**General Method Justification**

What led to developing this design over others? Why choose this design over others?

**Identifying Central Design Challenges**

Mechanics in Microgravity: The force of gravity is either smaller than on Earth, or so small it is hard to even detect. Hence the term microgravity. Systems on a spaceship cannot rely on the force of gravity since it will not be present. Washing machines that tumble clothing on Earth cannot be used on spaceships for this reason (among many others).

Size Constraints: There is only limited space on a spaceship. It is only worth bringing a washing machine if it takes up significantly less room than having the capacity to pack an ample supply of clean clothing and store soiled clothing. For prototypes, the target size is to be able to fit in an EXPRESS Locker on the ISS.

Fluids in Microgravity: In microgravity, fluids behave differently than they would on earth. Issues such as surface tension, and a tendency to float everywhere since gravity isn't there to keep it down. This means open containers cannot be used in space. Rigid sealed containers bring other challenges, such as adding or removing a fluid. Unless there is a vacuum in a closed container, there is always some type of fluid inside to begin with. To add the desired fluid, the fluid already inside the container needs to be removed. To take fluid out, a new fluid needs to be added in its place. On Earth, the density of fluid means that the lighter air remains in the top of a container while water or another fluid will congregate and pool on the bottom. Without gravity, water and air, or any mixture of fluids, will mix. This makes strictly rigid containers a poor choice for hydraulic systems.

Limited Water: In a spaceship, there is a finite amount of water on board, and it needs to be conserved. Additionally, leaked water, having a tendency to float around, will break machinery on a spaceship. Because of these reasons, only small amounts of water are allowed to be used at once for a wash cycle.

Limited Production of Vibrations: The washing machine cannot produce excessive vibrations. Resonant frequencies acting on a ship mean even small oscillating forces can cause serious damage to a spacecraft. This is a huge problem for space since they are made to be as light as possible, and forces produced and acted on the ship can’t be dissipated into the external environment.

No Detergents Can be Used: If a washing machine becomes useless once there is no more detergent, it has no use in space, since unless a way of making detergents in space isn't discovered, there is no way to get more. Additionally, water is hard to recover and make usable once detergents and other mixes have been added.

System Compatibility: The system needs to be either compatible with other systems capable of performing other stages of the wash process, or must be able to complete them itself.

Energy Efficiency: The design cannot use processes that use a lot of energy such as using heat to improve the effects of agitation. Being that the machine is non-critical to supporting life in space, it should have a low energy footprint to justify being used on the space station. If every system used an absorbent amount of power, the production of power would not meet the demands of each component on the vessel.

Other: Other design features that aren’t necessary for function, but are very important such as repairability, relative simplicity, resistant to jamming, among others.

**Addressing Outlined Problems**

*It is worth noting that these problems don’t necessarily translate to a design approach being impossible to make, though they might make designing a working system harder. This was just the thought process used to come up with this particular design.*

As outlined above, closed rigid containers are not very good for use in space. Based on this information, approaches to designing machines that use closed rigid containers and complicated geometry such as roller designs become hard to design and are complicated.

The issues that come with using rigid containers in space makes them a poor option for machine design in this context. Because of this, fluid containers are generally not rigid objects. Examples of this would include astronauts using bags to drink from. When there is none of the desired fluid in a container, the volume of the container can be zero, but can increase for the fluid being added. Bags and other containers that don't have rigidity are also hard to design for, and wear out easily, so using bags is also something to be avoided for machines that work by mechanical processes like the washing machine.

There is another way to store fluids in space as well. Fluids can be stored in rigid containers by sealing a side and allowing it to move. When there is no fluid in the container, the movable side can be moved to touch the other side, and when fluid is added, the movable side moves back and allows for space to be taken up by the fluid.

To limit vibrations, rotational movements that displace a lot of mass or create a lot of force have to be avoided. This disqualifies any mechanical process using centrifugal force to function. Additionally, fast movements have to be avoided for similar reasons.

Since containers need to be filled completely with fluids, containers can only accommodate the fluids stored within and the volume of the clothing item. The fluids accounted for can either be only the water allowed, or the water allowed and air. This is a key aspect of the design that needs to be worked around, as a machine designed to operate with 500 liters of water will need to to be larger and accommodate for more than that of a machine designed to operate with 500 milliliters of water. Chamber size is also a key component of machine size as well, so this is an important design aspect to consider.

**Finding Solution Using Derived Constraints**

Knowing what was found above, how can clothing actually be washed? The key is using the constraints outlined above, to come up with a process that can carry out all the phases of the wash process.

It was found above that containers containing fluids should be rigid yet have a variable size for machinery. It is noteworthy that by moving the side of this container, fluid can also be displaced, this is how some pumps, called reciprocating positive displacement pumps work. Going further with this idea, compressing and decompressing clothing has been a method of washing clothing for ages. Potentially compressing and decompressing a clothing item can be done with a piston. With this one process, clothing can be agitated, but also fluid in the clothing can be displaced and sent to various locations. This means that using a piston, clothing can be soaked with water, agitated, and have at least a majority of the water removed by compressing the clothing and controlling where the fluid displaced goes.

To flesh out this design more, it is important to address some other factors:

Where Displaced Fluid Be Sent: Fluid displaced by the piston needs to go somewhere. Put simply, fluid can either go to a reservoir within the system, or be expelled as needed. In the case of wash water, it is contained in the system for the duration of the wash process, and only removed from the system once the wash process has been concluded. It is noteworthy that when the piston extends and contracts, the space created above the piston is the same as the space removed below it. For this design the reservoir used will be the space created in this way.

How Air is Accounted for in the System: Air, much like water needs to be accounted for. If the container for the clothing only has room for the allowed amount of water and the clothing item itself, and all the fluid in the system can be expelled by the piston through compression, the container can be completely filled with water. While in actuality not all the air can be removed from the system, enough can be for the system to be operational.

**Basic Idea of Design**

A slow moving piston is used to compress clothing and move fluid. Fluids can either be introduced into or removed from the system via compression. Displaced fluids not expelled are sent to a reservoir formed by the space formed above the piston when it extends. By controlling the movement of fluids using this method, each phase of the wash process can be accomplished.

**Assumptions Made in Design:** One main assumption for this design is that fluid in the system is enough of a portion of the desired fluid to other materials in the mixture is high enough that the whole area occupied by the fluid can be treated as such. As an example, if an initially dry clothing item has water added to the system, the chamber with the shirt enough air evacuated that the amount of it in the chamber is negligible. In practice other components may be needed in order for this ideal to be achieved, but for the sake of designing the system, fluid

**Key Advantages of Design**

Fundamental Simplicity of Design: Each function of the washing machine can be performed by and directed with the use of this design.

Flexibility of Wash Process: The wash process is free to have many different modifiers applied to it, whether it be new hardware to allow for additional functionality such as filters for wash water or additional pumps, or software to modify the wash process for a given clothing item.

Fluid Separation: Since air and water are kept separate throughout the entire wash process, no additional complexity needs to be added to the design to separate these different fluids, reducing failure points.

Small: With the wash chamber only being designed to have the capacity to hold the allowable amount of water and the clothing item, the baseline size is already projected to be much smaller than the maximum dimensions outlined.

Produces Few External Forces: Since flow of fluid generated by the movement of a relatively large piston head, and the force acting on the shirt does not need to be fast or violent to compress it, the components of the system can move slowly, meaning vibrations created by the system can be minimized.