

Lecture 1 – Introduction

Stanford CS343D (Winter 2026)

Fred Kjolstad

Course staff



Fred Kjolstad



Christophe Gyurgyik

Administria

- Syllabus at <https://cs343d.github.io>
- Discussion will happen through [Ed](#)
- Office Hours
 - Fred: Tuesdays 4-5pm in CODA 456
 - Chris: Friday 10-11am CODA east common area

Goals of the Course

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- Introduce you to domain-specific and collection-oriented programming languages from the past

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- Get you thinking about abstractions and semantics
- “What are the three biggest ideas in computer science? Abstraction, abstraction, abstraction.”
-Paul Hudak

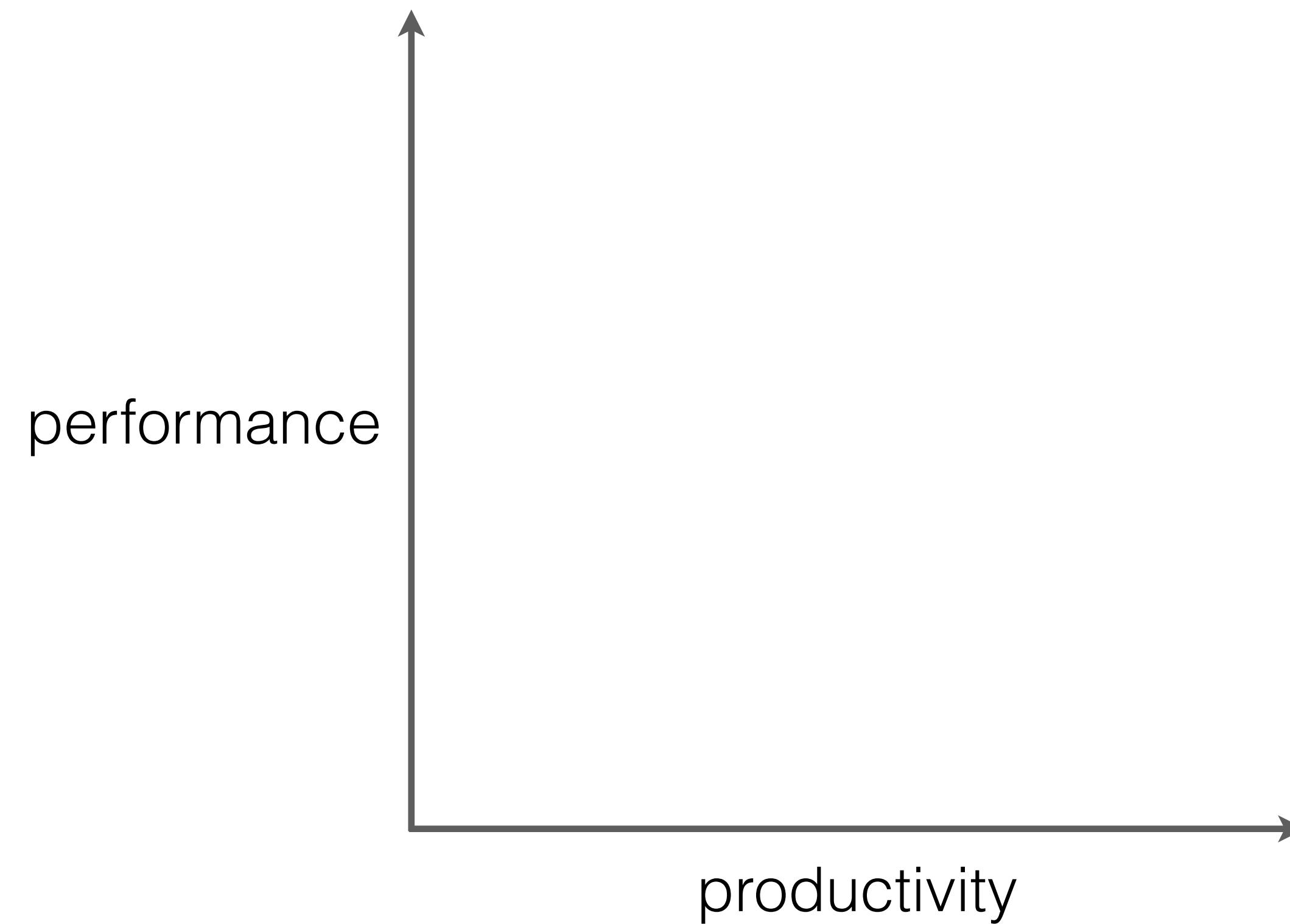
Expectations

- Read papers and engage in class (25%)
 - ~2 readings per class
 - Classes will have a lecture followed by paper discussion
 - Everyone will get a chance to lead a discussion
- Two assignments (20%)
 - MiniAPL
 - Sparse Coiteration Code Generation
- Essay (15%)
- Project (40%)

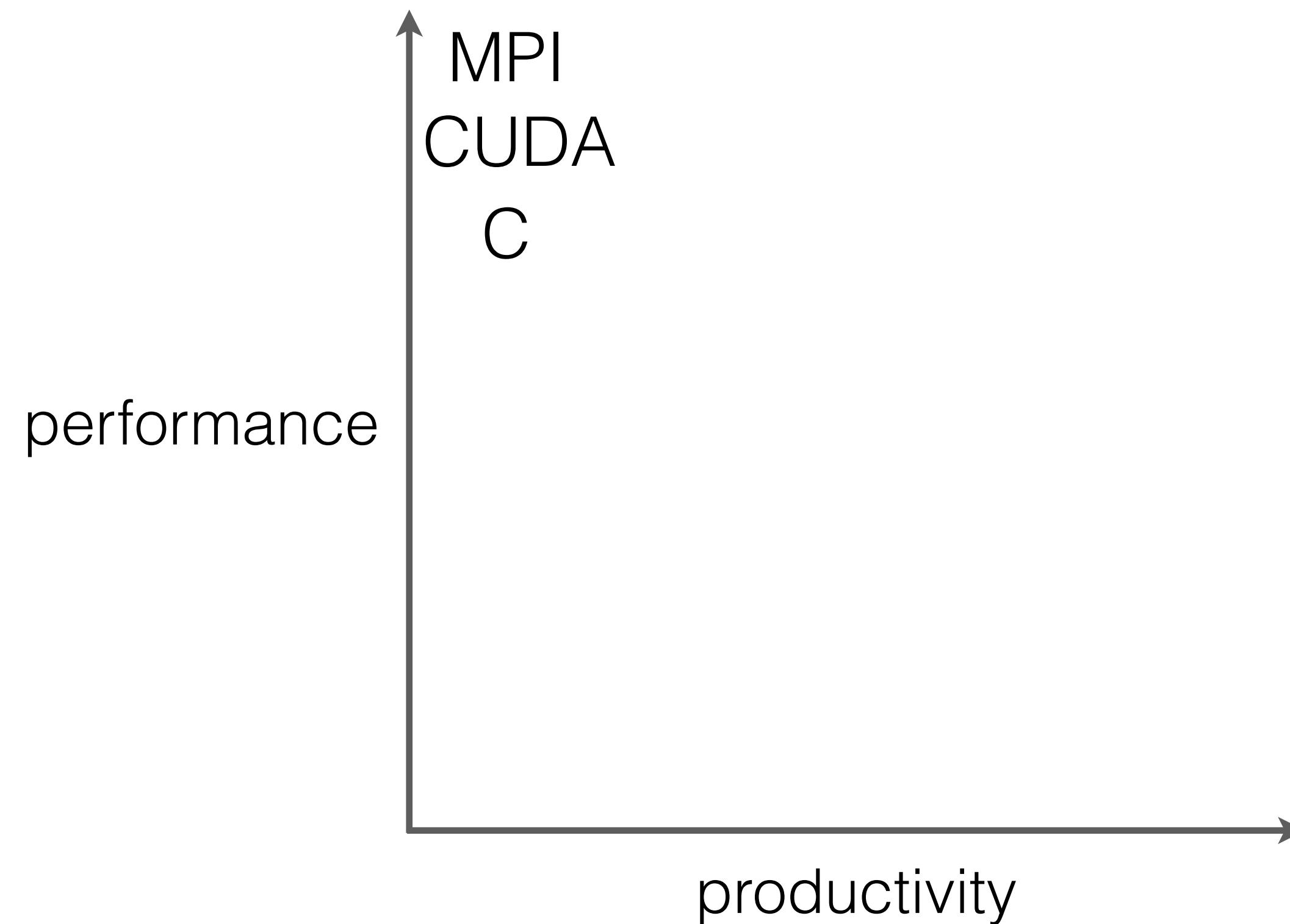
What is the purpose of programming languages?

It is all about productivity, performance, and correctness

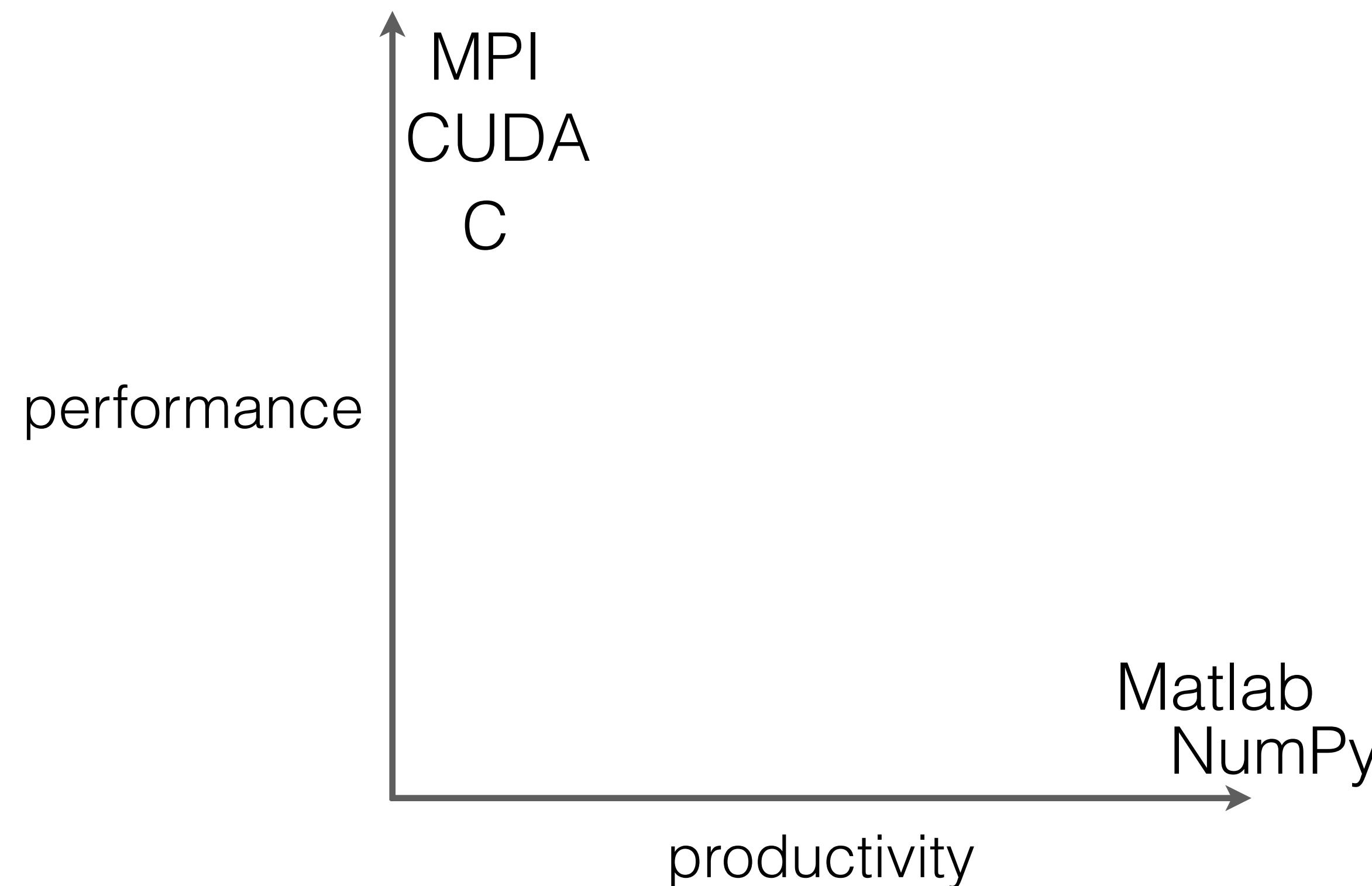
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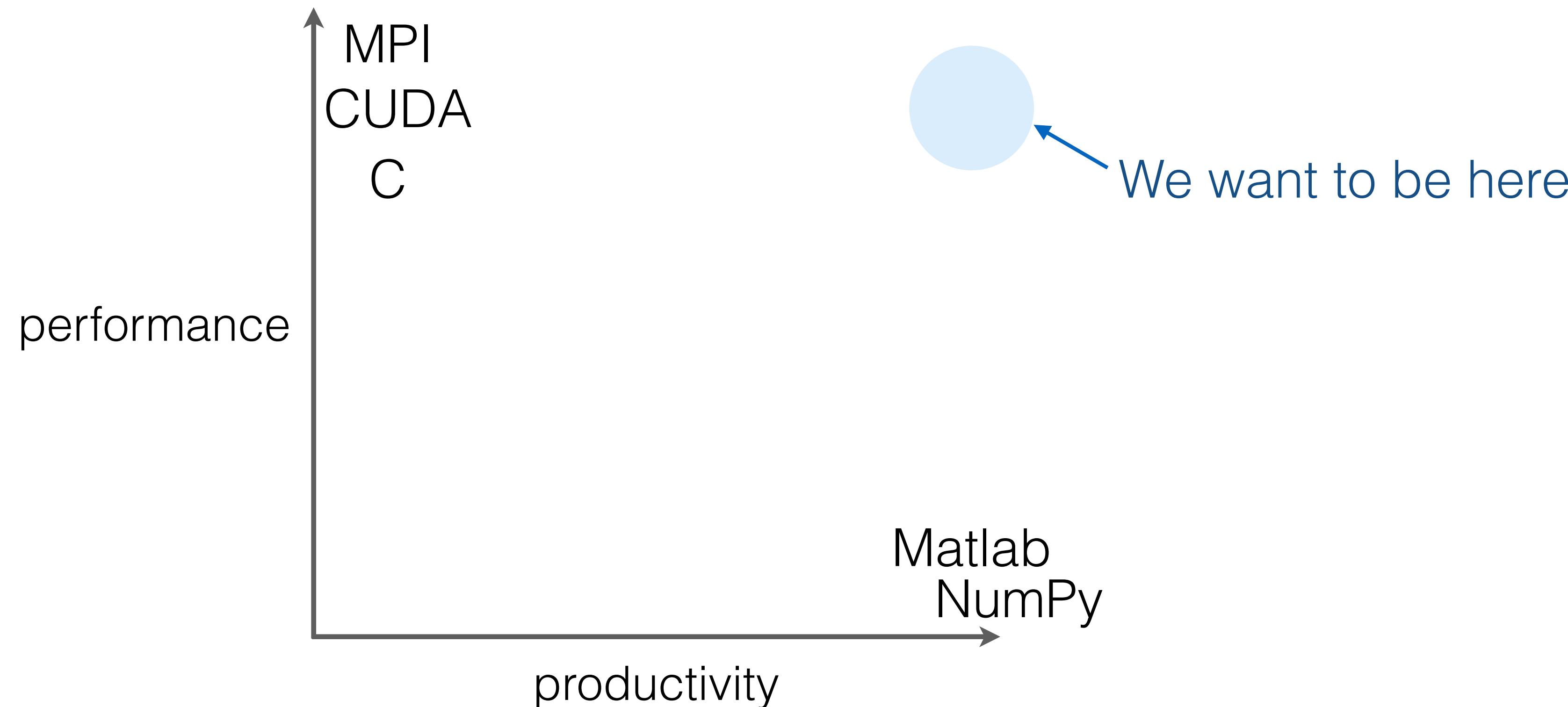
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It is all about productivity, performance, and correctness



Performance translates to less time and less energy

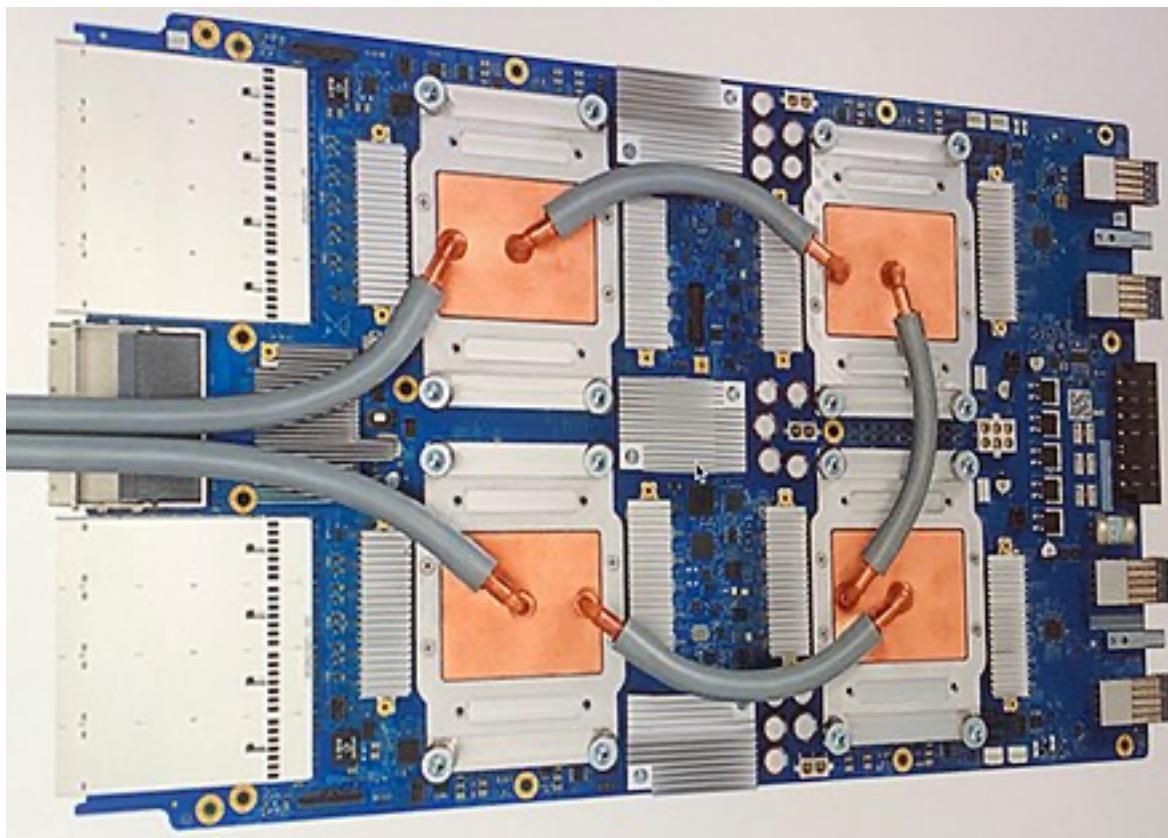


Data centers

Performance translates to less time and less energy



Data centers



Tensor Processing Unit

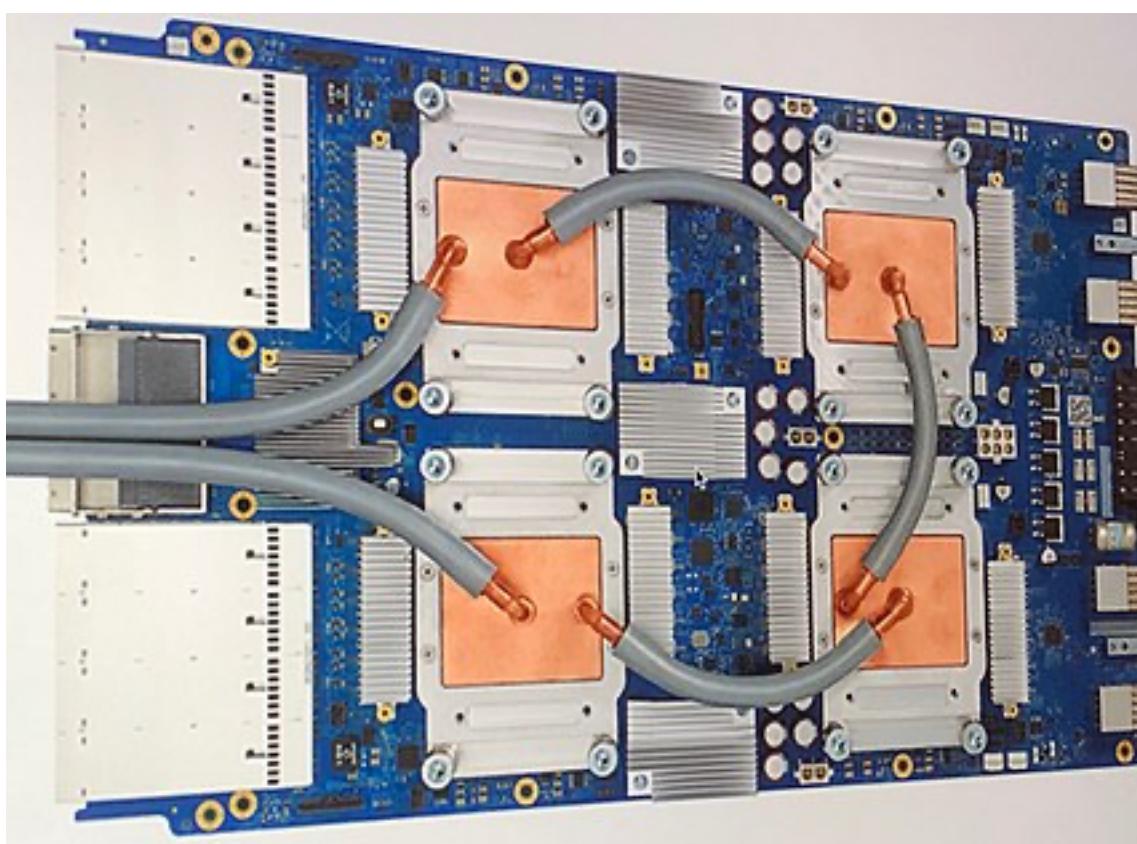
Performance translates to less time and less energy



Data centers



Supercomputers



Tensor Processing Unit

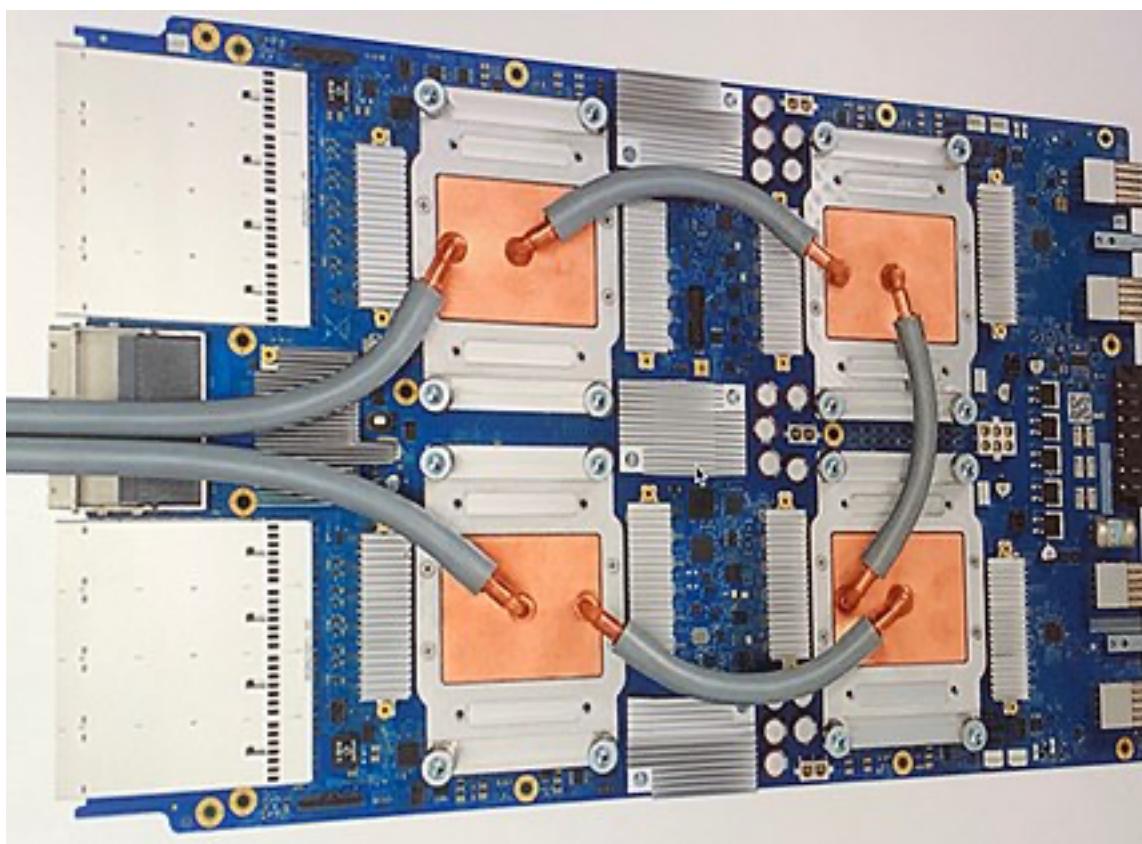
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Data centers



Supercomputers



Tensor Processing Unit



Self-driving cars

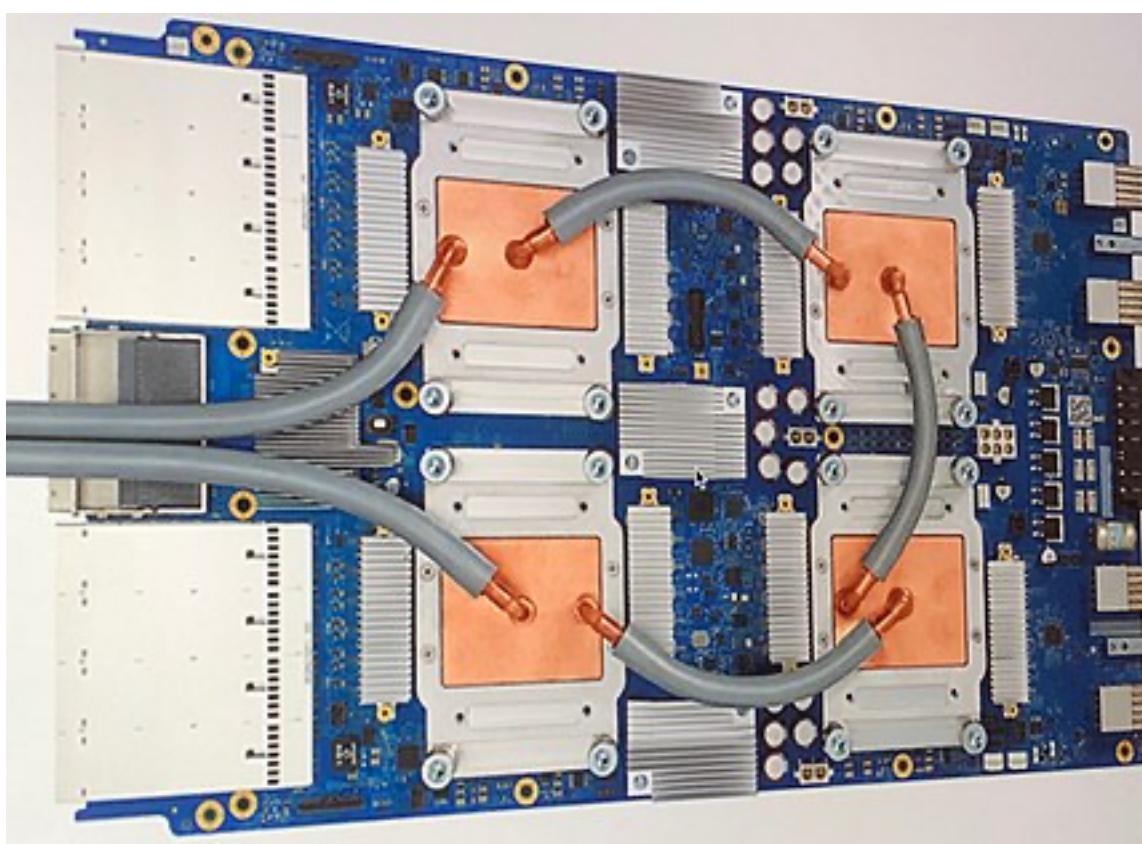
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Supercomputers



Tensor Processing Unit



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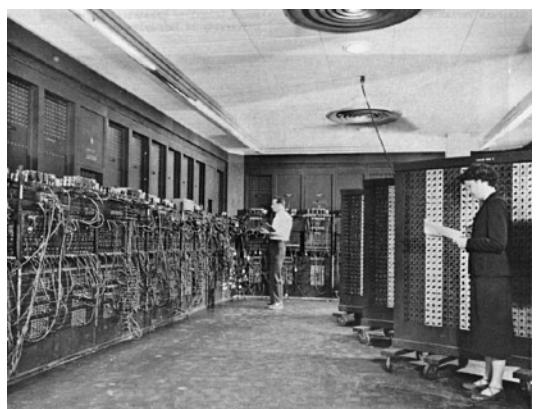


Cell-phone batteries

Eras of Computing

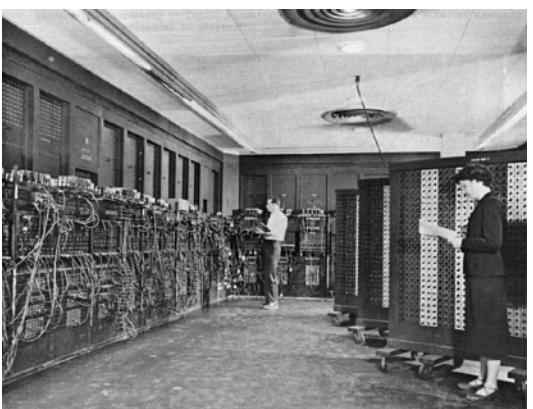
Simulation

(1945–1965)

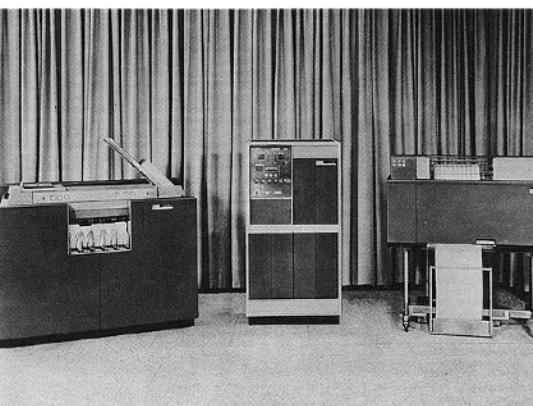


Eras of Computing

Simulation (1945–1965)

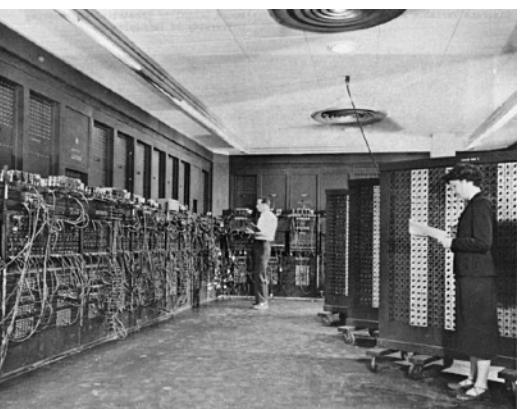


Data processing (1965–1984)

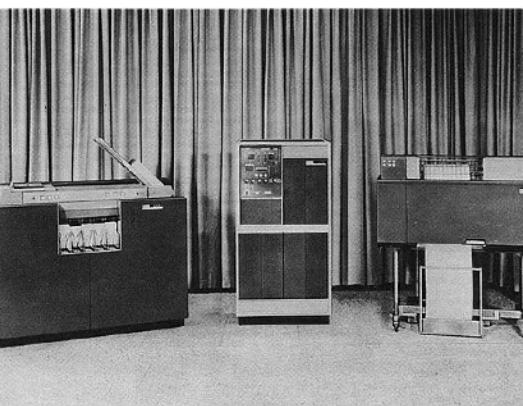


Eras of Computing

Simulation (1945–1965)



Data processing (1965–1984)



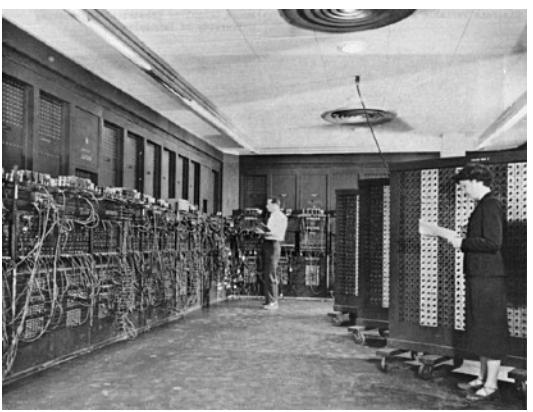
Personal Computing (1984–1995)



Eras of Computing

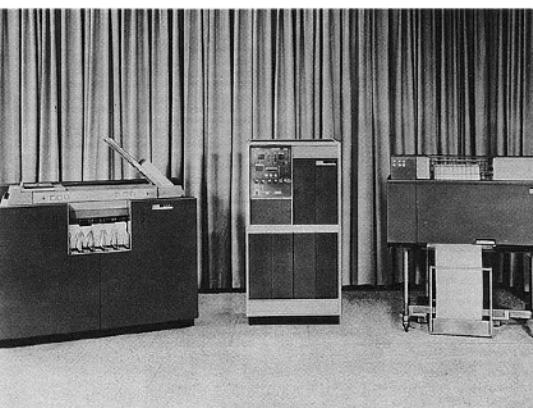
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Data processing

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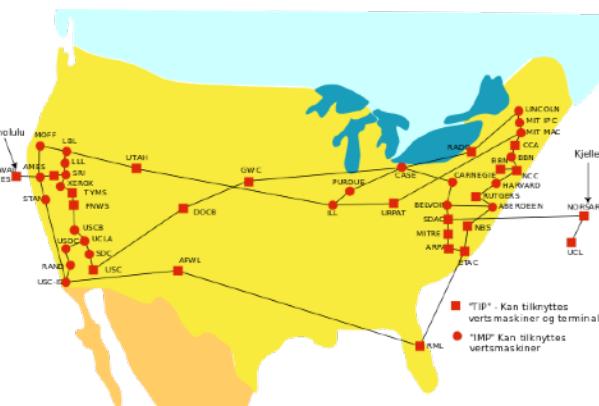
Personal Computing

(1984–1995)



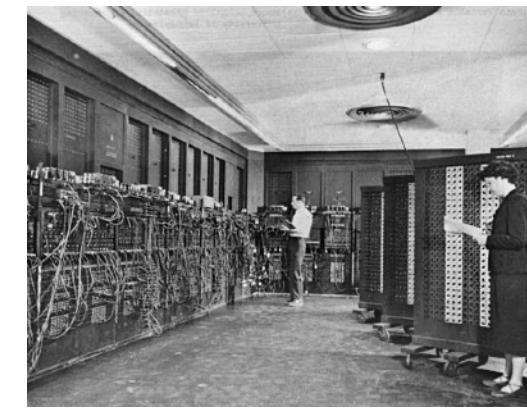
Communication

(1995–2020)

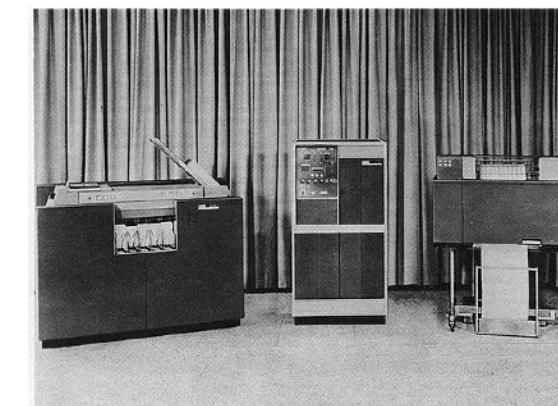


Eras of Computing

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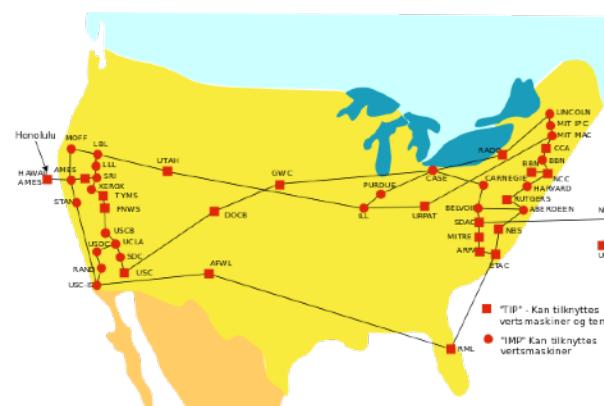
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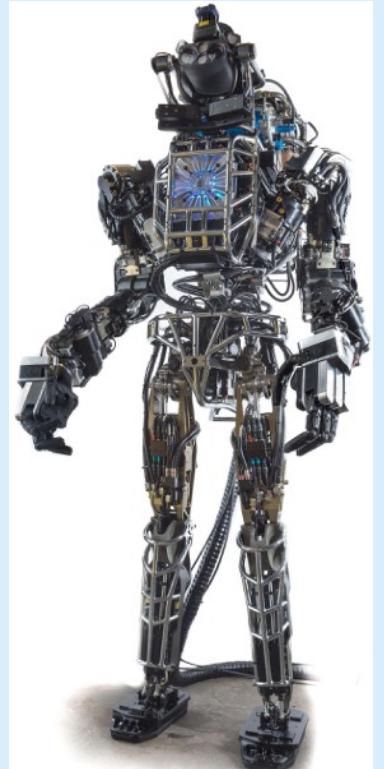


Interaction and AI

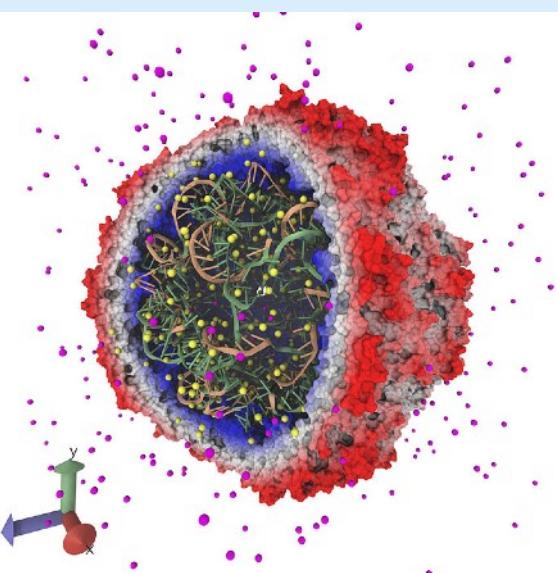


Modern applications are performance hungry

Simulation and Optimization



Graphics Simulations

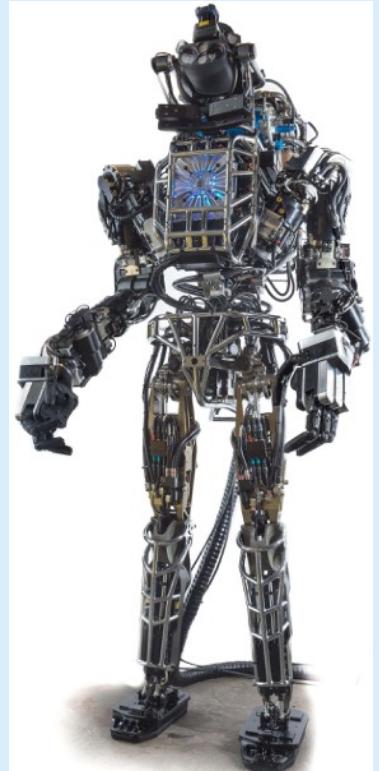


Virus Modelling

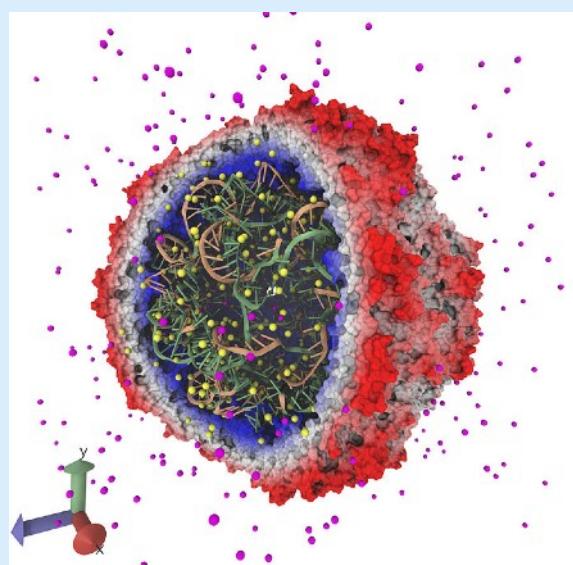
Robotics

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Graphics Simulations



Robotics

Virus Modelling

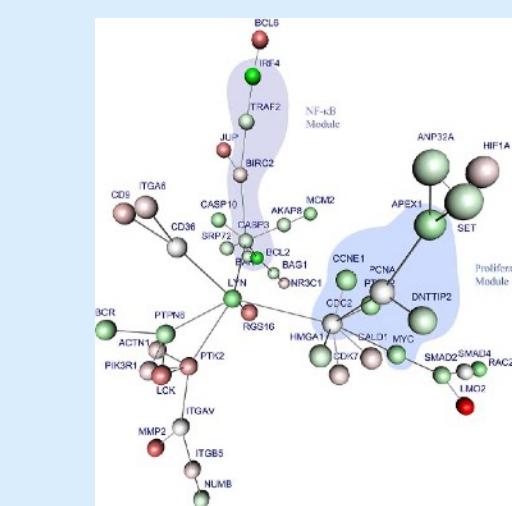
Data Analytics



Social Networks

Kristina	★★★★★	Great Product
	March 30, 2017	Color: White Verified Purchase
		Great product. Large enough for all spoons and fits nicely on my stovetop. Would definitely buy it again.
Teresa	★★★★★	Excellent buy
	October 25, 2017	Verified Purchase
		This is a great product for your boy who loves sports! It was a good value as well. Other stores sell for 3x the cost. I bought one for a basketball and football and my 9 year old loves it in his room. Solid item too, not flimsy. Will hold items nicely.
Lisa	★★★★★	I was really disappointed. The spoon holder it self was great and ...
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		This product came with a manufacturer's chips in it. It is not the sellers fault but I do not know how many in this batch this seller may have. I was really disappointed. The spoon holder it self was great and larger than I expected.
Sarah	★★★★★	Malfunctioned within a month. Waste of \$.
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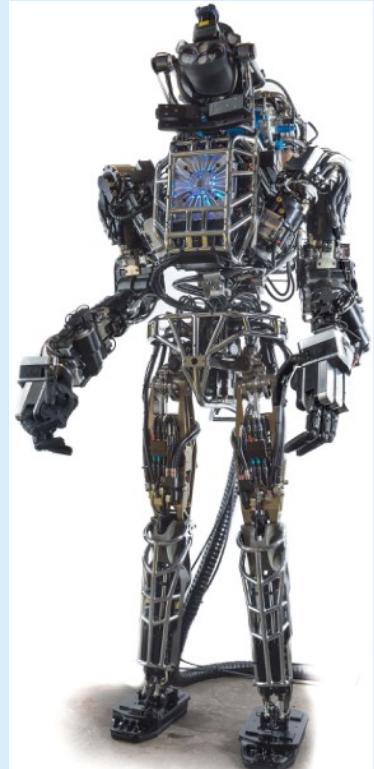
Recommender Systems



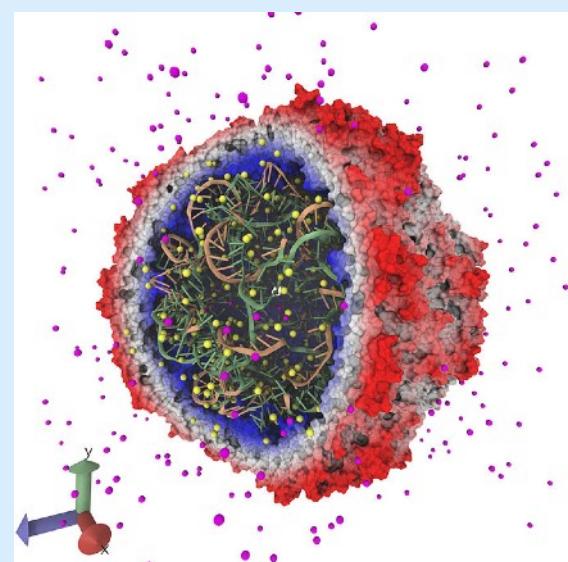
Computational Biology

Modern applications are performance hungry

Simulation and Optimization



Graphics Simulations



Robotics

Virus Modelling

Data Analytics

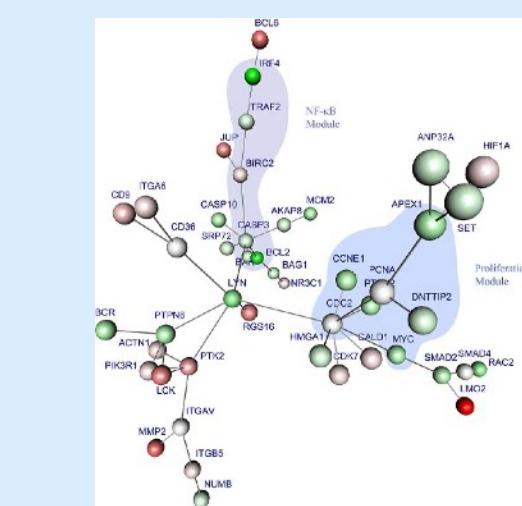


Social Networks

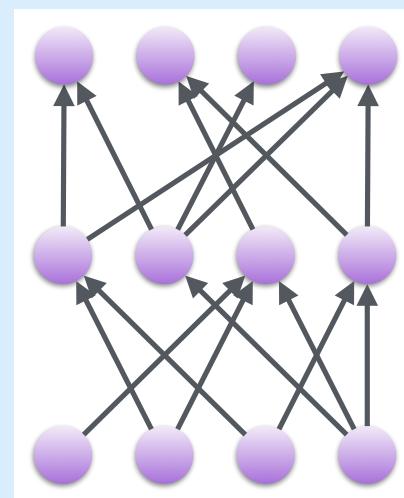
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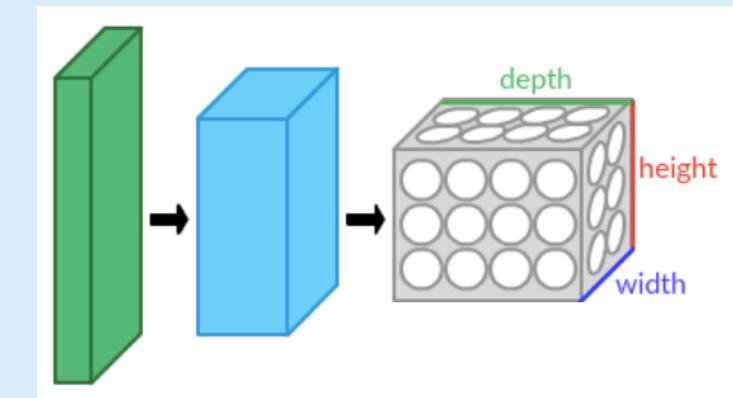
Computational Biology



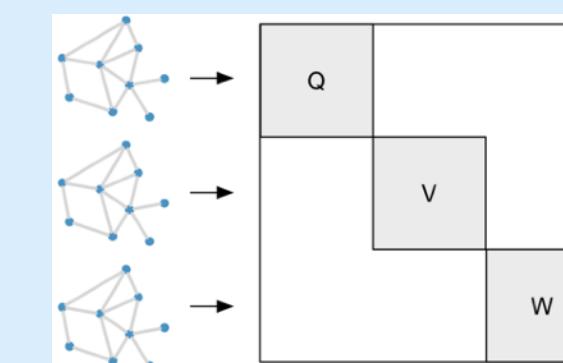
Machine Learning



Neural Networks



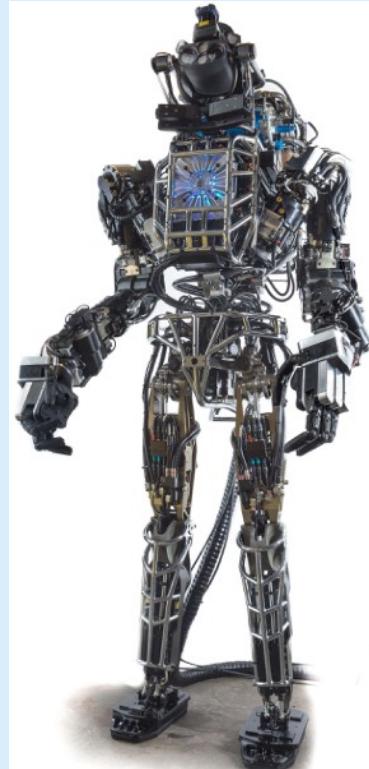
Convolutional Networks



Graph Convolutional Network

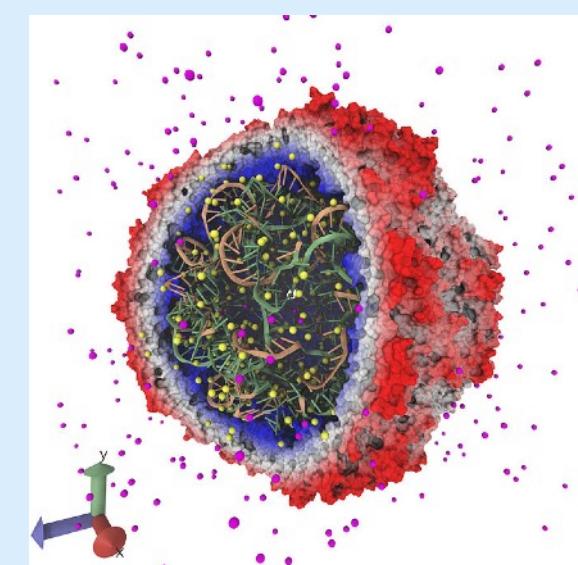
Modern applications are performance hungry

Simulation and Optimization



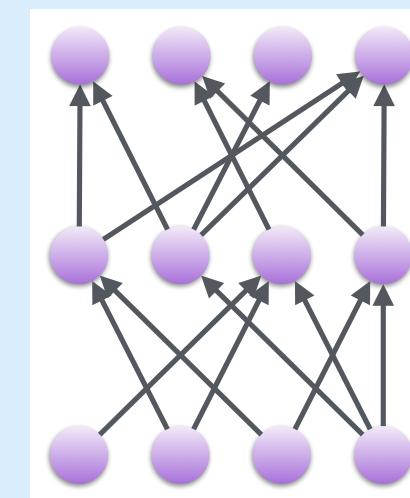
Graphics Simulations

Robotics

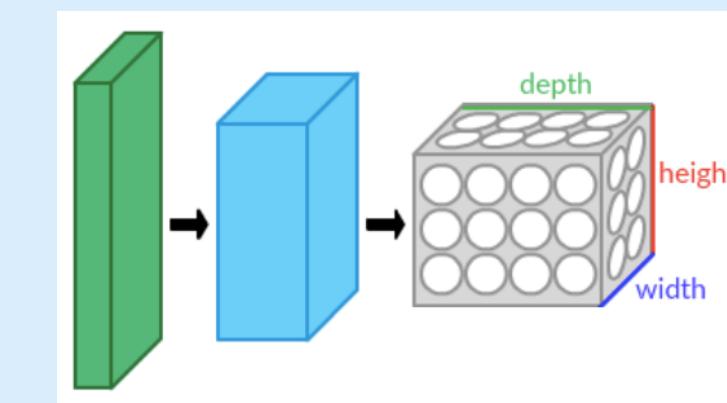


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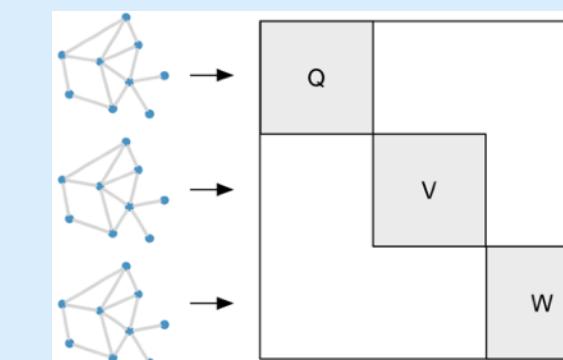
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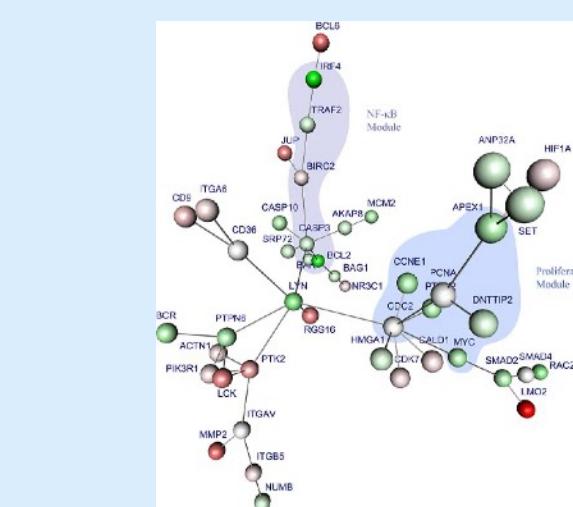
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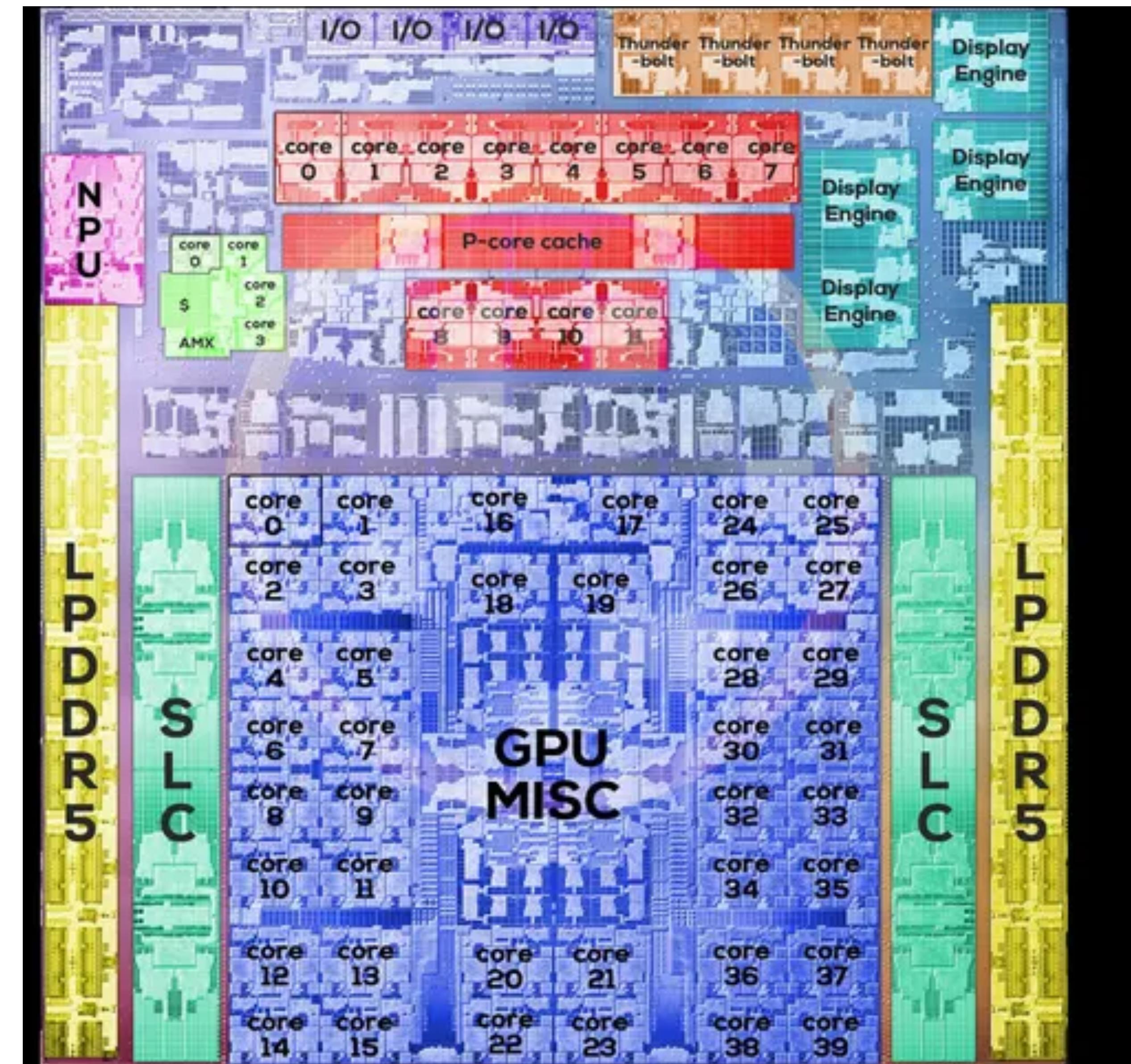
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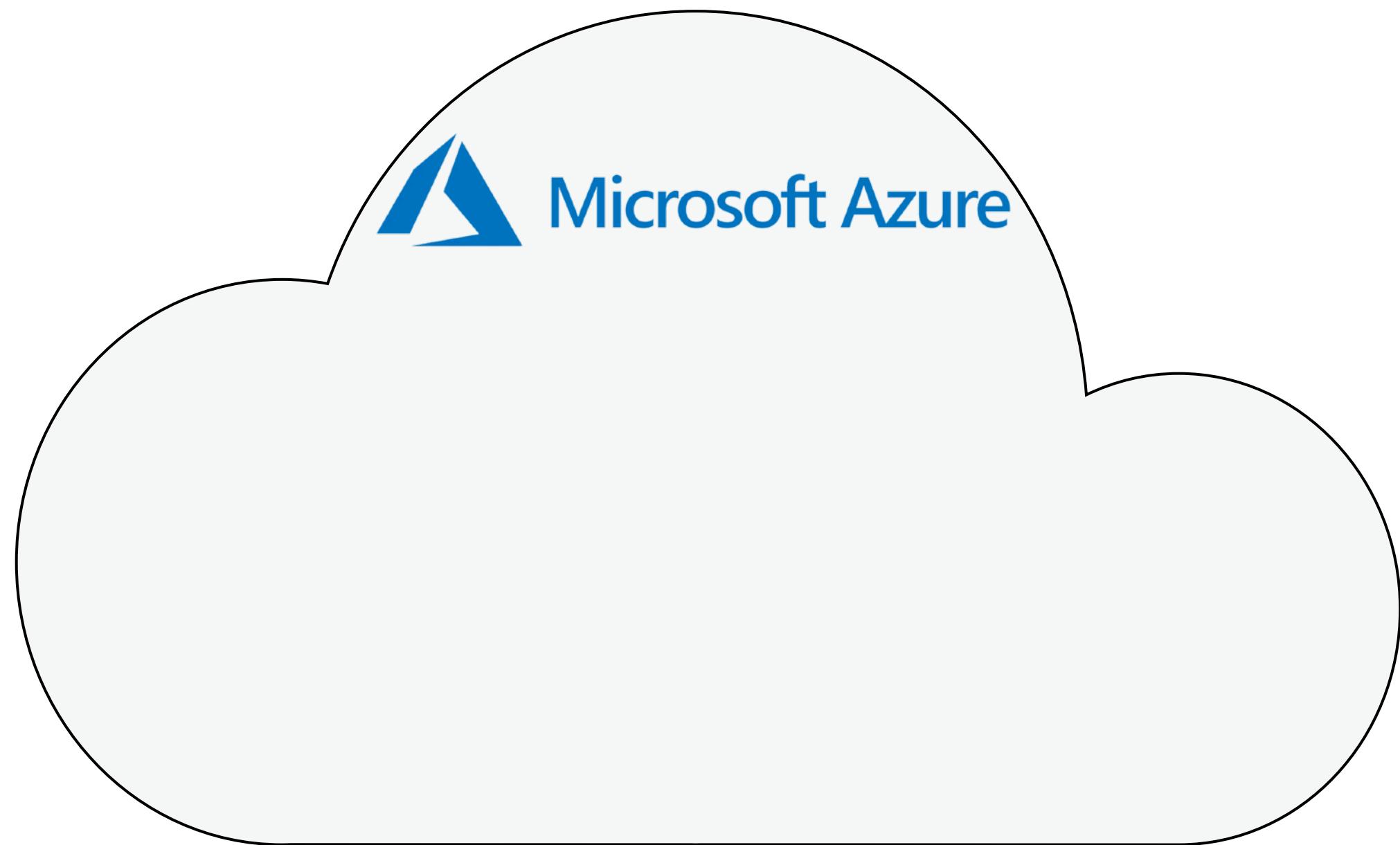
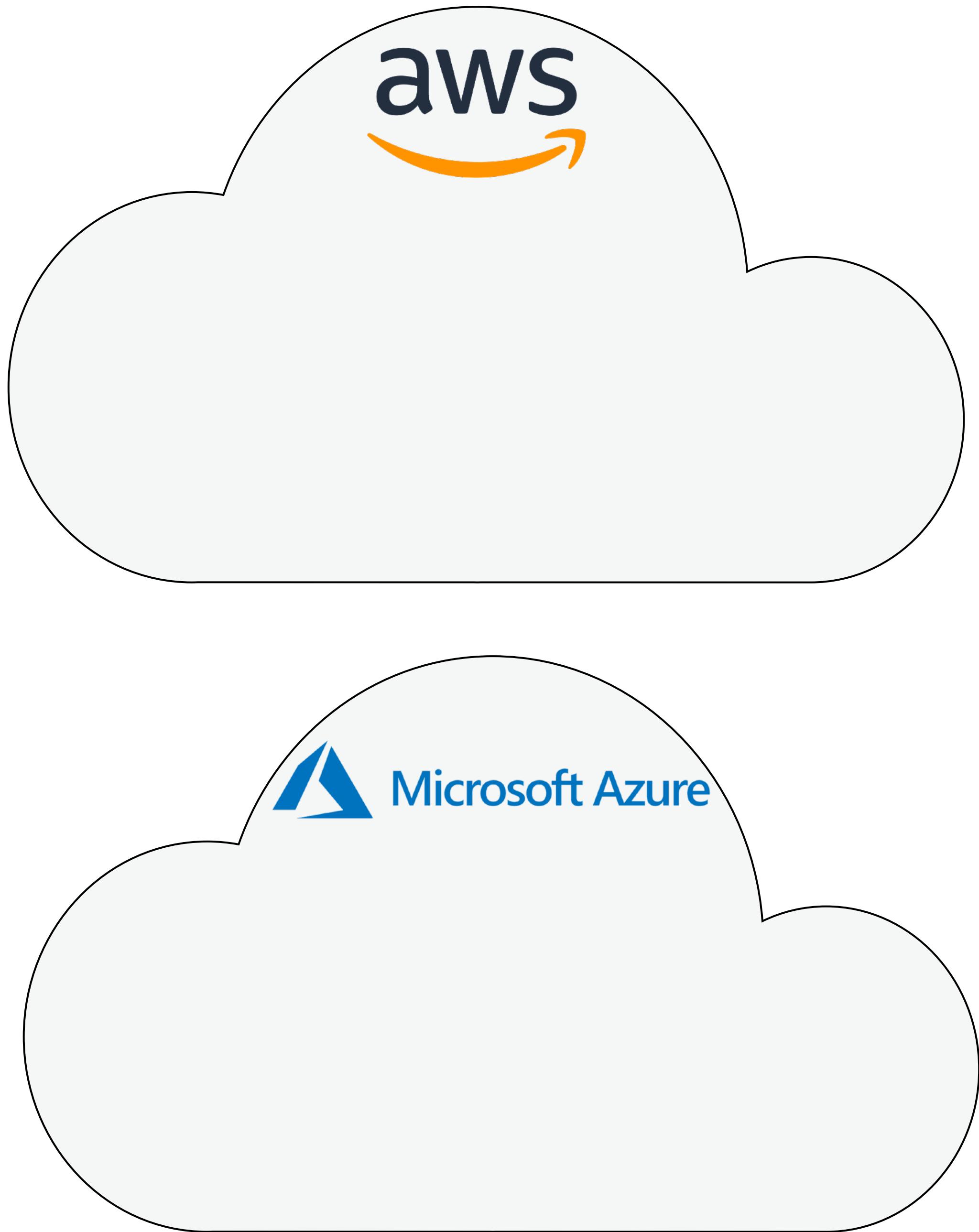
Computational Biology

Modern hardware is heterogeneous and programming it is hard

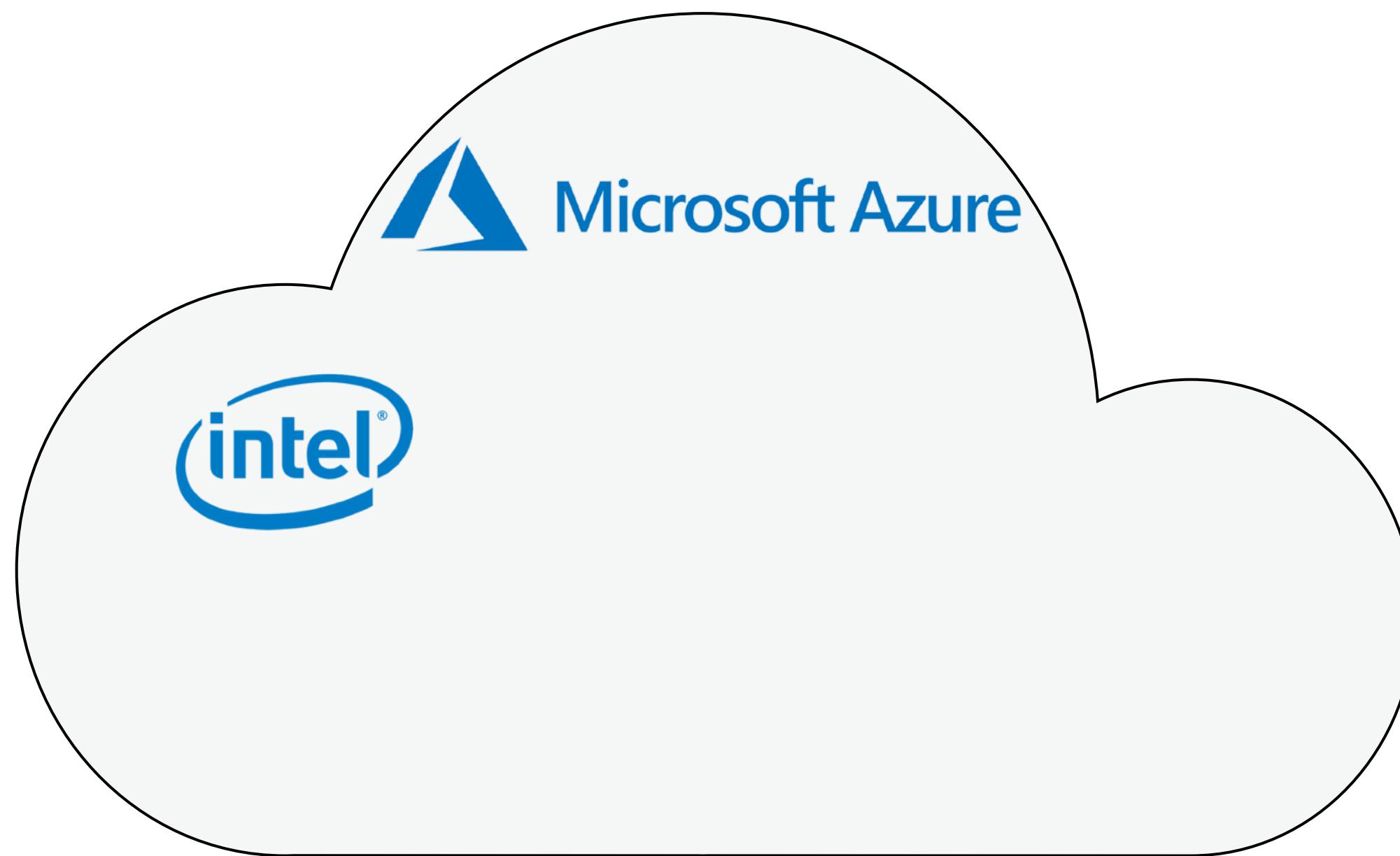
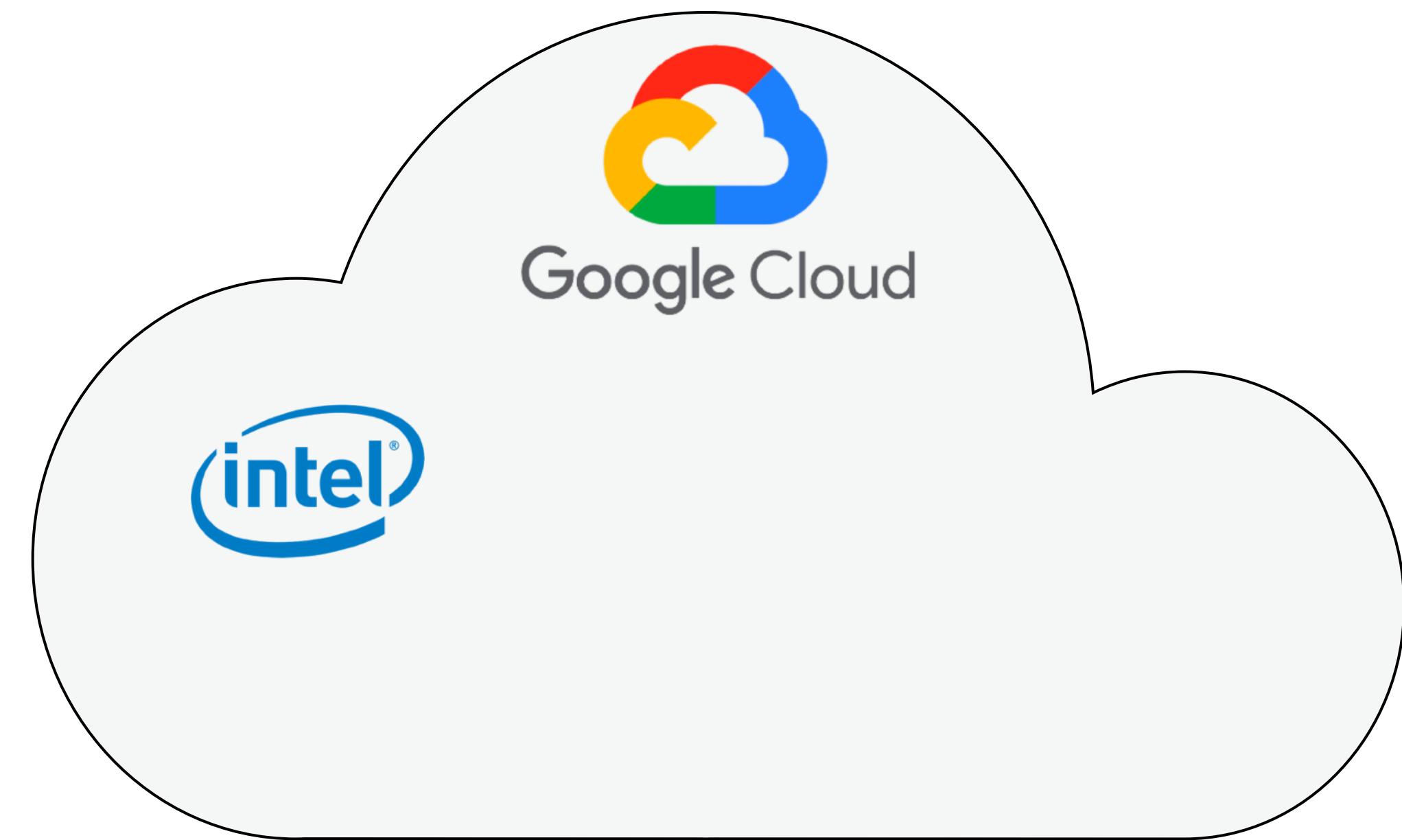
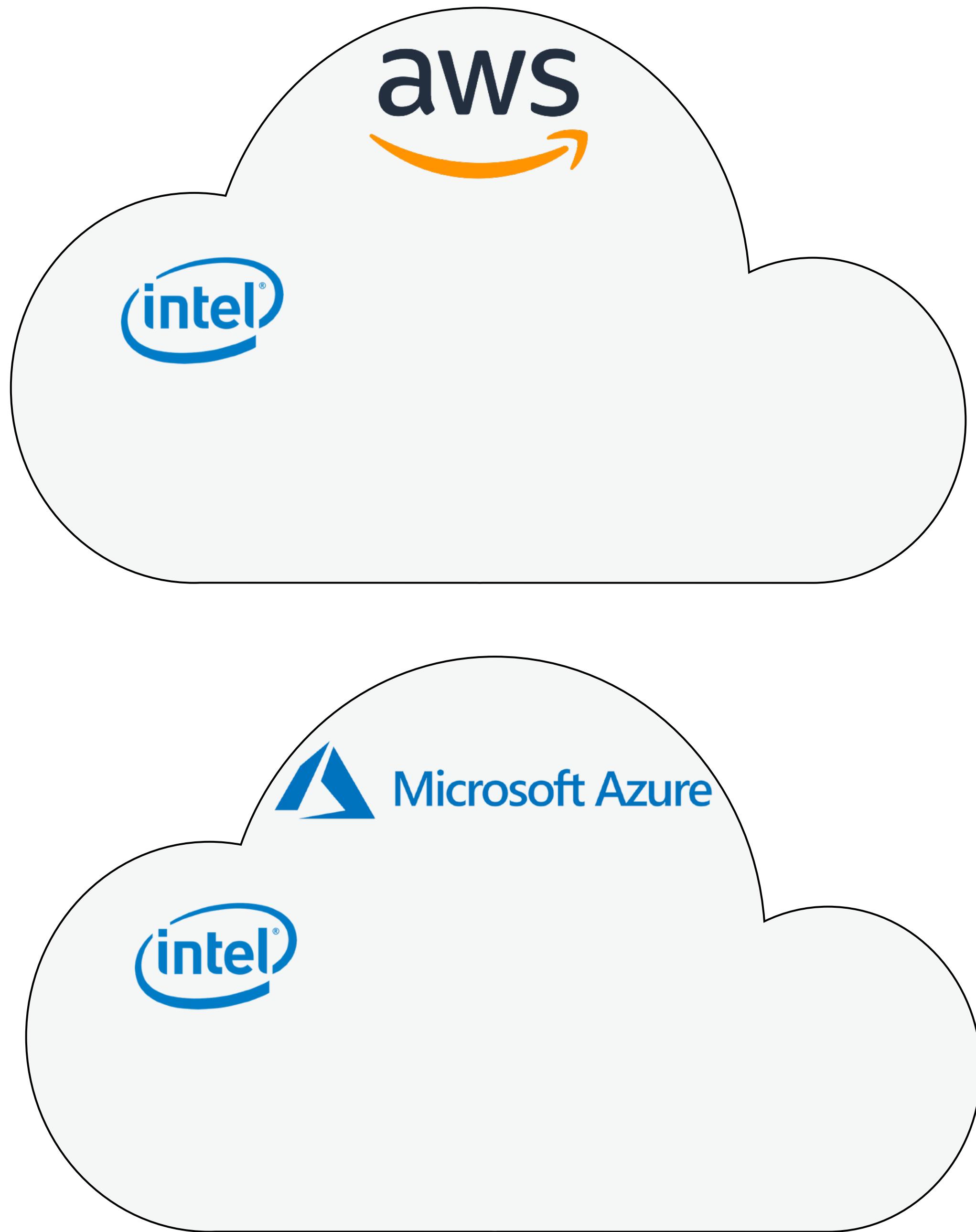
Apple M3 Chip



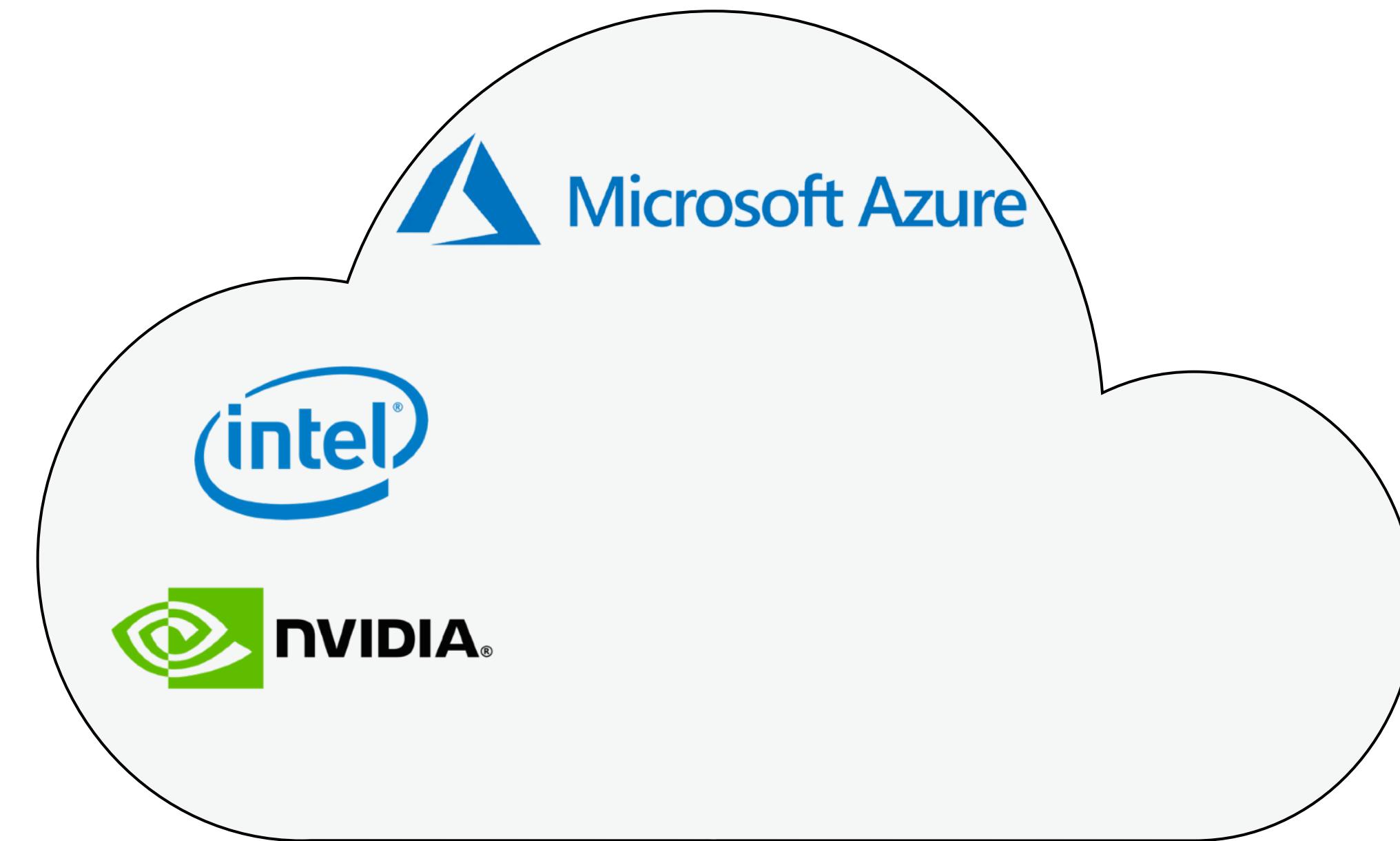
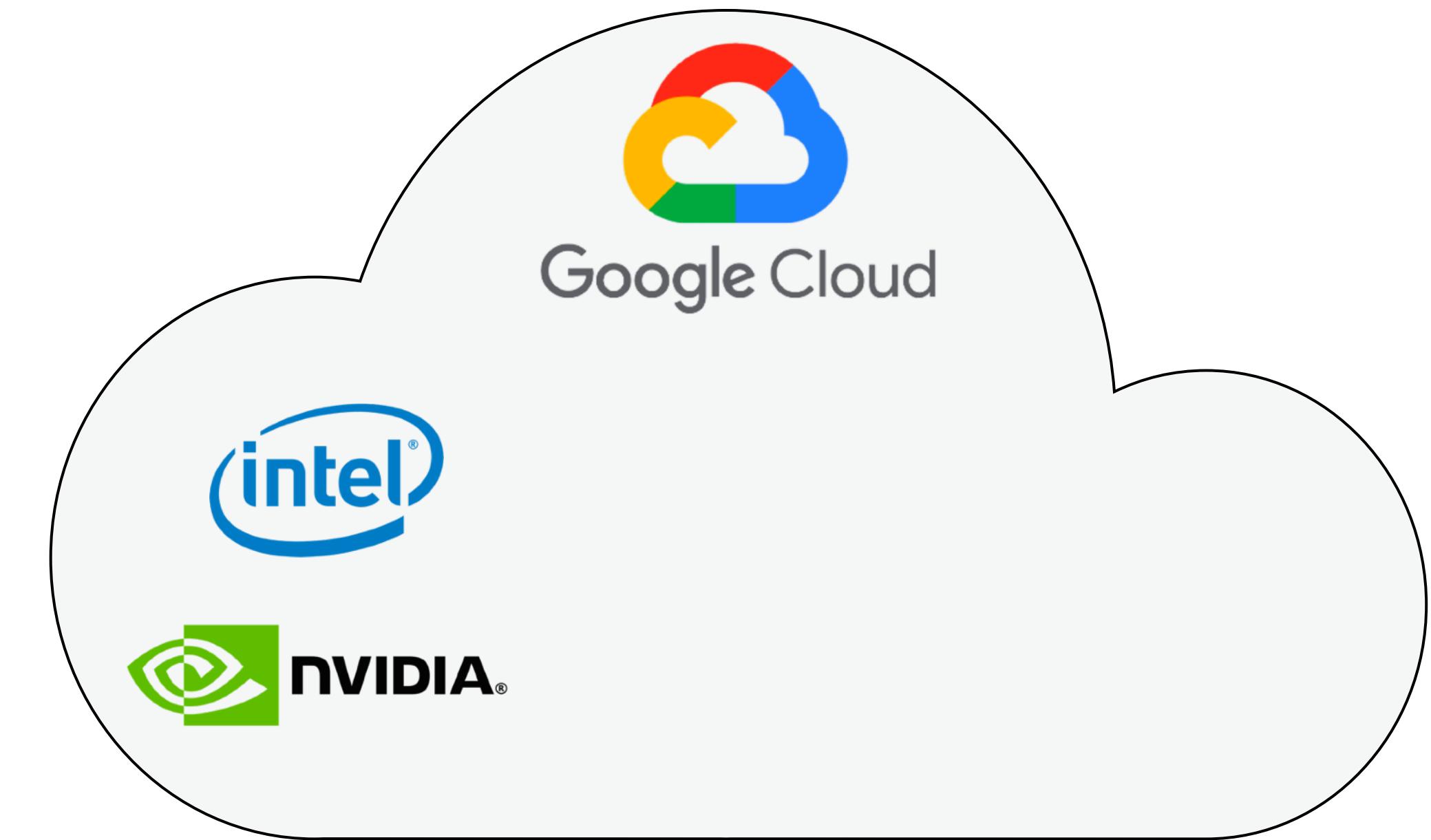
Hardware in the Clouds



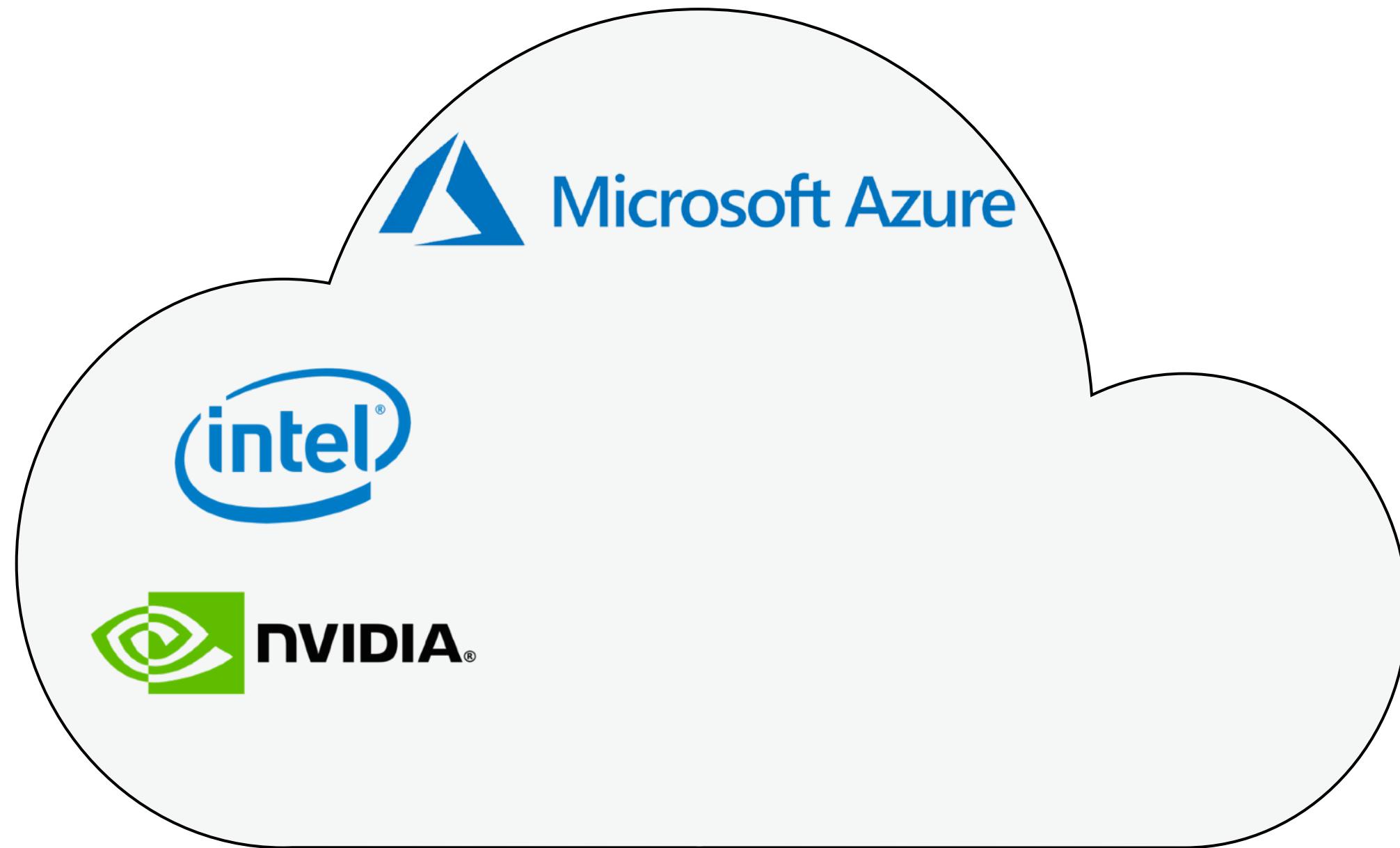
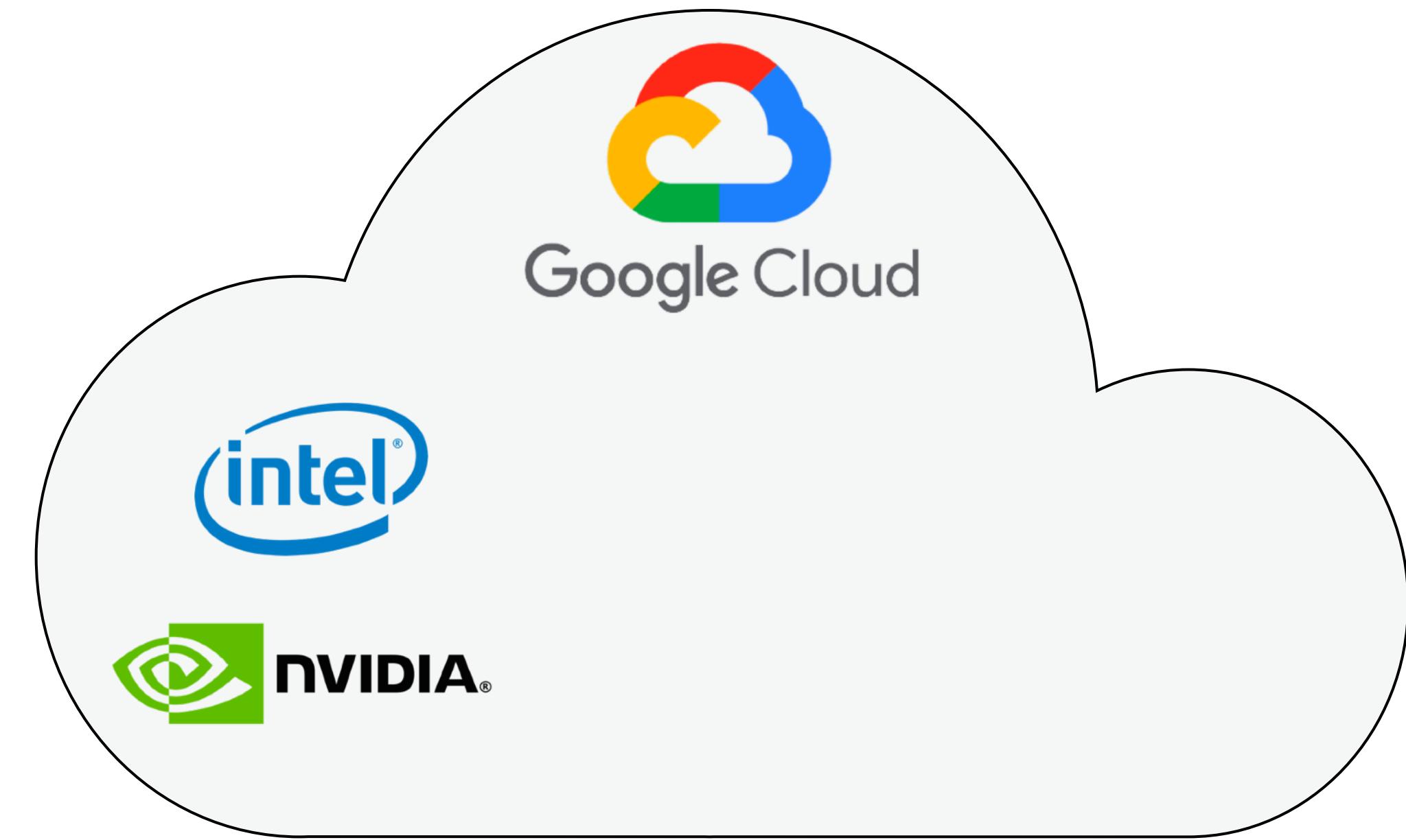
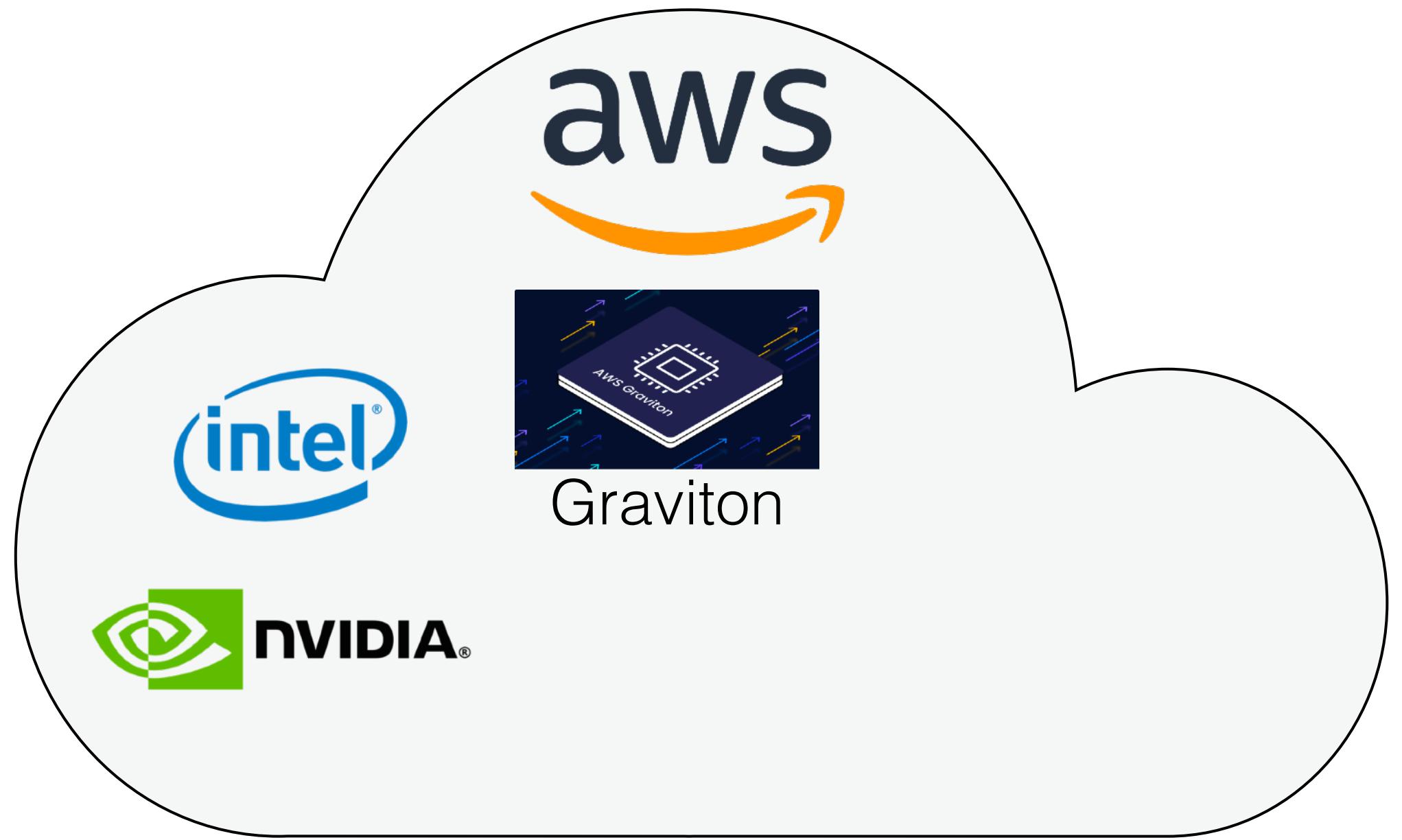
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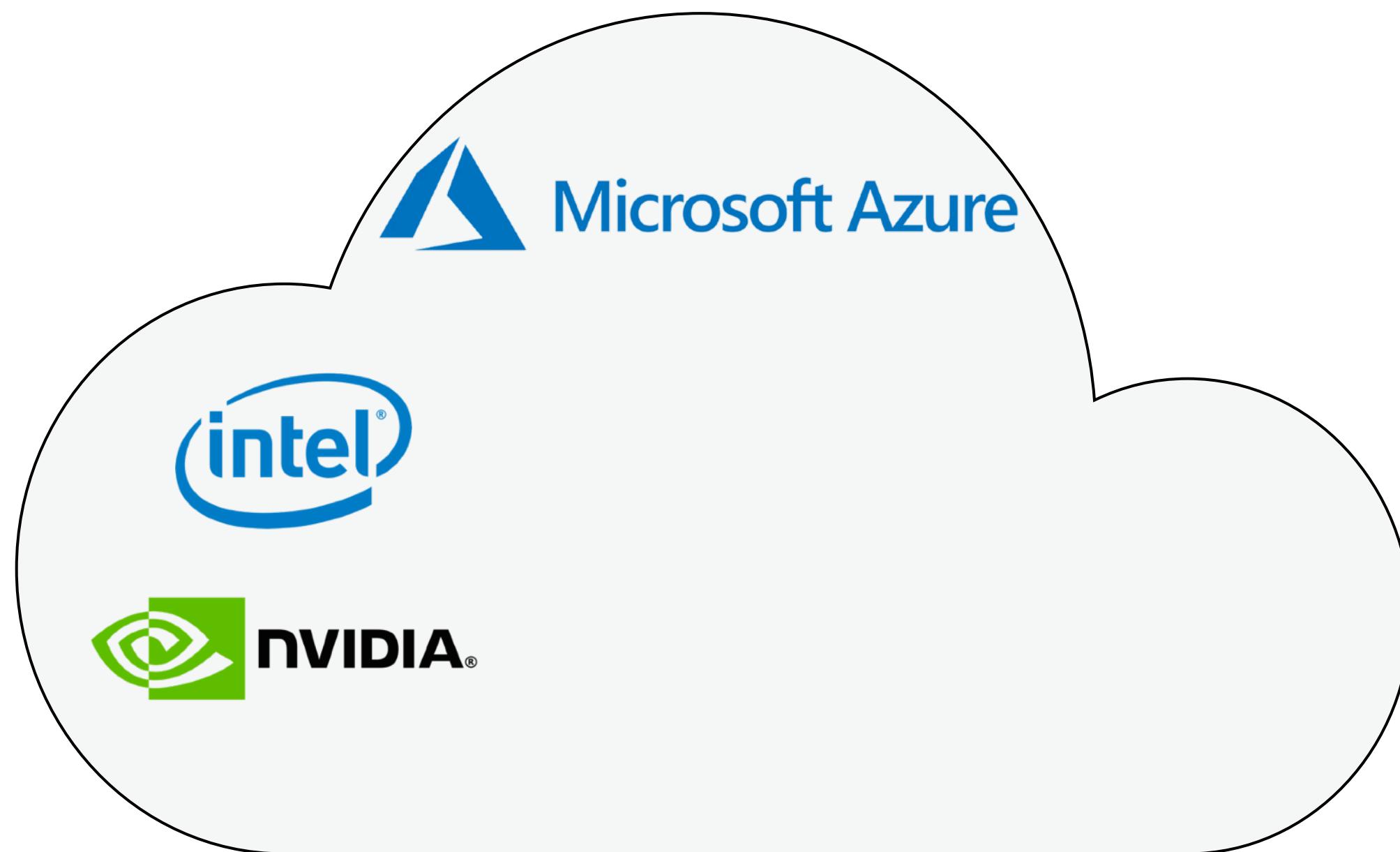
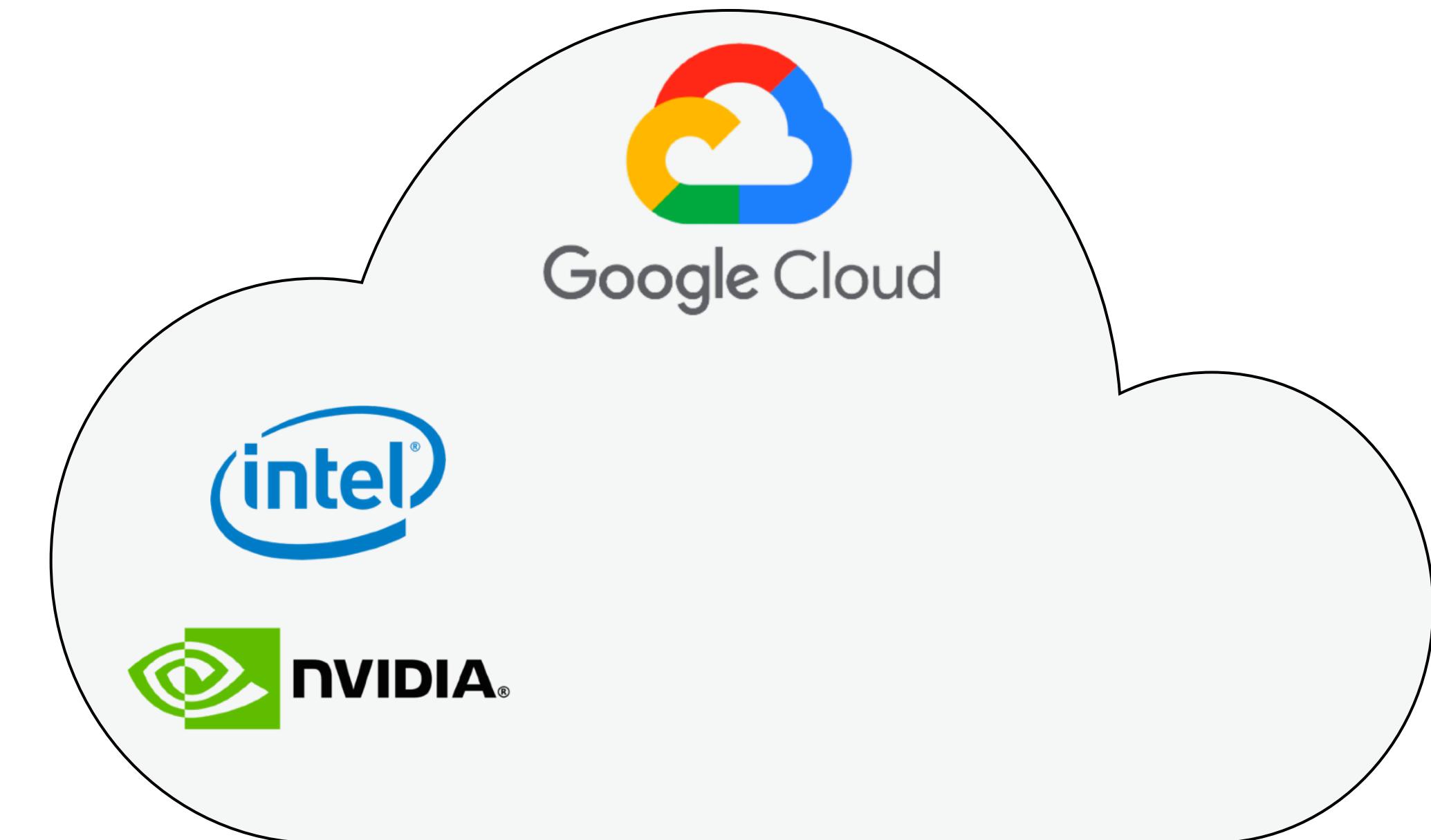
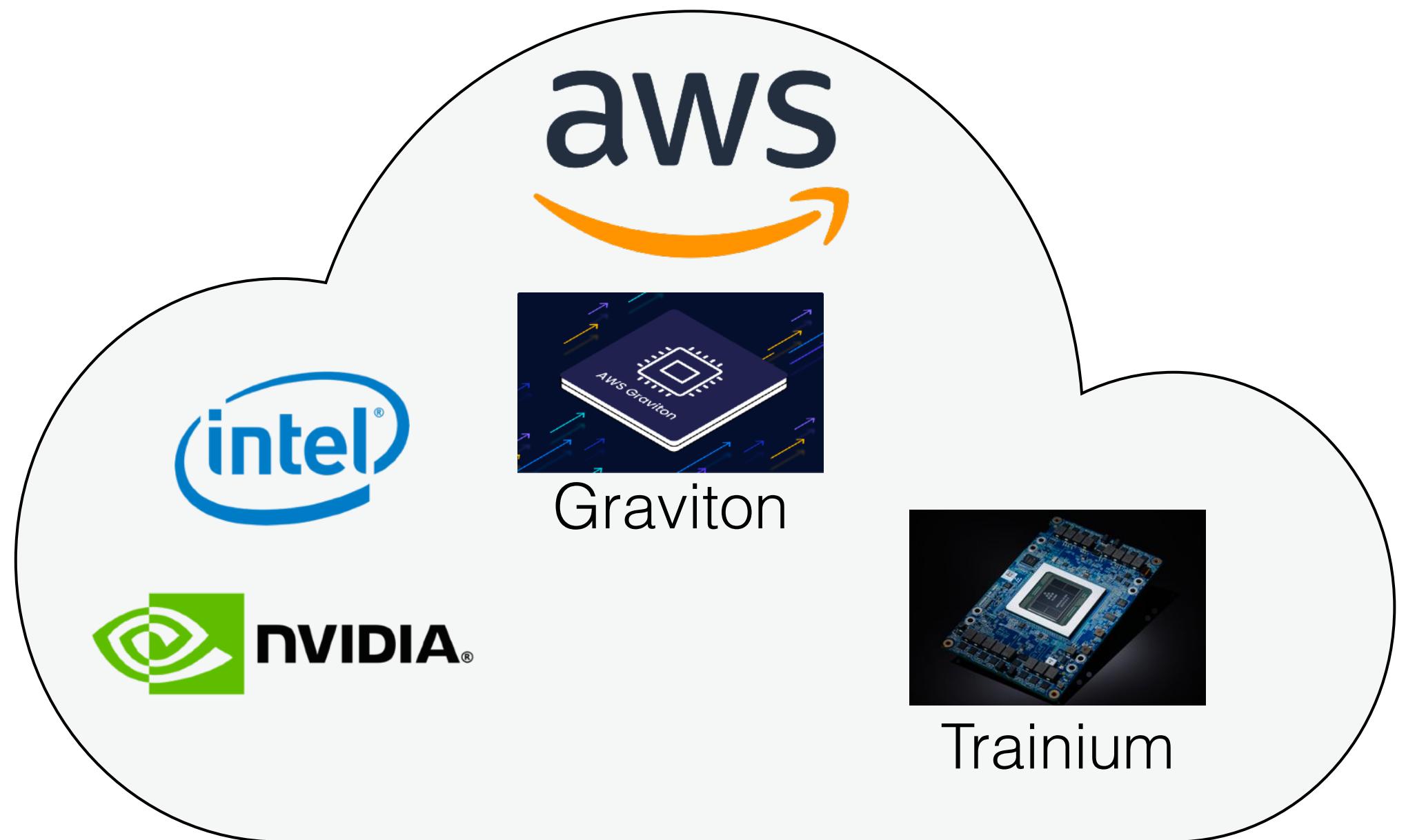
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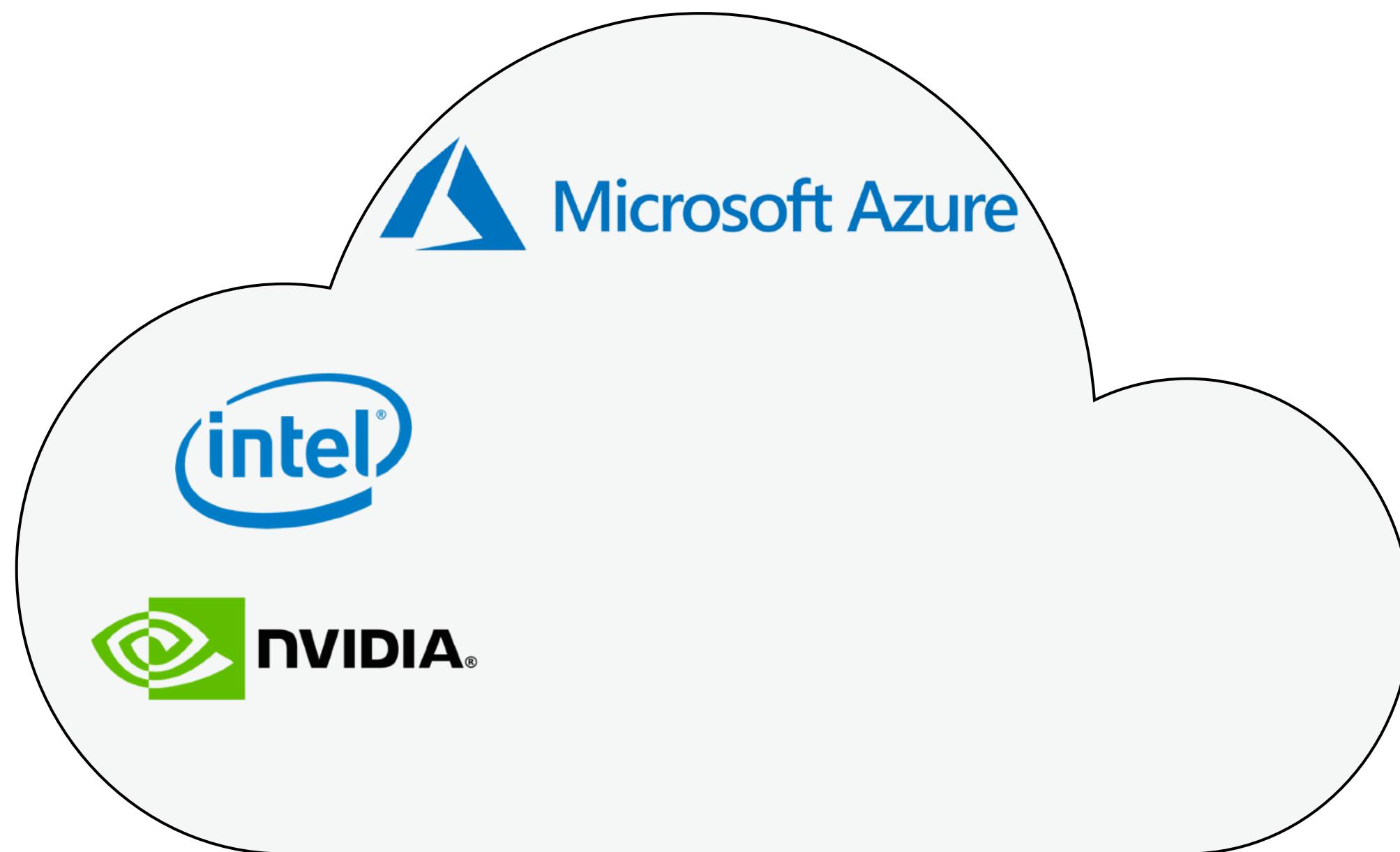
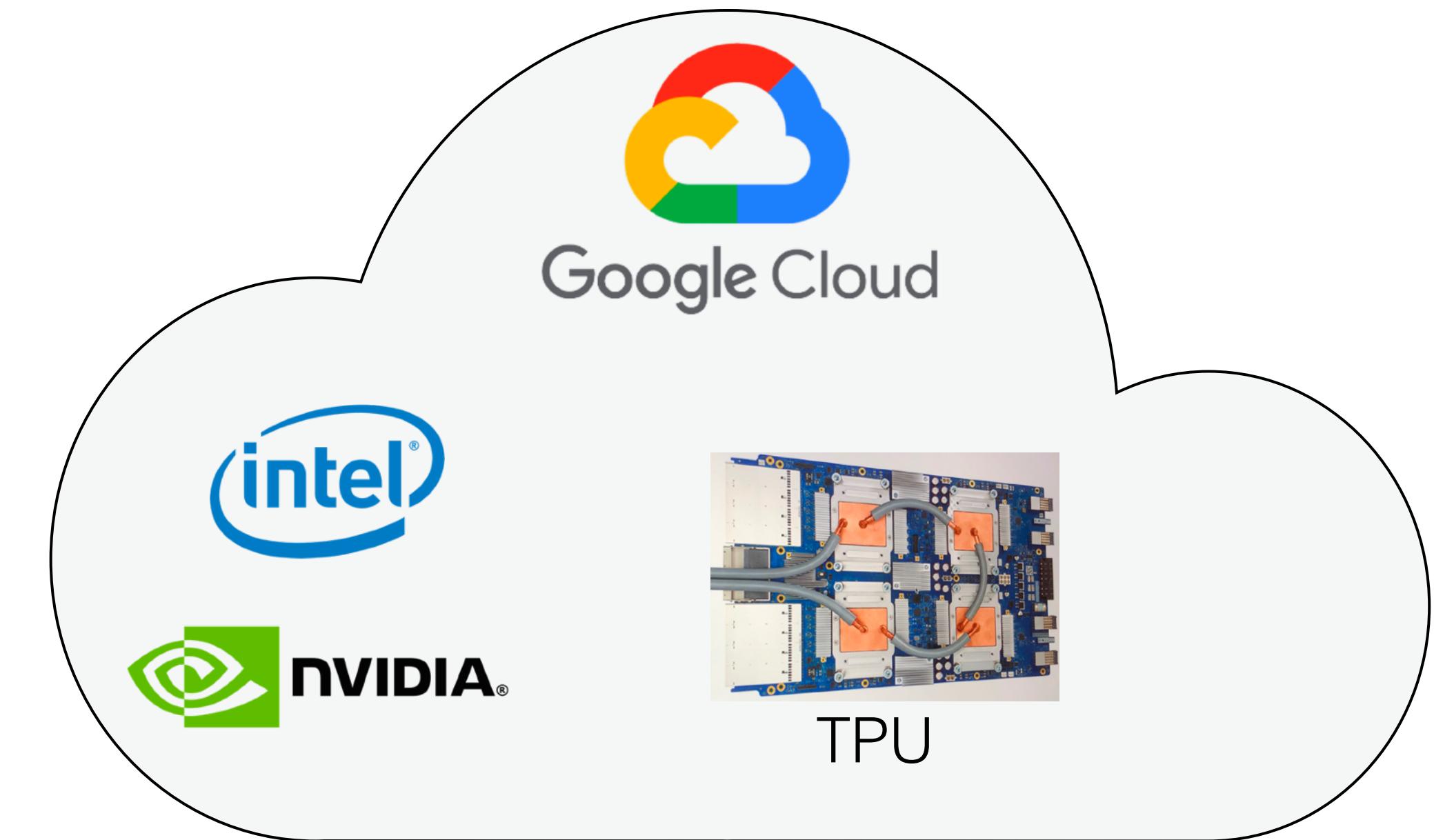
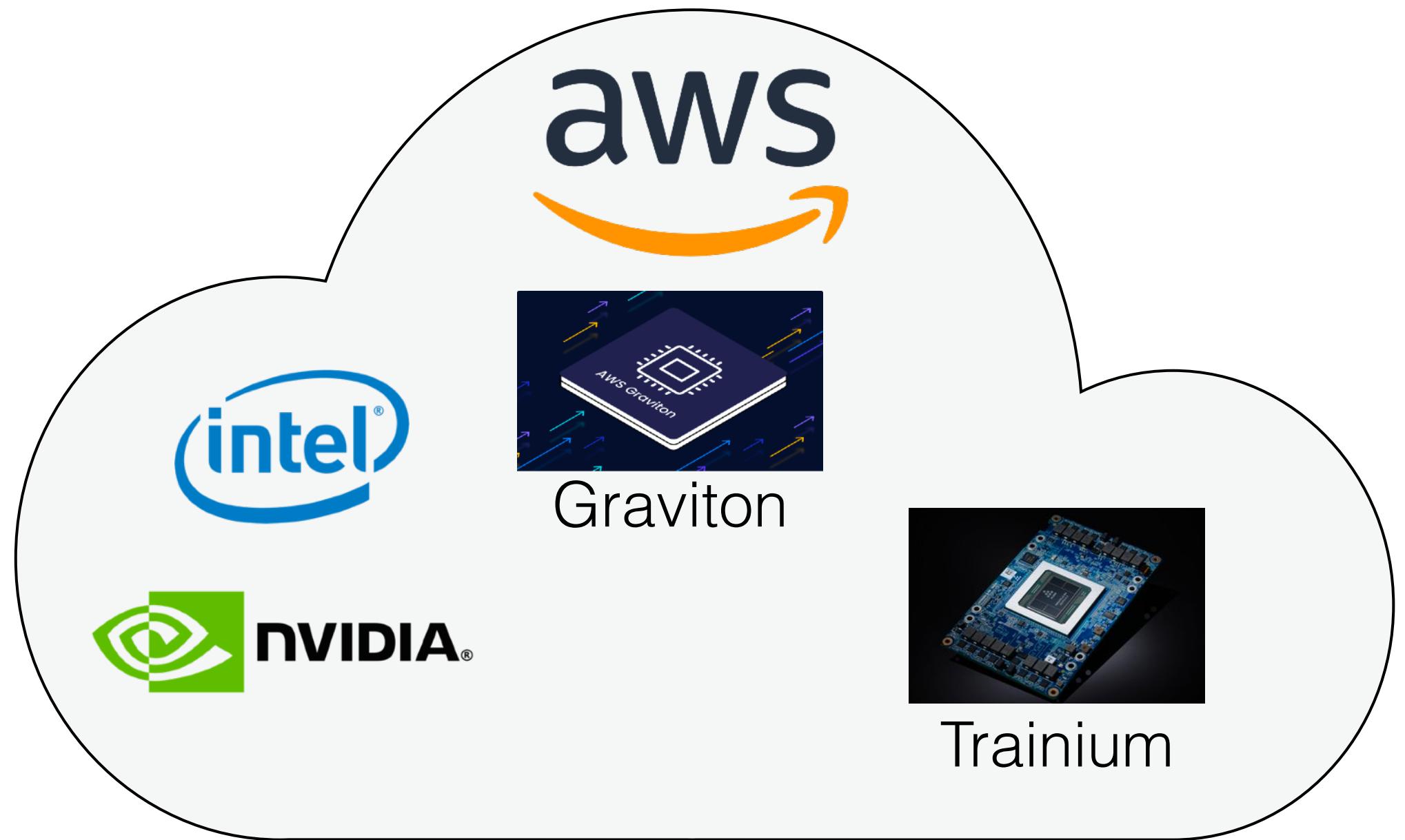
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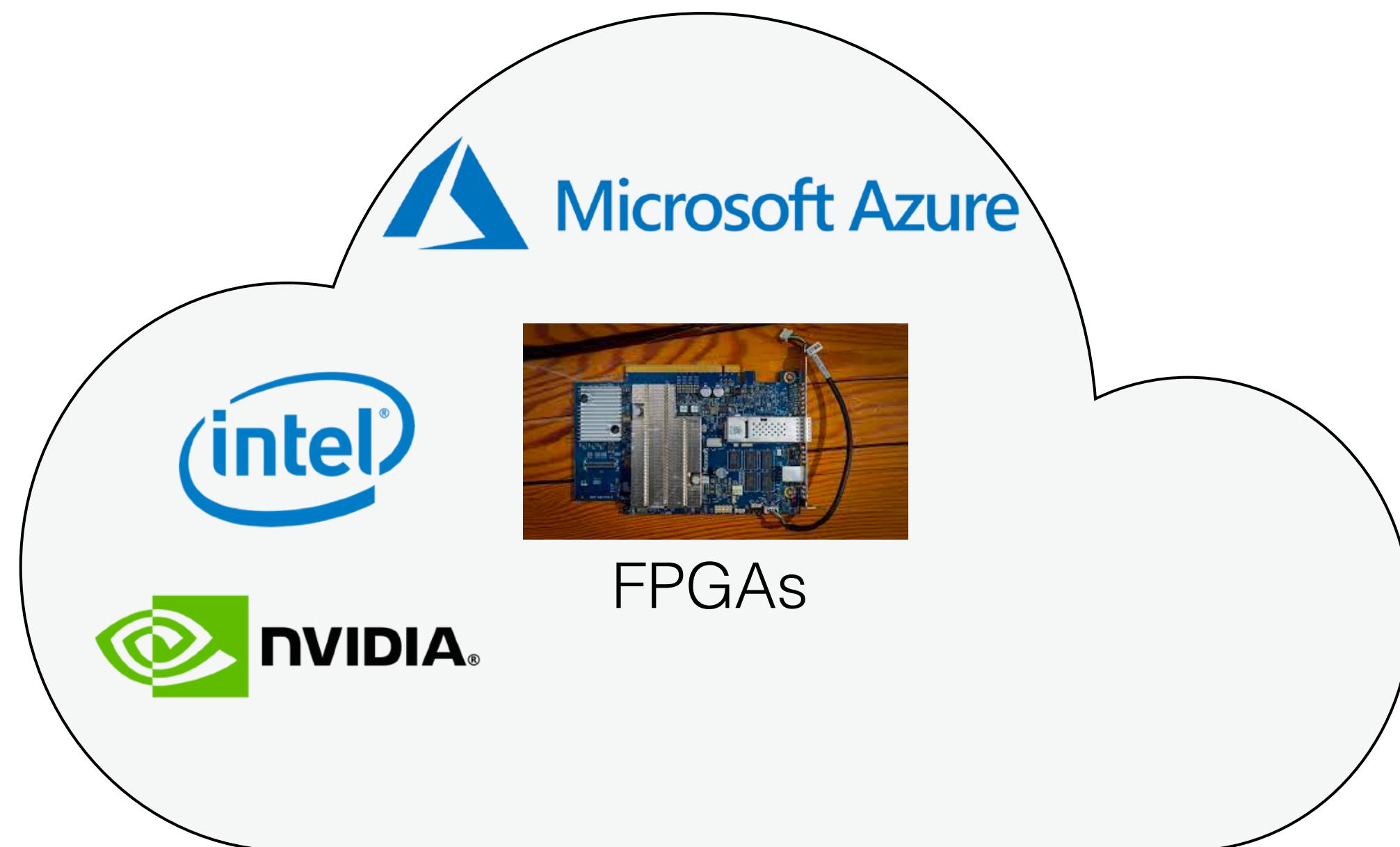
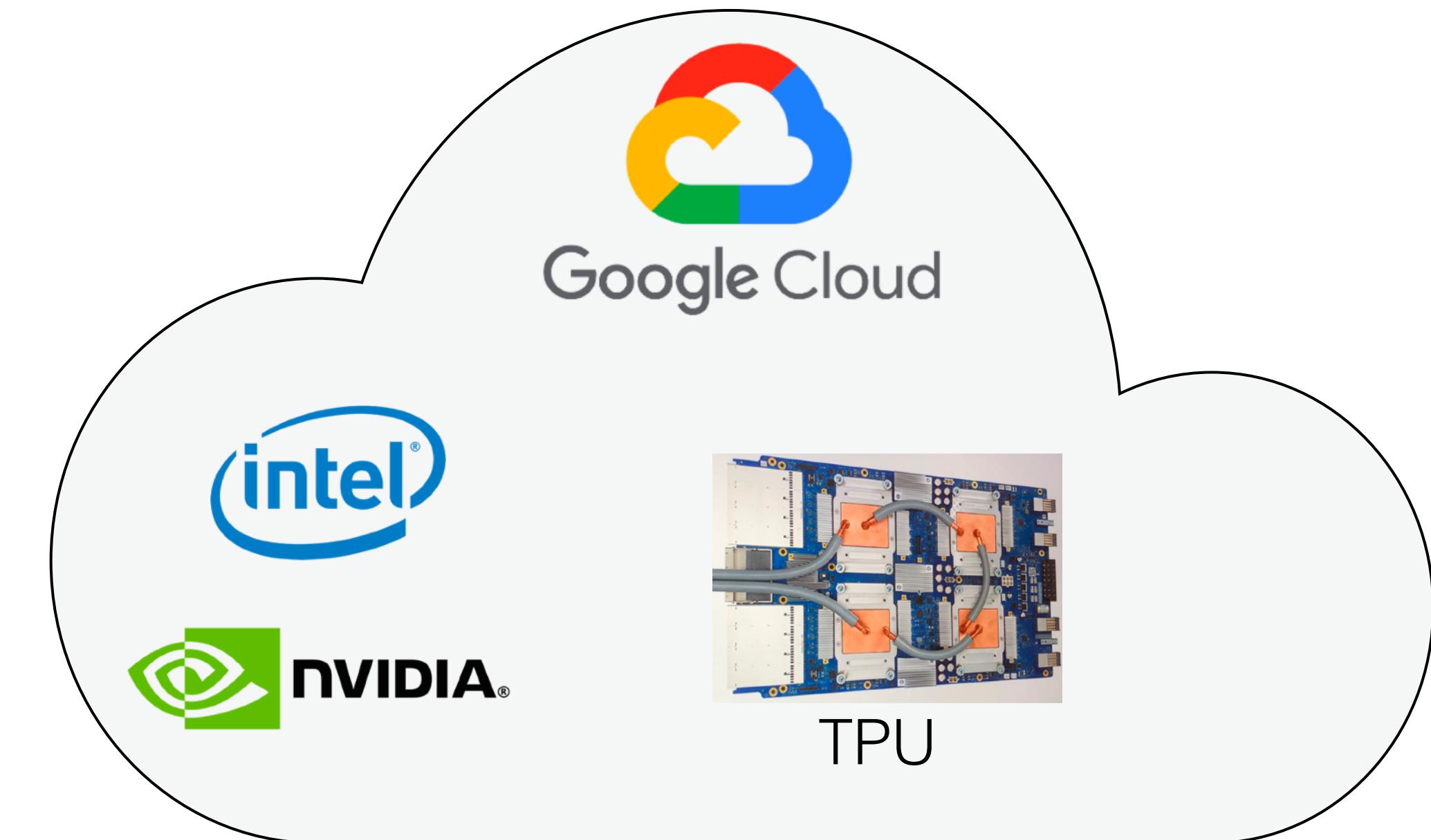
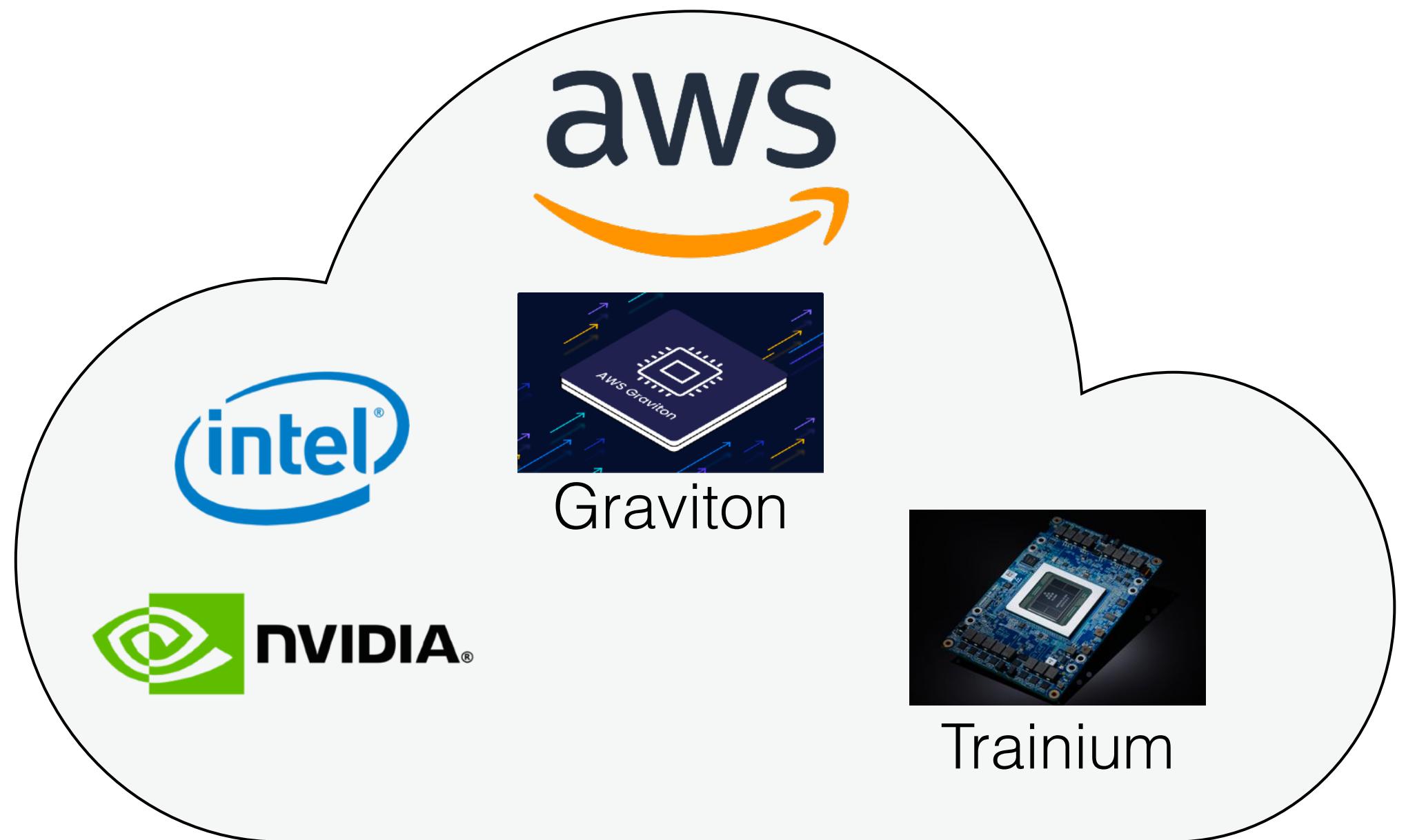
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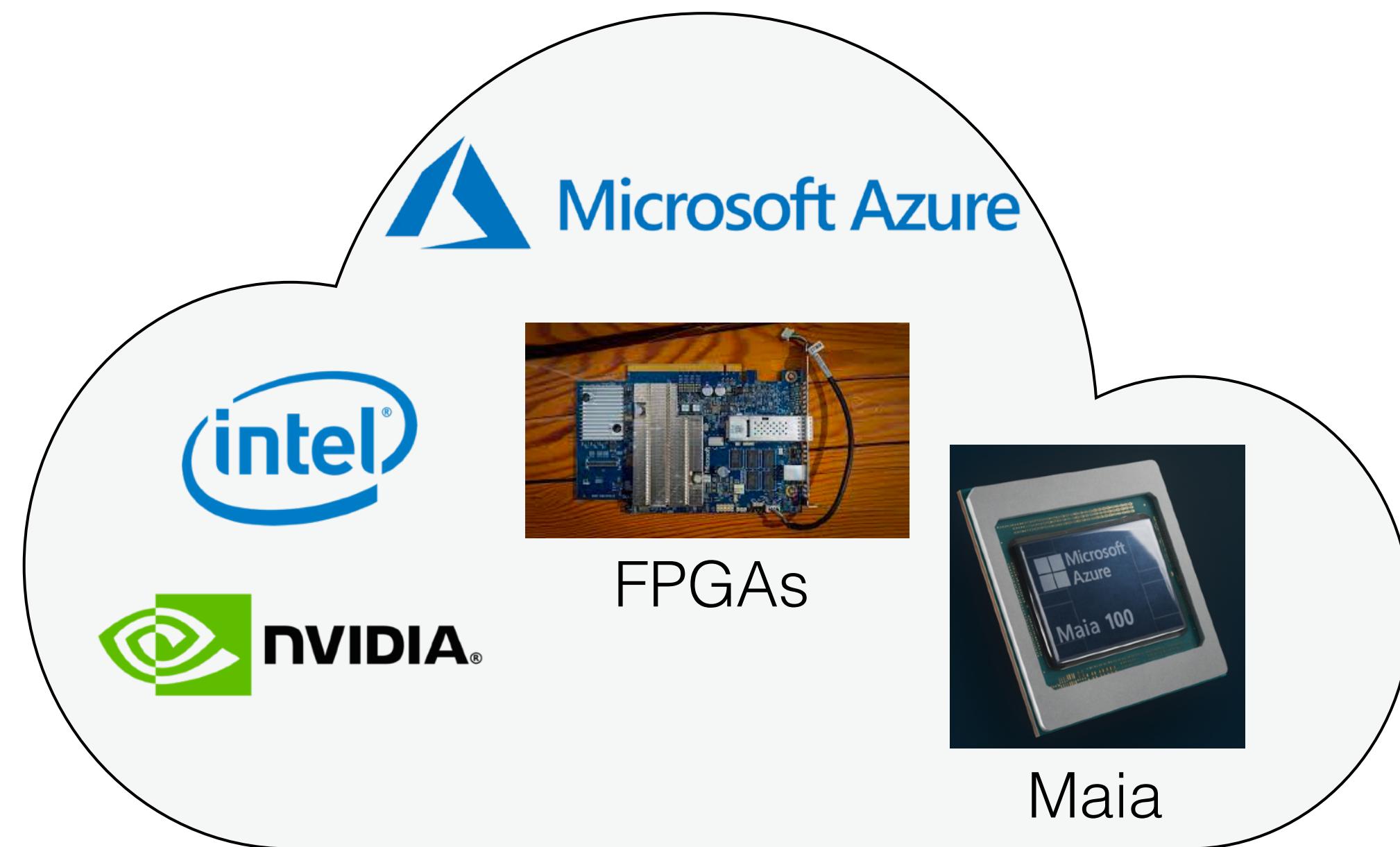
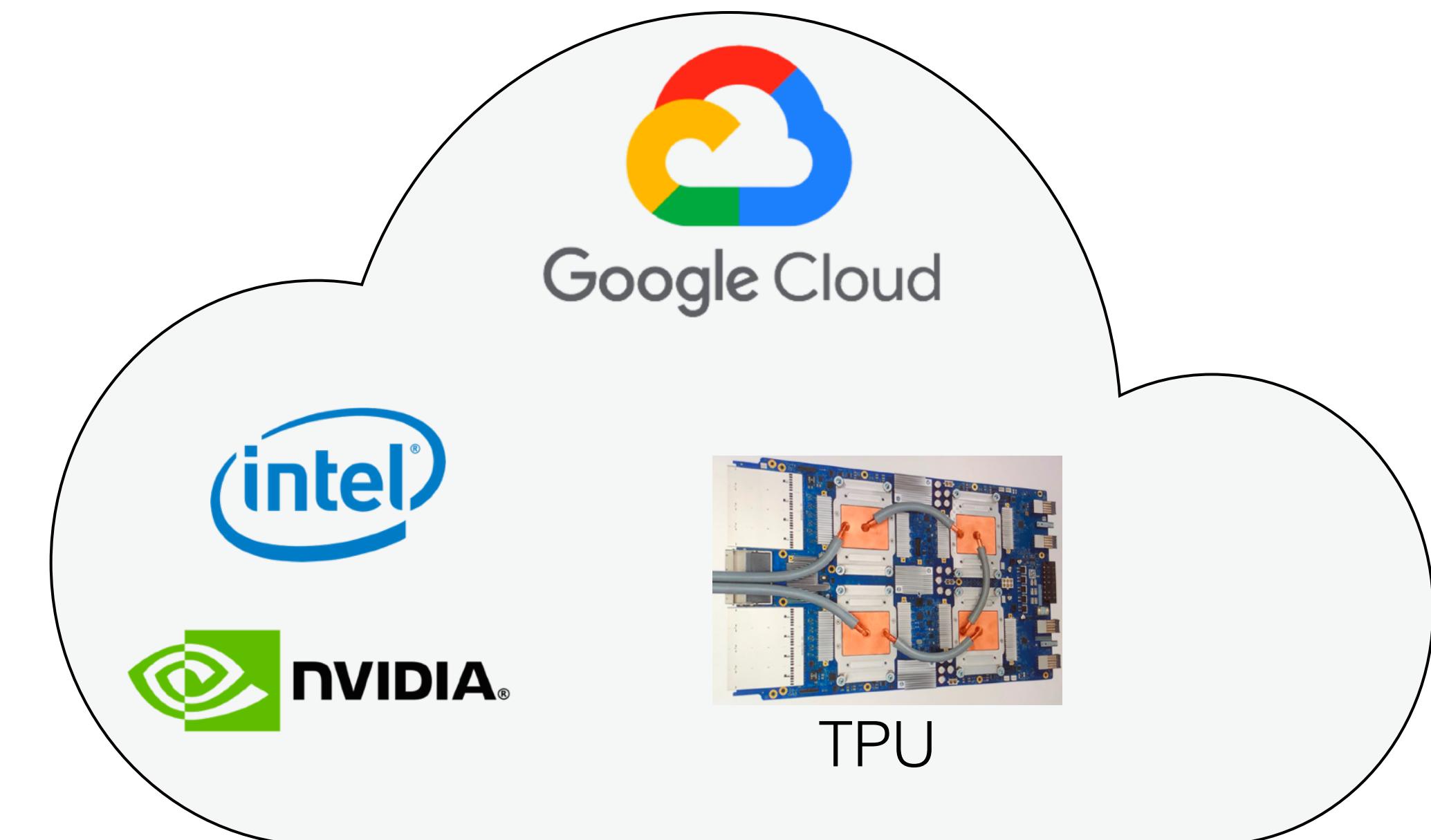
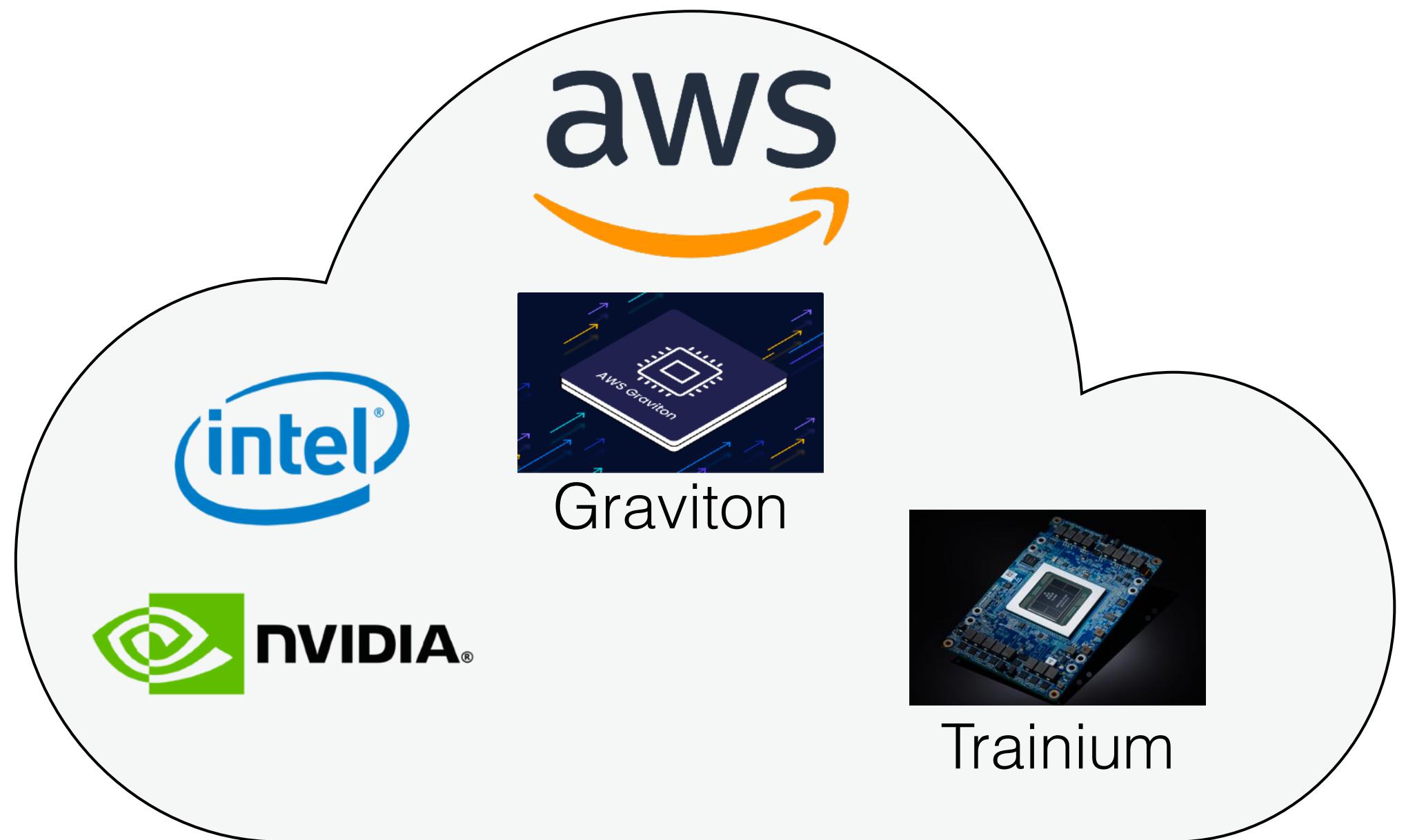
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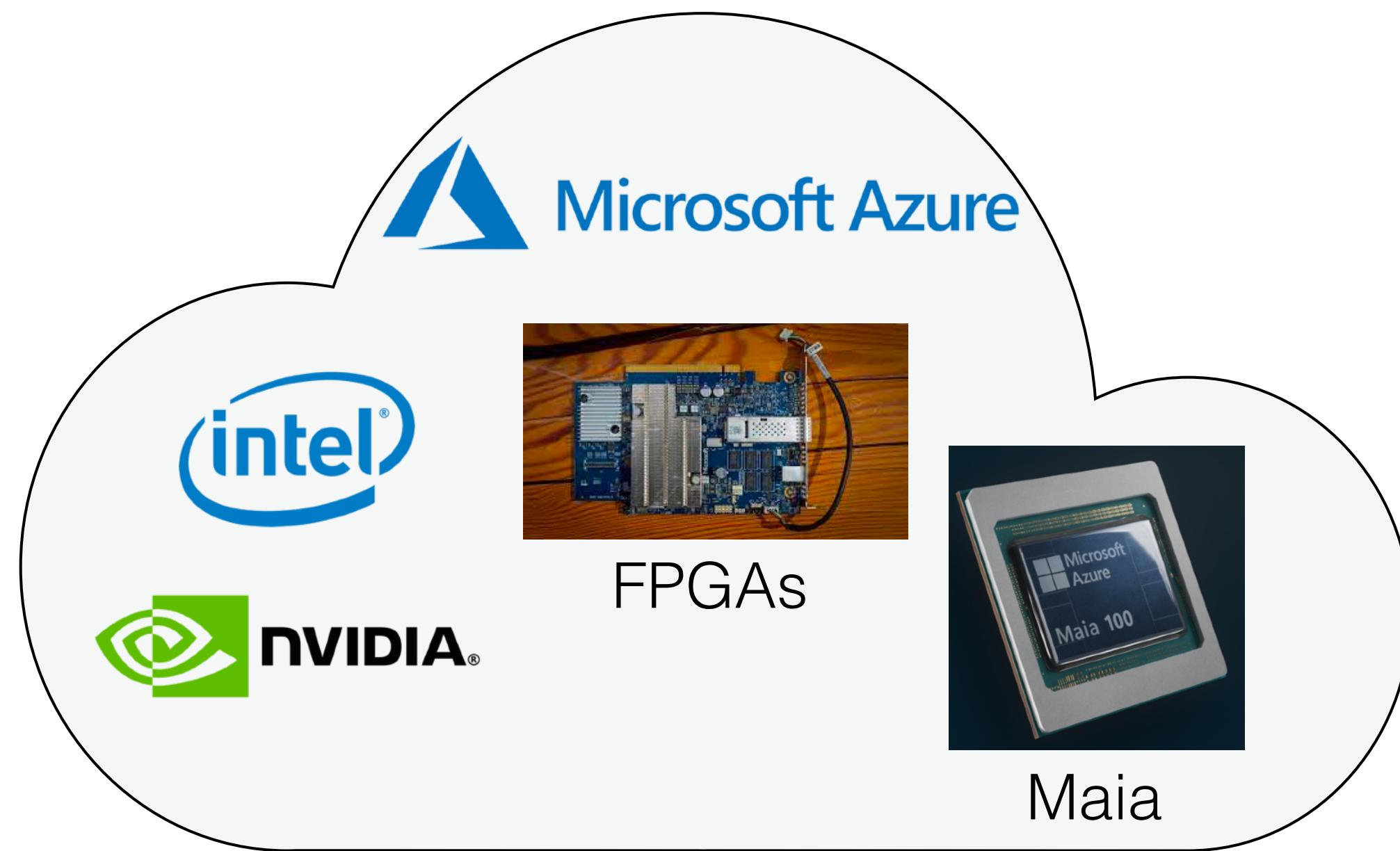
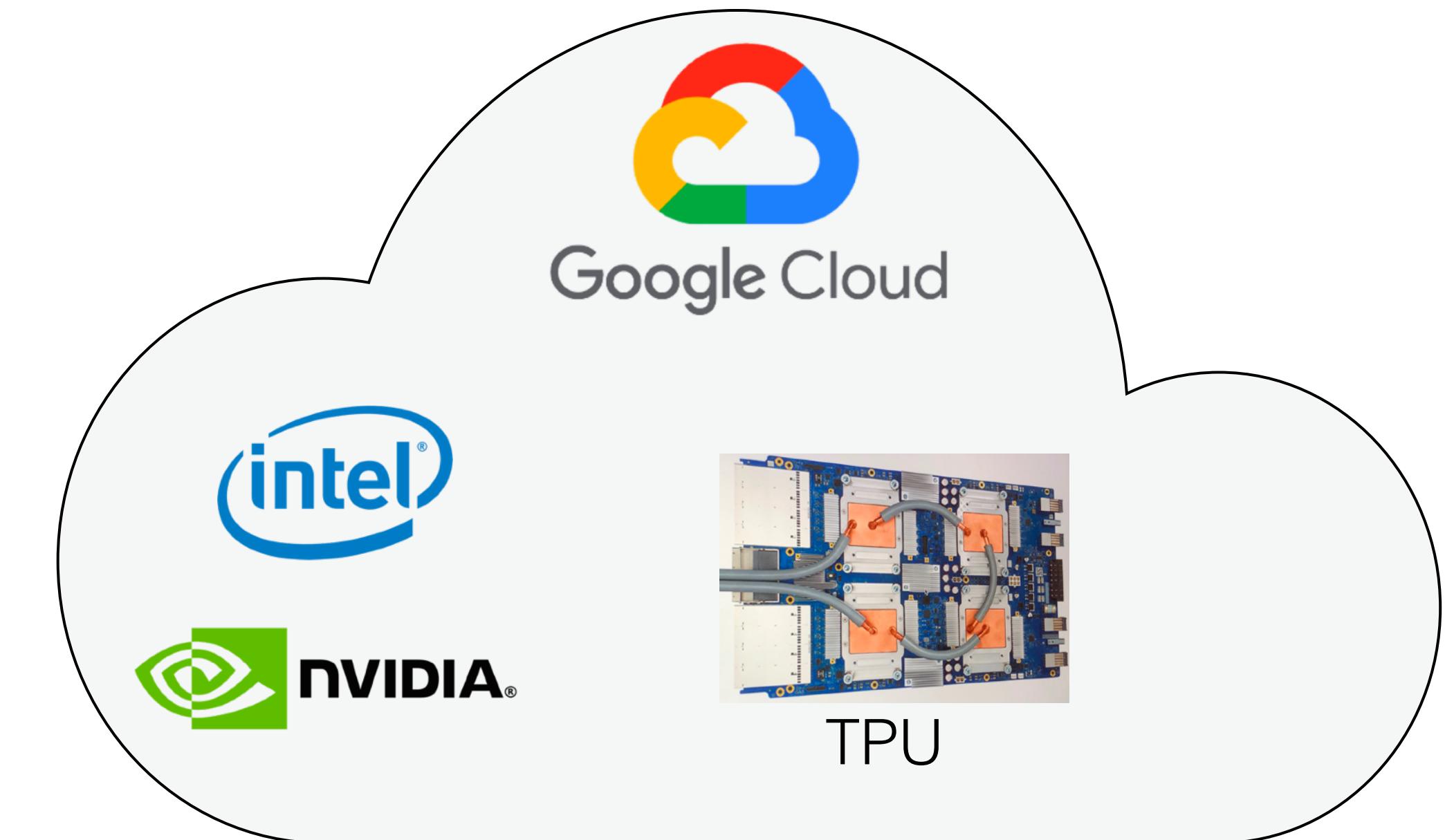
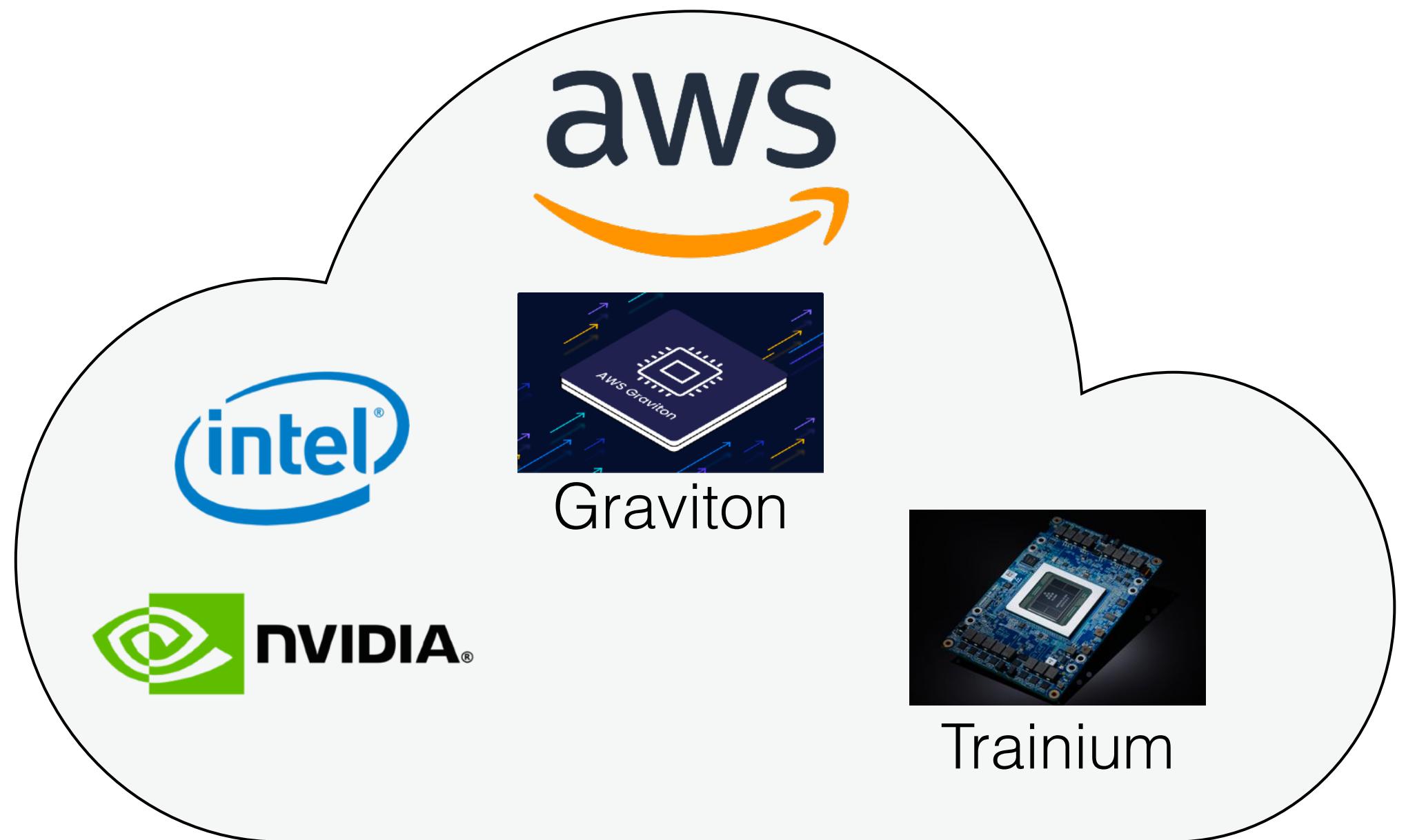
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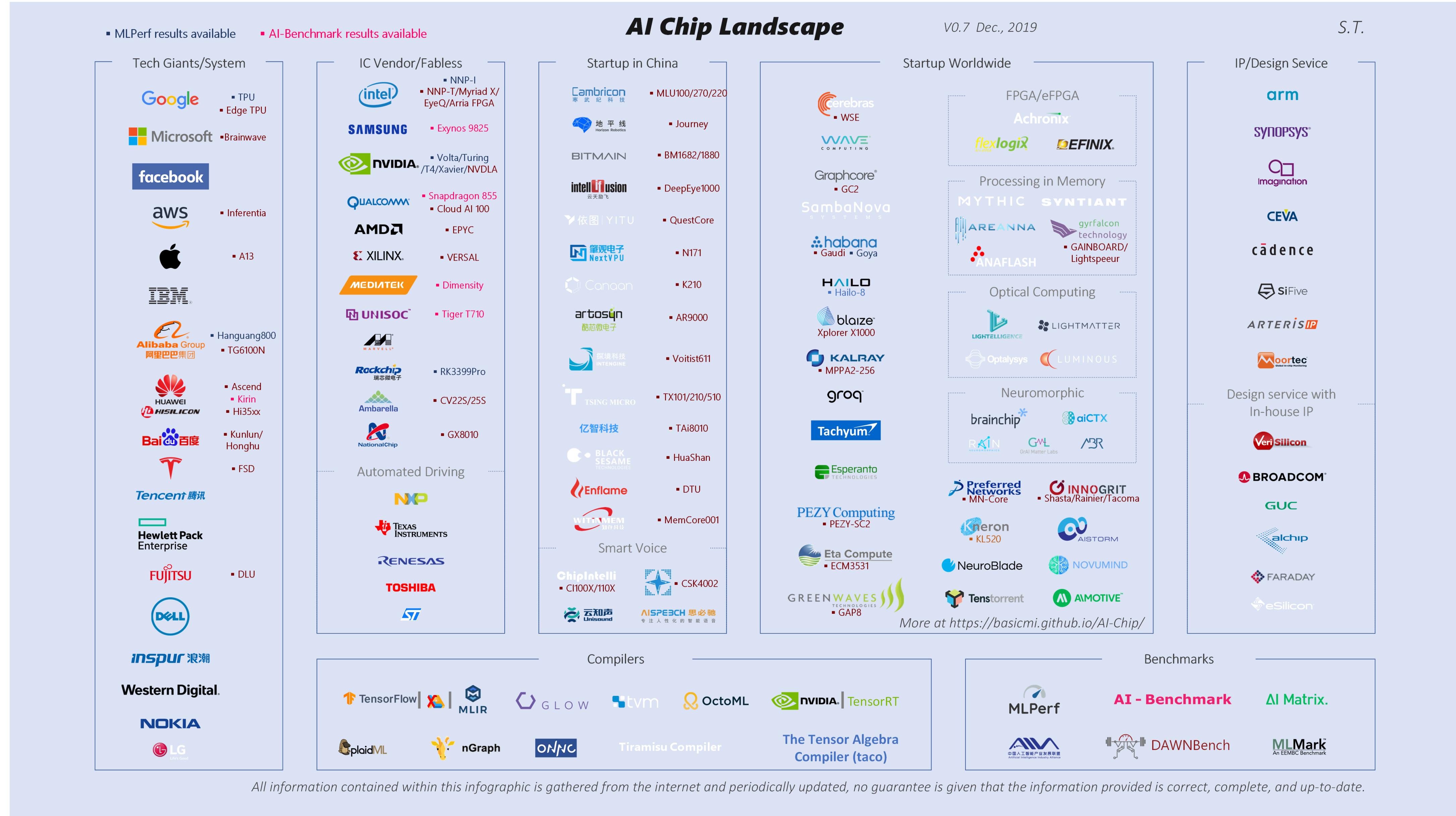
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Hardware in the Clouds

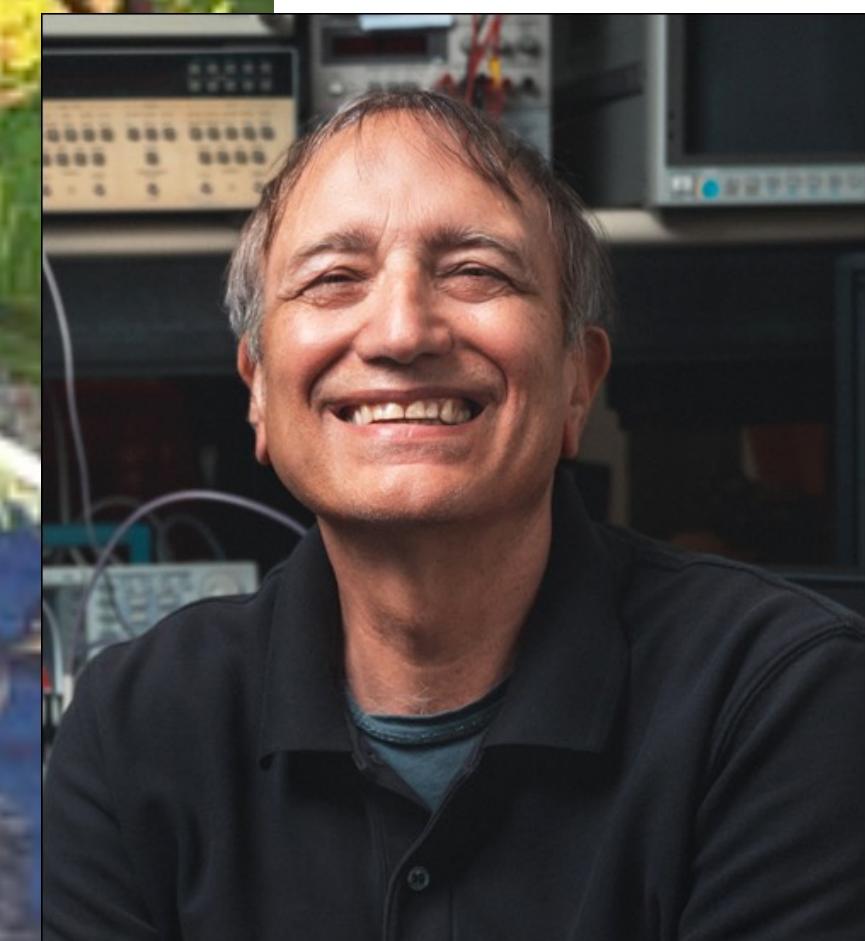


A lot of industry activity (2019 to now)

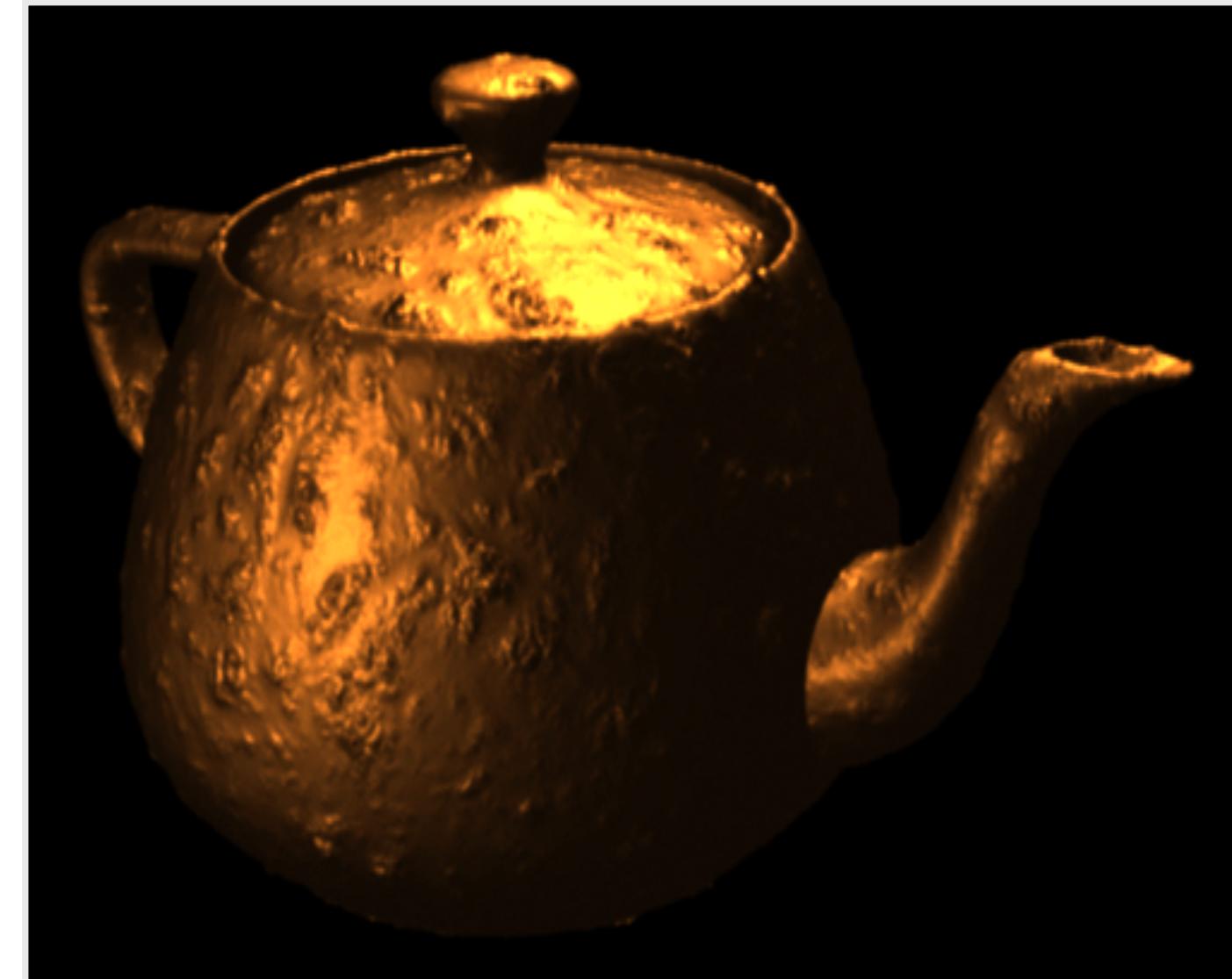


The Road to Point Reyes
Lucasfilm 1984

R.E.Y.E.S = Renders Everything You Ever Saw



```
surface corrode(float Ks=0.4, Ka=0.1, rough=0.25) {  
    float i, freq=1, turb=0;  
  
    // compute fractal texture  
  
    for( i=0; i<6; i++ ) {  
  
        turb+=1/freq*noise(freq*P);  
  
        freq*=2;  
    }  
  
    // perturb surface  
  
    P -= turb * normalize(N);  
  
    N = faceforward(normalize(calculateNormal(P)));  
  
    // compute reflection and final color  
  
    Ci = Cs*(Ka*ambient()+Ks*specular(N,I,rough));  
}
```



Little Languages (DSLs)

Jon Bentley, CACM 29(8), 1986

Defining “little” is harder; it might imply that the first-time user can use this system in an hour or master the language in a day, or perhaps the first implementation took just a few days. In any case, a little language is specialized to a particular problem domain and does not include many features found in conventional languages.

UNIX "DSLs"

bash, csh - shell programming

awk - processing strings

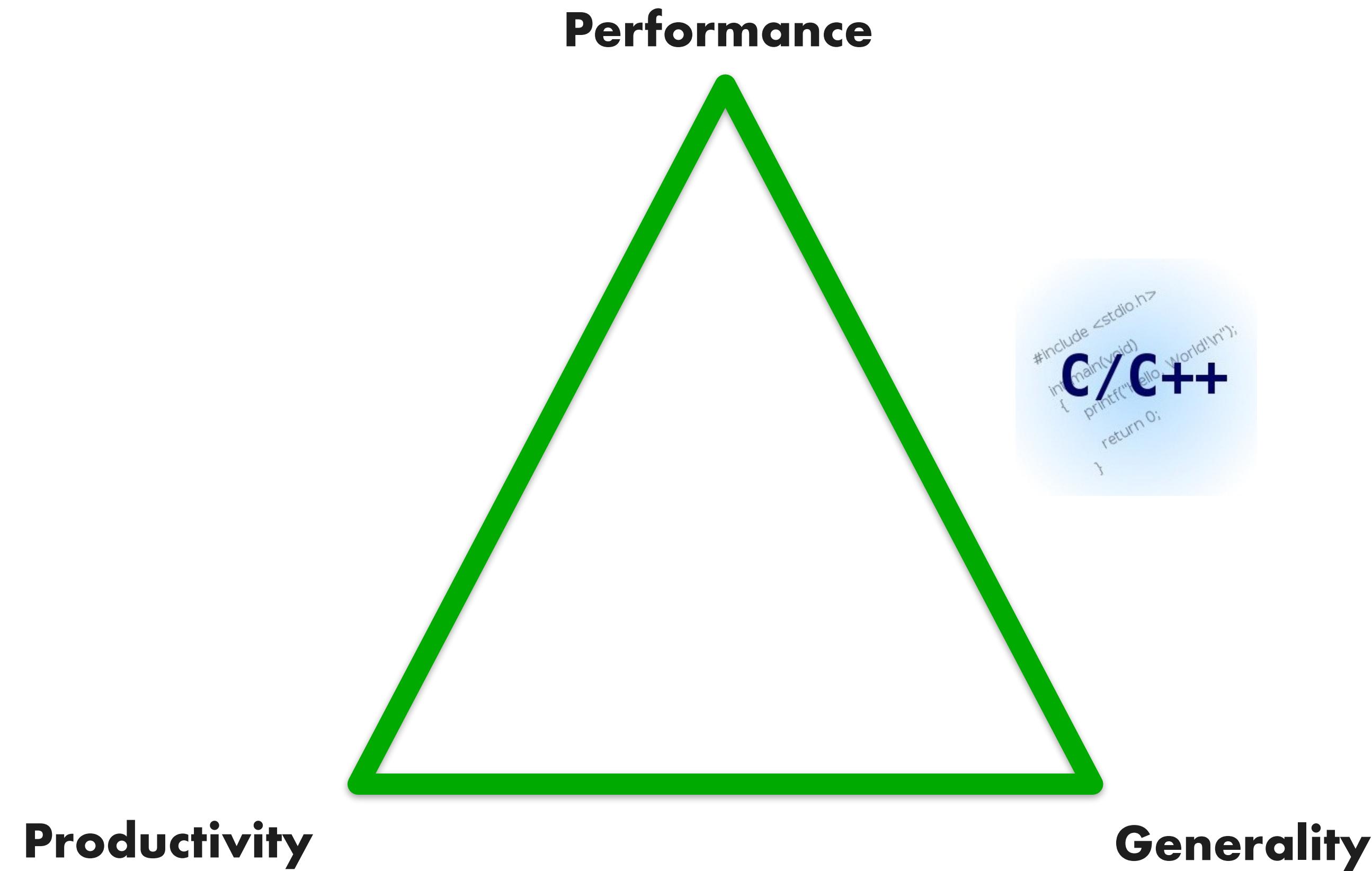
sed - regular expressions

troff, pic, tbl, eqn, ...

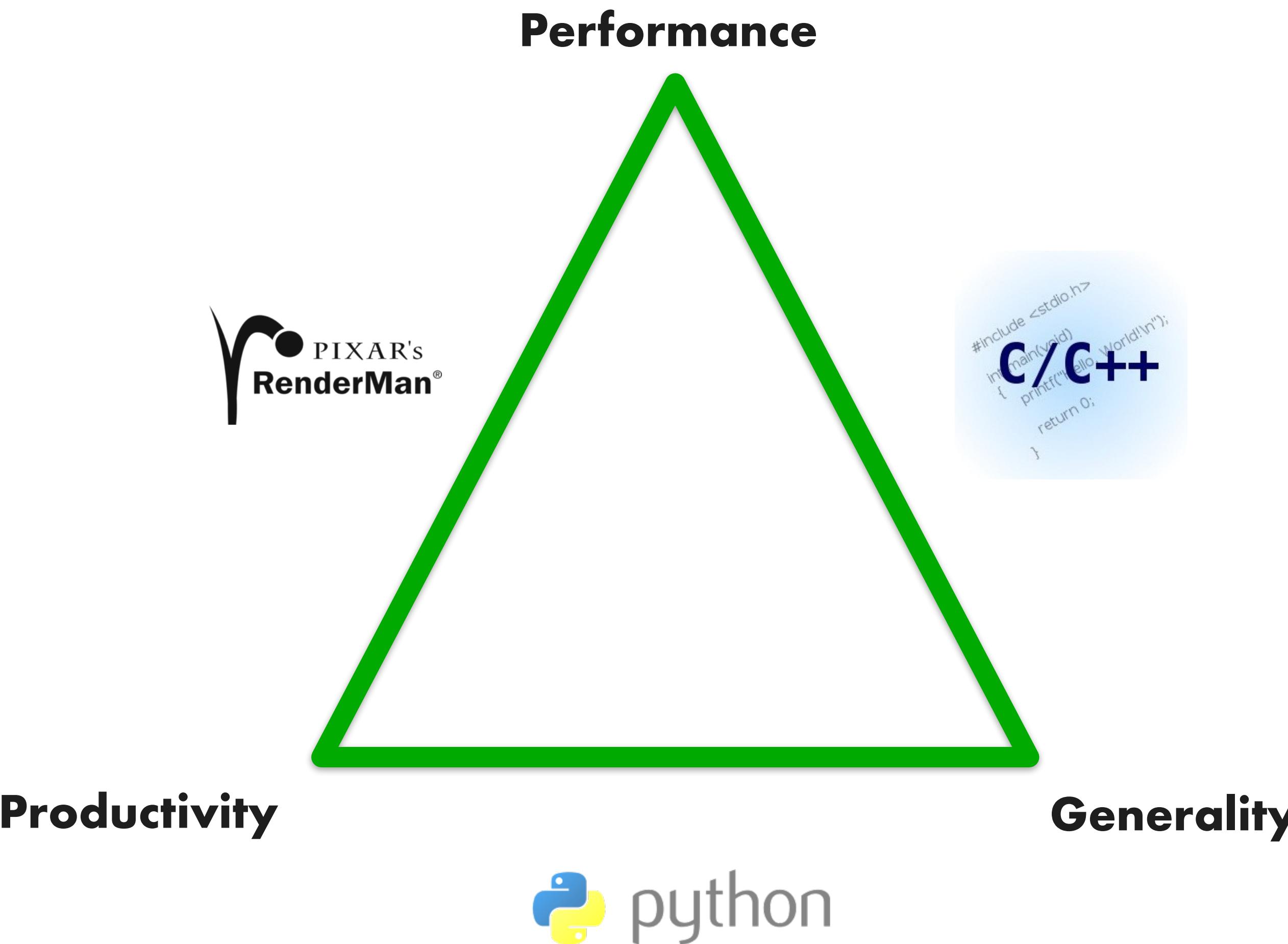
printf formatting

...

Programming Languages



Domain-Specific Languages



Graphics Libraries

```
glPerspective(45.0);
for( ... ) {
    glTranslate(1.0,2.0,3.0);
    glBegin(GL_TRIANGLES);
        glVertex(...);
        glVertex(...);

        ...
    glEnd();
}
glSwapBuffers();
```

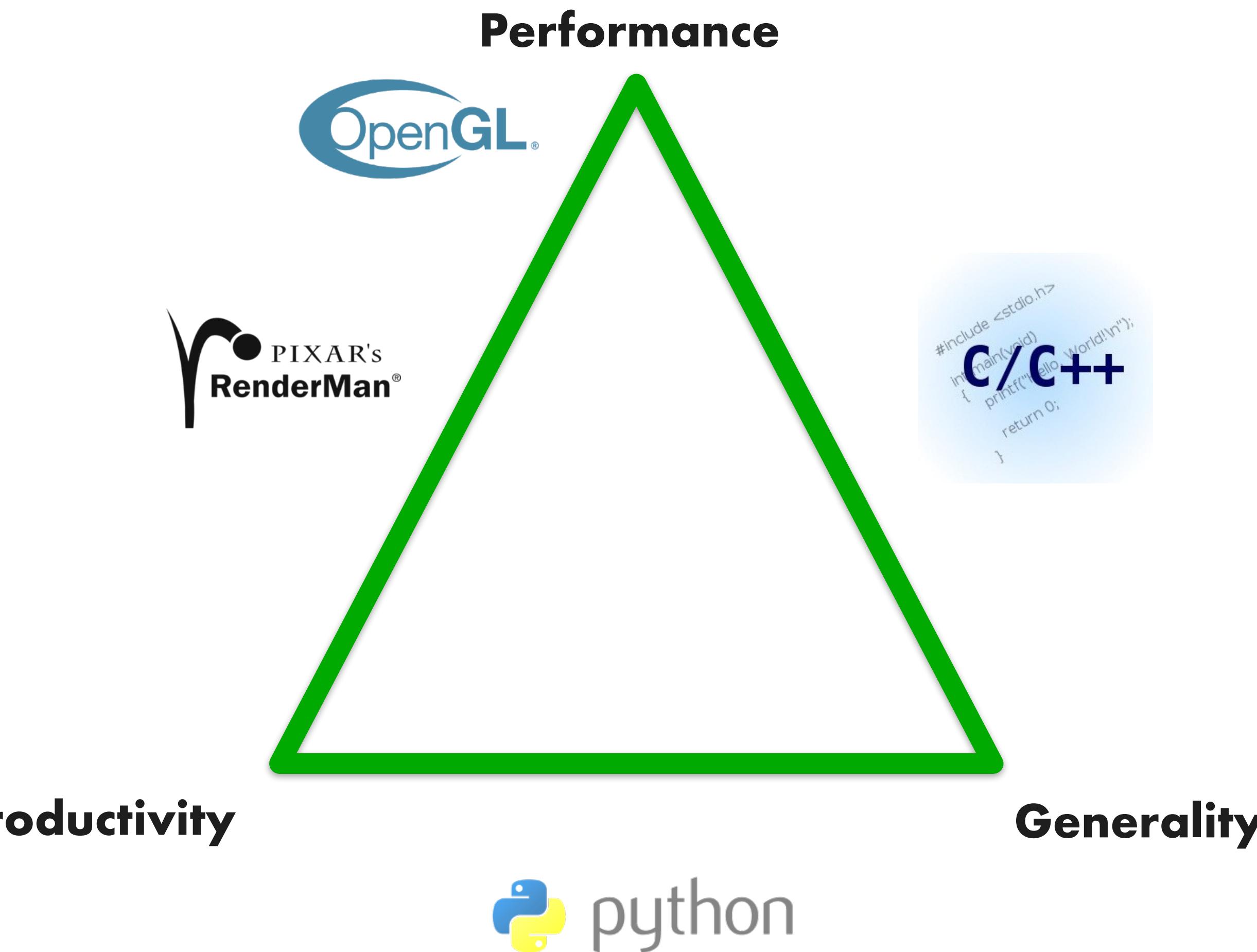
OpenGL “Grammar”

`<Scene> = <BeginFrame> <Camera> <World>
<EndFrame>`

`<Camera> = glMatrixMode(GL_PROJECTION)
<View>
<View> = glPerspective | glOrtho`

`<World> = <Objects>*
<Object> = <Transforms>* <Geometry>
<Transforms> = glTranslatef | glRotatef | ...
<Geometry> = glBegin <Vertices> glEnd
<Vertices> = [glColor] [glNormal] glVertex`

Domain-Specific Languages



Advantages

Productivity

- Graphics library is easy to use

Portability

- Runs on wide range of GPUs

Performance

- Runs in parallel

Advantages

Productivity

Portability

Performance

Encourage innovation

- Allows vendors to radically optimize hardware architecture to achieve efficiency
- Allows vendors to introduce new low-level programming models and abstractions

Restrictions

- Vertices/Fragments are independent
- Rasterization can be done in hardware
- Textures are read-only; texture filtering hw
- Specialized scheduler for pipeline
- ...
- Allows for super-optimized implementations

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**Abstraction is about
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Abstraction is about restrictions, in order to get useful properties

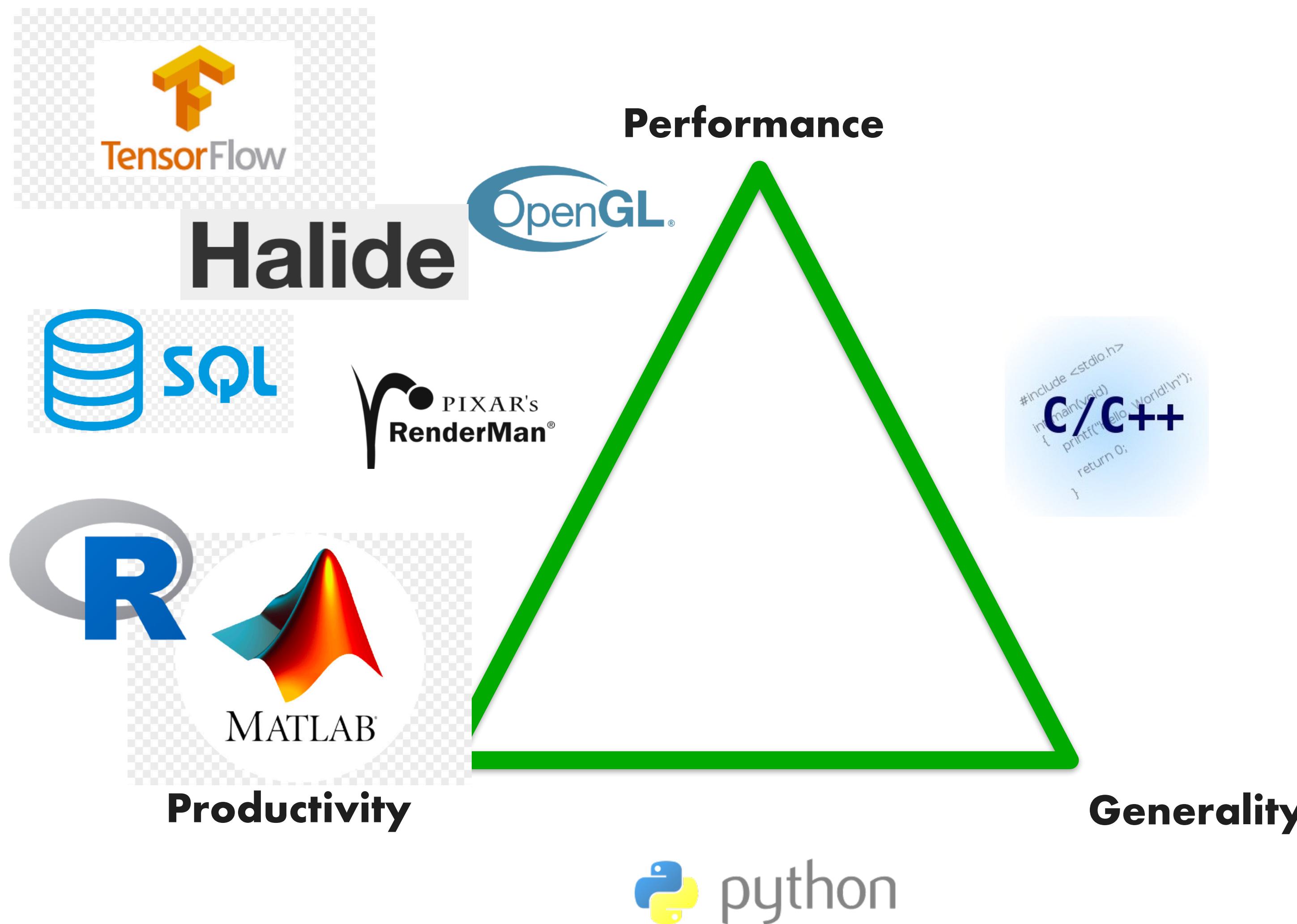
Domain-Specific

A language or library that exploits domain knowledge for productivity and performance

Widely used in many application areas

- matlab / R
- SQL / map-reduce / Microsoft's LINQ
- TensorFlow, pytorch

Domain-Specific Languages



Why DSLs Work

Advantages

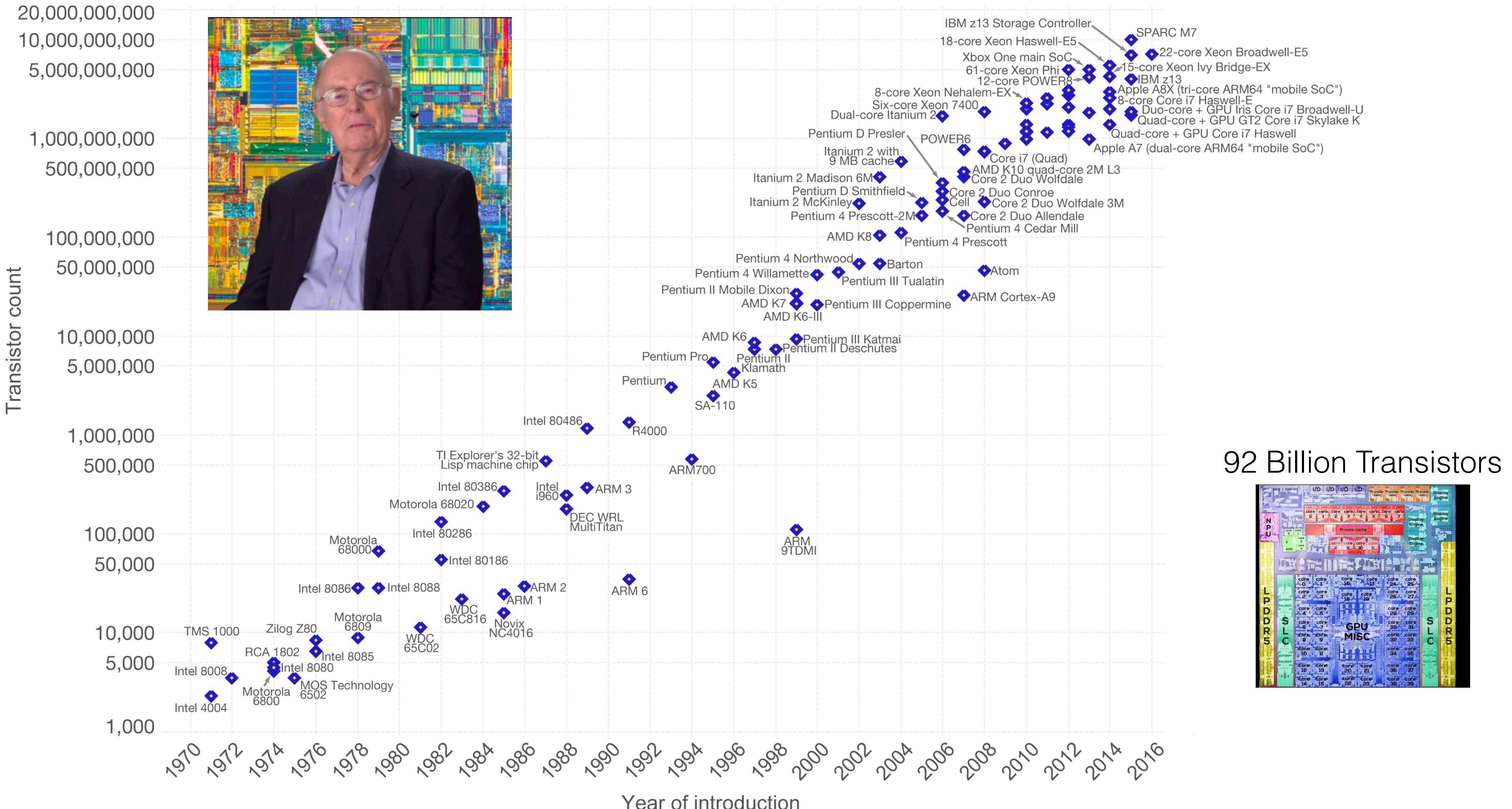
- Add the semantics of the domain
 - High-level program transformations
 - Restrict programming language
 - Less-general computations
 - Guarantee static analysis
- Known parallelization strategies
 - Someone has shown how to robustly do it

=> Tractable

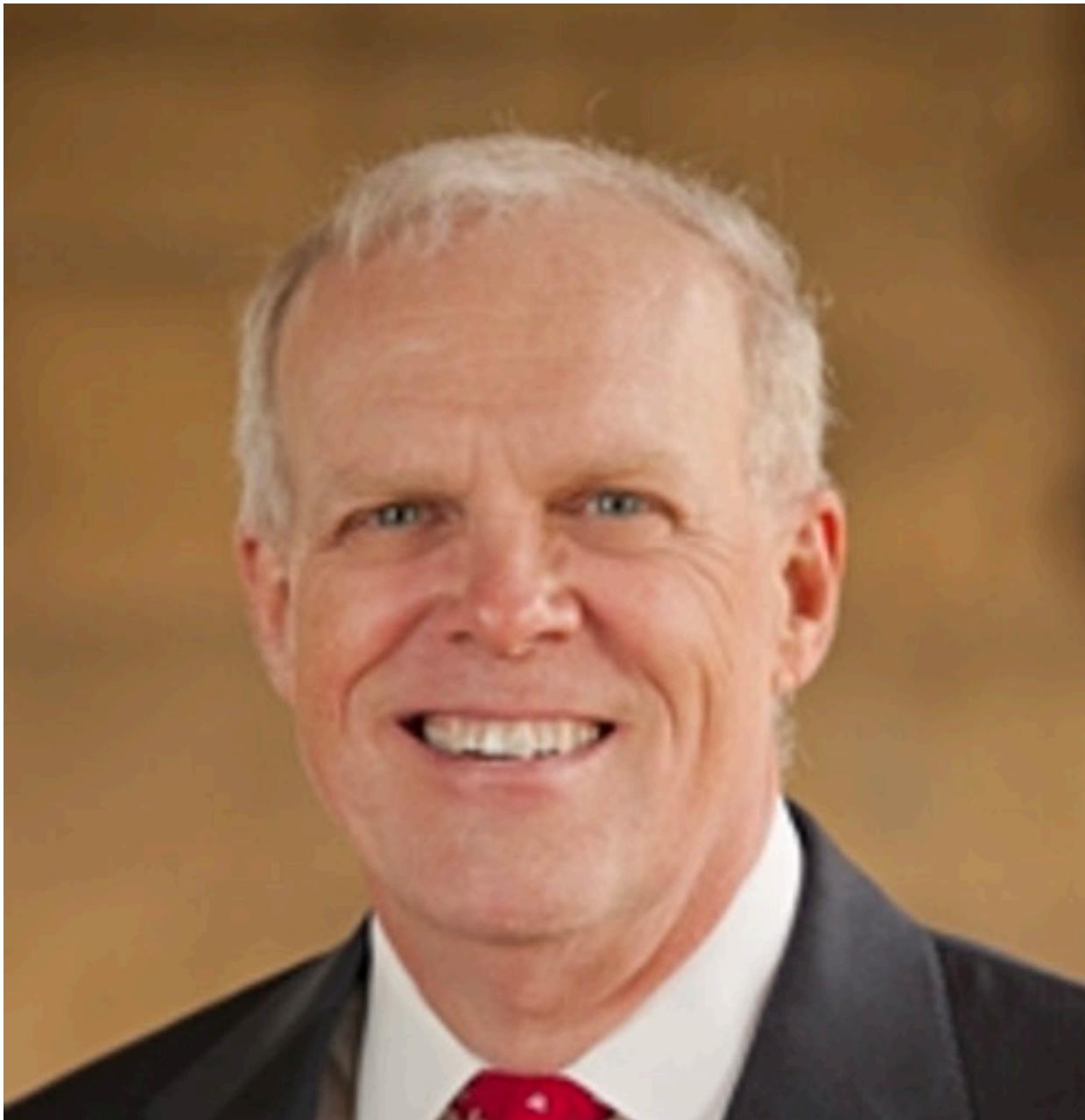
Moore's Law – The number of transistors on integrated circuit chips (1971-2016)

OurWorld
in Data

Moore's law describes the empirical regularity that the number of transistors on integrated circuits doubles approximately every two years. This advancement is important as other aspects of technological progress – such as processing speed or the price of electronic products – are strongly linked to Moore's law.



A New Golden Age for Computer Architecture: Domain-Specific Hardware/Software Co-Design



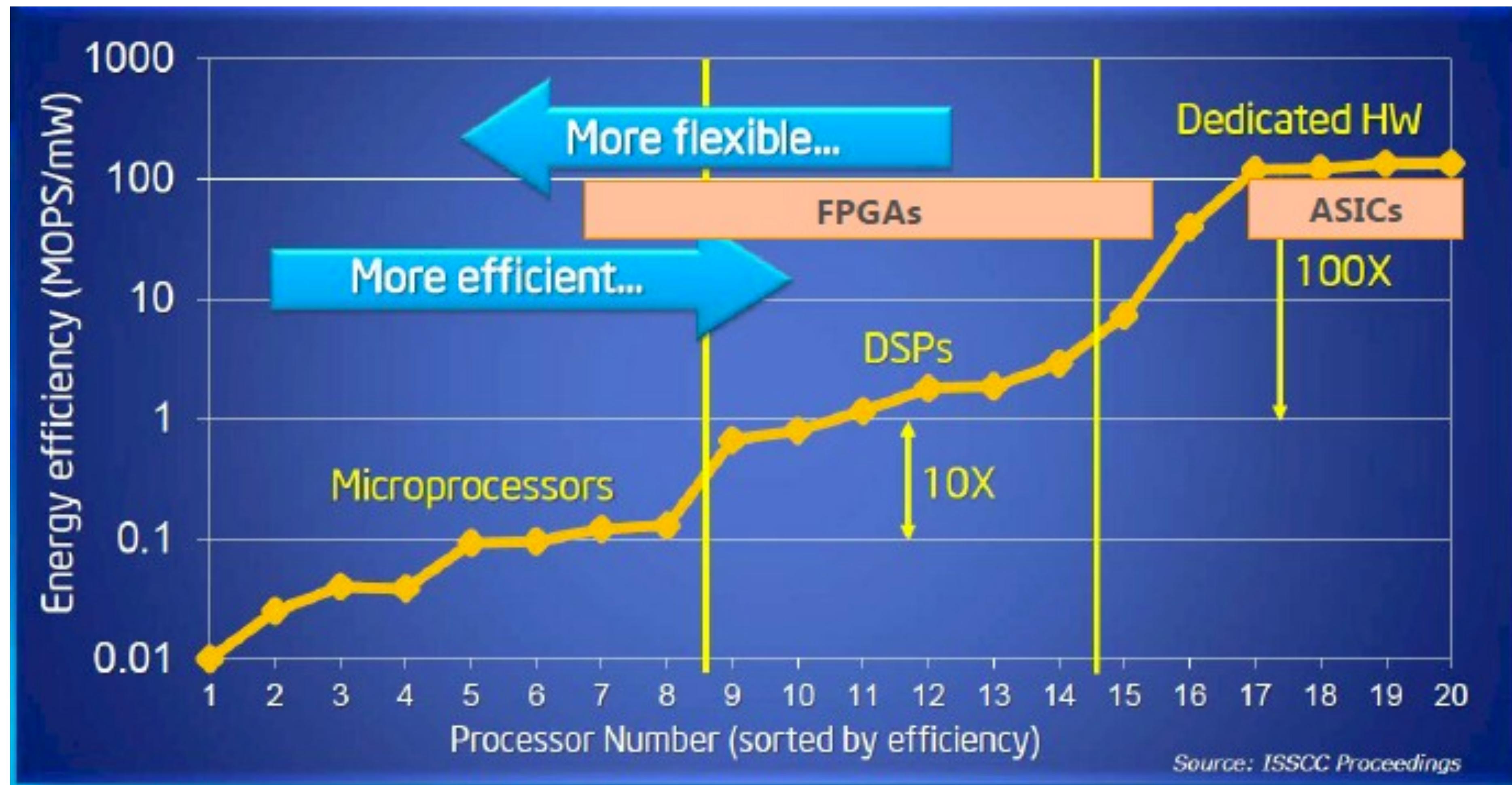
John Hennessy



David Patterson

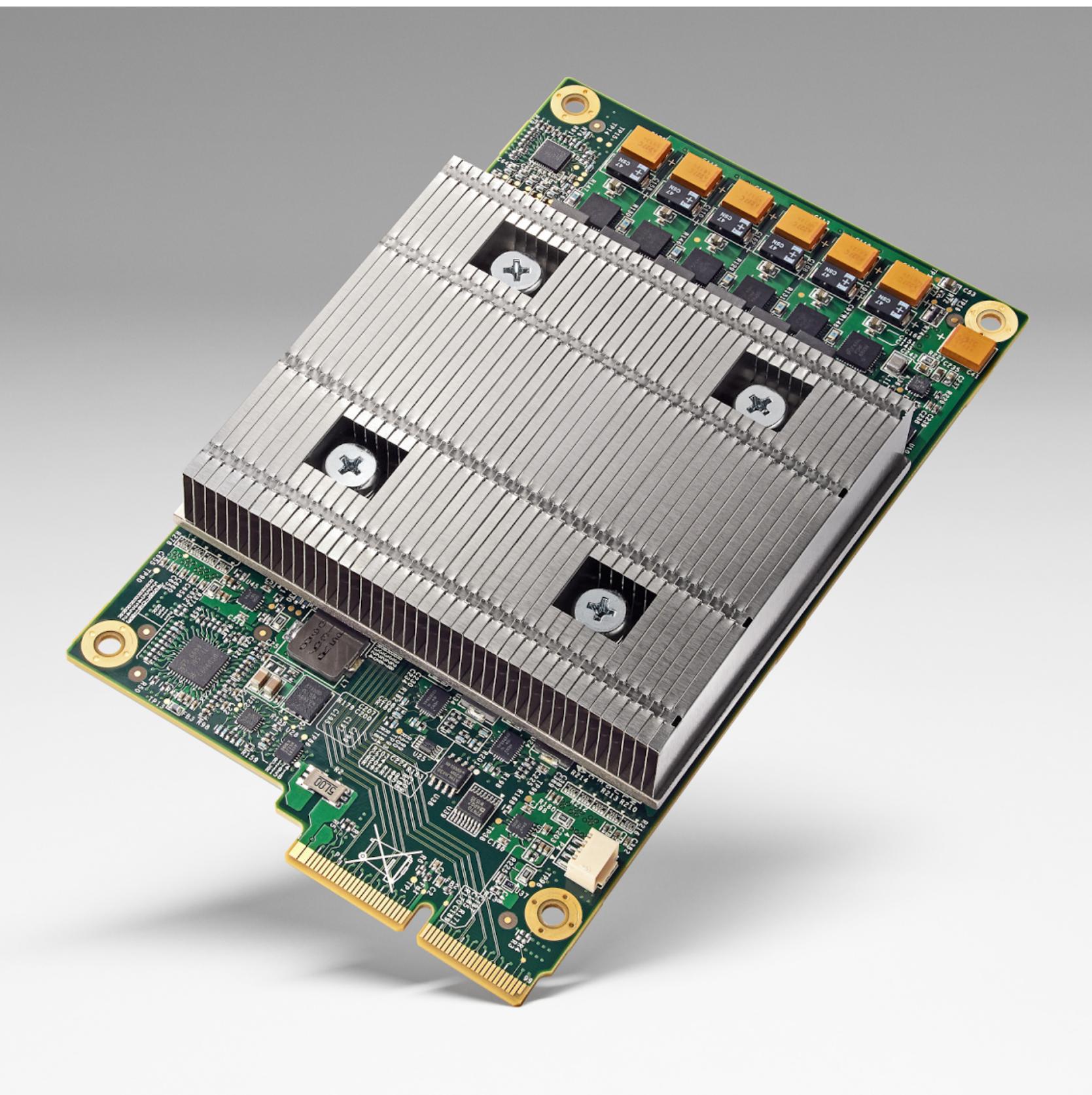
2017 Turing Award

Large efficiency gains with domain-specific architectures

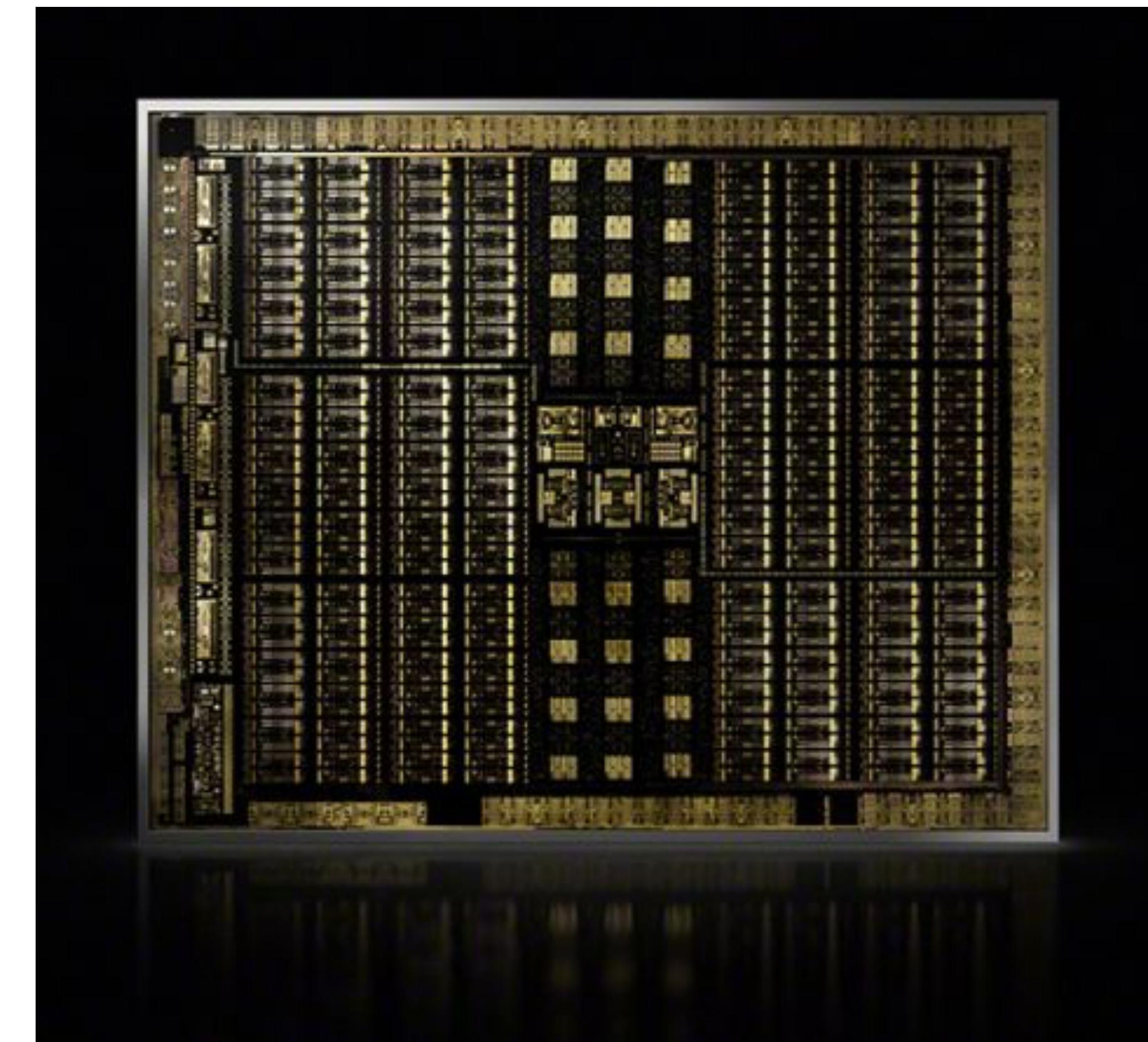


Source: Bob Broderson, Berkeley Wireless group

Domain-Specific Architectures



Google TPUs



NVIDIA GPUs

Collection-Oriented Languages

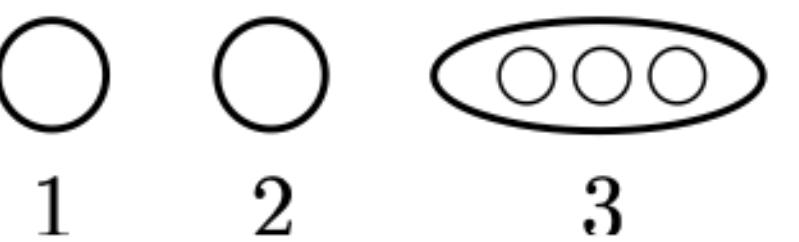
Lists
Lisp M58



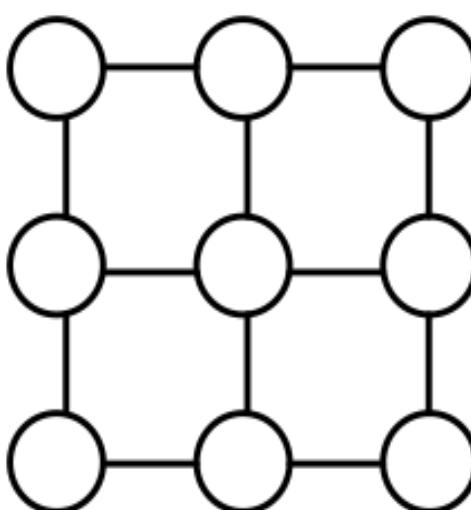
Sets
SETL S70



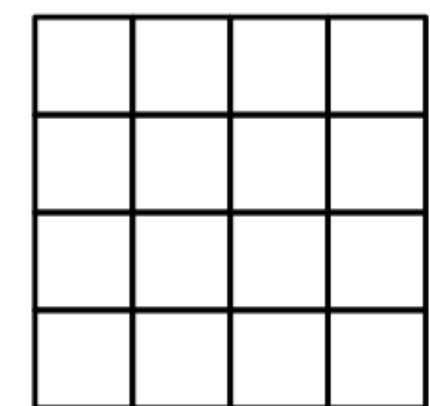
Nested Sequences
NESL B94



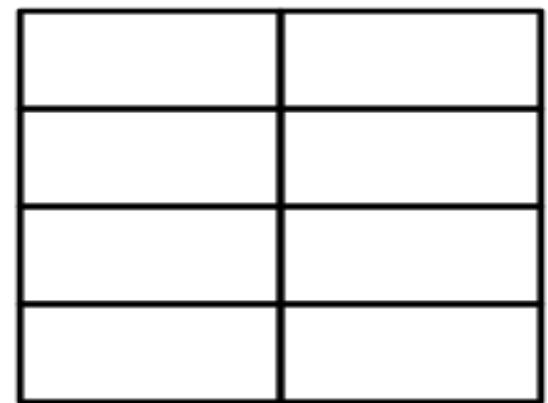
Grids
Sejits S09, Halide



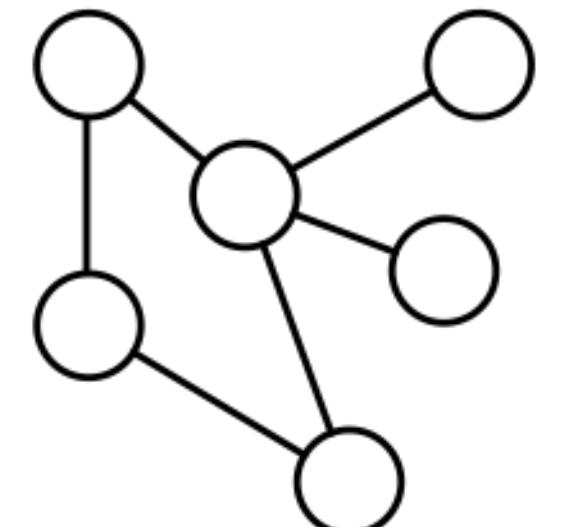
Arrays
APL I62



Relations
Relational Algebra C70,



Graphs
GraphLab L10



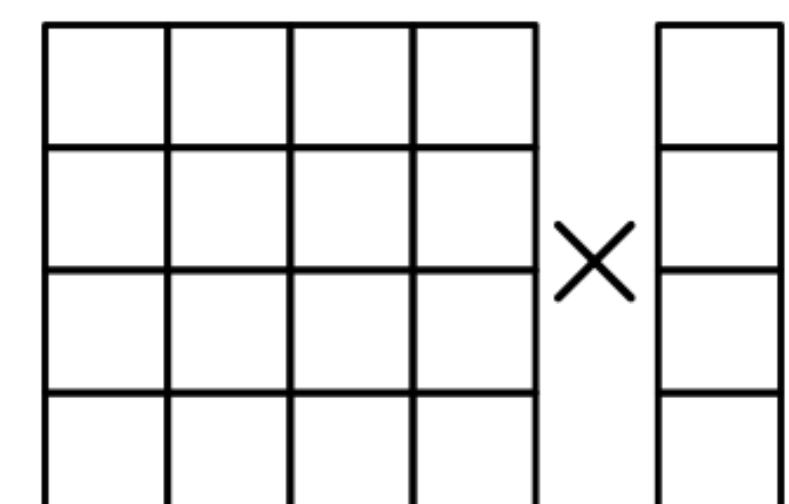
Meshes
Liszt D11



Vectors
Vector Model B90



Matrices and Tensors
Matlab M79, taco K17



A collection-oriented programming model provides collective operations on some collection/abstract data structure

Modern Collection-Oriented Languages



Halide

