Advanced Programming Languages in the Enterprise Datacenter

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Two big ideas

Advanced Programming Language technology is a secret weapon in enterprise computing

Farm where the fertilizer is thickest: Enterprise Systems

Plan of Talk

- Enterprise software
- The problem and opportunity for PL research
- Applying ML and partial evaluation in enterprise software: a case study
- Summary and Future work

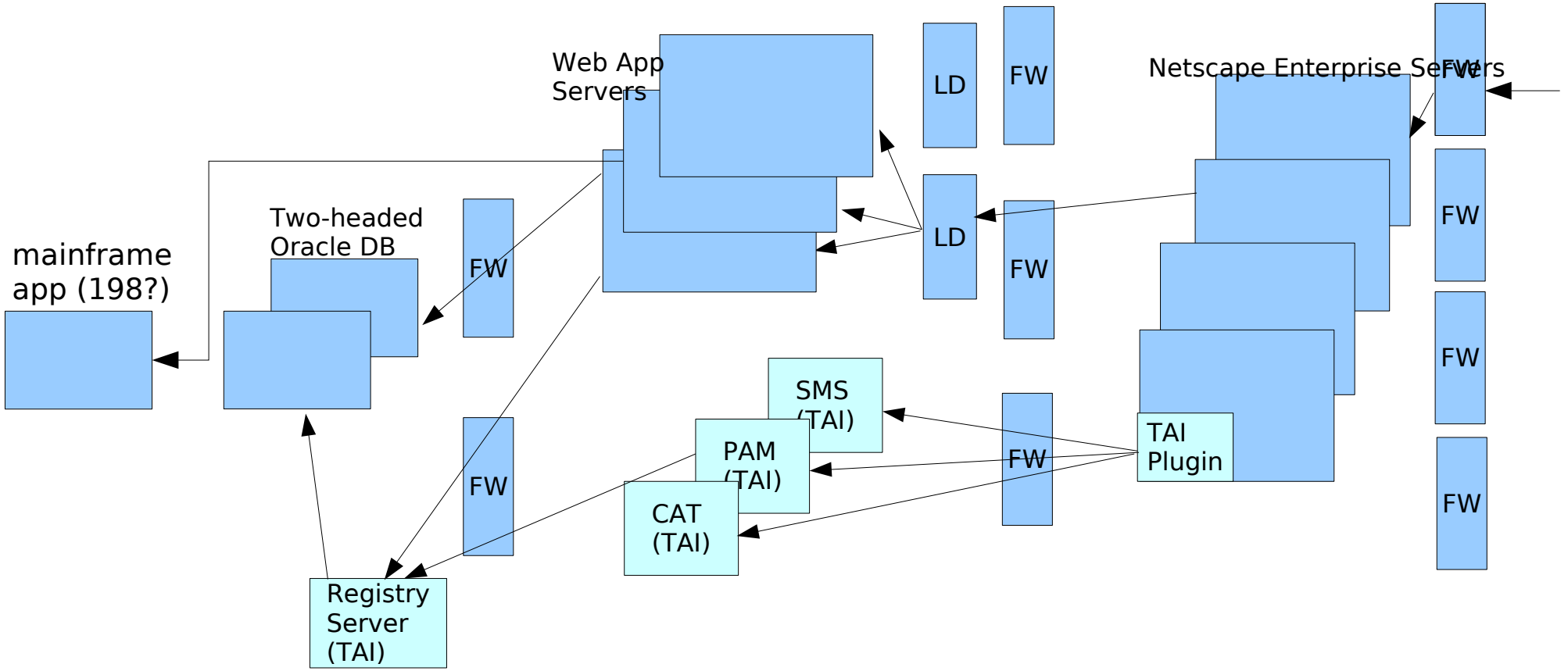
Enterprise software systems

- Run our *world*
- Comprise millions of lines of application code
- Written by many thousands of programmers
- Run on sometimes thousands of machines
- Cost many millions of dollars

Names have been changed to protect paying customers

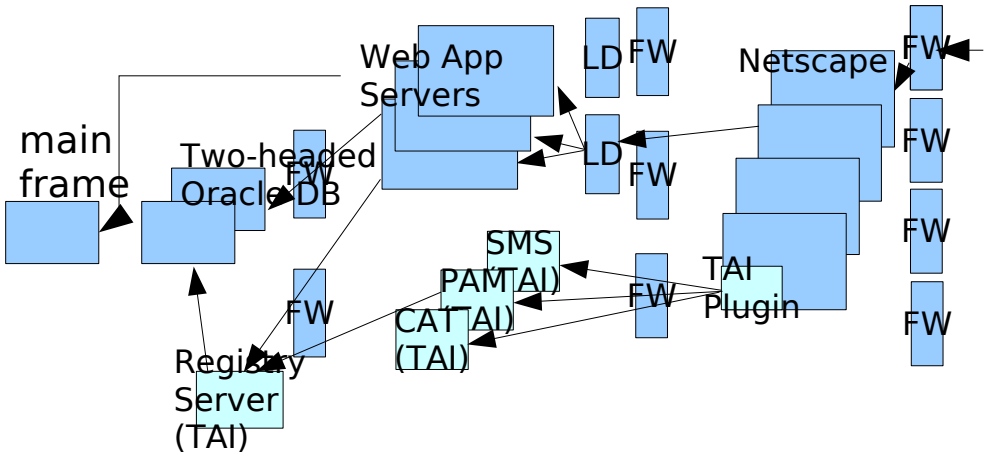
FredCo Bank (2000)

One (slice of one) of the biggest banks' electronic checking system



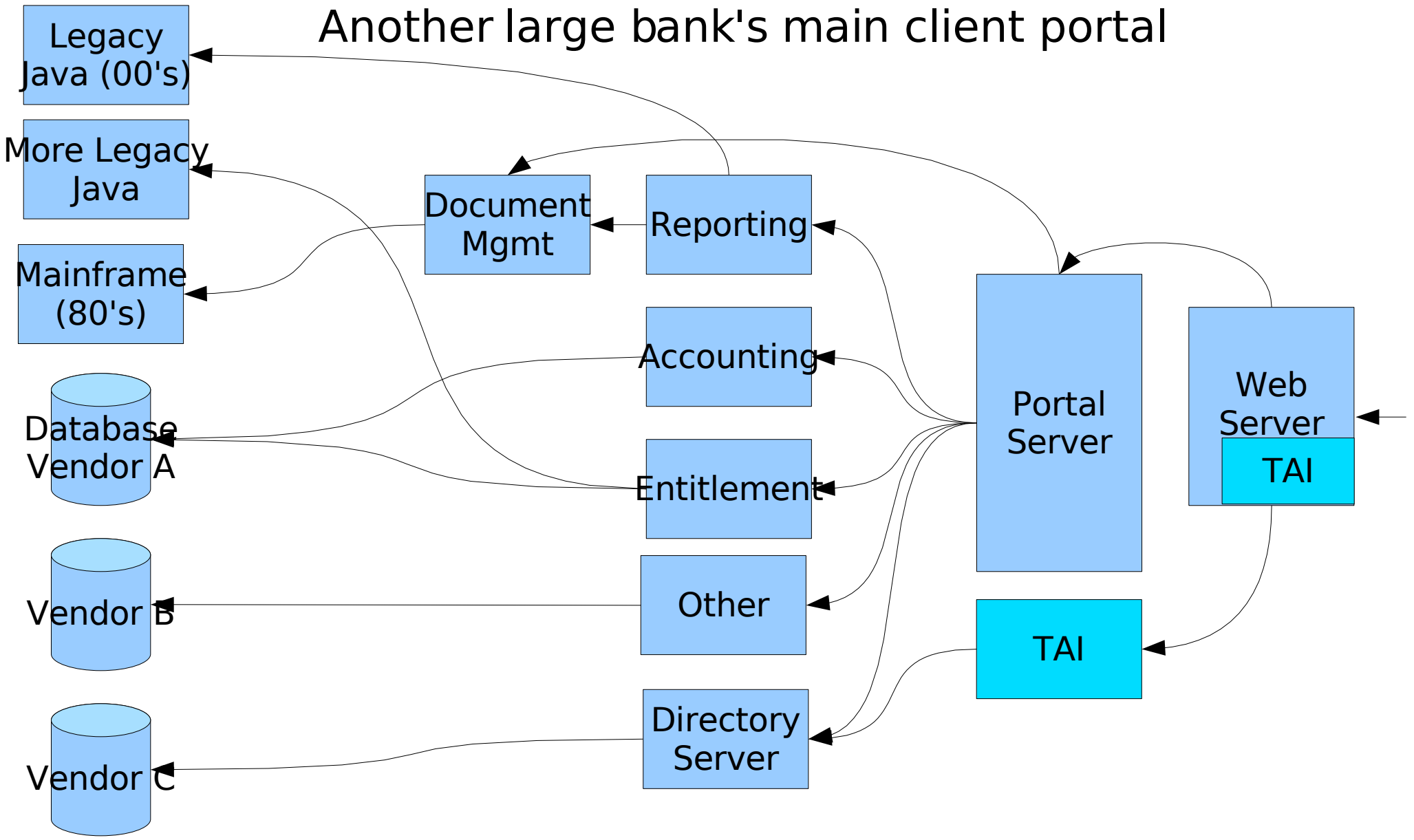
FredCo Bank (2000)

- One out of ~10 slices of systems is shown
- All slices independently developed
- More “layers” to the left of diagram



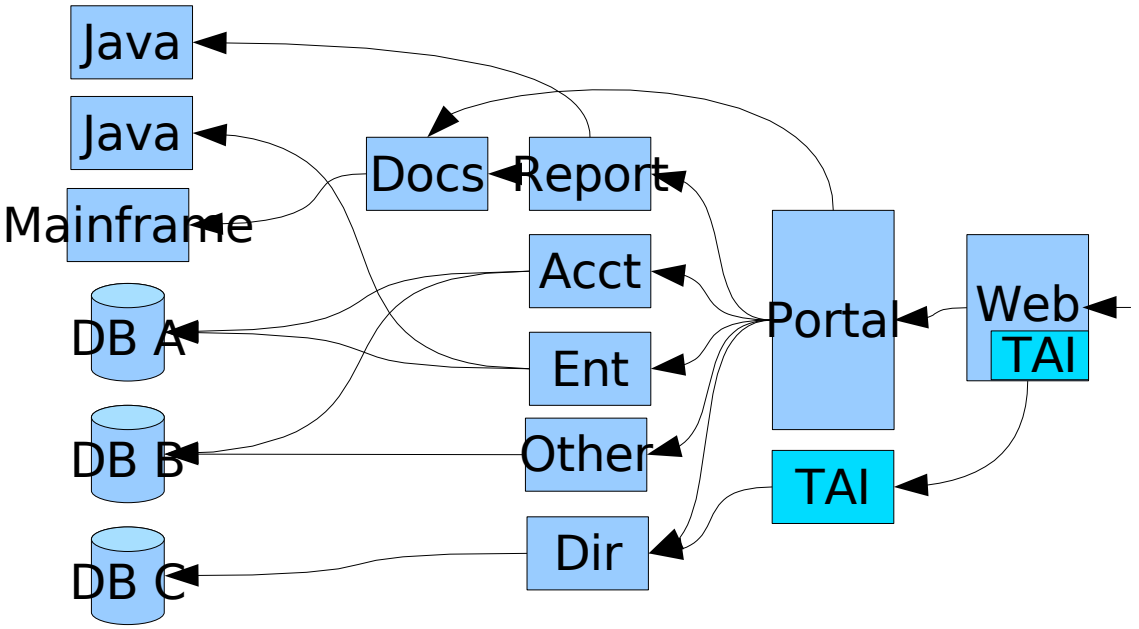
- RPCs flow right-to-left, synchronous
- All persistent side-effects reside in DBs

Jeff's Bank (2004)



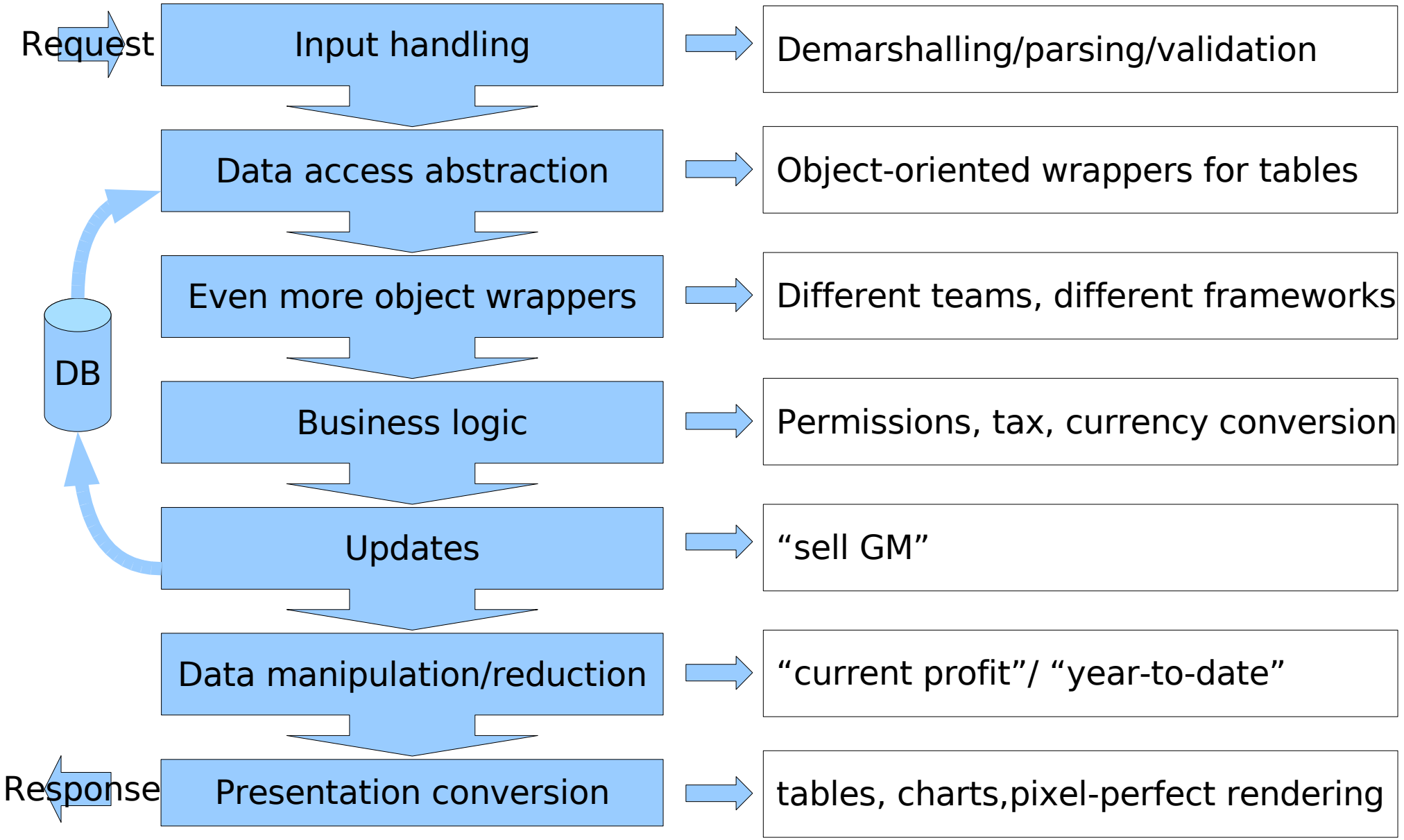
Jeff's Bank (2004)

- Layers of systems grow by accretion over time (decades)
- Only communication is RPC



Osiris Private Bank (2001)

(inside the app-server)



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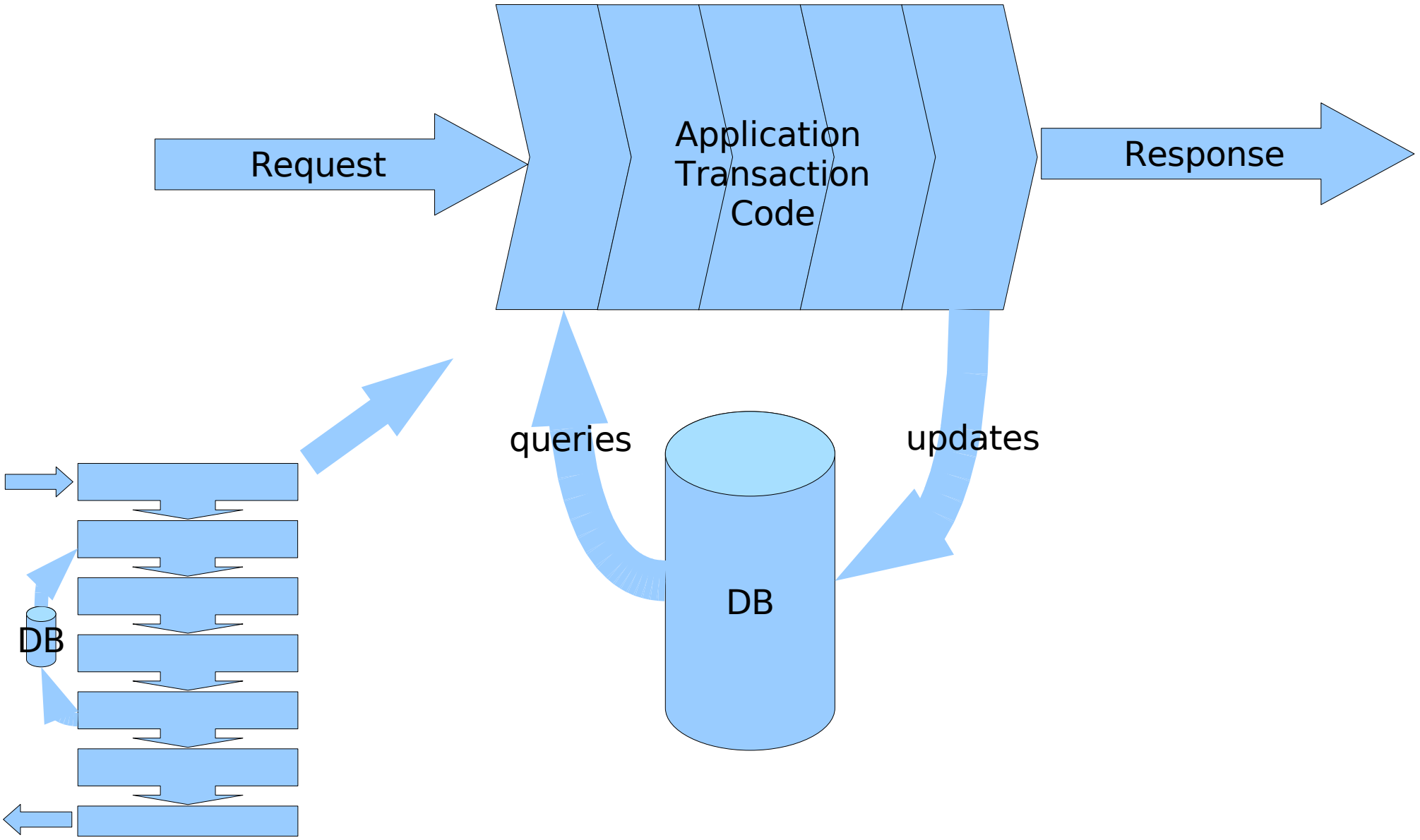
“Farm where the fertilizer is thickest” (1)

- Individual layers written by **independent teams**
- Often written at **different times/decades/continents**
- **Lack of skill/experience** results in layer after layer of framework
- Lack of business interest prevents consolidation
- Natural tendency to **“wrapper” rather than extend/fix**
- Strong functional interfaces separate components
- Side effects in DBs, not program variables
- Dynamic languages, static code

“Farm where the fertilizer is thickest” (2)

- Component and network interfaces are referentially transparent positions
- The “components” are externally “functional”
- Late-stage large-grain optimization is feasible

This should look familiar



And indeed it is ....

- Combinational logic is “functional”
- DIP sockets are referentially transparent positions
- State change via register update
- FP, Haskell, HOL ... for hardware
- Components are externally “functional”
- Nodes and layers are referentially transparent positions
- Transactions' side-effects all in DB
- *FP for the enterprise?*

All the reasons pure functional technology was good for describing circuitry should apply to these systems

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An experimental demonstration

Putting FP to work

- Find candidate “component” of an application
- Replace component with a pure functional implementation
- Show this replacement is more efficient
- Go *further*, replace *more,* make it *even faster, even simpler*

Subsystem is XSL
Replace with *ML*

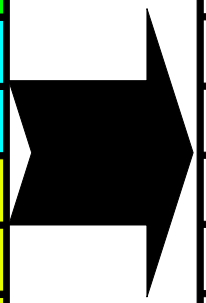
The XSL language

- E**X**tensible **S**tylesheet **L**anguage
- Simple dynamically-typed functional language
  - Often dynamically compiled
- Data is all trees (XML)
  - Processors often use universal datatype (cf. LISP s-expressions)
- Usually statically typable
- Type system is remarkably ML-like
- Invariably embedded in a larger server application
- Almost all server-side uses are static code

Example Stylesheet

- XSL stylesheet takes in a list of (model,year,accessory), and outputs a list sorted by model, and by year, of accessories
- Not beautiful, not useful, just a simple motivating example

Prelude	1998	Tires
Prelude	1998	Mufflers
Prelude	1998	Heater Motor
Prelude	1999	Tires
Prelude	1999	Mufflers
Accord	1988	Starter
Accord	1988	Mufflers
Accord	1988	Clutch
Accord	1987	Oil Filters
Accord	1987	Air Conditioning



Accord	1988	Starter, Mufflers, Clutch
Accord	1988	Starter, Mufflers, Clutch
Accord	1988	Starter, Mufflers, Clutch
Accord	1987	Oil Filters, Air Conditioning
Accord	1987	Oil Filters, Air Conditioning
Prelude	1998	Tires, Mufflers, Heater Motor
Prelude	1998	Tires, Mufflers, Heater Motor
Prelude	1998	Tires, Mufflers, Heater Motor
Prelude	1999	Tires, Mufflers
Prelude	1999	Tires, Mufflers

Input XML DTD and ML type

```
<!ELEMENT Output (Row*)>

<!ELEMENT Row (MODEL,YEAR,ACCESSORIES)>

<!ELEMENT MODEL (#PCDATA)>
<!ELEMENT YEAR (#PCDATA)>
<!ELEMENT ACCESSORIES (#PCDATA)>
```

```
module Source = struct
  type output = row list
  and row = {model: model; year: year; accessories: accessories}
  and model = string
  and year = string
  and accessories = string
end
```

Output XML DTD and ML type

```
<!ELEMENT Output (MODEL*)>

<!ELEMENT MODEL  (YEAR*)>
  <!ATTLIST MODEL name CDATA #REQUIRED>

<!ELEMENT YEAR   (PartList)>
  <!ATTLIST YEAR date CDATA #REQUIRED>

<!ELEMENT PartList (ACCESSORIES*)>
<!ELEMENT ACCESSORIES (#PCDATA)>
```

```
module Dest = struct
  type output = model list
  and model = name * year list
  and year = date * accessories list
  and accessories = string
  and name = string
  and date = string
end
```

The Stylesheet

```
<xsl:stylesheet xmlns:xsl="http://www.w3.org/XSL/Transform/1.0"
      xmlns="http://www.w3.org/TR/REC-html40" result-ns=""
      indent-result="yes">
<xsl:template match="Output">
<Output>
<xsl:apply-templates select="Row">
<xsl:sort select="MODEL"/>
<xsl:sort select="YEAR"/>
</xsl:apply-templates>
</Output>
</xsl:template>
<xsl:template match="Row">

<xsl:variable name="model">
<xsl:value-of select="./MODEL"/>
</xsl:variable>

<xsl:variable name="year">
<xsl:value-of select="./YEAR"/>
</xsl:variable>

<MODEL name="{$model}">
 <YEAR name="{$year}">
  <PartList>
  <xsl:copy-of select="/Output/Row/MODEL[text()=$model]/
                       ../YEAR[text()=$year]/../ACCESSORIES"/>
  </PartList>
 </YEAR>
</MODEL>
</xsl:template>
</xsl:stylesheet>
```

(1) Sort by MODEL

(2) Sort by YEAR

(3) Get MODEL

(4) Get YEAR

(5) Output MODEL and YEAR

(6) Output all ACCESSORIES for that MODEL/YEAR

The ML Program

```
let transform_output (o:Source.output) =

let transform_row (r:Source.row) =
  let model = r.Source.model in
  let year = r.Source.year in
    (model,
       [(year,
         map_succeed
         (function
                ({Source.model=model';Source.year=year';} as r')
                  when model=model' && year=year' -> r'.Source.accessories
             | _ -> failwith "caught")
         o)]) in

let sort_by_model_then_year =
  Sort.list (fun r r' -> r.Source.model <= r'.Source.model
                              or r.Source.model = r'.Source.model &&
                                   r.Source.year <= r'.Source.year)
  o in
  ((List.map transform_row sort_by_model_then_year):Dest.output)
```

(1+2) Sort by MODEL/YEAR

(3) Get MODEL

(4) Get YEAR

(5) Output MODEL and YEAR

(6) Output all ACCESSORIES for that MODEL/YEAR

What's better about ML?

- Datatype specialized to XML DTD
- Program specialized to types
- Standard FP technology applies
- View types eliminate serialization & parsing
  - XSL often embedded in apps (good)
  - App data translated to XML strings (bad)
  - Parsed back to generic trees (bad)

Digression: View Types

Is it a list or an array? Does it matter?

```
type 'a list = Nil | Cons of 'a * 'a list

module type LIST = sig
  type 'a t
  val inNil : unit -> 'a t
  val inCons : 'a ->'a t -> 'a t

  val isNil : 'a t -> bool
  val isCons : 'a t -> bool

  val outNil : 'a t -> unit
  val outCons : 'a t -> 'a * 'a t
end
```

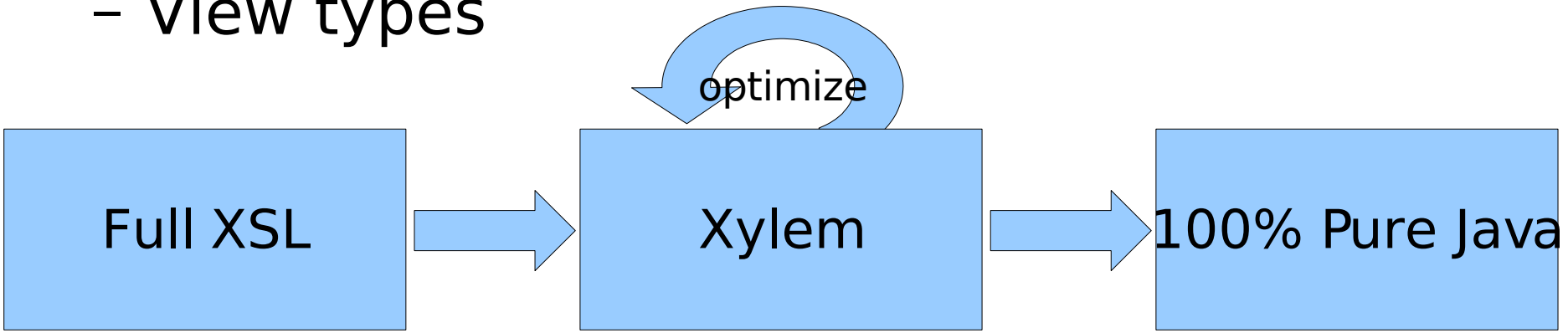
A Commercial Realization

(Joint work with Xylem Team)

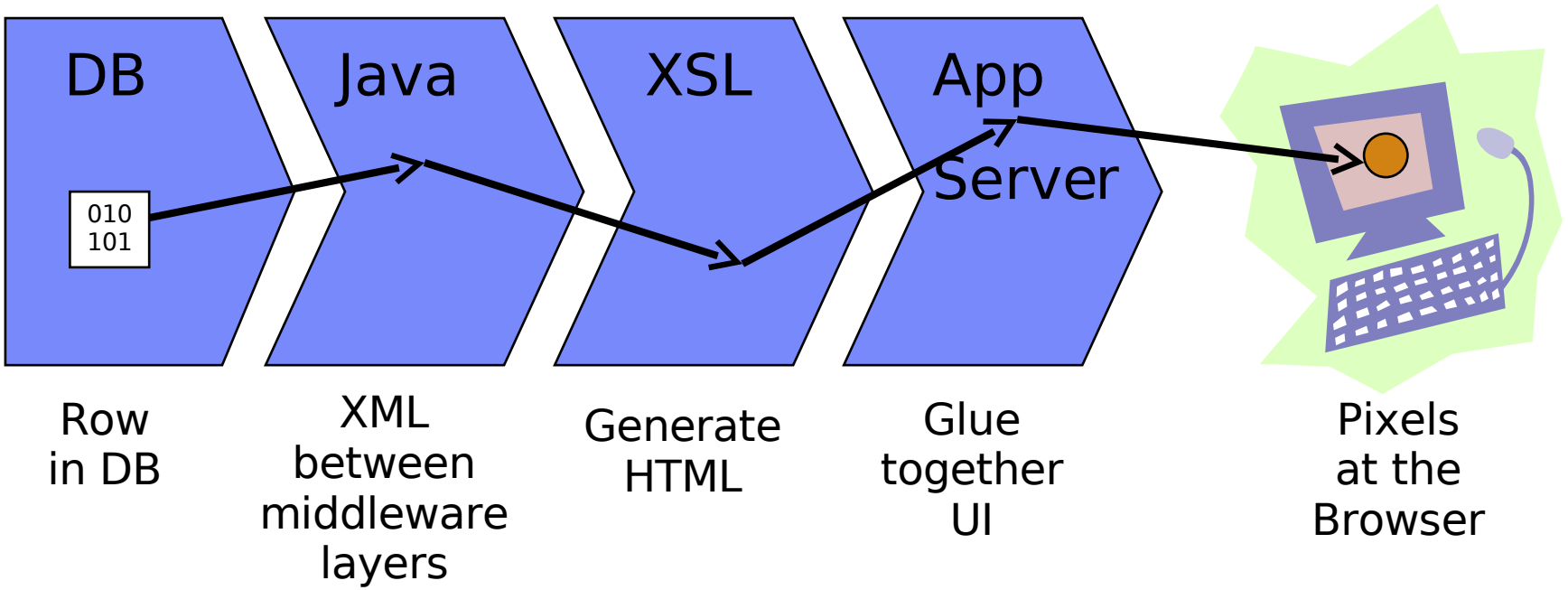
- Xylem (what is it)
- A real application in a real customer
- What we did & how it went
- Where it's going

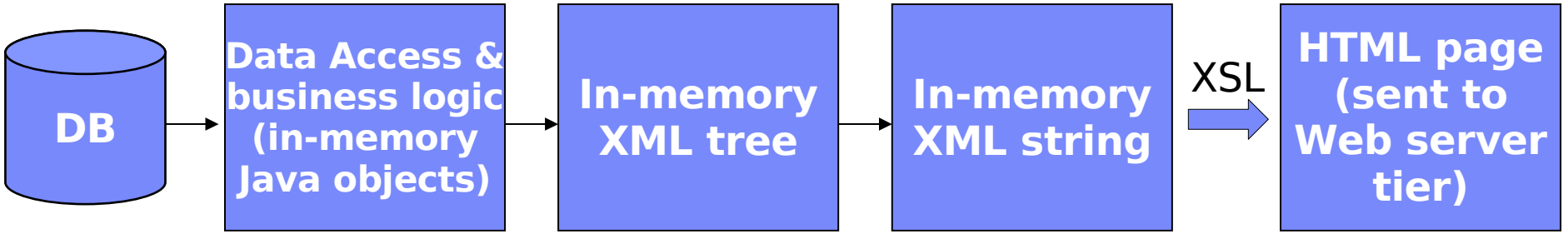
The Xylem Intermediate Language

- Simple polymorphic ML
- Simple module system
- Simple optimizations
  - Simplistic reduction and deforestation
  - Data-type specialization
  - View types

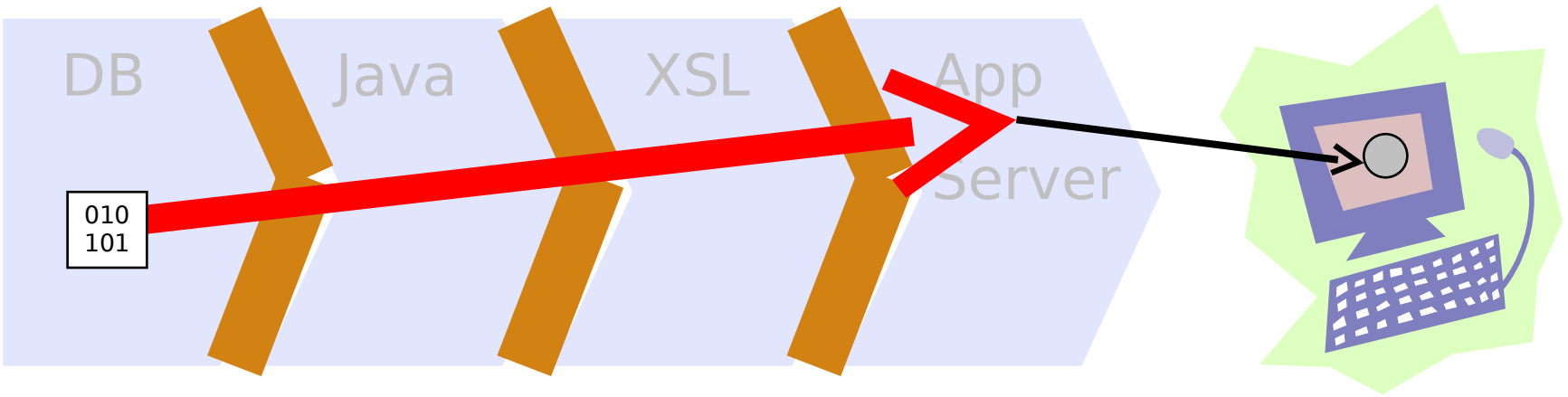


A real application



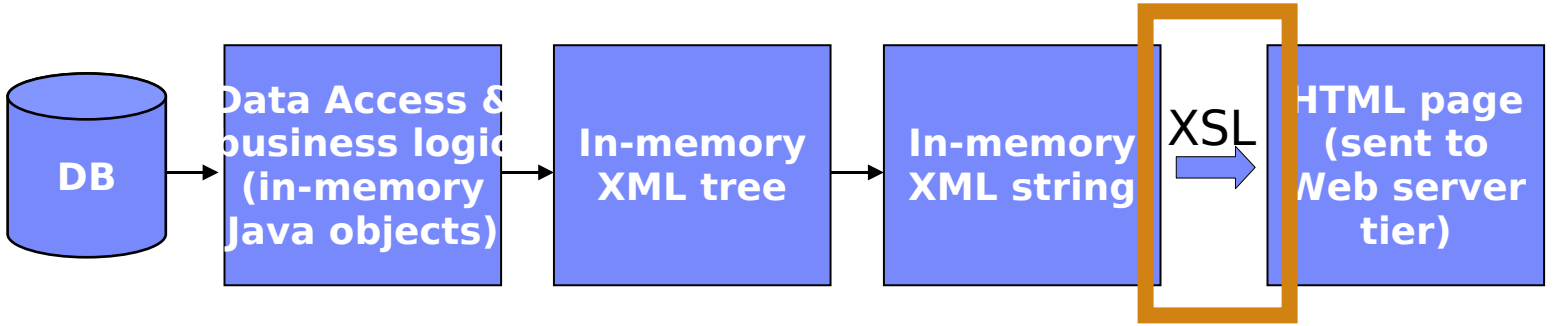


The (ultimate) goal

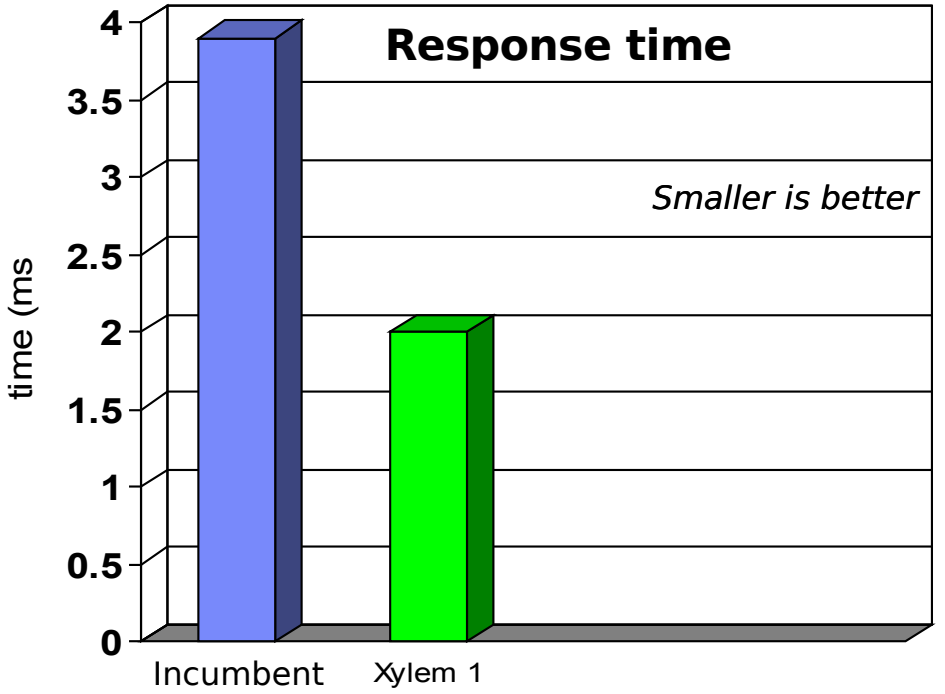


- ~99.9% probability that you have used this app
- 80% of workload at this customer
- Validation in *live* production system

Xylem 1: a faster XSL

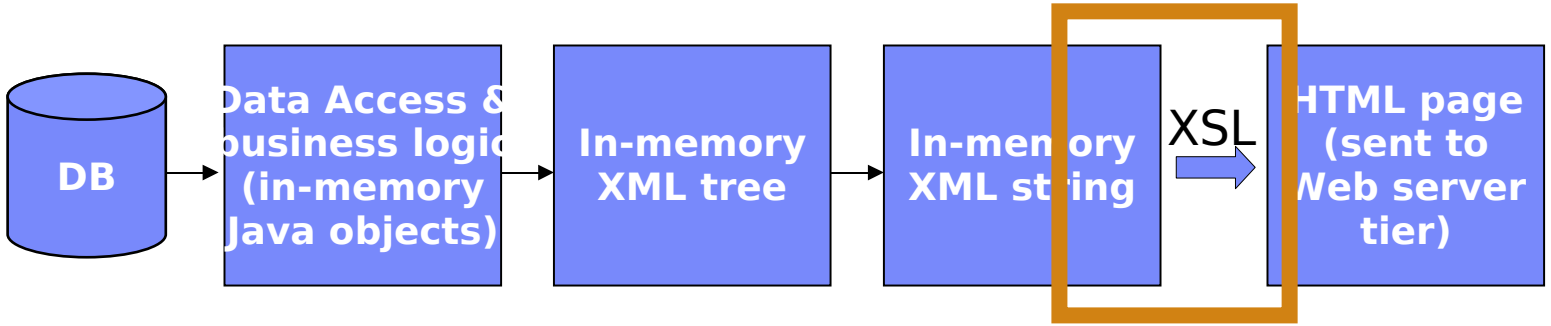


- Xylem + fast parser
- 2x faster than competitor

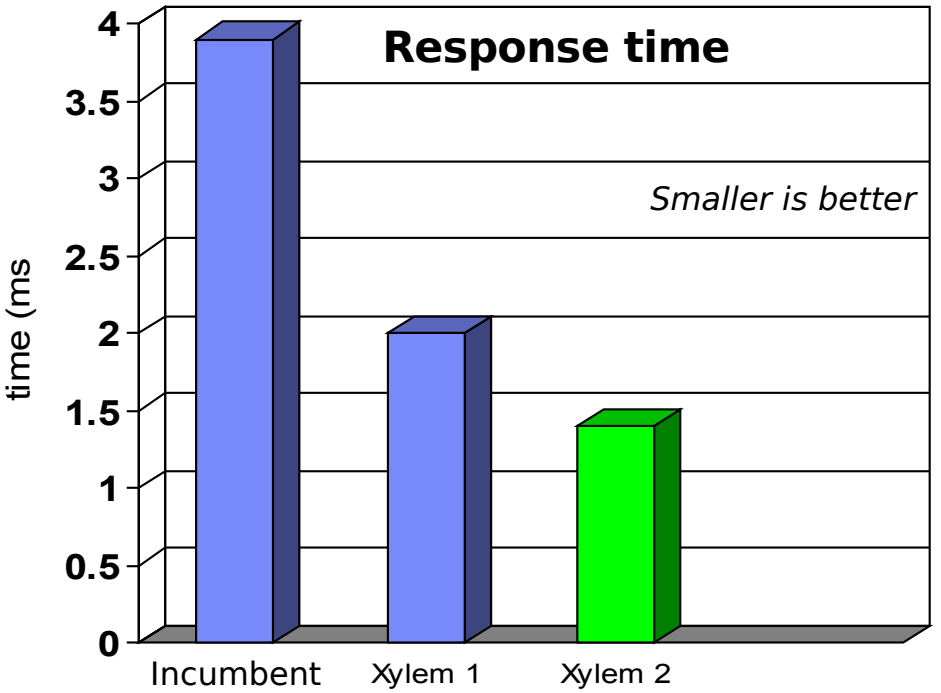


- **Partial evaluation**
- **Deforestation**

Xylem 2: Data structure specialization

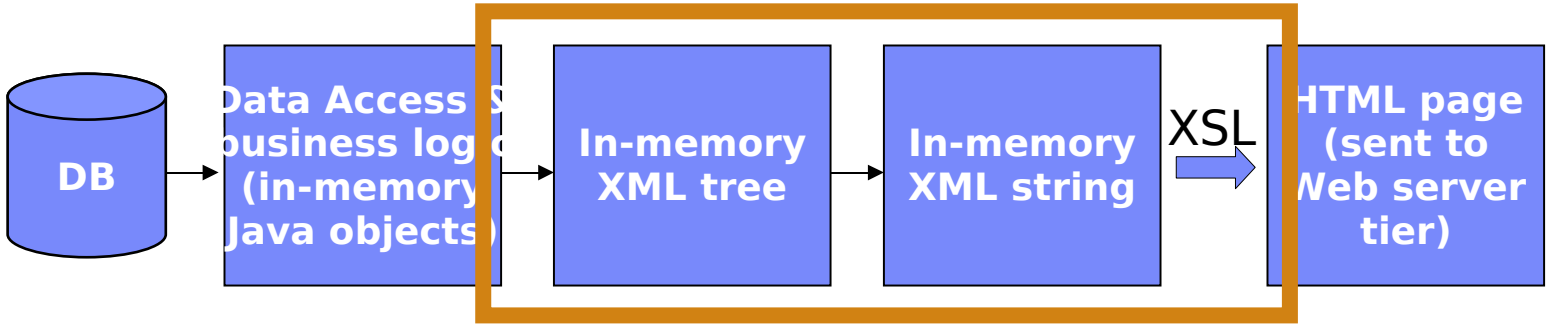


- Xylem + fast parser
- Schema-directed datatypes, parsing/deserialization
- 2.8x faster than competitor (represents 30% improvement over Xylem 1)

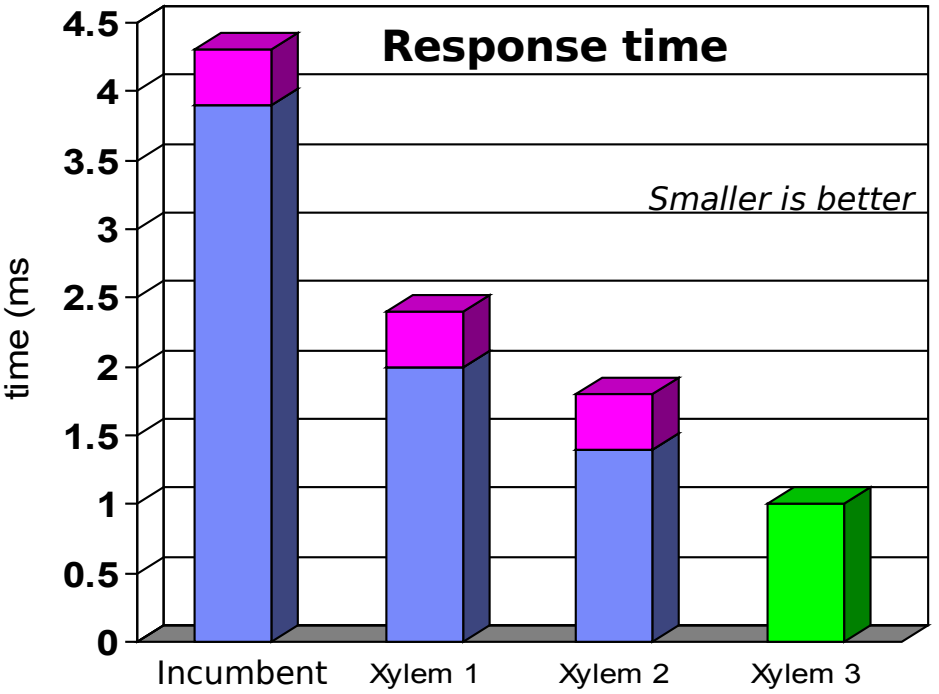


- Partial evaluation
- Deforestation
- **Precise ML datatypes**

Xylem 3: No parsing at all

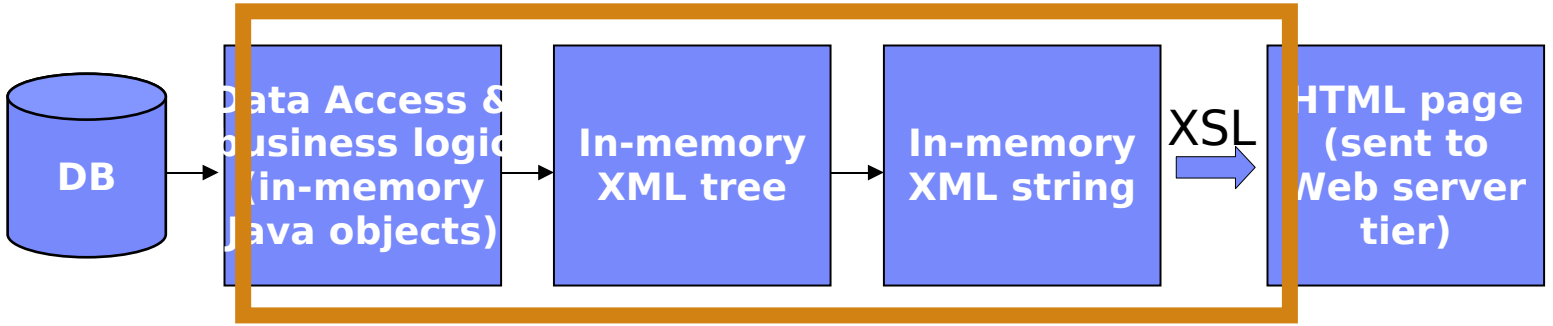


- Xylem + fast parser
- Schema-directed datatypes, parsing/deserialization
- 4.3x faster than competitor (represents 44% improvement over Xylem 2)
- Not much left: 0.4ms serialization for a 7k document

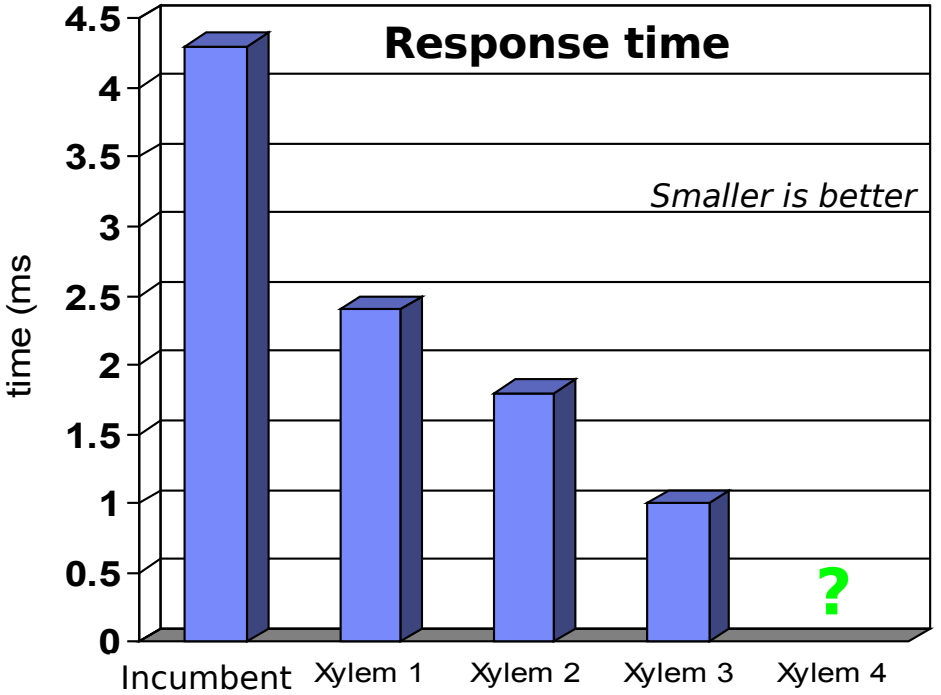


- Partial evaluation
- Deforestation
- Precise ML datatypes
- **View types**

Xylem 4: Query Pushdown
(future work)



- All preceding optimizations
- **Schema-directed DB access**
- How much faster can it get?



What is of note?

- Same runtime, same app-server, same JVM
- Neil Jones: **find nontrivial invariants that classical compilers cannot discover**
- Immense opportunity: ***simpler*** programs, **greater** performance
- Business software: unique opportunity
- FP technology is the secret weapon
  - Partial evaluation
  - Deforestation
  - Type specialization
  - View types

Outcome of Experiment

- Faster
- Cheaper
- Simpler
- More “robust”

- **In production *today***
- ***40%* decrease in CPU utilization for first production app**

Come for the speed
Stay for the simplicity

Xylem's Future

- Query pushdown, update
- Apply technology to other parts of e-business stack
  - Presentation (portals)
  - RPC (XML-RPC, SOAP) marshallers
  - Workflow (BPEL)
  - Messaging (Java Messaging Service, pub/sub)

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Future work

- Streaming, ETL (extract/transform/load)
  - Lazy languages
- Query pushdown
  - Logic programming
- Model/view/controller (MVC) UIs
  - I/O automata, reactive systems
- Code-generation to client (AJAX)
  - Attribute grammars