Alternative Motorboat Propulsion System

Project 3516

FINAL REPORT

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Introduction

The Grand Canyon River Outfitters Association (GCROA) is the association of all the companies that provide public motorized rafting tours of the Colorado River in the Grand Canyon. In 2007, GCROA signed a ten year contract extension with the National Parks Department which allows the companies to operate in the Grand Canyon. GCROA proposed, to the National Parks Department, research in alternatives to fossil fuel. The research and conversion of their rafts eventually became part of the contract. Over the ten year contract GCROA has agreed to spend up to one million dollars in non-fossil fuel research and raft conversion. To support GCROA's initiative to become more environmentally friendly, the National Parks agreed to match GCROA's spending on alternative fuels development.

Of the 16 companies that make up the GCROA, only Colorado River Discovery (CRD) has concessions from the National Park Service to give commercial tours of Glen Canyon as well as the Grand Canyon. To give these tours, CRD has created a unique raft that is made up of inflatable military pontoons that are attached to the sides of a steel frame, with a 135-hp Honda BF135 Marine Outboard to propel the raft. The tour starts at the Glen Canyon Dam and ends 15 miles downstream at Lee's Ferry. There are two tours a day: the first is at 7 AM and the second at 1 PM. During the tour, the CRD guide talks about the local history and wildlife, and answers the passengers' questions. The raft drifts downstream with the river current for most of the tour. It would take at least 6 hours to float downstream, so the guide occasionally uses the motor, at low speeds and short intervals, to make it to Lee's Ferry in 4 hours. This also allows the guides to maneuver around obstacles and stay in the current. After the passengers are dropped off, the guide drives the raft back upstream to Glen Canyon Dam. The upstream trip is made in 1 hour or less. When the raft returns it refuels and then leaves for the second trip downstream. At the end of the day all the boats are taken back upstream again and moored at CRD's dock at the bottom of Glen Canyon Dam.

Since CRD signed the contract to eliminate fossil fuels from their operations in the Grand Canyon, they need a new design. Their first priority is to eliminate fossil fuels. Although not contractually required for the Glen Canyon, their need to do this for their Grand Canyon trips leads them to need the same for their Glen Canyon trips in order to do keep one type of fuel. Secondly, they need to have enough power to travel upstream in under and hour. If the new system can not get the boats back in time, they will be unable to run two trips daily, which would greatly reduce their profits. Third, the new design needs to maintain the positive aspects of their current system, meaning it needs to be as durable and reliable as the current one. CRD does not want to have to worry about the system not functioning or about a little abuse causing the system to fail. Lastly, the new design aspect is a quiet running system, so the tour guide can hear the tourists. The quiet operation is only necessary for the downstream portion of the trip, because the passengers are only there during this portion. CRD wants power, durability, reliability, no fossil fuels, and quiet operation, while still being able to whole fit the design in the open spaces of the existing rafts.

Technical Specification

In order to determine what part of the customer needs were most important to the system, the QFD matrix below helped us arrive at the conclusion that we most needed to focus on how we propel the raft downstream, in order to maintain a four hour trip and reduce noise.

QFD Matrix:

Voice of Customer	Customer Importance	Downstream Speed (mph)	Upstream Speed (mph)	Noise Level (dBA)	Gas Consumed (gallons)
		Critical to Quality			
Propel Raft Downstream	5	●			
Propel Raft Upstream	5		●		
Reduce Noise	4	○		●	
Reduce Gas Consumption	5	○	○		●
Absolute Importance		72	60	36	45
Relative Importance		33.8	28....	16.9	21....

In order to satisfy these requirements, the main functional requirements simplify down to reducing noise on the downstream segment and moving the raft back upstream within an hour. To complement these functional requirements are the constraints that there are to be no fossil fuels used, the noise downstream should be below 65 dBA, the raft's structure cannot be extensively modified, and the system needs comparable durability and reliability with the current one.

We are proposing a solution that features a dual system, sometimes referred to as a 'hybrid' design. This is not to be confused with the system in a hybrid car, where both an internal combustion engine and electric motor can power the drive shaft simultaneously. Instead, it features both an electric motor and an internal combustion engine based on ethanol to accomplish the needed requirements. The design matrix below shows how this breaks down, as will be elaborated on further on. As is seen, the Design Matrix is inherently uncoupled.

Design Matrix:

	DP0:	DP1: Electric motor	DP1.1: Batteries	DP1.1.1: Honda quiet generator	DP1.1.1.1: Compartment with quiet board	DP1.1.1.2: Ethanol	DP1.1.1.2.1: Same process as for outboard	DP1.1.1.3: Rectifier	DP1.1.2: Seat compartments mounts	DP1.1.2.1: Sliding cabinet	DP1.1.2.2: Rubber seals	DP1.1.3: Sealant	DP1.2: Mounts directly on existing motor	DP1.3: Standard steering with existing assembly	DP1.4: Sealed connetors	DP2: Ethanol conversion	DP2.1: Multiple small tanks	DP2.2: Custom circuit board	DP2.2.1: Analyze board	DP2.2.2: SPICE	DP2.3: Large tank at HQ
FR0:	X																				
FR1: Reduce Noise		X														O	O	O	O	O	O
FR1.1: Power motor			X										O	O	O	O	O	O	O	O	O
FR1.1.1: Recharge batteries				X					O	O	O	O	O	O	O	O	O	O	O	O	O
FR1.1.1.1: Silence generator					X	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O
FR1.1.1.2: Fuel generator					O	X		O	O	O	O	O	O	O	O	O	O	O	O	O	O
FR1.1.1.2.1: Convert motor for ethanol					O		X	O	O	O	O	O	O	O	O	O	O	O	O	O	O
FR1.1.1.3: Convert power					O	O	O	X	O	O	O	O	O	O	O	O	O	O	O	O	O
FR1.1.2: Mount batteries				O	O	O	O	O	X			O	O	O	O	O	O	O	O	O	O
FR1.1.2.1: Allow battery access				O	O	O	O	O		X	O	O	O	O	O	O	O	O	O	O	O
FR1.1.2.2: Seal compartment from water				O	O	O	O	O		O	X	O	O	O	O	O	O	O	O	O	O
FR1.1.3: Seal battery connection				O	O	O	O	O	O	O	O	X	O	O	O	O	O	O	O	O	O
FR1.2: Mount motor			O	O	O	O	O	O	O	O	O	O	X	O	O	O	O	O	O	O	O
FR1.3: Steer motor			O	O	O	O	O	O	O	O	O	O	O	X	O	O	O	O	O	O	O
FR1.4: Insulate connections			O	O	O	O	O	O	O	O	O	O	O	O	X	O	O	O	O	O	O
FR2: Travel upstream in 1 hour		O	O	O	O	O	O	O	O	O	O	O	O	O	O	X					
FR2.1: Store fuel		O	O	O	O	O	O	O	O	O	O	O	O	O	O		X	O	O	O	O
FR2.2: Modify Carbueretor		O	O	O	O	O	O	O	O	O	O	O	O	O	O		O	X			O
FR2.2.1: Determine control interface		O	O	O	O	O	O	O	O	O	O	O	O	O	O		O		X	O	O
FR2.2.2: Design ethanol control board		O	O	O	O	O	O	O	O	O	O	O	O	O	O		O		O	X	O
FR2.3: Refuel tanks		O	O	O	O	O	O	O	O	O	O	O	O	O	O		O	O	O	O	X

While the electrical system is more complicated in its requirements, the ethanol system may be the most work. The current fuel system on the boat involves three four-gallon gas canisters with a fuel line connecting them all to the motor. The new system would involve similar containers and lines, but compatible with ethanol, and going both to the main motor and the generator supplementing the batteries. One of the large advantages of this is that ethanol, though somewhat less powerful than gasoline, is entirely water soluble, which means that water in the fuel does not cause a major problem, and that an accidental spill will not endanger the environment.

However, the modification of the fuel to air ratio inside the motor may be much more complicated than the electrical system. As Honda's web site specifies, their motor "utilizes a Linear Air-Fuel Sensor, along with the Engine Command Module, to automatically adjust the air-fuel mix according to speed and load - maximizing power throughout the RPM range and providing twenty percent greater fuel economy in the cruise mode from 2000 to 4500 RPM." What this boils down to is unlike simply modifying a carburetor valve, a new control board would have to me made based on the old one, but optimized for ethanol. As the Honda quiet generator has a similar board, the research required would easily go beyond the scope of this project. However, if Honda is willing to participate, then it could become possible to purchase the motor and generator OEM in the future. As such the conversion to an ethanol system may not be entirely feasible for this project. However, if the concept can be proved on a smaller scale, then Honda is much more likely to be convinced this is a good investment.

Top-level Design

The current pontoon contains a 135 Honda motor that propelled the pontoon. To solve the problem of reducing noise an electrical motor will be purchased with three batteries plus a battery charger. To recharge the batteries on the pontoon a silent (Honda) generator will be purchased. The generator, batteries, plus battery charger will be stored in a storage box that needs to be constructed on the pontoon for it to be stored away from view. This storage box is constructed with sound board plus sound foam inside to further reduce noise, with tubes running for air input and exhaust output to and from the generator. The electrical motor will be mounted on the original 135 Honda motor.

Subsystem/Sub-assembly Design (Hardware)

For this part of the design we searched for commercial electric motors that would drive three ton 25 foot raft. Due to the small quantity of boats to be modified it would not be very cost effective smart to design a custom electric motor to do the task. Searching the internet for possible choices and yielded three possible solutions:

1. A German company Torquedo makes a model named Cruse that is equivalent to a 6 HP gas motor and is an outboard. It looked like a nice unit but was expensive at $2500.
2. A second unit made by Navigator that attaches to the present outboard. The cost was decent, ranging from $800 to $1500, but more information and specifics were difficult to find, leading to its dismissal.
3. We found a company Minn-Kota that builds many electric drive trolling motors. The prices ranged from $800 to $1500 depending on the model and the company appeared sound, with a lot of information on the different models easily available on their web site.

As the space in the rear of the boat is limited, the optimal solution was to select a motor that could be attached to the current outboard. This also allows the guide to steer either motor with the same hydraulic steering column, which is already installed on the boat. Both Minn Kota and Navigator made such motors, with similar prices. However, due to the scarcity of details on the Navigator motors, Minn Kota was selected. More detailed analysis is as follows:

If space permits, a second outboard electric trolling motor with batteries will be added. A Trolling motor would supply 100-150 lbs of thrust and would use 25A/hr at 24VDC or 25*8=200A-hr/day. For a 12C lead-gel battery with a capacity of 200Ah this would require at least 2 batteries. The Torqeedo Cruise supplies 121 lbs of thrust at 83 amps, uses 24 volt and weighs 40lbs. They state that it is the equivalent of a 6 HP gas unit. They have a graph that shows that the Cruise can propel a 6000 lb boat 35 km at 3 knots and 70 km at 2 knots using 2 -12 V-200 Ah lead-acid batteries. This boat range and speed is close to our needs. They also make battery cables, battery extension cables, external speed controllers, and batteries. The 24 V batteries they make is a lithium-manganese type that has a higher energy density than lead acid which will reduce the weight and size which is important in our use. The problem with this is the expense - 2200 British pounds each, compared to a gel cell deep cycle battery at $200-$400 each. They recommend for the distance above that two 12V lead-gel batteries be used. If this method will work, using the Torqeedo Cruise motor and the lead-gel battery, it would be a good solution since all of the items could be purchased and the final long term boat modifications could happen very soon. It would eliminate the downstream gas consumption used by the present Honda motor. This motor generates 121/(24*83)=.061 lbs/Watt. While this is a good motor, it is very expensive, and it will have to be mounted separate of the existing outboard, which brings the question of space.

A second method would be to use a Navigator trolling motor that attaches to the present Honda motor. They come in a one motor design that generates 55 lbs of thrust at 24 amps, a two motor that generates 110 lbs of thrust at 48 amps and a three motor that generates 165 lbs of thrust at 72 amps. have not found much information for this system on the internet other than the price. have seen some negative feedback from people who say they have had problems with these units. have no idea how reliable these reports are. have been unable to find a link to the manufacture.

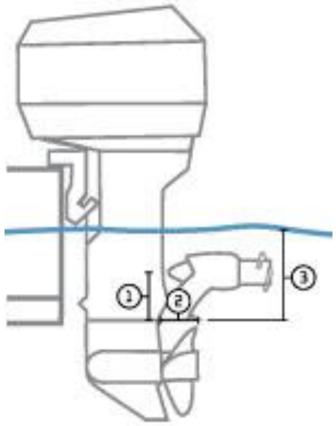
The third choose was another engine mount motor made by Minn Kota. It comes in models the following models:

Model	Volts	Thrust	Shaft Lengths
MK202/EM	36	202	—
MK160/EM	24	160	—
MK101/EM	36	101	—
MK80/EM	24	80	—
MK55/EM	12	55	—

From a dealer, the following prices were listed:

Dual motor	202 lbs thrust	36V/98A	$1450
Dual motor	160 lbs thrust	24V/116A	$950
Single motor	101 lbs thrust	36V/49A	$850
Single motor	80 lbs thrust	24V/58A	$750
Single motor	55 lbs thrust	12V/50A	$550

Because they are mounted on the Honda motor the steering would be the same as the Honda and would be semi-protected from damage by the Honda. This system will not interfere with boat or motor performance, and does not require stowing or deploying. These motors are not likely to be damaged because mounting on the cavitation plate places the motor higher and further back than the main outboard propeller (see below). The 36V dual motor is the best choice, as the rafts are somewhat larger than the average fishing vessel.



The next step is to determine how much thrust is needed to drive the boat downstream. This will be tested during the next site visit using a towing boat and a spring scale to tow a second boat and measure the force required at various speeds. Once this data is known, the current and total battery capacity can be calculated necessary to complete both daily trips can be calculated.

The next part of the system is the batteries. The batteries for this are similar in technology but not the same as a normal car battery. A deep cycle battery is designed to discharge as much as 80% before being recharged. A car battery is typically a starter battery, and is designed with thin porous plates to maximize surface area for the chemical reaction and produce a much greater current. However, if these are discharged more than 5% before being recharged, the material can dissolve and fall apart. The typical car battery would fail after roughly 25 cycles if discharged 80% and recharged.
A gel cell battery is designed with lead gel, and requires no water to be added during it lifespan. As these are the only batteries of this type that will not leak dangerous chemicals when tipped over, it is the obvious choice over other types of lead acid batteries. Batteries of this type are manufactured by many different companies, but for the capacity necessary, they cost roughly $400 each.

The next part of the system is the generator. This serves two purposes – two supplement the batteries and recharge them. As liberal power estimations conclude that to travel with only battery power would require ten or more batteries, weighing upwards of 500 lbs, and being quite expensive, it becomes necessary to supplement the power of the batteries with another source. Honda makes a generator that is tested to produce only 59dBA at full load. As the Minn Kota motor package already comes with a charger intended for 115V AC, this will not require any more additional hardware. In order to keep the batteries accessible but shielded from water, they will be stored in the same type of cabinet as the generator, on a sliding shelf. This will allow them to be serviced or replaced when necessary, and still shielded from water to avoid shocks.

To summarize the key points for each main component:

MOTOR SYSTEM (shown in blue)

- We chose a Minn-Kota electric motor that mounts on the present Honda 135 HP motor so that steering the boat would be done from the same position if either gas or electric drive.

- The motor system consists of a motor, electronics box and a speed controller and are purchased as a unit. This assures that motor and electronics is correctly matched.
- The motor is a 36VDC motor that's speed is controlled by controlling the duty cycle of the signal to the motor. Thus for low thrust the average duty cycle is low and the battery drain is low. Our motor will probably draw less than 10ADC. Since the electronics control connects and disconnects the battery 36VDC from the motor very little power is lost in the electronics box. Thus almost all the power is used by the motor.
- The duty cycle set by the controller unit depends on the setting of the speed controller. For our use the duty cycle will be about 10%.
- The controller receives 36 VDC from the battery and outputs the duty cycle to the motor based on the speed controller setting.
- The speed of the motor is the average value of the duty cycle (ie. If the duty cycle is 50% the average voltage is 18v).
- The motor, electronics box and speed controller are all sealed against water and can be mounted in different locations.

BATTERY AND CHARGING SYSTEM (shown in orange)

- The Battery system consists of 3-12 VDC 96 AH gel cell deep cycle batteries connected in series to make 36Vdc.
- Gel Cell batteries were chosen because the chemical is contained so battery can not spill, can be mounted in any position and output little or no gases (hydrogen).
- The batteries are charged by a Minn-Kota three output charger that uses a three stage regulation (bulk, absorption and maintenance). This is very important for a long battery life and safety.
- The charger is powered by 115 VAC that comes from either the shore via a cable or a 115VAC generator.
- Each regulator output can provide 15A maximum.
- The charging current is reduced in three steps to prevent overcharging of the batteries (this gives them longer life).
- The batteries should be able to power the boat for the trips downstream.

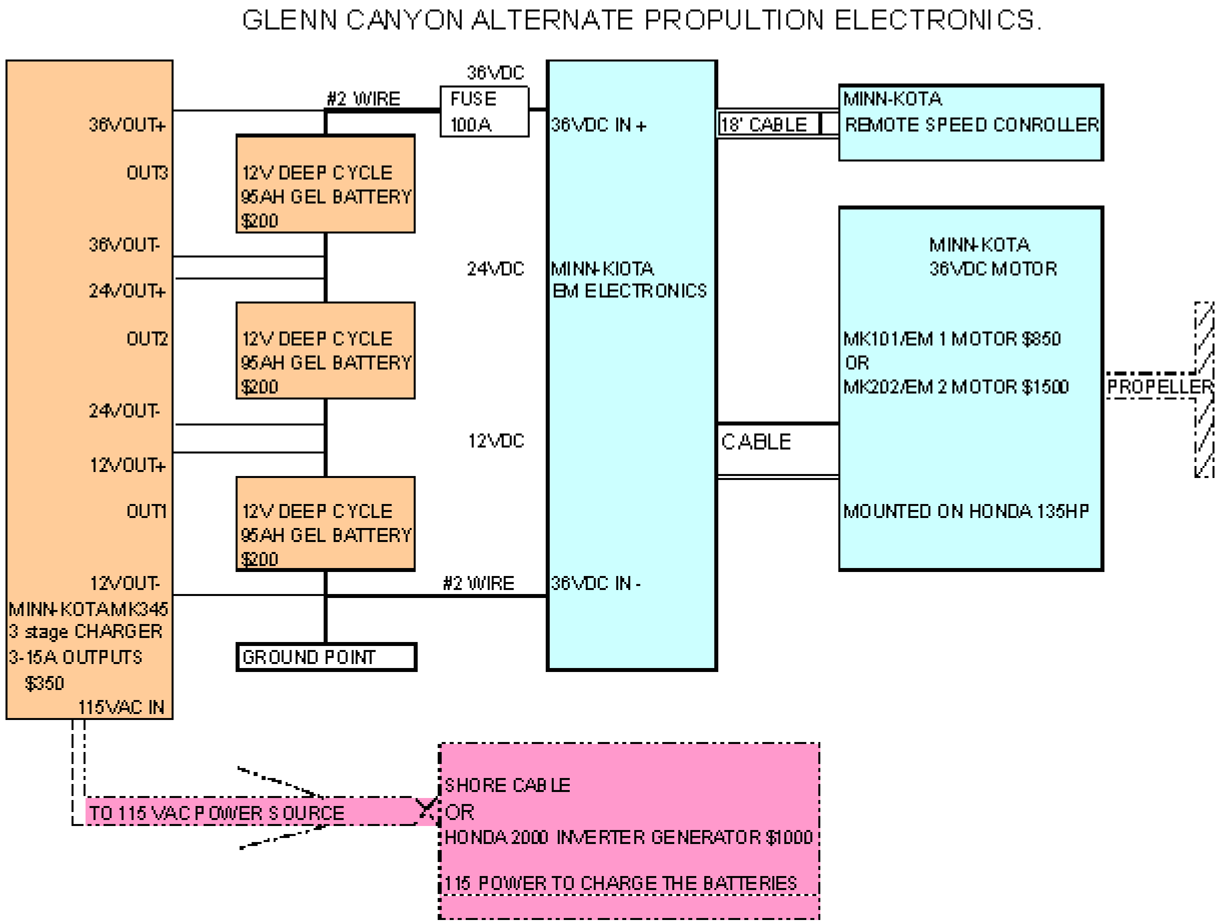
- Larger size batteries (183 A-h and 225 A-h) are available if more storage power is required.
- The charger is FCC compliant and is UL listed to marine standard 1236.

115 VAC POWER SOURCE (shown in red)

- The battery charger can be powered by a 115VAC cable connected from the shore to the boat.
- Recharge can occur overnight unattended and then unplugged from the boat in the morning.
- The battery charger can also be powered by a low noise inverter generator (Honda 2000i or equivalent) which generates 115VAC.

- Recharging the batteries using the generator, should be supervised by a person (to monitor the generator while it is on). Care should be taken when using a generator. The exhaust may contain CO which is very dangerous. It should only be used in the open where Humans can not breath the exhaust. Also care should be used if the generator is wet so as to avoid danger of shock.
- Generator usage is desirable where no 115VAC is available.
- The recharge time for the batteries is estimated to be 4-6 hours.

Electrical system diagram



Quiet Board

The last subsystem is the compartment for the generator. To further reduce noise, it will be lined with sound resistant lining. For this, the cheapest viable solution is a substance called Quiet Board™. The manufacturer's web site best describes it:

"Quiet Board is comprised of porous expanded polypropylene beads which are formed into a semi-rigid, water resistant panel. The cylinder shaped beads are nonporous, but the hollow cores and cracks between adjacent beads allow sound to travel into the panel where it is absorbed. Quiet Board is a washable, lightweight and impact resistant product with very good resistance to chemicals, bacteria and fungi. Quiet Board can be installed as a wall panel, ceiling tile and hanging baffle. Due to its water resistant properties, this product may be used in marine applications."

As this is water resistant, it is superior to most other forms of soundproofing materials. It also comes in pre-formed boards, allowing it to simply be cut to size and glued into place, avoiding complicated installation. Specifications are as follows:

TECHNICAL DATA:

PROPERTIES

Physical Property	Value	Test Standard
Color	White & Charcoal	n/a
Thickness	1" & 2"	n/a
Density	2.8 lbs/ft³	ASTM D-3575
Porosity (Molded Compression Ratio @ 10%)	30%	JPSI Internal
Elongation	13%	ASTM D-3575
Tensile Strength	27 PSI	ASTM D-3575
Tear Strength	18.8 lbs/ 1"	ASTM D-3575
Compression Set	9%	ASTM D-3575
Compression Strength @ 25% Strain @ 50% Strain @ 75% Strain	 23 PSI 35 PSI 79 PSI	ASTM D-3575
Water Absorption	0.0065 lbs/in³	ASTM C-272
Water Vapor Permeability	0.000066 lbs.ft²/hrmmHg	ASTM E-96
Thermal Conductivity @ 75°F	0.26 (K) BTU-in/(ft²-hr- °F)	ASTM C-177
Thermal Stability Linear Dimensional Change 24 hrs. @ 225°F	1.0%	ASTM D-3575
Thermal Resistance	3.8(R)	ASTM C-177

PROPERTIES – cont.

Physical Property	Value	Test Standard
Coefficient of Linear Thermal Expansion 70°F to -40°F 70°F to -180°F	 0.000064 in/in/°F 0.000108 in/in/°F	ASTM D-696
Chemical Resistance (auto fuels, fluids, solvents)	Pass	Various
Flammability	Meets	MVSS 302
	Flame Spread Index 3 (1" Thick) 5 (2" Thick)	ASTM E-84
	Smoke Development Index 84 (1" Thick) 113(2" Thick)	ASTM E-84

SOUND TRANSMISSION LOSS

Freq. Hz	125	250	500	1000	2000	5000	STC
1" (dB)	6	5	7	8	10	15	9
2" (dB)	9	8	10	10	17	22	13
1" between ⅝ gypsum (dB)	27	27	29	31	32	45	32

NORMAL SOUND ABSORPTION/NOISE REDUCTION

Freq. Hz	125	250	500	1000	2000	4000	NRC
1" Wall mount (%)	0.05	0.06	0.21	0.80	0.65	0.75	0.45
1" Wall w/ ¾ Airspace (%)	0.06	0.13	0.51	0.79	0.62	0.79	0.50
1" Wall w/1"BAP* (%)	0.11	0.58	1.07	0.71	0.74	0.72	0.85
2" Wall Mount (%)	0.07	0.21	0.81	0.85	0.93	0.88	0.70
2" Wall w/ ¾ Airspace (%)	0.10	0.29	0.99	0.74	0.90	0.93	0.75
2" Wall w/1"BAP* (%)	0.17	0.81	0.97	0.85	0.89	0.92	0.90
1" Ceiling E400 (%)	0.46	0.59	0.42	0.49	0.76	0.86	0.55
2" Ceiling E400 (%)	0.51	0.52	0.52	0.72	0.77	0.89	0.70
1" Wall C423 12"spacing (%)	0.04	0.07	0.20	0.83	0.81	1.00	0.50
2" Wall C423 12"spacing (%)	0.09	0.21	0.82	.11	1.11	1.12	0.80

* BAP = Bonded Acoustical Pad

Analysis

Below is a failure mechanism analysis table, summarizing the various problems that might commonly arise in the system, and the methods used to prevent or reduce their occurrence, or to overcome their effects.

FMEA Table

Item	Function	Potential Failure Mode	Effect	Potential Cause	Current Control
Batteries	Power electric motor	Run out of charge	Loss of power	Not enough batteries	Supplement with generator to charge batteries
				Batteries old	Replace batteries
		Loss of chemical reactants		Cracked casing	Gel cells - do not leak

Electric motor	Provide power to propeller	Motor failure	Motor stops working	Impact from collision	Finish trip with main outboard
					Mounted on cavitation plate - unlikely to damage
				Burnt out motor	Minn Kota controller regulates safe power
Electrical connections	Connect batteries, generator, and electric motor	Electric short	Electrical system stops working, potential injury	Water in system	Insulate electrical system
Propeller	Convert mechanical power to thrust for boat	Broken propeller	Drop in power	Hit a rock	Swappable propellor parts
Outboard motor	Provide large power to propeller	Motor failure	Loss of upstream travel	Hit a big rock	Swap boats
Fuel	Provides chemical energy for outboard and generator	Spill	Environmental damage	Human error	Ethanol fuel is eco-friendly
Generator	Supplements power, charges batteries	Motor stops	Loss of supplemental power	Inadequate maintenance	Finish trip with outboard

Budget and Suppliers

The University of Arizona Engineering department gives $2000 to each Senior Design team. CRD has not offered money for this year's project, but they only expect a design idea and validation of the design. Thus, the maximum budget is $2000, but the part costs are closer to $5000 (see budget below). This deficit causes a problem finding parts. Unless CRD decides to endorse the design and provide extra funding, the parts have to be donated, discounted, or bought used to meet the budget.

The main purchase is the electric motor from Minn-Kota that is roughly $1500.00. This item is not available for shipping and must be purchased from a specific dealer. There might be a method to purchasing it for less then price listed by contacting the manufacture and discussing the project to them that is done by engineering students as a senior design. Unfortunately, items such as this are not commonly found on eBay or similar sites with the exact specifications needed. The gel batteries are also an important factor to make the pontoon function down stream. These, however, can likely be bought at cheaper prices than MSRP, because several companies make them. The Honda super quiet generator has an MSRP of $1999.95. This type of item might be found at a cheaper price used, on sites such as craigslist or eBay.

One of the methods that could be accomplished to reduce the noise is to design a storage container on the pontoon. The storage container will be constructed with 1 inch thick sound board plus quiet board foam glue around the inside walls. There will also have to be two outlets for the generator to have an exhaust and air input. The exhaust line should be directed away from the customers.

Budget:

Material	**Quantity**	**Price ($)**
Electric Motor	1	1500
Charger	1	350
Batteries	3	1050
Generator	1	2000
Conversion Kit	2	600
Sound Box	1	200
Miscellaneous	_	400
Total	_	$6100

No available discounted suppliers have been found, which necessitates finding alternatives to the ideal design. The Minn Kota electric motor is integral to the design so it will not be replaced if it can not be found at a discount. The other parts might be substituted for alternatives to meet the budget. In example the Honda Whisper Quiet Generator, that the design specifies, might be replaced with a used Honda generator along with making the sound box thicker to reduce the extra noise. This allows verification and testing of the Ethanol/Electric dual system design. Furthermore, conversion of a small Honda outboard that is not computer controlled would allow proof of concept as well as provide data on power after conversion.

Specification Review

We settled on a Minn Kota Mk202/EM motor for the following reasons: The motor generates 202 lbs of thrust. When the boat is being propelled downstream, this will be more than enough, and will provide adequate power for quick maneuvering in order to avoid obstacles. The motor also attaches to the Honda outboard so the crew can steer the boat from the same position (tight space). The motor unit comes in three parts: the electric motor that attaches to the Honda, the electronics unit which is separate so it can be mounted as required, and the speed controller which can be mounted next to the outboard speed control. The cost of this unit is $1500. This unit requires 36 VDC to power it. We chose three 12 VDC deep cycle batteries that are rated at ~100A-h. We also recommend a gel-cell type battery so if it tips over the acid will not spill out. The gel-cell is a sealed battery. The batteries are charged by a Minn-Kota three stage three output battery charger. This charged is designed to charge three 12VDC batteries in series. Thus the batteries do not have to be disconnected to be charged. It is a sealed unit so water will not damage it and there is no danger from shock if some one touches it when wet. It also meets UL and Marine standards. The charger is powered by 115 VAC. It can be power by connecting it to shore power or a generator that outputs 115 VAC. The charger requires about 6A AC. By using a three stage charger the voltage and current to the batteries is carefully controlled to safely charge the batteries. If the voltage and current is not controlled bad things can happen. The battery acid can boil and spill and the battery life is greatly reduced. A quality charger is a must.

Closure

Colorado River Discovery wants four main things out of the new propulsion system: the power to get back upstream, 15 miles, in an hour or less, a reliable system that is also durable, non-fossil fuel propulsion and a silent operation for the downstream tour. An extensive system is needed to meet these requirements. The ethanol converted Honda creates the power needed to reach 18 mph and get back upstream. Both the Honda engine and Honda generator already are durable and reliable, and the dual system redundancies add to the reliability. Also the dual system, electric and ethanol, allow for a quiet mode during tours. The generator creates the most noise. The ethanol converted generator is below the noise requirements, but it will be housed in a sound box to ensure quiet ambience on the river.

Most of the parts of the design are off the shelf parts. So the main challenge will not be creating the system, but instead finding the parts that will not exceed the very limited budget or fabricating inexpensive alternatives. The end goal is to have a working design that will be implemented on one of Colorado River Discovery's raft, but the main focus of the will be on converting a Honda generator to ethanol and creating a sound box for it.

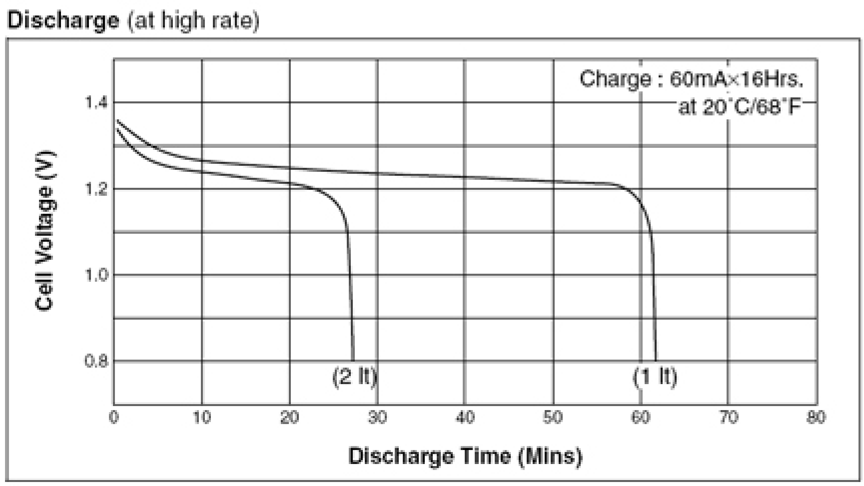
Appendix A – Questions from Presentation

1. How will the extra weight effect the performance of the raft? Will the extra weight reduce the number of passengers?

The rafts are made out of military-quality pontoons, which are also used to build bridges for tanks to drive across. The only effect extra weight might have is to affect the rafts ability to plane above the water on the return trip, which allows for significantly reduced drag, and thus greater fuel economy. Testing during the on-site visit showed that with the current outboard system, the boats were able to plane even with 10 people extra on them, or nearly 2000 lbs of extra weight. The new system design will not add more than 500 lbs to the current configuration.

What is the thrust of the electric motor?
Minn-Kota has rated the thrust of their motor at 202 lbs when using a 36 volt battery that supplies 15 amperes of current.

How many amps can the battery supply during continuous usage?
This will depend on the battery chosen. A typical battery discharge cycle resembles the graph below. Further manufacturer specifications will be necessary to determine which batteries will provide enough continuous power for our needs.



Courtesy of http://web.engr.orst.edu/~sanforan/display/display.htm

Appendix B - Abbreviations

GCROA	Grand Canyon River Outfitters Association
CRD	Colorado River Discovery
V	Volts
hp	Horsepower
lbs	Pounds
A-h	Ampere-hours
EM	Engine mount
MPH	Miles per hour
VAC	Volts AC
VDC	Volts DC