SETE 2008

For the Enterprise -

Enhanced Capabilities through Integration

Adaptivity in Networked Complex Systems

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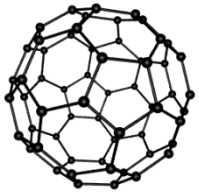
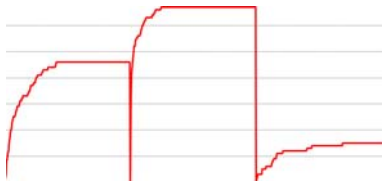
Overview of Talk



Agility, Network Science, Complex Adaptive Systems

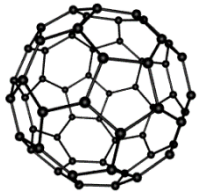
A Simulation Experiment …



… and Results

What does it all mean?

What is Agility?



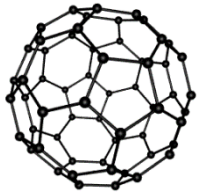
US Army: **"the ability of friendly forces to act faster than the enemy"**

Alberts & Hayes: **"resilience, responsiveness, flexibility, innovation, and adaptation"**

Enabling Future War Fighting: **"Agility allows forces to cope with the unexpected … ability to anticipate change"**

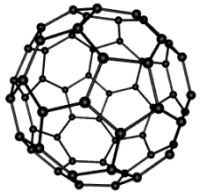
See A.H. Dekker: "Measuring the Agility of Networked Military Forces," *Journal of Battlefield Technology*, Vol 9, No. 1, March 2006.

Levels of Agility

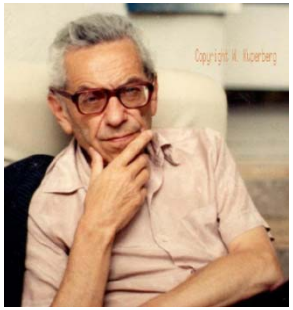


Level	Type	Time-scale	Drivers
1	Tactical / operational (OODA loop)	Seconds to days	Sensors, C2, platform speed, platform flexibility
2	Organisational agility	Days to years	Organisational interoperability, organisational learning, creativity
3	Re-evaluate, Reconceptualise, Re-equip	Years	Organisational learning, creativity, strategic planning, agile acquisition

Network Science: a potted history



Leonhard Euler, 1735 – beginnings



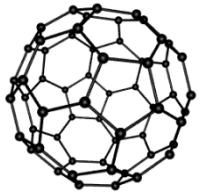
Paul Erdős, 1959 – random networks

Robert Tarjan, 1971 – algorithms


Albert-László Barabási

Albert-László Barabási, 1999 – complex nets

Network metrics drive Agility



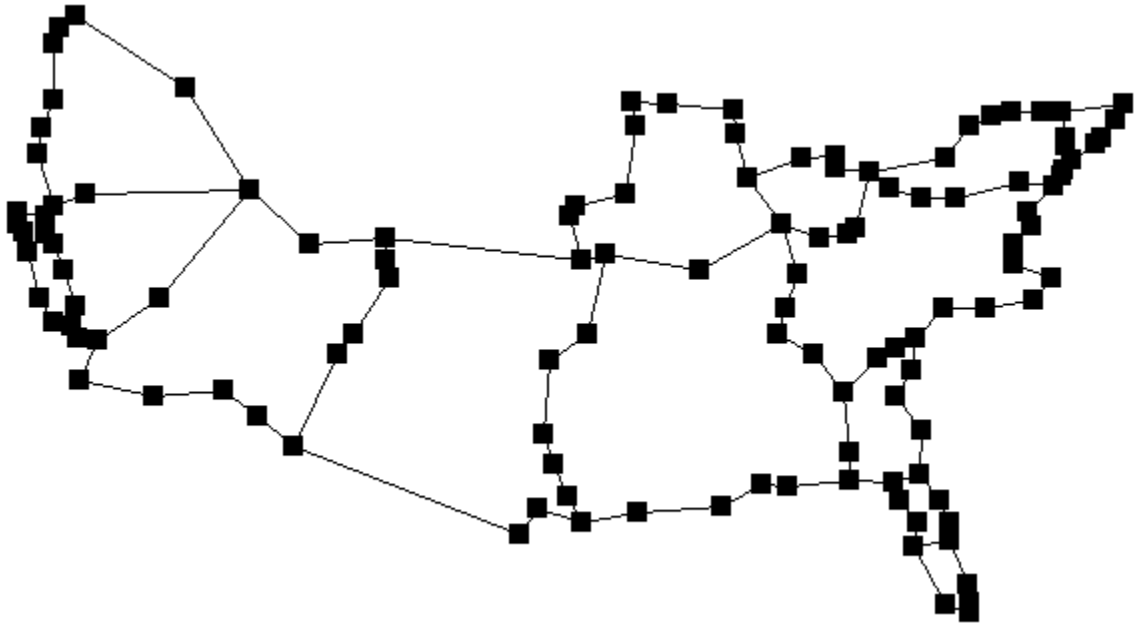
11.8 **Average distance (“hops”) between nodes**

→ Responsiveness

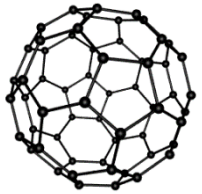
2 **Connectivity (no. of independent paths)**

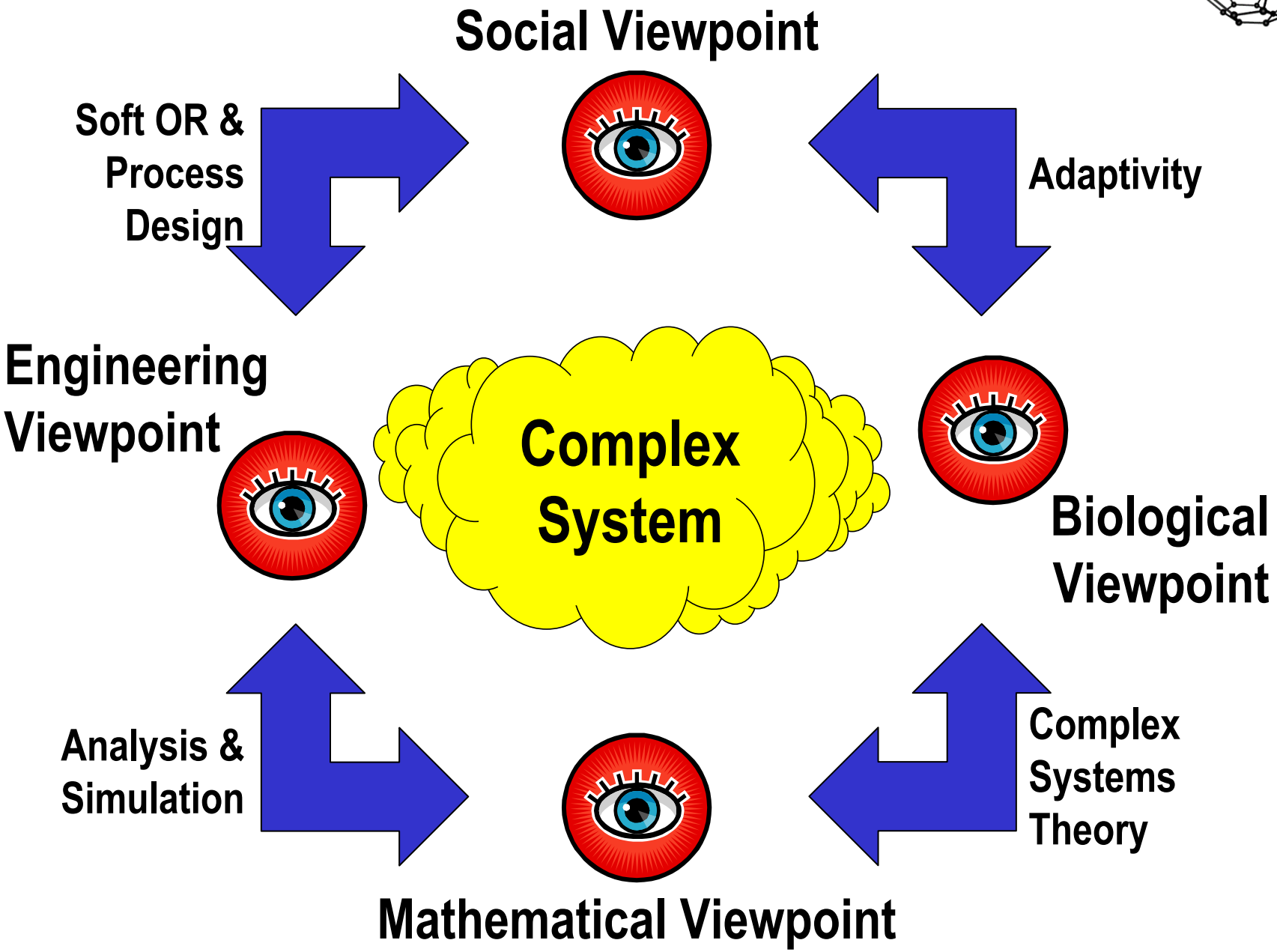
→ Resilience

→ Robustness

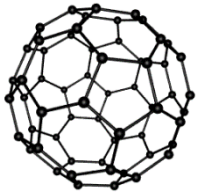


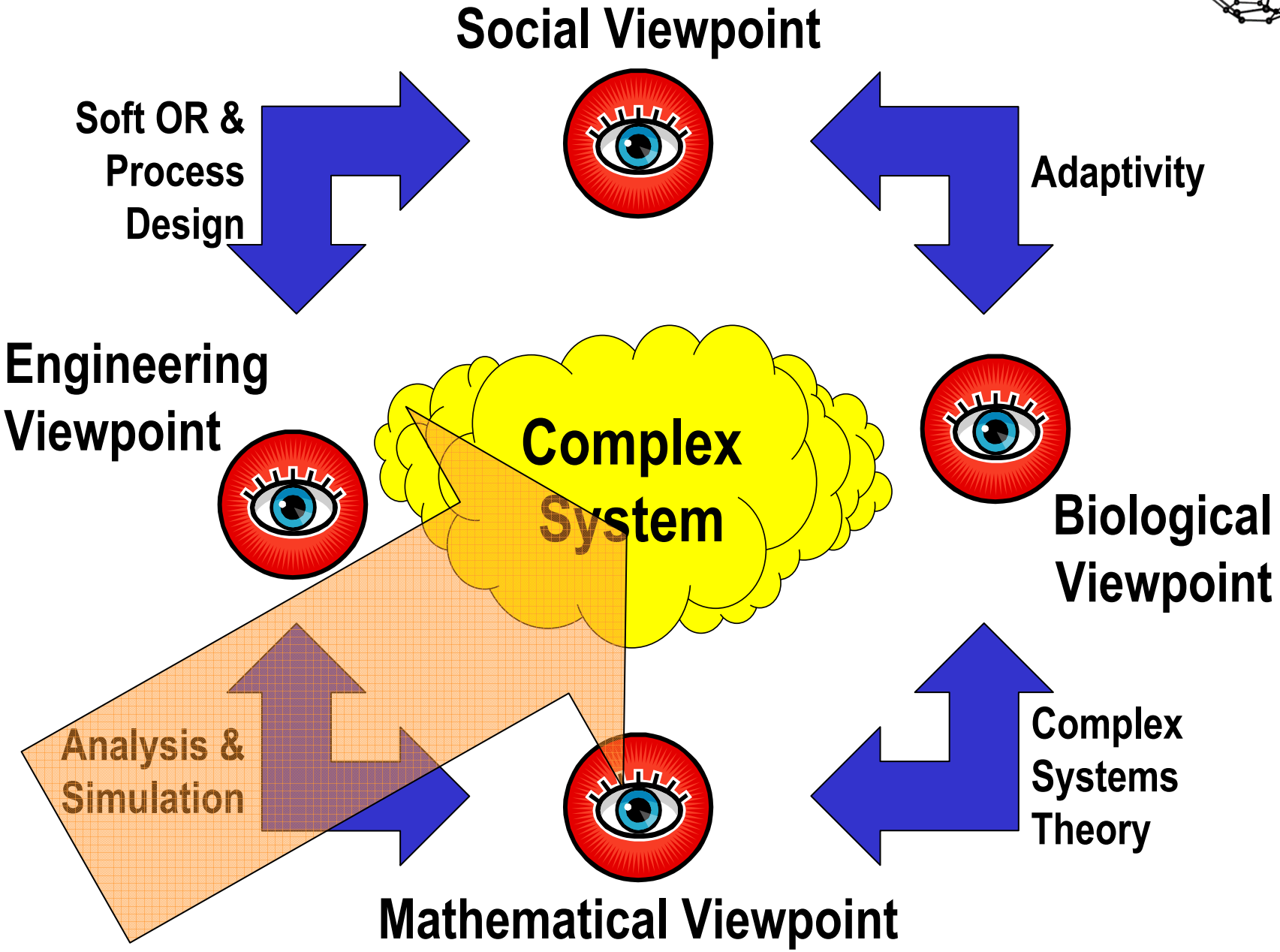
Complex Adaptive Systems



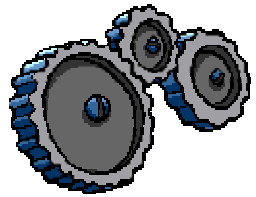


Complex Adaptive Systems



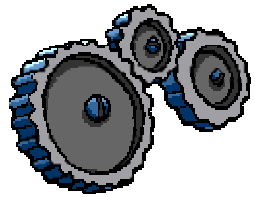


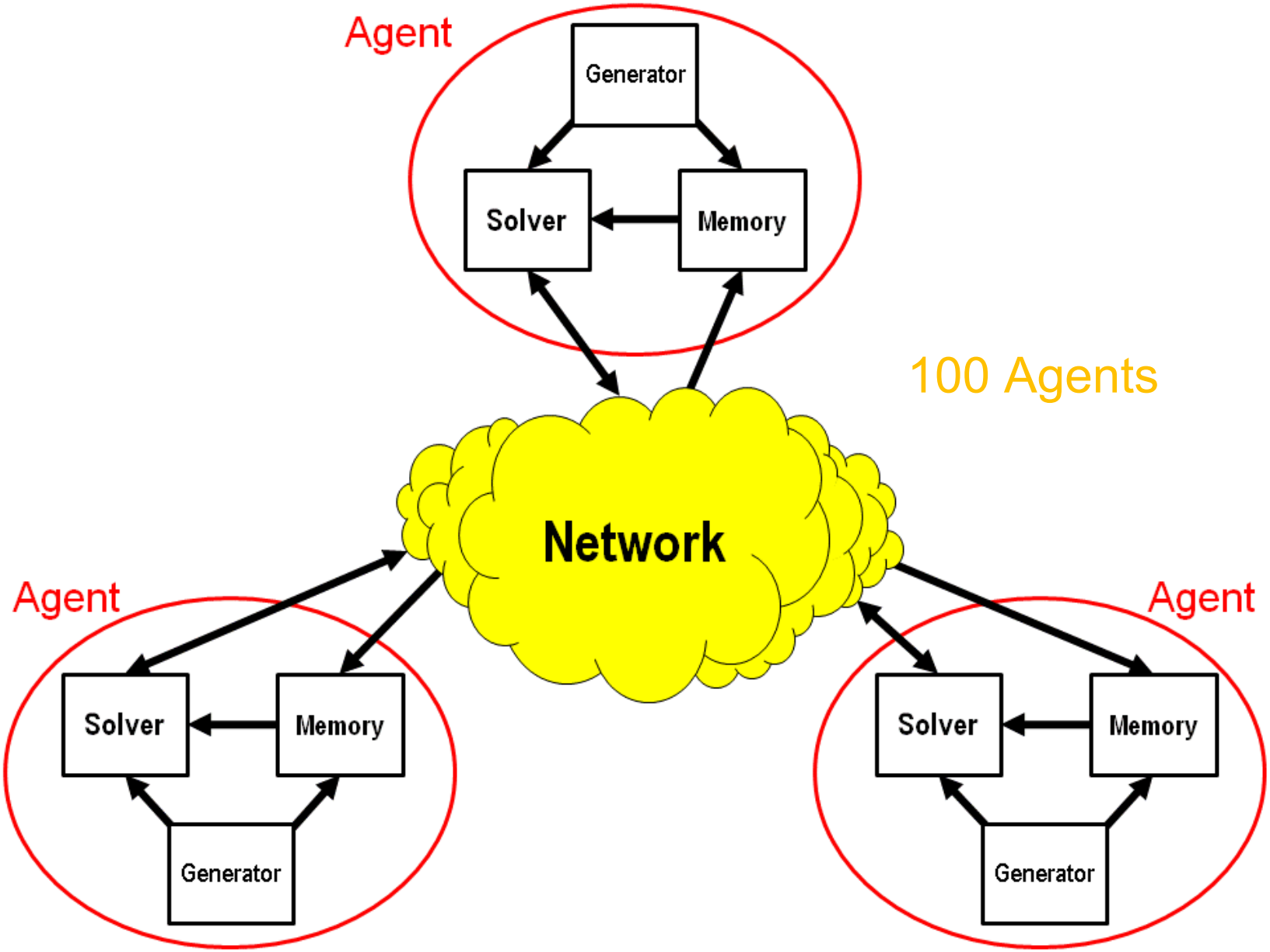
A Simulation Experiment



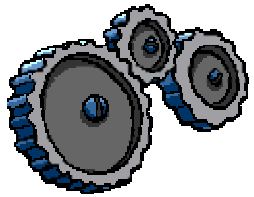
- Use a simulated network of communicating **agents**
- … to explore agility …
- … in a collaborative context …
- … where each agent has a **problem** to solve

Experimental Agent Network





2 Types of Agent Problems



(1) Find 4 squares adding up to a target x

e.g. $0^2 + 1^2 + 1^2 + 4^2 = 18$

– used in Phase 1 (training)

– different target in Phase 2 (operational)

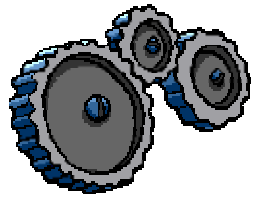
(2) Find 2 primes adding up to an (even) target x

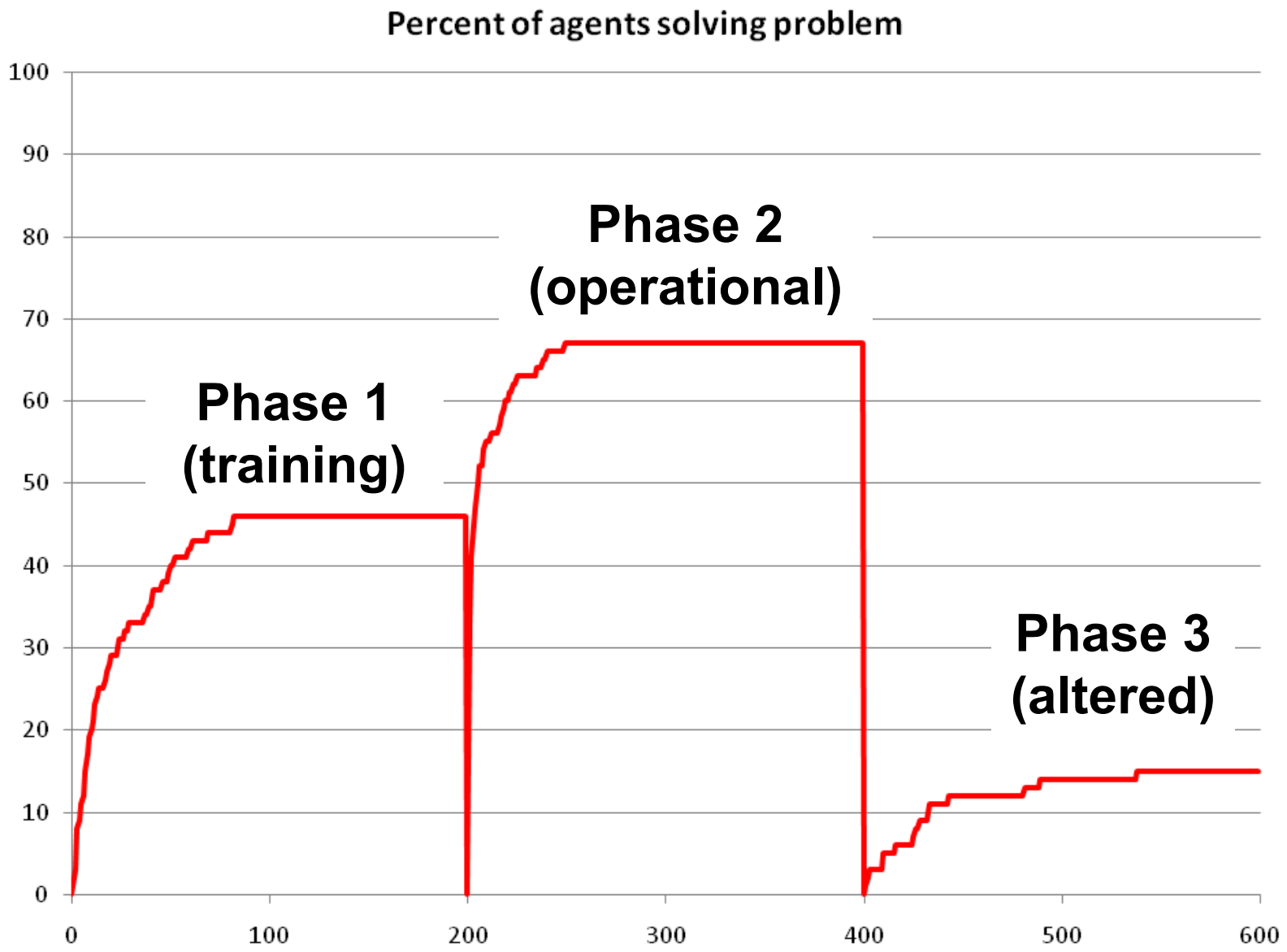
e.g. $13 + 5 = 18$

– Phase 3 (altered), different concept of “useful”

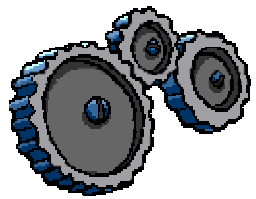
– Need to **unlearn** previous concept

Base Performance





3 Agent Improvements



(R) Improved (Random) network

- lower average distance (3.4 instead of 12.9)
- more effective communications

(M) Adaptive Memory

- slots in “full” memory can be replaced

(A) Adaptive procedures

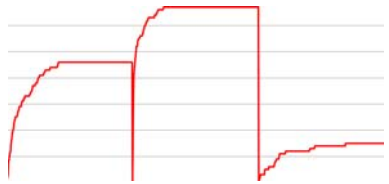
- copy data-item generator from useful agent

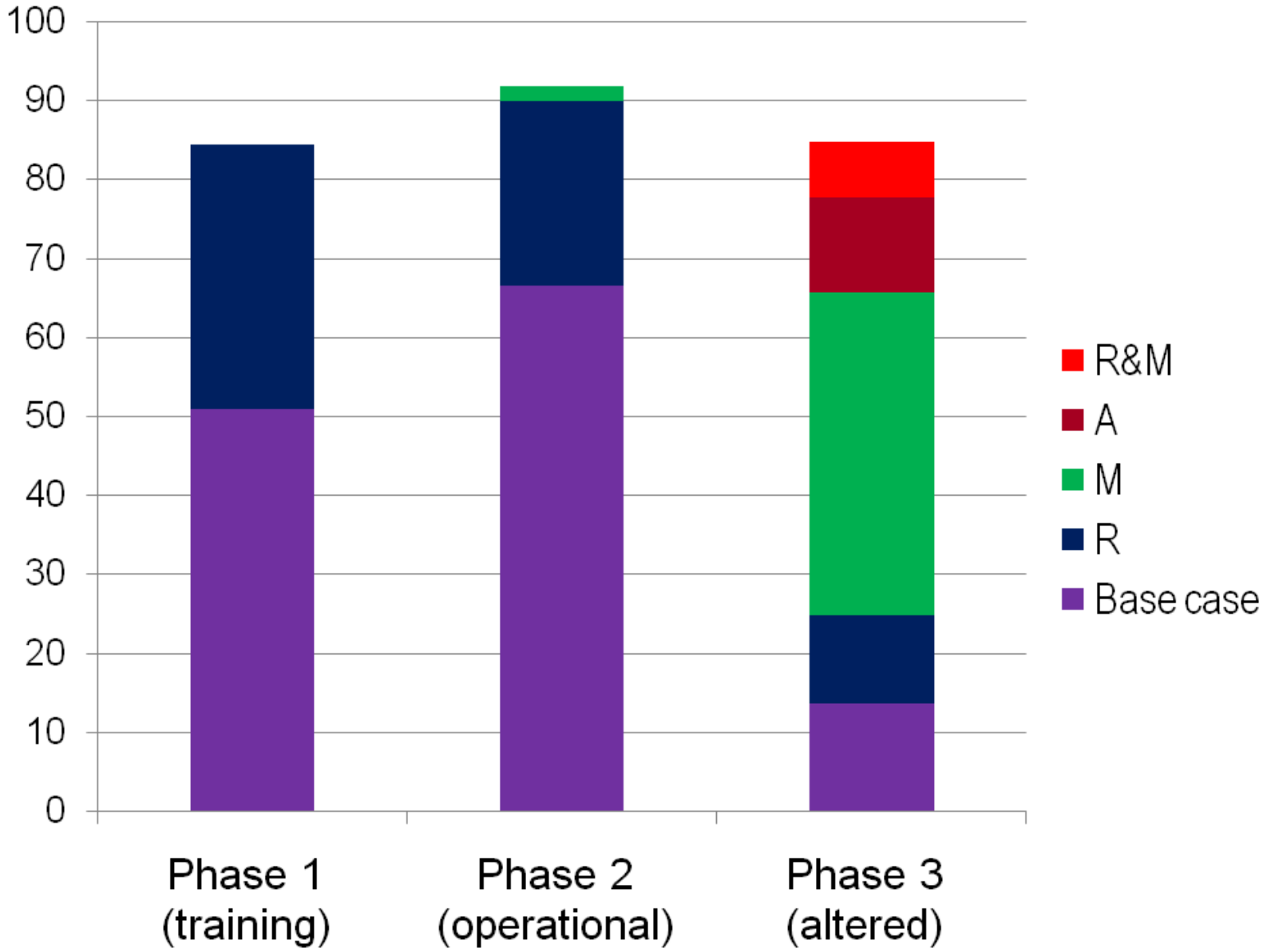
Consider all 8 combinations (100 runs of each)

Results (% of agents solving problem)

		Phase 1 (training)	Phase 2 (operational)	Phase 3 (altered)
Effects:	Base case	50.9	66.5	13.6
	R	33.5	23.3	11.1
	M	–	2.1	41.1
	A	–	–	12.4
	R&M	–	–	6.7
Overall		84.5	91.9	84.9

Results (% of agents solving problem)





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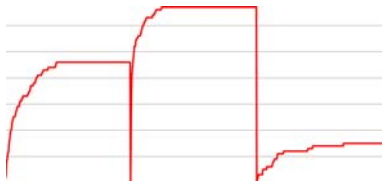
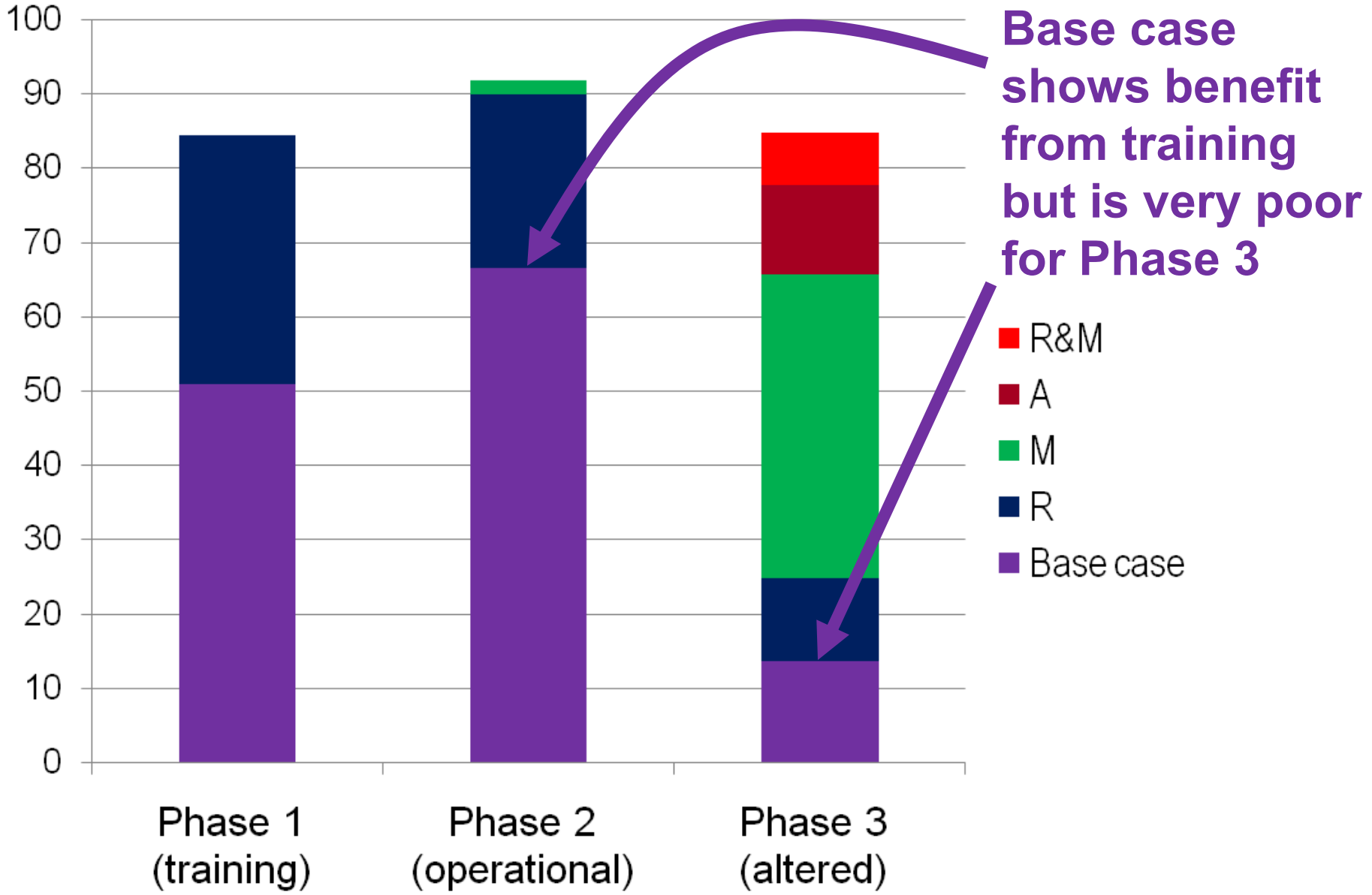
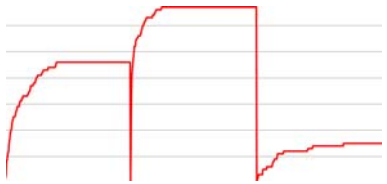
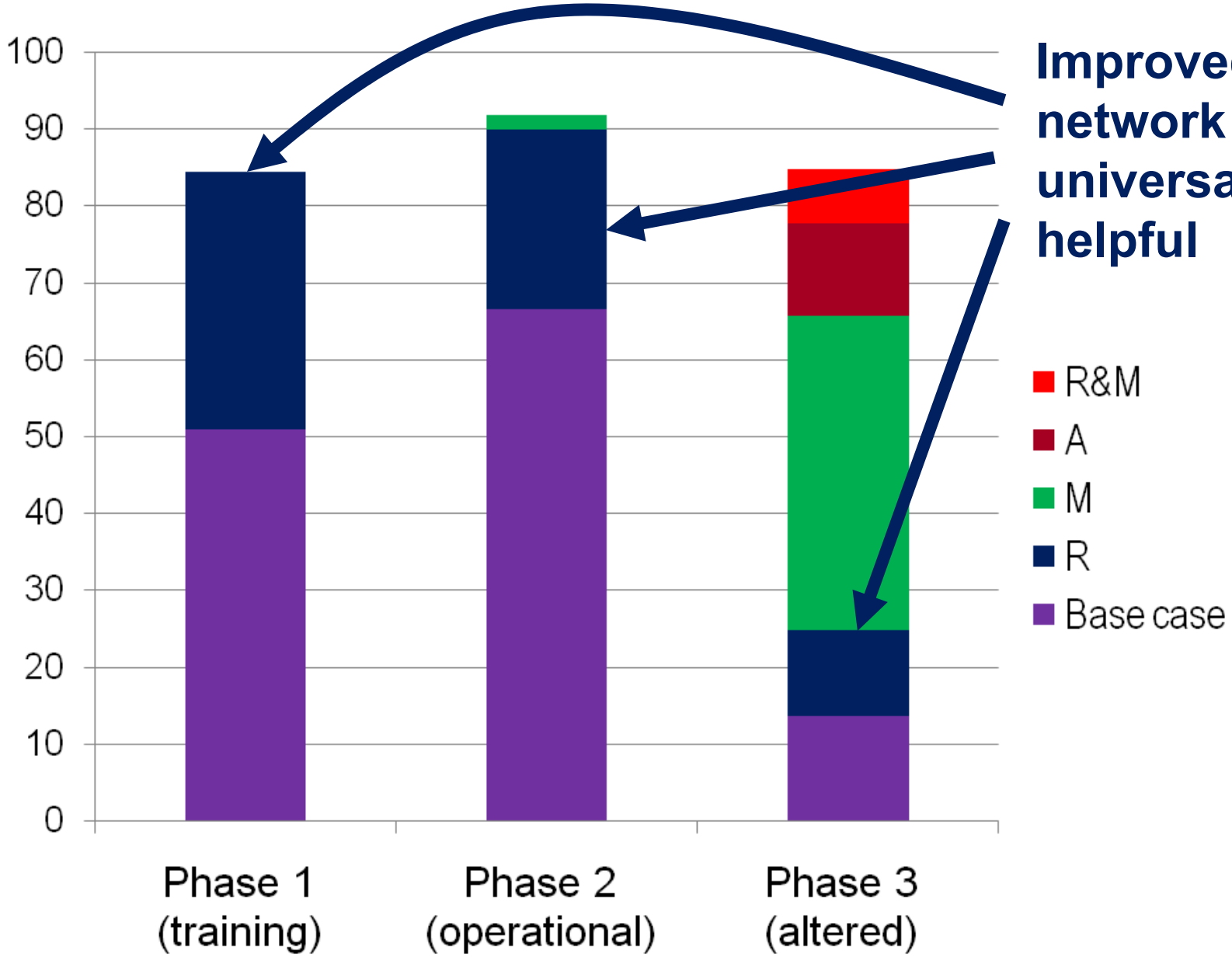




Base case shows benefit from training but is very poor for Phase 3

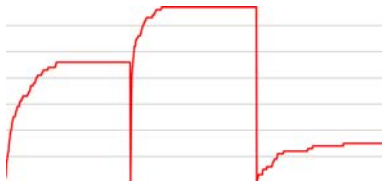
Results (% of agents solving problem)

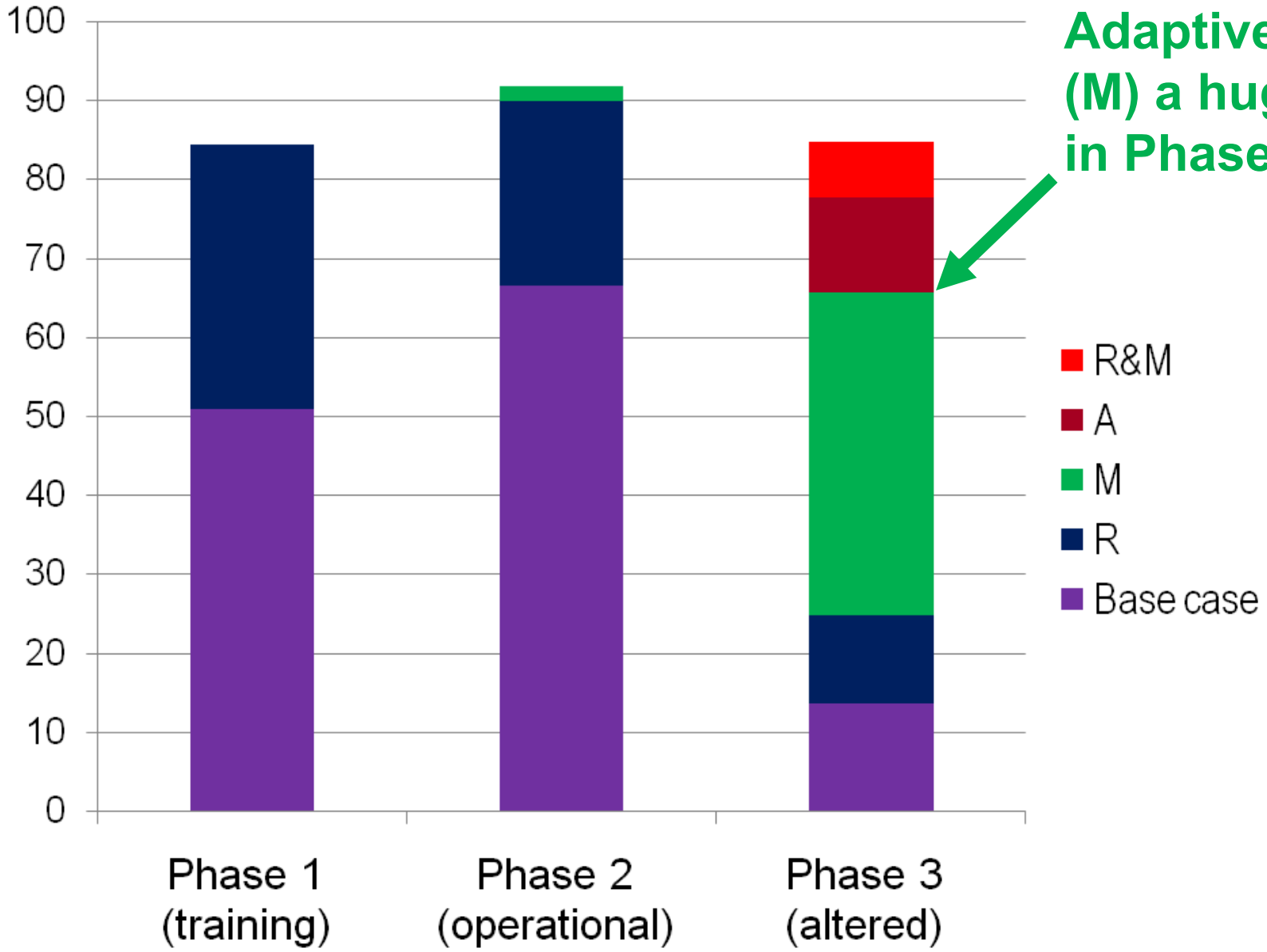




Improved network (R) is universally helpful

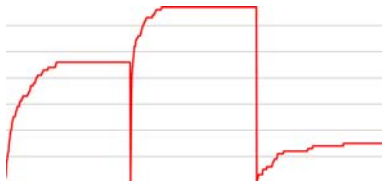
Results (% of agents solving problem)

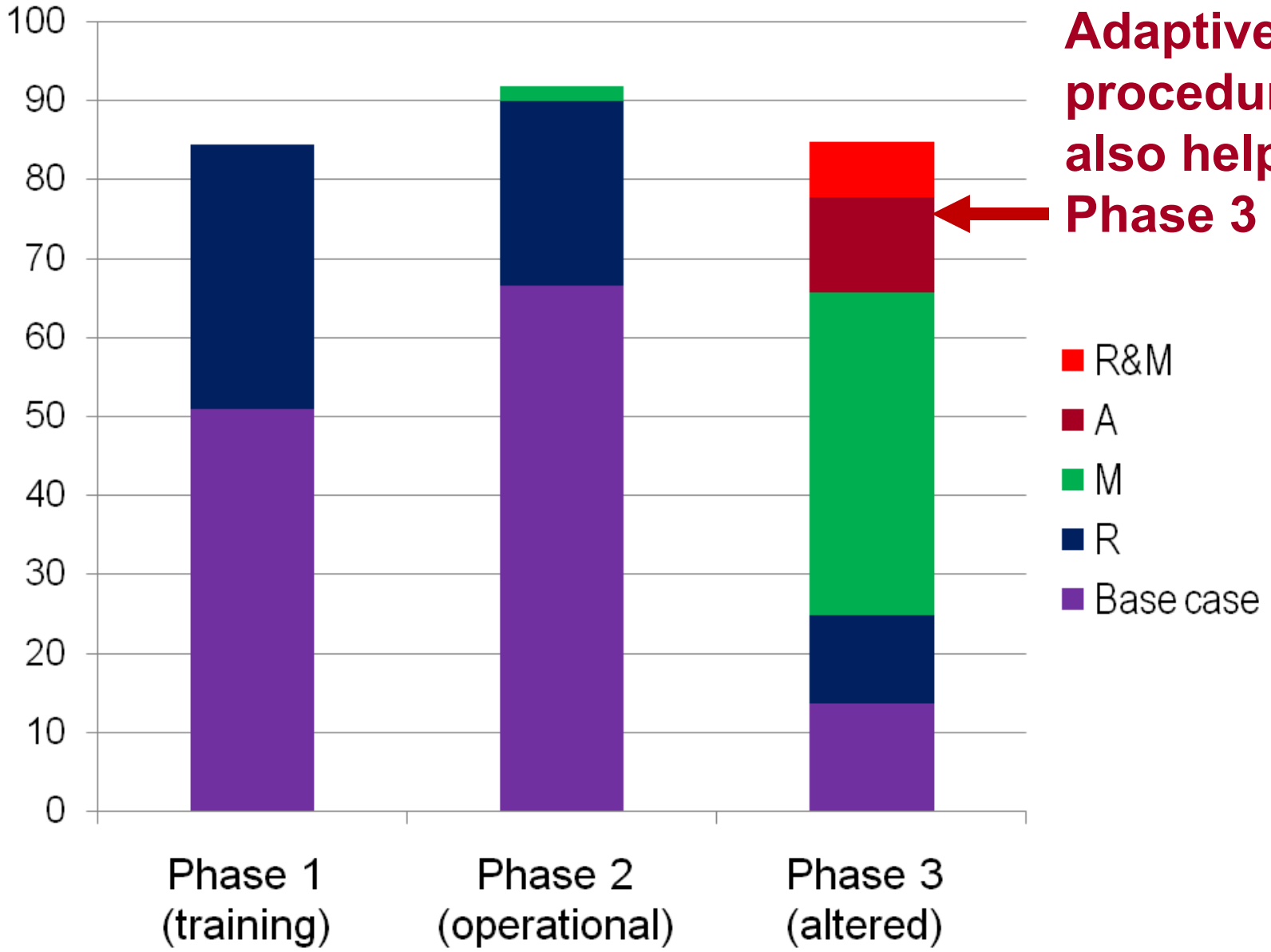




Adaptive memory (M) a huge benefit in Phase 3

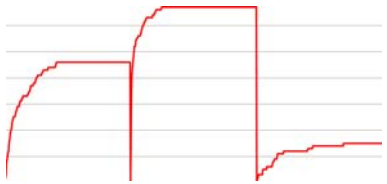
Results (% of agents solving problem)

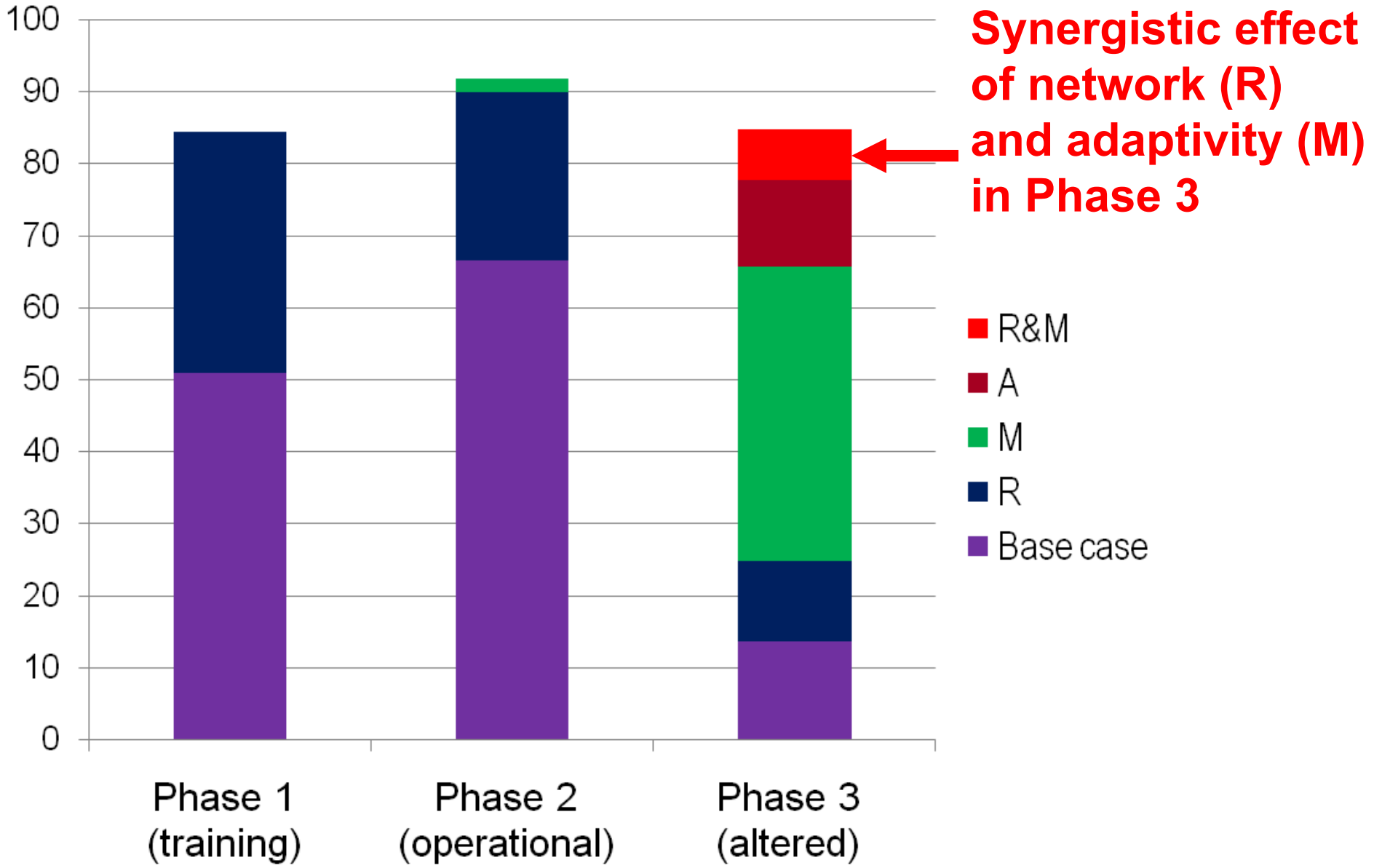




Adaptive procedures (A) also help in Phase 3

Results (% of agents solving problem)





Synergistic effect of network (R) and adaptivity (M) in Phase 3

What does it all mean?

- **Greater changes need more adaptivity**
- **Both systems being acquired and the Acquisition System itself must be adaptive**
- **There is a synergy between network quality and adaptivity:** access to information *vs* learning
- **Network must link to adaptive components of systems:** do messages go to a place where learning can happen?

Adaptive Mechanisms

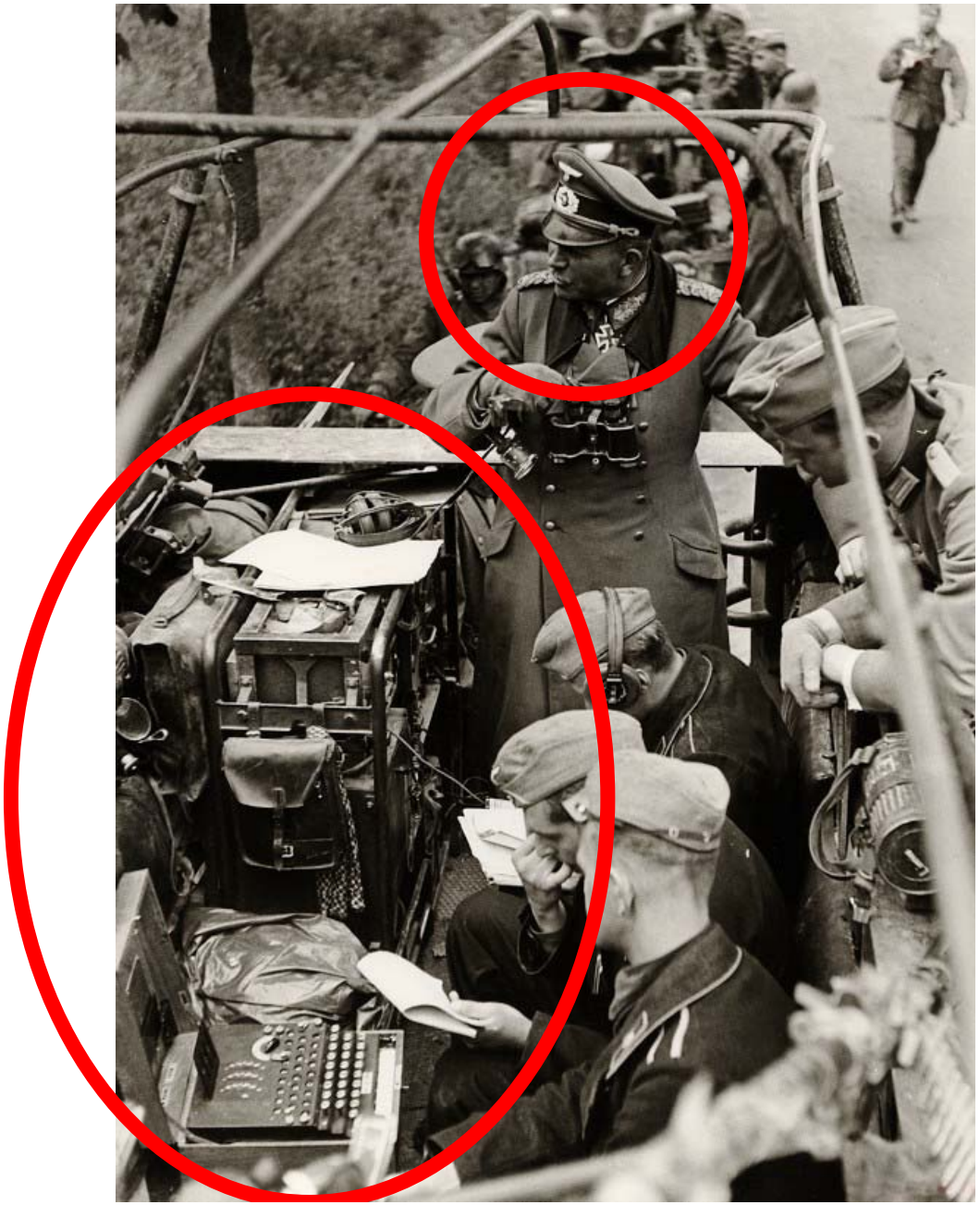
- **Knowledge Dissemination (R)**
- **Knowledge Bases (M)**
- **Organisational Learning (M)**
- **Process Improvement (A)**
  - Using metrics to ensure real improvement
- **Strategic Planning (A)**
  - To generate options
- **Effective Experimentation (A)**
  - To eliminate poor options

Heinz Guderian, 1937

- **Communicating** the vision
- **Unlearning** old doctrine
- **Experimentation** to develop new doctrine

Guderian as Commander

Network and adaptation



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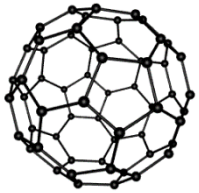
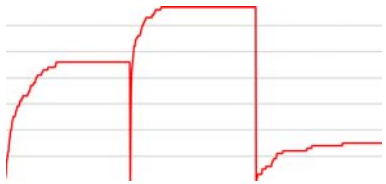


Agility, Network Science, Complex Adaptive Systems

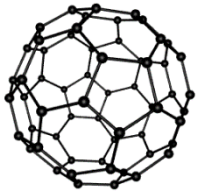
An agent-based simulation experiment …



… shows benefit of networking / adaptivity

High change needs more adaptivity

Any Questions?



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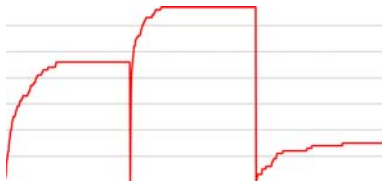

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