



Strategic Considerations for Neuromorphic Computing

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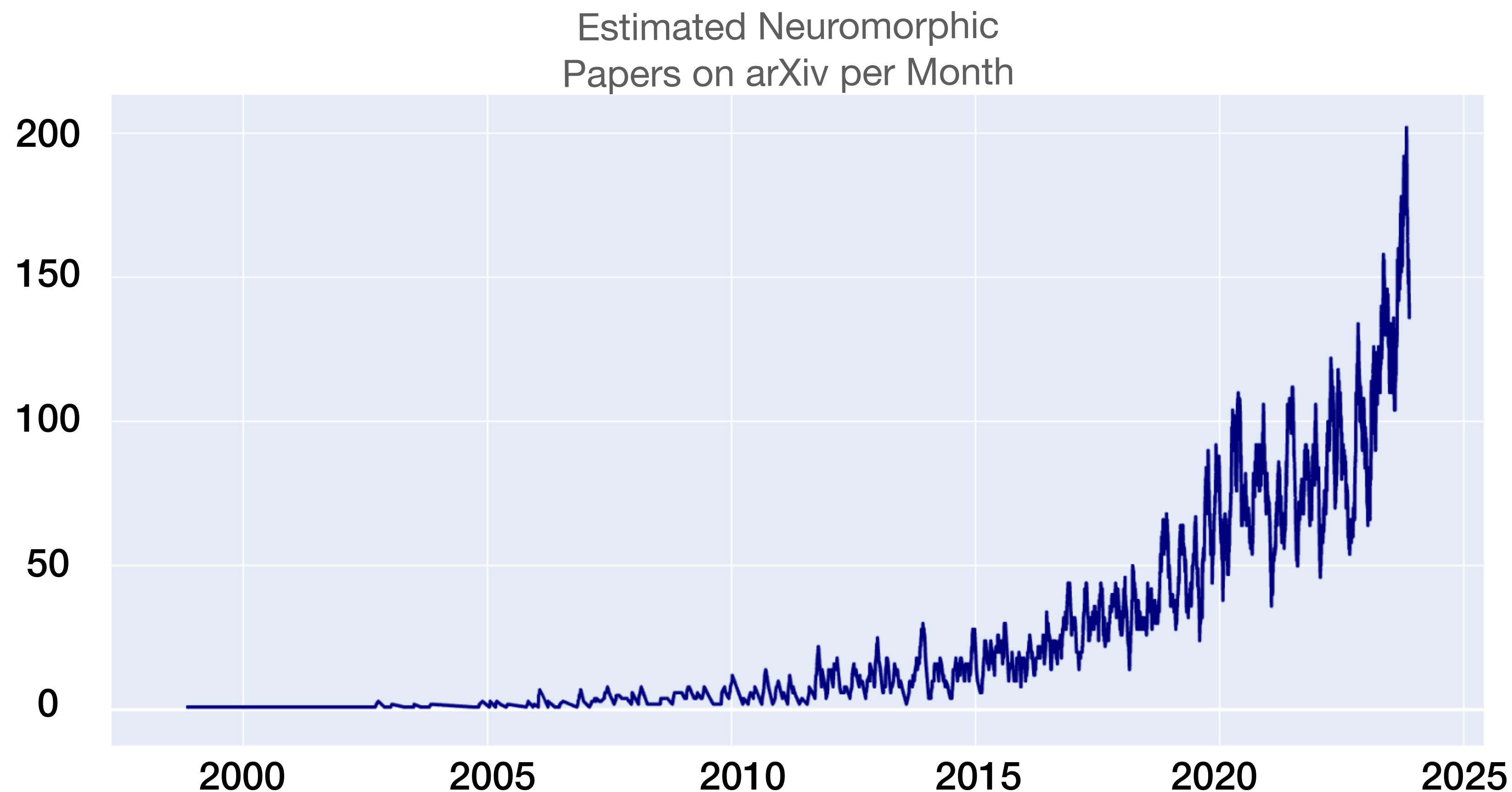


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**Why do I always need to explain
what "neuromorphic" means?**

Neuromorphic Output is Healthy



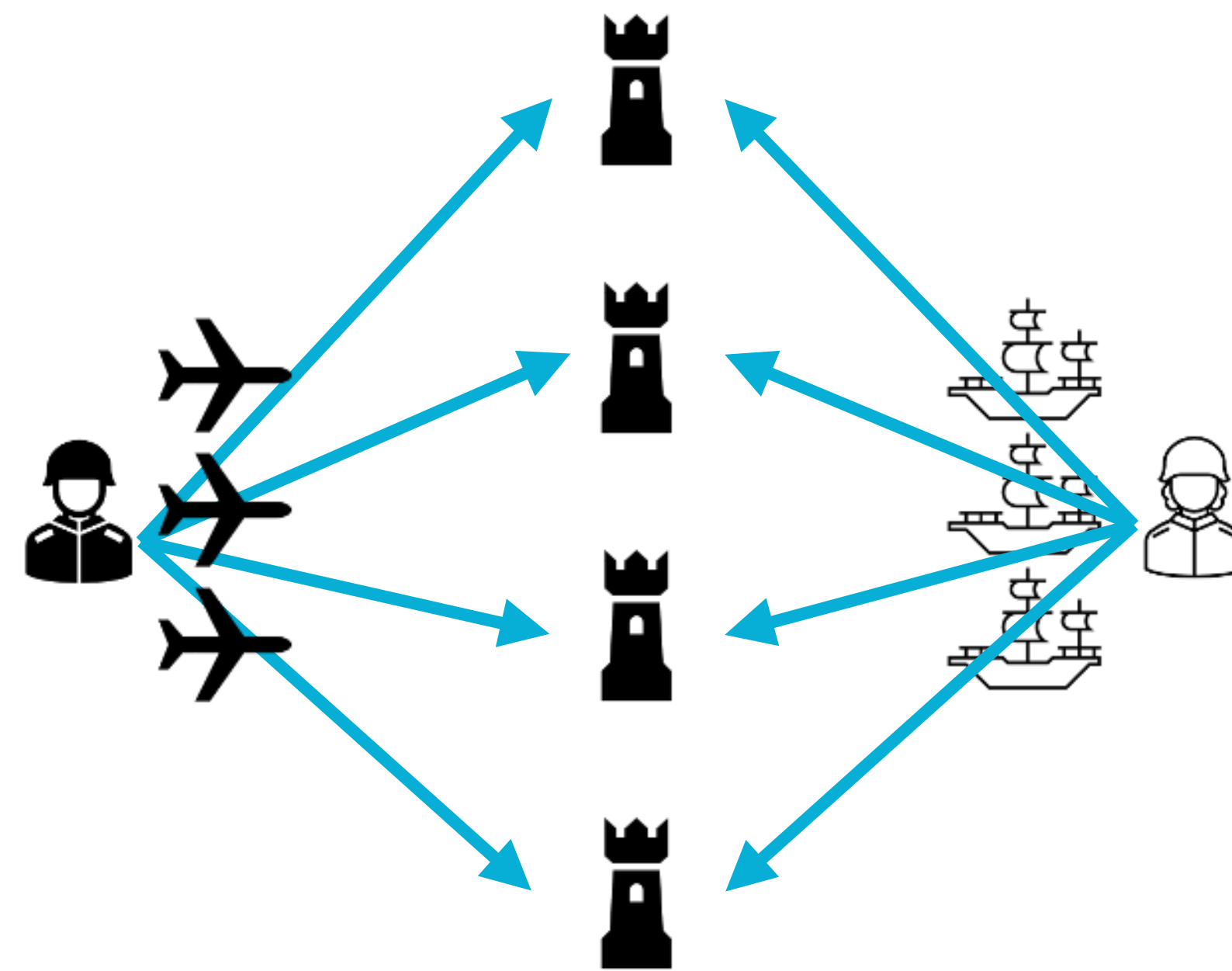
Hypothesis: The field is in a boom cycle, but we struggle to gain awareness from outside the field.

Thinking about Research Strategically

- There are many aspects and approaches to strategic planning and its intersection with research efforts
- Our focus today: How do we choose research directions that maximize impact given our limited resources?
- One option: Use Game Theory concepts as a method to provide introspection into the decisions we make
 - i.e. Papers, Proposals, and Collaborations
- This will only be a small piece of the pie
- Two analyses today: Colonel Blotto and an Assurance Game

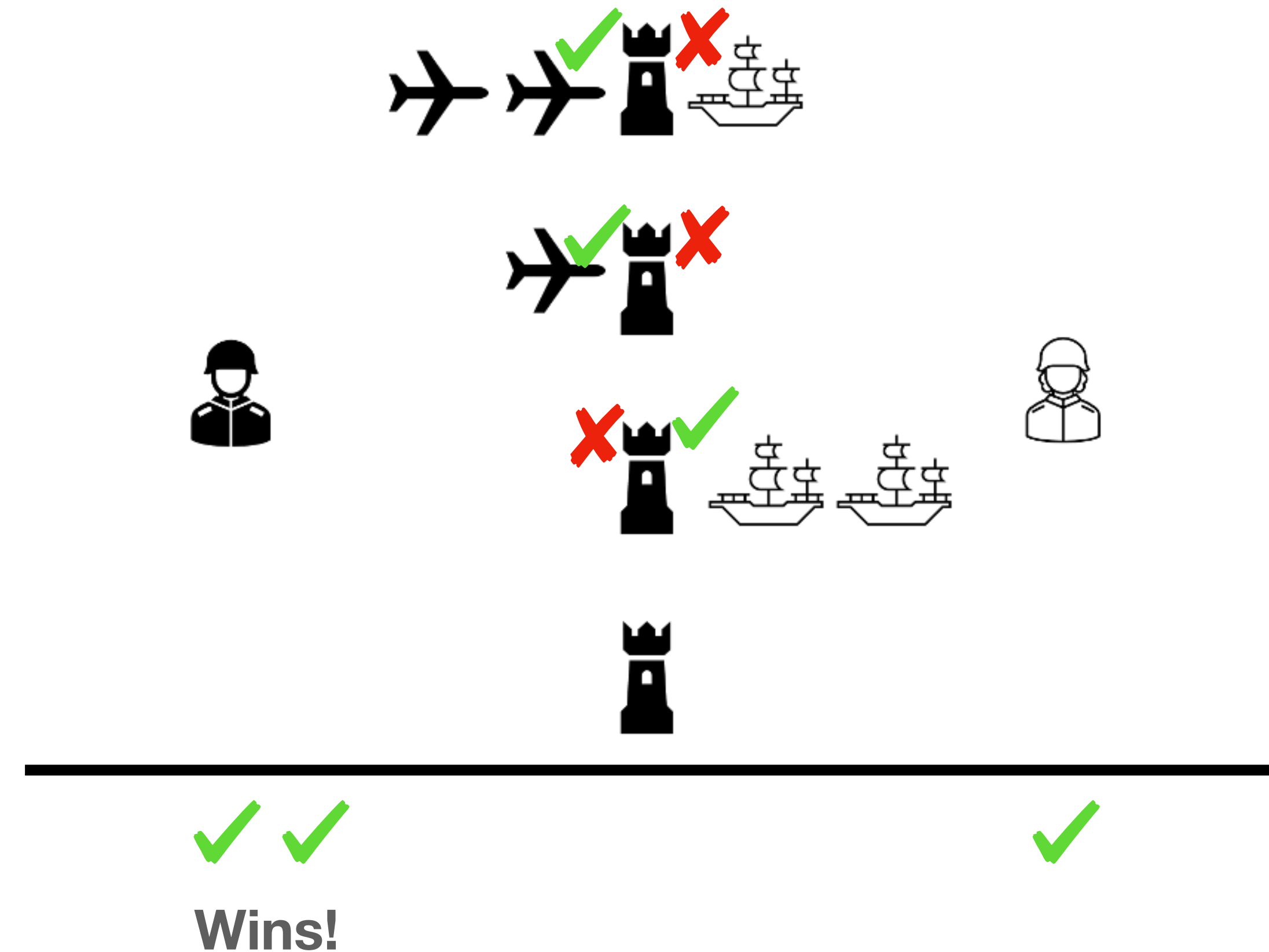
Where do we spend our focus? The Colonel Blotto Game

- Zero-sum resource allocation game (Borel, 1921)
- Two players have to assign resources to various battlefields
- Limited resources mean no single allocation is ideal
- Whoever puts more resources at any battlefield wins that battlefield
 - Resources and battlefields may have different weightings



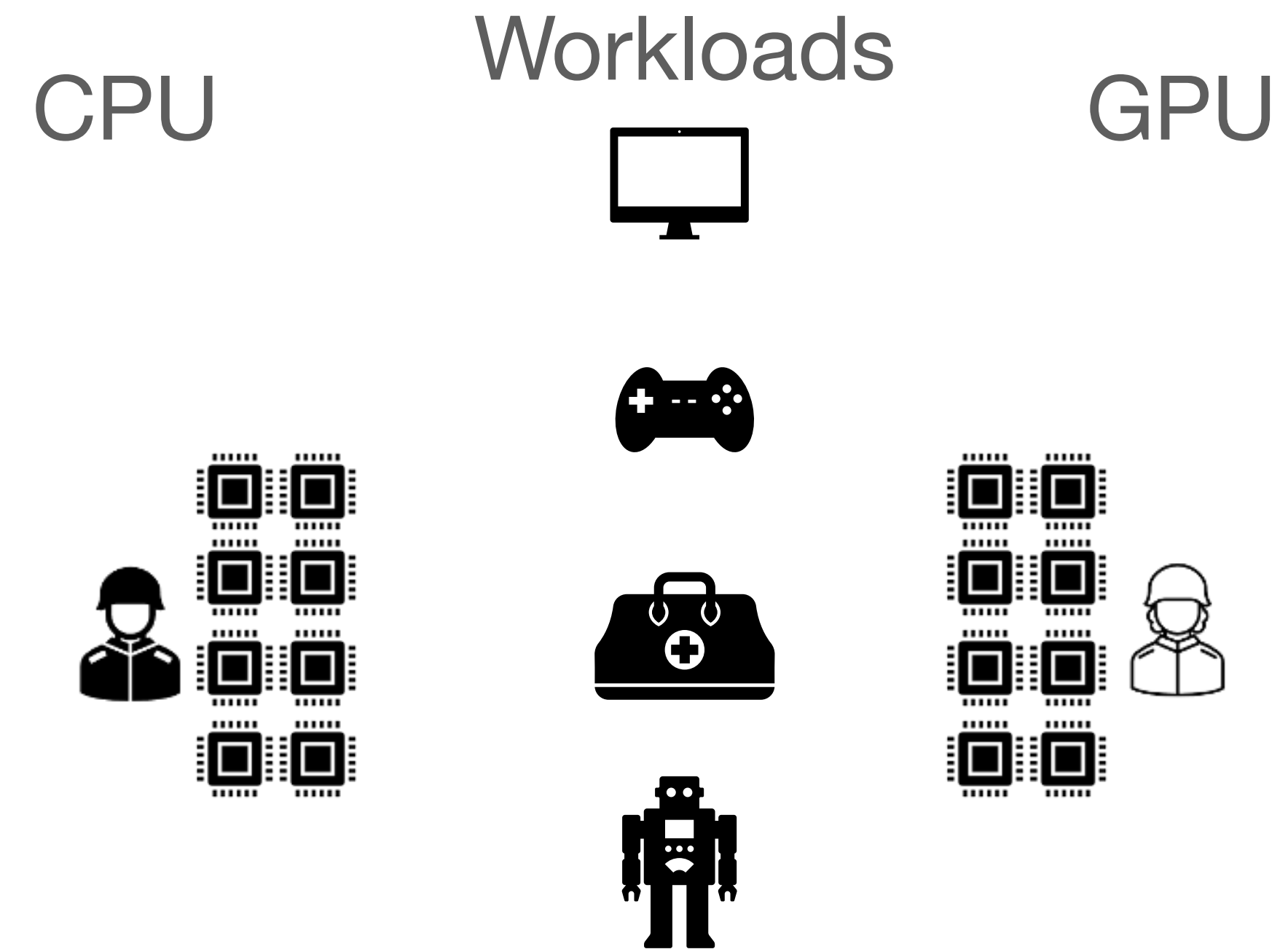
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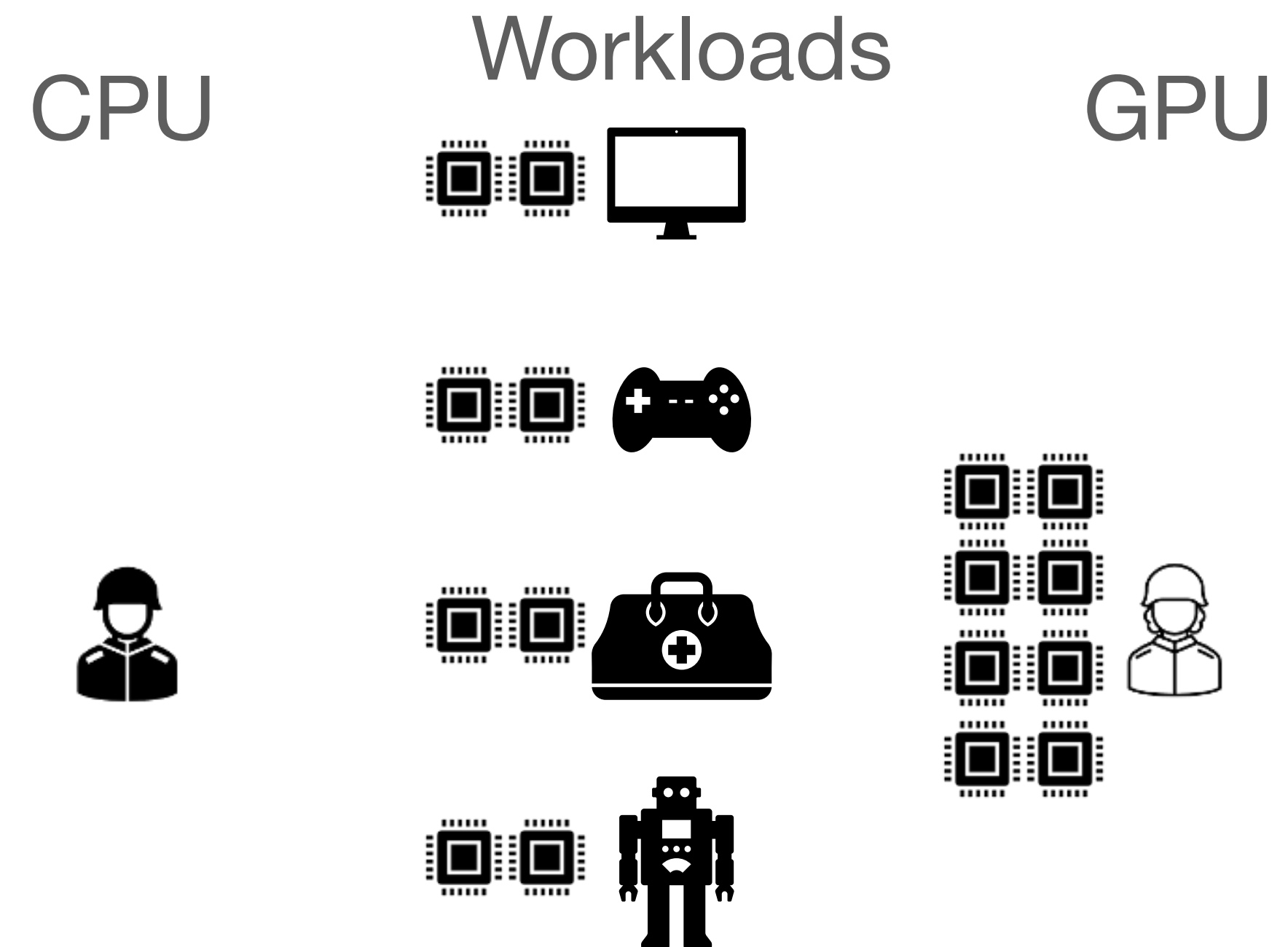
Colonel Blotto - Computing Edition

- At a high level – consider computing
 - Battlefields are computations/workloads
- Comparing different architectures
 - CPU generality vs GPU specialized performance



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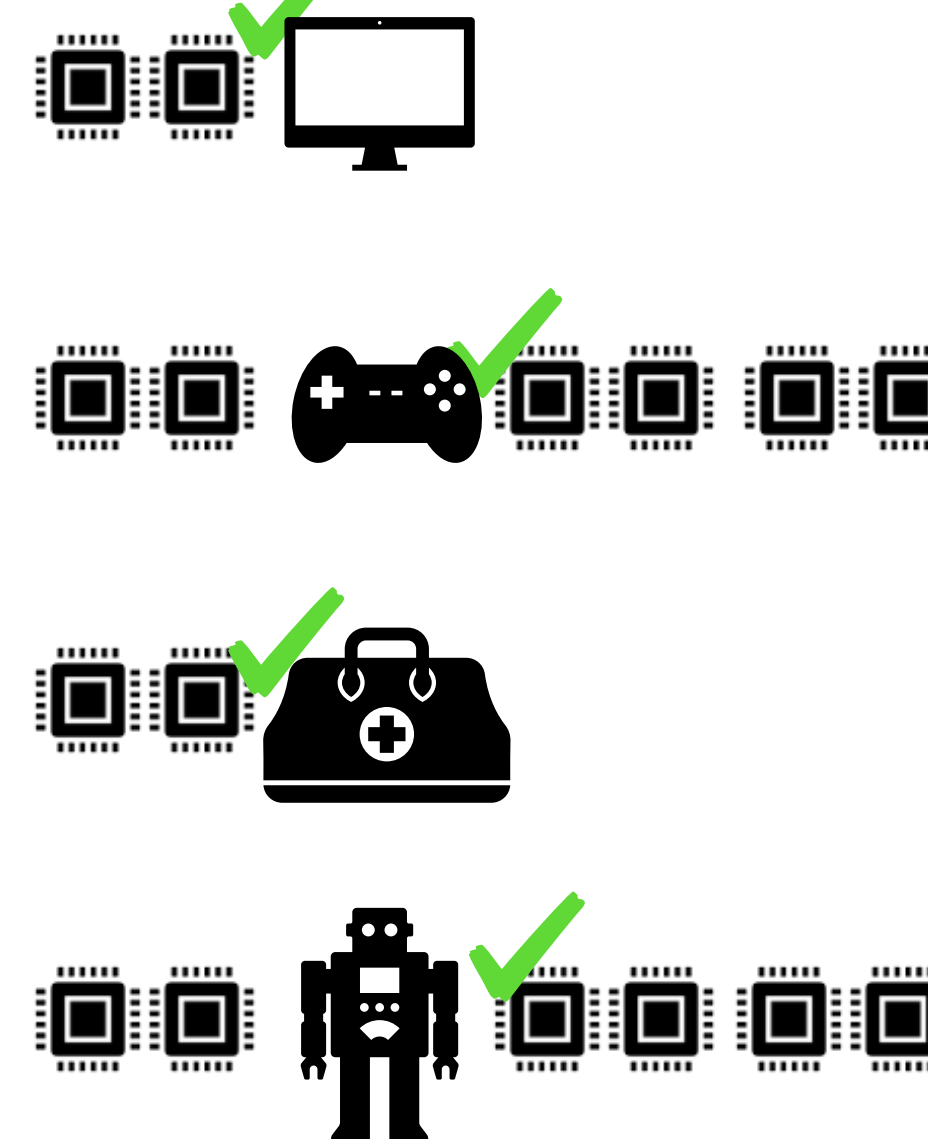
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CPU

Workloads

GPU



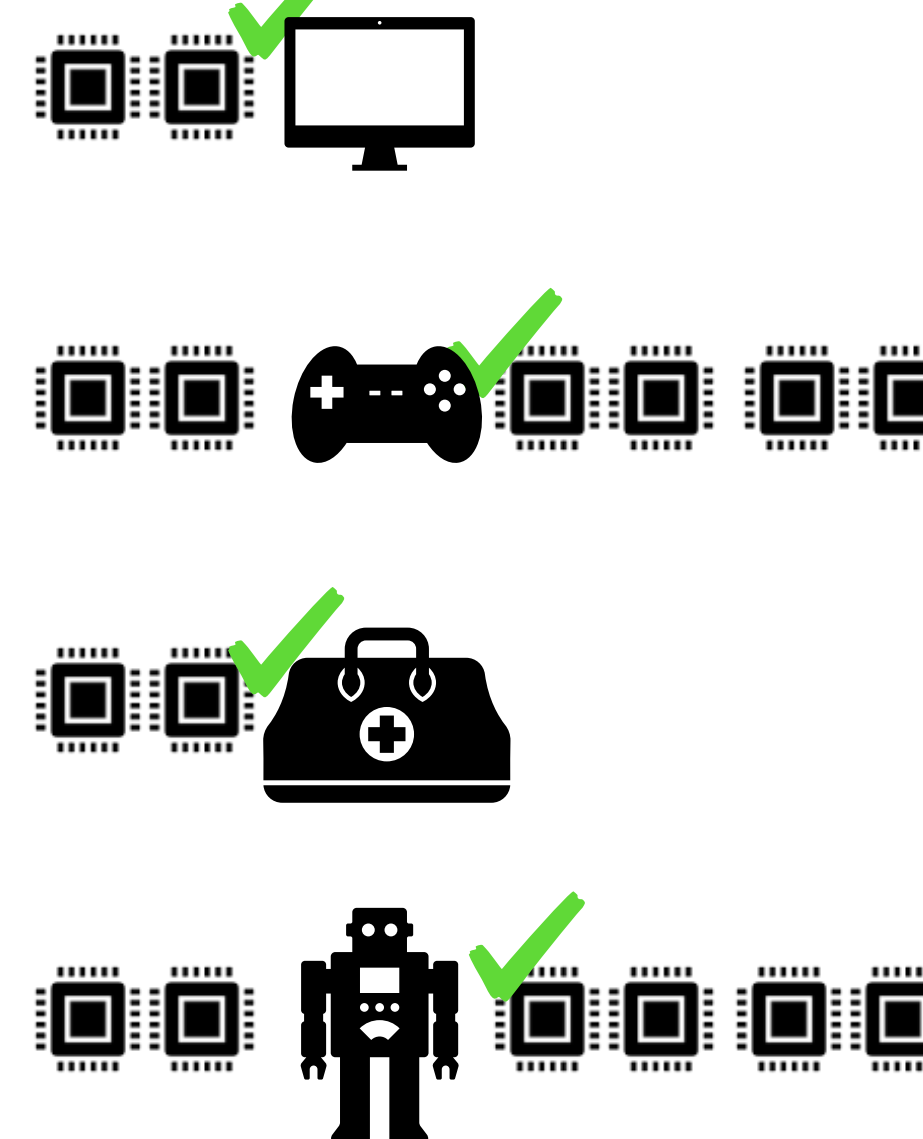
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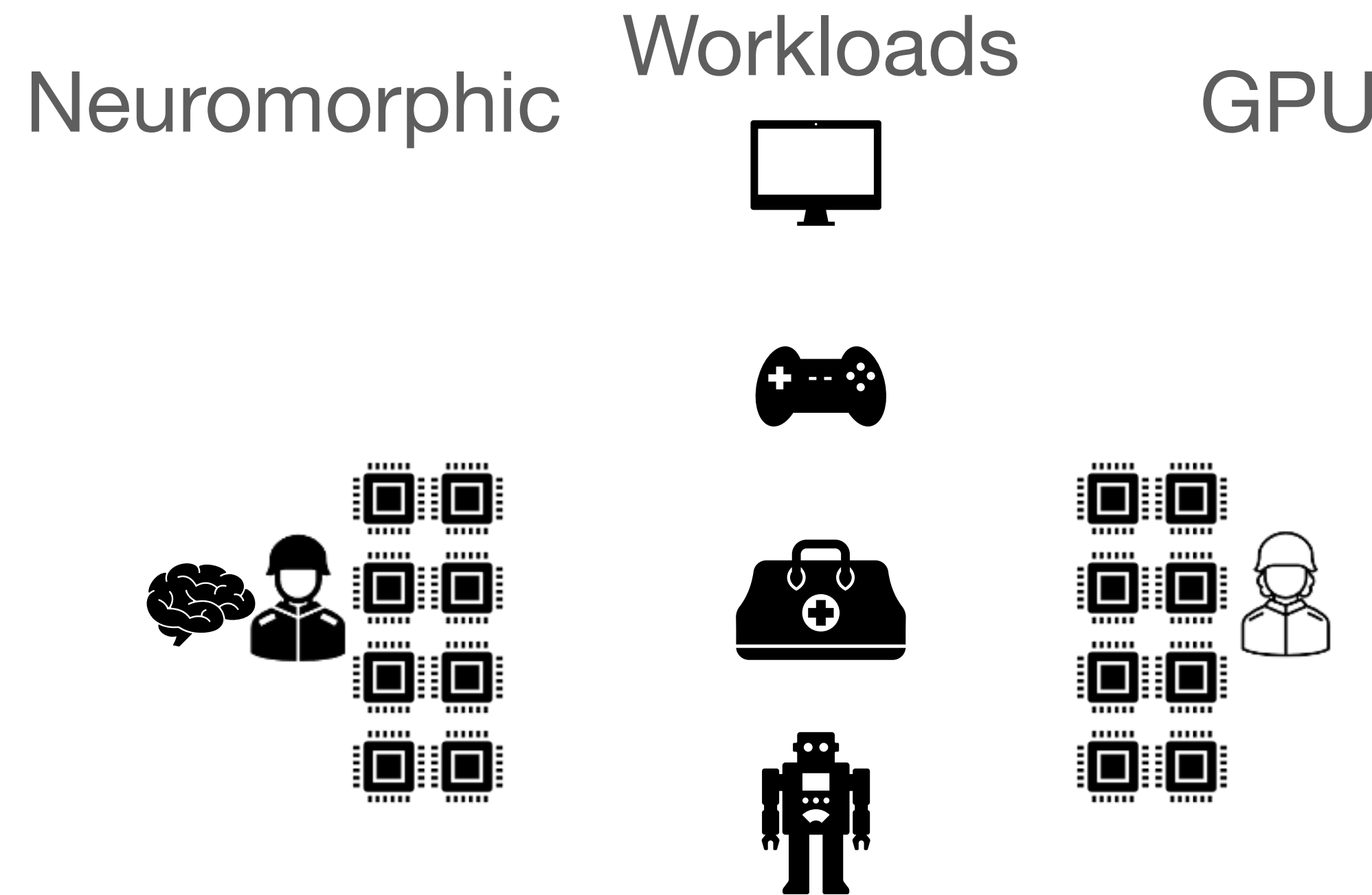
Workloads

GPU



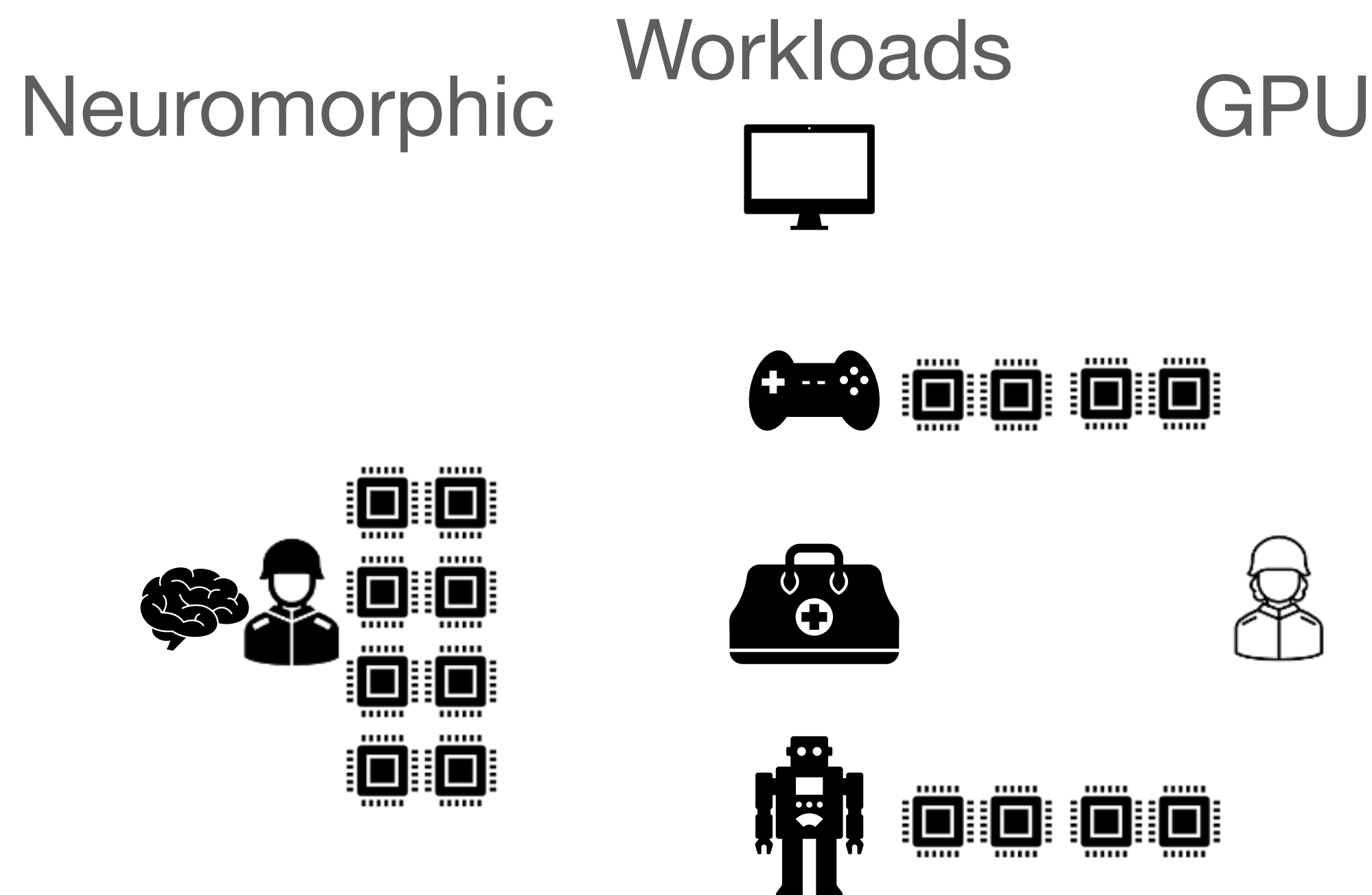
Colonel Blotto - Neuromorphic Computing

- Like GPUs, neuromorphic will excel at *specific* tasks
- Competing where GPUs do well will require exceeding specialization
- Adopting a similar strategy but with worse performance will not win



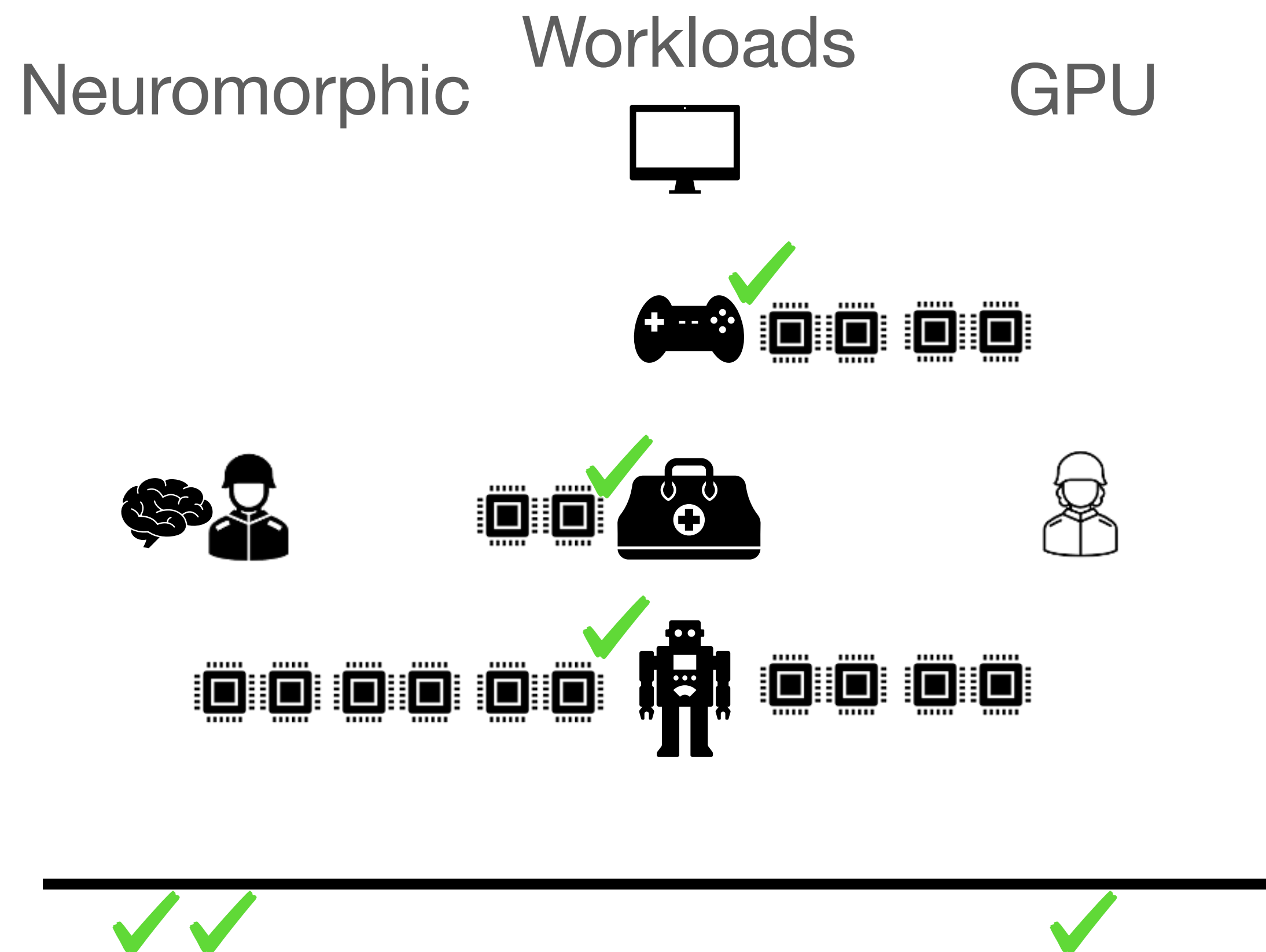
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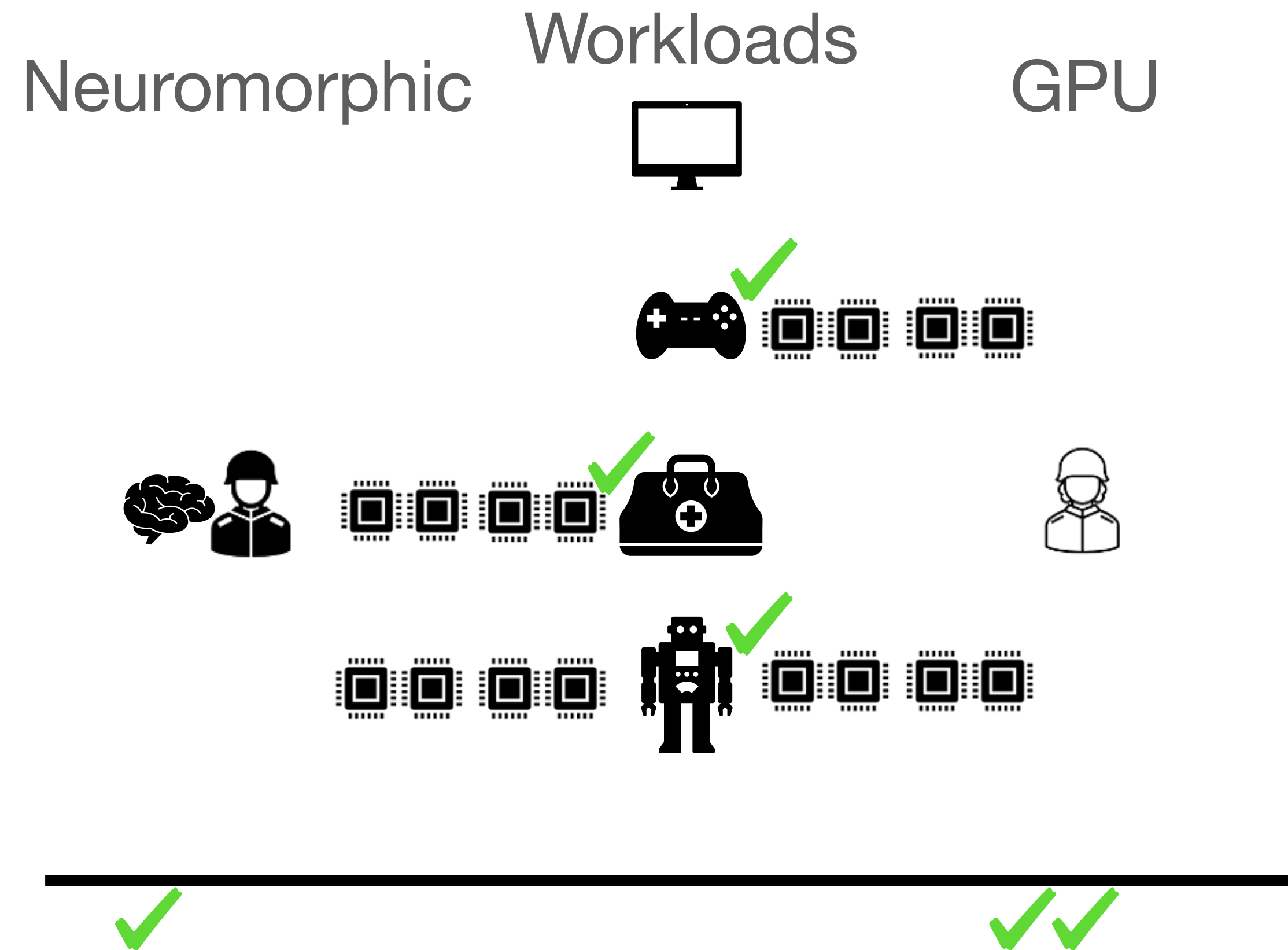
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- Like GPUs, neuromorphic will excel at *specific* tasks
- Competing where GPUs do well will require exceeding specialization
- Adopting a similar strategy but with worse performance will not win
- Focusing on existing gaps offers opportunity
 - Especially true given differences in market share



What does this mean?

- Playing to the same positions but with less benefit never wins
- We have to be careful of sunk costs
- Communication and careful planning regarding applications can help mitigate challenges
 - Effectively change the rules of the game
- Heterogeneous and Co-Designed solutions exist in real life, but don't exist in the game

Neuromorphic Co-Design as a Game?

- Co-Design: the mutual benefit of coordinating design choices of layers in a technology stack
- Understanding how we arrive at co-design is challenging, even when focusing on a specific type (algorithm/architecture co-design)
 - Do we need known spiking neural algorithms whose theoretical promise can justify architectural instantiation?
 - Can novel architectures precede algorithmic theory and spur innovation?
 - Can either algorithms or architectures be pursued without being a lottery for the other?

An Assurance Game

- Traditionally known as "Stag Hunt" here we call it "Swordfish/Anchovy"
- Players can team to catch a Swordfish giving the highest reward
- But a single player cannot catch a Swordfish alone
- We can use "Swordfish/Anchovy" to assess Co-Design strategies

		Player 2	
		Swordfish	Anchovy
Player 1	Swordfish	a, a	c, b
	Anchovy	b, c	d, d

$$a > b \geq d > c$$

P1 = S, P2 = S then both players get a

P1 = A, P2 = A then both players get d

If only one player chooses S, that player gets c ; the other player gets b

Adapting for Co-Design

- Rather than two fishers we have
 - Architecture Player (designing a new architecture)
 - Algorithm Player (designing a new algorithm)
- Each player can go for the "big fish" and try for a spiking solution (S) **or** they can play it safe and go for a traditional artificial neural network solution (A)

We hope that spiking provides a benefit, but the specific values are not critical

		Algorithm Player	
		S	A
Architecture Player	S	5,5	1,3
	A	3,1	2,2

P1 = S, P2 = S then both players get 5

P1 = A, P2 = A then both players get 2

If only one player chooses S, that player gets 1; the other player gets 3

Strategies for the Co-Design Game

- Two pure strategies lead to Nash equilibria
 - (S,S) is reward dominant
 - (A,A) is risk dominant
- But assuring (S,S) requires *collaboration*
- Without collaboration, most would adopt a **mixed strategy**
 - $x\%$ of the time, choose S
 - $(1-x)\%$ of the time, choose A
- Mixed strategy equilibrium is at...
1/3rd SNN, 2/3rd ANN

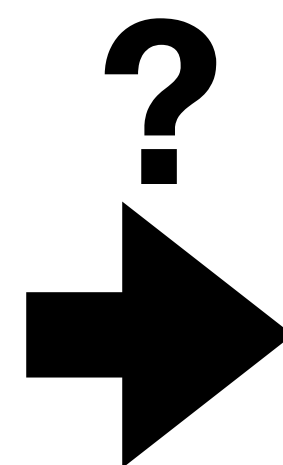
		Algorithm Player	
		S	A
Architecture Player	S	5,5	1,3
	A	3,1	2,2

Even though SNN offers greater reward, the pareto-optimal strategy is majority ANN.

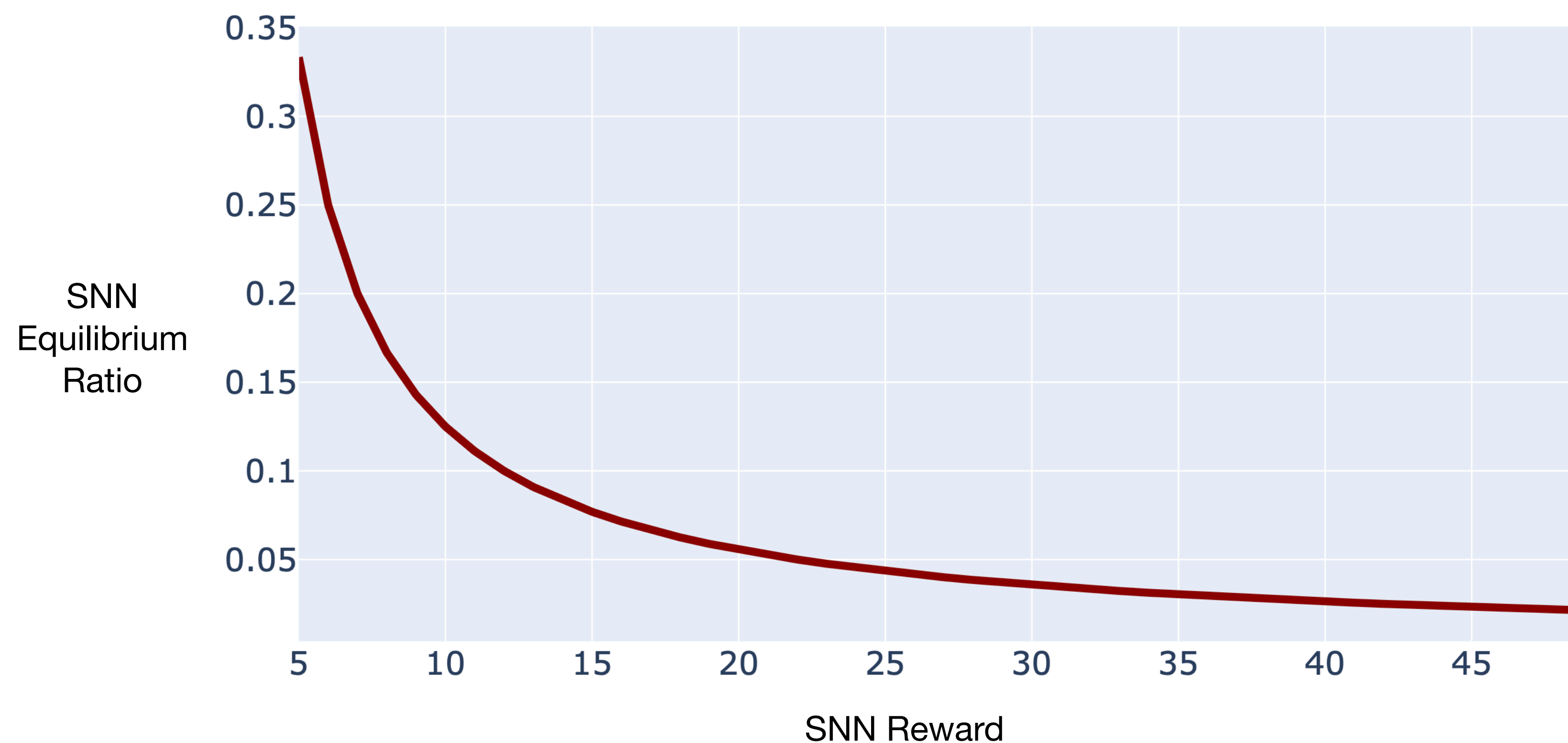


Risk Aversion Leads to ANN Stability

		Algorithm Player	
		S	A
Architecture Player	S	5,5	1,3
	A	3,1	2,2



		Algorithm Player	
		S	A
Architecture Player	S	15,15	1,3
	A	3,1	2,2



Increasing the SNN reward decreases the SNN uptake at the equilibrium.

What does this mean?

- The mixed strategy may not be the 'best' strategy overall (What is 'best'?)
- The mixed strategy equilibrium is a Nash equilibrium
 - A player cannot *unilaterally* improve their outlook
- Instead, we view this as suggesting co-design can be mutually beneficial but requires active collaboration

Discussion and Closing Points

- Game Theory is rich with different frameworks for analysis
 - We presented just two games and associated viewpoints
- Formal analysis can provide introspection into our field
- Understanding how we determine research directions will help keep neuromorphic healthy

Neural Exploration & Research Lab (NERL)

- Enables researchers to explore the boundaries of neural computation
- The research conducted in the lab evaluates what is possible with neural hardware and software for national security benefit and the advancement of basic research
- Consists of a variety of neuromorphic hardware & neural algorithms providing a testbed facility for comparative benchmarking and new architecture exploration





Thanks!