Architectural Implications of Brick and Mortar Silicon Manufacturing

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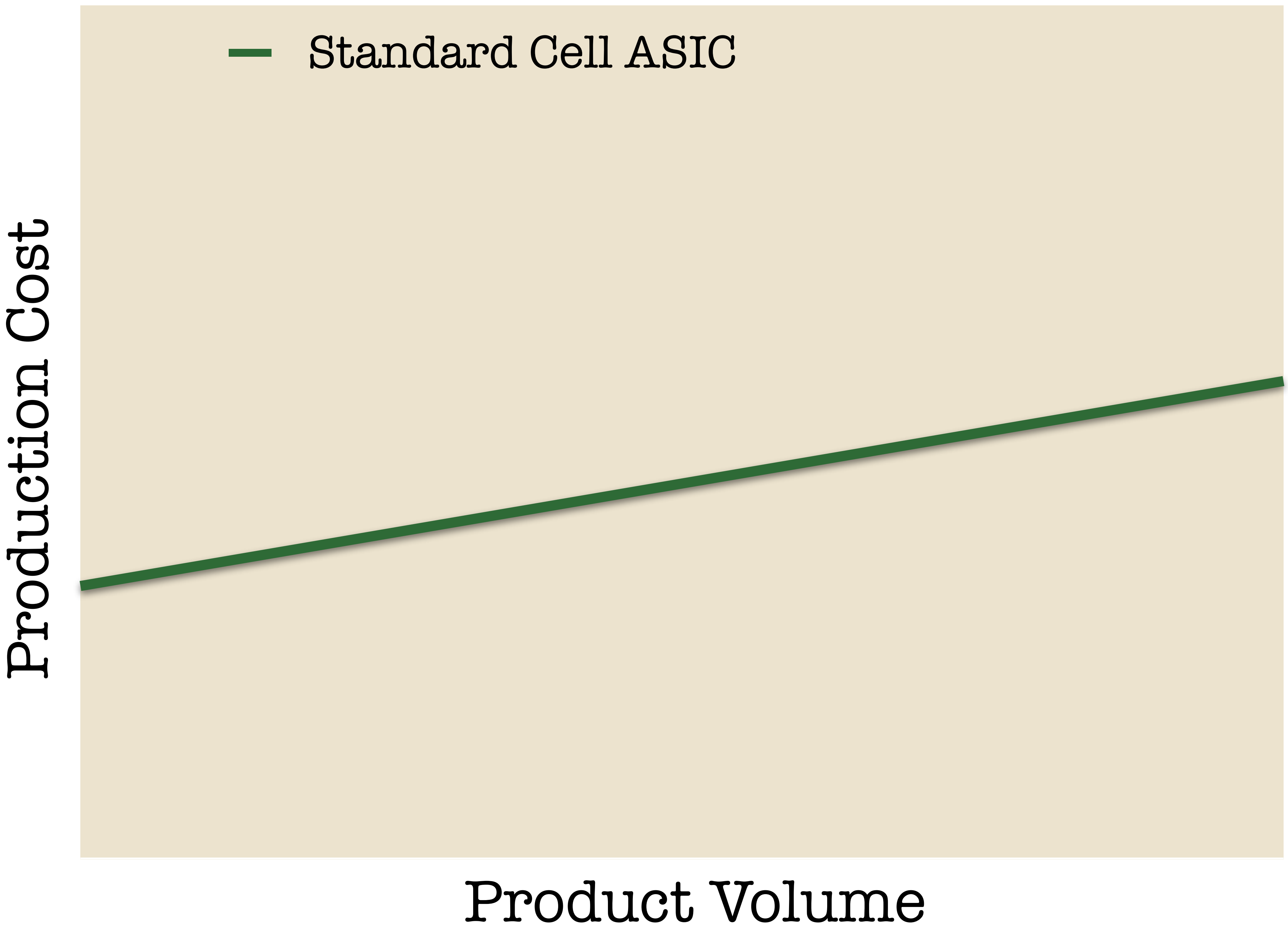
Cost of Production



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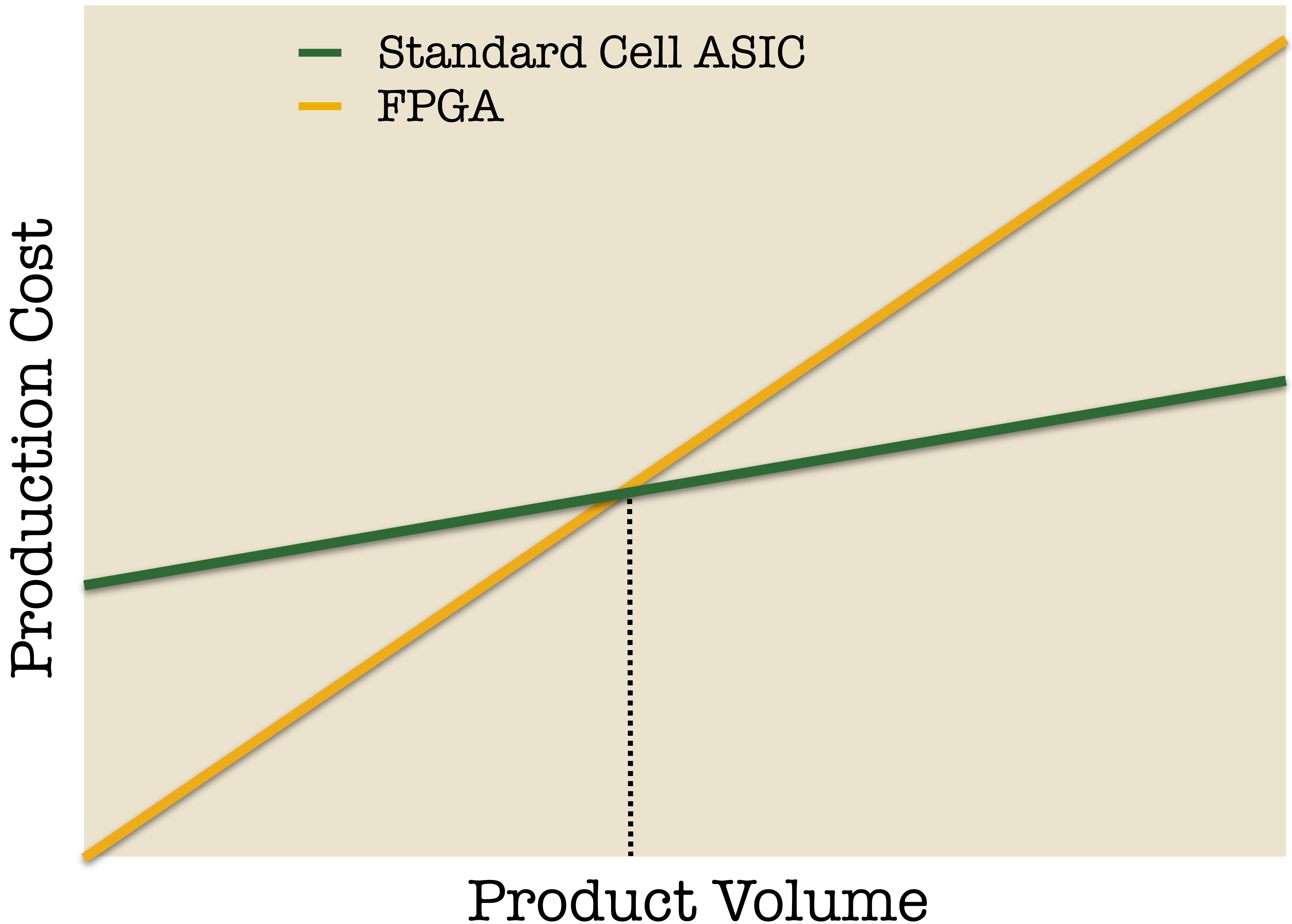
Cost of Production



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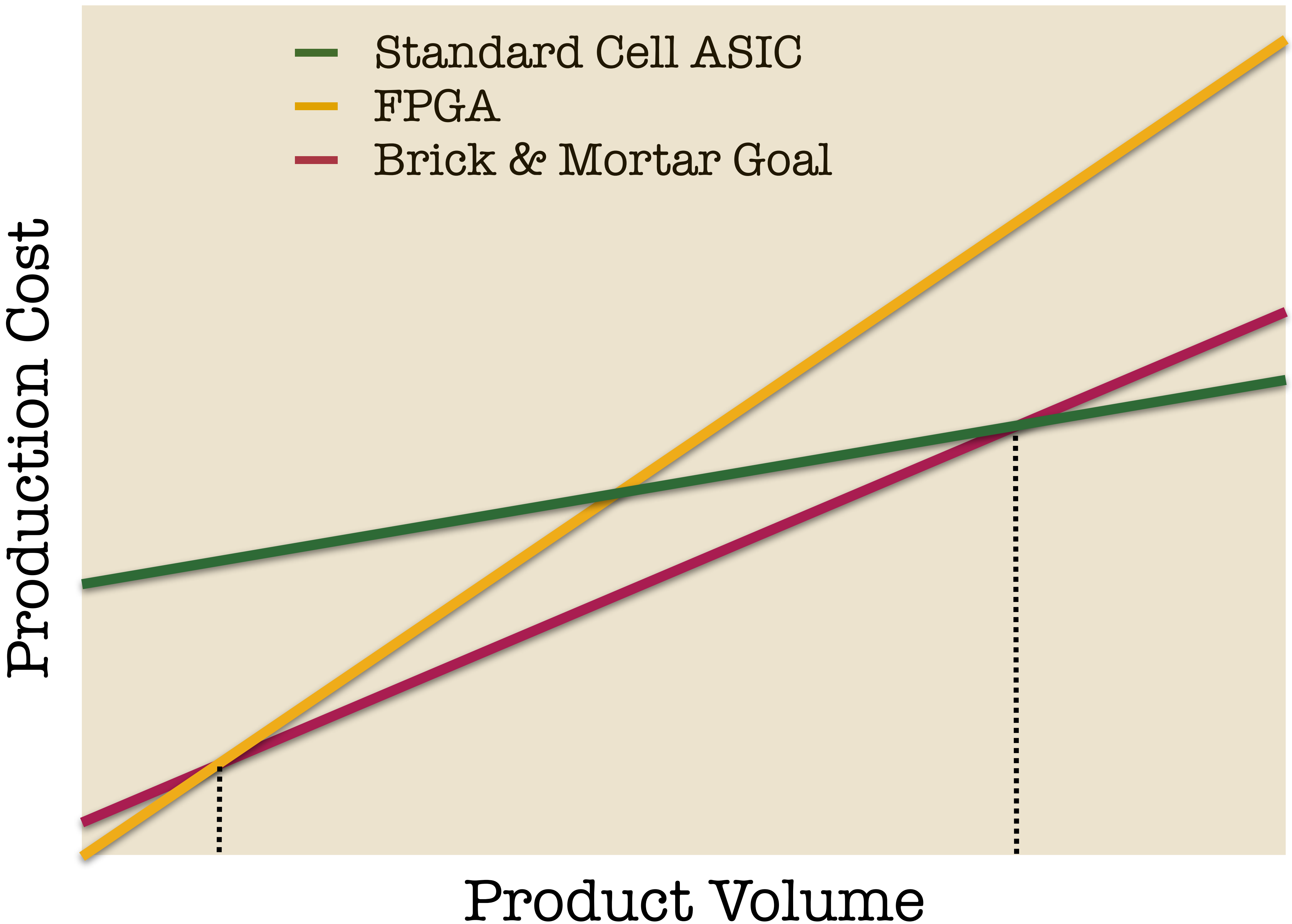

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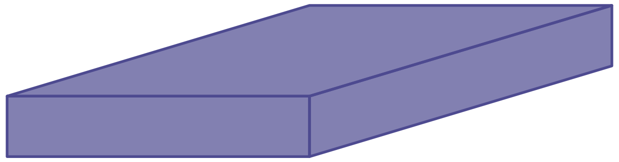
Brick and Mortar Chips



1. Bricks

- Mass-produced ASICs
- Standard interface
- Fixed set of functions

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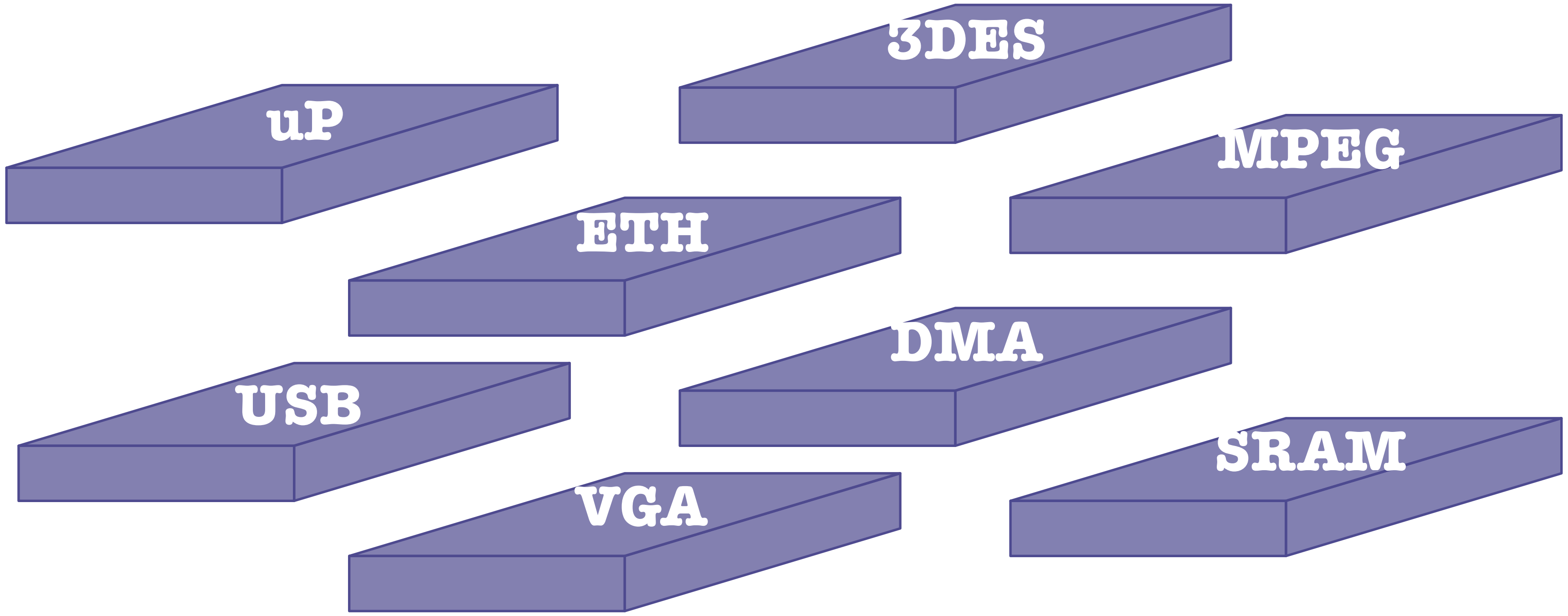

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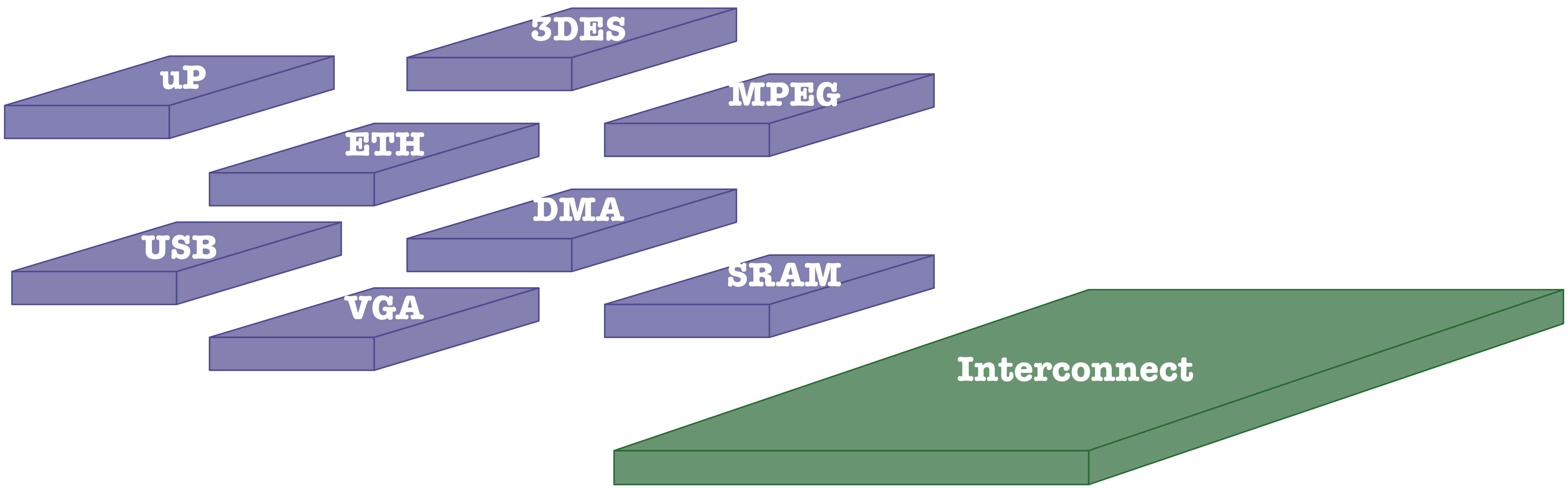

1. Bricks

- Mass-produced ASICs
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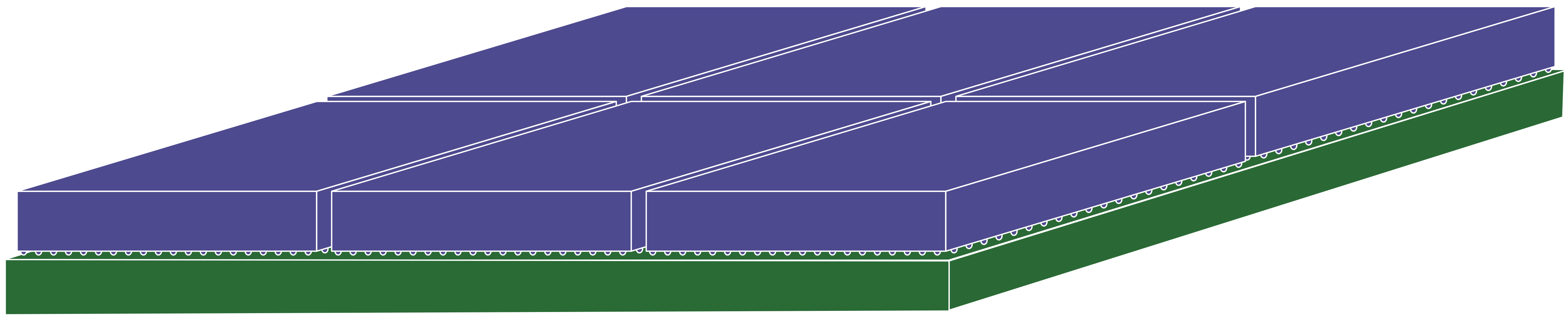
2. "Mortar"

- Mass-produced ASIC
- Standard interface
- Single, interconnect function

Brick and Mortar Chips



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3. Assembly

- Alignment
  - e.g. robotics, fluidic
- Bonding
  - e.g. flip-chip, proximity

Benefits of Brick and Mortar

- **Chip manufacture**: mask-free, fab-free, improved yields
- **Chip performance**: mostly ASIC
- **Chip design**: uses today's SoC design flow

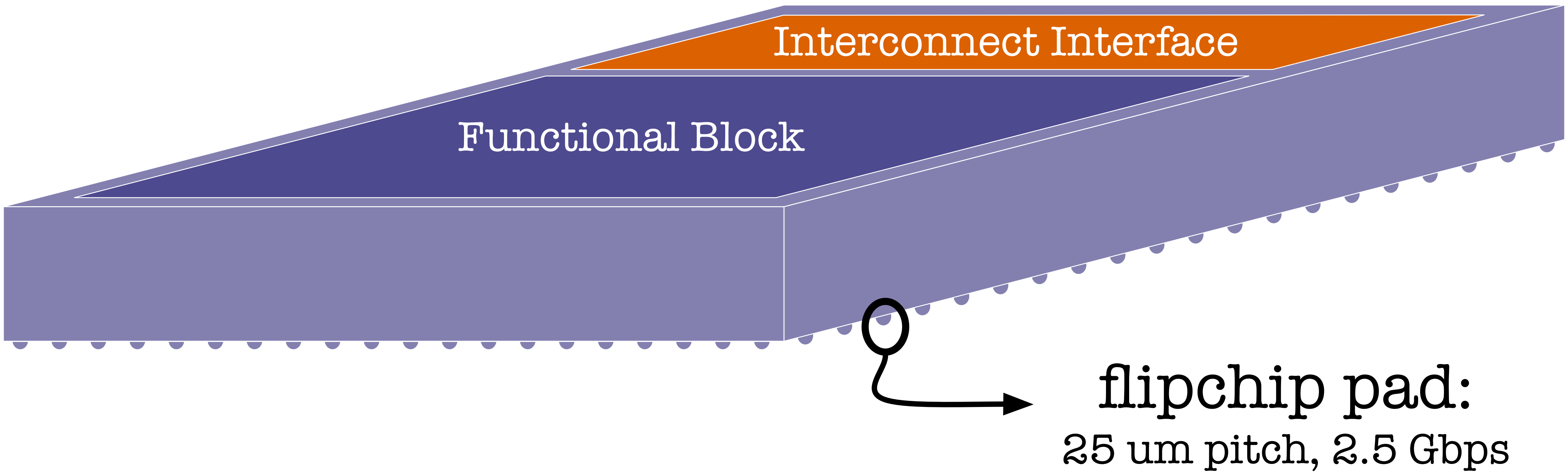
Why Should Architects Care?

- Good architecture essential for viability
  - Brick function and form-factor
  - Inter-brick interconnect design

Outline

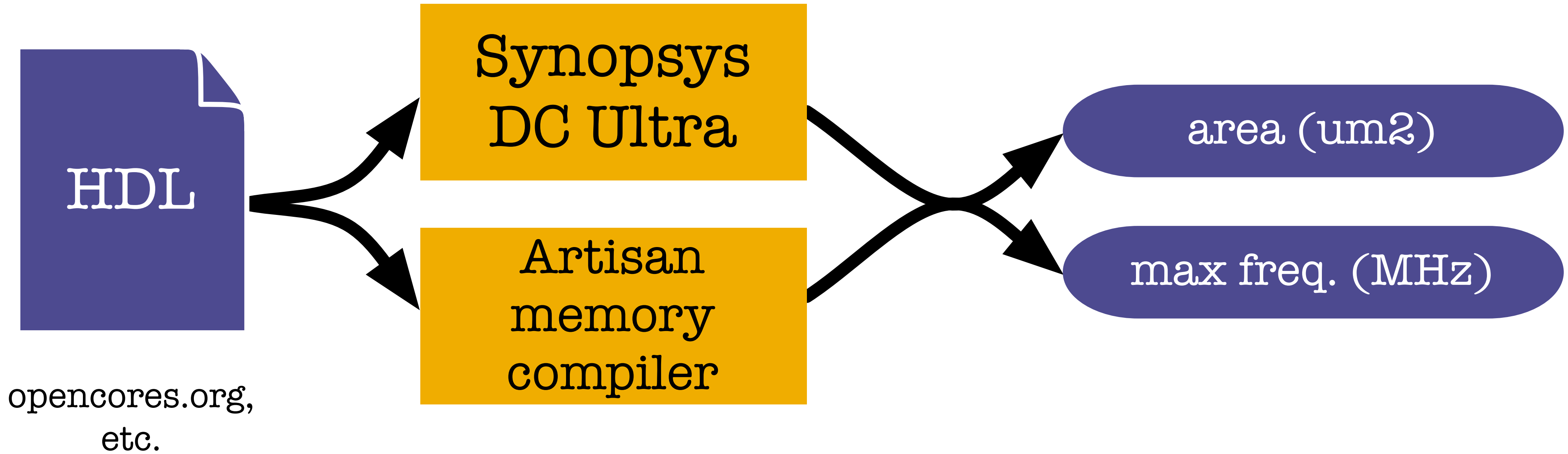
- Brick and Mortar Chips
    - Definition
    - Potential
    - Architectural Questions
- Brick and Mortar Architecture
    - Bricks
    - Interconnect
- Brick and Mortar Assembly
    - Options
    - Interaction with architecture

Brick Form Factor



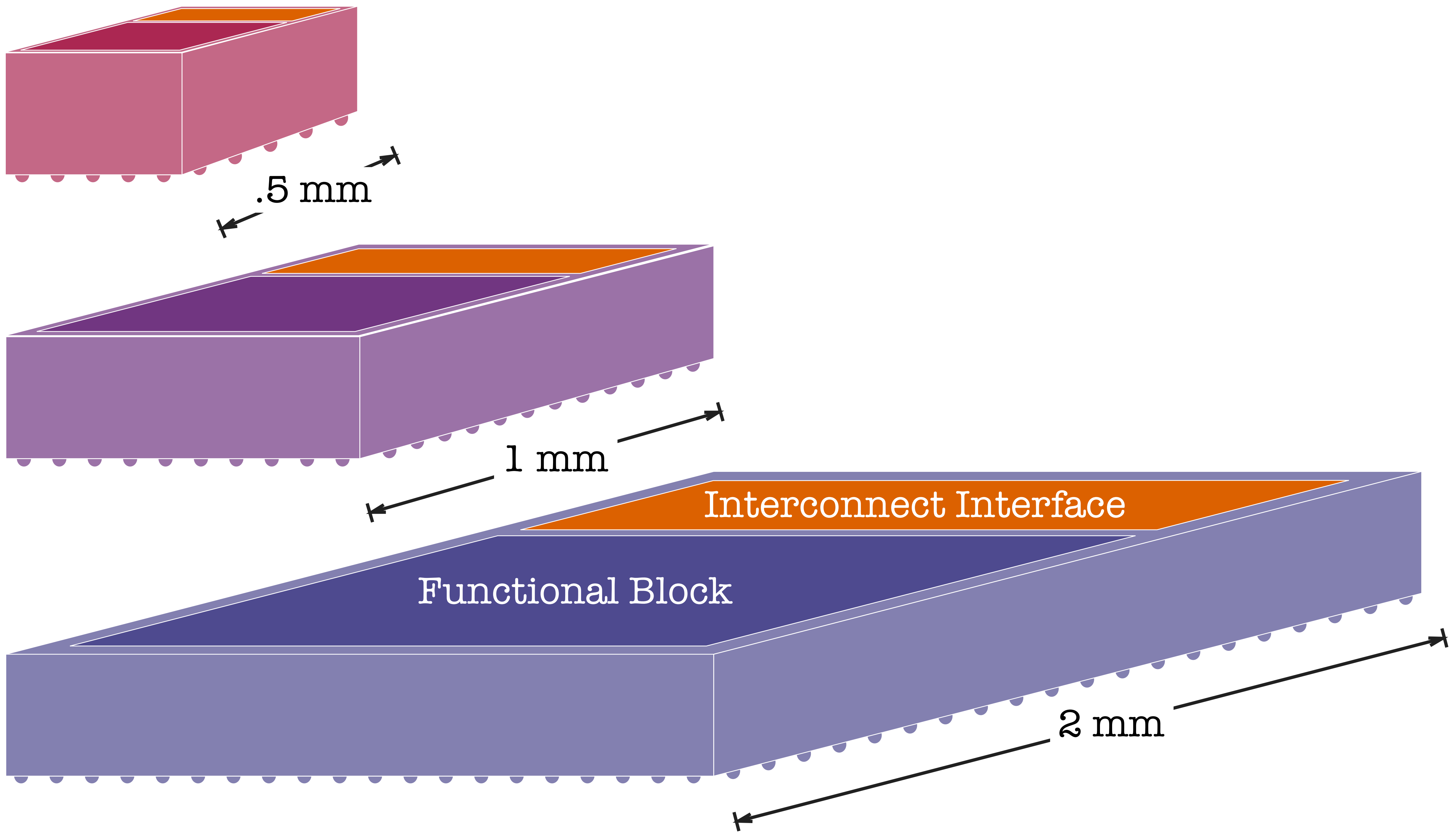
- Each brick . . .
  - is square
  - has 15% of area reserved for extra circuitry
  - has one surface covered with flipchip pads

Brick Architecture



Function Description	Area (um2)	Max Freq. (MHz)
USB 1.1 Physical Layer	2,201	2941
JPEG Decoder	625,457	629
RISC Core + 256K Cache	3,111,025	1087

Multiple Brick Sizes



Brick Size Selection

Function Description	Circuit		Freq. Range at Brick Size		
	Area (um2)	Max Freq. (MHz)	Small	Medium	Large
256 K SRAM (single-ported)	2,729,344	2315	No Space	No Space	N/A - 2315
JPEG Decoder	625,457	629	No Space	N/A - 629	No Benefit
VGA/LCD Controller	4,301	1219	N/A - 1046	N/A - 1219	No Benefit

- Smallest brick to fit circuit, unless bandwidth **severely** constrained

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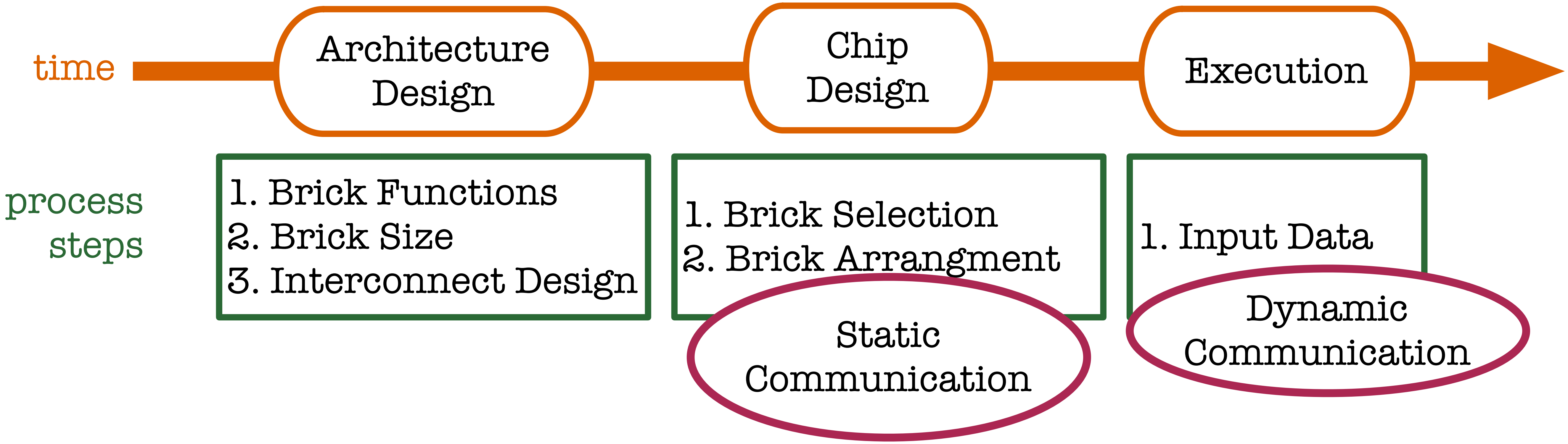
Interconnect Dilemma



- General purpose interconnect facilities
  - Communication known at design time ⟶ configurable wires
  - Dynamic communication ⟶ packet-switched net

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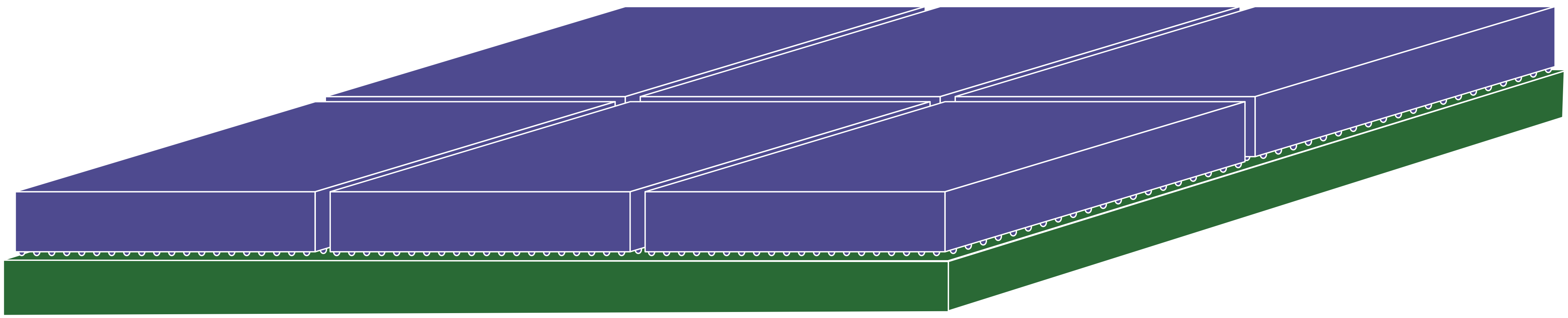
Brick and Mortar Chips



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Assembly Alternatives

- Alignment
  - Robotic
  - Self-Assembly
  - Martha + tweezers
  - ...
- Bonding
  - Flip-chip
  - Proximity
  - ...

Assembly Alternatives

- Alignment
  - Robotic — $$$, but fast
  - Self-Assembly — $, but slow
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- Alignment
  - Robotic $$$, but fast
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- Bonding
  - Flip-chip medium-density, but more robust connection
  - Proximity high-density
  - ...

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  - Robotic — $$$, but fast
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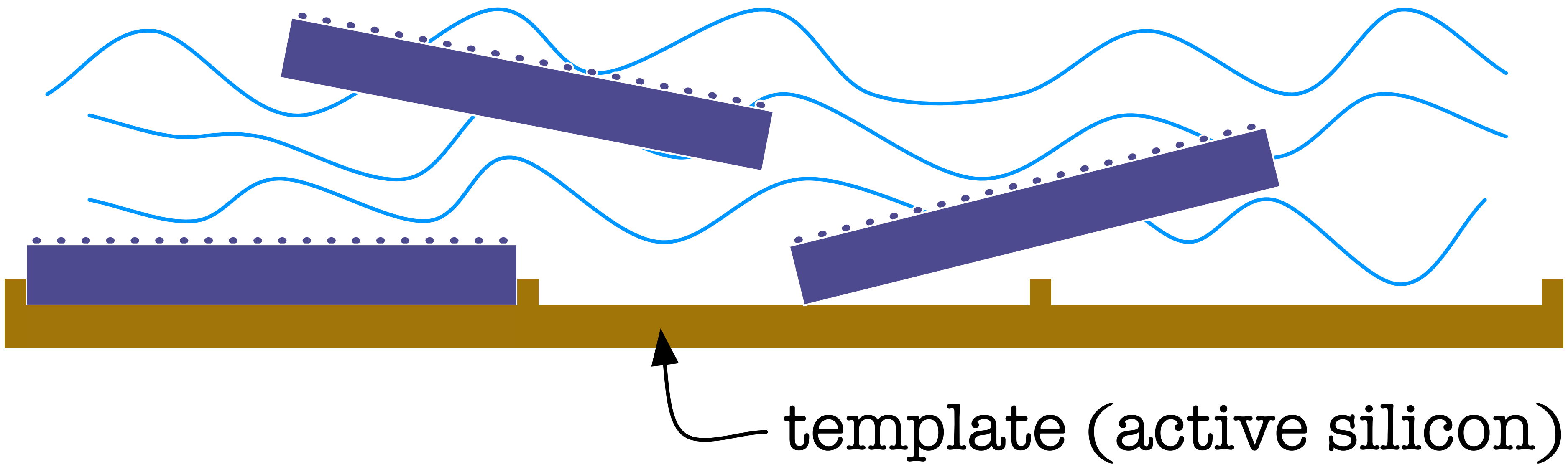
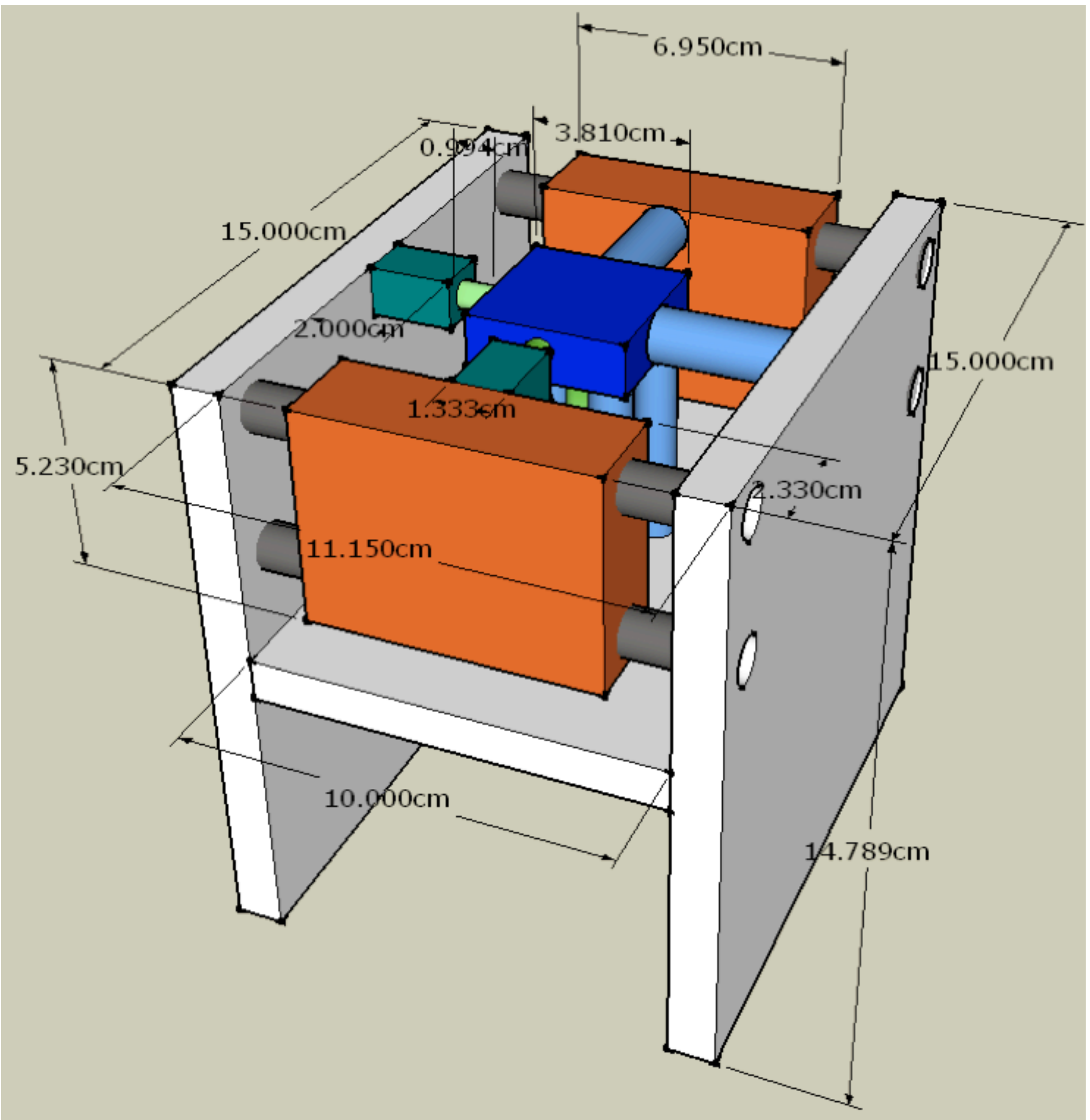
- Bonding
  - Flip-chip — medium-density, but more robust connection
  - Proximity — high-density
  - ...

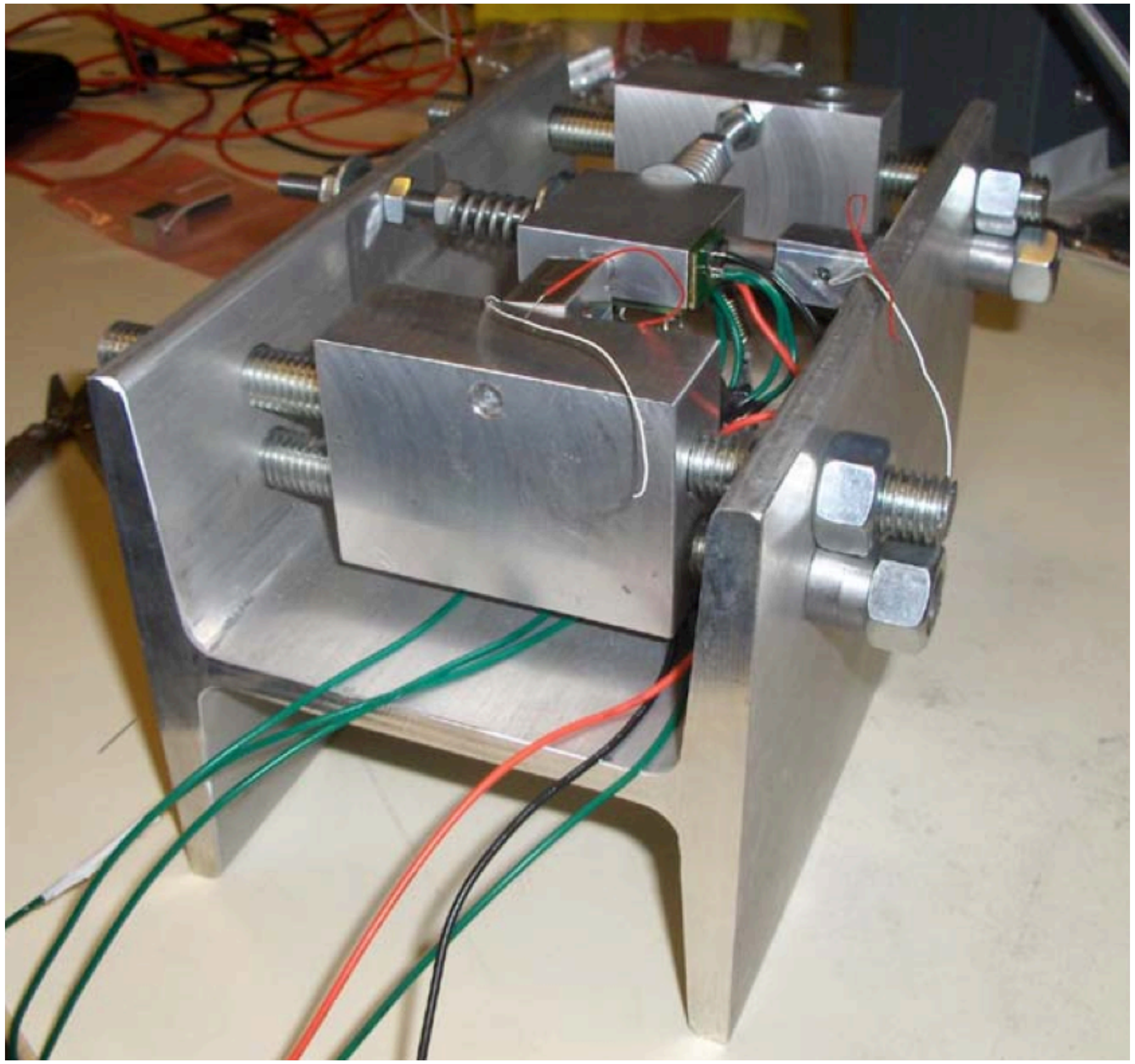
Alignment:
Fluidic Self Assembly



- Template - brick communication via proximity communication
  - Brick type check, BIST, speed grade
- Polymer on template can grip or eject bricks

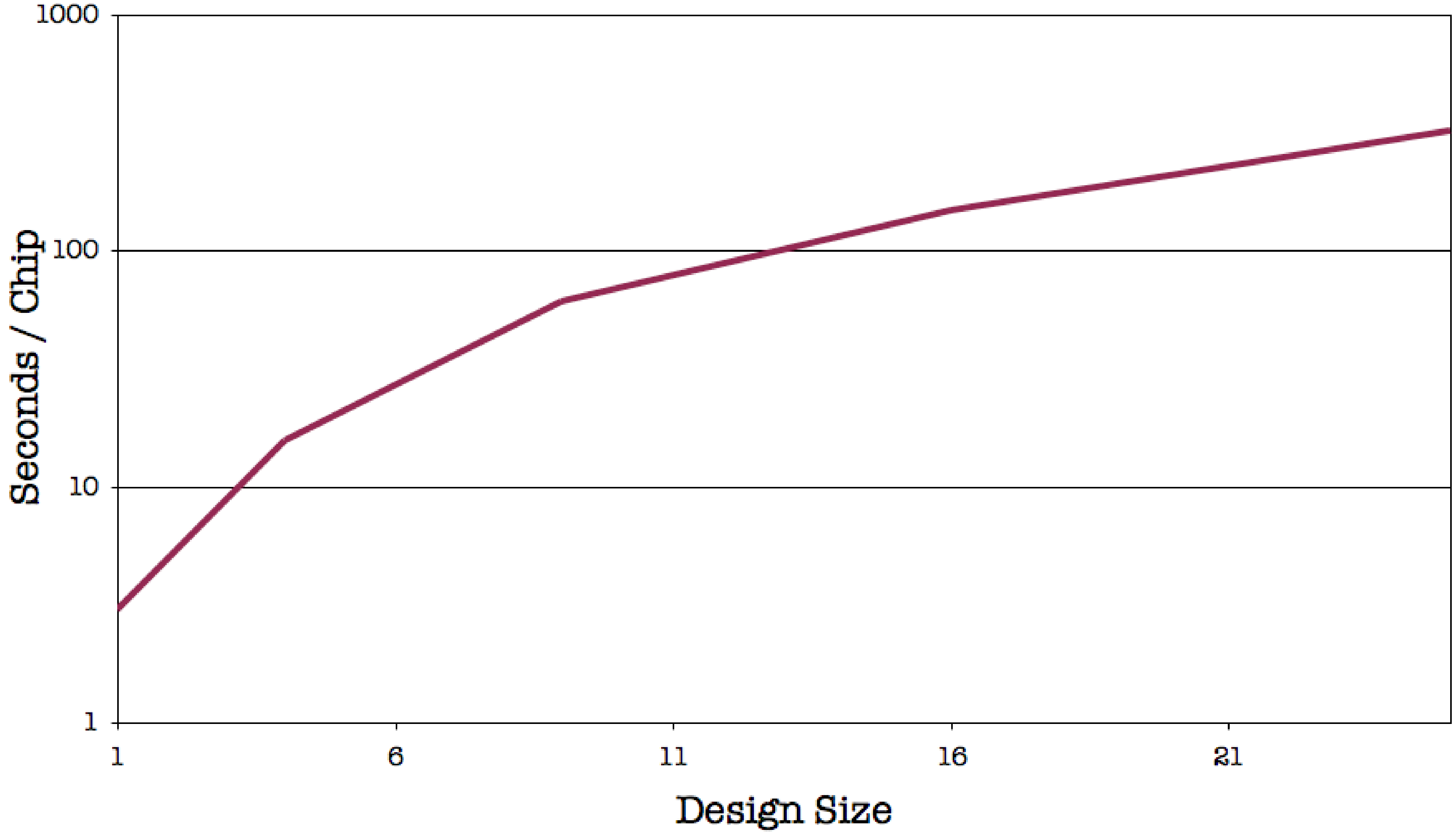
Alignment:
Fluidic Self Assembly





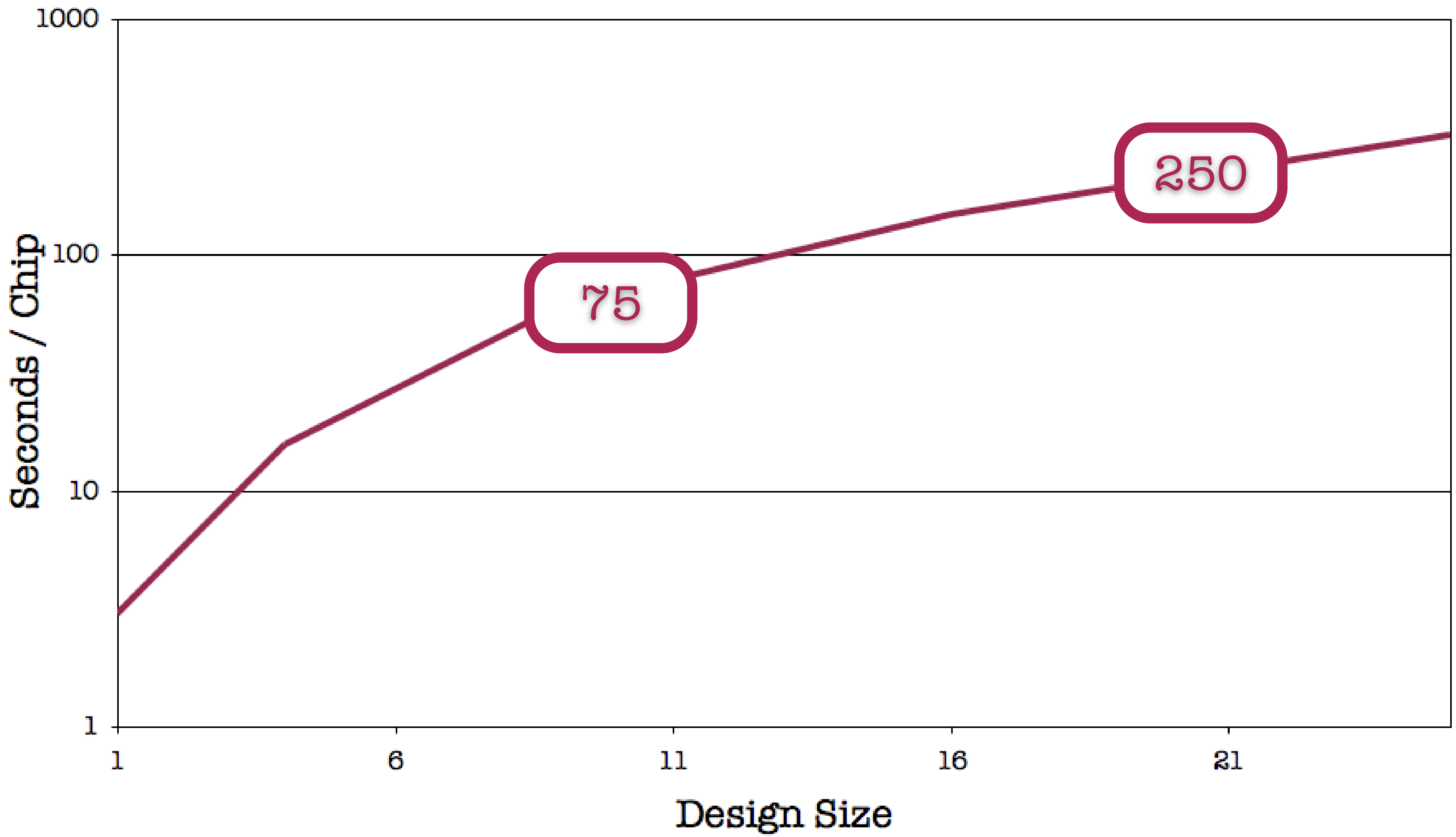
- Washington EE experimental system

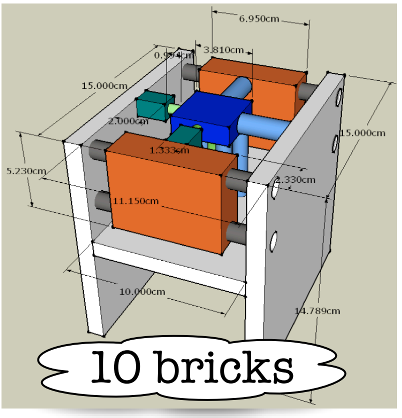
Assembly Time v. Number of Bricks

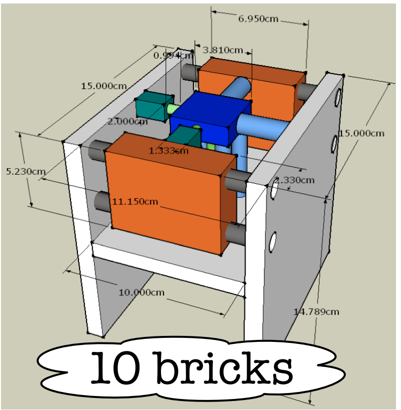


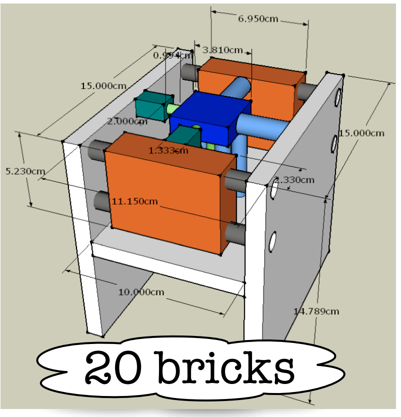
- Statistical simulator driven by experimentally derived rates of assembly and disassembly

Assembly Time v. Number of Bricks

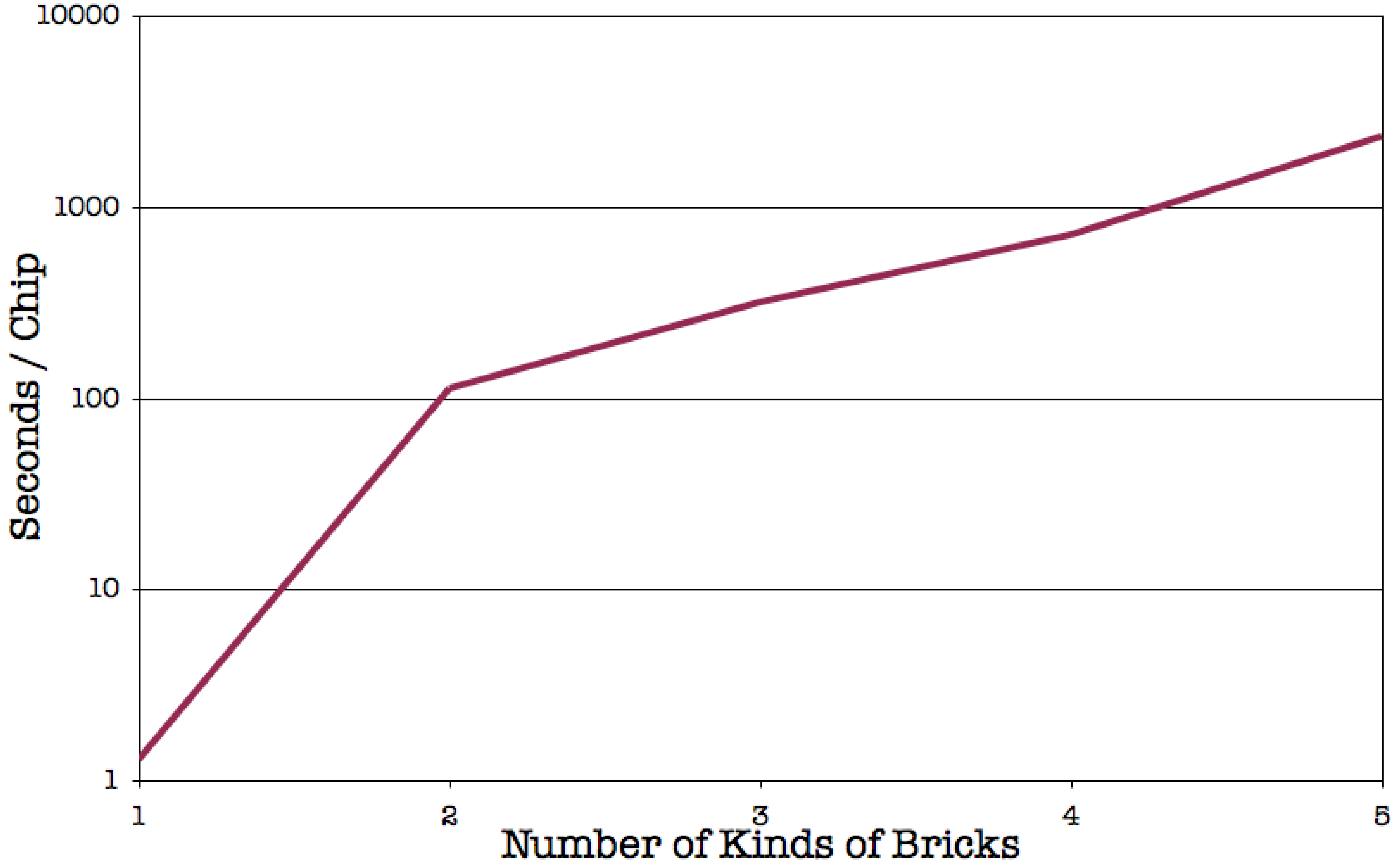


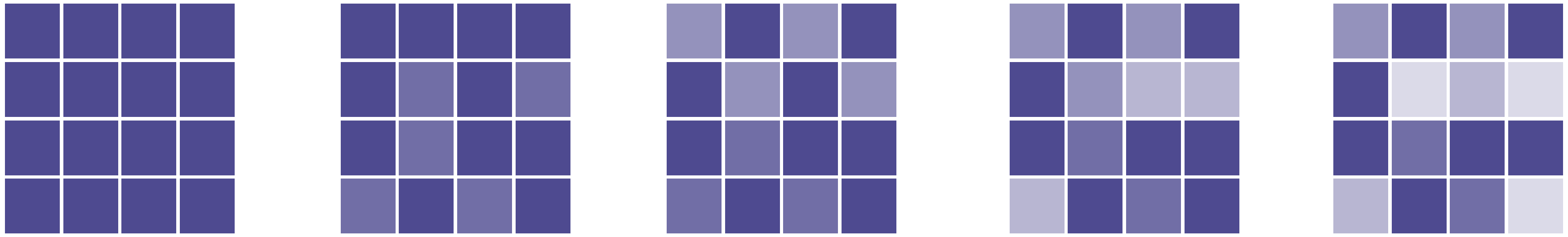






Assembly Time v. Kinds of Bricks





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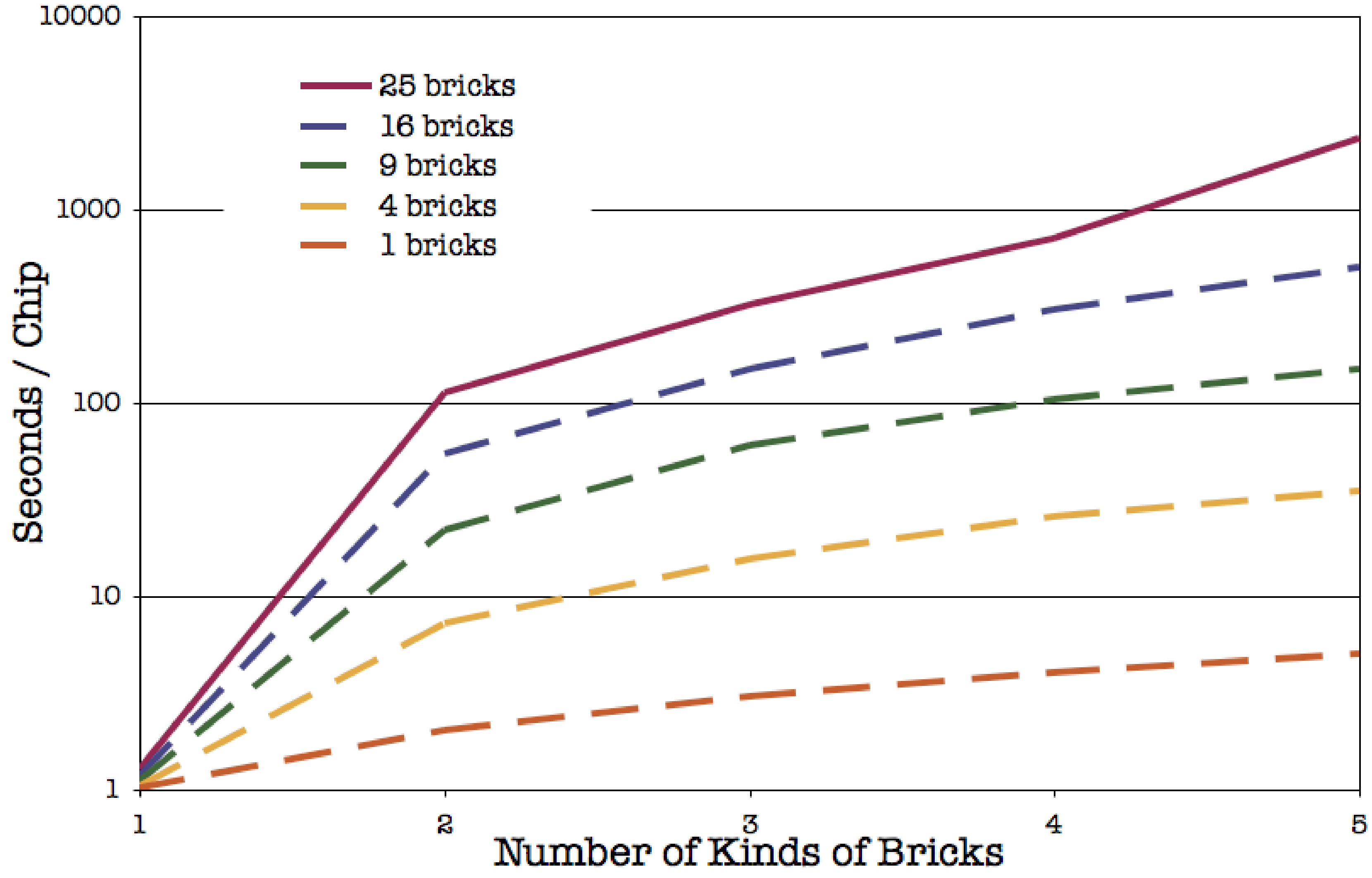

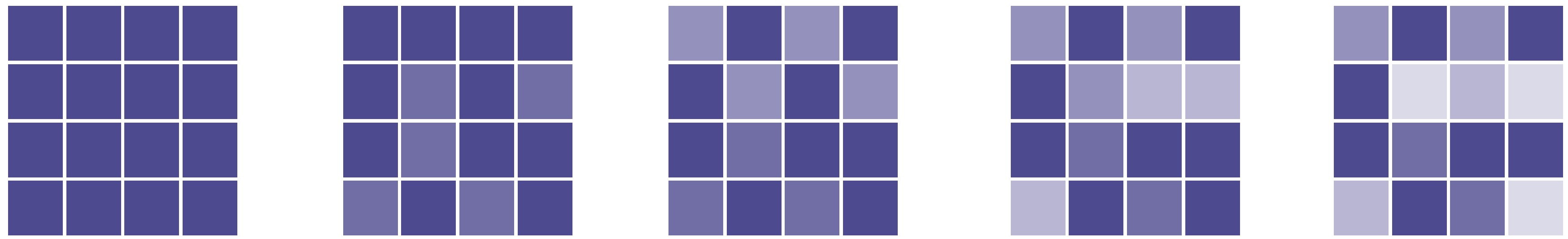

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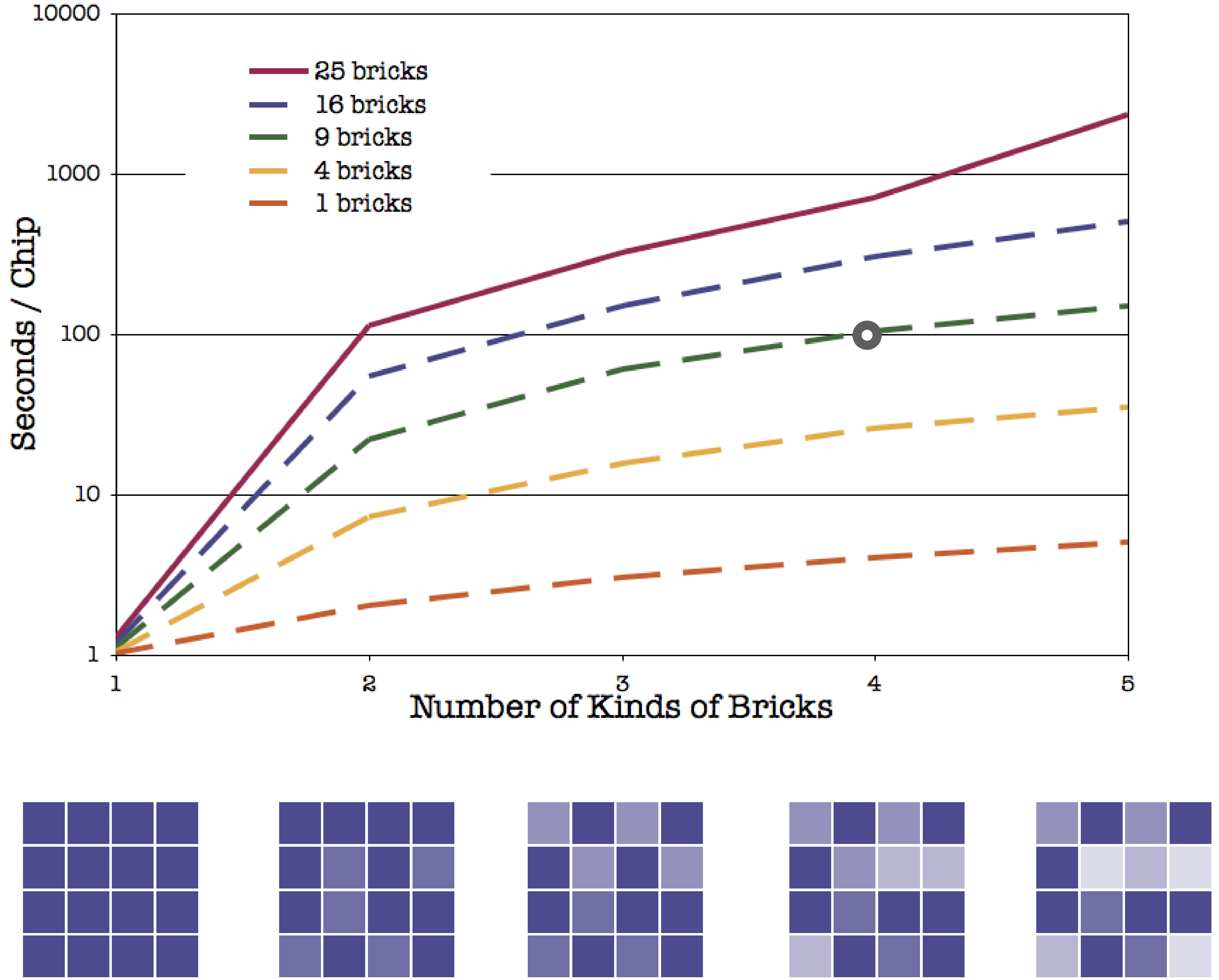

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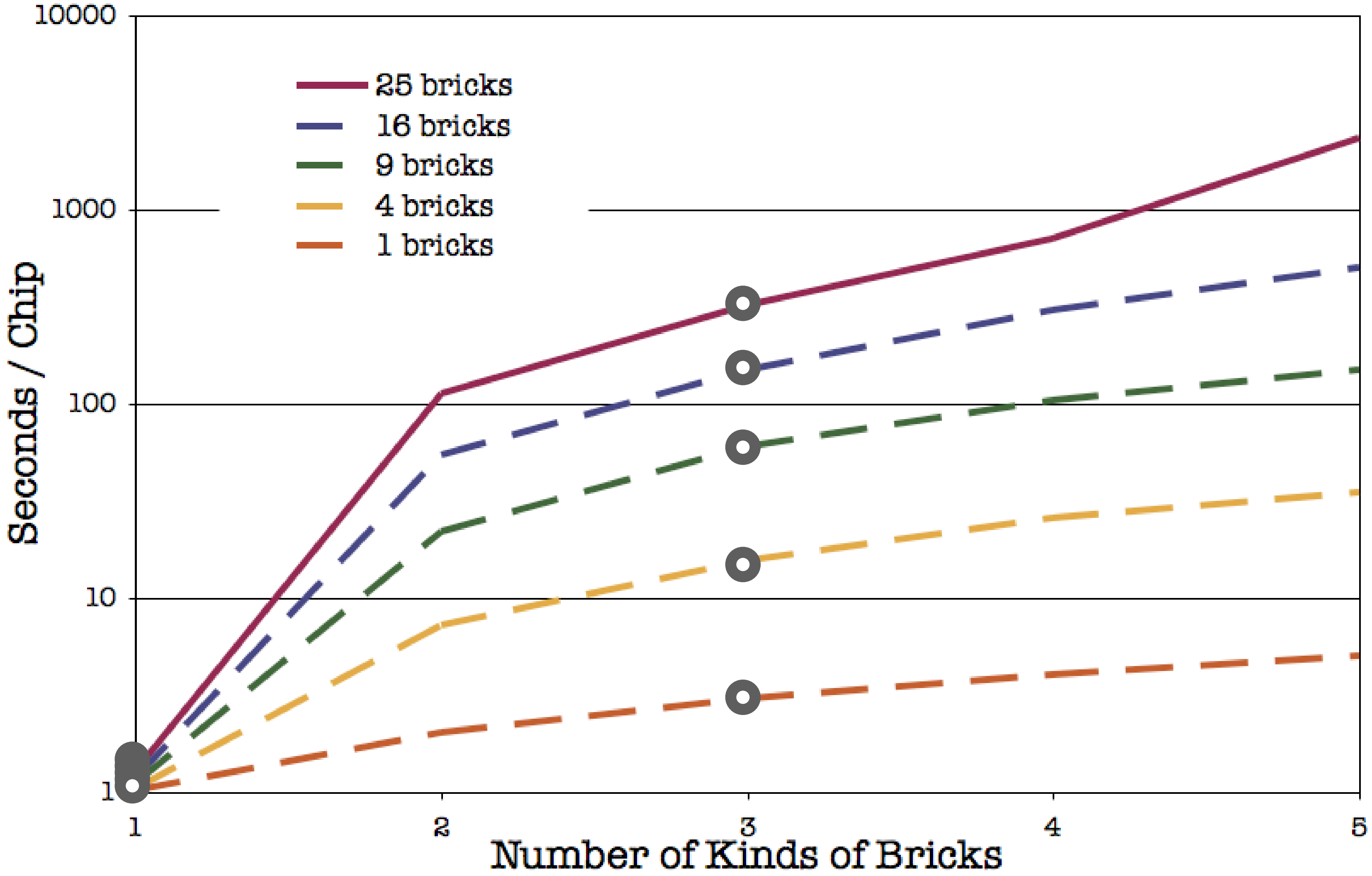
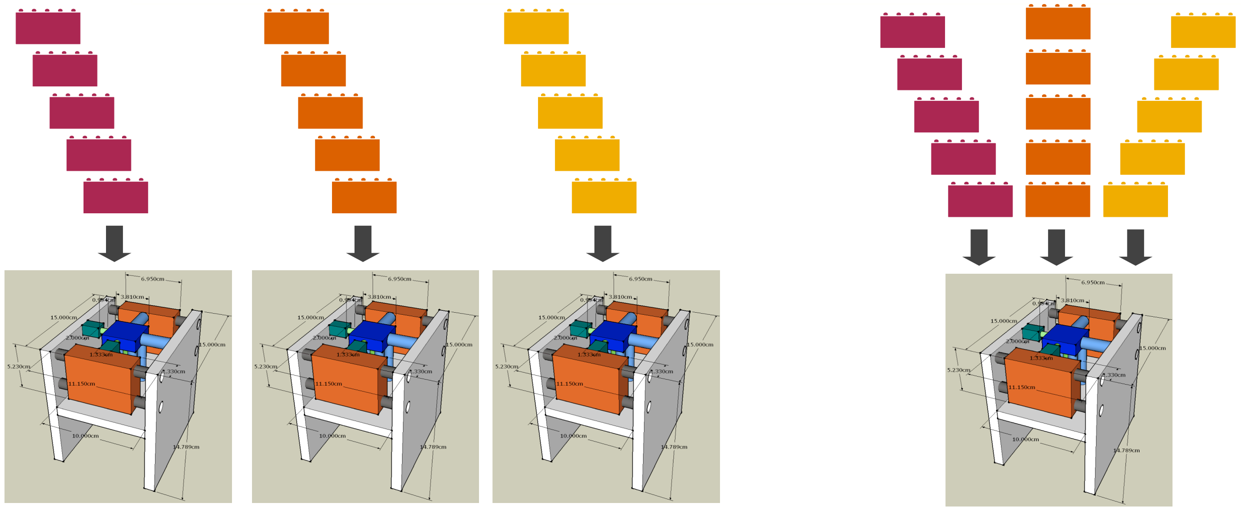
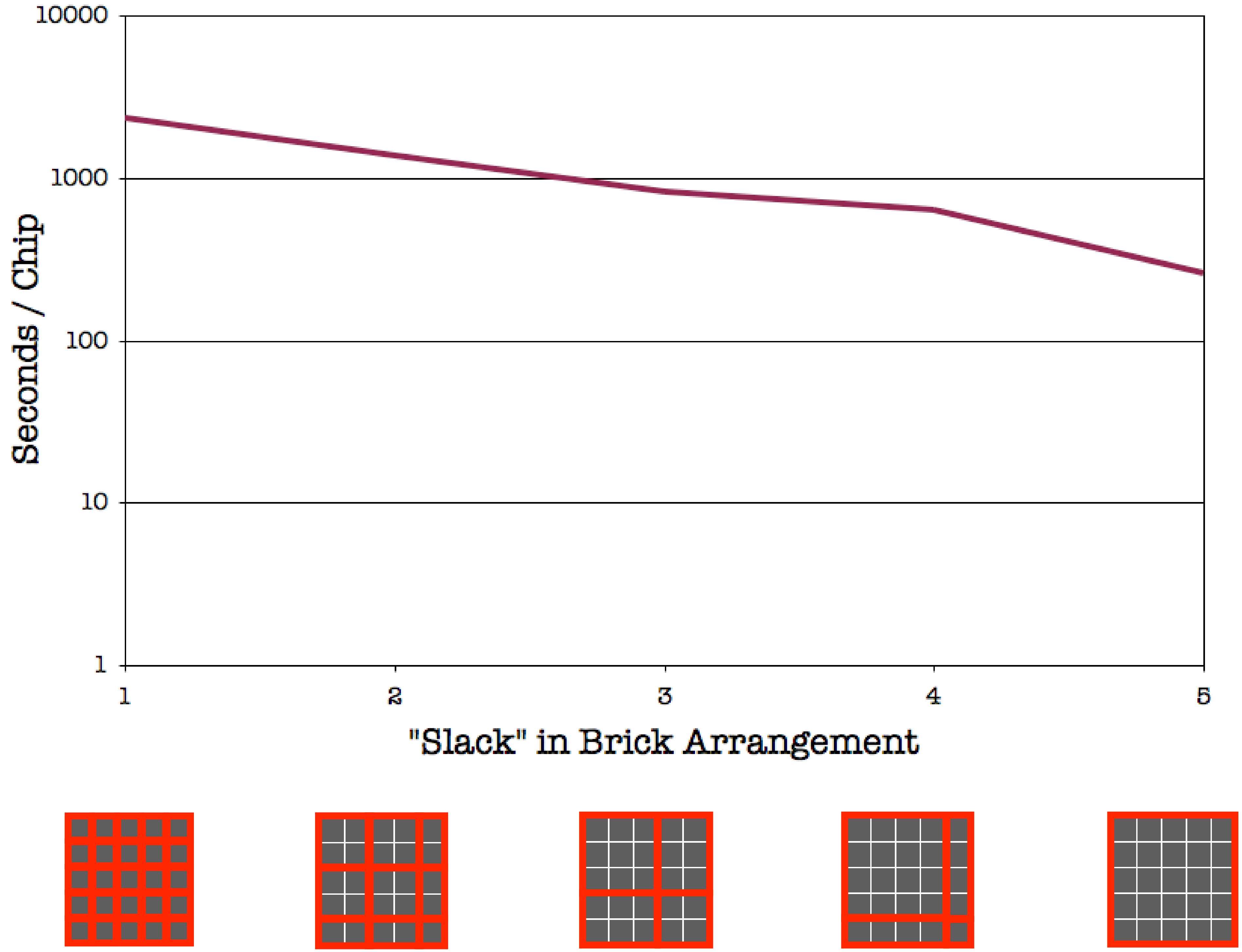
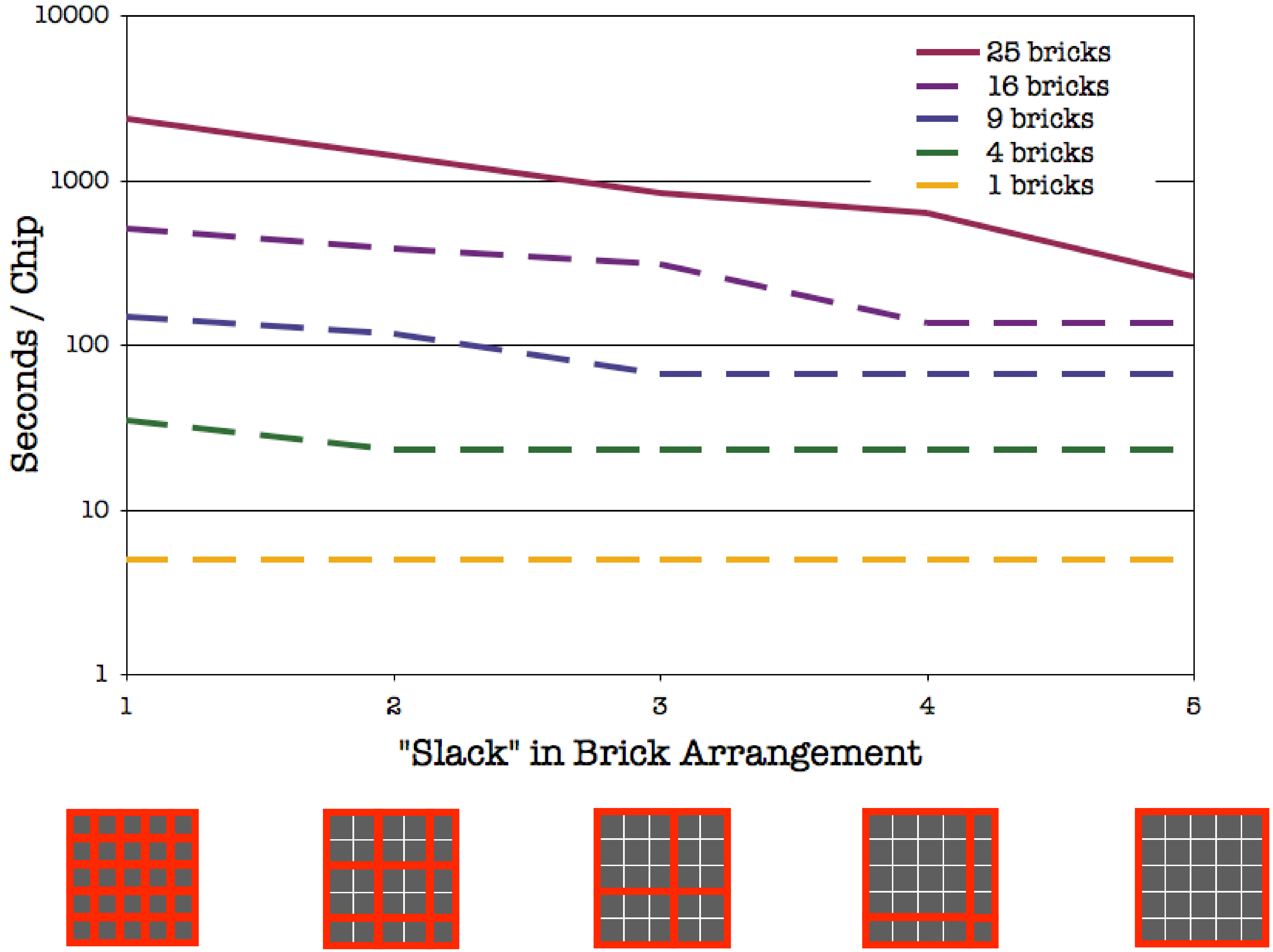




Assembly Time v. Brick Arrangement Slack



Evaluating Slack: Design Size



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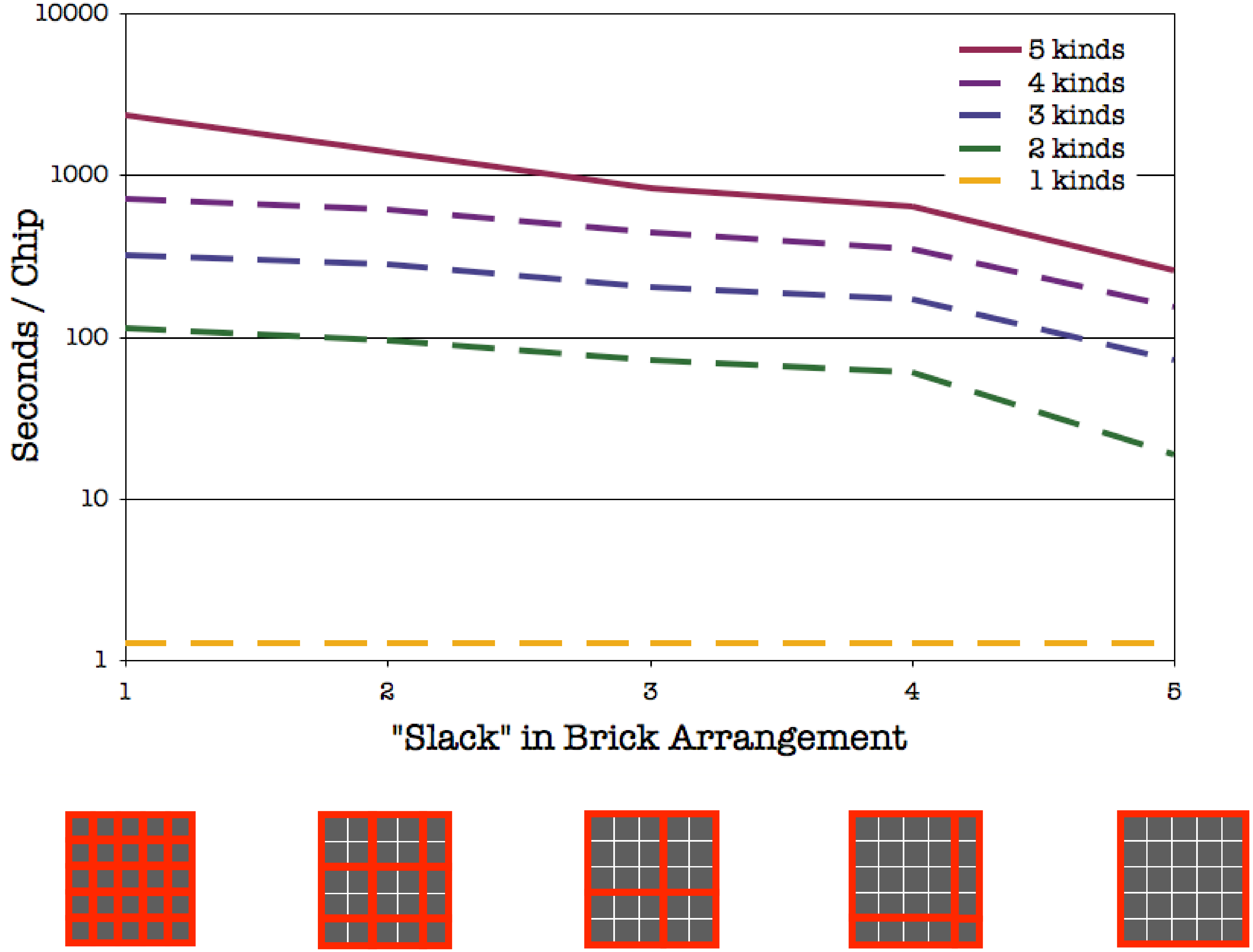

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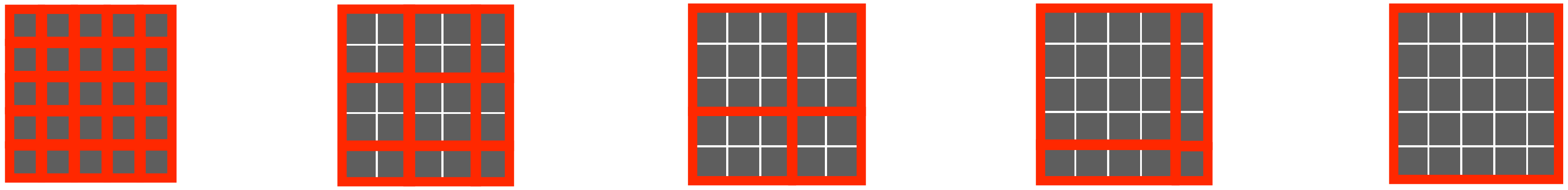

Assembly and Architecture

- Architecture can assist assembly by
  - Reducing the number of kinds of bricks
    - i.e., two brick kinds v. one slightly reconfigurable circuit
  - Accommodating variable assemblies

Conclusion

Brick and Mortar process offers ASIC-like chips without the masks and fabs

Architecture is crucial to meet the performance goals of the process

With low-cost assembly techniques, can meet the economic goal as well