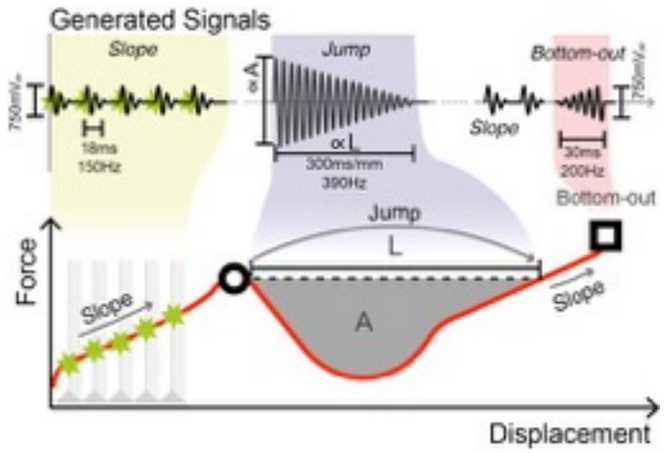
Haptic Feedback Design for a Virtual Button Along Force-Displacement Curves

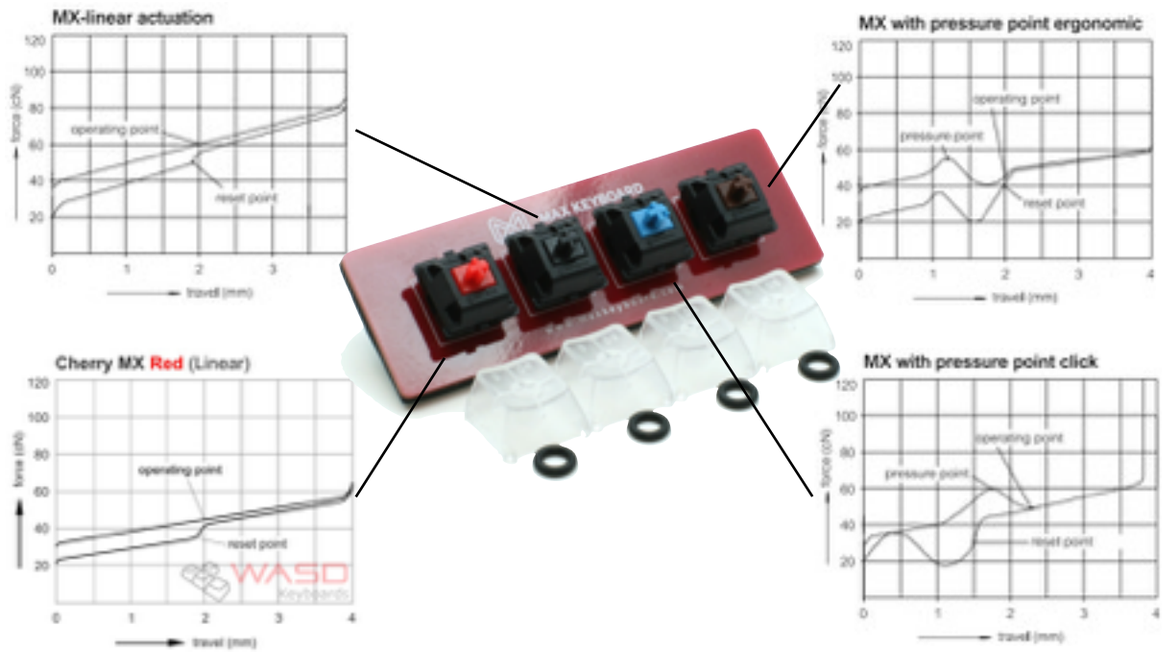
Sunjun Kim and Geehyuk Lee
KAIST HCI Lab



thanks to..

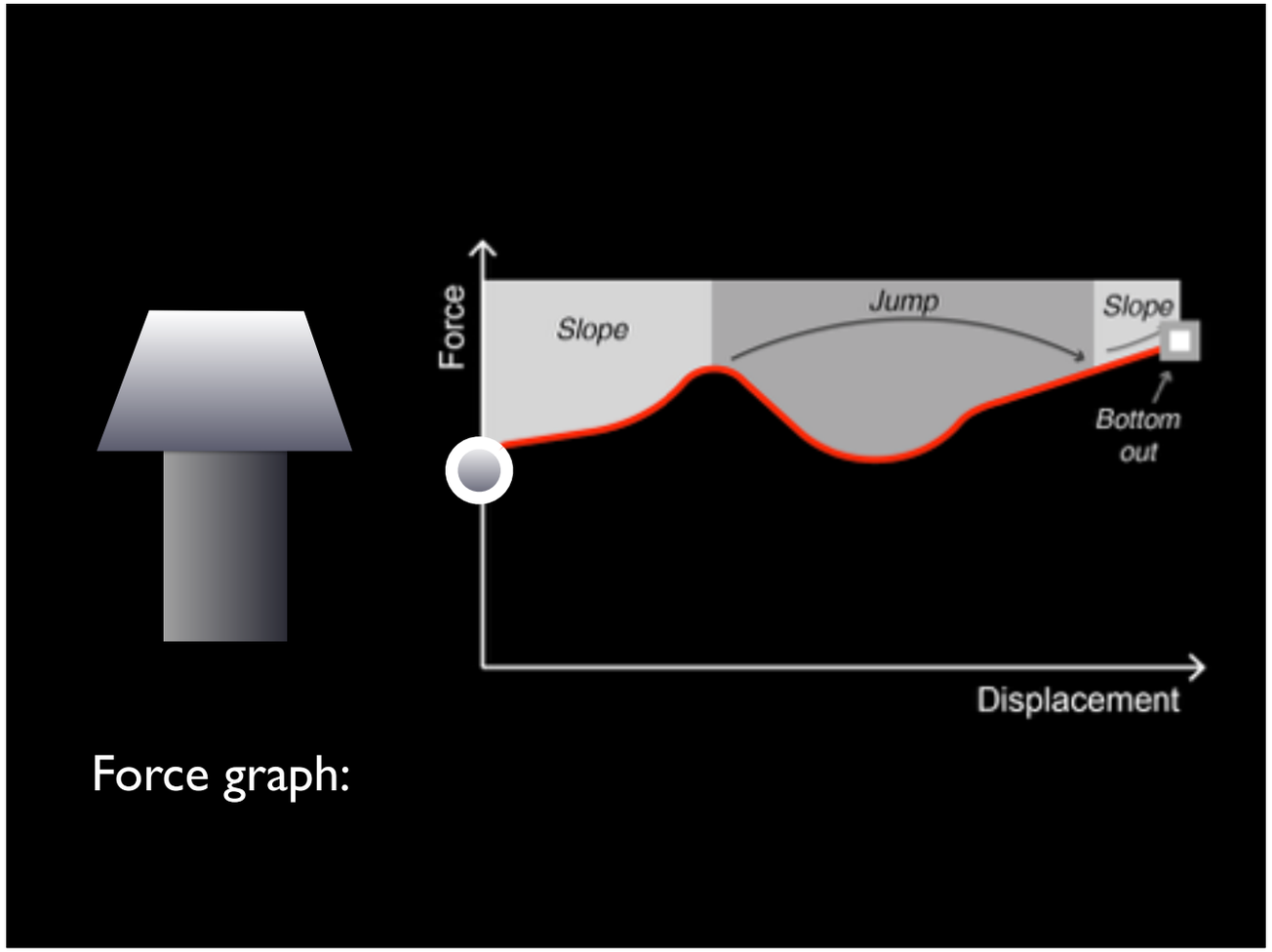
I love typing a keyboard. I enjoy the feeling of key presses.
Sometimes, I make my own keyboard like this picture. The most important thing, is the key switch selection.

It determines the feeling of the keyboard.
Mechanical keyswitch makers, such as Cherry Corporation, manufactures various types of switches.

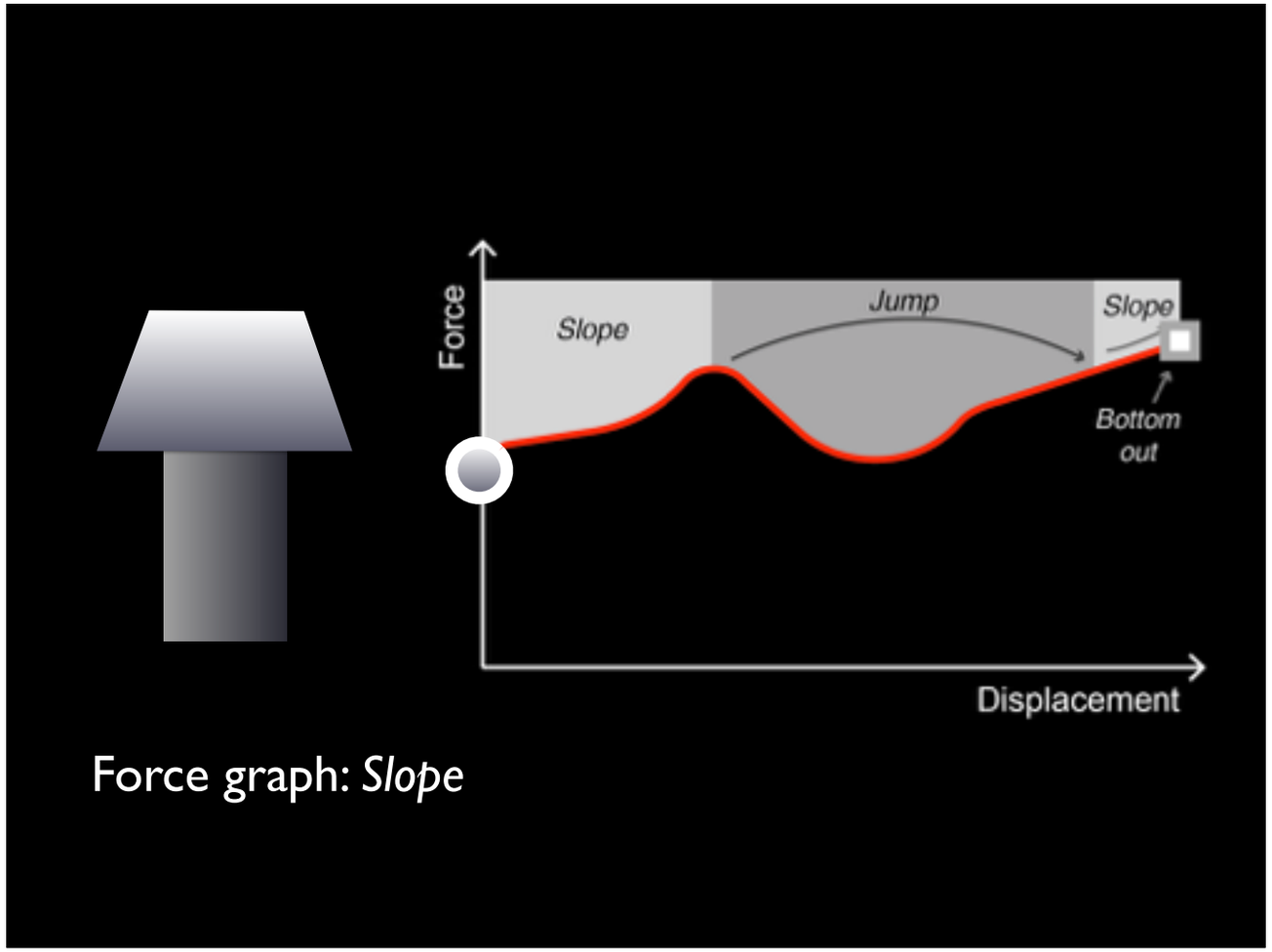


http://www.wasdkeyboards.com/media/guide/graph-mx-red.jpg
http://www.maxkeyboard.com/images/detailed/0/Max-Cherry-Sampler-Kit-001.jpg
http://cherrycorp.com/english/switches/pdf/mx_cat.pdf

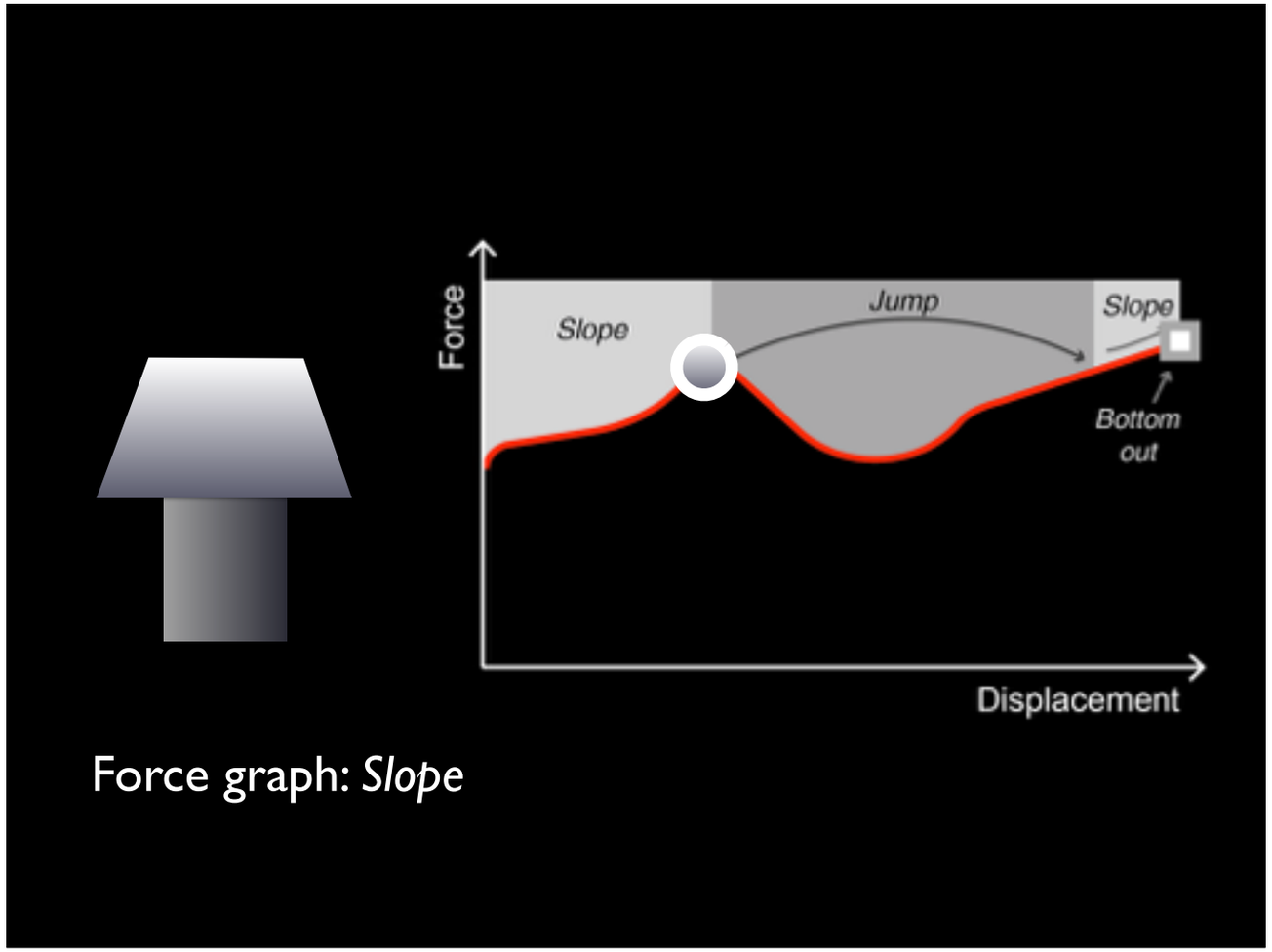
They describe the tactile characteristic of the switches by those graphs. We will call them force graph in this talk. Let's see how to read these graphs in detail.



This is a force graph of a typical tactile type switch. X axis is the displacement, or travel, and the y axis is the applied force at that displacement. Let's see what happens when we press a key switch.



First, the key is gently pressed down until the collapse point. We call this section in the force graph as the slope. In this section, it feels like pressing a spring.



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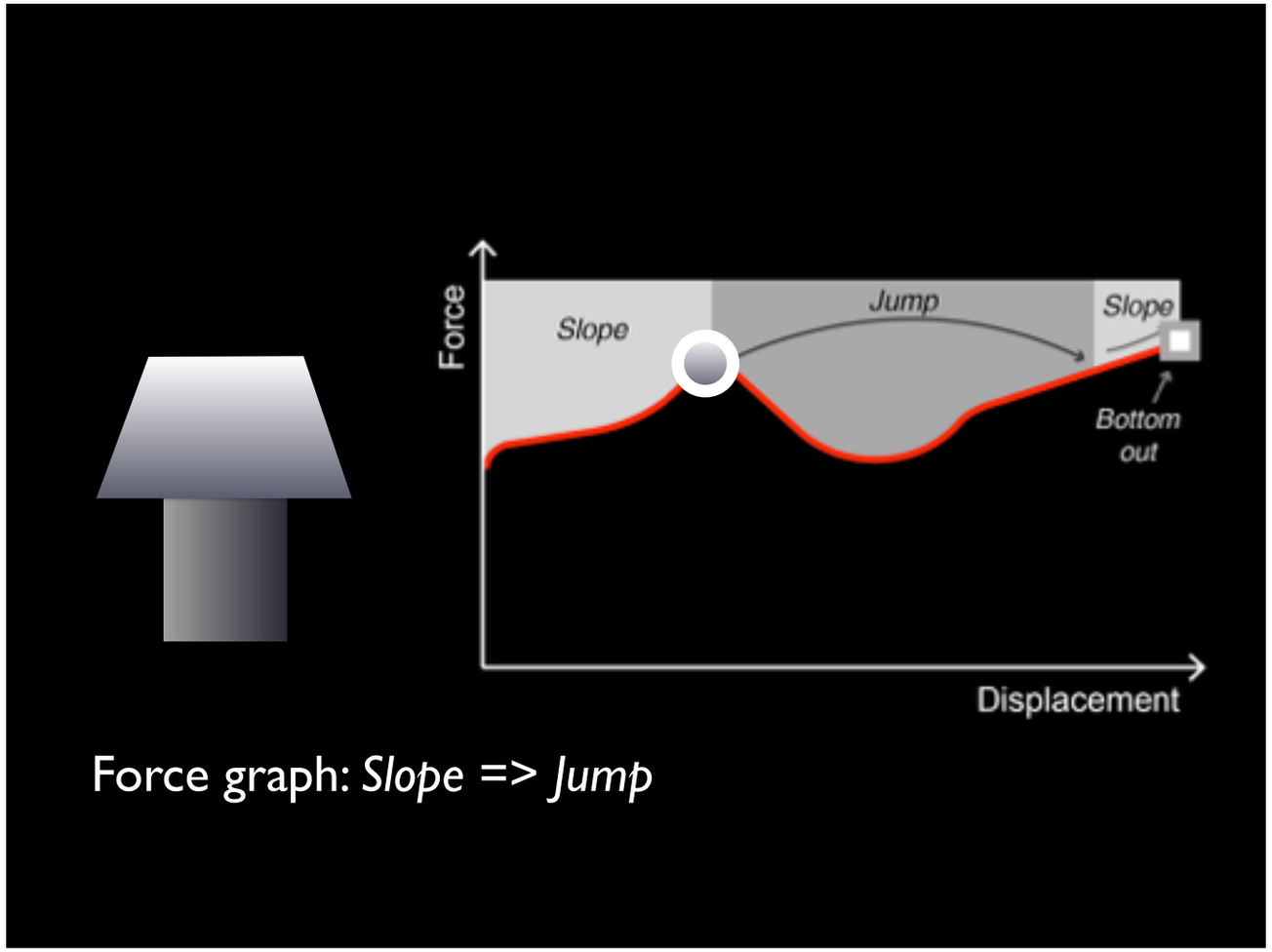
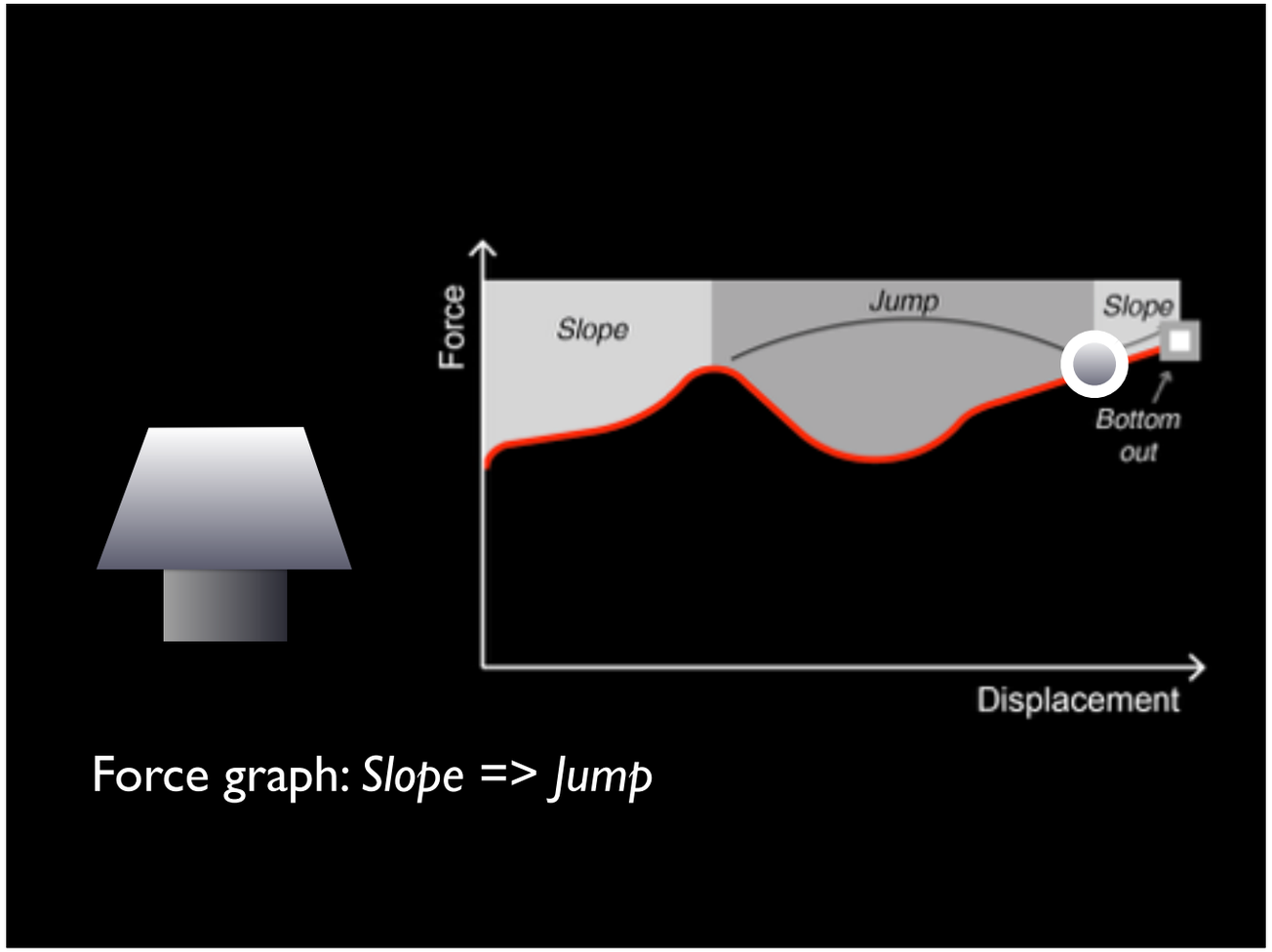


An then, at some point, the key suddenly collapse. We call this “jump”, and it is represented as a valley on the force graph.



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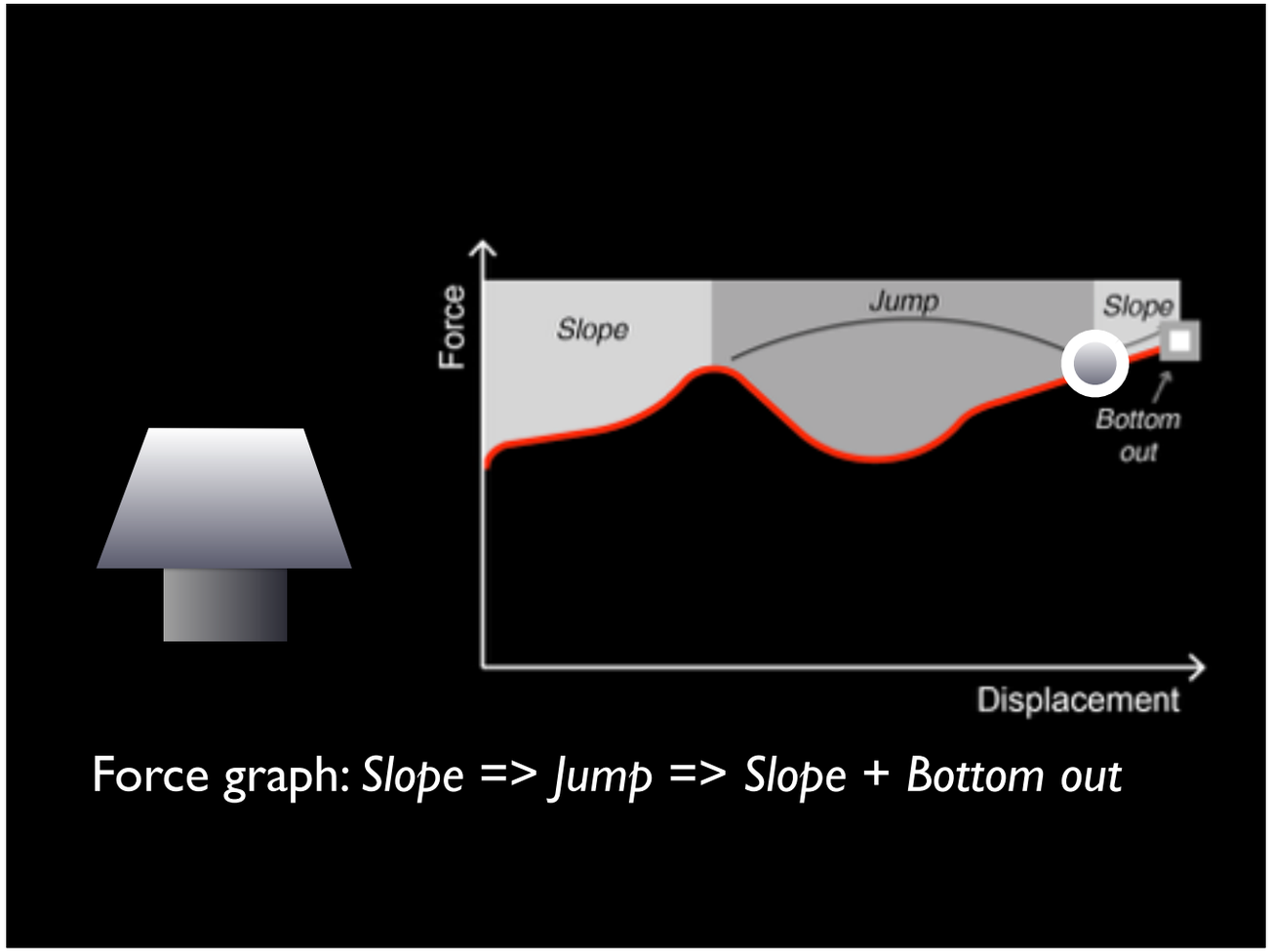
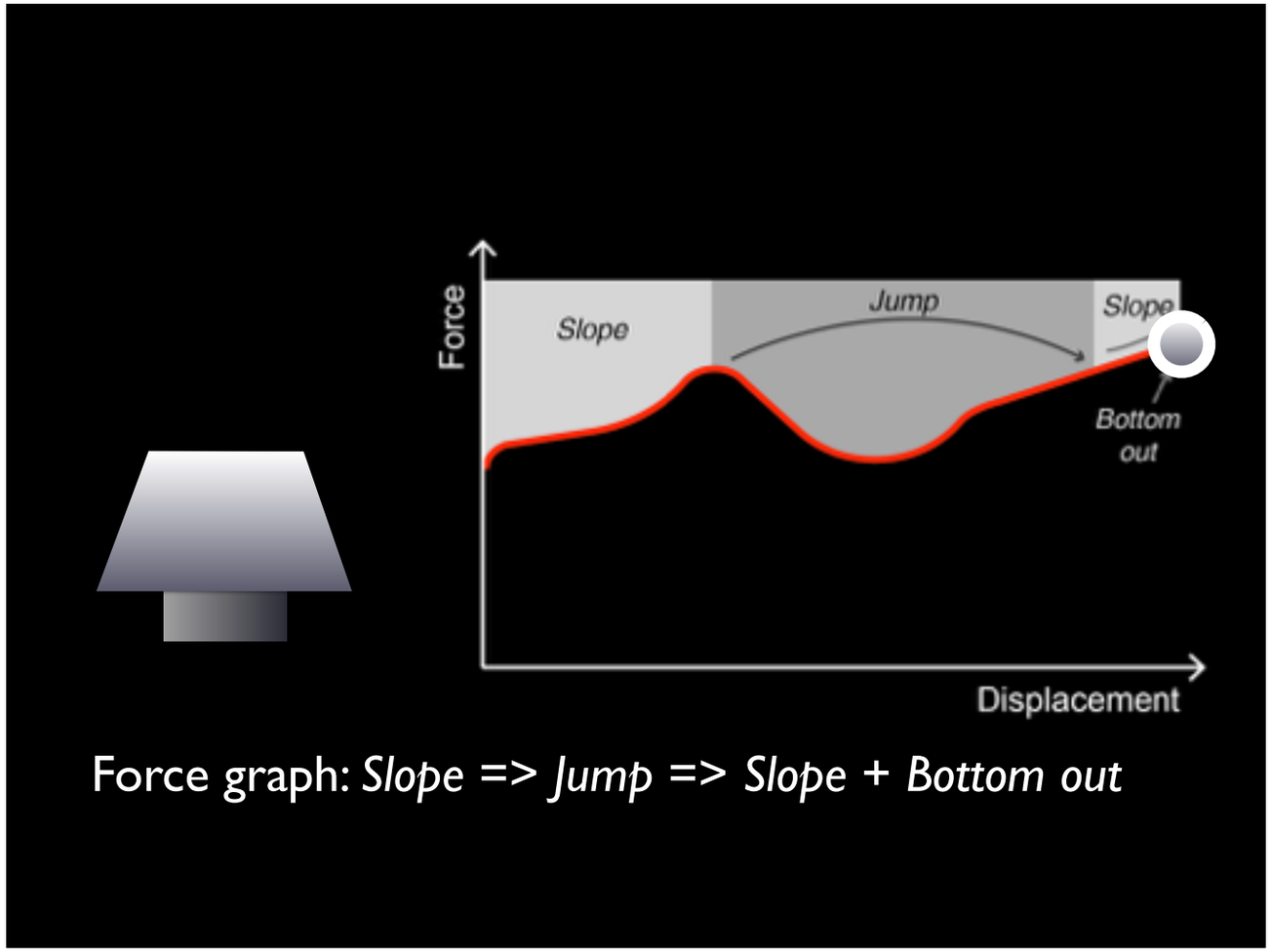


After another small slope, the key reaches its maximal travel. At this point, it feels like a finger bump on the table. We call this point as the bottom-out point.



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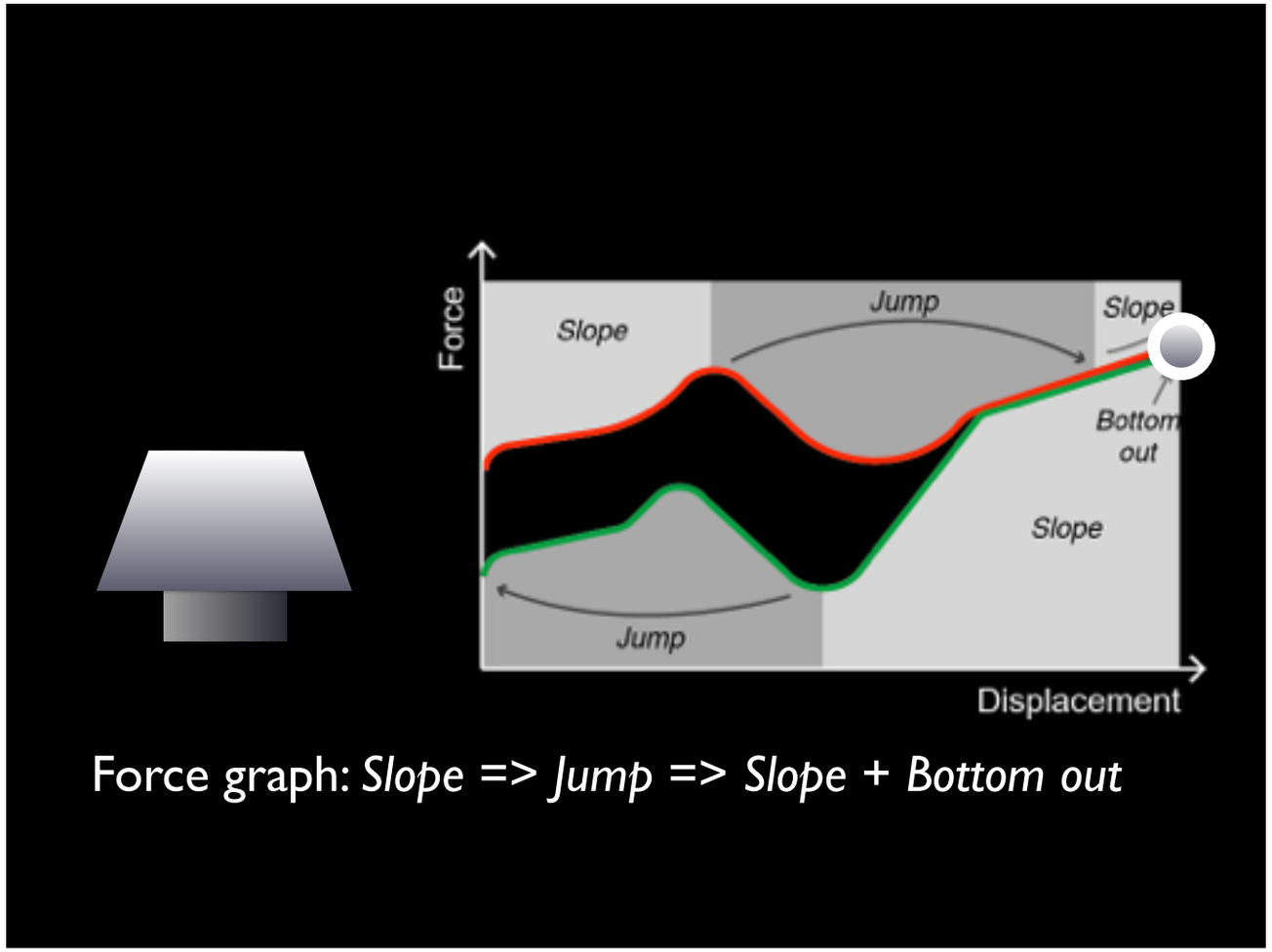
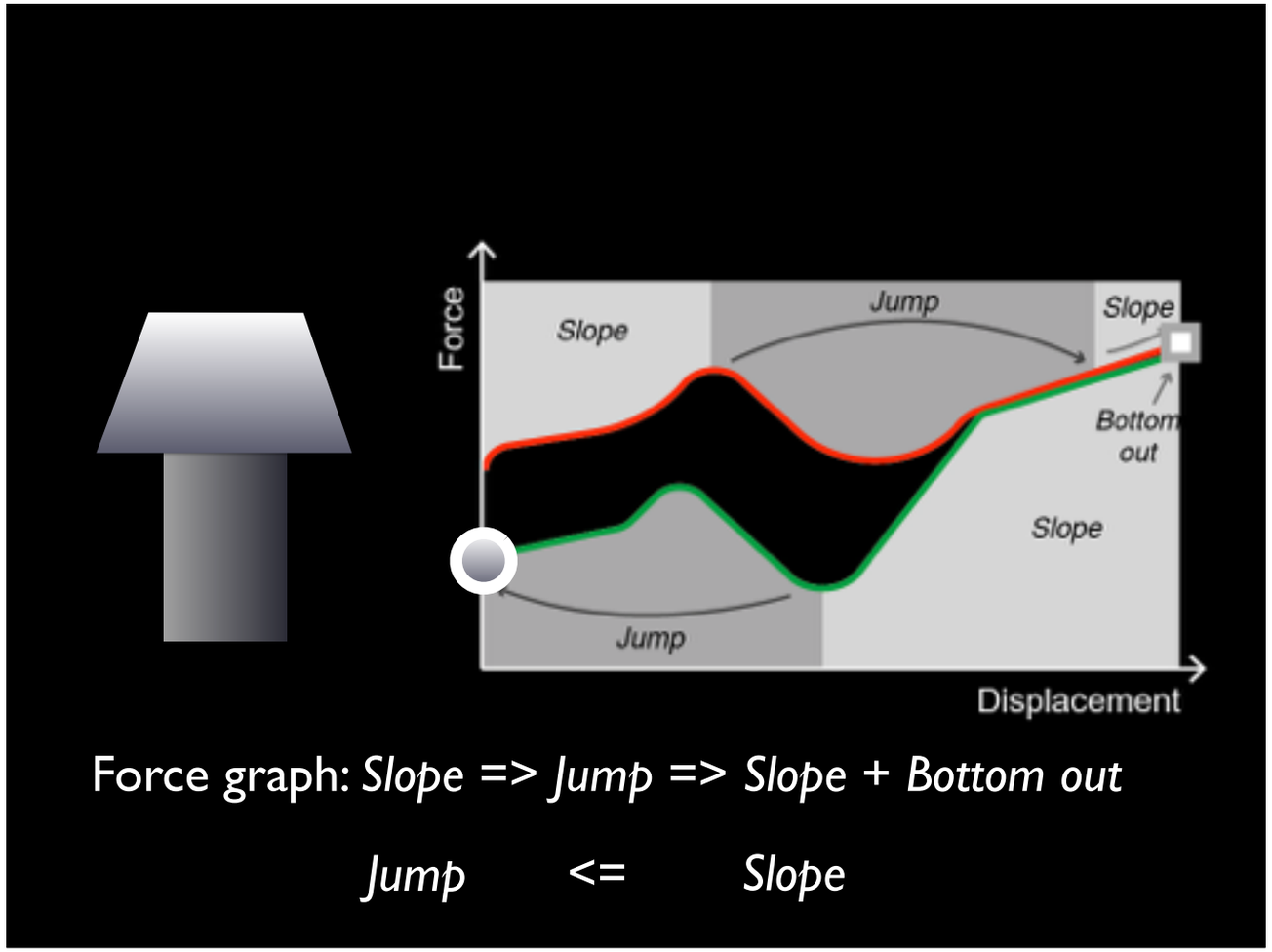


Some buttons have different force curves at pressing and releasing. We call them press curve, and release curve, respectively. in this case. it have a slope and jump at its release curve. It suddenly pops out during release.



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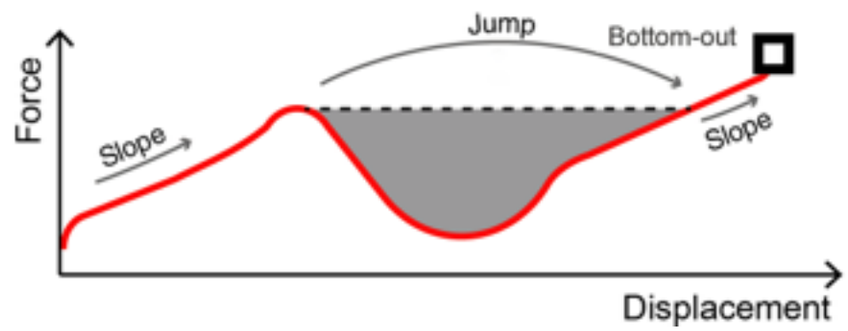
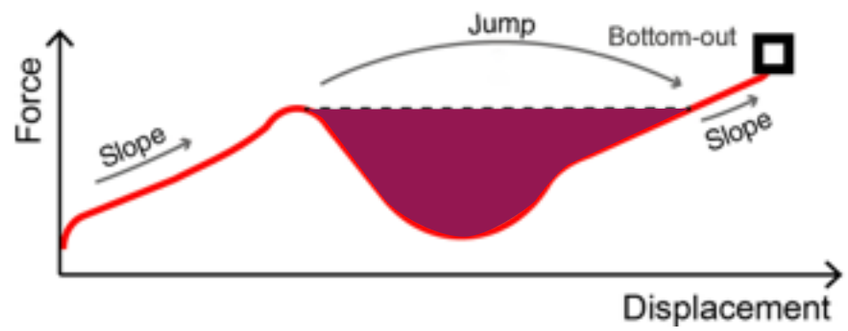
Let’s move our topic to mobile touchscreen devices. It is well known that touchscreen provides poor haptic feelings. I do agree with it. So I want to regenerate the pleasure of pressing a key on the touchscreen devices.

Related works



Most of previous virtual button studies are concentrated on the static feedback signals on jump section of the graph. It is natural that it is the most distinct part of the physical button dynamics. / Some other works tested a dynamically generated haptic feedbacks along to the different pressure. / Some works adopted force-displacement curves to describe the button movement, however they requires bulky force feedback devices and not for to the mobile devices.

Related works



Kim, J. et al., *Haptics* '12

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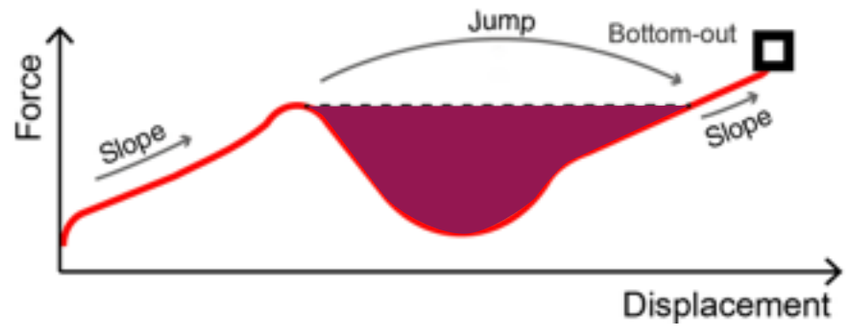

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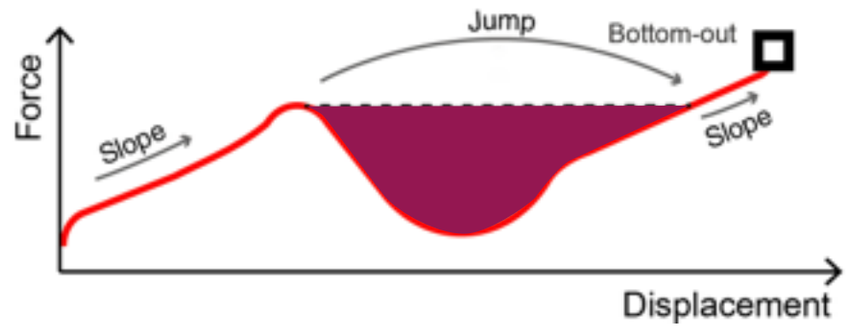

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Weiss, M. et al., CHI '11

Scilingo, E. et al., *Haptics* '10

Doerrer, C. and Werthschuetzky, R. EuroHaptics '02

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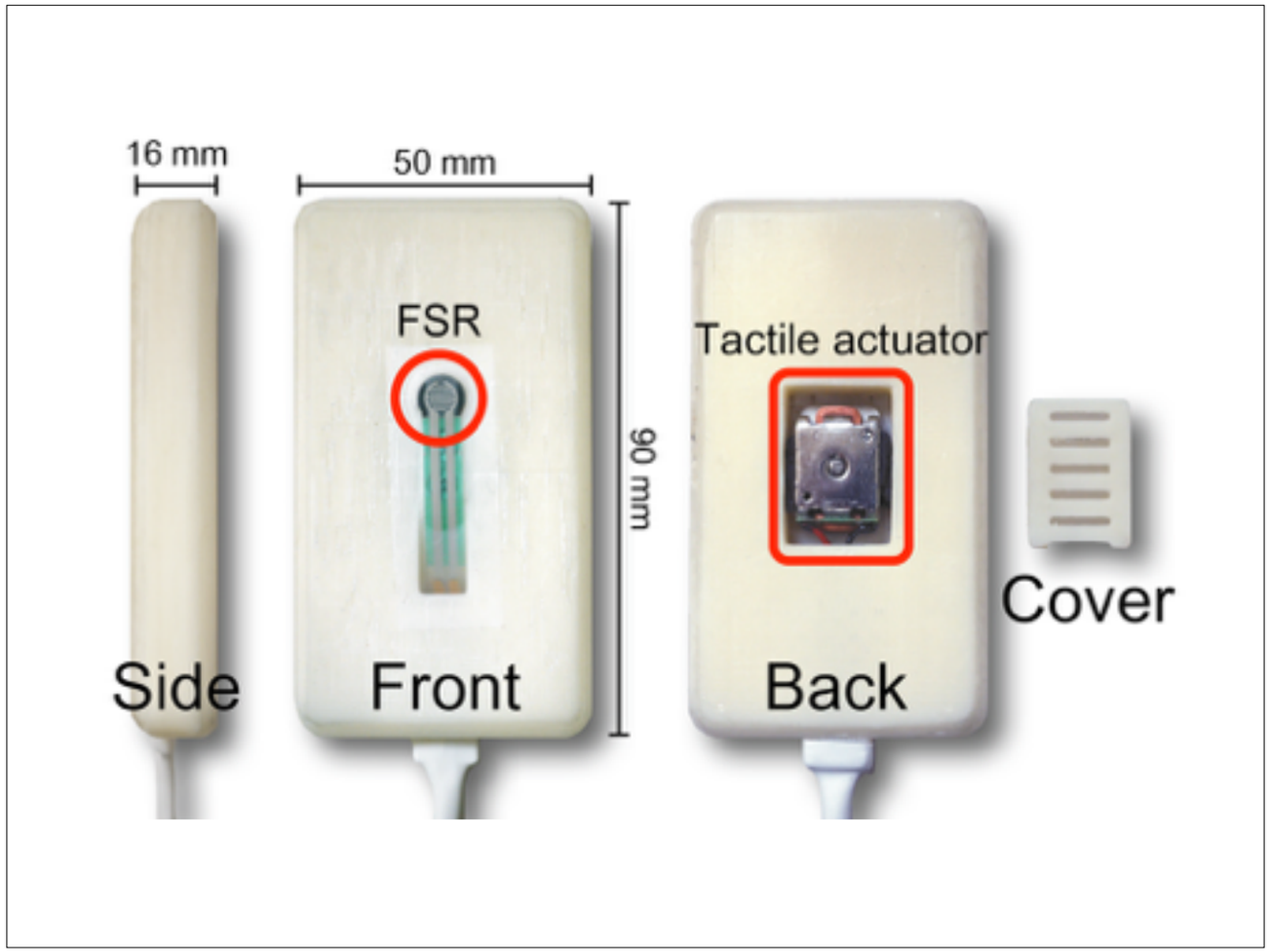
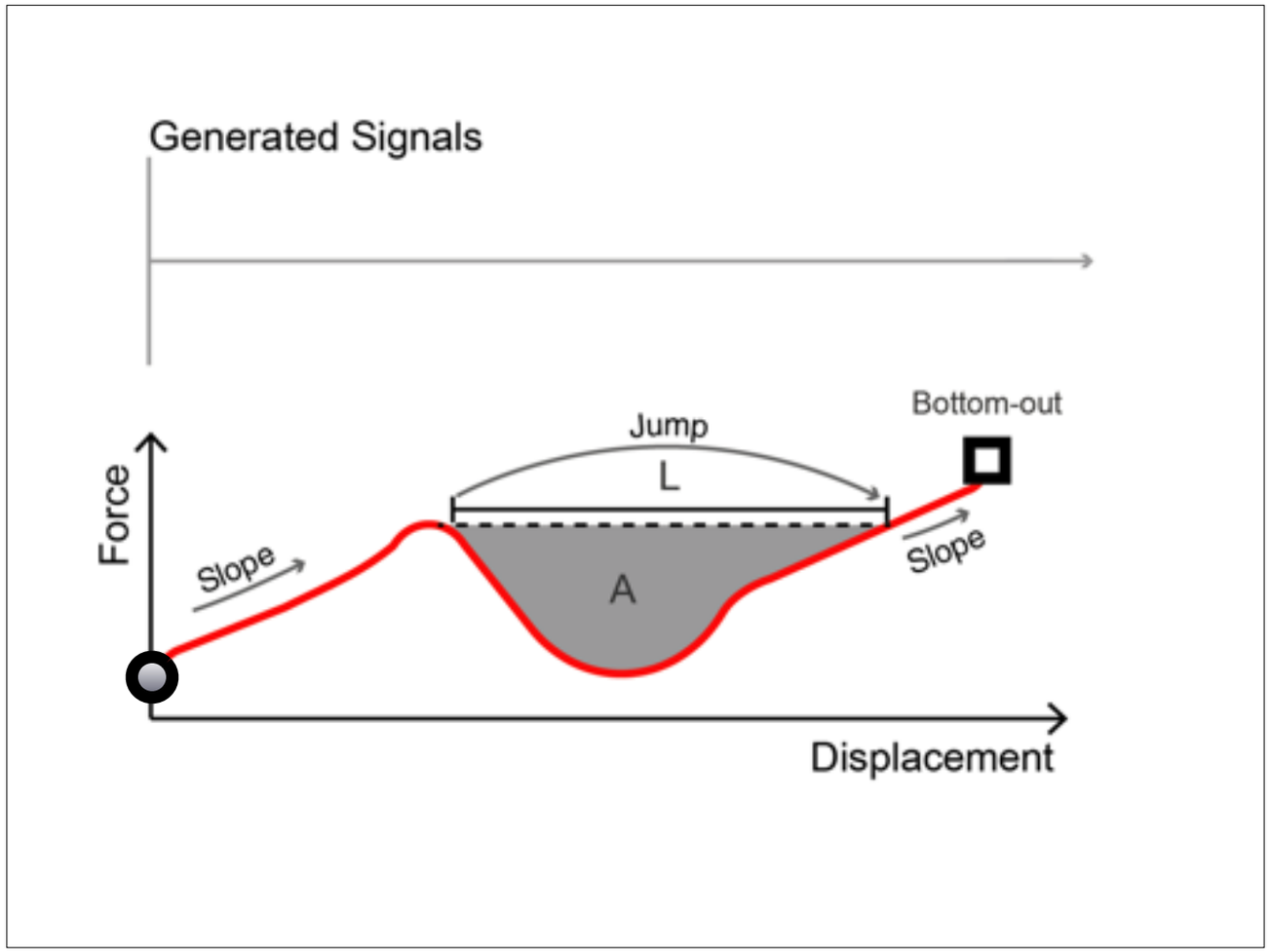
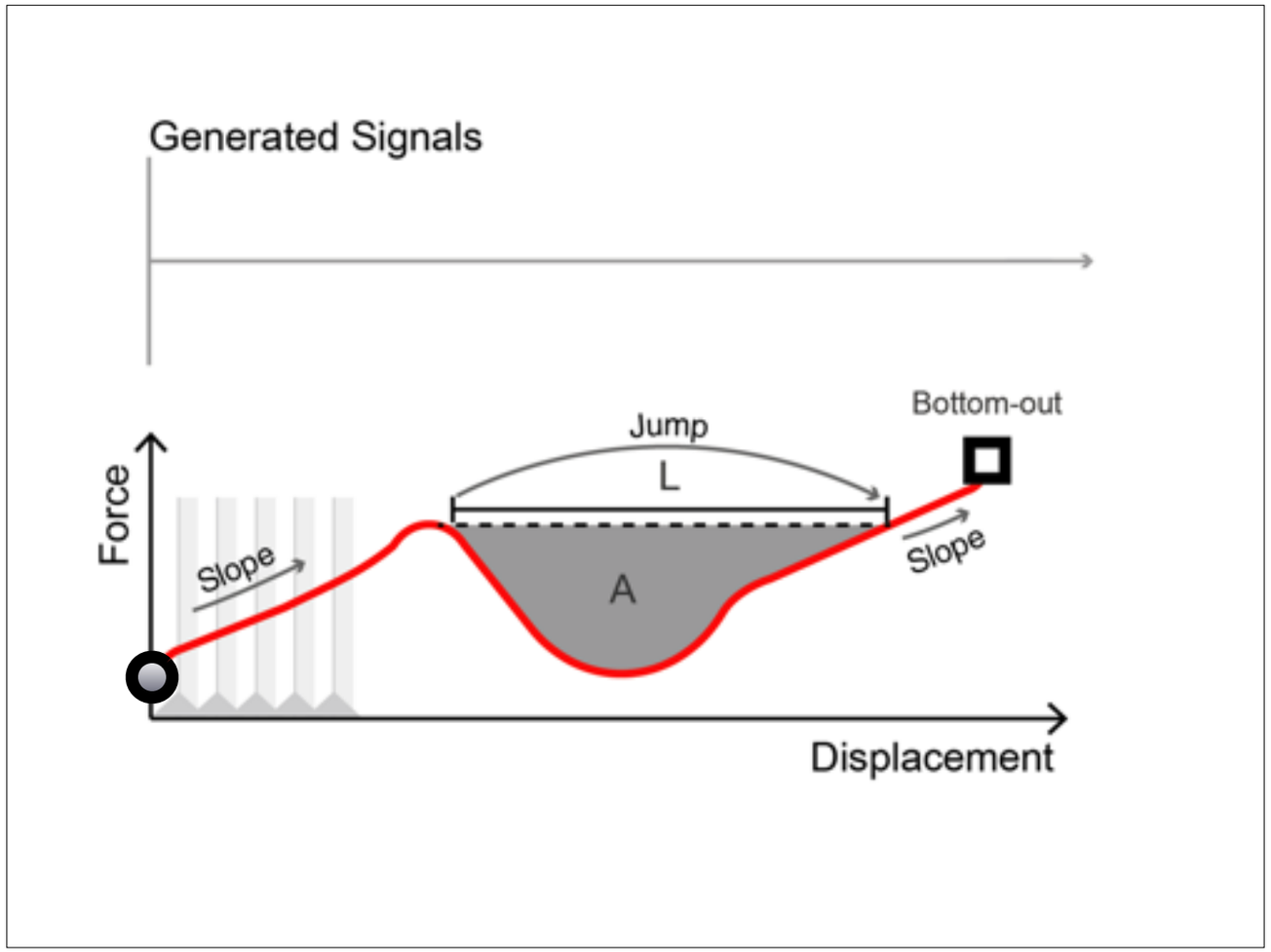


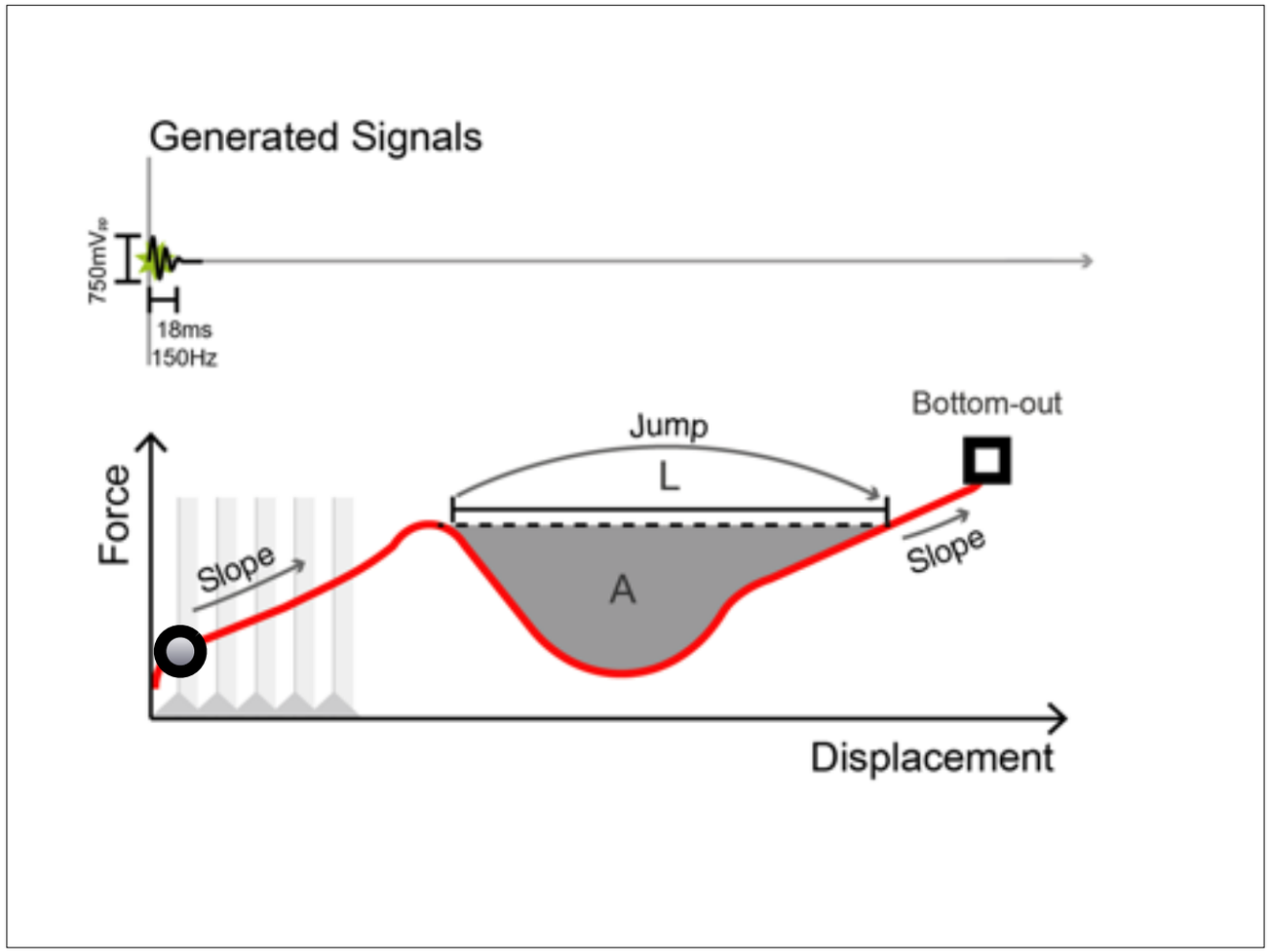
Because the force feedback device requires complex system, the best available option for the mobile device is a tactile feedback device.
In our work, we made a device which have a force sensor and wide-range tactile actuator. It uses voice coil, and it can play various range of frequencies.



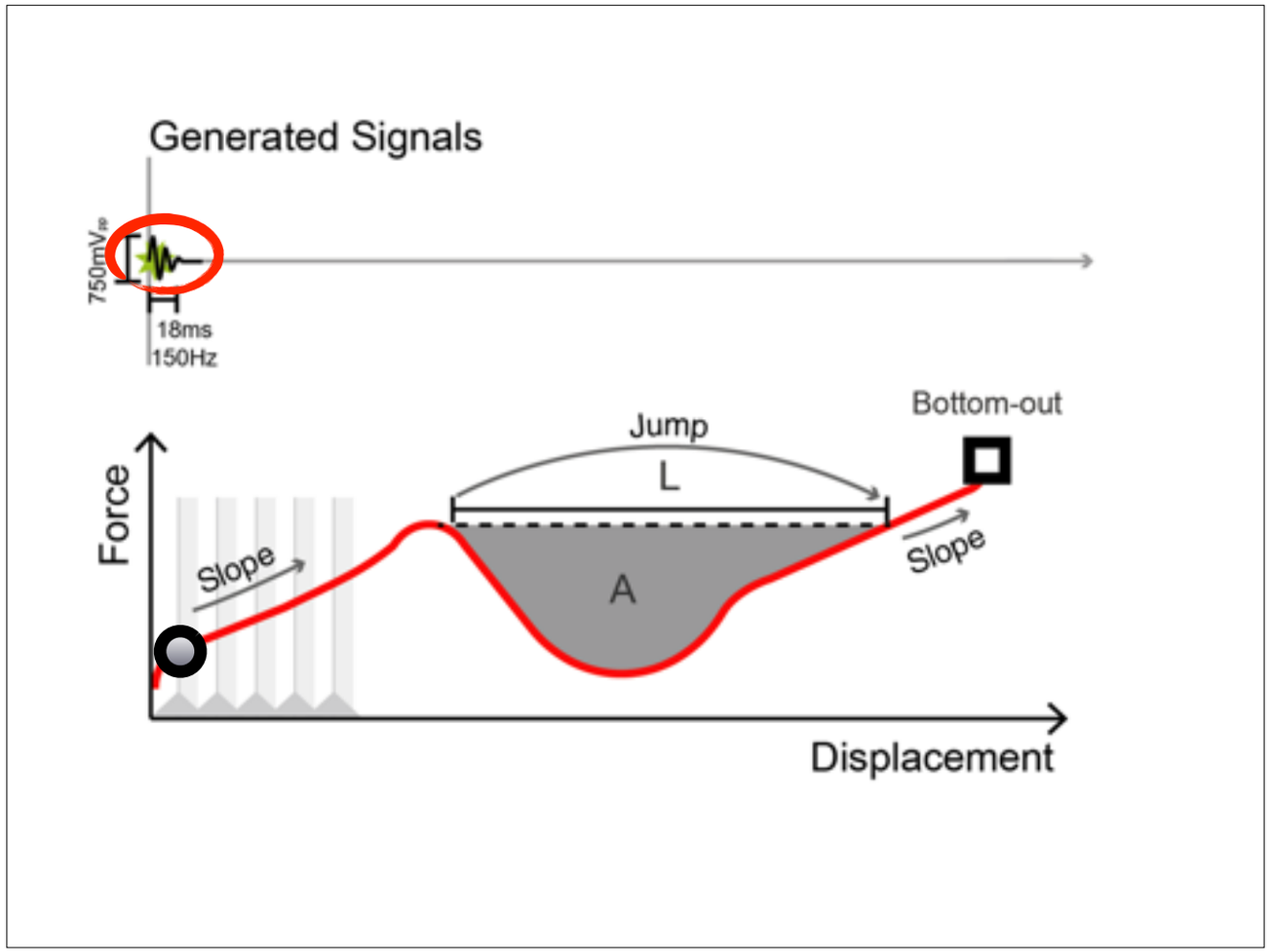
The most challenging part in our work was that to generate a sense of kinesthetic movement only with a tactile feedback device.



For this problem, Johan Kildal proposed a haptic grain model. He generated grain scratching feelings while pressing a rigid surface. It gives an illusionary compliance, in other word, illusionary kinesthetic movement.
Following his work, we designed similar feedback generation method for slope section. / evenly distributed grooves along to the displacement axis / kildal's work



then we generate a brief burst of grain signal while user press the virtual button and pass a single groove.



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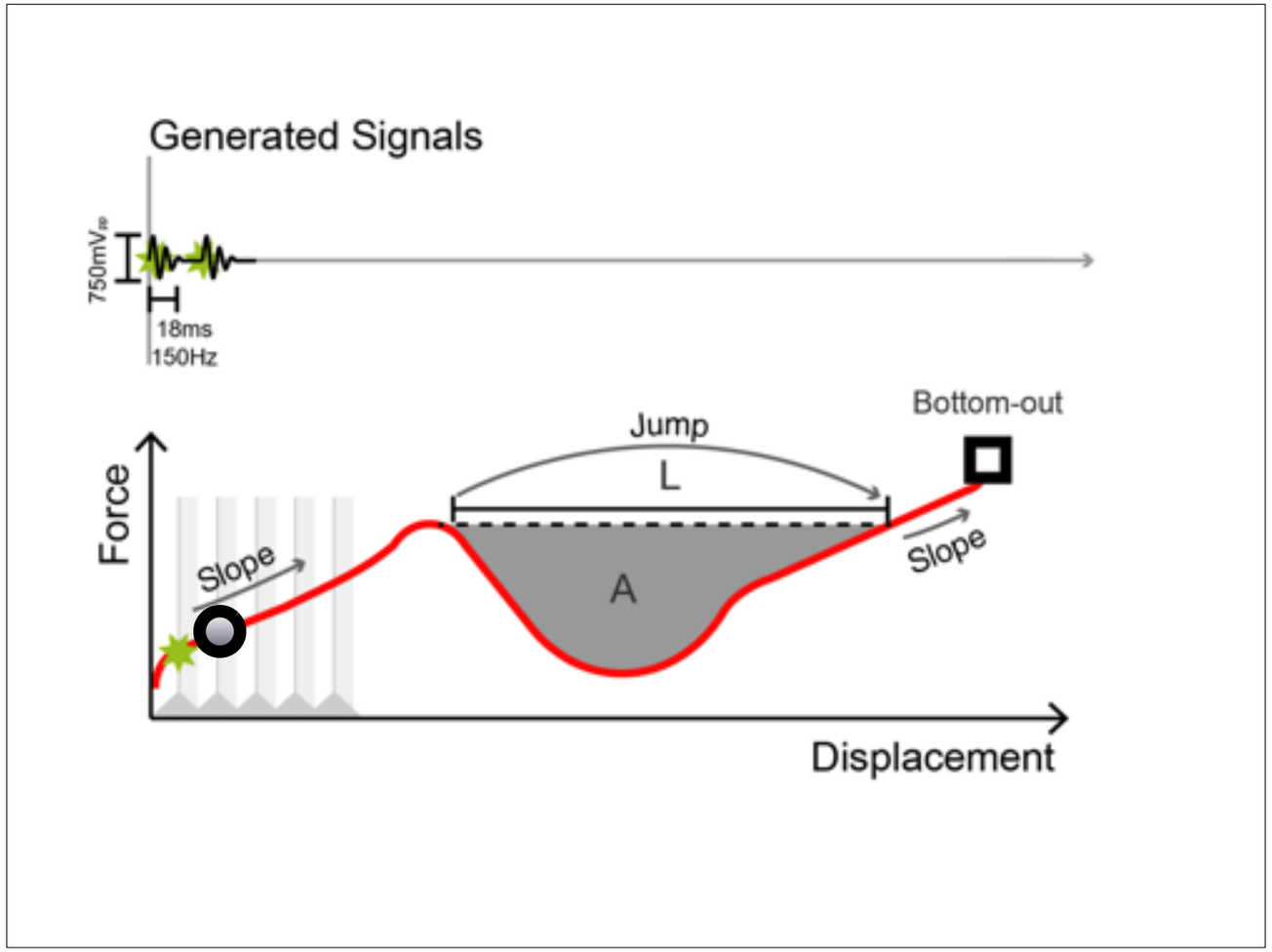
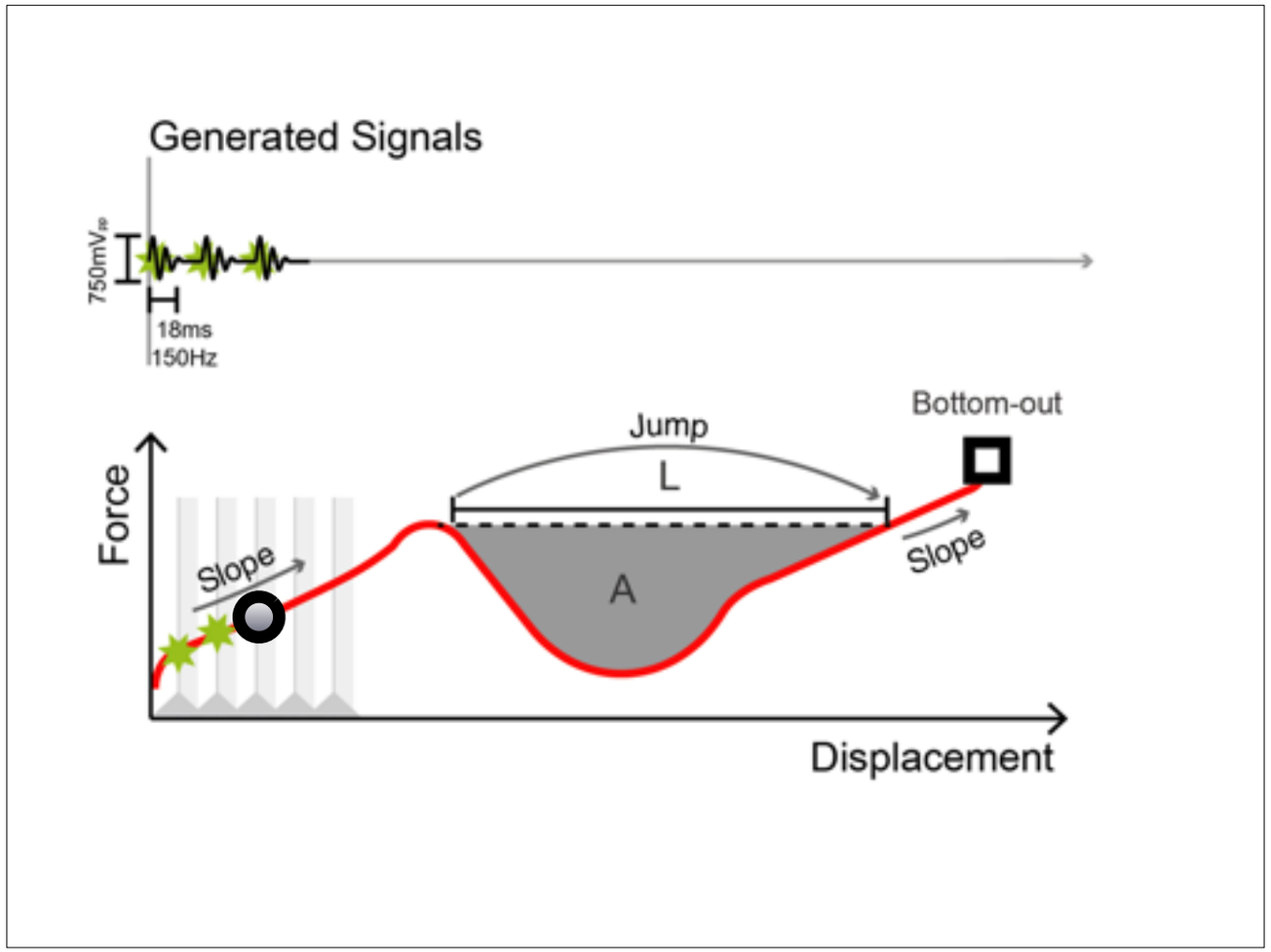
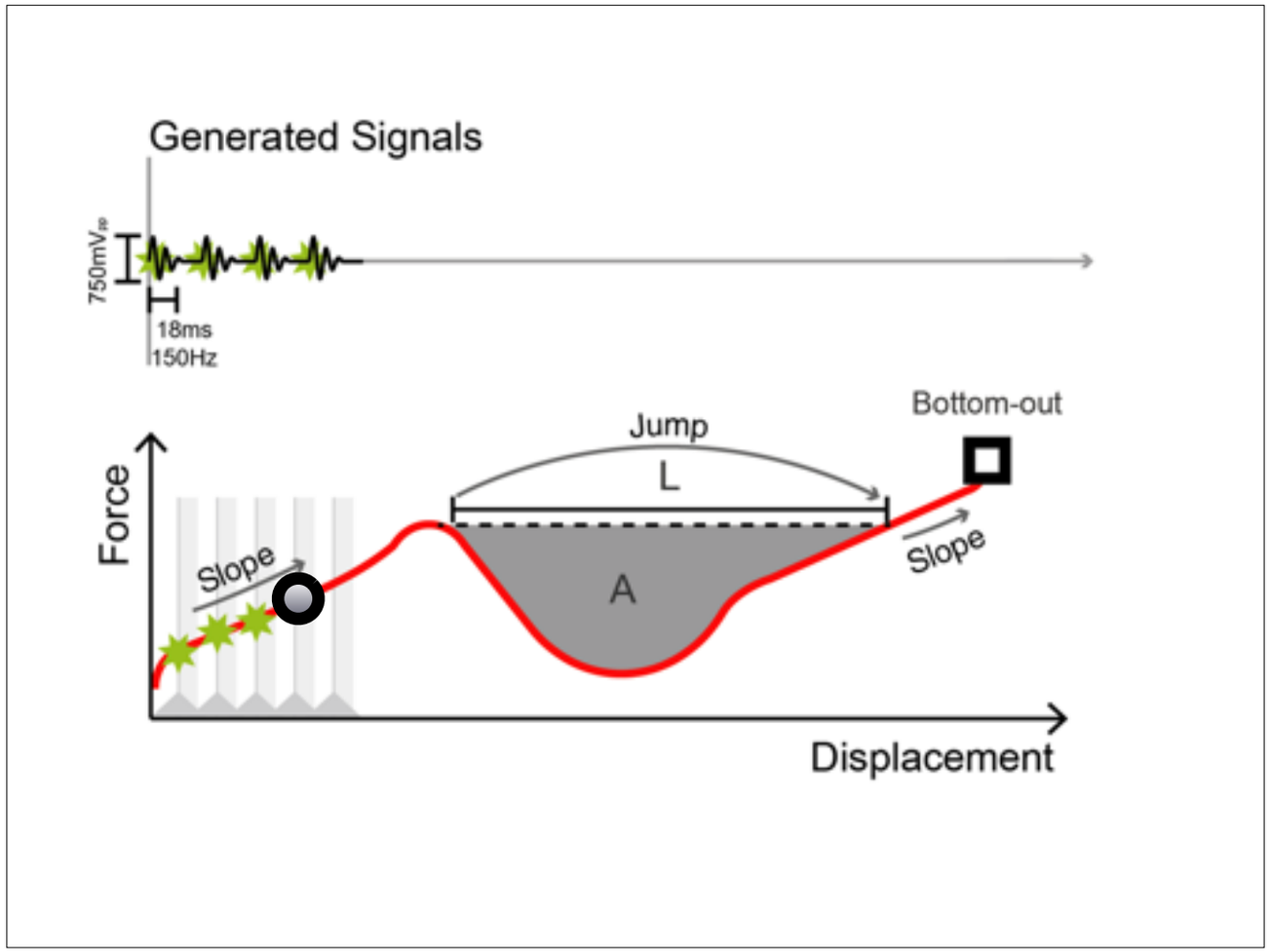


We've done this all the way to the collapse point.


Generated Signals
750mV
18ms
150Hz
Bottom-out
Jump
L
Force
Slope
A
Slope
Displacement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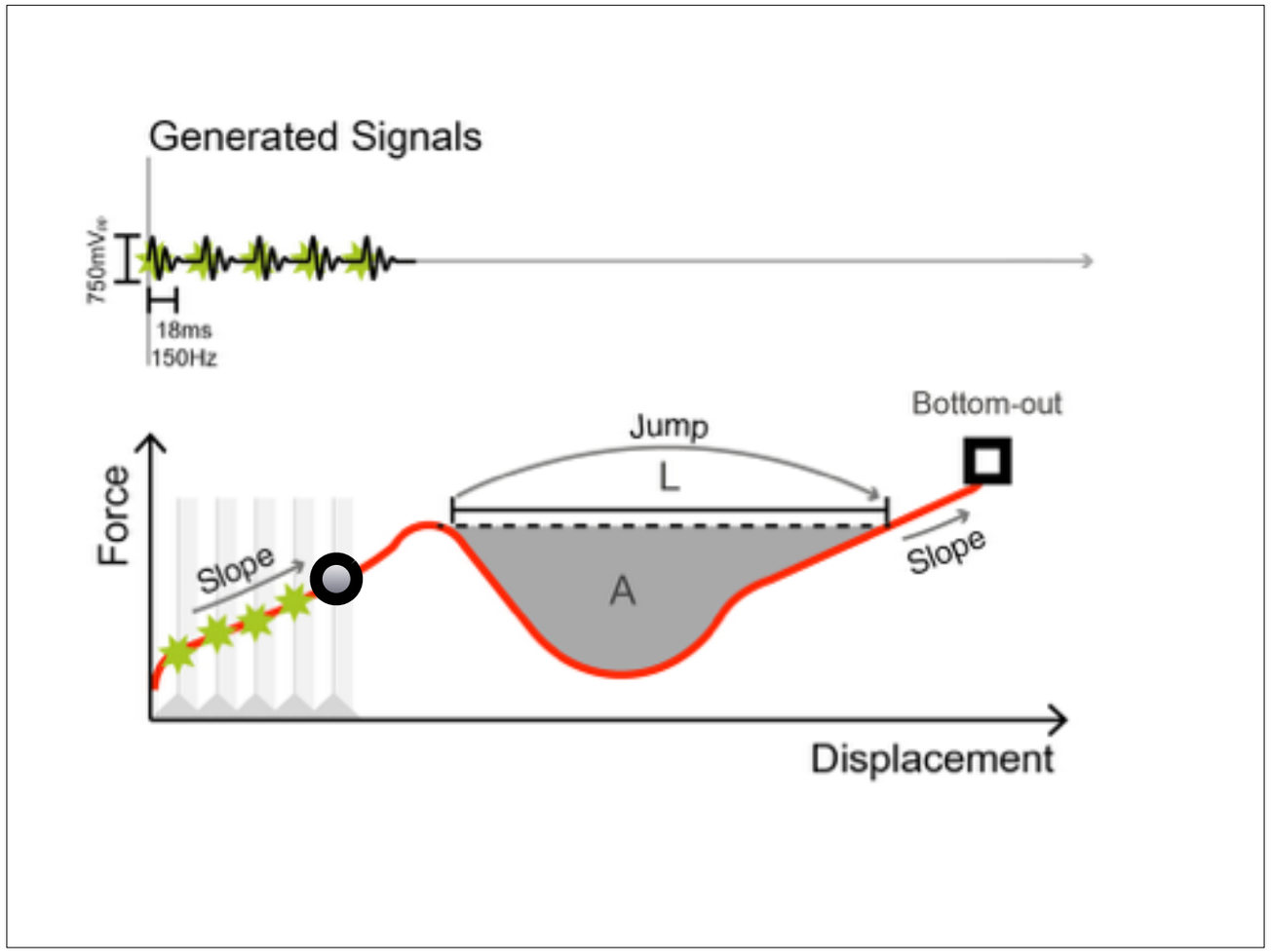
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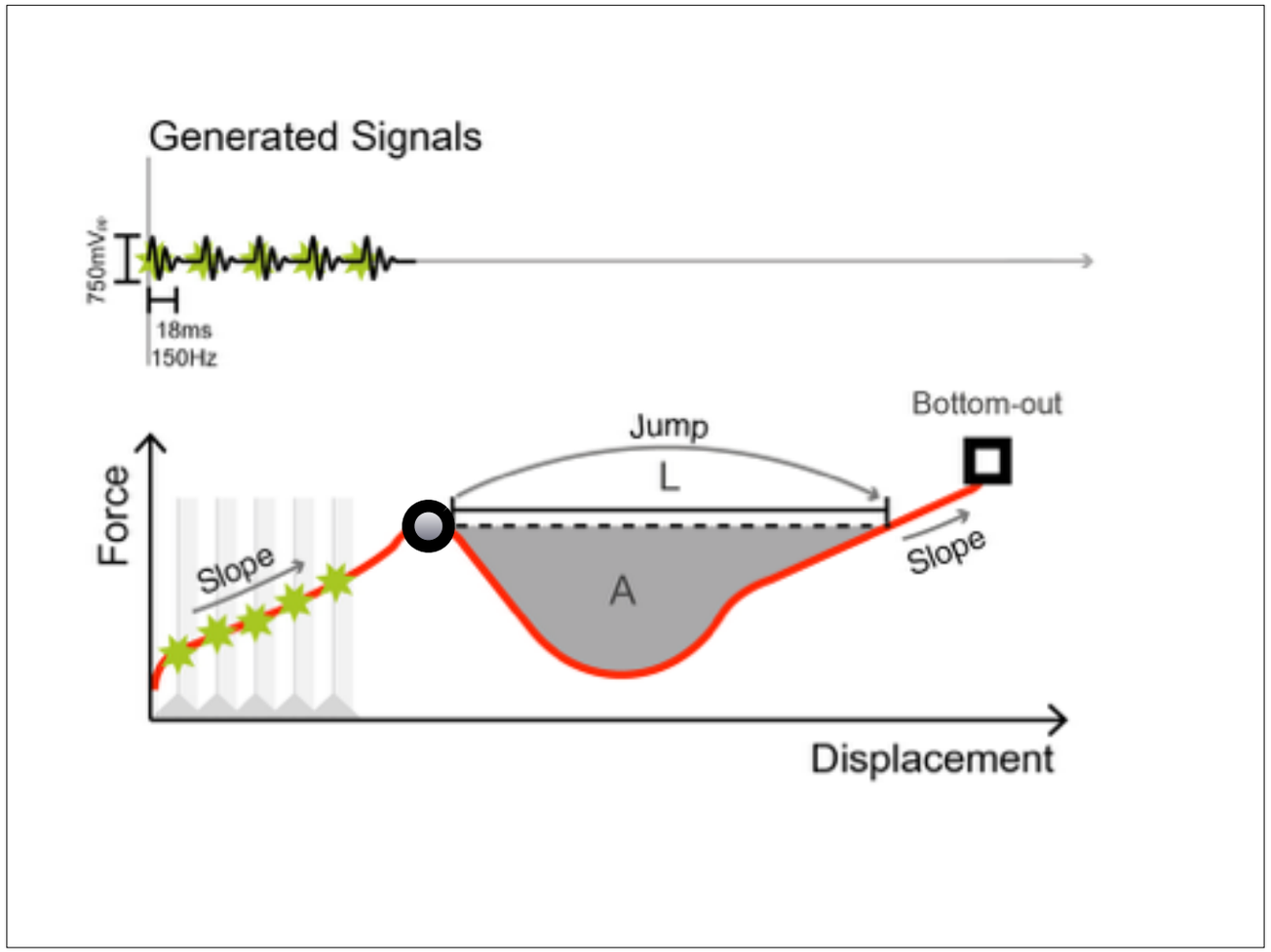
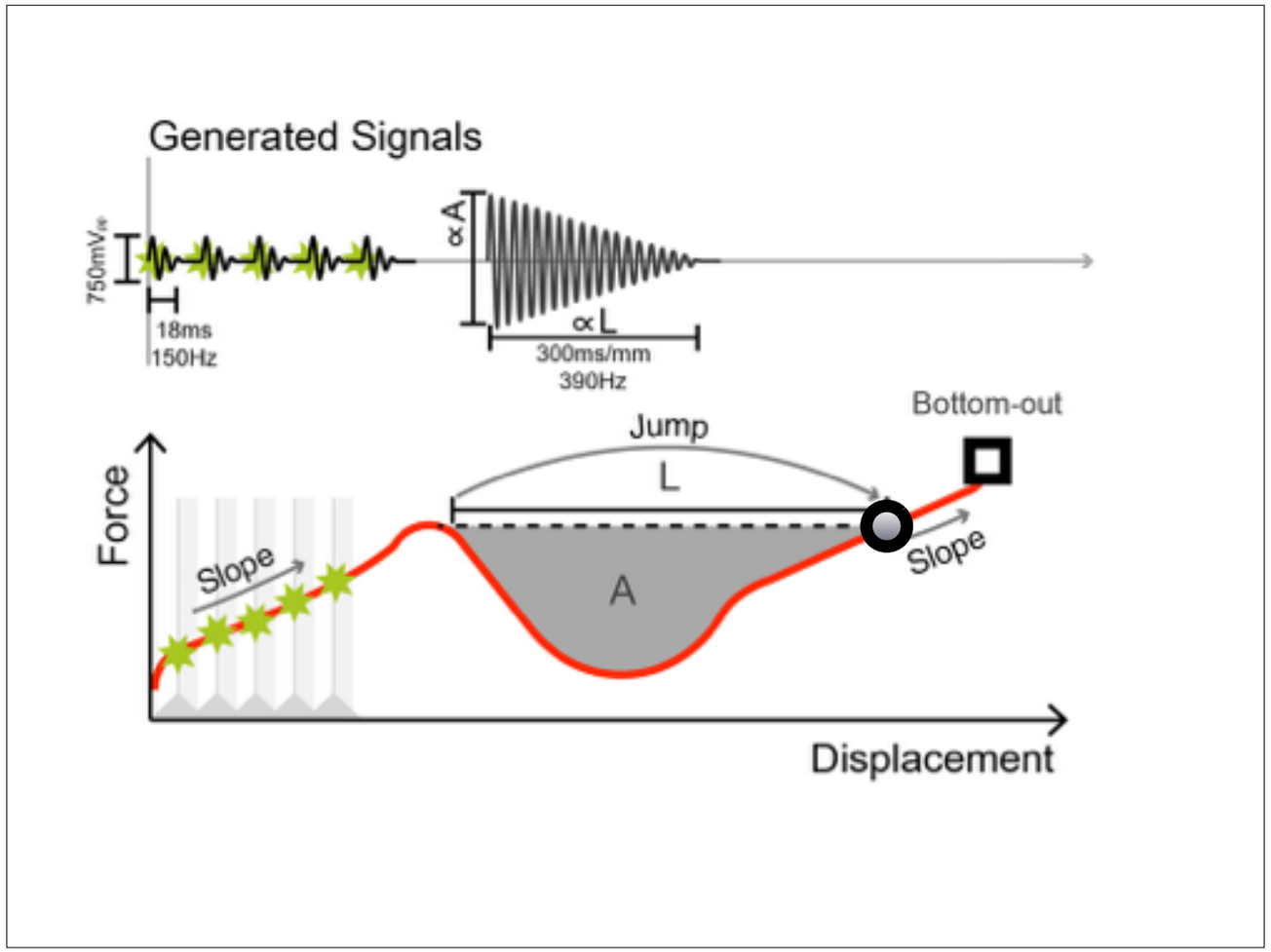
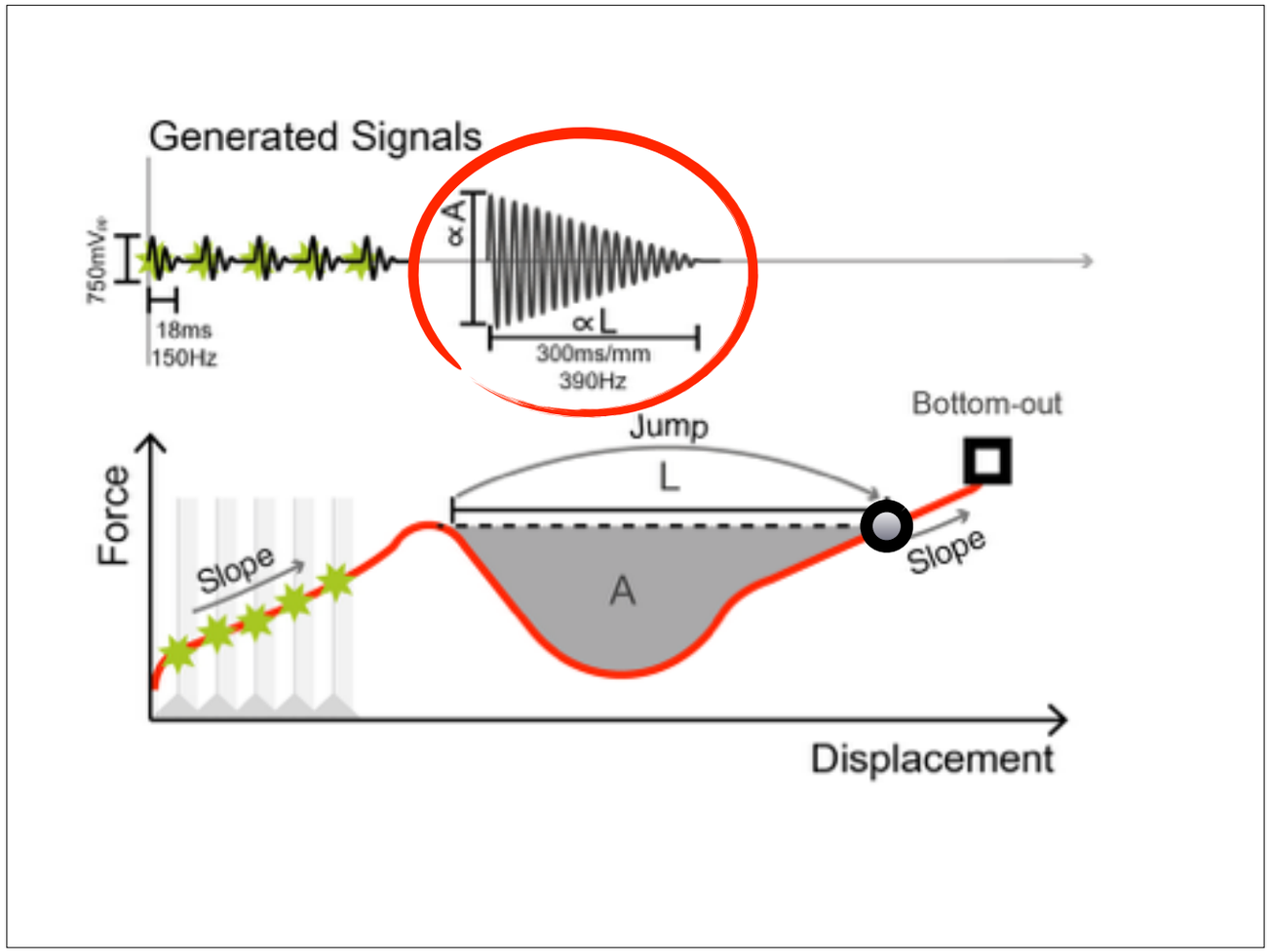


When it reaches the point of collapse,



it generates a big and strong burst of signal. The length and the amplitude is determined by the displacement and the depth of the valley. It makes an distinct clicking feeling.



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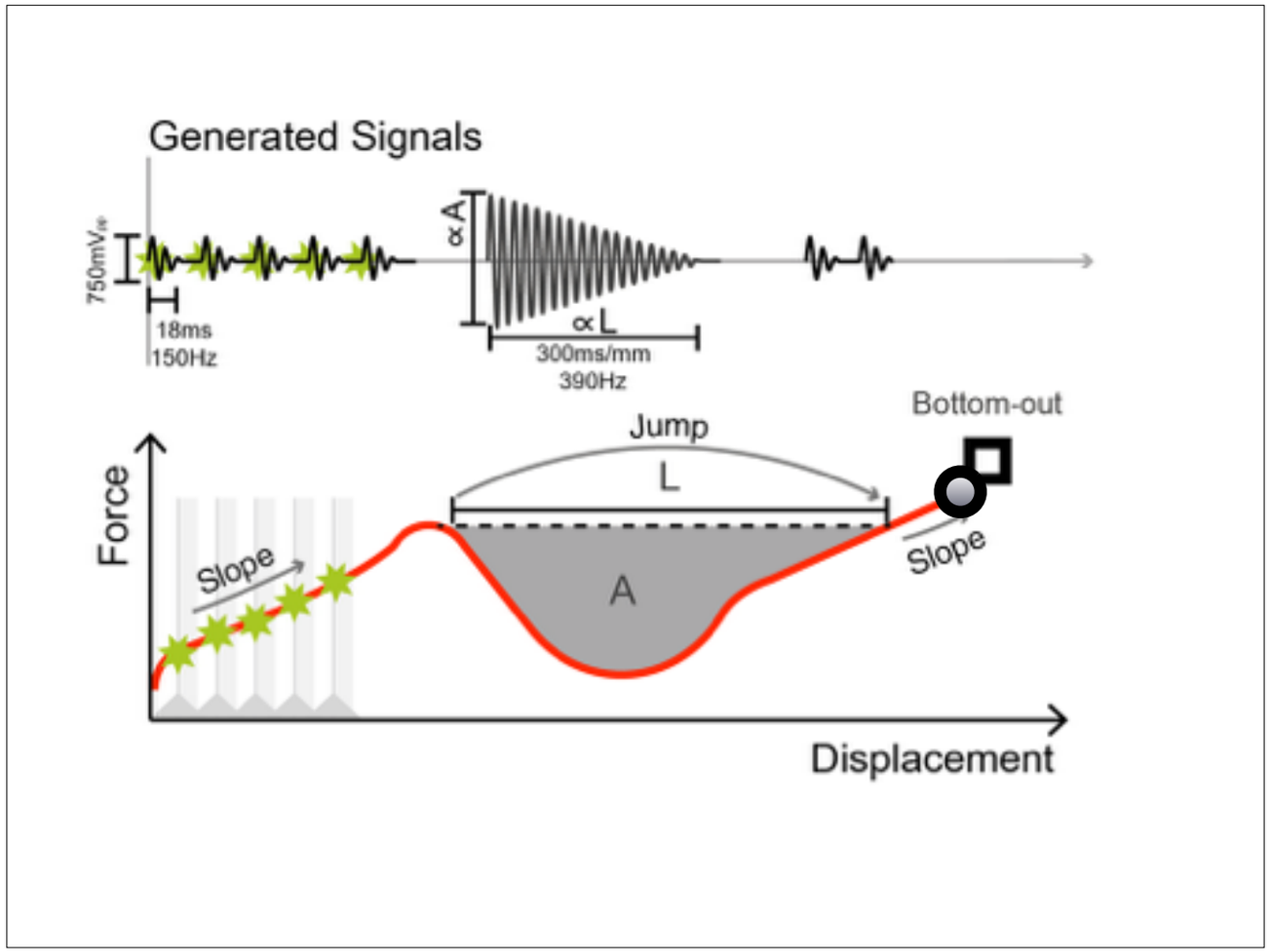
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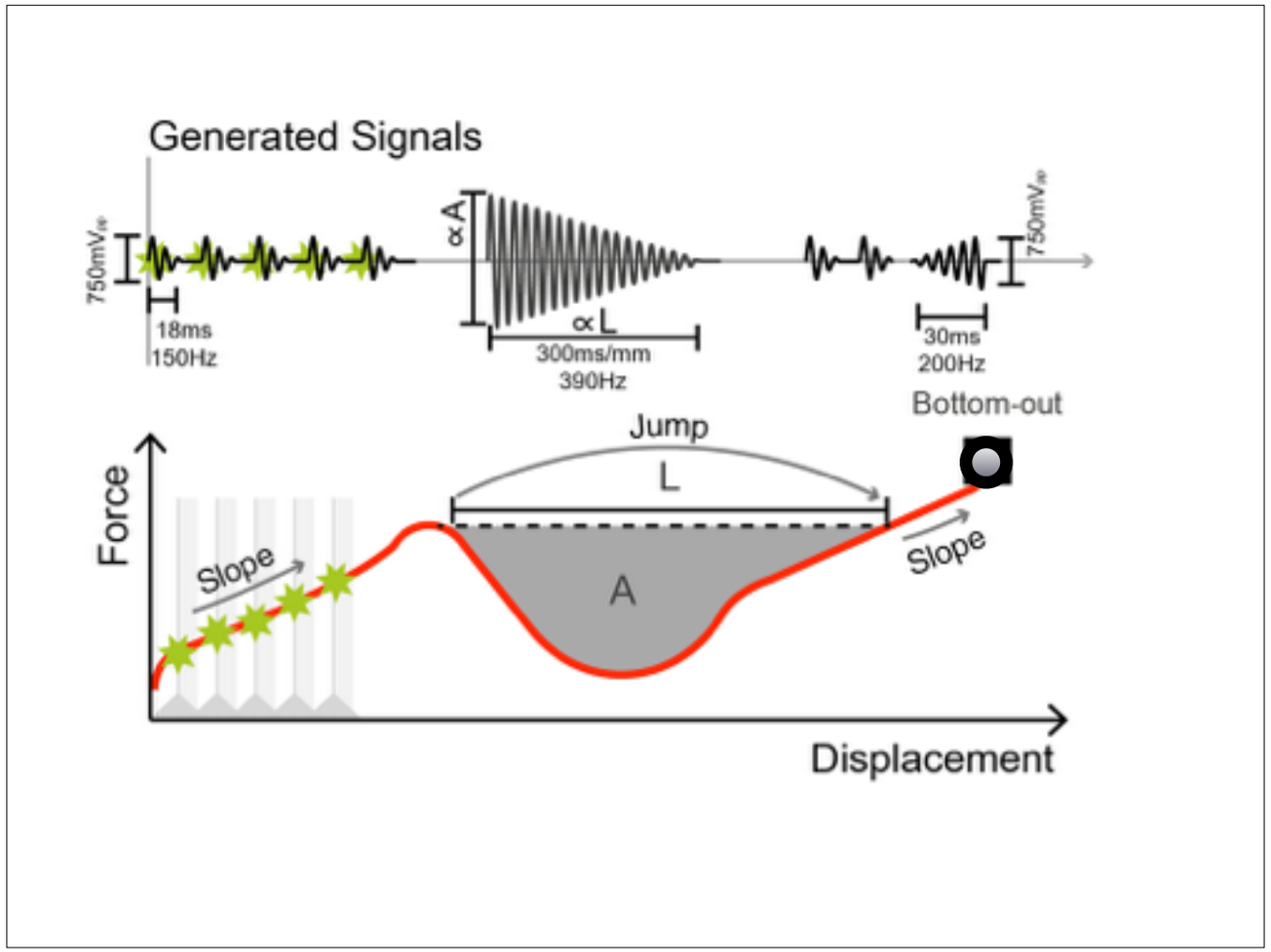
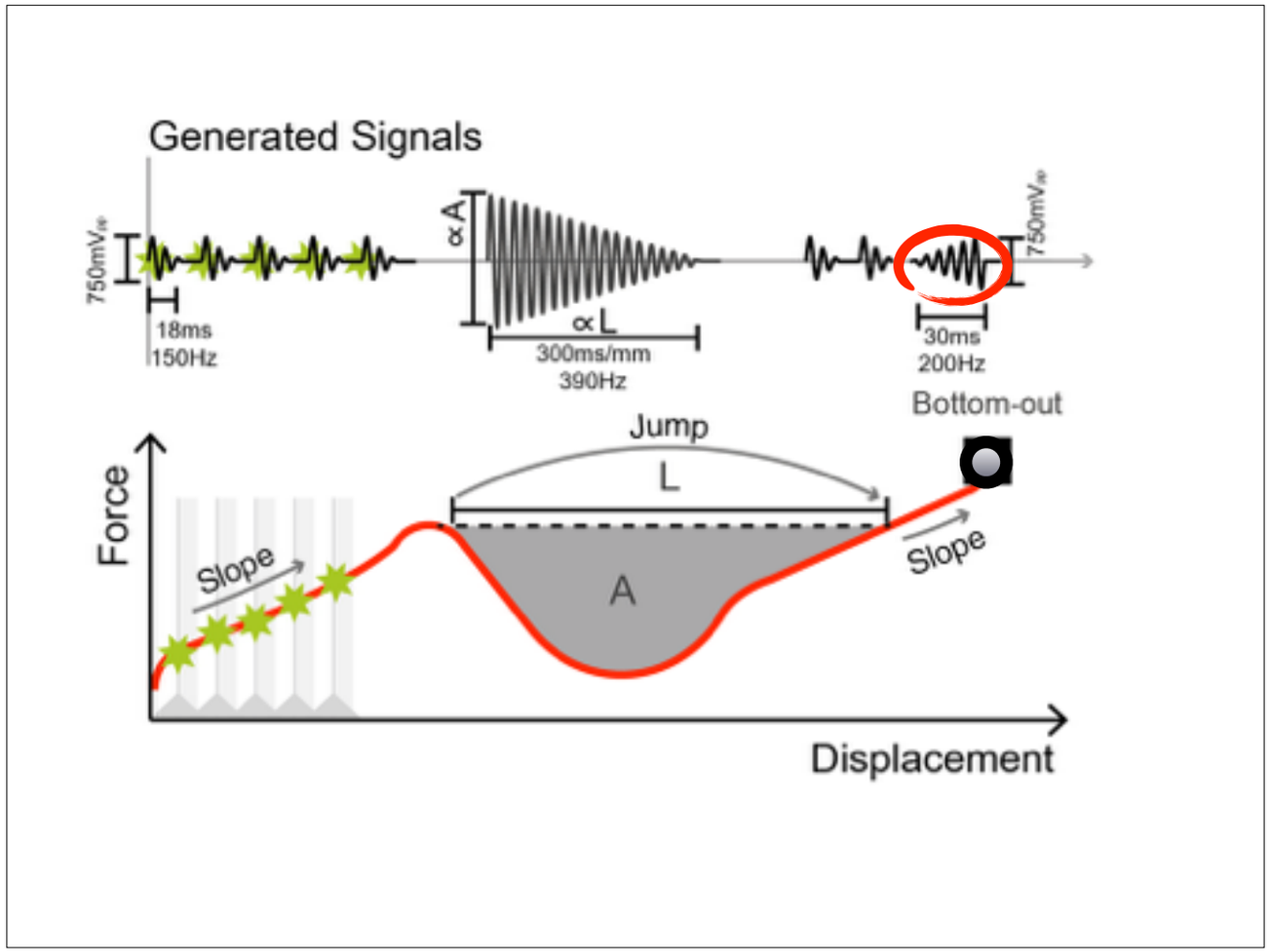


reaches bottom-out point. / short burst of signal with increasing envelope. It gives sudden stop sensation that is telling that it’s the end of the travel.



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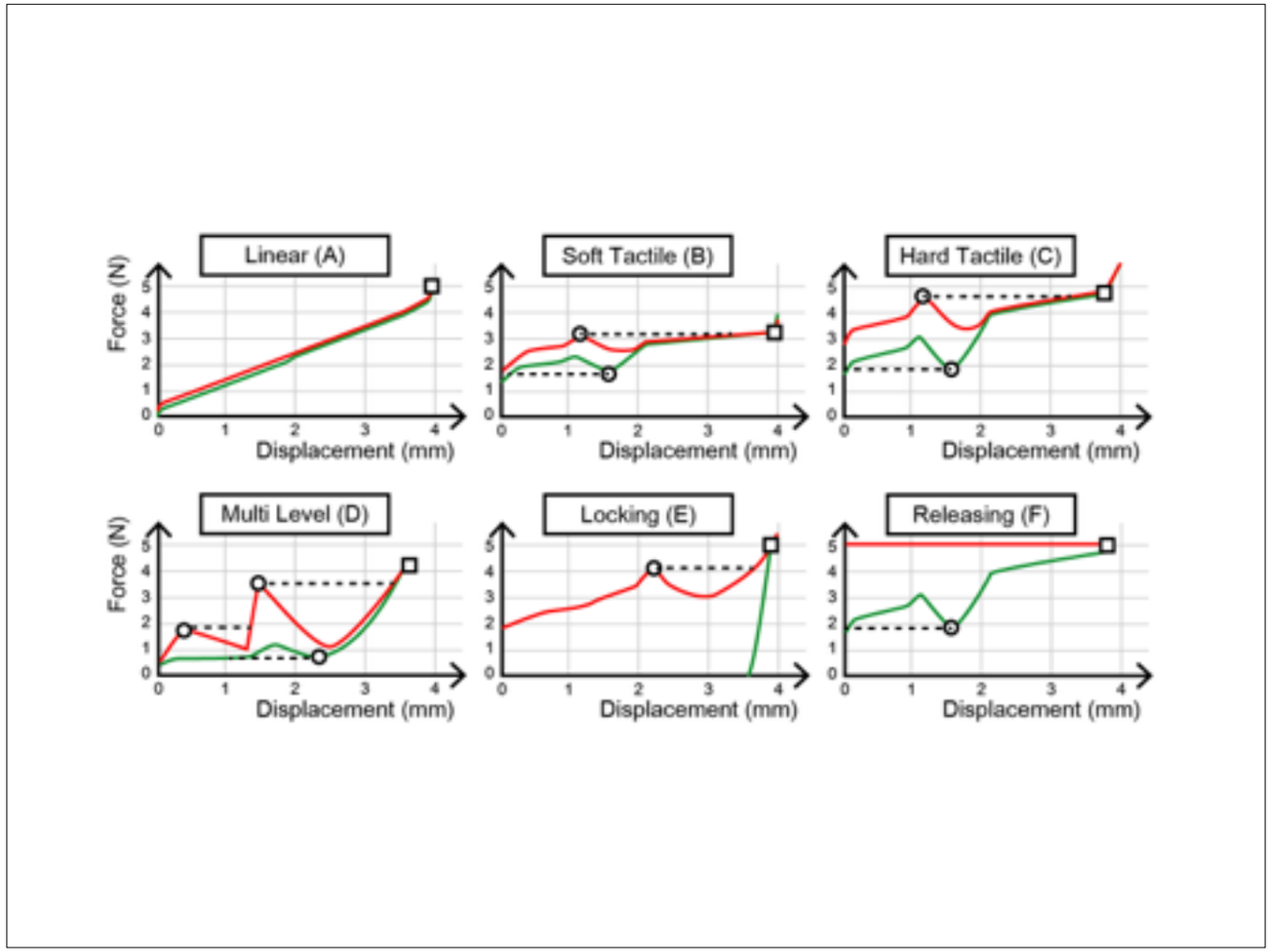
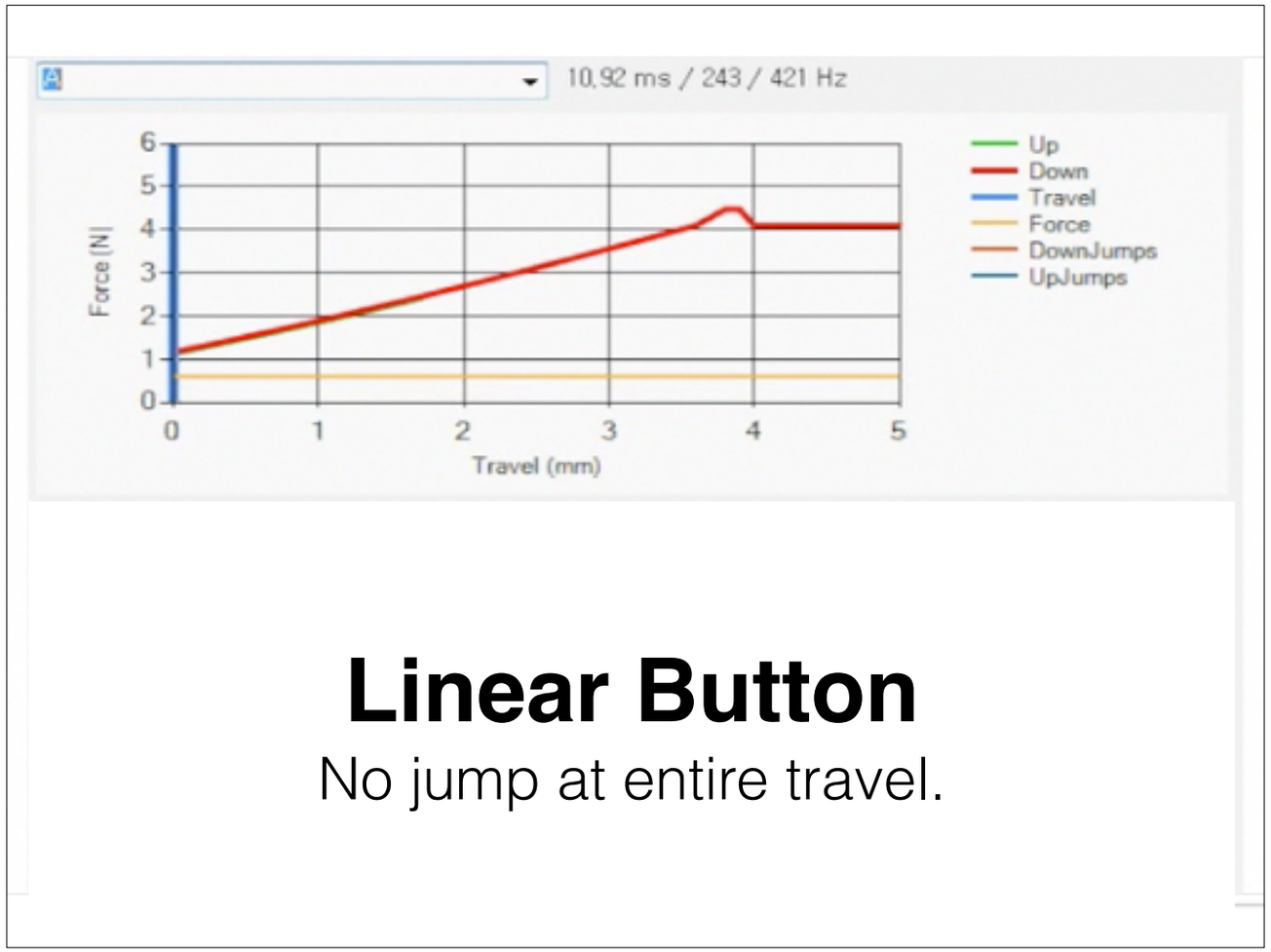
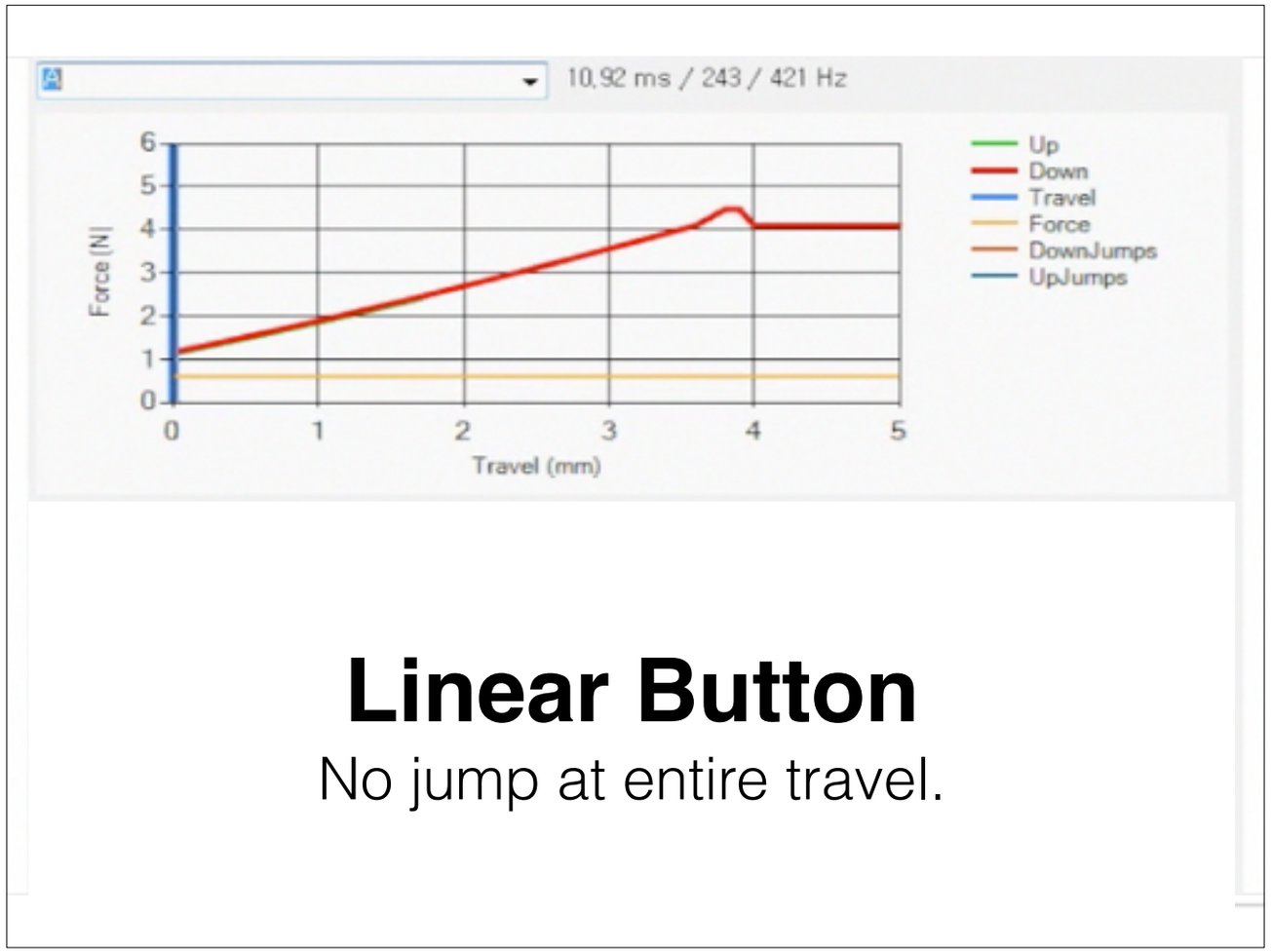


We designed six different graphs for virtual buttons, and the feedback signals are generated following the method we introduced just before.

For time constraint, we describe the button A, C and D only. For more detail for other buttons, please check our paper, or come to our demo tonight.



Linear button have no jumps at entire travel. It feels like press a spring. The sound you can hear is the signal that transfer to the tactile actuator.



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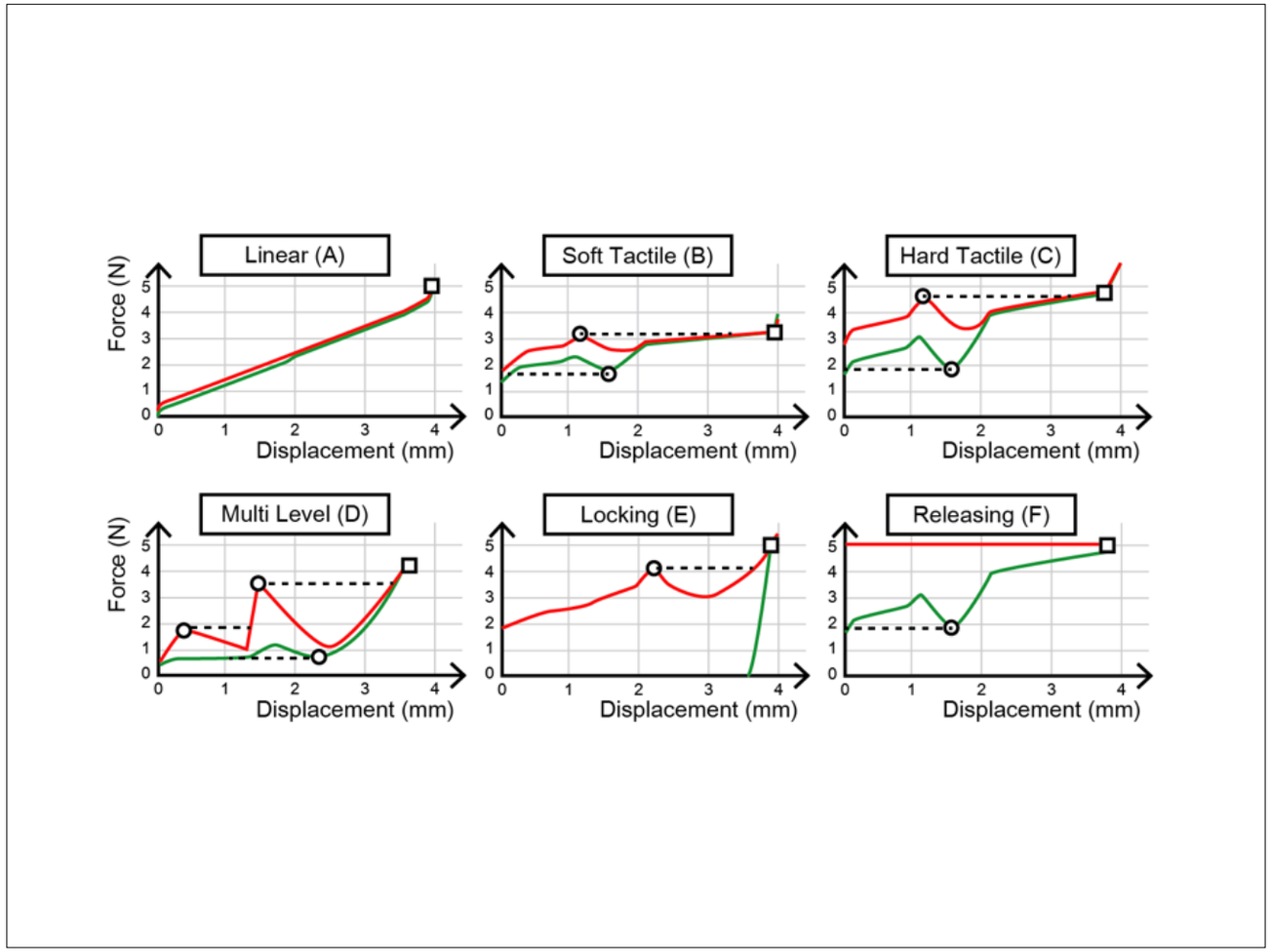
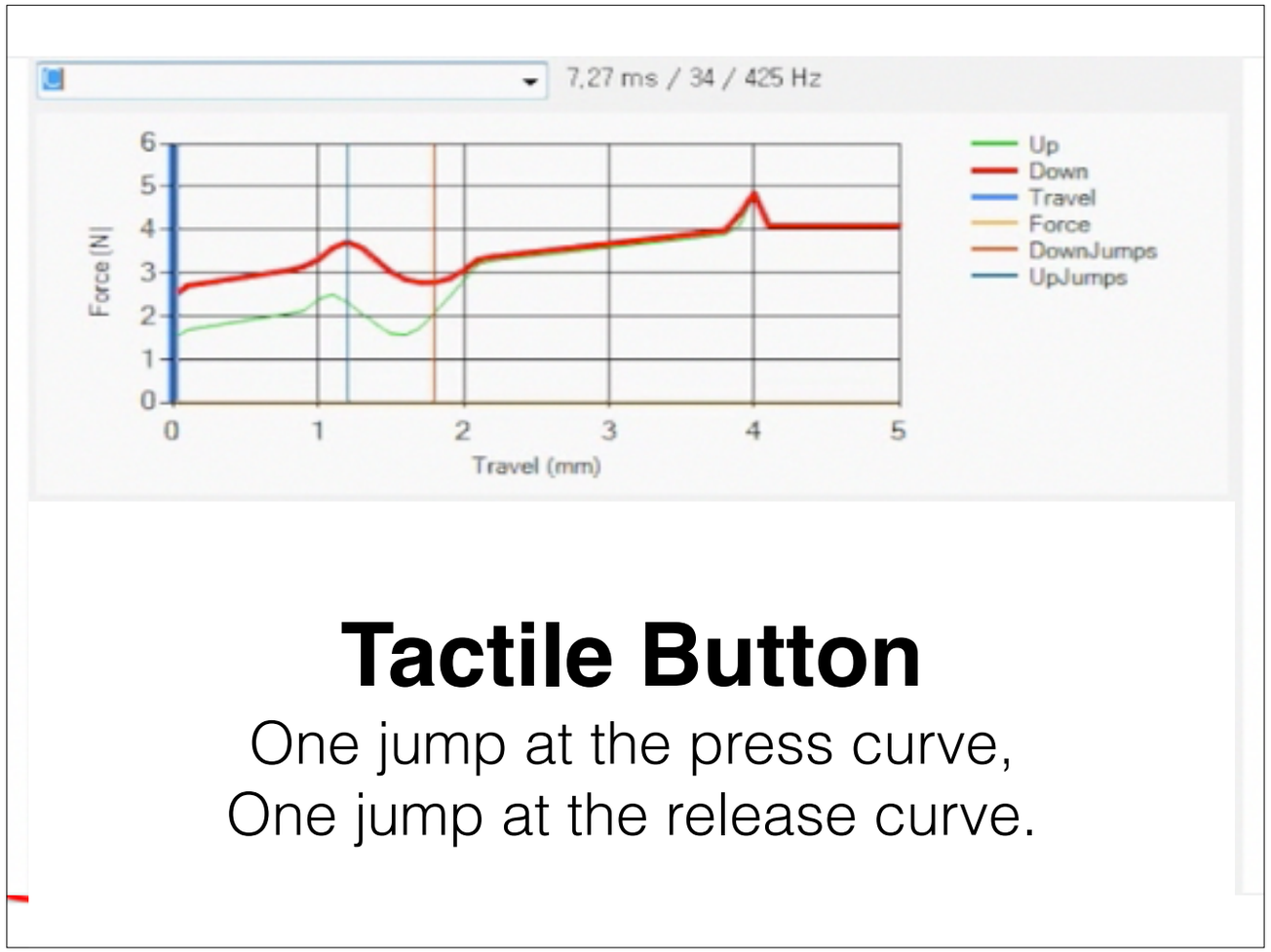


tactile button have one jump at press curve, and another one at release curve. Typical tact button have similar profile.



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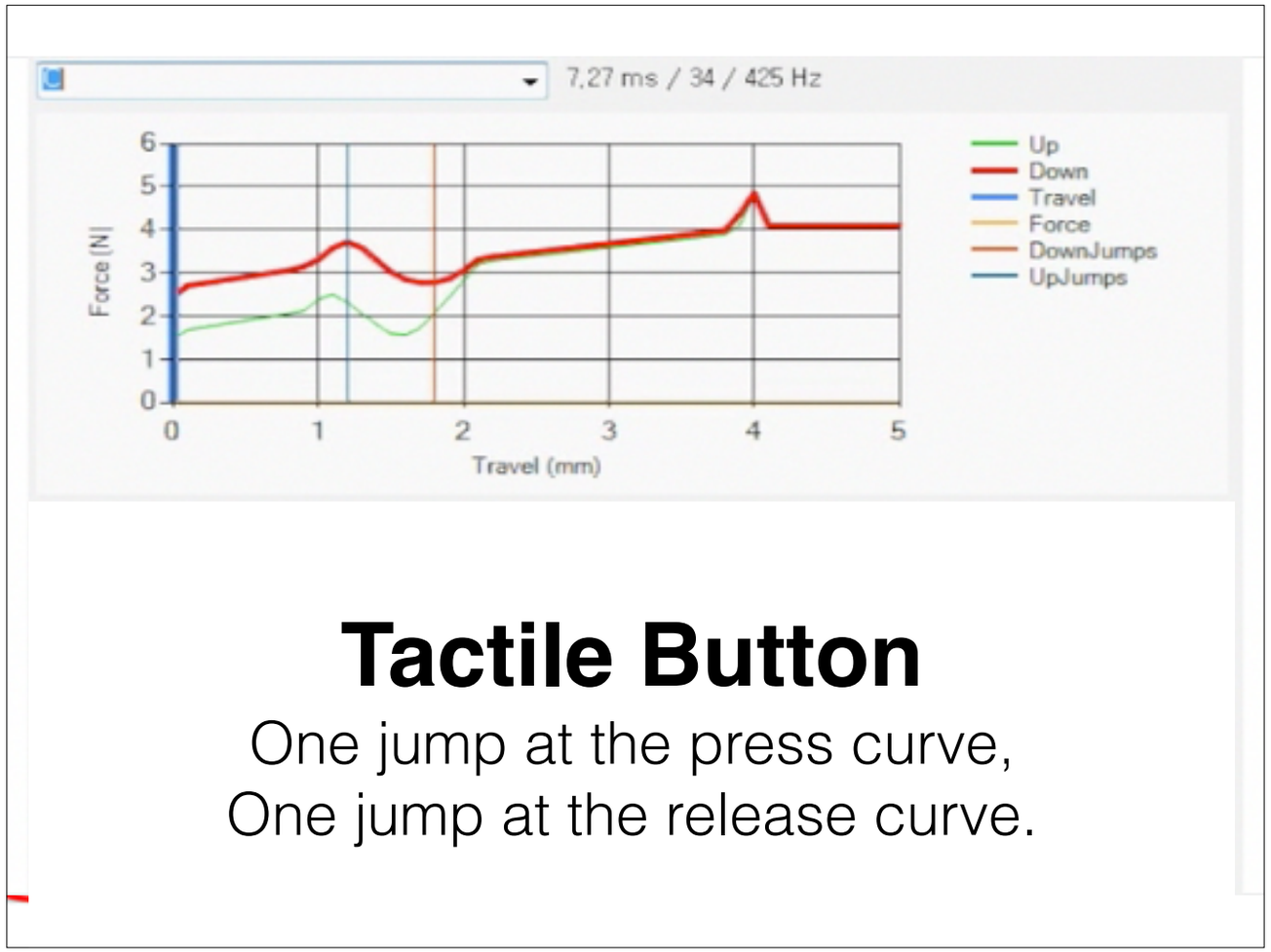

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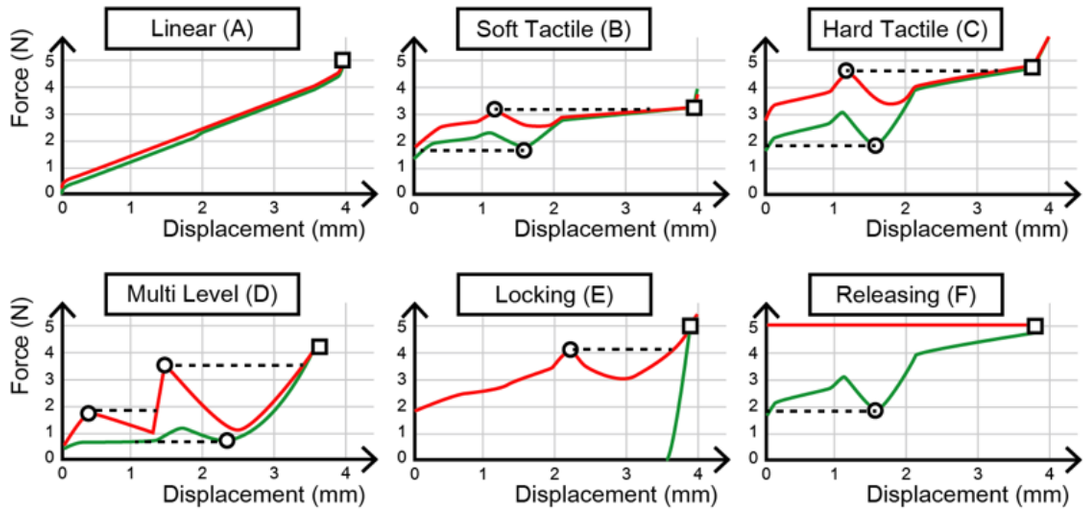
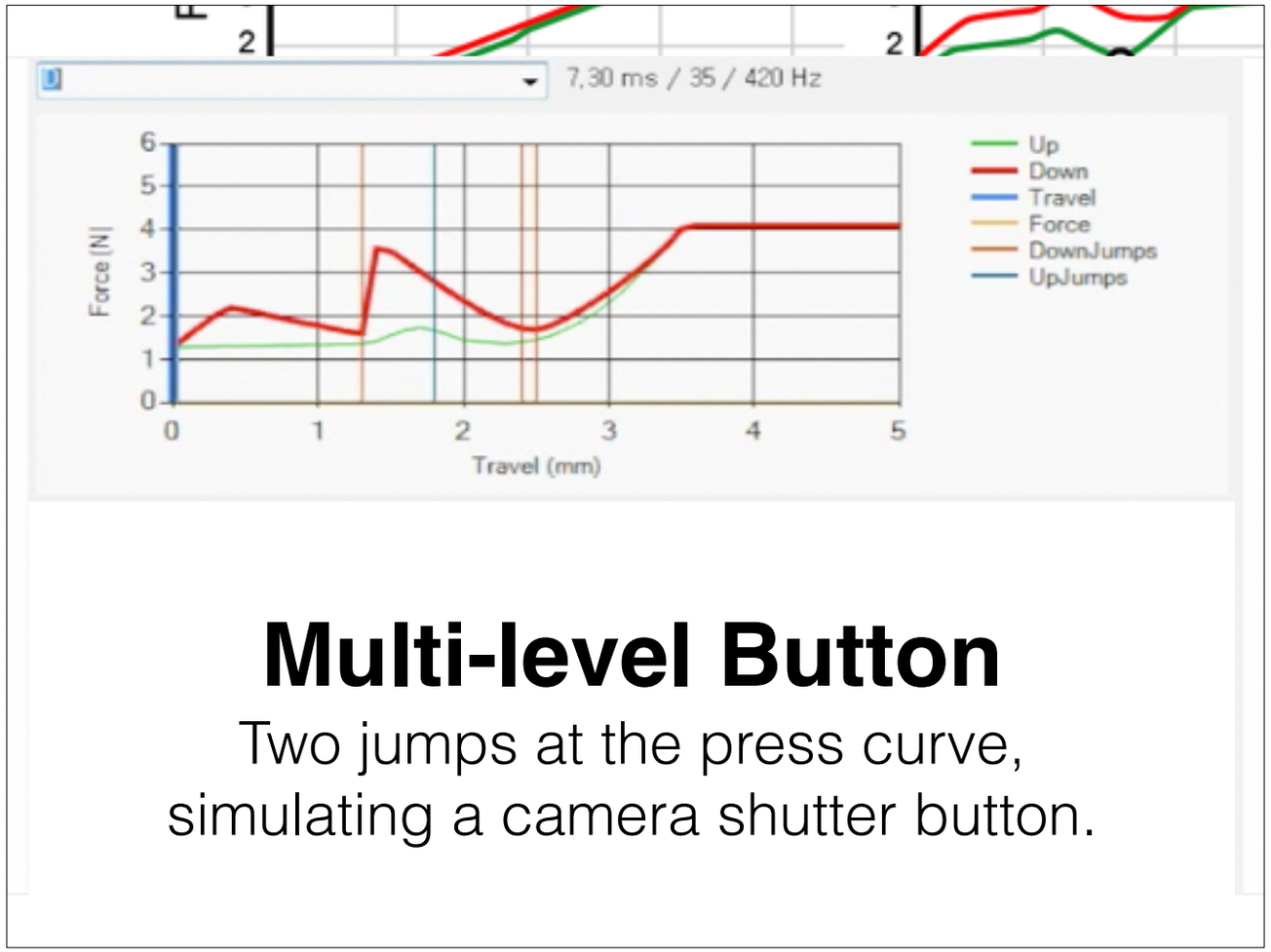


Multi-level button have two jumps at the press curve. It act likes a camera shutter button.



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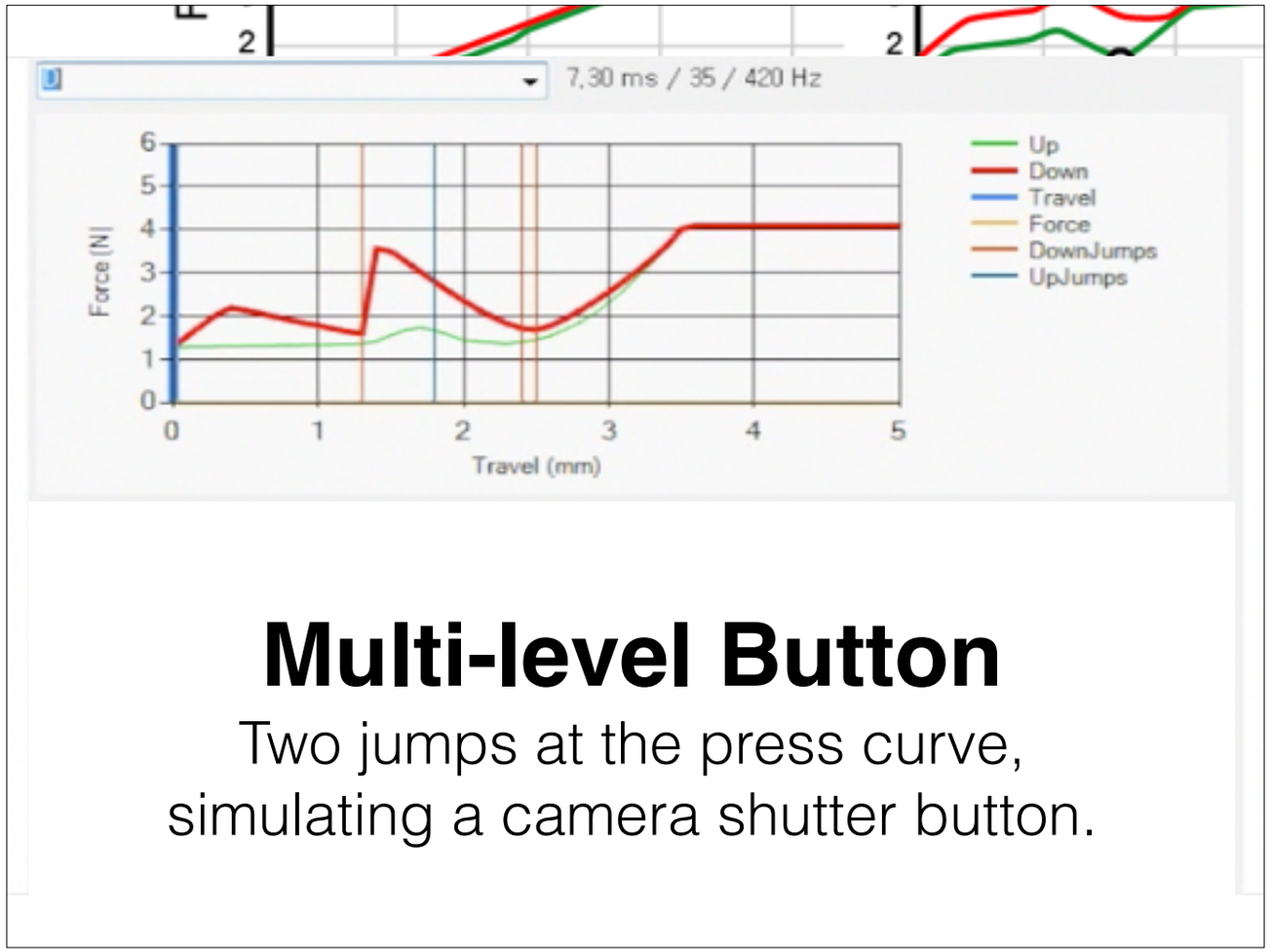

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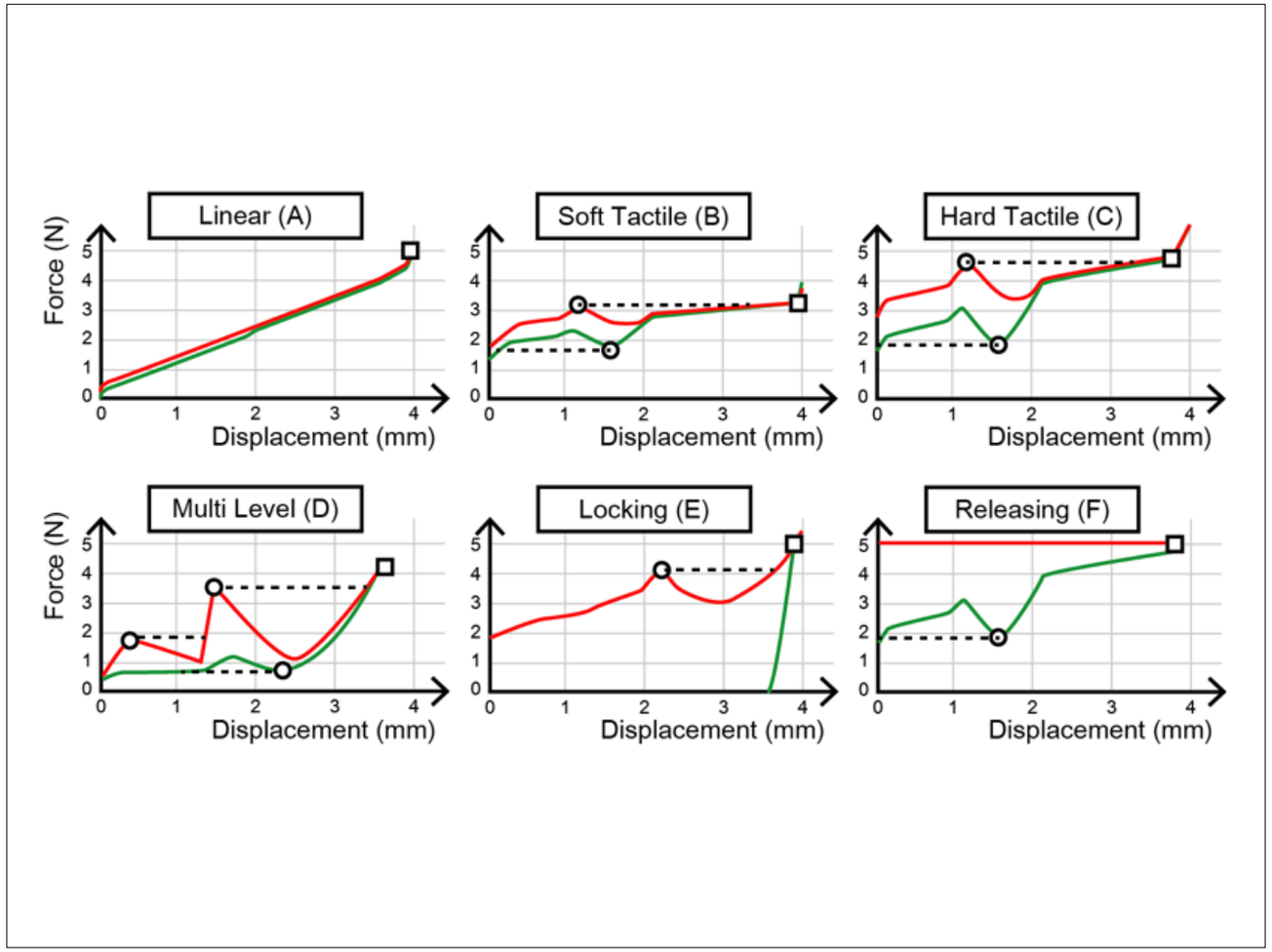

We give six examples here, but more and more virtual buttons can be simulated if we simply give a new force graph to the system.

User Evaluation #1

Pairwise comparison: ABX Test

- Tested 15 pairs (6 different buttons)
- 9 participants (Normal) + 9 participants (Noisy)

3 MIN TO GO! At this time, we designed six different virtual buttons. We tested that those buttons are really generate different feelings.
For this, we conducted pairwise comparison test, called ABX test.
A, B, X.. A participant passes the test when there are 9 right answers out of 10 trials.
Normal and Noisy condition. / Device Significantly generates Noise /
noise canceling headphone that plays an ambient noise eliminate the effect from the device noise.

User Evaluation #1

Pairwise comparison: ABX Test

Group / Measure	*Normal*	*Noisy*
Avg. time (SD)	20.9 min (6.2)	23.3 min (8.4)
Aggregated Errors / Trials	8 / 1350 (0.59%)	46 / 1350 (3.41%)
ABX test result # Fails / Total	1 / 135 (0.74%)	8 / 135 (5.93%)

Table 1. Summary of the test result (10 trials per one ABX test)

At the normal condition, ...
At the noisy condition, ..., which is 94% success rate.
From this result, we concluded that our proposed method can make different types of virtual buttons only by changing the force graph.

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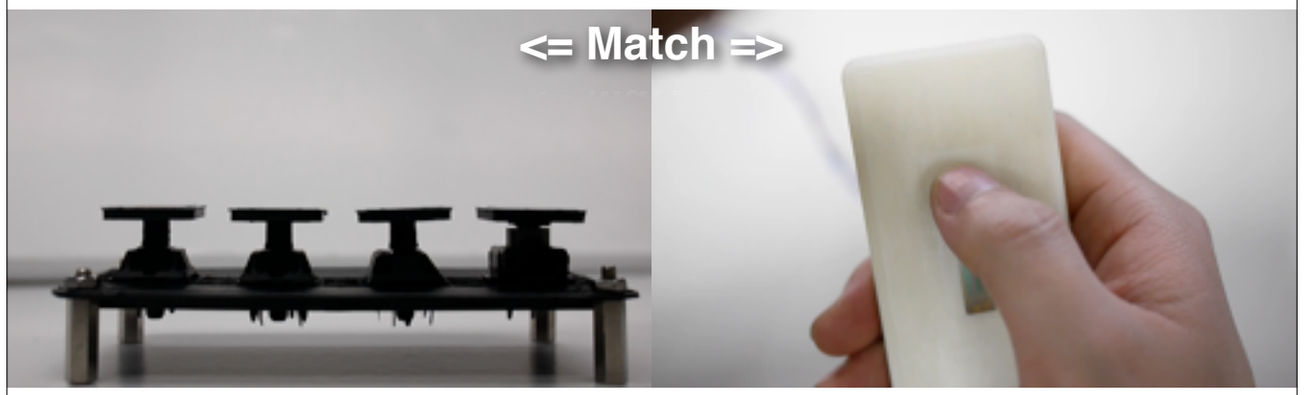
User Evaluation #2

Physical-Virtual button matching

- 18 participants



- Success rate **79.2% (76 / 96 pairs)**

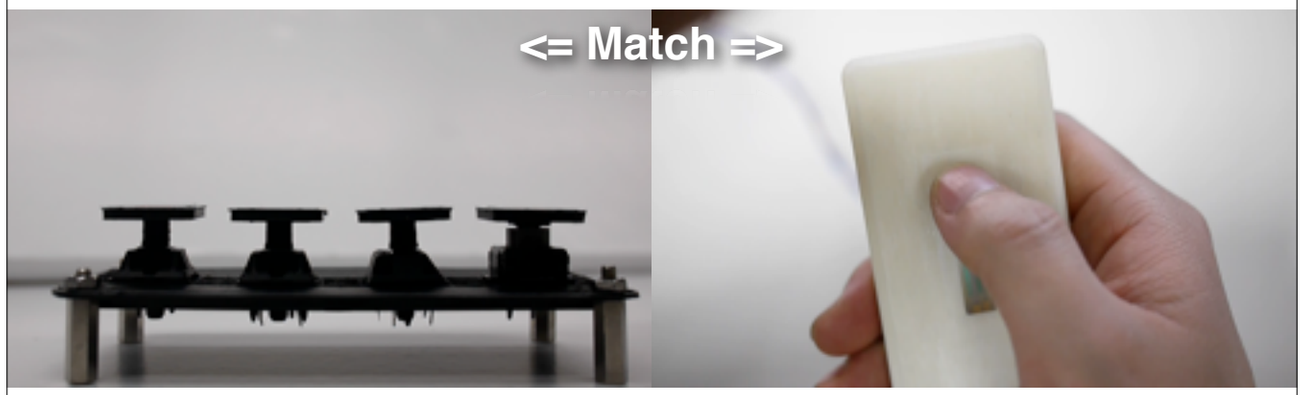
Participants made 96 pairs between virtual and physical buttons. Among them,

Considering the different nature of the virtual and physical button, We think about 80% of success rate is pretty impressive.

User Evaluation #2

Physical-Virtual button matching

- 18 participants



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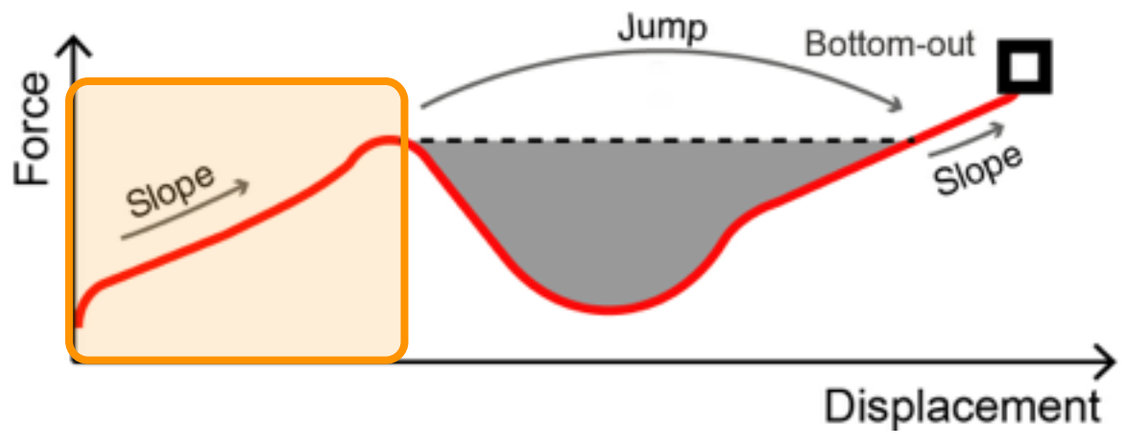
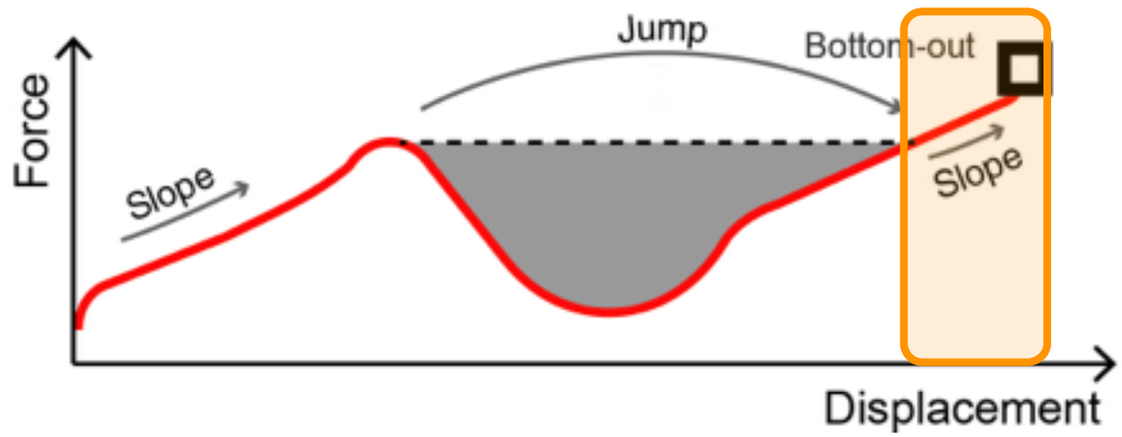
Applications



The good thing of our idea is that it providing haptic feedback before and after jump / have some applications.
test a button slightly

Applications



apply more force after jump / force sensitive switch with a haptic feedback.

Haptic Feedback Design for a Virtual Button Along Force-Displacement Curves

- Enhance the haptic feedback of a virtual button by providing vibrotactile feedback along **the entire length of a force-displacement curve of a real physical button**.

- **Future works**
  - Jump only vs. Entire force curve
  - Richer signal for Jump

our base condition – jump only feedback versus feedback at entire force curve.

Simple signal => reflecting previous works, ...

DEMO TONIGHT!