ClangIR: Upstreaming an Incubator Project

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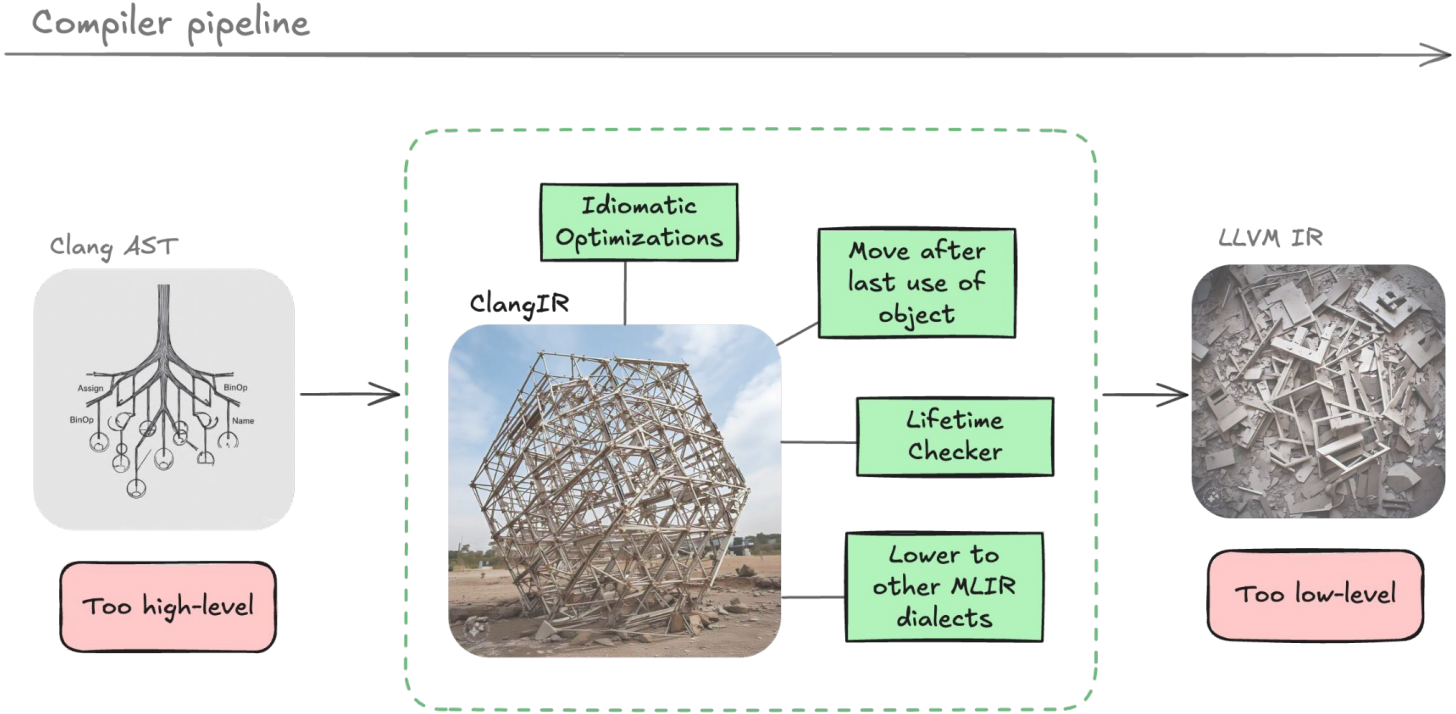
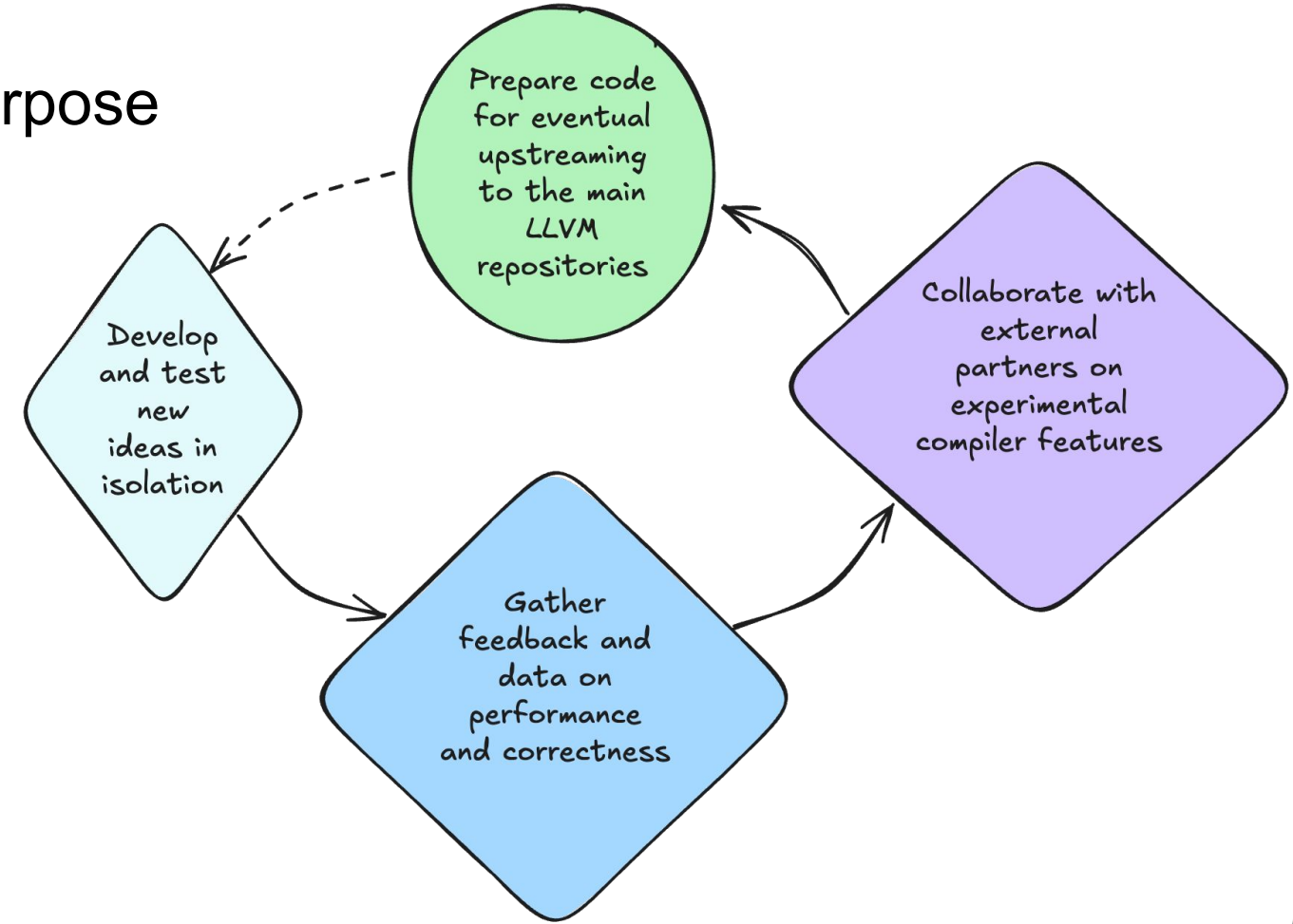
ClangIR recap

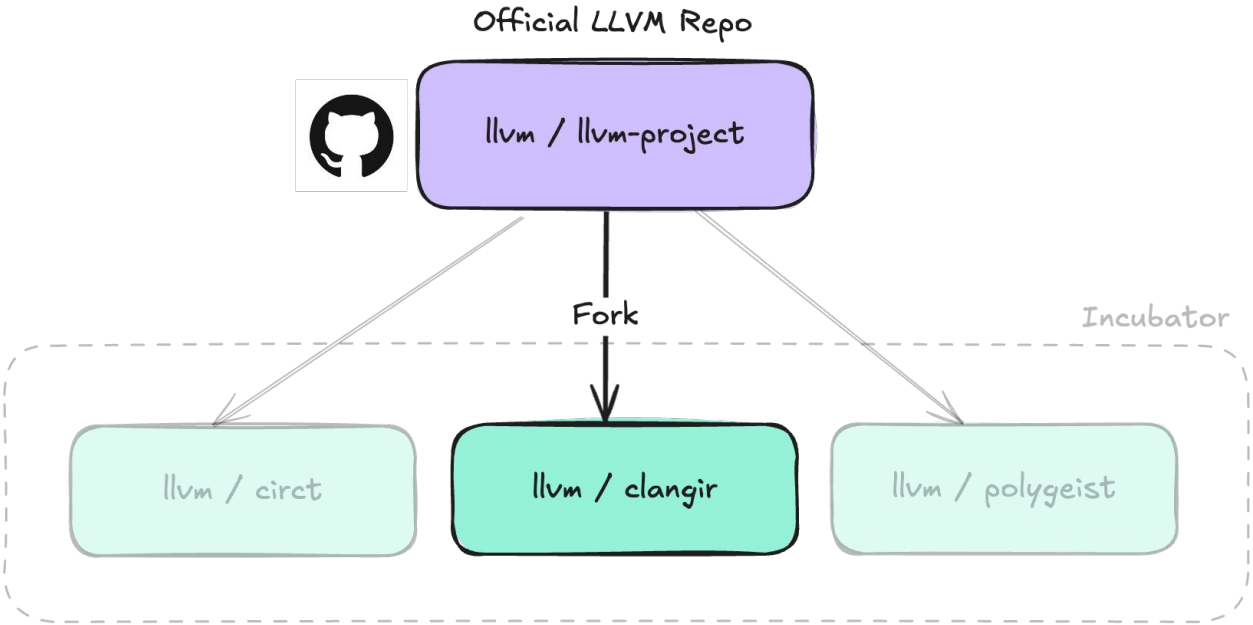


ClangIR timeline

ClangIR timeline

Incubator's purpose




Official LLVM Repo
llvm / llvm-project
Fork
Incubator
llvm / circt
llvm / clangir
llvm / polygeist

From RFC to incubator

C/C++ MLIR frontend working group.

Move to LLVM incubator.

Incubation advantages

Ability to use CI and other LLVM project infrastructure

Project visibility

- Path for building upstreaming agreement
- The LLVM umbrella attracts more contributors

Incubation downsides

Less visibility than llvm-project

Users prefer llvm-project over a fork

Investment risk

- Might never meet the bar
- Never upstreamed

Incubation process is not formalized, consensus can be challenging

Life in clangir incubator

clangir.org guides

LLVM practices enforced ⚠️

Paving the way for upstreaming

Additional freedom for exploration 👩🏽‍🔬

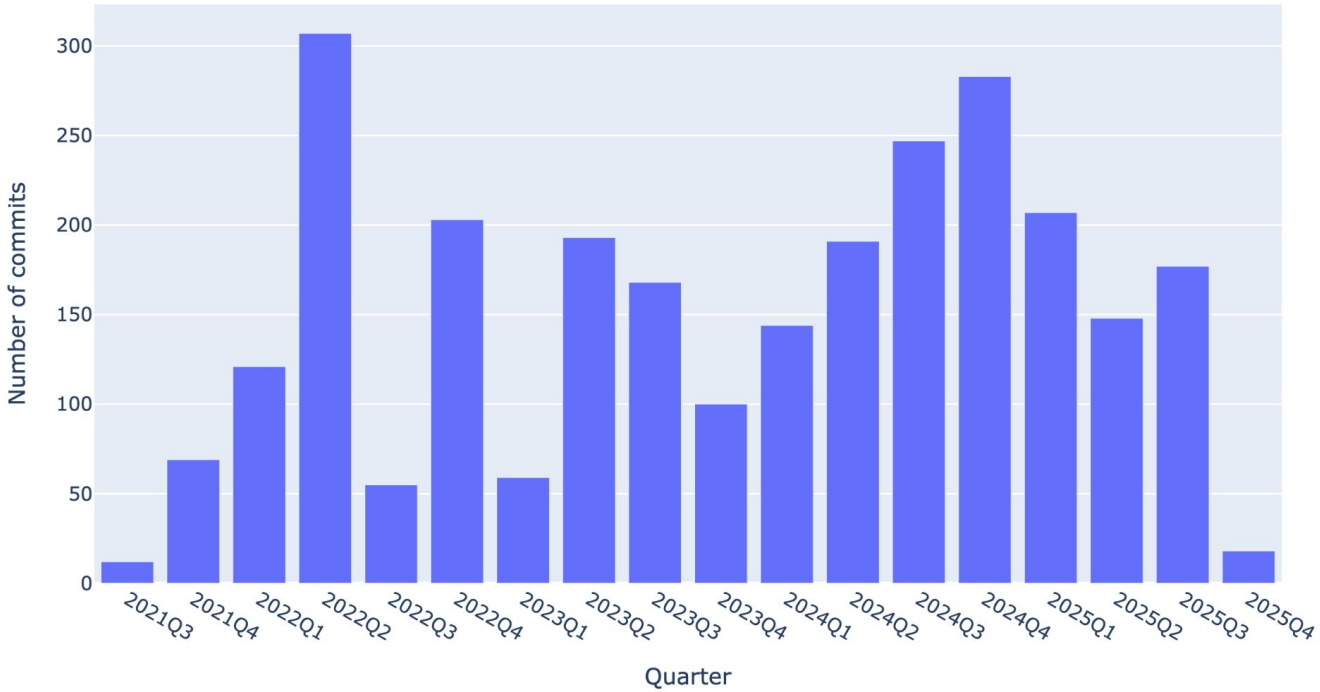
Challenges

Wait! I heard this was working

Always in motion is top-of-tree 🏃

Upstream and incubator differences

Contributions



Authors come and go ✈️

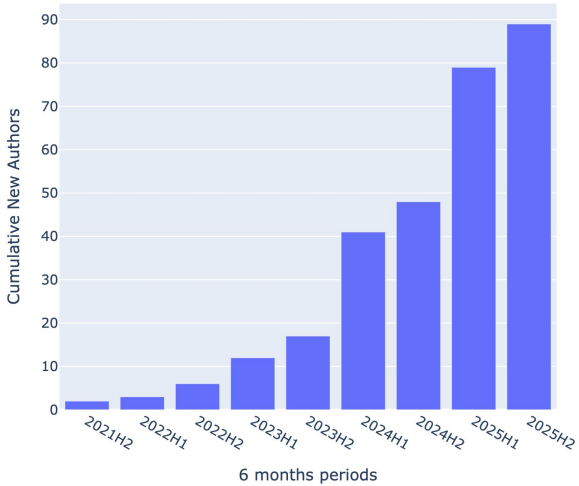
Contribution span varies

Good for incremental pieces (e.g. builtins)

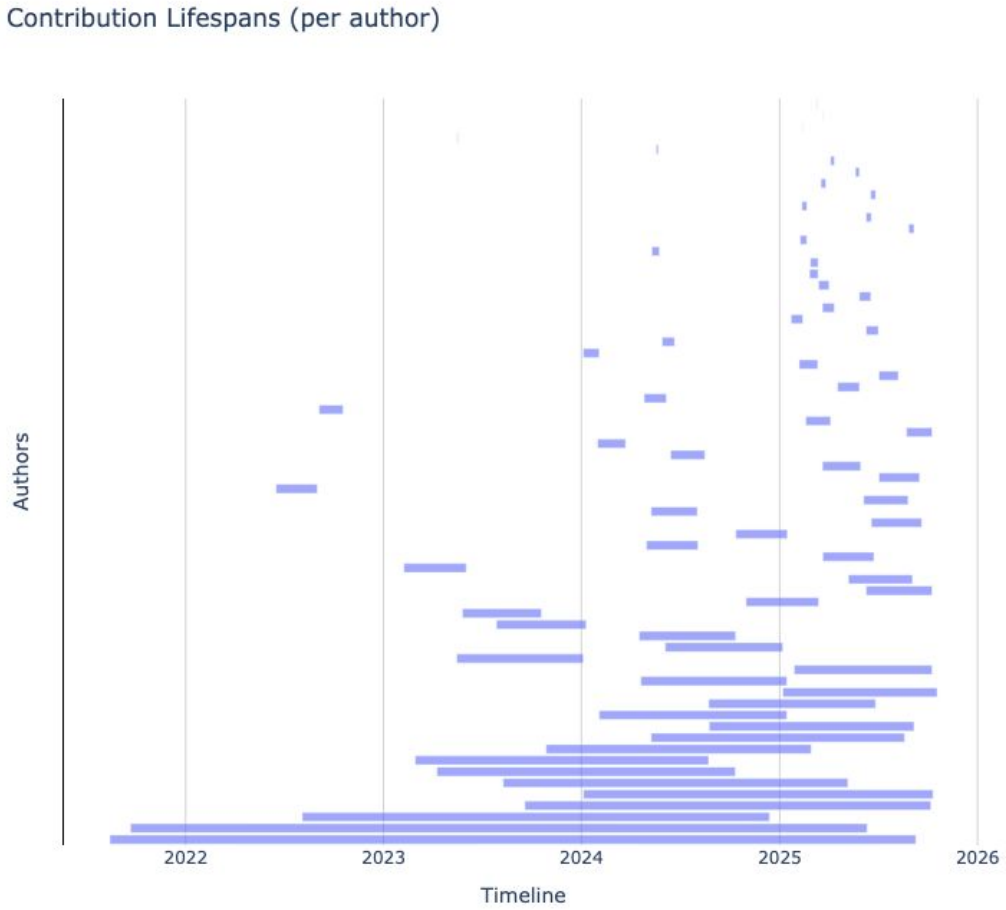
    Especially attractive to newcomers

Bad for solidifying expertise

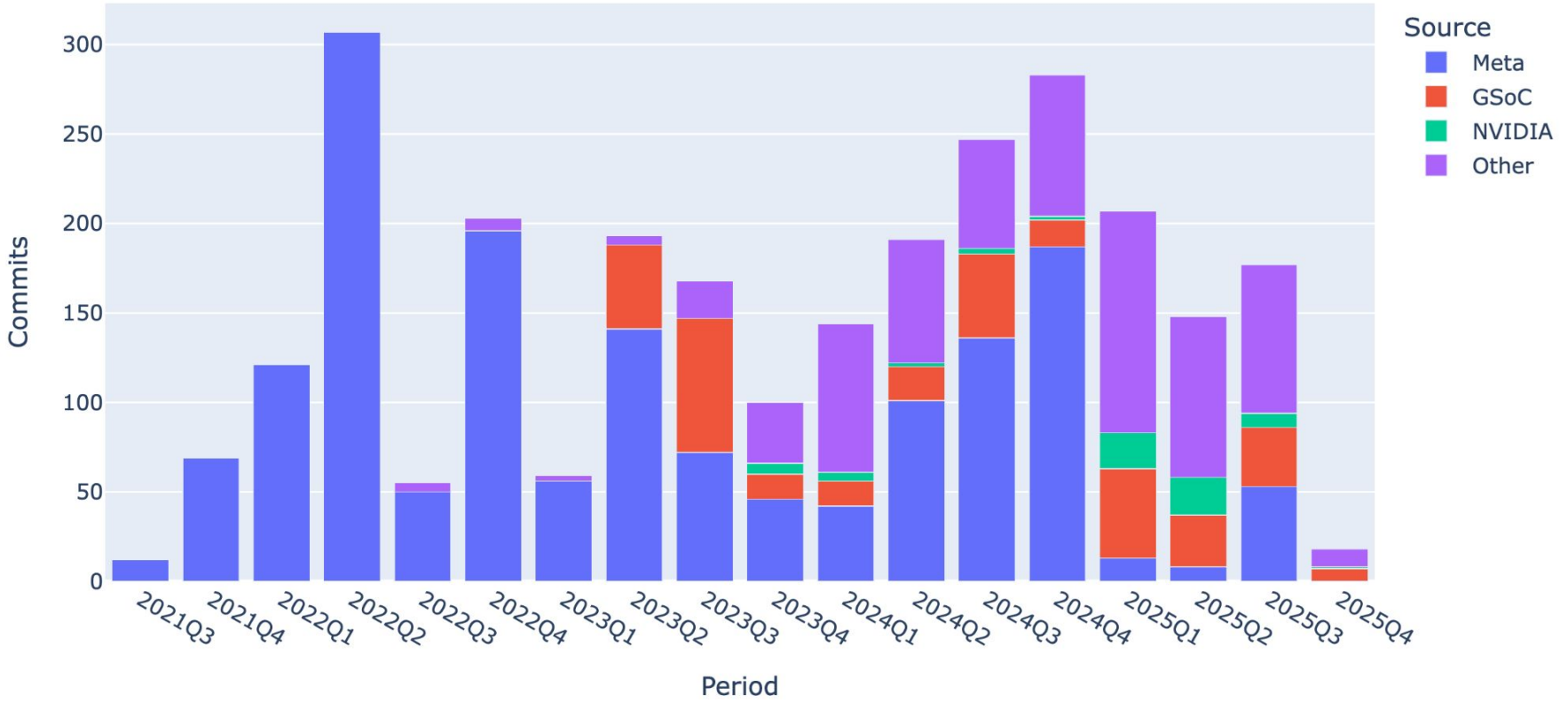
Some couldn't wait for upstreaming



23 only contributed once



Incubator: Grouped Commits per Quarter



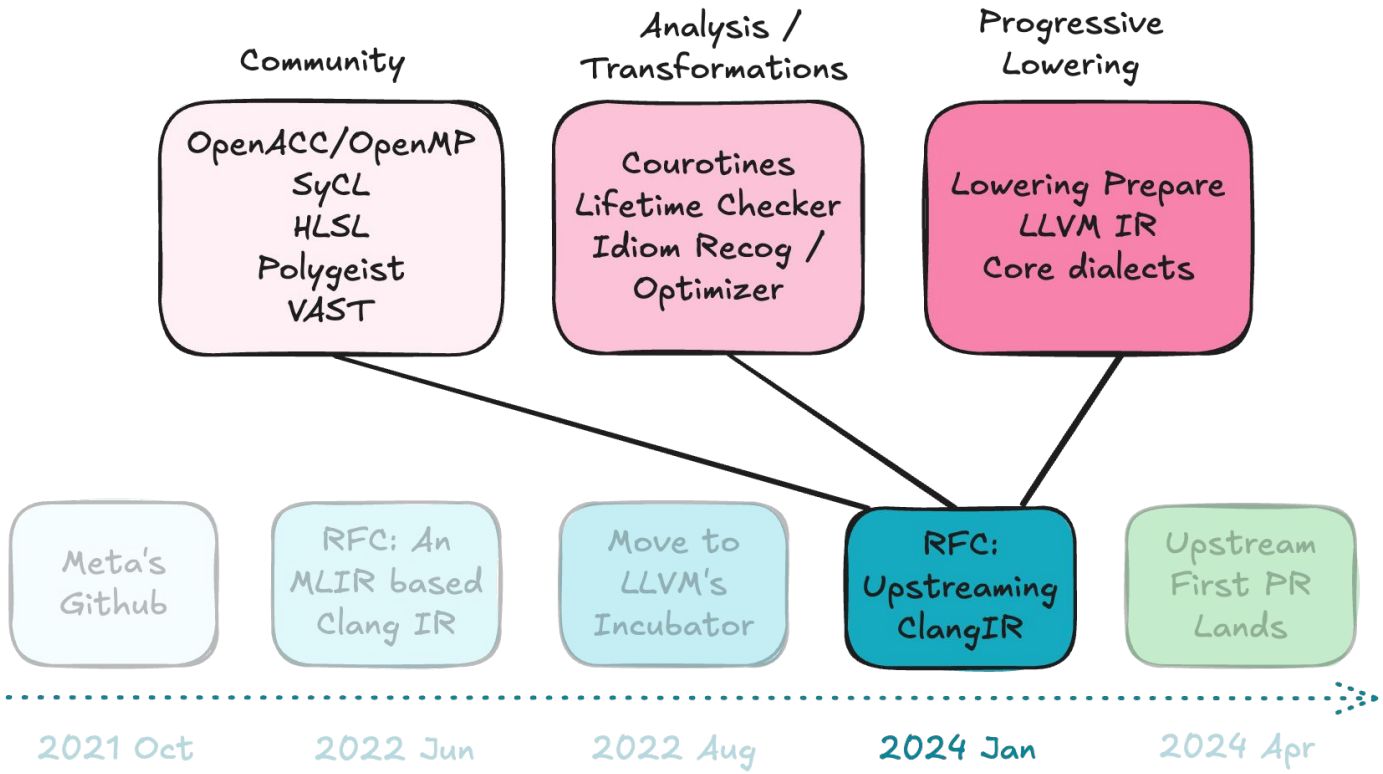
Incubator - In hindsight

Challenging

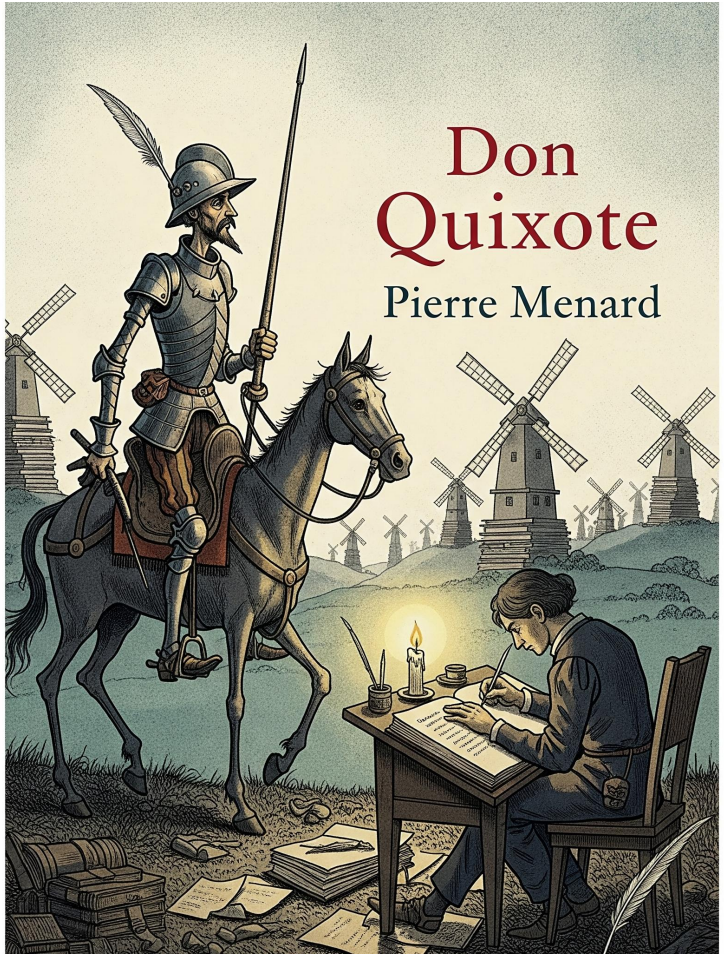
… but worth it

Community up and running

Steady progress in upstreaming


Community
Analysis / Transformations
Progressive Lowering
OpenACC/OpenMP
SyCL
HLSL
Polygeist
VAST
Courotines
Lifetime Checker
Idiom Recog / Optimizer
Lowering Prepare
LLVM IR
Core dialects
Meta's Github
RFC: An MLIR based Clang IR
Move to LLVM's Incubator
RFC: Upstreaming ClangIR
Upstream First PR Lands
2021 Oct
2022 Jun
2022 Aug
2024 Jan
2024 Apr

Upstreaming begins 🚀

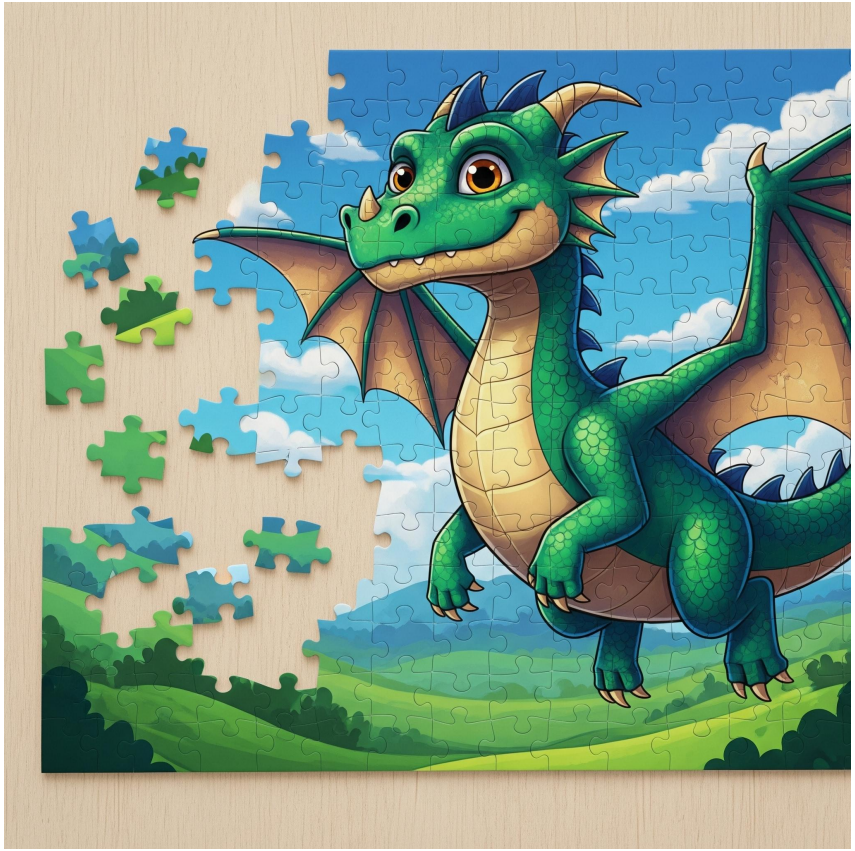


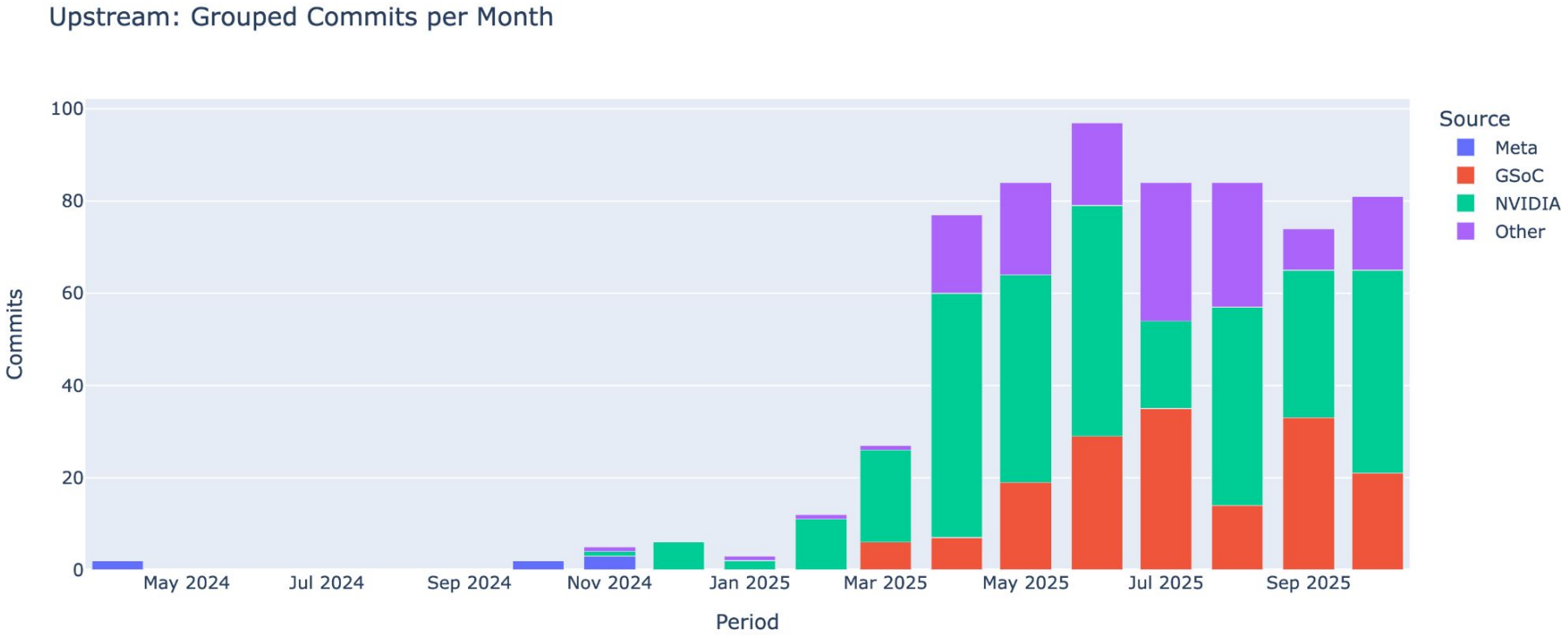
A useful accident

- The contributors to the upstreaming effort are mostly different than the original contributors to the incubator
- Pierre Menard: Author of the Quixote
  - New contributors creating the same code
  - Fresh perspectives bring new context
- Wax on, wax off
  - Learning by going through the motions
- Result: twice as many people have deep understanding of the code

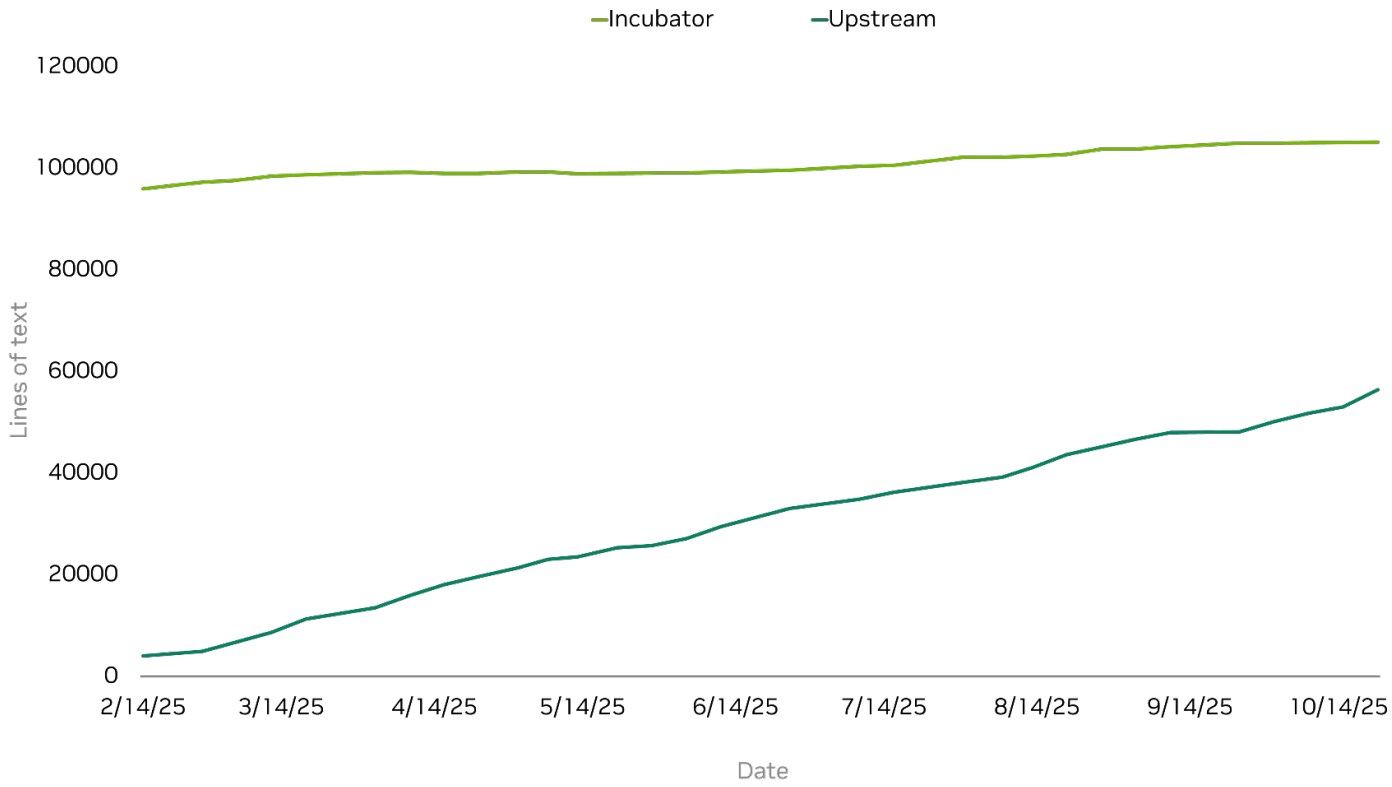
Going live!

- Doing everything *as if* from scratch
  - The clang maintainers didn't want the incubator project merged en masse
  - There was no practical way to "replay" the incubator commits
- Each PR for upstreaming code is treated exactly as if it were a new contribution
- Each PR is held to the same standards as any LLVM contribution
  - Contributor must thoroughly understand the code
  - All functionality must be tested
  - Conformance to coding standards
  - Single purpose
  - Isolated change, as small as possible

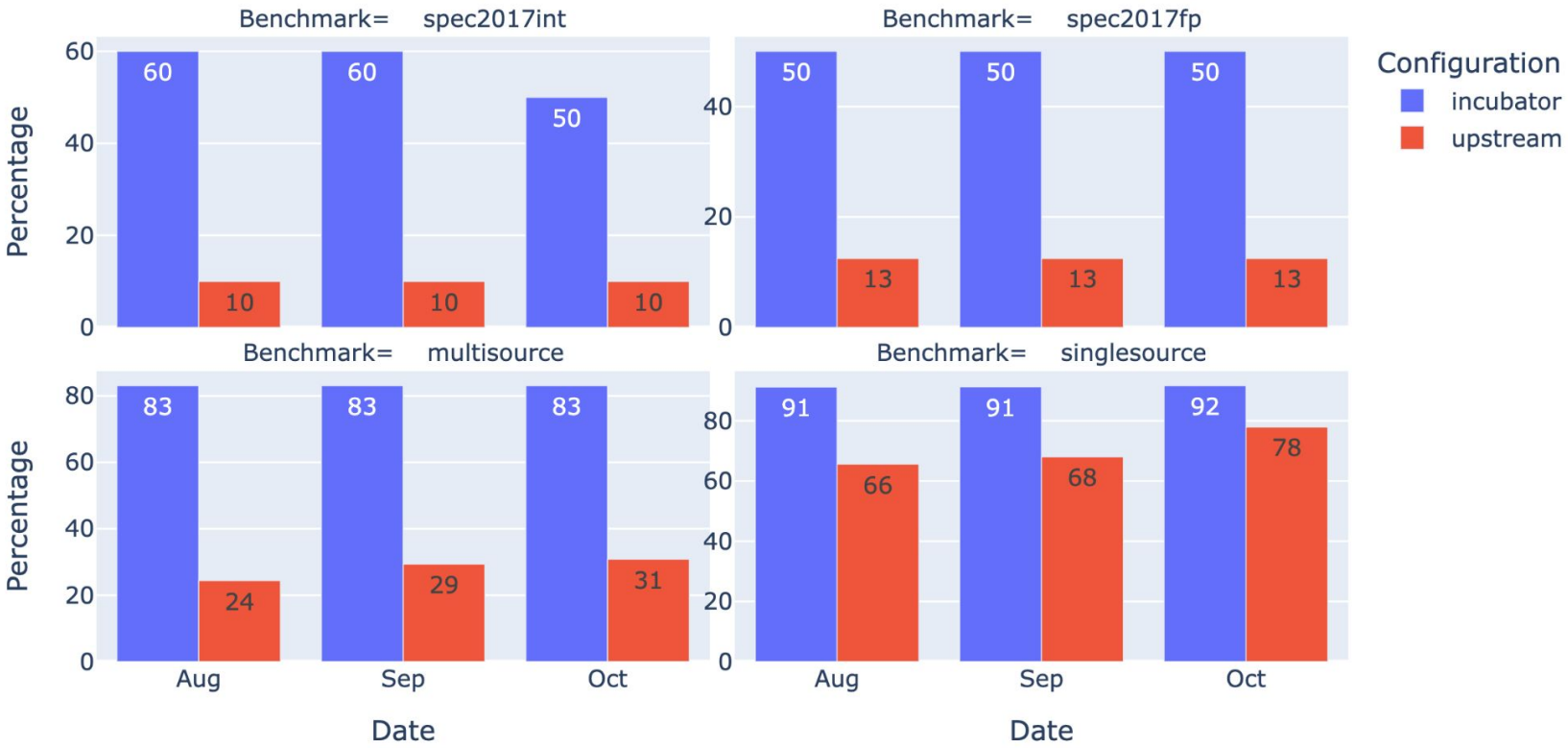



Upstream: Grouped Commits per Month
Commits
100
80
60
40
20
0
May 2024
Jul 2024
Sep 2024
Nov 2024
Jan 2025
Mar 2025
May 2025
Jul 2025
Sep 2025
Period
Source
Meta
GSoC
NVIDIA
Other

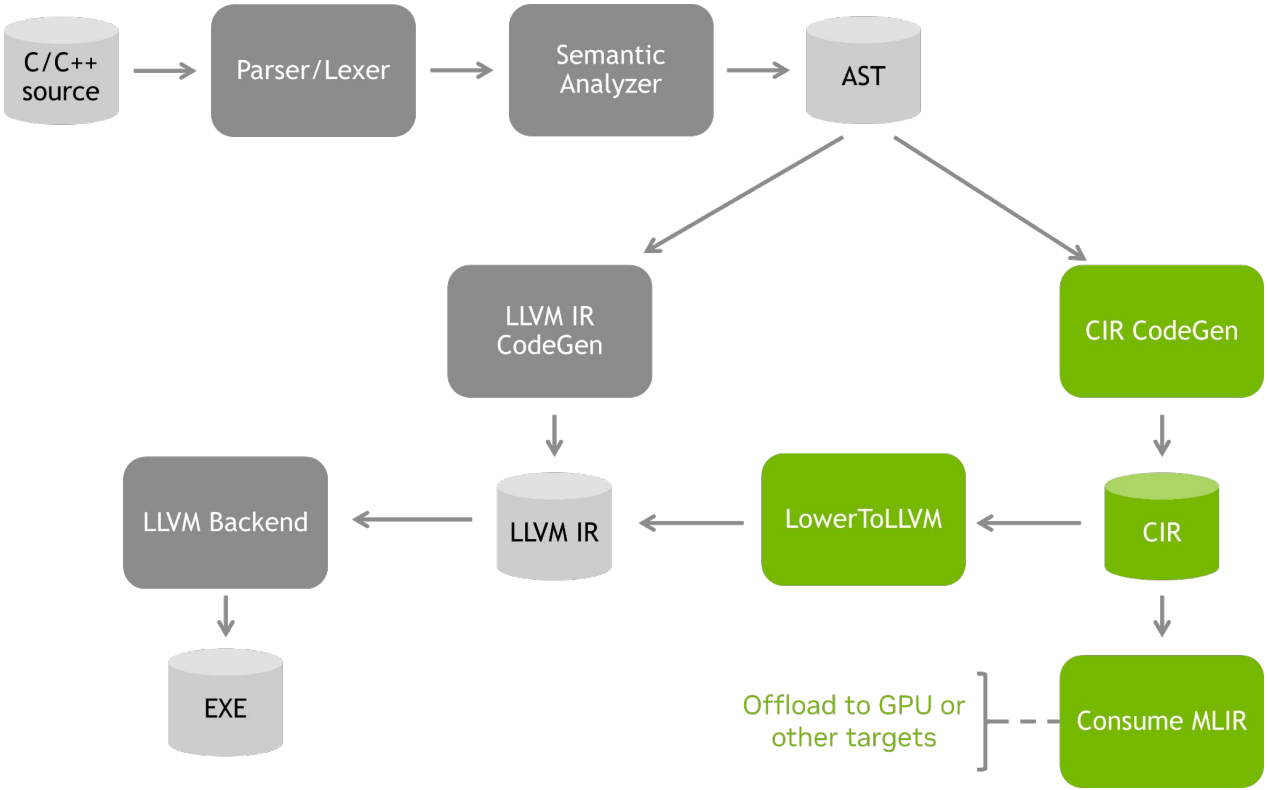
Upstreaming progress



Passing Benchmarks (% of completion)



CIR Won’t Always Go To LLVM IR



Growing pains

- Build problems
  - The ClangIR build sometimes gets broken by changes in MLIR or other parts of clang
  - Sometimes the incubator code is using AST interfaces that no longer exist upstream
    - This is part of the pain of rebasing the incubator
    - It also adds some overhead to the upstreaming process
- Chasing two moving targets
  - The incubator tried to follow the structure of clang's LLVM IR codegen
    - …at the time the incubator code was written
  - Development is still proceeding in the incubator
  - Upstreaming pulls from the incubator, but we also need to check for changes in LLVM IR codegen

Trying to synchronize with classic codegen

- We want generated CIR to be semantically equivalent to the LLVM IR clang generates
- LLVM IR codegen is always changing
- Strategies
  - We've tried to use the same code structures whenever possible
    - CIRGenFunction looks very much like CodeGenFunction
  - Most of our tests check LLVM IR lowering from CIR and direct LLVM IR codegen
    - This will alert us when something changes in the non-CIR path
  - Eventually we'd like to run all existing codegen tests with CIR enabled

Embarrassingly Parallel Code?

clang/lib/CIR/CodeGen/CIRGenExprScalar.cpp

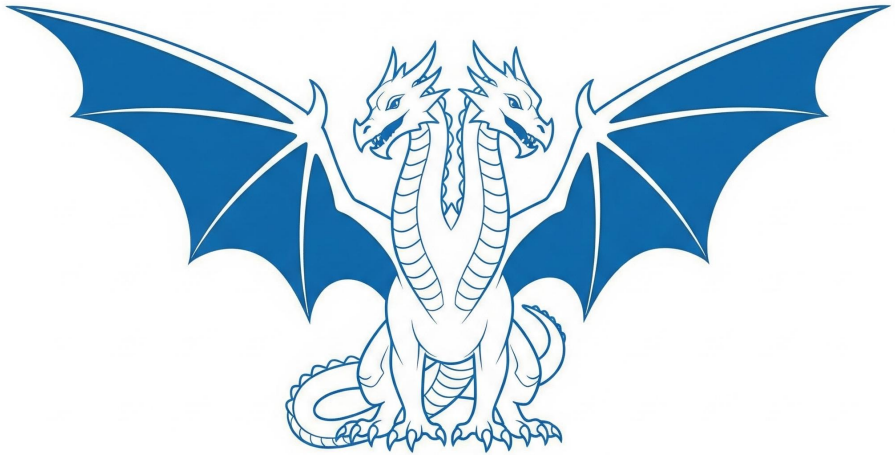
```
  // Unary Operators.
  mlir::Value VisitUnaryPostDec(const UnaryOperator *e) {
    LValue lv = cgf.emitLValue(e->getSubExpr());
    return emitScalarPrePostIncDec(e, lv,
cir::UnaryOpKind::Dec,
                                   false);
  }
  mlir::Value VisitUnaryPostInc(const UnaryOperator *e) {
    LValue lv = cgf.emitLValue(e->getSubExpr());
    return emitScalarPrePostIncDec(e, lv,
cir::UnaryOpKind::Inc,
                                   false);
  }
  mlir::Value VisitUnaryPreDec(const UnaryOperator *e) {
    LValue lv = cgf.emitLValue(e->getSubExpr());
    return emitScalarPrePostIncDec(e, lv,
cir::UnaryOpKind::Dec,
                                   true);
  }
  mlir::Value VisitUnaryPreInc(const UnaryOperator *e) {
    LValue lv = cgf.emitLValue(e->getSubExpr());
    return emitScalarPrePostIncDec(e, lv,
cir::UnaryOpKind::Inc,
                                   true);
  }
```

clang/lib/CodeGen/CGExprScalar.cpp

```
// Unary Operators.
Value *VisitUnaryPostDec(const UnaryOperator *E) {
  LValue LV = EmitLValue(E->getSubExpr());
  return EmitScalarPrePostIncDec(E, LV, false, false);
}
Value *VisitUnaryPostInc(const UnaryOperator *E) {
  LValue LV = EmitLValue(E->getSubExpr());
  return EmitScalarPrePostIncDec(E, LV, true, false);
}
Value *VisitUnaryPreDec(const UnaryOperator *E) {
  LValue LV = EmitLValue(E->getSubExpr());
  return EmitScalarPrePostIncDec(E, LV, false, true);
}
Value *VisitUnaryPreInc(const UnaryOperator *E) {
  LValue LV = EmitLValue(E->getSubExpr());
  return EmitScalarPrePostIncDec(E, LV, true, true);
}
```

Code sharing

- How do we keep CIR in sync with clang's LLVM IR codegen?
- Move common code into shared components
- Can we use templates or concepts to abstract IR-specific interfaces?



Getting help

- Upstreaming work requires discipline
- It doesn’t require prior in depth understanding
- A great way to learn!
- We’ve gotten a lot of help from great new contributors
- If you’d like to get involved, let us know!
- Come to the ClangIR roundtable tomorrow at 2:15

NVIDIA

Help Us Shape the Future

Meet us Tuesday during the LLVM Developers' Meeting 2025:

Tuesday: 3:00 Meet & Greet the LLVM Foundation Sponsors/California Ballroom

6:00 Evening Reception/Guildhouse

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