Modes of Composition

in functional Scala programming

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Why Strongly-Typed Functional Programming?

- When measured in Total Cost of Ownership (TCO), effectful functional programming is, or will become*, the *cheapest* way to build software
  - Cost to build
  - Cost to maintain & support
  - * Cost to learn ?

- We do FP not because it is more principled or more expressive, but because the qualities translate into lower total cost
  - Building software remains an extremely expensive process; measures that reduce cost have a big impact

Pure Functional Programming

- Functional Programming == “Programming with Functions”
  - `f: (P1, P2 .. Pn) => R`
  - Only inputs are parameters `P1, P2 ..` Pn. Not affected by anything else.
  - Computes or evaluates a result R. Has no other effect on the world.
  - Deterministic & side-effect free
  - Referentially transparent - a function invocation is equivalent to, and replaceable by, its result
    - f(P1, P2.. Pn) == R

- Great conceptual model
  - But how to extend to applied programming where side-effects are desired?

Effectful Functional Programming

- Effectful FP: a variant for expressing *effects & actions*
  - `f: (P1, P2 .. Pn) => F[R]`
  - `F[R]` is an *effectful* value

- When an effectful value is *run* or *interpreted*
  - The effects or actions described by F happen. These might be “side-effects”, external actions upon the world. But there are other effects like errors, or asynchrony, that can be included in F without affecting the world.
  - A value R is yielded or computed

A Spectrum of Effectful Values

An effectful value can be a pure action, where the result value is trivial

```
IO(println(“hello world”)): IO[Unit]
```

An effectful value can be a pure value, where the effect is trivial

```
Id(“hello world”): Id[String]
```

An effectful value can represent some effects that yield a value

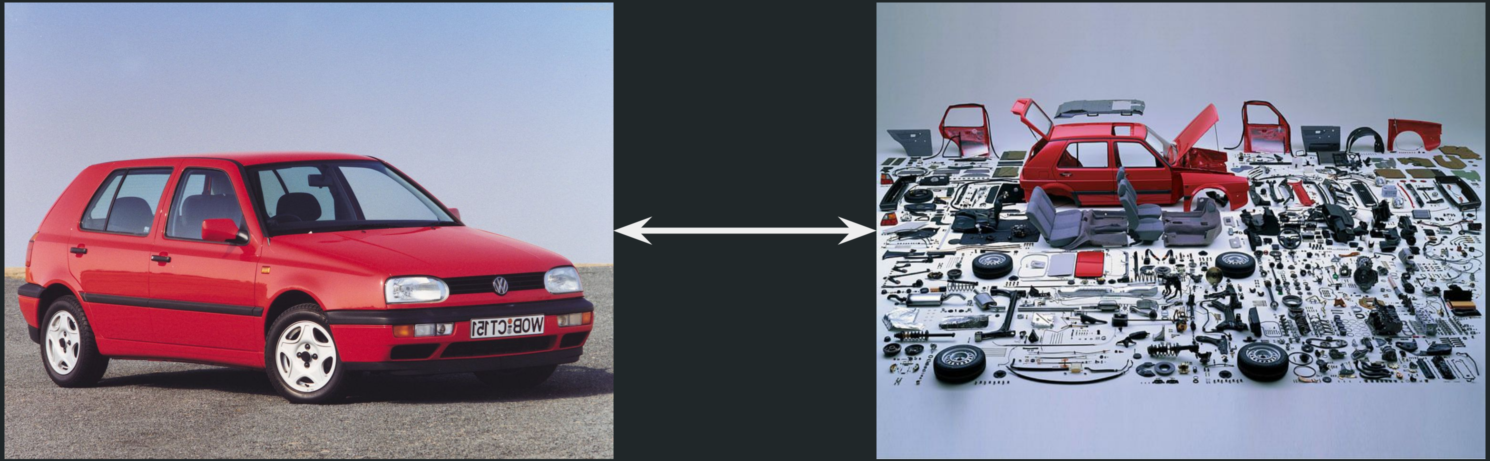
```
IO(datastore.readCustomer(12546)): IO[Customer]
```

Turning Effectful Values into Effects

- Effectful functional programs compose effectful values together into a complete program that causes the effects in the desired sequence
  - All reads, writes and interactions with the environment, the screen, network, storage, the system clock etc
  - *How* they are composed is the topic of this workshop - we'll examine that in detail

- Running Effectful Functional Programs
  - At the top level, the value representing the whole program is set in motion with a single call that triggers effects (in these examples, `unsafeRunSync`)

Composition and Decomposition

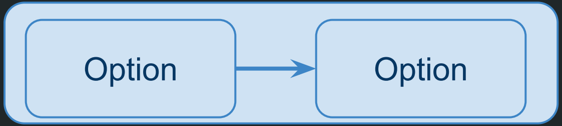


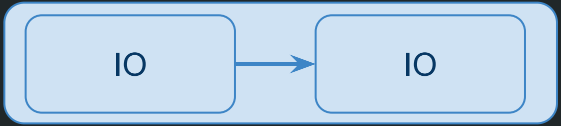
- How are large systems assembled from smaller components?
- How can large problems be broken down into many smaller independent ones?

Modes of Composition

- *An effectful value depends upon the result of another, or must happen after*
    - *Monadic operators*

- `FlatMap`, aka `Bind`, composes two effectful values into a larger value of the same type
    - The second operations happens after the first and may depend upon the value it yields
    - Flatmap operator is written symbolically as `>>=`
- The “meaning” of the composition depends upon the type of effect present in the value





Modes of Compo

```
for {
  number <- parseAsNumber(string) //Option[Int]
  root     <- squareRootIfPositive(number) //Option[Int]
} yield root
```

- *An effectful value dep*
  - *Monadic operators*

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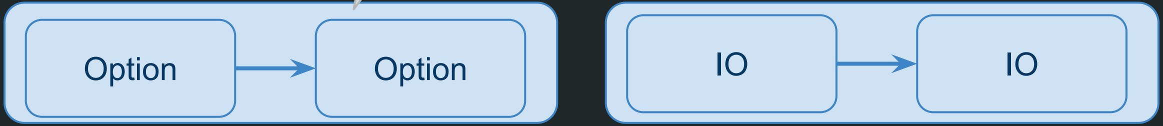
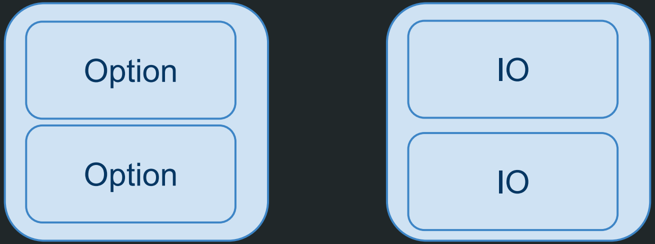


Modes of Composition

- *Independent effectful values can be run together concurrently*
  - *Applicative (or Semigroupal) operators*

- Multiple independent effectful values can be composed in parallel into a larger value of the same type using `Semigroupal.tupledN` operators
  - Operations can’t depend upon each other’s outputs and happen in an undefined order

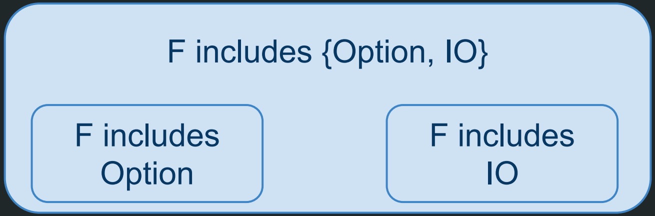
- The “meaning” of the composition still depends upon the type of effect present in the value



Modes of Composition

- *An effectful value can incorporate several different effects*
  - *Tagless Final style and/or Monad Transformers*

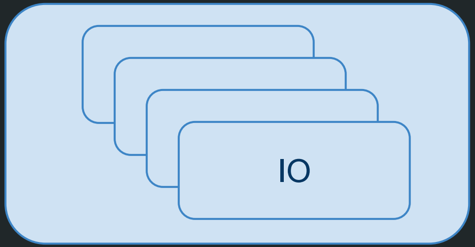
- If part of our program includes an Option effect, and another includes an IO effect, how can we compose them together?
  - The effects present in our program are a *Set of Constraints.* We can add to the set when needed.



Modes of Composition

- *An effectful value is composed of repeated actions or computations*
  - *FS2 Streams*

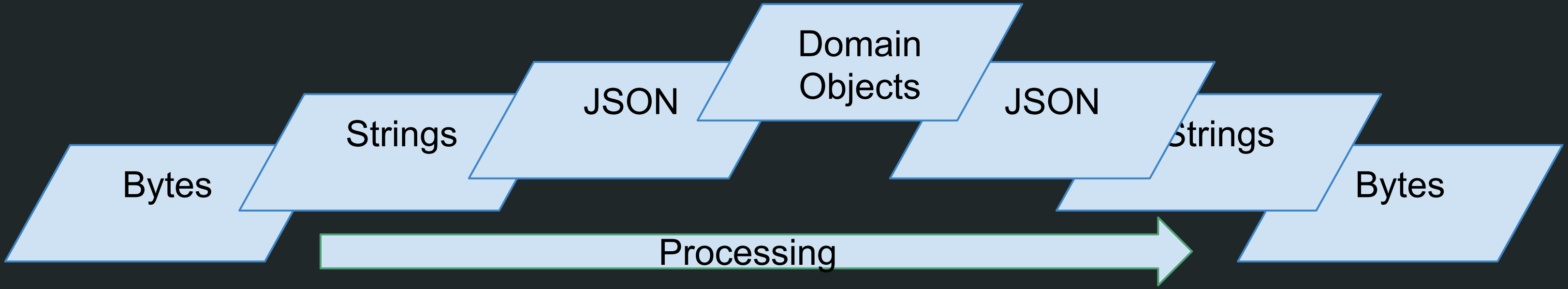
- Functional Streams model effectful values that repeat a variable or infinite number of times, either by
  - polling or reading the environment to pull each new value
  - generating each value from an internal computation process



Modes of Composition

- An effectful value is internally composed of layers
  - Different rules or invariants apply in each layer

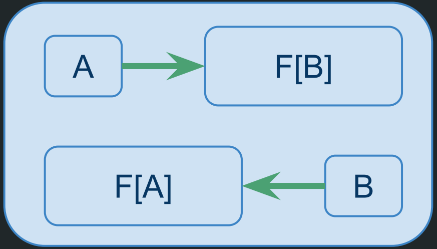
- The typical structure sees weakly typed layers on the outer rings of an application and one to many more strongly typed interior layers
  - Data representation is different in each layer



Modes of Composition

- *An effectful value and it's (approximate) inverse are paired together to create an effectful isomorphism*
  - *Resources, Codecs, Functional Optics, Sagas*

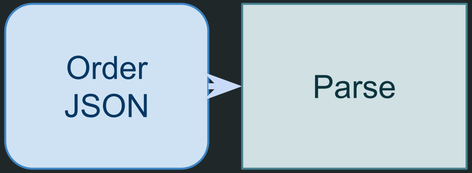
- The inverse of a function reverses, or undoes, its effect
- When paired, a function and its inverse enable a program to "travel" between a mode where the function applies, and one where its doesn't
  - Turns out useful in a broad variety of superficially unrelated situations



Strong Types

- Strong Types are the most cost-effective way to improve software quality
  - Strong guarantees founded in formal logic
  - Documentation for humans and machines alike
  - Highly resistant to bitrot
- What makes types “strong”?
  - Ideally, the type describes all valid values and *no invalid values*.
- We habitually flout that principle
  - eg Person(name: String, age: Int)

Business Scenario: Order Processing



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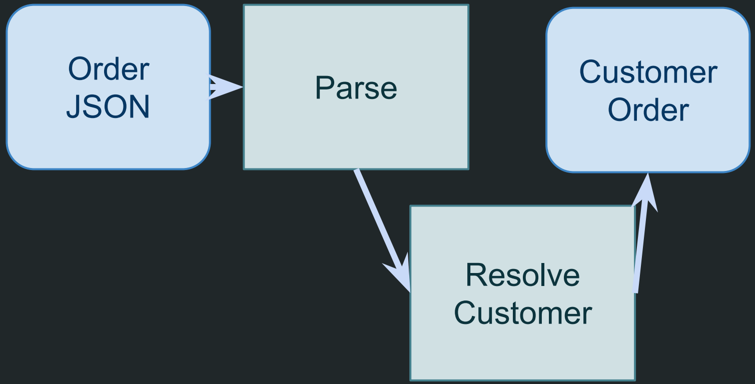

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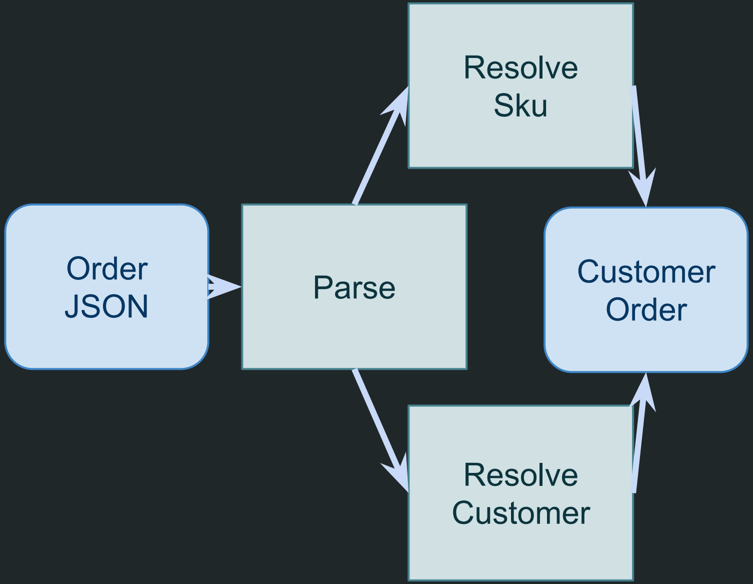

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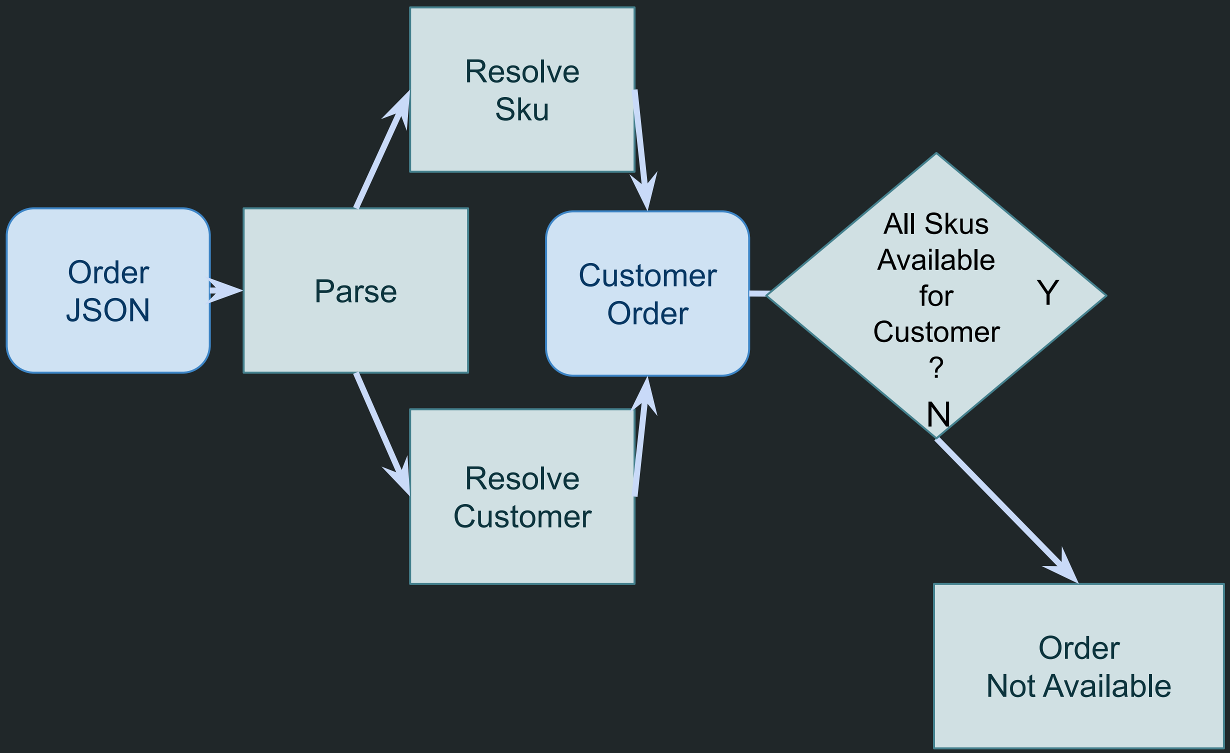

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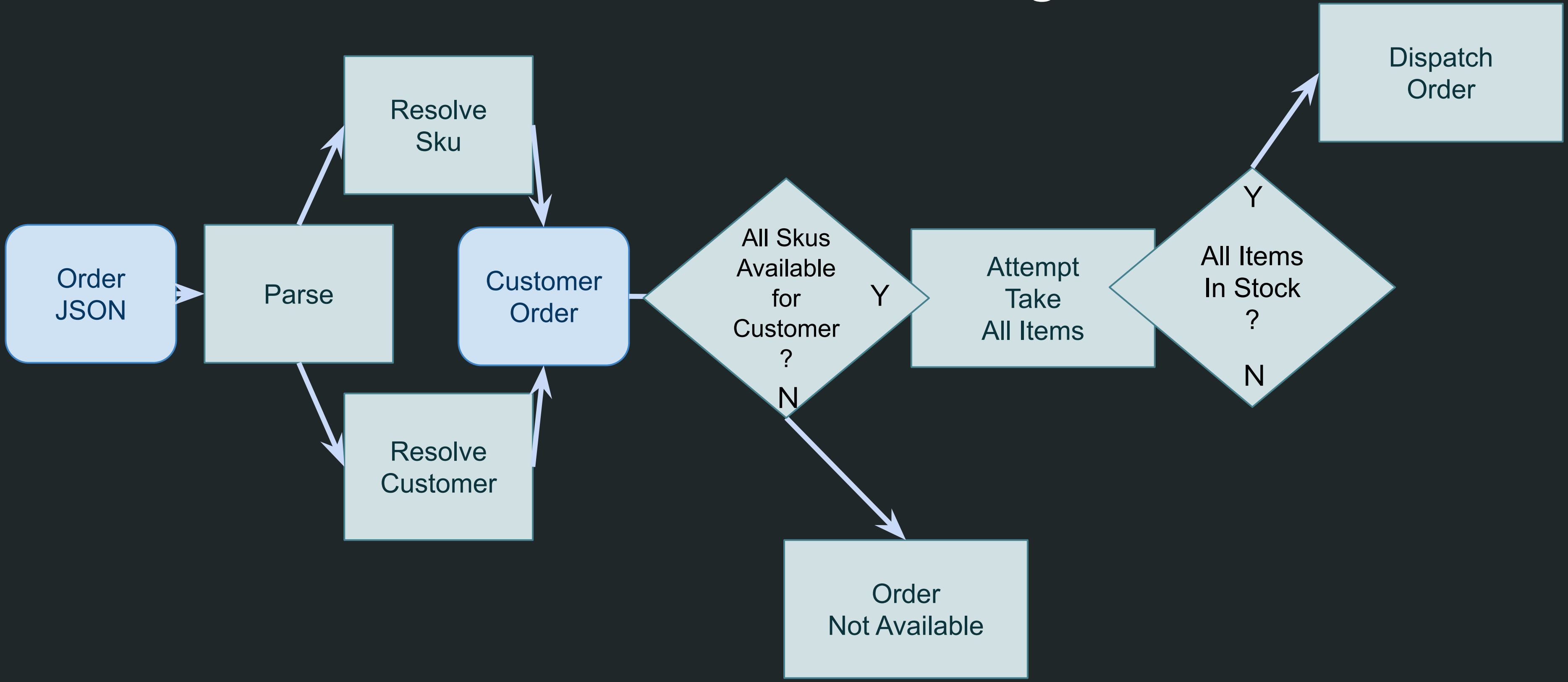

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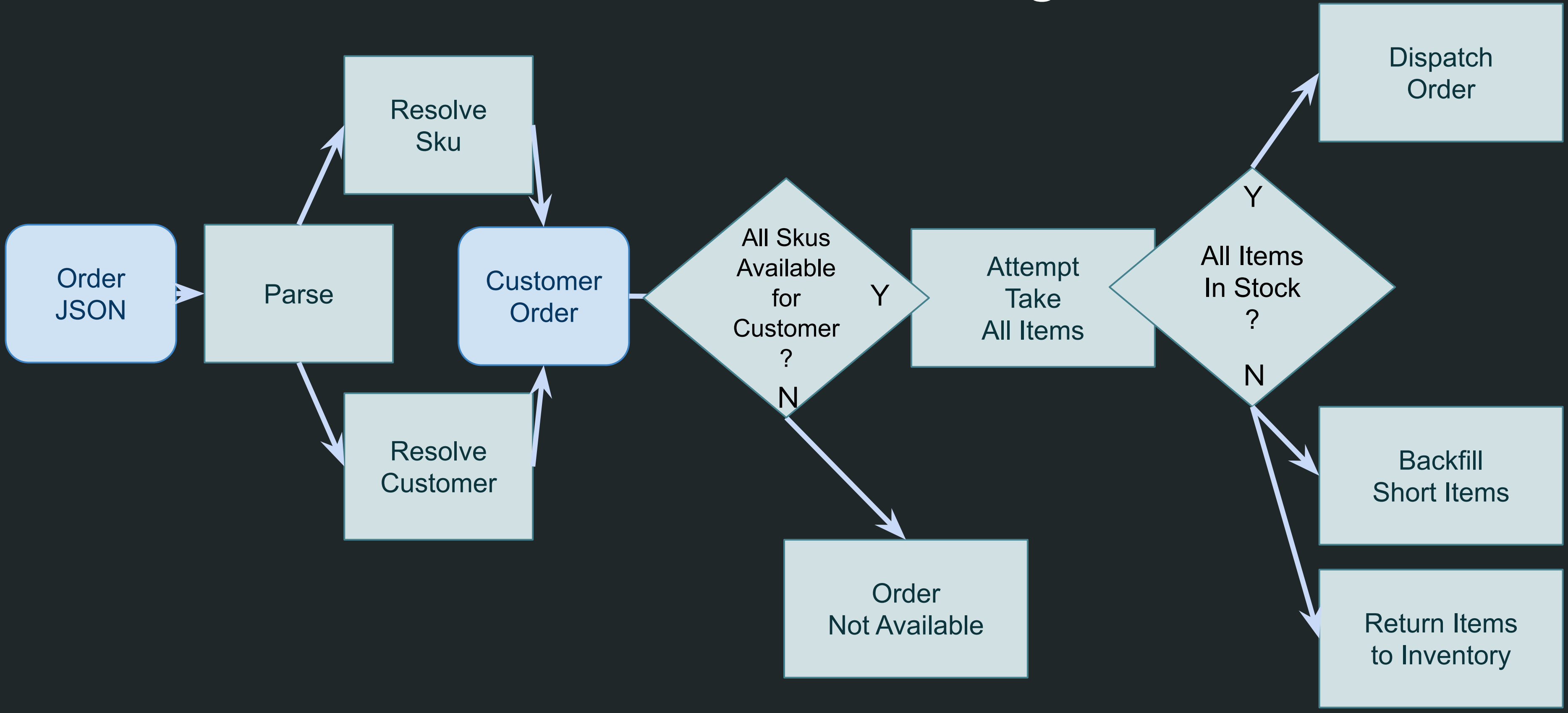

Workshop Approach: Type-driven Development

- The hands-on aspect of this workshop takes a “color-by-numbers” approach
- Existing code scaffolds have “typed-holes” which participants need to complete
- Aka “Type-Driven Development”
  - approach advocated by Edwin Brady (creator of the Idris language) where missing parts of a program, described by a type, are gradually filled in
- Using compositional operators to combine parts into a working whole