University of Colorado
Department of Aerospace Engineering Sciences

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Project Definition Document (PDD)

Team 18 - Automated Battery System for Testing Reliability and Continuity Tool (ABSTRACT)

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I. Approvals

	Name	Affiliation	Approved	Date
Customer		EnerSys		
Course Coordinator		CU/AES		

II. Stakeholders

A. Project Customers

EnerSys Advanced Systems **1751 S Fordham St STE 100, Longmont, CO 80503**	
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Brendan Cunningham brendan.cunningham@eas.enersys.com	Dylan Guderian dylan.guderian@eas.enersys.com

B. Team Members

Jeffrey Azuma jeaz7262@colorado.edu	Haotian Chen hach3562@colorado.edu	Jack Davis jada2196@colorado.edu
Nicholas Dembiczak nide5629@colorado.edu	Ryan Gao yuga7360@colorado.edu	Hrithik Hiranandani hrhi8877@colorado.edu
Alex Miceli almi1140@colorado.edu	Andrew Peterson anpe8446@colorado.edu	Ryan Sievers rysi3391@colorado.edu

III. Problem or Need

Throughout the aerospace industry, high quality batteries are critical to the success of many different and varying missions. EnerSys currently powers over thirty active missions using their 8s16p space flight batteries. These batteries that are used need to have great health throughout the process of the mission. This time period includes many months in storage, and during this, the health can deteriorate due to environmental factors. To combat this, EnerSys must perform a manual quality check of these batteries three times before sending them off to customers. These checks test each battery for its continuity, voltage, resistance, and isolation. The issue with this process is that the current procedure takes a significant amount of time, as it requires the test engineer to manually measure the characteristics of the battery between each and every combination of the battery pin outs. From this issue arises the EnerSys ABSTRACT Senior Project team. ABSTRACT (Automated Battery System for Testing Reliability and Continuity Tool) is an automated piece of equipment that performs continuity, voltage, resistance, and isolation tests to accurately and efficiently verify each battery. This piece of technology will automatically cycle through each combination of pins which will save the test engineers time and money.

Figure 1 EnerSys 8s16p Battery

IV. Previous Work

In order to gain a better understanding of automated functional testers, some preliminary research was conducted on other systems that already exist with similar functionality, as well as what is novel about this automated tester. One current automated battery tester is the SPEA T100BT. This product can test a range of products, including battery cells, battery modules, and battery packs. There are also a variety of tests that it can run, ranging from electrical, optical, geometric, and thermal, which are completed within the three different stations inside the tester. An array of tools can be fitted to the tester in order to allow it to perform the different tests, such as a vision camera, laser meter, illuminator, thermal sensor, and electrical probes. The size of the test area can also be customized to handle a large battery unit, up to around 10 feet in length. While this is a very sophisticated automated tester, it differs from the EnerSys ABSTRACT in the complexity of the tests. The T100BT is created to run a wide range of tests, but seems to be oriented to simple battery cells, or large groups of these cells. The ABSTRACT is designed to be able to run a series of automated tests that will cycle through each pin combination multiple times for one battery. This should also have the functionality to be terminated in the event of a faulty test or at the technician's discretion.

Another automated battery tester used in the EV industry is the Chroma's Battery Pack Power HIL Testbed Model 8610. This integrated testbed serves to validate and calibrate an EV battery pack, test its reliability and durability, and simulate charging and discharging cycles the battery will experience while driving. The Model 8610 testbed is quite unique, as its range of tests it can put the battery through spans from hardware verification to software verification, both in the context of fault injection. In addition to simulating charging and discharging profiles seen during driving operations, the testbed can monitor communication signal errors.

Though the ABSTRACT is not a continuation from a previous project, it holds many similar characteristics to other automated battery testers. Where this project is unique, however, comes from its ability to monitor data in real time as it cycles through the different testing pin combinations. ABSTRACT will provide the user the ability to run fully autonomous tests while also being able to start and stop the runs at any time. Furthermore, ABSTRACT will enable the user to view faulty data, outputted by the machine during operation.

V. Specific Objectives

The project can be broken down into two levels of success criteria. The first level corresponds to the minimum that must be completed for the project to be considered a success. The second level details further objectives that may be attempted to satisfy the customer's needs, wherever cost and time permit.

System	Level 1	Level 2
Hardware	Functional prototype	Finished product - Ready to Use
	Fabricated enclosure	
Electronics	Developed logic for reporting measurements	Wireless communication capability
	Developed logic for taking measurements	
	Fabricated circuit boards	
Software	Developed GUI Interface	Live plotting capability
	Automatic pin combination cycling	
	"Hands-off" automation capability	

VI. High Level Functional Requirements

A. Functional Requirements

ID	Requirement	Description
R1	Continuity Testing	System shall cycle through each combination of pins to measure continuity
R2	Voltage Testing	System shall cycle through each combination of pins to measure voltage in the range of TBD (V)
R3	Resistance Testing	System shall cycle through each combination of pins to measure resistance in the range of TBD (Ω)
R4	Isolation Testing	System shall cycle through each combination of pins to measure isolation
R5	Failure Response	System shall respond to and return faulty data
R6	User Interface (UI)	System shall respond to commands to start/pause/stop at technician's discretion, and test for a chosen duration, and display data.
R7	ESD Compliance	System shall be ESD compliant
R8	Power Compatibility	System shall employ a power supply compatible with standard wall outlet, ground pin included

The focus of the mission is to fulfill requirements R1-R4. These are the most important aspects directly relating to the problem being solved, which is the ability to autonomously test continuity, voltage, resistance, and isolation. Requirement R5 addresses a further step in the autonomy of the product in the case that faulty data should be found. If a test is run and an issue were to occur with the battery, it is important that the tester reports this finding so that the issue can be addressed. In addition to being fully autonomous, requirement R6 states that the user shall be able to start and stop the test at any time, and choose duration of testing. Requirements R7 and R8 ensure that the EFBT shall also be designed to operate in the environment that it will be used in and be compatible with standard wall outlets.

B. Concept of Operations (CONOPS)

The figure below outlines the Concept of Operations, which has been split into the three main phases of the mission: Test Setup, Testing Process, and Data Output. In the Test Setup phase, the battery is connected to the functional battery tester by the user. There are several tests to run in order to verify that the battery works properly, and the user can customize the duration and number of tests. The user will then start the testing process and the tester will automatically begin running the prescribed testing setup. In the Testing Process phase, the automated battery tester connects to a pin or pin combination. From this, data on continuity, voltage, resistance, and isolation is collected from each of these pin combinations. If faulty data is found, the test could be stopped automatically or manually by a technician. This process is repeated as required for the complete test of the battery. In the final Data Output phase, the automated battery tester displays live data to a GUI interface. If there is data that failed parameters, this must also be output for the user to view.

The automated battery tester then outputs a result file at the end of the test and must have the capability to plot the results.

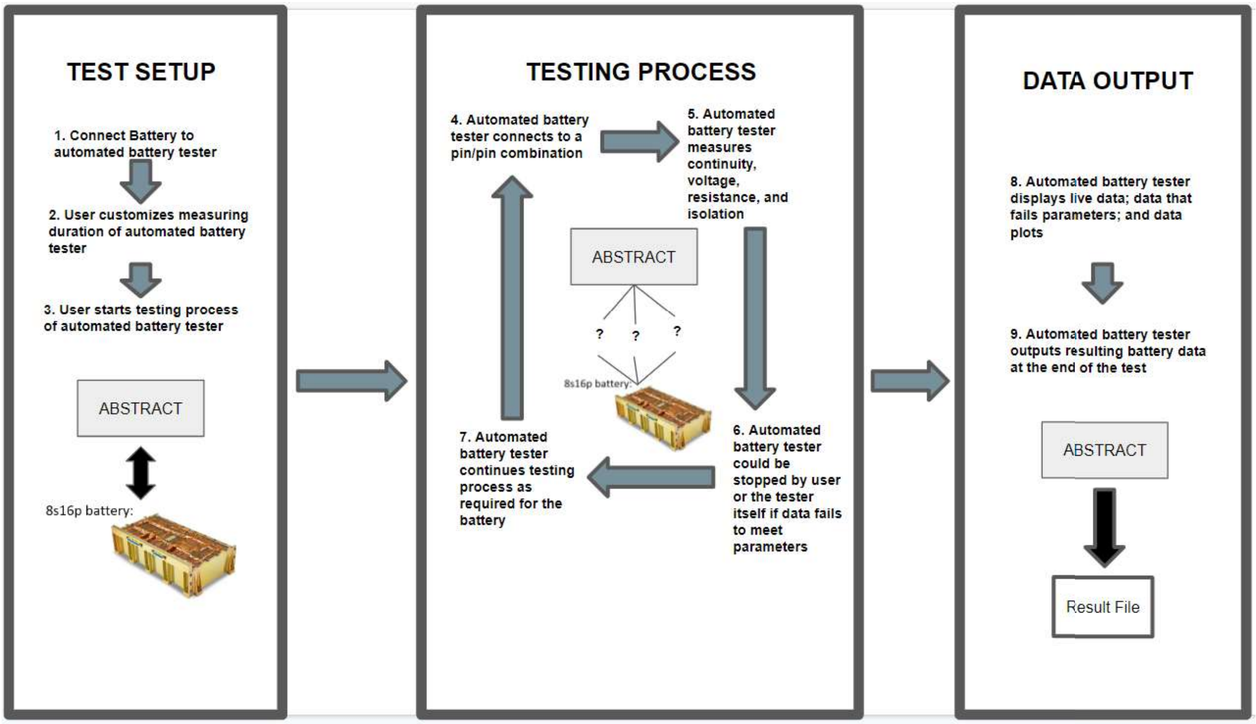

Figure 2 Team ABSTRACT Concept of Operations

VII. Critical Project Elements

ID	Critical Project Element	Reasoning	FR
CPE1	Sensing Hardware	The hardware utilized in the system shall be able to accurately and precisely measure desired values (ranges TBD).	R1-5
CPE2	User Interface	The system shall possess a method by which the technician can alter the testing process as desired and monitor progress.	R6
CPE3	Testing/Validation	The automated battery tester shall be built with safety and grounding in mind, for human operation. The automated battery tester shall be ESD compliant. The system shall interface with an 8s16p battery as specified by the customer, and not damage the battery. The system shall take and display data accurately.	R1-4 R7
CPE4	Integration	The automated battery tester shall seamlessly connect to the pins of a battery with no issue. The automated battery tester shall include software that enables it to interface with a computer. The system shall make use of a wall outlet as its source of power.	R6, R8
CPE5	Sensing Software	System shall be able to collect and interpret data to display and gather into output files.	R1-6

VIII. Sub-System Breakdown and Interdependencies

The system as a whole can be broken down into several subsystems, along with pieces involved with each. A graphic displaying this breakdown can be found below.

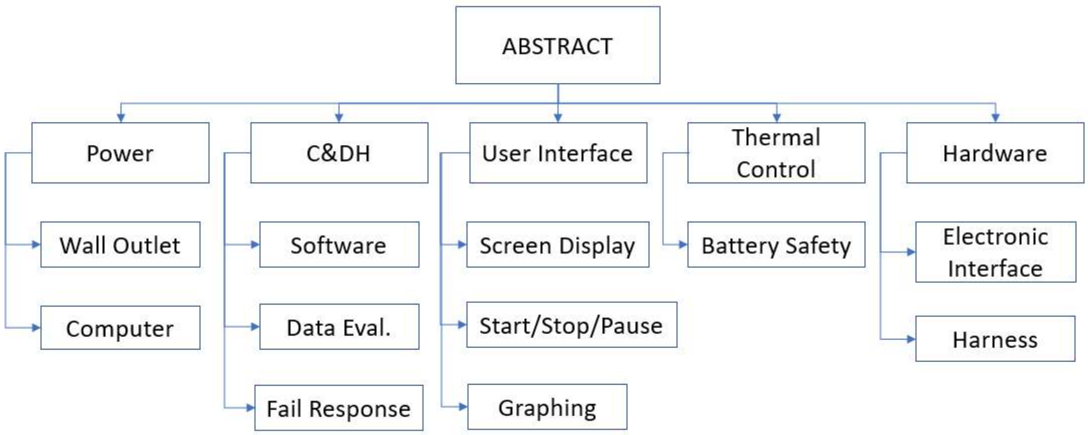

Figure 3 ABSTRACT Subsystem Breakdown

Each subsystem demonstrates interdependencies amongst the other subsystems. The power subsystem relies on the electronic interface of the hardware subsystem, as it is imperative that the electronic circuits used are compatible with a standard wall outlet and grounded plug. Additionally, the thermal control subsystem guarantees that the power subsystem or battery itself does not overheat the hardware subsystem. Command and Data Handling (C&DH) receives the hardware subsystem measurements, interprets the data, and passes it on to the User Interface subsystem, which displays the data to the user. The User Interface also demonstrates control over the electronic interface, by choosing how the testing procedure is conducted, and also affects the power subsystem. It is imperative that these interdependencies are considered throughout the development of this project, as each subsystem must cooperate with the others to ensure the success of the product as a whole.

IX. Team Skills and Interests

Team Member	Skills/Interests	CPEs
Jeffrey Azuma	Experience with SolidWorks, manufacturing, and basic machining. Interested in hardware and testing.	CPE1, CPE3, CPE4
Haotien Chen	Experience with software (MATLAB, SolidWorks), operation (manufacturing, assembling, testing). Interested in hardware, testing, and safety.	CPE1, CPE3, CPE4
Jack Davis	Experience with MATLAB, systems engineering (ART), and applied math. Interested in the software and GUI of the system.	CPE2, CPE3, CPE4, CPE5
Nicholas Dembiczak	Experience with MATLAB, systems engineering, electronics, and composite structures. Interested in the electronic operations of the system.	CPE1, CPE3, CPE4
Ryan Gao	Experience with software (MATLAB and SolidWorks) manufacturing, assembling, CNC machining. Interested in hardware manufacturing and testing.	CPE1, CPE3, CPE4
Hrithik Hiranandani	Experience with software (SolidWorks and MATLAB), manufacturing, and engineering management. Interested in systems engineering, testing, and safety.	CPE3, CPE4
Alex Miceli	Experience with software (MATLAB, C++, Python), systems engineering (Cameo), and engineering management. Interested in any software assistance needed; being a successful project manager.	CPE2, CPE3, CPE4
Andrew Peterson	Experience with software (MATLAB, C++, Arduino, Assembly), electronics (Altium), and testing. Interested in the software integration of the system.	CPE2, CPE3, CPE4, CPE5
Ryan Sievers	Experience with software (MATLAB, C++, SolidWorks) and engineering management. Interested in systems integration and testing and team dynamics.	CPE3, CPE4

X. Resources

Critical Project Elements	Resource/Source
CPE 1	Outside Expertise: Dr. Dennis Akos, Dr. Zoltan Sternovsky, Trudy Schwartz, Bobby Hodgkinson Facilities: Smead Aerospace Electronics Laboratory
CPE 2	Outside Expertise: Bobby Hodgkinson, Trudy Schwartz
CPE 3	Outside Expertise: Dr. Dennis Akos, Dr. Zoltan Sternovsky, Trudy Schwartz, Bobby Hodgkinson Facilities: Smead Aerospace Electronics Laboratory
CPE 4	Outside Expertise: Trudy Schwartz
CPE 5	Outside Expertise: Dr Scott Palo, Dr Dennis Akos

XI. References

1. https://www.spea.com/products/t100bt-battery-testing-equipment/
2. https://www.chromaate.com/en/product/battery_pack_integrated_testbed_8610_190