

# Practical quantum-accelerated scientific computing

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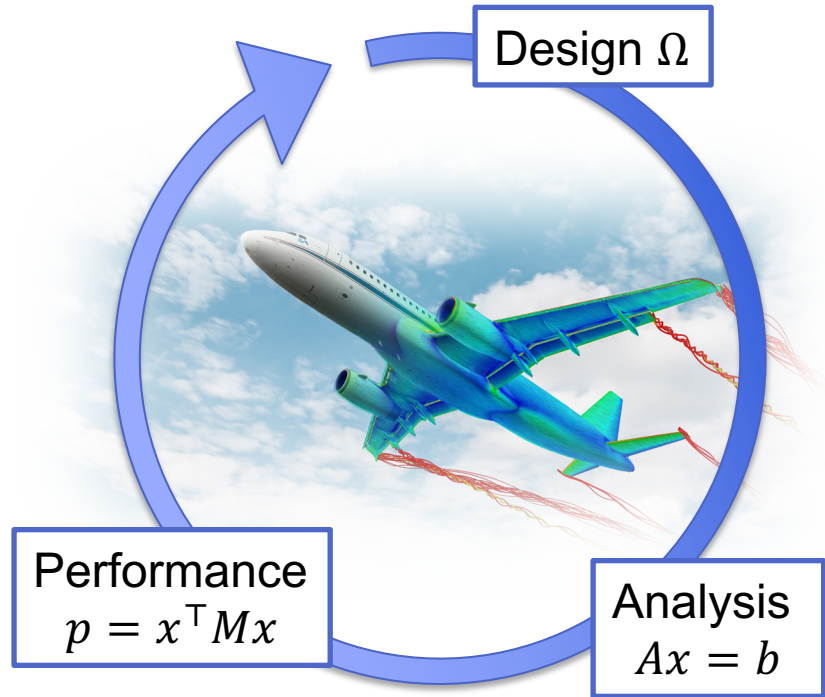
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**DCSE**

**Enabling Technology for Industry**

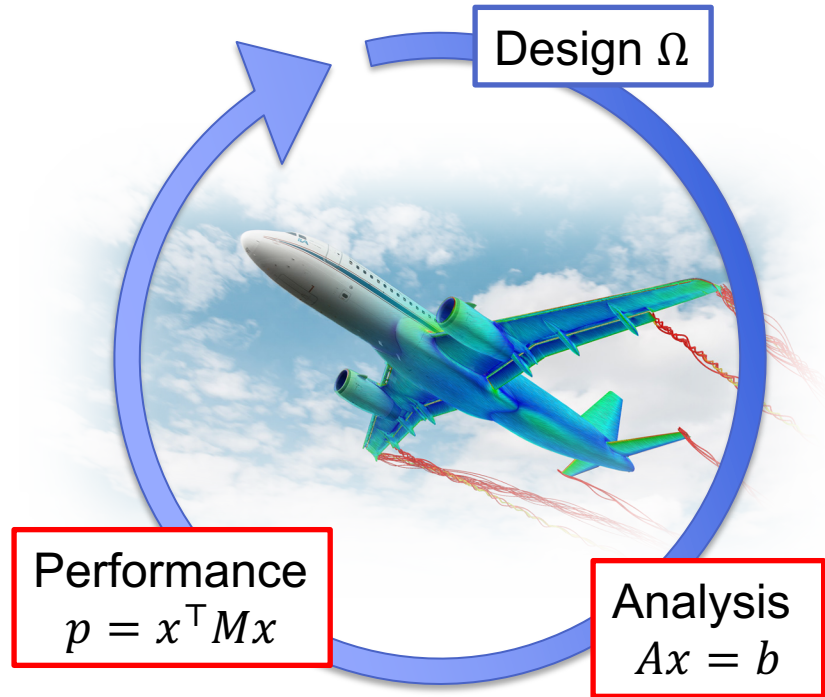
# Research

- Numerical methods for PDE problems of physical systems
  - Discretization methods
  - Solution methods
  - Optimization methods
- Implementation on parallel high-performance computing hardware
  - Parallel compute clusters
  - GPU and FPGA accelerators



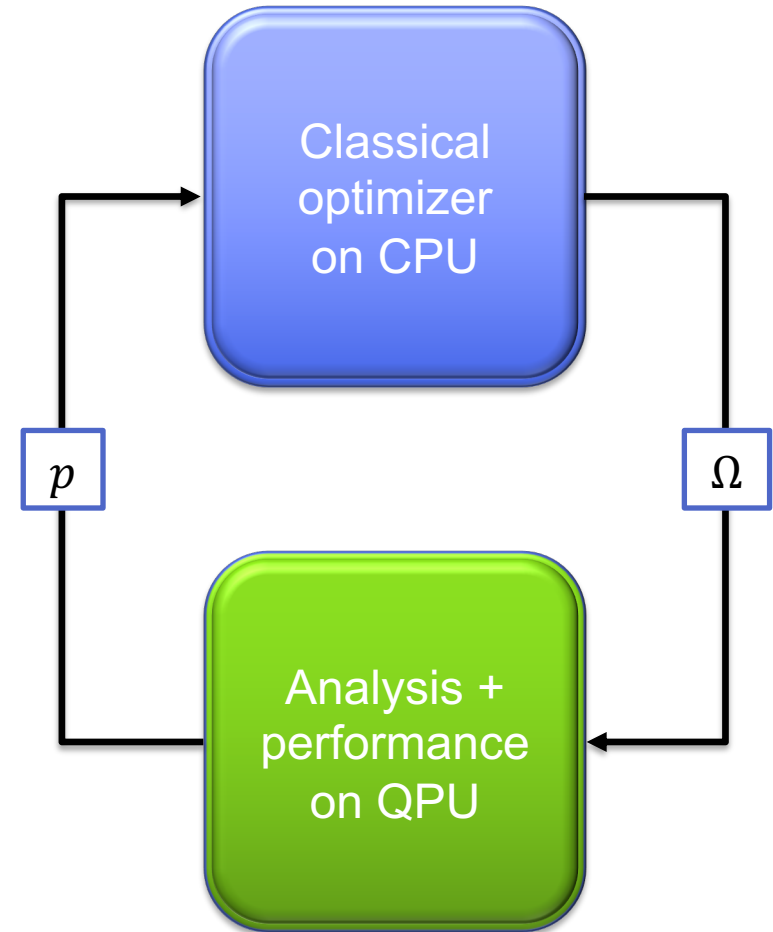
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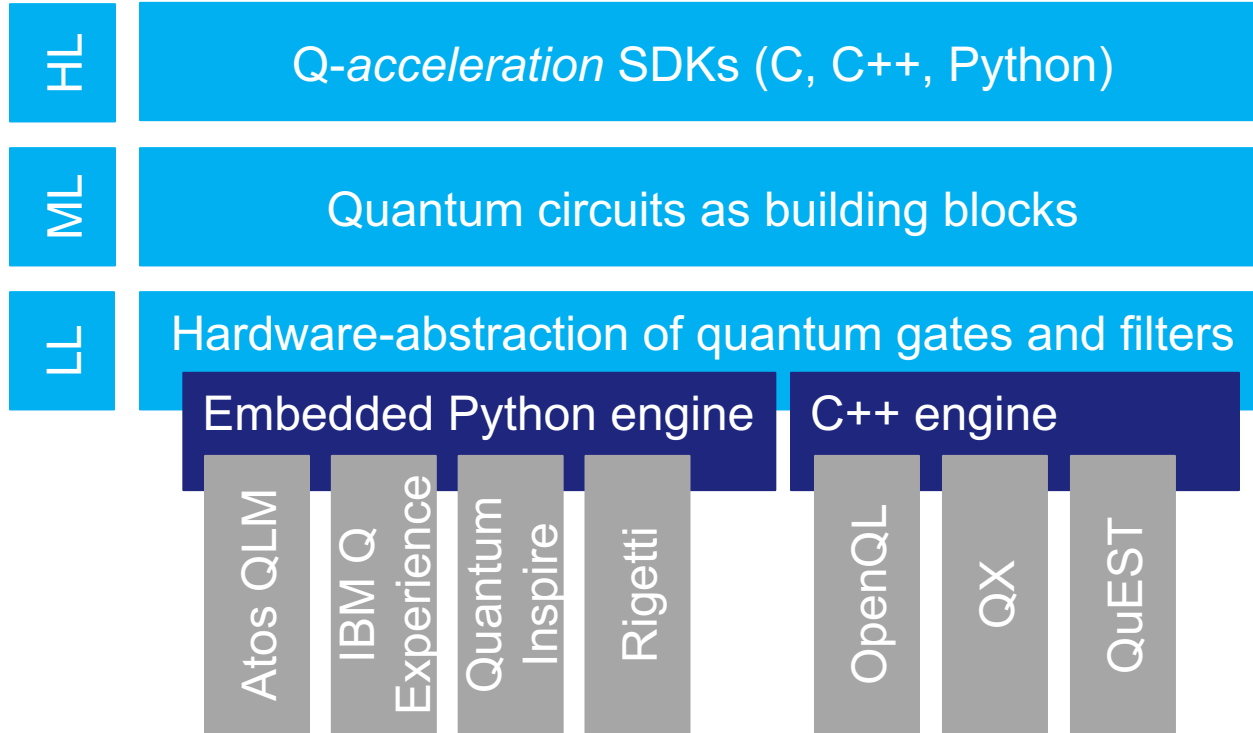


# Research

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  - **QPU accelerators**



# Kwantum expression template LIBrary



# The 'CUDA' of quantum computing

```
OPENQASM 2.0;
include "qelib1.inc";
qreg q[6];
creg c[6];
h q[0];
cu1(1.570796326794896558) q[1], q[0];
cu1(0.785398163397448279) q[2], q[0];
cu1(0.392699081698724139) q[3], q[0];
cu1(0.196349540849362070) q[4], q[0];
cu1(0.098174770424681035) q[5], q[0];
h q[1];
cu1(1.570796326794896558) q[2], q[1];
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h q[4];
cu1(1.570796326794896558) q[5], q[4];
h q[5];
swap q[0], q[5];
swap q[1], q[4];
swap q[2], q[3];
```

```
auto expr = qft(init());
```

```
QData<6, openQASMv2> q;
expr(q); // Quantum kernel
```

```
QJob* job = q.execute(...);
json result = job->get();
```

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swap q[0], q[5];
swap q[1], q[4];
swap q[2], q[3];
```

```
auto expr = qft(init());
```

```
QData<6, cQASMv1> q;
expr(q); // Quantum kernel
```

```
QJob* job = q.execute(...);
json result = job->get();
```

```
version 1.0
qubits 6
h q[0]
cr q[1], q[0], 1.570796326794896558
cr q[2], q[0], 0.785398163397448279
cr q[3], q[0], 0.392699081698724139
cr q[4], q[0], 0.196349540849362070
cr q[5], q[0], 0.098174770424681035
h q[1]
cr q[2], q[1], 1.570796326794896558
cr q[3], q[1], 0.785398163397448279
cr q[4], q[1], 0.392699081698724139
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h q[2]
cr q[3], q[2], 1.570796326794896558
cr q[4], q[2], 0.785398163397448279
cr q[5], q[2], 0.392699081698724139
h q[3]
cr q[4], q[3], 1.570796326794896558
cr q[5], q[3], 0.785398163397448279
h q[4]
cr q[5], q[4], 1.570796326794896558
h q[5]
swap q[0], q[5]
swap q[1], q[4]
swap q[2], q[3]
```

## Technology preview: *Integer arithmetic in LibKet*

- `QInt<#qubits>` class with overloaded arithmetic operators and automatic conversion between C++ integer types and JSON results

```
QInt<4> a = 4, b = 6;  
auto expr = a+b;
```

```
QData<8,cQASMv1> q(expr);  
QJob* job = q.execute_async(...);
```

```
// do other tasks
```

```
QInt<4> c = job->get();  
cout << c; // -> 10;
```



## Ongoing and planned activities

- **LibKet** project funded by 4TU.CEE (~50k)
- **Quantum simulator** project funded by NWO-XS (~50k) start in 2020
- BSc: Driebergen (Q-POSIT), vd Lans (practical QC), Looman (Q-integer arithmetic), Nugteren (Q-integer arithmetic), Ubbens (QLSA)
- MSc: Sigurdsson (practical QLSA) ongoing
- HP: v Loenen, Swart, vd Velde (VHQCA) just started

### Planned

- Quantum computer benchmark a la LINPACK (in LibKet)
- Collaborative research project on *practical* quantum-accelerated scientific computing with ... **YOU?**