FAMU/FSU College of Engineering

EML 4551/4552
SENIOR DESIGN 2003

TEAM #3

6 February 2003

PROPOSAL FOR SPONSORSHIP

Design Team
Blunt, Michelle
Brinson, Thomas
Coldwell, Brian
English, Ned

February 6, 2003

Mini Baja Powertrain Design Team
409 Midflow St.
Tallahassee, FL 32304

To Whom It May Concern:

Every year the Society of Automotive Engineers (SAE) host collegiate Mini-Baja design competitions all around the world. Student representatives from various colleges with SAE chapters compete their vehicles to gain recognition, experience with working in a team, and to form networking groups. This is the first year of participation for our school (FAMU/FSU College of Engineering) in the Mini Baja competition.

Our senior design team project is to design and construct the powertrain system for a small ATV (all-terrain vehicle) that will be taken to the SAE competition in Orlando, FL (April 4-6, 2003). To level the playing field, all teams competing will use a Briggs and Stratton 10 hp engine, and are not allowed to "fix up" the engines. The competition will include events that test acceleration, speed, towing capacity, land and water maneuverability. The size of the vehicle is restricted to be 8 ft. long and 5 ft. wide.

Our powertrain system design uses a torque converter that functions as a continuously variable transmission (CVT), working in conjunction with a gearbox to transmit torque to a driveline consisting of a chain and sprockets. The vehicle is expected to utilize its 10 hp engine and reach a maximum velocity of 48 mph with the capability of pulling 7250 lbs.

This project is for our senior design class; however, adding to its significance is the fact that it is the start of future ongoing projects in which students will try to improve upon our initial design. We firmly believe this project will strike an interest and encourage students in the field of engineering. We hope you will consider supporting our senior design project. **Upon receipt of funds, sponsors will receive a form from the SAE Club for tax purposes, because contributions are tax deductible**. If you are interested in supporting the team, or have any questions, contact us at minibajapowertrain@engineer.com or team member Thomas Brinson at 850-574-5915. Thanks for your support.

Sincerely,

Thomas Brinson, Michelle Blunt, Brian Coldwell, and Ned English
The Mini Baja® Powertrain Design Team

TABLE OF CONTENTS

EXECUTIVE SUMMARY

The FAMU-FSU Chapter of the Society of Automotive Engineers (SAE) accepts the challenge presented for over 25 years by the annual SAE Mini Baja® Collegiate Design Series competition. The challenge is for students to manage their time, resources, and curriculum throughout school semesters while designing and constructing the optimal All-Terrain Vehicle (ATV).

Proper time and resource management has helped to fully design the Mini Baja® Powertrain, which is ready for construction. The powertrain meets or exceeds all specifications governed by the local SAE club and the 2003 competition rules, including a maximum speed of 45 mph and a towing capacity of 7250 lbs. These specifications are met using a continuously variable transmission (CVT) and a high-low gearbox with a limited-slip differential. The primary difficulty encountered is managing the absent financial resource. Consistent with average Mini Baja® competition vehicle costs, the estimated total expense to build the powertrain is **$1070.84**, just over 35% of the overall **$3000** expense to build the entire Mini Baja®. Thus, the student-governed SAE club relies heavily on corporate sponsorship and local donations to subsidize the expenses incurred in building both this Mini Baja® and the SAE Formula Race Car. Such generous charity is the lifeblood of this organization.

The powertrain designed by the FAMU-FSU College of Engineering will help lead to a victory in the annual SAE competition in Orlando, Florida in April 2003. The semester involves purchasing components, assembly and construction, and testing for the rigorous operating conditions at the competition. The powertrain is designed specifically for off-road operation, efficiently transmitting power from the engine to the rear wheels, and the SAE club is confident in its performance. SAE collegiate design programs prepare students for industrial project management and design. As such, your sponsorship in our program is much appreciated and will prove to be a worthwhile investment not only to this club and competition, but also to your organization and the automotive industry.

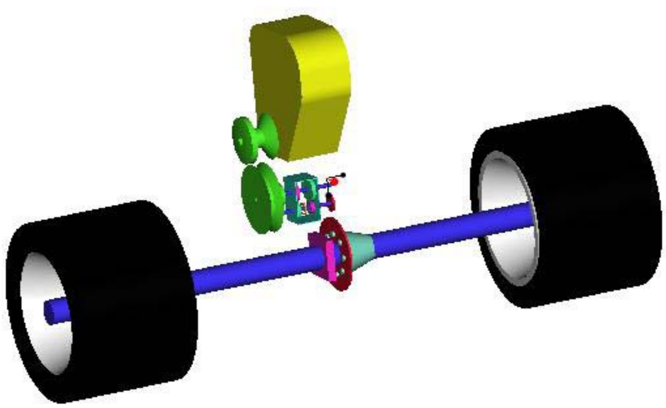

Figure 1: SAE Mini Baja® Powertrain.

1 INTRODUCTION

The SAE Mini Baja® competition originated at the University of South Carolina in 1976 and has expanded into 3 annual regional competitions – East, Midwest, and West – as well as several international competitions. The FAMU-FSU chapter of SAE – advised by Dr. Patrick Hollis, Dr. Chiang Shih and President Patrick Middleton – will participate in the Mini Baja® East competition (for the first time) in April 2003 in Orlando, Florida. The objective of the competition, as stated by SAE, is for university students to function as a team to design, build, test and promote a vehicle while competing within the limits of the rules in addition to generating financial support for their project and managing their educational priorities. The vehicle will be a rugged, single seat, off-road recreational vehicle intended for affordable sale to the non-professional weekend off-road enthusiast. The vehicle must be safe, easily transported, easily maintained and fun to drive. It should be able to negotiate rough terrain without damage. The complete rules and details of the competition may be found on the SAE website located at:
http://www.sae.org/students/mbrules.pdf.

The goal is to transmit maximum power from a Briggs & Stratton 10 hp engine and perform the best at the competition in April. Several components have been selected to optimize the design, some are stock components and some will be fabricated in the on-campus machine shop. This proposal first justifies each component of the powertrain system and explains the anticipated response of the vehicle. Next, managerial information is explained, including the spring schedule. The most vital element of this proposal involves the cost report, which outlines the expenses of each component within the powertrain design.

Once the SAE Club receives sufficient financial assistance, the powertrain components will be purchased and assembled. Simultaneously, the chassis and other subsystems will be constructed. Next, the subsystems will be integrated for a final product, which will then compete in April.

2 TECHNICAL DATA

2.1 The Engine's Power Curve

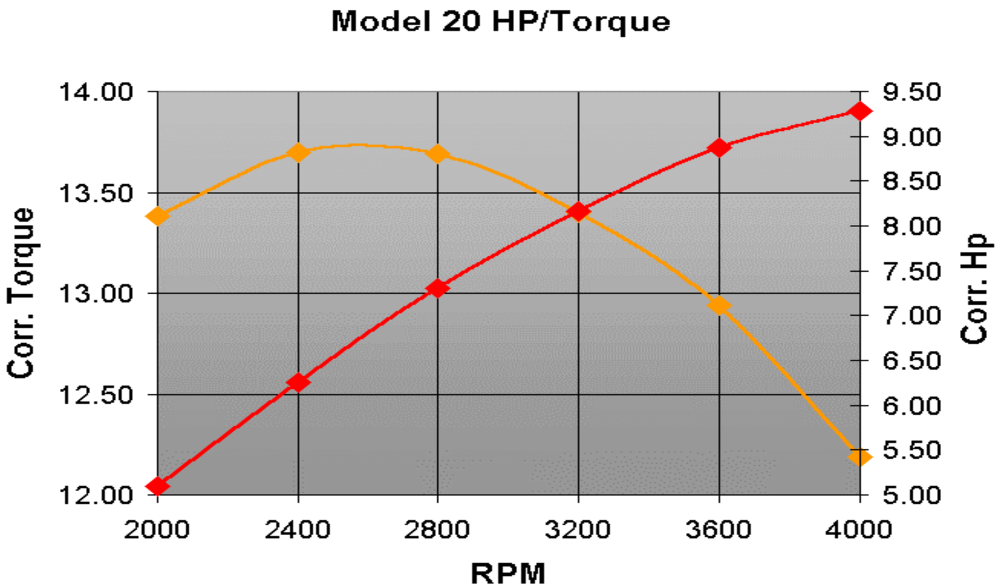

Figure 2-1: Power curve for Briggs and Stratton Intek engine model 205400 (10 hp). www.briggsandstratton.com

During SAE competition, a governor will be placed on the engine, restricting its revolutions per minute to 3600; therefore, any information depicted in Figure 3-1 that is beyond 3600 rpm is considered irrelevant for our design purposes. According to Figure 3-1, the peak (maximum) torque is approximately 13.7 ft*lbs at 2600 rpm, while the peak horsepower is about 8.9 hp at 3600 rpm. Over the rpm range from peak torque to peak horsepower, the torque decreases by 5% and the power increases by 25%; therefore, the optimum available operating engine speed is 3600 rpm. The powertrain is designed so that the torque converter will first engage the engine at 2000 rpm. The maximum torque will be utilized by opening the throttle until 2600 rpm is reached. The maximum power will be utilized by opening the throttle all the way until maximum rpm is reached. The torque converter is rated well beyond 3600 rpm for up to 25 hp as a factor of safety.

2.2 Acceleration

The Mini Baja® vehicle will constantly change velocity as it navigates the rough off-road terrain; therefore, the acceleration of the vehicle is very important. The acceleration is key to maintaining a high average velocity throughout the competition. Further, one of the competition events directly measures the acceleration by timing the vehicle to travel 100 feet from rest. Since the exact rate at which the torque converter switches ratios is unknown, calculating the acceleration of the vehicle proved to be a rough, yet reasonable estimate.

The team assumed that the vehicle would be traveling at constant acceleration at the low and high ends of the torque converter. Obviously this is not the case for the ranges in between, but for the low and high ratio limits of the torque converter, the team assumed constant acceleration. This assumption is validated because at the low end of the torque converter, the vehicle cannot travel any slower and at the high end of the torque converter the vehicle cannot travel any faster. After assuming constant acceleration at each extreme of the torque converter, the acceleration values were calculated for at these extremes for both low and high gear. These values were then averaged to obtain an average acceleration of the Mini Baja® car. The acceleration values are listed in Tables 2.2.1-2.2.2.

Table 2.2.1 – Vehicle acceleration values (m/s^2) of the low and high gear

	LOW END OF CVT	HIGH END OF CVT	AVERAGE
LOW GEAR	*4.766*	*1.393*	*3.079*
HIGH GEAR	*2.459*	*0.624*	*1.542*

Table 2.2.2 – Average overall vehicle acceleration (m/s^2)

	AVERAGE
Overall Vehicle Acceleration	*2.31*

According to the above tables, the acceleration average is higher for the vehicle while it is in low gear. From this calculation, the team concludes that it would be best if the vehicle could switch from low to high gear while driving. The driver of the vehicle should be able to start out in low gear and take advantage of the high acceleration. Once the maximum velocity of the low gear is obtained, the vehicle would no longer accelerate in that gear, so the driver would then switch to high gear and continue accelerating. To avoid grinding the gears into place, a synchronizer is needed to shift the gears while the vehicle is in motion. The team would not be able to manufacture a synchronizer because of the complicated and precision parts that are associated with it; however, a used motorcycle transmission will provide the gears, shafts, and synchronizers; while the gearbox will be manufactured at the on-campus machine shop. The high gear ratio will be 1.25:1 (however, in overdrive so .8:1), and the low gear ratio will be 1.47:1.

2.3 Velocity

Now that the acceleration of the vehicle is known (see Table 2.2.2), the velocity of the vehicle can be calculated. Listed in Table 2.3.1 are the velocity values of the car as a function of time.

Table 2.3.1 – Velocity of vehicle as time progresses

TIME (sec)	VELOCITY (mph)
1	5.168
2	10.335
3	15.503
4	20.67
5	25.838
6	31.005
7	36.173
8	41.341
9	46.508
10	51.676

Maximum velocity of the vehicle will be reached in about 9 seconds. Theoretically, the maximum velocity of the vehicle will be about 48 mph; slightly greater than the 45 mph.

2.4 Distance

The acceleration of the vehicle listed in Table 2.2.2, was very useful when solving for the amount of distance traveled by the vehicle as a function of time. The values for the amount of distance traveled by the vehicle are listed in Table 2.4.1.

Table 2.4.1 – Distance traveled by the vehicle as time progresses

TIME (sec)	DISTANCE (ft)
1	3.79
2	15.158
3	34.106
4	60.633
5	94.739
6	136.424

In the acceleration test at competition, the vehicle is expected to reach 100 feet in a little over 5 seconds. This is acceptable given the restricted engine.

2.5 Components

To meet the engineering specifications, several components comprise the FAMU-FSU SAE Mini Baja® powertrain. These components include:

- Briggs and Stratton Intek Model 205432 10 hp engine
- Comet-OEM 40 Series torque converter
- High-low gears with synchronizers
- Custom manufactured gearbox
- #41 Drive Chain
- Comet-OEM SCD-1 Limited-Slip Self-Differential Kit
- Heavy-Duty 12- and 72-tooth sprockets

See the Cost Analysis section for a detailed description of all components.

3 COST ANALYSIS

3.1 Component Breakdown

SAE rules state that the vehicle manufacturing cost must be less than $3000 (material and labor cost). Overhead and tooling are factored into this estimate. The following estimates were found at http://www.kartworld.com. This section outlines the cost of each component. For more information please refer to section 4.2, Total Cost, or Appendix C for a tabulated cost analysis. Note that this cost analysis is approximated before construction of the powertrain. Estimates are subject to change.

3.1.1 Engine

Briggs and Stratton Corporation will provide the 10 horsepower engine used in the competition. Briggs and Stratton has generously provided the new engines for the Mini Baja Teams without charge. Teams only pay $150 for shipping and handling of the 10 hp OHV Intek Model 205432 required engine. The engine contains a 3.120-inch bore and one-inch crankshaft. MSRP: $628.00; OEM price is $350.00.

3.1.2 Torque Converter

The 40 Series Torque Converter System is well designed for our 3600 rpm, 10 hp engine; the mechanical advantage of this system ranges from 3:1 to 1:1. The Torque Converter system consists of a drive clutch, driven clutch, jackshaft kit, and a drivebelt. This system transmits sufficient torque to tow another vehicle or climb hills at its low end, while smoothly exchanging that torque to meet the maximum velocity spec at its high end. The drive clutch connects to our one-inch diameter engine crankshaft, which comes in a 1" bore. The model 40 series uses a 7/8" top width symmetric belt where the driven clutch is mounted with the spring side inboard. The belt running on both clutches goes to the driven clutch.

The driven clutch connects to the jackshaft, and comes in a 5/8" bore and a 3/4" bore. These driven clutches also come in 7-1/2" and 8-1/2" diameter. The 8-1/2" driven clutch will give you more low speed power. The driven clutch and the drive sprocket will be mounted on the jackshaft where a 40 series belt will be attached. The drive clutch costs $130, the driven clutch costs $124.50 costs the drive belt costs $27.35, and the jackshaft costs $27.95; the total system costs $309.80.

3.1.3 Chains

Depending on the distance from the engine to the rear sprocket and sprocket sizes, chains on a go-kart are usually between 3 and 4 feet. Three feet was approximated, but four feet will be purchased at $1.95 per foot as backup. The differential, discussed later, requires a #41 chain size. A connecting link, sometimes called a master link, will be provided connecting the two ends of a chain together ($1.39). A chain breaker will also be provided to drive the pins completely out of the chain link requiring no additional tools. This handy device breaks chains by simply snugging the inner barrel of the chain breaker against the chain link and screwing in the center pin.

PJ1 chain lube will be used to lubricate the chains ($9.35). Ideal for on and off road use, the chain lube will reduce wear and friction in the chain. Motor oil was considered, however it tends to fly off and does not properly lubricate the chain.
The chain lubricant clings to chain and does not make a mess as motor oil does. Chain lube was also found to increase use between adjustments. The connecting link, chain breaker, and chain lube are all listed under "Miscellaneous" in the Cost Analysis table. The total chain cost is $23.49.

3.1.4 Differential

One of the most difficult components of a powertrain to manufacture is the differential. Because of this the Comet SCD-1 Self-Differential kit will be purchased containing what is needed to build the differential. The differential includes the differential housing half with bearing, 16 tooth bevel gear, retaining ring, 10 tooth bevel gear kit, pinion shaft, nut & bolt kit, 5/16-18 x 1-1/2 Hex Head bolt, grease pack, and sealant. Differential unit installation requires two axle shafts with two bearings and one brake on each shaft, which are not included.

This kit uses high strength aluminum alloy housings tapered in design to give added strength to the unit. The steel-cut pinion gears and straight beveled gears are combined with bearings that are self-lubricating. The SCD-1 is designed for applications where conventional differential action is required. Axle size and sprocket are not included in the differential unit kit. $149.00

3.1.5 Sprockets

For a live 1" axle the #41 chain was used for both the 72-tooth and the 12-tooth sprockets. Other sprockets were found/discovered for #41 chains with 72 teeth, but they were more expensive. AZT 5314 for the Deluxe Aluminum sprocket and AZT 5314 Heavy-Duty Sprocket both cost $49.75 compared to $46.35 of the Comet SCD-1 72-tooth sprocket.

The 12-tooth "B" type sprocket will be used containing a hub on one side and keyway of 3/16 inches with a 5/8-inch bore costing $7.80 excluding the machined keys. An additional $50 will be added for the hardware we do not already have.

3.2 Total Cost

The materials required to build the Mini Baja® powertrain will be funded by the FAMU-FSU Chapter of SAE. The total dollar amount actually paid by the FAMU-FSU Chapter of SAE for the Mini Baja powertrain is estimated as **$1070.84**. This cost includes the materials that must be purchased, with a ten percent window added for unexpected supplies. The total cost to build a single Mini Baja® vehicle is estimated at **$3000**. This cost includes overhead, labor, and materials. If support cannot be provided for the entire vehicle, it is our hope that there will be enough for the powertrain system.

4 CONCLUSION

The FAMU-FSU Chapter of SAE has designed the powertrain for its inaugural Mini Baja® vehicle. The club proposes to construct the powertrain and the remainder of the vehicle early in the spring semester in order to compete in the April 2003 Mini Baja® East competition in Orlando, Florida.

Myriad powertrain options have been thoroughly researched to arrive at the optimum design presented here. With this powertrain, the Mini Baja® vehicle is expected to reach a maximum velocity of 48 mph and pull a payload up to 7250 lbs. The total dollar amount for the powertrain is anticipated at **$1070.84**, while the entire vehicle cost is estimated to be **$3000** (including powertrain cost). Thus, pending corporate financial sponsorship, the powertrain components will be purchased, modified, assembled, and tested, giving the team the practical experience of engineering design and construction. Once integrated into the Mini Baja® vehicle, the powertrain will lead the FAMU-FSU College of Engineering to an outstanding performance at competition.

The powertrain must satisfy the engineering specifications and all customer desires. Further, this subsystem must fully integrate with all other vehicle systems for a final Mini Baja® vehicle. To ensure such, fluid communication was maintained with all customers by means of weekly meetings. Several parties interacted with the design team in this process:

> FAMU-FSU Chapter of SAE
> Patrick Middleton – Local SAE chapter Mini Baja® President
> Dr. Patrick Hollis – Faculty Advisor; hollis@eng.fsu.edu
> Dr. Cesar Luongo – Senior Design Course Instructor; luongo@magnet.fsu.edu

The above design team and above key personnel may be contacted at the FAMU-FSU Mini Baja® powertrain email address, minibajapowertrain@engineer.com.

Now that the calculations and computer analysis details have been discussed, compared, and finalized, ordering is the next step on our agenda. At this point, SAE has not procured sufficient funding for the project. The procurement time of the funding and vehicle manufacturing will be the driving force for the spring. The powertrain will be the final component added to the assembly of the vehicle once the chassis and suspension have been assembled. Once all systems of the vehicle have been built, testing will commence on the vehicle from that point until the competition in early April. In the event that funding is limited, only the powertrain system will be constructed, mounted, and tested.

5 Appendix A - Cost Analysis; Mini-Baja Powertrain

COMPONENTS	SUBSIDARIES	SPECIFICATIONS	COST (avg)
ENGINE		Briggs & Stratton 10 Hp OHV Intek Model 205432 engine	*$130* for SAE Teams / $350 retail
CVT (Torque Converter)		Torque Ratio (1:1), 1" diameter Crankshaft	
	Drive Clutch		*$130*
	Driven Clutch		*$124.50*
	Drive Belt		*$27.35*
	Jackshaft		*$27.95*
Gearbox		High/low/reverse	*$275.00 est.*
Chain		#41; $1.95/ft	*$7.80(4 feet)*
Sprocket			
	12-tooth	#41 chain	*$7.80*
	72-tooth	#41 chain	*$46.35*
Differential			*$149.00*
Miscellaneous	Live axle hub for 8" ATV wheels		*$12.95*
	Mounting hub lug nuts (4 required)		*$0.85*
	17 oz. chain lube		*$9.35*
	Chain Breaker		*$17.95*
	Spare Center Pins (pack of 5)		*$4.95/pack*
	Chain Connecting link		*$1.39*
	Machined Keys	3/16" x 3/16" x 3/4"	*$0.30*
		Subtotal	**$973.49**
		10% addition for Tax and unexpected expenses	**$97.45**
		Total (with 10% window)	**$1070.84**

6 Appendix B - Cost Analysis; Mini-Baja Vehicle

Projected 2003 Mini Baja Budget

COMPONENTS	DETAILS	COST BREAKDOWN
Drivetrain	Actual powertrain (without engine)	$940.84
Chassis Material		$300.00
Tires		$400.00
Shocks and Steering Components	Includes linkages, cables, etc.	$500.00
Brake System		$400.00
Safety Equipment	Includes seal, restraints, suits, fire extinguishers	$450.00
Cost of car		**$2,990.84**
Registration Fees	Competition Registration and Engine Fee	$300.00
TOTAL		**$3,290.84**

Estimated total Mini Baja Competition Cost……………………………………**$3,290.84**