CERN IdeaSquare Journal of Experimental Innovation, 2018; 2(1): 46-50
DOI: https://doi.org/10.23726/cij.2018.798

IDEASQUARE COFFEE-PAPER

Soap bubbles and flying to the moon

In addition to its main purpose of publishing experimental innovation research related results, CIJ also publishes more light, inspirational food-for-thought intended "IdeaSquare Coffee Papers". These pieces are collaborative efforts prepared by visiting researchers from various walks of life visiting or staying at CERN IdeaSquare premises. The identity of the contributing authors is kept anonymous (although known) but helpful hints can be found in the literature references. Editors of this section are Dr. Markus Nordberg and Dr. Valeria Brancolini.

EXECUTIVE SUMMARY

This time the experimental innovation team at IdeaSquare explores the science (and excitement) behind soap bubbles seeking for keys to achieve “order of magnitude jumps” in projects.

INTRODUCTION

Looking for inspiration on a sunny summer morning, the IdeaSquare experimental innovation team decides to enjoy a nice coffee break outside. The selected place is CERN Microcosm garden. This interesting spot exhibits “historical artefacts” that pioneered a long time ago the searching of the fundamental constituents of the Universe at CERN. The team seeks for a shadowy shelter under the Big European Bubble Chamber (BEBC) (Fig. 1). BEBC was a large size detector formerly used to study particle physics at CERN[1]. The Bubble chamber was invented in 1952 by Donald A. Glaser, for which he was awarded the 1960 Nobel Prize in Physics[2]. We were told that the bubbles in a glass of beer inspired him. Although he refuted this story, beer played a significant role in his invention since he did experiments using beer to fill early prototypes[3].

Fig. 1 The Big European Bubble Chamber (BEBC) in the CERN Microcosm garden.

The conception and construction of giant bubble chambers such as the BEBC was based on the *know-how* acquired through smaller bubble chambers such as the 30 cm hydrogen chamber, which came into operation at CERN in 1960. It

[1] The chamber body, a stainless-steel vessel, was filled with 35 cubic metres of superheated liquid hydrogen, liquid deuterium or a neon-hydrogen mixture, whose sensitivity was regulated by means of a movable piston weighing 2 tons.
[2] https://en.wikipedia.org/wiki/Donald_A._Glaser
[3] In case that you are interested in the nerdy details, as charged particles coming out of collisions enter the bubble chamber filled with liquid at a high pressure, a falling piston quickly decreases the pressure of the liquid producing a “boiling phase”. While travelling through the chamber, the charged particles create an ionization track, around which the liquid vaporizes, forming microscopic bubbles. Bubble density around each track is proportional to a particle's energy loss and grows in size as the chamber expands as the piston falls, until they are large enough to be seen or photographed. Several cameras are mounted around the chamber allowing a three-dimensional image to be captured.

was followed four years later by the 2 m hydrogen chamber. BEBC was indeed a several orders of magnitude jump! As stimulating morning coffee conversations in gardens go, we asked ourselves whether there could be a "more universal" relation between "orders of magnitude jumps and bubbles". In particular soap bubbles. This coffee paper attempts to reproduce this Ariadne's thread the best as we can[4].

SOAP BUBBLES CARRY MY DREAMS UP HIGH[5]

Our team believes soap bubbles are amazing fun for everyone[6]. They come in all spherical sizes from tiny to gigantic. A soap bubble has two spherical surfaces (inside and outside) with a thin layer of liquid in-between that we call the filmOne of many examples is the unintended "butterfly" consequences that MEMs accelerometers and gyroscopes (normally used for car navigation systems) had for the video game industry.

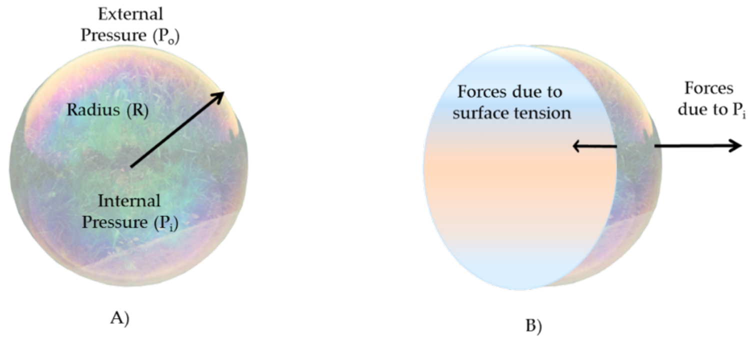

Fig. 2. Soap bubble in equilibrium.

Like in a balloon, the pressure P_i inside a soap bubble should be at least slightly greater than that on the outside, P_o,- otherwise we will have no bubble (Fig. 2 A). Now, assume that the soap bubble does not move and is cut into two halves (Fig. 2 B). Being at rest, each half has no acceleration. According to Newton's second law of motion[7], zero acceleration implies that the net force acting on each half must be zero. In other words, all forces are in equilibrium which means that their sum must be zero[8]. Let's see now what kind of forces are at play. First, the magnitude of the force due to each surface of the film is the product of the surface tension γ[9] and the circumference ($2\pi R$). The total force due to the inner and outer surfaces is then twice this amount or $-2\gamma(2\pi R)$. The minus sign denotes here that this force points to the left in the drawing. We also assume the film sufficiently thin enough so that its inner and outer radii are nearly the same, R. Second, there is a force caused by the air pressure inside the bubble[10]. At each point on the surface of the bubble, the force due to the air pressure is perpendicular to the surface and is directed outward. The total force as illustrated in Fig. 1B is equal to the product of the pressure P_i inside the bubble times the circular cross-sectional area of the spherical hemisphere, $P_i(\pi R^2)$. Using these expressions for the forces at play due to the surface tension and air pressure, and the equilibrium condition (i.e. the sum of all forces acting on a bubble must be zero) we can write:

$$-2\gamma(2\pi R) + P_i(\pi R^2) = 0$$

Then solving for P_i gives us:

---

[4] Ariadne in Greek mythology was the daughter of Minos, King of Crete. She fell in love with Theseus (the mythical king and founder-hero of Athens), and helped him by giving him a sword and a ball of thread, so that he could find his way out of the Minotaur's labyrinth.

[5] This sentence belongs to the lyrics of the Dressy Bessy indie rock-band song Bubbles that one of our more musical team members was playing during our coffee discussions.
https://www.youtube.com/watch?v=RiFDEziHJRI https://en.wikipedia.org/wiki/Dressy_Bessy

[6] Cyril Isenberg, *The Science of Soap Films and Soap Bubbles,* Dover 1992.

[7] $F = ma$, (force equals mass times acceleration).

[8] The mathematical expression will be $\sum F = 0$, being F, the forces.

[9] Surface tension is a sort of elastic force. It for example allows aquatic insects like water striders, usually denser than water, to float and stride on a water surface. We do not worry about water temperatures here.

[10] For a moment, we ignore the external pressure P_0.

$$P_i = \frac{4\gamma}{R}$$

But (as we mentioned), the pressure outside the bubble P_o is not zero, we need to look at the difference between the inside and outside pressures. Therefore, we have:

$$P_i - P_0 = \frac{4\gamma}{R}$$

This result tells us that the difference in pressure depends on the surface tension and the radius of the sphere. Just in case you too want to impress your (nerdy) friends, the equation above is known as Laplace's law, after the French physicist and mathematician Marquis Pierre Simon de Laplace who is sometimes referred as the Newton of France.[11]

One interesting observation about this formula is that greater pressure exists inside a smaller soap bubble (smaller value of R) than inside a larger one. Also experiments show that large bubbles last longer than small ones[12]. This observation turned out to be important while our team reflected upon "order of magnitude jumps" and what can trigger them.

FLY ME TO THE MOON[13]

Carried away by the vision of soap bubbles flying high in the sky, the IdeaSquare experimental innovation team then investigated Moon-shot projects as examples of achieving "order of magnitude jumps". We tried to look for a common denominator. After long hour of debate at IdeaSquare and many soap bubbles floating around we concluded that this common denominator is *passion.* Passion is the "secret weapon" of the courageous who breathe at the intersection of a far-reaching goal and the requirement of radical solution to produce "order of magnitude jumps". For us evidence clearly emerged from Cristopher Columbus' trip all the way to the Apollo Programme and the deciphering of the Human Genome or the discovery of the Higgs Boson.

But what about the bubbles? Well, after long hours at the CERN Library we found that we were not the only ones obsessed with bubbles. Monika Gisler and Didier Sornette from ETH Zurich have actually proposed a theory of "Social Bubbles" as levers of "order of magnitude jumps" after analysing examples such as the Apollo and Human Genome programmes[14]. The social bubble hypothesis claims that strong social interactions between enthusiastic supporters weave a network of reinforcing feedbacks. It leads to widespread endorsement and extraordinary commitment by those involved, beyond what would be rationalized by a standard cost-benefit analysis[15]. The consequence is "order of magnitude jumps"[16].

In our view, this theory is consistent with the consequences of Laplace's law as well as with the results coming from the experiments with bubbles mentioned before: the bigger the bubble, the better[17]; and the more passionate pioneers are pursuing, committing and collaborating for an inspiring goal the more chances to achieve it. Remember the experimental evidence coming from Laplace's law: large bubbles (less inside pressure) last longer than small ones.

With this in mind, our self-appointed/self-taught IdeaSquare innovation management team declared a universal recipe for "order of magnitude jumps":

1. Dough your "unreachable goal".
2. Spice it with the largest possible network of committed and passionate individuals.
3. Bake it carefully allowing it to grow but not to pop by reinforcing feedback.

---

[11] https://en.wikipedia.org/wiki/Pierre-Simon_Laplace

[12] T. Gilet et al. *How long will a bubble be?*, https://arxiv.org/abs/0709.4412

[13]Frank Sinatra's 1964 version of the 1954 song by Bart Howard that was closely associated with the Apollo missions to the Moon, https://en.wikipedia.org/wiki/Fly_Me_to_the_Moon . But of course the more senior members of our theme already knew that.

[14] Gisler, Monika and Sornette, Didier and Grote, Gudela, Early Dynamics of a Major Scientific Project: Testing the Social Bubble Hypothesis (June 27, 2013). Available at SSRN: https://ssrn.com/abstract=2289226 or http://dx.doi.org/10.2139/ssrn.2289226

[15] Monika Gisler, Didier Sornette and Ryan Woodard, Innovation as a Social Bubble: The Example of the Human Genome Project, Research Policy 40, 1412-1425 (2011).
(http://arxiv.org/abs/1003.2882
Monika Gisler and Didier Sornette, Exuberant Innovations: The Apollo Program, Society 46, 55-68 (2009), DOI: 10.1007/s12115-008-9163-8
(http://arxiv.org/abs/0806.0273 and http://ssrn.com/abstract=1139807).

[16] D. Sornette, Nurturing Breakthroughs; Lessons from Complexity Theory, Journal of Economic Interaction and Coordination 3, 165-181 (2008), DOI: 10.1007/s11403-008-0040-8.
(http://arxiv.org/abs/0706.1839)

[17] Remember the experimental evidence coming from Laplace's law: large bubbles (less inside pressure) last longer than small ones.

LOOP-DE-LOOP[18]

Although very self-content with our recipe, we wanted to refine further our model. Once passion was identified as the main driver behind "orders of magnitude jumps", it was necessary to think deeper about what was the exact mechanism keeping this passion alive for long time periods. At the end of the day, "orders of magnitude jumps" are the consequence of working towards a seemingly unreachable solution for a huge problem or vision, and this cannot be achieved overnight. Surely there will be moments of fear and tears and passion would be the only grip to keep going. Hence, the longer the passion lasts, the longer the bubbles live, the longer the chances to make "orders of magnitude jumps" towards a Moon-shot type of goal.

After hours of staring at Lapalce's law equation, the IdeaSquare experimental innovation team realised that bubbles are fragile objects in equilibrium governed by the subtle feedback between internal and external pressures. Apply a little more of internal pressure and the bubble will pop; apply less and it will collapse due to the external pressure. In physics jargon bubbles can be considered as *systems in equilibrium*. Suddenly we got the Aha! For the bubble to last long, the feedback needs to be of two kinds: reinforcing and balancing. Only then the perfect equilibrium can be reached and the bubble will last.

Again back at CERN's library we found to our delight that Peter Senge from the MIT Sloan School of Management perfectly defined these two types of feedback in his landmark book *The Fifth Discipline*[19]. On one side he distinguishes *reinforcing (or amplifying) feedback* processes as engines of growth and on the other side *balancing (or stabilizing) feedback* operating whenever there is a goal-oriented behaviour. Just as our bubble's equilibrium caused by the interplay between internal and external pressures.

This last insight (thanks to Peter), allowed us to refine step 3 of our recipe as follows:

1. Dough your "unreachable goal".
2. Spice it with the largest possible network of committed passionate enthusiasts.
3. Bake it carefully allowing it to grow but not to pop by reinforcing and balancing feedback.

Moreover, we are ready to offer you our "quick and dirty" strategic management guide in case you are involved in a project trying to achieve an "order of magnitude jump" but did not quite know how to describe it. Here it is (Fig. 3):

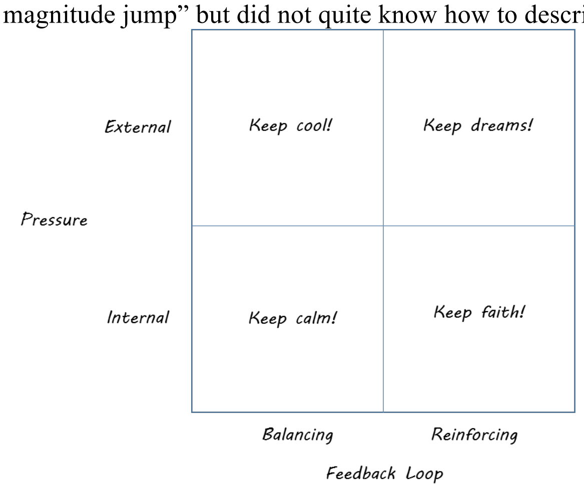

Fig. 3. IdeaSquare experimental innovation team "quick and dirty" strategic management matrix for "order of magnitude jumps" projects.

The matrix above offers you the basics you will need to remember and transmit to your passionate fellow colleagues:

1. Too much inside overenthusiasm (internal pressure) could be damaging; balance it by remaining calm.
2. If the internal pressure grows because you become desperate along the way: reinforce yourselves and keep faith!
3. Too much overenthusiasm from outside (external pressure) could be damaging; balance it by staying cool.
4. In case people will lose their faith on you, threaten to cut your budget or tell you that it is impossible: reinforce yourselves and keep your dreams alive! Amplify your passion!

---

[18] The young component of our IdeaSquare innovation team retaliated to Sinatra by playing Loop-de-Loop https://www.youtube.com/watch?v=wnuHId1_dS8 ; a song by the alternative US rock band Ween featuring in the SpongeBob episode "Your Shoe's Untied." When SpongeBob forgets how to tie his shoes, he is roared by Gary (his snail friend), who appears to have shoes too, so he plays the song with a record player under his shell. https://en.wikipedia.org/wiki/Ween .

[19] Peter Senge, *The Fifth Discipline: The art and practice of the learning organization*, Doubleday, New York, 1990.

"TWO BEERS OR NOT TO BEERS, THAT'S THE QUESTION!"

This time, IdeaSquare's experimental innovation team was triggered by the question of how to achieve "order of magnitude jumps".

Seeking for an answer we have identified that an "unreachable goal" and the passion to achieve it is an excellent way to start. Investigating the science of soap bubbles gave us further insights about how to keep this passion alive. Also, it provided us very useful insights about the strategies to follow when things get either sour or too sweet.

We kindly offer you, our scientific recipe and, as an extra bonus, a "quick and dirty" strategic management matrix for "order of magnitude jump" projects.

Enjoying bubbling beers we say good-bye, or better, see you later, citing, we think, the great Shakespeare in his apocryphal words.

Cheers.