Engineering of Systems 1

Deliverable 5

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Insights:

There were many insights gained by the Functional Analysis process. The hierarchical function tree made the team think in ways they had never thought before. Starting with the top level function of our product, which was to trim unwanted vegetation, and cascading to the right toward lower levels required a thorough analysis of each and every function until we arrived at the bare bone elements. For example, under a higher level function like “Protect User” we branched off with an element “Block Projectiles” but couldn’t branch off with any more elements as this task is accomplished by a component being between the user and the product to “block” the projectiles.

The Subtract and Operate Approach helped the team think about and map the components of the product to its functions. Doing this allowed the team to gain insight on which components held high interactions and which components held low interactions with functional elements. For example, components with many arrows protruding from them suggest that they play an important role in the functionality of the product while components with only one arrow protruding from them suggest a smaller role in the overall functionality of the product. In our diagram, it is visually noticeable that components like the piston, spark plug, alternator, and throttle cable are important to our product’s functionality.

When going through the process of mapping components to functions, it was extremely useful to mentally think about how functionality would be affected if a certain component was removed. For example, we would ask ourselves questions like “How would functionality be affected if we removed the switch component?”. This would then lead us to answer “Generating an electrical connection would certainly be affected.” This tool helped not only with the mapping process but also helped us to discover components that didn’t map to a function but were nonetheless necessary. An example of this is the spacer in the engine assembly which doesn’t map directly to a function but is a necessary part of the assembly to keep a stable position of the clutch.

Brainstorming:

We first determined as a group the top level function of our product, Trim Unwanted Vegetation. We spent 60 minutes brainstorming the inputs and outputs relating to energy, information, and material for trimming unwanted vegetation. For instance, some material inputs required that we came up with is filling the weed whacker with gas, oil, and string. Some examples of information inputs required are the location, weather, gas-oil mix ratio, and the condition of the vegetation. Likewise, some examples of energy inputs required are the pull force on the pull string, grip force on the trigger, and the vibration from the weed whacker. The full set of input requirements that were created can be found below in Table 1.

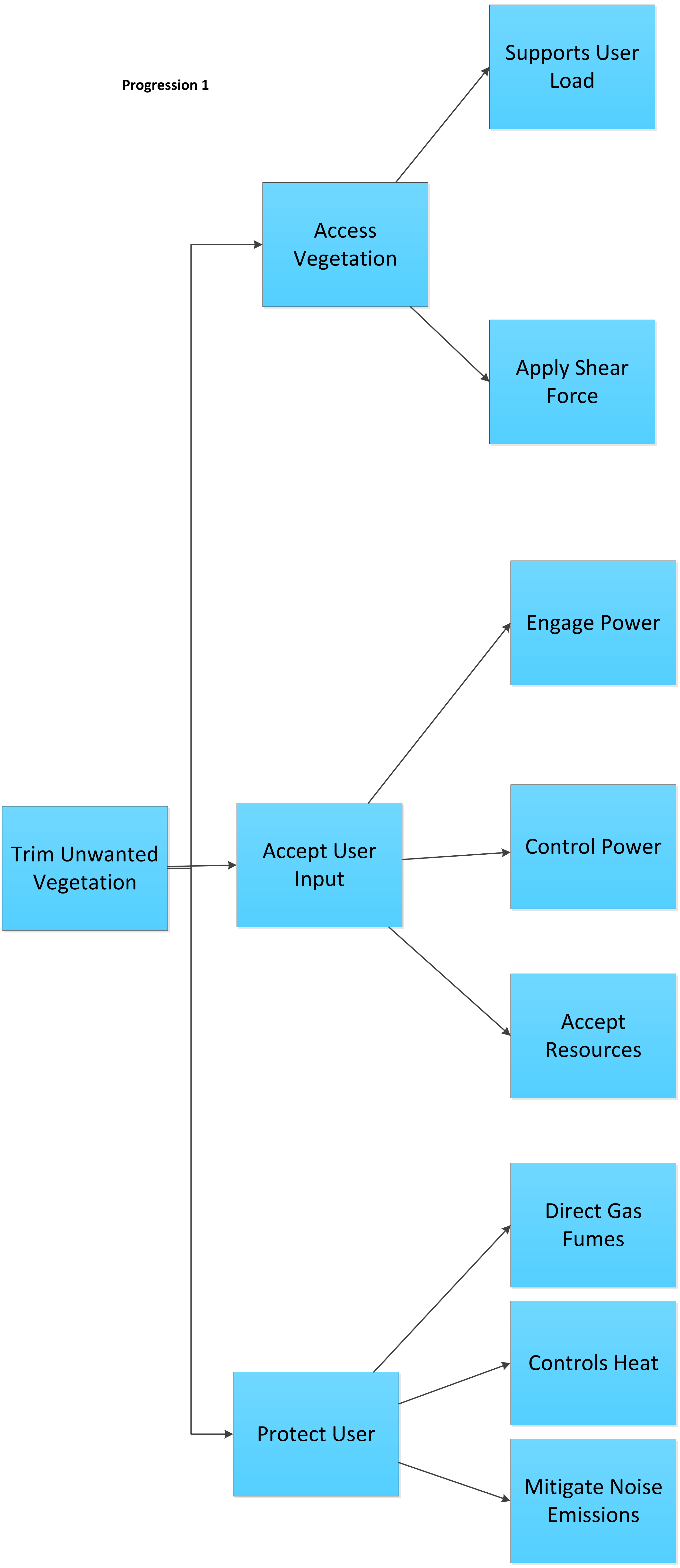
The outputs section consisted of the results of the top level function during and after the operation. For example, some material outputs include vegetation debris, gas fumes, and string debris. Some examples of information outputs relating to the material outputs are amount of gas consumed, string consumption, and job status. Likewise, some examples of energy outputs, which overlap with energy inputs, are machine vibration, noise, and operator fatigue. An example of overlap is Machine Vibration, since starting the weed whacker is an input and includes machine vibration while actually using the weed whacker once it is started to trim the unwanted vegetation also includes vibration. The full set of output results that were created can be found below in Table 1.

As users with experience, it was easier for us to come up with the input requirements necessary for the weed whacker to operate at its top level function as compared to the outputs. This is because the user has to manually feed the weed whacker before it operates so this part was intuitive for the team whereas for outputs the only intuitive elements are the vegetation clippings, noise emissions, and gas fumes. Overall, the brainstorming went smoothly.

Table 1

Inputs (Before and Starting Operation)			Top Level Function	Outputs (During and After Operation)		
Energy	Material	Information		Energy	Material	Information
Work Duration	Weed Whacker	Domestic vs Commercial Job		Machine Vibration	Vegetation Debris	Job Status (in process, complete)
Work/Rest Cycle	Clothing	Time of Year		Machine Power	Gas Fumes	Vegetation Condition
Engine Combustion	String	Product Brand		String Angular Velocity	String Debris	Amount of Gas Used
Rotational energy	Gas	Product Model #		Shear Force on Vegetation	Trimmed Vegetation	String Consumption
Electrical	Oil	Vegetation Condition	Trim Unwanted Vegetation	Operature Fatigue		Weed Wacker Condition
Pulling Force (String)	Guide Wheel	Location		Heat		
Grip Force (Trigger)	Attachment Capable	Weather		Noise		
Static Work (Holding)	Grass/Weeds	Gas Tank Status (Full, Empty)		Electrical		
Pushing (Primer and choke)	Safety Glasses	Fuel Type (Oil mix)		Dynamic Work (Guiding)		
Machine Vibration	Gloves	Fuel Consumption		Static Work (Holding)		
Noise	Gas Fumes	String Status				

Progression 1



Progression 1 Discussion:

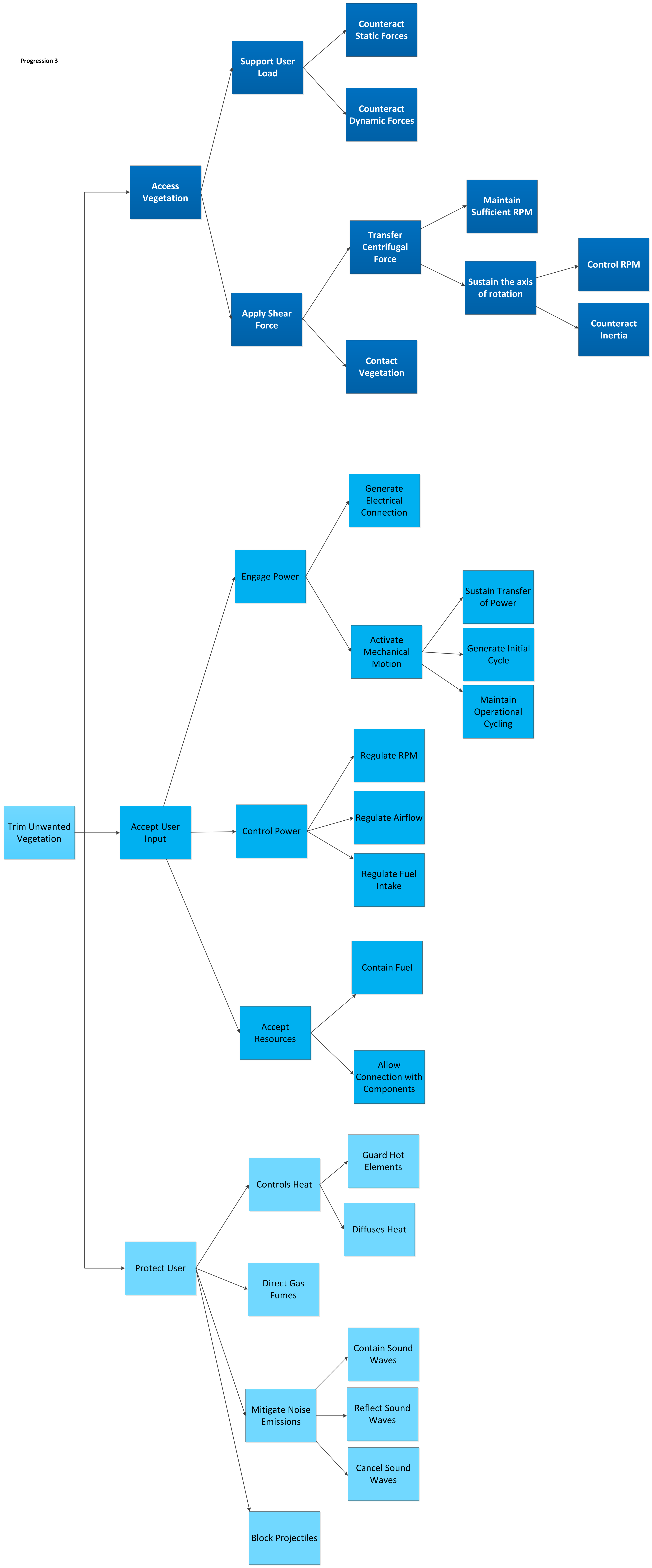
Progression 1 above involved breaking down the top level function of our product, which we decided was “Trim Unwanted Vegetation.” We then thought of how our weed whacker performed the function of trimming unwanted vegetation and branched off of our top level function with three second-level functions. The three second-level functions that came to mind were to “Access Vegetation,” “Accept User Input,” and “Protect User.” These were chosen because the weed whacker must come in contact with vegetation, be compatible with the user, and keep the user safe to trim unwanted vegetation. From here, we thought about how each of these second level functions was performed. “Access Vegetation” was broken down into the sub functions “Support User Load” and “Apply Shear Force.” These were chosen because the weed whacker must be able to withstand the carrying forces of the user and have the ability to cut into the vegetation. “Accept User Input” was broken down into the sub functions “Accept Resources,” “Engage Power,” and “Control Power.” These were chosen because the weed whacker requires a set of resources to operate, needs the user to start it up, and needs the user to control the power. Finally, “Protect User” was broken down into the sub functions “Direct Gas Fumes,” “Control Heat,” and “Mitigate Noise Emissions.” These were chosen because the weed whacker tries to mitigate exposure to harmful gas emissions by the user, prevent burning the skin of the user, and protect the user from flying projectiles while operating. Determining the levels for the first progression was challenging due to the group wanting to state too generally how the function of the weed whacker is accomplished. The end result was a rather small and undetailed functional tree.

Progression 2

Progression 2 Discussion:

Progression 2 above involved breaking down the third level function of our product. We thought of how our weed whacker performed the function of “Support User Load” and branched off with “Counteract Static Forces” and “Counteract Dynamic Forces”. These were chosen because the forces that the weed whacker must withstand are static, holding the weed whacker, and dynamic, guiding the weed whacker. “Apply Shear Force” was broken down into the sub functions “Transfer Centrifugal Force” and “Sustain the axis of rotation”. These were chosen because the weed whacker must convert the forces from the shaft into the rotation of the cutting head, and then maintain the position of the cutting head so the shear force can be applied. “Engage Power” was broken down into the sub functions “Generate Electrical Connection” and “Activate Mechanical Connection.” These were chosen because the weed whacker is powered by electrical wiring and mechanical motion. “Control Power” was broken down into the sub functions “Regulate RPM” and “Regulate Airflow.” These were chosen because the weed whacker has internal mechanisms that are kept active through certain levels of RPM in the engine and airflow through the carburetor. “Accept Resources” was broken down into the sub functions “Contain Fuel” and “Connect with Components”. These were chosen because the weed whacker requires fuel to operate and components such as cutting string to function purposefully. The second progression brought in detail that the first progression lacked, mainly in the “Access Vegetation” and “Accept User Input” sections. These additional sub functions start to present a clearer visual of how our product operates and begins to lean towards the components directly related with each sub function.

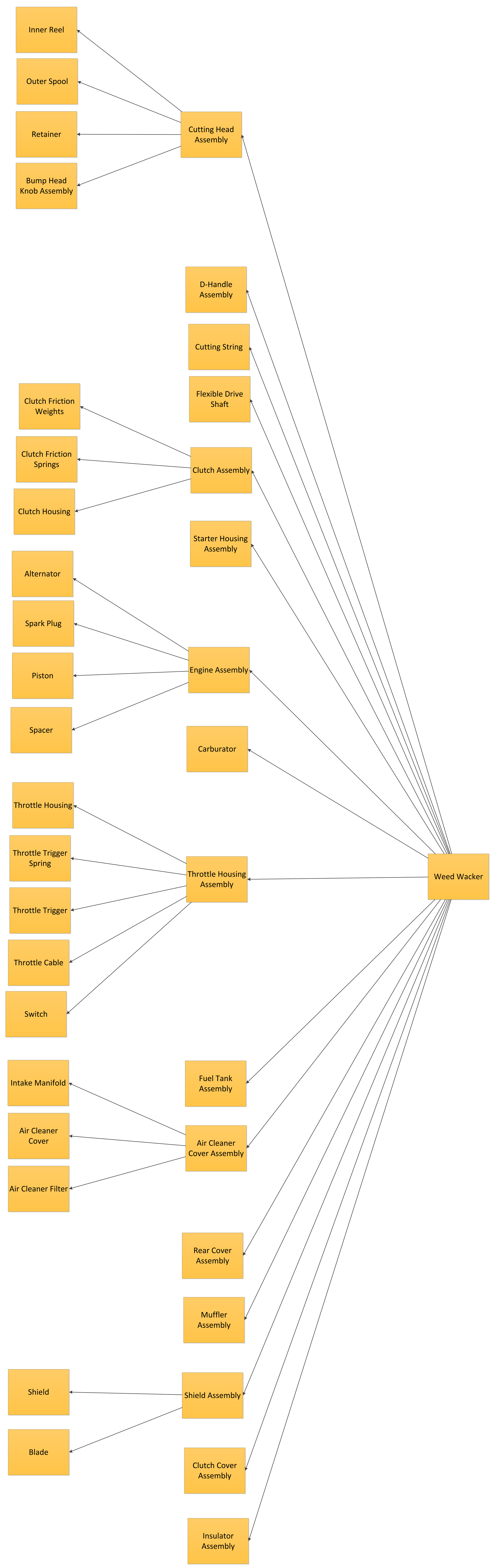
Progression 3



Progression 3 Discussion:

Progression 3 above is very similar to progression 2 with a more detailed breakdown in the 3 major subsections. Each of the 3 subsections is color coded to make the diagram easier to follow when the final analysis is developed. The first change that we made was to add sub functions to “Apply Shear Force”. We added “Contact Vegetation” in replacement for “Sustain the axis of rotation” since it is required in order to apply the shear force to the vegetation. We then moved “Sustain the axis of rotation” to be a sub function of “Transfer Centrifugal Force” since it is required to even maintain the centrifugal force. We also added “Maintain Sufficient RPM” as a sub function of “Transfer Centrifugal Force” since a certain RPM is needed in order to overcome the inertia of the cutting head. Under “Sustain the axis of rotation” we added “Control RPM” and “Counteract Inertia” since both are of those are needed in order for the rotation to occur successfully. Within the next subsection of “Accept User Input” we added more sub functions to “Activate Mechanical Motion.” One of the sub functions that we added was “Sustain Transfer of Power” since the power needs to be applied continuously in order to make the mechanical motion. The next one added was “Generate Initial Cycle”, which is pull starting the weed whacker, and this is needed in order to start the mechanical motion. The last one we added to this group of subsections was “Maintain Operational Cycling” since this is the cycle of the alternator to maintain the running of the engine. Under the subsection “Control Power” we added “Regulate Airflow” since airflow is goes hand and hand with “Regulate Fuel Intake” which we already had there. The airflow plays a key role in the controlling of the power. Under the second-level function “Protect User” within the subsection “Control Heat” we added “Guard Hot Elements” and “Diffuse Heat.” Both of these are ways in which our product controls the heat emitted by the engine through dissipating heat and physically guarding the hot components of the weed whacker. We also added three subsections to “Mitigate Noise Emissions” and they are “Contain Sound Waves,” “Reflect Sound Waves” and “Cancel Sound Waves.” Each of these are ways that the weed whacker deals with sound in order to protect the user’s hearing. This is the final progression of the functional tree for the top level function of “Trim Unwanted Vegetation.”

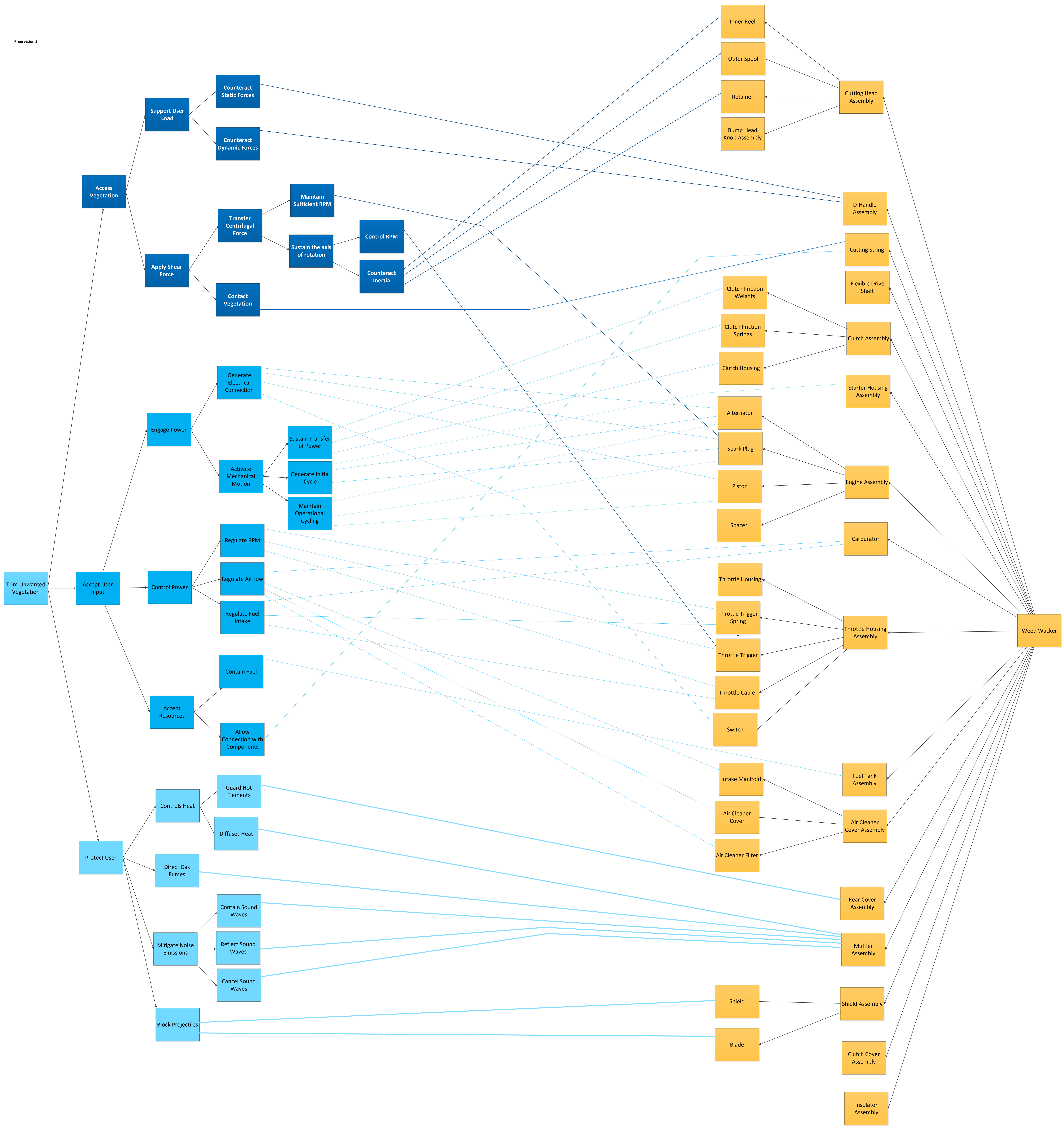
Progression 4



Progression 4 Discussion:

The structural diagram above is the fourth progression of our Functional Analysis. The full breakdown logic of the above diagram is available in the Bill of Materials, in the Appendix. The group created this by evaluating the Part Name column in the Bill of Materials. The components that the group felt were the most influential to the functional structure of our weed whacker appear in the third level. All of the sub-assemblies under the Subsystems column in the Bill of Materials were included in the second level. The top level was the weed whacker itself. The components included under “Cutting Head Assembly” are “Inner Reel,” “Outer Spool,” “Retainer,” and “Bump Head Knob Assembly.” The components included under “Clutch Assembly” are “Clutch Friction Weights,” “Clutch Friction Springs,” and “Clutch Housing.” The components included under “Engine Assembly” are “Alternator,” “Spark Plug,” “Piston,” and “Spacer.” The components included under “Throttle Housing Assembly” are “Throttle Housing,” “Throttle Trigger Spring,” “Throttle Trigger,” “Throttle Cable,” and “Switch.” The components included under “Air Cleaner Cover Assembly” are “Intake Manifold,” “Air Cleaner Cover,” and “Air Cleaner Filter.” Finally, the components included under the “Shield Assembly” are “Shield” and “Blade.” Fasteners for each of the assemblies were left out of the diagram in order to mitigate clutter and disorganization. However, they will be addressed later.

Progression 5

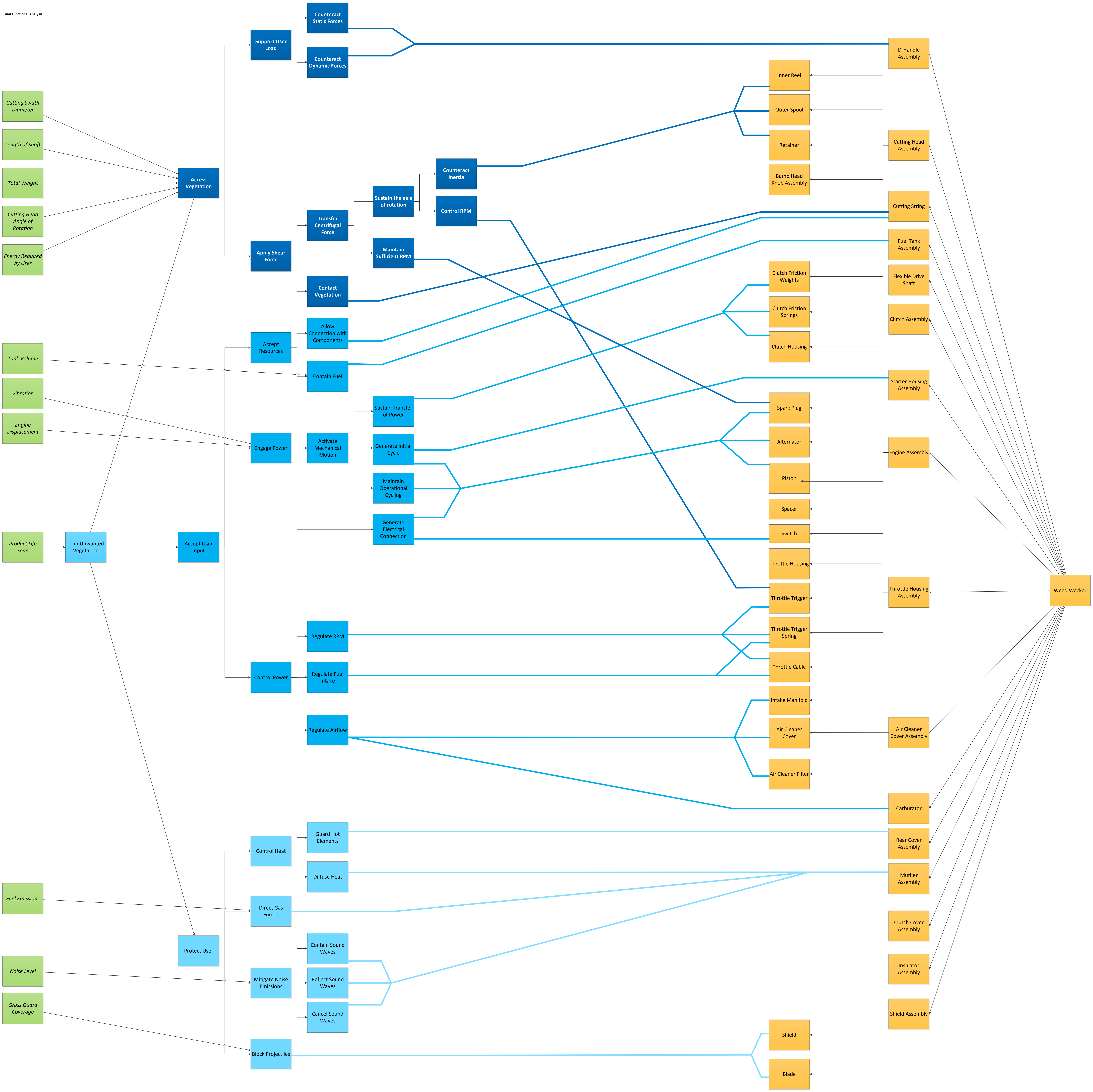


Progression 5 Discussion:

Progression 5 above represents the full relationship between the lowest tier of functional and structural elements for our product. Levels 3 through 6 in the functional tree on the left are connected to levels 2 and 3 of the structural tree on the right. Connections are only made between "dead end" sublevels that cannot be broken down any further. As mentioned earlier, we excluded the fasteners for each assembly in the structural diagram to minimize visual complexity. If we had included the fasteners for each assembly in the above diagram, they would have a connection with "Counteract Static Forces" and "Counteract Dynamic Forces" since the fasteners are the components that are holding each assembly together.

This Progression exemplifies how intertwined the functions and components of this product are, meaning a change in one component can have a diverse effect on the product's functionality. The color coded logic introduced in Progression 4 is justified above in Progression 5 as it helps to visually organize the variety of connections. The connections were drawn from function to component(s) until the full relationship network was developed. Due to the messy nature of the above diagram, further reorganization was necessary.

Final Functional Analysis



Final Functional Analysis Diagram Discussion:

The Final Functional Analysis Diagram captures the interrelationships between our product's engineering metrics, functionality, and structural design. The connections between the functionality and physical structure were reorganized to produce a clean design and ease of flow. The sub functions "Counteract Static Forces" and "Counteract Dynamic Forces" are connected to the D-Handle assembly. These connections are made because the subsystem withstands the forces from the user gripping the D-Handle while holding, guiding, and cutting with the weed whacker. "Counteract Inertia" is connected to "Inner Reel," "Outer Spool," and "Retainer." These connections are made because the inner reel and outer spool are responsible for containing and rotating the cutting string as centrifugal force is transferred from the drive shaft to the cutting head assembly. The connection is made to the retainer because the retainer is responsible for maintaining a stable connection between the drive shaft and remaining components of the cutting head assembly. "Control RPM" is connected to the "Throttle Trigger" because the weed whacker continually regulates the RPM. As the operator squeezes the trigger the RPM increases and as the operator releases the trigger the RPM decreases. "Contact Vegetation" is connected to "Cutting String" because the cutting string is the component that comes into contact with the vegetation.

"Allow Connection with Components" is connected to "Cutting String" because the cutting string is a separate and disposable resource that is fed into the weed whacker. "Contain Fuel" is connected to "Fuel Tank Assembly" because the fuel tank is solely responsible for the storage of the gas/oil mixture. "Sustain Transfer of Power" is connected to "Clutch Friction Weights," "Clutch Friction Springs," and "Clutch Housing." The friction weights, which are connected by the friction springs, pull apart due to the centrifugal force created by the pull string. The weights then create friction around the interior walls of the clutch housing, which is connected to the drive shaft, to sustain the transfer of power between the engine and the drive shaft. "Generate Initial Cycle" is connected to "Starter Housing Assembly" because the starter housing includes the pull string which the user pulls to create the first cycle in the engine to activate the mechanical motion of the weed whacker. "Generate Initial Cycle," "Maintain Operational Cycling," and "Generate Electrical Connection" are each connected to the "Spark Plug," "Alternator," and "Piston." "Generate Initial Cycle" makes these connections because of the transfer of momentum from the pull string to the "Spark Plug," "Alternator", and "Piston" in the engine assembly to engage the power of the weed whacker. "Maintain Operational Cycling" makes these connections because the "Spark Plug," "Alternator," and "Piston" are the key components responsible for the continuous operation of the engine when the weed whacker is running. "Generate Electrical Connection" makes these connections because an electrical current is required to allow the spark plug to fire and propel the mechanical activity of the alternator and piston. "Generate Electrical Connection" is connected to "Switch" because the electrical wires must be live for an electrical current to flow to the engine assembly. "Regulate RPM" is connected to "Throttle Trigger," "Throttle Trigger Spring," and "Throttle Cable." These connections are made because as mentioned previously, when the operator squeezes the trigger the RPM increases and as the operator releases the trigger the RPM decreases. This is due to the change in the electrical current of the "Throttle Cable." "Regulate Fuel Intake" is connected to "Throttle Trigger Spring" and "Throttle Cable" because as the electrical current changes, the amount of fuel required fluctuates to accommodate the demands of the engine. “Regulate Airflow” is connected “Intake Manifold,” “Air Cleaner Cover,” “Air Cleaner Filter,” and “Carburetor.” These connections are made because the “Intake Manifold,” “Air Cleaner Cover,” and “Air Cleaner Filter” allow the entrance of air while the “Carburetor” dictates the flow of air necessary for the engine assembly to control the power of the weed whacker.

“Guard Hot Elements” is connected to “Rear Cover Assembly” because the “Rear Cover Assembly” directly prevents the user from coming into physical contact with the hot components during the operation of the weed whacker. “Diffuse Heat,” “Direct Gas Fumes,” “Contain Sound Waves,” “Reflect Sound Waves,” and “Cancel Sound Waves” are each connected to “Muffler Assembly.” “Diffuse Heat” is connected because the components involved with the muffler assembly absorb and dissipate most of the heat from the engine during operation. “Direct Gas Fumes” is connected because the muffler pulls in gaseous fumes and funnels them out of the product in a direction away from the user. “Contain Sound Waves,” “Reflect Sound Waves,” and “Cancel Sound Waves” are connected because the muffler absorbs noise emissions and cancels them through reflection of sound waves. “Block Projectiles” is connected to “Shield” and “Blade.” “Shield” is connected because it physically impedes the projectiles of grass, shrubbery, rocks, and cutting string from striking the user. The “Blade” nips the cutting string to prevent the over extension of string which could result in tangling or hitting the users’ legs.

The connections between the engineering metrics and functionality are shown on the left side of the diagram. “Cutting Swath Diameter” is connected to “Access Vegetation” because a large diameter will allow for more access to vegetation and a bigger area of shear force to apply. “Length of Shaft” is connected to “Access Vegetation” because a longer shaft will support the user load by allowing for a smaller range of dynamic motion while accessing vegetation. “Total Weight” is connected to “Access Vegetation” because a lighter product will reduce the size of the dynamic and static forces that the product must counteract to support the user load. “Cutting Head Angle of Rotation” is connected to “Access Vegetation” because a wider range of rotation will reduce the dynamic force of the user to apply various cutting angles on vegetation. “Energy Required by User” is connected to “Access Vegetation” because it requires energy to physically manipulate the product during operation. “Tank Volume” is connected to “Contain Fuel” because the amount of fuel that the weed whacker can hold will determine how much work can be done before needing to fill up again. “Product Life Span” is connected to “Trim Unwanted Vegetation” because life span is directly related to how long that the product can perform the top level function. “Fuel Emissions” is connected to “Direct Gas Fumes” because the level of emissions will determine how safe for the user and environmentally friendly the product is. “Noise Level” is connected to “Mitigate Noise Emissions” because the level of noise relates to how much noise contamination is put off by the product which can affect both the user and environment. “Grass Guard Coverage” is connected to “Block Projectiles” because the guard size relates to the level of protection the user had from flying projectiles.

Updated Engineering Metrics:

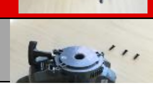
When thinking about whether or not we should revise our Engineering Metrics, we determined that second-level functions which didn't connect to a current engineering metric could potentially need a new engineering metric. Potential Engineering Metrics that we could add to our list include Heat Emission, Engine Torque, Yield Strength of Drive Shaft, Attachment Capability, and Revolutions per minute (RPM). Heat Emission would connect to "Control Heat" since the engine needs to stay within a certain temperature range in order to not overheat. Engine Torque would connect to "Apply Shear Force" as the engine torque is highly related to how well the cutting head performs the shearing function. Yield Strength of Drive Shaft would connect to "Support User Load" since the yield strength is what determines if the shaft will bend under certain stresses, such as hitting the ground to protrude more cutting string. Attachment Capability would connect to "Accept Resources" as this would relate directly to the number of possible attachment combinations the product has. RPM would connect to "Control Power" as this would directly correlate with how many RPM the weed whacker puts out during full throttle as compared with half throttle. Table 2 below outlines the current and additional engineering metrics and which function each metric is connected to.

Table 2

Current Engineering Metrics	Functional Connection
Cutting Head Angle of Rotation	Access Vegetation
Total Weight	Access Vegetation
Grass Guard Coverage	Block Projectiles
Energy Required by User	Access Vegetation
Tank Volume	Contain Fuel
Vibration	Engage Power
Length of Shaft	Access Vegetation
Product Life Span	Trim Unwanted Vegetation
Noise Level	Mitigate Noise Emissions
Fuel Emissions	Direct Gas Fumes
Cutting Swath Diameter	Access Vegitation
Engine Displacement	Engage Power
Additional Engineering Metrics	**Potential Functional Connection**
Heat Emission	Controls Heat
Engine Torque	Apply Shear Force
Yield Strength of Drive Shaft	Support User Load
Attachment Capability	Accept Resources
RPM	Control Power

Appendix:

Product Name	2-Cycle 25cc WeedWhacker Gas Trimmer
Product Number	316.71137
Product Dimensions	4' 9" X 16 3/4 " X 9 1/4"

Sub System	Part #	Part Name	Picture	Dimensions (Inches) Length	Width	Height	Diameter	Quantity
Cutting head assembly	710 - 001	Bump Head Knob Assembly				3/4	1 3/4	1
	710 - 002	Inner Reel				1 1/8	3 1/4	1
	710 - 003	Spring		1 1/8			7/8	1
	710 - 004	Outer Spool				1 3/4	3 1/2	1
	710 - 005	Retainer					5/8 X 3/8	1
D-Handle Assembly	720 - 001	D-Handle bolt		2			3/16	1
	720 - 002	D-Handle washer					5/8 X 3/16	1
	720 - 003	D-Handle wingnut					3/16	1
	720 - 004	D-Handle		5 1/2	5 7/8	3/4		1
Shield Assembly	730 - 001	Shield		10 1/2	8 1/2	2 1/4		1
	730 - 002	Blade		1 1/2	3/4	1/16		1
	730 - 003	Shield Bolt		1 7/8			3/16	1
	730 - 004	Shield Wingnut					3/16	1
	730 - 005	Blade Screw		7/16			1/8	2
	730 - 006	Blade Nut					1/8	2
	730 - 007	Shield Washer					5/16 X 3/16	1
Throttle Housing Assembly	740 - 001	Throttle Housing		8	3 3/4	3/4		2
	740 - 002	Switch		3/4	1	5/8		1
	740 - 003	Housing Screws		3/4			1/8	5
	740 - 004	Housing Screw		5/16			1/8	1
	740 - 005	Throttle Trigger Spring		1/2			1/8	1
	740 - 006	Throttle Trigger		2 1/4	1 1/4	5/8		
	740 - 007	Throttle Cable		20 1/2			1/2	1
	740 - 008	Split Lume		11 1/2			1/2	1
	740 - 009	Zip ties						2
Clutch Cover Assembly	750 - 001	Clutch Cover		8 1/8			4	1
	750 - 002	Clamp Screw		1 1/2			3/16	1
	750 - 003	Cover Screw		3/4			3/16	3
	750 - 004	Anti Rotation Screw		5/16			1/8	1
	750 - 005	Clamp Nut					3/16	1
Rear Cover Assembly	760 - 001	Rear Cover		5 1/8	5 1/8	3		1
	760 - 002	Cover Screw		3/4			3/16	1
	760 - 003	Housing Screw		9/16			3/16	2
Fuel Tank Assembly	770 - 001	Fuel Tank Clip		1/2	5/8	3/16	3/16	2
	770 - 002	Tank Screw		7/8			3/16	2
	770 - 003	Fuel Tank		6	2 1/2	3		1
	770 - 004	Fuel Cap				7/8	1 7/8	1
Air Cleaner Cover Assembly	780 - 001	Air Cleaner Cover		4	3	1 1/4		1
	780 - 002	Air Cleaner Filter		2	3 1/4	1/4		1
	780 - 003	Air Cleaner Bolts		2 1/2			3/16	2
	780 - 004	Intake Manifold		2 1/4	3 3/4	5/16		1
Insulator Assembly	785 - 001	Insularot Screw		7/8			3/16	2
	785 - 002	Washers					3/16	2
	785 - 003	Lock Washers					3/16	2
	785 - 004	Carburator O-ring				1/16	11/16	1
	785 - 005	Insulator		2 11/16	2 1/2	2		1
	785 - 006	Insulator Spacers		3/8			3/16	2
	785 - 007	Insulator O-ring		11/16	13/16			1
Clutch Assembly	790 - 001	Clutch Housing		2	2 1/2		9/16	1
	790 - 002	Clutch Friction Weights		1 1/2	3/4	1/2		2
	790 - 003	Clutch Springs		3/4			3/8	2
	790 - 004	Center Clutch Mount		1 1/4	5/8	9/16		1
	790 - 005	Large Washer					1 1/8 X 3/8	1
	790 - 006	Small Black Washer					9/16 X 5/16	1
Flexible Drive Shaft	791 - 001	Flexible Drive Shaft		46			1	1
Carburator	792 - 001	Carburator		2	2 1/2	1 1/8		1
Muffler Assembly	797 - 001	Muffler		5 3/8	5 1/16	2 7/8		1
	797 - 002	Muffler Screws		3/4			1/4	2
Starter Hou	794 - 001	Starter Housing		8 1/2	7	5 1/4		1

sing Assembly	794 - 002	Starter Housing Screw		7/16			5/32	3
Cutting String	795 - 001	Cutting String Piece 1		70				1
	795 - 002	Cutting String Piece 2		72				1
Engine Assembly	796 - 001	Piston		2 7/8	1 3/8	1 3/8		1
	796 - 002	Engine		6 1/2	4 3/4	7		1
	796 - 003	Spacer		2			3/8	1