Design and Development of an Intake Alignment Device

Final Report

Team 3

Members:

Ferriez Johnson (ferriez1.johnson)

Matthew Burst (msb10f)

Troy Placid (trp12)

William Bridges (wjb11c)

Landon Kipker (lrk14b)

Advisors

Dr. Hellstrom

Sponsor

Dr. Michael Hayes, Cummins, Inc

Instructor

Dr. Nikhil Gupta

Date Submitted: 12/5/17

Table of Contents

Table of Figures

Table of Tables

ABSTRACT

Racing has always been the pinnacle of available technology. It gives people the ability to push our limitations with new materials and technologies that eventually trickle their way down into our daily lives. Our task is to devise a faster way for top fuel drag racing engines to level the intake manifold and bolt down properly. It must be a simple, reusable, fast, and durable piece of equipment to decrease the amount of time it takes the team to rebuild the engine. This could lead to tools used in every mechanic shop ensuring parts are properly mounted to prevent gasket failures, increase the life of motors, and decrease repair time.

ACKNOWLEDGMENTS

Thank you to Dr. Michael Hayes, our Cummins Inc. liaison, for his guidance and support throughout the project, as well as providing a nitromethane engine to aid in the design and testing of our product. Additionally, the team would like to thank Dr. Gupta and Dr. Shih for providing instruction and oversight to the team. Finally, the team would like to thank faculty member Dr. Hellstrom, for being a source of knowledge and expertise. Their advice and contribution has been a tremendous aid to each of our team members for the development of this project.

1. Introduction

Cummins works with the NHRA in Top Fuel Nitromethane engine development. After every 1000 foot race, the engine must be rebuilt. The engine is generally rebuilt over a 20 minute period. Traditionally, in order to insure that the intake manifold is lying flat on a plane, dial gauges are used around each bolt to ensure precision. This process takes a lot of time, but if a new digital tool is created this time can be significantly reduced.

2. Project Definition

2.1 Background Research

Our project involves working with a drag racing engine. Our areas of concern in the engine are the engine block and the intake manifold. In order to fully understand the project scope, we must understand each individual component in the assembly, which are discussed in the following paragraphs. Aside from the engine components, we will be testing different methods of determining if the intake manifold is sitting flat on a plane to a certain degree of accuracy. We will explore the benefits of various sensors used to determine the plane's accuracy.

A supercharger on a car is an air compression device. This compressed air allows the engine to burn more fuel in the cylinder, and hence deliver more power to the crankshaft. Drag race cars are famous for their high performance and speeds, so a supercharger is necessary for the car to meet the required performance standards. Below the supercharger is the intake manifold. This is responsible for actually supplying the compressed air from the supercharger into the piston cylinders. It is important that this manifold provides an even and smooth distribution to the cylinders, or else the combustion will not be clean and uniform. There are many undesirable effects of this sort of unclean combustion, including extra forces that decrease the efficiency of the engine. These forces can also add extra stress that can cause connections to fail or start to separate.

Our project is concerned with ensuring that the intake manifold is lying flat on the engine block. These two can become slightly separated at the connection screws due to the amount of vibration the typical drag car engine receives. To put the drag racer into perspective, most cars produce about 100-200 horsepower. Our drag car produces 10,000 horsepower. At such a high power, there are extremely high vibrational forces on the engine parts. Due to these high forces, certain drag race components must be replaced after every race. When putting the engine back together it is crucial for the intake manifold to be sitting flat on the engine block. If not, the engine may suffer excess wear or failure. For this purpose, a dial gauge level is used to give feedback to the mechanic so that the engine can be assembled properly. A better option is a digital level because of its ability to quickly give feedback.

2.2 Need Statement

As a team, we must design a tool that is able to assist the crew with ensuring the intake manifold is sitting flat on the engine block. In order to do this we must follow our sponsor's constraints and requirements. In the near future, we will receive an engine from our sponsor to test our final design. Until then we will be using a prototype to test the concept we choose.

2.3 Goal Statement and Objectives

Our overall goal as a team is to create a tool to ensure that the intake manifold is flat on an engine block on a TOP Fuel nitromethane drag racing engine. This tool should help shorten the time it takes to rebuild the motor in between races. It should be easy and quick to use, and much faster than the methods that are currently used.

2.4 Constraints

The constraints given to the our team by Cummins are that the power supply for the device has to be internal. Cummins does not want to have to plug in the device to an external outlet in order to run the device on top of the engine. [1]

Cummins requires the device to read values in under one second and it has to be accurate within ± 0.005 in. Cummins also requires a fast calibration and startup of the device so that time is saved rebuilding the engine, along with a method for quick repeatable placement.

The casing for the device that holds the computer module needs to be durable and withstand drops. The readout from the computer needs to be able to be read from each side of the engine, since there are mechanics working on each side of the engine.

2.5 Product Specifications

Our device must determine how much to turn each bolt on the intake manifold to keep it from deforming and remain level to the five thousandths of an inch. This means our product must be accurate to the ± 0.005 in. As it is being used in a race and the engine must be rebuilt quickly. This defines every other parameter. The device must be portable to allow them to easily place it on top of the engine. It must also be a stand alone device meaning have its own internal programming, battery, and display. Which allows for quick setup and cleanup. The display method that will be used must be visible from both sides of the engine as the mechanics will be working on it from both sides at the same time. The device cannot be in the way of anything they are working on during the installation process. It therefore cannot be larger than the flat surface of the intake manifold. The prototype cannot cost more than $2,000 to build. This makes the decision of what measurement device to use that is that accurate and cost effective very important. The sensors themselves will be most of the cost of the device. The sensors will connect to an arduino that is programmed to know how much to turn each bolt to make the mating surfaces of the intake manifold uniform and level. That information will be sent to the display that will tell the mechanic how much to turn each bolt. All in all it needs to be put on the engine, used, and put away in under 30 seconds. Our goal is to bring this down to 15 seconds.

3. Design and Analysis

3.1 Concept Generation

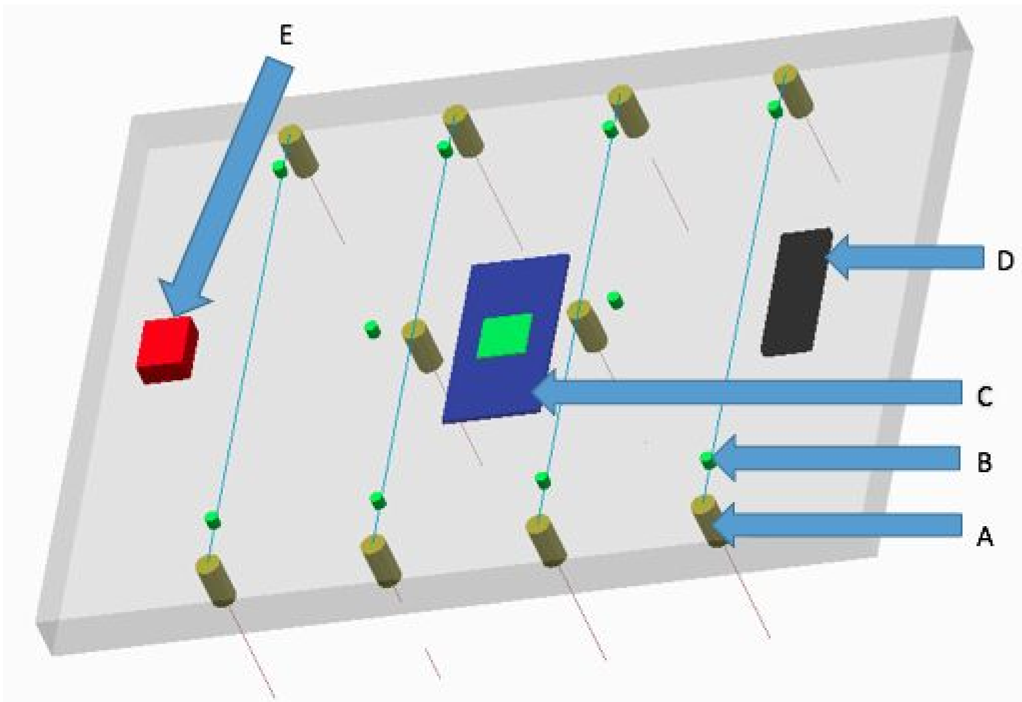

Figure 1: Conceptual design of alignment device
(A: Sensor, B: RGB-LED, C: Microprocessor, D: Battery & E: Switch)

Shown above is the general conceptual design of our alignment device. The housing is shown transparent here in order to show the internal components of the system. The arduino board is shown in blue, with the letter C pointing to it. This is sitting inside the housing. The arduino is what will hold all of the connections to the sensors. On top of the arduino is a chip, shown just as a small green square sitting on top of the arduino. This represents all the electrical components that will be located on the board. It is the microprocessor for the entire system. This is where the sensors will connect in order to have their input processed. It will hold the code to convert the analog data from the sensors into a useful calculation to tell if the intake manifold is lying flat or not. The sensors(10 of them) are shown in gold and indicated by the letter A. These are what will actually do the measuring to insure that the different areas of the intake manifold are sitting on the same plane. The sensors are shown with thin lines pointing downward.

These represent the measurements that the individual sensors. Once these sensors perform their specific function, they will relay their analog data to the arduino, and the code inside the arduino will decide if that portion of the intake manifold is lying flush with the engine block. The portion of of the board that will actually produce an output are the LED lights. These are shown as small, green cylinders (10 of them), indicated by the letter B. The LED lights will light up individually. Once the sensor measures that the portion of the board that it is measuring is flat on the engine block, the arduino will send a signal to corresponding LED and the LED will turn on. This means that that area is good, and the mechanic can stop adjusting that corresponding screw and move on to the next one. The mechanics will know they are finished once all the LED lights are lit up. At this point, all the screws are within the required ± 0.005 in of each other and the intake manifold is sitting flat on the engine block. The battery for the device is shown as a black rectangle and is indicated by the letter D. It is important that our device have its own power source because we want it to be a stand alone device. Finally, the power button is shown in red, and indicated by the letter E.

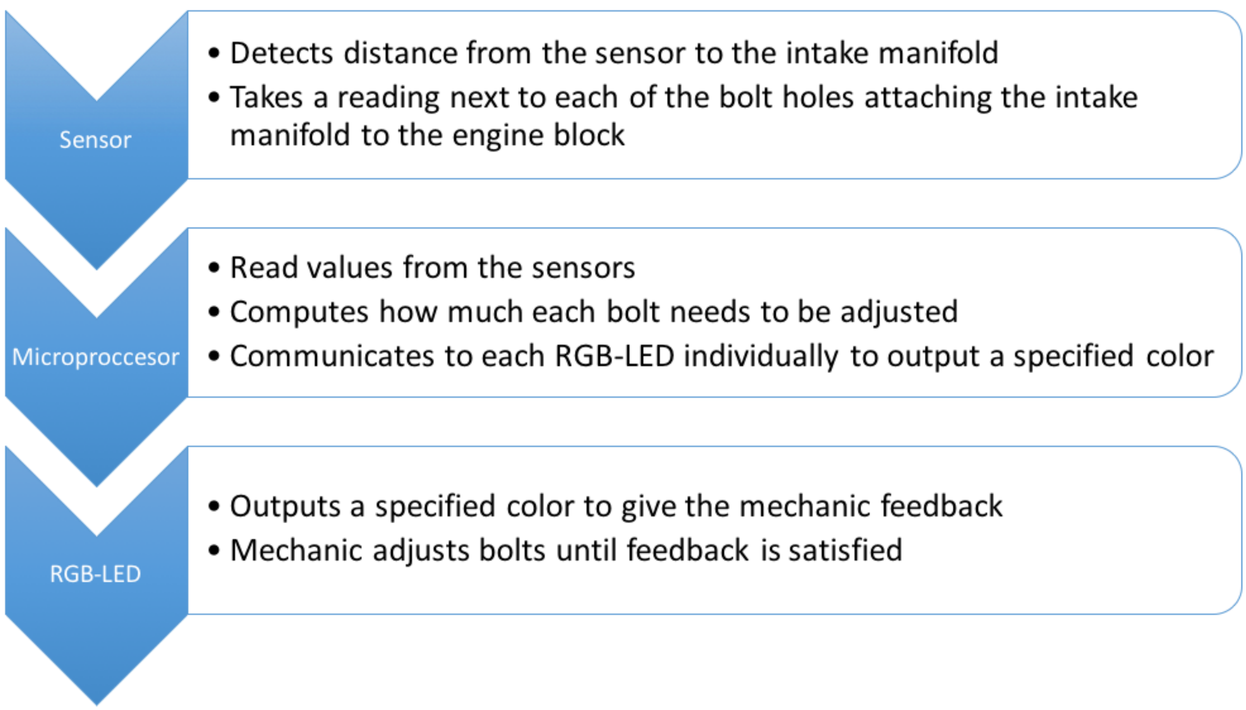

Figure 2. Functions of the tool

3.1.1 Concept #1

Concept #1 is to use a laser distance device to accurately read if the intake manifold is flat on the engine block. The device that will be created for concept #1 will consist of ten laser sensors connected to a microprocessor. The lasers will aim down perpendicular to the base of the intake manifold next to each of the bolts and read back a distance to the microprocessor. The microprocessor will then determine which bolts need to be tightened in order for all the bolts to be within ± 0.005 in of each other. Since the device will be emitting a diode down from a sensor onto the intake manifold there will not be any parts coming from the top of the intake to the bottom of the intake like Cummins currently does with dial gauges. With no parts touching the bottom of the intake manifold there is not a change of error from a bent shaft or from friction from the shaft and the base of the intake manifold. As a bolt needs to be turned the LEDs on the board will light up to tell the technician which bolt needs to be turned.

3.1.2 Concept #2

Concept #2 is similar to concept #1 except instead of utilizing lasers for measurement pressure sensors will be used to measure the difference in pressure. By having a pressure difference between the ten sensors the device will be able to tell that the intake is not flat. As the bolts are tightened down the pressure will increase and decrease until all of the sensors read off the same pressure, meaning that all the bolts are tightened the same and that the intake manifold is flat on top of the engine block. After the manifold is flat the supercharger will be able to be safely mounted on top. Unlike concept #1, concept #2 will have to have a mount that holds the pressure sensors from the top of the manifold. This method is similar to the current method by Cummins in which dial indicators are used to measure inclines in elevation which means that the intake is not flat on the engine block. Both the original Cummins dial indicator approach and concept #2 will be in constant contact with the base of the intake manifold, and if it is not than the values read will not be accurate. The pressure sensor will tell the controller which LED needs to be lit up in order for the technician to turn the bolts to level the intake.

3.1.3 Concept #3

Concept #3 is the digital dial indicator. This works exactly the same way as the traditional dial indicator except it has a faster feedback because now has electrical components as opposed to all mechanical components. In reference to our figure above describing the general setup of our device, the “sensors” will actually be individual market dial indicators. These are available ready to use, and we will be essentially rewiring them to connect to the central arduino. We will attach a rod to the bottom of each individual dial indicators to extend down to touch the intake manifold. These rods will measure a distance, and relay that distance to the central arduino. With this data, the arduino will be able to tell if all the distances are within ± 0.0025 in of each other. If so, all the LEDs will be lit up.

3.2 Evaluating Concepts

Table 1. Pugh Matrix

	Baseline	**Alternative Solutions**		
Criteria	**Current Solution**	**Concept #1**	**Concept #2**	**Concept #3**
Feasibility	3	2	3	5
Cost	2	2	5	3
Performance	1	4	4	4
Maintainability	3	3	4	4
Simplicity	3	1	2	5
Total	**12**	**13**	**18**	**21**

3.3 Concept Selection

From the Pugh Matrix the best selection for concept generation was concept 3. Concept 3 is to use digital indicators to replace the dial indicators that are currently used by the Cummins team. The digital indicators is a proven option with aligning the intake to the engine block. The laser indicators is an advanced option that would that is more precise but at the cost of durability, and not being able to quickly recalibrate the device. Another setback of the laser alignment system is that if the beam of the laser is disrupted, then it will throw off the alignment process. This could happen if there was some large particles in the air, such as fog or sawdust. The underlying need of this project is that the alignment process needs to be faster, so digital indicators seems to be a better fit. The pressure sensor is also a good option, but it is not very feasible. All it takes is a small vibration of the entire system in order to disrupt the reading of the pressure sensor. With the mechanics constantly adjusting screws to align the intake manifold, there will be far too much vibration for the pressure sensing system to be feasible. Along with the remaining factors, we agreed that the digital indicators are the best option.

4. Methodology

4.1 House of Quality

It is key to physically access and take measurements of the engine components. The dimensions will have a large effect on the amount of precision needed from the tool. A House of quality is constructed to identify which aspects that need to be emphasised in the design of the device. It showed where corners can and cannot be cut to meet the needs of the consumer.

HOUSE OF QUALITY		TECHNICAL SPECIFICATIONS								
		DISPLAY LOCATION	BATTERY OPERATED	SET UP TIME	INFORMATION PROCESSING TIME	SIZE	MEASUREMENT LOCATION	TYPE OF INFORMATION DISPLAY	CASE MATERIAL	ACCURACY OF MEASUREMENT DEVICE
CUSTOMER NEEDS										
FASTER THAN WHAT THEY USE NOW	10		2	6	10			4		
SEEN FROM BOTH SIDES OF THE ENGINE	5	7					3	3		
FAST SET UP	6		3	6		4	3			
DOES NOT GET IN THE WAY OF INSTALL	10					4	5			
STAND ALONE DEVICE	4		5							
FITS IN TOOLBOX	6					4				
SIMPLE INTERFACE	5	3						5		
DOES NOT BREAK	6								5	
ACCURATE TO 0.005"	10									10
TOTAL TIME LESS THAN 30 SECONDS	10	3	4	5	6			4		
Saftey	20									20
SCORE		80	98	146	160	88	83	120	30	500
WEIGHT		6.130268	7.509579	11.18774	12.26054	6.743295	6.360153	9.195402	2.298851	38.31418
RANK		8	5	3	2	6	7	4	9	1

Figure 3. House of Quality

As we can see the precision of the device is paramount as that directly deals with the safety of the driver. This device absolutely needs to meet those specifications no matter the cost. Other factors such as the casing that is used can have corners cut to meet price points.

The second stage involved brainstorming solutions. This included picking out the various components needed to complete the device. Once an array of parts have been compiled we chose which ones should be purchased. This will be done by minimizing the cost while selecting a system of parts that will achieve results at or above the required constraint values.

The third stage is to prototype the device (The test rig-Figure 5). This involves putting together the components and programming the tool. Fabrication of custom parts will also be done during this stage. The prototype will then be tested and benchmarked.

The fourth stage is translating from the prototype to the final design. Any issues with the prototype will be corrected. This could involve new components or software adjustments.

4.2 Resource Allocation

Table 2. Budget

Item	Estimated Cost
Aluminum Plate	$30
Microprocessor	$25
10 digital indicators	$750
10x RGB-LEDs	$15
Miscellaneous (wiring, switches, etc.)	$100
Total Cost	**$920**

Table 3. Resource Allocation

Team Member	*Task*	*Time Allotted*
William Bridges	Brainstorm Concepts	1.5 weeks
	Assist in Sensor Research	2 weeks
	Material Acquisition	2 weeks
	Assist with Fabrication	2 weeks
Matthew Burst	Brainstorm Concepts	1.5 weeks
	Assist with Engine Shipment	1 week
	Develop Code	Continuous
	Fabricate Baseplate	2 weeks
Ferriez Johnson	Brainstorm Concepts	1.5 weeks

	Website Development	Continuous
	Test Device	2 weeks
	Revise Device	2 weeks
Landon Kipker	Brainstorm Concepts	1.5 weeks
	Assist in Code Development	Continuous
	Test Device	2 weeks
	Revise Devise	2 weeks
Troy Placid	Brainstorm Concepts	1.5 weeks
	Research Sensors	2 weeks
	Test Device	2 weeks
	Revise Device	2 weeks

Table 2 gives a rough estimate of how the budget will be allocated and spent on each item. The Budget explains where the money will bme spend, and around how much money will be spent on each different part for the project. There is extra money left over in order to account for last minute changes and for errors with our initial estimate on the cost of each item.

Table 3 explains how the work between each member will be divided up and what part of the project each team member will be working on and for the duration of that time. All team members brainstormed together in order to get the initial idea for the project and from there the work will be divided up between them.

4.3 Gantt Chart

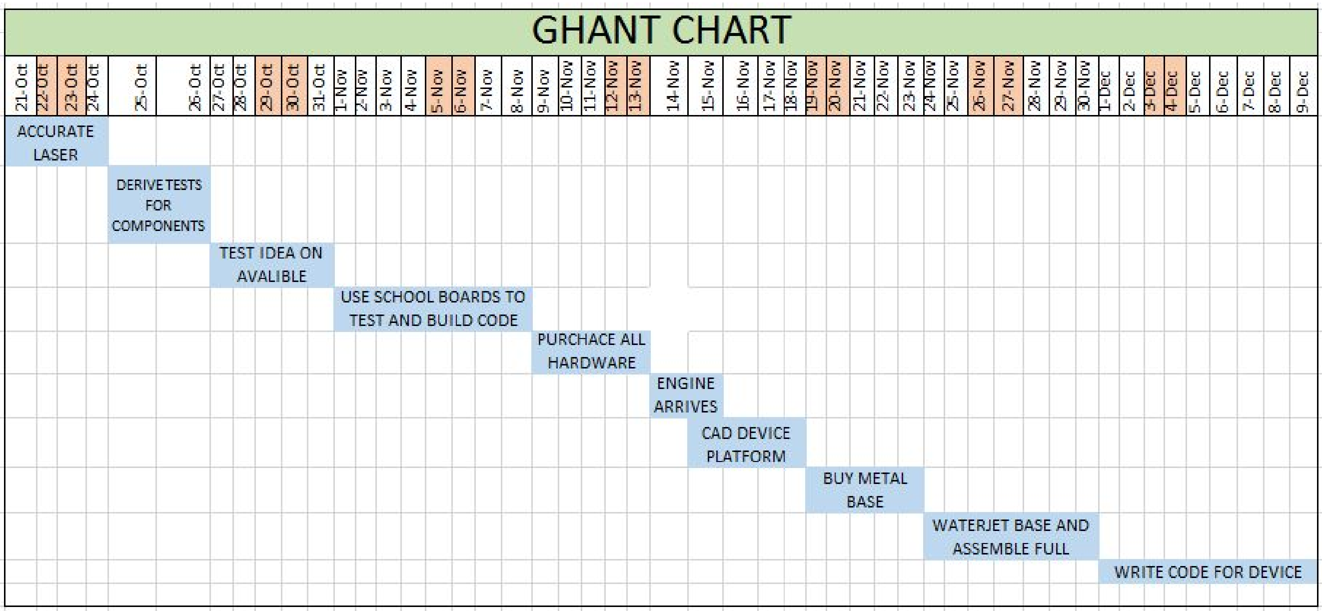

Figure 4. Gantt Chart

There have been some slight hold backs on the Ghant chart due to the engine not coming in as we had planned and thus a test rig needs to be built. This should not impede our timeline by much. We have the metal and are ready to start building the test rig. Cad models have been built for both the final product as well as the test rig. Testing has been done on similar indicators to ensure we can get the information to the board as needed. The redesign of a test rig has slowed the purchase of the hardware. All we need to purchase is four digital dial indicators and four LED lights. Coding will begin at the start of next semester.

4.4 Cad Models

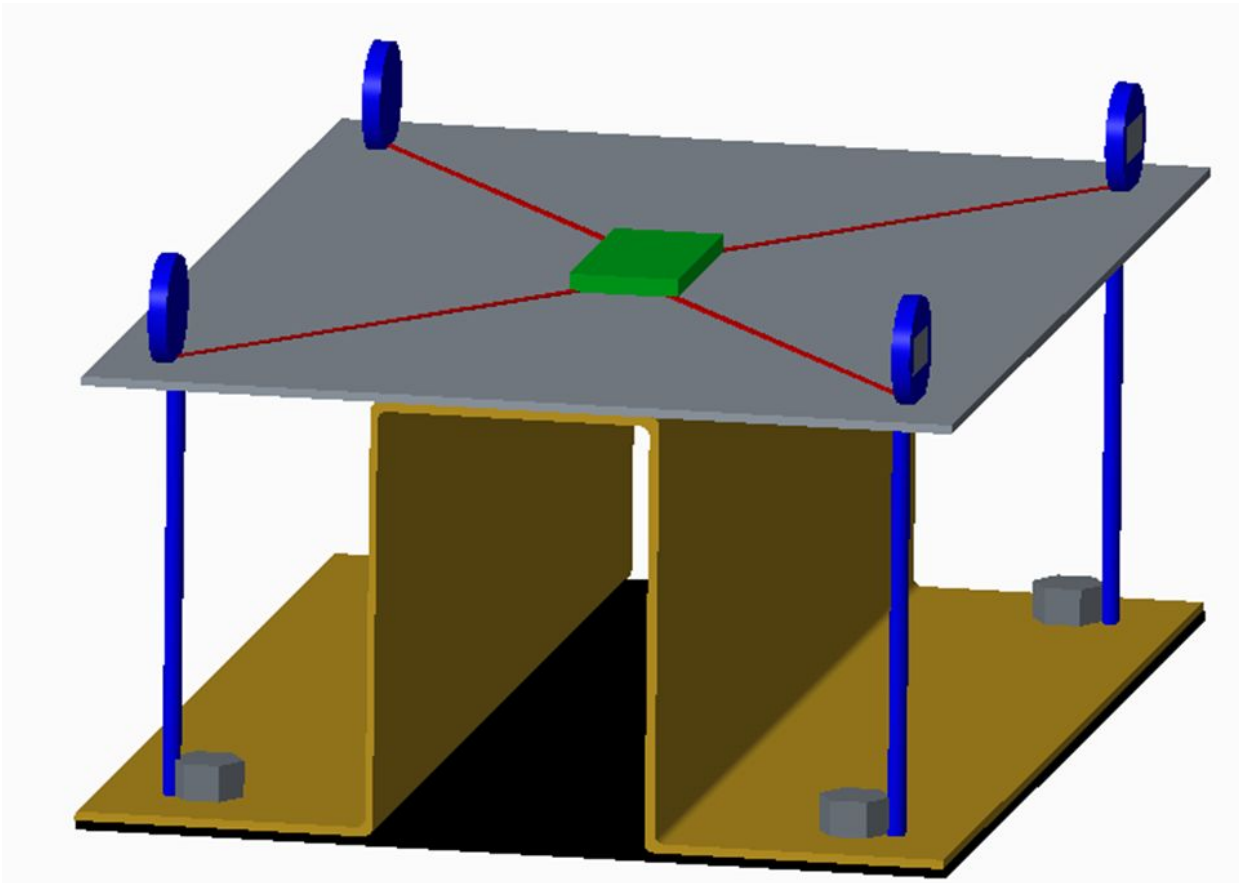

Figure 5. CAD prototype design

Our prototype includes a base (seen in black at the bottom of Figure 5), a plate bolted to the base to mimic the intake manifold (seen in brown in the middle of Figure 5), and a half sized measuring device to test our idea and begin the programming process for the full sized model. This will tell us if the idea will work well enough to continue with the design process. We will be able to make any needed changes to the final design to make it work as well as it can.

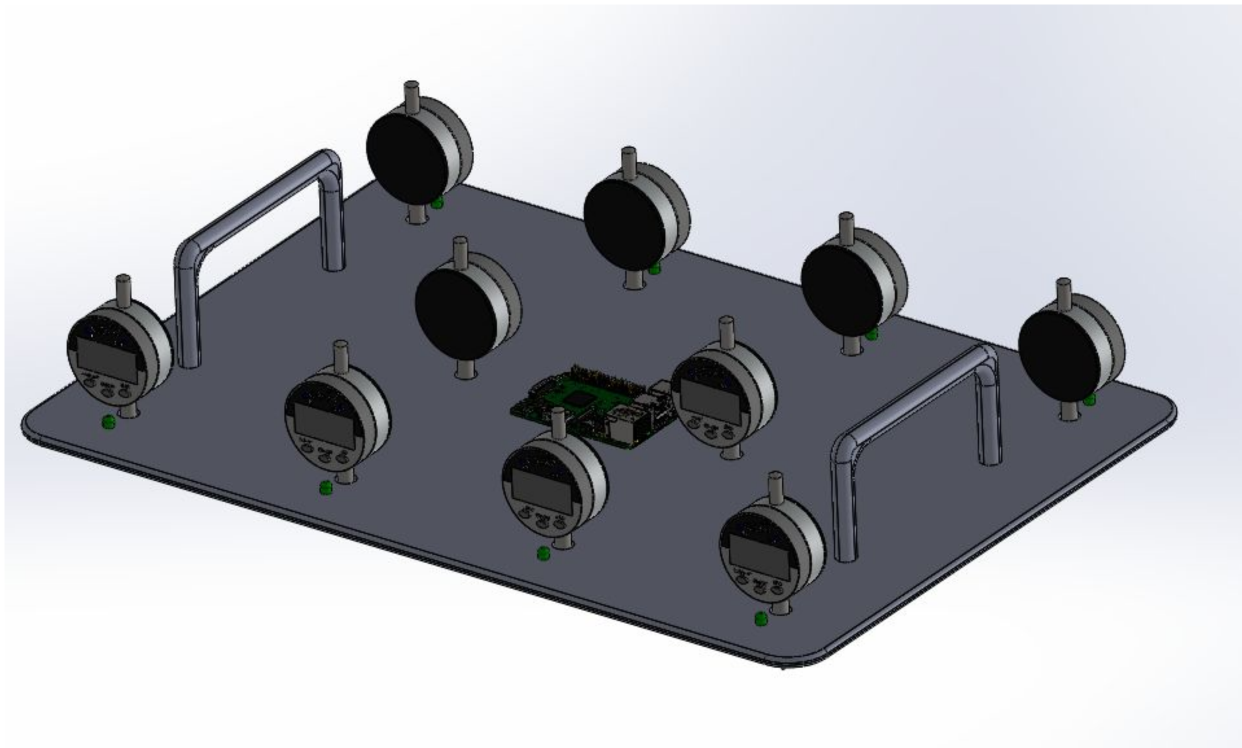

Figure 6. CAD Final Design

The full sized model will have the same 10 dial indicators they have for the tool they use now as well as a similar shape. The main improvement is to have a computer indicate exactly what bolt to turn when to allow for a much faster installation without any guess work or coordination needed between crew members.

5. Conclusion

The goal of our project is to design and construct a tool which will give feedback to ensure that the intake manifold is laying flat on the engine block, to the point that the connection screws are all within ± 0.0025 inches of each other. If part of the intake manifold is not lying flat on the engine block, the entire engine could catastrophically explode. We proposed three main ways of aligning this component. After evaluating them, we decided that a dial indicator alignment system was the best option.

The need for this project arises from the current alignment process being too slow. We would like to give quick, real time feedback to the mechanics working on the engine so that they may align the intake manifold as quick as possible. We currently do not have an engine so a test rig was designed and is being built to allow us to test the device to ensure it is functional before we move to a full scale device.

Biography

William Bridges: Lead Design Engineer

William is a Florida State University Mechanical Engineering student from Orlando, Florida with a focus on manufacturing. He has competed for five years on FSU's track and cross country teams. Upon graduation he plans on working for Nissan Motor Company Ltd at their Nashville, Tennessee headquarters.

Matthew Burst: Project Leader and Programmer

Matthew is a Florida State University Mechanical Engineering Student from Jupiter, Florida with a focus on dynamics. He has run a small engineering design company for 5 years and is currently baja team captain for SAE. Matt plans on pursuing a career in the automotive or aerospace fields upon graduation.

Ferriez Johnson: Web Designer

Ferriez is a Florida Agricultural and Mechanical University student from Milwaukee, Wisconsin. He has experience and a strong passion to work in the automotive or manufacturing industry after graduation.

Landon Robert Kipker: Lead ME

Landon Robert Kipker is a Florida State University Mechanical Engineering student from Tallahassee, FL. Landon plans to work in weapons design when he graduates with an interest in American firearm companies.

Troy Placid: Research Coordinator

Troy Placid is a Florida State University Mechanical Engineering student from Naples, FL. Troy plans to pursue a Master's degree in Aerospace Engineering upon graduation.

References

[1] Hays, Michael, D.Eng. "Project Overview." Telephone interview. 28 Sept. 2016.
[2] Hays, Michael, D.Eng. "Information Session." Meeting. 20 Oct. 2016.