*Figure 1. Torque equilibrium. Resultant of and points directly at wheel center*

*At constant velocity,*

*Figure 2. Horizontal forces equilibrium. , , , are internal forces.*

At stall,

X:

Y:

*Torque from contact point of front wheels*

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*Figure 3. Equilibrium equations for OSV stalling on an incline.*

*Equation 1. Stall torque in one rear wheel on an incline.*

*Equation 2. Tractive effort and torque maximum to avoid digging into the sand.*

*Figure 4. Motor Torque vs RPM found by converting the motor’s data sheet using a reductioin ratio of 100 and an efficiency of 60%.*

It was decided that the wheels must be 3d printed because the design calls for a very narrow range of dimensions that could not be fulfilled by any wheels on the market. The wheel dimensions were chosen to allow the OSV to clear the pool of water and take the platform above the water. The diameter was calculated with the height of the pool in mind, and the width was calculated with the dimensions of the OSV versus the diameter of the pool in mind. The width was optimized for sliding over sand while still allowing the OSV to drive over the pool. It was decided that the diameter of the wheels would be 107mm and the width 44mm. The wheels will be placed 11.15cm away from the center of mass, measured in the direction of motion, and 1cm inward from the edge of the OSV to allow for the chain and sprocket system. They will be housed in two-sided wheel housings to hold them in the same orientation.

The torque calculations were derived with the models depicted in figures 1, 2, and 3. Equation 1 was used with the following dimensions: a radius *r* of 5.35cm, a width *w* of 4.4cm, a diameter *d* of 10.7cm, a height *h* of the center of mass of 11cm, a mass *m* of 3kg, an acceleration *g* due to gravity of 9.8, an angle of incline *ϴ* of 35°, and a length ℓ between the center of mass and center of a wheel of 11.15cm. Using this equation, the minimum torque per wheel required was determined to be 22Ncm. Using equation 2, the maximum torque that could be output to avoid digging into the sand was found to be 27.5Ncm at 0°. Only the scenario with a 0° incline was considered because it was determined that the wheels digging on an incline would not be a problem. The digging would reduce the incline since the front wheels would begin to dig the sand before the rear wheels. Using these parameters, a 12V motor with a rated torque of 46Ncm was chosen. Each wheel would have its own motor. The motor has a variable torque and angular velocity. Since the maximum torque required for OSV operation is lower than the torque at which the wheels begin digging the sand, it was determined that this motor would always operate under the torque for digging, yet always be able to provide enough torque to overcome the sand and any inclines of the sand.

The drive train was designed with the platform mechanism in mind. It was determined that the motors and wheels must be separated so that the motors would not be in the way of the OSV successfully getting over the pool. To achieve this, the four motors would be placed on the base of the OSV and drive the wheels using a system of chains and sprockets. The sprockets would be sized at around a 1:1 ratio initially but, because of the need to reduce OSV velocity, may end up being around a 1:3 ratio. The chains and sprockets would be oriented to the outside of the OSV, so that there will be maximum clearance on the inside to fit the pool between the wheels. Using the torque vs. RPM graph in figure 4 and a wheel radius of 5.35cm, the range was obtained for OSV velocity for between operation at 35° and at 0°, with 1:1 sprockets. With a wheel sprocket that is 3 times wider than the motor sprocket, a theoretical mechanical advantage of 3 is introduced. This means that the torque output is 3 times the torque input and the angular velocity output is one-third the angular velocity input. The wheel would still need the same torque to overcome its resistance, so the motor would output much less torque. This would increase the angular velocity of the motor because angular velocity is inversely proportional to torque. However, as seen in figure 4, reducing the torque by a third does not increase angular velocity threefold because the two quantities are related by a constant. Overall, this design is expected to reduce the angular velocity, and thus the OSV velocity, by approximately 50%, while lightening up on motor current draw due to the lower motor torque requirement.

The steering system will be differential steering and not require any servos. It will turn by adjusting the relative speeds of the different wheels. Pulse-width modulation will be used to lower the angular velocity of certain motors. This can be performed at the motor bridge and be controlled by the arduino. PWM can be used to proportionally lower the effective current and voltage that is applied to the motor. The motor will then draw more current at the battery to produce the same torque, but its voltage will be lower and be constant. Torque is directly proportional to current because current produces the magnetic field inside the motor that drives the motor shaft. However, angular velocity is directly proportional to voltage because motor voltage is used to overcome the counter-electromotive force produced by the rotor spinning through the motor’s magnetic field. The motors that need to slow down will be fed lower voltage and therefore output a lower angular velocity at the cost of requiring higher current draw to produce the same torque. However, this will not impact battery capacity requirements because the increased current draw is balanced out by the <100% duty cycle, and total power draw will be roughly the same.