My Five Golden Guidelines for Research

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Golden Opportunities

- Many youth feel there is no great work left to be done.
- Not true – the golden era continues.
- There are lots of challenging problems left.
- And their impact will be great in
  - today's global economy
  - and in tomorrow's unimaginable world.
- These are times of enormous change.
- And times of enormous opportunity.

Don't Forget

- **But as we rush headlong into the future, we must not forget where all this came from – we must not ignore the lessons from history.**
- Most of today's youngsters cannot remember a time when there was no Internet.
- They cannot imagine that their parents are "of this era"
- Don't underestimate those seniors.

My Five Golden Guidelines to Research

1. Conduct the 100-year test.
2. Don’t fall in love with your model.
3. Beware of mindless simulation.
4. Understand your own results.
5. Look for “Gee, that’s funny!”

Richard Hamming

"Why do so few scientists make significant contributions and so many are forgotten in the long run?"

“If you don't work on important problems, it's not likely that you'll do important work.”

Richard W. Hamming, “You and Your Research”, March 7, 1986.

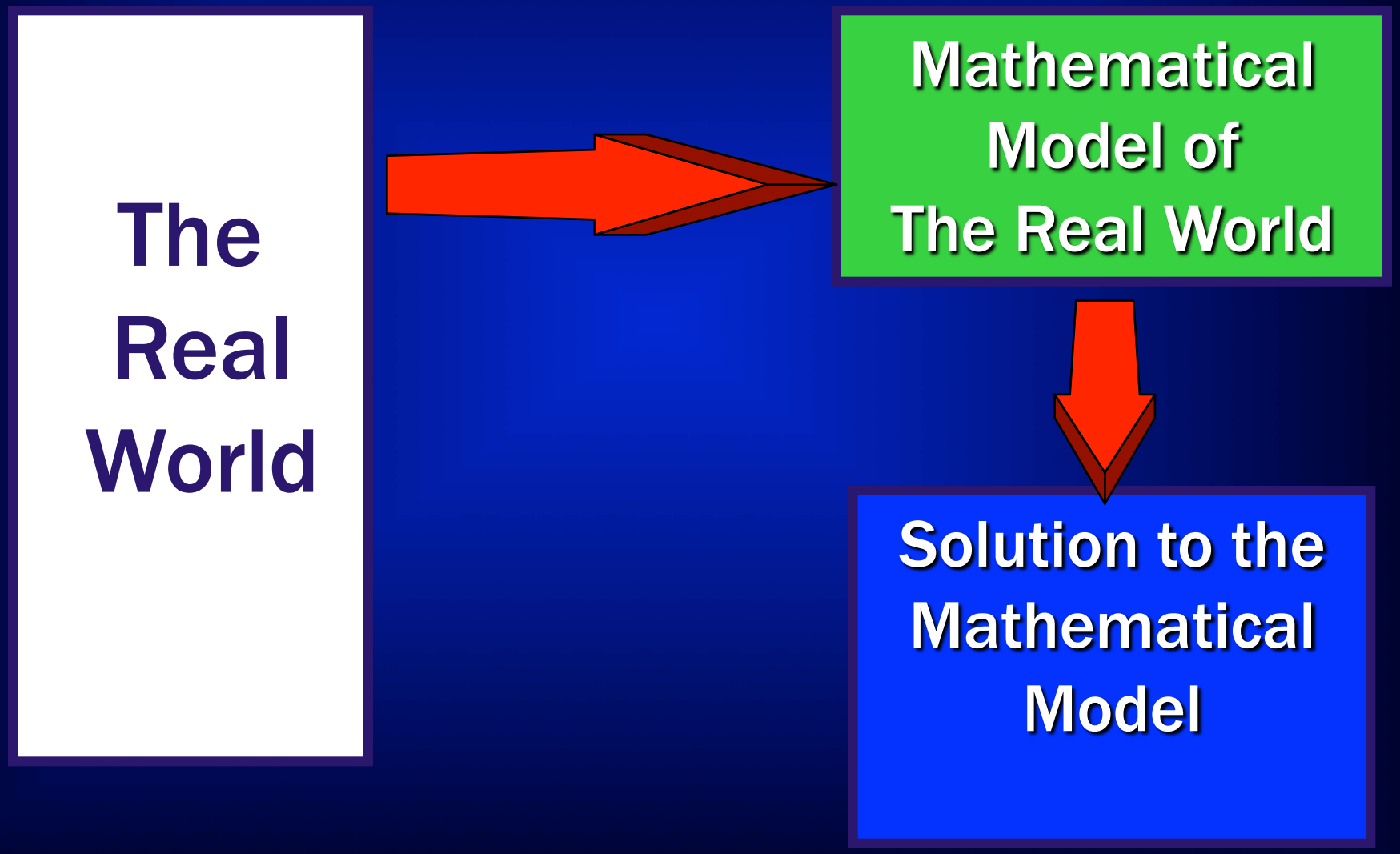
1. The 100 Year Test

- Hamming once asked me,

"What progress of today will be remembered 1000 years from now ?"

Will your work be remembered 100 years from today?

2. The Modeling Process



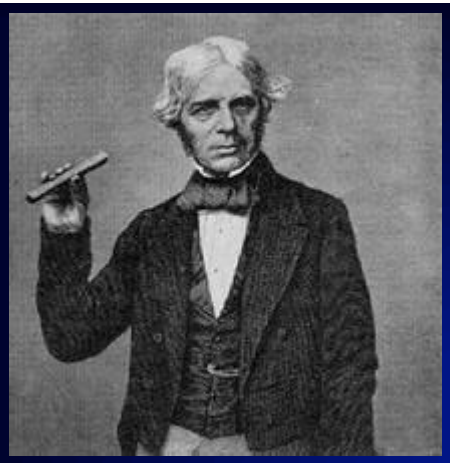
2. But Don't Fall in Love With Your Model

The Real World

Approximation

Mathematical Model of The Real World

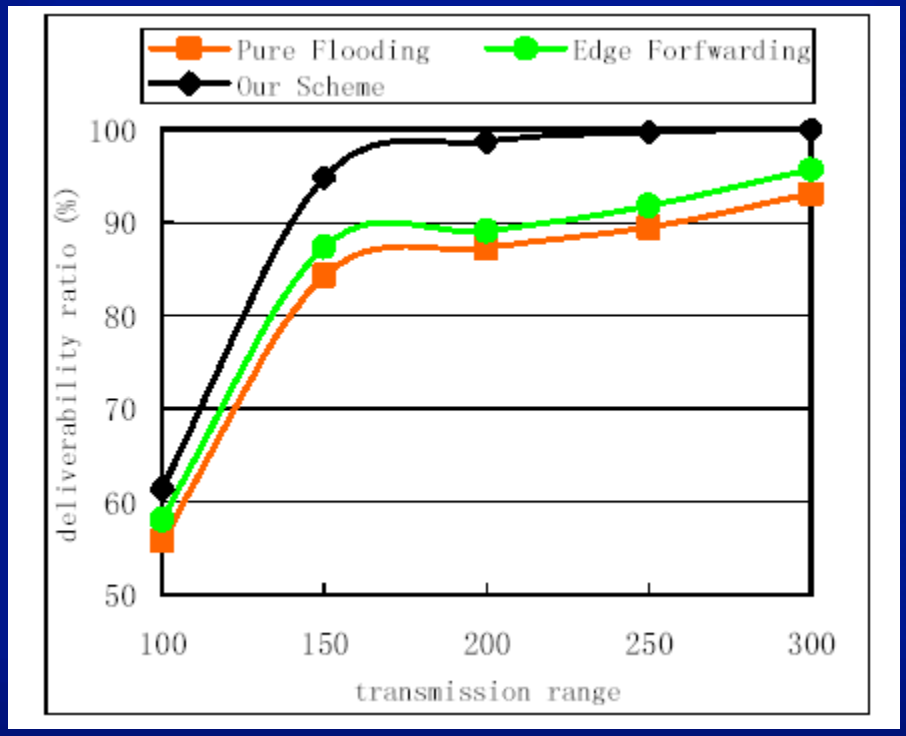
Solution to the Mathematical Model



Michael Faraday

- "I could not imagine much progress by reading only, without experimental facts and trials … I was never able to make a fact my own without seeing it. “ (Faraday: 1827)
- Faraday performed in his brain the work of a great mathematician without using a single mathematical formula” (Hermann von Helmholtz : April 5, 1881)

3. Beware of Mindless Simulation



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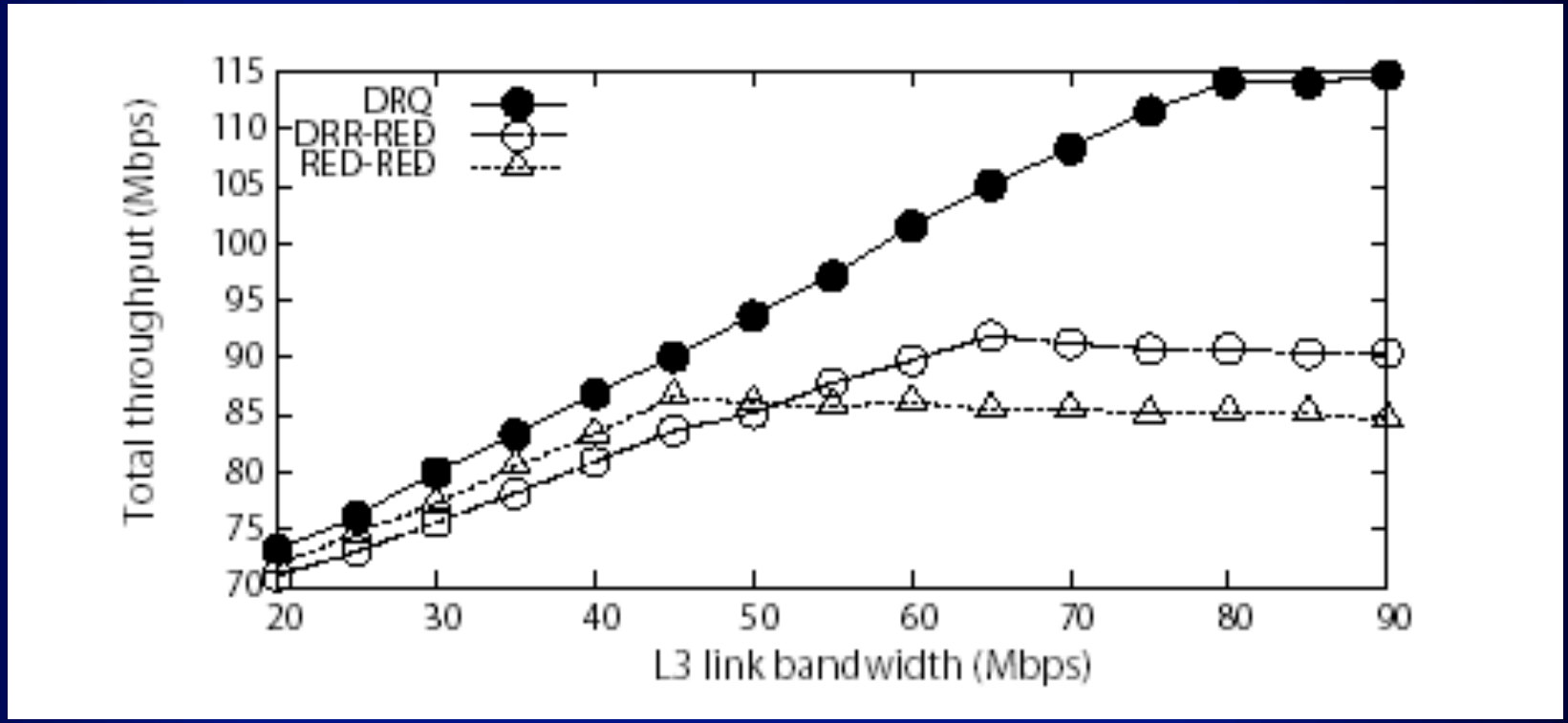

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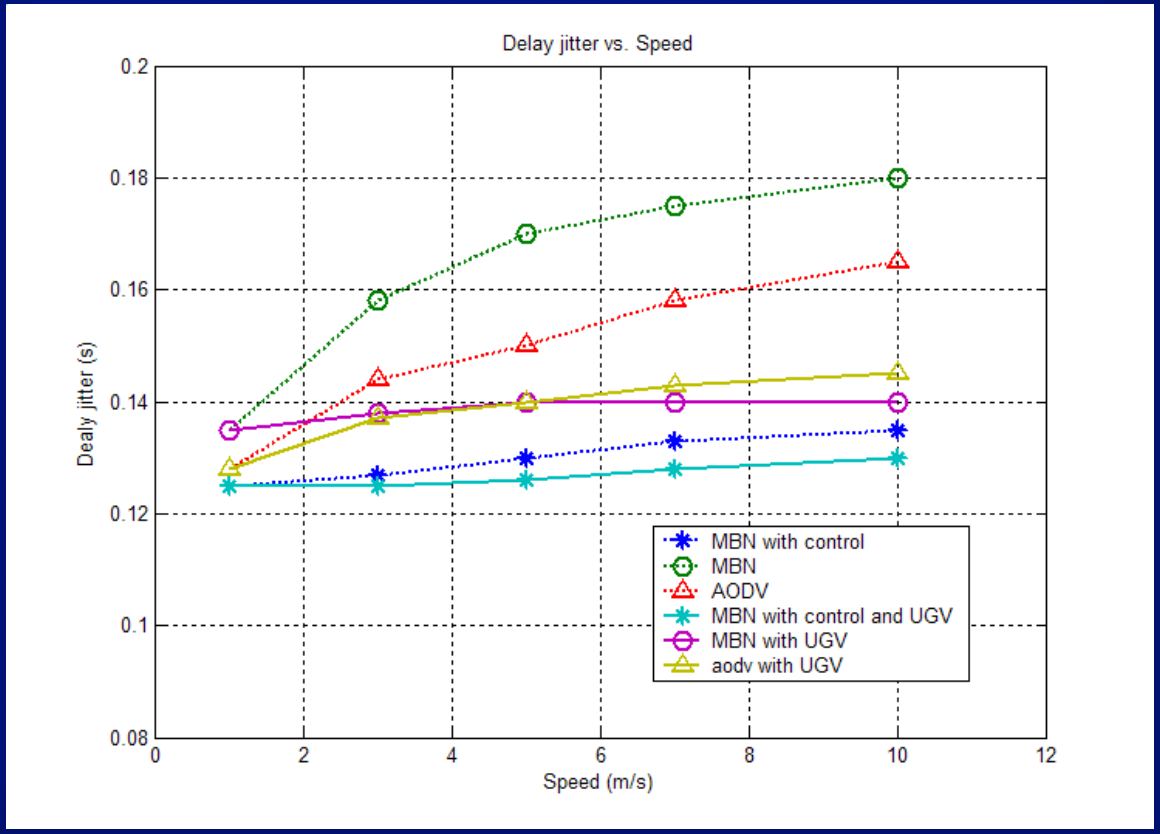

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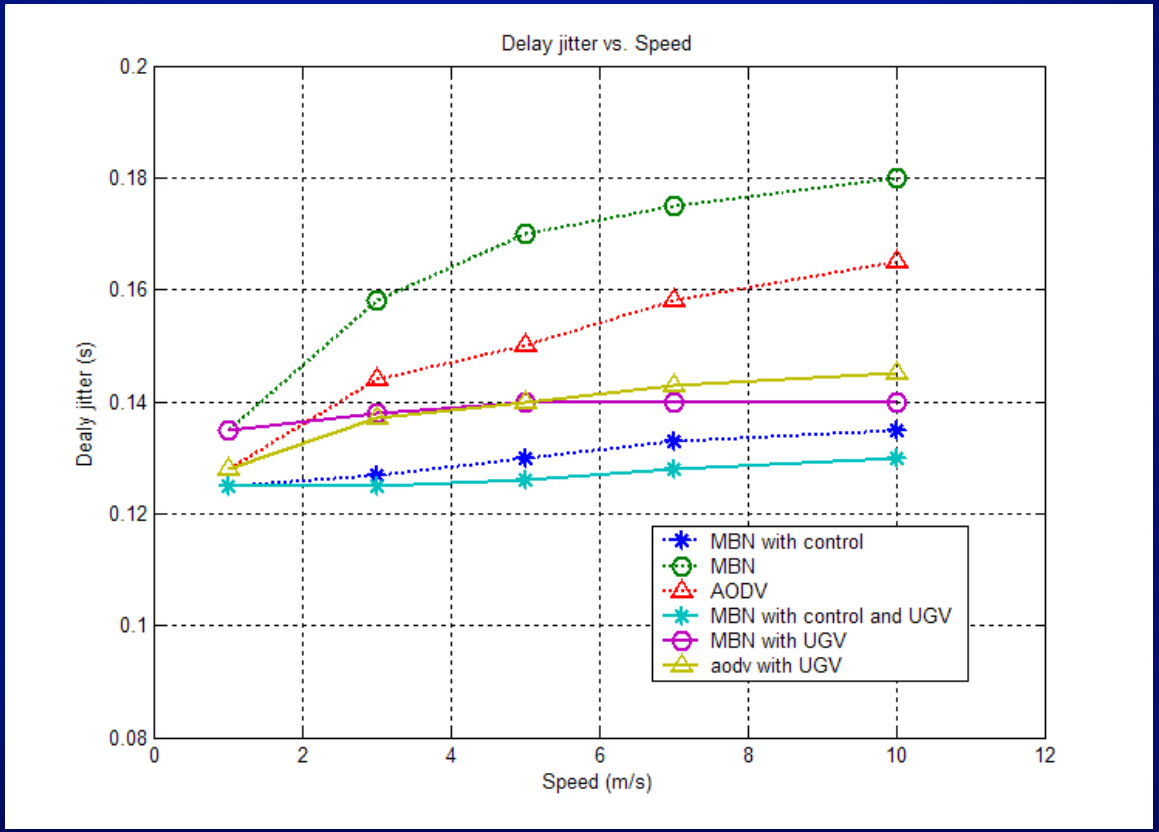

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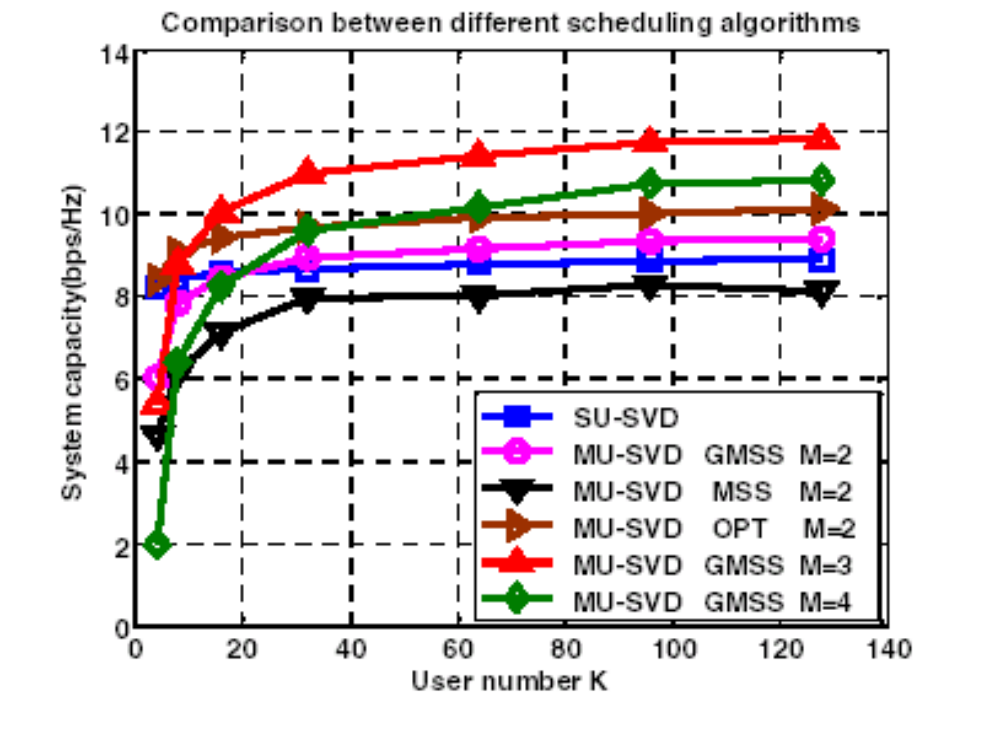

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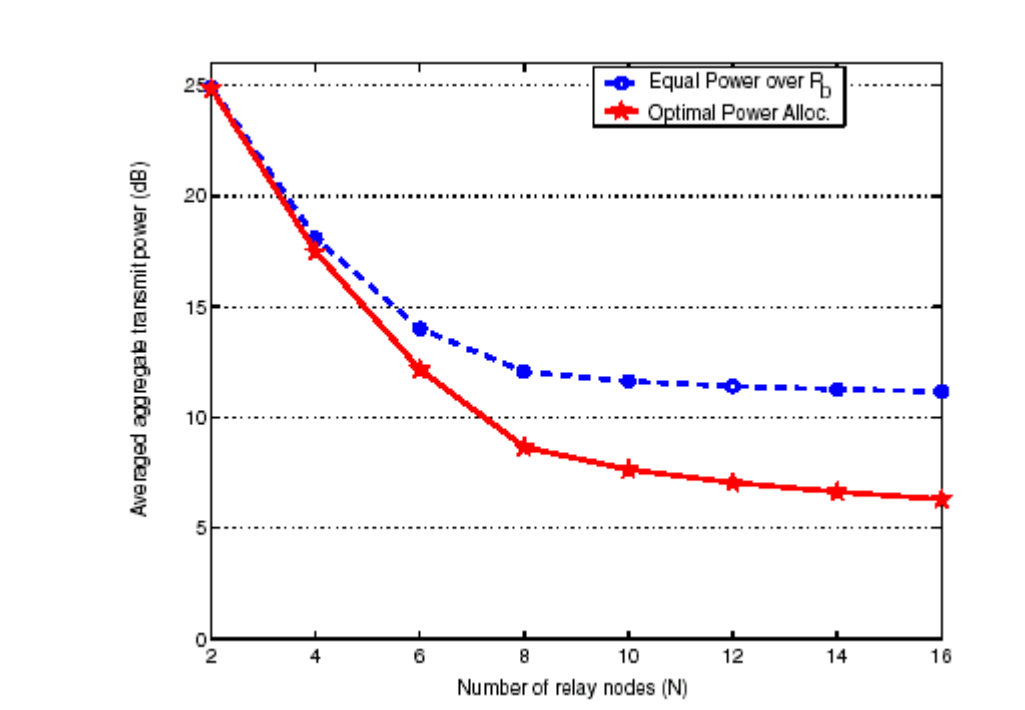

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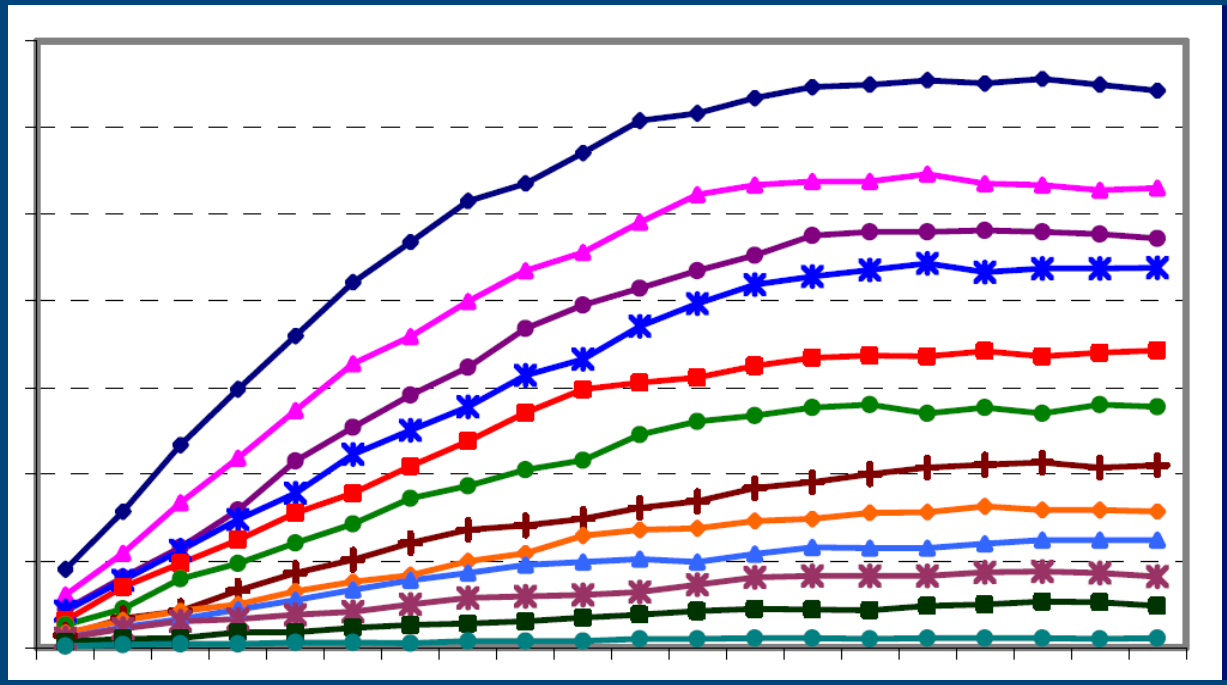
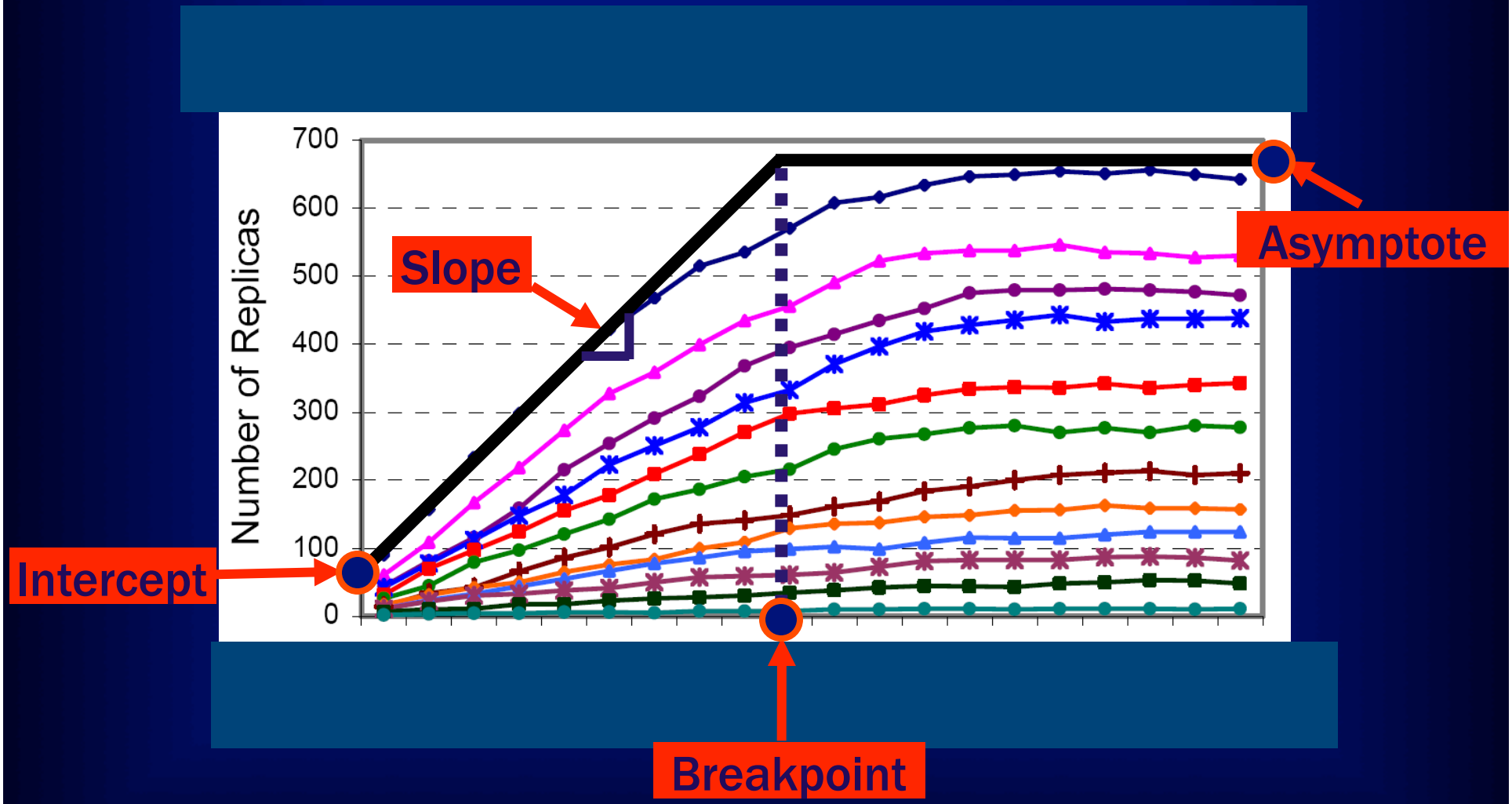


3. Beware of Mindless Simulation
Ask the Obvious Questions

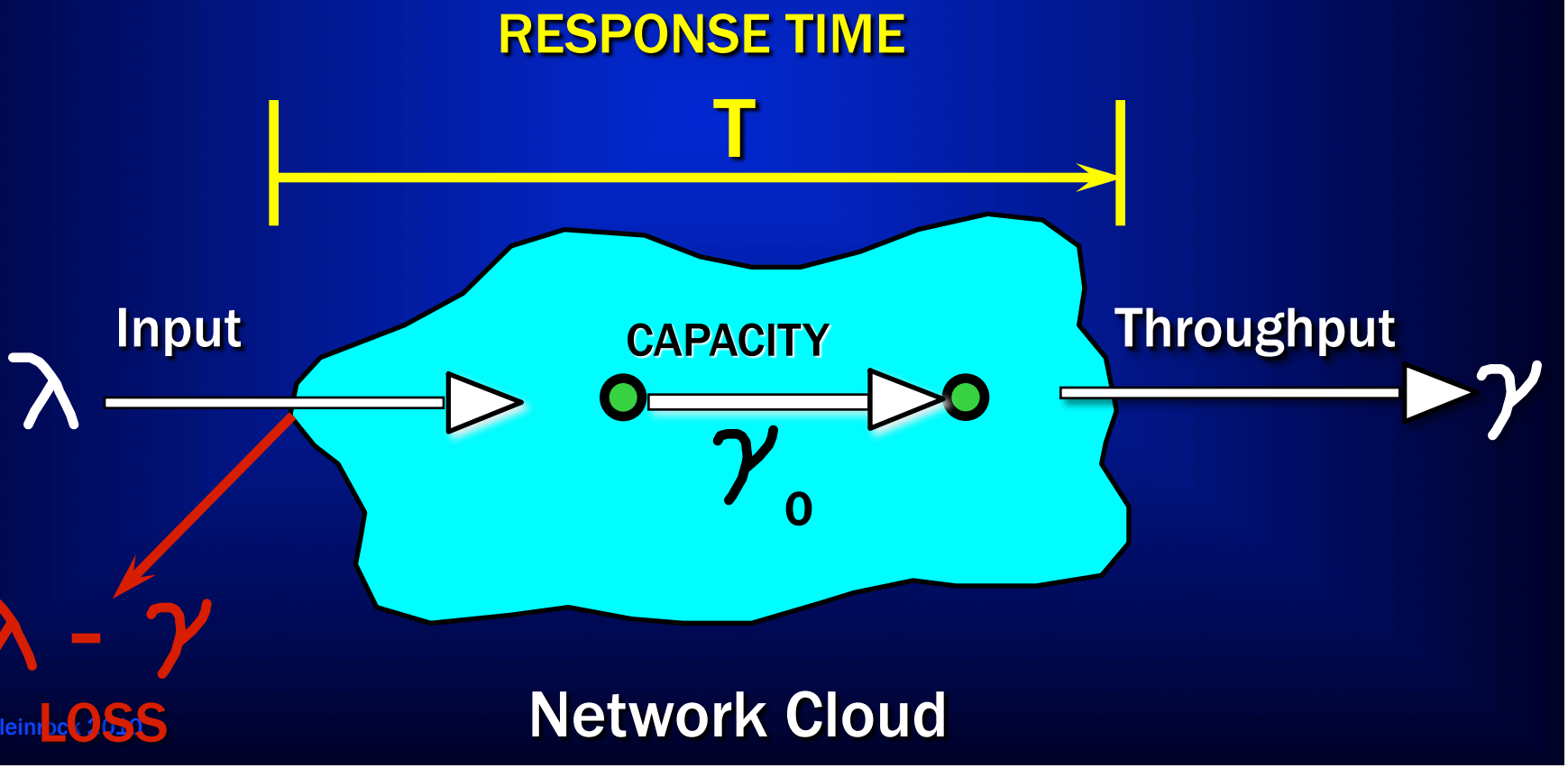


4. Understand Your Own Results

Response Time

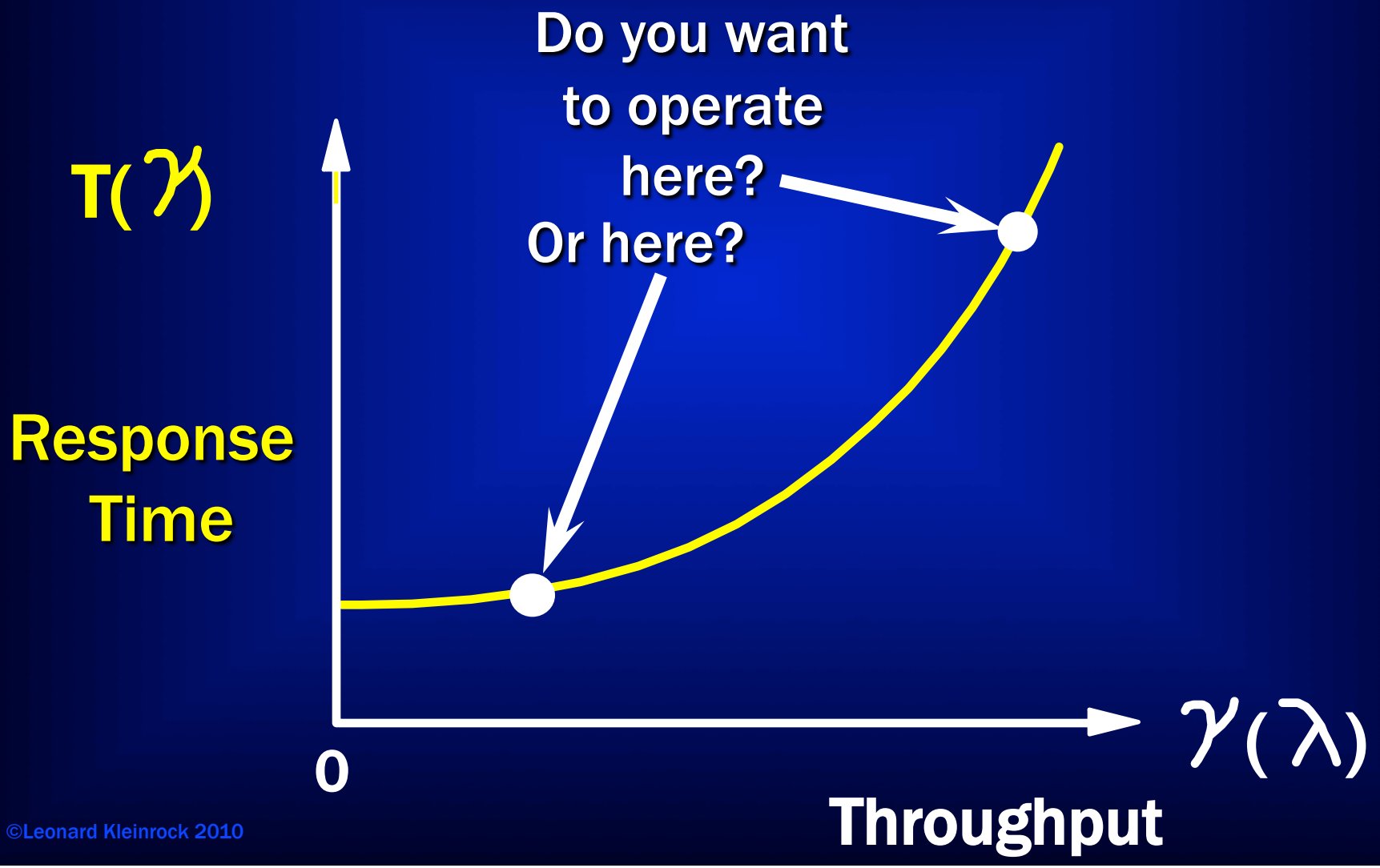
Throughput

Loss



Response Time vs Throughput

Now let's ask a good question:

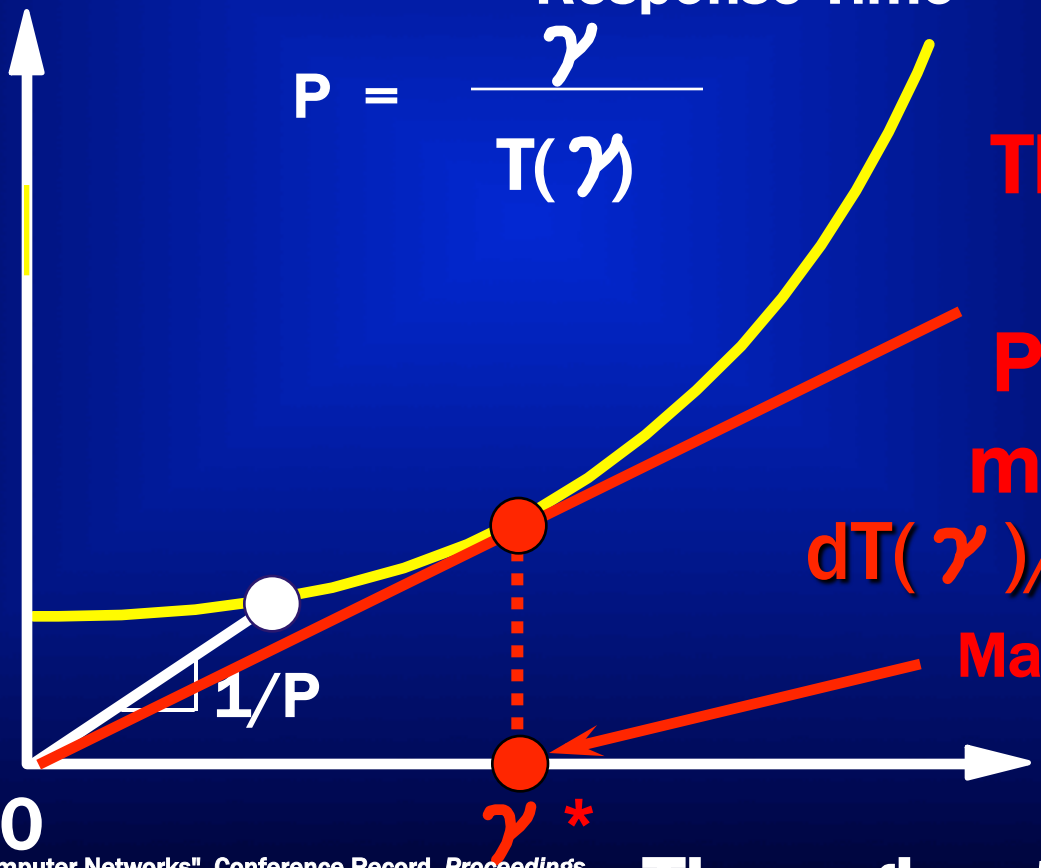


4. Understand Your Own Results

Let me define a new metric of performance:

$$\text{POWER} \triangleq \frac{\text{Throughput}}{\text{Response Time}}$$

$$P = \frac{\gamma}{T(\gamma)}$$



The main result Power is max when

$$dT(\gamma)/d\gamma = T(\gamma)/\gamma$$

Max Power Point

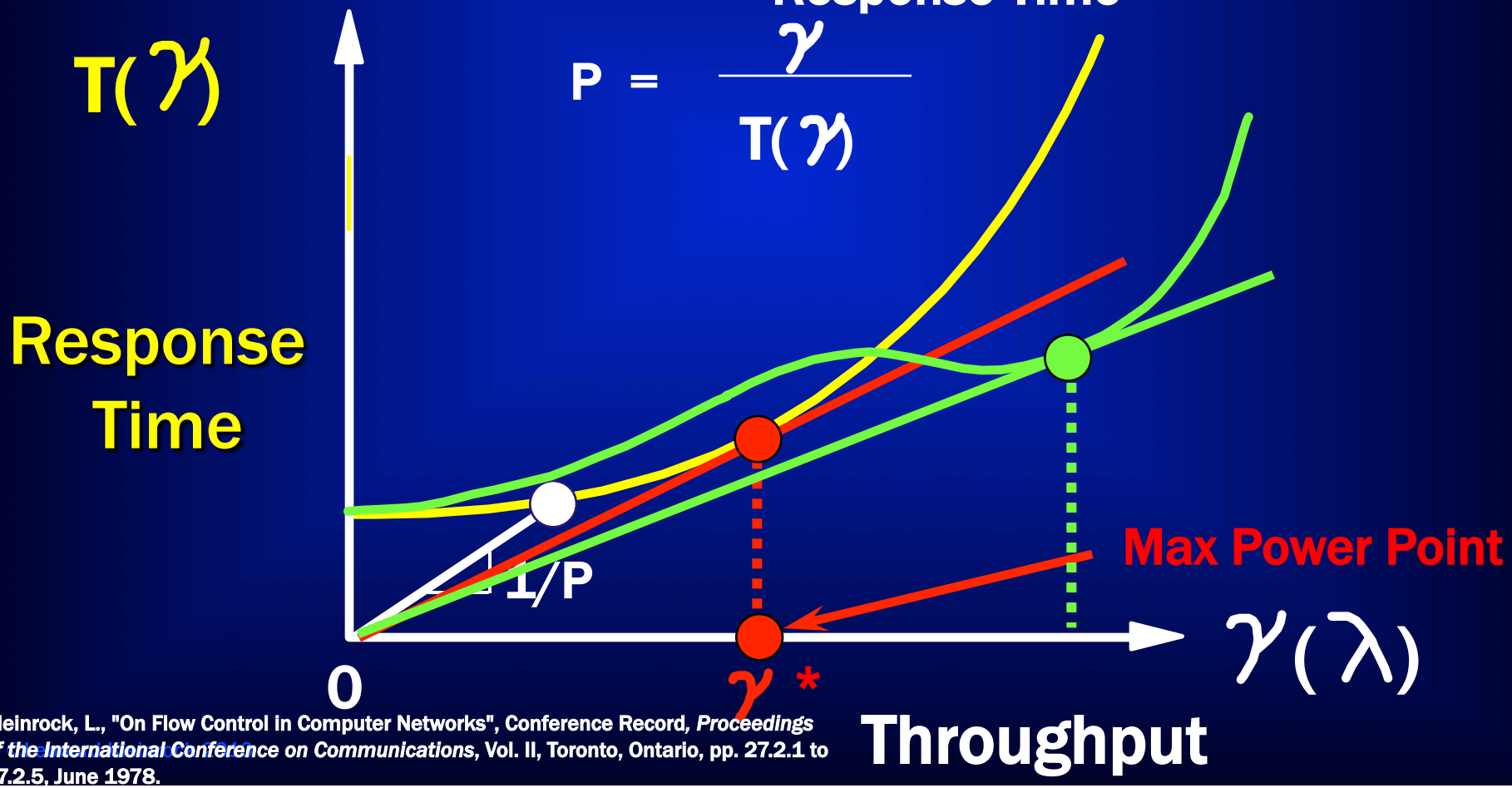
Kleinrock, L., "On Flow Control in Computer Networks", Conference Record, *Proceedings of the International Conference on Communications*, Vol. II, Toronto, Ontario, pp. 27.2.1 to 27.2.5, June 1978.

4. Understand Your Own Results

We need a new metric of performance:

$$\text{POWER} \triangleq \frac{\text{Throughput}}{\text{Response Time}}$$

$$P = \frac{\gamma}{T(\gamma)}$$



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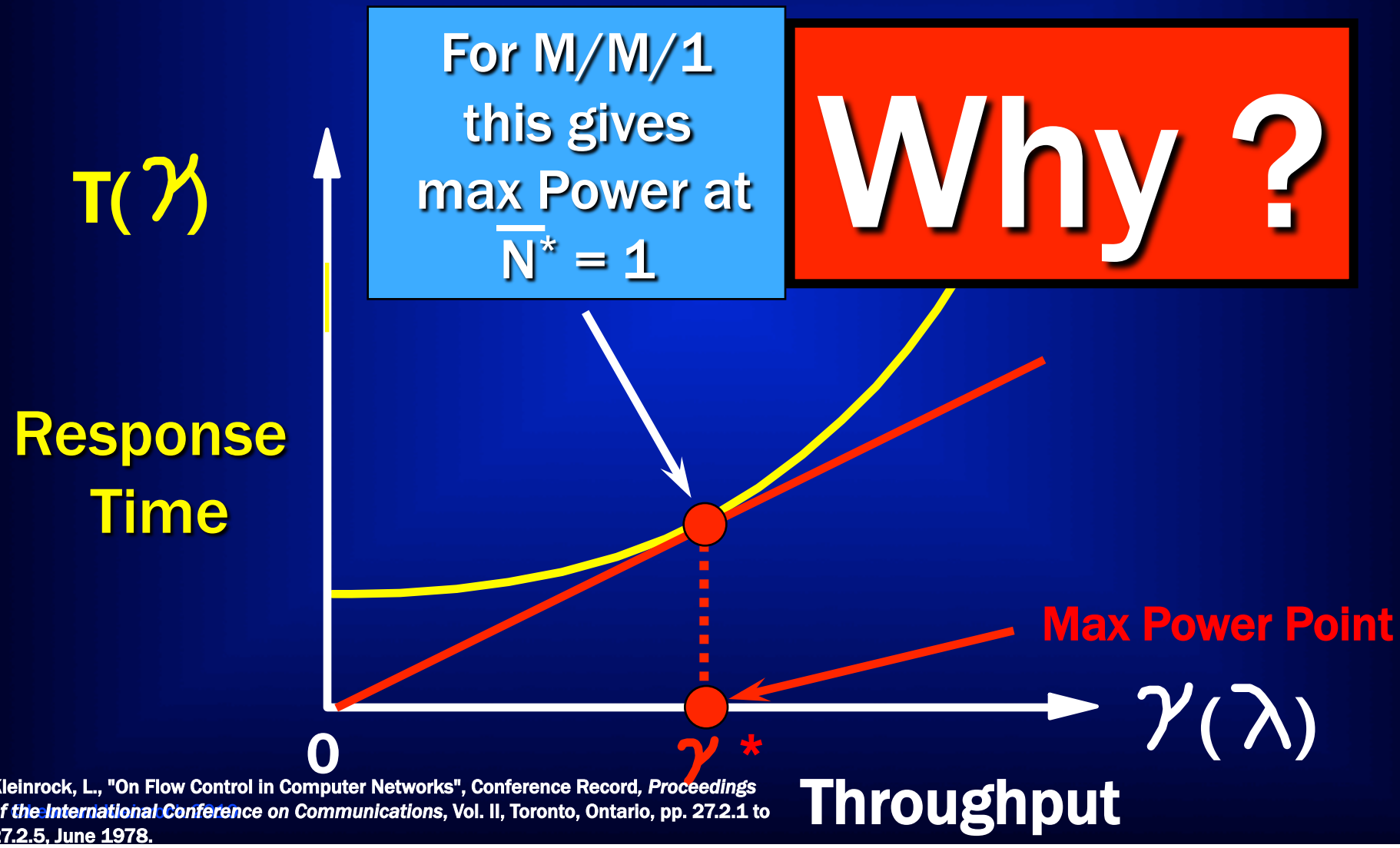
4. Understand Your Own Results

Let's Dig Deeper on Understanding



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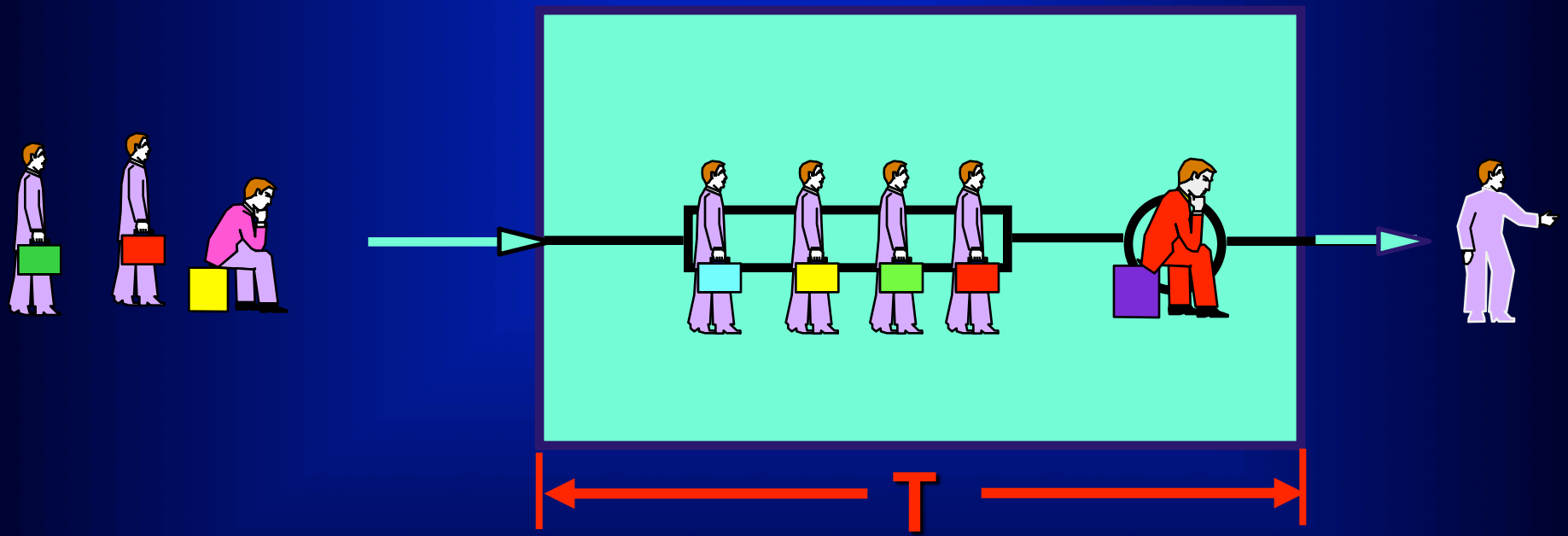
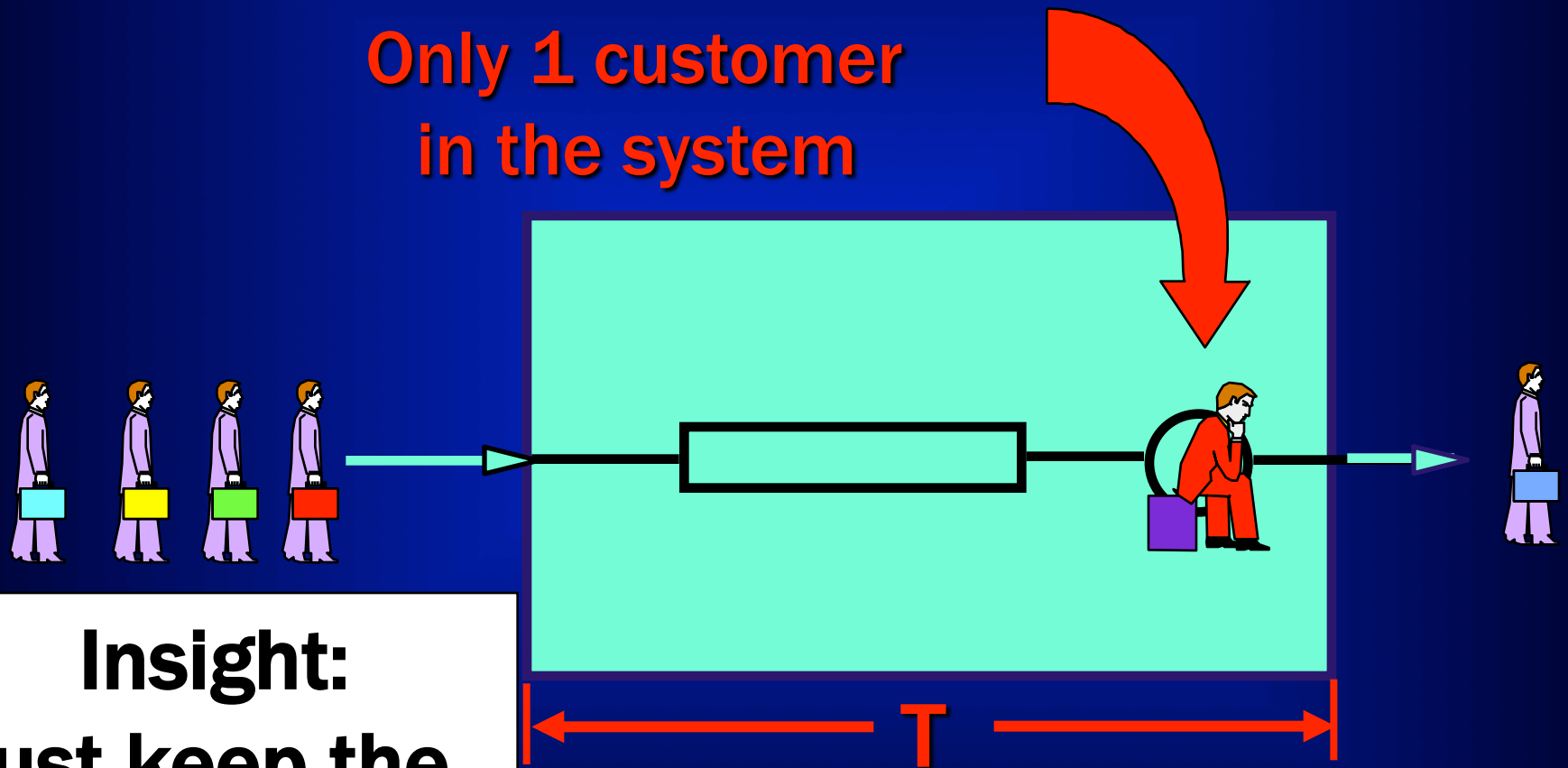
4. Understand Your Own Results
Use Your Intuition



T = Min

Eff = Max

4. Understand Your Own Results
Use Your Intuition



Insight:
Just keep the pipe full!

T = Min

Eff = Max

4. Understand Your Own Results

- Our intuition says put exactly one person in the queueing system
  - This was from "deterministic" reasoning.
- We can't actually do that in general
- BUT our earlier result said that we should adjust the system to achieve an average of one person in the queueing system, i.e.,

At Max Power
$N^* = 1$
for M/M/1

5. Gee, that's funny!

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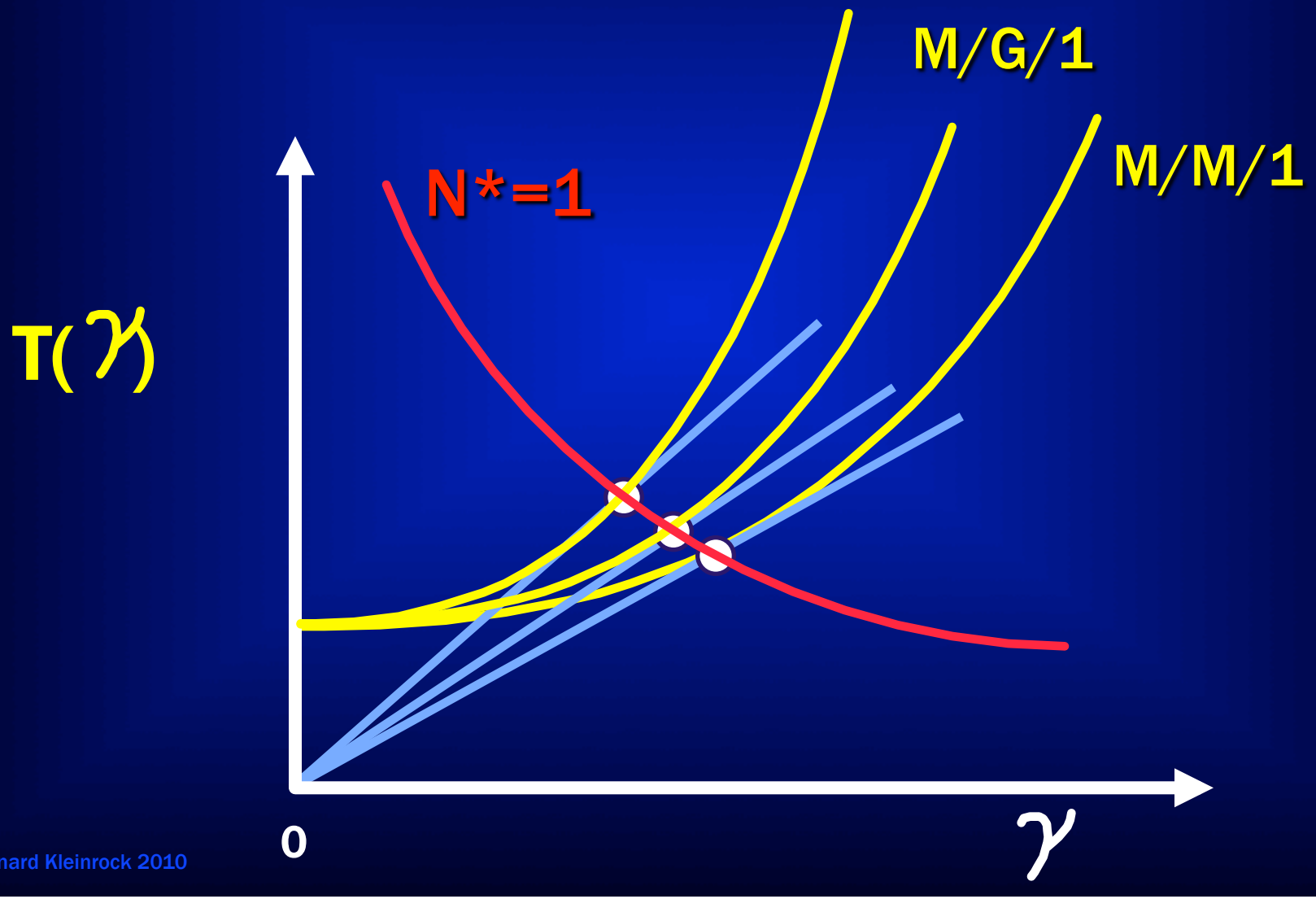
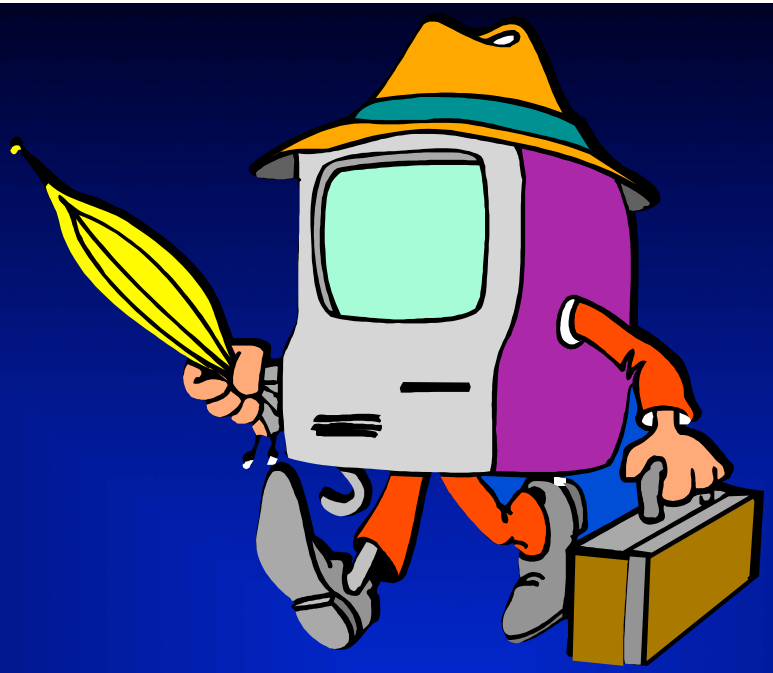
What can we say for M/G/1 ?



More on Modeling

- Moving the frontier is tough
  (we mislead our students)
- Once you do it, you will be able to repeat it
  (students don't believe us)
- Teach your students to understand their results!
- Generalization usually comes when you can
  see the simplicity of a solution
- Keep your interest in related areas - areas where
  something might happen.



Thank You

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