Risk	Possibility	Severity	Contingency and Mitigation Plan
Unable to make modeled humanoid stand or function in physics simulation.	High	Medium	Add additional starting conditions for external loads to start in a standing position and then have robot maintain said position. Isolate greater system to only a single ligament like an arm or leg and then slowly add components to root cause failure point. Perform 2D simulation to further constrain movement. Concede and acknowledge existing limitations of design and highlight the beloved root cause if this can still not be resolved. Perform kinematic analysis in order to outline hypothetical ability to stand.
CAD to URDF pipeline does not function properly and outputs incorrect model (ie. wrong center of mass, mass, joint relationship). Thus unable to run simulation.	Medium	Medium	Debug python, physically import STL files into environment then define in a custom XML file to define joint characteristics. Create approximated representation in the event this solution does not work. Utilize visualization tools like URDF debug tool to verify COM and all component properties.
Motors that have been spec'd do not have public information on dimensions and motor properties.	Medium	Low	Reach out to supplier for additional specification details. Choose an alternative motor with similar properties that has additional information on motor specifications.
Power Requirements to enable joint actuation and linkage movement is far greater than payload capacity of robot.	High	Low	Increase battery density or total power package to match requirements. Opt for additional lightweighting of hardware or understand if there are alternative hypothetical power management solutions that could mitigate the high parasitic power draw ie. lower power sensors or motor control solutions that could be implemented. Understand if motors may need additional supporting mechanisms or may need to be changed to reduce power draw.
CAD models are deleted or are corrupted and are not saved. Deleting or removing models.	Low	High	Create backup files of CAD at each design cycle to ensure there is a history of files used. Utilize Onshape file management system and ensure a stable internet connection available while working on CAD. Ensure there is centralized file management through OnShape.
CAD model assemblies are under defined and mates and ranges of motion are left undefined.	Low	Low	Troubleshoot assemblie and verify mates are defined. Protocol enforced to ensure all joint ranges of motion are defined prior to design or during design are modified. Mates are constrained for proper assembly of complete assembly. Ensure mates are not over constraining motion if they are not supposed to exist.
Hardware BOM is not fully complete due to missing components or unaccounted for hardware.	Medium	Low	Assess missing components in BOM. Perform routine indexing of draft BOMbs during design cycles to account for all parts or identify missing components. If component is missing and can be specified off the shelf then it must be specified. If a component is missing and requires significant design work too late in the project to design, acknowledge missing component, outline design requirements and functionality, and hypothetical implementation.
Part manufacturing methods via machining are too complex or are not possible based on defined part geometry.	High	Low	Perform DFM assessment during hardware design of components. If component cannot be manufactured revise components to make them manufacturable. If component cannot be made to fit process assess the adoption of an alternative process for component or alternative component design.
System is not defined with safety risks in mind and designed hardware is capable of harming human (ie. sharp part, hardware torque limits, etc.)	Medium	Medium	For hardware designs ensure hardware does not have sharp points and utilize chamfers and fillets as needed to ensure components do not have sharp edges. For mating points ensure that the sharp points do not exist once they have been assembled. Safety systems from electrical system are out of scope, but torque and sudden movement risks should be assessed to ensure harm risks are mitigated via mechanical components when necessary.
Joint layout configuration is not possible due to mass constraints, power demands, or costs.	High	Low	An alternative joint configuration should be defined to reduce complexity, power draw, and the drawbacks of the new configuration should be assessed to make sure it still is capable of performing location or ranges of motion. Alternative mechanisms for joints can be evaluated or tradeoffs in linkage mass or actuator sizing can be made.
Joint ranges of motion and desired torque cannot be achieved due to mechanism designs and physics constraints.	Medium	Low	Alternative actuators may be specified to achieve required torque if needed or an updated upper bound on torque should be defined. Range of motion limitations should be characterized in sim to understand how it affects robot and adjustments to design should be made if the validation fails.

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Project is not fully complete (ie. only arms are designed, or upper torso, or lower body) leaving incomplete humanoid design.	Medium	Medium	Completed components should be presented. Ongoing review of progress and blockers in project should be communicated to project advisor and project sponsor to assess where technical assistance can be provided to resolve issues. Risks of inability to complete full design should be discussed with capstone professor and a proper plan to evaluate scope and deliverables should be discussed. In addition, work that has been completed should be identified and presented as project. Additional and remaining work should also be discussed and technical issues and limitations should be discussed as part of learnings and discussions section.
Hardware design is not fully documented and is not publishable to an open source forum.	Medium	Medium	To mitigate risk documentation for designed components and design progress should be made as work is done. This will limit the risk of no documentation being made at the very end of the project. Revisions should be made at the end, but documenting design processes and technical studies should be made on a weekly basis to track and compile progress. These contents can be revised and compiled for publication of the project for open source work.
System is too delicate and is not robust to collisions or unintended forces imparted on system within reason. System cannot withstand shocks or impacts imparted due to it falling on its own weight.	Medium	Low	Static FEA should be performed on designed hardware components with defined loads in order to assess weak points and components should be designed to a reasonable factor of safety. In addition mechanisms and assembled components should have proper fastening and mating interfaces to mitigate failure point risks. Load studies may potentially be done on larger subassemblies of the humanoid in order to better understand system level FEA loads.
Softwares or programming packages require excess compute power that we do not have access too or are time limited byf (ie. FEA mesh resolution, lightweighting analysis, or physics simulation)	High	Medium	Mesh or analysis load should be simplified to fit local compute constraints. If local compute job cannot be completed escalate to K-scale to utilize Andromeda cluster or create simplified alternative analysis job in order to perform technical analysis.
Gap in accuracy between physics simulation testing and physical hardware representation is so great that designed system is inaccurately represented.	High	Low	Physics environment parameters must be checked and verified prior to running simulation to ensure an accurate environment is created. If the simulation is missing or unable to reflect a physical parameter, this should be disclosed in technical write up for additional assessment.
Physics simulation platform parameters are incorrect and do not reflect physics or have unjustified suppression of physics phenomenons, resulting in accurate simulation validation.	High	Low	Physics environment parameters must be checked and verified prior to running simulation to ensure an accurate environment is created. If the simulation is missing or unable to reflect a physical parameter, this should be disclosed in technical write up for additional assessment.
Designed parts will lead to system overheating due to poor thermal management.	Medium	Medium	Basic thermal analysis of hardware designs and actuator temperatures should be performed to ensure housings and actuators are compatible and are designed with thermal constraints in mind.
Designed parts cannot handle loads or when assembled cannot handle loads and would lead to part failure if manufactured to spec. (ie. part shears, fractures, breaks, etc.)	Medium	Medium	Static FEA should be performed on designed hardware components with defined loads in order to assess weak points and components should be designed to a reasonable factor of safety. In addition mechanisms and assembled components should have proper fastening and mating interfaces to mitigate failure point risks. Load studies may potentially be done on larger subassemblies of the humanoid in order to better understand system level FEA loads.
Designed hardware does not account for electronics and sensor footprint.	Medium	Low	Defined electronics, cabling, sensors, and any additional circuitry packages should have preliminary footprint definitions so component space will be accounted for in design.
Designed hardware does not account for cable and bend radiuses associated with ranges of motion.	Medium	Low	Cables for actuators and electronics should be accounted for, bend radii and cable routing solutions should be assessed to ensure there are no pinch points and robot has sufficiency design for wiring internally or external to the robot.
System operation is too brittle to indoor environments due to humidity, heat, or dust.	Medium	Low	Environment range should be defined or limiting constraints should be defined. If hardware related components should mitigate risk of failures due to general environment in a warehouse setting or household setting.
Mass distribution among joints and linkages inhibits locomotion of humanoid or could lead to tipping angles in various motions in its defined workspace.	High	Low	Validate functionality in simulation and revise based on performance, Perform FEA to ensure components are not overengineered. Determining center of mass of complete system and subassemblies to evaluate critical angles for tipping. Reduce critical tipping risk as needed.

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Humanoid feet and legs are not designed to handle unstable terrain and could slip if it interacts with planes that are not perfectly level.	Medium	Low	Understand angle and leg design and investigate foot pad materials and total component design to be tolerance to uneven surfaces. If not possible concede design flaw in write up and point of improvement.
Assembly and humanoid maintenance is not feasible due to system design and cannot be assembled or maintained long term.	Medium	Medium	Design for assembly should be kept in mind during the design process and once a subassembly has been defined it should be proofed out for assembly. If a tooling strategy is required for assembly it should be defined. If the components cannot be assembled from parts this should be noted and design should be refined to enable proper assembly with minimal tooling overhead. In addition of components like actuators, electronics, or cabling needs to be accessed a well defined strategy for accessing components should be defined and feasible. If it is not a design should be refined to enable this or access points should be added to allow for repair.
System is not designed with calibration in mind for actuators thus motors cannot be calibrated. System cannot operate.	High	Low	Actuator encoder configuration should be known and subject matter experts at k-scale should be consulted to discuss the feasibility of design while accounting for proper calibration of actuators as needed. If the are not, then hardware should be revised to enable proper calibration.
System is not tolerant to vibrations and system is not compliant enough to handle impacts.	Medium	Medium	Utilizing simulation softwares like SolidWorks simulation should be leveraged as necessary to understand components vibration characteristics. In addition, specifying materials, and creating spring and mass models for basic level analysis of component stiffness should be done in order to validate subsystems that are dealing with significant impacts like legs.
Shock hazard is not mitigated due to electrical malfunction risks. System is not properly grounded.	Medium	Low	Grounding should be accounted for and assessed to ensure that the risk of shock hazards and electrical failure modes induced by hardware are minimized.