Data-oblivious Computation

A common paradigm for private and secure computation

David Darais (Galois, Inc.)

TWO WORLDS

Traditional Computation **???**

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Traditional Computation

Bubble sort is the worst

???

Bubble sort is the best

TWO WORLDS

Traditional Computation	**???**
Bubble sort is the worst	Bubble sort is the best
Insertion sort is mediocre	Insertion sort is (also) the best
Merge sort is the best	Merge sort is the worst

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RAM/array access is O(1)	RAM/array access is O(log(N))
Data structures + recursion = easy	Data structures + recursion = hard

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Fully Homomorphic Encryption

Secure Multiparty Computation

Constant Time Execution

Information Flow Control

Differential Privacy

Protects secrets ***during computation***

Protects secrets ***after release***

Fully Homomorphic Encryption	Secure Multiparty Computation	Constant Time Execution	Information Flow Control	Differential Privacy

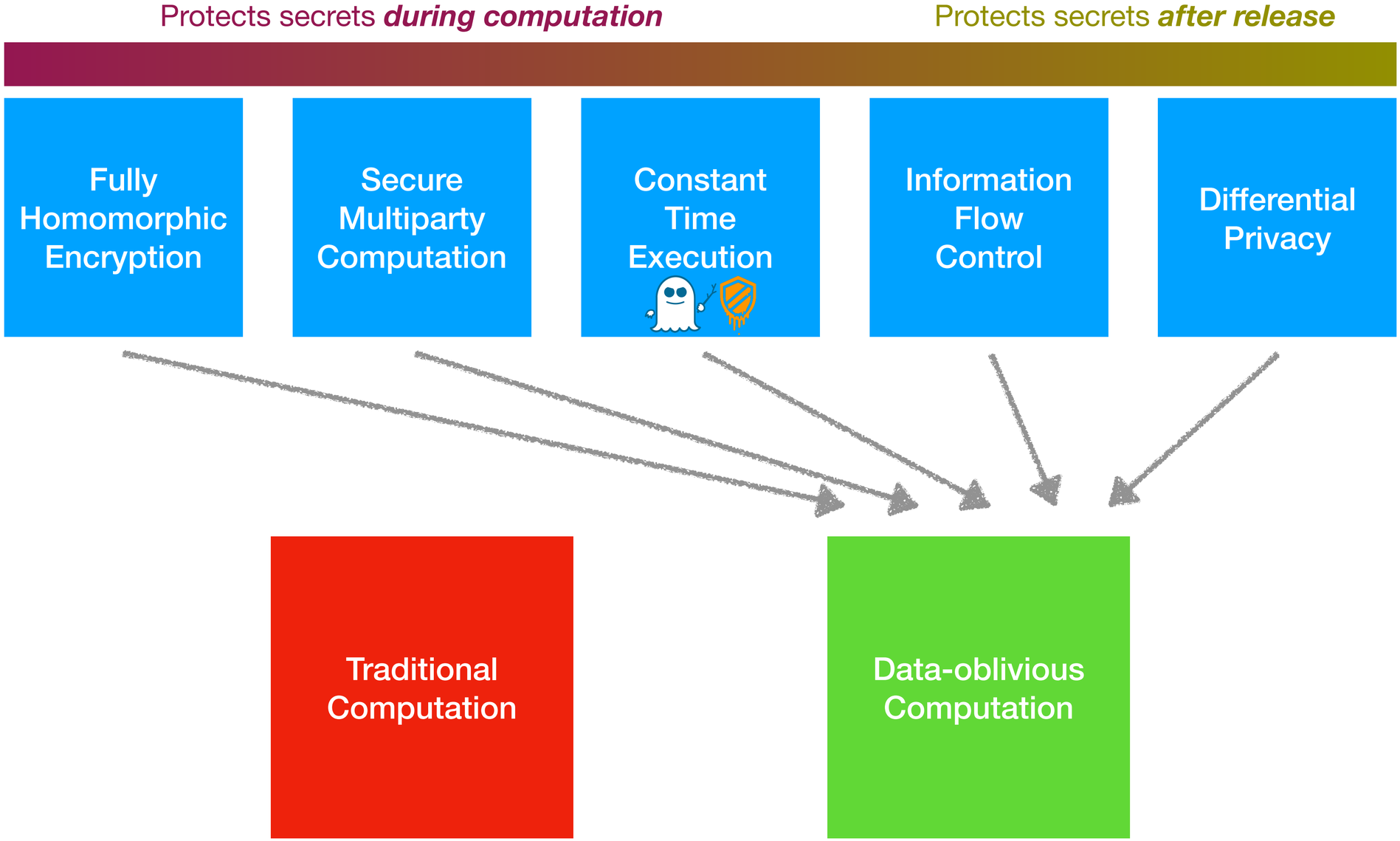
Protects secrets ***during computation***

Protects secrets ***after release***

Fully Homomorphic Encryption	Secure Multiparty Computation	Constant Time Execution	Information Flow Control	Differential Privacy

Performance is critical

Correctness is critical


Protects secrets *during computation*
Protects secrets *after release*
Fully Homomorphic Encryption
Secure Multiparty Computation
Constant Time Execution
Information Flow Control
Differential Privacy
Traditional Computation
Data-oblivious Computation

TWO WORLDS

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TWO WORLDS

PROBLEM

No programming language or compiler understands data-oblivious computation

CONTROL FLOW

Traditional Computation

```
if (raining) {
    ice_in_coffee = false;
    flavor = “hazelnut";
    drink = new_coffee(ice_in_coffee,
                       flavor,
                       null);
} else {
    ice_in_coffee = true;
    additive = “cream";
    drink = new_coffee(ice_in_coffee,
                       null,
                       additive);
}
```

CONTROL FLOW

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} else {
  ice_in_coffee = true;
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  drink = new_coffee(ice_in_coffee,
                     null,
                     additive);
}
```

Data-oblivious Computation

```
ice_in_coffee_A = false;
flavor_A = "hazelnut";
drink_A = new_coffee(ice_in_coffee_A,
                     flavor_A,
                     null);
```

```
ice_in_coffee_B = true;
additive_B = "cream";
drink_B = new_coffee(ice_in_coffee_B,
                     null,
                     additive_B);
```

```
drink = raining ? drink_A : drink_B;
```

EARLY DAYS FOR DO

Traditional Computation

Data-oblivious Computation

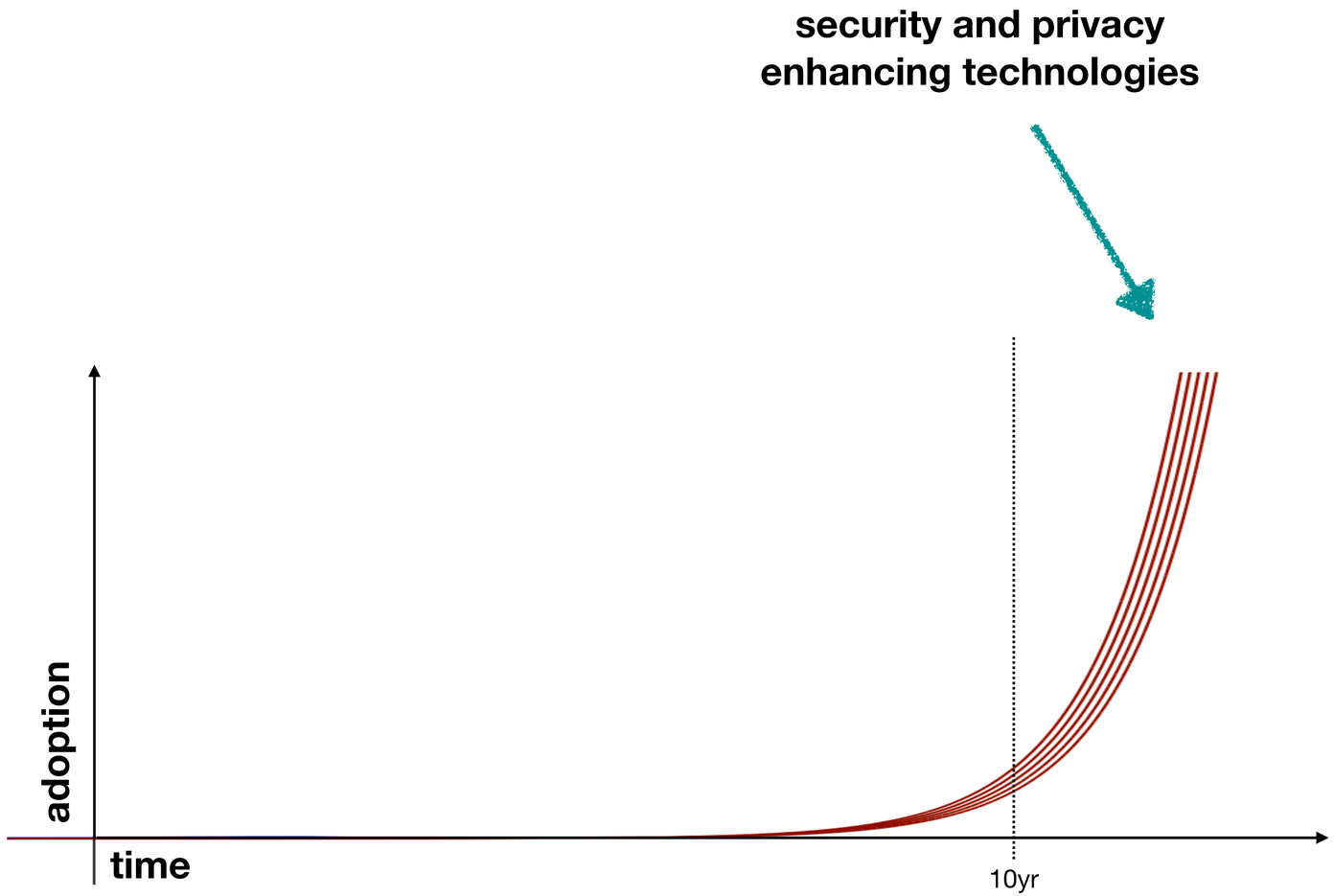
EARLY DAYS FOR DO

Traditional Computation	Data-oblivious Computation
Decades of hardware/ISA research	
Decades of compiler/IR research	
Formal methods and analysis tools	
100% bug-free tools (CompCert)	
High performance applications	

EARLY DAYS FOR DO

Traditional Computation	Data-oblivious Computation
Decades of hardware/ISA research	<1 decade of hardware/ISA research
Decades of compiler/IR research	<1 decade of compiler/IR research
Formal methods and analysis tools	~0 formal methods and analysis tools
100% bug-free tools (CompCert)	~0 bug-free tools
High performance applications	Low performance applications

A CALL TO ARMS



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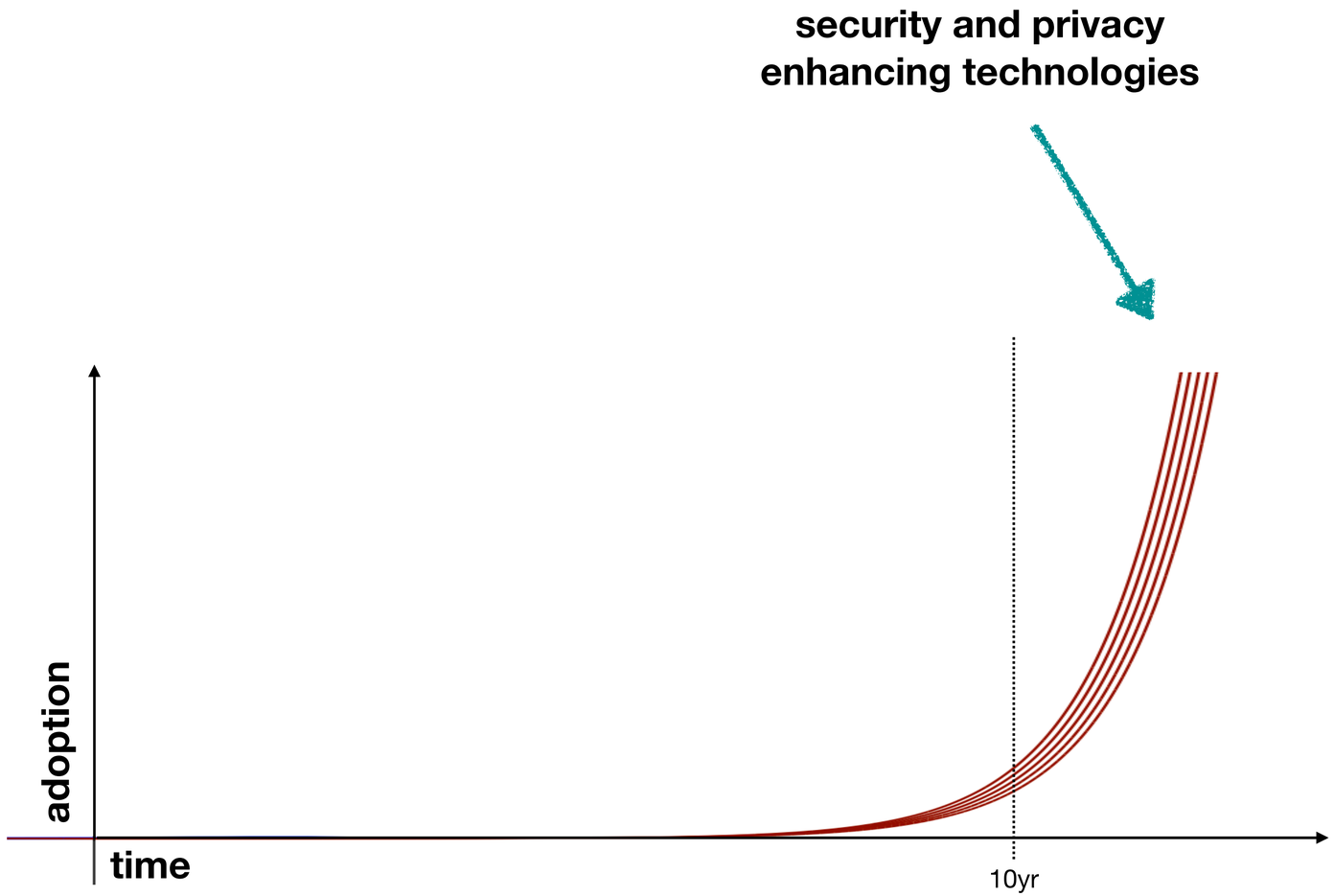

WHERE WE ARE

Oblivious Data Structures (ORAM)

DO ISAs (TinyRam)

DO Formal Methods (PMTO)

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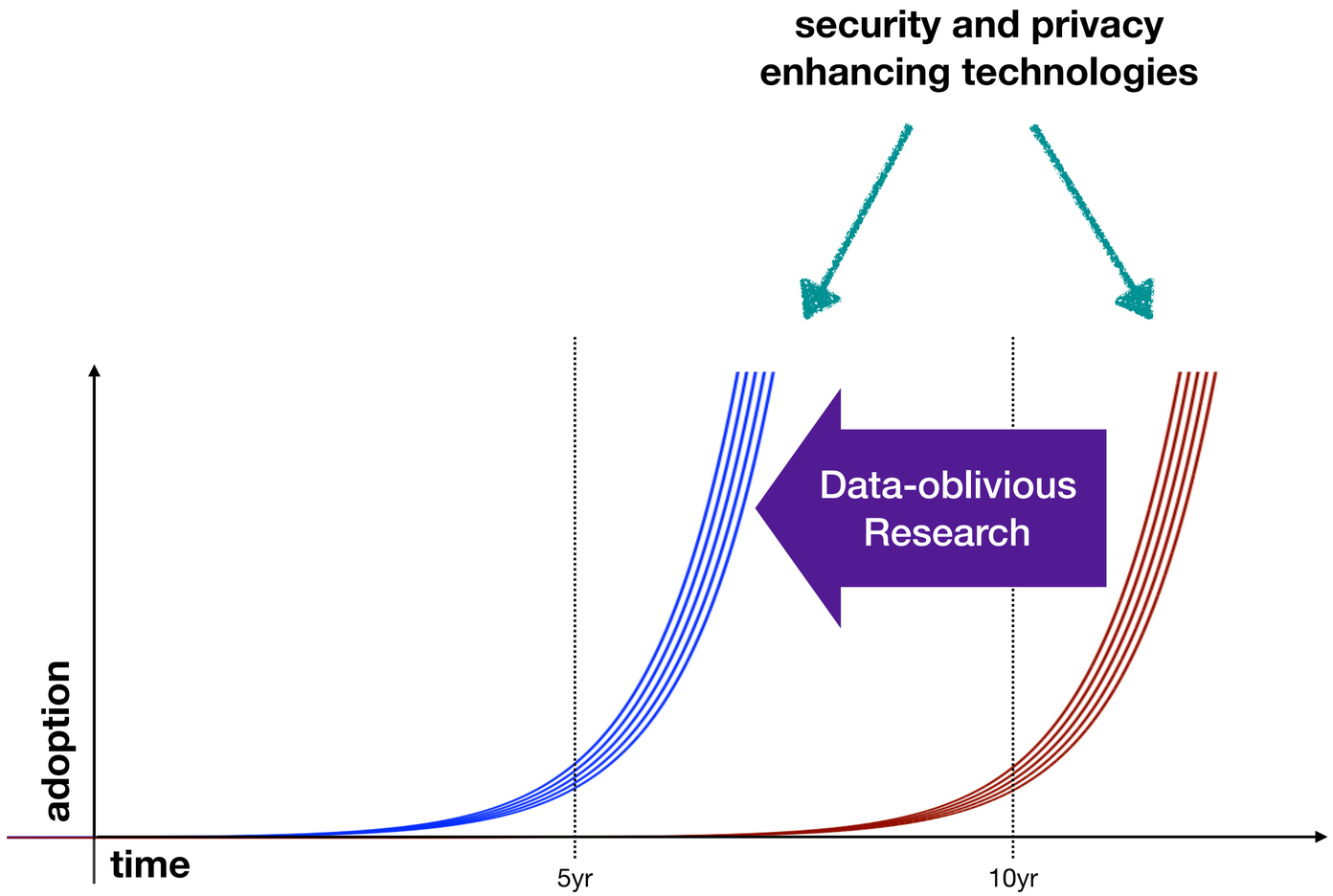

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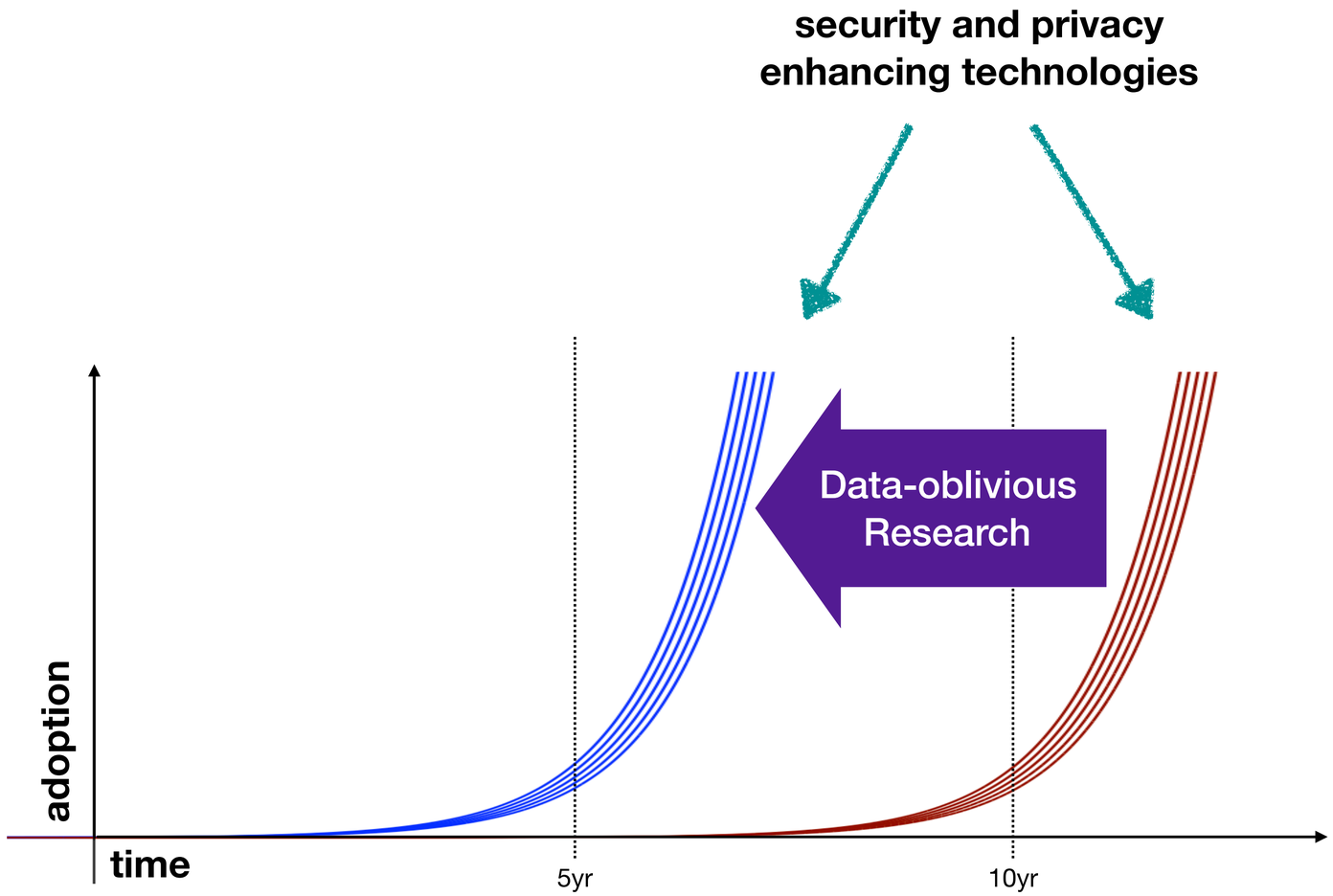

WHERE WE ARE

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WHAT WE NEED

Prog. languages for DO (**usability**)

Compilers for DO (**performance**)

Static analyses for DO (**accuracy**)

Data structures + libs for DO (**flexibility**)

Formal methods for DO (**assurance**)

Domain independence (**ubiquity**)

END

RAM ACCESS

Traditional Computation

```
if (raining) {
  shopping[next_id] = "umbrella";
} else {
  shopping[next_id] = "sunglasses";
}
next_id++;
```

RAM ACCESS

Traditional Computation

```
if (raining) {
  shopping[next_id] = "umbrella";
} else {
  shopping[next_id] = "sunglasses";
}
next_id++;
```

Data-oblivious Computation

```
tmp = shopping[next_id];
shopping[next_id] = raining  ? "umbrella"
                             : tmp;
tmp = shopping[next_id];
shopping[next_id] = !raining ? "sunglasses"
                             : tmp;
next_id++;
```