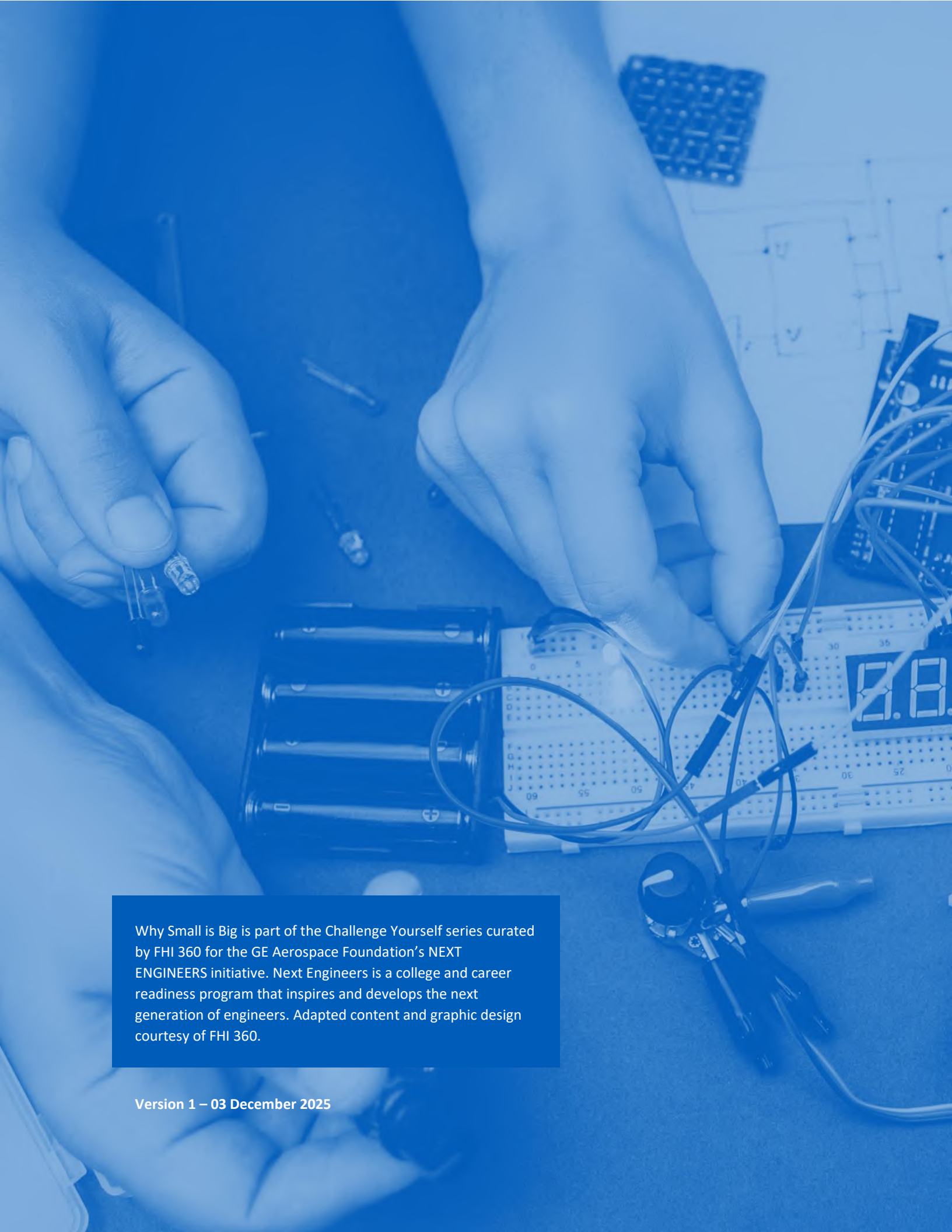
NEXT ENGINEERS

CHALLENGE YOURSELF

Tiny Machines Part 1: Why Small is Big

Nano Engineering



Why Small is Big is part of the Challenge Yourself series curated by FHI 360 for the GE Aerospace Foundation's NEXT ENGINEERS initiative. Next Engineers is a college and career readiness program that inspires and develops the next generation of engineers. Adapted content and graphic design courtesy of FHI 360.

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NERD OUT

The big world of the small

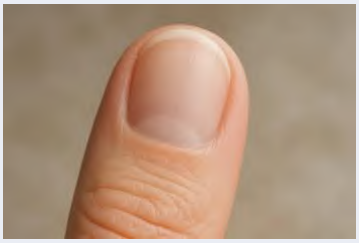
Welcome to the very big world of the very small. You may have heard about nanotechnology but what exactly is it and why does it matter? Nanotechnology is manipulating molecules (and even individual atoms) to make things that use the unique properties of matter at very small scales.

But how small are we talking? Nanotechnology deals with things between 1 and 100 nanometers. A nanometer (nm) is one billionth of a meter. That means that the difference between a nanometer and a meter is the same as the difference between a marble and the Earth.

The scale of things by NNI is used under fair use
https://www.nano.gov/nanotech-101/what/nano-size

DID YOU KNOW

Your fingernails grow about 86,000 nm per day or about 1 nm per second.



HAVE A THINK

If people were the size of nanoparticles, how many people could you fit into a teacup?

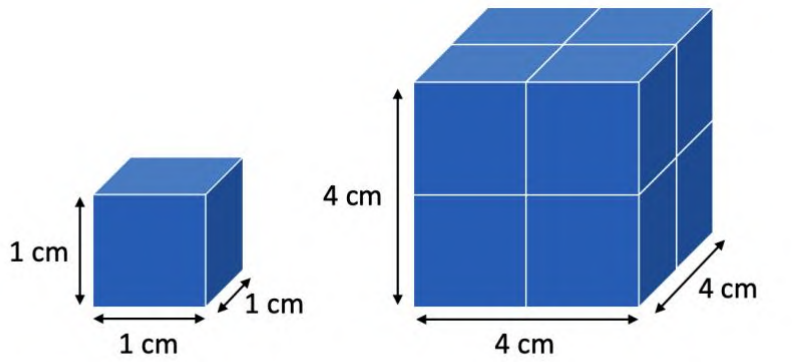
For a visual sense of this scale, have a look at the interactive animation at *Secret Worlds: The Universe Within* (https://micro.magnet.fsu.edu/primer/java/scienceopticsu/powersof10/index.html). Here you can step through different levels of magnification from the Milky Way galaxy down to individual protons.

Why it matters

It turns out that nanoparticles can exhibit different properties from things at the human scale. Some are stronger while others are more reactive. Some have different magnetic properties, while some are better conductors of electricity and heat. Still others can change color depending on how big they are. For example, a nano gold bar can appear red or purple (depending on its size) and has a lower melting point than an ordinary gold bar.

This 'strangeness' is partly because, at the nano scale, **quantum** effects tend to dominate. It is also because at this scale, surface area plays a much larger role. The ratio of surface area to volume is much greater.

Take the following two blocks as an example.



Surface area = 6 cm^2	Surface area = 24 cm^2
Volume = 1 cm^3	Volume = 8 cm^3
Surface area : Volume = 6 : 1	Surface area : Volume = 3 : 1

The smaller block has a greater **surface area to volume ratio**. It has more surface area per unit volume. This can make nanomaterials behave in some unusual and unexpected ways.

We know that the total surface area of a 1 cm^3 block is 6 cm^2. If we divided this 1 cm^3 block into blocks each 1 mm^3 in volume, what would the total surface area of all these blocks be in cm^2?

Hint: If there are 10 mm in 1 cm how many 1 mm^3 blocks would fit inside a 1 cm^3 block?

DID YOU KNOW

The ordinary rules of nature we are so familiar with don't work at the nano level. Here, things follow quantum mechanics , a set of rules that control how atoms and sub-atomic particles interact. **If You Don't Understand Quantum Physics, Try This!** (12:44) (https://www.youtube.com/watch?v=Usu9xZfabPM).

LEARN MORE

To learn more about nanotechnology and why it is increasingly important, read the article called **Ten things you should know about nanotechnology** (https://www.nanowerk.com/nanotechnology/ten_things_you_should_know_3.php)

Natural nanotech

As clever as scientists and engineers are, nature is just as clever. Nature basically runs on nanotechnology! For example, geckos can climb walls so easily because of nano-hairs on their feet that get so close to the wall that the atoms in the hairs are attracted to the atoms in the wall making the gecko's feet stick. What would you do with this superpower? What useful products can you imagine that would use similar nano-engineering?

Or how about the amazing colors of some butterfly and bird wings. These are not all normal pigments. Some of these colors are because of nanostructures. Depending on their size they refract light differently and, therefore, look different colors. What amazing uses can you think of for materials made up of these kinds of nanostructures?

If you want to find out more about natural nanotechnology, start by watching these great videos.

- *Natural Nanotech: How Geckos Climb Walls* (1:42) (https://www.youtube.com/watch?v=Gy3SPnAwVgc)
- *Natural Nanotech: Bright Colors from the Nanoscale* (1:42) (https://www.youtube.com/watch?v=OBo3n7W4aL8)

Watch *The Tiny Guide to Nanotechnology* (4:57) (https://www.youtube.com/watch?v=YYxRi5rs2Gw) and *Big Things from a Tiny World* (1:51) (https://www.youtube.com/watch?v=lN2qmYFzq7Y) for excellent summaries of nanotechnology.