Delphi Final Report

Figure 1: Camshaftless Engine shown with Cargine technology (*Free Valve*).

Cargine Technology
Camshaftless Engine

Russell Bauer, Jack Titus

Aaron Lacombe, Ali Alkhatib

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Penn State

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Executive Summary:

For the Delphi design project, the team asked to improve improve car technology to be either safe, green, or connected, and after analysis we chose to focus on green. Early in the project a survey helped determine what Delphi goal to focus on. The survey asked people to rank three possible ideas: a car with body signal reader, a carbon fiber cabin, or a smaller and more effective engine. After reviewing the data, the smaller and effective engine won. Next research guided how this engine would be more fuel efficient, and three different types of engines emerged as options: free valve, downsizing and turbocharging, and direct injection. We conducted an Analytical Hierarchy Process (AHP) to determine our design objectives and calculated the weights for the objectives. Then we created a Design Selection Matrix with the three engine designs and rated them with the design objectives and the AHP weights to decide our winning design, which was the Free Valve engine. This engine officially called the camshaftless engine was patented in 2011 by Koenigsegg,a supercar manufacturer, created the company Cargine to explore this idea. This new and improved engine removes the camshafts of the engine and replaces them with the Cargine technology (*Koenigsegg).* These changes reduce weight of the engine by 30% and will enable cars independent control of pistons to improve fuel efficiency. (Navarro) This engine will enable cars to be more fuel efficient and reduce the emission of CO_2 meeting Delphi's goal of a greener car.

Introduction:

Instead of developing a brand new concept for cars, this project focuses on promoting a technology that is new to the automotive industry. The team chose the camshaftless engine, which has been developed by a supercar manufacturer, Koenigsegg, and a new company called Cargine to develop it. This engine, patented in 2011, is rather unique. A traditional internal combustion which uses camshafts to open and close the valves. This new engine replaces the camshafts with a compressed air system, making the engine 50% smaller in size, and 30% lighter (Noe). A unique aspect of this engine is that it can switch to only two cylinders while the car is idling. It saves gas, reduces carbon dioxide emissions, and makes cars overall more fuel efficient. This new concept is much more environmentally friendly than the traditional engines used today and is the engine of the future. Delphi can develop the powertrain interconnections to this engine for major car manufactures, and bring the Cargine engine into broad use around the world.

Problem Statement:

The Delphi project objective was to ' "identify technologies and opportunities to make cars and trucks safer, greener, and more connected." ' Our group focused on making cars and trucks greener, with the goal to reduce fuel consumption and CO_2 emissions.Cars today have big engines that are heavy making the car less fuel efficient and the engines also release CO_2 that hurts the environment. These problems are what our engine needs to improve.

Research:

In order to prove the usefulness of the Free Valve engine, a table was set up to compare various features of the Free Valve engine and other recent engines trying to achieve the same goal of a greener internal-combustion engine.

Engine	Weight	Fuel Economy	Power	Size	Conclusion
Free Valve	30% reduction from similar engines	up to 12.8% increase over average	about the same as similar engines	50% reduction from similar engines	advantages in weight and size reduction
Volkswagen TDI	about the same as similar engines	up to 66% increase over average	only 150hp (very low torque as well)	about the same as similar engines	can only be used on small, light cars
Ford EcoBoost	about the same as similar engines	up to 20% increase over average	turbochargers produce about two cylinders' worth of power	about the same as similar engines	downfalls of torque due to turbocharger lag

These comparisons show that the extreme weight reduction alone does not give the Free Valve engine a fuel economy advantage over its competitors. However, its unique ability to run on only two cylinders if needed increases its fuel economy even more. Furthermore, the Free Valve engine does not lose any power or acceleration abilities in return for gas mileage, unlike the other two engines shown. With further development and testing, the mpg increases will become even closer among these three engines.

Customer Needs:

Customers in today's market are interested in cars with improved safety, efficiency, and connectivity. Our engine design focuses on making the car more green. In the consumer needs one for the concerns was cars produce too much emissions of gases and will harm the environment. Since this engine allows independent control of pistons the engine can run smoother and more effectively, in turn producing less CO_2 emissions. Also one of the consumer statements said they wanted a lighter car because it would be more fuel efficient and with our engine being 50% smaller it is 30% lighter improving fuel efficiency up to 12.8% (Jaynes).

Figure 2 (Below): List of customer statements and needs for safe, green and connected.

DELPHI Project - Fall 2014

Customer statement:	Example Customer Need:
Project Objective	
Identify technologies and opportunities to make cars and trucks safer, greener, and more connected.	Project design will enhance cars or trucks and make them safer, greener and more connected.
Project background	
There are up to 50 computers buried beneath the skin of the cars and trucks that you see every day on the road.	Distributed computers are an integral part of modern cars.
You wouldn't know they (the computers) were there. But each of them is making that vehicle safer, greener, and more connected.	Car computerss are hidden from the user, so the users only interface with what they need to.
Many of those computers were designed and built by Delphi.	Design should be compatible with all Delphi systems.
It seems every day we're hearing in the news about "cars of the future", ones that will park themselves, drive themselves, talk to us, use fuel more efficiently, report data to insurance companies, avoid accidents, etc.	Design should be future oriented.
What does this ("cars of the future") mean in terms of the **technologies needed** to enable safer, greener, more connected cars and trucks?	Design should take into account technology to meet the Safe, Green, Connected goals.
What does this ("cars of the future") mean in terms of **societal acceptance** to enable safer, greener, more connected cars and trucks?	Design should take into account societal acceptance to meet the Safe, Green, Connected goals.
What does this ("cars of the future") mean in terms of **policies** needed to enable safer, greener, more connected cars and trucks?	Design should take into account policy to meet he Safe, Green, Connected goals.
What does this ("cars of the future") mean in terms of the **supporting systems** needed to enable safer, greener, more connected cars and trucks?	Design should take into account systems design to meet the Safe, Green, Connected goals.
Project Description	
Each design team should choose one (or a combination) of Delphi's three target areas—Safe, Green, Connected—as described below.	Design must incorporate or address one of the Megatrends.
Safe: Our ultimate goal is to help make zero fatalities, zero injuries, and zero accidents a reality	If focusing on Safe, design would drive accidents to zero
Protecting the driver and passenger is of upmost importance.	The design should protect the driver and passengers even better than current designs.
Airbags are an example of a reactive safety feature after a crash occurs.	*case example*
Safety features now being designed into cars are more proactive to avoid the crash all together.	The design should enable the car to avoid accidents.
Sensors are used to detect dangerous situations, and can alert the driver or even take over control of the car to avoid the situation	The design may incorporate driver alters or take over control of the acr to avoid unsafe conditions.
The use of smart phones while driving is also a major safety concern.	The design must decrease the risk of danger through cell phone use.
Green: We're passionate about creating a world with zero emissions	If focusing on Green: the design should help drive emissions to zero.
Protecting the environment is also very important to the vehicles of the future.	The design can not increase the ecofootprint of the vehicle or its use.
Hybrid and electric vehicles are becoming more popular as an alternative to traditional cars.	The design may incorporate hybrid or electric vehicle technology.
There are also other alternative fuels being explored.	The design can allow for alternative fuel considerations.
However, by simply reducing the weight of avehicle or having products that make engines run smarter or more efficient can dramatically improve fuel economy.	The design should improve fuel economy by decreasing weight, or increasing fuel efficiency, or...
Connected: We have the technology to allow seamless connectivity in the vehicle—it's what consumers want, and we can make it a reality.	If focusing on Connected: The design should enable the user / vehicle to be more "connected".
The vehicle of the future should be optimally connected to maximize the driver's and passengers' experience while minimizing the driver's distraction.	The connected design should maximize the driving / riding experience while minimizing distractions.
Connecting the vehicle itself and all its sensors to the outside world should not be overlooked.	All systems inputs and outputs must be considered.
The vehicle of the future will have 100s of sensors collecting data which may be very beneficial to others.	The data collected from sensors is eaility interpreteted and available for anaylsis to meet the Connected (and Safe and Green) goals.
For example, if a car is doing 5-mph on a 65-mph interstate, an algorithm would determine a traffic jam was present and alert other approaching vehicles of the situation.	*case example*
The brakes could be applied for very close vehicles, or navigation systems could re-route approaching vehicles to avoid the congestion.	*case example*
Project entries in one (or more) of these three categories should first include background research into current technologies being deployed today.	The deliverbables will include appropriate background research.
The project team may then choose to modify an existing feature/function or create a new technology for enhancing the vehicle of the future.	The design may be new or a modification of a current technology as long as innovation or improvement is part of the design.
The scope of the project should include a systems diagram, an example of the user experience (i.e., a Concept of Operations), as well as the approximate cost of this new feature	Design will inlcude a systems diagram, ConOps, and cost analysis.

Concept Generation:

When deciding what consumer need to focus on, we invested time into testing our ideas to produce more confidence in the final results. First we were given customer statements with customer needs (shown above) and we had to evaluate what customers were looking for in today's vehicles. Ideas for these concepts were created by individual creativity and researching existing models and patented ideas. We later were given the Design Concept Refinement and Survey Preparation to narrow down all of our ideas to only three: 1) a car with motion body signal reader, 2) a carbon fiber cabin, and 3) a smaller and more efficient engine. The car with motion body signal reader would allow you to use turn signal with your hands, would read the position of your head and if looking away or down for too long of a time making your car go off the road the car will progressively slow down, and this design would be safe and connected. The carbon fiber cabin would make the car lighter, for better fuel efficiency, is a stronger material than steel, so it helps improve safety. The smaller and more efficient engine would be more expensive but would produce fewer emissions and be more fuel efficient. We then created a survey (Appendix 1) which was completed by sixty people (forty-five males and fifteen females). The survey presented each idea and asked people to rank the concepts they wanted to see in cars. The idea that was ranked highest was the more fuel efficient engine; therefore, our focus shifted to Delphi's megatrend goal for greener vehicles.

Concept Selection:

After deciding on a green and more fuel efficient engine for our design we created an Analytical Hierarchy Process (AHP) to prioritize our design objectives/features (see Figure 1). The seven engine features the team thought were most important were: simplicity, fuel efficient, green, cost effective, socially acceptable, longevity, and universal. The AHP defined the relative weights for these seven design features. Three engine ideas that were researched that could be more green were: 1) free valve system, 2) downsizing and turbocharging, and 3) direct injection engines. After applying scores (1-5 scale) to how each engine suited the project objectives and applying the AHP weight,the best design choice the Concept Selection Matrix (Figure 2) showed the free valve system engine.

	A	B	C	D	E	F	G	H	I
1		Simplicity	Fuel Efficient	Green	Cost Effective	Socially Acceptable	Longevity	Universal	
2	Simplicity	1	5	1	3	0.33	2	3	
3	Fuel Efficient	0.2	1	0.5	0.33	0.33	0.75	0.75	
4	Green	1	2	1	0.75	0.33	2	1	
5	Cost Effective	0.33	3	1	1	0.25	1	0.75	
6	Socially Acceptable	3	3	3	4	1	5	3	
7	Longevity	0.5	1.5	0.5	1	0.2	1	0.33	
8	Universal	0.33	1.5	1	1.5	0.33	3	1	
9	Total	6.36	17	8	11.58	2.77	14.75	9.83	Grand Total: 70.29
10	Weight	0.09	0.24	0.11	0.16	0.04	0.21	0.15	

Figure 3 (above): The Analytic Hierarchy Process helped prioritize our seven design features, and yielding the AHP weight for each feature.

	A	B	C	D	E
1		AHP Weight	Free Valve	Downsizing and Turbocharging	Direct Injection
2	Simple	0.09	3	5	4
3	Fuel Efficient	0.24	5	3	4
4	Green	0.11	5	5	3
5	Cost Effective	0.16	3	5	4
6	Socially Acceptable	0.04	4	2	4
7	Longevity	0.21	4	3	4
8	Universal	0.15	3	4	4
9	Total		27	27	27
10	Total (weighted)		3.95	3.83	3.74

Figure 4 (above): Using the AHP weights in the Design Selection Matrix, the Free Valve design was the "winner."

Final Description:

Based on surveys and selection matrices, a smaller and more efficient engine was decided as the winning concept. This idea is defined by a few key requirements defined by the team: the engine must be smaller than a standard engine, it must provide as much power as the engine it replaces, and it must be more fuel-efficient and therefore produce less CO_2 than the engine it replaces. To achieve these requirements, and engine currently in development by Koenigsegg was chosen. This engine is different from standard internal-combustion engines in that it is camshaftless. In a camshaftless engine, an air compressor and solenoids that open and close the valves replace the camshaft. These changes lead to a drastically smaller engine, reducing the size of the engine by about 50% and the weight by about 30%. The solenoids also achieve a perfect square wave, where the valve is either entirely open or entirely closed; this achievement is impossible with a camshaft. Finally, as each solenoid can be controlled independently, it is possible to run the engine on any number of its total cylinders.

Systems Diagram:

	A	B	C
1	**Inputs**	**Camshaftless Engine**	**Outputs**
2	Cargine Technology	Air valve syestem allows piston control	CO2 emmisions (less)
3	Fuel	Replaces camshaft with Cargine technology	

Figure 5: Inputs and Outputs for our Free Valve Engine

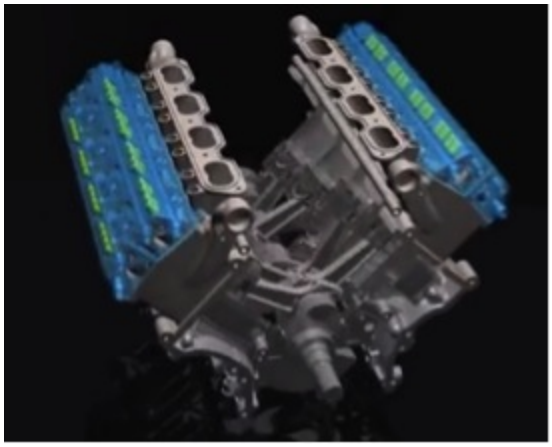

Figure 6 (Above): Image of a V8 engine with the pistons controlled by camshafts (*Free Valve*).

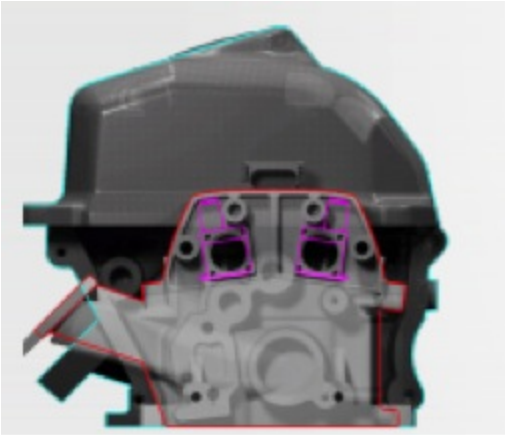

Figure 7 (Top Right):Image of a V8 engine with the camshafts replaced by the Cargine technology of the air valve system to allow independent control of pistons (*Free Valve*).

Figure 8 (Right): Image showing the 50% size reduction from regular engine to the camshaft engine which results in a 30% weight reduction. (*Free Valve*).

Scenarios:

Scenario 1

The car slows down at a stoplight, and as the brakes are applied, the air compressor sends air to only two cylinders, allowing the engine to idle at the stoplight using only two cylinders. When the accelerator is pressed again, the compressor then activates the rest of the cylinders as well, giving full torque upon acceleration.

Scenario 2

The car is driving on the highway, and the driver applies cruise control. If the engine has more than four cylinders, the compressor selects only four of those cylinders and uses those to maintain speed, as high torque is not required at constant speeds. When cruise control is deactivated, the compressor reactivates all cylinders.

Total Cost Analysis:

Step 1

The price of this engine is not easy to calculate specifically. Since it is not a new technology, and builds off of existing technology, the price is a rough estimation. In order to calculate the price roughly, the cost of parts is divided by 2.34. Then that number is added to the NRE cost per production. Finally, the QA labor cost is added. The cost of a traditional engine used the automotive industry today is around $6,000. The camshaftless engine comes in around $7,760.

Step 2

To further analyze the cost of this engine, adult drivers were surveyed. After surveying a small sample of ten adults ranging in ages 30-50, most adults were willing to pay for this new feature. Most subjects said they would pay $1,000-$2,000 more for this engine compared to a stock engine. This is perfect because the price of the new engine is around $1,800 more than the traditional engine. The reasoning behind the numbers was that the engine would eventually pay itself back by saving the user money on gas. Also, the costs of production may decrease over time as the engine becomes more popular.

Life Cycle Analysis:

When compared to the internal combustion engine, the camshaftless engine is significantly less harmful toward the environment. The camshaftless engine can credit its fuel efficiency to its air compression system, which replaces the big and heavy camshafts on the standard internal combustion with its new air compression system. By replacing the camshafts with an air compression system, the size of the internal combustion engine decreases by fifty percent, while its weight decreases by 30%. As a result of this reduction in size and weight, it has been verified that fuel consumption reduces by twelve to seventeen percent, when compared to a standard four cylinder two liter engine (*Freevalve*).

Cargine, the company created by Koenigsegg to research and explore the camshaftless technology, predicts that the camshaftless engine will eventually reduce fuel consumption by 25%, reduce harmful emissions by 50%, and reduce engine size by 25%, while increasing torque by 30%. When combined with pneumatic hybrid technologies, fuel consumption is reduced by 50%, harmful emissions are reduced by 60%, power and torque increases by 50 %, however the engine size remains the same (*Freevalve*).

What also makes the camshaftless engine greener toward the environment is the fact the engine idles at two cylinders, instead of four, when compared to the internal combustion engine. Thus, while waiting a light or stuck in traffic, less fuel is used and thus less CO_2 emissions are released into the environment. Also, the camshaftless engine can run on any number of cylinders at any given time, with a two cylinder minimum. This means that with an eight cylinder camshaftless engine, only four cylinders will be in use when going 100 kilometers (60 mile per hour), and all eight cylinder will be in use when going 150 kilometers (approximately 93 miles per hour). This means that when less power needs to be used, less fuel and CO_2 emissions will be released into the environment (*Freevalve*).

Because of its innovative and versatile ways, the camshaftless engine has much less of an impact on the environment over the course of its lifetime than the internal combustion engine.

Conclusion:

This project provided future engineers in the College of Engineering at Pennsylvania State University with a hands-on introduction to the engineering design process. Students taking this Engineering Design course had the opportunity to brainstorm design concepts, select the best design, prototype, and carry out a design to improve the future of the automotive industry. The students helped Delphi improve cars in one or more of the three goals to make cars green, safe, and connected.

For this group's design selection process, the group surveyed over fifty people ranging from teenagers to adults in their fifties. The final concept was selected because of its practicality and popularity. The camshaftless engine concept is already patented, and the technology all exists. The engine does not compromise safety and the likelihood of failure is no different than engines used currently. It's lightweight and ability to control the amount of cylinders makes this engine greener than any engine currently in the industry.

The engine may currently be more expensive, but as time goes on new ways to produce the engine will be used and the cost of the engine will decrease. The group decided that the higher cost would not be an issue because most of the surveyed adults were willing to pay more for the engine, knowing that they will save money gas with a more efficient engine and a lighter vehicle. After following the design process, the group decided that the camshaftless engine was the best concept and would greatly impact the automotive industry.

Appendices:

1. Survey

DELPHI Design Concept Survey:

Hello, my name is _____ and I am a prospective engineer in engineering design 100 and I would appreciate your time if i could ask you a few questions for a quick survey.

1. Gender: M/F
2. Age:____
3. Do you have a driver's license? Y/N
4. Do you own a car? Y/N

5. Do you have an accident history? Y/N

As first-year engineering students, we are working with DELPHI, a car technology company focusing on improving car safety, making cars more safe for

the environment, and making cars able to connect with other cars and their surroundings.

For our project we have had to create ideas that we thought would benefit DELPHI's goals to improve cars, and we would appreciate if you could rank our ideas in order of importance and usefulness. The information gathered could help to improve cars of the future.

Our three ideas are:

1) Car with body motion signal reader
   a. use turn signals with hands
   b. if your head goes too much off road will progressively slow down car
   c. safe and connected
2) Carbon Fiber cabin
   a. its lighter which helps out gas efficiency
   b. stronger so can help safety
3) Smaller and more efficient engine
   a. for a slightly higher price, the engine would produce fewer emissions
   b. engine would also be more fuel efficient
   c. it would not lose any power

Do you think any of these ideas could be improved?

Do you have any ideas that you feel could improve cars or you find necessary for later cars?

Thank you for your time and have a great day.

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