Death by 32 Bits

RAPID7

4,294,967,296

- Human Population
- IPv4 Addresses
- Fast Networks
- Cheap Memory
- 32-bit Processors

World Population

6 billion+

China

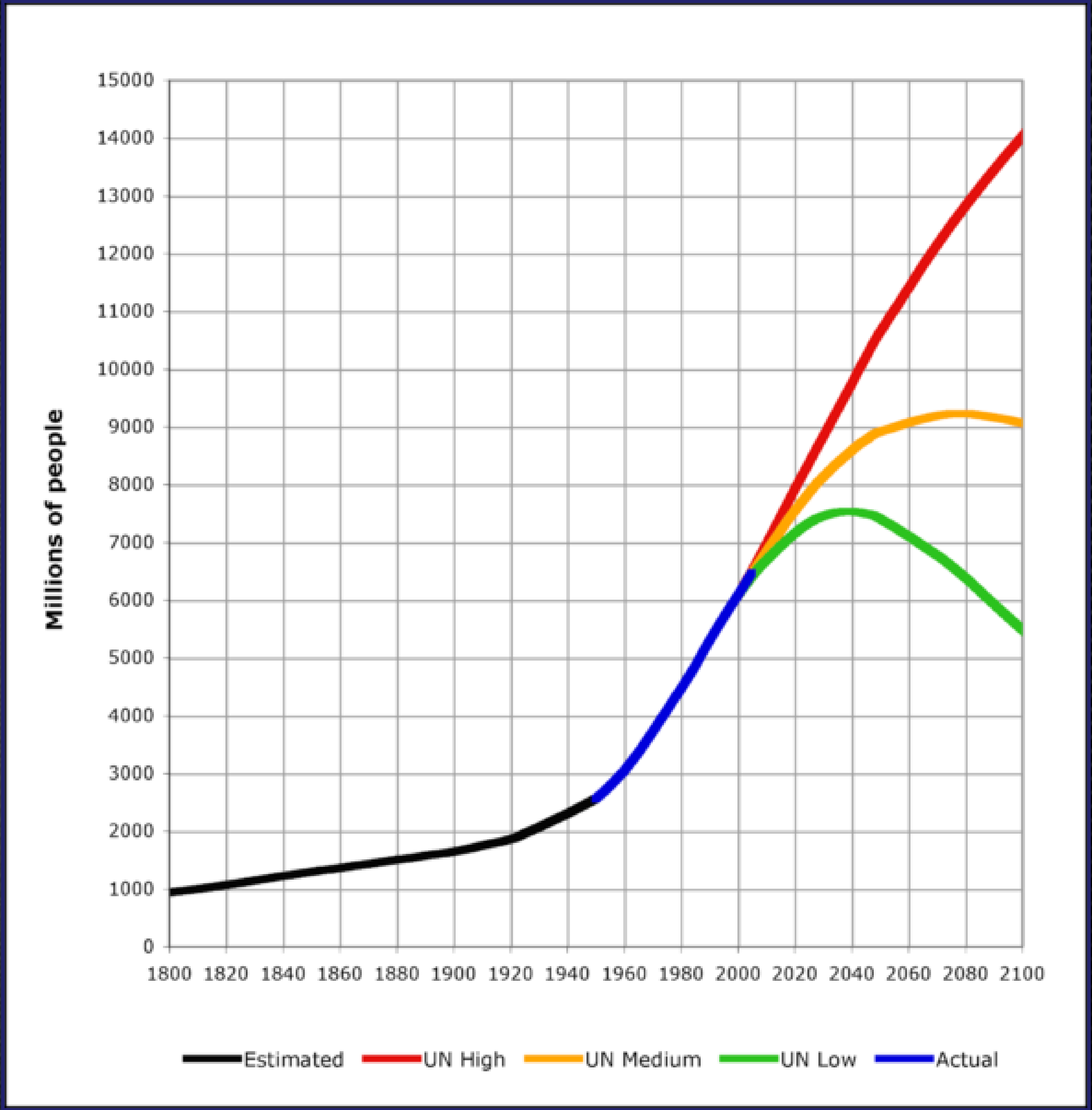
1.3 billion+

India

1.1 billion+

USA

305 million+



Source: http://en.wikipedia.org/wiki/World_population

Internet Usage

China

22.48%

USA

72.35%

Growth Rates

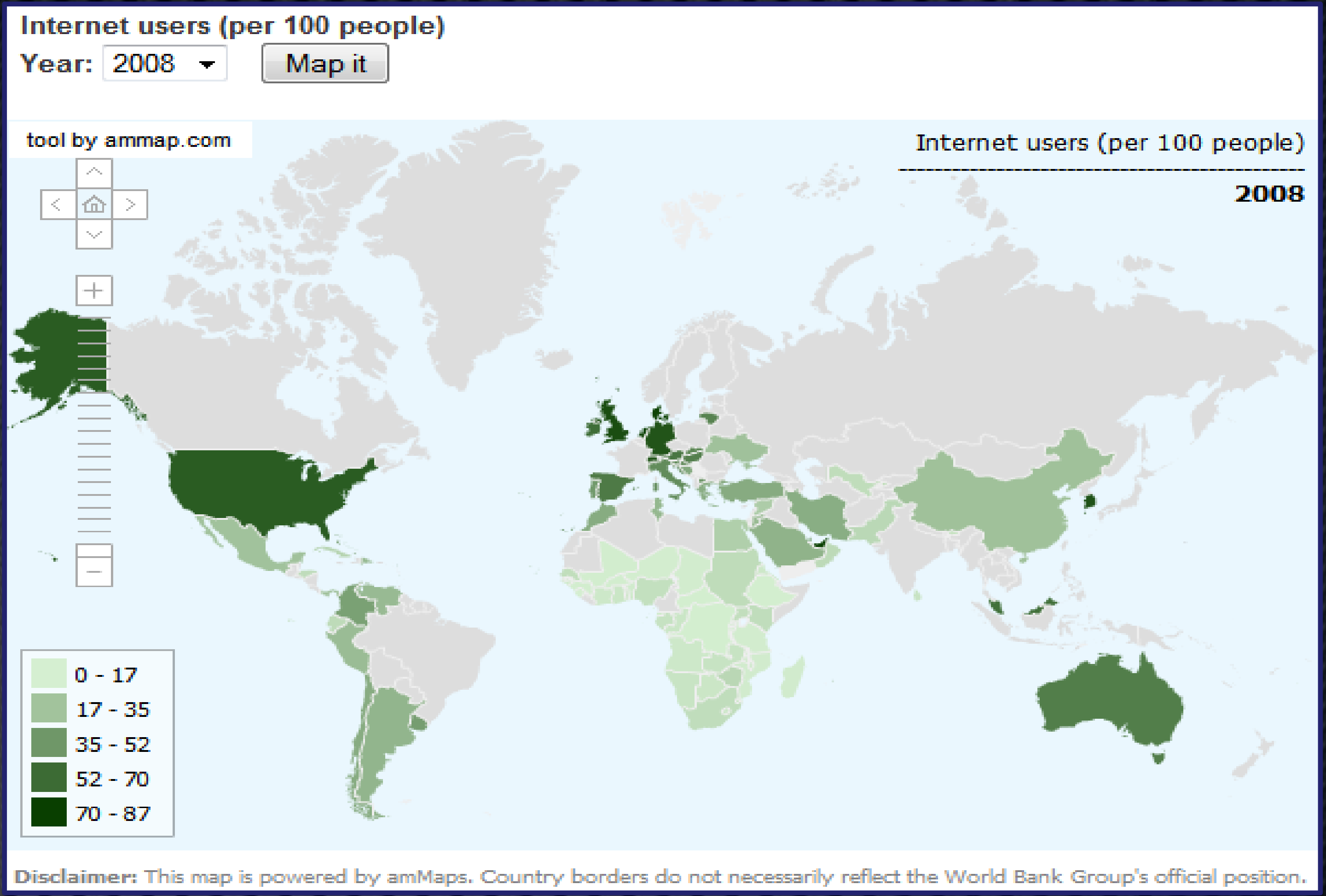
USA

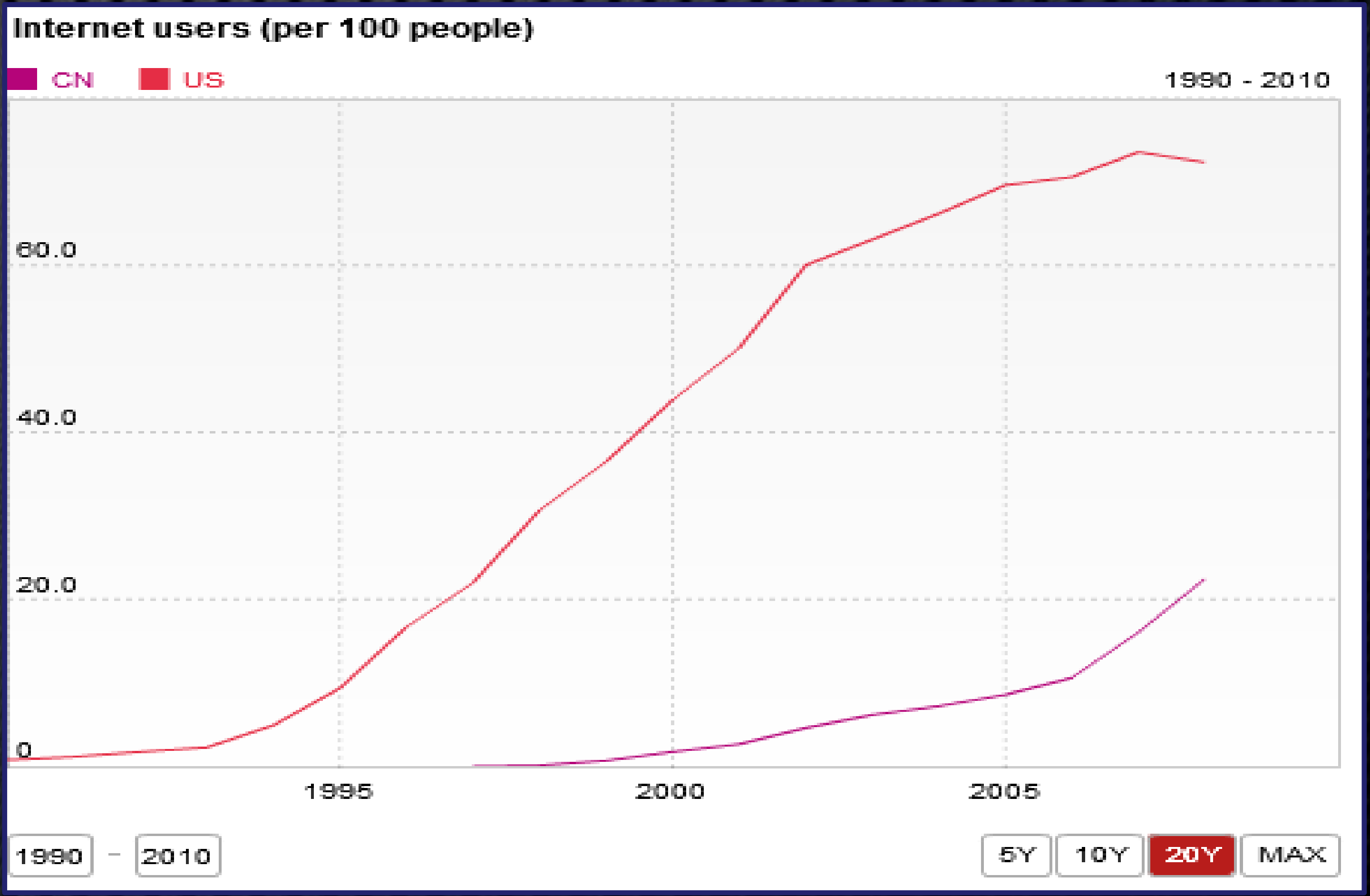
22% 12 years ago

Flat since 2007

China

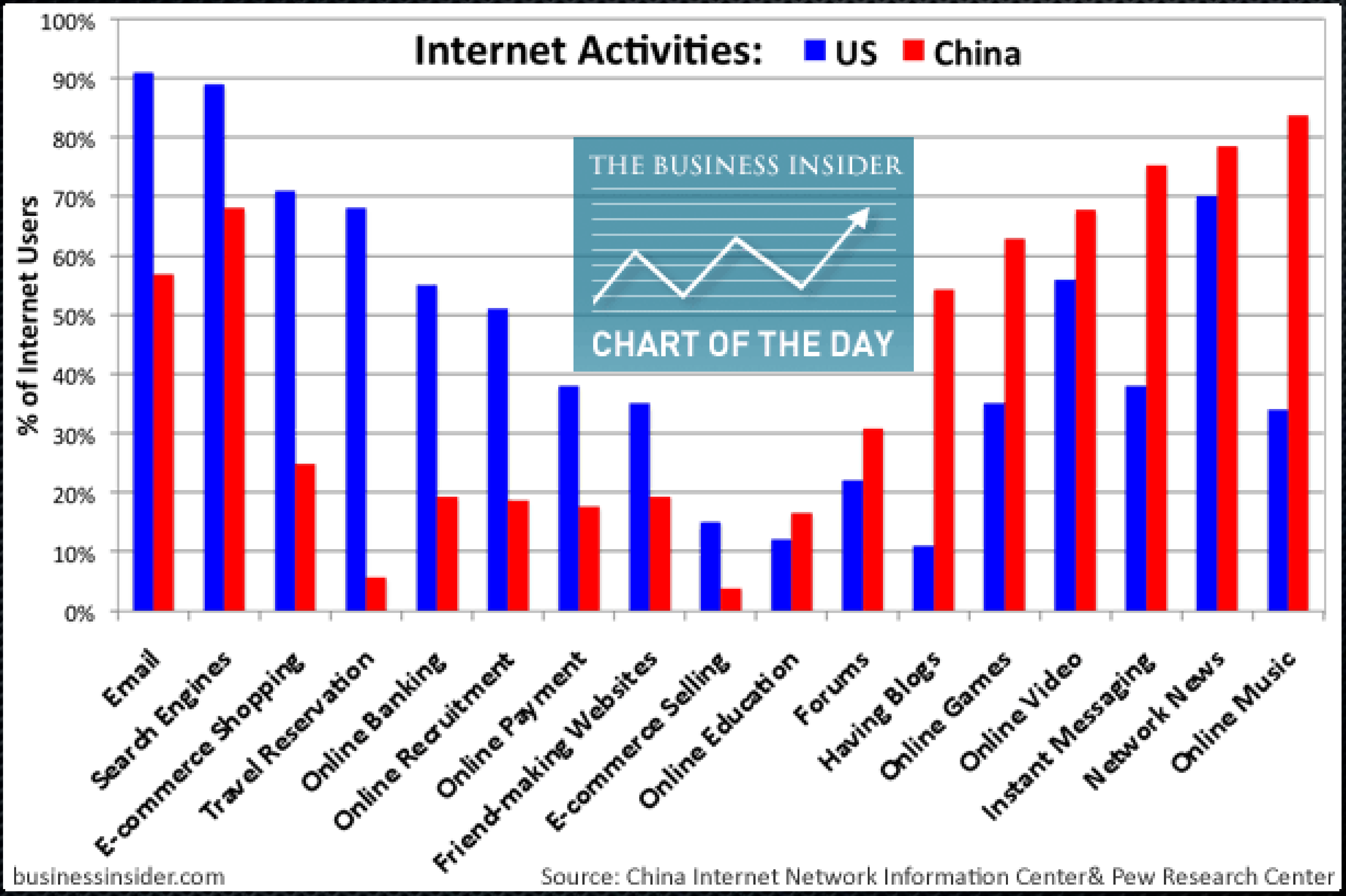
50% by 2012?





Source: http://datafinder.worldbank.org/internet-users

Internet Usage - USA vs China



Internet Population

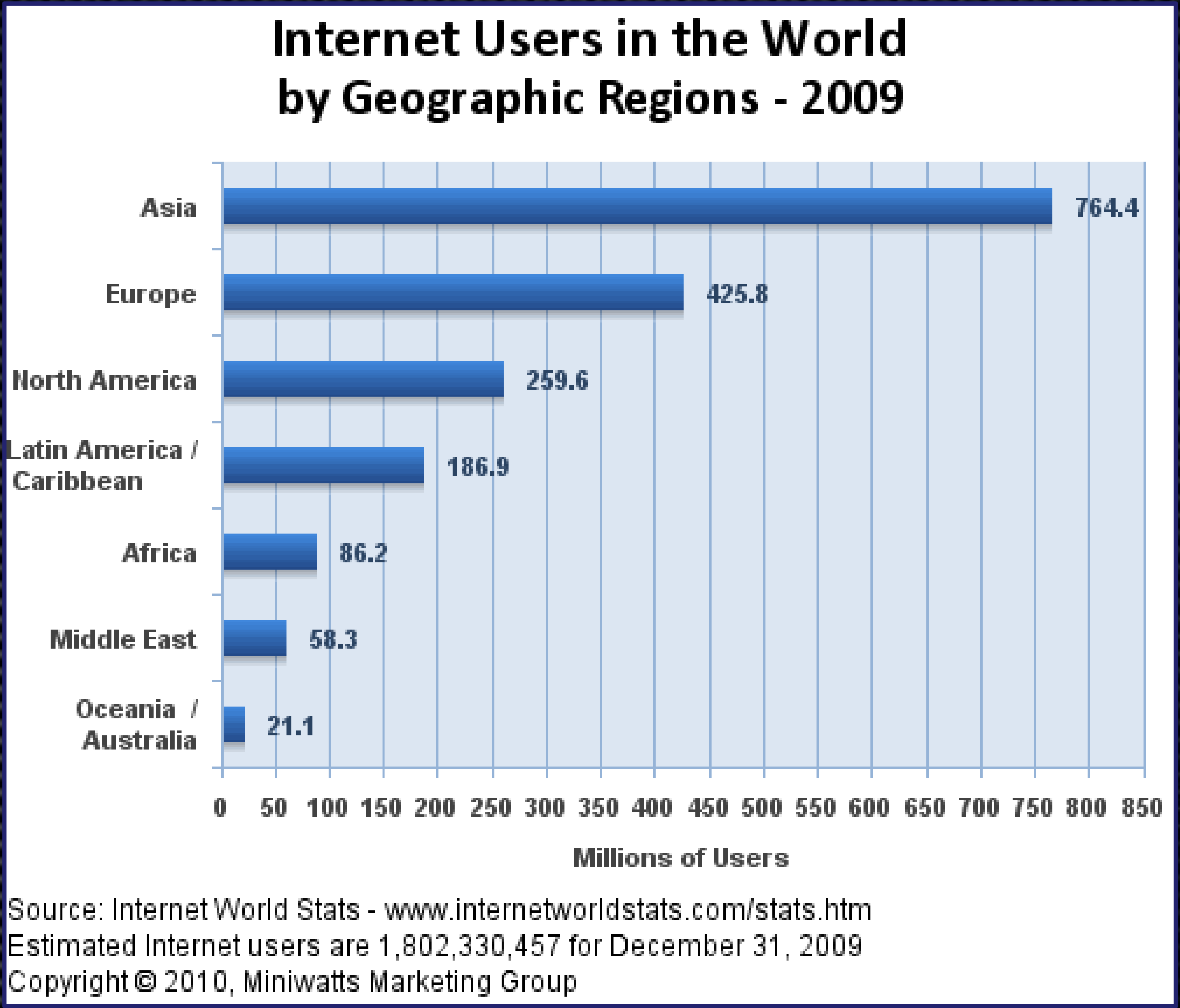
1.8 billion+

China

300 million+

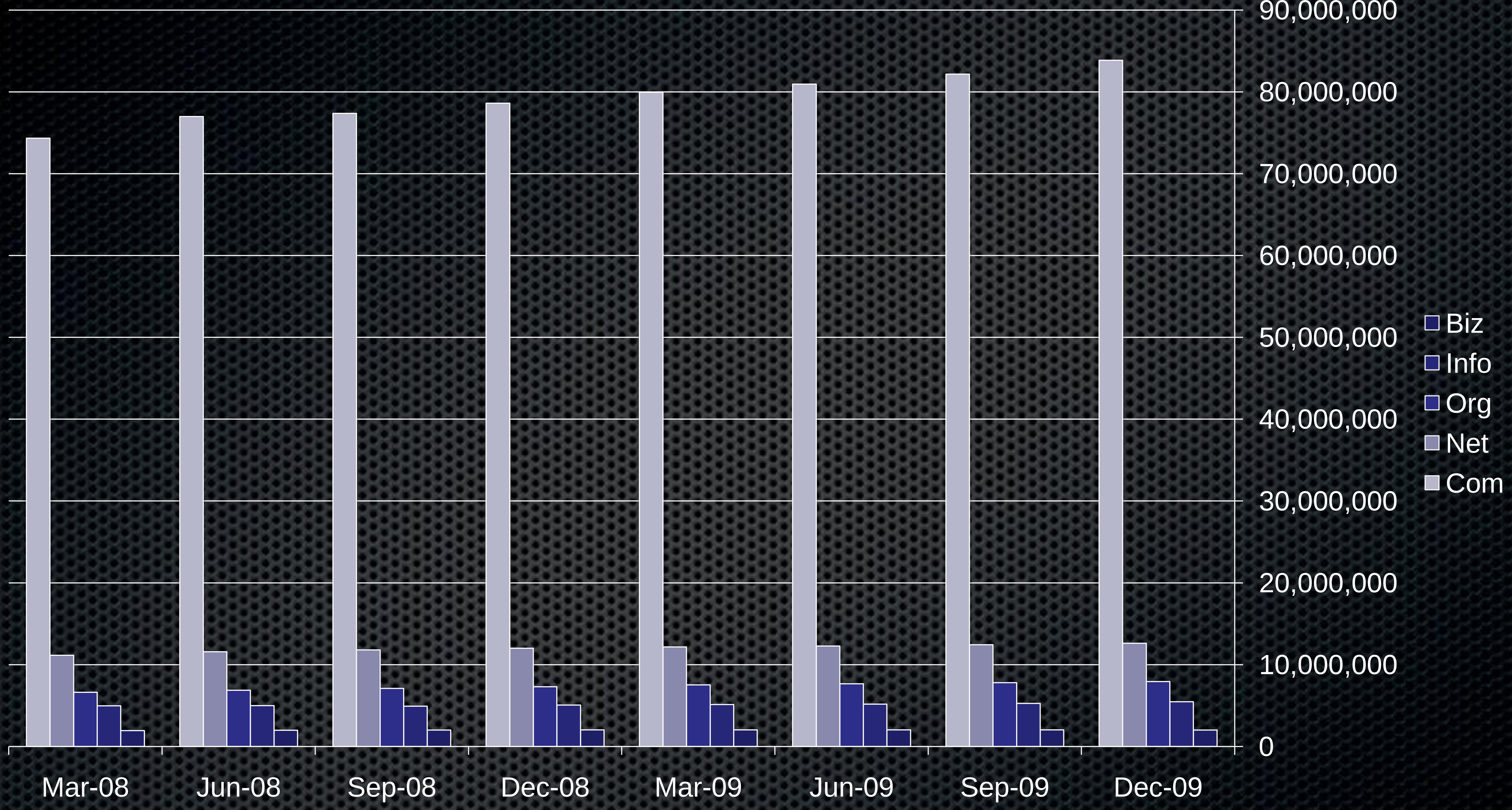
USA

200 million+



1.8 billion is 42% of the 32-bit max

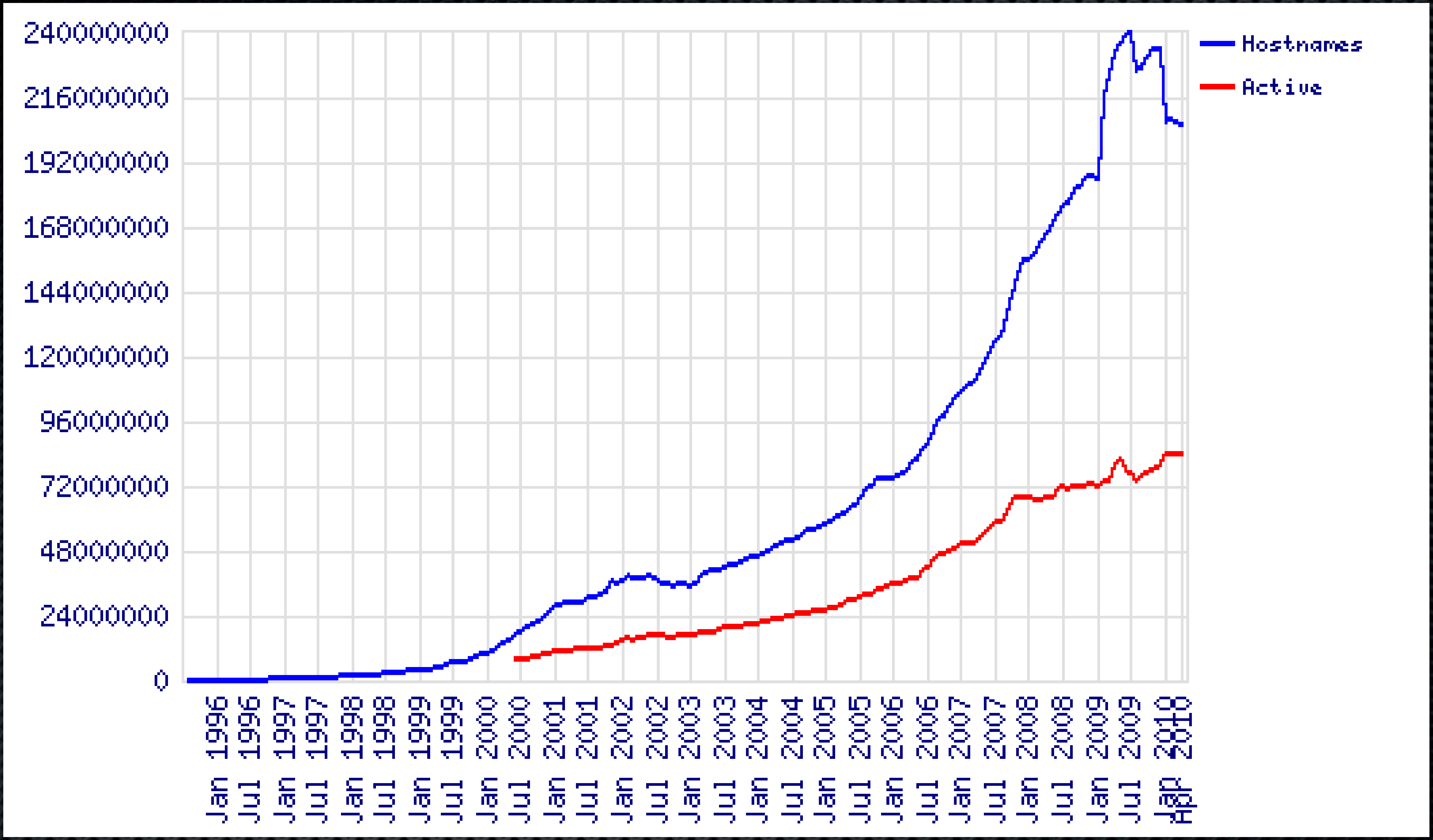
Domain Names: 2008 to 2009



84 million registered .coms

Source: http://www.zooknic.com/Domains/counts.html

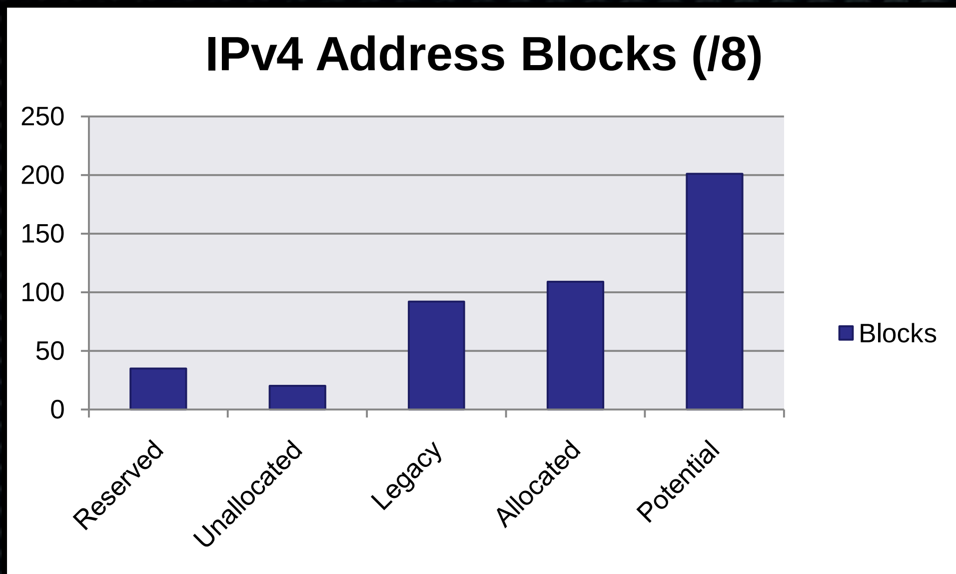
Active Sites: 1996 to 2010 (Netcraft)



84 million active web sites

Definition: http://news.netcraft.com/active-sites.html

Allocated IPv4 Address Space



Total number of IPv4 addresses:		
2^32:	4294967296	4294.97 million
Class D+E:	536870912 -	536.87 million -
Nets 0 and 127:	33554432 -	33.55 million -
RFC 1918:	17891328 -	17.89 million -
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Usable:	3706650624	3706.65 million

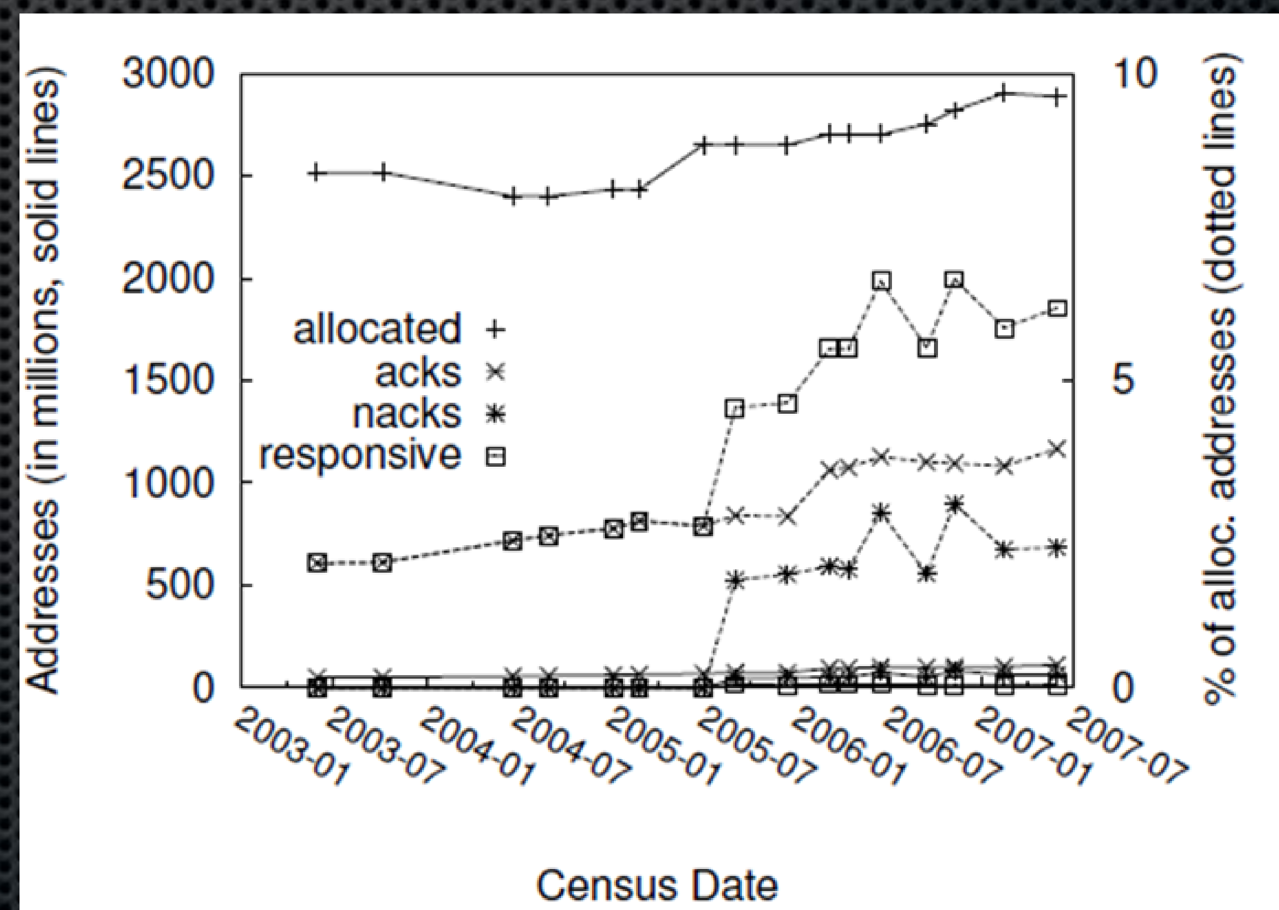
IPv4 Addresses

3.70b possible

3.37b allocated

334m available

~1.7b active*



Source: http://www.iana.org/assignments/ipv4-address-space/ipv4-address-space.txt
Source: http://www.bgpexpert.com/addressespercountry.php
Source: http://www.isi.edu/~johnh/PAPERS/Heidemann08a.pdf

Population vs Domains vs IP Addresses

Approximate ratios

- **1** internet user per 3.72 humans
- **1** user per active IP address
- **9** users per registered hostname
- **17** US residents per 100 users
- **21** users per registered .com
- **21** users per active web site

IP address ratios

- **86%** of the IPv4 space is usable
- **91%** of usable space is allocated
- **50%** of this space is active

Packet Transmission Speed

A 1000 byte packet, once per second

`1000 bytes * 8 bits = 8 kbps`

A 40 byte packet, once per second

`40 bytes * 8 bits = 0.32 kbps`

A 100m ethernet network card

`1514 bytes * 8 bits = 12.12 kb`

`1514 bytes * 8246/sec = 100 Mbps`

`40 bytes * 312500/sec = 100 Mbps`

Reality is more complicated (IPG, software)

`Decent server can send about 50k pps`

`Bandwidth required is 400k/byte`

Network Bandwidth vs IPv4 Space

Single-request TCP exploit (conn + send)

`3.5 days = 3.37b * 4 @ 50k pps`

Single-packet exploit to ALL allocated IPs

`19 hours = 3.37b @ 50k pps`

Single-packet exploit vs US

`8.34 hours = 1.50b @ 50k pps`

Single-packet exploit vs China

`1.37 hours = 247m @ 50k pps`

Single-packet exploit vs Russia

`10.3 minutes = 31m @ 50k pps`

Network Bandwidth vs Clouds

Bandwidth is relatively cheap

- Small packets = low bandwidth
- Billing is based on "transfers"

Clouds makes blocking the source hard

- Get a new IP anytime you like
- Handy for penetration tests

Clouds make internet-wide attacks easy

- 10 servers = Russia in 60 seconds
- Cost = ~$50.00 USD

IPv6 – 128 bits of fun

Network ranges become "unscannable"

- Hosts are allocated a /64 each

Finding systems becomes the hard part

- Local networks are discoverable
- Remote networks depends on DNS

Legacy software rarely binds to IPv6

- Fewer extra services running

Still some downsides

- Not all firewalls block IPv6 correctly
- Easy to hide remote rogue systems
- Hosts are IPv6 ready, users are not

System Memory Pricing

RAM is cheap

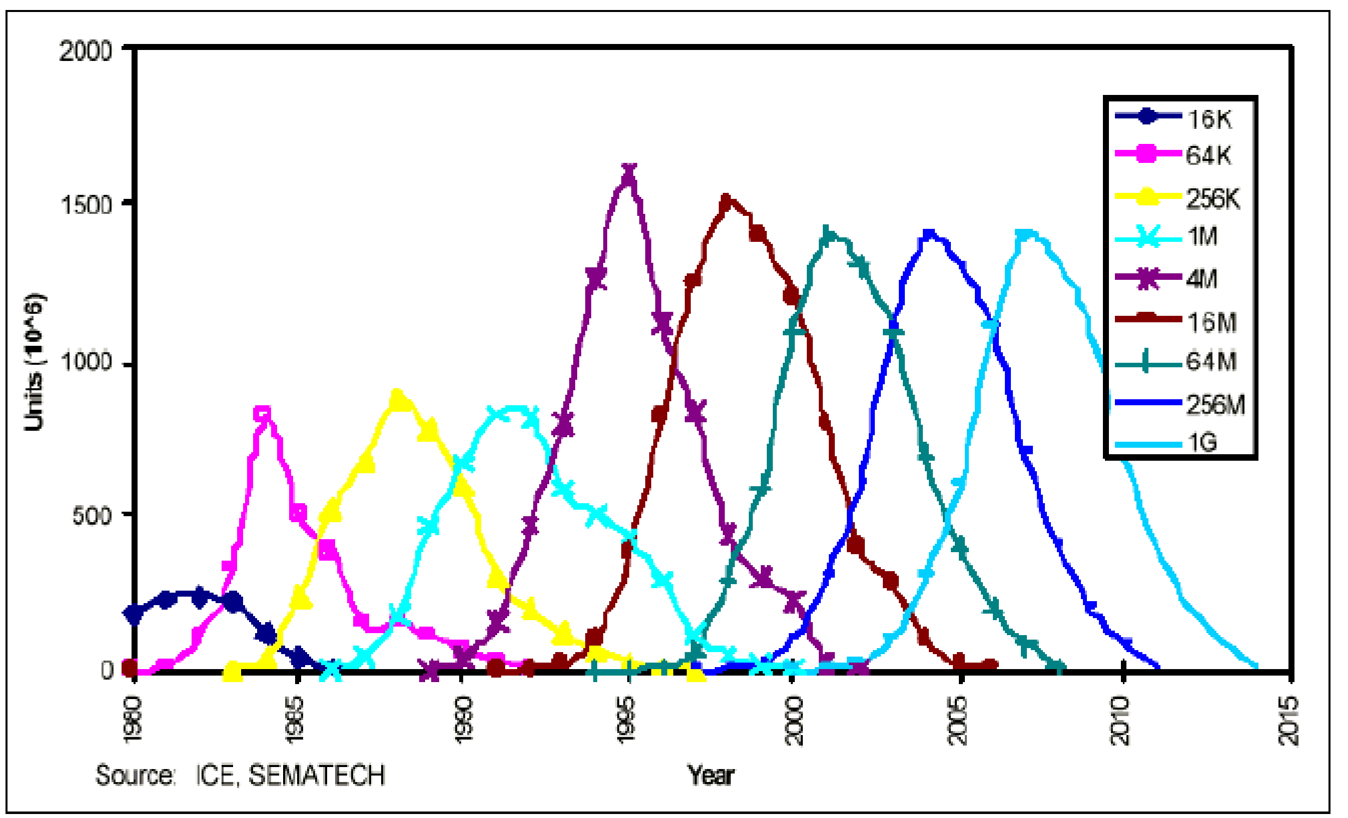
- $23.00 for 1Gb (DDR3 @ 1333Mhz)
- $0.02 per megabyte
- Netbooks ship with 1G or 2g
- Video cards “average” 512M

Supply drives price

- 6 years to peak

Old RAM costs more

- Based on supply



DRAM Unit Volume by Generation [37]

Source: http://www.pricewatch.com/system_memory/
Source: http://www.tezzaron.com/about/papers/dram_pricing.pdf
Source: http://store.steampowered.com/hwsurvey/

System Memory Availability

Cheap RAM increases software requirements

- Windows 2000 **32Mb minimum**
- Windows 7 **1024Mb minimum**
- Office 2000 **8Mb minimum (+OS)**
- Office 2010 **256Mb minimum (+OS)**

Gamers (as usual) are a good indicator of trend

84% have 2Gb or more
27% have 4Gb or more
4% have less than 1G

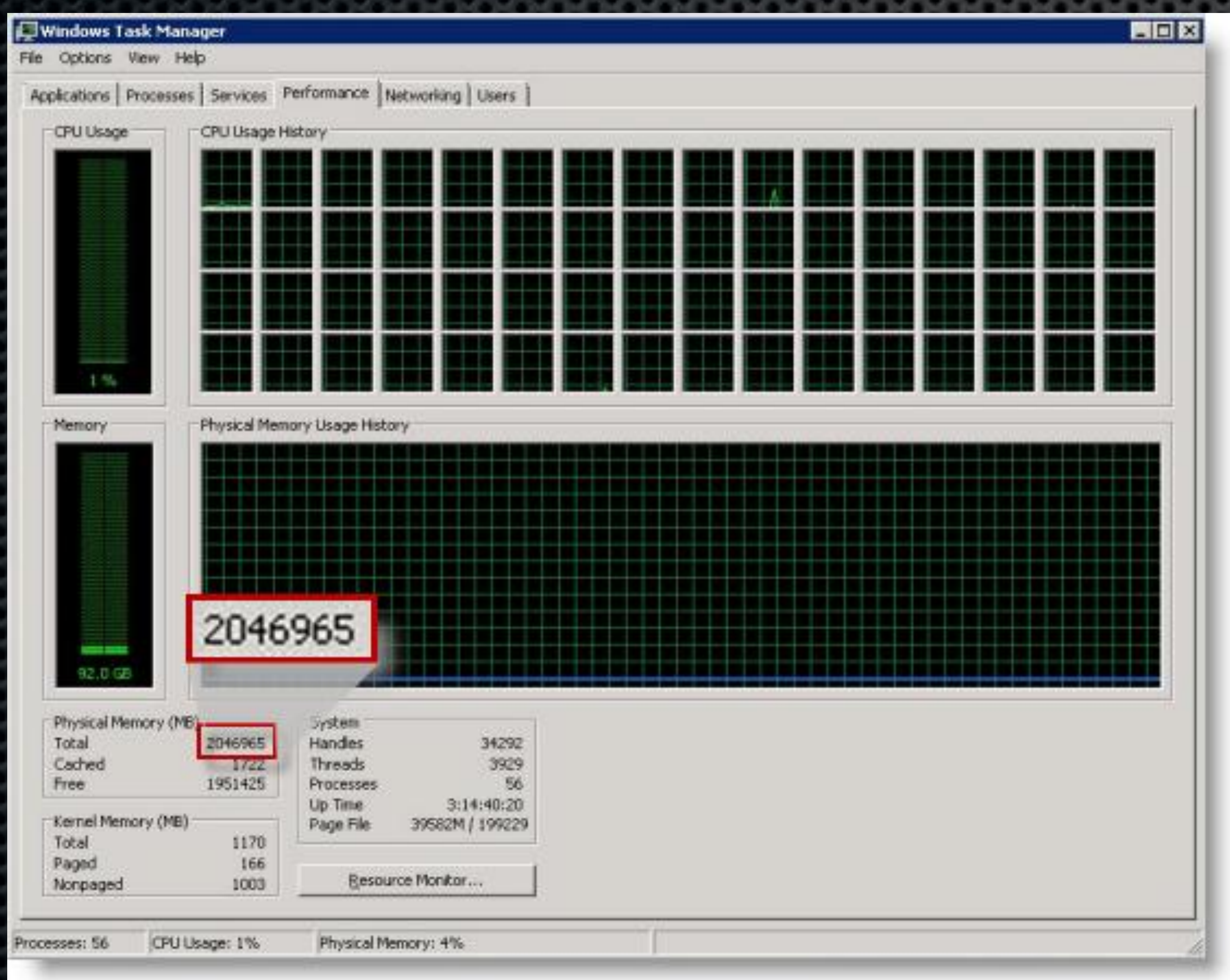
Less than 512 MB	(-0.13%)	0.66%
512 Mb to 999 MB	(-0.31%)	3.88%
1 GB	(-0.33%)	10.93%
2 GB	(-0.69%)	**28.82%**
3 GB	(0.00%)	28.09%
4 GB	(+0.76%)	18.19%
5 GB and higher	(+0.70%)	9.43%

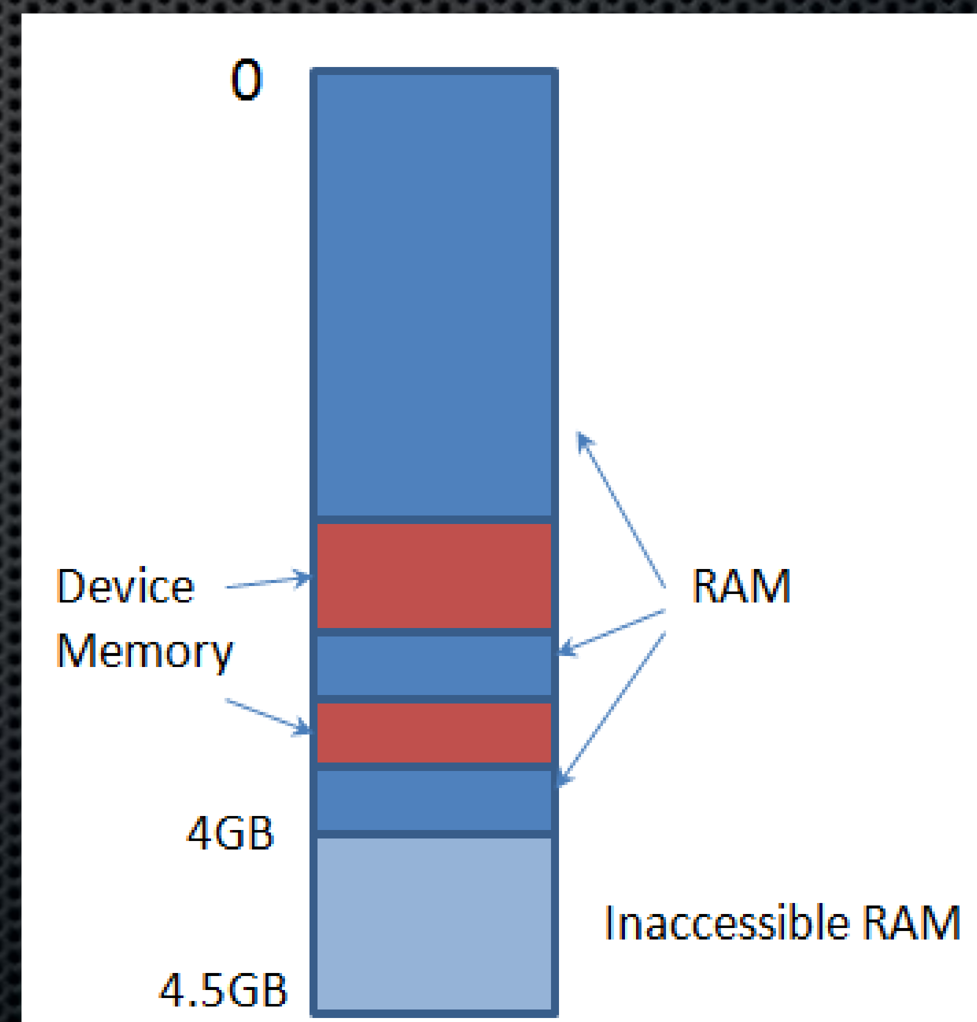
Source: http://store.steampowered.com/hwsurvey/

System Memory vs 32-bit Processors

32-bit CPUs can only address 32-bits of memory

- Virtual memory must also include device I/O
- PAE and other tricks help, but are not efficient
- Real maximum is between 2.0Gb and 3.5Gb





Source: http://blogs.technet.com/markrussinovich/archive/2008/07/21/3092070.aspx

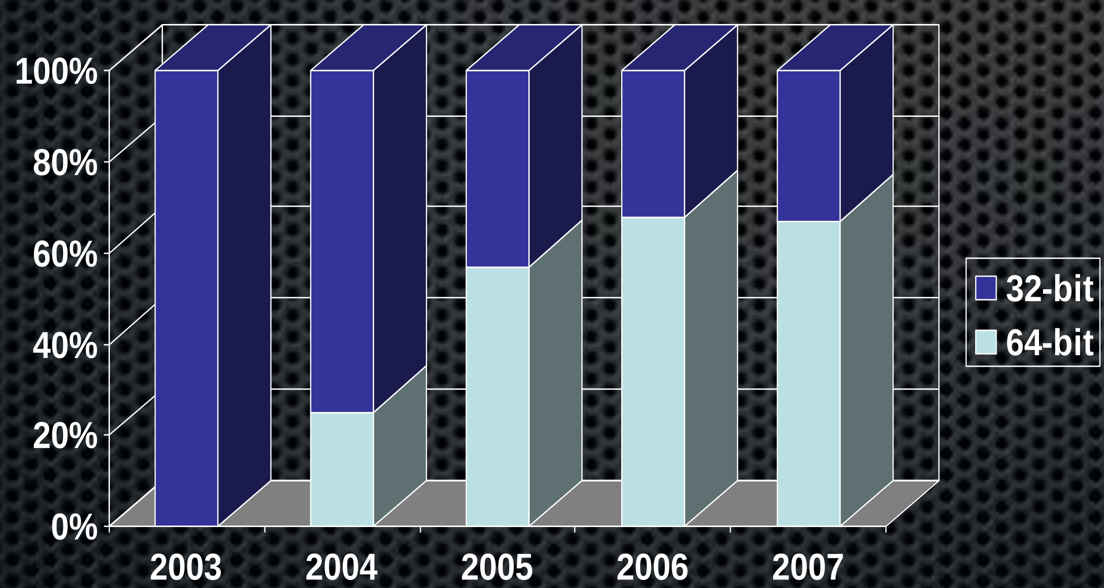
32-bit vs 64-bit Penetration

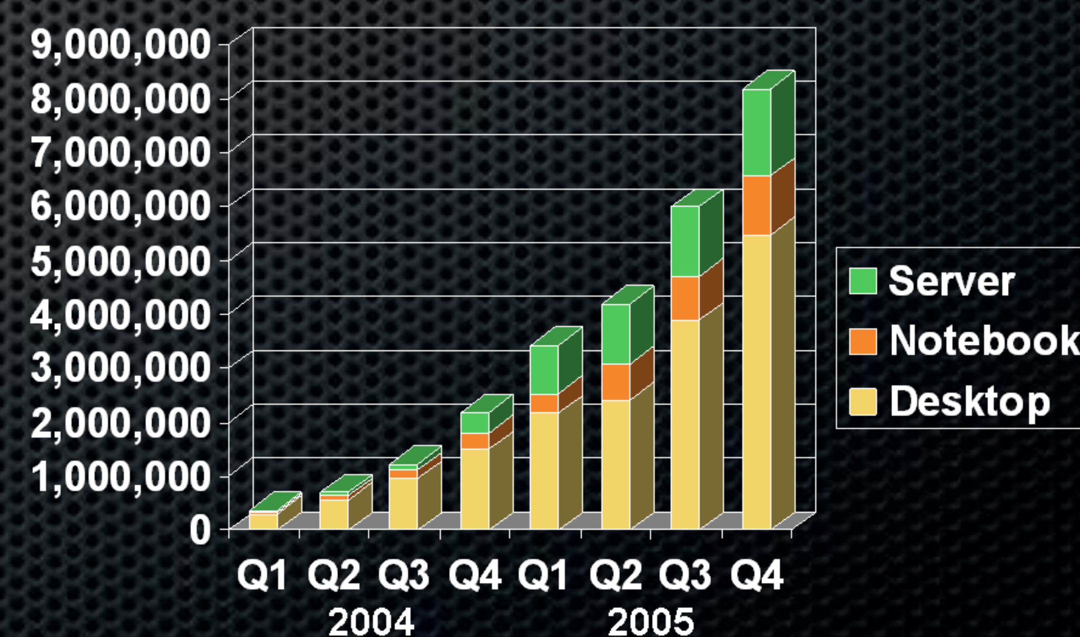
We turn to the Gamers for trends

- **33%** run 64-bit Windows
- **28%** run 32-bit Vista / 7
- **54%** of Vista / 7 are 64-bit!

Windows XP 32 bit	(-1.72%)	38.61%
Windows 7 64 bit	(+1.43%)	24.42%
Windows Vista 32 bit	(-0.19%)	16.69%
Windows 7	(+0.33%)	11.25%
Windows Vista 64 bit	(+0.15%)	7.75%
Windows XP 64 bit	(+0.02%)	0.62%
Windows 2003 64 bit	(-0.03%)	0.44%
Windows 2000	(+0.10%)	0.10%
Other	(-0.08%)	0.12%

Great stats from Microsoft WinHEC 2006





Source: http://store.steampowered.com/hwsurvey/

Source: http://download.microsoft.com/download/5/b/9/5b97017b-e28a-4bae-ba48-174cf47d23cd/BUS080_WH06.ppt

32-bit Exploit Mitigations

Newer operating systems try to block exploits

- Prevent execution of data: DEP + NX
- Limit predictability of memory: ASLR
- Limit exception handlers: /SafeSEH
- Prevent return address overwrites: /GS

Newer techniques bypass most if not all

- Bypass /GS with smashed exception handlers
- Sometimes bypass /SafeSEH with VEH
- Bypass DEP with Return-Oriented-Programming (ROP)
- Bypass ASLR with heap spraying or brute forcing

Security mitigations are limited by the 32-bit platform

32-bit Integers

x86 integers indicate sign in the high bit

- **`0x00000001`** = 1 signed or 1 unsigned
- **`0xFFFFFFFF`** = -1 signed or 4,294,967,296 unsigned
- **`0x7FFFFFFF`** = 2,147,483,647
- **`0x80000000`** = -2,147,483,648

Even smart coders didn't account for huge input

```
int i = strlen(input); // casting bug
if (i < MAX_LEN)
  badness();
```

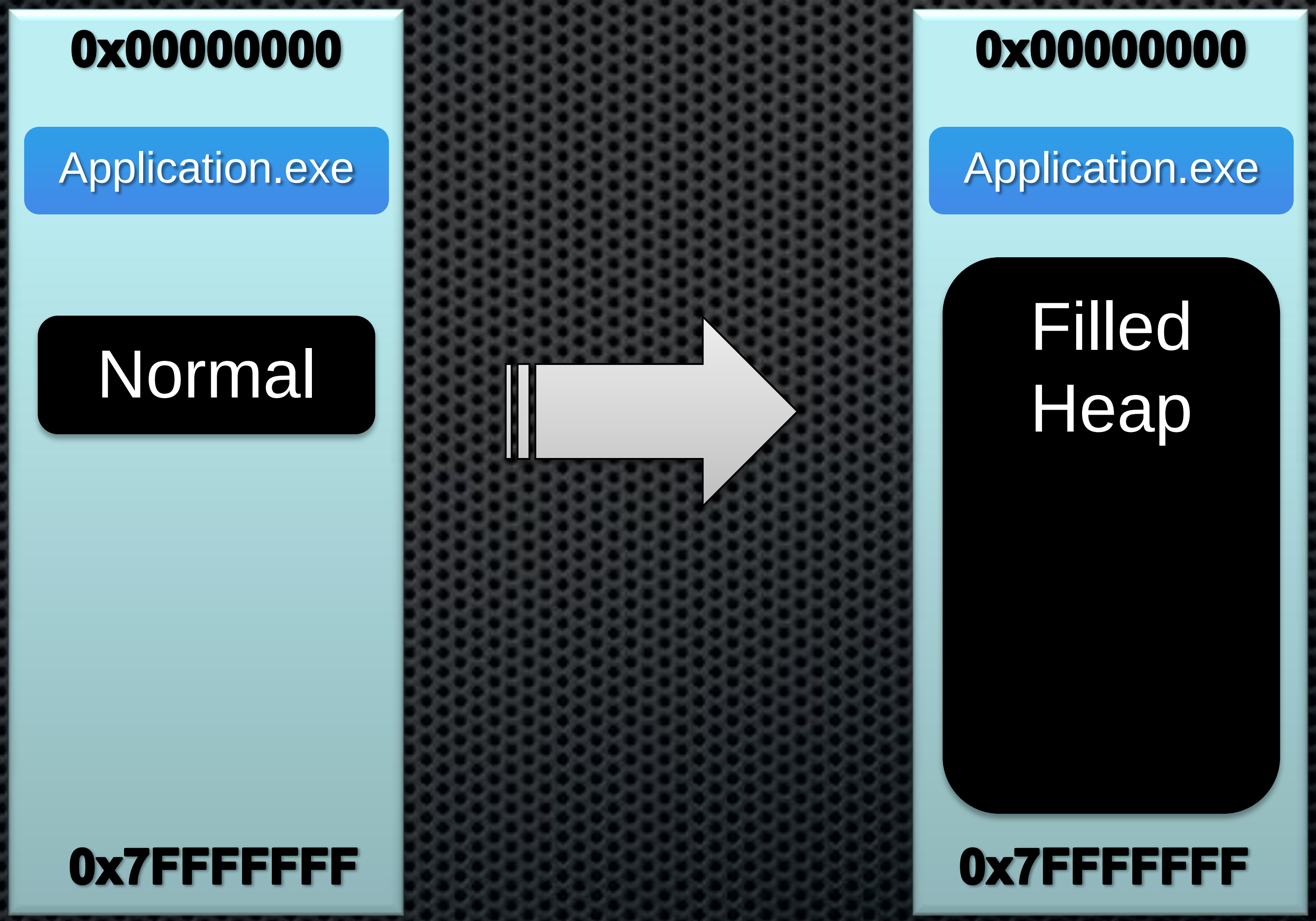
Solutions for legacy code?

- Set process memory limits to under 2G
- Force migration to 64-bit platforms

32-bit Memory Prediction

The 32-bit virtual memory space is relatively tiny

- Attacker supplied files or scripts negate ASLR
- Most client-side applications are vulnerable
- Address prediction leads to DEP bypass



32-bit Attacker Memory Control

The user process is normally limited to 2Gb

- Transferring 2Gb of data is not feasible (yet)
- Client-side code can easily allocate memory
  - Javascript, Java, Flash, .NET, etc

Trivial to do without client-side scripting

- Builtin protocol compression (gzip, deflate)
- Compressed containers (docx, odt, zip, ole)
- Compressed graphics and sound (mp3, png)

Often possible against server-side applications

- Protocol compression works as well (SSL)
- XDR and NDR encoding control allocations
- HTTP Content-Length and File Uploads

32-bit Memory Control via Graphics

24-bit graphics are ubiquitous

- Pixels stored as one byte for Red, Blue, and Green
- 32-bit graphics include one byte alpha channel
- Allows for 16.7 million colors per pixel plus alpha
- Memory allocation determined by dimensions

Examples

- 1 x 1 white block with no transparency

  `FF FF FF 00`

- 32 x 32 white block with full transparency

  `FF FF FF FF x 1024 (4096 bytes)`

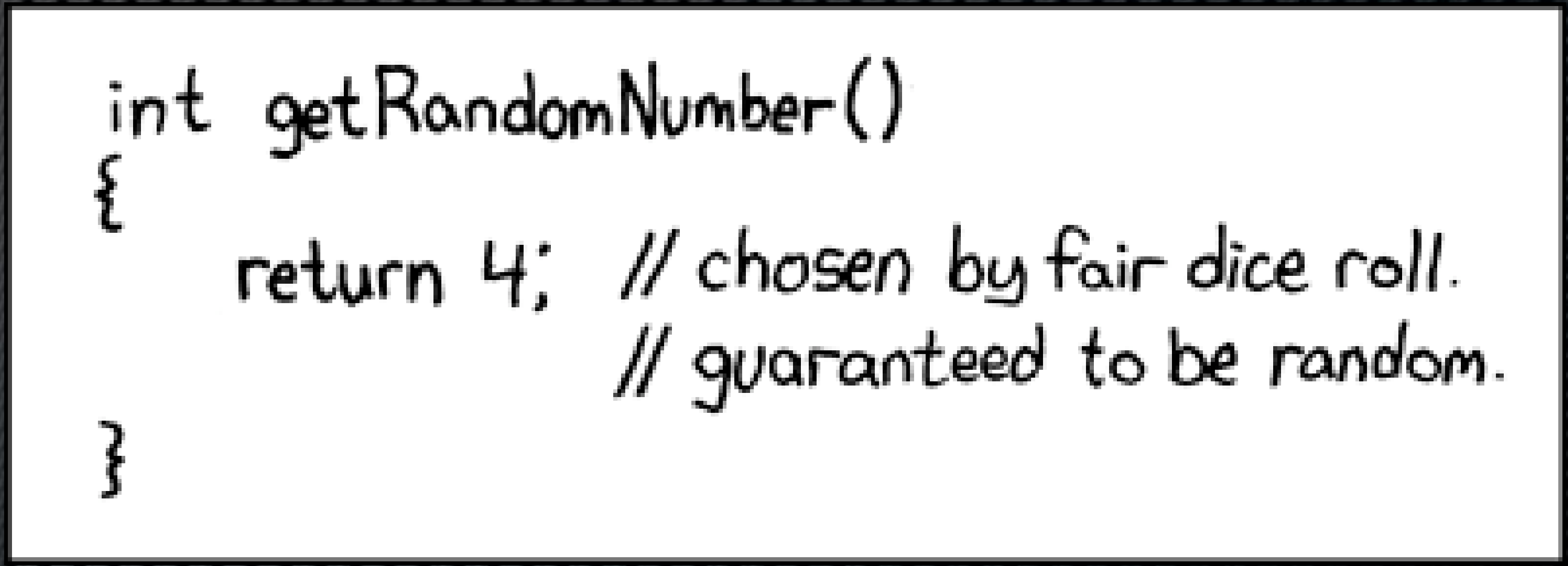
- 16384 x 16384 image for x86 “debug trap”

  `CC CC CC CC x 268435456 (1Gb+)`

32-bit Application Security

Eulogy

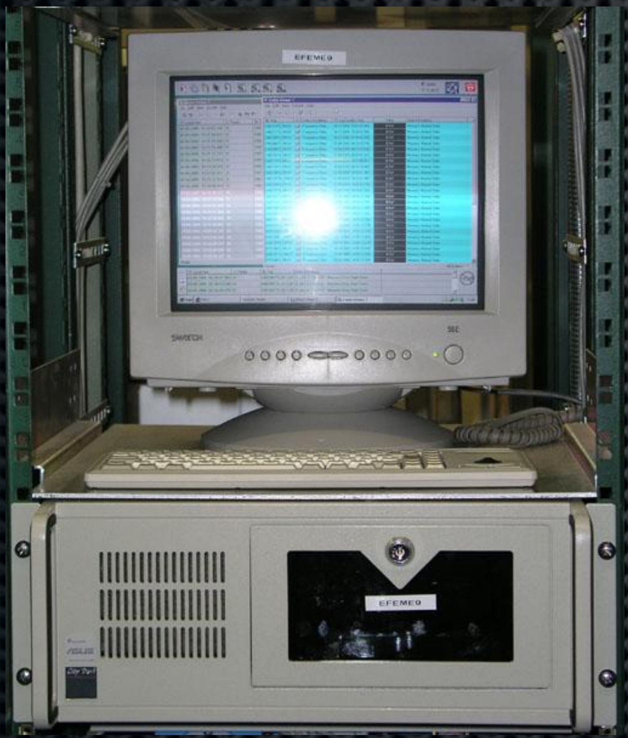
- 32-bit app developers never expected 2 Gb of input
- Mitigation methods are limited by the platform
- Only so random a 32-bit value can become



32-bit Legacy

32-bit is here to stay

- 32-bit x86 is the “new” platform for SCADA gear
- x64 is backwards compatible with 32-bit x86
- Embedded CPUs are primarily 32-bit (ARM, MIPS)



64-bit Application Security

64-bit computing has numerous security benefits

- No need for software DEP, NX is built-in
- The stack is non-executable by default
- Randomization actually effective (48-bits)
- Better kernel protection in Windows
- ELF64 ABI mandates register passing

“This is the end of exploit development” - <censored>

64-bit Application Security

64-bit builds can actually be less secure

- Qmail on 64-bit is trivially exploitable (and unpatched)
- Problems when 64-bit pointers meet 32-bit integers
- Windows 64-bit still runs exploitable 32-bit apps
- Unexploitable 32-bit bugs become possible
- Return Oriented Programming (ROP) still possible

4,294,967,296

is a small number after all

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