PDR script

Thank you, Michael.

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The mechanical system was designed to 2 main functional requirements. The first being that SKADI shall provide force and motion cues correlating to the phase in jump. As seen in the conops, we will be simulating the takeoff phase where the ramp begins to curve. We will cue when the user is to prepare for flight by enacting forces analogous to those caused by this curve. We’ll talk more about the specifics of this soon, but I wanted to mention another important goal of this system which is to minimize forces on the user that would not be felt during a real jump as to preserve the efficacy and immersion of the training simulation.

We also designed this system to the functional requirement of SKADI being able to support all forces generated by the athletes and itself. In terms of simulation design, we chose to minimize the velocities and therefore momentums that would be part of this design. This also comes with the added advantage of creating a safer experience for our athletes.

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To begin this design, we first had to develop two models. One to estimate what forces are felt by the skiers during a jump, and one to see how we will be able to mimic these forces mechanically. To begin the development of these models we had to make a few assumptions. First, we looked at what masses of jumpers we would be dealing with. According to the 2014 Sochi Olympics database, skiers’ masses range up to 98 kg. We multiplied this maximum mass by the maximum G force we will enact (1.1 Gs). We doubled this mass to account for the gear they will be wearing and any movements they might make. Next, we estimated that the platform itself could be up to 50 kg, so we tacked that on as well. Finally, we added a factor of safety of 2 to the entire expected mass to give us a total of 540 kg for which we must design.

Based on a recent study on Normal accelerations, we found that 0.02 vertical Gs is the minimum added acceleration that a human can detect, so we must generate more than this during our simulation.

Finally, to break into the design loop, we assumed that kinematic calculations could be used to give us an idea of where to start with our design in terms of time, displacement, velocity, and acceleration. We made sure to use a numerical model to develop the simulation further and ensure that the resultant design met all of our needs.

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The idea of compression as the takeoff phase cue was originally brought to our attention by our contacts at Nordic so we wanted to ensure that this change in force was a valid property of the jump. Looking at our force model of the in-run and takeoff phases to the right, we can see that the compressive G force does increase dramatically at the transition between phases designated by an increased lightness in color on the graph. So yes, this type of cue will be sufficient. Some initial calculations showed us that matching the magnitude of on-ramp accelerations would be unfeasible given our constraints on size and budget, so we decided to generate a scaled down version of these accelerations. Based on our findings of 0.02 minimum detectable Gs, we decided to add a FOS of 3 and design for at least 0.06 Gs to ensure the athlete would feel the cue.

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Once we knew what we wanted to do to these athletes, we had to figure out how to do it. We performed a kinematic study to find out what types of accelerations can be generated with the time and volume constraints we’re working with. The portion of the jump we are simulating is supposed to span about 2.5 seconds and based on some preliminary research on actuators we knew we would have to operate within about 1 meter. Using these constraints, we tried to find a balance of minimizing velocity while maximizing acceleration. This study yielded a happy medium of 0.033 Gs and a maximum 0.8 m/s. We used this acceleration as an average to generate a gaussian distribution describing the athlete’s acceleration profile.

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Why did we use a gaussian distribution? In the practical world, forces cannot be enacted immediately so we need some non-infinite slope to describe how the accelerations will be applied. This distribution is defined by a maximum, an average, and time which match our design constraints.

\*We also found that a gaussian profile of accelerations requires more mechanical ability than other profiles that we might use instead. We recognize that there is value in flexibility and designing to this profile grants us some flexibility.

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To continue with the theme of practicality, we wanted to enact these accelerations without throwing our athletes at the ceiling. Thus, we decided to mimic the motion of an elevator. We will start the simulation by putting the athlete into a near free-fall to generate velocity, and then apply the upward acceleration profile to counteract this velocity, eventually bringing the athlete to rest. We used an ode45 integration model to cyclically design this system and ensure the user is brought to rest.

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The user states corresponding to the resultant system design can be seen here on the left showing that the user is displaced no more than 0.8 meters and ensuring that their velocity begins and ends at rest.

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These states correspond to the user acceleration profile shown here where they begin in free-fall, the actuators begin pushing up, and then follow the gaussian curve described earlier. With this design, we found that we can enact a total of 1.1 Gs on our athletes which exceeds our desired 1.06 Gs. For this design to work, we need a mechanical actuator that can provide 1075 N of force and an acceleration of 1.1 Gs. This actuator must also be at least 0.8 meters in length, \*and it must be able to apply an impulse of 930 N/s.

I’ll now turn it over to Landon to discuss the actuators we found to meet these needs.