Introduction to modern C++

Olve Maudal

C++ has evolved a lot since it was first introduced as "C with classes" with primitive support for object-oriented programming. In particular during the last 10-15 years the common use of the language has changed "dramatically" and the language itself has evolved accordingly. Modern C++ (C++11/14) is still very suitable for object-oriented programming, but now the language also provides good support for generic programming and functional programming. All of this while C++ is still a low-level language that can be used to create programs that compete with programs written in assembler both in terms of speed and size.

We start with a brief history of C++ before focusing on new features in C++11/14 and a demonstration of some typical modern programming techniques.

a 3.5 hour workshop (including lunch)
Lysaker, Jan 29, 2015

- Brief History of C and C++
- New features in C++11/14
- Generic Programming
- The future of C++

- Evolution of Ski Jumping
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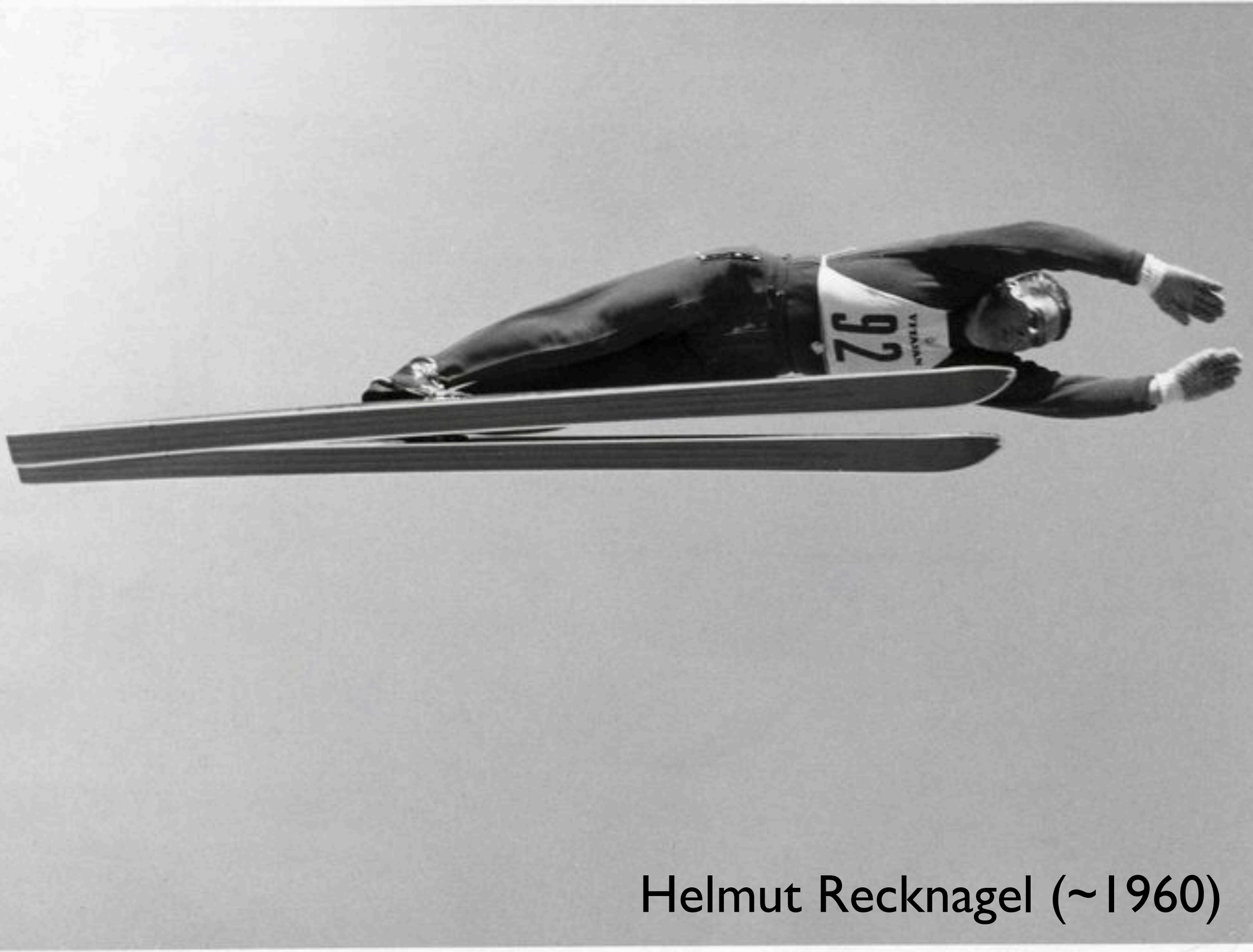
Evolution of Ski Jumping

http://www.aftenposten.no/fakta/innsikt/Da-skiene-ble-vinger-7459947.html

Opptrekk (1905)

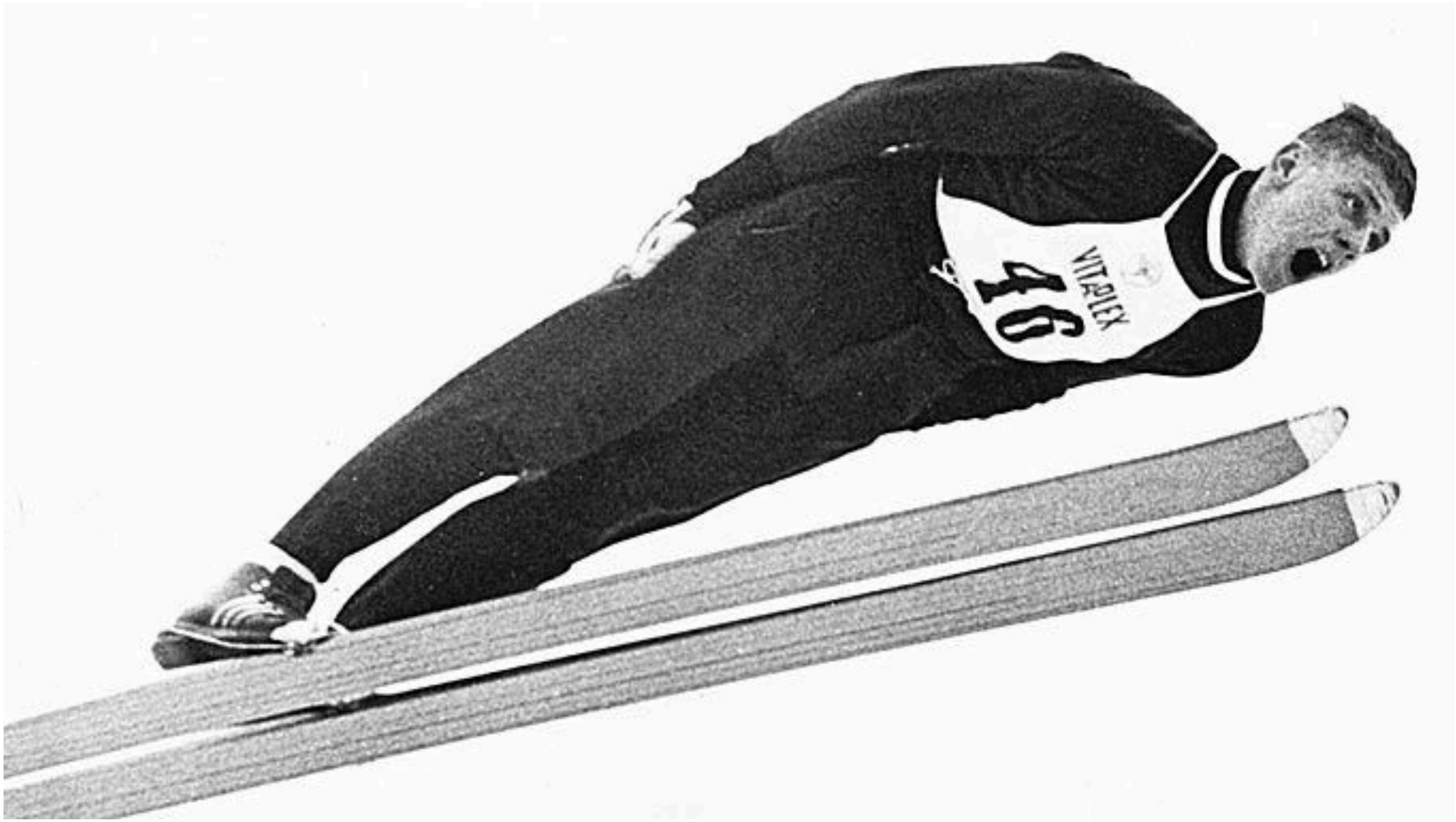
Kongsberg knekk, Birger Ruud (1947)

Matti Pietikäinen (1954)



Helmut Recknagel (~1960)

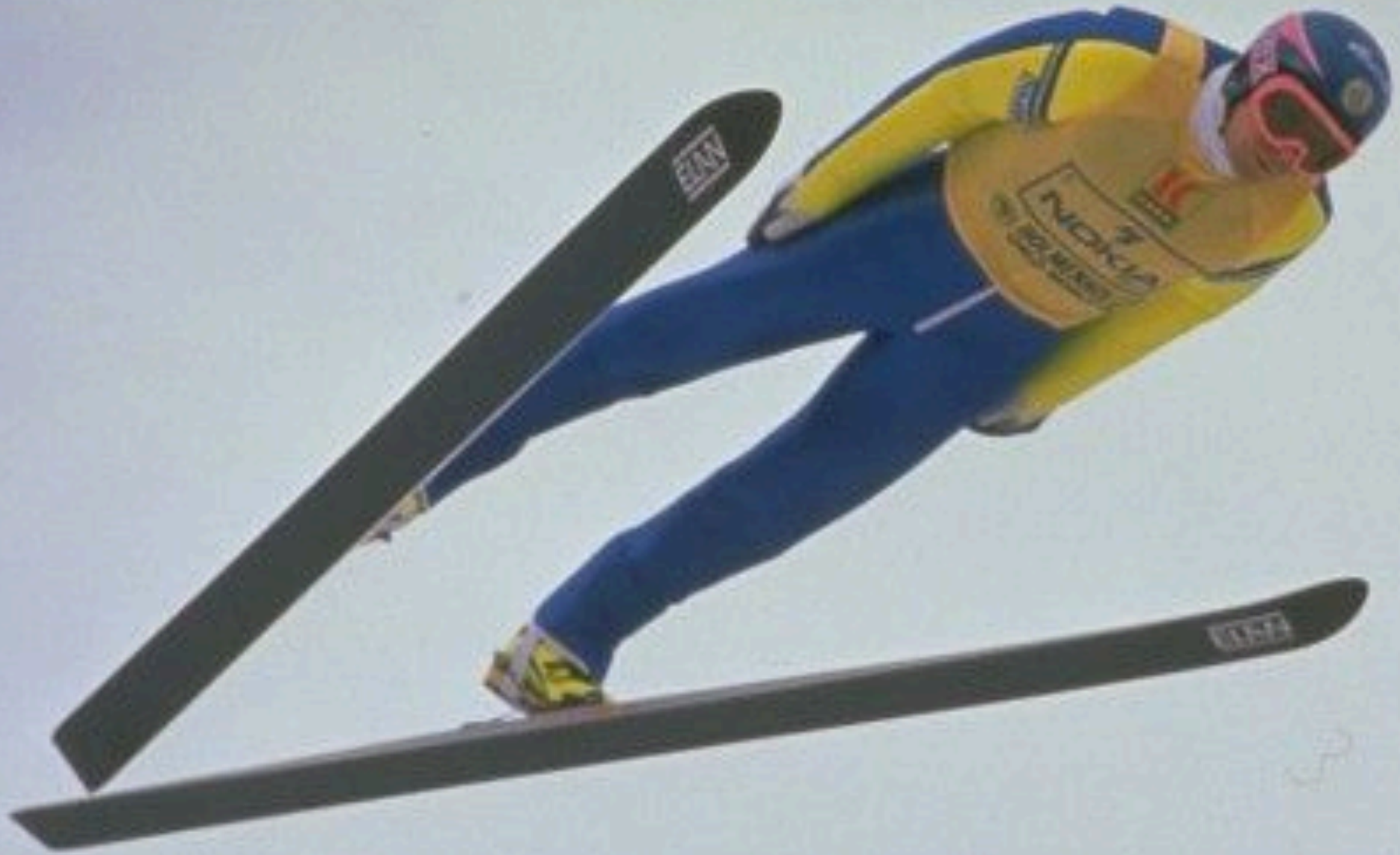
Finnestilen, Bjørn Wirkola (1964)



Finnestilen, Lars Grini (1967)

Sideflyt, Per Bergerud (1981)

Sideflyt, Per Bergerud (1983)



V-stilen, Jan Bokløv (1989)

Kamikaze, Noriaki Kasai (2004)

Dykkstil/W-stil, Andreas Wank (2012)

Brief History of C and C++

40's
Machine code, symbol tables and Assembler

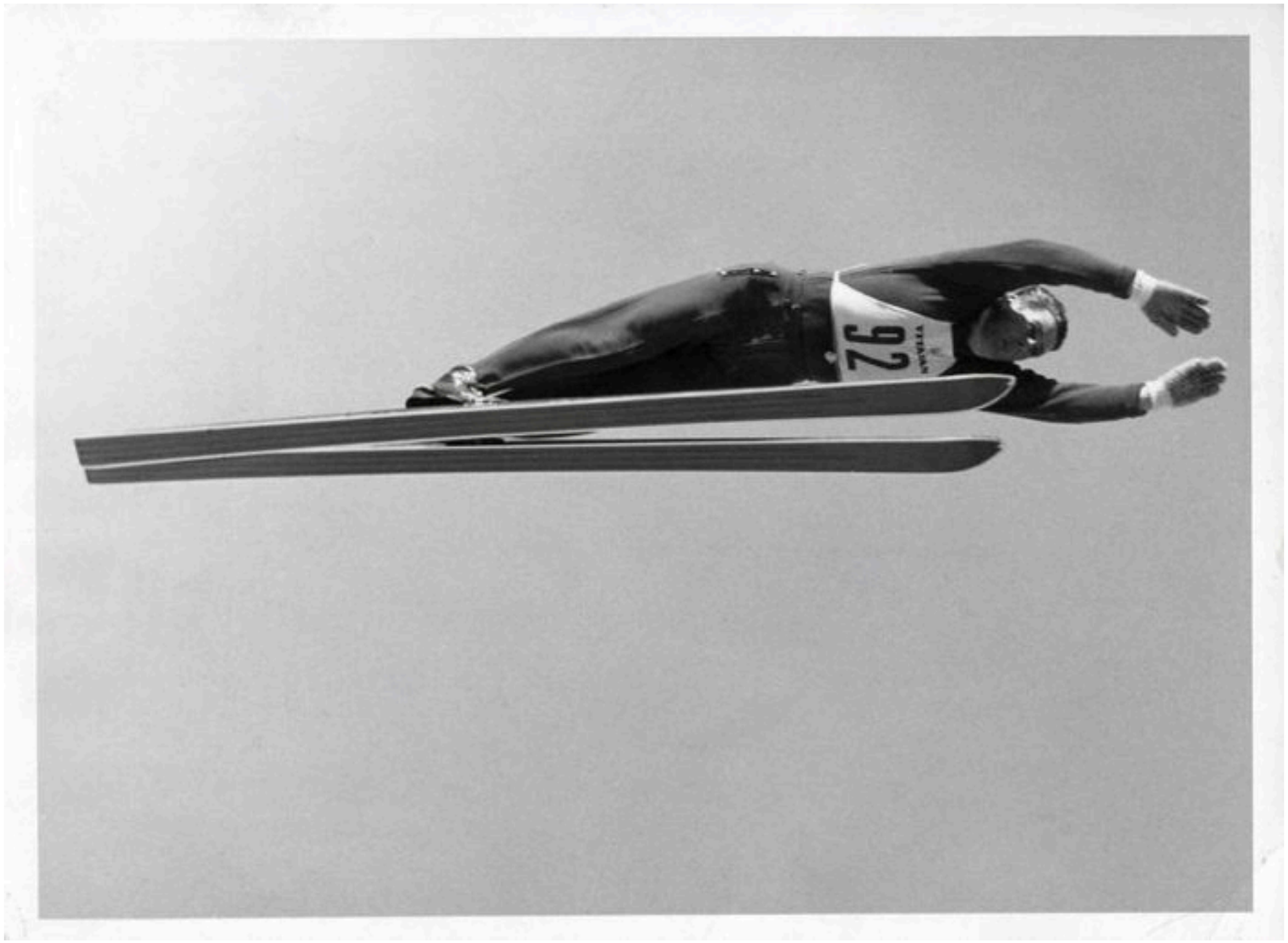
50's
Fortran, Lisp, Cobol, Algol

50's
Fortran, Lisp, Cobol, **Algol**

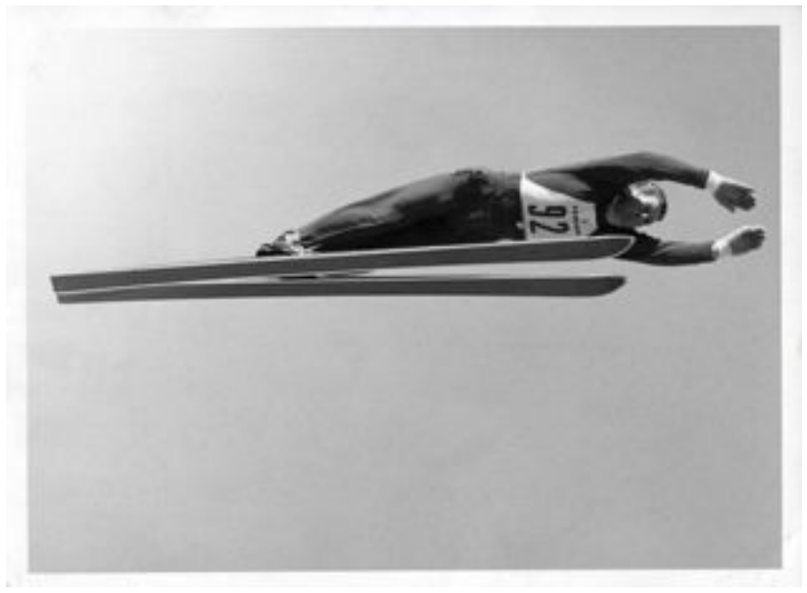
60's

many, many new languages appeared in this period. In particular...

CPL



60's
... and Simula



Both CPL and Simula were examples of **very** elegant languages...

... but there was also a need for brutally efficient languages

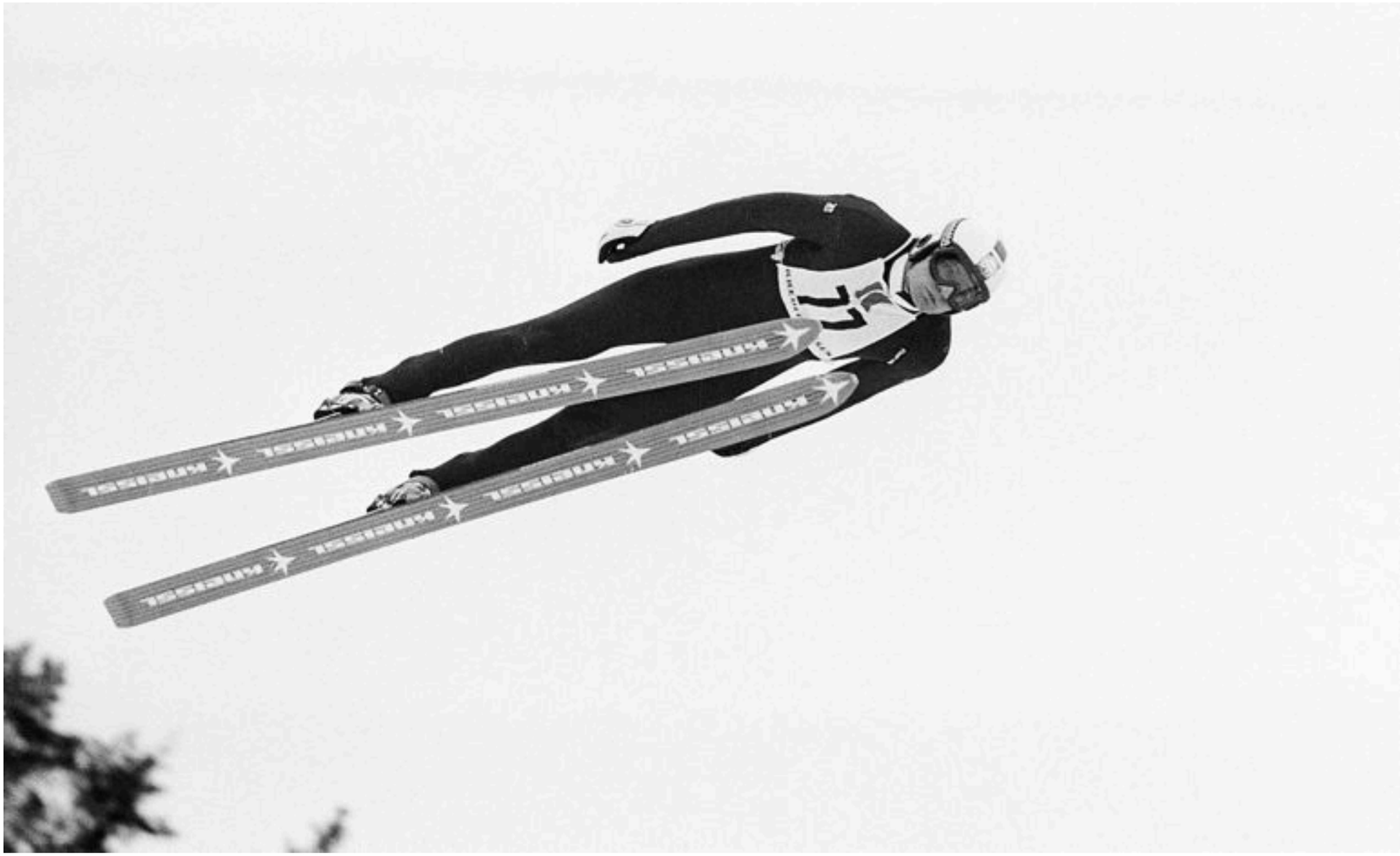
... but there was also a need for brutally efficient languages

70's
BCPL, B, C

After frustrating experience with BCPL, Bjarne Stroustrup combined the efficiency of C with some of the elegance from Simula...

80's

C with classes, C++/CFront, ARM



C++ was improved and became standardized

90's
X3J16, C++arm, WG21, C++98, STL

Ouch... Template Metaprogramming

C++03, TR1, Boost and other external libraries

While the language itself saw some minor improvements after C++98, Boost and other external libraries acted like laboratories for experimenting with potential new C++ features. Resulting in...

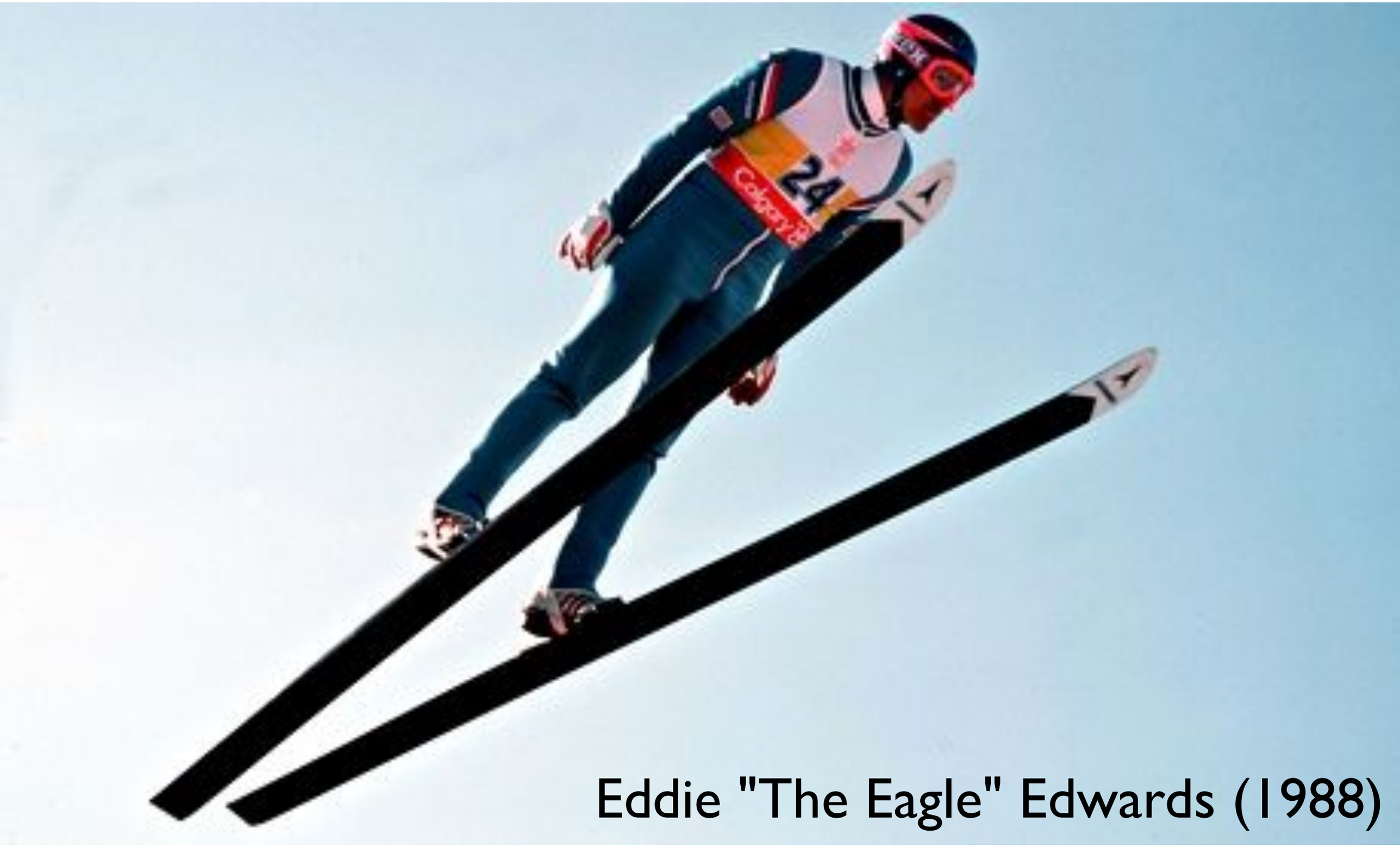
C++11/C++14

With the latest version C++ feels like a new language

The next major version is expected in 2017

The future of C++?

The success of C++ can also be meassured in that it has inspired a lot of other programming languages. Java, C# and D, just to mention a few



Eddie "The Eagle" Edwards (1988)

History of C

- CPL (1963)
- BCPL (1966)
- B (1969)
- Unix (1969-1973)
- Early C (1972)
- K&R C (1978)
- X3J11 established (1983)
- ANSI X3.159-1989 (C89 / ANSI C)
- ISO/IEC 9899:1990 (C90, same as C89)
- WG14 first meeting in 1994
- ISO/IEC 9899/AMD1:1995 (C95, minor update)
- ISO/IEC 9899:1999 (C99)
- ISO/IEC 9899:2011 (C11, current version)

History of C++

- PhD, Simula, BCPL (Cambridge)
- C with Classes (Cpre, 1979)
- First external paper (1981)
- C++ named (1983)
- CFront 1.0 (1985)
- TC++PL, Ed1 (1985)
- ANSI X3J16 meeting (1989)
- The Annotated C++ Reference Manual (1990)
- First WG21 meeting (1991)
- The Design and Evolution of C++ (1994)
- ISO/IEC 14882:1998 (C++98)
- ISO/IEC 14882:2003 (C++03)
- ISO/IEC TR 19768:2007 (C++TR1)
- ISO/IEC 14882:2011 (C++11)
- soon ISO/IEC 14882:2014 (C++14)

Modern C++ by Example

unless specified otherwise, all these code snippets should compile cleanly with a modern C++ compiler

```
#include <iostream>
#include <vector>

static void transmit_item(int i)
{
    std::cout << i << std::endl;
    // ...
}

static void transmit_log(const std::vector<int> & log)
{
    for (std::vector<int>::const_iterator it = log.cbegin();
         it != log.cend(); ++it)
        transmit_item(*it);
}

int main()
{
    std::vector<int> log{20,24,37,42,23,45,37};
    transmit_log(log);
}
```

Consider this small toy program...

```
#include <iostream>
#include <vector>

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{
    std::cout << i << std::endl;
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}

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        transmit_item(*it);
}

int main()
{
    std::vector<int> log{20,24,37,42,23,45,37};
    transmit_log(log);
}
```

```
$ g++-4.9 -std=c++1y -Wall -Wextra -pedantic -Werror foo.cpp && ./a.out
20
24
37
42
23
45
37
$
```

```
#include <iostream>
#include <vector>

static void transmit_item(int i)
{
    std::cout << i << std::endl;
    // ...
}

static void transmit_log(const std::vector<int> & log)
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}

int main()
{
    std::vector<int> log{20,24,37,42,23,45,37};
    transmit_log(log);
}
```

This shows a "traditional" way of looping through a collection of objects.

```cpp
#include <iostream>
#include <vector>

static void transmit_item(int i)
{
    std::cout << i << std::endl;
    // ...
}

static void transmit_log(const std::vector<int> & log)
{
    for (std::vector<int>::const_iterator it = log.cbegin();
         it != log.cend(); ++it)
        transmit_item(*it);
}

int main()
{
    std::vector<int> log{20,24,37,42,23,45,37};
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}
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```cpp
#include <iostream>
#include <vector>

static void transmit_item(int i)
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    for (std::vector<int>::const_iterator it = log.cbegin();
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        transmit_item(*it);
}

int main()
{
    std::vector<int> log{20,24,37,42,23,45,37};
    transmit_log(log);
}
```

But why do we have to write all this stuff? In this case, wouldn't it be nice if the compiler could just figure out which type we need to store the return value from `log.cbegin()`?

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#include <vector>

static void transmit_item(int i)
{
    std::cout << i << std::endl;
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}

static void transmit_log(const std::vector<int> & log)
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static void transmit_item(int i)
{
    std::cout << i << std::endl;
    // ...
}

static void transmit_log(const std::vector<int> & log)
{
    for (decltype(log.cbegin()) it = log.cbegin();
         it != log.cend(); ++it)
        transmit_item(*it);
}

int main()
{
    std::vector<int> log{20,24,37,42,23,45,37};
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}
```

```
#include <iostream>
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    for (decltype(log.cbegin()) it = log.cbegin();
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int main()
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    std::vector<int> log{20,24,37,42,23,45,37};
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`decltype` gives us type deduction in C++. Or even better...

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static void transmit_log(const std::vector<int> & log)
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    for (auto it = log.cbegin();
         it != log.cend(); ++it)
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}

int main()
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    std::vector<int> log{20,24,37,42,23,45,37};
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```

We can just use the new meaning of the keyword `auto`

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}
```

Looping through an array like this is something C++ programmers often do. So the language now provides a new way of looping through ranges of objects.

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#include <vector>

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static void transmit_log(const std::vector<int> & log)
{
    for (auto i : log)
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int main()
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```

Introducing:
range based for-loop.

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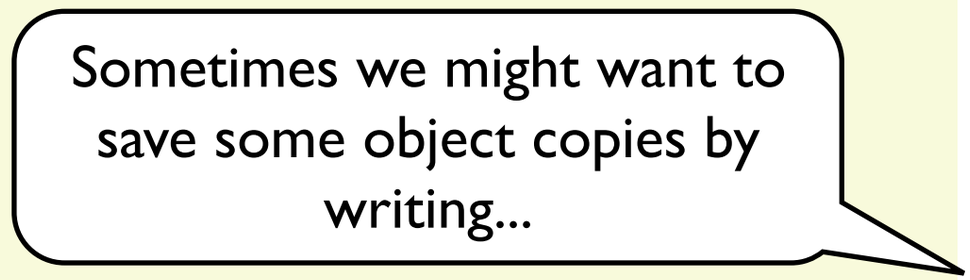

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    for (auto i : log)
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}

int main()
{
    std::vector<int> log{20,24,37,42,23,45,37};
    transmit_log(log);
}
```

Sometimes we might want to save some object copies by writing...

```
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#include <vector>

static void transmit_item(int i)
{
    std::cout << i << std::endl;
    // ...
}

static void transmit_log(const std::vector<int> & log)
{
    for (const auto & i : log)
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{
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```

But even for simple loops like this you will often see that **STL algorithms** are used instead.

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static void transmit_log(const std::vector<int> & log)
{
    std::for_each(log.begin(), log.end(), transmit_item);

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int main()
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Because it now works on both containers and arrays.

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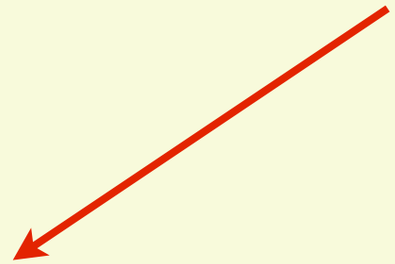

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And here we basically say: Just take this data object, it is yours, do whatever you want with it. I promise to never refer to it again after this.

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rvalue references and the corresponding **move semantics** are very important contributions to modern C++. It reduces the need to create copies of objects while still being able to use **value semantics** as a programming style (ie, avoiding the need to use pointers for everything).

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}

int main()
{
    std::vector<int> log{20,24,37,42,23,45,37};
    transmit_log(std::move(log), mycomp);
}
```

This is an example of
parameterize from above

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#include <iostream>
#include <vector>
#include <algorithm>

static void transmit_item(int i)
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    std::cout << i << std::endl;
    // ...
}

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    return lhs > rhs;
}

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```

I am now going to introduce function objects and lambdas. Let's first simplify the code, before introducing algorithms for filtering out and removing log values.

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        filter(int limit) : lim(limit) {}
        bool operator()(int i) { return i <= lim; };
        int lim;
    } myfilter(23);
    log.erase(std::remove_if(std::begin(log), std::end(log), myfilter),
              std::end(log));
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int main()
{
    std::vector<int> log{20,24,37,42,23,45,37};
    transmit_log(std::move(log));
}
```

Here we have created code to remove all log items that are 23 or below.

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}

int main()
{
    std::vector<int> log{20,24,37,42,23,45,37};
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}
```

Notice how we have created a "function" on the fly by overloading the call operator on an object. This is an example of a **function object**, sometimes called a **functor**.

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Suppose we want to parameterize from above again, by passing in the limit.

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Such function objects are sometimes very useful. New in C++11 is a convenient syntax for creating these functions.

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int main()
{
    std::vector<int> log{20,24,37,42,23,45,37};
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```

This is a lambda expression that creates a function object on the "fly". We are **capturing** the value of the variable `limit` and using it to initialize the function object.

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You can of course also pass function objects around as any other objects.

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    std::function<bool (int)> myfilter = [limit](int i) { return i <= limit; };
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... and the same is true for the log. Anything that we can iterate over, and that contains some items that we can transmit should be fine.

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And while we are at it, let's generalize the code for `transmit_item` as well

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```
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int main()
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Here we will get an understandable compile error if the type of the log items are not of integral type. However, you can, with some work, define your own traits and constraints. Eg, something like this:

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There are some proposals for the next versions of C++ to include better syntax for such constraints.

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This proposal is a step towards something called Concepts. I am not going to explain that, so let's clean up the code so I can show one final thing.

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```
#include <iostream>
#include <vector>
#include <algorithm>

static void transmit_item(int i)
{
    std::cout << i << std::endl;
    // ...
}

static size_t transmit_log(const std::vector<int> & log)
{
    std::for_each(std::begin(log), std::end(log), transmit_item);
    return log.size();
}

int main()
{
    std::vector<int> log{20,24,37,42,23,45,37};
    size_t items = transmit_log(log);
    std::cout << "# " << items << std::endl;
}
```

```
#include <iostream>
#include <vector>
#include <algorithm>

static void transmit_item(int i)
{
    std::cout << i << std::endl;
    // ...
}

static size_t transmit_log(const std::vector<int> & log)
{
    std::for_each(std::begin(log), std::end(log), transmit_item);
    return log.size();
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}
```

Transmitting the data probably takes some time, and we might want to do something else while waiting for the log to be transmitted. Let's simulate that, and show an example of how concurrency is supported in modern C++.

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#include <vector>
#include <algorithm>

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}

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```cpp
#include <iostream>
#include <vector>
#include <algorithm>
#include <chrono>
#include <thread>

static void transmit_item(int i)
{
    std::cout << i << std::endl;
    std::this_thread::sleep_for(std::chrono::milliseconds(200));
    // ...
}

static size_t transmit_log(const std::vector<int> & log)
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    std::for_each(std::begin(log), std::end(log), transmit_item);
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    std::vector<int> log{20,24,37,42,23,45,37};
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#include <iostream>
#include <vector>
#include <algorithm>
#include <chrono>
#include <thread>
#include <future>

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{
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    std::for_each(std::begin(log), std::end(log), transmit_item);
    return log.size();
}

int main()
{
    std::vector<int> log{20,24,37,42,23,45,37};
    auto res = std::async(std::launch::async, transmit_log, log);
    size_t items = res.get();
    std::cout << "# " << items << std::endl;
}
```

```
#include <iostream>
#include <vector>
#include <algorithm>
#include <chrono>
#include <thread>
#include <future>

static void transmit_item(int i)
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}
```

```
$ g++-4.9 -std=c++1y -Wall -Wextra -pedantic -Werror -pthread foo.cpp
```

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#include <iostream>
#include <vector>
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    size_t items = res.get();
    std::cout << "# " << items << std::endl;
}
```

... and now we can do some stuff between calling transmit_log until we need the result from calling that function.

```cpp
#include <iostream>
#include <vector>
#include <algorithm>
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static void transmit_item(int i)
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    std::cout << i << std::endl;
    std::this_thread::sleep_for(std::chrono::milliseconds(200));
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static size_t transmit_log(const std::vector<int> & log)
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int main()
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    // ...
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static size_t transmit_log(const std::vector<int> & log)
{
    std::for_each(std::begin(log), std::end(log), transmit_item);
    return log.size();
}

int main()
{
    std::vector<int> log{20,24,37,42,23,45,37};
    auto res = std::async(std::launch::async, transmit_log, log);
    for (int i=0; i<5; i++) {
        std::this_thread::sleep_for(std::chrono::milliseconds(77));
        std::cout << "do something else..." << std::endl;
    }
    size_t items = res.get();
    std::cout << "# " << items << std::endl;
}
```

```
#include <iostream>
#include <vector>
#include <algorithm>
#include <chrono>
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static void transmit_item(int i)
{
    std::cout << i << std::endl;
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    return log.size();
}

int main()
{
    std::vector<int> log{20,24,37,42,23,45,37};
    auto res = std::async(std::launch::async, transmit_log, log);
    for (int i=0; i<5; i++) {
        std::this_thread::sleep_for(std::chrono::milliseconds(123));
        std::cout << "do something else..." << std::endl;
    }
    size_t items = res.get();
    std::cout << "# " << items << std::endl;
}
```

```cpp
#include <iostream>
#include <vector>
#include <algorithm>
#include <chrono>
#include <thread>
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static void transmit_item(int i)
{
    std::cout << i << std::endl;
    std::this_thread::sleep_for(std::chrono::milliseconds(200));
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}

static size_t transmit_log(const std::vector<int> & log)
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    auto res = std::async(std::launch::async, transmit_log, log);
    for (int i=0; i<5; i++) {
        std::this_thread::sleep_for(std::chrono::milliseconds(123));
        std::cout << "do something else..." << std::endl;
    }
    size_t items = res.get();
    std::cout << "# " << items << std::endl;
}
```

```
20
do something else...
24
do something else...
do something else...
37
do something else...
42
do something else...
23
45
37
# 7
```

Modern C++
- move semantics (rvalue references, value semantics)
- type deduction (decltype, auto)
- better support for OOP (attributes, member initialization, delegation)
- compile time computation (templates, static_assert, constexpr)
- template metaprogramming (traits, constraints, concepts)
- robust resource management (RAII, unique, shared)
- high-order parallelism (atomic, mutex, async, promises and futures)
- functional programming (algorithms, lamdas, closures, lazy evaluation)
- misc (chrono, user-defined literals, regex, uniform initialization)

!