Internet Economics & Financial Technology

Computer Science COMSM0019

Lecture 11:
Economic Agents and Market-Based Systems III

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University of BRISTOL

Thus far, lectures I & II (08 & 09) have been quite academic

…microeconomic theory (L08)

…conference/journal papers on robot traders (L09)

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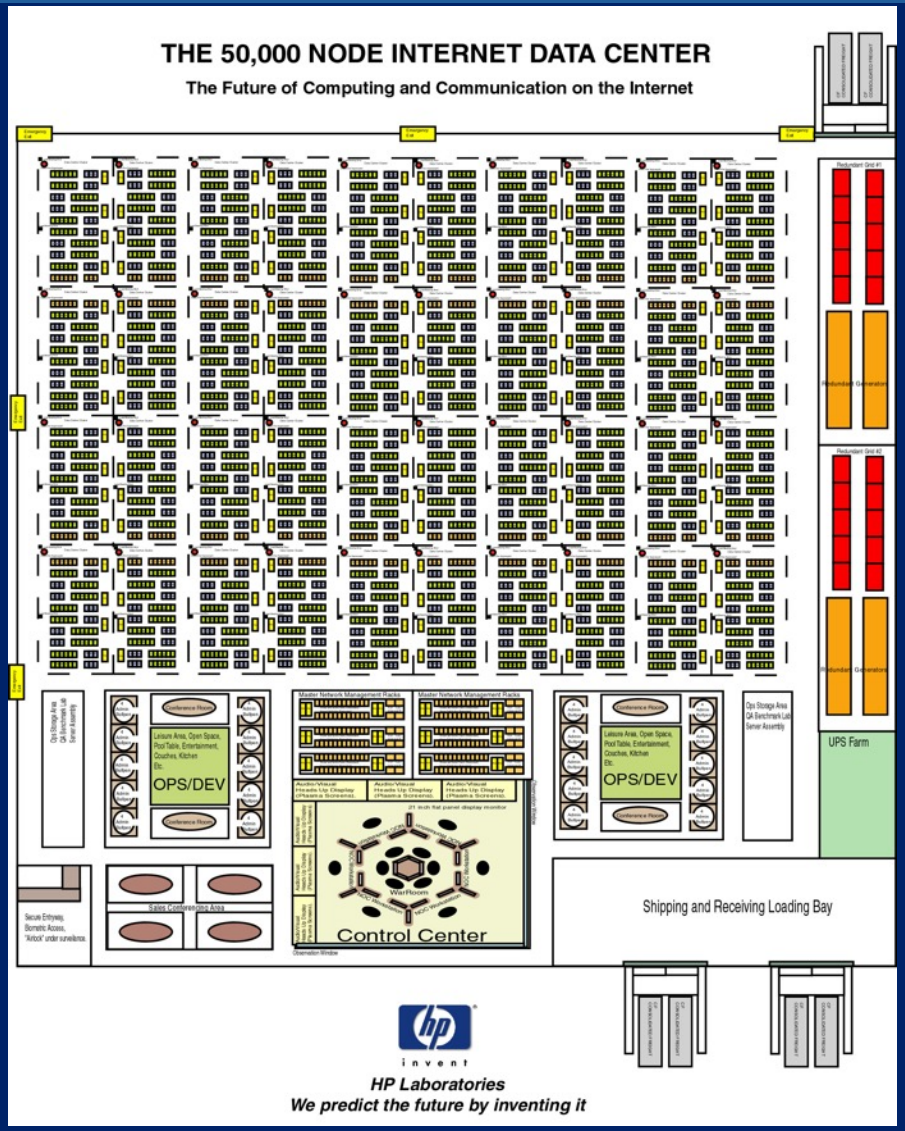
Now let's look at real-world applications/implications…

ZIP designed for markets in data centres…



50,000 blade-servers

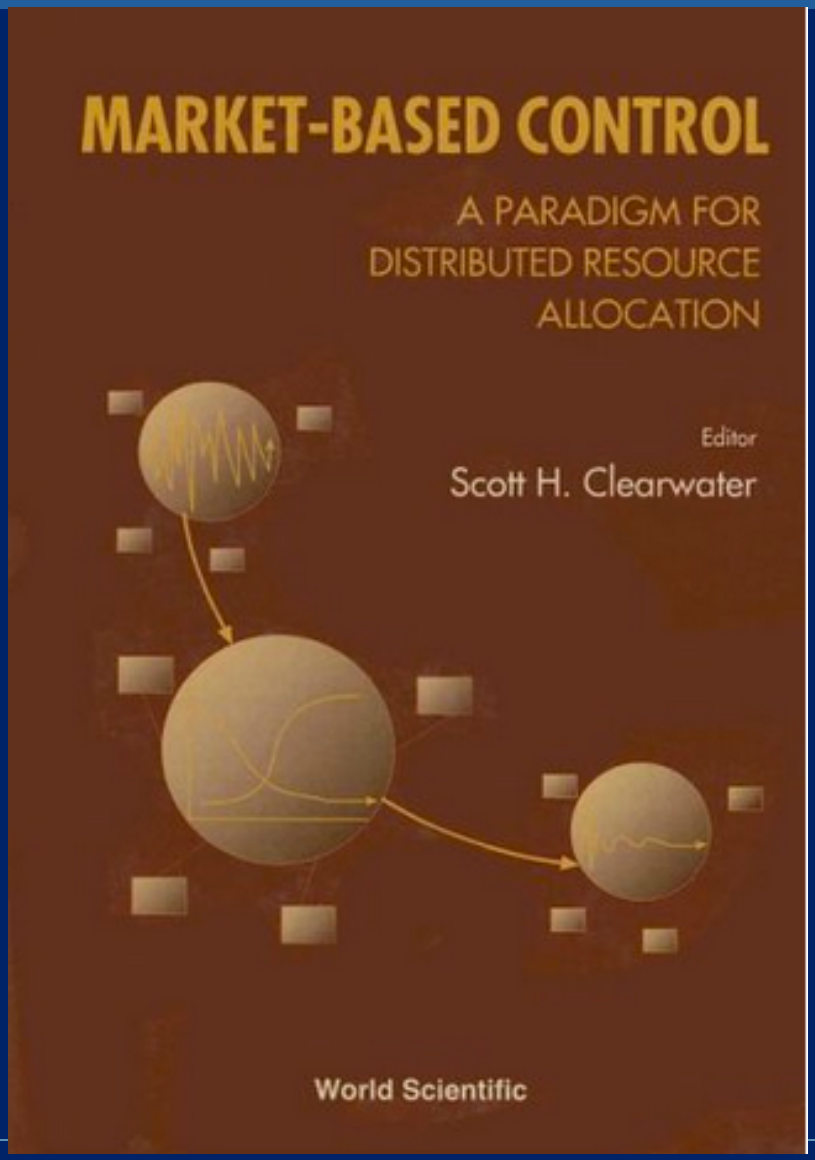
in a very big shed

with a very big air-conditioning system

Utility Data Center (UDC)

Just one shed in a global network…

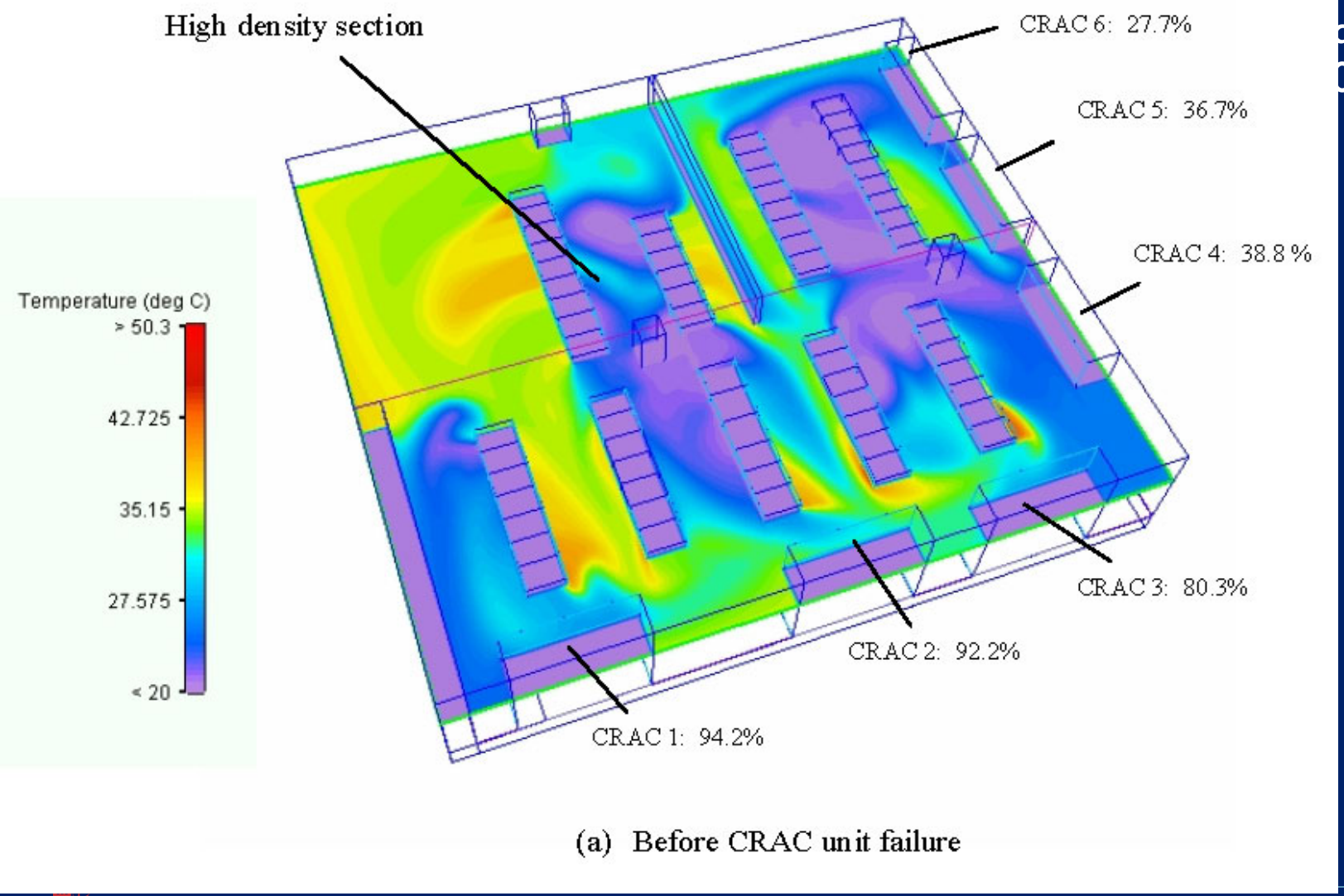
S. Clearwater, editor (1995)



If you can't stand the heat…

M. H. Beitelmal & C. D. Patel (2004) *Thermo-Fluids Provisioning of a High Performance High Density Data Center.* HP Labs Tech. Report HPL-2004-146.

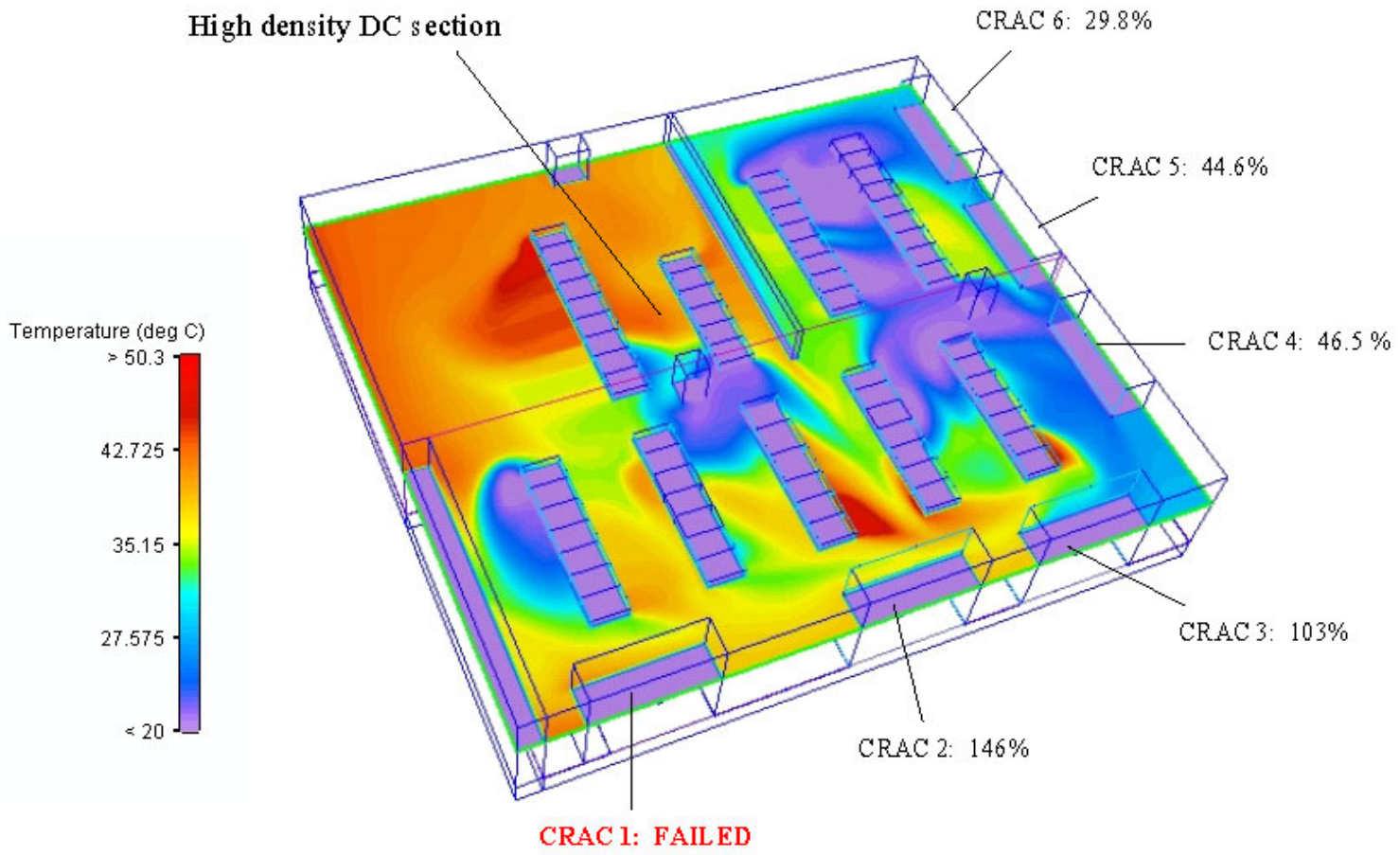
If you can't stand the heat…



(a) Before CRAC unit failure

a High
004-146.

If you can't stand the heat



(b) After CRAC unit failure

(a) Before CRAC unit failure

If you can’

Hi

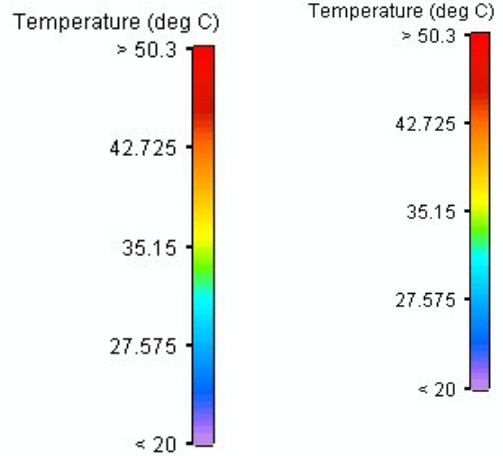


FIG. 5. Temperature Plane Plot after CRAC unit failure and load redistributed.

(b) After CRAC unit failure

(a) Before CRAC unit failure

But…

ZIP & MGD better than humans, actually

(at IBM T.J.Watson Research Labs in 2001…)

- Tested trader-bot algorithms: ZI-C, ZIP, Kaplan's "Sniper", & IBM's own "MGD"
- Pitted human traders against trading agents in experimental economics lab
- Both ZIP and MGD beat humans
- HP's ZIP did at least as well as IBM's MGD traders (and maybe better?)
  - Average efficiencies: ZIPs=1.030; MGDs=1.023; Humans=0.876

"…the successful demonstration of machine superiority in the CDA and other common auctions could have a much more direct and powerful impact – one that might be measured in billions of dollars annually."

- R Das, J E Hanson, J O Kephart, & G Tesauro. Agent-human interactions in the continuous double auction. *Proceedings IJCAI-01*, Seattle, 2001

  http://www.research.ibm.com/infoecon/researchpapers.html

…and so are AA and GDX

Experiment	Trades			Performance			Market	
Strategy	A-A	A-H	H-H	Eff(A)	Eff(H)	Δ Profit(A-H)	Eff	Profit Disp
AA	41%	32%	27%	1.078	0.867	27%	0.978	793
GDX	33%	42%	25%	1.040	0.866	23%	0.954	568
ZIP	39%	30%	31%	1.014	0.941	9%	0.978	418

Table 2: Summary of the nine human vs. agent experiments. For each strategy, the table displays: the strategy employed by all six agents; the percentage of trades made between two Agents, an Agent and a Human, and two Humans; the average efficiency of Agents and Humans; the percentage difference between Agent surplus and Human surplus; the market efficiency and the profit dispersion. The mean maximum theoretical profit per trader per simulation is 2107. Lower profit dispersion and higher mean efficiency values are better. All numerical values are mean values over three experiments.

M. De Luca and D. Cliff (2011) Human-Agent Auction Interactions: Adaptive-Aggressive Agents Dominate. *Proc. IJCAI 2011*. http://www.ijcai.org/papers11/Papers/IJCAI11-041.pdf

Foresight Driver Review DR3

nment

Foresight Driver Review DR3

Technology Trends in the Financial Markets: A 2020 Vision

Prof Dave Cliff, UK LSCITS Initiative, Computer Science, University of Bristol.
Dr Dan Brown, Computer Science, University College London.
Prof Philip Treleaven, Computer Science, University College London.

Summary

The global financial markets have been proactive early-adopters of new technologies for most of their history. In the past quarter of a century, since the instigation of the "big bang" switch to paperless electronic trading, the City of London has led the world in the adoption of new information and communications technology (ICT) for the provision of electronic trading facilities, and the associated distribution of data and news feeds. This hunger for new technologies looks unlikely to be diminished in future.

As well as many opportunities, ICT development has additionally brought risks (some of which are non obvious and even counter intuitive) for which there is an immediate requirement for careful and thorough evaluation.

New technologies may come in the form of new hardware, new software (including algorithms), or (most likely) combinations of the two. As new technologies become available and more widely adopted, they may significantly alter what market actions and activities are possible, and in the longer term they may significantly alter the socio-economics of the financial markets, and hence also the necessary regulatory and political frameworks that financial institutions operate in.

(Slides 14 to 83 are illustrations to Foresight Review DR3…)

New Scientist June 2nd, 2007

Where have all the traders gone?

Time is running out for Wall Street's high rollers. A new breed of traders is muscling in, says **Robert Matthews**

BRAD BAILEY was visiting the trading floor of an investment bank in New York City when he first noticed it. As a former Wall Street trader, he should have felt at home amid all the screens, phones and bustle of billions of dollars in trades. But that was just it: there wasn't any bustle. In fact, there were hardly any traders. "You could hear a pin drop," he recalls. Then it sank in: machines had taken over the role of people and computer servers don't make any noise.

There's a quiet revolution happening all over the financial world. Gone are the days of Gordon Gekko lookalikes screaming obscenities and dumping a loss-making stock onto an unsuspecting market. Investors have realised that the processing speed and sheer volume of trades a computer can make can help them to outwit the sharpest of dealers. As a result, they are investing heavily in what has fast become an arms race between investors. Their goal is to develop the best "algorithmic trading" systems – software that helps decide which trades are the most profitable, and then does the deals. Ten years ago, algo-trading was almost non-existent, but according to a recent report by Bailey, now at the Boston-based consulting firm Aite Group, one-third of all trading decisions in US markets are now made by machines. He predicts that by 2010 more than half will be done this way. At Deutsche Bank in London, over 70 per cent of a category of foreign currency trades, called "spot trades", are now carried out without human intervention every day. All this will have an impact on more than just high-rolling investors. Even if you don't own any shares you can bet that millions of those owned by your pension fund are already being bought and sold using "algo" trading techniques.

"70 per cent of foreign currency trades are carried out without human intervention"

It's not hard to see why algorithmic trading is so attractive. Machines can make multiple trades, monitor thousands of stocks and do it all at breakneck speed. Crucially, they can do it without anyone noticing. There are big profits to be made in buying and selling shares that other traders haven't yet realised are being lucratively traded. The more discreetly you can do this – by spreading the deal over lots of small trades, for example – the less likely other traders are to wake up to the opportunity and dilute your profit potential. Such discretion is near impossible for a human, as it requires constant monitoring of the market to make sure your trades don't alter stock prices in an unfavourable direction.

As a result, investment houses are becoming increasingly tech-savvy. Eavesdrop on traders today and you are more likely to hear talk of "low latency access" (which we'll get to later) than of what they'd like to do to a rival's neck.

"Anyone who's been on Wall Street since the early 1990s will have had to reinvent themselves," says Bailey. Back then, success as a trader hinged on an instinct for what the market was "thinking", plus reactions fast enough to make the most of the opportunities the market presented. In the early years of computerised trading, when machines were simply communication tools, hitting a key a few tenths of a second faster than a competitor could make a real difference to your profit margin. Nowadays human traders struggle to keep up. "Silicon is taking over from carbon on Wall Street," says Bailey, as beige boxes proliferate across trading floors.

Computers have the edge over humans in many ways. Take something as simple as reaction time. When a human trader sees a stock change price, he might react in a few hundred milliseconds. A computerised trader is at least 10 times faster: depending on how much you are willing to fork out to speed things up. A few hundred milliseconds might seem insignificant, but if the price changes by a fraction of a per cent in the split-second before a trade worth many millions, it could mean a swing of tens of thousands of dollars. The key for any trader is "low latency" market access – that is, minimal delay between placing an order and seeing it fulfilled.

To achieve this, traders naturally have ultra-fast software, running on top-of-the-line computers with the very best processors and memory capacity. But there is a more direct, and perhaps less obvious, way to speed things up: moving closer to the source. Trading companies pay top dollar to snuggle their servers as close as possible to those of the stock exchange. With access to such "proximity servers", their electrons can beat those of their rivals to the punch. Last year one of the biggest hitters in the algo-based trading world, Deutsche Bank, paid an undisclosed sum to proximity-server supplier BT Radianz to shave milliseconds off its trading times.

Stealth-trading is another area in which machines have the upper hand. For example, many of the leading brokerage firms now have computers running so-called volume-weighted average price (VWAP) algorithms. These algos slice up big transactions, then ▸

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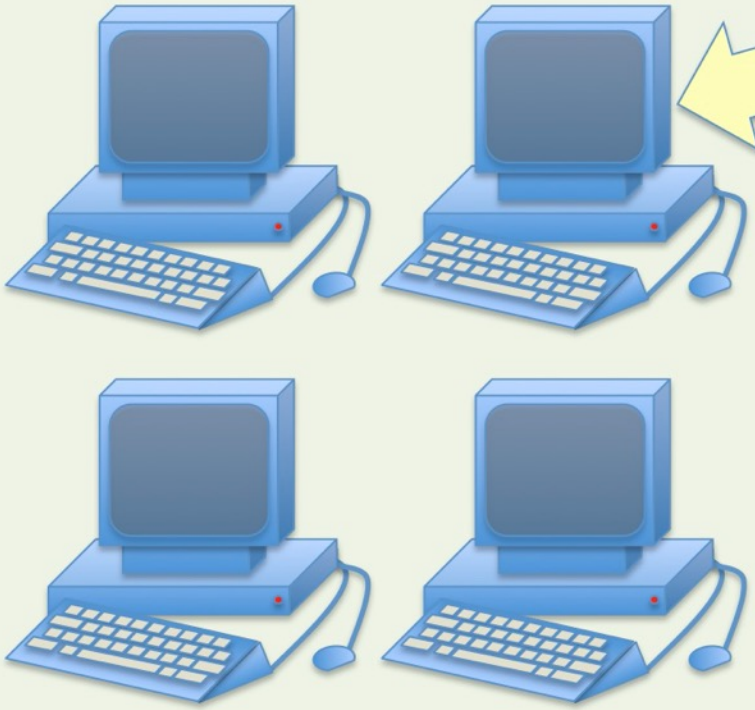

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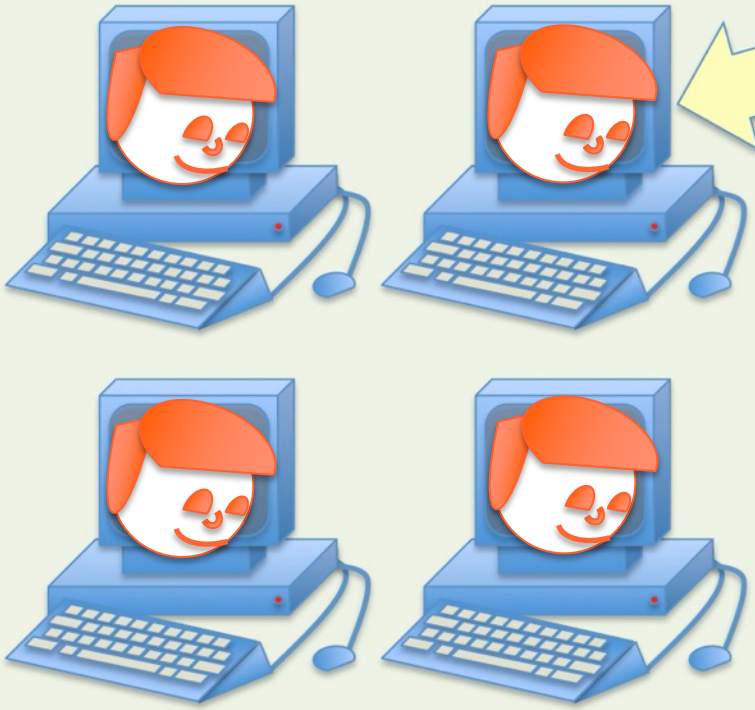

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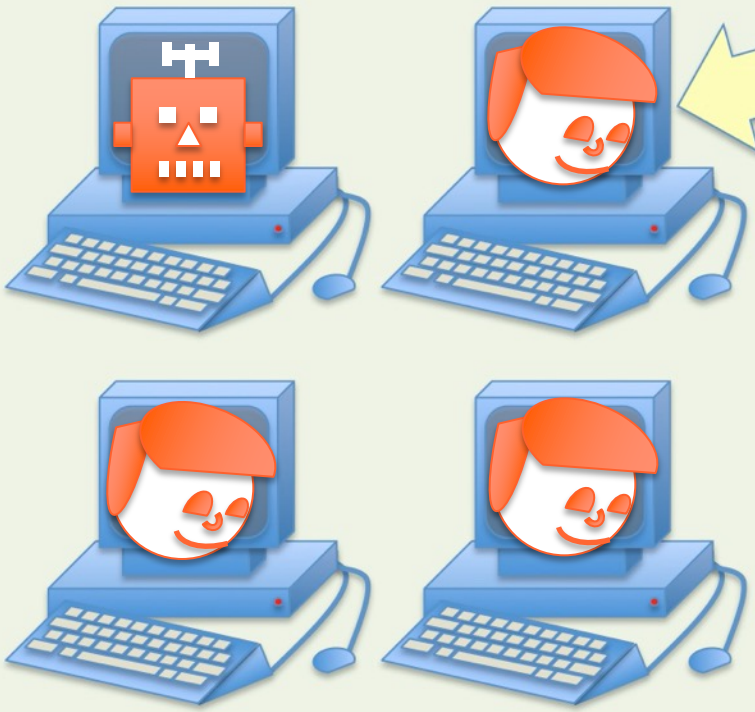

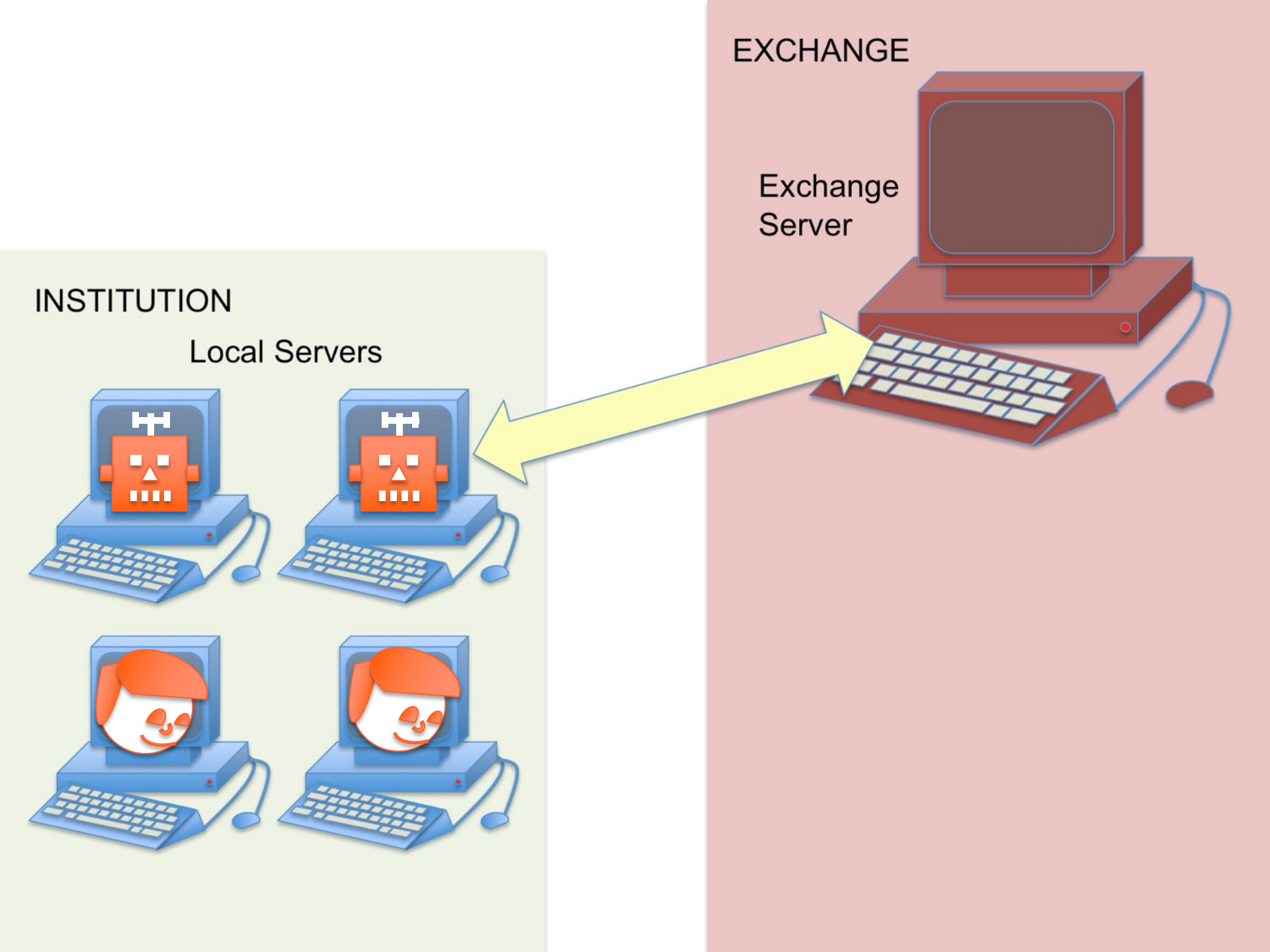
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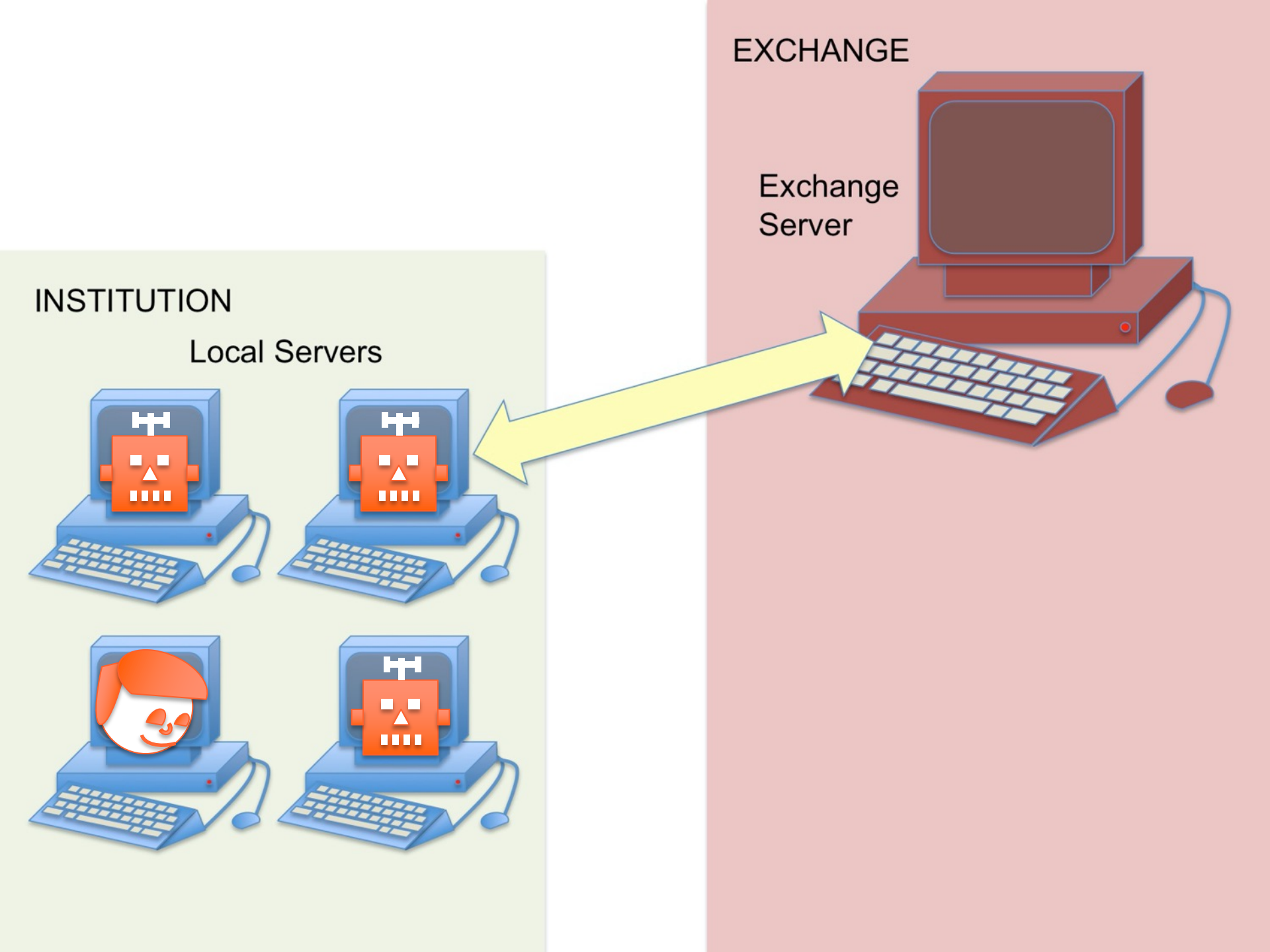
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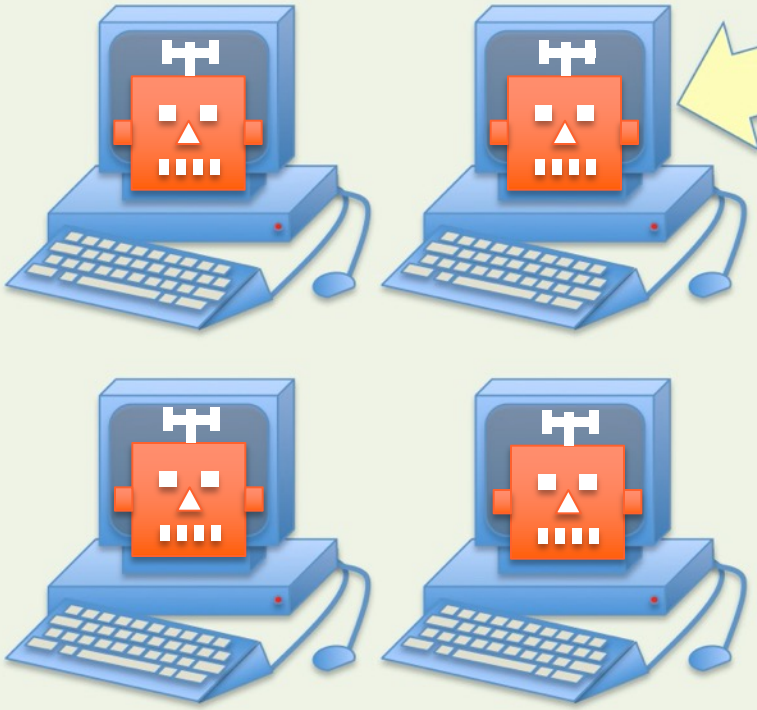


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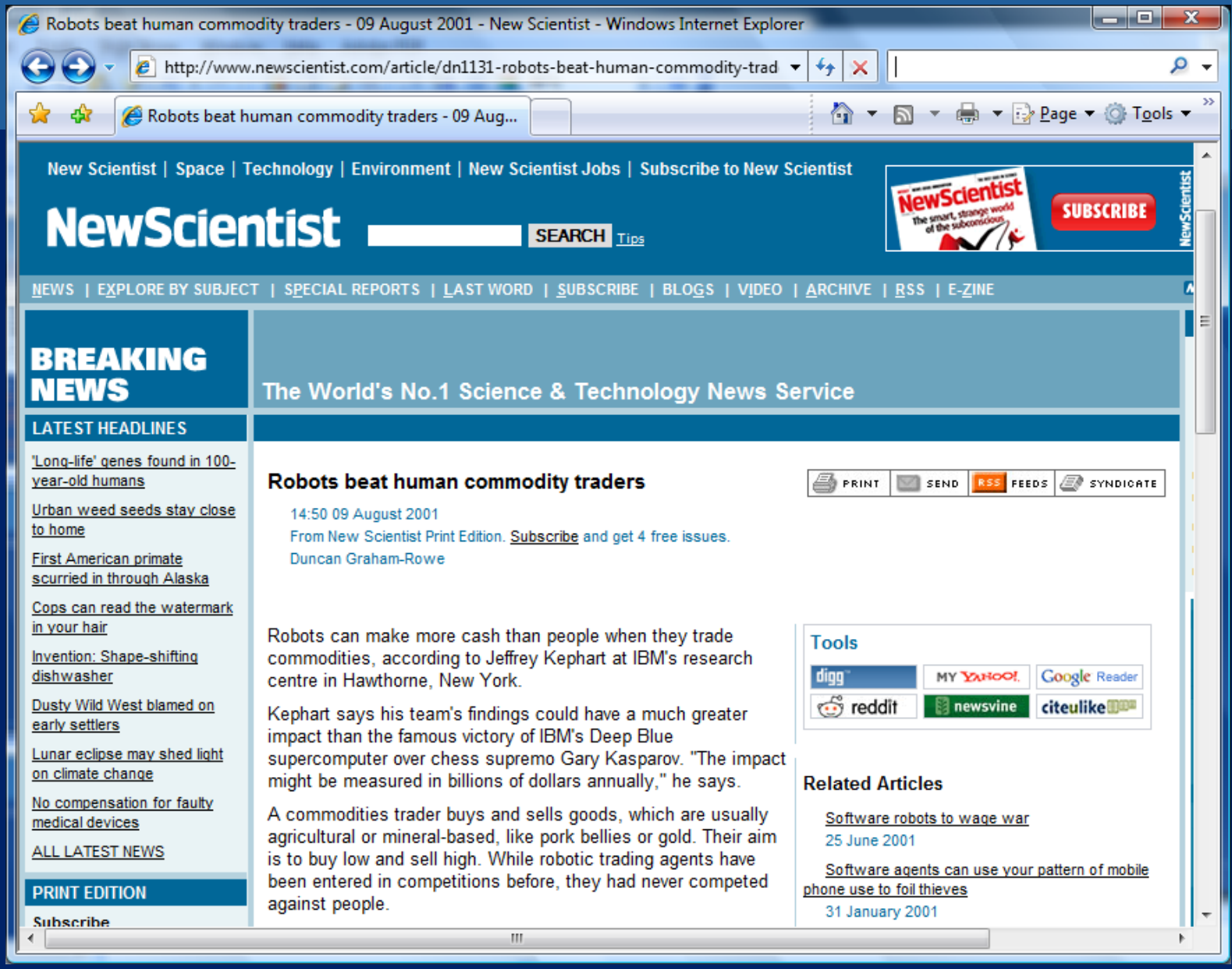
Robots beat human commodity traders - 09 August 2001 - New Scientist - Windows Internet Explorer
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Duncan Graham-Rowe
Robots can make more cash than people when they trade commodities, according to Jeffrey Kephart at IBM's research centre in Hawthorne, New York.
Kephart says his team's findings could have a much greater impact than the famous victory of IBM's Deep Blue supercomputer over chess supremo Gary Kasparov. "The impact might be measured in billions of dollars annually," he says.
A commodities trader buys and sells goods, which are usually agricultural or mineral-based, like pork bellies or gold. Their aim is to buy low and sell high. While robotic trading agents have been entered in competitions before, they had never competed against people.
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To appear in *The Proceedings of the International Joint Conferences on Artificial Intelligence (IJCAI)*, Seattle, USA (August, 2001).

Agent-Human Interactions in the Continuous Double Auction

Rajarshi Das, James E. Hanson, Jeffrey O. Kephart and Gerald Tesauro
Institute for Advanced Commerce
IBM T.J. Watson Research Center
30 Saw Mill River Road, Hawthorne, NY 10532, USA

Abstract

The Continuous Double Auction (CDA) is the dominant market institution for real-world trading of equities, commodities, derivatives, etc. We describe a series of laboratory experiments that, for the first time, allow human subjects to interact with software bidding agents in a CDA. Our bidding agents use strategies based on extensions of the Gjerstad-Dickhaut and Zero-Intelligence-Plus algorithms. We find that agents consistently obtain significantly larger gains from trade than their human counterparts. This was unexpected because both humans and agents have approached theoretically perfect efficiency in prior all-human or all-agent CDA experiments. Another unexpected finding is persistent far-from-equilibrium trading, in sharp contrast to the robust convergence observed in previous all-human or all-agent experiments. We consider possible explanations for our empirical findings, and speculate on the implications for fu-

to humans or other agents [Kephart *et al.*, 2000]. (Throughout this paper we use the term "agent" to refer exclusively to a software agent, as opposed to a human economic agent.) Whether their main business is ontology translation, matchmaking, network service provision, or anything else, these agents will charge a fee for their goods or services, and will negotiate both as buyers and as sellers with other agents. Thus they will have to be economically intelligent, capable of making effective decisions about pricing, purchasing, or bidding.

If this vision is to be realized, then it must be demonstrated that, within their domain of application, agents can attain a level of economic performance that rivals or exceeds that of humans on average, without introducing undue risk. Otherwise, people would not entrust agents with making economic decisions.

The purpose of this paper is to provide such a demonstration. Through a series of controlled laboratory experiments in which humans and agents participate simultaneously in a realistic auction (a Continuous Double Auction, or CDA), we show that software agents can consistently ob-

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Agent-Human Interactions in the Continuous Double Auction

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These and other features make game-theoretic analysis of the CDA intractable. Another notable difference is that the successful demonstration of machine superiority in the CDA and other common auctions could have a much more direct and powerful financial impact—one that might be measured in billions of dollars annually.

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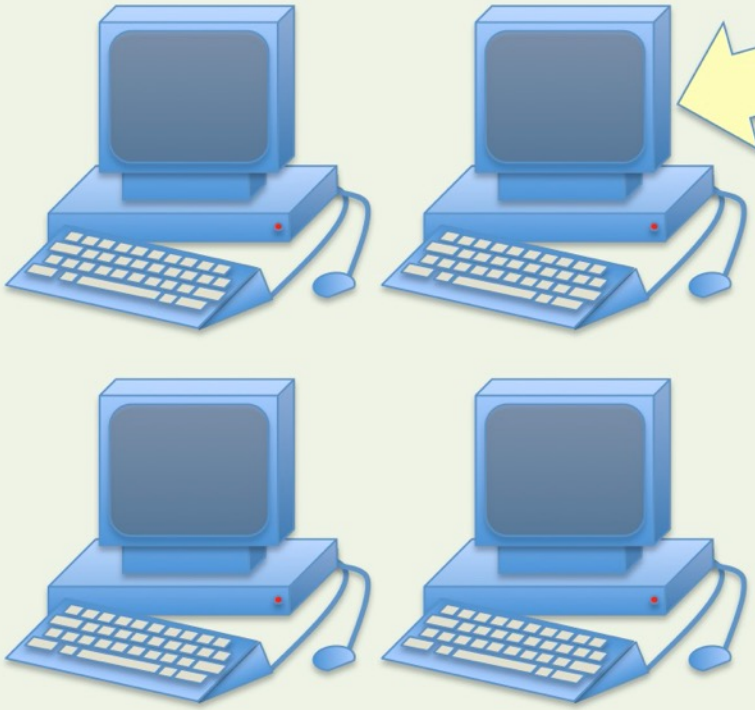

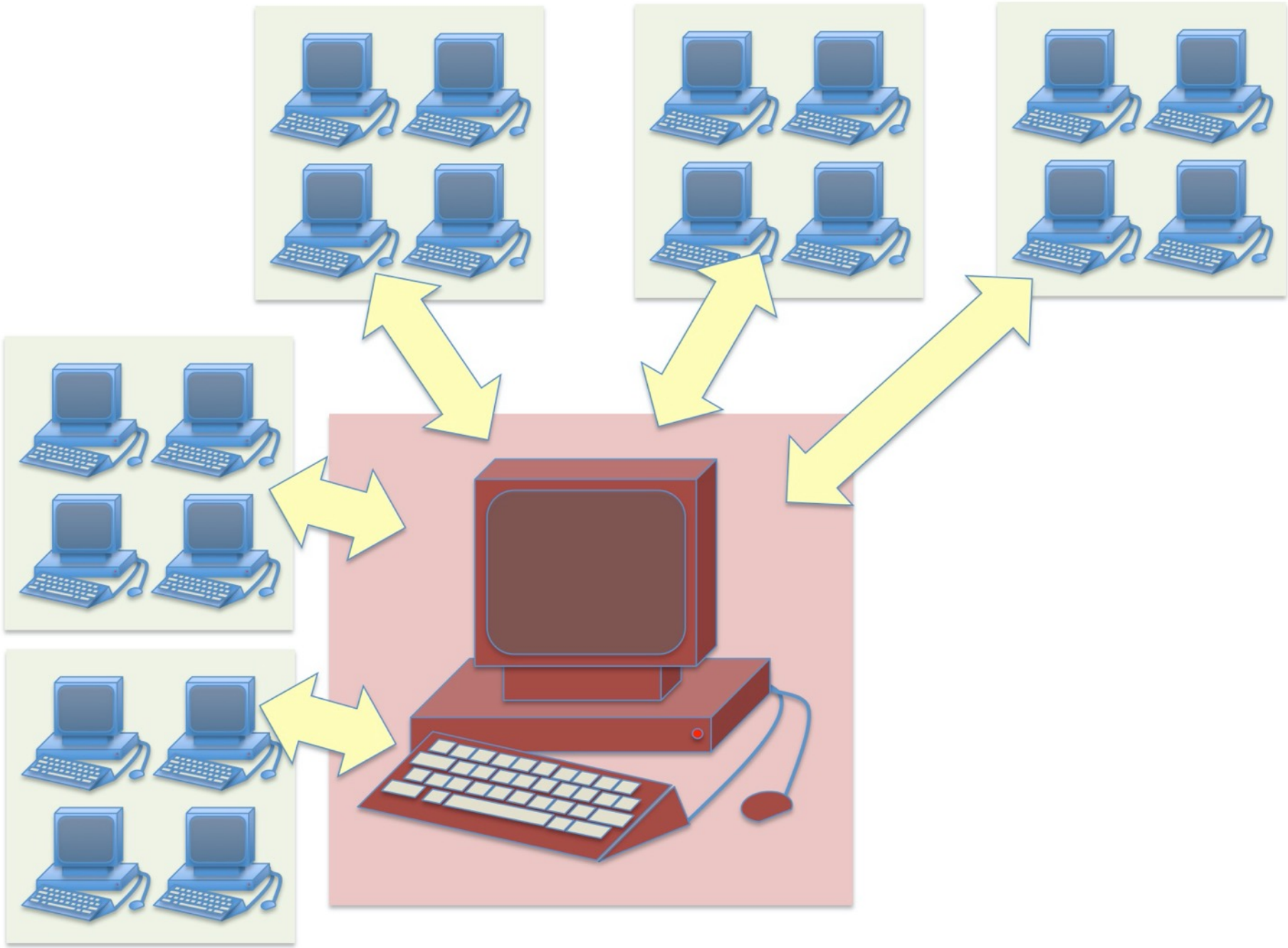

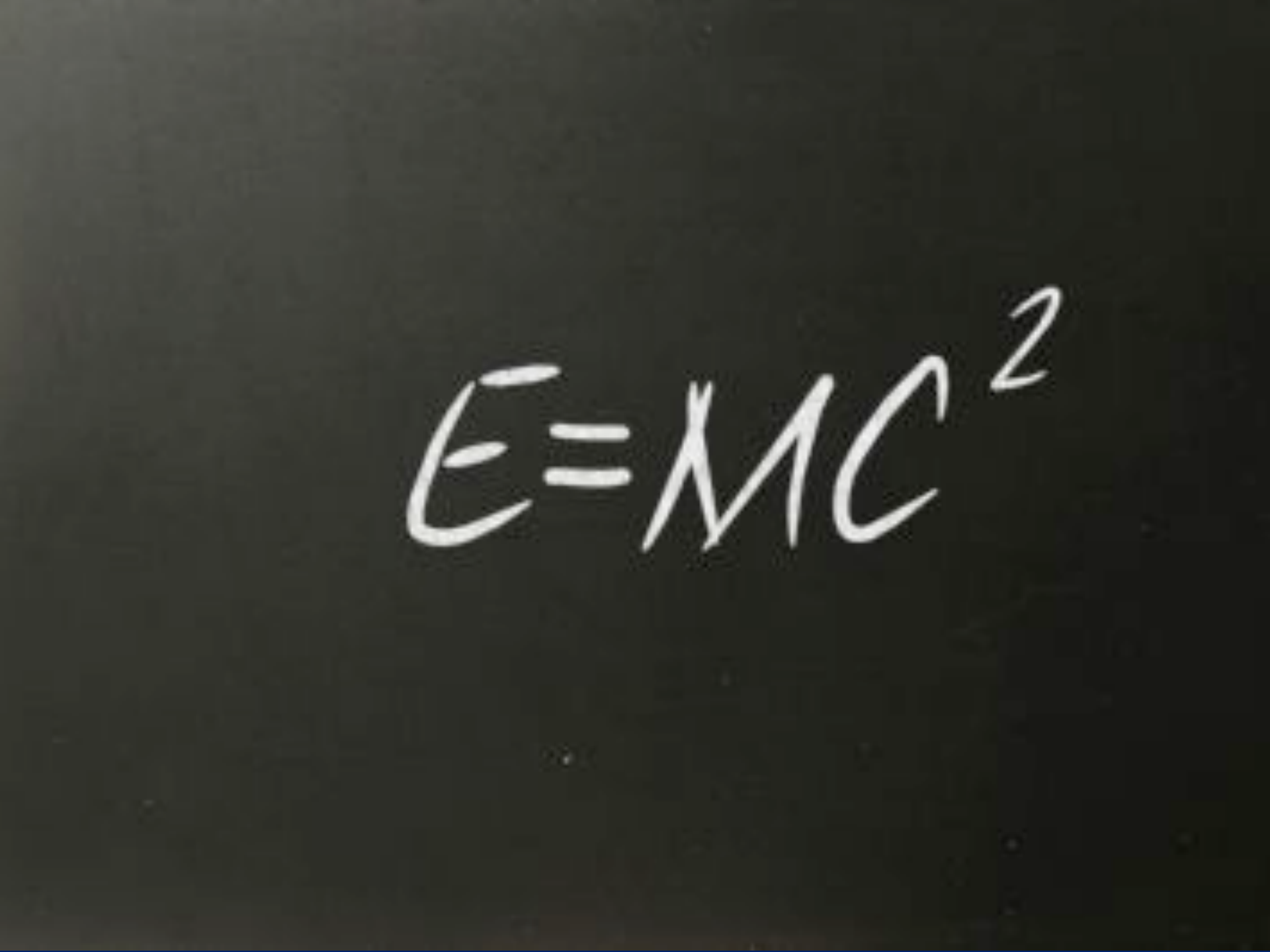
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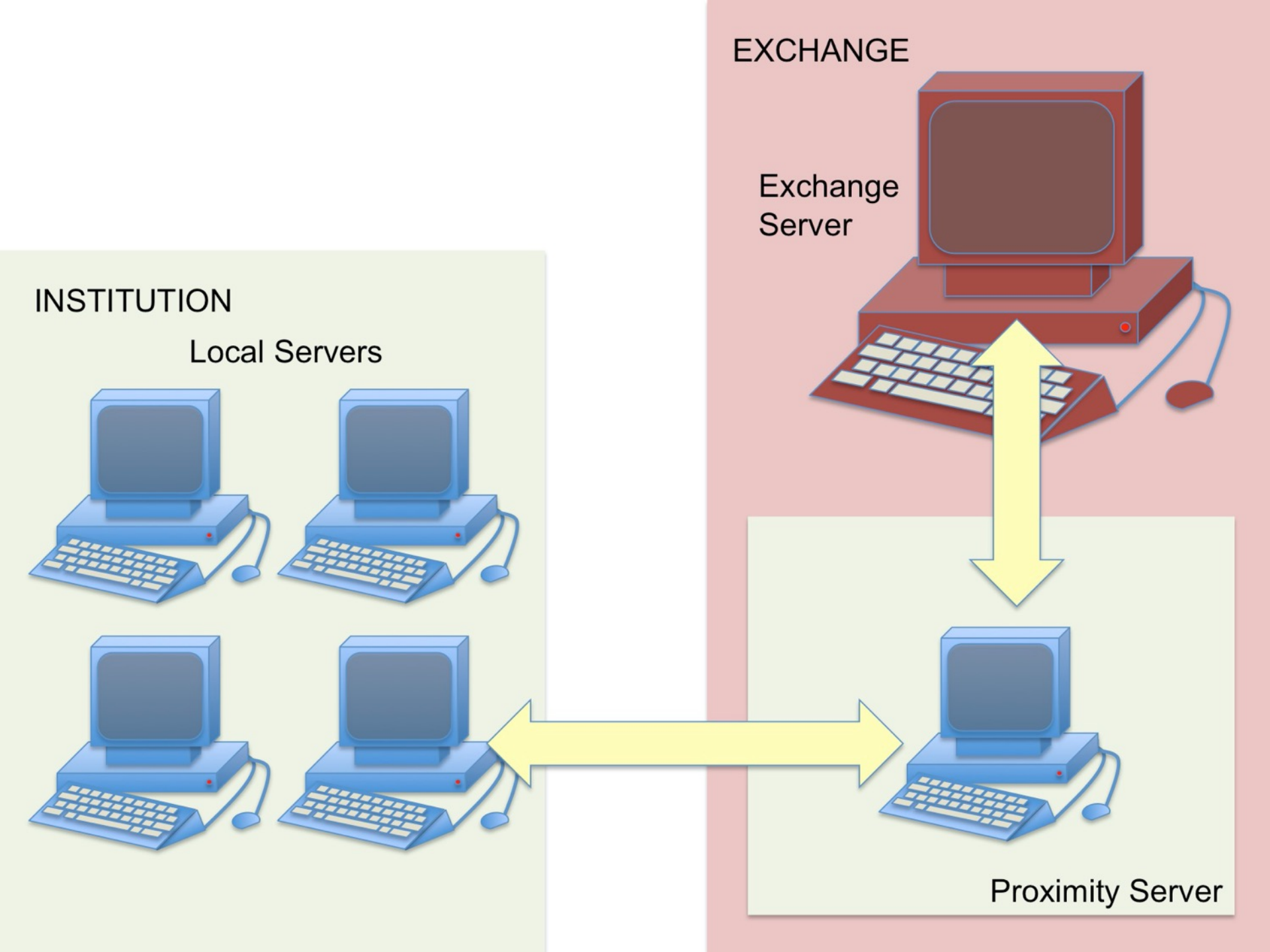
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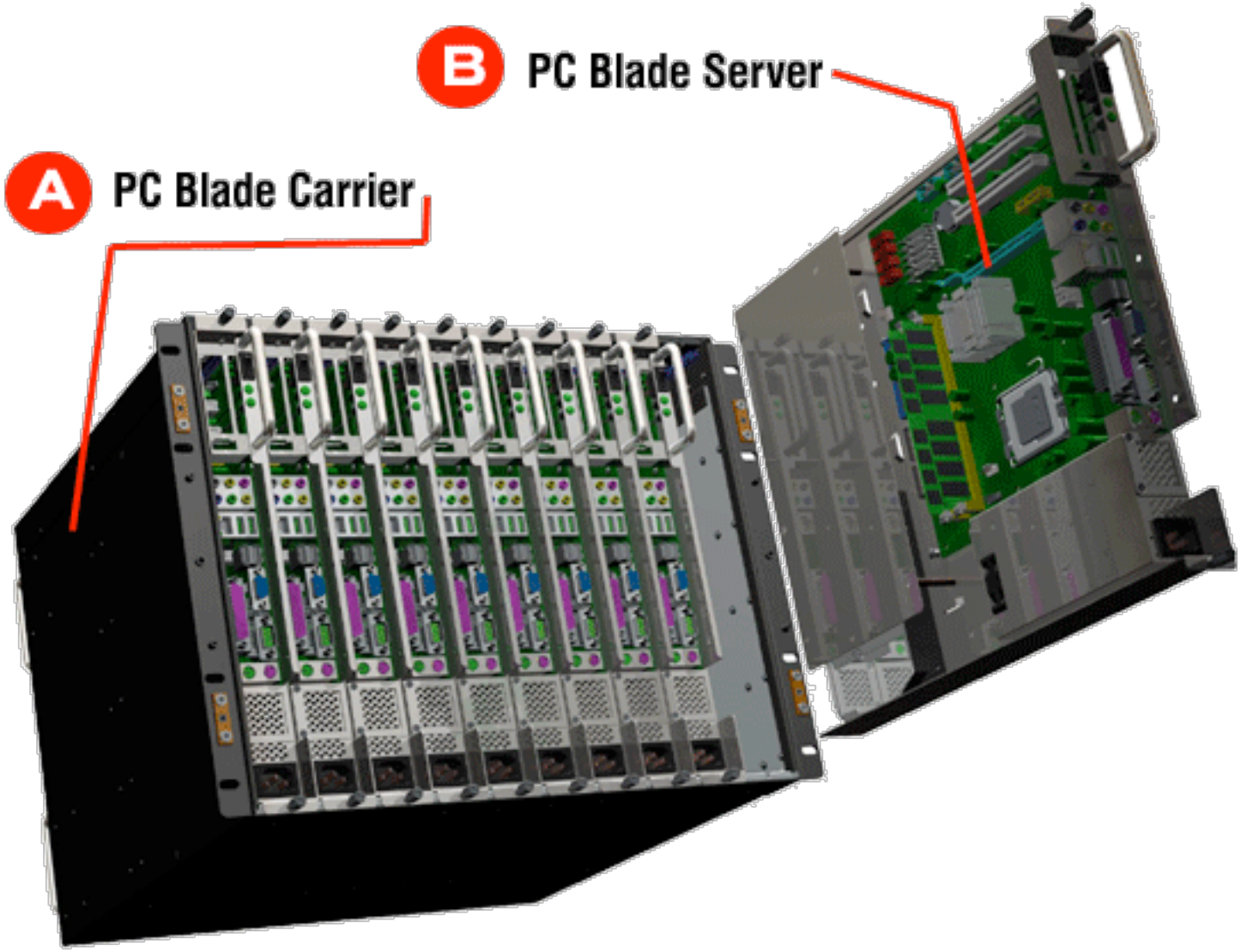
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PC Blade Server
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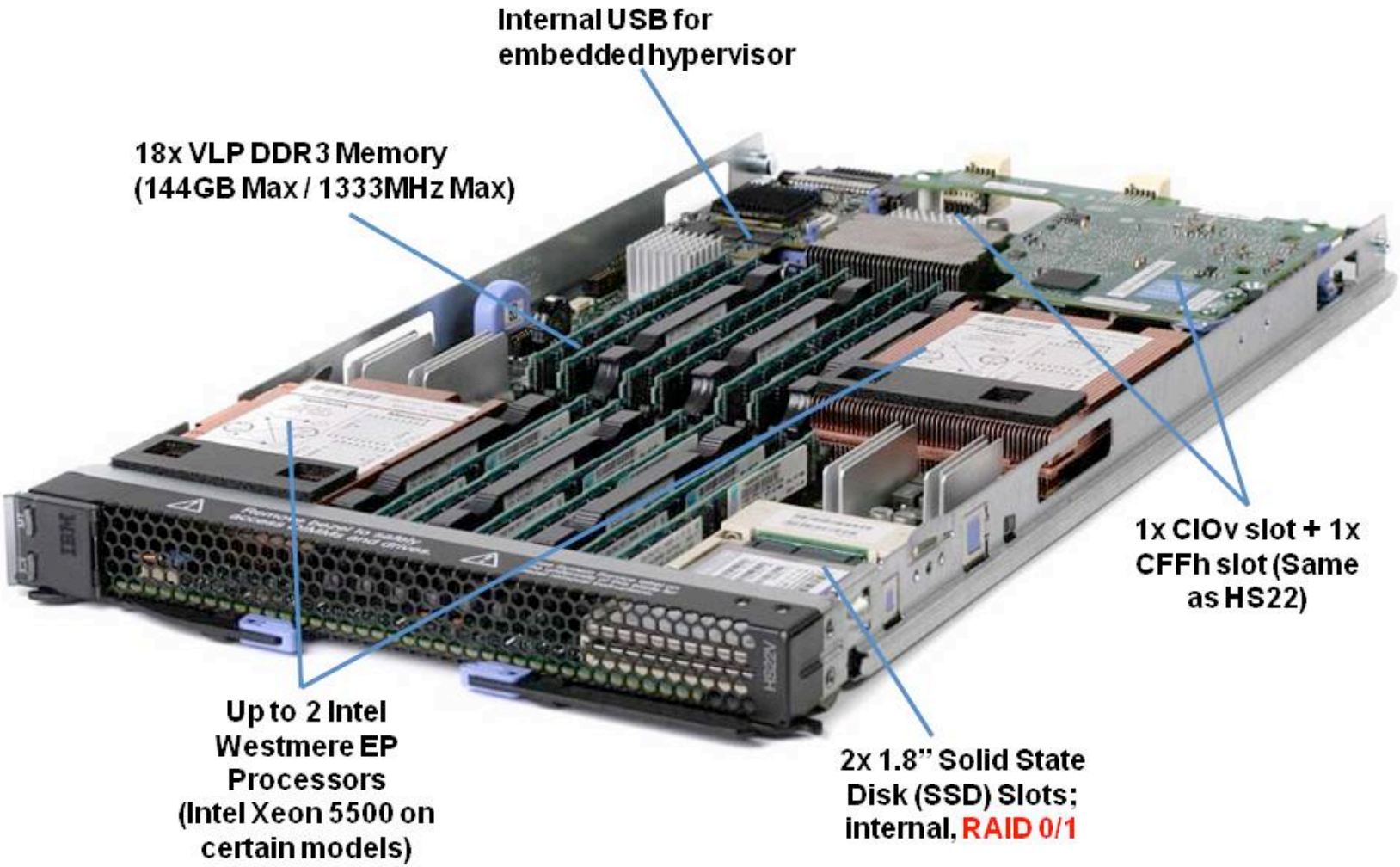
Internal USB for embedded hypervisor
18x VLP DDR3 Memory (144GB Max / 1333MHz Max)
1x CIOv slot + 1x CFFh slot (Same as HS22)
Up to 2 Intel Westmere EP Processors (Intel Xeon 5500 on certain models)
2x 1.8" Solid State Disk (SSD) Slots: internal, RAID 0/1


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intel
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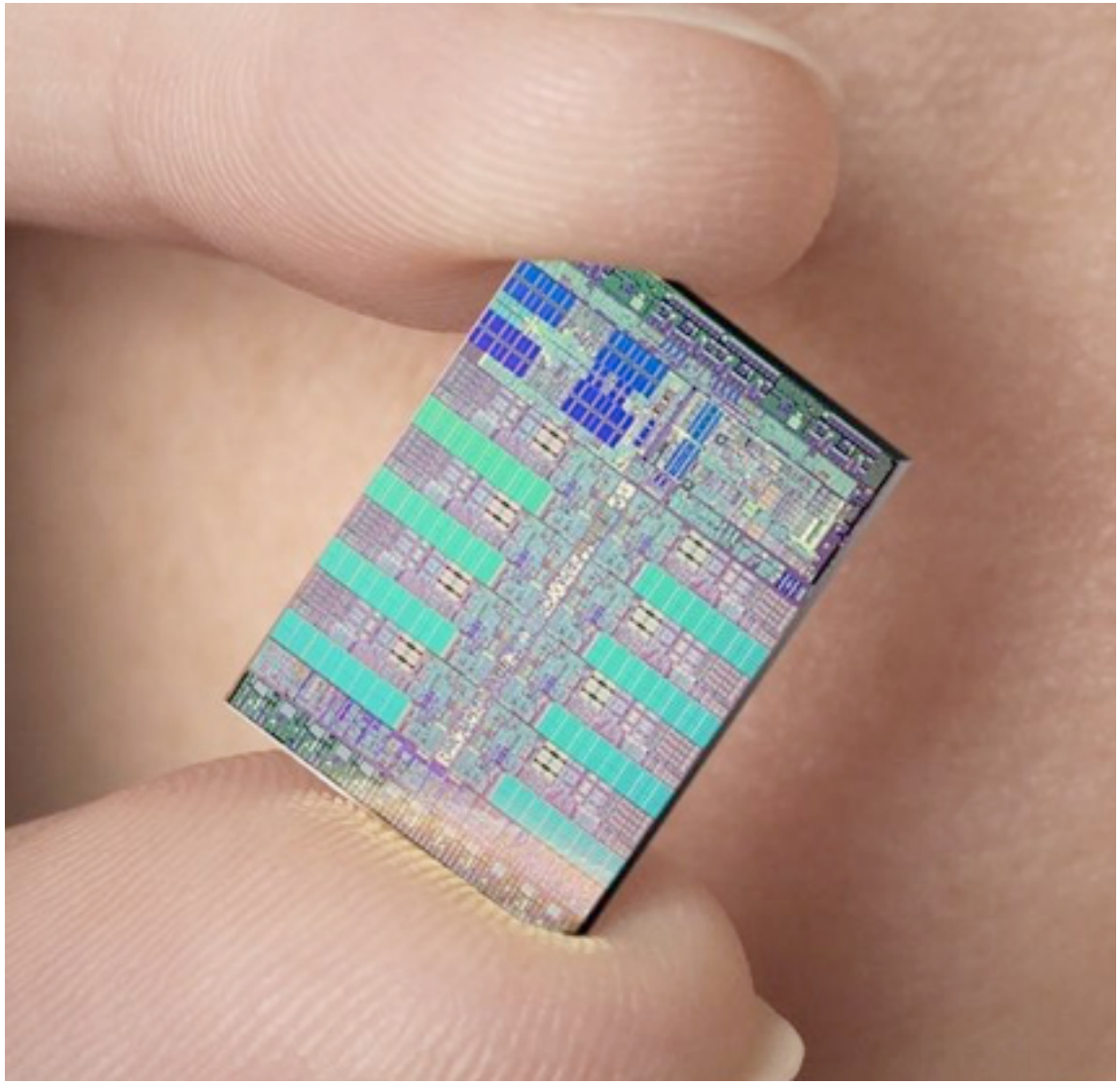
quad-core

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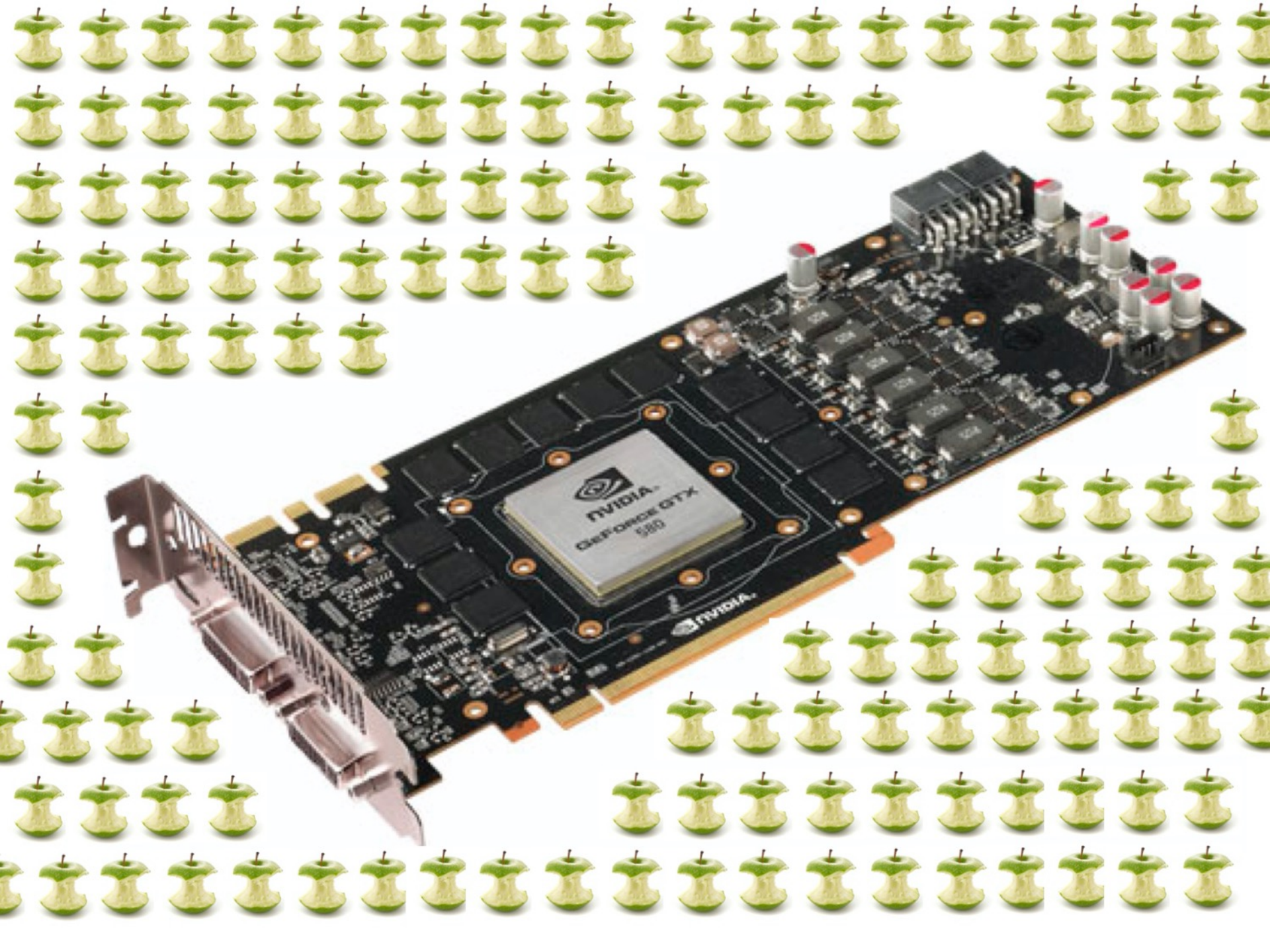
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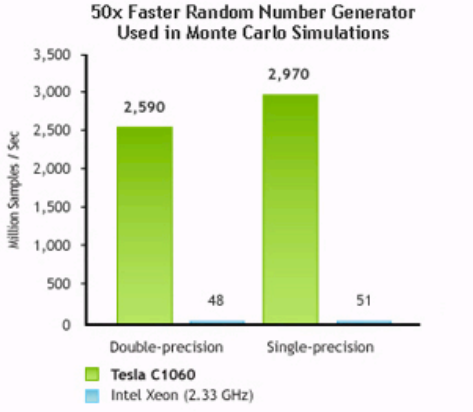
There is ongoing work in options pricing, risk analysis, and algorithmic trading using CUDA. This work along with some representative charts on random number generators and Monte-Carlo simulations are presented below.



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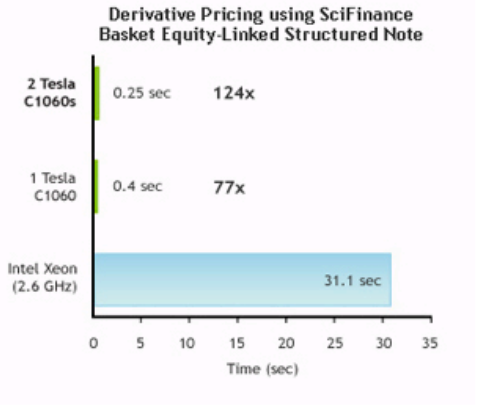

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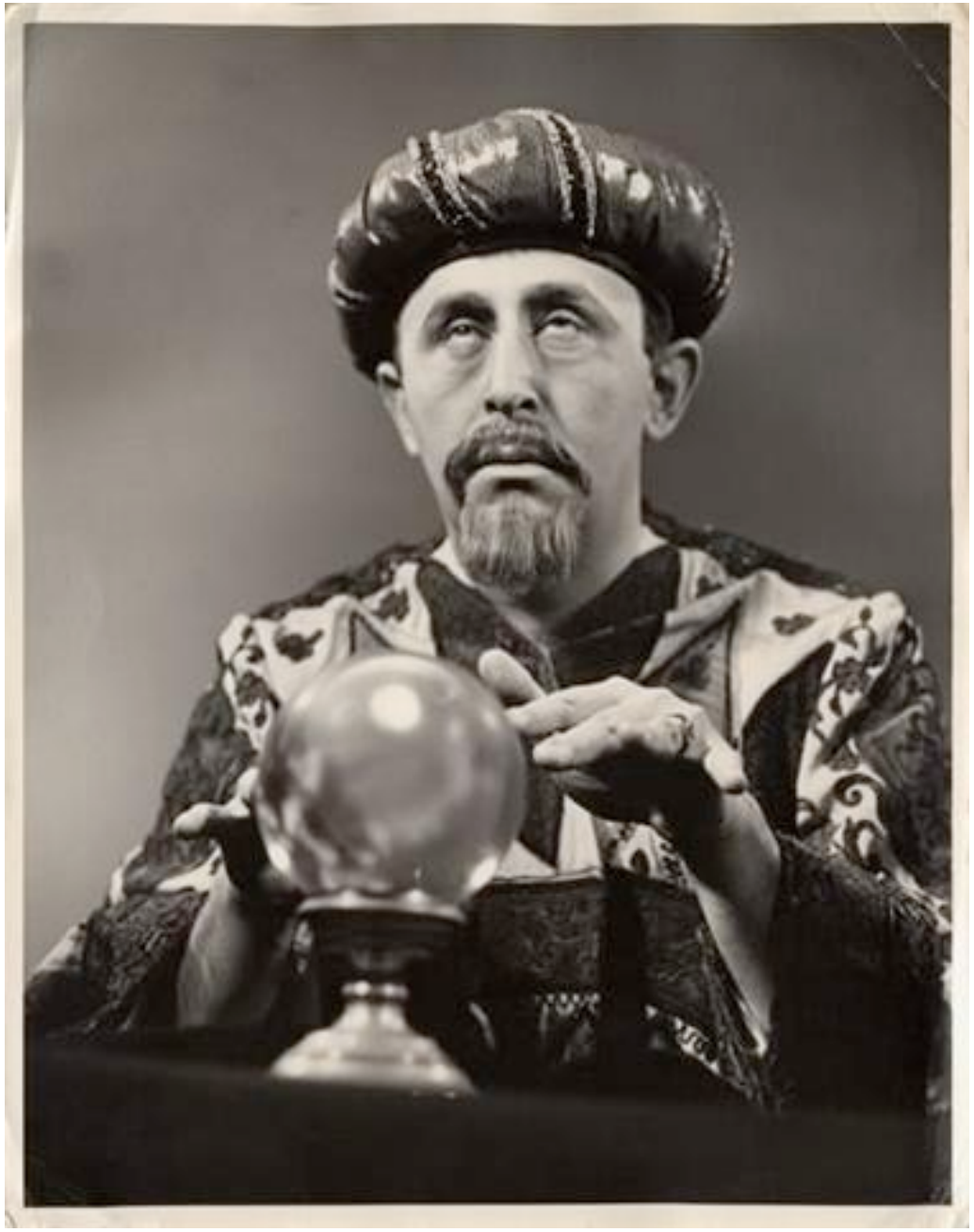
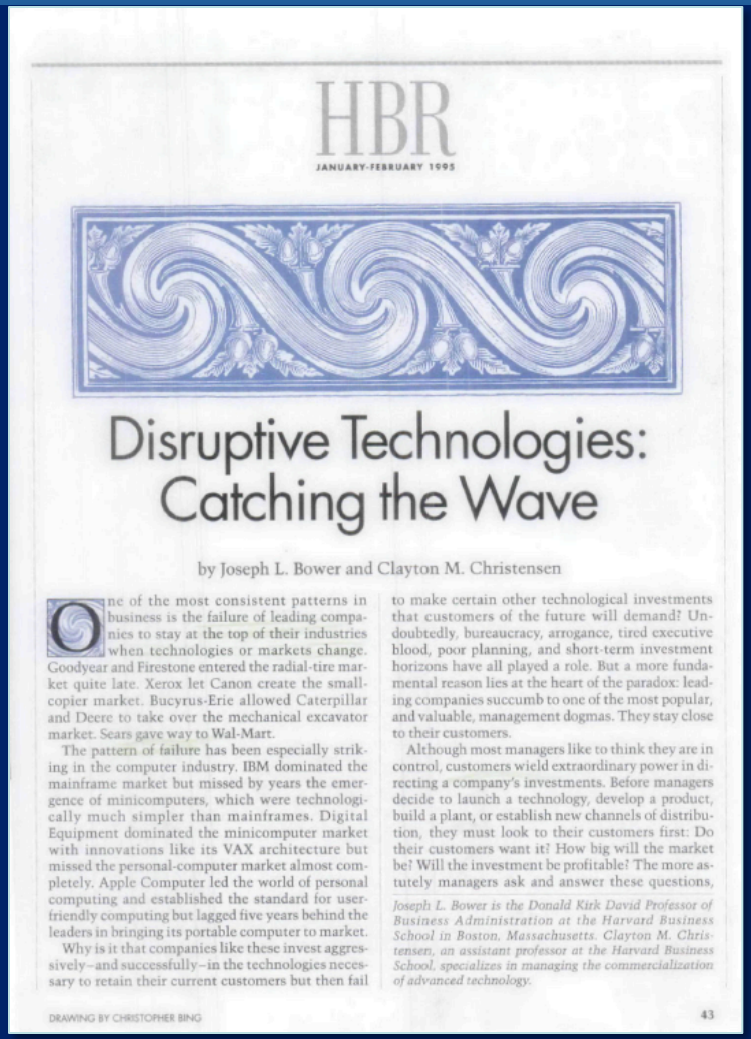


J. Bower & C. Christensen (1995) Disruptive Technologies: Catching the Wave. *Harvard Business Review,* Jan-Feb 1995, pp.43-53



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JANUARY-FEBRUARY 1995

Disruptive Technologies: Catching the Wave

by Joseph L. Bower and Clayton M. Christensen

One of the most consistent patterns in business is the failure of leading companies to stay at the top of their industries when technologies or markets change. Goodyear and Firestone entered the radial-tire market quite late. Xerox let Canon create the small-copier market. Bucyrus-Erie allowed Caterpillar and Deere to take over the mechanical excavator market. Sears gave way to Wal-Mart.

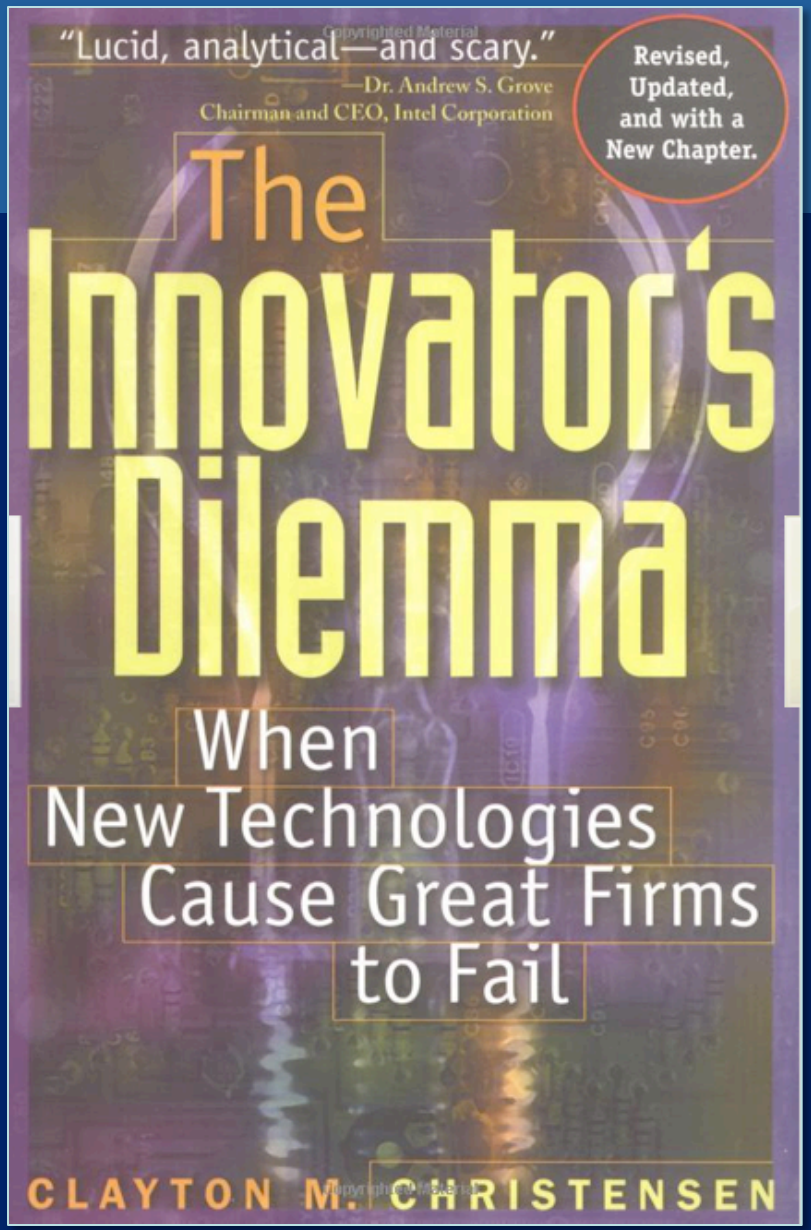
The pattern of failure has been especially striking in the computer industry. IBM dominated the mainframe market but missed by years the emergence of minicomputers, which were technologically much simpler than mainframes. Digital Equipment dominated the minicomputer market with innovations like its VAX architecture but missed the personal-computer market almost completely. Apple Computer led the world of personal computing and established the standard for user-friendly computing but lagged five years behind the leaders in bringing its portable computer to market.

Why is it that companies like these invest aggressively–and successfully–in the technologies necessary to retain their current customers but then fail to make certain other technological investments that customers of the future will demand? Undoubtedly, bureaucracy, arrogance, tired executive blood, poor planning, and short-term investment horizons have all played a role. But a more fundamental reason lies at the heart of the paradox: leading companies succumb to one of the most popular, and valuable, management dogmas. They stay close to their customers.

Although most managers like to think they are in control, customers wield extraordinary power in directing a company's investments. Before managers decide to launch a technology, develop a product, build a plant, or establish new channels of distribution, they must look to their customers first: Do their customers want it? How big will the market be? Will the investment be profitable? The more astutely managers ask and answer these questions,

Joseph L. Bower is the Donald Kirk David Professor of Business Administration at the Harvard Business School in Boston, Massachusetts. Clayton M. Christensen, an assistant professor at the Harvard Business School, specializes in managing the commercialization of advanced technology.

DRAWING BY CHRISTOPHER BING


"Lucid, analytical—and scary."
—Dr. Andrew S. Grove
Chairman and CEO, Intel Corporation
Revised, Updated, and with a New Chapter.
The Innovator's Dilemma
When New Technologies Cause Great Firms to Fail
CLAYTON M. CHRISTENSEN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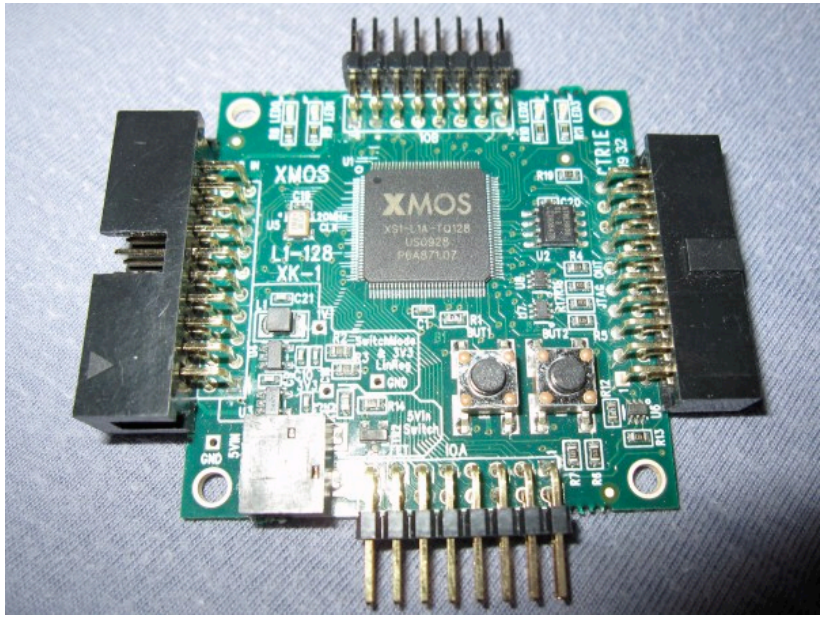
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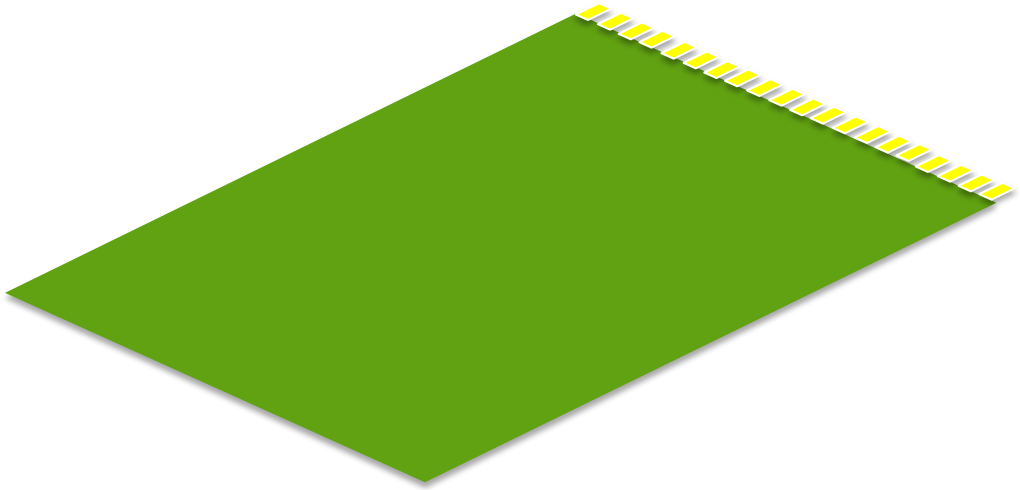

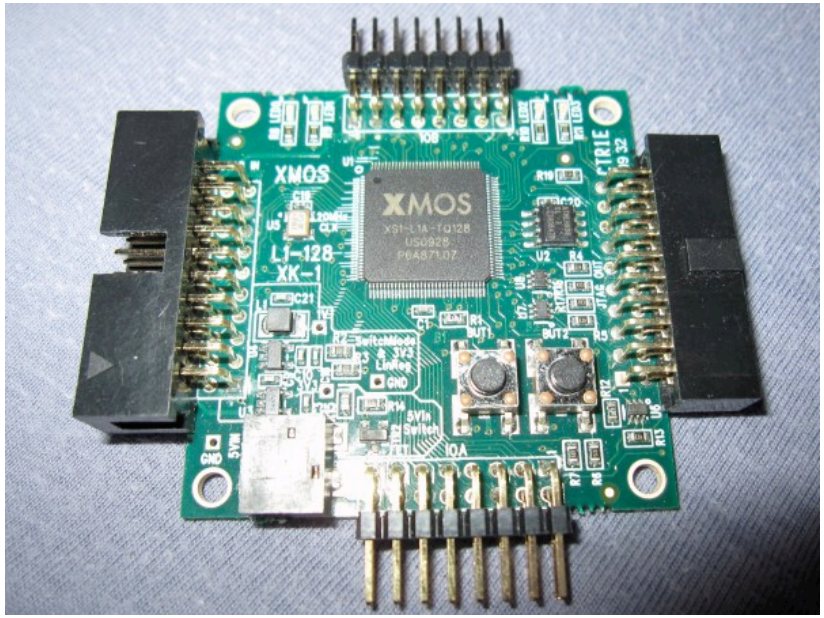
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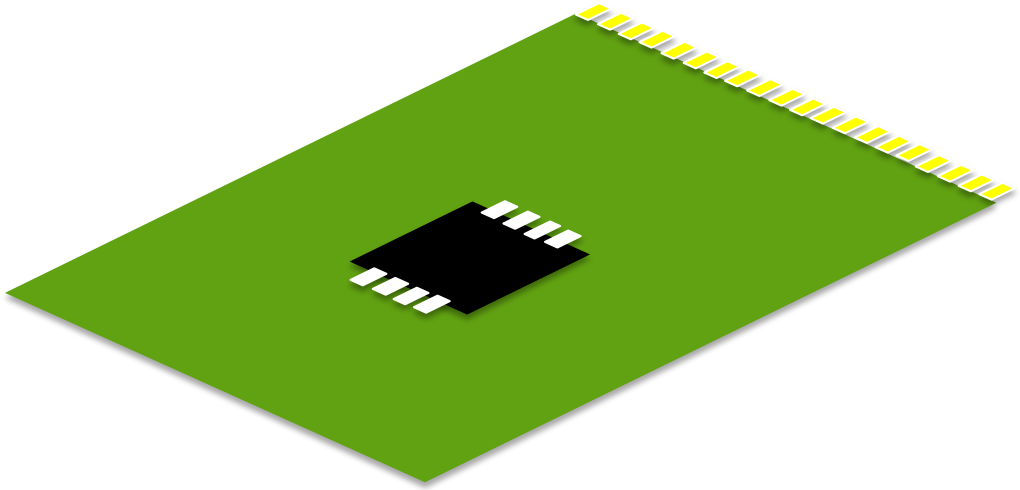


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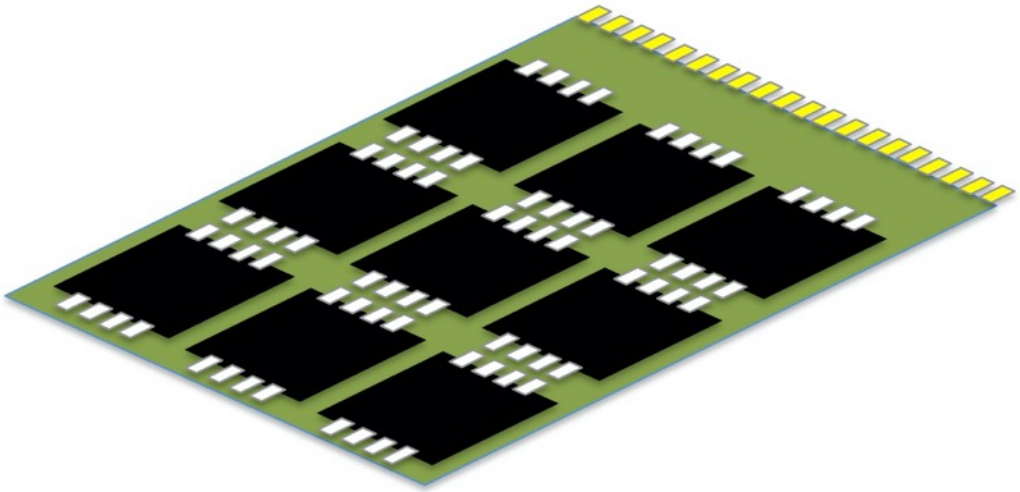


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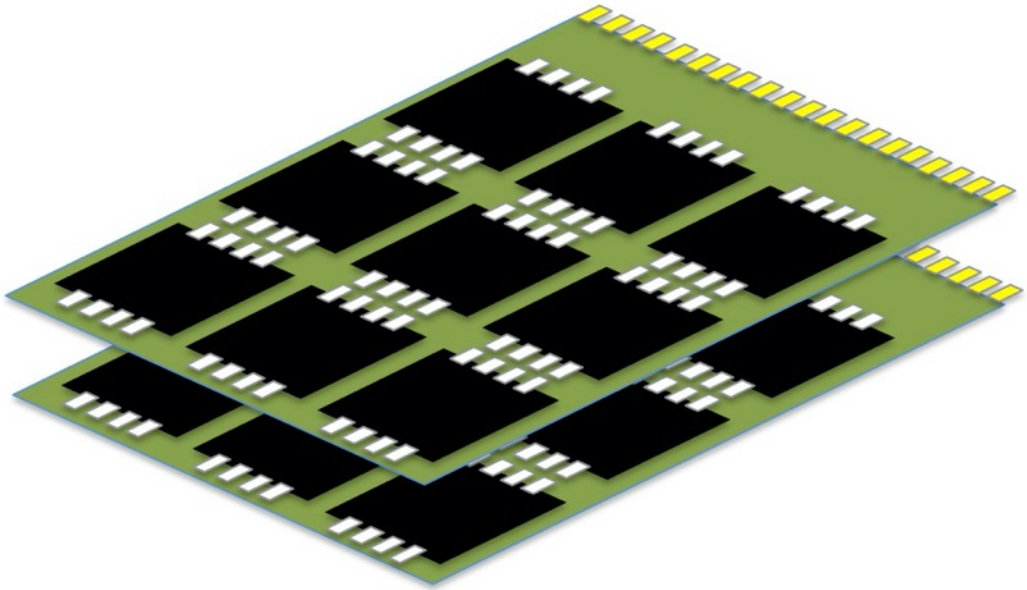


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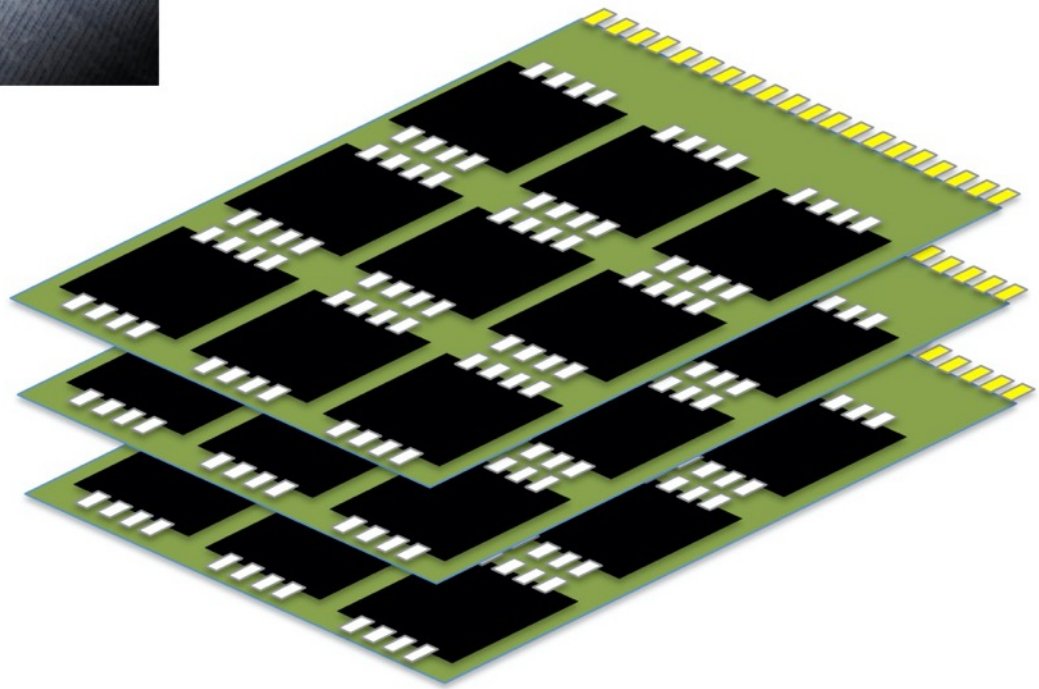

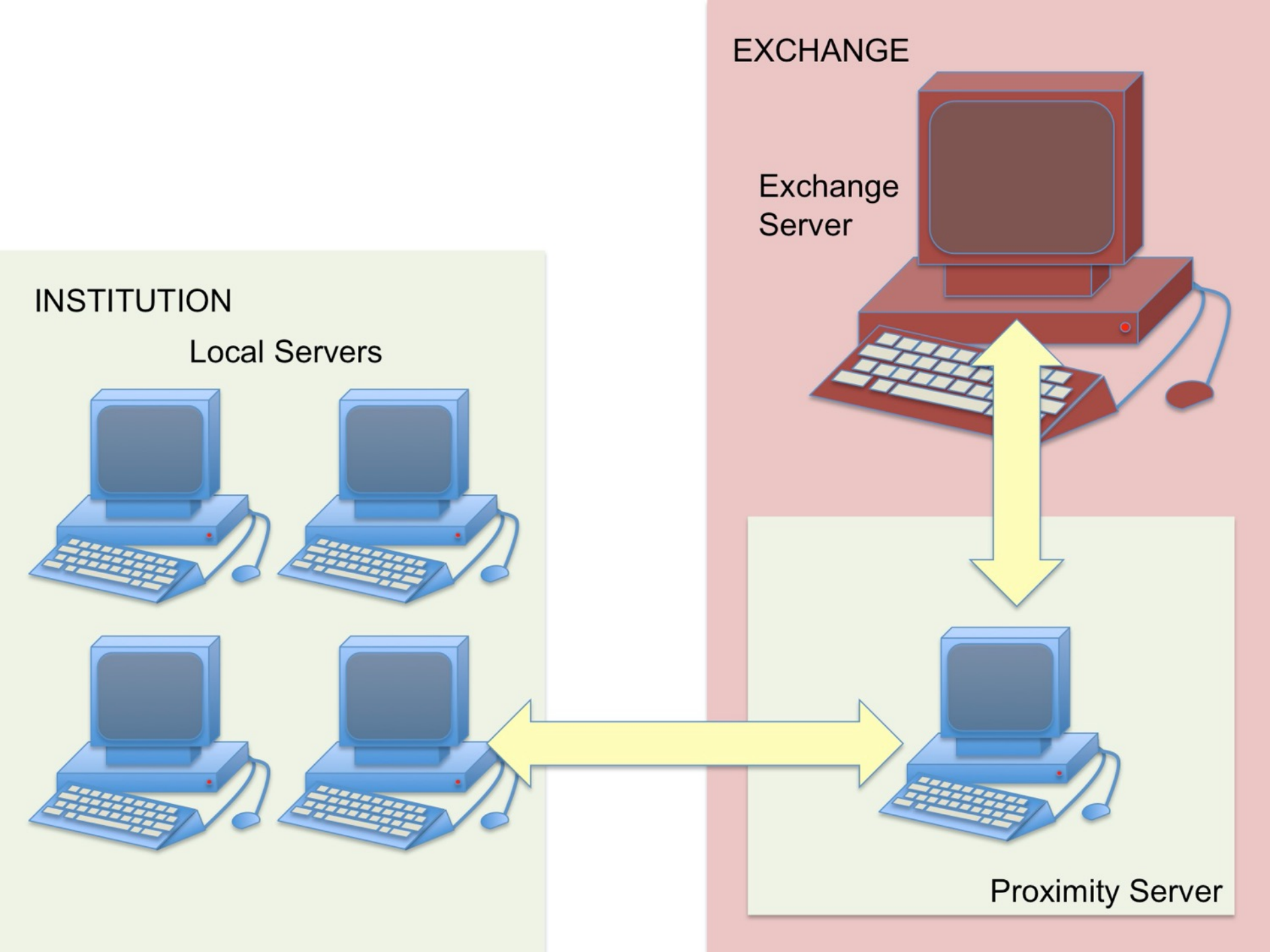
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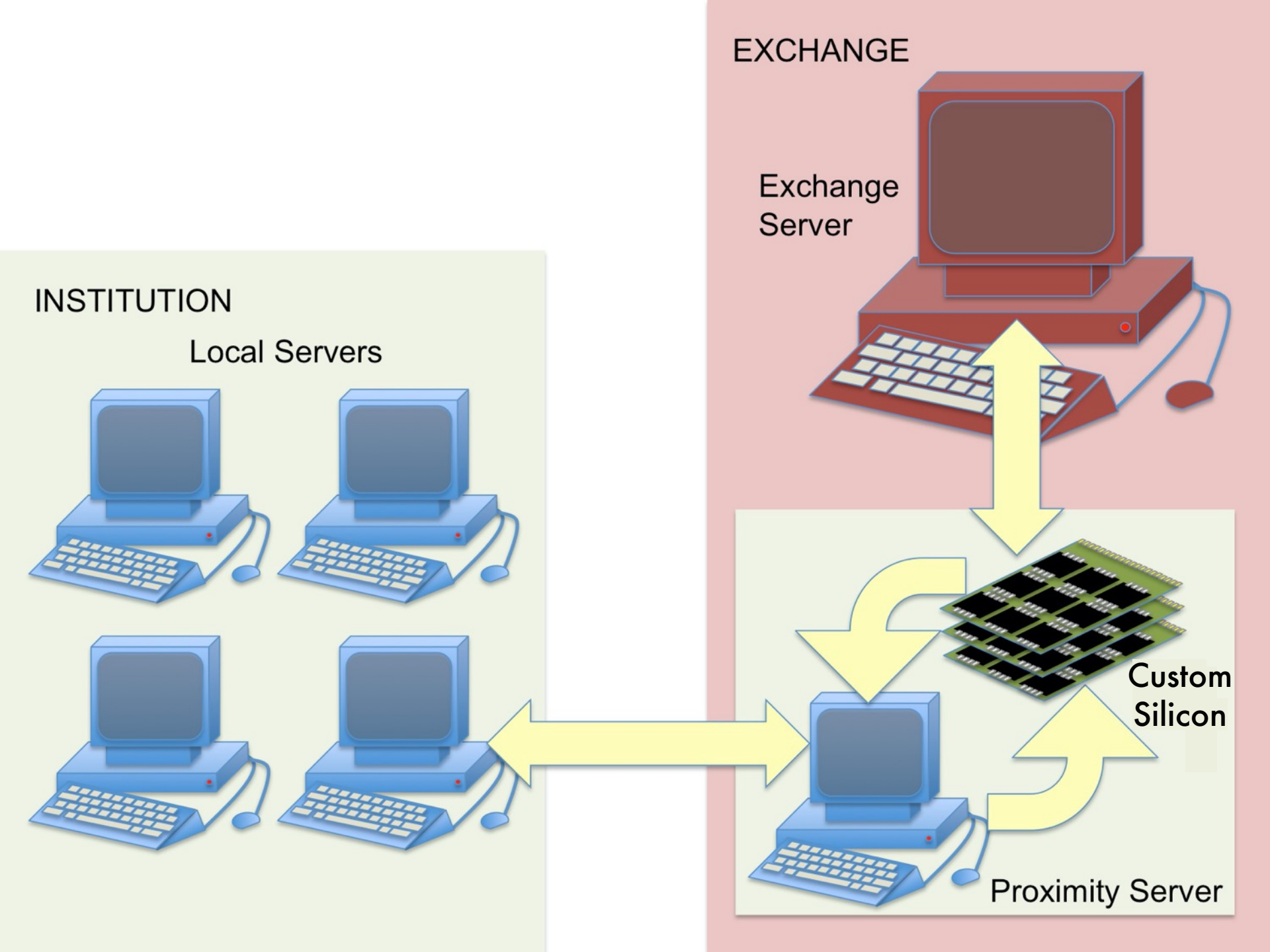
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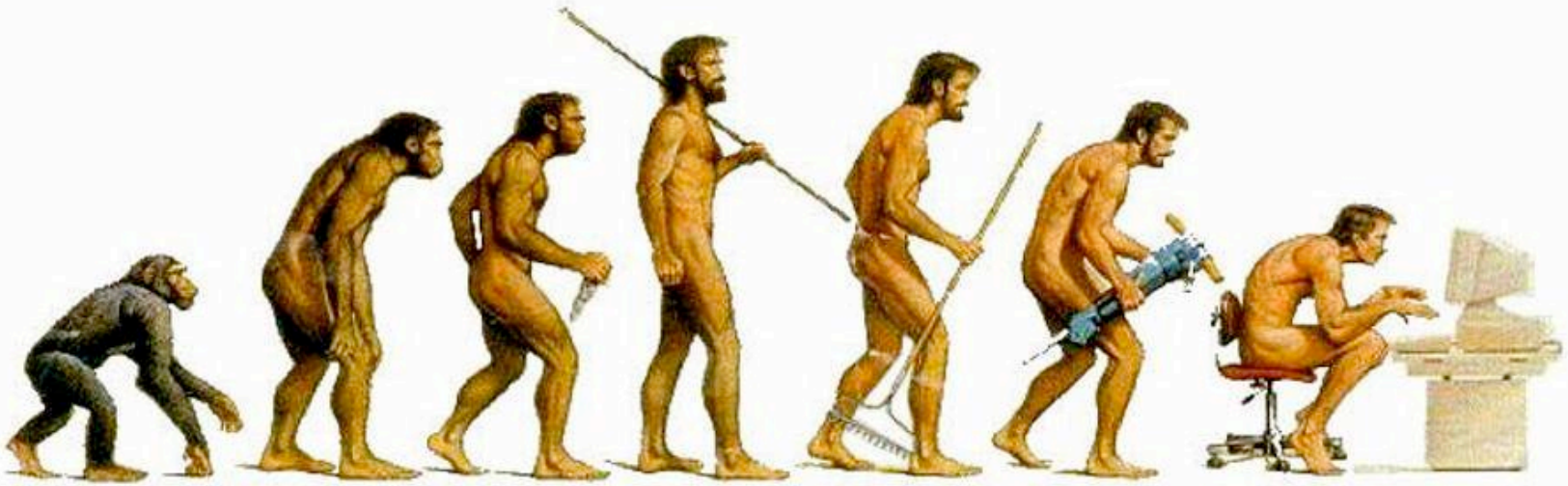


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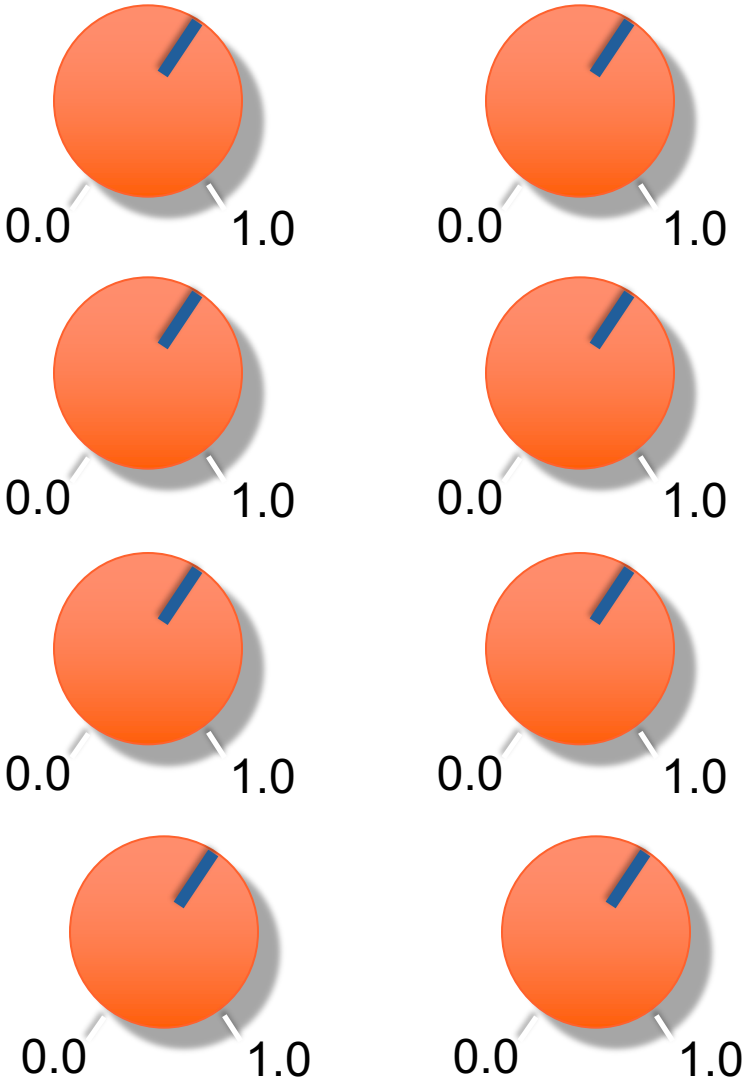
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The Economist Nov 30th, 2002

The future's still not clear

French national champion, by pushing Crédit Lyonnais into the arms of Crédit Agricole. But when Crédit Agricole refused to pay €44 per share ($44), the lowest price he was prepared to accept, he lost patience. BNP Paribas, the auction's winner, bid €2.2 billion, or €58 a share, for the stake, a 49% premium over the market value and a quarter more than the next-highest bid. Advisers to Mr Mer joked that BNP Paribas's bid document must have contained a typing error.

The losers from the sudden sale are Crédit Agricole and Crédit Lyonnais's chief executive, Jean Peyrelevade. Having refused to pay €44 a share in a private deal, Crédit Agricole reportedly offered that amount in the public auction, only to lose. Part of the problem is that Crédit Agricole's decentralised, mutual structure makes it difficult for its "barons" in the countryside to agree on anything quickly.

Mr Peyrelevade, who wants to keep his bank independent, has so far maintained what one French banker calls a Soviet balance of power between the bank's biggest shareholders. As soon as one looms too large, he courts another. This time though, he miscalculated, stringing out his negotiations with Crédit Agricole to a point where Mr Mer stopped believing that the two banks had any real desire to merge.

Mr Peyrelevade now faces the likelihood that BNP Paribas or, just possibly, Société Générale, will bid for the whole of Crédit Lyonnais once a shareholder pact designed to protect the bank from takeover ends at the end of June 2003. Either bank would fold Crédit Lyonnais's wholesale banking business into their own operations. To avoid that, Mr Peyrelevade may have to run back to Crédit Agricole, which already owns 10.5%, with more conciliatory words than those of recent months.

For now, BNP Paribas denies that it intends to buy the whole of Crédit Lyonnais. But Michel Pebereau, its chairman, is unlikely to have paid such a high price for the stake unless he has designs on the whole. With Crédit Lyonnais in its grip, BNP Paribas would increase its share of the French retail banking market from 8% to 14%.

One likely opponent of any such move would be AGF, the French insurance subsidiary of Germany's Allianz, which owns about 10% of Crédit Lyonnais. French bankers are preparing themselves for a battle to echo the one that Banque Nationale de Paris (BNP), Paribas and Société Générale waged in 1999, which ended with BNP wresting control of Paribas. As one banker says, "BNP Paribas is usually the winner." ■

Financial markets

Robo-traders

Computerised trading agents may help humans build better markets

THANKS to slumping markets, investment banks are shedding many of their highly-paid traders. When markets recover, the banks might be tempted to replace them with rather cheaper talent. One alternative has been around for a while but has yet to catch on: autonomous trading agents—computers programmed to act like the human version without such pesky costs as holidays, lunch breaks or bonuses. Program trading has, of course, been done before; some blamed the 1987 stockmarket crash on computers instructed with simple decision-making rules. But robots can be smarter than that.

Dave Cliff, a researcher at Hewlett-Packard Laboratories in Bristol, England, has been creating trading robots for seven years. In computer simulations he lets them evolve "genetically", and so allows them to adapt and fit models of real-world financial markets. His experiments have suggested that a redesign of some markets could lead to greater efficiency.

Last year, a research group at IBM showed that Mr Cliff's artificial traders could consistently beat the human variety, in various kinds of market. Nearly all take the shape of an auction. One well-known type is the English auction, familiar to patrons of the saleserooms of Christie's and Sotheby's, where sellers keep mum on their offer price, and buyers increase their bids by stages until only one remains.

At the other extreme is the Dutch auction, familiar to 17th-century tulip-traders in the Netherlands as well as to bidders for American Treasury bonds. Here, buyers remain silent, and a seller reduces his price until it is accepted. Most markets for shares, commodities, foreign exchange and derivatives are a hybrid of these two types: buyers and sellers can announce their bid or offer prices at any time, and deals are constantly being closed, a so-called "continuous double auction".

Mr Cliff's novel idea was to apply his evolutionary computer programs to marketplaces themselves. Why not, he thought, try and see what types of auction would let traders converge most quickly towards an equilibrium price? The results were surprising. In his models, auctions that let buyers and sellers bid at any time—like most of today's financial exchanges—were less efficient than ones that required relatively more bids from either buyers or sellers.

These "evolved auctions" also withstood big market shocks, such as crashes and panics, better than today's real-world versions. Mr Cliff's most recent results, which will be presented in Sydney, Australia, on December 10th, show that the best type of auction for any market depends crucially on even slight differences in the number of buyers and sellers.

Bank of America has been investigating these new auctions, along with robotic traders, for possible use in electronic exchanges. The hope is that today's financial auctions and online marketplaces might work better by becoming more like their English and Dutch forebears. But what to call such multi-ethnic hybrids? Here's introducing the "Cliffhanger". ■


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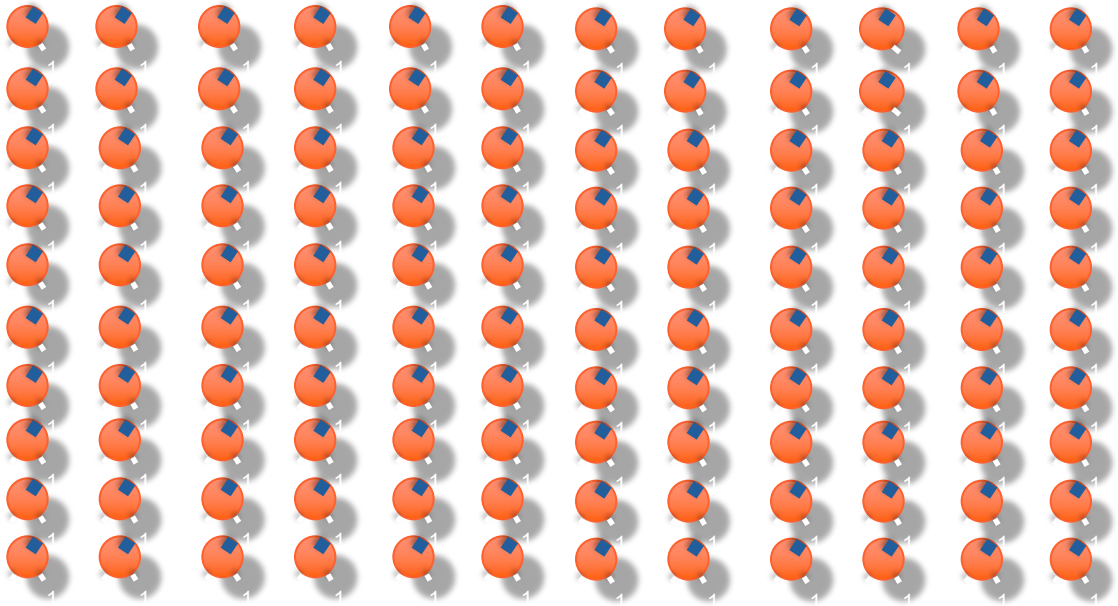

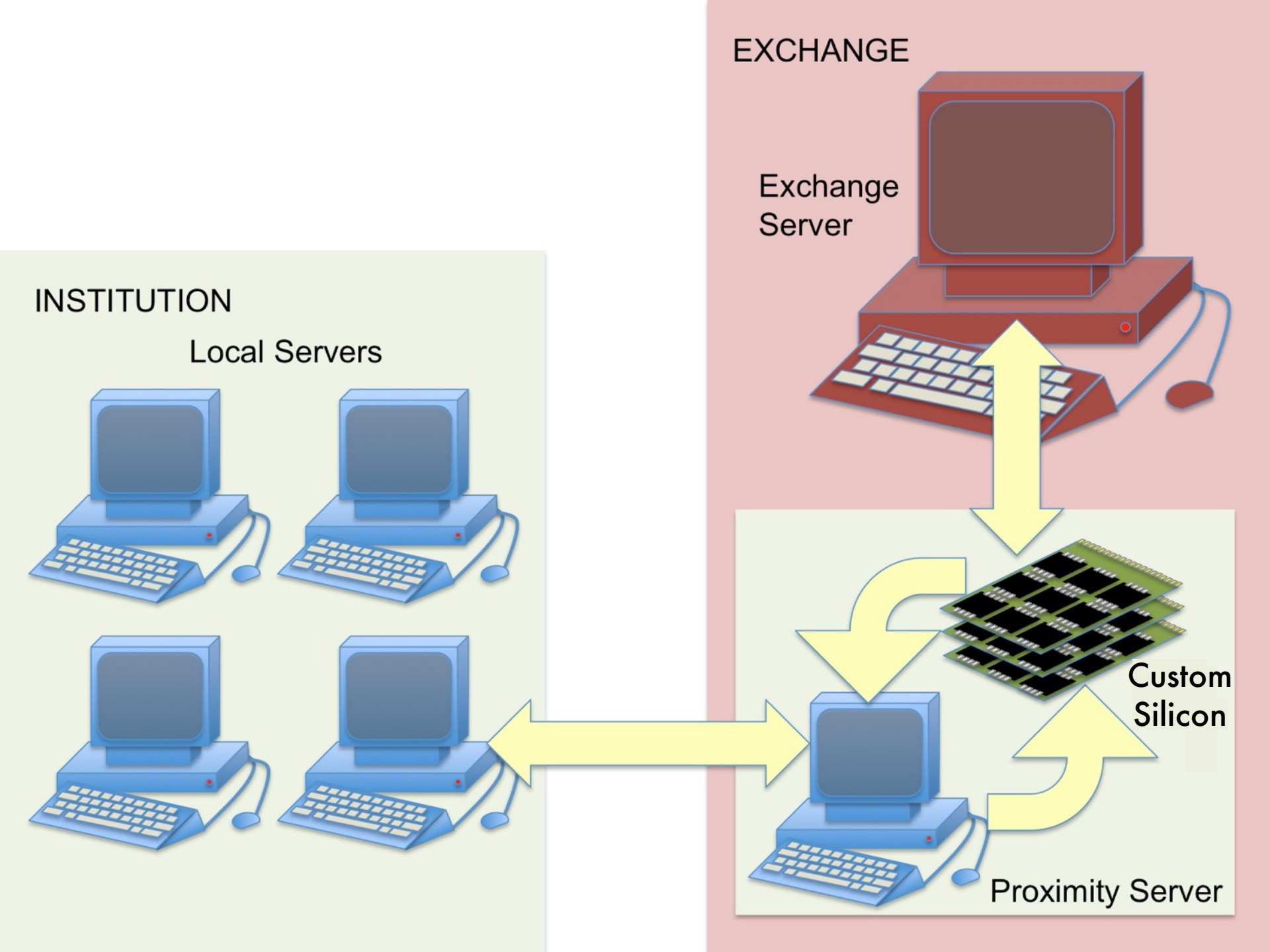
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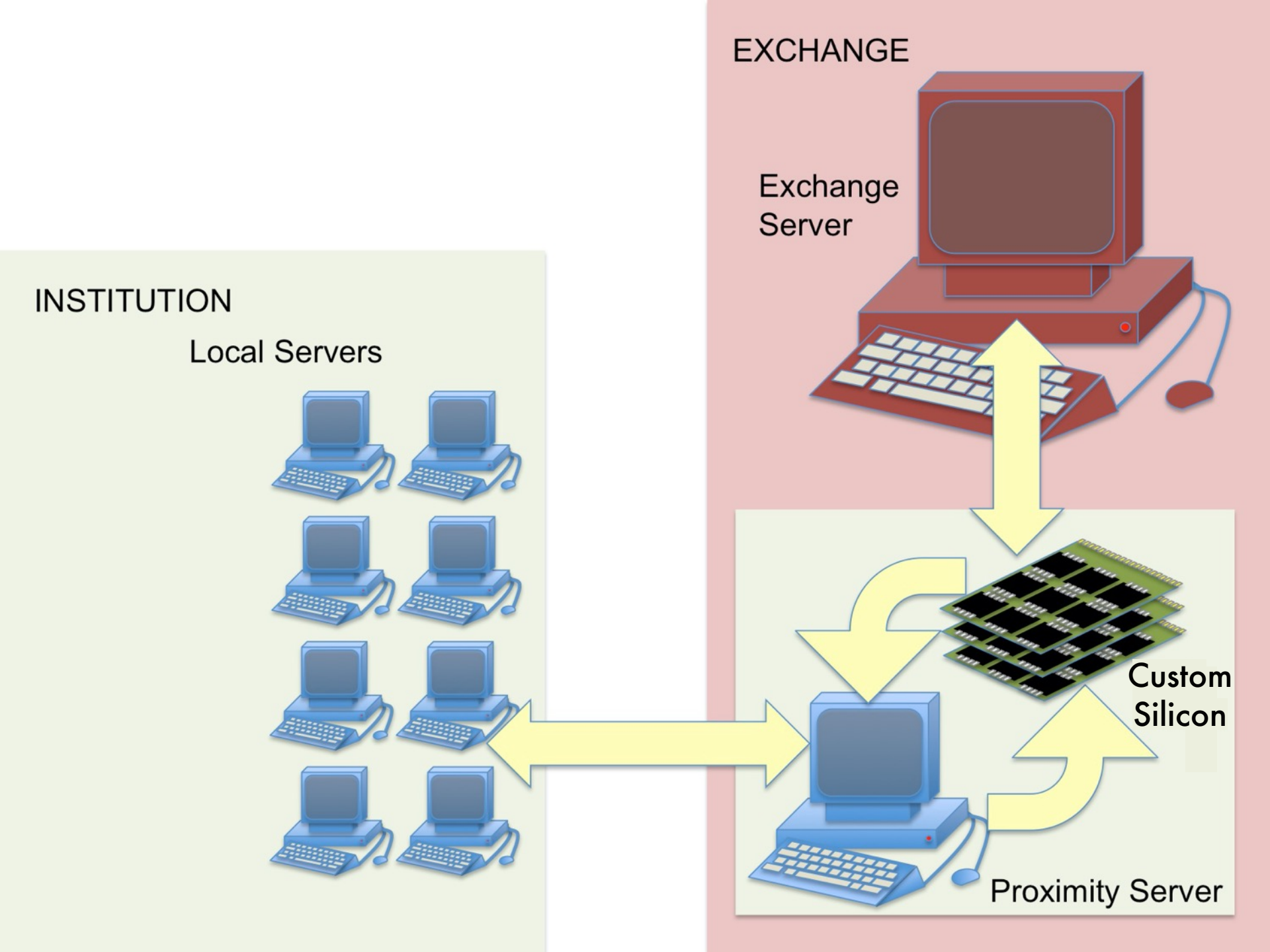
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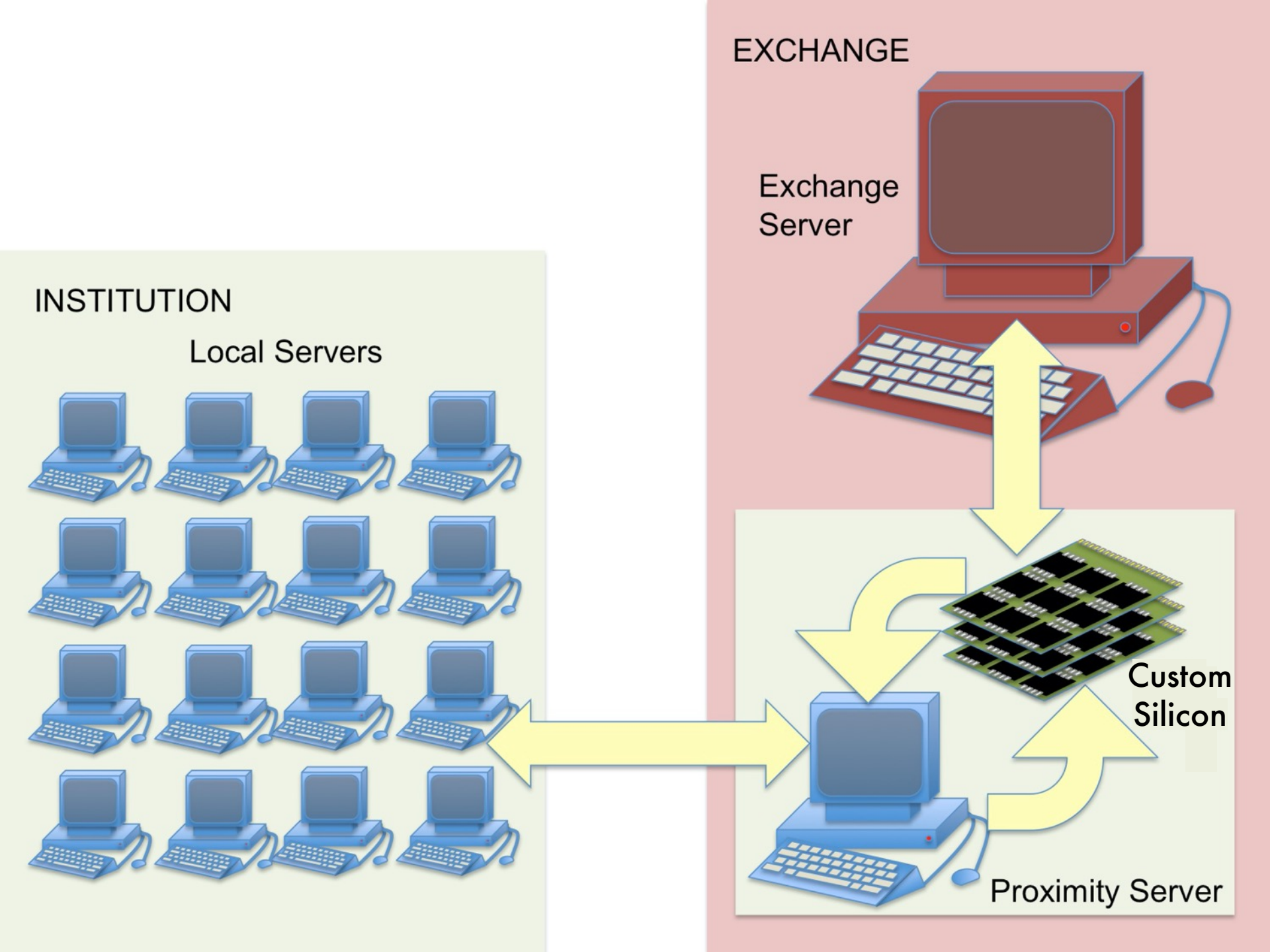
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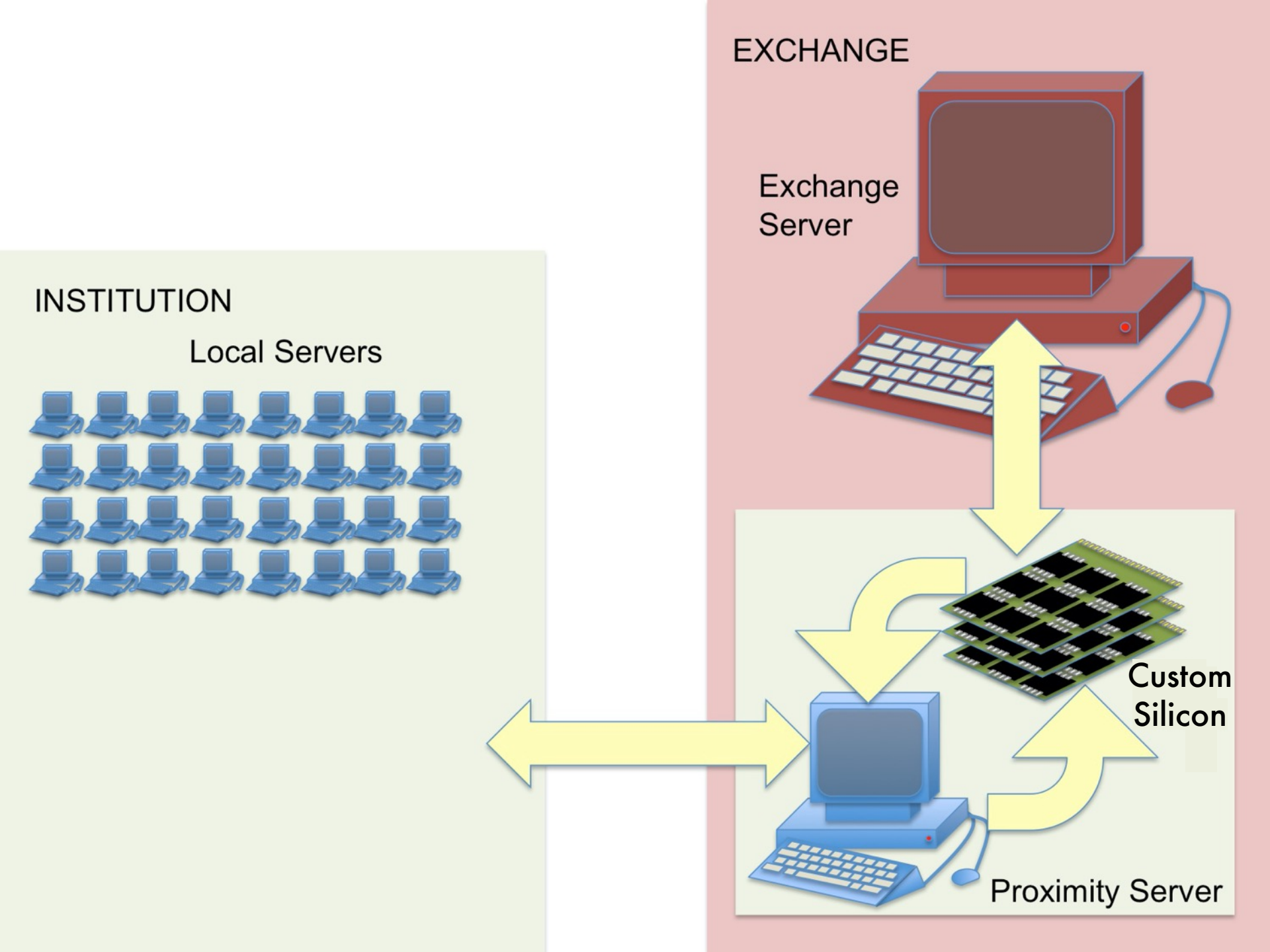
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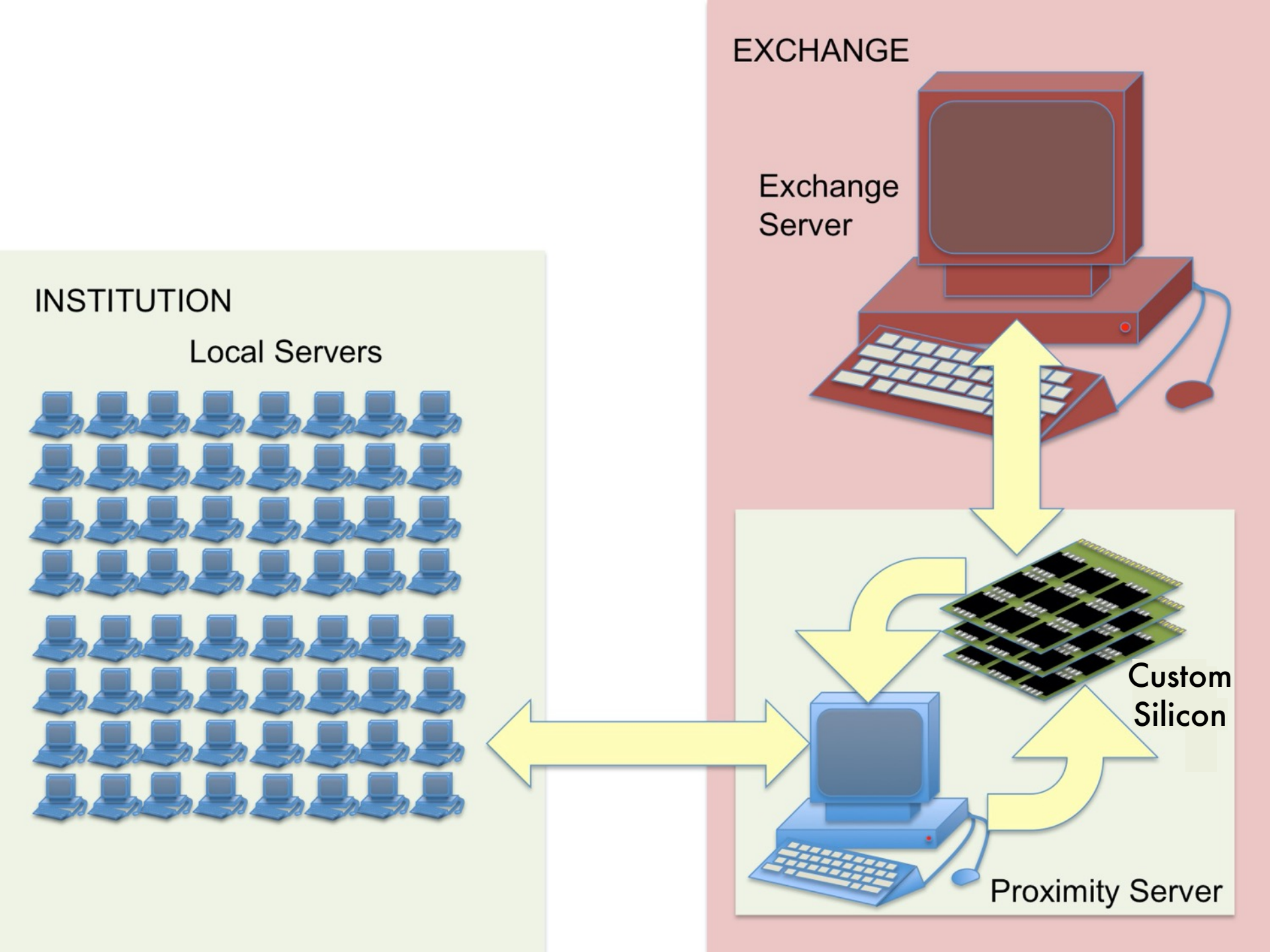
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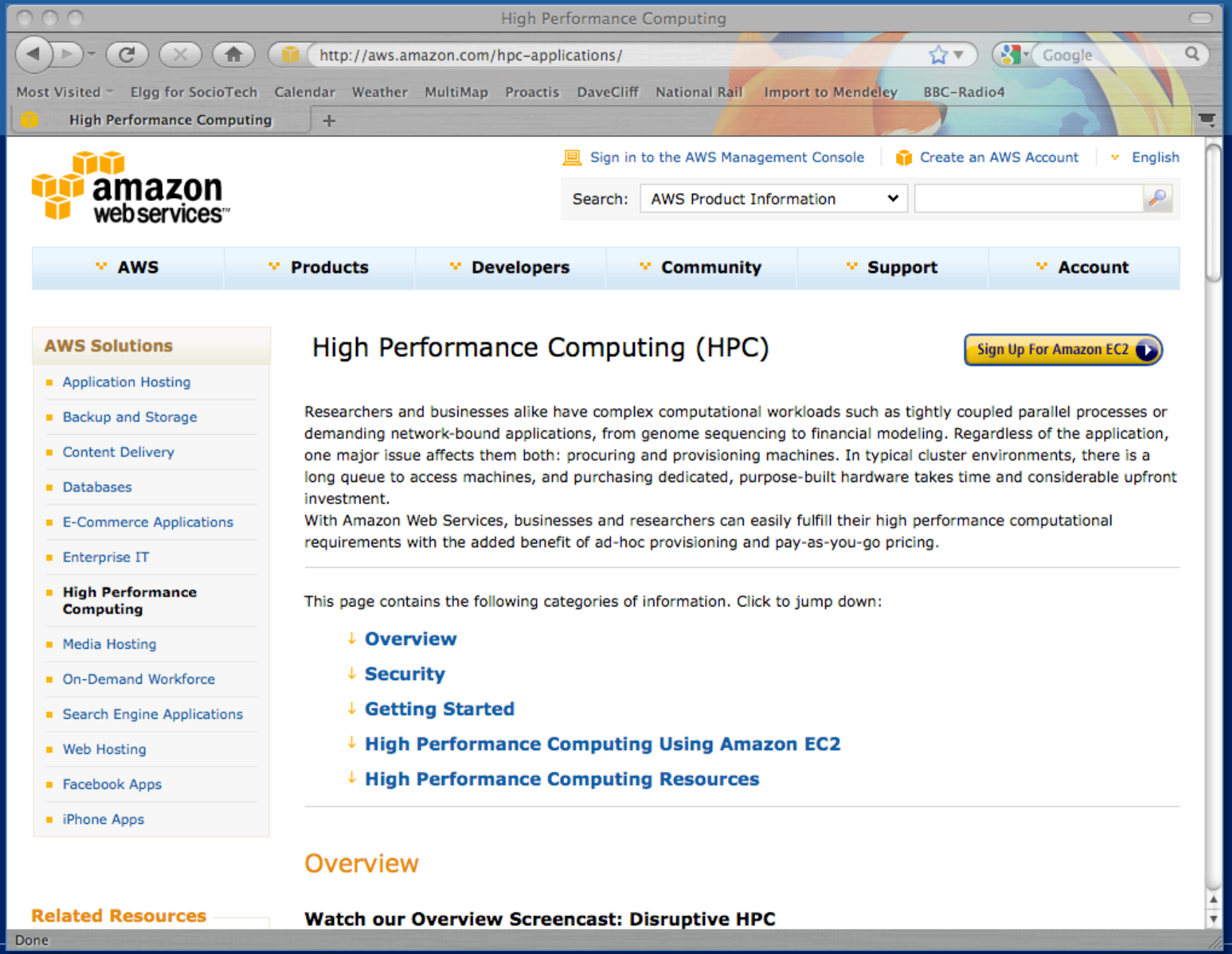
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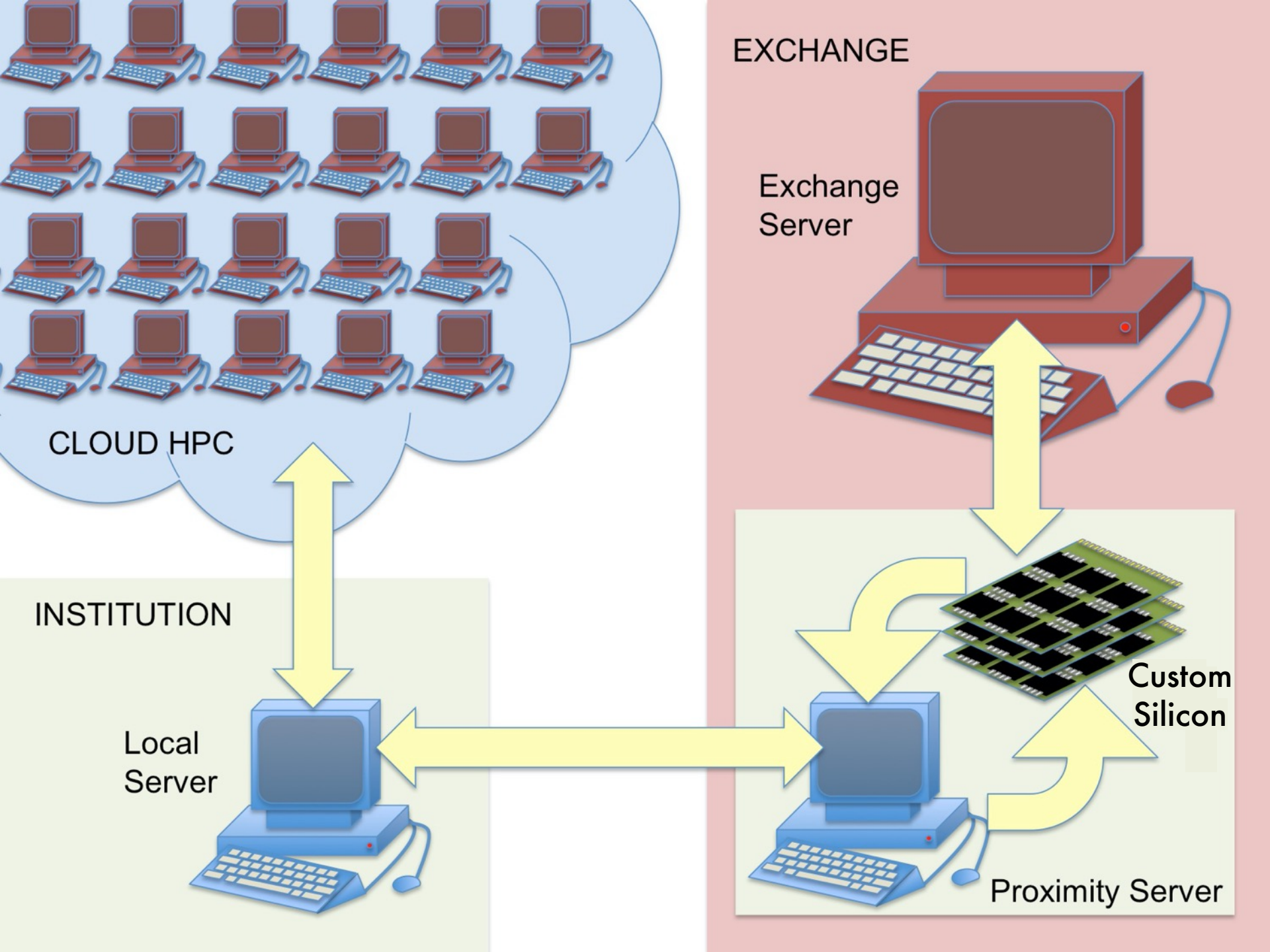
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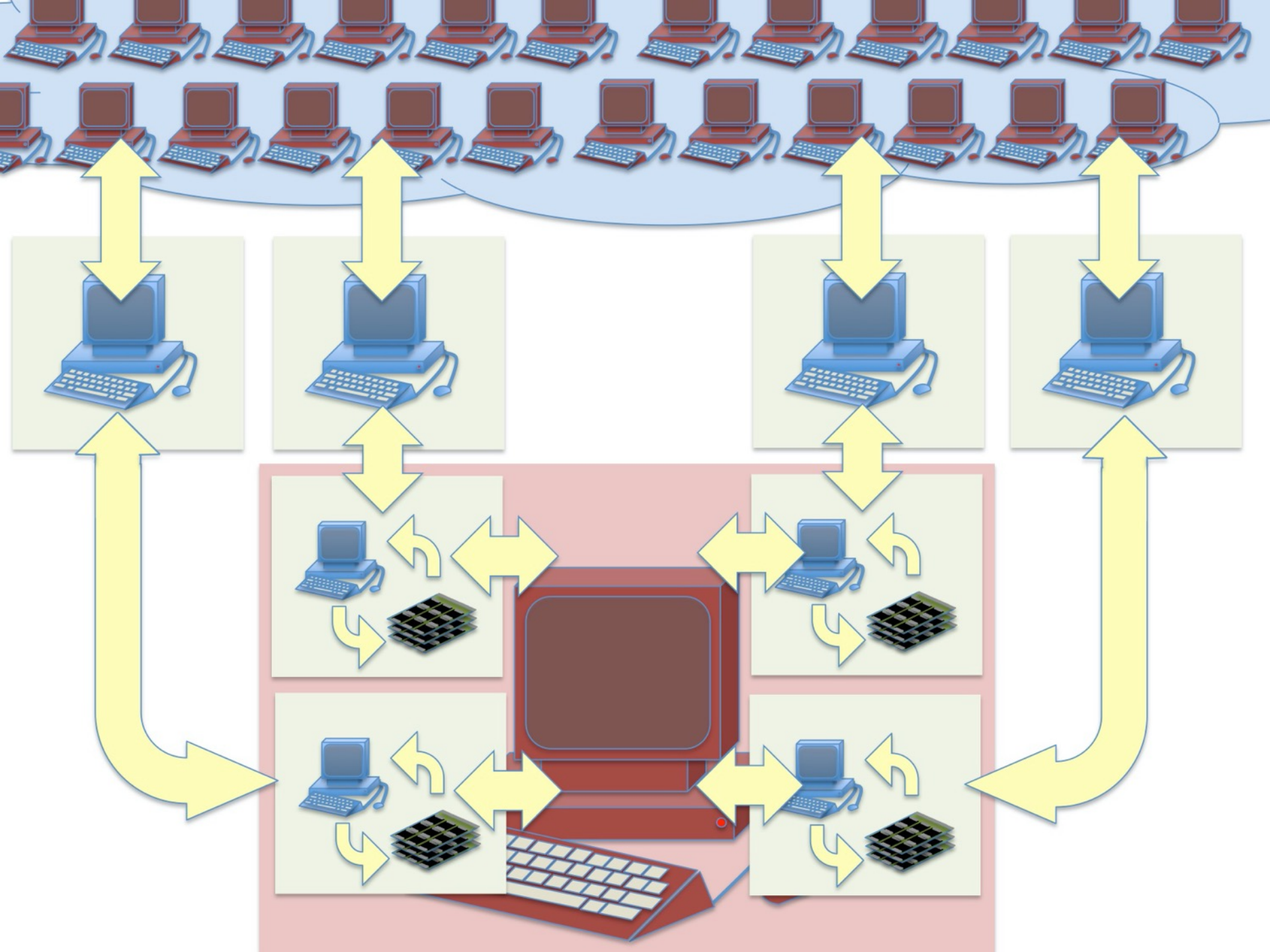

PHYSICAL REVIEW E **82**, 056104 (2010)

Relativistic statistical arbitrage

A. D. Wissner-Gross[1,*] and C. E. Freer[2,†]
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(Received 29 July 2010; revised manuscript received 10 October 2010; published 5 November 2010)

Recent advances in high-frequency financial trading have made light propagation delays between geographically separated exchanges relevant. Here we show that there exist optimal locations from which to coordinate the statistical arbitrage of pairs of spacelike separated securities, and calculate a representative map of such locations on Earth. Furthermore, trading local securities along chains of such intermediate locations results in a novel econophysical effect, in which the relativistic propagation of tradable information is effectively slowed or stopped by arbitrage.

DOI: 10.1103/PhysRevE.82.056104 PACS number(s): 89.65.Gh, 05.40.−a, 05.45.Xt

I. INTRODUCTION

Recent advances in high-frequency financial trading have brought typical trading latencies below 500 μs [1], at which point light propagation delays due to geographically separated information sources become relevant for trading strategies and coordination (e.g., it takes 67 ms, over 100 times longer, for light to travel between antipodal points along the Earth's surface). Moreover, as trading times continue to decrease in coming years (e.g., latencies in the microseconds are already being targeted by traders [2]), this feature will

(given by a *cointegrating vector*) is stationary [6,7]. Because of this stationarity, the linear combination described by the cointegrating vector will exhibit long-term reversion toward an equilibrium value [6–9].

Within financial markets, the relevant time series are typically the logarithms of the prices (log-prices) of financial instruments. Some of the simpler instances of cointegrated time series arise from interchangeable financial products, whose prices will therefore not drift far apart [6]. Such pairs should be expected for commodities or foreign currencies

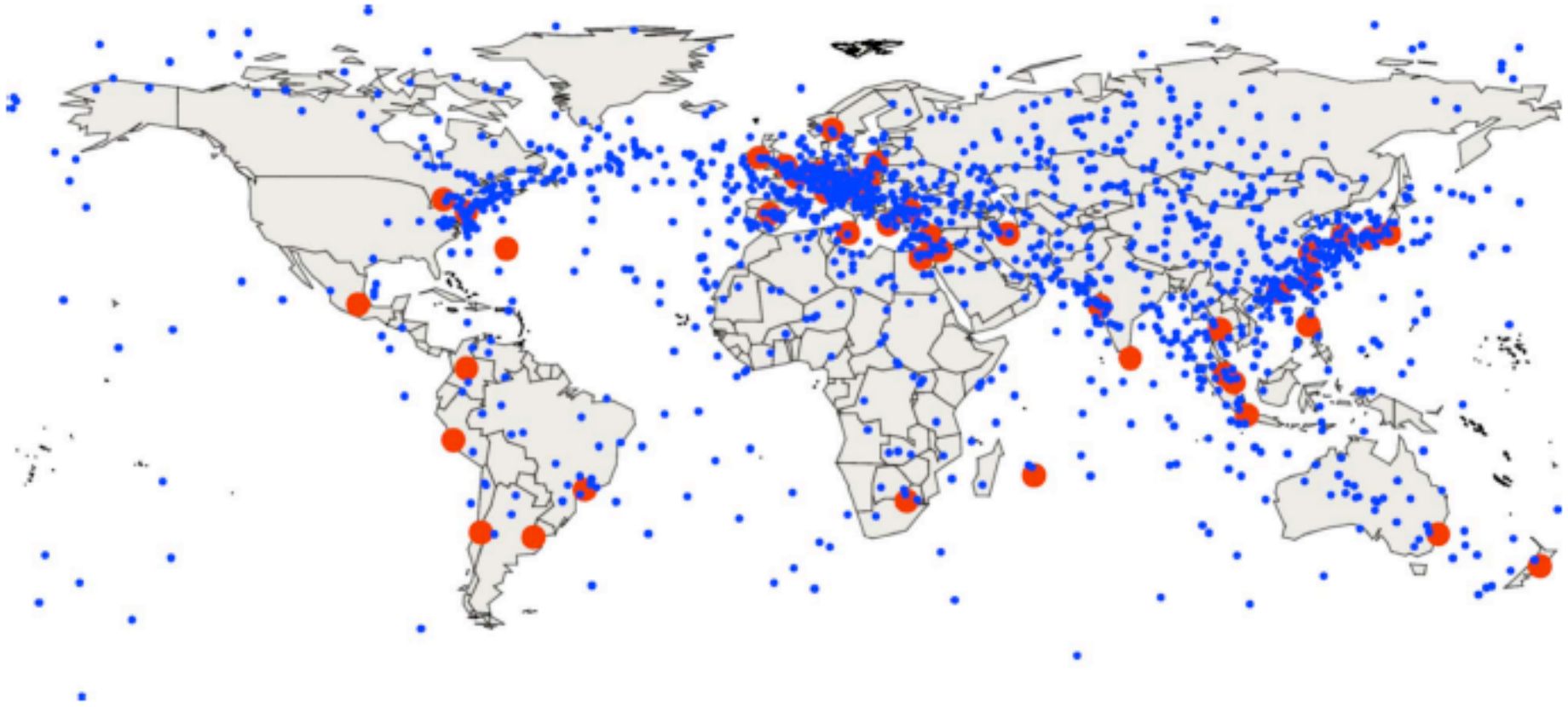

FIG. 2. (Color online) Optimal intermediate trading node locations (small circles) for all pairs of 52 major securities exchanges (large circles), calculated using Eq. (9) as midpoints weighted by turnover velocity (from 2008 data reported by the World Federation of Exchanges [49]). While some nodes are in regions with dense fiber-optic networks, many others are in the ocean or other sparsely connected regions.

Foresight Driver Review DR4

The Global Financial Markets: an Ultra-Large-Scale Systems Perspective

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+44 79 77 55 22 50; dc@cs.bris.ac.uk

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+1 412 268 7638; lmn@sei.cmu.edu

Abstract

We argue here that, in recent years, the global financial markets have become a complex adaptive ultra-large-scale socio-technical system-of-systems, and that this has important consequences for how market systems should be engineered and managed in future. The very high degree of interconnectedness in the global markets means that entire trading systems, implemented and managed separately by independent organizations, can rightfully be considered as significant constituent entities in the larger global super-system: that is, the global markets are an instance of what is known in the engineering literature as a *system-of-systems* (SoS). The sheer number of human agents and computer systems connected within the global financial-markets SoS is so large that it is an instance of an *ultra-large-scale system;* and that largeness-of-scale has significant effects on the

The two Foresight reviews, DR3 and DR4, that this lecture is based on are required reading.

DR3: https://www.gov.uk/government/publications/computer-trading-technology-trends

DR4: https://www.gov.uk/government/publications/computer-trading-global-financial-markets

So is the Bower & Christensen (1996) article (L01)

https://hbr.org/1995/01/disruptive-technologies-catching-the-wave


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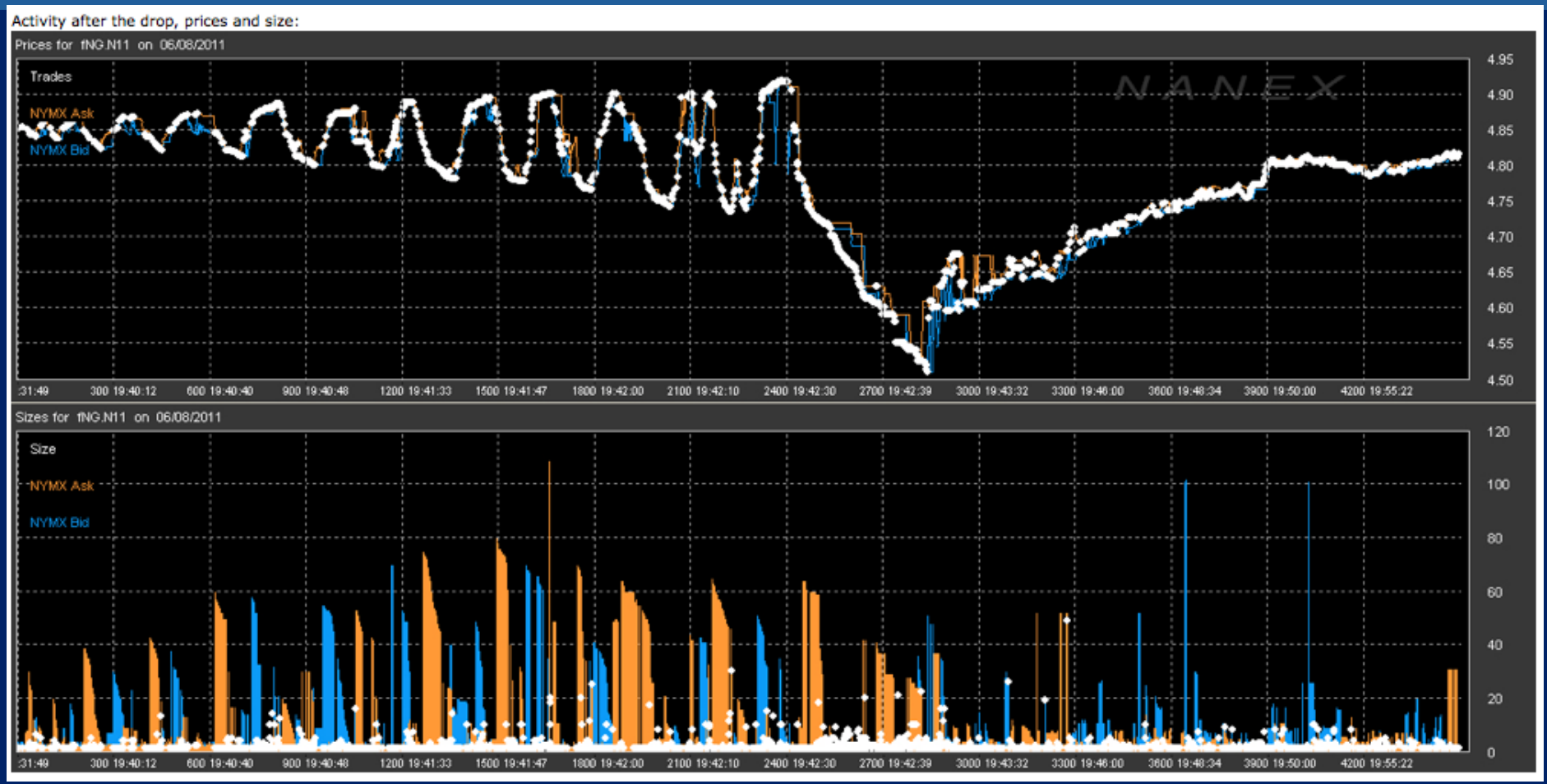


http://www.nanex.net/StrangeDays/06082011.html

The BATSCrash, 23/3/12

http://www.nanex.net/aqck/2970.html

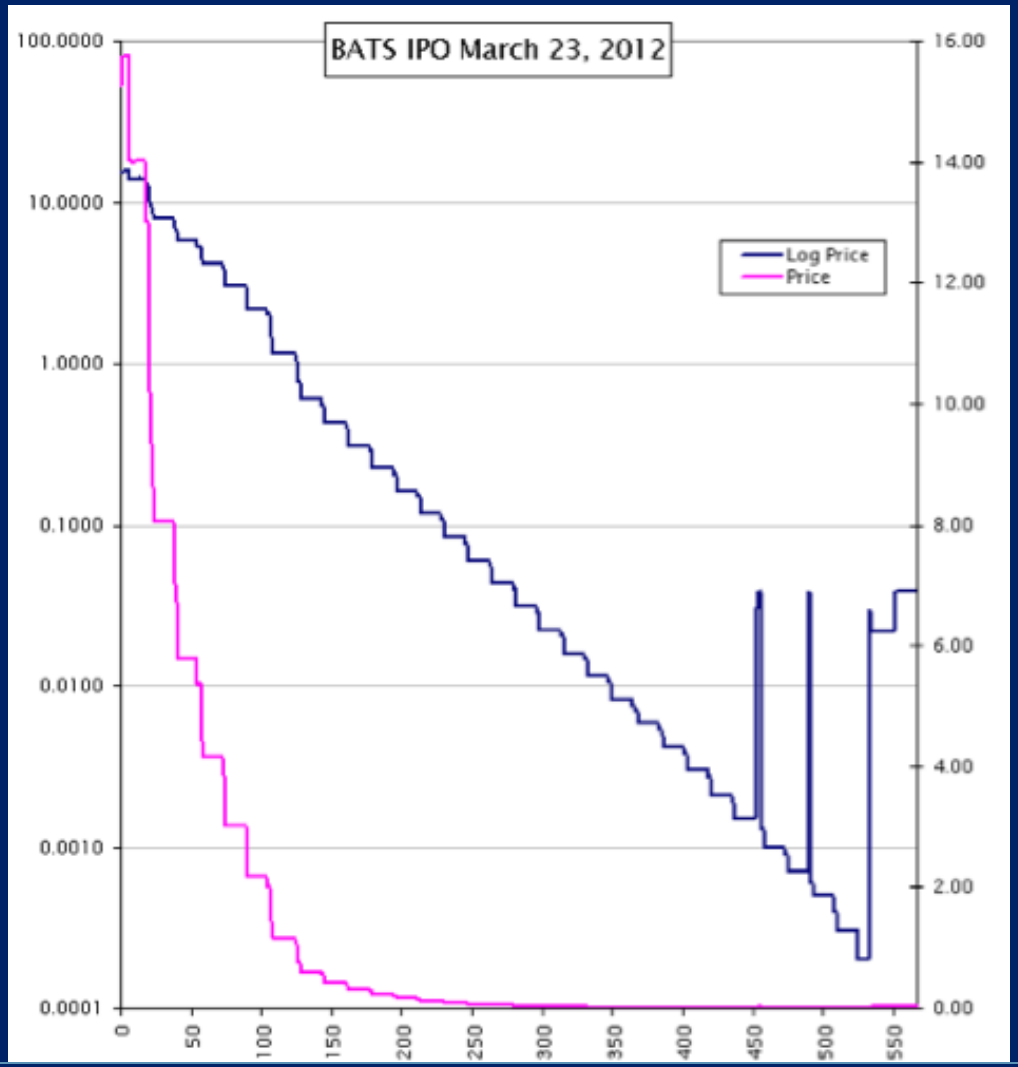
- The March 23, 2012 IPO of BATS was brief.
- BATS began trading at 11:14:18, initial price of $15.25.
- +900 ms from opening, BATS price was $0.2848.
- Within +1.5 seconds, the price bottomed at $0.0002.

- 567 trades were executed before the stock was halted.

- BATS cancelled its IPO.

The BATSCrash, 23/3/12

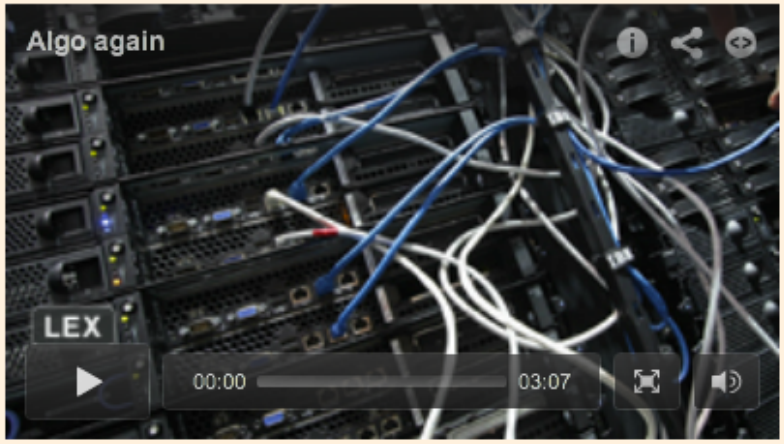
http://www.nanex.net/aqck/2970.html



August 3, 2012 7:04 pm

Knight Capital – a disturbing pattern

As the Michael Caine character says after a sidekick gets a controlled explosion wrong in *The Italian Job*: "You're only supposed to blow the bloody doors off." They know the feeling at Knight Capital, the Wall Street brokerage where a software upgrade on Wednesday blew up the company. With Knight's share price down 70 per cent since then, the company facing the possibility of bankruptcy and vultures circling, the episode is another milestone in the brief but eventful history of what happens when computers mimic humans.



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www.ft.com/cms/s/0/2f7d3b28-0d7c-11e2-bfcb-00144feabdc0.html

Last updated: October 3, 2012 11:09 pm

Nasdaq suffers fresh high-profile gaffe

By Arash Massoudi in New York and Alan Rappeport in Washington

Nasdaq suffered its second high-profile embarrassment in six months when it was forced to cancel trades in Kraft Foods after a trading glitch caused the company's shares to soar nearly 30 per cent.

The error marred the completion of the recently split group's switch to Nasdaq and evoked memories of the exchange's botched handling of the Facebook flotation in May.

http://www.ft.com/cms/s/0/9869b272-0ecd-11e2-9343-00144feabdc0.html

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October 5, 2012 10:45 am

Indian shares suffer $60bn 'flash crash'

By Neil Munshi in Mumbai and Philip Stafford in London

Almost $60bn was temporarily wiped from the stock market value of India's biggest companies on Friday when a "flash crash" on the country's stock exchange triggered a near 16 per cent slide in the main index.

India's National Stock Exchange, Asia's fourth largest bourse based in Mumbai, was

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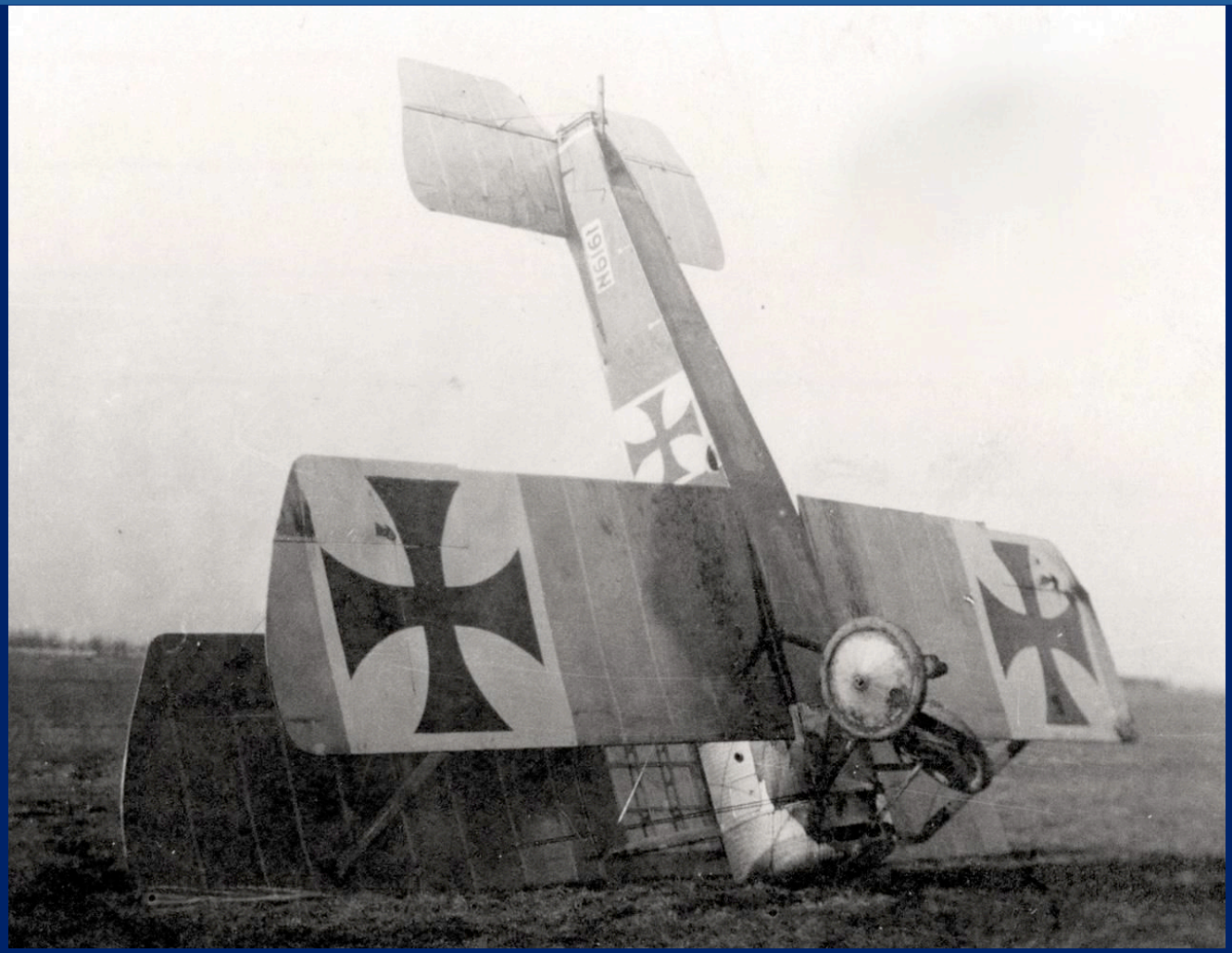

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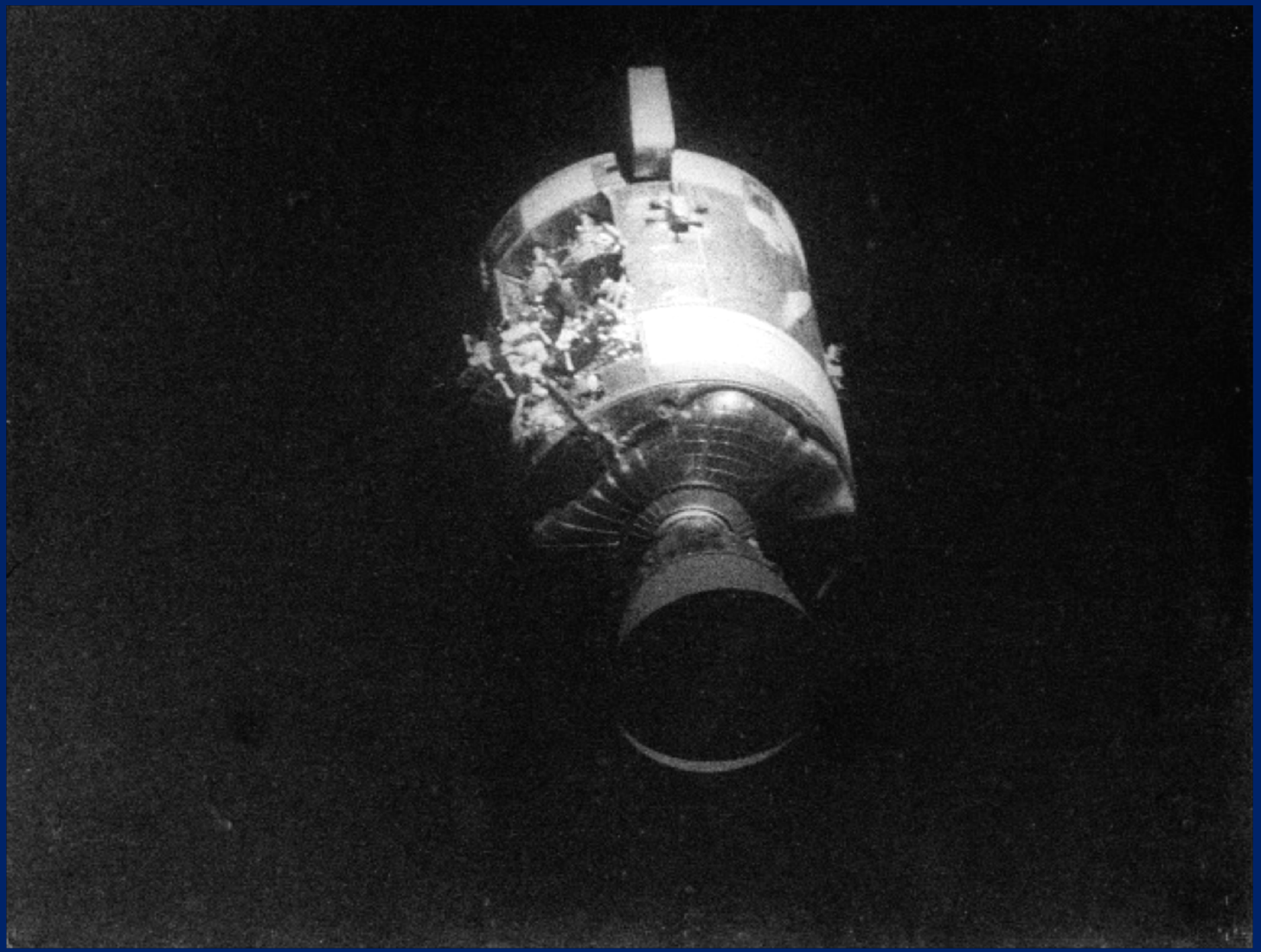

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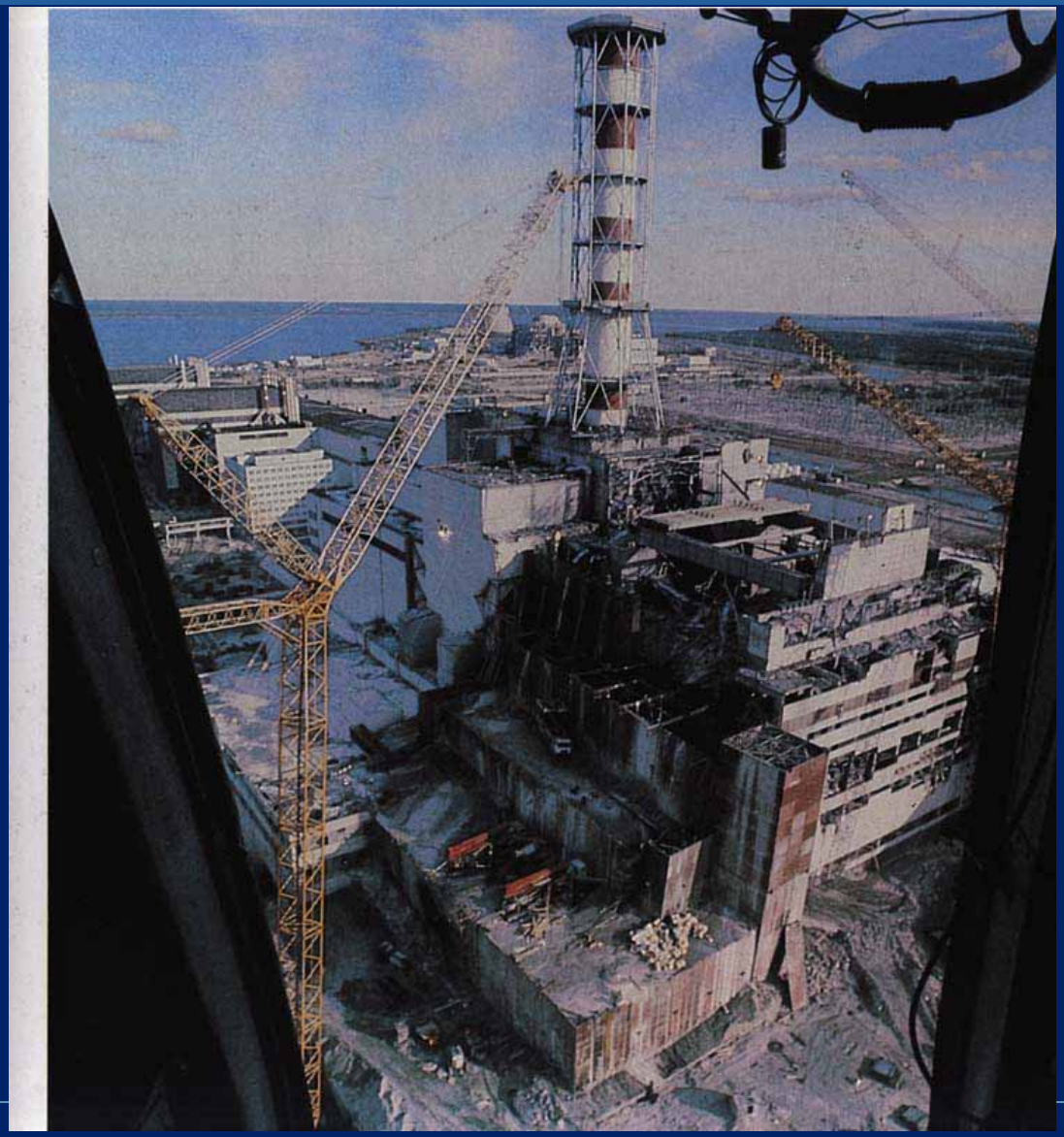

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www.calxibe.com
BREAKING NEWS
CNN
SHUTTLE FOLLOWED BY MULTIPLE
VAPOR TRAILS OVER TEXAS

WTF?

WTF?


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▼ 998.50 / 9.2%
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GOLDS ↓ 1536.93 -8.43 DBFX 1536.05/1537.8 DBFX
At 18:02 Op 1545.75 Hi 1546.1 Lo 1525.45 Prev 1545.35
GOLDS Comdty
Hide
Scrolling Window 1000
Mode Trade Only
Volume
Flat Filter
1536.93 -8.43 -.55%
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1540
1536.93
1535
1525
GOLDS Comdty
Last Price 1536.93
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17:08:54
18:00:33


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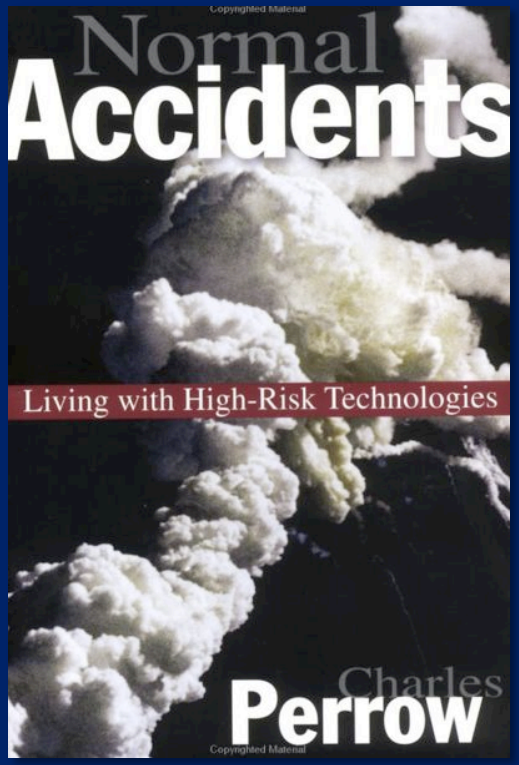
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Living with High-Risk Technologies
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1984

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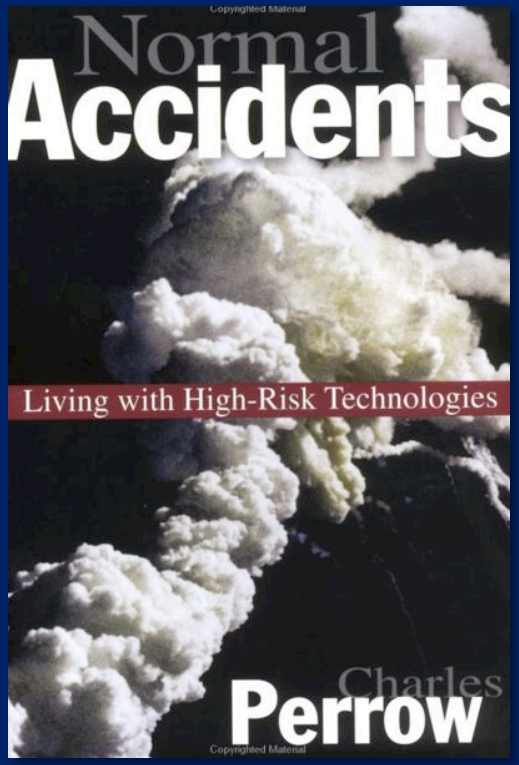

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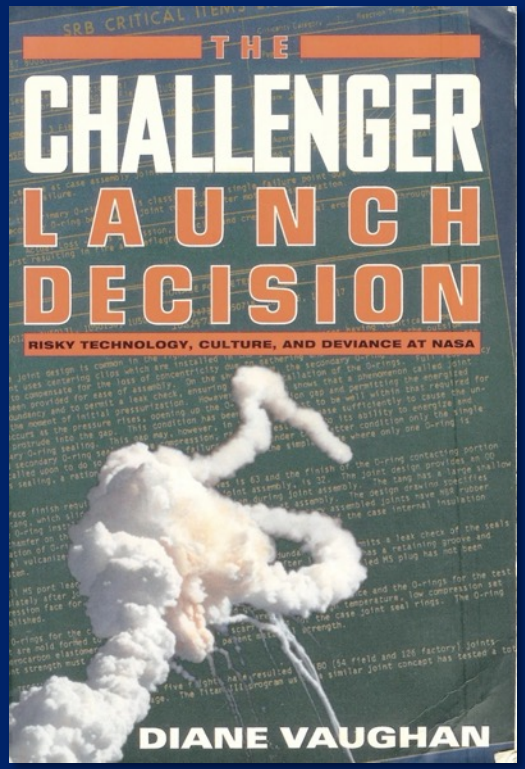

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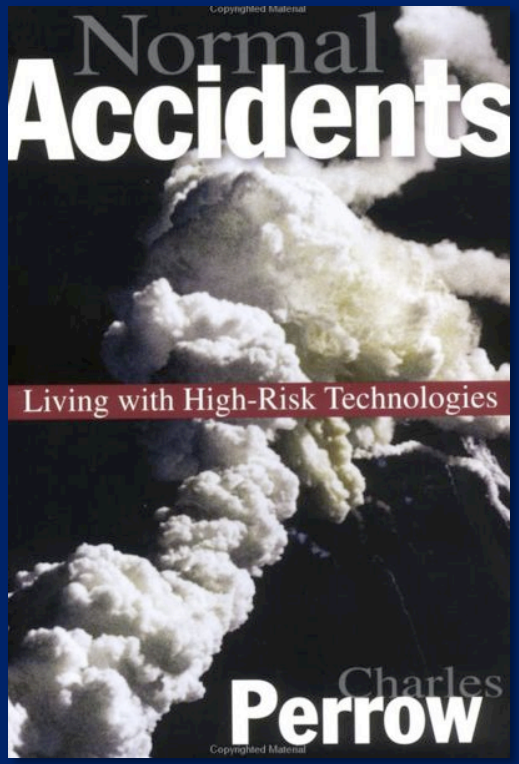

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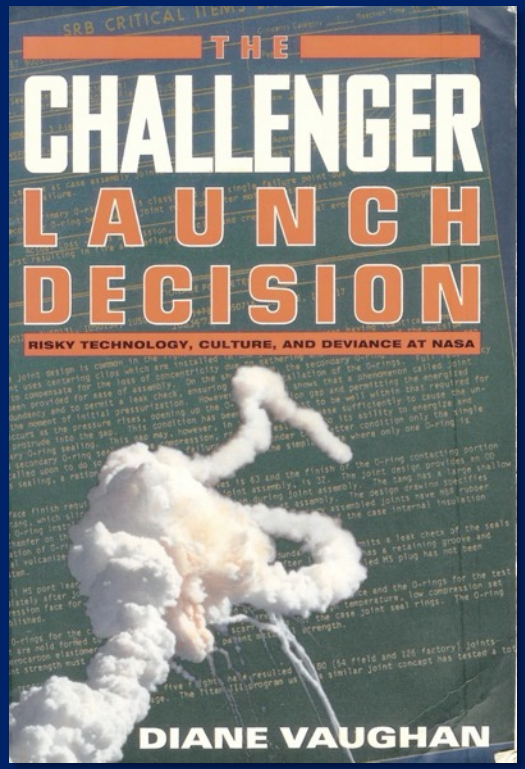

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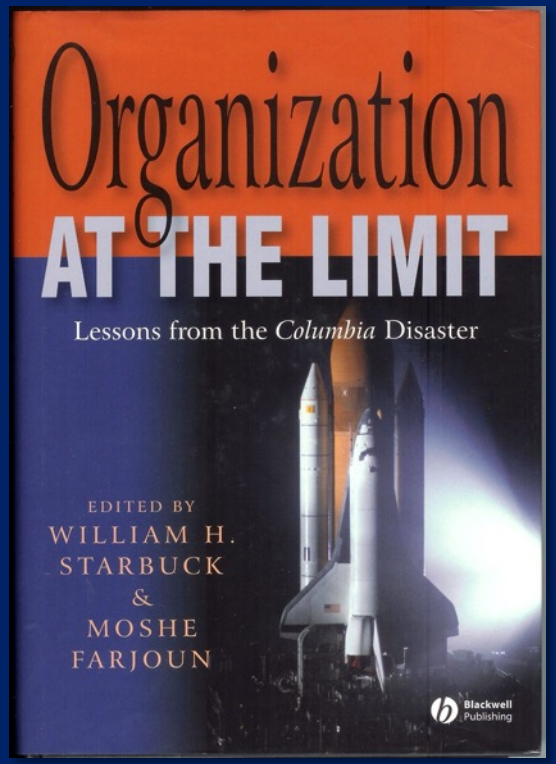

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BEAR STEARNS

LEHMAN BROTHERS

WTF?

BEAR STEARNS

AIG

LEHMAN BROTHERS

WTF?

BEAR STEARNS

Freddie Mac

AIG

LEHMAN BROTHERS

WTF?

BEAR STEARNS

FannieMae

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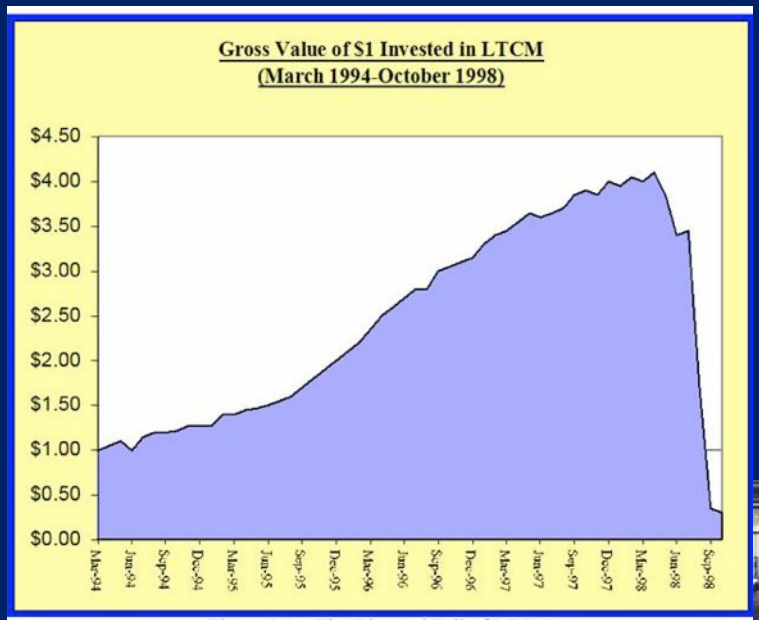

Figure 3.1 – The Rise and Fall of LTCM
(from Lowenstein 2001)

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LEHMAN BROTHERS

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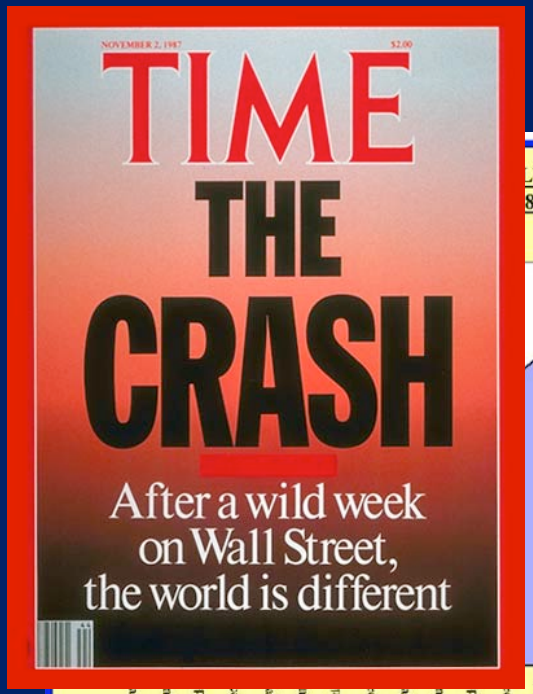

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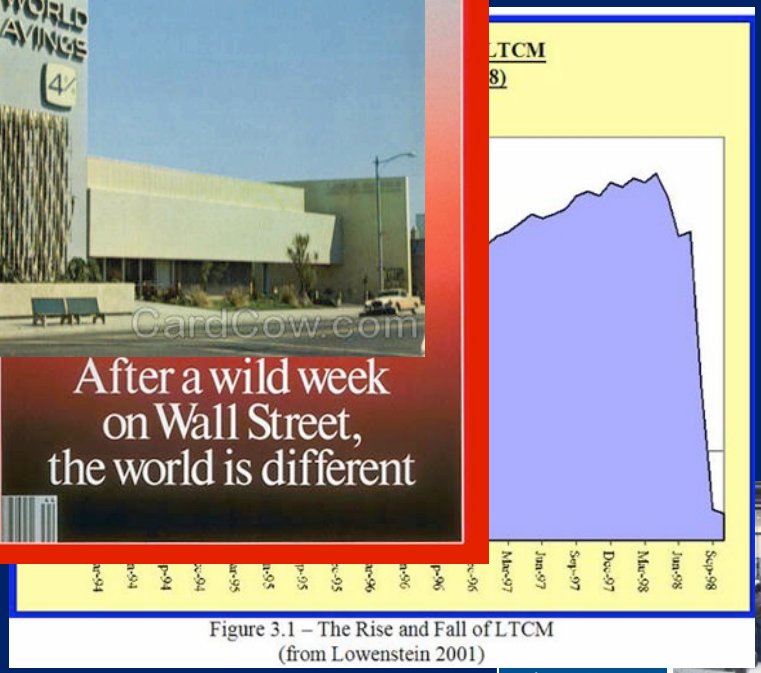
WTF?

After a wild week on Wall Street, the world is different



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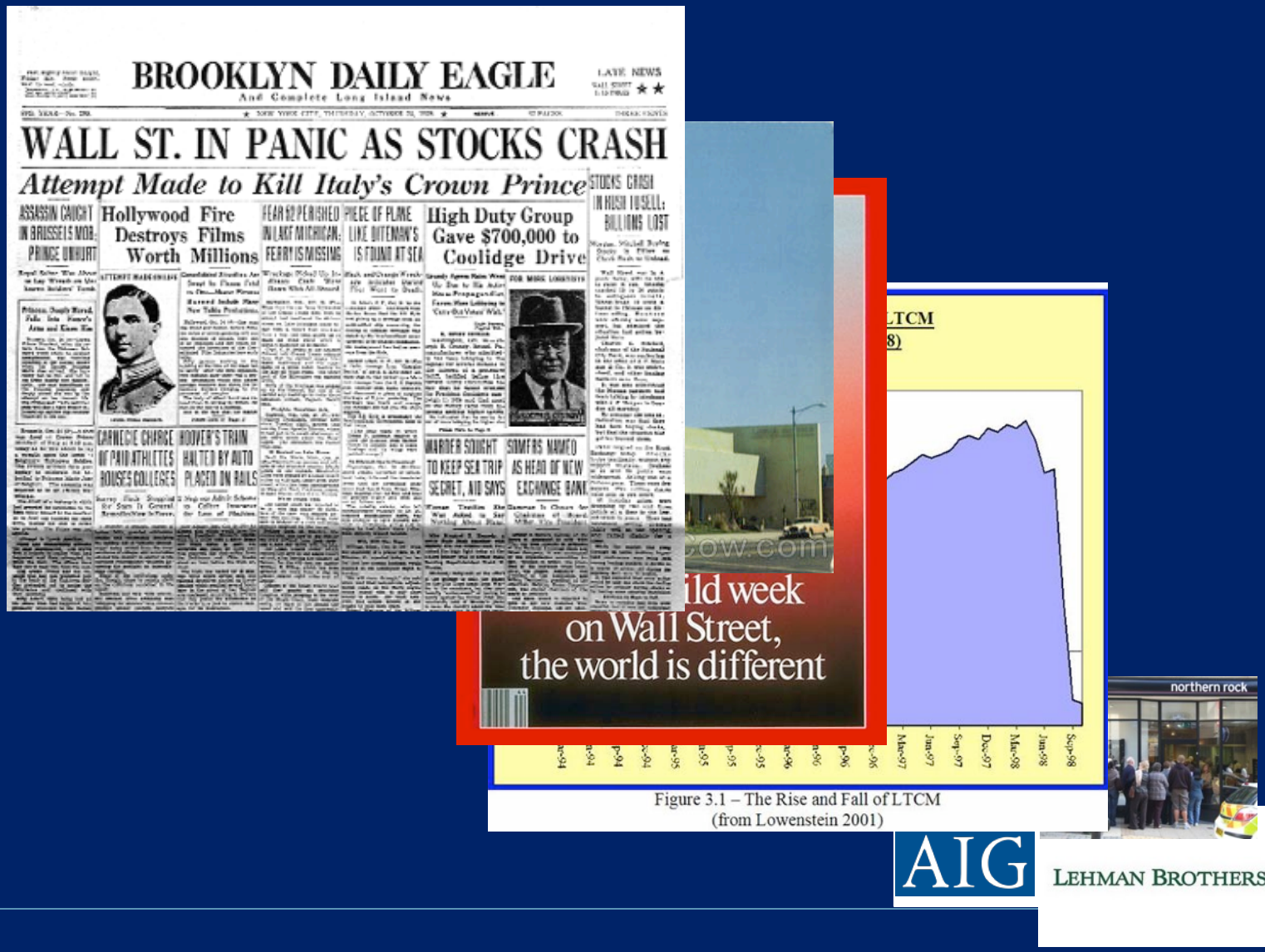
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(from Lowenstein 2001)
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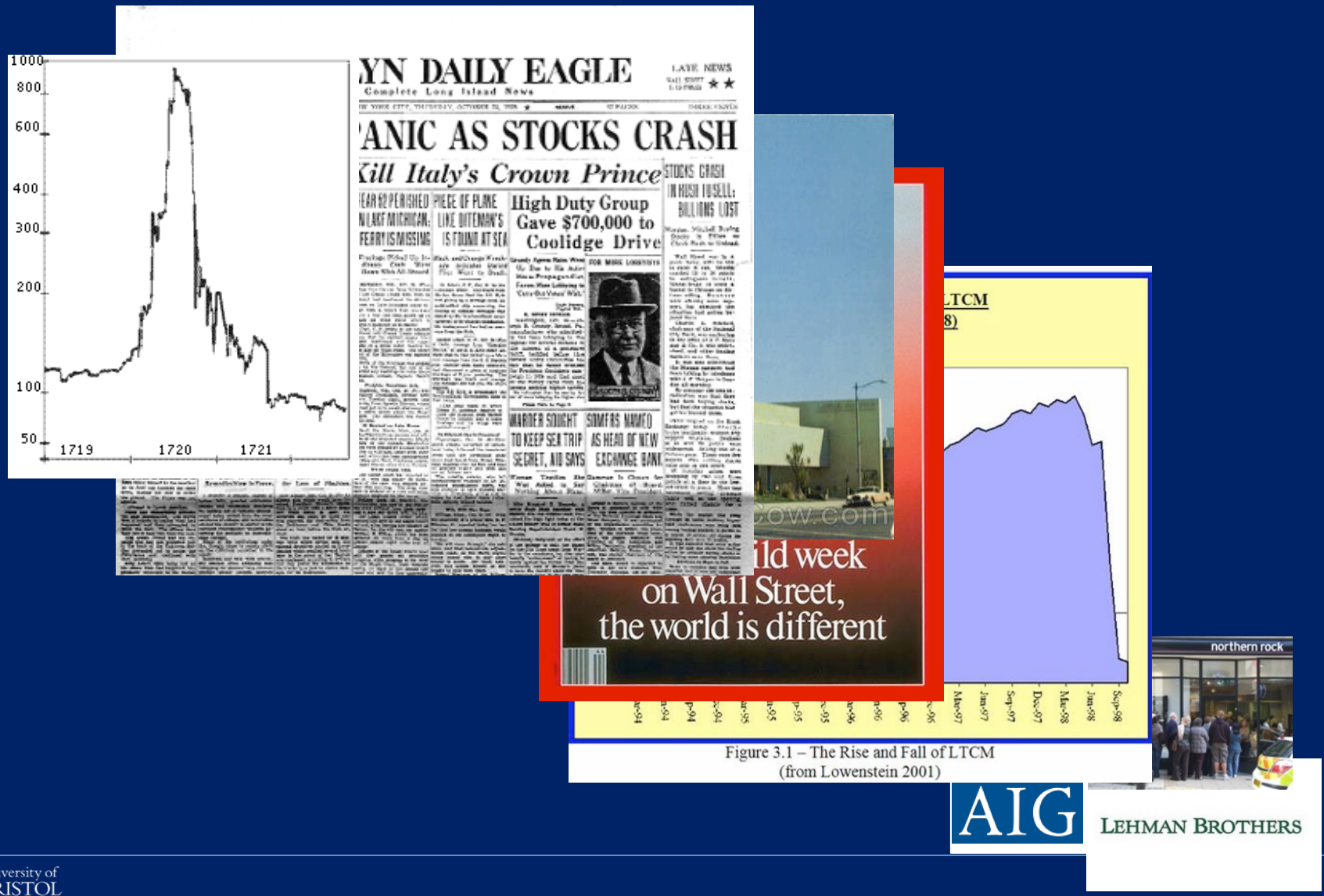

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LATE NEWS
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Kill Italy's Crown Prince
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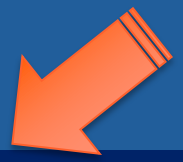

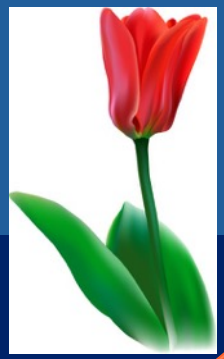

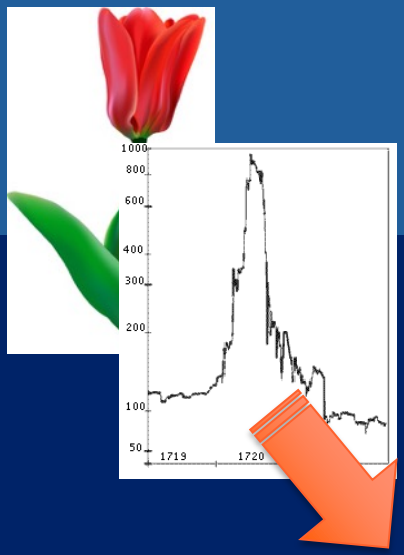
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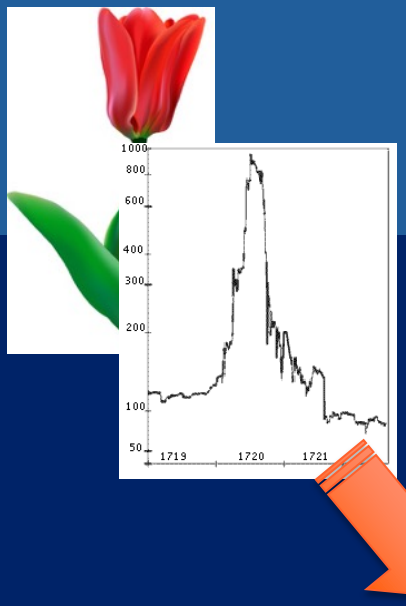
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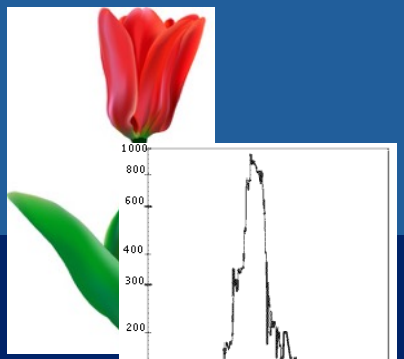

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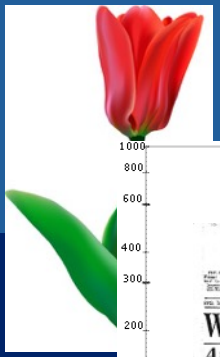

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LATE NEWS

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ASSASSIN CAUGHT IN BRUSSELS MOB... PRINCE UNHURT

Hollywood Fire Destroys Films Worth Millions

FEAR 92 PERISHED IN LAKE MICHIGAN... FERRY IS MISSING

PIECE OF PLANE LIKE BITENOW'S IS FOUND AT SEA

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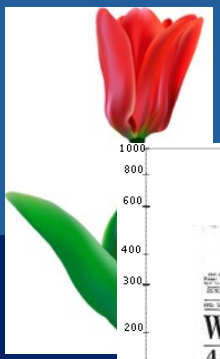

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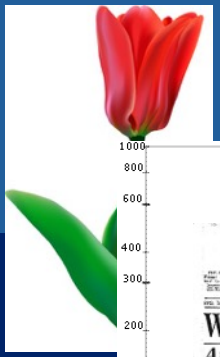

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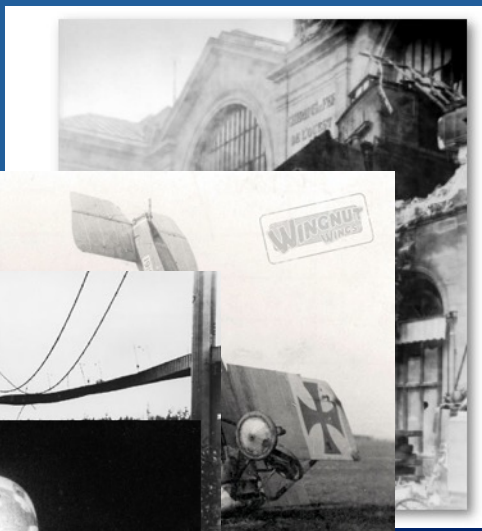


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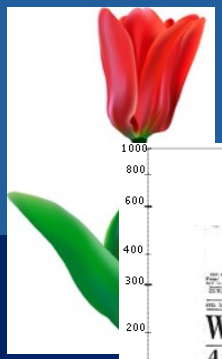

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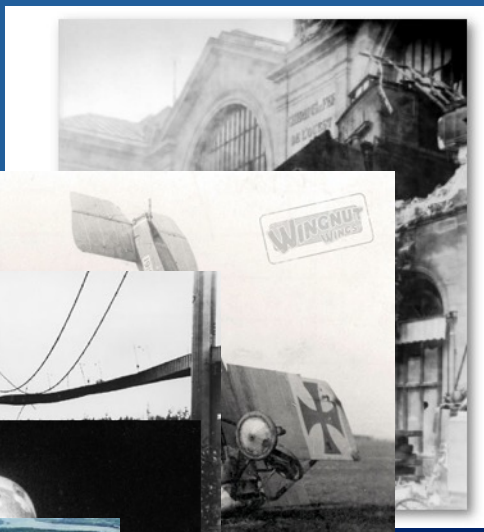

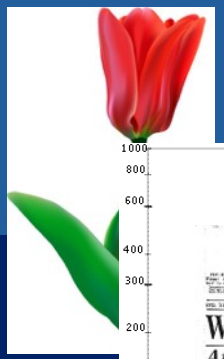

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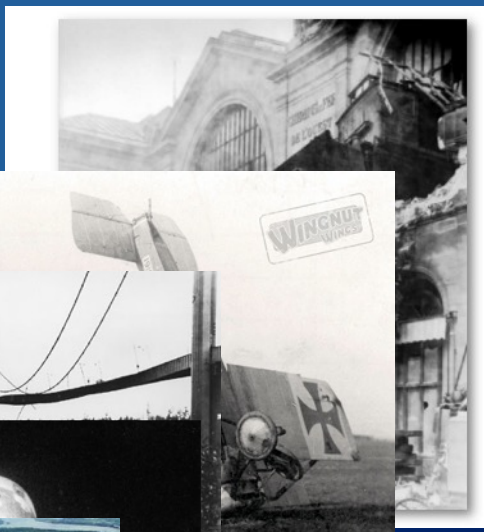

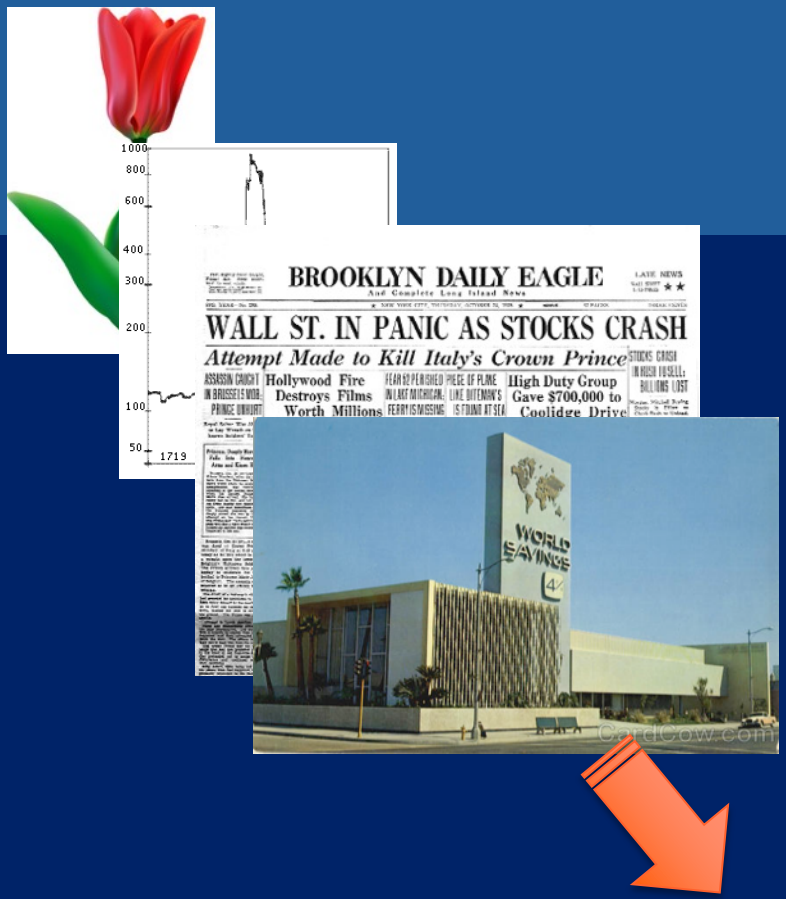
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After a wild week on Wall Street, the world is differe


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Gross Value of $1 Invested in LTCM
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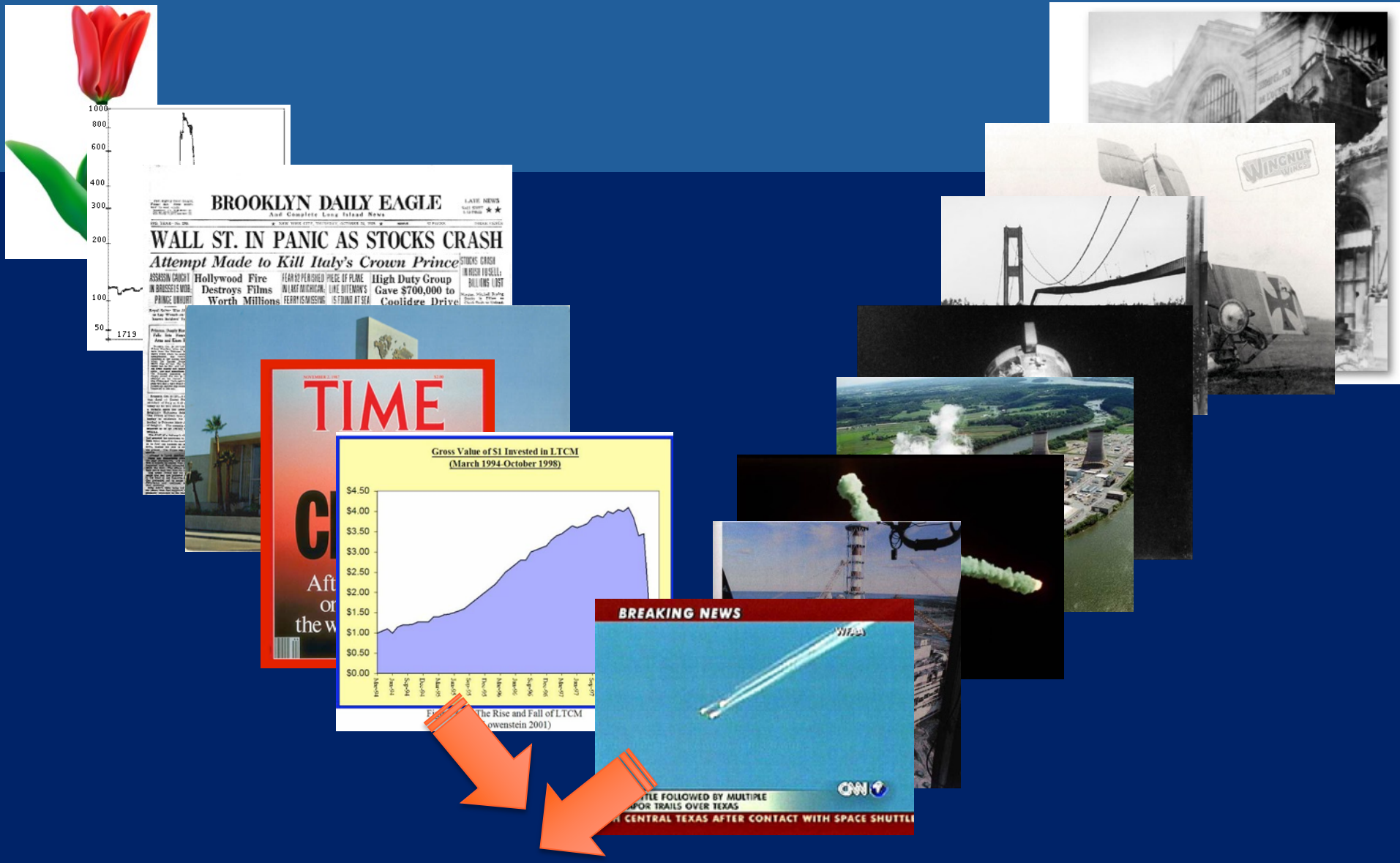
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The Rise and Fall of LTCM
BREAKING NEWS
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CENTRAL TEXAS AFTER CONTACT WITH SPACE SHUTTLE


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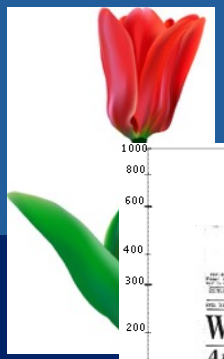

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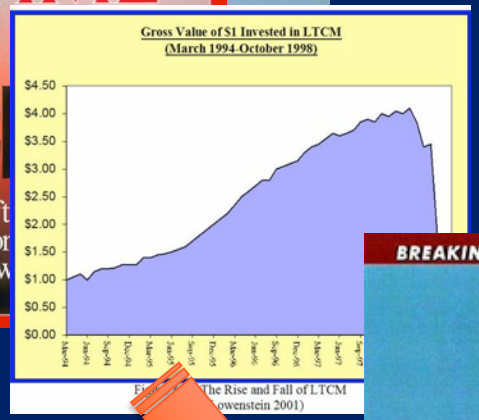

The Rise and Fall of LTCM
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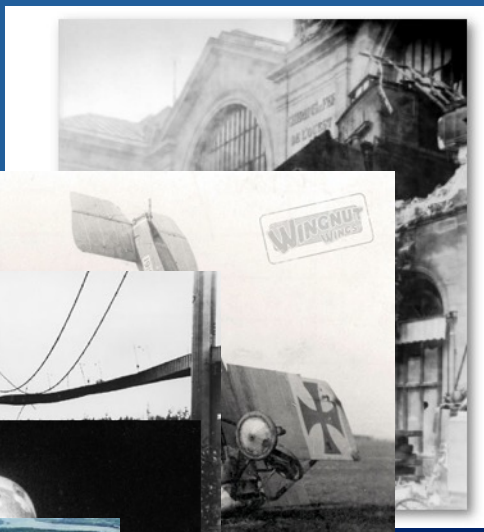


http://www.cs.bris.ac.uk/home/dc/Foresight_NetGov_v2a.pdf

Networked Governance in the Global Financial Markets

Sketch for a Foresight project; third draft, Feb. 2010 (with minor edits Apr. 2010).

Prof. D. Cliff, UK Large-Scale Complex IT Systems Initiative, University of Bristol, dc@cs.bris.ac.uk

The past 15 years has seen a surprising, but well-documented, major technology transition in most industrialised economies to the use of advanced telecoms (wireless mobile and wired broadband) for accessing information via the internet and the world-wide-web. There are at least three major technologies that look set to combine in coming decades, in such a way that major transitional disruptions (either positive or negative) look likely for western industrialised societies such as the UK in terms of how citizens interact with each other, how business is done between firms, and how both firms and people interact with institutions of government.

The three technologies likely to combine in disruptive ways are the world-wide-web (especially in its currently much-vaunted incarnation as "Web2.0"), coupled with the easy accessibility of cheap remotely-accessible ultra-high-power computing facilities (so-called "Cloud Computing"), coupled with advanced apparently-intelligent automated processing of machine-readable information (so-called "computational intelligence" and "semantic web" technologies). But these three technologies are not the only ones making rapid advances. It is already clear that advances in materials and manufacturing, in the psychopharmacology of drugs for cognitive enhancement, and in brain-machine

Our work

Foresight projects

Current projects

Future of Computer Trading in Financial Markets

Lead Expert Group

Computer Trading in Financial Markets - press notice

The Future of Computer Trading in Financial Markets

Advances in technology continue to transform how our financial markets operate. The volume of financial products traded through computer automated trading taking place at high speed and with little human involvement has increased dramatically in the past few years.

For example, today, over one third of United Kingdom equity trading volume is generated through high frequency automated computer trading while in the US this figure is closer to three-quarters.

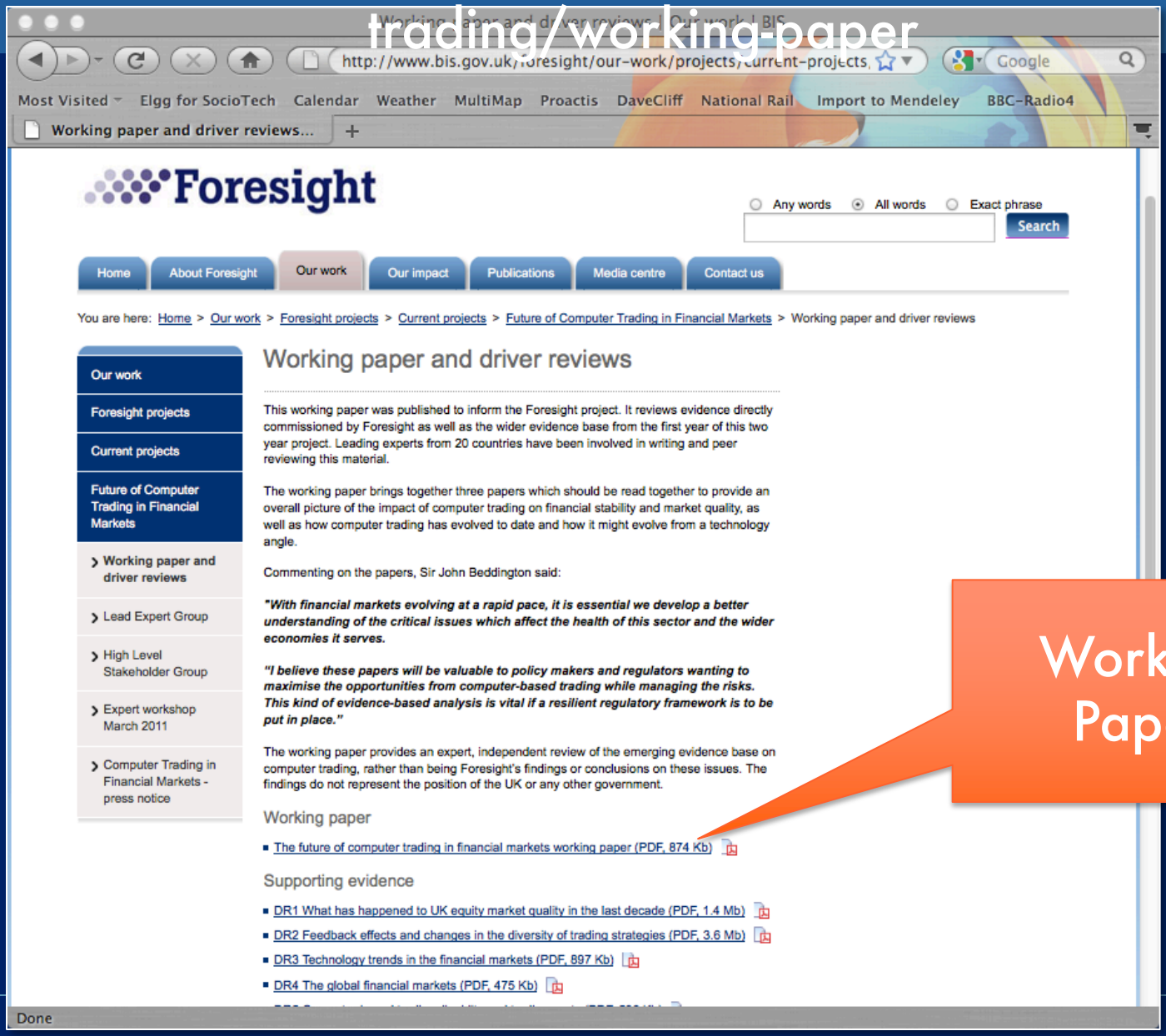
Current projects

- Global Food and Farming Futures
- International Dimensions of Climate Change
- Global Environmental Migration
- The Future of Computer Trading in Financial Markets

Published projects

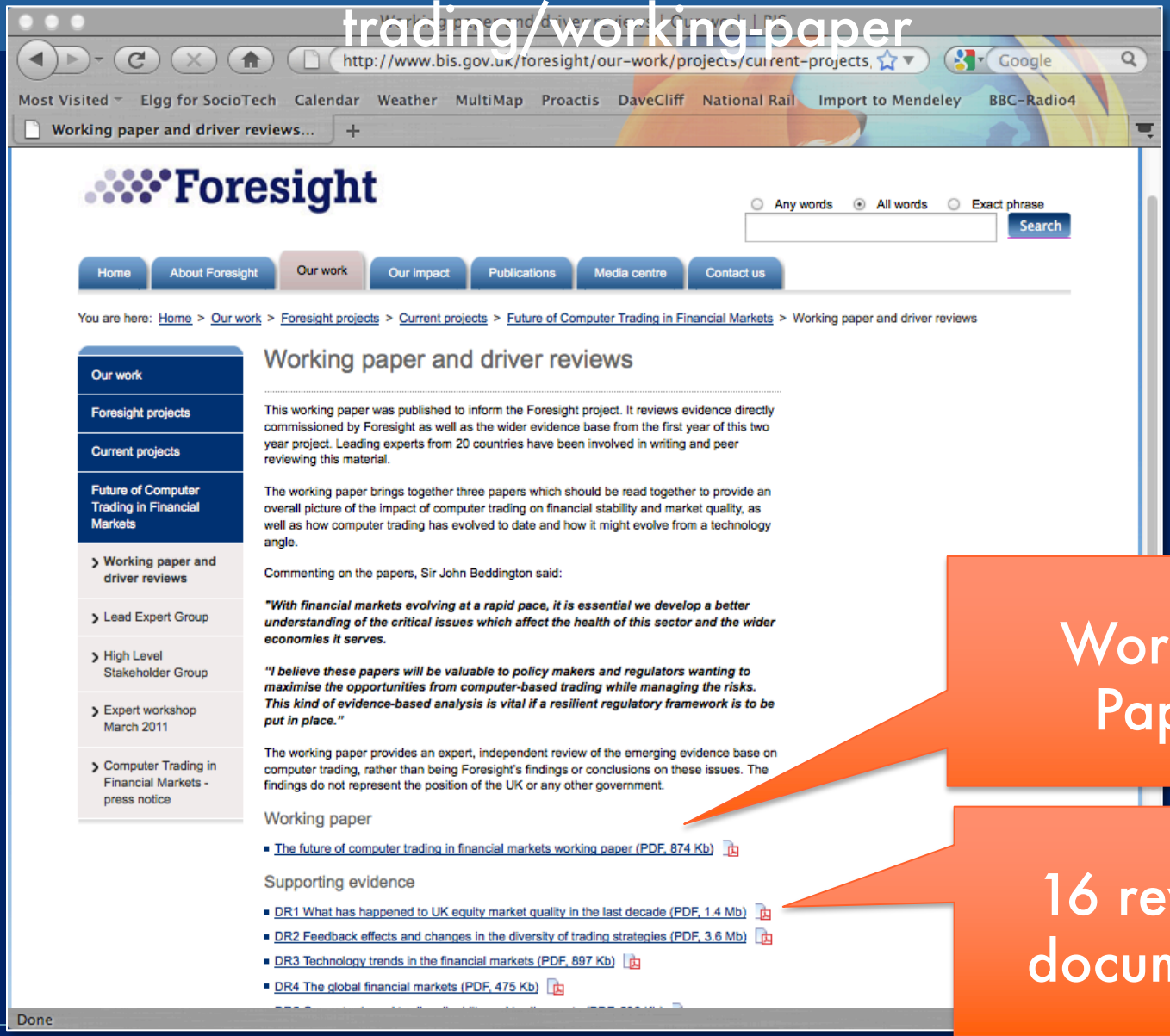
- Technology and Innovation Futures
- Land Use Futures

http://www.bis.gov.uk/foresight/our-work/projects/current-projects/computer-trading/working-paper



Working Paper

http://www.bis.gov.uk/foresight/our-work/projects/current-projects/computer-trading/working-paper



Working Paper

16 review documents

http://www.bankofengland.co.uk/publications/speeches/2011/speech509.pdf

BANK OF ENGLAND

Speech

The race to zero

Speech given by

Andrew G Haldane, Executive Director, Financial Stability and member of the interim Financial Policy Committee

International Economic Association Sixteenth World Congress, Beijing, China

8 July 2011

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"zero" => low-latency trading

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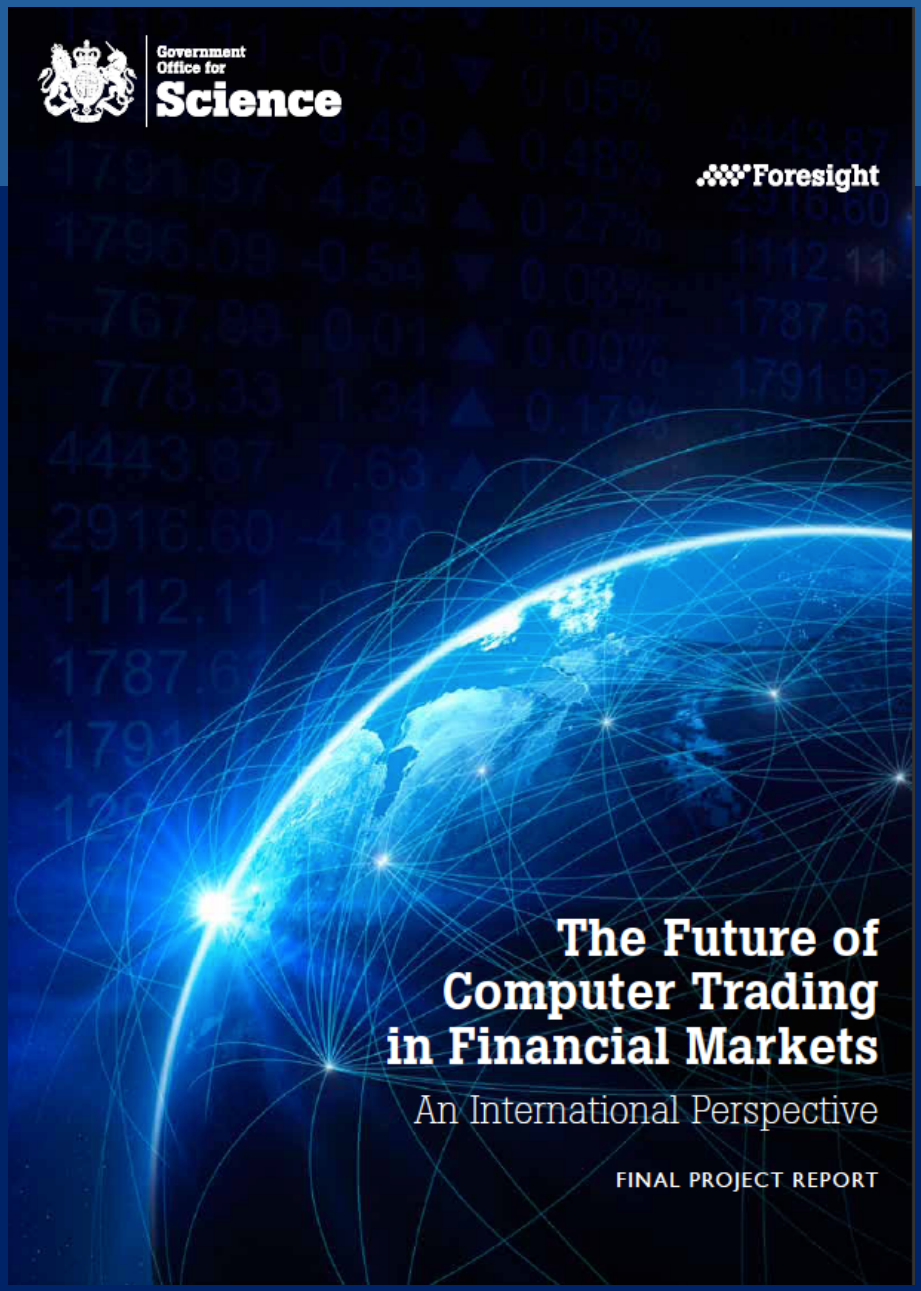

Government Office for Science
Foresight
The Future of Computer Trading in Financial Markets
An International Perspective
FINAL PROJECT REPORT

Archive

PARLIAMENTARY COMMISSION ON BANKING STANDARDS JOINT COMMITTEE

Monday 26 November 2012

Grimond Room
Meeting started on Monday 26 November at 4.25pm. Ended at 6.23pm

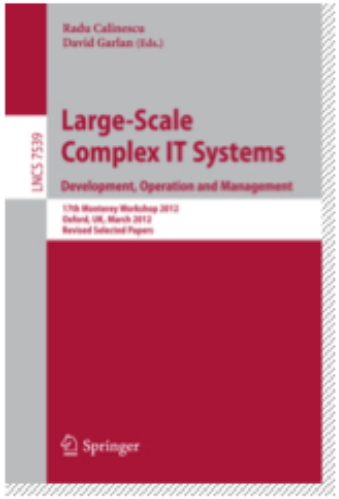
Panel on wholesale competition
Witnesses

i. Dave Cliff, Professor of Computer Science at the University of Bristol, Jean-Pierre Zigrand, Reader in Finance at the London School of Economics, Oliver Linton FBA, Chair of Political Economy at the University of Cambridge

ii. Alexander Justham, CEO, London Stock Exchange plc

Visit the Committee's homepage.

Embed this meeting on your site



Large-Scale Complex IT Systems. Development, Operation and Management

17th Monterey Workshop 2012, Oxford, UK, March 19-21, 2012, Revised Selected Papers

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Calinescu, Radu; Garlan, David (Eds.)

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The reductionism behind today's software-engineering methods breaks down in the face of systems complexity.

BY IAN SOMMERVILLE, DAVE CLIFF, RADU CALINESCU, JUSTIN KEEN, TIM KELLY, MARTA KWIATKOWSKA, JOHN MCDERMID, AND RICHARD PAIGE

Large-Scale Complex IT Systems

ON THE AFTERNOON of May 6, 2010, the U.S. equity markets experienced an extraordinary upheaval. Over approximately 10 minutes, the Dow Jones Industrial Average dropped more than 600 points, representing the disappearance of approximately $800 billion of market value. The share price of several blue-chip multinational companies fluctuated dramatically; shares that had been at tens of dollars plummeted to a penny in some cases and rocketed to values over $100,000 per share in others. As suddenly as this market downturn occurred, it reversed, so over the next few minutes most of the loss was recovered and share prices returned to levels close to what they had been before the crash.

This event came to be known as the "Flash Crash," and, in the inquiry report published six months later,[7] the trigger event was identified as a single block sale of $4.1 billion of futures contracts executed with uncommon urgency on behalf of a fund-management company. That sale began a complex pattern of interactions between the high-frequency algorithmic trading

» key insights

- Coalitions of systems, in which the system elements are managed and owned independently, pose challenging new problems for systems engineering.
- When the fundamental basis of engineering—reductionism—breaks down, incremental improvements to current engineering techniques are

Communications of the ACM, 55(7) July 2012

» key insights

- **Coalitions of systems, in which the system elements are managed and owned independently, pose challenging new problems for systems engineering.**
- **When the fundamental basis of engineering—reductionism—breaks down, incremental improvements to current engineering techniques are unable to address the challenges of developing, integrating, and deploying large-scale complex IT systems.**
- **Developing complex systems requires a socio-technical perspective involving human, organizational, social, and political factors, as well as technical factors.**

January 2015 Exam

Question 1

1(a). Describe the key technology developments in the global financial markets that have led to the current situation in which many human traders have now been replaced by automated trading systems.

[10 marks]

1(b). The sociologist Diane Vaughan introduced the phrase "normalization of deviance" in her groundbreaking analysis of the *Challenger* space shuttle accident. Explain what is meant by this phrase, and how Vaughan applied it to the two space-shuttle disasters.

[7 marks]

1(c). Discuss to what extent you think that normalization of deviance is an issue in the current financial markets, and what actions you think regulators should take (if any) to ensure stability in the financial markets.

[3 marks]

Thank you for listening