



Chapel

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In cooperation with:





Parallel Applications

Workshop

Alternatives to MPI+X
November 19th, 2021

Aerospace Engineering

- National Objectives (Commercial & Defense)
- Flight testing extremely costly (Dollars and Humans)
- Simulation-Based Engineering have emerged from R&D ('90s-2010') to production
 - Disciplinary (manufacturing, aerodynamics, etc.)
- Technology push:
 - Multidisciplinary: link 'fields'
 - fully coupled systems: link 'software'
- Solution: democratizing HPC
 - Unified OS, languages, memory, architecture



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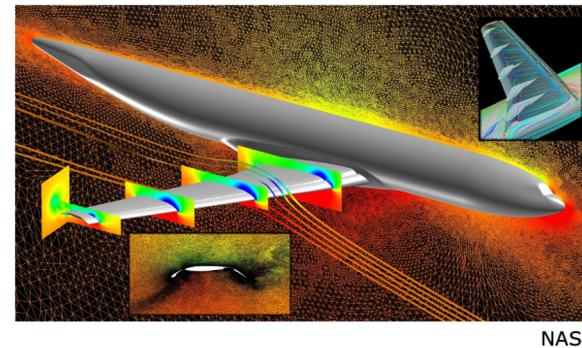
Aerodynamic Design Toolset



Bombardier
Flight tests ~100 000\$/hr



ETW
Wind-tunnel ~1000-10 000\$/hr



Numerical Simulations (CFD) ~100-1000\$/hr



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Workflow



physics

$$\rho \left(\frac{\partial \vec{u}}{\partial t} + \vec{u} \cdot \nabla \vec{u} \right) = -\nabla p + \nu \Delta \vec{u}$$

Acceleration Pressure Viscosity

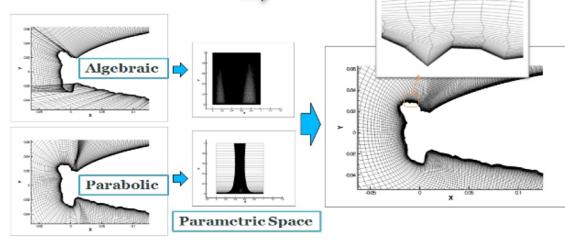
$$\nabla \cdot \vec{u} = 0$$

Continuity Equation

MIT

mathematics

macro → micro



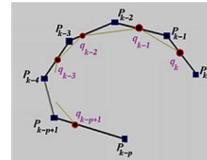
Mesh generation
0.01-10 billions unknowns

```
Finclude <stdio.h>
int main()
{
    int a[10];
    printf("Enter student's scores: \n");
    for(i=0; i<10; i++)
        scanf("%d", &a[i]);
    printf("Your student's scores are: \n");
    for(i=0; i<10; i++)
        printf("%d\n", a[i]);
    return 0;
}
```

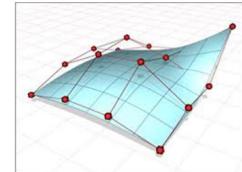
Proprietary source codes



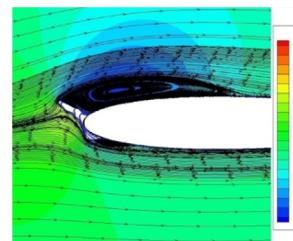
Supercomputers



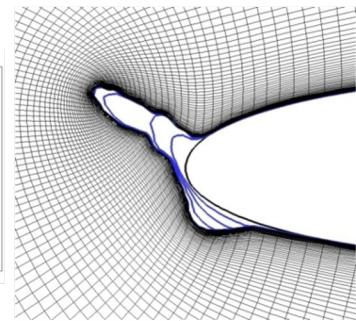
Parametrisation
(NURBS)



Geometry (CAD)



solution:
i) flow, ii) droplets



Time step

Enablers



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Education

- Technology used to be in academia
 - Research centers
 - Industry
- Handled by Professors, Research Associates, Post-Docs, highly specialized skill sets
- Now handled by MSc students
 - Push towards undergraduate training
- Example 1: Polytechnique Montréal adopted Python in all U.Grad courses (no more Matlab)
 - Python introduced at Bombardier through students! Technology push
- Example 2: Chapel used in 3D Navier-Stokes solver, will it see same success? (hopefully!)



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Educational challenges

- Physics
- Applied Mathematics
- Numerical analysis
- Programming languages
- OPEN-MP (**MSc**)
- MPI (**PhD, slow progress**)
- Mixed CPU-GPU (**failure in technology push**)
- Time-to-debug (1 Million+ lines, 10 hrs runs)

How to you fit that:

- in U. Grad?
- in Ph.D. (with MSc dropping?)

So far, experience has shown Chapel is step change towards this goal.