Supercomputers in Science

from the big bang to climate change

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what is EPCC?

- Edinburgh Parallel Computing Centre
  - founded in 1990
- The Supercomputing Centre at the University of Edinburgh

James Clerk Maxwell Building, The King's Buildings
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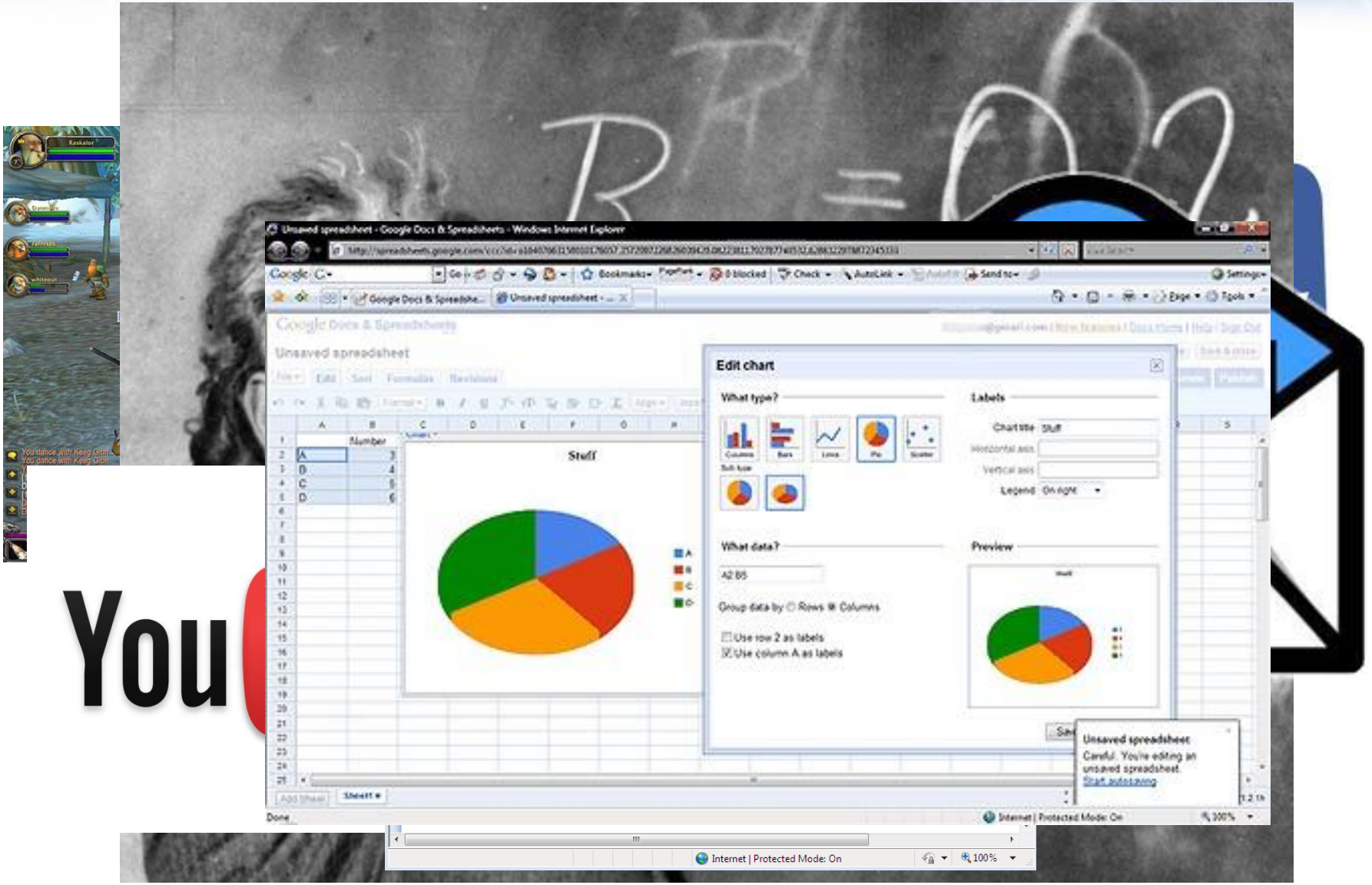
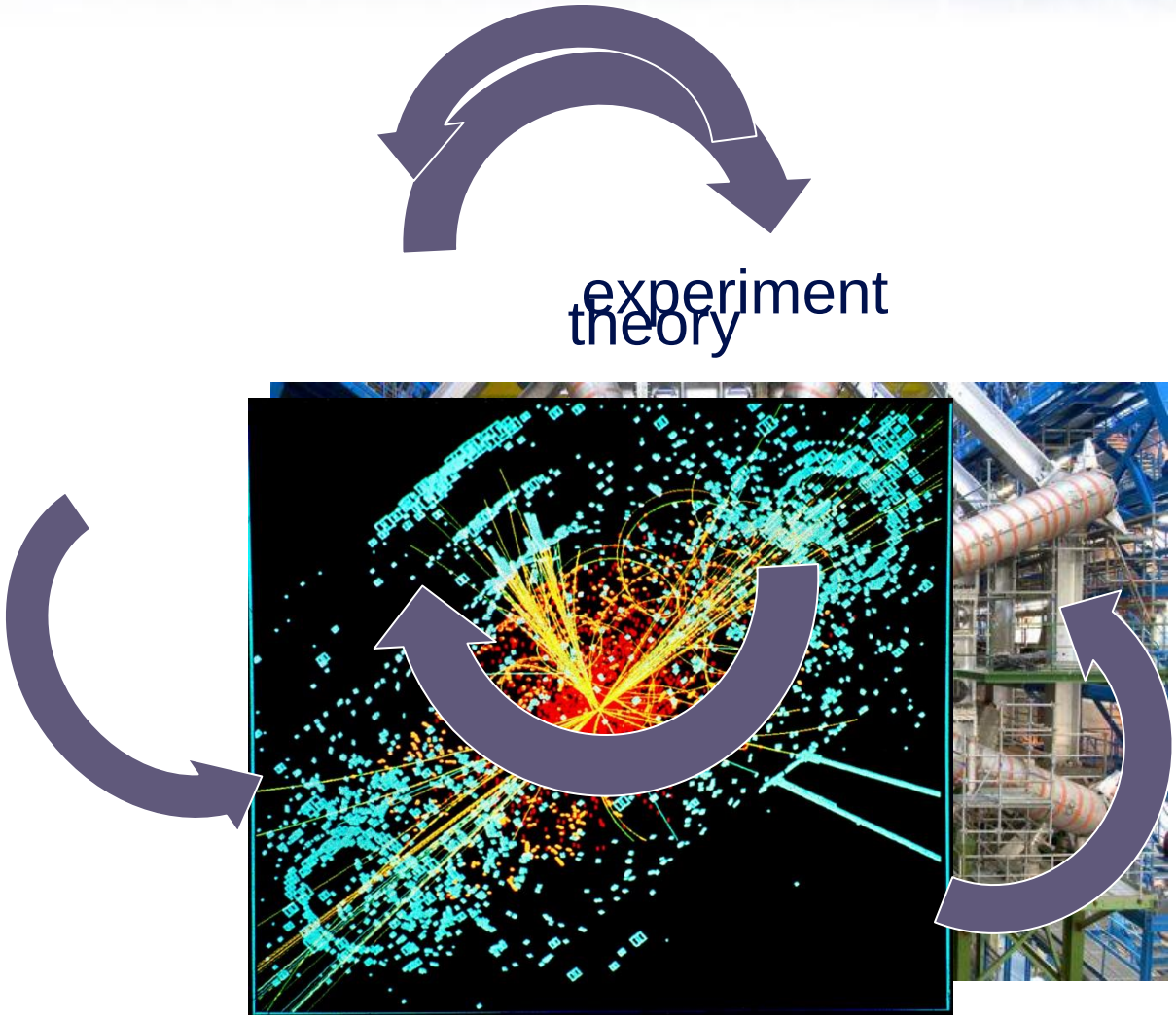
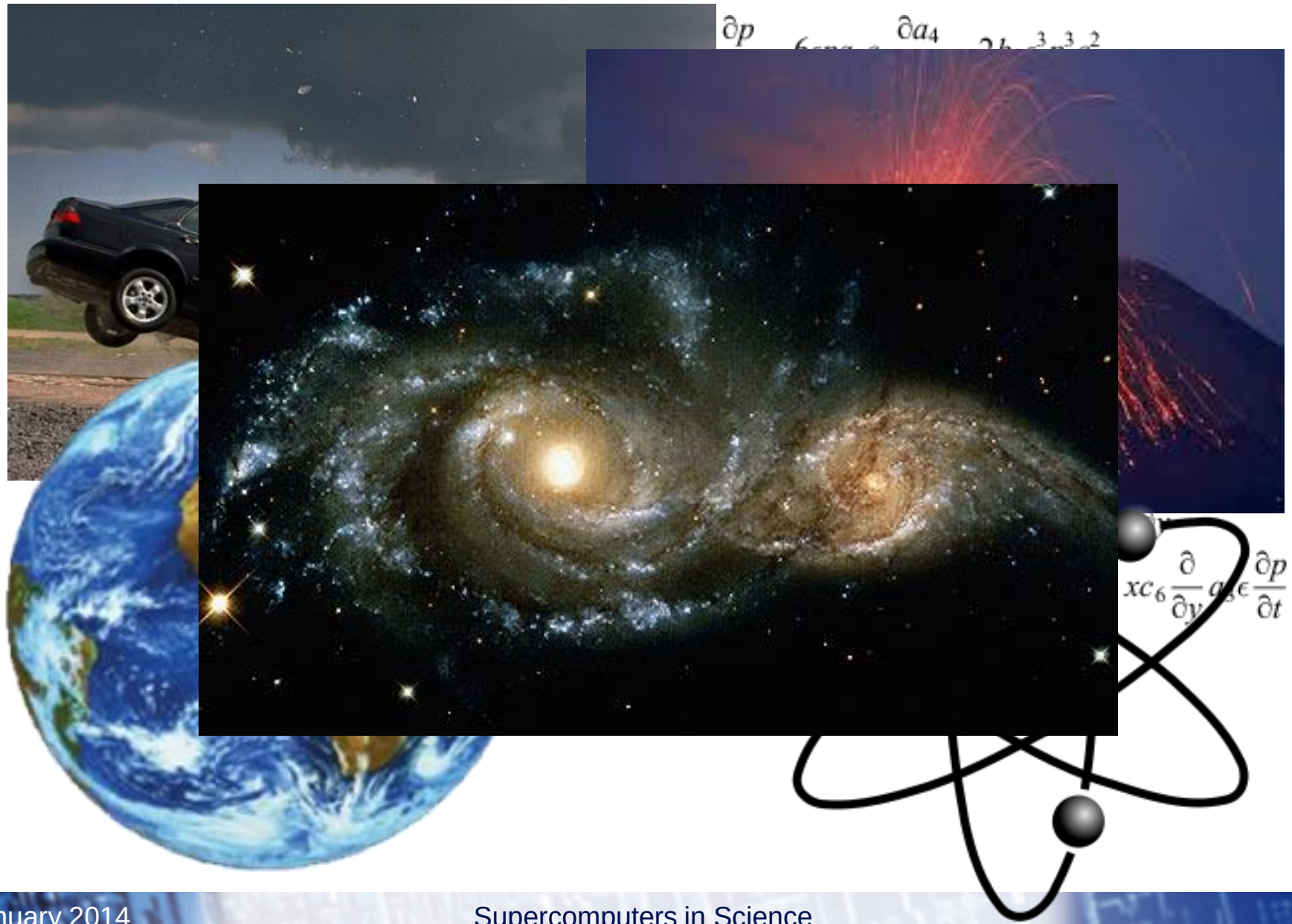
what are computers used for?



computational science



why?


∂p
∂a_4
$xc_6 \frac{\partial}{\partial y} \frac{\partial p}{\partial t}$

what is the world's yearly income?

1	Aadel Abdali	Afghanistan	£873
2	Aamir Abdali	Afghanistan	£798
3	.....	.....	.....
4	.....	.....	.....
5	.....	.....	.....
6	.....	.....	.....
7	.....	.....	.....
8	.....	.....	.....
9	.....	.....	.....
10	.....	.....	.....

… further down

5,303,422,761	....	....	.....
5,303,422,762	....	....	.....
5,303,422,763	Mark Henson	UK	£28,176
5,303,422,764	Mary Henson	UK	£37,866
5,303,422,765	....	....	.....
5,303,422,766	....	....	.....
5,303,422,767	....	....	.....
5,303,422,768	David Henty	UK	£1,234
5,303,422,769	....	....	.....
5,303,422,770	....	....	.....

… near the bottom

5,342,564,831	…… ……	….	……
5,342,564,832	…… ……	….	……
5,342,564,833	…… ……	….	……
5,342,564,834	Elisa Windsor	UK	£23,677
5,342,564,835	Elizabeth Windsor*	UK	£38,356,973
5,342,564,836	…… ……	….	……
5,342,564,837	…… ……	….	……
5,342,564,838	…… ……	….	……
5,342,564,839	…… ……	….	……
5,342,564,840	…… ……	….	……

(* The Queen)

… the end

6,999,999,991	.....	.....	.....	.....
6,999,999,992	.....	.....	.....	.....
6,999,999,993	.....	.....	.....	.....
6,999,999,994	.....	.....	.....	.....
6,999,999,995	.....	.....	.....	.....
6,999,999,996	.....	.....	.....	.....
6,999,999,997	.....	.....	.....	.....
6,999,999,998	.....	.....	.....	.....
6,999,999,999	Zojj	Zinyama	Zimbabwe	£3,564
7,000,000,000	Zuka	Zinyama	Zimbabwe	£1,236

computer program

```
set running total to zero
start at top of list
add income to total
go to next item in list
repeat if not at end of list
print total
```

how long does it take?

Year	Intel CPU	Frequ-ency	Operations per second	Time per operation	Time per loop	Total time
1966						
1971						
1993						
2012						

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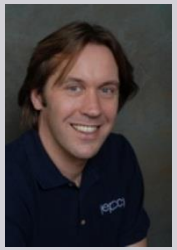
1966	 Me	1 Hz	1	1 second	3 seconds	**650 years**
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2012						

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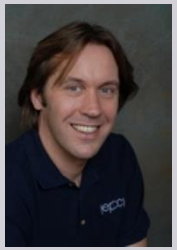
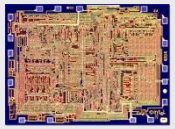
1966	 Me	1 Hz	1	1 second	3 seconds	**650 years**
1971	 i4004	100 KHz	100 thousand	10 micro-seconds (millionths of a second)	30 micro-seconds	**2½ days**
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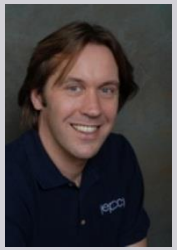
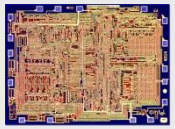
1966	 Me	1 Hz	1	1 second	3 seconds	**650 years**
1971	 i4004	100 KHz	100 thousand	10 micro-seconds (millionths of a second)	30 micro-seconds	**2½ days**
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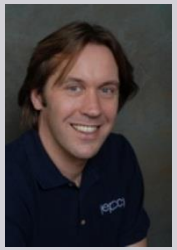
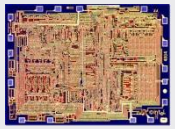
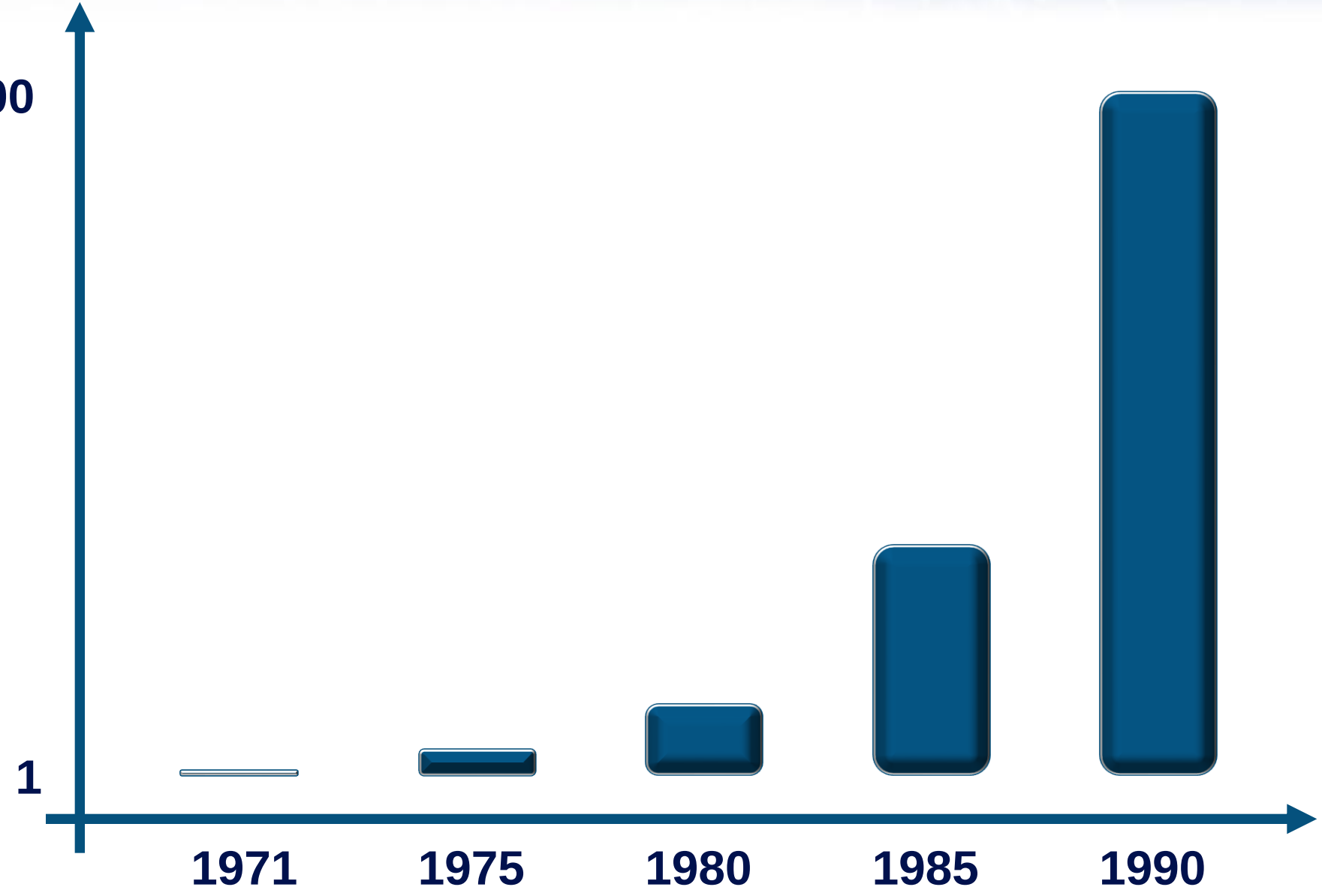
1966	 Me	1 Hz	1	1 second	3 seconds	**650 years**
1971	 i4004	100 KHz	100 thousand	10 micro-seconds (millionths of a second)	30 micro-seconds	**2½ days**
1993	 Pentium	60 MHz	60 million	17 nano-seconds	50 nano-seconds	**6 minutes**
2012	 Core i7	3 GHz	3 billion	0.3 nano-seconds (billionths of a second)	1 nano-second	**7 seconds**

how much faster?



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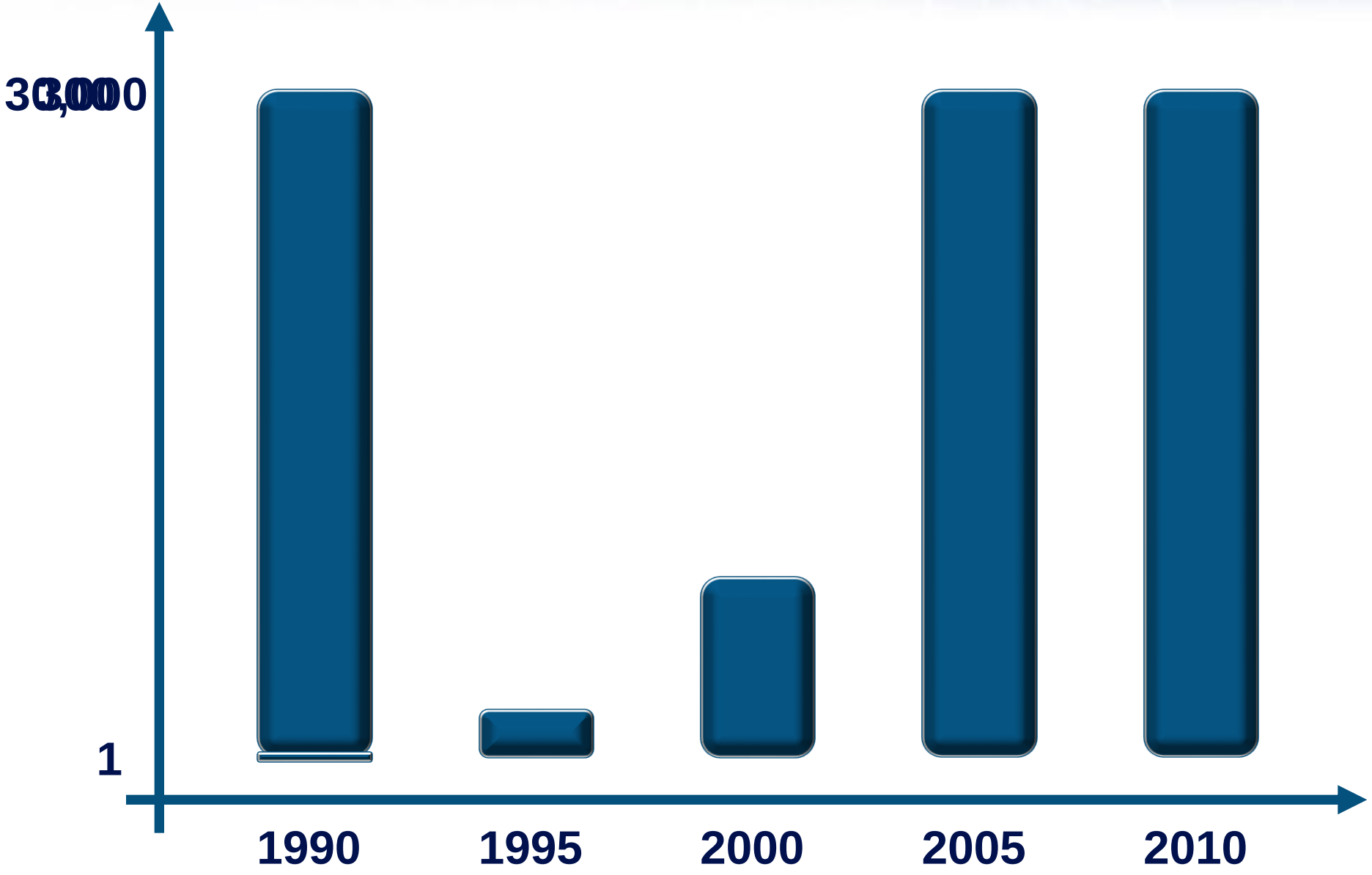
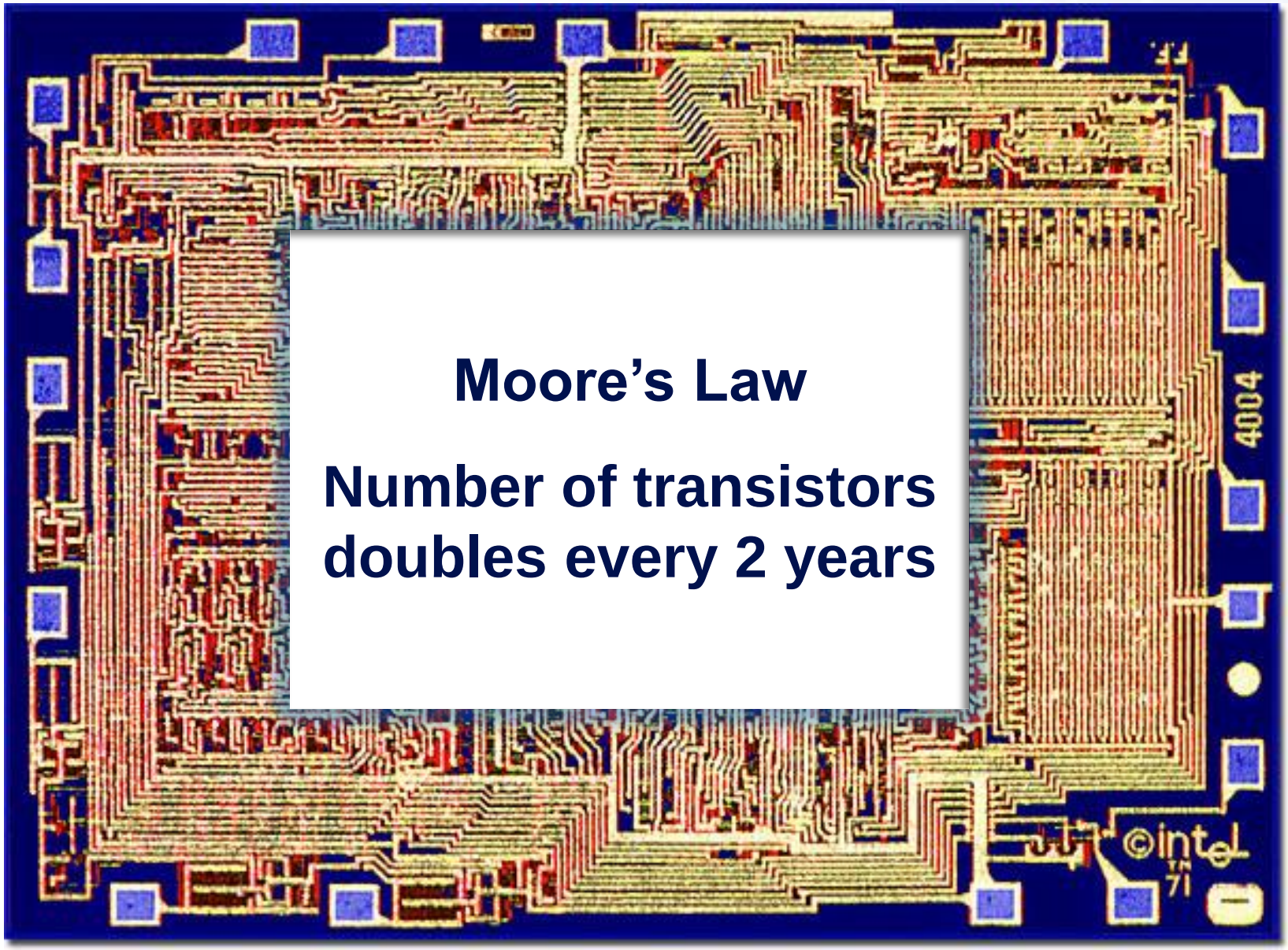


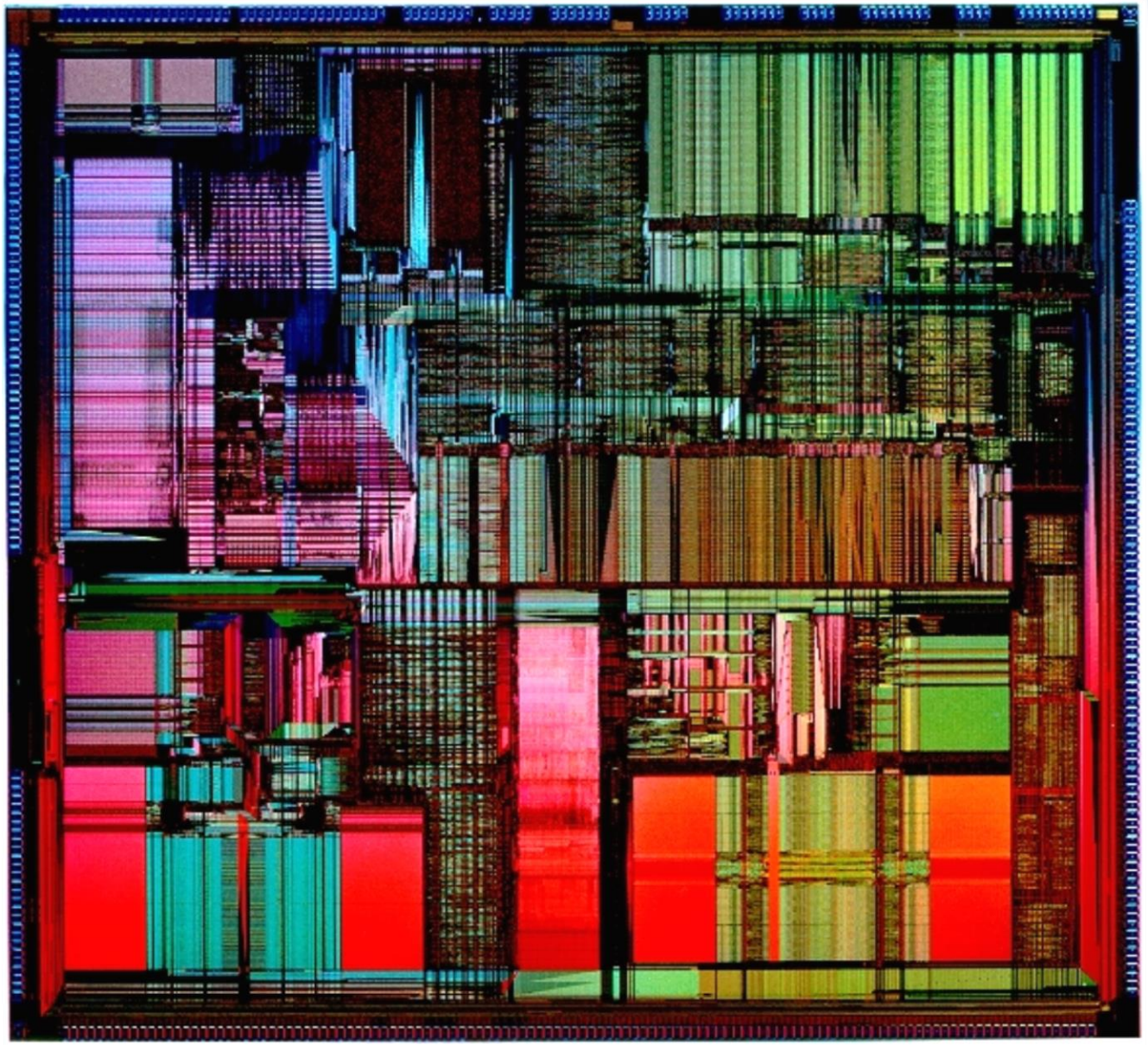
two thousand transistors (1971)



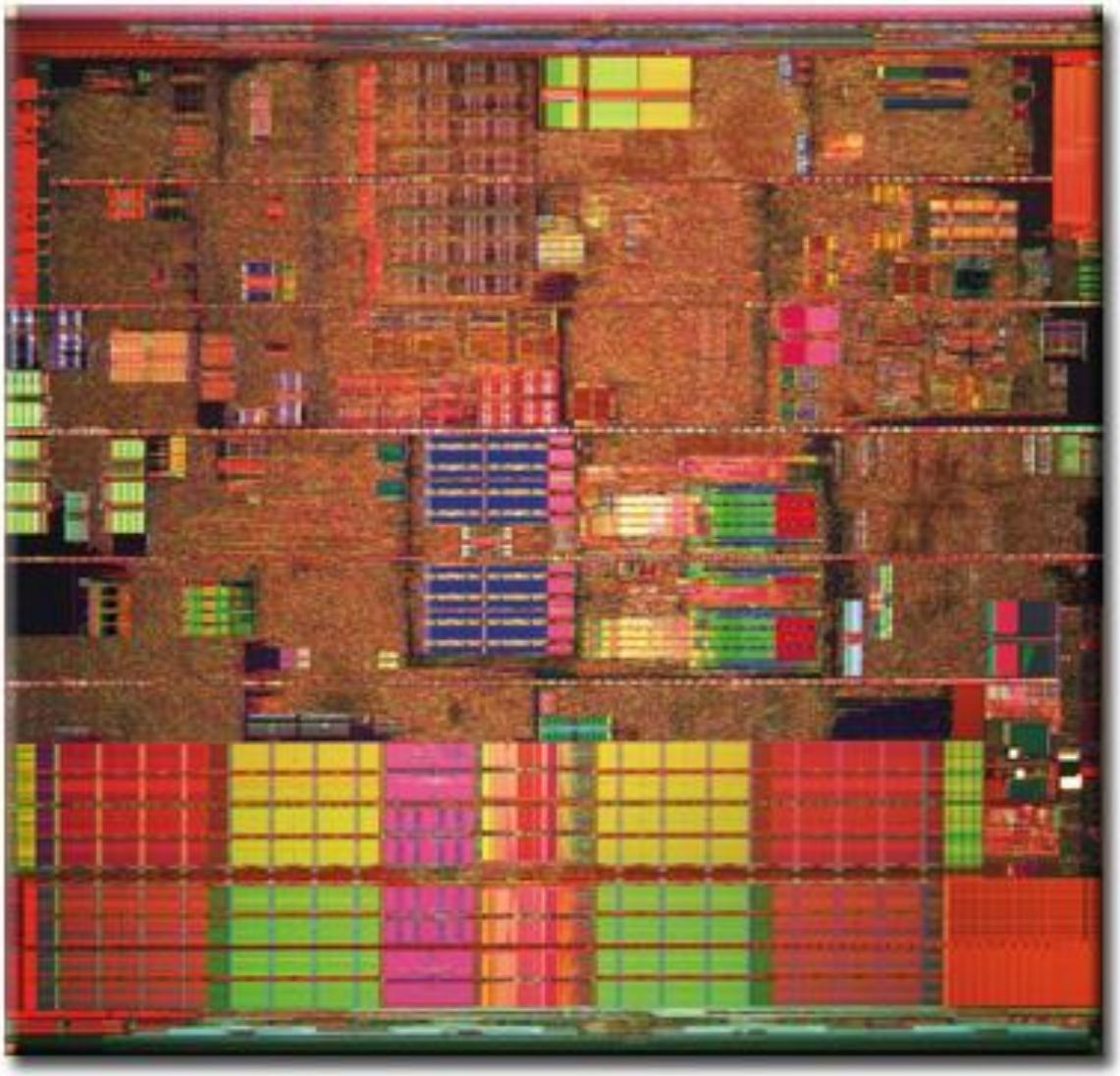
Moore's Law

Number of transistors doubles every 2 years

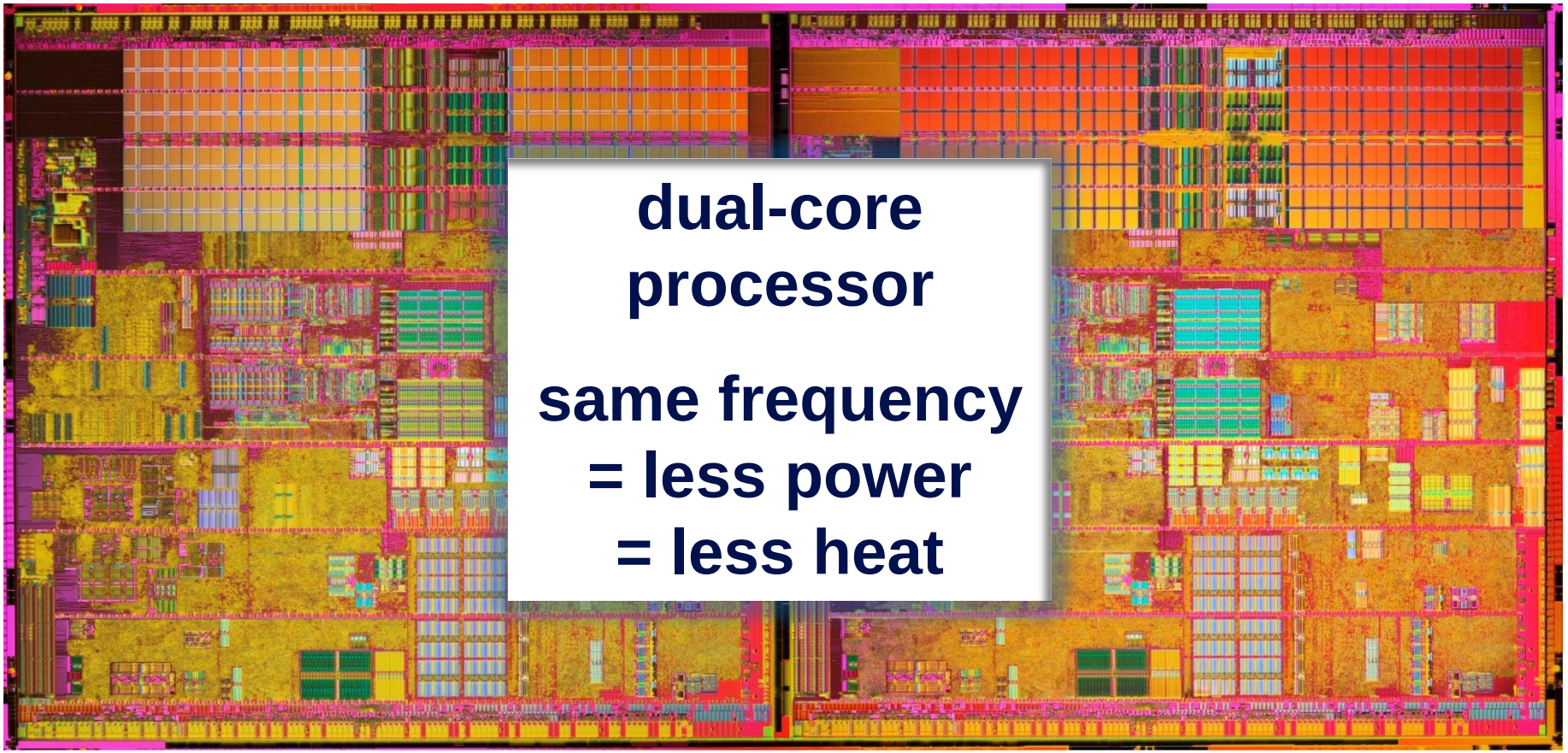
three million transistors (1993)



100 million transistors (2004)



200 million transistors (2006)



serial vs parallel computing

serial ► adjective [*attrib*] *Computing*

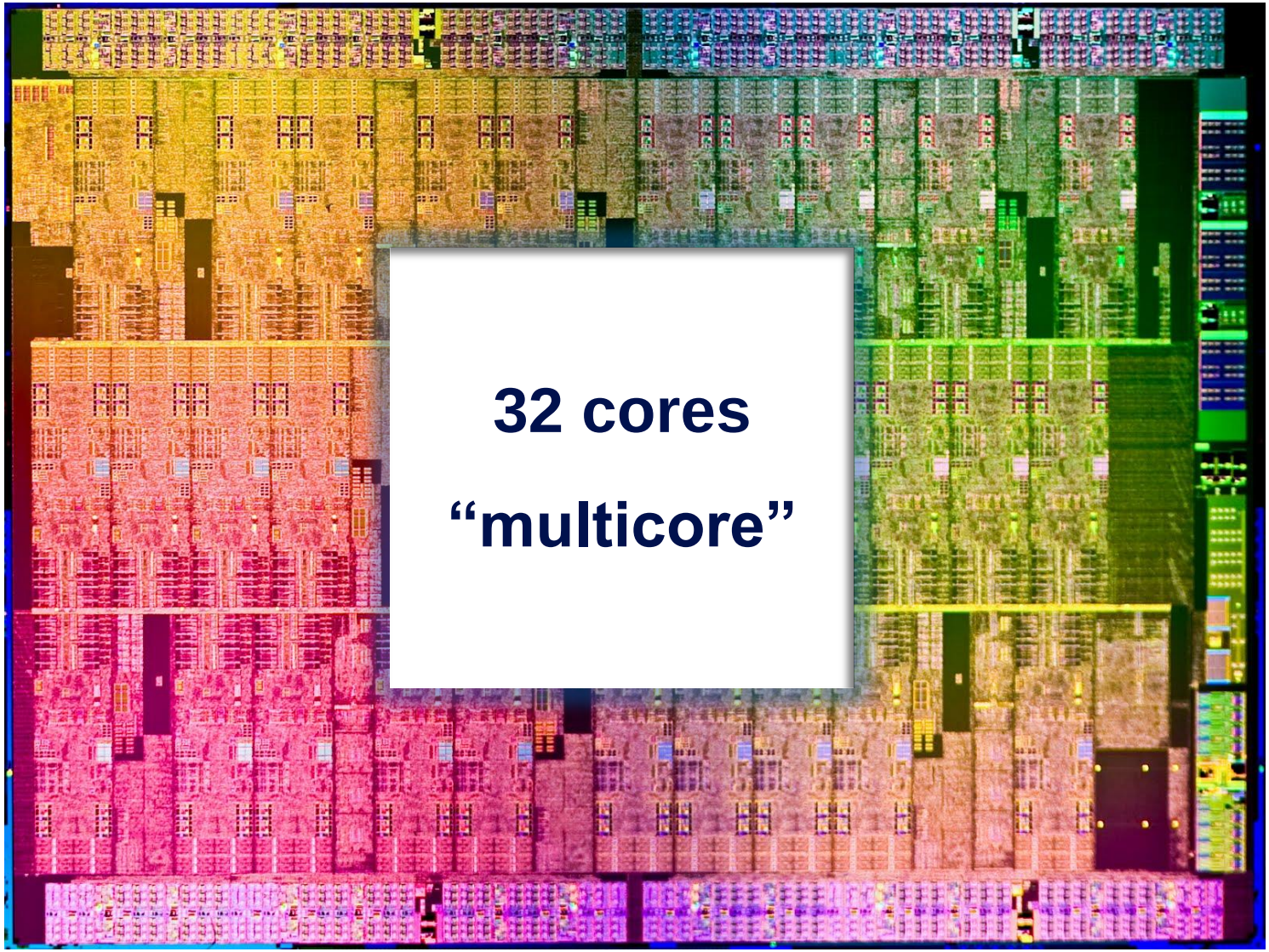
parallel processing ► noun [*mass noun*] *Computing*

a mode of operation in which a process is split into many parts, which are executed simultaneously on different processors attached to the same computer.

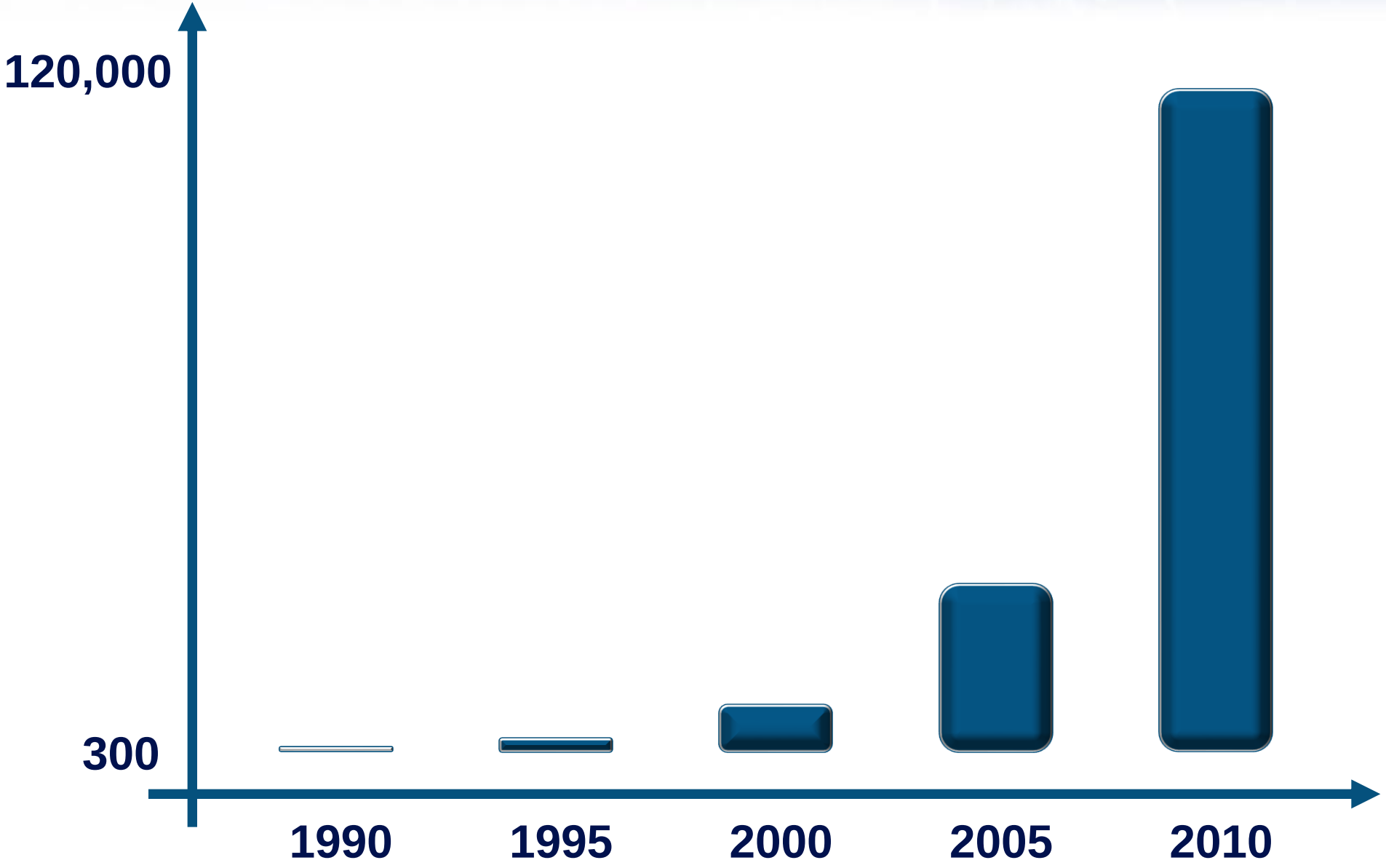
parallel computer program

```
if I am core 1:
  total1 = sum top half list
if I am core 2:
  total2 = sum bottom half list
wait for both cores to finish
total = total1 + total2
print total
```

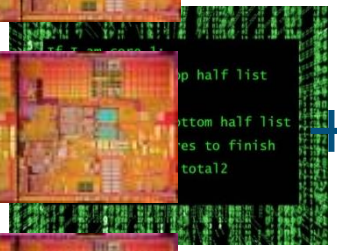
four billion transistors (2012)



how much faster in parallel?



parallel supercomputers



+ =

= ***super fast***

Cray XE6 run by EPCC at Edinburgh

5632 CPUs

90,112 cores

90,112 GB

1 Megawatt

very fast network

Cray XC30 run by EPCC at Edinburgh

9840 CPUs

118,080 cores

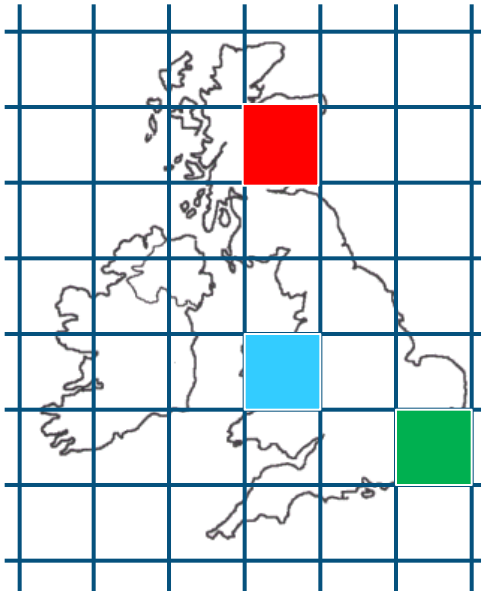
338,944 GB

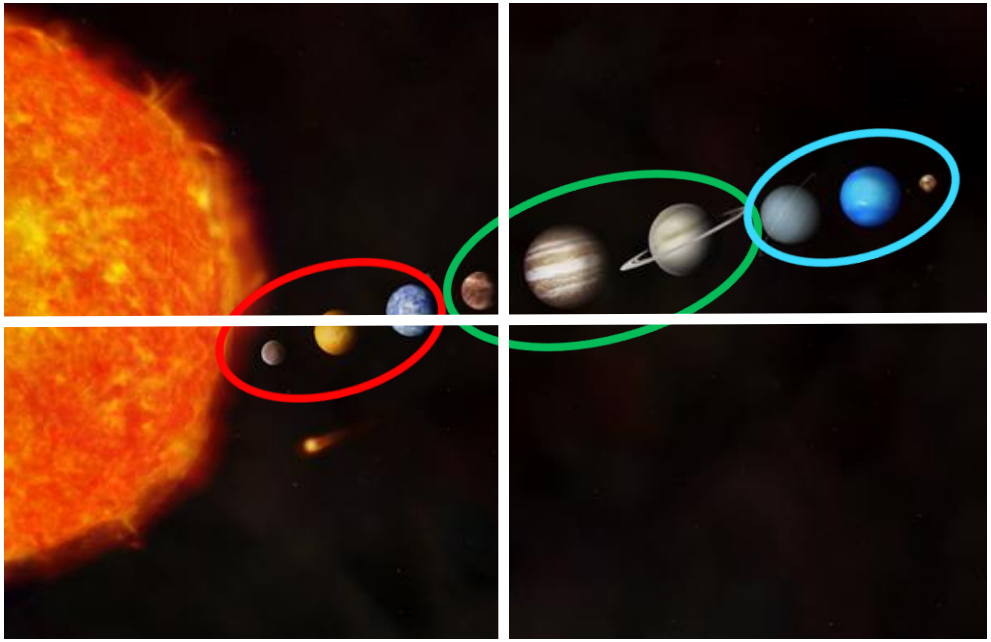
1 Megawatt

even faster network and CPUs

archer

parallel computer simulations

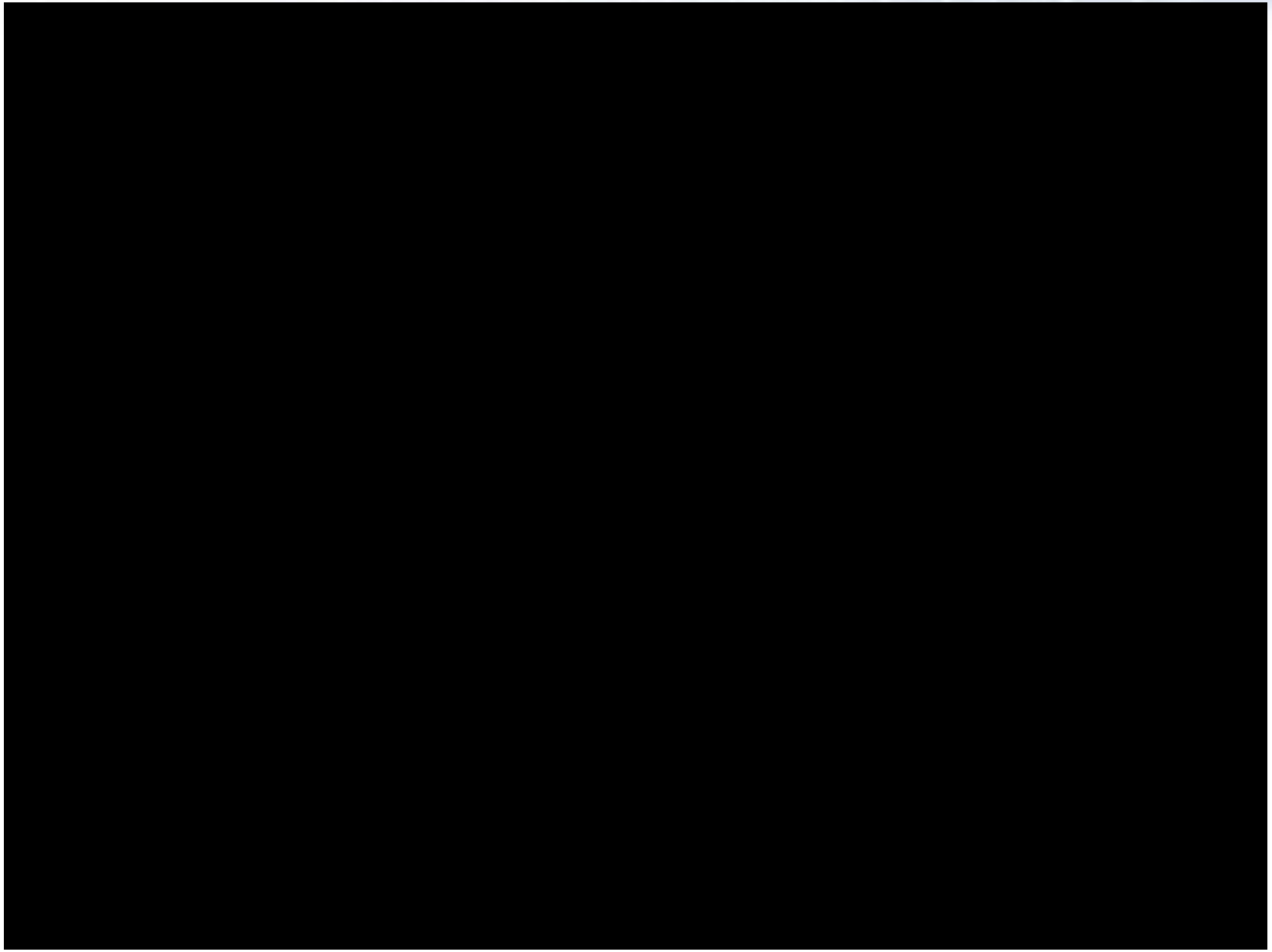




universal experiment

```
using System;                              // C# does not import a .h file, uses metadata
namespace FirstApplication                 // scope for classes. No Obj-c counterpart
{
    class Person                           // only uses class implementation
    {
        private DateTime birthDate;    // a private field accessible to this class
        private int ageOn(DateTime date)   // a private method
        {
            TimeSpan span = date.Subtract(birthDate);  //uses a .notation to invoke
            return span.Days;
        }
        public int age                     // this is a property.
        {
            Get                            // just a getter; it's a read-only property
            {
                return this.ageOn(DateTime.Now);
            }
        }
        public Person( DateTime dob)   // instance constructor. Unlike Objective-C
        {                                  // it combines allocation and initialization
            birthDate = dob;
        }
    }
    class Program                         //Unlike Obj-C, another class in the same file.
    {
        static void Main(string[] args) // main entry point into the program
        {
            Person p = new Person(new DateTime(1973,11,12));  //construct an instance
            System.Console.WriteLine("The age is  is" + p.age.ToString());
            DateTime dt = p.birthDate; //error in compilation birthDate is private
        }
    }
}
```

big bang: R.Cen & J. Ostriker, Illinois



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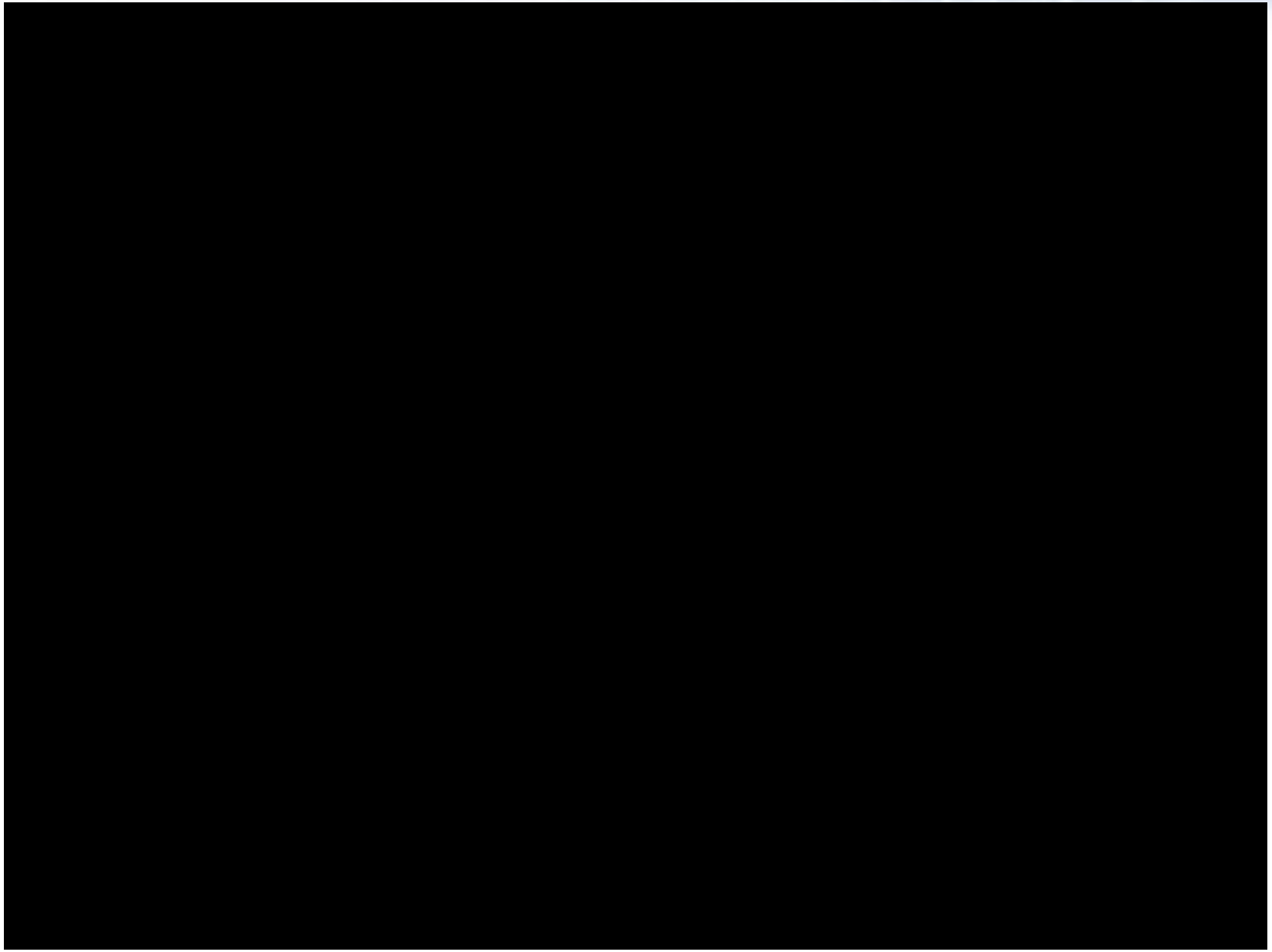

big bang: project stargate at SC'09

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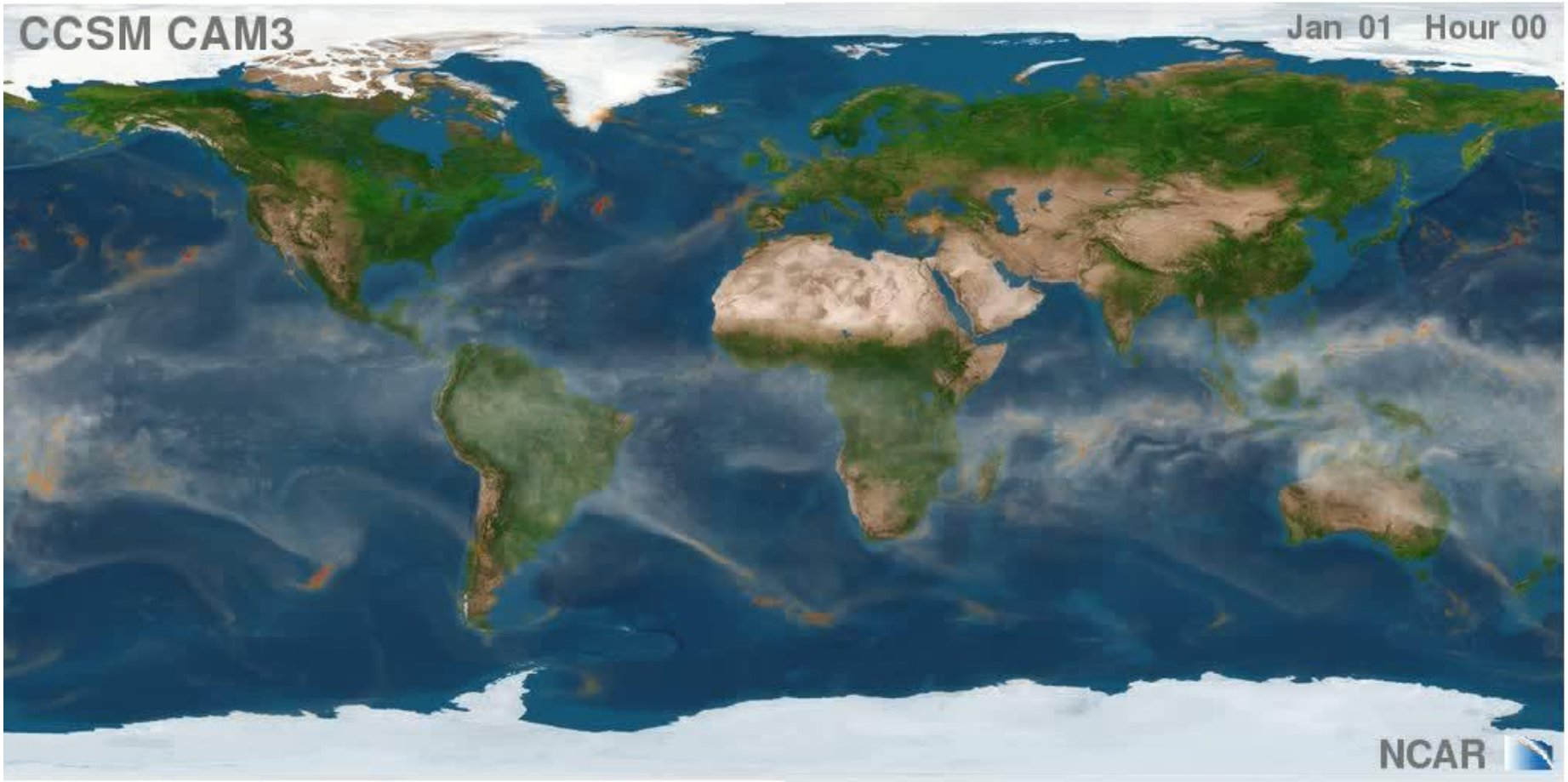
climate modelling: UCAR



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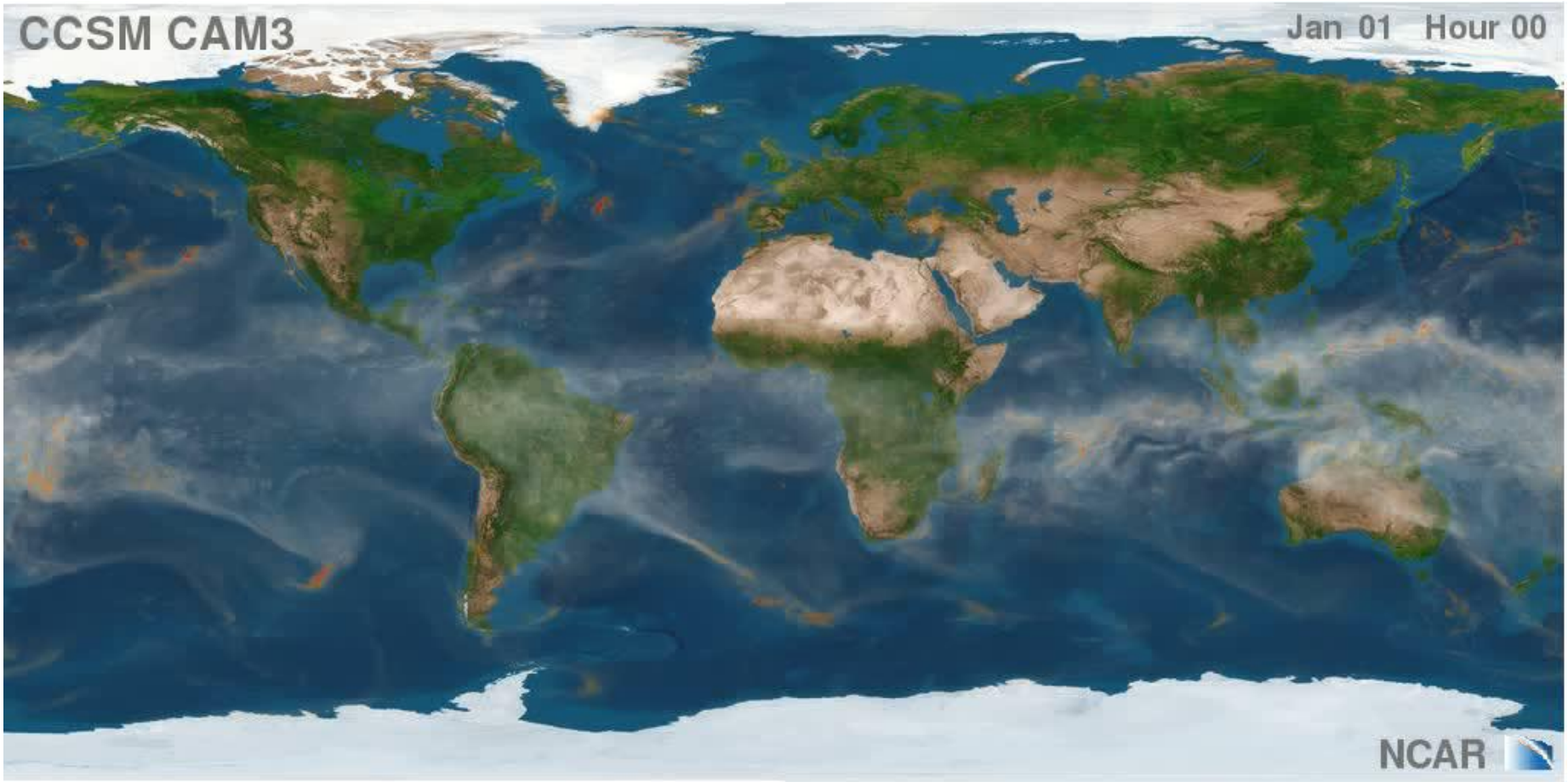
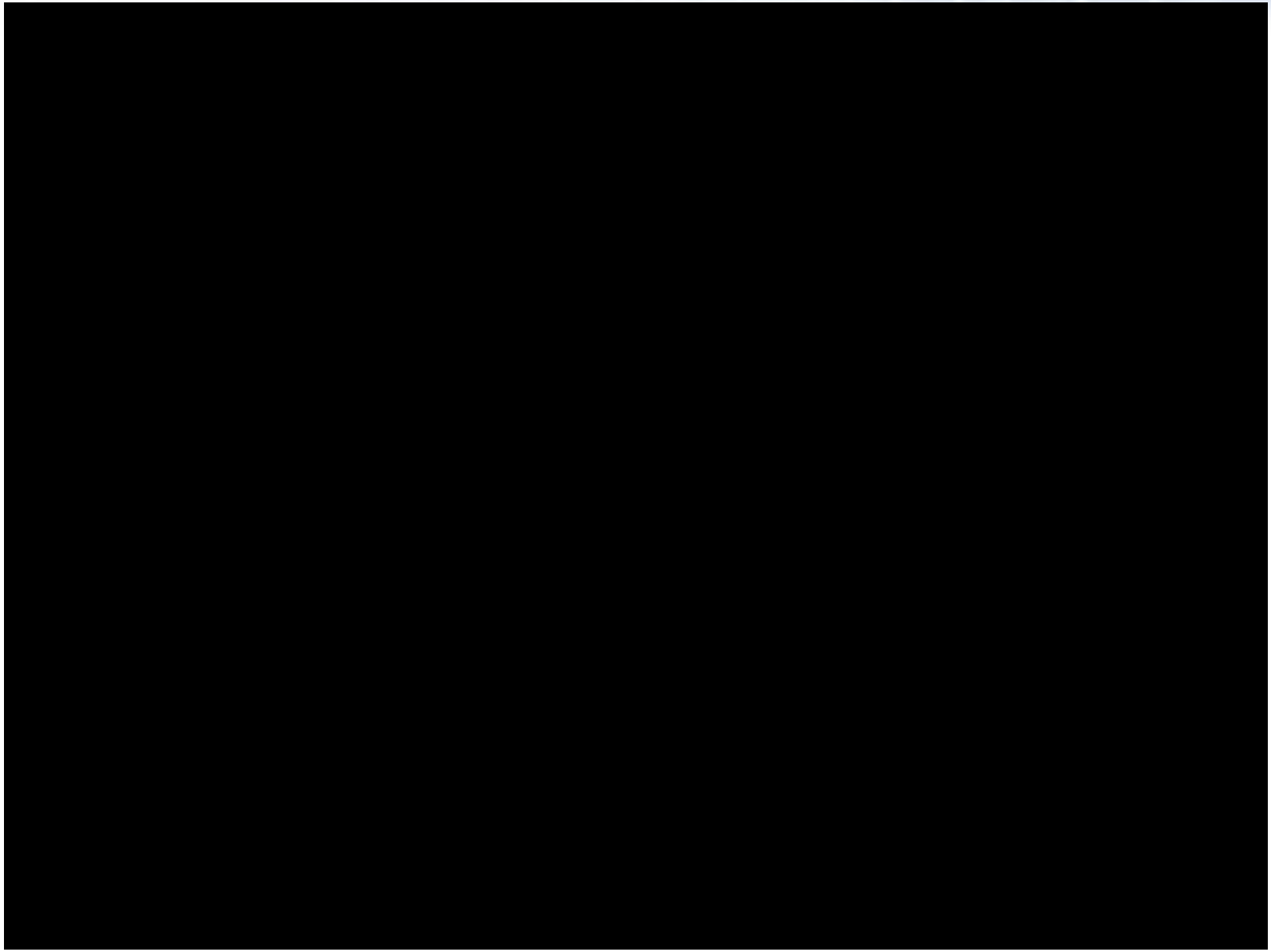


ocean modelling: ECCO2 / NASA



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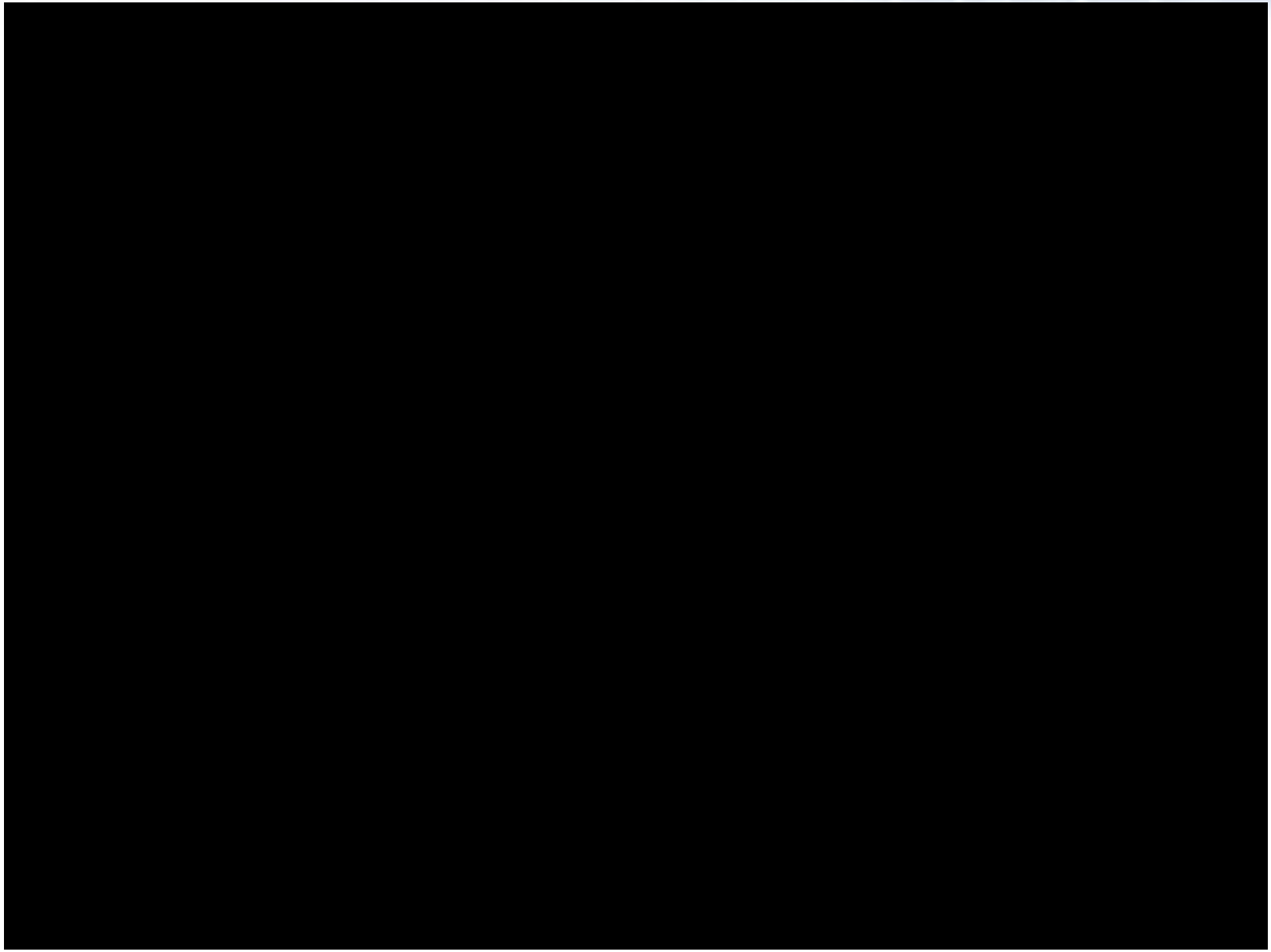
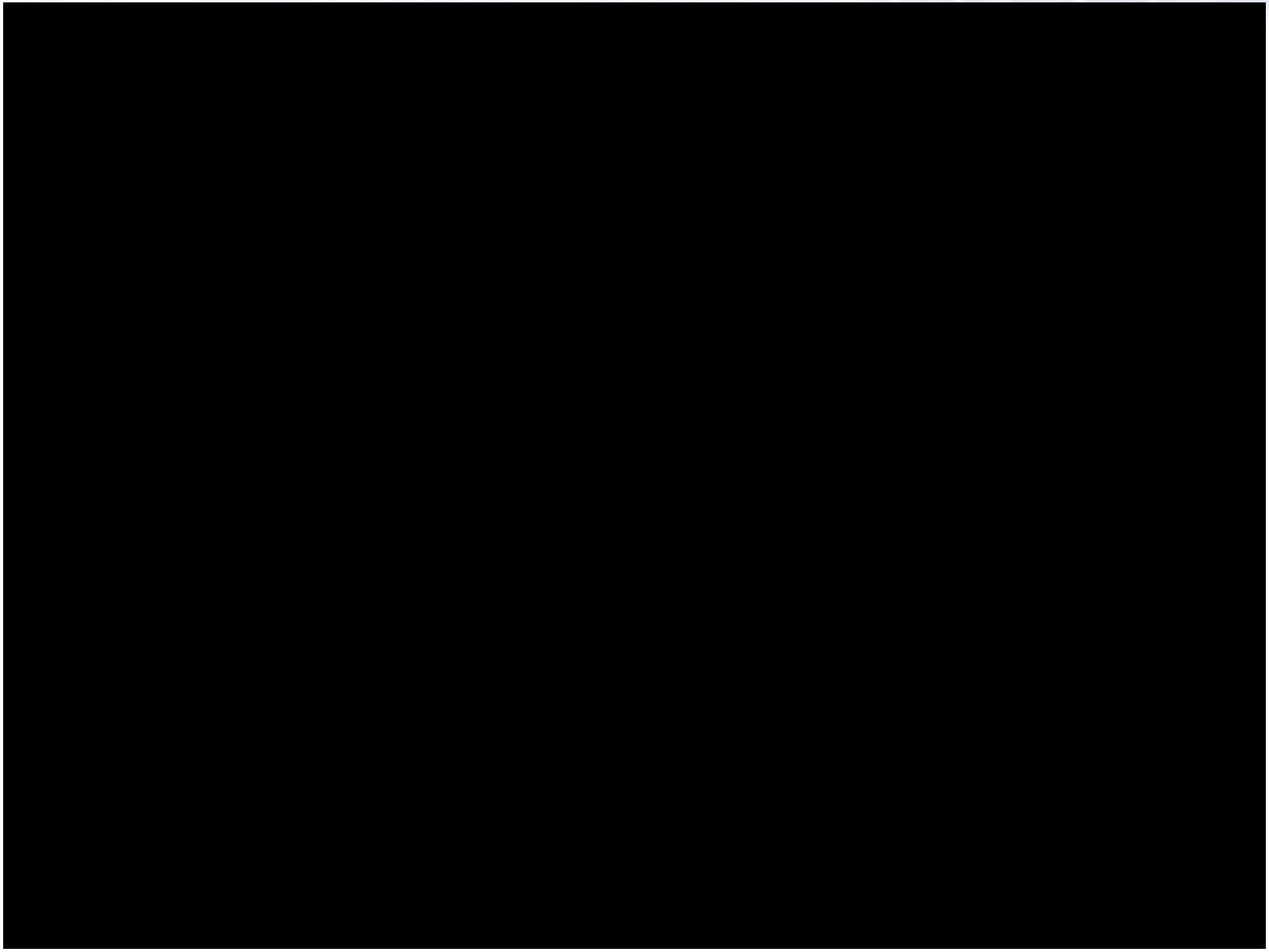


ocean modelling: close up



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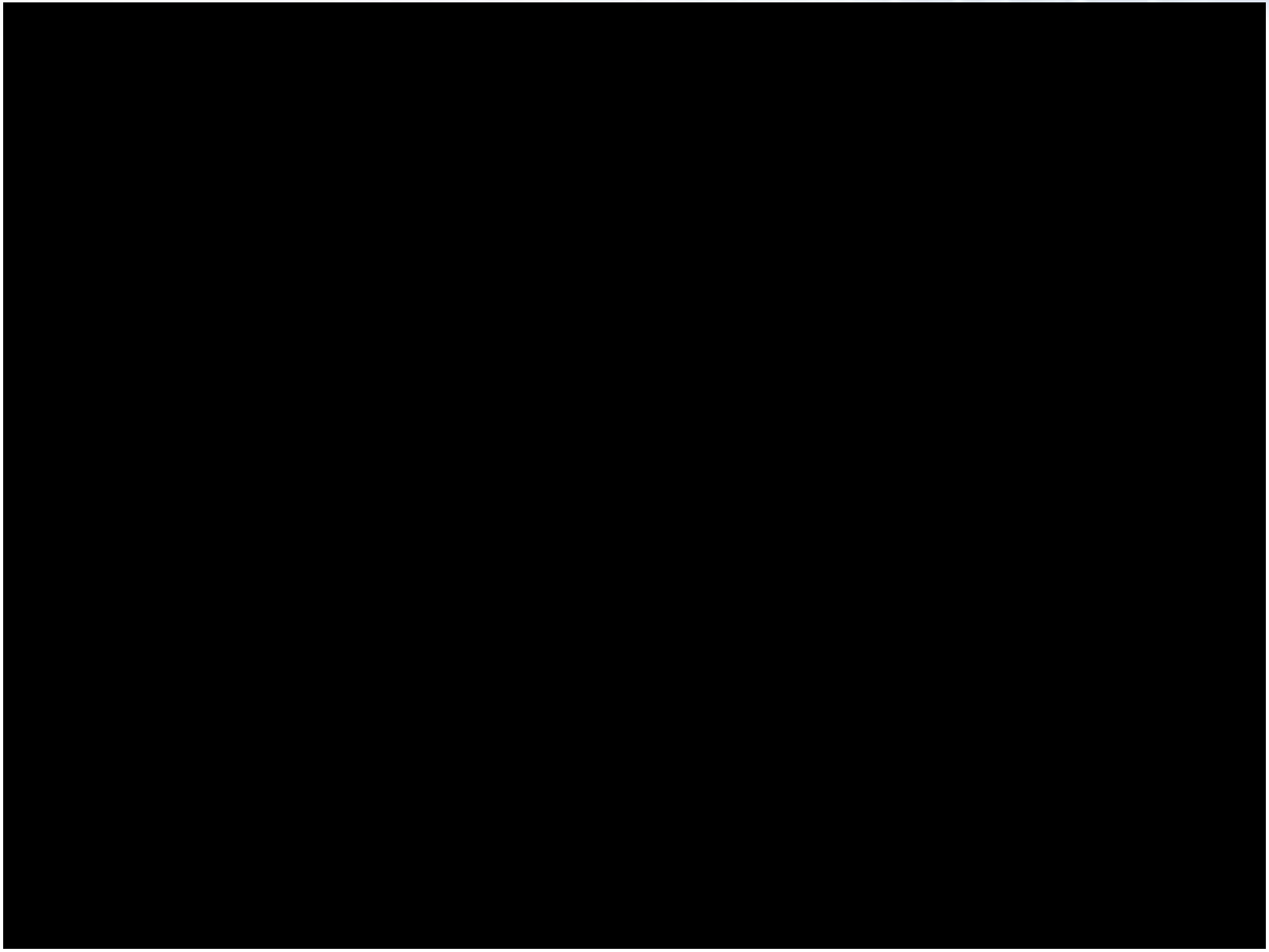
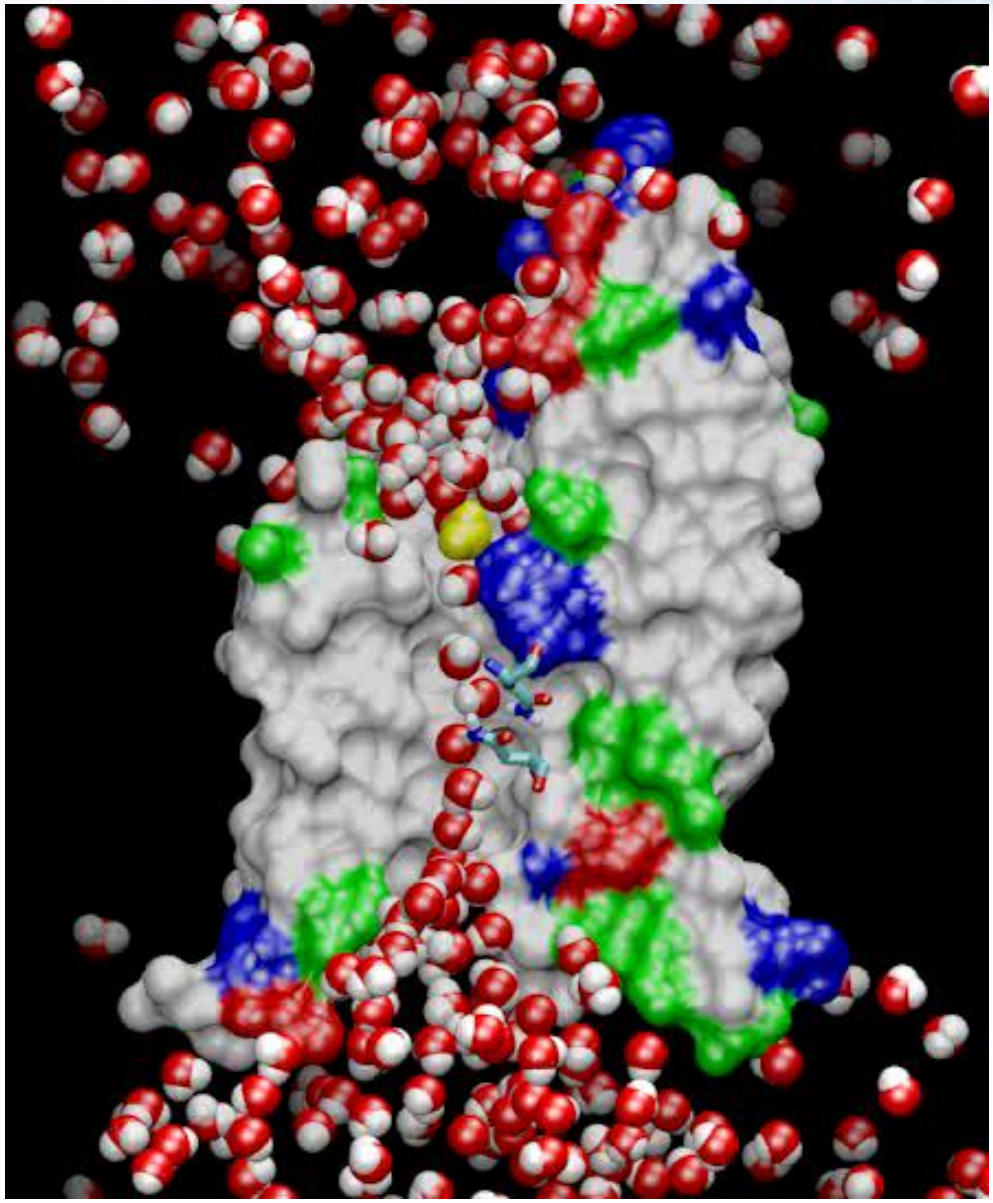


cell membranes: Science, 296:525-530, 2002



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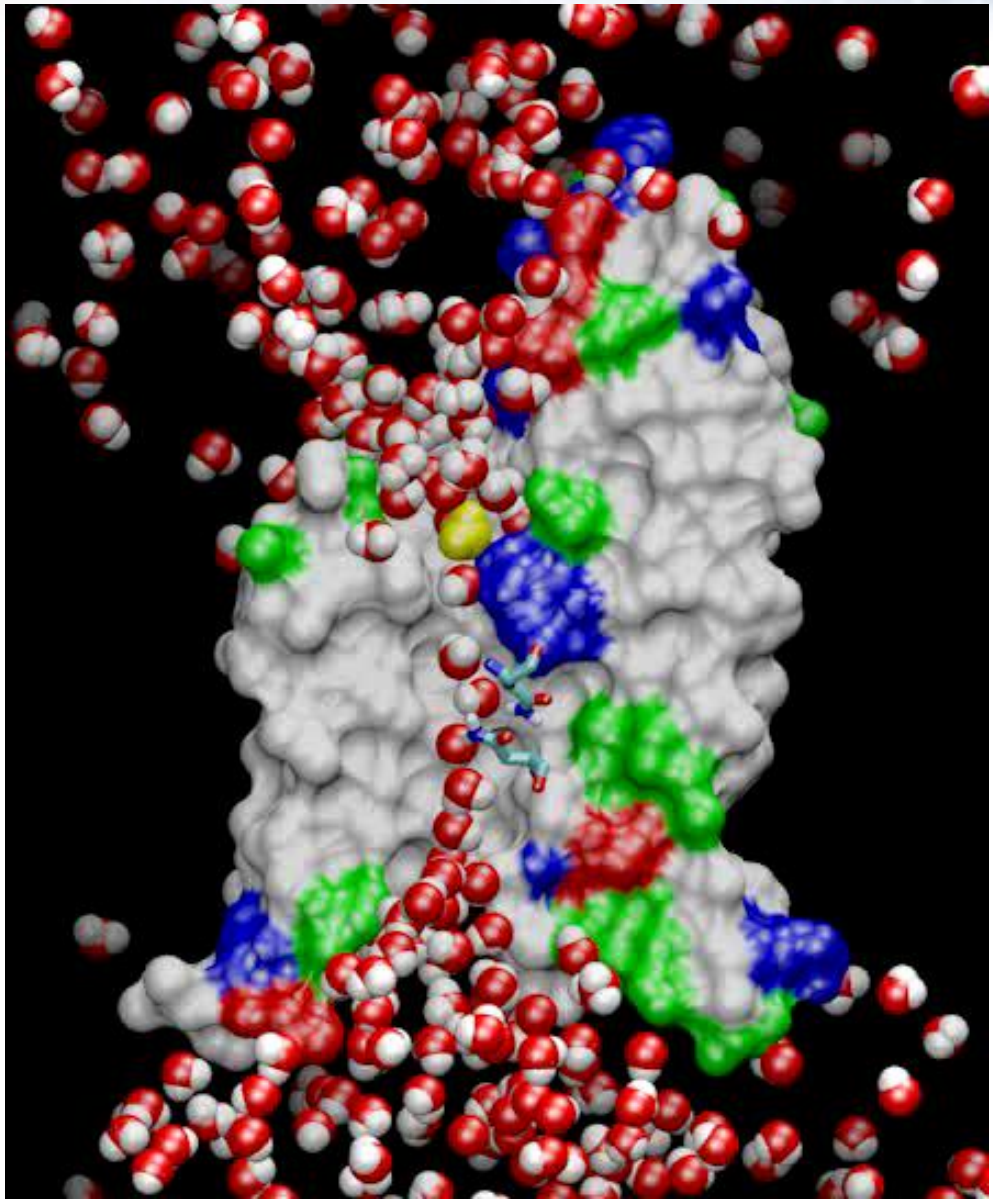
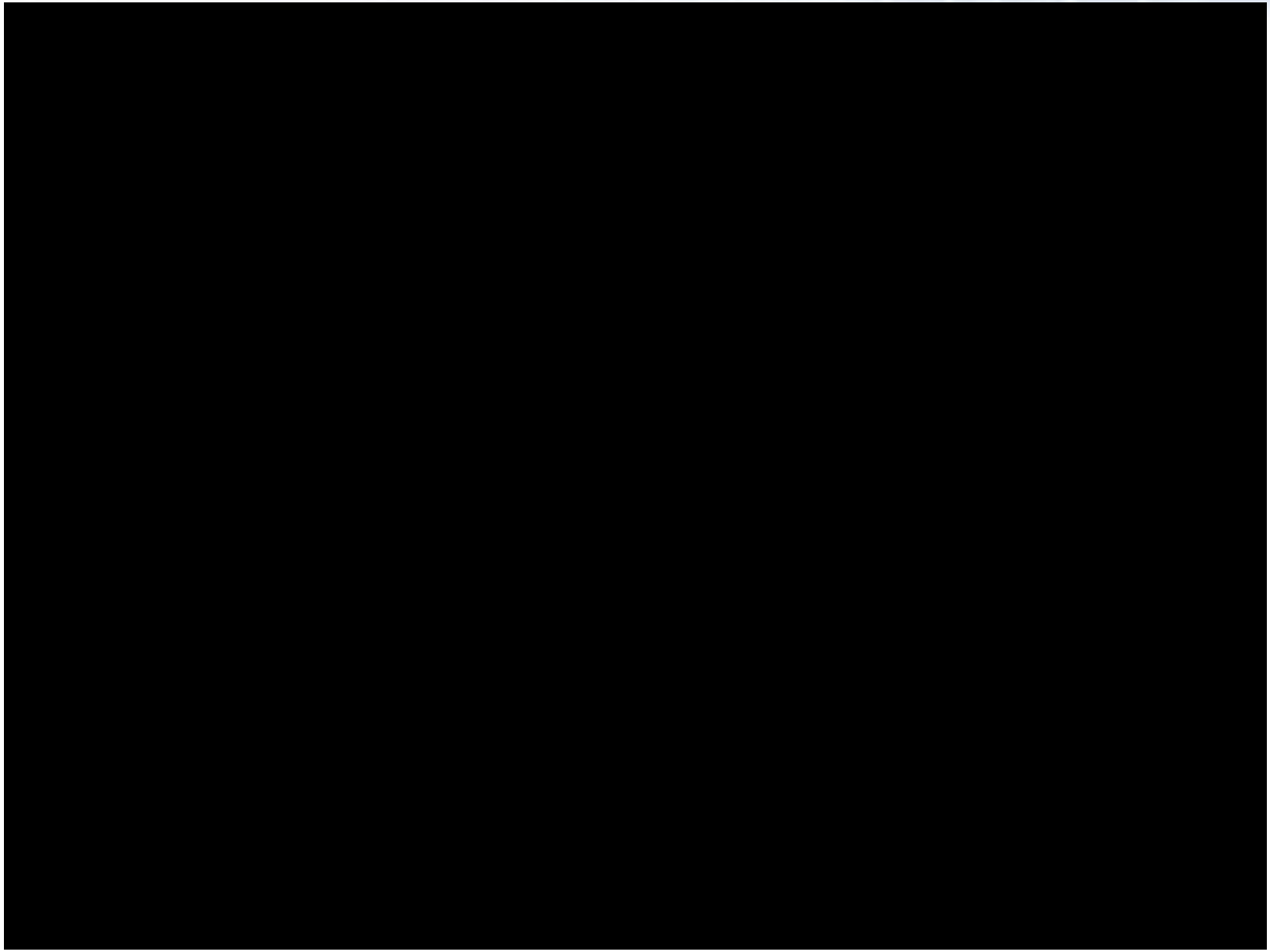


four legs or two? Dr Lee Margetts



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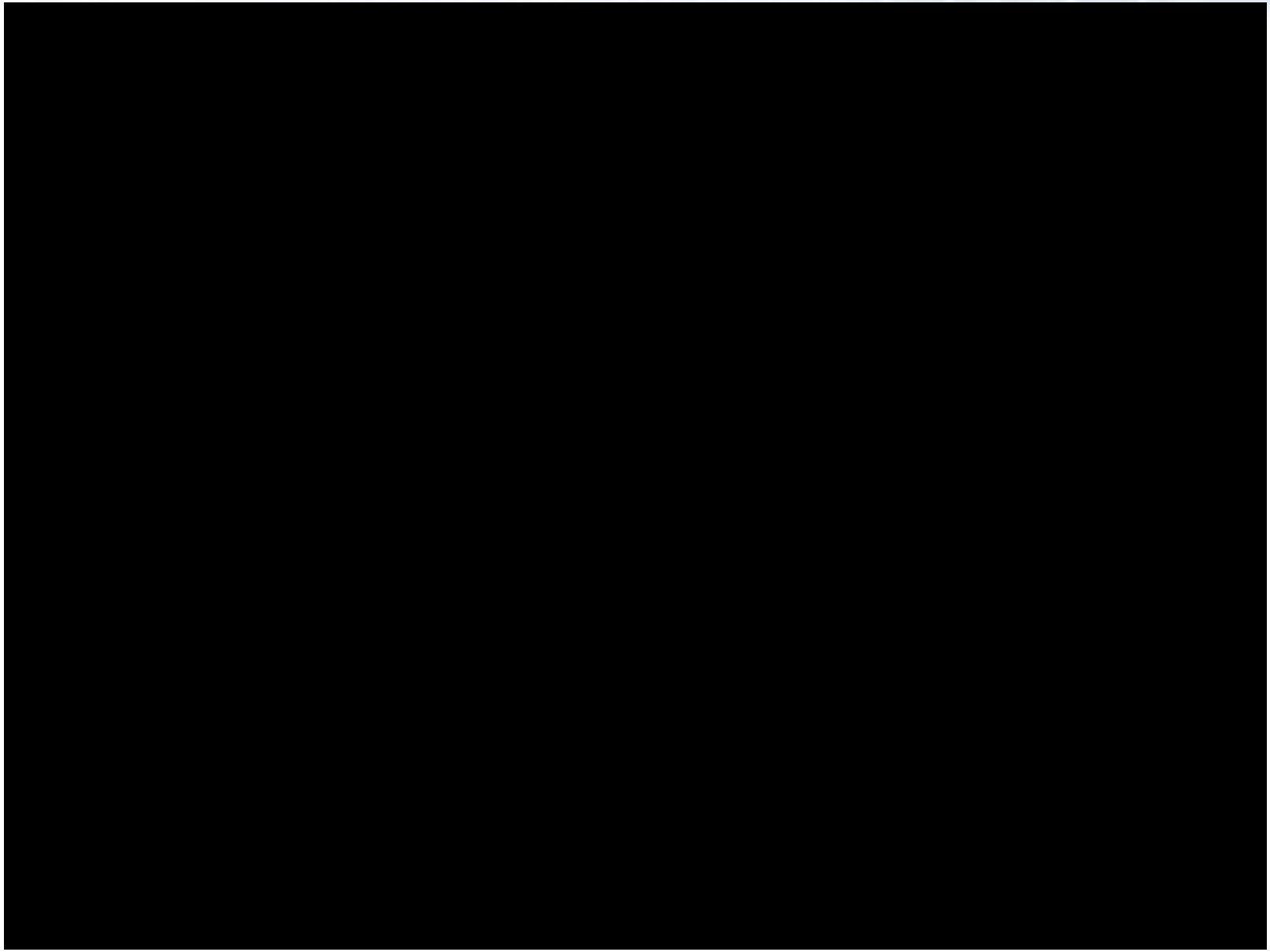
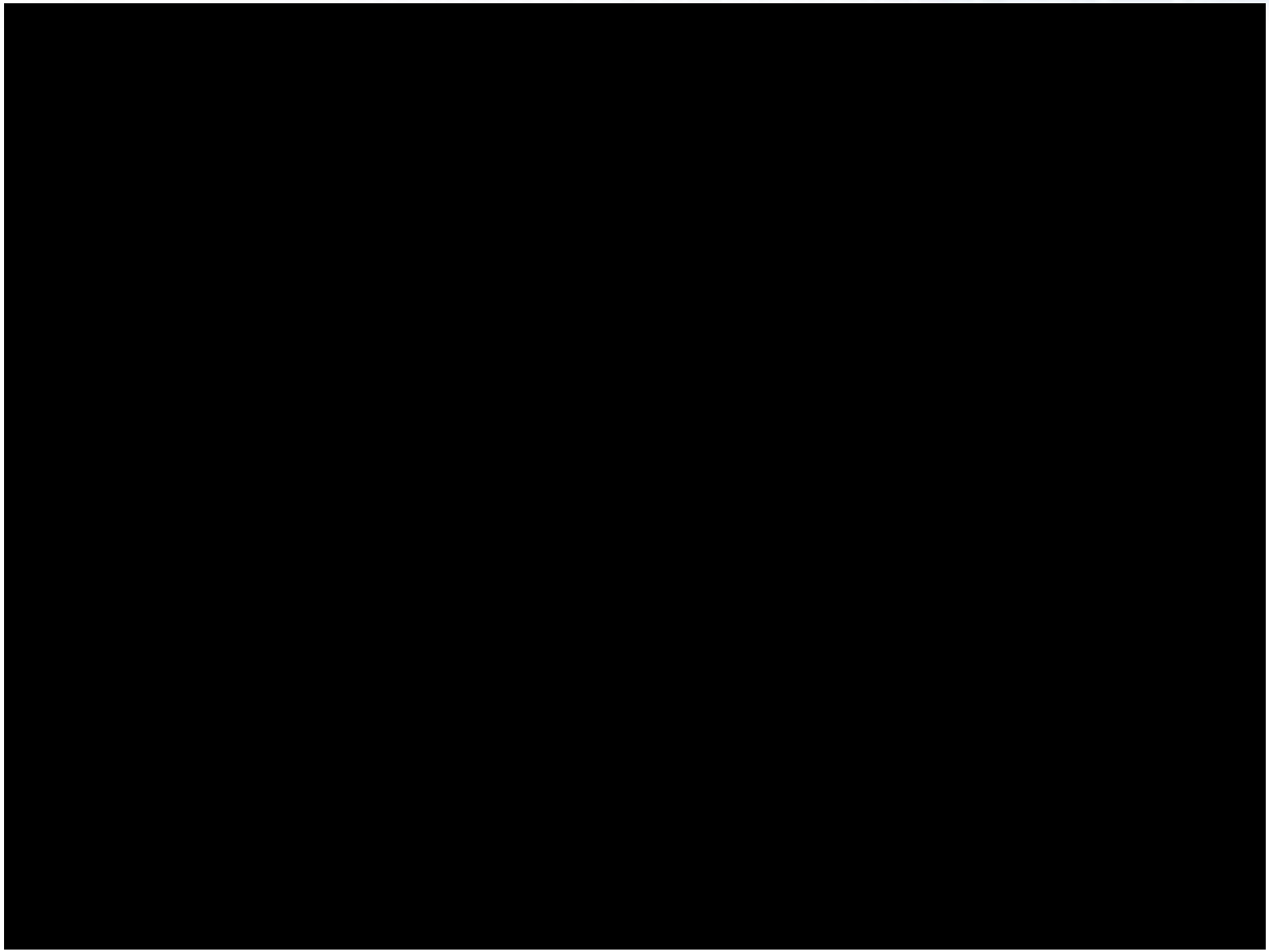


running hadrosaur



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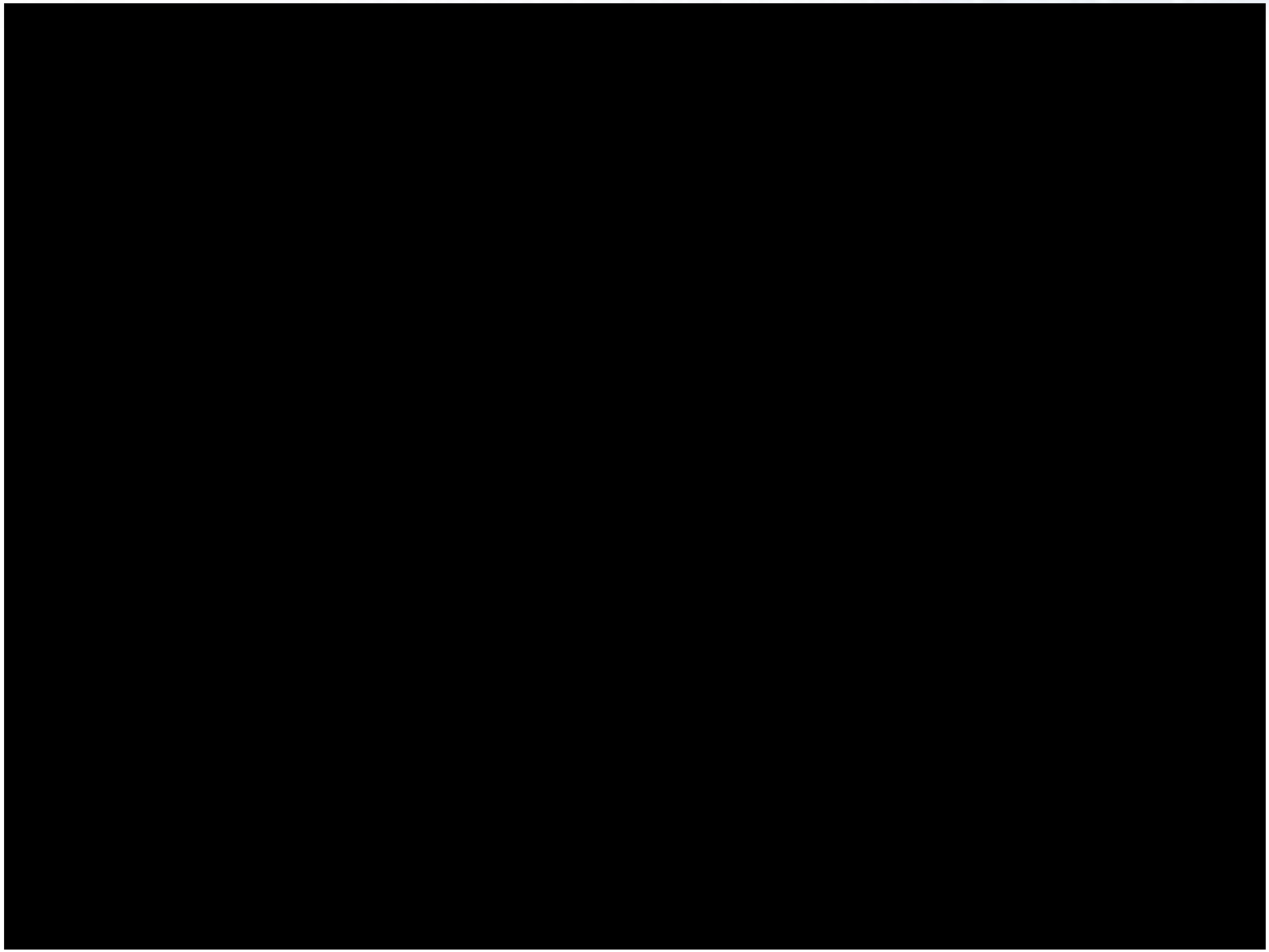

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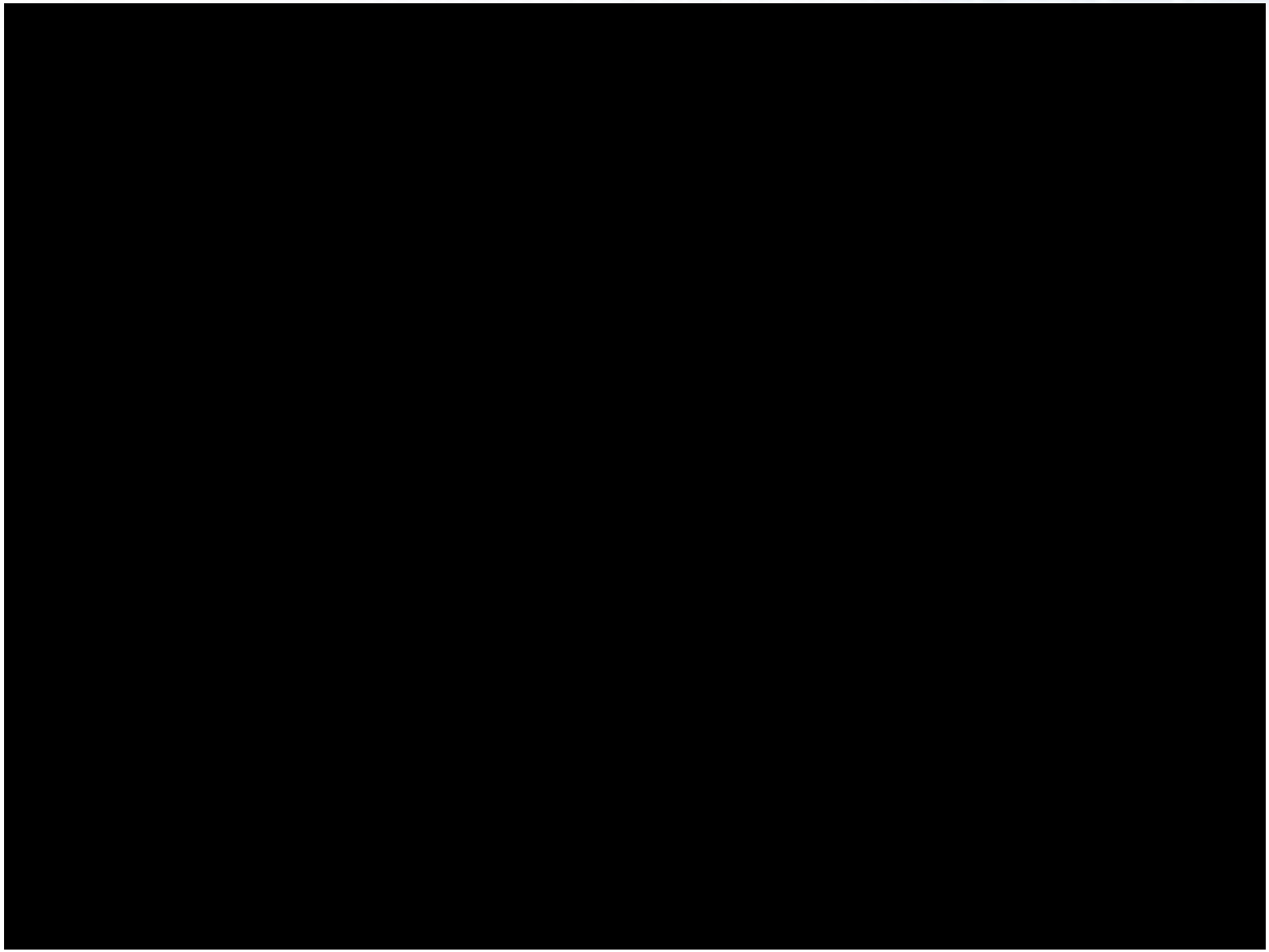
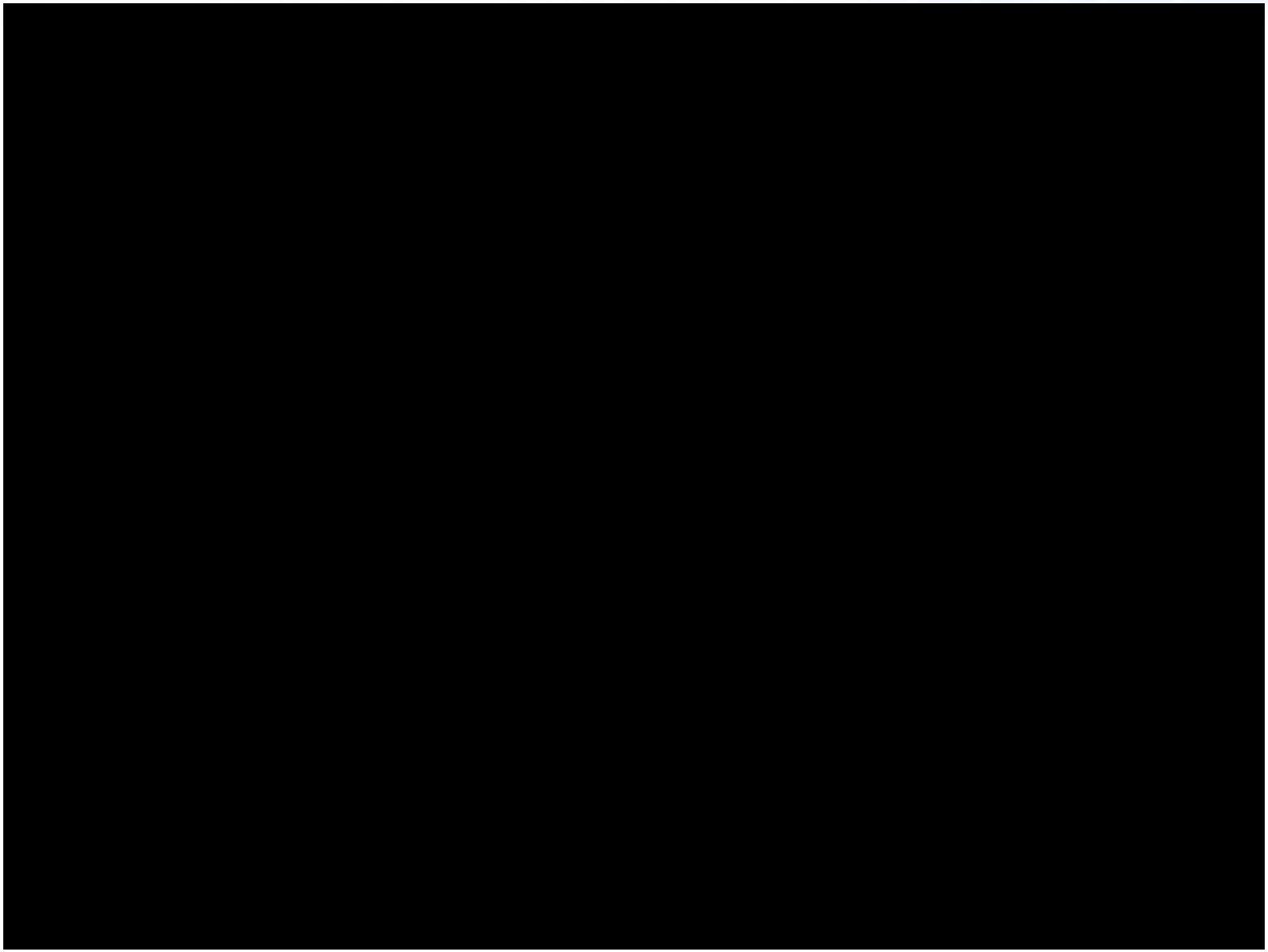


hopping hadrosaur



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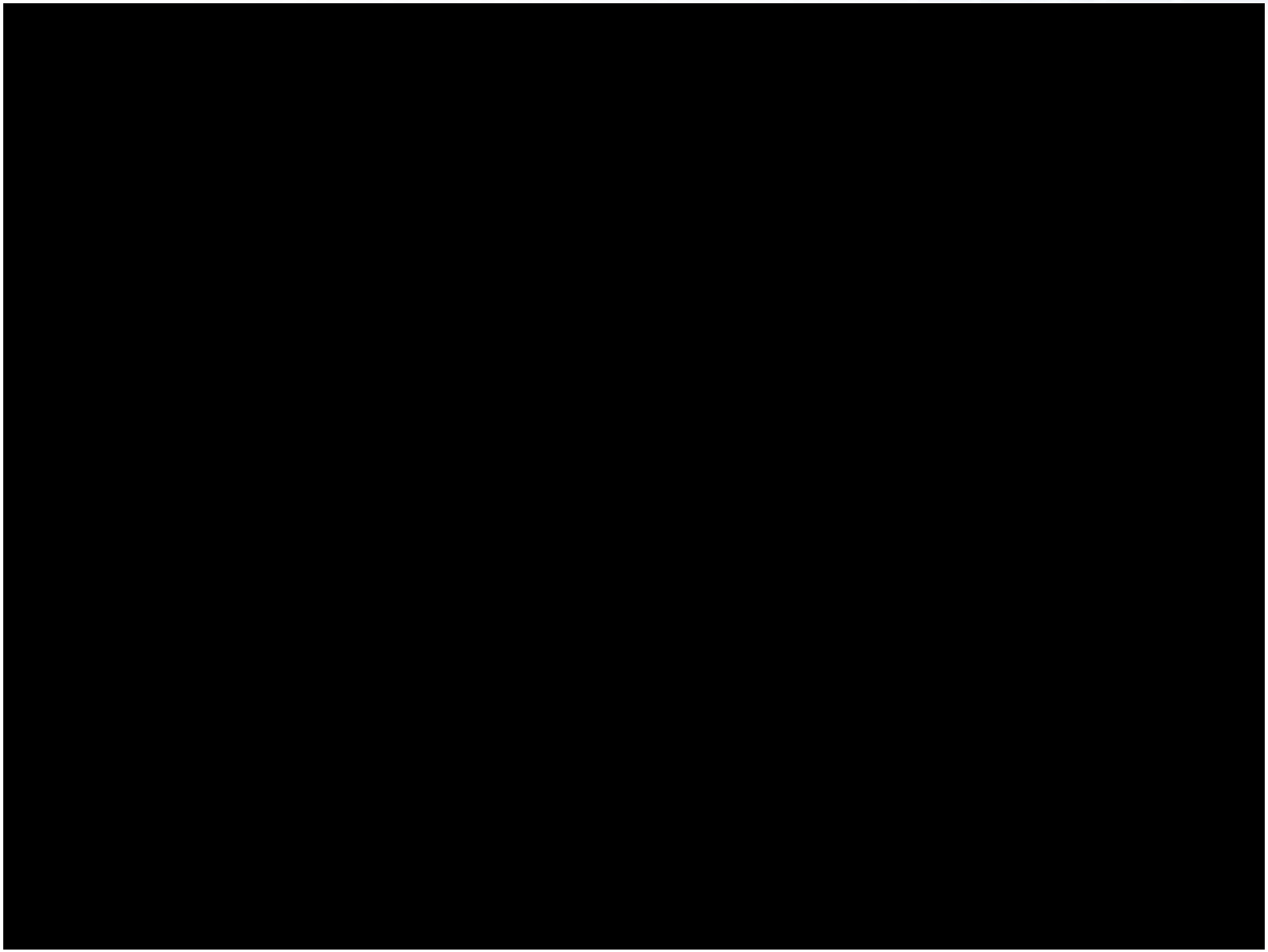
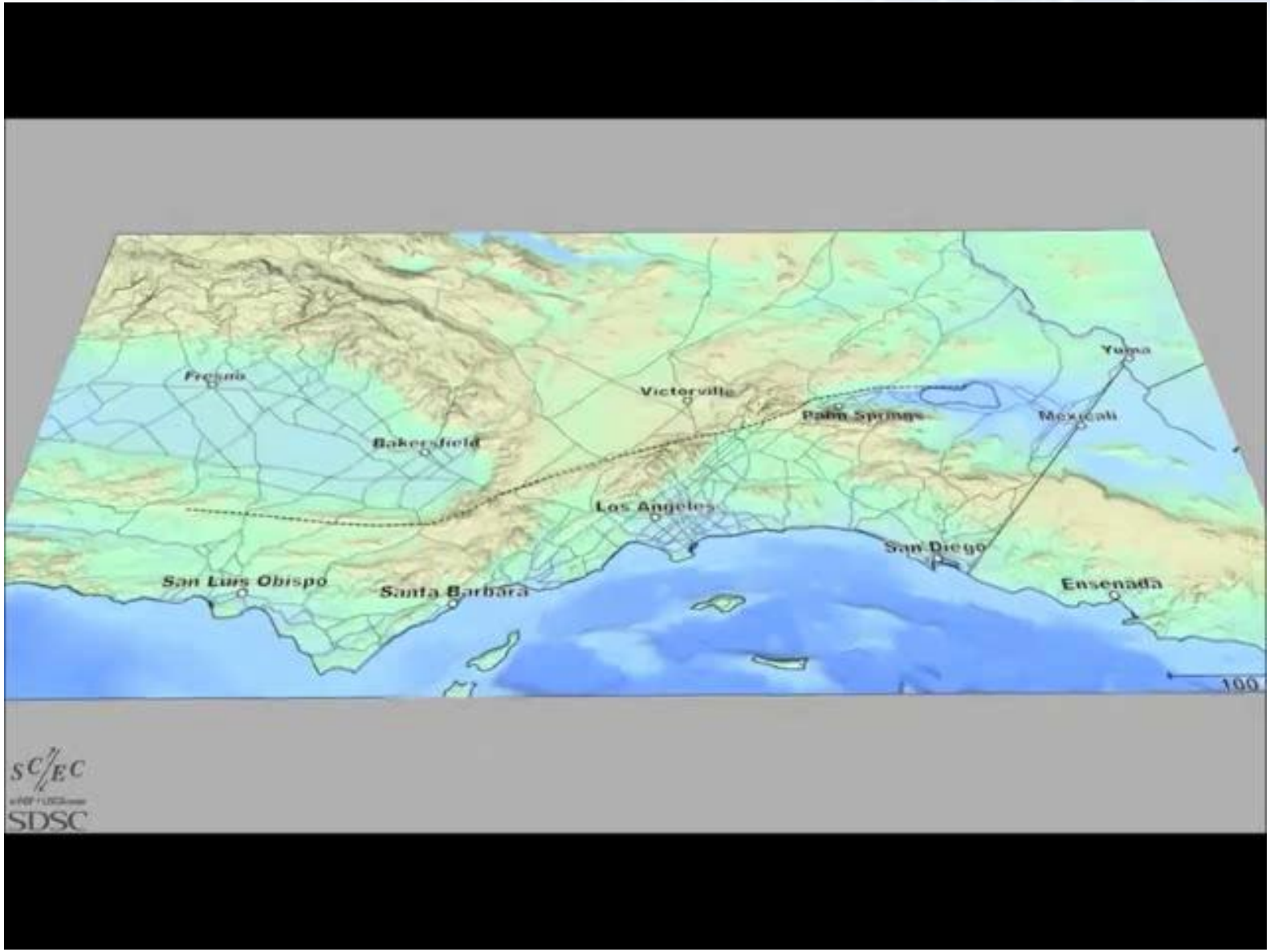


california earthquake: argonne labs



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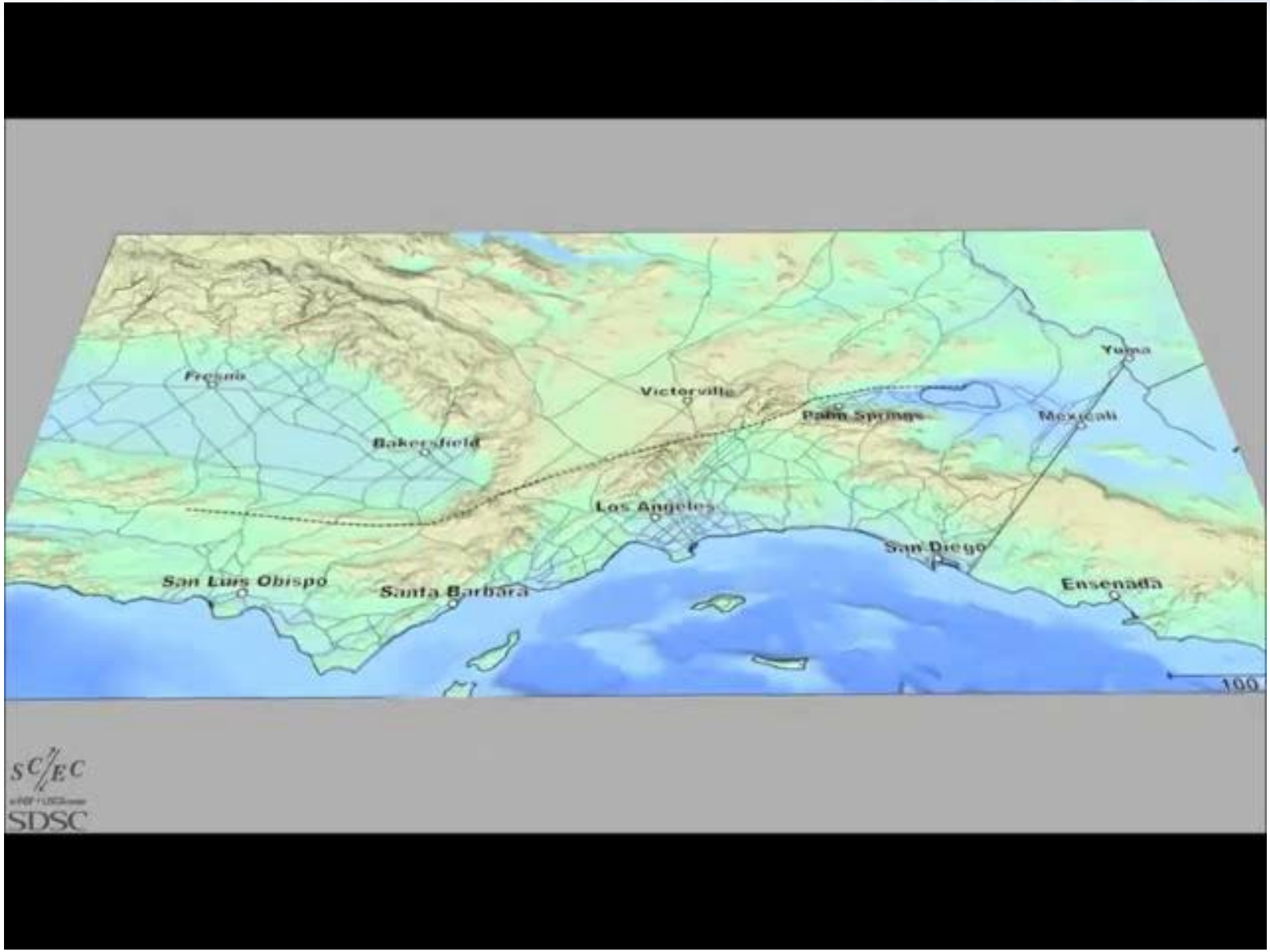

flush: Barcelona Supercomputing Center

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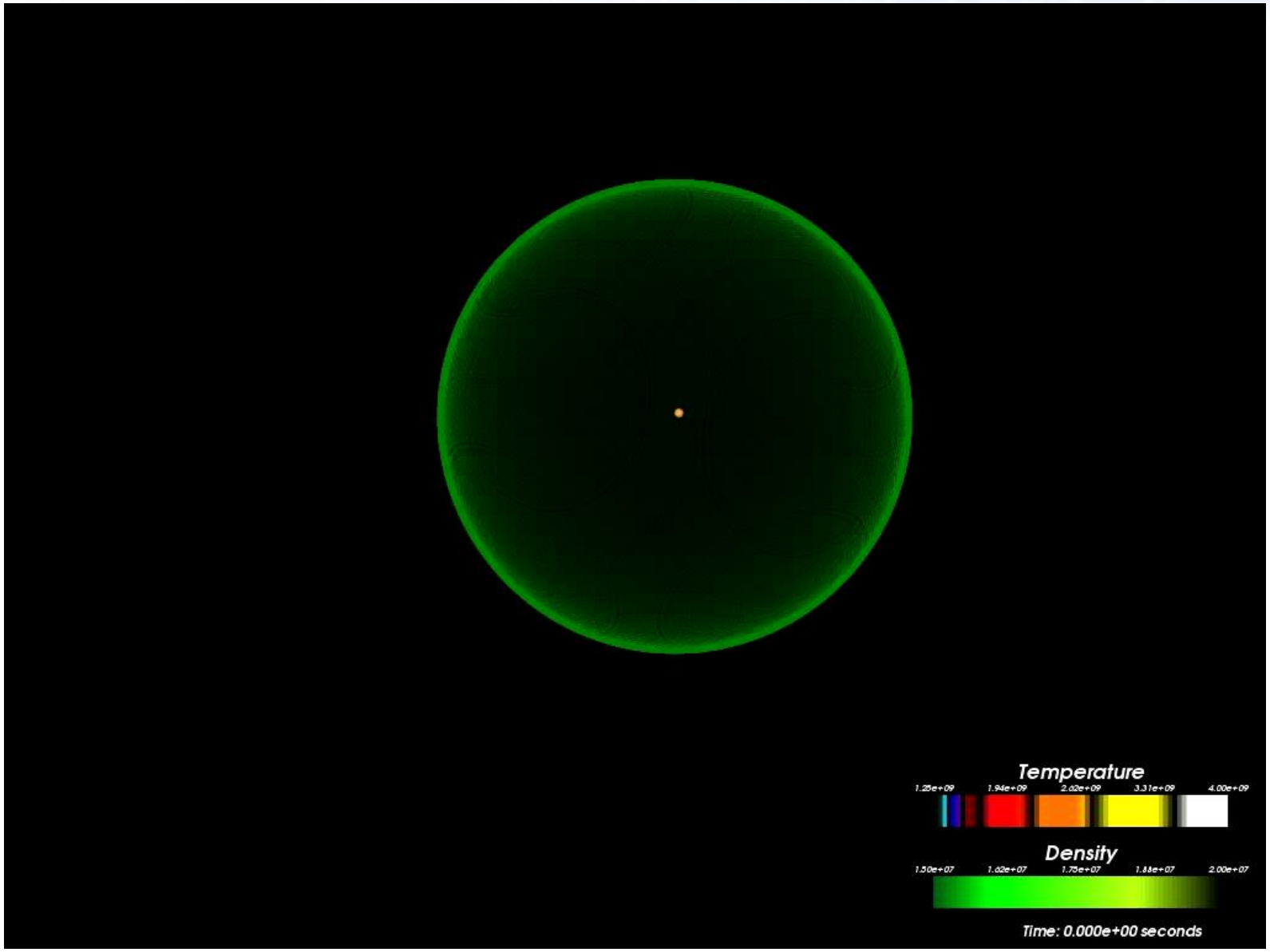
supernova: Argonne National Labs



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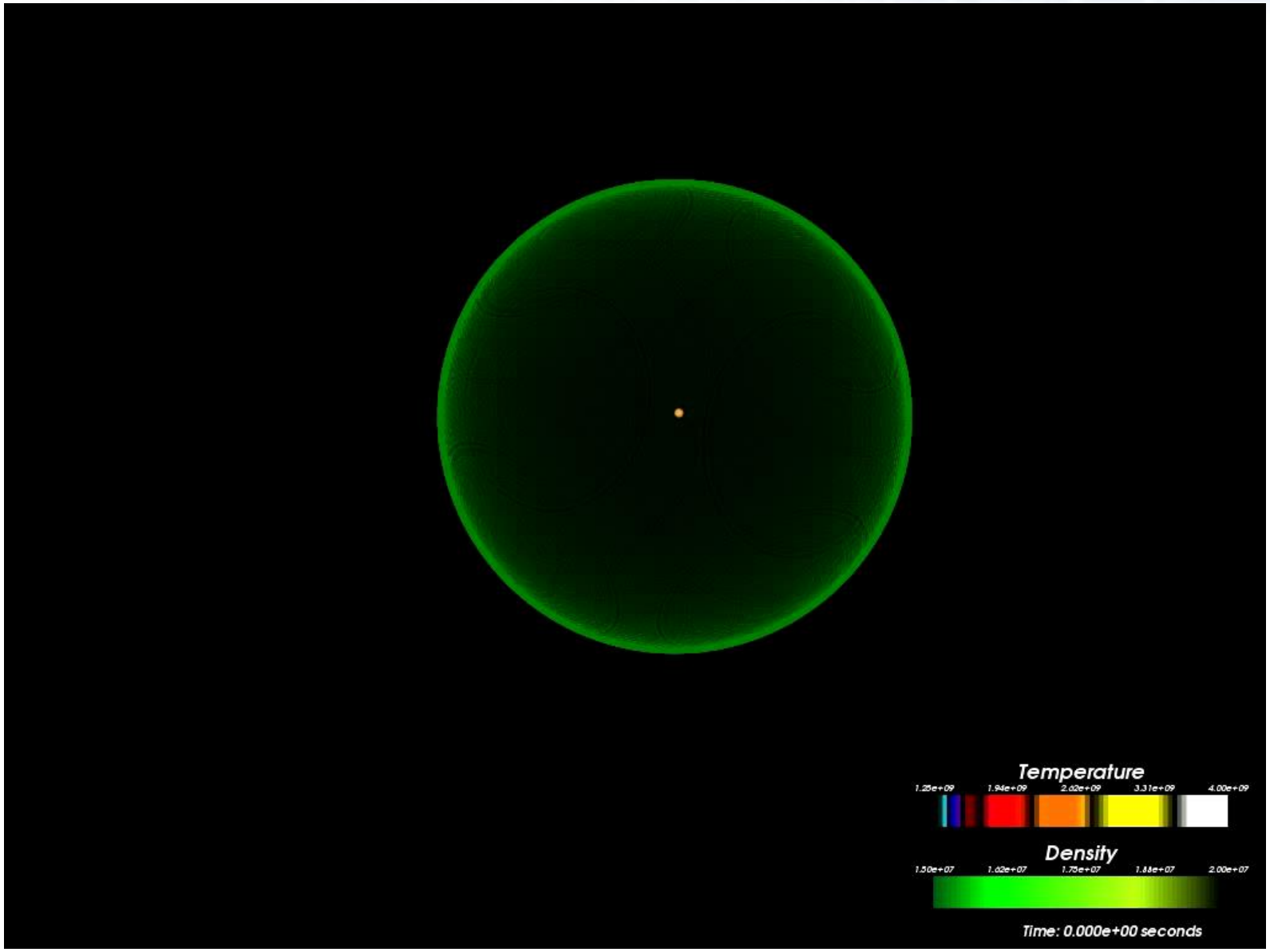
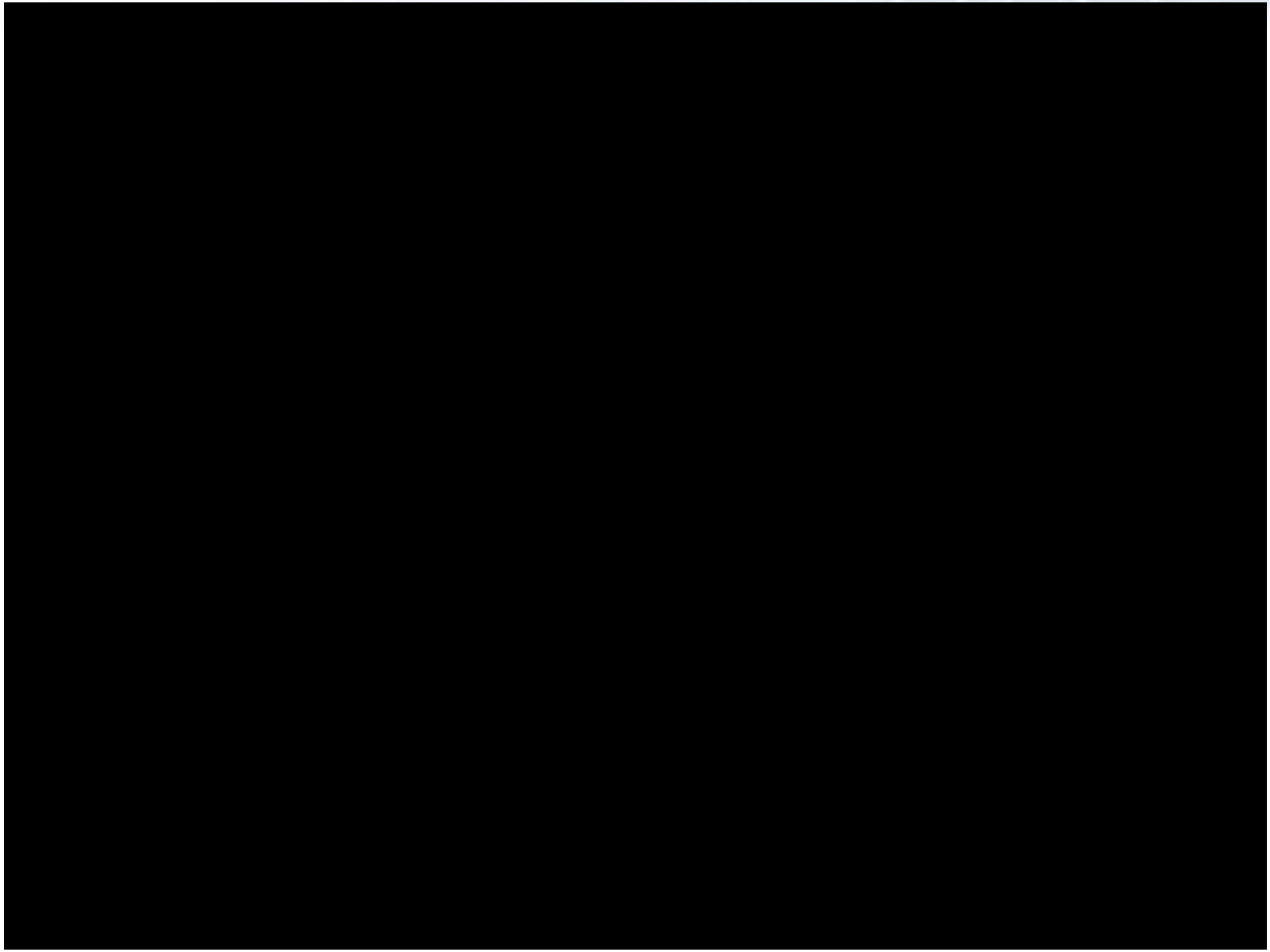


hurricane katrina: satellite photos



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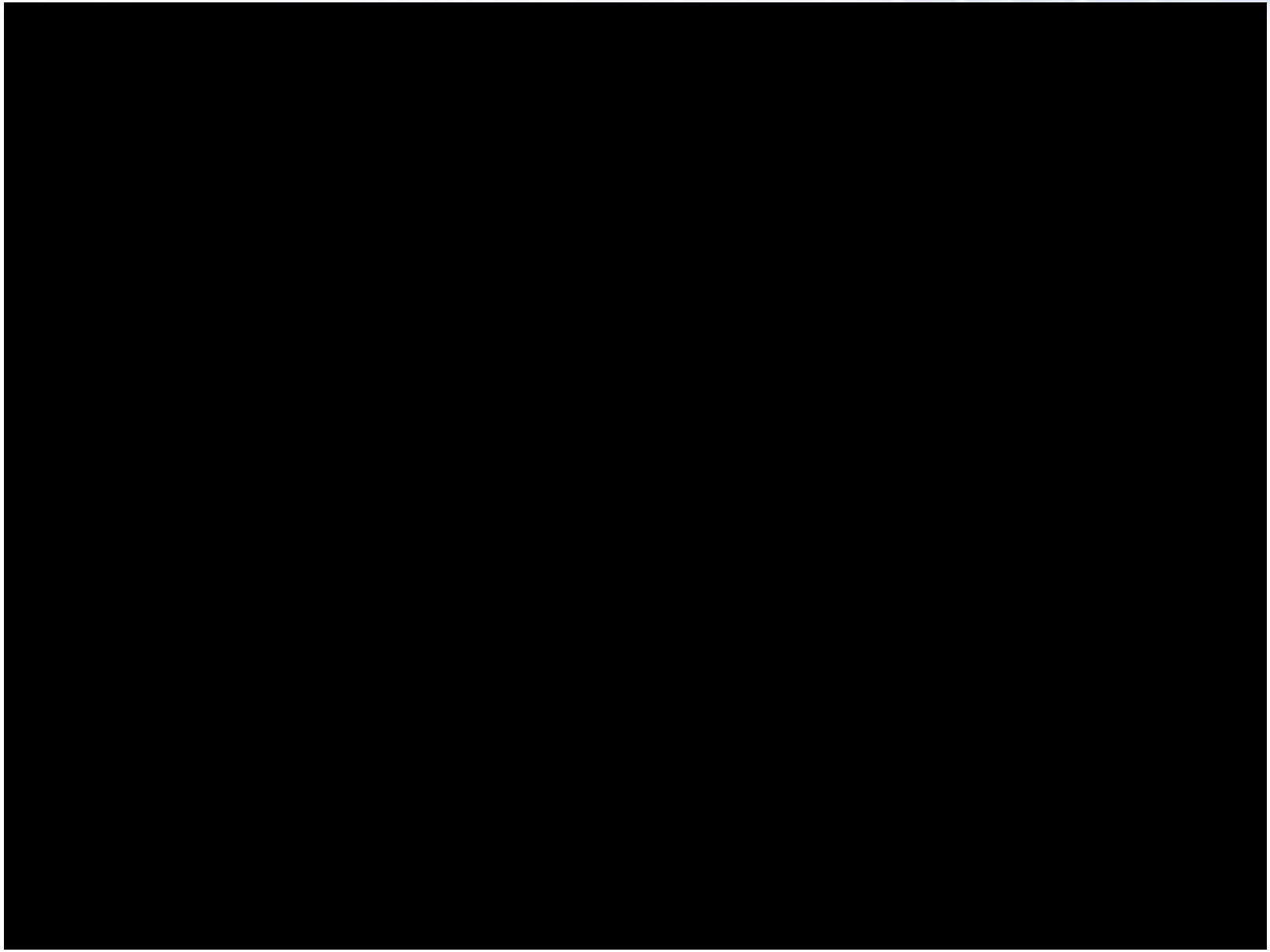
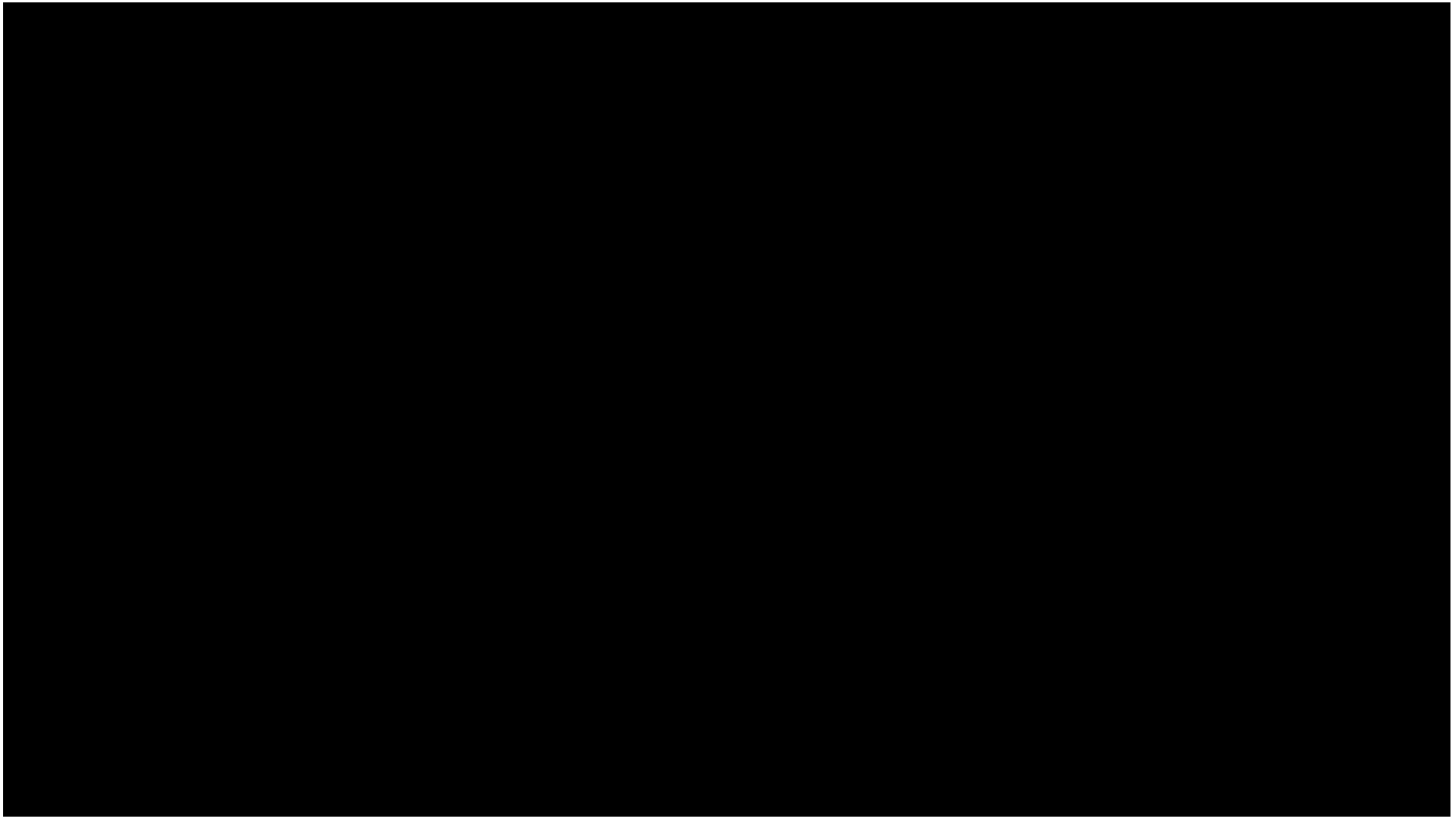


katrina: NCAR computer simulation



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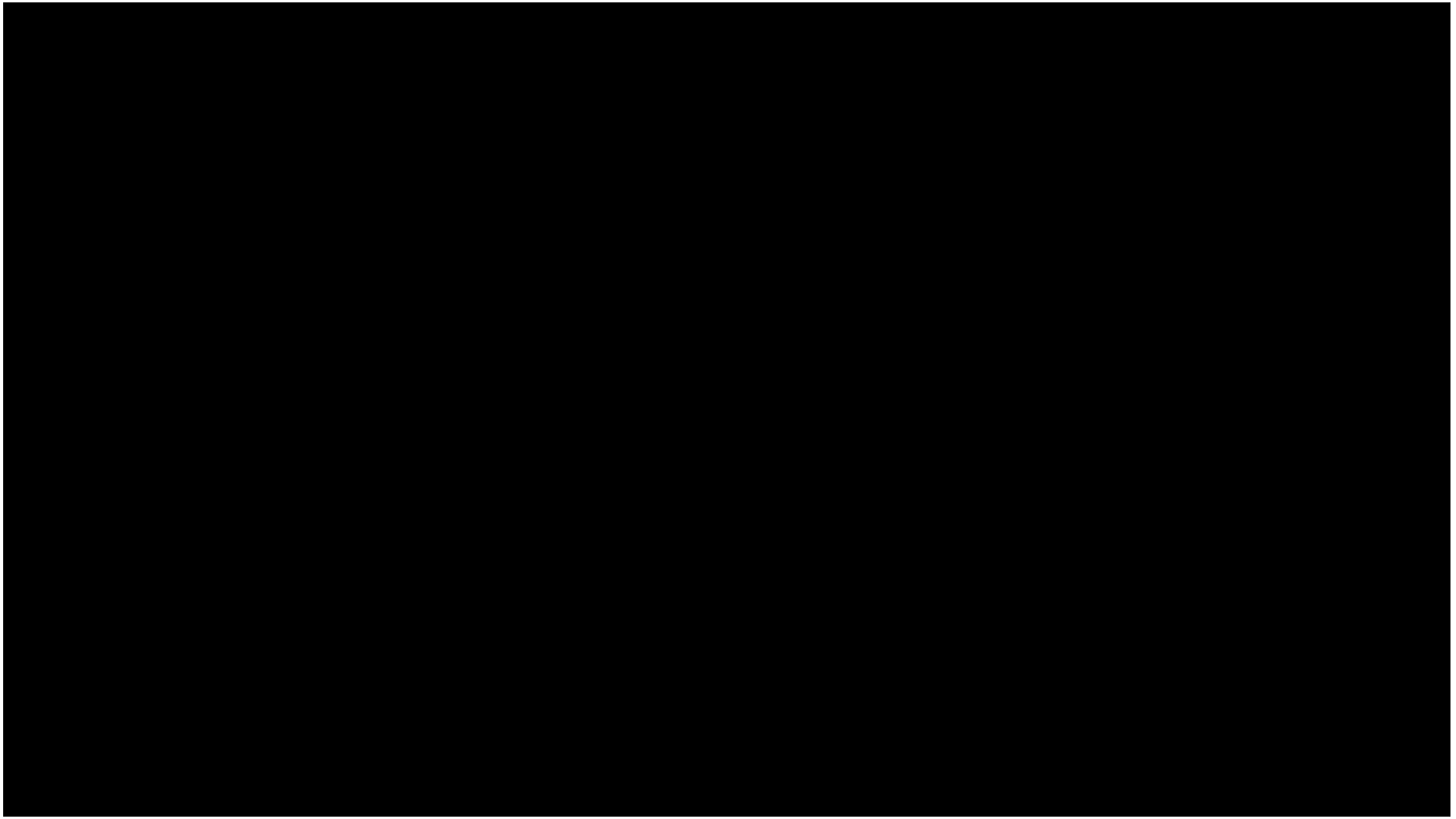
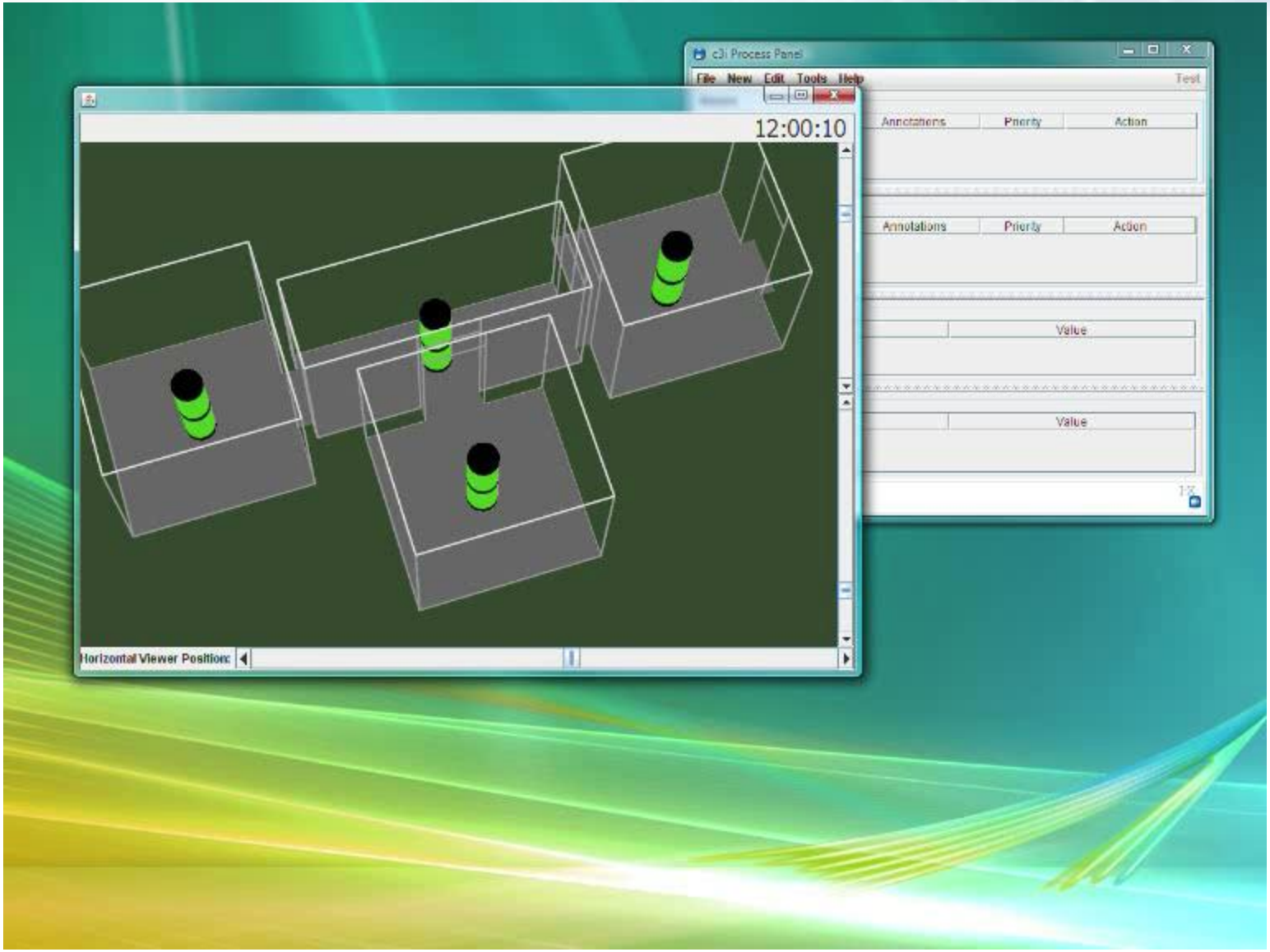
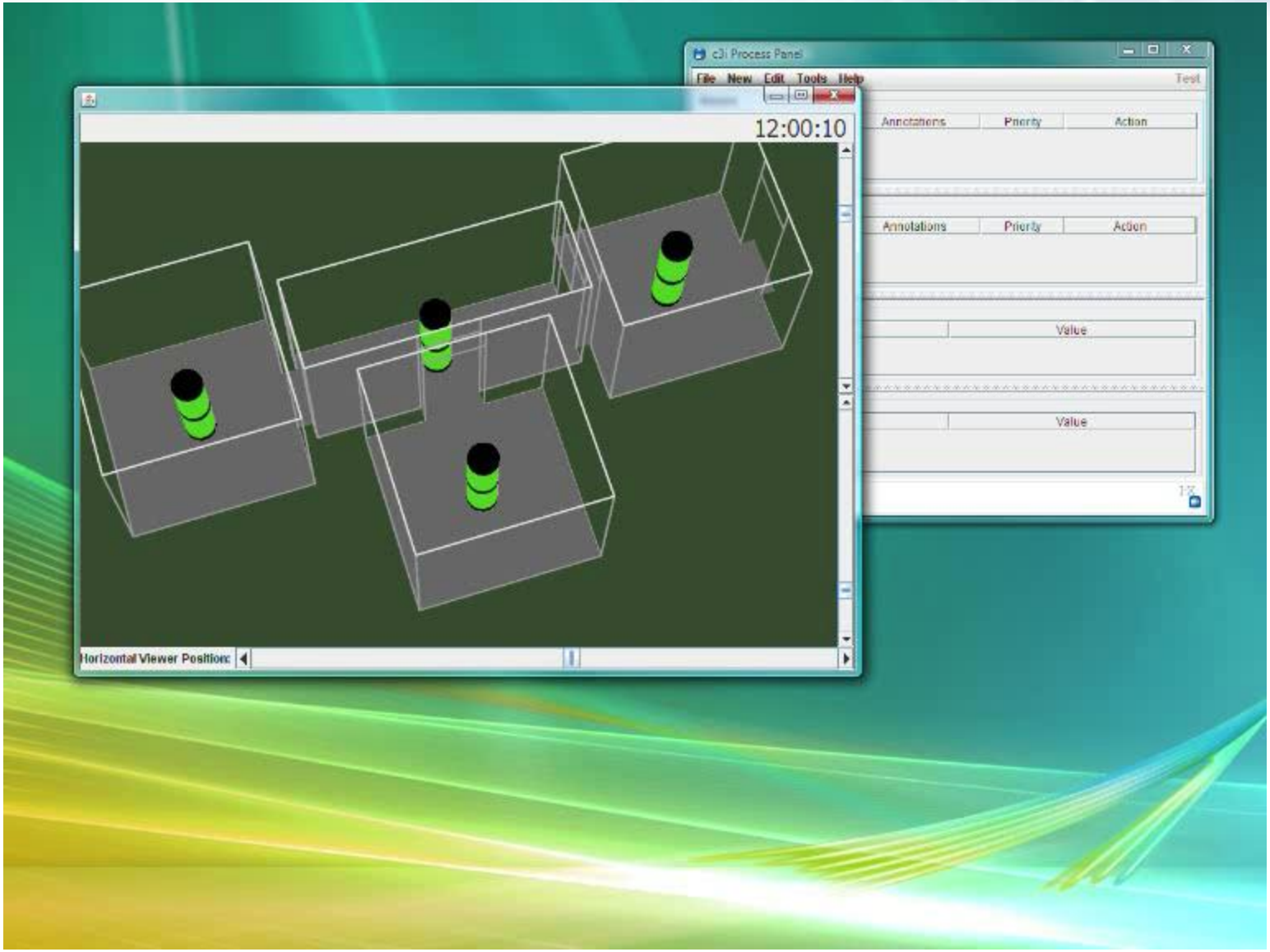


fire simulation: FireGrid project



fire simulation: FireGrid project



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