMC08-WS FR WS FR-AM AM-5-6 IEEE EMC 2008 August; "Overview of Component Level EMC Characteristics Overview of Component Level EMC Characteristics for HEV application"

Step 2-3 - Identify, Discover & Understand Requirements



Identify Source of Requirements:

North America, Asia, and Europe Module EMC standards
Military standards

Discover & Understand Requirements:

Radiated RF Emissions
Conducted RF Emissions
RF Immunity
Magnetic Field Immunity
Power Cycling & Transient Immunity
Electrostatic Discharge

How do these requirements change for an Energy Storage System?

Things to Consider in Testing a System

If the vehicle supplies the loads, charging, and regenerative charging from braking to the Energy Storage System:

- What would be required to mimic the vehicle interactions when testing the system?
- How would this system level testing affect the test time required when running through the different modes of operation?
- If the testing is not done at the system level first, what will be the impact to the number of vehicles required for verification (not validation) at the vehicle level?

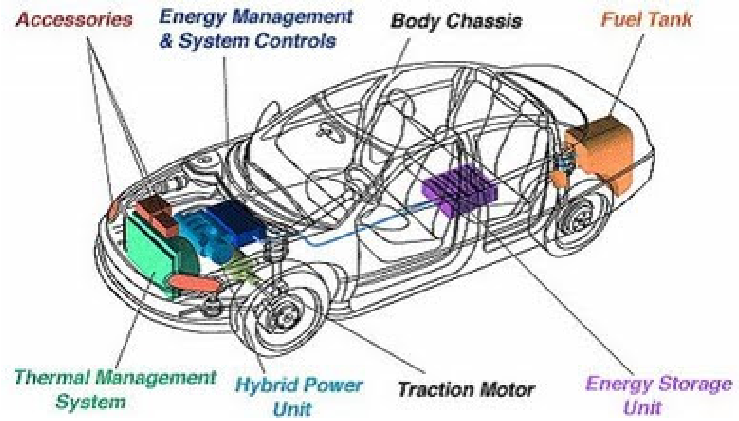
Note:
Validation is confirming that a product or service meets the requirements.
Verification is process for quantifying and accepting the requirements.

Things that must be Addressed in Test Plan

Due to the increased complexity of the Energy Storage System, the following items need to be addressed with the test lab and documented in the test plan:

- Will the test lab have the capability for increased monitoring of the various modules in the system during testing?

- What additional equipment is needed to simulate sensors, loads, data bus, etc. of the vehicle operation of the System Under Test?

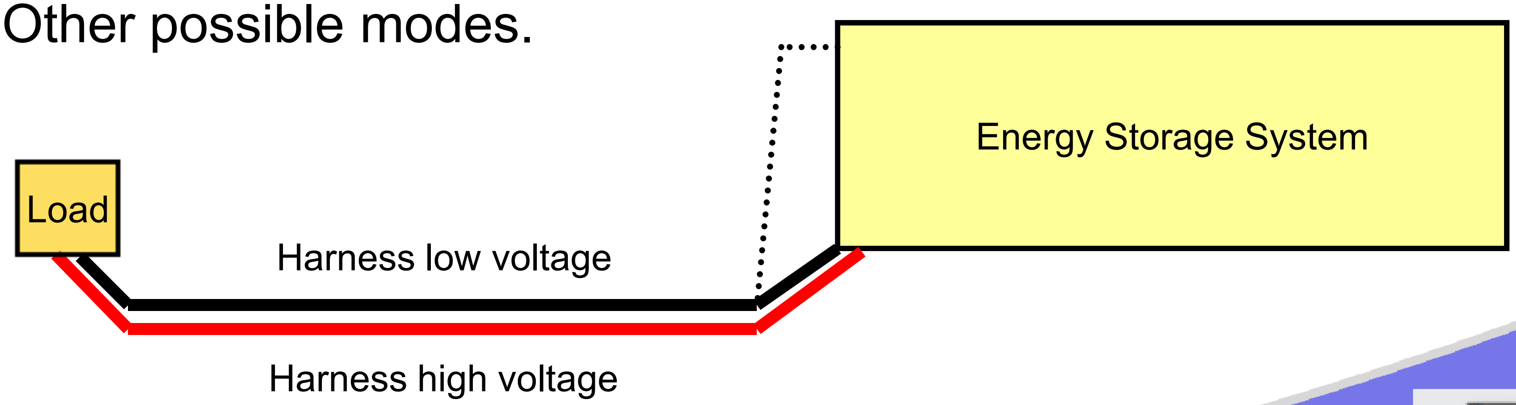


www.hybridextrication.com

Radiated RF Emissions & Immunity

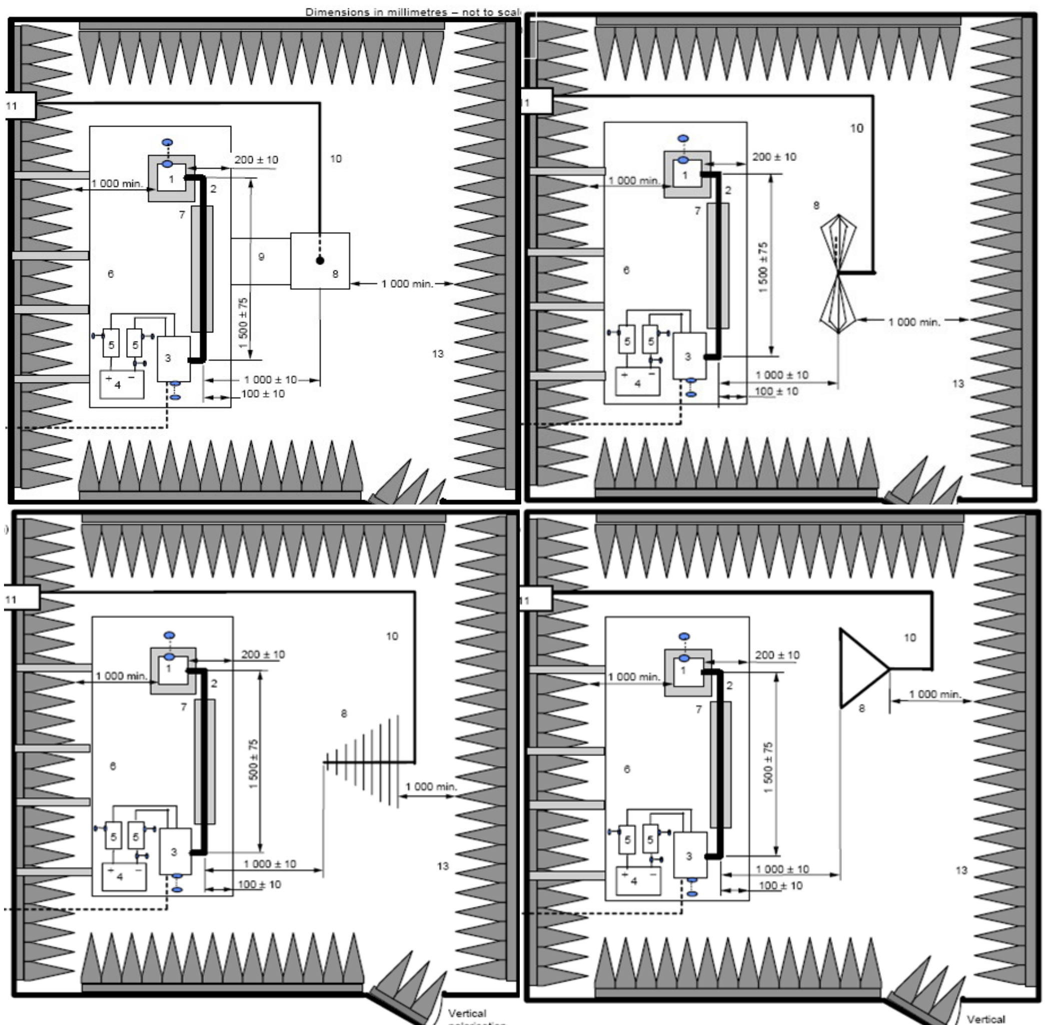
The second thing to consider in performing a radiated emission or immunity test is how to place the high and low voltage wiring harness for the Energy Storage System.

- Test the low voltage wiring harness, no power to high voltage.
- Test the high voltage wiring harness, no power to low voltage.
- Test with power to both high and low voltage wiring harnesses.
- Test with power to both high and low voltage wiring harnesses, but shield high voltage wiring harness.
- Other possible modes.



Radiated RF Emissions & Immunity

When testing a system for EMC, the test plan must address the minimum dimensions of the test setup.



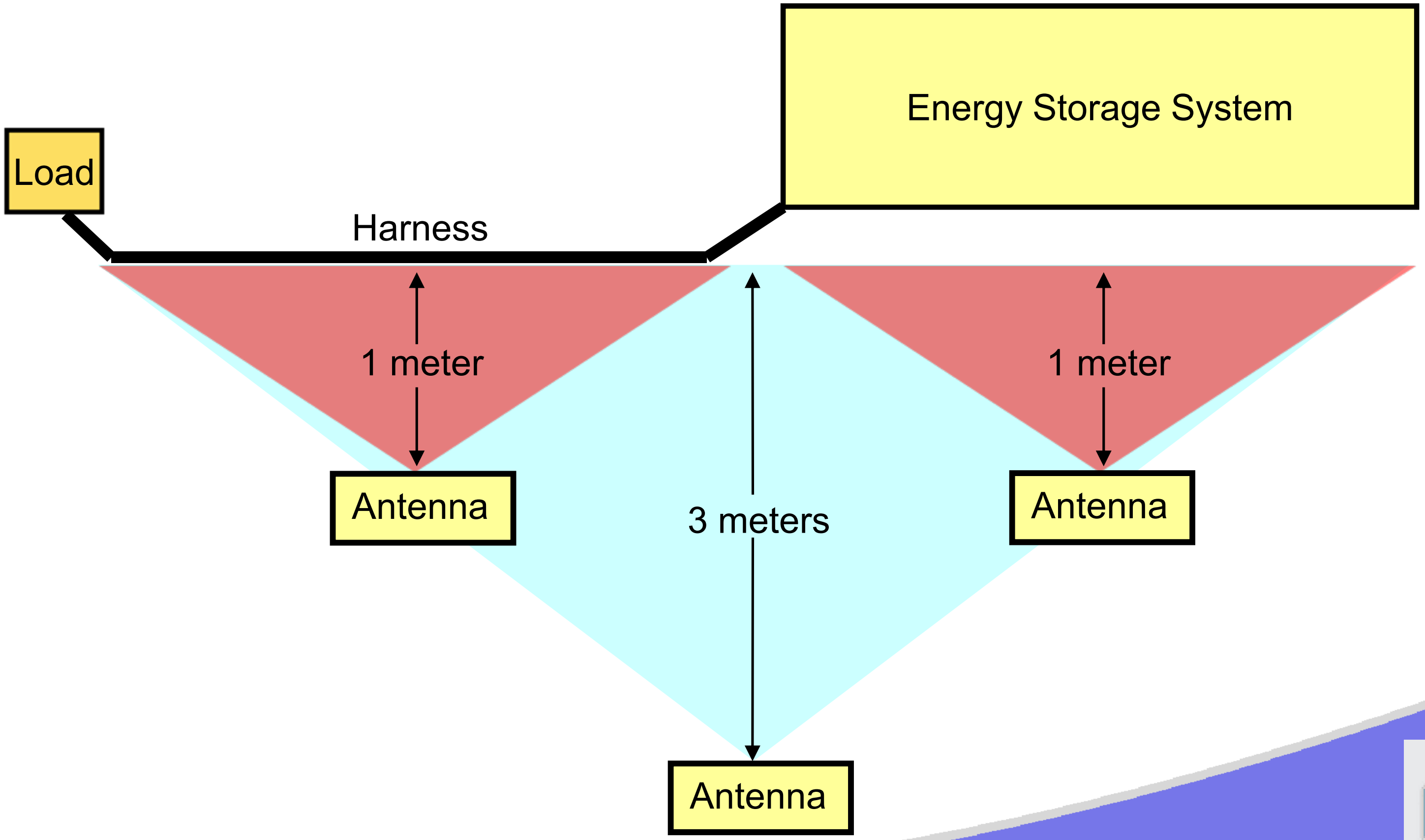
IEC CISPR 25 Edition 3.0 2008-3

In writing the test plan, you need to collaborate with your test lab to meet the following requirements:

- Will the system fit on the ground plane?
- Is the spacing for the antenna in the front and back still adequate?
- How will the system be placed on the ground plane?
- Does the system meet the minimum setbacks from the edge of the ground plane?

Radiated RF Emissions & Immunity

When performing a radiated emission or immunity test with a specified wiring harness length, the antenna is typically centered on the wiring harness. However, the Energy Storage System length can be the same size or larger and some EMC specifications require you to center the antenna on the wiring harness or the DUT or both.

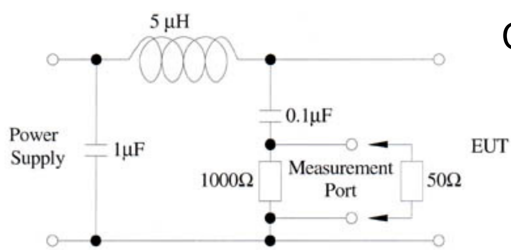


Conducted RF Emissions

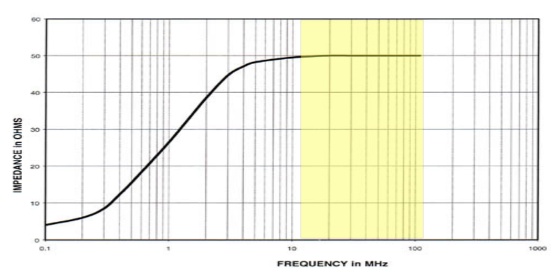
Conducted RF Emissions from an Energy Storage System can be divided into two parts: high and low voltage.

- For the low voltage, EMC standards use a LISN to provide the DUT supply lines with repeatable and repetitive RF impedance over the designed frequency range tested.
- When testing high voltage supply lines to the DUT, the test plan needs to define what LISN to use and how to accommodate the shielded or non-shielded lines to the LISN.

What is a **L**ine **I**mpedance **S**tabilization **N**etwork?



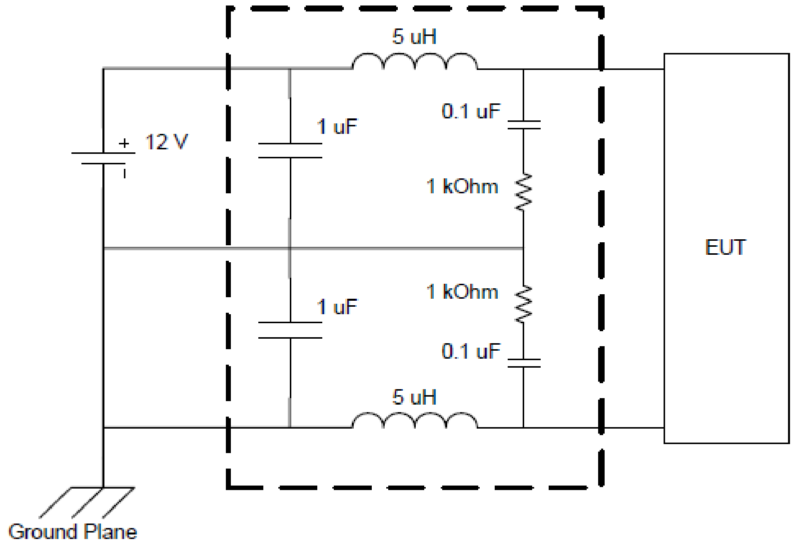
CISPR 25



- A low pass filter placed between the power supply and the DUT.
- Provides the DUT supply line with a repeatable and repetitive RF impedance over the designed frequency range.
- Conveys the DUT generated RF noise on the supply line to the 50 Ω measuring equipment.

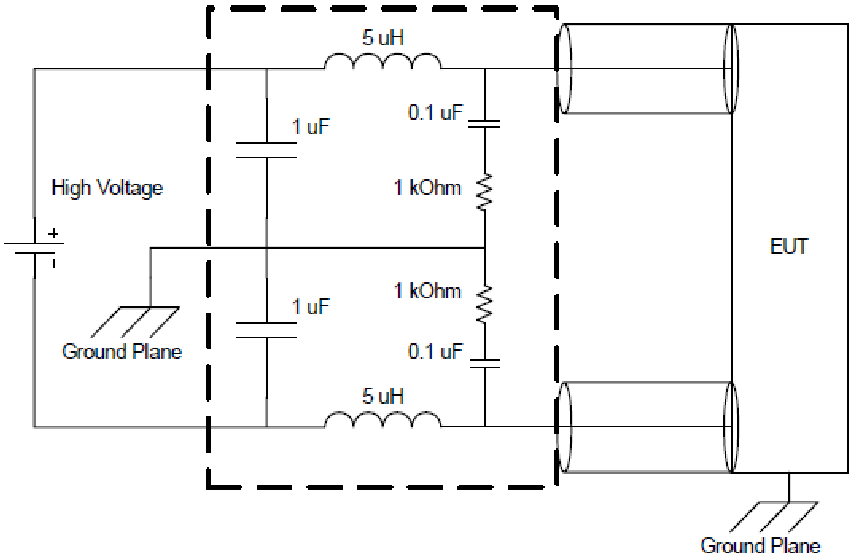
High Voltage Automotive EMC Component Measurements Using an Artificial Network

Standard 12V CISPR 25 LISN



- Measures DM voltage: 150 kHz < Vout < 100-200 MHz
- 1 uF on return generally shorted
- LISN defined to represent system impedances
- Generally no shielding

Example HV Automotive LISN Setup



- Measures CM voltage, generally between inner conductor and shield
- 1 uF generally much larger than HV cable shield capacitance
- 5 uH generally much larger than coaxial cable inductance
- Shielding termination not defined

http://www.ansoft.com/firstpass/pdf/High_Voltage_Automotive_EMC_Component_Measurements.pdf

Conducted RF Emissions

High Voltage Automotive EMC Component Measurements Using an Artificial Network

http://www.ansoft.com/firstpass/pdf/High_Voltage_Automotive_EMC_Component_Measurements.pdf

Magnetic Field Immunity

When writing a test plan for an Energy Storage System, one must consider how the magnetic fields will affect the system.

Below are some items which should be addressed:

1. Which sensors will be affected by the magnetic fields?
2. How will this affect the way the system reacts working normally?
3. Should the system have the high voltage and current lines working during testing to see if the added fields affect the contactors opening and closing?
4. How will the plastic or metal enclosure affect the paths for the magnetic fields?
5. How are the high current lines routed in the Energy Storage System near the magnetic field sensors, and is this representative of production intent?

Power Cycling & Transient Immunity

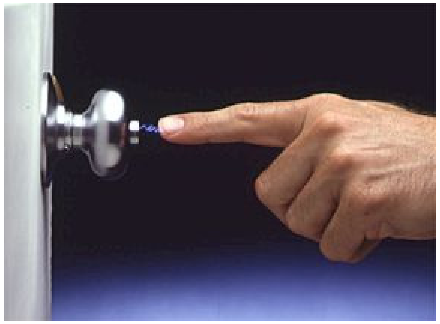
When testing the Energy Storage System for transient immunity and power cycling, one of the most important things to consider is how to monitor the system and what standards apply.

Below are a few items which need to be addressed in the test plan:

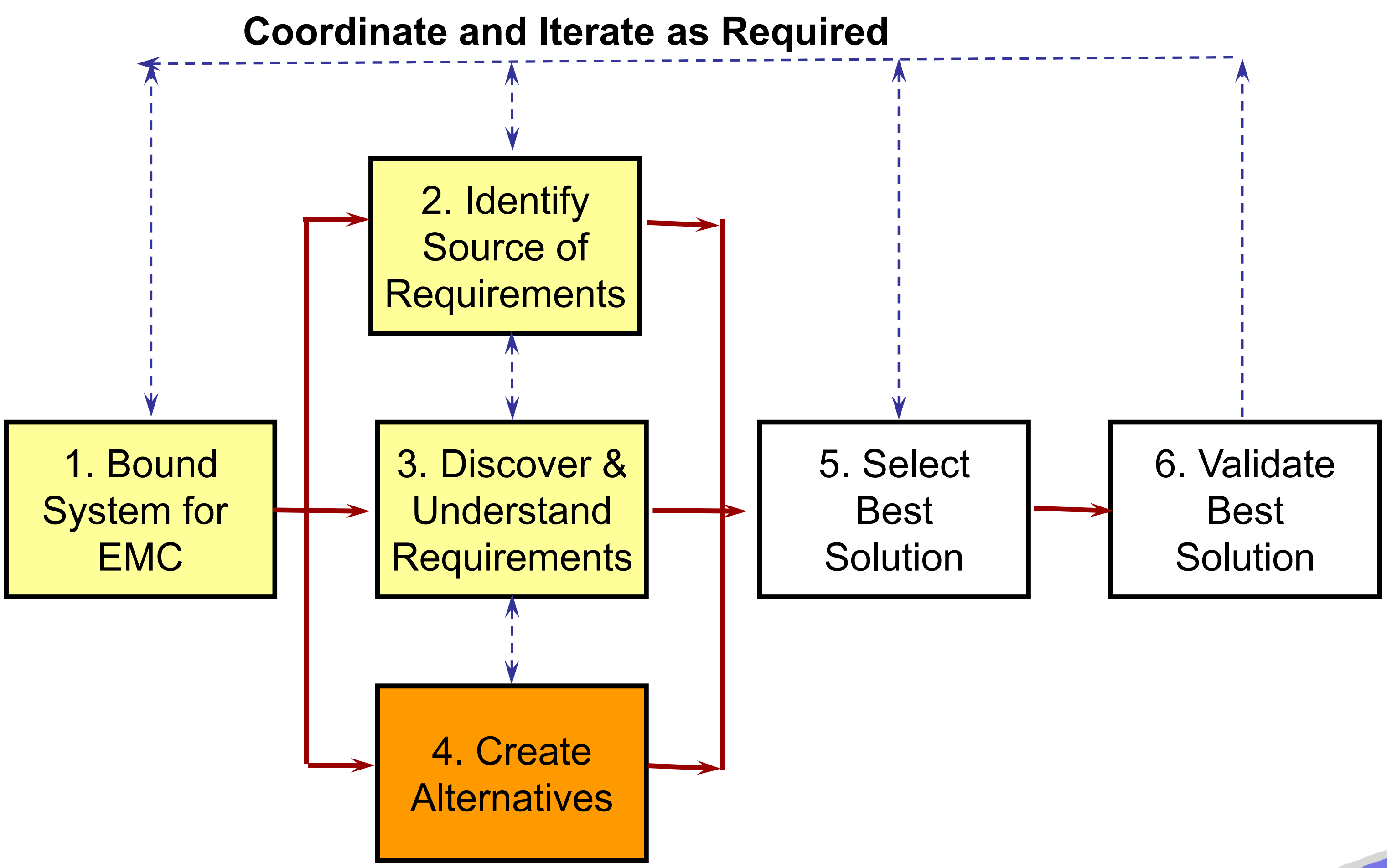
1. Use the diagnostic bus to monitor the multiple interfaces to the different modules in the system, provided the software will capture the anomalies.
2. Will the sensors be affected by the transients and give bad data to the system?
3. Define a way to monitor the contactors on the high voltage side to tell if they are truly open or closed.
4. Define where a DVM must be used to measure the voltage and current at different places in the system before and after the test.

Electrostatic Discharge Bench Test

- Due to having multiple modules in the Energy Storage System, where should the ESD test points be located?
- How should the test plan be specified using the resistive mat and bleed off resistor?
- Should the sheet metal of the vehicle body be part of the bench testing?

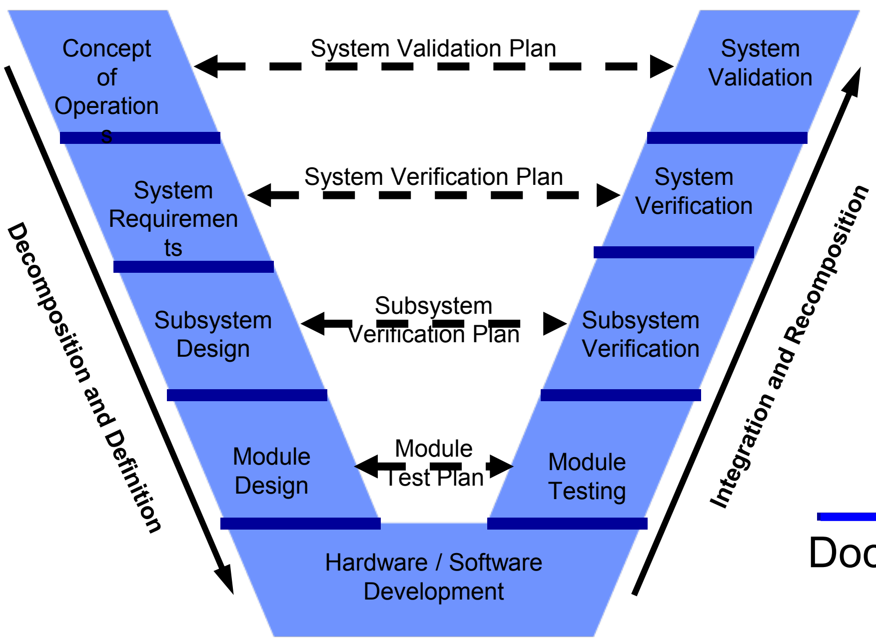


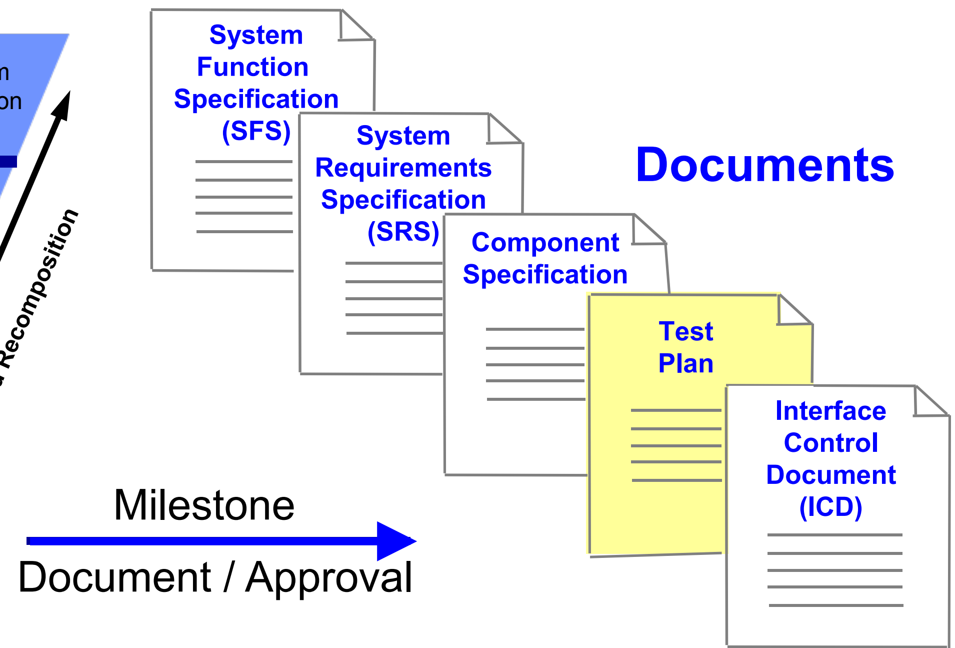
System Engineering Process



Summary

In order to meet the requirements for verification and validation of the Energy Storage System, a well defined Test Plan is Required!





For more information and technical papers go to: http://www.Jastech-emc.com

IN-HOUSE PROFESSIONAL EDUCATION COURSES

- Applying the Systems Engineering 7 Step Process
- EMC Shielding on Hybrid and Electric Vehicles

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