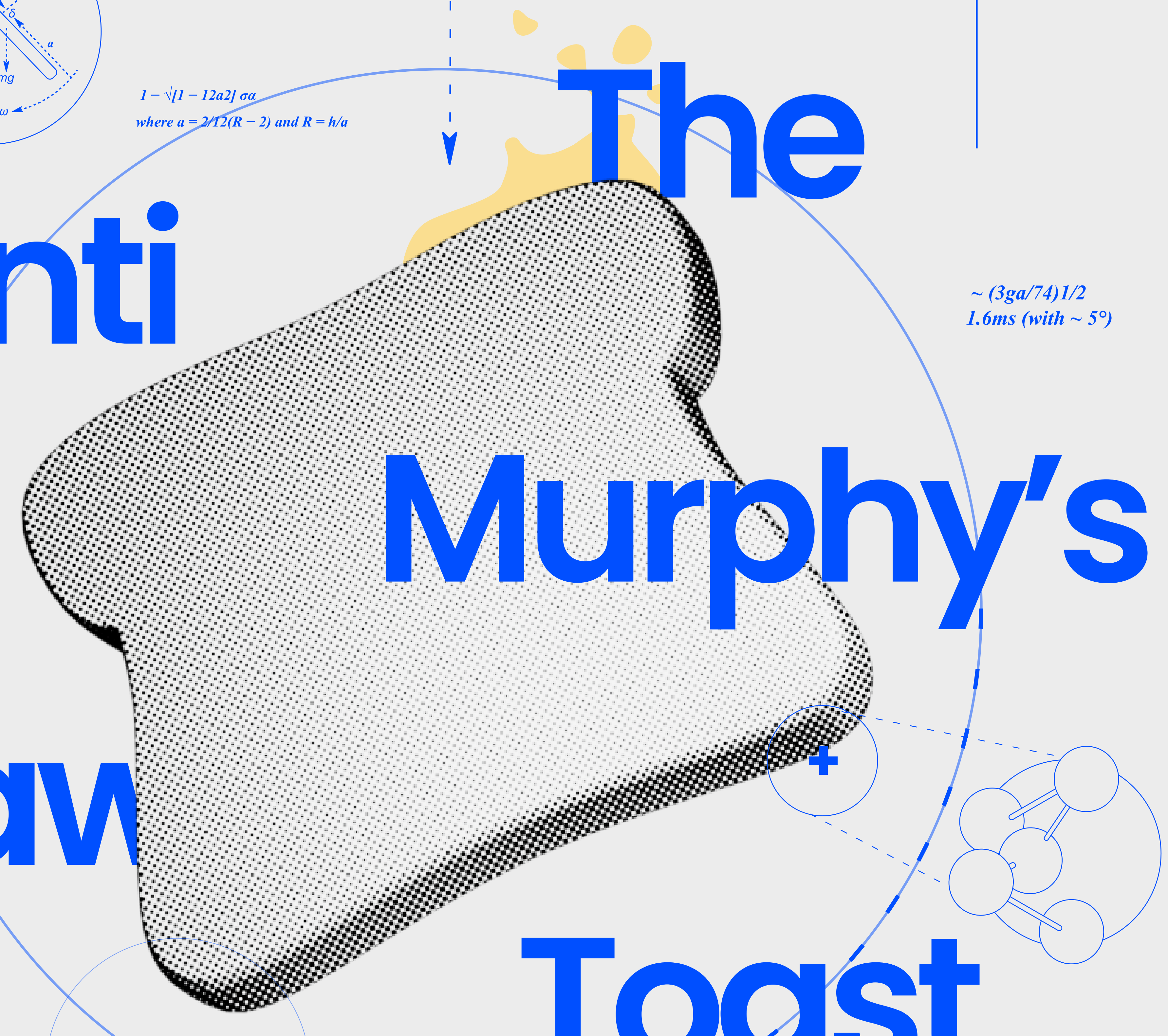
The science behind

The Anti Murphy's Law Toast



$1 - \sqrt{[1 - 12a2]}\ \sigma\alpha$

where $a = 2/12(R - 2)$ and $R = h/a$

$\sim (3ga/74)1/2$

1.6ms (with ~ 5°)

$$R = 2 + \frac{\pi^2 (1+3n^2)}{12n}$$

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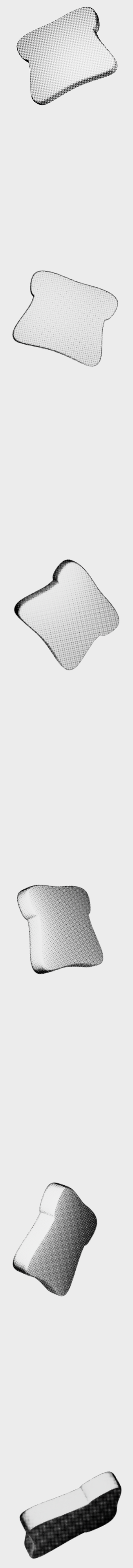
The first question: Does butter affect?

The phenomenon of toast falling from a table to land butter-side down on the floor is popularly held to be empirical proof of the existence of Murphy's Law. Furthermore, there is a widespread belief that it is the result of a genuine physical effect, often ascribed to a dynamical asymmetry induced by one side of the toast being buttered.

Quite apart from whether or not ***the basic observation is true, this explanation cannot be correct.*** The mass of butter added to toast (~4g) is small compared to the mass of the typical slice of toast (-35g), is spread thinly, and passes into the body of the toast. Its contribution to the total moment of inertia of the toast-and thus its effect on the toast's rotational dynamics-is thus negligible.

Similarly, the aerodynamic effect of the thin layer of butter cannot contribute a significant dynamical asymmetry. It is easily shown that for air resistance to contribute significantly to the dynamics of the falling toast, the height of fall must be of the order *of* $2(\rho_T/\rho_A)d$, where ρ_T is the density of the toast, *d* is its thickness and ρ_A the density of air.

The presence of butter will contribute only a small fraction of this total; supposing it to be a generous 25 per cent and taking the typical values of ρ_T ***~350kg m^{-3}***, ρ_T ***= 1.3 kg m^{-3}*** and ***d ~10^{-2} m***, we find that the toast would have to fall from a height over an order of magnitude higher than the typical table for the butter to have significant aerodynamic effects.



Context of falling toast.

In what follows we model the tumbling toast problem as an example of a rigid, rough, homogeneous rectangular lamina, mass ***m***, side ***2a***, falling from a rigid platform set a height ***h*** above the ground. We consider the dynamics of the toast from an initial state where its centre of gravity overhangs the table by a distance δ_o as shown in figure 1. Initially, we ignore the process by which the toast arrives at this state, and also assume that it has zero horizontal velocity; the important effect of a non-zero horizontal velocity is addressed later. Finally we assume a perfectly inelastic impact with the floor with zero rebound.

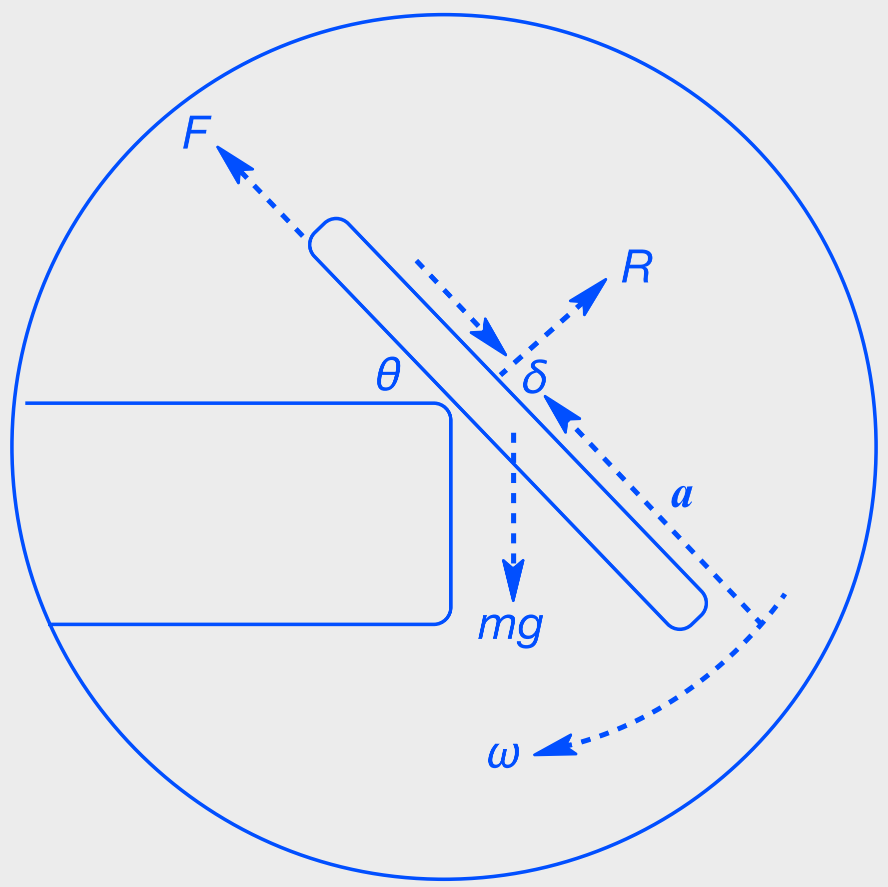


Figure 1. *The initial orientation of the rotating toast*

With these assumptions, the dynamics of the lamina are determined by the forces shown in figure 1: the weight, ***mg***, acting vertically downward, the frictional force, ***F***, parallel to the plane of the lamina and directed against the motion, and the reaction of the table, ***R***. The resulting angular velocity about the point of contact, ω, then satisfies the differential equations of motion

(1) $m\delta\omega^2 = F - mg\cdot\sin\theta$

(2) $m\delta\omega = R - mg\cdot\cos\theta$

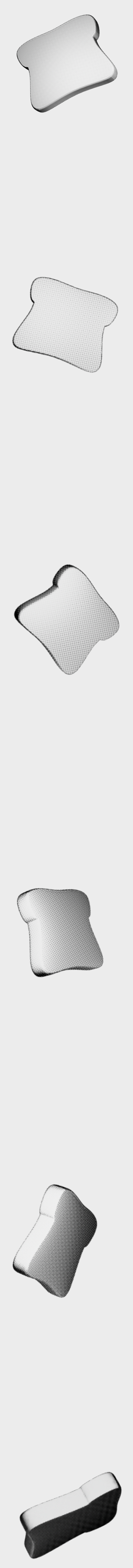
(3) $m(k^{2+}\delta^2)\omega = mg\delta\cdot\cos\theta$

where ***k*** is the appropriate radius of gyration, such that $k^2 = d/3$ for the rectangular lamina considered here. Multiplying (3) by 2ω and integrating from the initial conditions $\omega = 0$ at $\theta = 0$ leads to:

(4) $\omega^2 = (6g/a)\cdot[\eta/(1+3\eta^2)]\cdot\sin\theta$

where we have used $\delta \equiv \eta a$, with $\eta (0 < \eta \leq 1)$ being the 'overhang parameter'. Equation (4) is the central equation of the tumbling toast problem, as it gives the rate of rotation of the toast once it has detached from the table from a specific state of overhang.

Unless the toast can complete sufficient rotation on its descent to the floor to bring the buttered side facing upwards, the toast will land buttered-side down.



Considerations for toast design.

The scientific challenge in designing the toast is to decrease the risk that the angle at which the toast lands falls within the ***"Murphy's Law Range" of 90 degrees to 270 degrees***. This range is particularly problematic because it results in a high probability of butter-down landings. Experimental studies using standard toast under controlled conditions indicate that toast lands butter-side down approximately 62% of the time when dropped from a typical table height.

$$\theta = \omega r \sim \sqrt{\frac{9}{L}} \times \sqrt{\frac{h}{g}} \sim \sqrt{\frac{h}{L}}$$
$$\theta < 90^{o}$$
$$\theta > 270^{o}$$

Various strategies have been explored to mitigate the risk of butter-down landings.

(a) Height of fall. The height from which the toast falls may influence the probability of butter-up landings, with smaller or greater heights potentially affecting rotation dynamics.

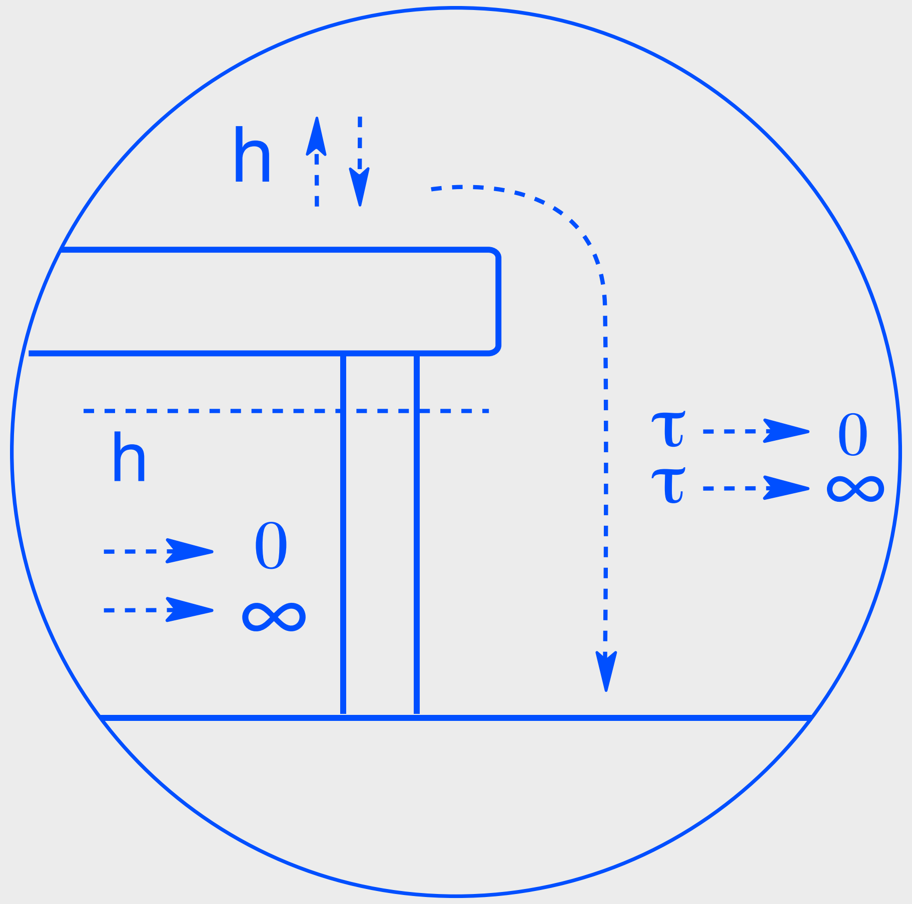
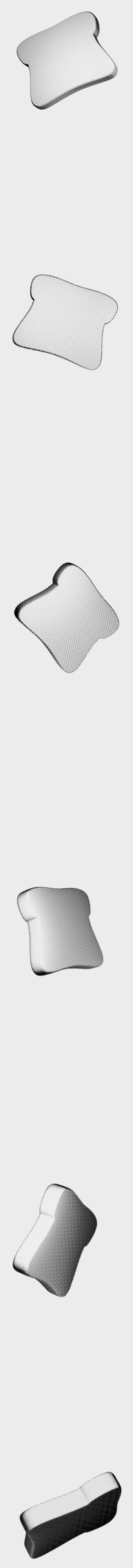


Figure 2. *The iinfluence of height of fall*



(b) Size of the toast. Altering the toast's dimensions could influence its rotation rate, with smaller or larger pieces behaving differently in free fall.

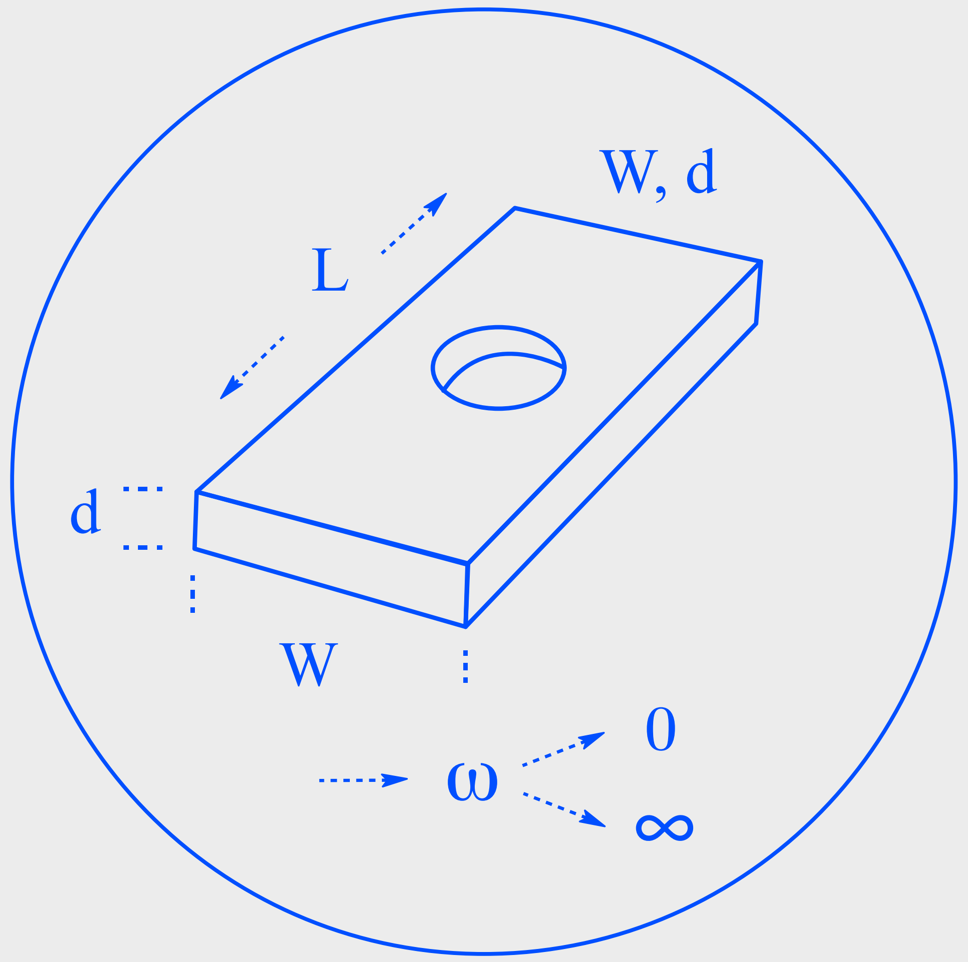


Figure 3. *The size of the toast*

(c) Forces acting on the toast. The key physical forces involved include aerodynamics, gravity, and friction, each of which affects the toast's motion from table to floor.

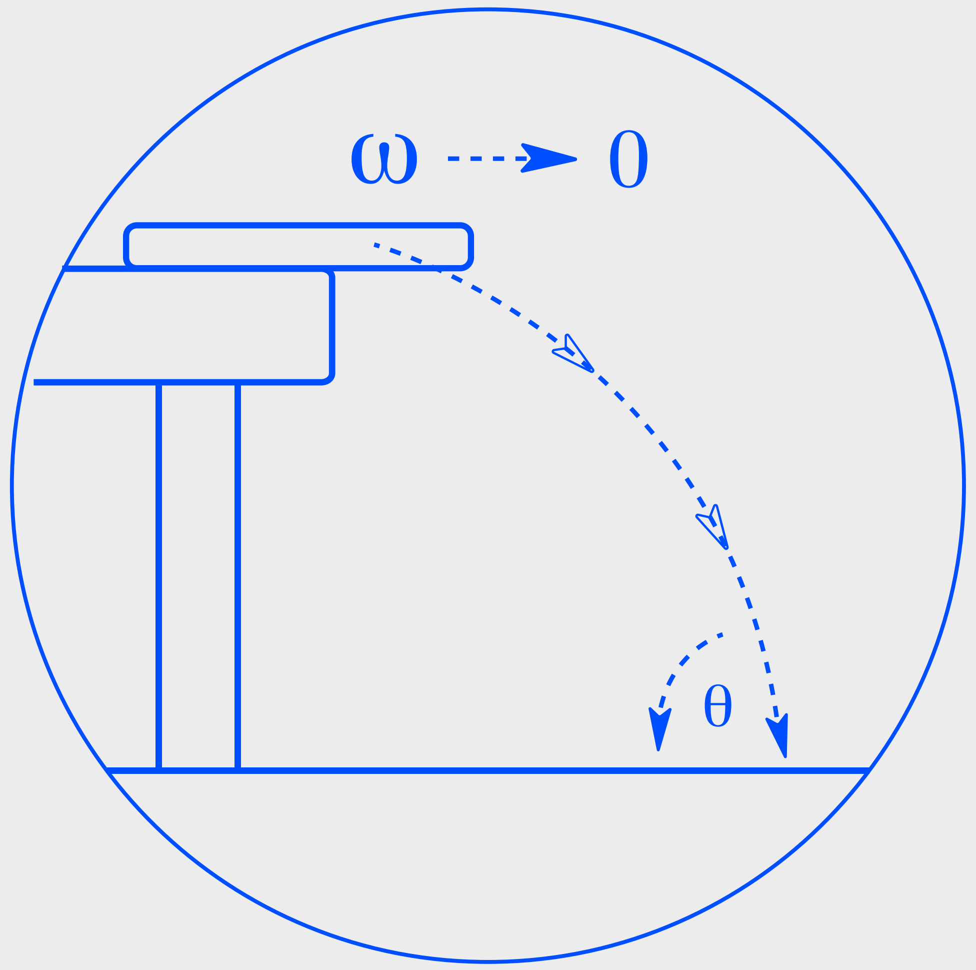
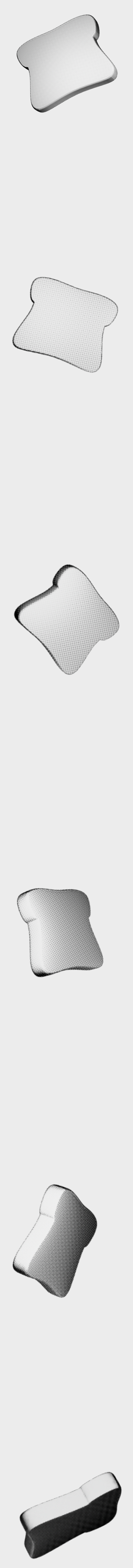


Figure 4. *Physical forces involved.*



Theorical insights.

Among these factors, theoretical analysis suggests that ***(a) The Height of Fall***, adjusting the height of the fall, is unlikely to provide a practical solution. This is because height only makes a meaningful difference at ***extreme values***, either absurdly ***low heights*** (Figure 5, where the toast barely has time to rotate) or ***dangerously high ones*** (Figure 6, where it undergoes multiple rotations before impact).

The findings from the study reinforce this conclusion, demonstrating that simply changing the height of the fall does not reliably improve butter-up landings.

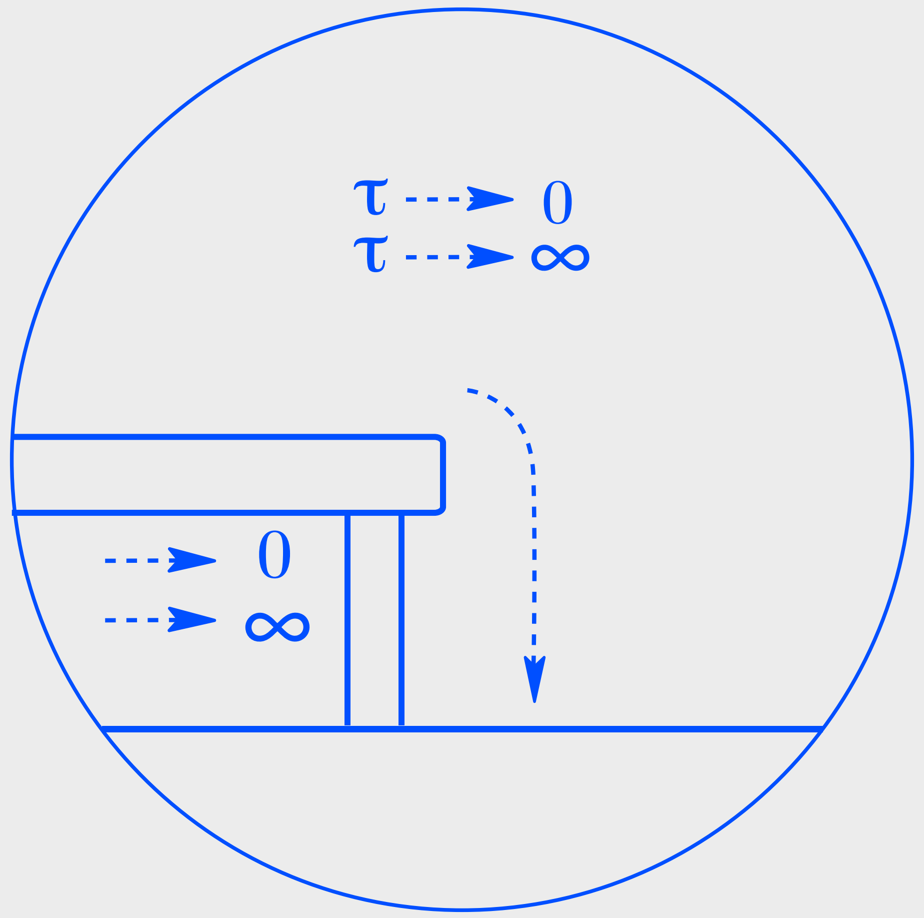


Figure 5. *Lower table*

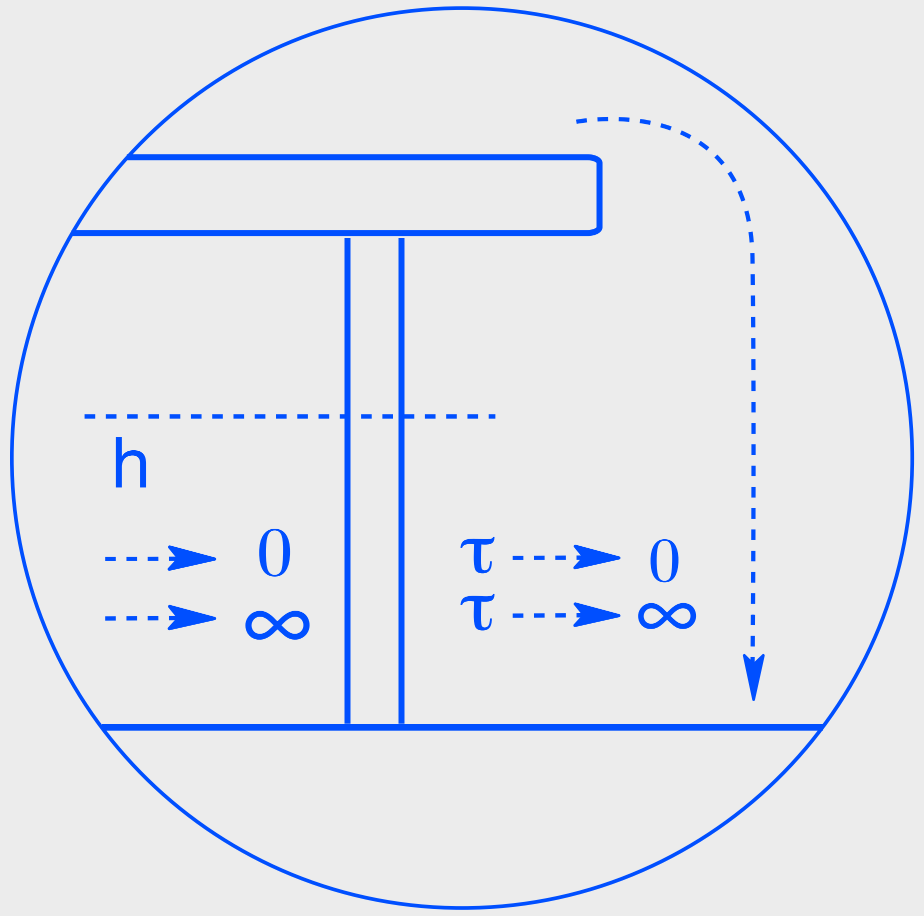


Figure 6. *Higher table*

The winning Anti-Murphy's Law Toast design.

The most effective approach to reducing butter-down landings involves manipulating factors ***(b) Size of the Toast*** and ***(c) Forces acting on the toast.***

When toast slides over the edge of a plate or table, friction at the contact points plays a major role in whether it starts rotating or simply falls in a more stable, ballistic motion.

Friction force is given by:

$$F_{Friction} = \mu N$$

where:

μ is the coefficient of friction (depends on the materials of the toast and plate).
N is the normal force, which equals the weight of the toast (Wt) under normal conditions.

Aerodynamic considerations play a minor role, but the slight reduction in weight. A gap on the edge reduces friction and weight, helping to reach "launch speed" for butter-up landings when jolted off a plate/table.

Smaller toast benefits from a higher initial launch speed when accidentally jolted off a table or plate. The reduced dimensions allow for a more immediate ballistic trajectory, decreasing the time spent sliding and rotating over the edge.

Reduced surface area means less interaction with frictional forces at the edge of the plate/ table, lowering the chances of initiating a downward rotation.

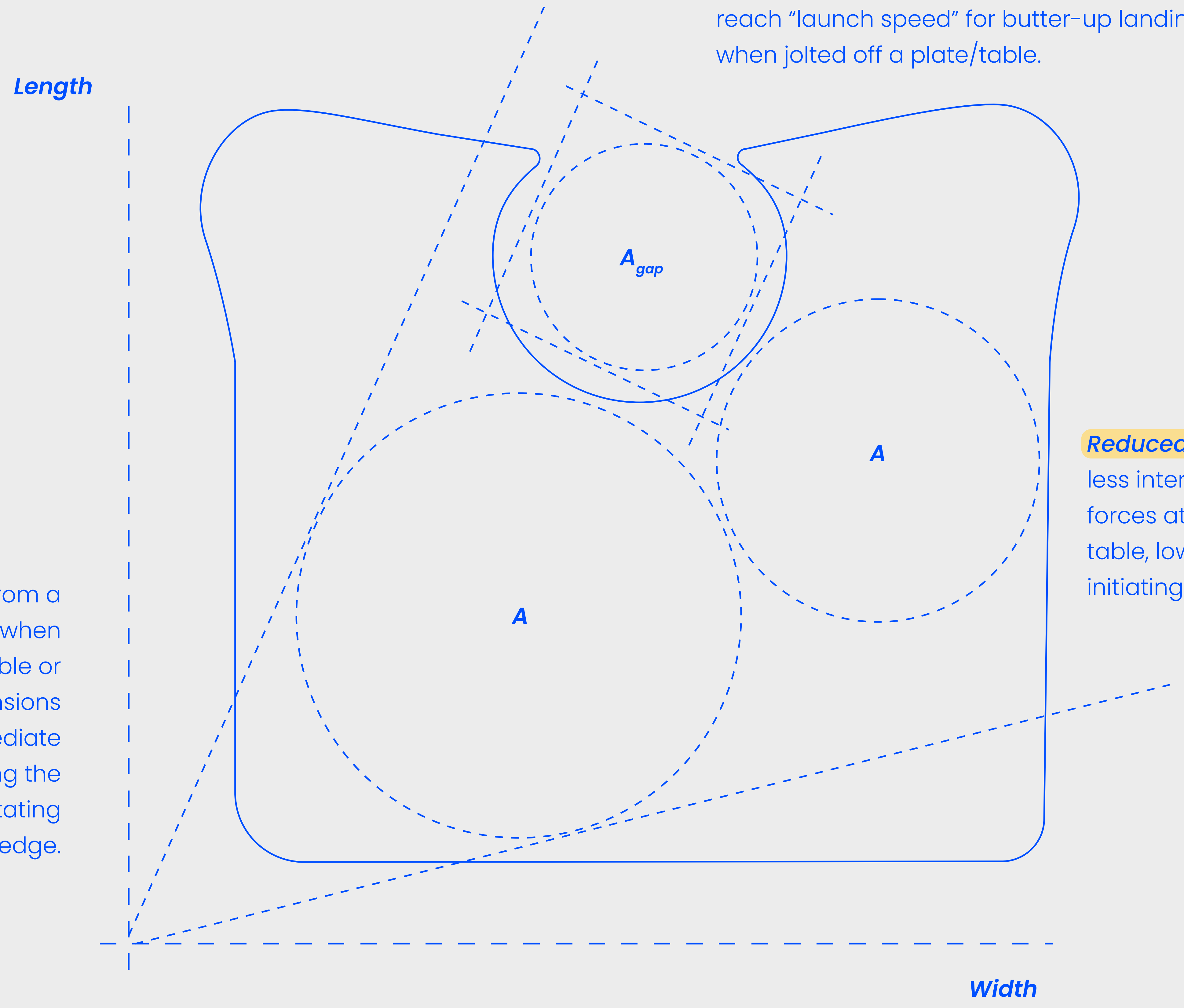
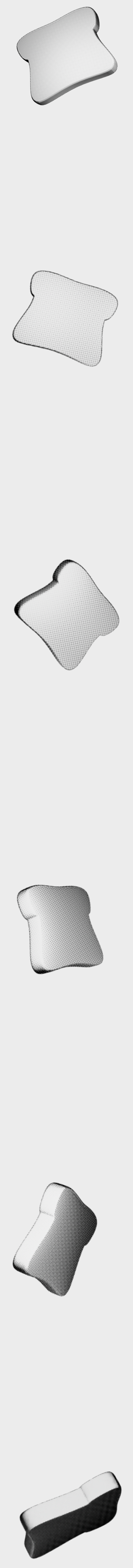


Figure 7. *The winning design*



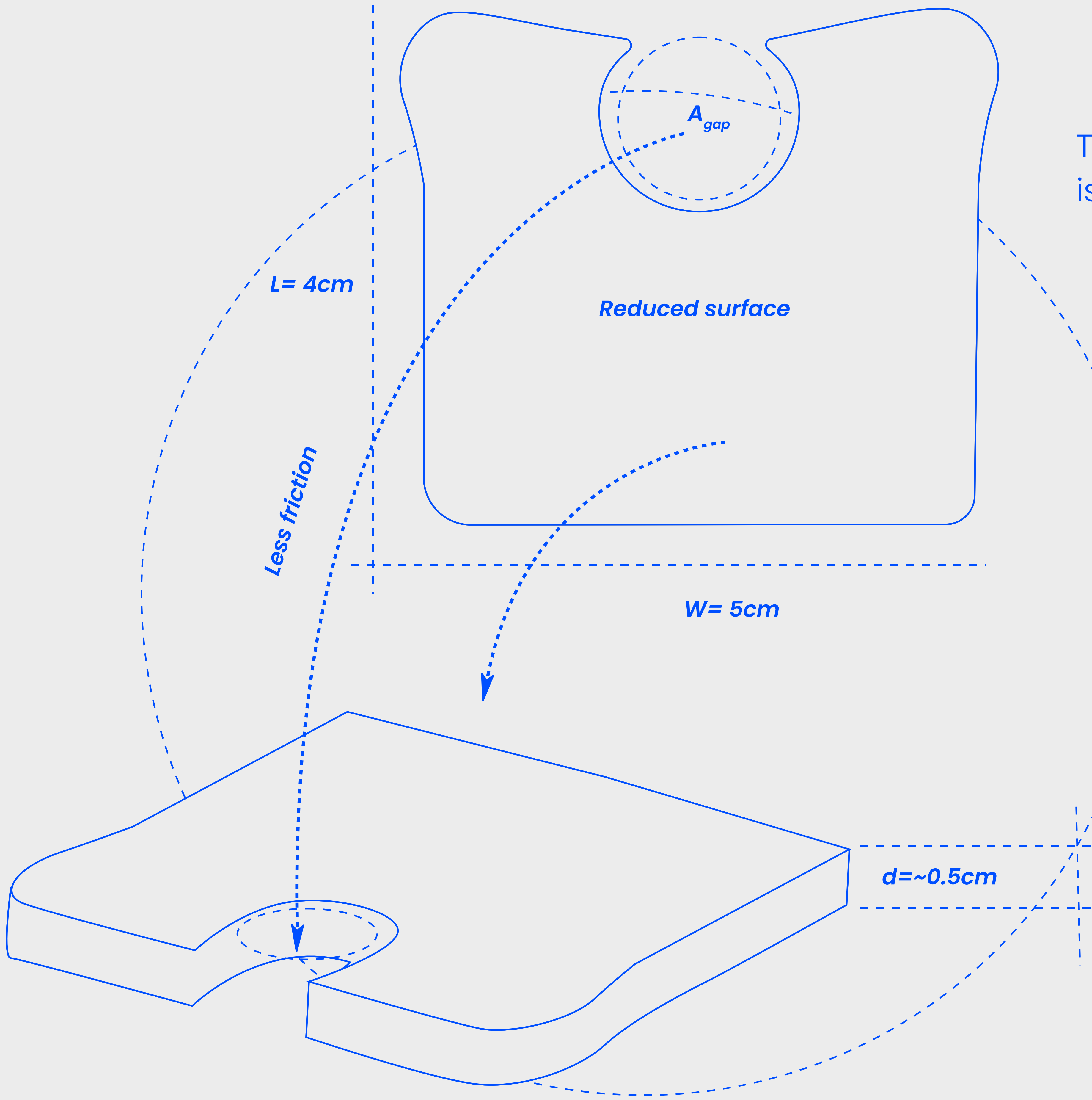
Specifications of the Anti-Murphy's Law toast design.

The final dimensions of the Anti-Murphy's Law Toast, approximately **4 cm × 5 cm × 0.5 to 0.8 cm,** strike a balance between effectiveness and practicality.

Taking into account the dimensions of the toast, The area of the gap is:

$$A = \pi r^2 = \pi(0.5)^2 = \pi(0.5)^2 \approx 0.785 cm^2$$

By adding a 0.785 cm radius circular gap, the toast has less surface in contact with the edge before it falls, which can lower the effective frictional force. Furthermore, the gap creates an uneven surface, meaning one side of the toast experiences less air resistance than the other. This difference in air drag can cause a stabilizing effect, reducing excessive rotation.



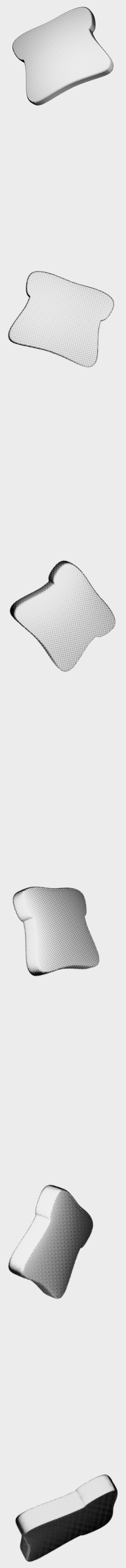
The total contact area (before falling) is now reduced by:

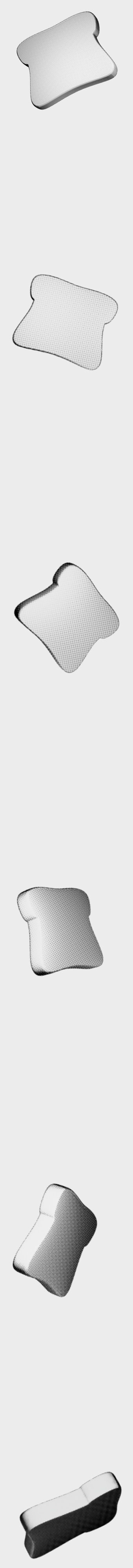
$$\frac{A_{gap}}{A_{edge}} = \frac{0.785}{4} = 19.6\%$$

As the toast leaves the table, its reduced dimensions and the presence of a small gap lower resistance, resulting in less applied torque (rotational force).

This combination minimizes rotation, allowing the toast to behave more like a simple falling object rather than a spinning one.

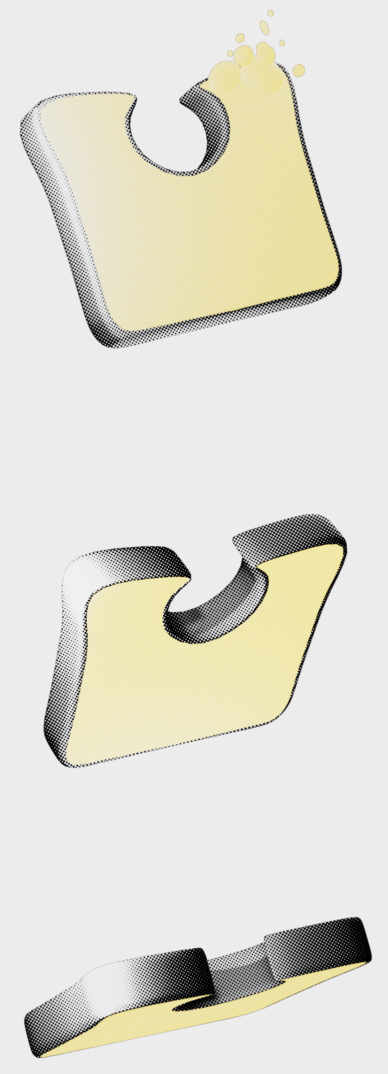
By controlling its motion at launch, the design helps the toast overcome the "Murphy's Law Range" and increases the likelihood of a butter-side-up landing.





This document gathers all the studies done by Robert Matthews, as well as some extended illustrations and calculations to help the understanding of certain aspects of the project. It also includes extracts from his original study, *"Tumbling Toast, Murphy's Law and the Fundamental Constants."*

Disclaimer: While the above is based on scientific principles to reduce the risk of "Murphy's Law of Toast", no guarantee of the complete elimination of this risk is either given nor implied.



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