# Science AMA Series: Hi Reddit, we're the pilots of molecule-cars from six countries involved in the smallest car race in history, the NanoCar Race. Ask us anything!

$Nano_{C}ar_{R}ace^{1}andr/ScienceAMAs^{1}$

[1]Affiliation not available

April 17, 2023

**Abstract**

Hi reddit! The NanoCar Race is an event organized by the CNRS, the French National Center for Scientific Research, in which molecular machines compete on a nano-sized racetrack. These "NanoCars" or molecule-cars can have real wheels, an actual chassis... and are propelled by the energy of electric pulses! Nothing is visible to the naked eye, however a unique microscope located at the CNRS's Centre d'élaboration de matériaux et d'études structurales (CEMES) in Toulouse (south-western France) will make it possible to follow the race. The six teams are: -The Green Buggy from Université Paul Sabatier (Toulouse, France): http://nanocar-race.cnrs.fr/equipesen-fr.php -The Swiss Nano Dragster from University of Basel (Switzerland): http://nanocar-race.cnrs.fr/equipesen-ch.php -Dipolar Racer from Rice University (Houston, USA) / Graz Universität (Graz, Austria): http://nanocar-race.cnrs.fr/equipesen-ua.php -Windmil from Technische Universität Dresden (Dresden, Germany): http://nanocar-race.cnrs.fr/equipesen-de.php -NIMS-MANA car from National Institute for Materials Science (Tsukuba, Japan): http://nanocar-race.cnrs.fr/equipesen-jp.php -Ohio Bobcat from Ohio University (Athens, USA): http://nanocar-race.cnrs.fr/equipes-us.php We are also with Claire-Marie Pradier, Scientific Deputy Director at the Institute of Chemistry of the CNRS and with Erik Dujardin, Research Director at CEMES CNRS in Toulouse France, who is heading the group who organized and is hosting the first-ever race of molecular cars. A genuine scientific prowess and an international human adventure, the race is a one-off event, and will be broadcast live on http://nanocar-race.cnrs.fr/indexEnglishLive.php and the NanoCar Race YouTube channel: https://www.youtube.com/c/NanoCarRace/live We'll be back at 11 am EST to answer your questions! AUA! Proof : http://imgur.com/a/1QhWh

the WINNOWER

REDDIT

# Science AMA Series: Hi Reddit, we're the pilots of molecule-cars from six countries involved in the smallest car race in history, the NanoCar Race. Ask us anything!

NANO_CAR_RACE R/SCIENCE

Hi reddit!
The NanoCar Race is an event organized by the CNRS, the French National Center for Scientific Research, in which molecular machines compete on a nano-sized racetrack. These "NanoCars" or molecule-cars can have real wheels, an actual chassis... and are propelled by the energy of electric pulses! Nothing is visible to the naked eye, however a unique microscope located at the CNRS's Centre d'élaboration de matériaux et d'études structurales (CEMES) in Toulouse (south-western France) will make it possible to follow the race.
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-Dipolar Racer from Rice University (Houston, USA) / Graz Universität (Graz, Austria): http://nanocar-race.cnrs.fr/equipesen-ua.php
-Windmil from Technische Universität Dresden (Dresden, Germany): http://nanocar-race.cnrs.fr/equipesen-de.php
-NIMS-MANA car from National Institute for Materials Science (Tsukuba, Japan): http://nanocar-race.cnrs.fr/equipesen-jp.php
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CORRESPONDENCE:

DATE RECEIVED:
April 29, 2017

DOI:
10.15200/winn.149338.80266

ARCHIVED:
April 28, 2017

CITATION:
Nano_Car_Race , r/Science , Science AMA Series: Hi Reddit, we're the pilots of molecule-

Thanks for doing and AMA and for promoting science in a fun and interesting way. I've watched parts of the stream and I have a few questions.

1. How are they built?
2. How do you transport the cars from lab to racetrack?
3. How was the racetrack built? What kind of material was used?
4. Can you steer them? If so how? Do they follow an electric gradient?
5. Are the cars racing on the same track, side-by-side, or on separate tracks? What would happen in case of a collision?

cars from six countries involved in the smallest car race in history, the NanoCar Race. Ask us anything!, *The Winnower* 4:e149338.80266 , 2017 , DOI: 10.15200/winn.149338.80266



6. Top Speed?
7. Distance from start to finish line?
8. Are there any animations of the cars that show how the different designs move along the track?
9. In case of a crash (or the car getting stuck) are you able to perform maintenance or replace it?
10. Where will you go from here? What is the next step after the race?
11. Will it be possible to genetically alter bacteria to produce the cars/nanobots?
12. Are you able to build nano-cars powered from sources other than electrical gradients, like say ATP? Like how the 'kinesin' molecule walks along microtubules in the cell.

Edit: More questions

DorvoG

Hi I am Francesca Moresco, leader of the Dresden team.

First question: Five of the six nanocars have been entierely synthesized by organic chemistry in solution. The cars car made of carbon, oxygen, hydrogen and nitrogen atoms only. Chemical reactions are performed to link the atoms together into molecules. Then molecular building blocks are sewed together to create the nanocars with more chemical reactions. Some cars need 12-15 chemical steps and several months of hard work ! For the german car, it is the same thing except for the very last step which has been performed this week directly on the racing surface: the modules are deposited on the gold surface, which is then slightly heated and the modules click in together and results in the NanoWindMill . NOrmally, four block are joined together but somehow today we got only 3 and so our car is slower than usual. But our pilot is trying hard!!

2nd question: To transfert the molecules from the vial where the chemist put them onto the surface where the racetracks are, the molecules are evaporated in ultra high vacuum in the microscope

3rd Question(How was the racetrack built? What kind of material was used?) Hi I am Tobias Meier, co-pilote of the Swiss Team. The race track is built on the surface of a gold single crystal. That's a perfectly pure gold crystal. The atoms spontanously organize on the surface and build regular rails that we use for the race track. To have such a atomically flat surface, we have to prepare the sample before to clean it. That's done by bombarding with ions. Afterwards we heat the sample to get flat terraces and the race track forms spontanously.

4th Question: HI I am Grant Simpson, pilot for the Rice-Graz Dipolar Racer Team. Our molecule contains specific chemical groups which produce a tiny dipole within the molecule. We then bring the tip the STM somewhere close the molecule and provide a voltage pulse. This voltage pulse creates a local electric field. The dipole of the molecule is attracted towards this field and the molecule moves over the surface. We can steer the molecule by choosing the position of the voltage pulse.

6th question:

This is Erik Dujardin from CEMES-CNRS, the team organizing the event Real speed (ie when the car is moving) is about 2mph. Average speed is between 3 and 20 nm/h.Details: Nanocars move one step at a time under each electrical pulse. Then we need to image to relocate the car. This takes time. If you just look at the steps, a 1-nm car jumps by 0.3nm per 0.5 second pulse, so it move about by its own size in a second. Converted into real-like car, this is about 10 km/h. Compare this to the speed of the cars engaged in the very first race in 1894: 18 km/h !Now, during this race, the nanocars will run about 100 nm in 30 hours, so about 3 nm/h as average speed..... with most of the time spent in taking images of the car at rest!

10th question(Where will you go from here? What is the next step after the race?) Hi this is Waka Nakanishi and Marek Kolmer, respectively the chemist and pilot of the MANA-NIMS Team, We think that all of us will come back to their research. We are working on -270oC (very cold) and under low pressure. To make the molecular machine to be used in our environment we need moderate condition. We would like to get those nanocars out of ultra high vacuum and be able to drive them in ambient conditions

In the most basic terms possible, how exactly do electric pulses cause a nano car to function as intended?

JaySayMayday

Hi I am Francesca Moresco, leader of the Dresden team. . It's called the inelastic effect: the electrical current during the pulse excites the molecules, which then relax and if all goes well will result in one forward step of the nanocar. One extra effect can be used, the electric field produced by the tip, which is the same that get your hair all spread out when you take out your woolen sweater in winter.

So how do you build the cars?

Stuckherefordays

Hi this is Eric Masson from the Ohio Bobcat Nanowagon team at Ohio University. I am the chemist who designed the car. We started with preparing the drive shaft, then the rear and front axles with a series or organic chemistry reactions. The last step was the connection of the drive shaft with the axles to get a chassis that has an "H" shape. We then added the chassis to water, and threw 4 wheels into the mixture. The wheels are pumpkin-shaped molecules that like to thread into axles. And this is it! We have our car in water. We then remove water, and send the car onto the surface.

So how do you build the cars?

Stuckherefordays

Hi this is Waka Nakanishi and Marek Kolmer, respectively the chemist and pilot of the MANA-NIMS Team, It obviously depends on the molecular structure. In our case, only one step to go. Basically mixing the part of nanocar structure in organic solvents and make new chemical bonds.

Can....can they drift?

solidpenguin

this is Erik Dujardin, Group leader of the NanoSciences Group in CEMES-CNRS, the group organizing the NanoCar Race, indeed, you could say that 3 of the nanocars (those without wheels) actually skid on the surface. For the wheeled ones, the electrical impulse can sometime induce a lateral movement of the car perpendicular to the wheel orientation .... that's drifting, right! But pilots usually do not like this to much as it pusjes the nanocar on the track sides where it can easily get trapped forever!

What real-world applications can you see coming from the ability to design and race microscopic vehicles?

pizzaboy192

HI I am Grant Simpson, pilot for the Rice-Graz Dipolar Racer Team. In general the field of nano machines has created a fantastic amount of interest (especially since the recent Nobel prize in chemistry). Although the field is still new, one can imagine a multitude of different applications. This could include drug delivery systems in biological applications. Also, cell membrane repair. Further, one can also apply such nanomachine to surface cleaning and atom transport in industry.

What real-world applications can you see coming from the ability to design and race microscopic vehicles?

pizzaboy192

Hi I am Francesca Moresco, leader of the Dresden team. Applications can be in the field of molecular electronics or molecular nanomachines, to perform calculations with molecula-sized elements.

So, how do you program these cars? DO you write any code on computer and load it? Or how do you do it? I am still amazed about it.

waveicle

HI I am Sebastien Gauthier one of the pilots of the French Toulouse Nanomobile Team: There is no program. This is real physics: wwe manually position the microscope tip above the molecule. When we chose carefully the location, and the pulse conditions - if we are lucky - the nanocar goes where we planned. Then we image it with the same tip (but in softer conditions) to see where it has gone and do it again

why did the swiss team build a robin reliant?

Caddy666

Hi I am Tobias Meier, co-pilote of the Swiss Team. We have chosen the structure of our Swiss Nanodragster, that ressembles the reliant robin, because it has a asymmetry which we use to control the direction of the mouvement of the molecule. A symmetric structure could not be easily geared in the desired direction.

Whats up tiny racers! How much horsepower and power to weight ratio? I'm looking for exact numbers here, hehe.

CriticalDispatch

Hi This is Saw Hla from Ohio team. I am a physics professor.
We usually use nanometers and seconds rather than horsepower, but I can estimate the power to drive a single nanocar. it is 1E-12N *1E-9m/s. This should be about 1E-24 hp (that is 1 millionth of a billionth of a billionth horsepower). This is very tiny amount.

How much does it cost to create a nano-car? I assume you can create multiple- unless they are one of a kind?

MrSteamie

This is Erik Dujardin, Group leader of the NanoSciences Group in CEMES-CNRS, the group organizing the NanoCar Race, We are taking about craftsmanship here! Rather than cost, we should say how much manpower and time . The synthesis takes between a few weaks and up to 2 years for a full time chemist (a Phd student for example). Developping and building the microscope we run the race on took 2 years for a team mixing the manufacturing company (Scienta Omicron in Germany) and our microscopist team members. Developping the protocols to prepare the gold surface and race tracks, deposit the molecules on the surface, and then manipulate them with this electron pulse method and image them is a know-how that we have acquired in our labs for the several past years.

Now, ShowMeTheMank is right, the nanocars ar produced by organic chemsitry in solution so with make billions of identical nanocars at once but much less arrive on the surface and then we use them one by one!

This sounds awesome! What type of advances can this lead to or is this just a demonstration of what is possible?

dfdx2

Hi This is Saw Hla (physicist) and Eric Masson (chemist) from Ohio team. We want to develop control transport at the molecular scale. For example, we will be able to transport information or nanocargo from point A to point B. Nature has many molecular machines including those that make our bodies function. We are learning from the nature and in this case, mimicking our world to develop functional nanoscale transport systems. This has to start with demonstration before getting actual applicable devices.

What happens if a wheel pops off, or if there is an accident?

CCarr33

HI I am Sebastien Gauthier one of the pilots of the French Toulouse Nanomobile Team. This actually happens!! Either we continue if the nanocar still moves or the rules allow us to use a spare nanocar that we find near the same track

What happens if a wheel pops off, or if there is an accident?

CCarr33

Hi This is Saw Hla (physicist) and Eric Masson (chemist) from Ohio team. Yes, it has already happened. What would happen if a real car in our world lost one wheel? When we lost one wheel, our nanocar got stuck and it no longer moved. From a chemistry point of view, we have observed that the chassis is easier to break than the (non-covalent/floating) connection between the axles and the wheels! Extremely surprising!

Asking for u/Drewcifer419 who is having account trouble:

What forces do nano-cars have to account for that average vehicles do not, if any?

Also, do any of the team members play online physics builders like Besiege or Robocraft

p1percub

HI I am Sebastien Gauthier one of the pilots of the French Toulouse Nanomobile Team. The force holding the nanocar on the surface is essentially van der Waals (weak forces). But the force that get the nanocar to move is rather related to the way the molecule relaxes after the injection of energy during the voltage pulse.

What are real world applications of nano-cars?

How can high school students like me get involved in stuff like this?

airfixfw

Hi this is Remy Pawlak, pilot of the Swiss nano Dragster. First of all, our nanocar molecule is already used in organic solar cell as a sensitizer. If you want to become a nanocar pilot, you should have interest in Physics, Chemistry and a bit of instrumentation... If you pick up Chemistry, your car will look nice. If you pick up Physics, it will be fast! In both cases, you need instrumentation to master our microscopes and synthesis setups.

How do you actually control it? Accelerate/Brake/Turning?

Phaedrus0230

Hi this is Tobias Meier, co-pilote and Rémy Pawlak of the Swiss Team. To propel the nanocar we inject a small amount of electrons from the tip to the molecule and we need an electric field to choose the direction. We don't have to brake because the molecule steps by 0.6 nm per electric pulse and stops. Then we have to pulse again. To accelarate you have to pulse more often.

What is the top speed ?

michaelbrules

HI I am Sebastien Gauthier one of the pilots of the French Toulouse Nanomobile Team. Real speed (ie when the car is moving) is about 2mph. Average speed is between 3 and 20 nm/h. Details: Nanocars move one step at a time under each electrical pulse. Then we need to image to relocate the car. This takes time. If you just look at the steps, a 1-nm car jumps by 0.3nm per 0.5 second pulse, so it move about by its own size in a second. Converted into real-like car, this is about 10 km/h. Compare this to the speed of the cars engaged in the very first race in 1894: 18 km/h !Now, during this race, the nanocars will run about 100 nm in 30 hours, so about 3 nm/h as average speed..... with most of the time spent in taking images of the car at rest!

What was the inspiration for nano-cars?

iMale

This is Erik Dujardin, Group leader of the NanoSciences Group in CEMES-CNRS, the group organizing the NanoCar Race, Good point, inspiration was really different for the 6 teams. Some are "technomimetic" ie you get inspired by real cars, simplify them (a car = a chassis, 4 wheels). For others they thought of the fastest vehicle on a atomically smooth surface, eventhough it did not look like a car but rather like a glider. Interestingly, in 1894 the first ever real car race took place in France with 200

different "cars" which looked very different form each other. Only 17 made it to the finish line and soon after the car industry started with the best working designs. For the next century, all cars worked basically on a single concept. Only recently, when this concept based on the explosive engine started to be questioned for ecological reasons, did engineer reconsider other possible concepts - maybe with some of them similar to the loosing cars in 1894!

Since all the cars look different in forms of aerodynamics is that a factor being that they are so small?

TsKLegiT

HI I am Grant Simpson, pilot for the Rice-Graz Dipolar Racer Team. Aerodynamics plays no role in the case of the nanocar race because the experiments are conducted in ultra high vacuum (the pressure here is similar to that found in interstellar space).

[deleted]

[deleted]

Hi I am Francesca Moresco, leader of the Dresden team. The race is a track with two curves, but not a closed circuit, 100 nm long. The microscope images a portion of the surface at a time before and after the movement of the nanocars.

How do you drive them? What surface do they drive on? Can you control them or is it like a mouse race where you let it go and hope it goes the fastest?

ibanezmelon

Hi this is Waka Nakanishi and Marek Kolmer, respectively the chemist and pilot of the MANA-NIMS Team, We drive the molecules on gold or silver surfaces. The molecules are driven by tunneling current resulting from a voltage pulse from STM tip. The control strongly depends on the molecule design, as some places are more sensitive. So we can control the move by precise injection of electrons into molecular states (sub Angstrom precision).

How do they even like... move?

Cabbagesavager

HI I am Grant Simpson, pilot for the Rice-Graz Dipolar Racer Team. In general, molecules can be moved by providing them with energy from, for example, electrons in the STM tunnel junction. Alternatively, molecules can be moved by following an electric field gradient. In both cases, it's possible to move the molecules nanometer by nanometer.

What advice would you give to any kids or young adults who want to pursue an interest like this?

Mosmordeus

HI I am Grant Simpson, pilot for the Rice-Graz Dipolar Racer Team. I think it's always easy to pursue a subject that is interesting for you. If you are excited by a subject, you will never get bored and this will strive you to do well. For me, i found chemistry and physics the most fun subjects at school. This made

me go to university to study it...which then brought me to this career...and also to participate in the nanocar race.

How long will the race take? What speeds are the cars expected to achieve? This is super cool btw!

Moridin_Naeblis

HI I am Sebastien Gauthier one of the pilots of the French Toulouse Nanomobile Team. We started the race 8 hours ago and it will last for almost another 24 hours. Re: speed see my answer above to michaelbrules.

Can you drift with them?

Beetletoes672

HI I am Grant Simpson, pilot for the Rice-Graz Dipolar Racer Team. This sounds like the movie 'The Fast and the Furious'! :) We haven't quite got to that stage with the nanocars!

Shouldn't the cars be drived by computers? If a Tesla can be driven by a computer it should be ease to make a program to drive this ones.

juanjodic

HI I am Grant Simpson, pilot for the Rice-Graz Dipolar Racer Team. The molecules are steered by computers. However, in our case there are humans controlling the computers. Perhaps one day we can automate the driving of the nanocars. Or - even better- the nanocars can be self-controlling.

Looks cool! I hope you take this without sarcasm nor judgement nor anything negative: what is it good for and why are you pursuing this?

BabiesLOVEclowns

Hi this is Tobias Meier, co-pilote and Rémy Pawlak of the Swiss Team. Good question! We like to study interactions between molecules and surfaces in general and on the atomic level. Interfaces are everywhere. The Nobel Prize for molecular machines in solutions is already gone. Now we focus on surfaces for the next one! ;-)

What is the biggest challenge?

SpellsThatWrong

Hi this is Tobias Meier, co-pilot and Rémy Pawlak, pilot of the Swiss Team. The challenge is to see four different molecules on one surface with one microscope. Another one is to run a single nanocar built of a few atoms for 100 nm and more 150 pulses. It can happen quite easily that the molecule jumps to the tip or moves uncontrollably. Our race track was on gold surface where you have a lot of natural traps because of the particular reconstruction.

How hard/easy is it to lose a car?

notquite20characters

Hi this is Tobias Meier, co-pilot and Rémy Pawlak, pilot of the Swiss Team. It's easy to loose the car. That's why we have to be delicate. If the pulse is too strong you destroy the nanocar structure or it can jump to your tip and is lost forever.

How do you drive it?

What material(s) is/are the race tracks made out of?

Aerospherology

HI I am Sebastien Gauthier one of the pilots of the French Toulouse Nanomobile Team. The nanocars are running on gold surface or (for one team) on silver. We power them with the electric pulse sent by our microscope tip to the molecule .The pulse excites the molecule. When it comes back to rest, it has moved by one step. And we start again

What are the tracks made out of?

RudeHero

HI I am Grant Simpson, pilot for the Rice-Graz Dipolar Racer Team. Our track is built on the surface of a silver single crystal. We constructed the track using controlled tip crashed from the stm tip. The track was 150nm long.

What, if any, implications does the technology hold for medicine?

Time_Stops

Hi This is Eric Masson (chemist) from Ohio team. The wheel portion of the car, called Cucurbituril, has some amazing properties that can be exploited in the medical field. As they can encapsulate other molecules in their cavities, they can protect drugs from degradation, but also help to solubilize them in water. They can even be used to trap some toxins and inactivate them in the body.

How fun is it to drive one of these cars?

funnyflywheel

Hi this is Waka Nakanishi and Marek Kolmer, respectively the chemist and pilot of the MANA-NIMS Team, It's really a fun, especially that we are doing this simultaneously with other drivers. You need to know that typically we spend hours alone in the labs and not share this activity with such a large public.

How fun is it to drive one of these cars?

funnyflywheel

Hi this is Tobias Meier, co-pilot and Rémy Pawlak, pilot of the Swiss Team. First hour a lot of fun. Second hour a bit less. Third hour we wonder why we are doing this. . . . Break . . 36th hour we will tell you tomorrow.

Wow! Thanks for doing this AMA. My question is: How long will the race take to complete?

Etroyer

Hi This is Saw Hla (physicist) and Eric Masson (chemist) from Ohio team. From Friday 11 am local time to Saturday 6 pm. Total is 31 hours.

Hi guys !

Few questions here : what is the max possible (in theory) speed of these little beasts ?

What is the theoretical range of these vehicles ?

Pillarsofcreation99

Hi This is Saw Hla (physicist) and Eric Masson (chemist) from Ohio team. It really depends on the car actually. In our case, our car is extremely fast. It is both a blessing and a curse. A blessing because, well, it goes fast, but a curse because we often lose track of our car on the surface!