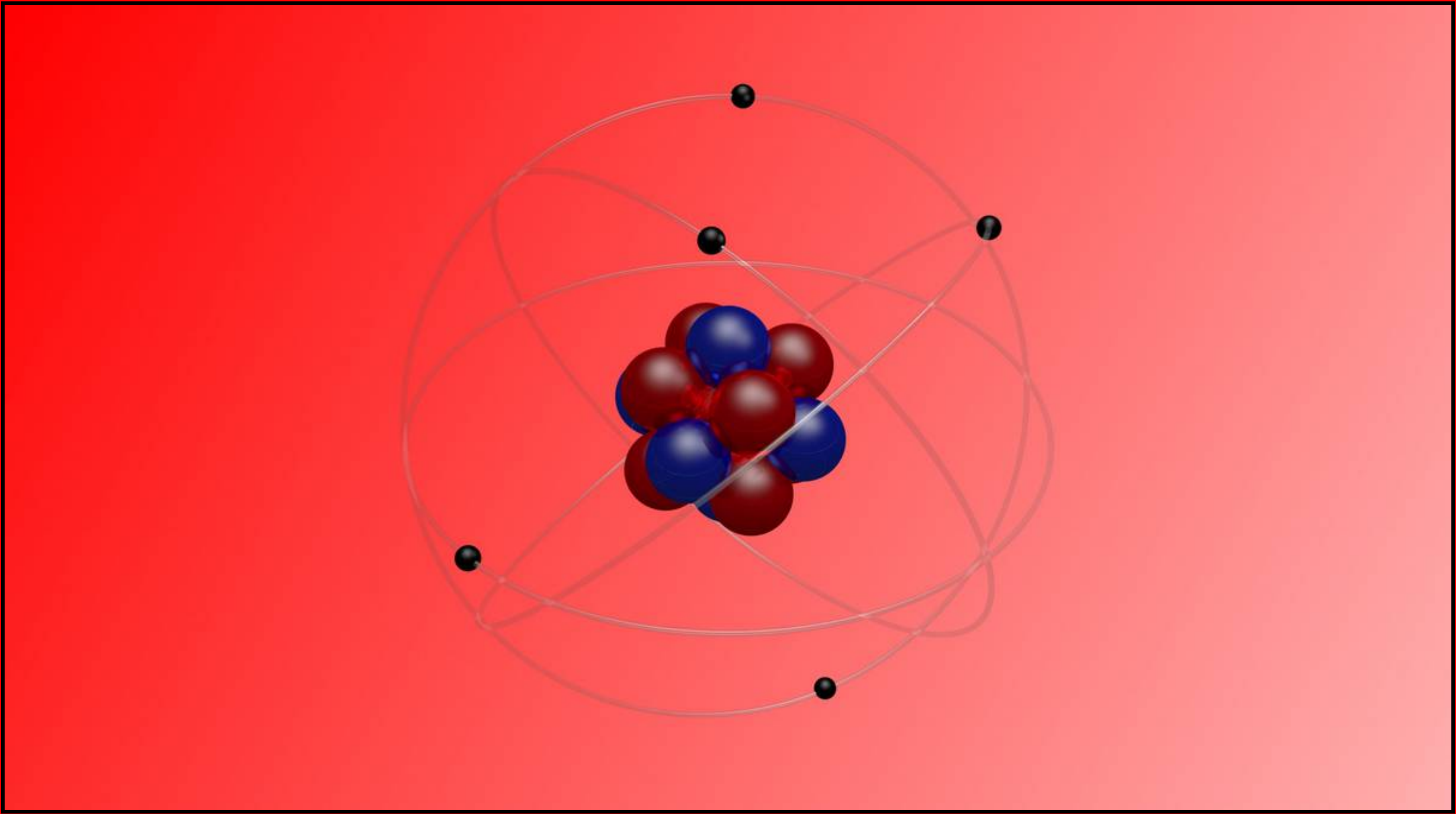

ATOMIC SPECIAL EDITION

Second red cats special edition

Monday, October 23, 2023

Maxim Thibodeau

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INTRODUCTION

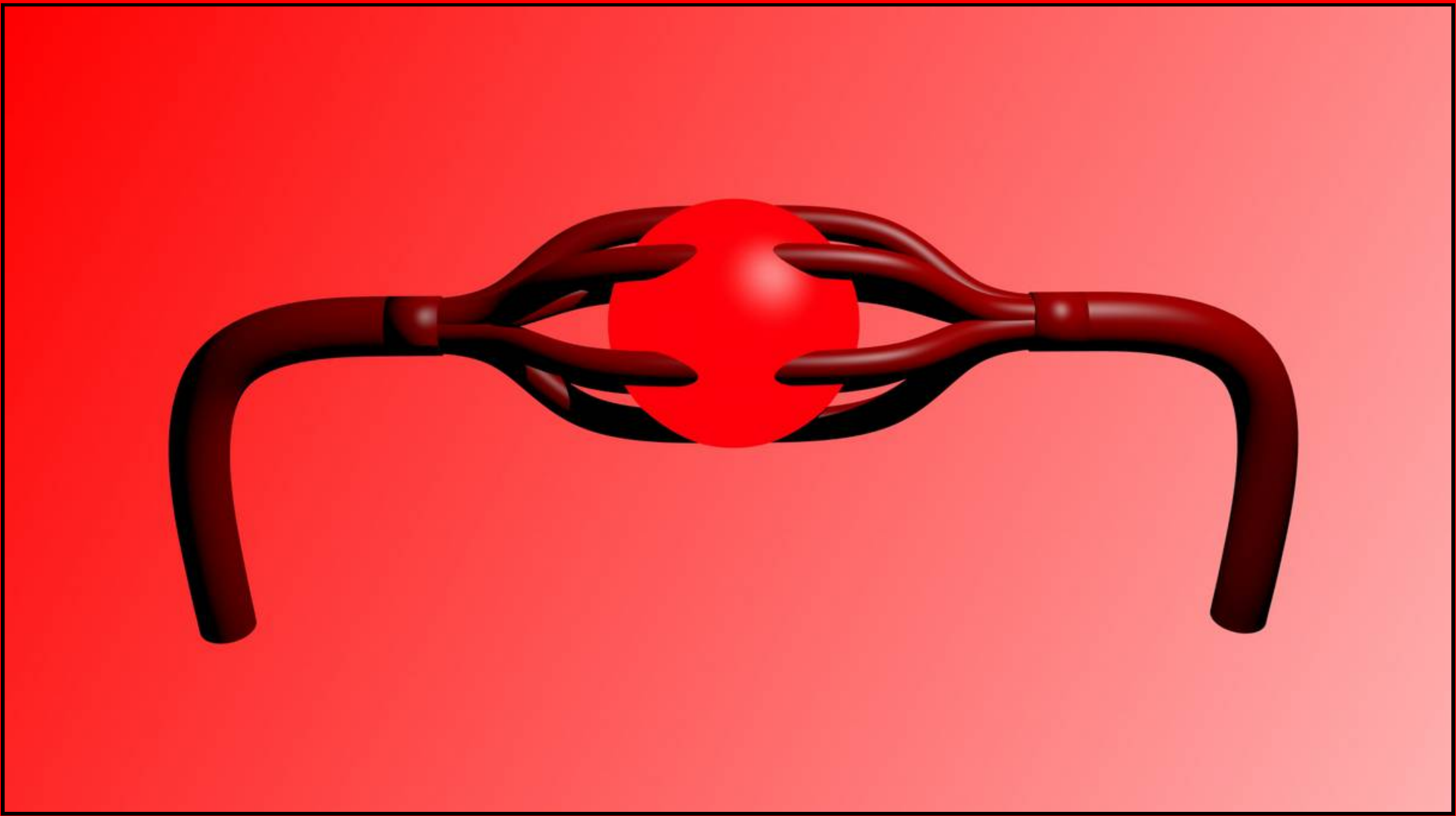
In this book I'm going to show you my new concept of nuclear thermos reactor, that I named "The EA Premium Cat Reactor", in relation with other kind of nuclear reactor that may be suitable for Mars colonization, and also for the nuclear engine of interplanetary high impulse spacecraft.

The first consideration, to be an acceptable device, is to being transportable to the specific location of the Base on the red planet :)

The second consideration, for the entire system of devices, is to being able to produce sufficient amount of electricity :)

The third consideration, for the entire system, is to be affordable in cost, in relation with the cost of a complete single complex, a base :)

THE EA PREMIUM CAT REACTOR

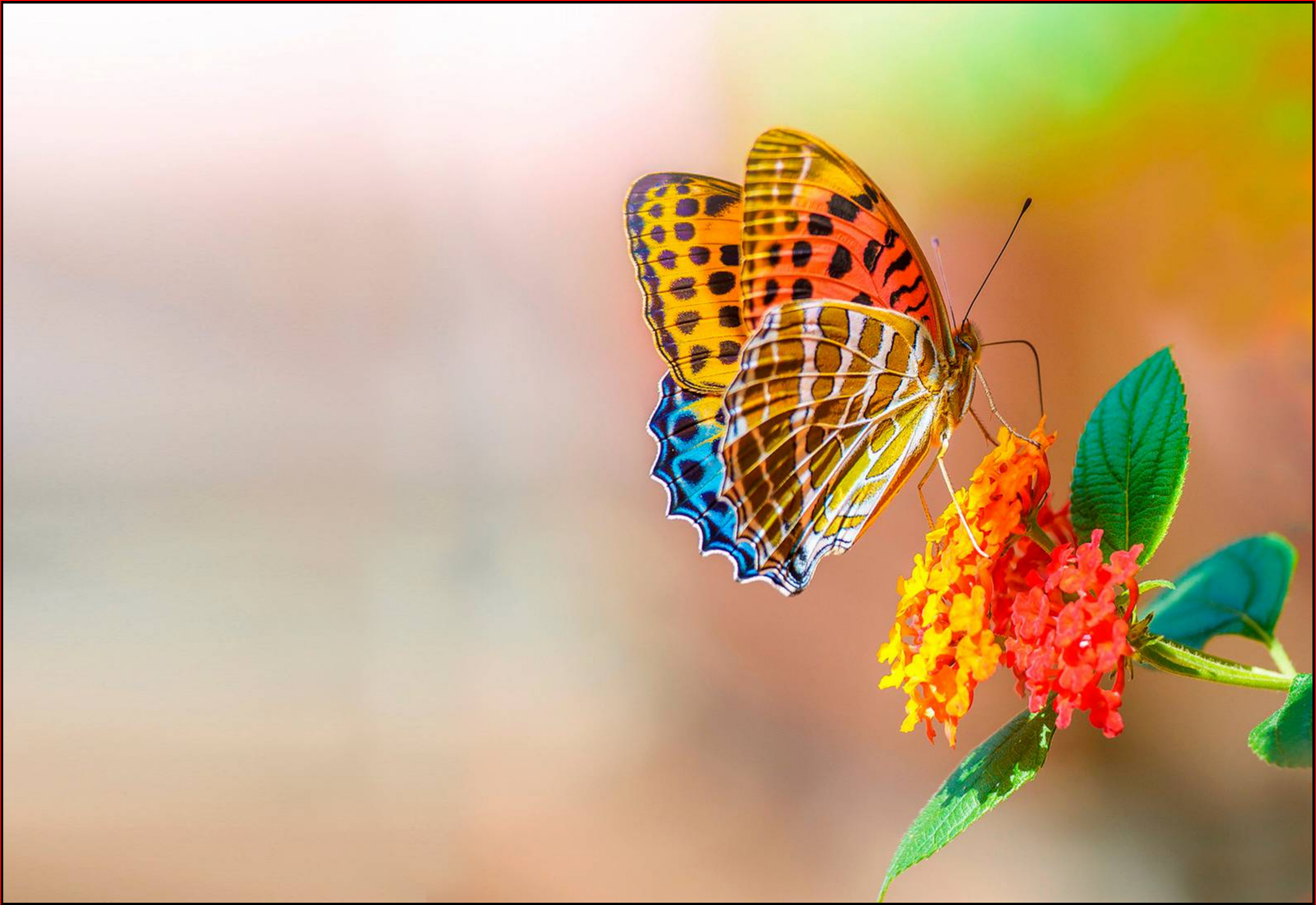


This image looks great, but why if it's possible, it do not exist actually, because it is simpler than a regular atomic reactor? I'm not sure, but I think it is difficult to implement, both the theoretical conception and practical one. And I'm still not 100% sure, it's going to work :)

What are the reasoning behind this conception, and what could we expect in relation of the wanted characteristics, described in the introduction:

- Being small and not too fragile
- Being powerful
- Being affordable

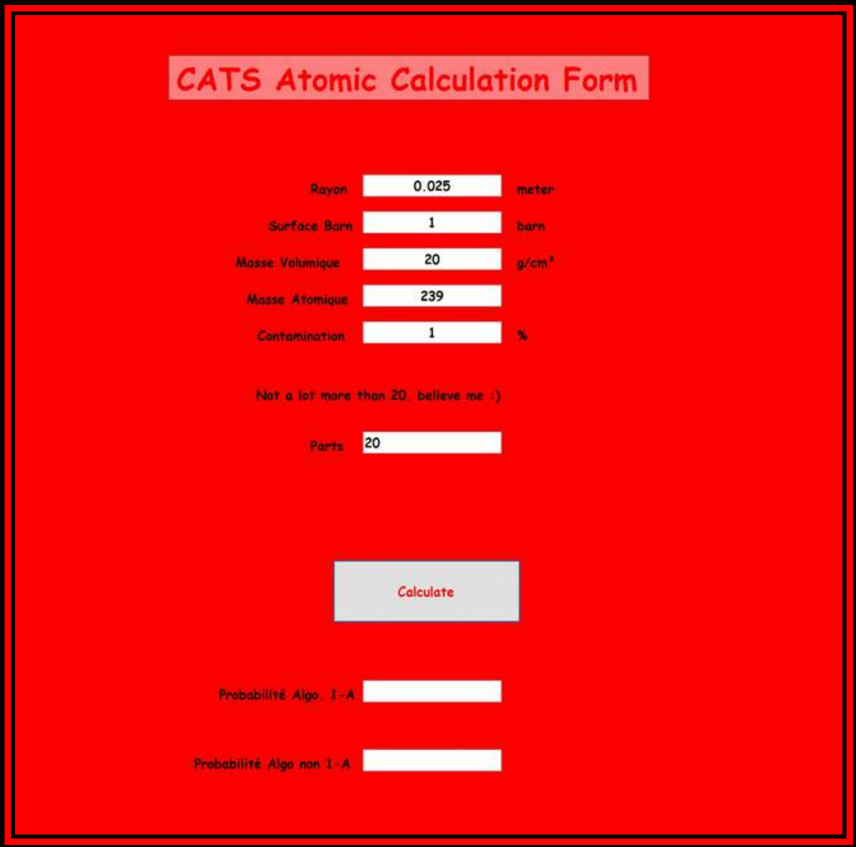
Well, it's small (less than 15 cm for the core), it's built in tungsten and with clearly enough thickness, but it's clearly not affordable and produce few electricity. Plutonium metal cost is pretty high 4,000 USD per gram, and my best expectation are about a little bit more than 32,000 watts per core...



MODIFIED NUCLEAR ALGORITHM 1-A

In order to achieve some number, I built this algorithm. It's working like this:

1. Base on the criticality of a Plutonium mass, about 5-11 kg
2. You find the rayon, base on density of the correct phase (temperature related)
3. The barn surface represent the probability of fission, with some deflector, it "increase"
4. You find the barn surface of the critical mass: to get probability of 50 ±0.01, or more precise :)
5. You repeat task 2-4, for the range where the reactor is going to operate, by keeping barn surface constant. Don't forget, rayon is modify by the density that is modify by temperature.
6. Find the delta probability of the more dense phase minus the less dense phase
7. For being able to produce heat we need 50+%
8. Saturate the high probability with some more contamination, until that point
9. Operate some calculation, to know the duration of reactor with that delta level of contamination versus the power of it: see sections "Design" and "Duration"



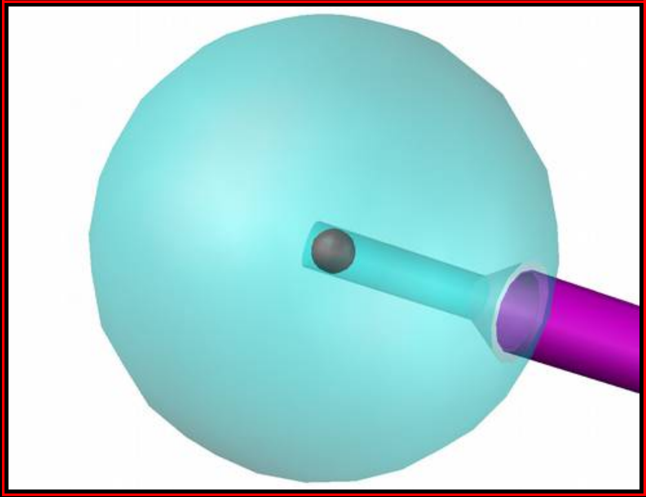
THE CODE

Written in C#, for simplicity, that way the form is simple to build. Watch out for your eyes, it's almost all red :)

```
using System;
using System.Collections.ObjectModel;
using System.Windows.Forms;


namespace masseCritique2
{
    public partial class Form1 : Form
    {
        Random R = new Random(DateTime.Now.Millisecond);

        public Form1()
        {
            InitializeComponent();
        }

        private void button1_Click(object sender, EventArgs e)
        {
            Collection<Collection<Collection<bool>>> sphere = Create_Sphere(float.Parse(textBox1.Text), float.Parse(textBox1.Text), int.Parse(textBox6.Text));

            double Nbr_Avogadro = 6.022E23;
            double masse_volumique = double.Parse(textBox3.Text) * 1E6;
            double rayon = double.Parse(textBox1.Text);

            double volume = 4 / 3 * 3.14159 * Math.Pow(rayon, 3);
            double masse = masse_volumique * volume;
            double Nbr_Atomes = masse/double.Parse(textBox4.Text) * Nbr_Avogadro;
            double densite_lineaire = Math.Pow(Nbr_Atomes / volume, 0.3333);

            double surfaceBarn_atome = double.Parse(textBox2.Text) * 1E-28;

            int part = int.Parse(textBox6.Text);

            double totalSize = 0;
            long cntr = 0;

            double tmop = 2 * rayon / part;

            float prob = float.Parse(textBox8.Text)*10;

            for (int i = 0; i < sphere.Count; i++)
            {
                double tt = 0;
                long cntr1 = 0;
                for (int j = 0; j < sphere[i].Count; j++)
                {
                    for (int k = 0; k < sphere[i][j].Count; k++)
                    {
                        if (sphere[i][j][k] == true)
                        {
                            for (int z = 0; z < part; z++)
                            {
                                /*if(R.Next(0,1000) > prob)*/ tt += Get_moyenne_distance(tmop, sphere, i, j, k, prob);
                                cntr1++;
                            }
                        }
                    }
                }
                totalSize += tt;
                cntr += cntr1;
            }

            double distance_moyenne = (totalSize/cntr);
            double surface_theorique = Math.Pow(1 / densite_lineaire, 2);

            double probabilite = (surfaceBarn_atome) / (surface_theorique) * 100 * densite_lineaire * distance_moyenne;

            textBox5.Text = probabilite.ToString();

            Algorithm_Non_1A();
        }
```

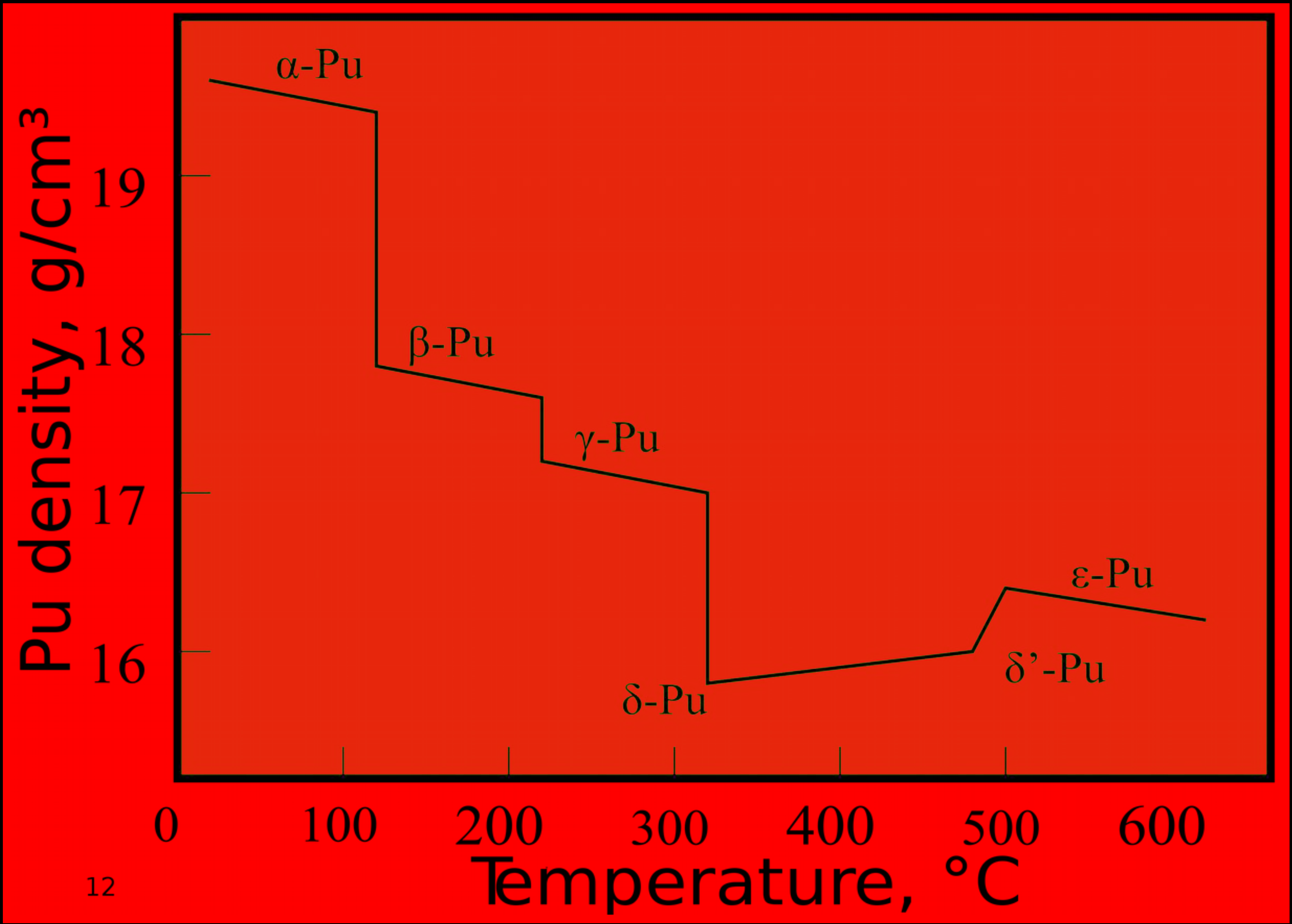
```
private void Algorithm_Non_1A()
{
    Collection<Collection<Collection<bool>>> sphere = Create_Sphere(float.Parse(textBox1.Text), float.Parse(textBox1.Text), int.Parse(textBox6.Text));

    double Nbr_Avogadro = 6.022E23;
    double masse_volumique = double.Parse(textBox3.Text);
    double rayon = double.Parse(textBox1.Text);

    double volume = 4 / 3 * 3.14159 * Math.Pow(rayon, 3);
    double masse = masse_volumique * volume;
    double Nbr_Atomes = masse / double.Parse(textBox4.Text) * Nbr_Avogadro;
    double densite_lineaire = Math.Pow(Nbr_Atomes / volume, 0.3333);

    double surfaceBarn_atome = double.Parse(textBox2.Text);


    int prob = int.Parse(textBox8.Text);


    double distance_moyenne = rayon;
    double surface_theorique = Math.Pow(1 / densite_lineaire, 2);

    double probabilite = (surfaceBarn_atome) / (surface_theorique) * 100 * densite_lineaire * distance_moyenne;

    // by asumption of the same probability of Pu-240 and Pu-239

    probabilite -= prob / 100.0 * probabilite;

    textBox9.Text = probabilite.ToString();
}

private double Get_moyenne_distance(double step, Collection<Collection<Collection<bool>>> sphere, int x, int y, int z, float prob)
{

    double cntr = 0;
    long cntr2 = 0;

    for (int i = 0; i < sphere.Count; i++)
    {
        for (int j = 0; j < sphere[i].Count; j++)
        {
            for (int k = 0; k < sphere[i][j].Count; k++)
            {
                int RRR = R.Next(0, 1000);

                if (sphere[i][j][k] == true)
                {
                    float distance = (float)Math.Sqrt(Math.Pow(x * step - i * step, 2) + Math.Pow(y * step - j * step, 2) + Math.Pow(z * step - k * step, 2));

                    if (RRR > prob) cntr+=distance;
                    if(distance > step) cntr2++;
                }
            }
        }
    }

    return cntr / cntr2;
}

private Collection<Collection<Collection<bool>>> Create_Sphere(float rayon, float rayonI, int parts)
{
    Collection<Collection<Collection<bool>>> sphere = new Collection<Collection<Collection<bool>>>();

    double step = 2 * rayon / parts;

    for(int i = 0; i < parts; i++)
    {
        Collection<Collection<bool>> tmp2 = new Collection<Collection<bool>>();
        for(int j =0; j < parts; j++)
        {
            Collection<bool> tmp = new Collection<bool>();
            for(int k = 0; k < parts; k++)
            {
                bool test = false;

                float distance = (float)Math.Sqrt(Math.Pow(rayon - i * step, 2) + Math.Pow(rayon - j * step, 2) + Math.Pow(rayon - k * step, 2));

                if (distance < rayonI) test = true;

                tmp.Add(test);
            }
            tmp2.Add(tmp);
        }
        sphere.Add(tmp2);
    }

    return sphere;
}
```

THE DESIGN



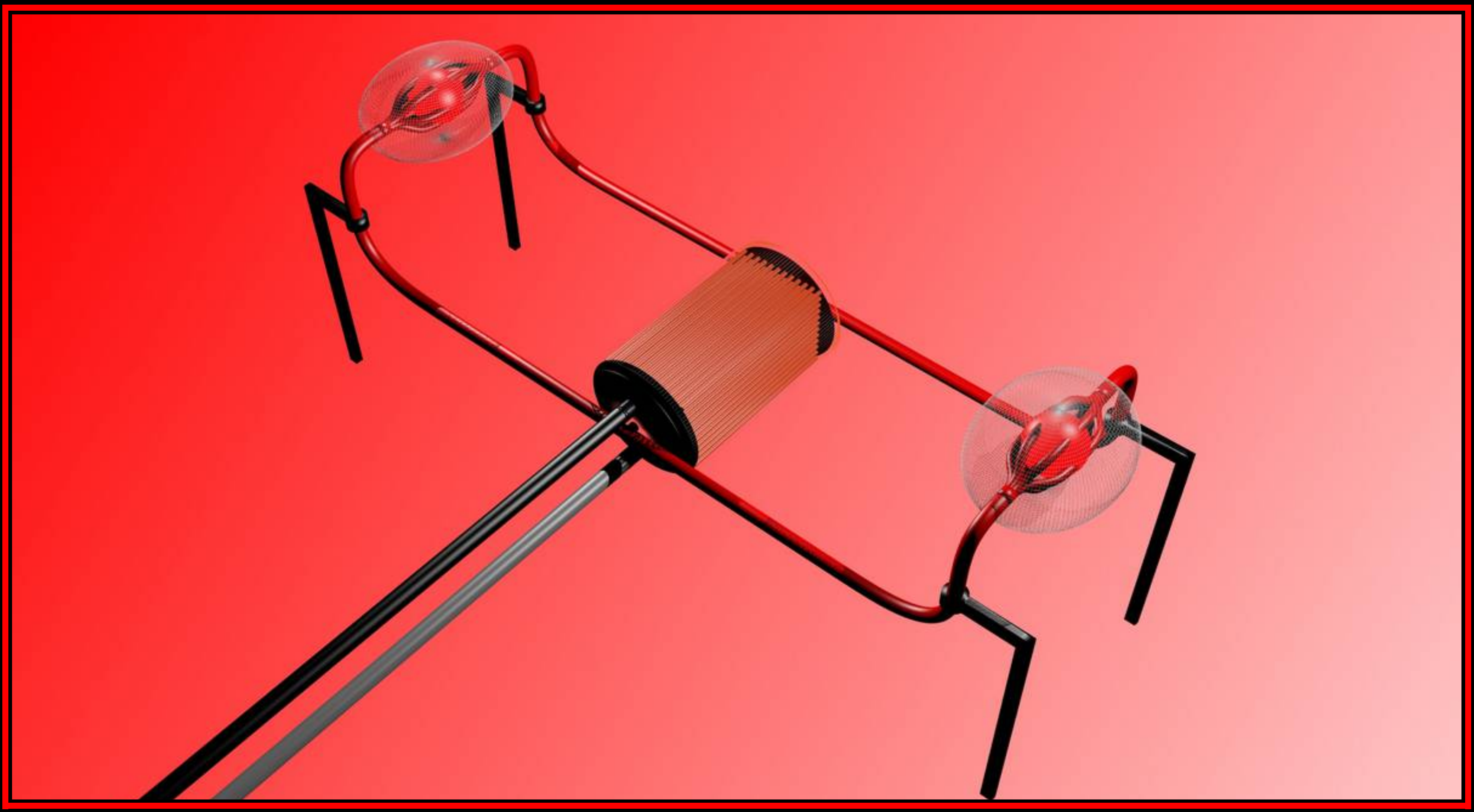
Maybe the external sphere is a bit to big, but it's an old drawing... That way we could achieve more protection during the escape of earth, and now the tube is not necessary (I will, one day redraw this picture).

To have a good heat transfer, we need a good contact zone between the core and the shell, it could not be solid to solid because of the different dilatation coefficient of the materials. So, I want to use Tin, and fill the hole up to a certain level to take the maximum dilatation volume in count :()



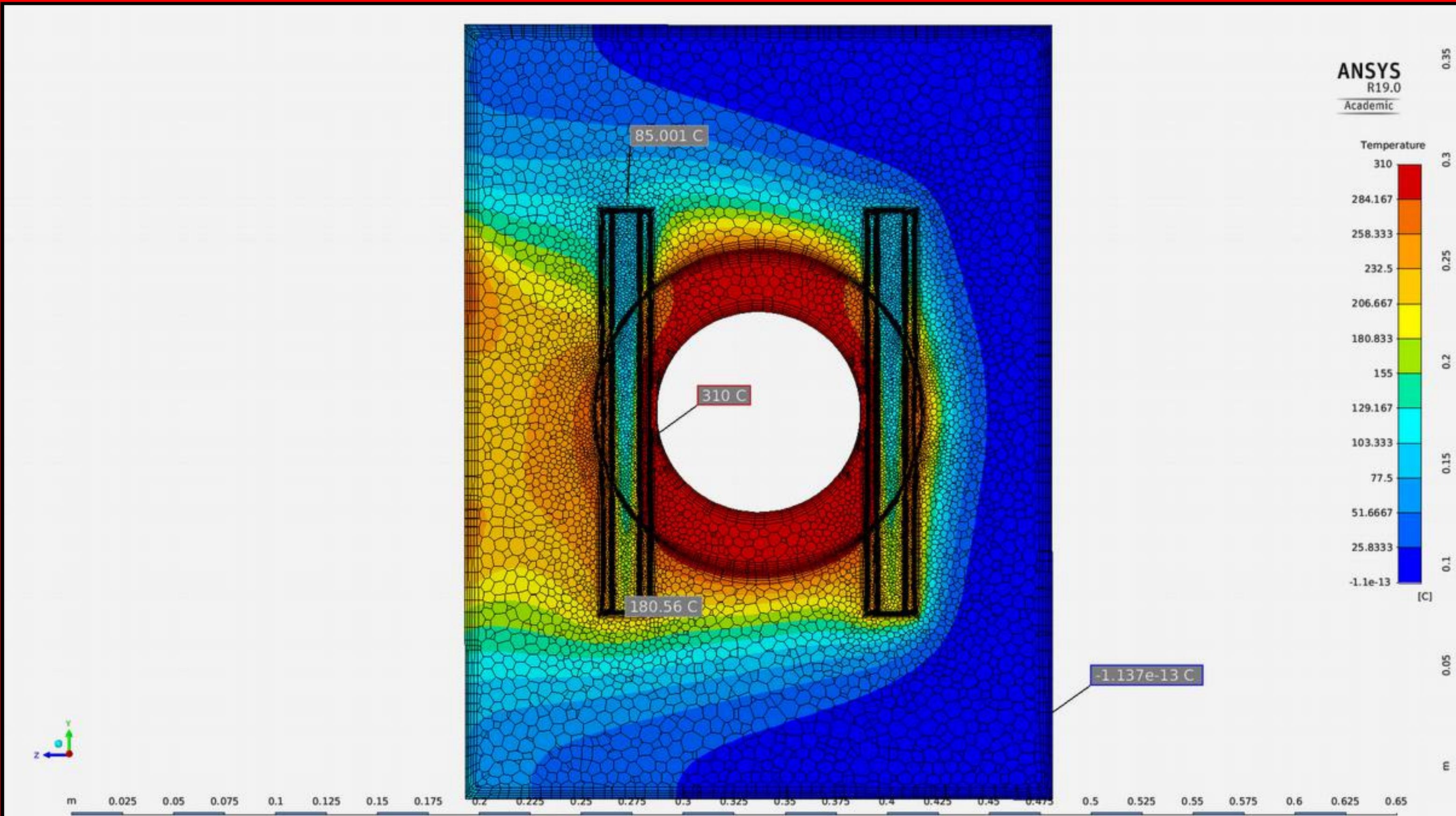
By Plutonium_density.svg: HarDNoxderivative work: Materialscientist (talk) - Plutonium_density.svg, CC BY-SA 3.0, https://commons.wikimedia.org/w/index.php?curid=11848688

In the heat transfer copper tube up to the evaporator, it will be Mercury, after up to the condenser it will be water vapour because we need a lot of it, and there is a lot on Mars. Major problematic, the temperature of the heart won't be able to exceed the Plutonium phase in use...

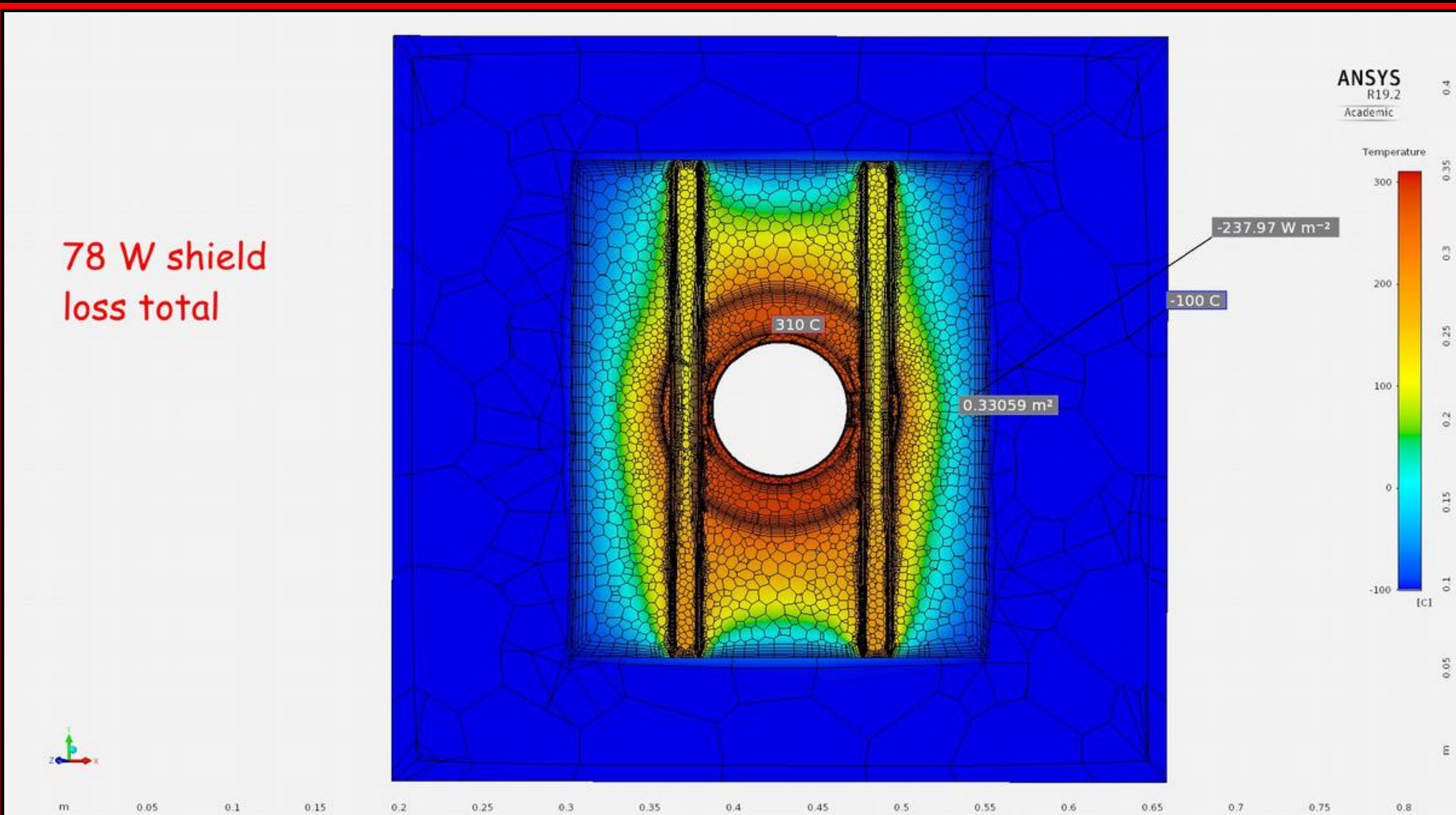


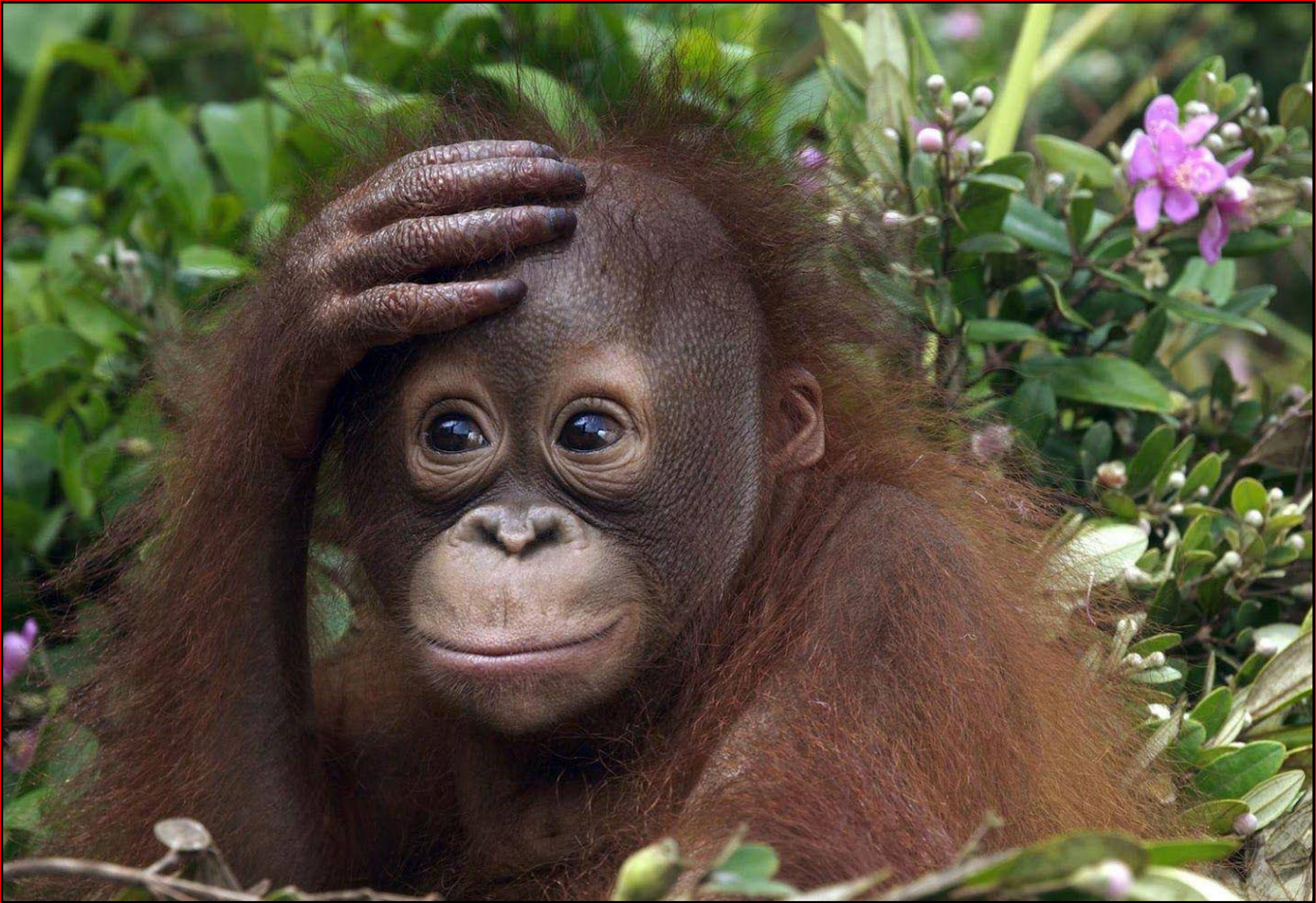
Those Gray net, represent a layer of shield, the most resilient matter for that purpose will do, I'm proposing Tungsten. The pipes will be in copper, as the sphere... It works like this: The mixture of Plutonium, will produced heat following this reaction:

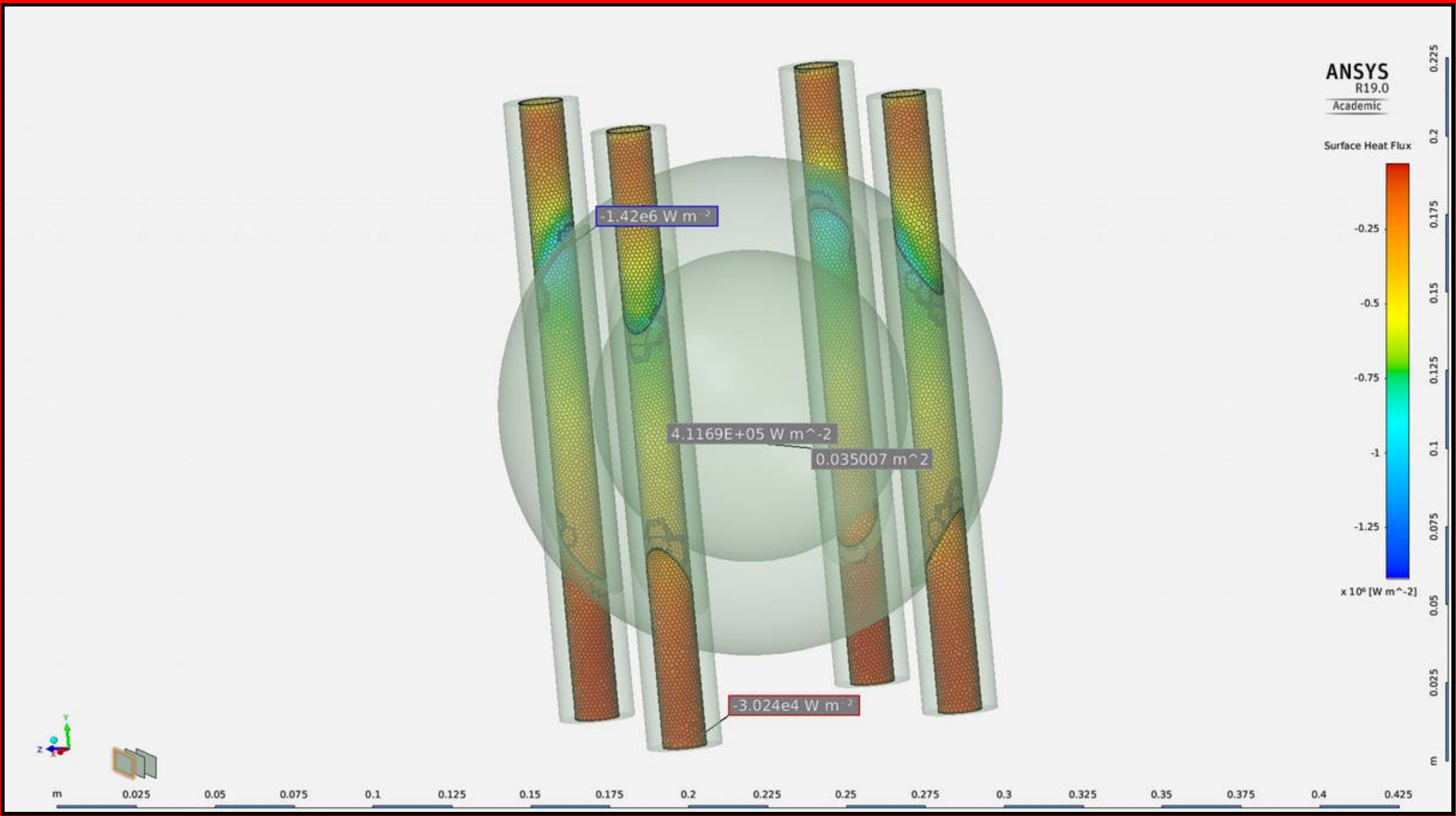
- One neutron + Pu-239 = 2 neutrons per neutron captured, in critical condition of about 50.01% of producing two others neutrons.
- The Plutonium volume will growth under heat effect, and loosing is criticality. It will stabilized at a density X-Cat :)
- The tungsten-carbine, will reflect a certain quantity of neutron, with the objective to reduced the critical mass and save money (0.09 m of diameter, maybe more...).
- Some fail safe devices will be included, the shell itself made of pure tungsten, evaporation of the Plutonium by the top, and the homogenization of the Tin and Plutonium if it melt :(
- Dynamic monitoring of the heat, by captors
- Wall to hide the system from the wind and control over this wall, that is not mandatory, but it could improve efficiency.
- Independents pumping systems for the mercury, to not loosing the reactor (the power production of it)
- Hundred's of this unit for energy security reasons :)



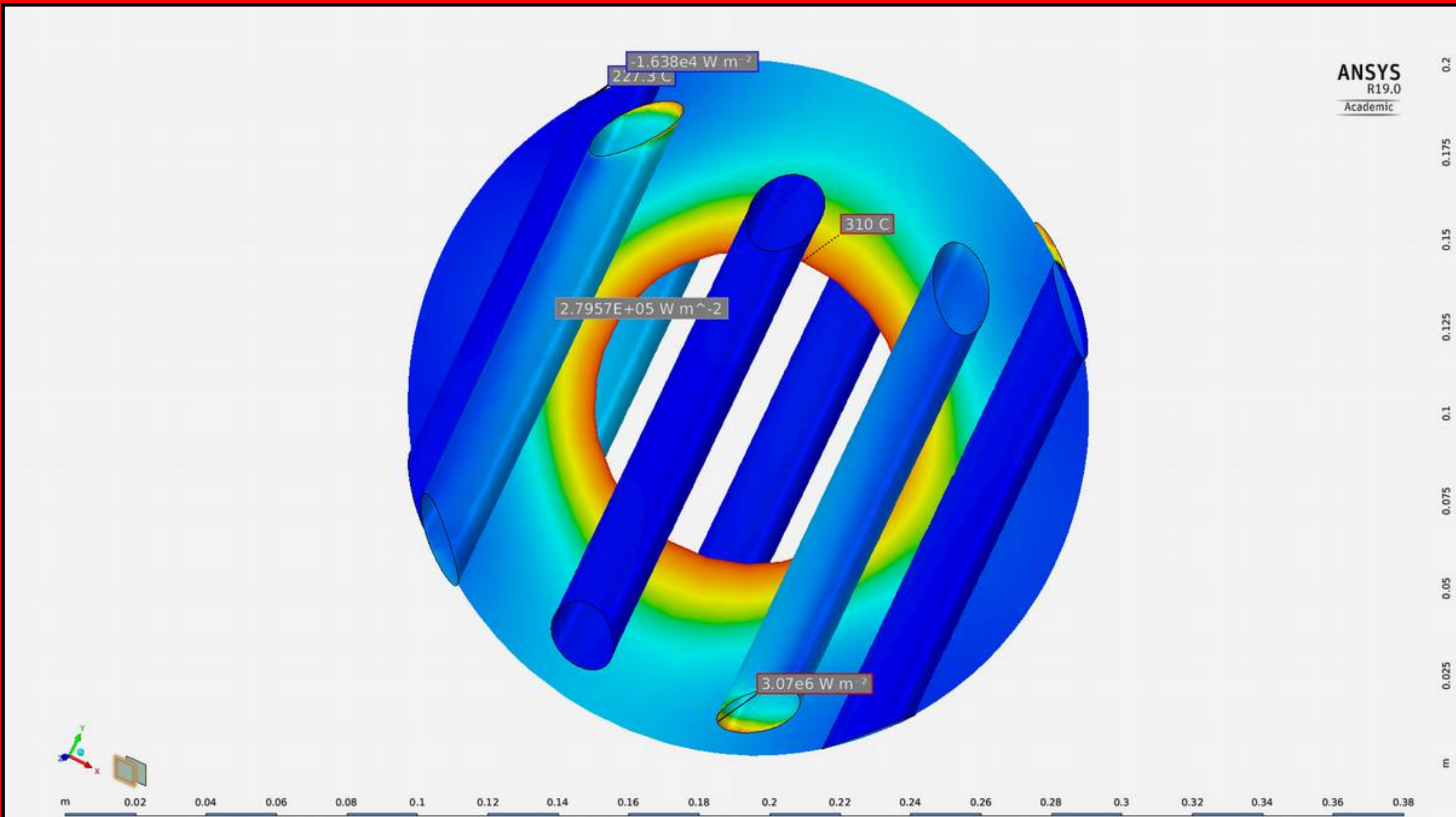
We could see the reactor at operating temperature, to that fact being possible, the fluid must circulate at a sufficient speed. The Mercury is entering on the top at 85°C and heated up to 180.6°C.



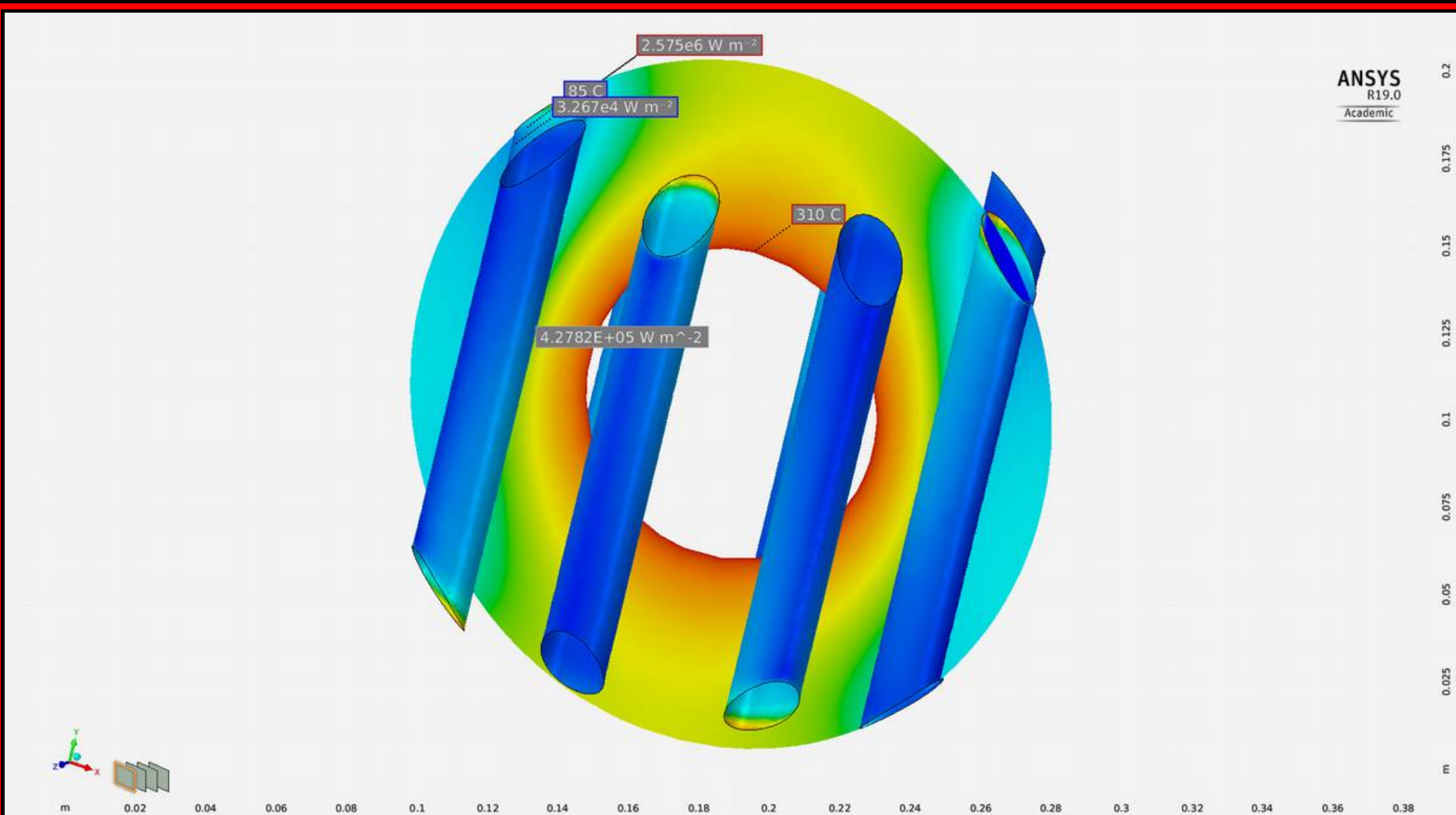


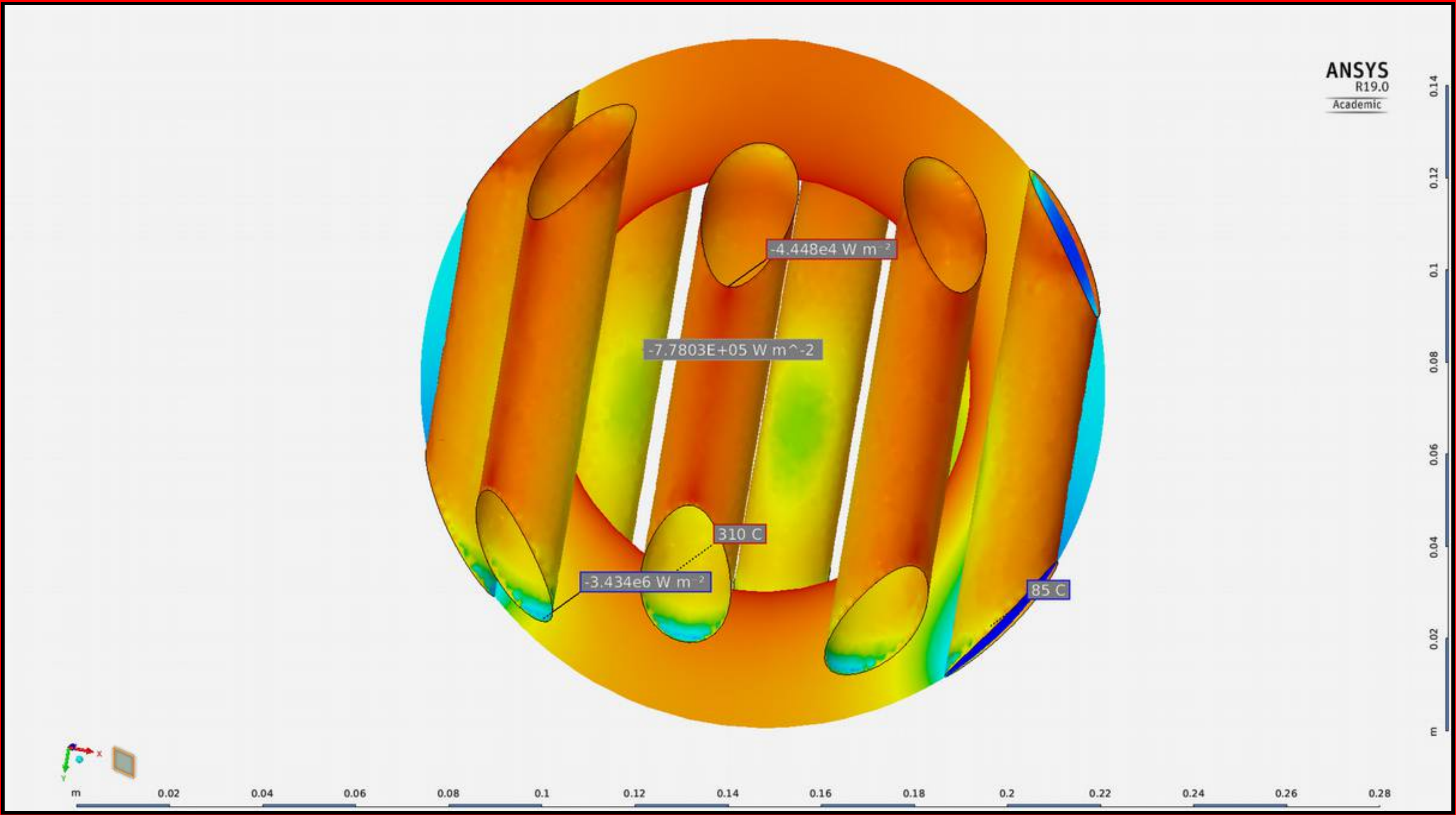


4.12E5 W/m² * 0.035 m² = 14 420 W

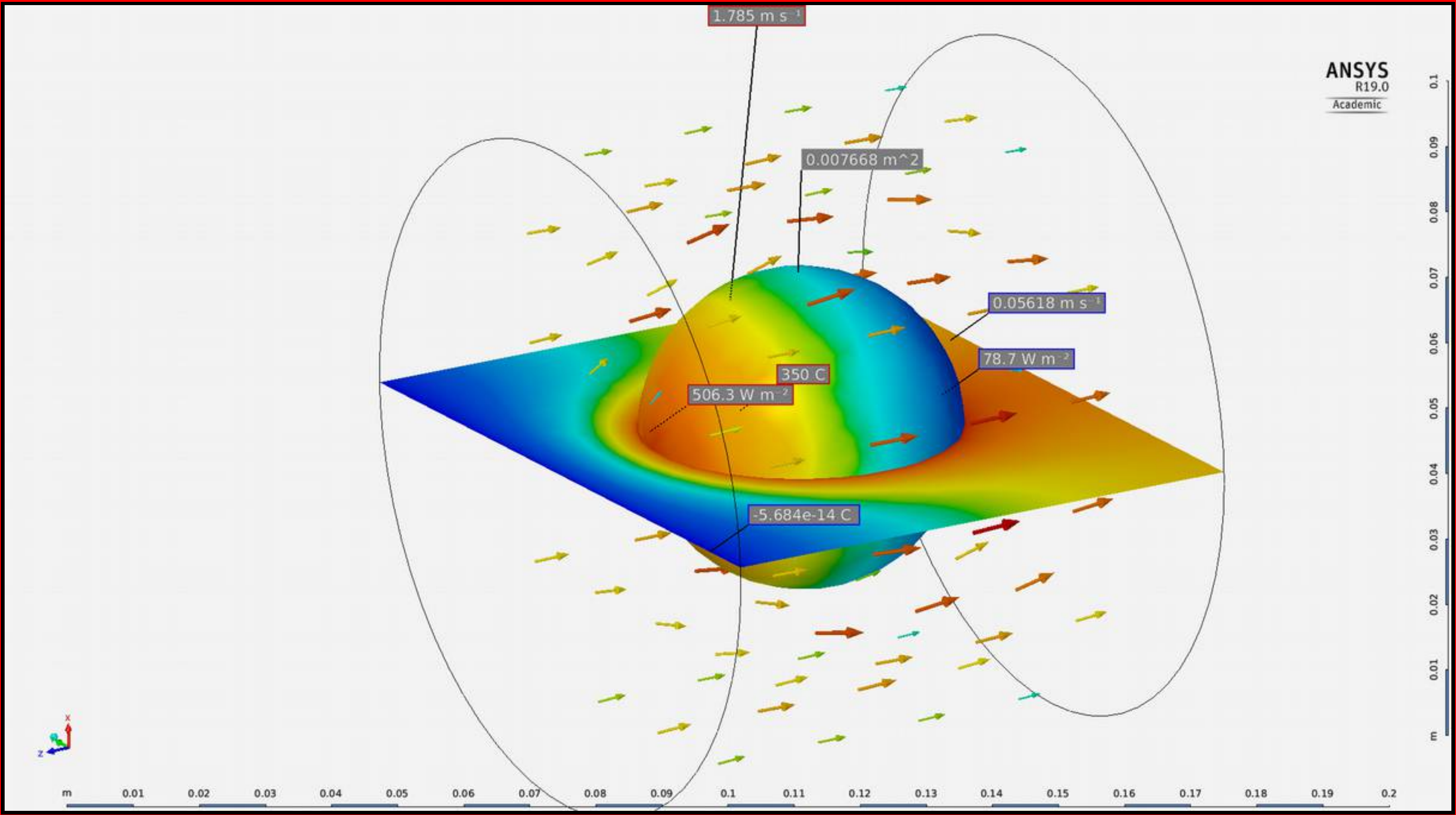


In the first image, only four tubes are in use, and in the second there is 8 tubes: the ratio is 1.53X heat flux in the second. 28 678 W in the second reactor in tungsten.





In this image, the shell is half the thickness of those on the previous page: 33 246 W, a factor of 1.16X better.



In this image, we could see the Pyrex sphere that contain the heated Plutonium. At a rate of 2 Watts of heat loosing, we will have more than 2602 J / 2 W = 1301 s = 20 minutes (Plutonium mass not taken into account) to insert it in the reactor, if it's not enough we could use a thicker container :)

THE DURATION (OLD DATA SET)

All this computation are relative to the criticality of an atomic Plutonium bomb at a diameter of 9 cm, with the neutron deflector. At that size, we know that the probability of producing 2 neutron by the occurrence of one neutron is close to 50+%. This fact will allow the reactor to produced self-sustain heat. Data:

Rayon: 0.045 m

Density of Sigma Phase: 15.85 g/cm^3

Atomic weight: 239 g/mol

Contamination (purity): 5%

By the simulation software this configuration gives a barn surface for a probability of 50.079% of about: 2.895 b

Rayon: 0.04396 m

Density of Sigma Phase: 17 g/cm^3

Atomic weight: 239 g/mol

Contamination (purity): 5%

barn surface: 2.895 b

By the simulation software, this configuration give a probability of 52.372%. The delta % of two phase = 2.293%, that amount could be lost in further contamination, with a safety margin of 0.293%, it gives 2% net lost.

0.293% gives a radius delta of about 50 micron. The subsequent contamination will need to be in order of 4.25% to fill the 2% probability left. This 4.25% of contamination could gives this amount of energy:

83.61E12 J/kg of fissile Pu-239

18 000 W of power for the reactor

2.153E-7 g/s of Pu-239

1 Years = 365 * 24 * 3600 = 3.15E7 s

The 4.25% give: 0.0425 * 6 kg(Pu-239) = 255 g

This 255 g could be constituted of 1/3 neutron depletion cycle

2.153E-7 g/s * 3.15E7 s = 6.79 g

255 g * (1/3) / 6.79 g = 10 years

1% gives a radius delta of about 0.17 mm. The subsequent contamination will need to be in order of 2.75% to fill the 1.293% probability left. This 2.75% of contamination could gives this amount of energy:

83.61E12 J/kg of fissile Pu-239

18 000 W of power for the reactor, thermal that gives 15 000 W electric

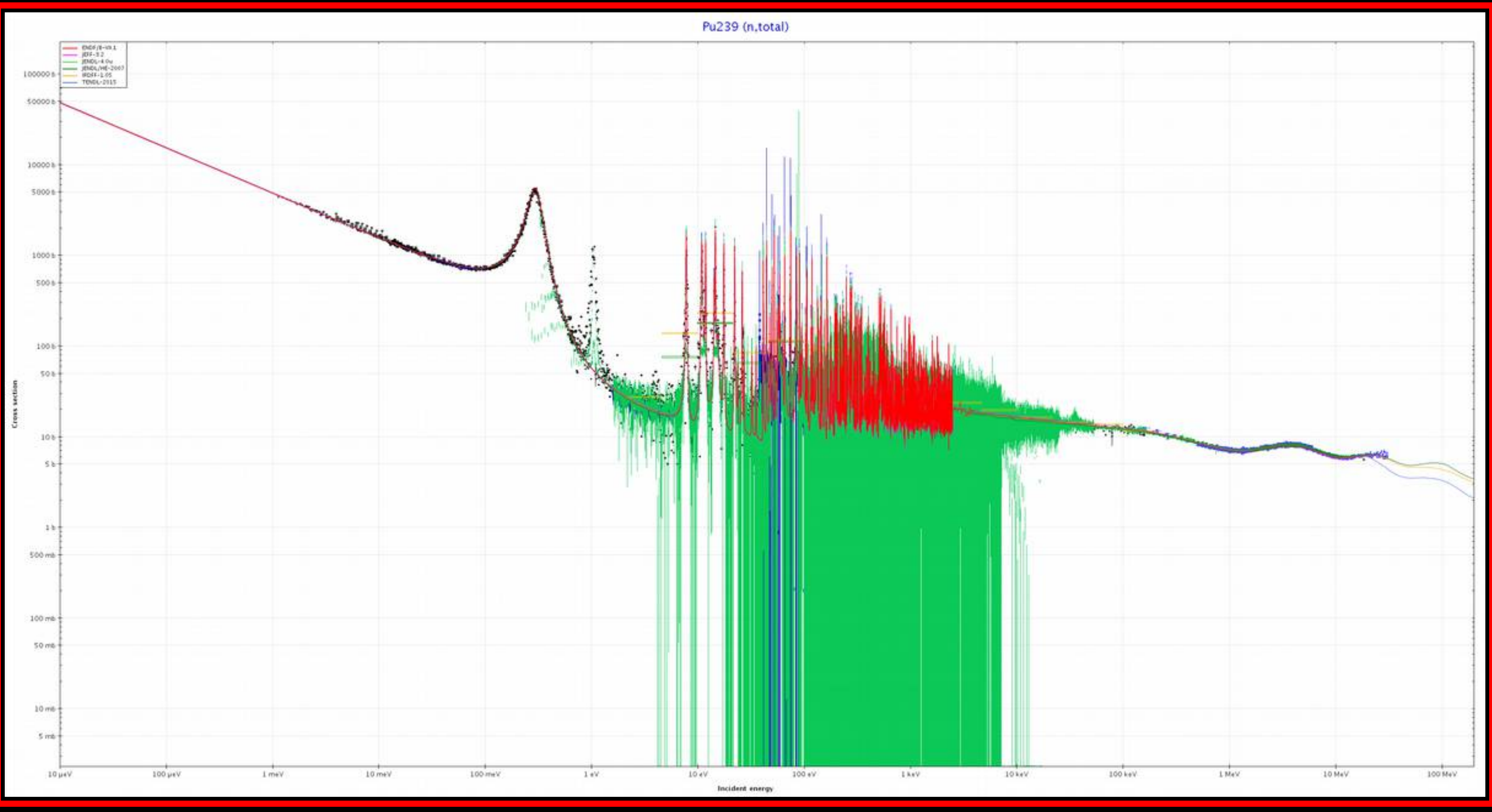
2.153E-7 g/s of Pu-239

1 Years = 365 * 24 * 3600 = 3.15E7 s

The 2.75% give: 0.0275 * 6 kg(Pu-239) = 165 g

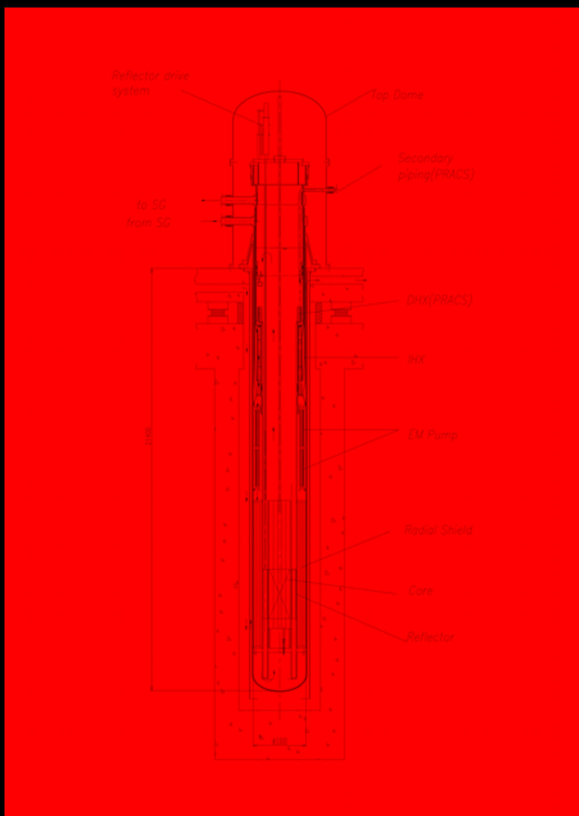
This 165 g could be constituted of 1/3 neutron depletion cycle

2.153E-7 g/s * 3.15E7 s = 6.79 g165 g *(1/3) / 6.79 g = 8 years

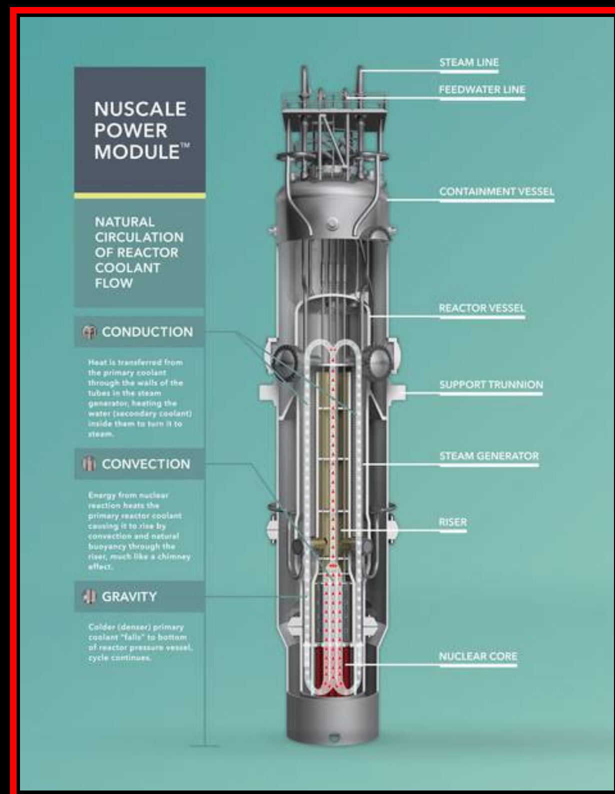


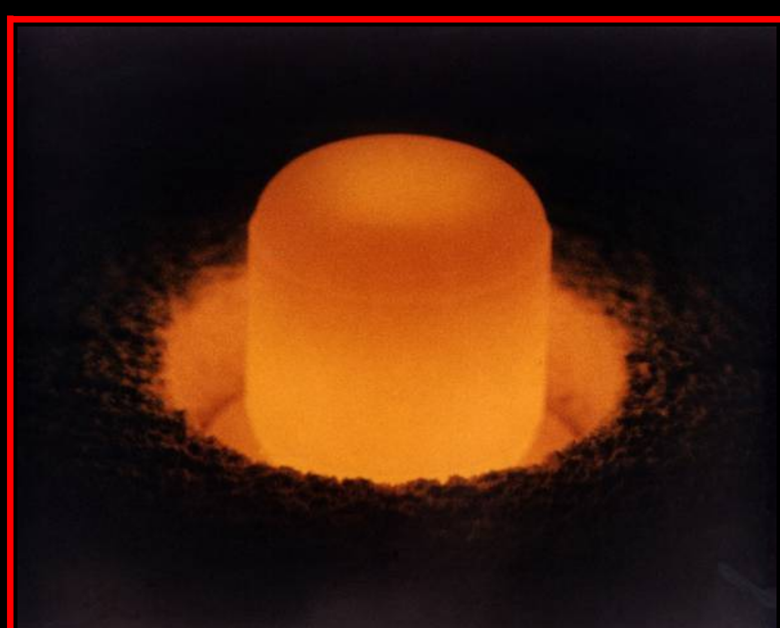
OTHER POSSIBILITIES

Toshiba 4S



NUSCALE





Pu-238 reactor

BOILER

TURBINE

I won't propose a new design for the turbines, but with so few power, produced by the nuclear device, I'm proposing to included two or more parallel boiler, related to their own reactors, to feed those turbines alternatively, with the positives aspect to increase pressure on input sides. That way, we may supply high pressure steam, in pulse to the turbine :()

CONCLUSION

I didn't include a complete section on the others possibilities, because they do not fulfill the conditions, unless you found a way to dismantle them. Only a reactor made with Pu-238 could do it, but with the actual production capacity, to get enough for only one base consisting of 200 kw of electricity, it could take 1,5 kg X 200 units, so 200 years of the maximum USA production that they will achieve in a decade :()

So, except if you want to allow the US government to build a project of the size of the Manhattan one, it can't :(

For the Plutonium-239, the one used in atomic weapon, there is in this world, much more than is needed, in a state close to be use in the CATS device :()

The World wide Plutonium stock: (the EA-CAT-PREMIUM-REACTOR has some tolerance to Pu-240 no need to military grade)

Nations	Pu-239 (kg)
Great-Britain	112 000
USA	100 000
France	75 000
Russia	50 000

This reference: Plutonium Certified Reference Materials Price List. U.S. Department of Energy. Fall 2007. gives us a price of 4 M USD per kg of Pu-239 (uncertain level of Pu-240, but it's not important). The critical mass of Plutonium is about, with deflector, 6 kg, so let's use 25 M USD per reactor of about 20 kW each:

1. 500 kW base = 25 reactors X 25 M USD = 625 M USD
2. Development of the device: 5 B USD
3. Total: 5 + 0.625 X 35 = 27 B USD, with a total of 5,25 tonnes of Pu-239 (military grade or not)
4. For the spaceships: All the rest :)

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