Creating Inflections


QUALCOMM
Panasonic


NVIDIA

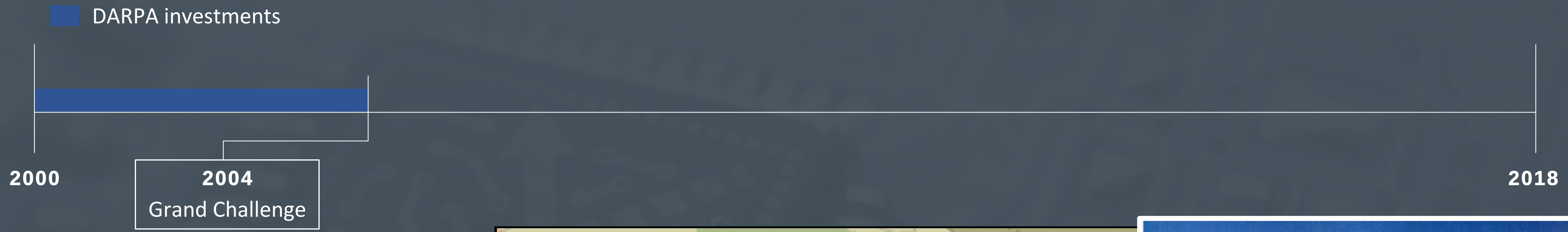

intel
AUTONOMOUS DRIVING
CLOUD
ARTIFICIAL INTELLIGENCE
CAR

DARPA investments

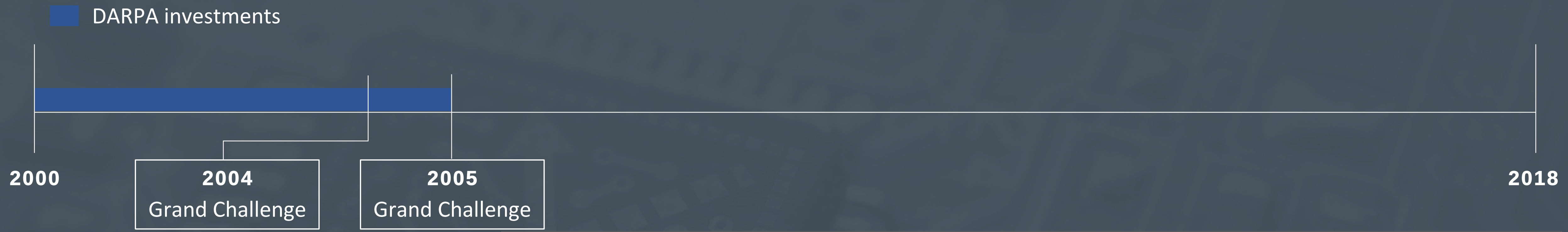
2000

2004
Grand Challenge

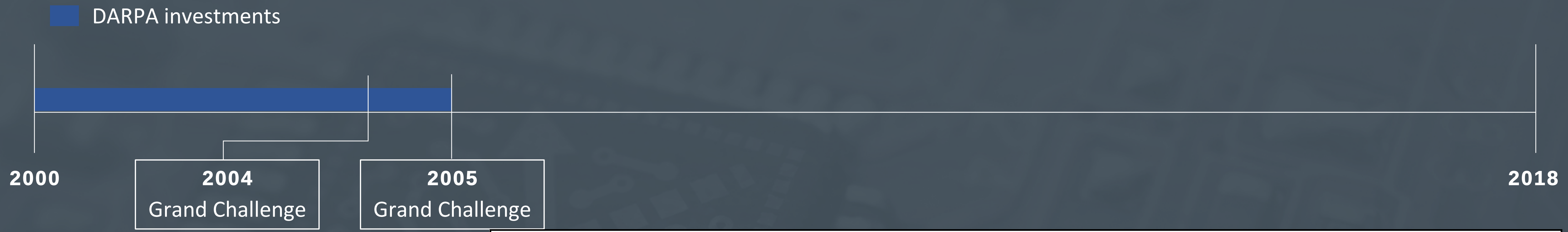
2018



Year 1


DARPA investments
2000
2004
Grand Challenge
2005
Grand Challenge
2018

Year 2


DARPA investments
2000
2004
Grand Challenge
2005
Grand Challenge
2018

Year 2

DARPA investments

2000

2004
Grand Challenge

2005
Grand Challenge

2018

Year 2

DARPA investments

2000

2004
Grand Challenge

2005
Grand Challenge

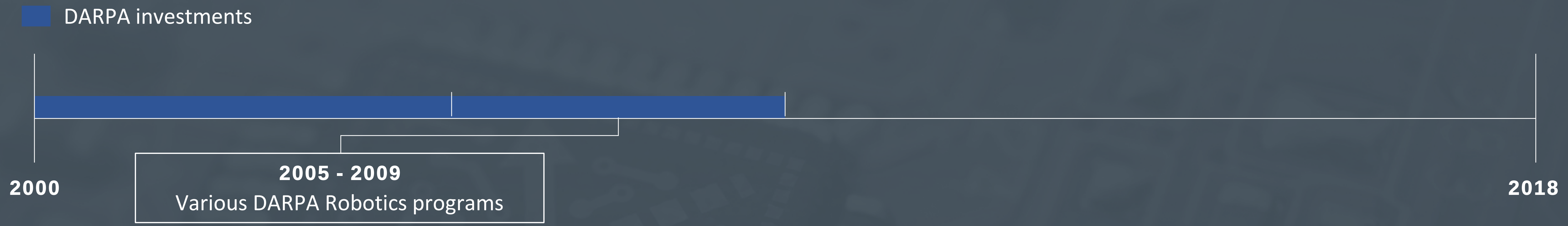
2018

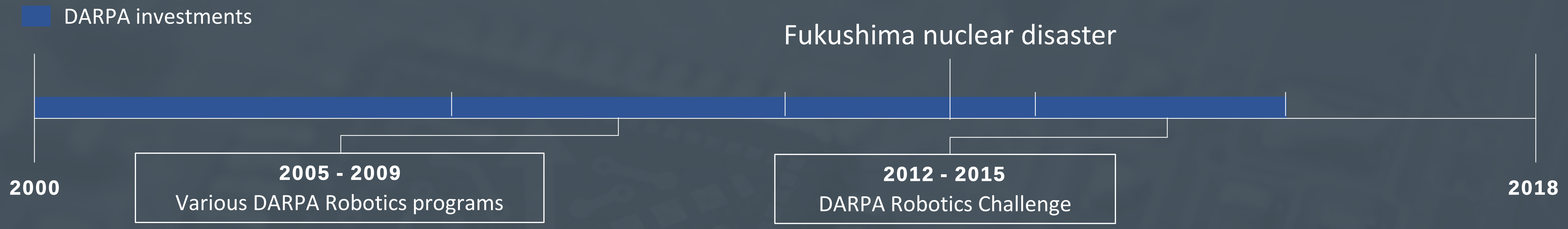
Year 2


DARPA investments
industry efforts
Self Driving Industry
2000
2004
Grand Challenge
2005
Grand Challenge
2007
Urban Challenge
2016
ACTUV Launch
2018

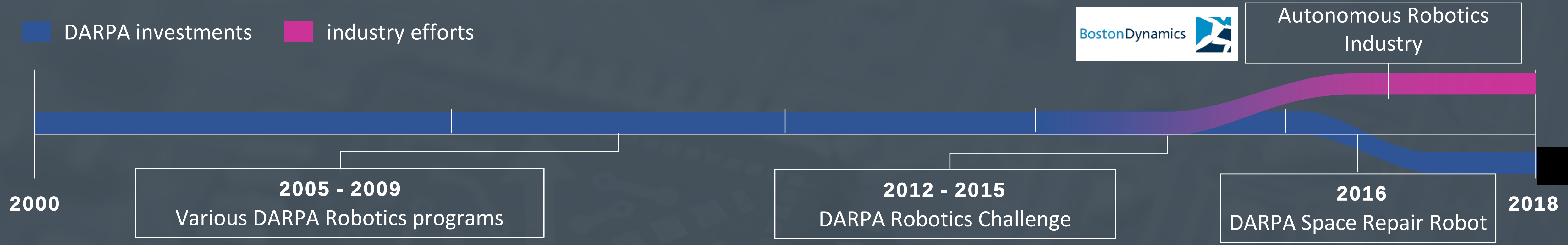

NVIDIA.

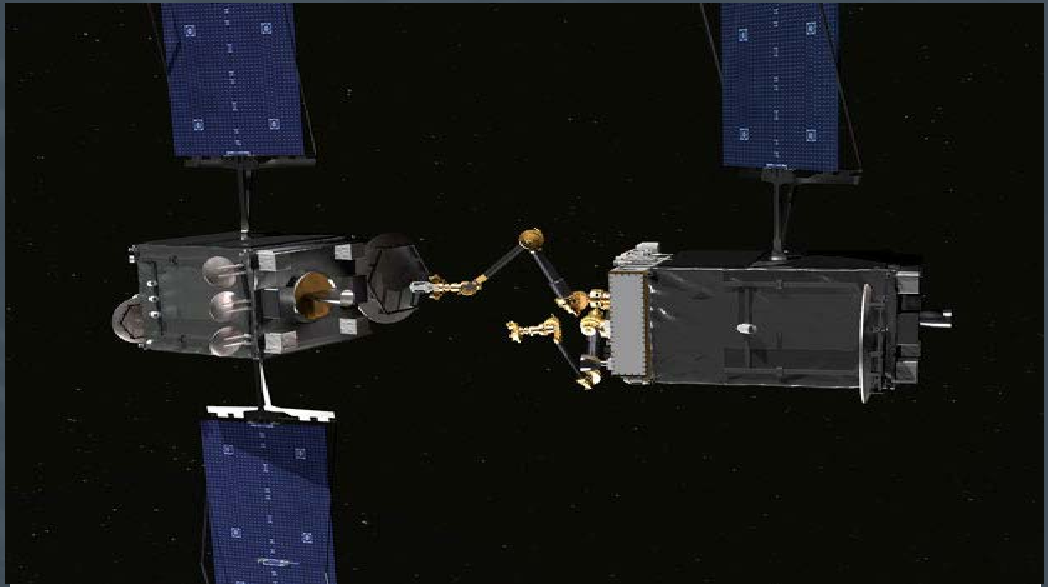

intel
AUTONOMOUS DRIVING


DARPA investments
2000
2005 - 2009
Various DARPA Robotics programs
2018



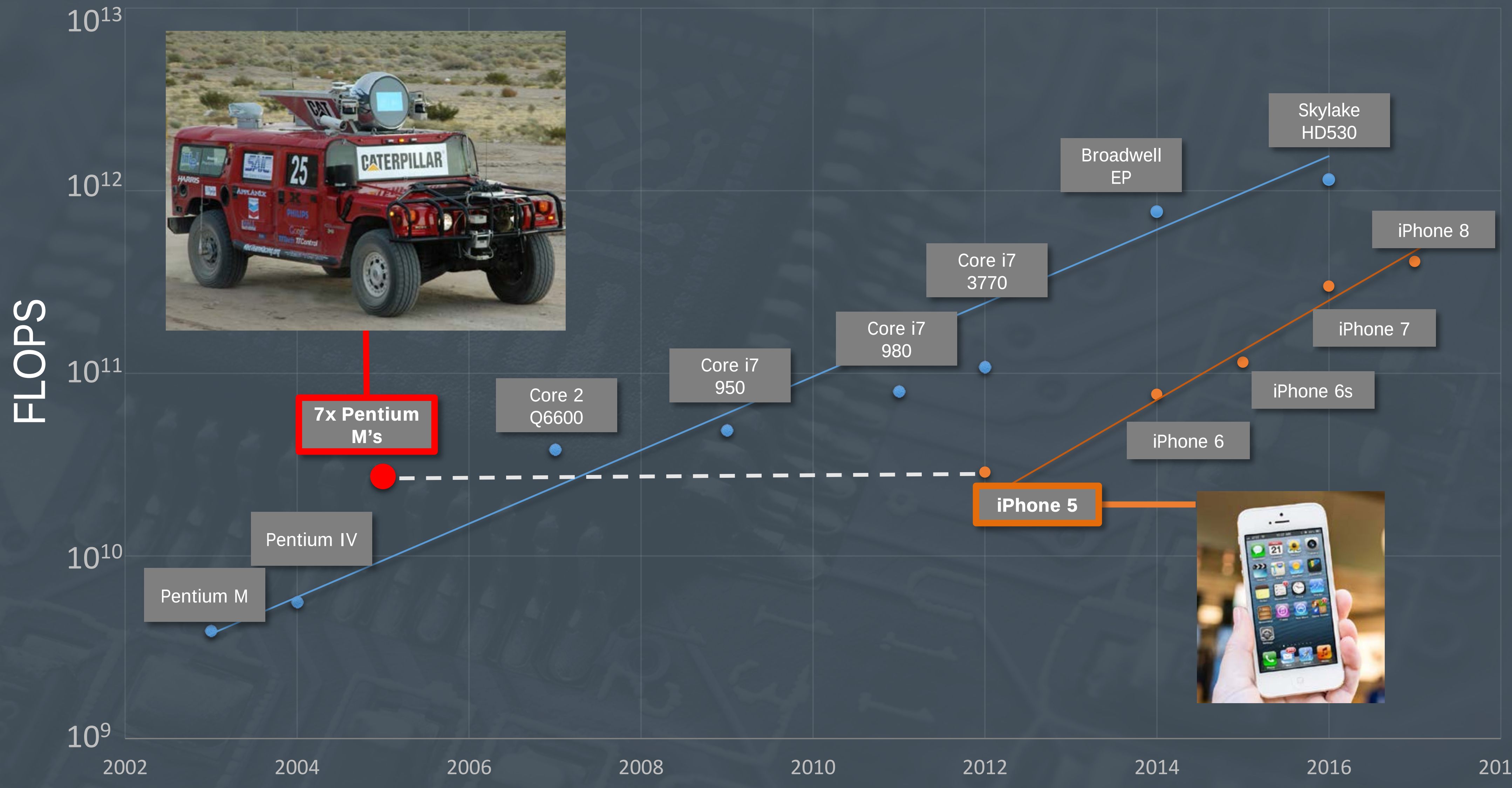
DARPA ROBOTICS CHALLENGE

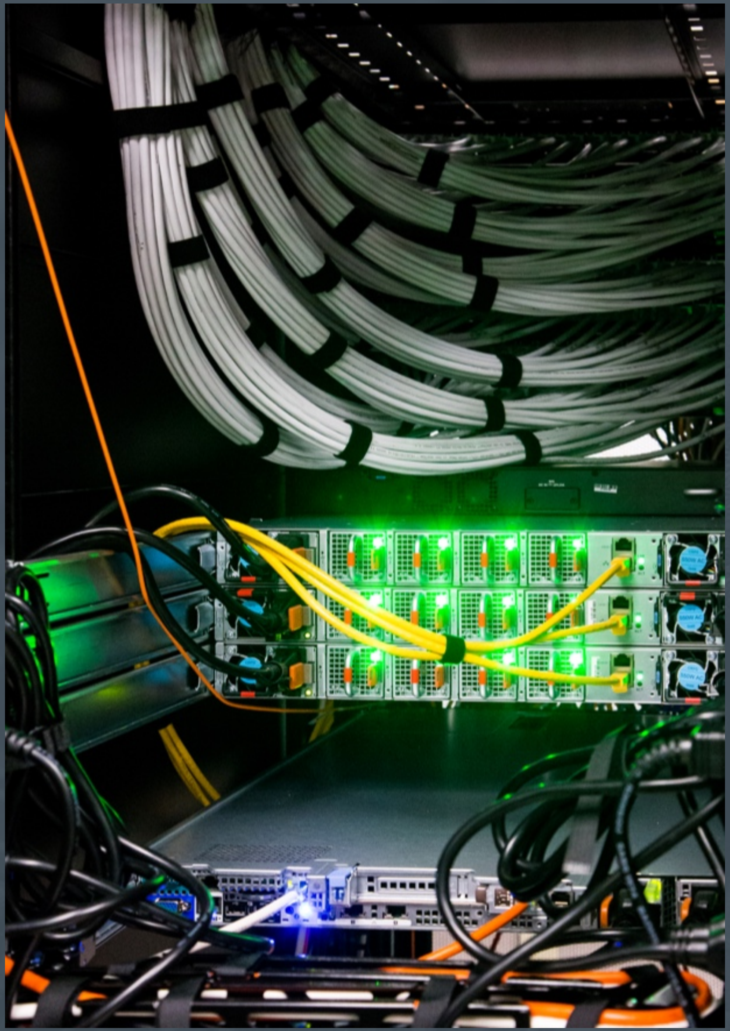

DARPA investments
industry efforts
Autonomous Robotics Industry
2000
2005 - 2009
Various DARPA Robotics programs
2012 - 2015
DARPA Robotics Challenge
2016
DARPA Space Repair Robot
2018



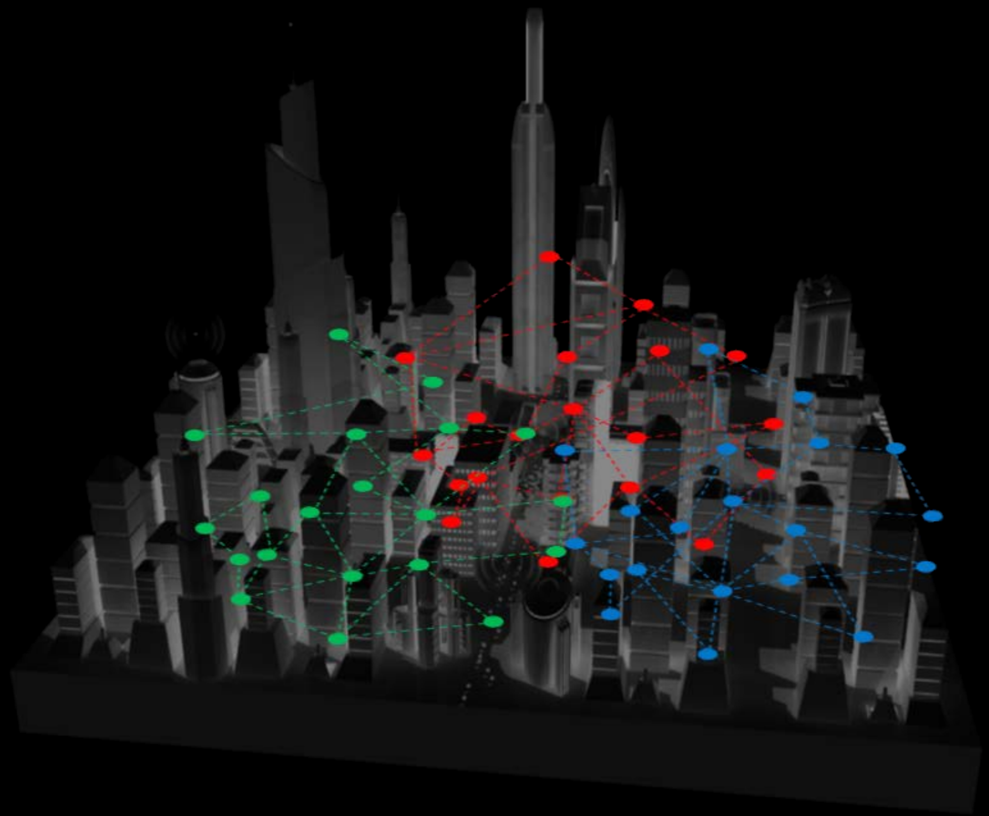
isolated
autonomy

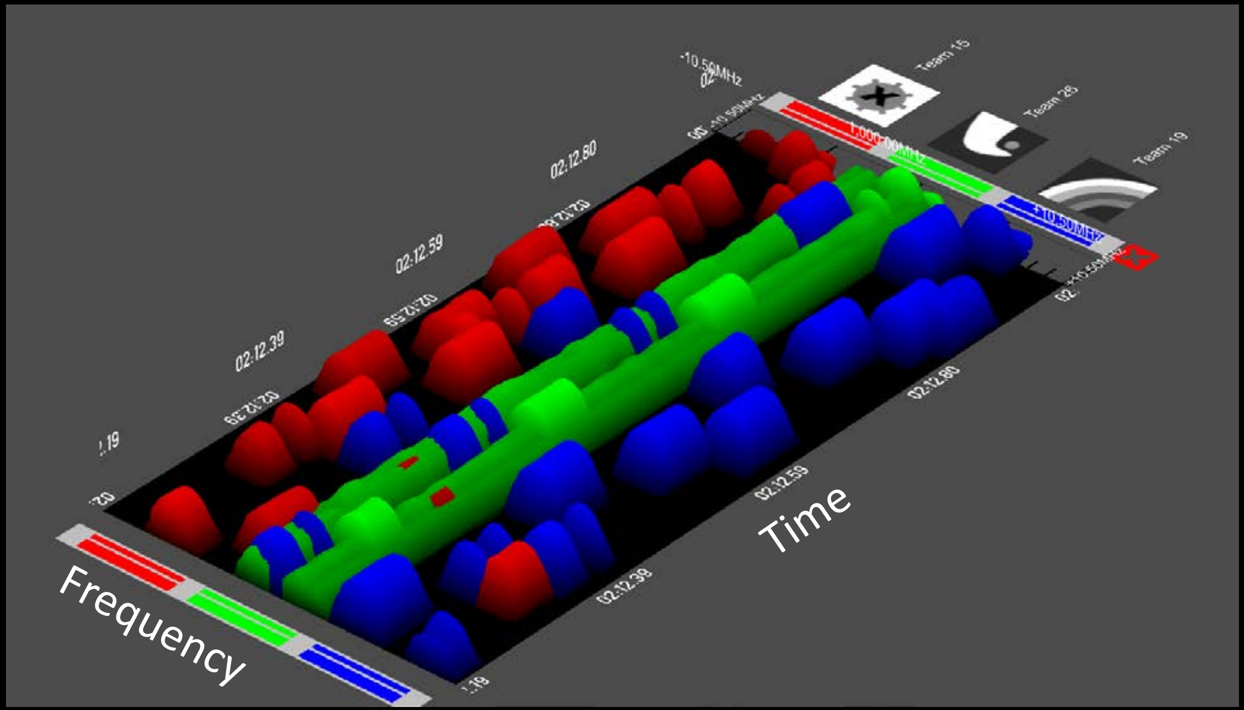
●


FLOPS
10^{13}
10^{12}
10^{11}
10^{10}
10^{9}
2002
2004
2006
2008
2010
2012
2014
2016
2018
Pentium M
Pentium IV
7x Pentium M's
Core 2 Q6600
Core i7 950
Core i7 980
Core i7 3770
Broadwell EP
Skylake HD530
iPhone 5
iPhone 6
iPhone 6s
iPhone 7
iPhone 8
CATERPILLAR
25

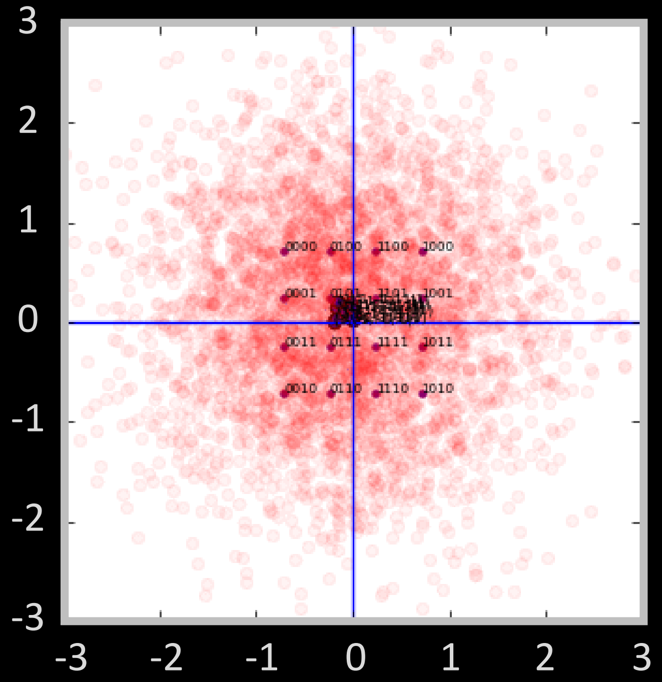


Spectrum Collaboration Challenge

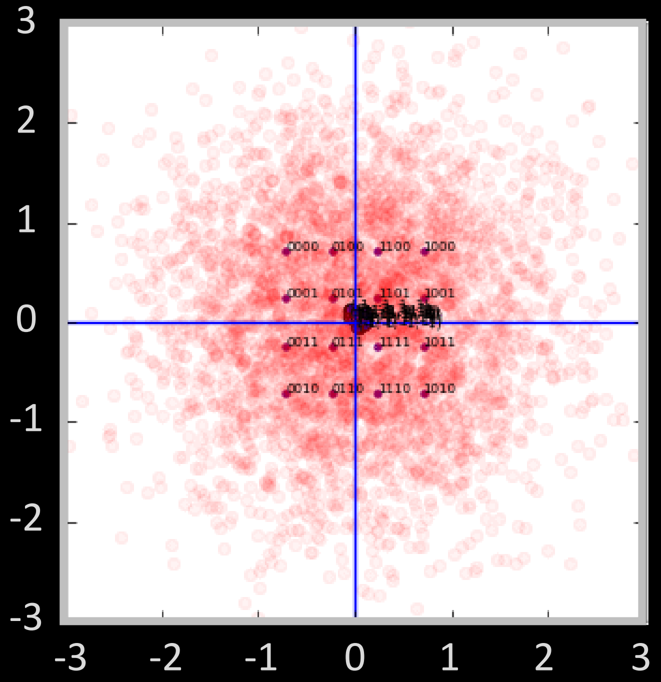




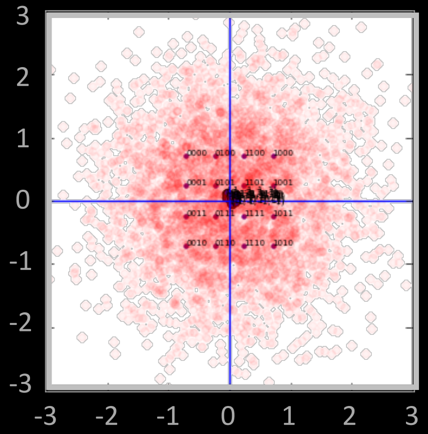
1-1 communication



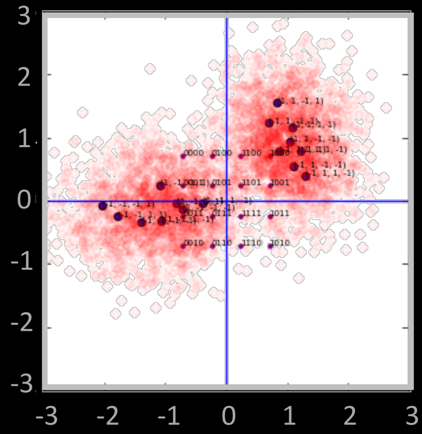
3
2
1
0
-1
-2
-3
-3 -2 -1 0 1 2 3
0000 0100 1100 1000
0001 1001
0011 0111 1111 1011
0010 0110 1110 1010



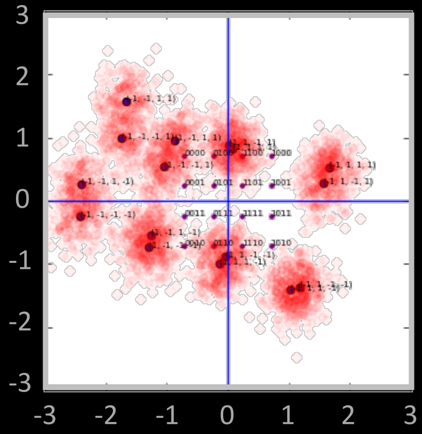
3
2
1
0
-1
-2
-3
-3 -2 -1 0 1 2 3
0000 0100 1100 1000
0001 0101 1101 1001
0011 1111 1011
0010 0110 1110 1010



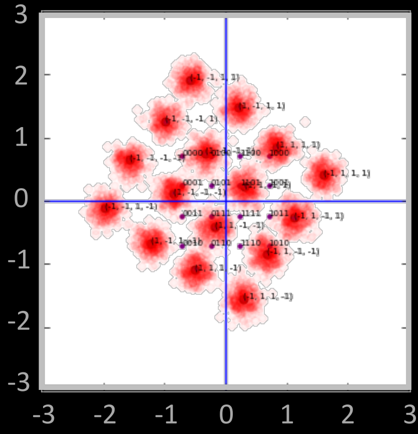
Initial distribution



Separation after lowering variance

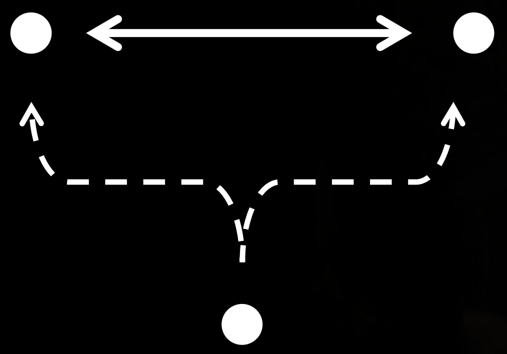


Splitting into pairs with minimal Hamming distance



Grey coded 16-QAM

observer communication



The Good

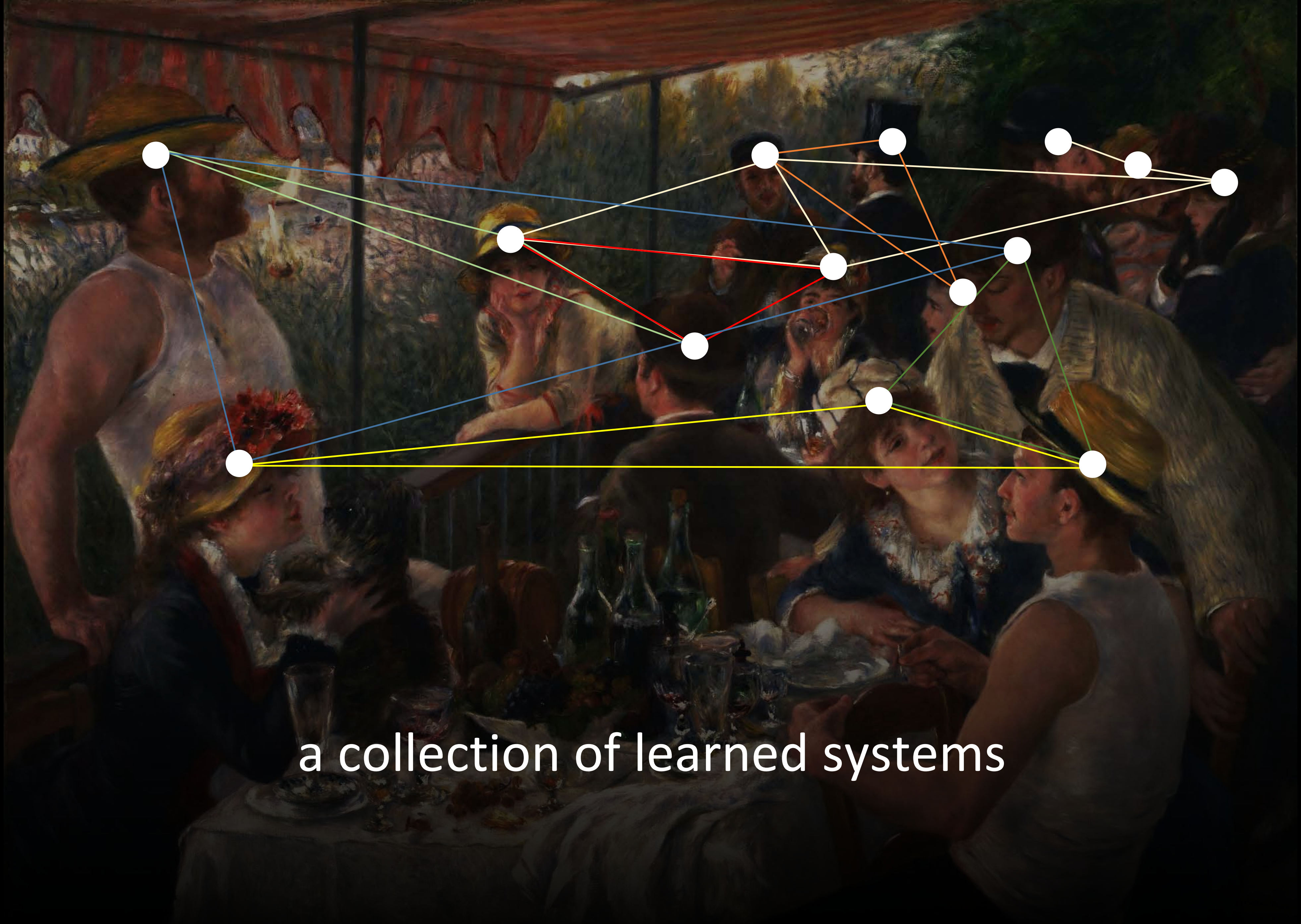

0b/s
0ms
MarmotE
0.00 pts
Bot Team #1
0.00 pts
Bot Team #2
0.00 pts
Match 468
CutThroat
Add New Spectrum
-10.50MHz
1,000.00MHz
+10.50MHz
00:00.00
-01:30
-01:00
-00:30
2D
Spatial Map
4x

The Bad

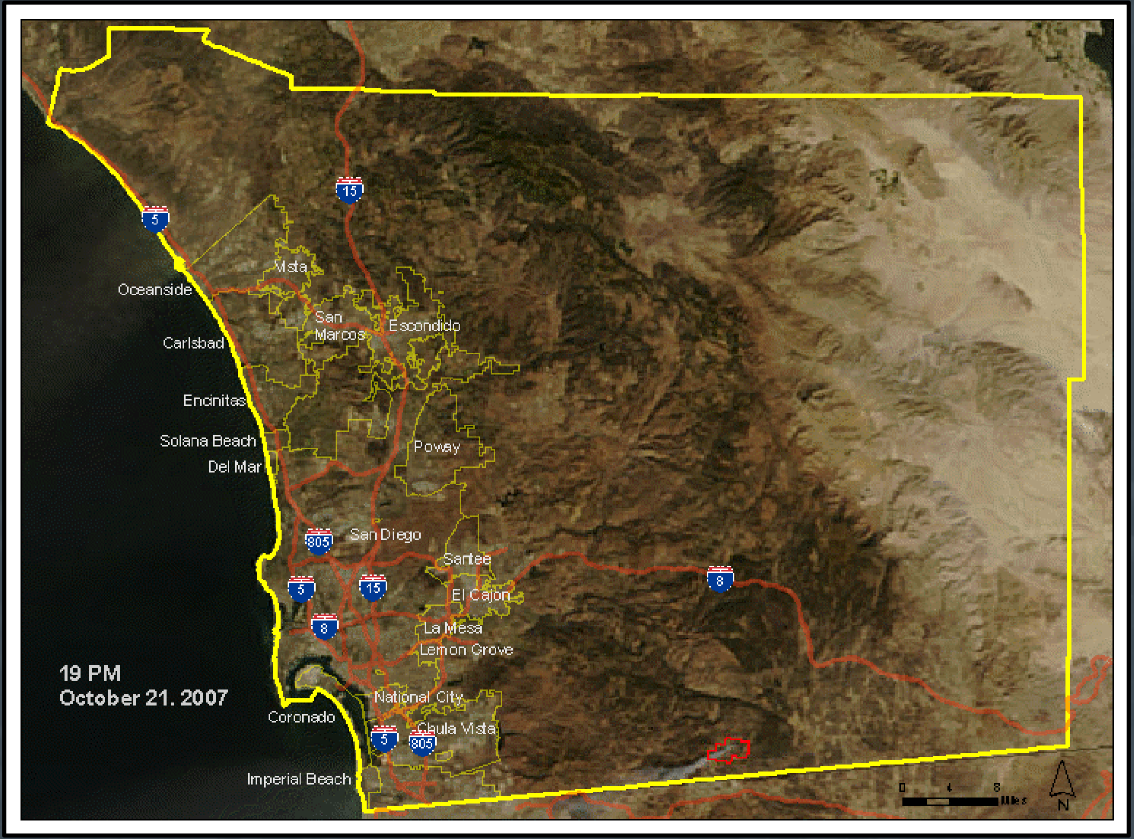

0b/s
0ms
Erebus
0.00 pts
0b/s
0ms
Bot Team #1
0.00 pts
0b/s
0ms
Bot Team #2
0.00 pts
Match 458
CutThroat
Add New Spectrum
-00:20
-00:10
-10.50MHz
1,000.00MHz
+10.50MHz
00:00.00
Spatial Map
2D
2x

The Ugly

0b/s
0ms
Spect. w/o Borders
0.00 pts
0b/s
0ms
Bot Team #1
0.00 pts
0b/s
0ms
Bot Team #2
0.00 pts
Match 461
CutThroat
Add New Spectrum
-01:00
-00:30
-10.50MHz
1,000.00MHz
+10.50MHz
00:00.00
2D
Spatial Map
8x



a collection of learned systems



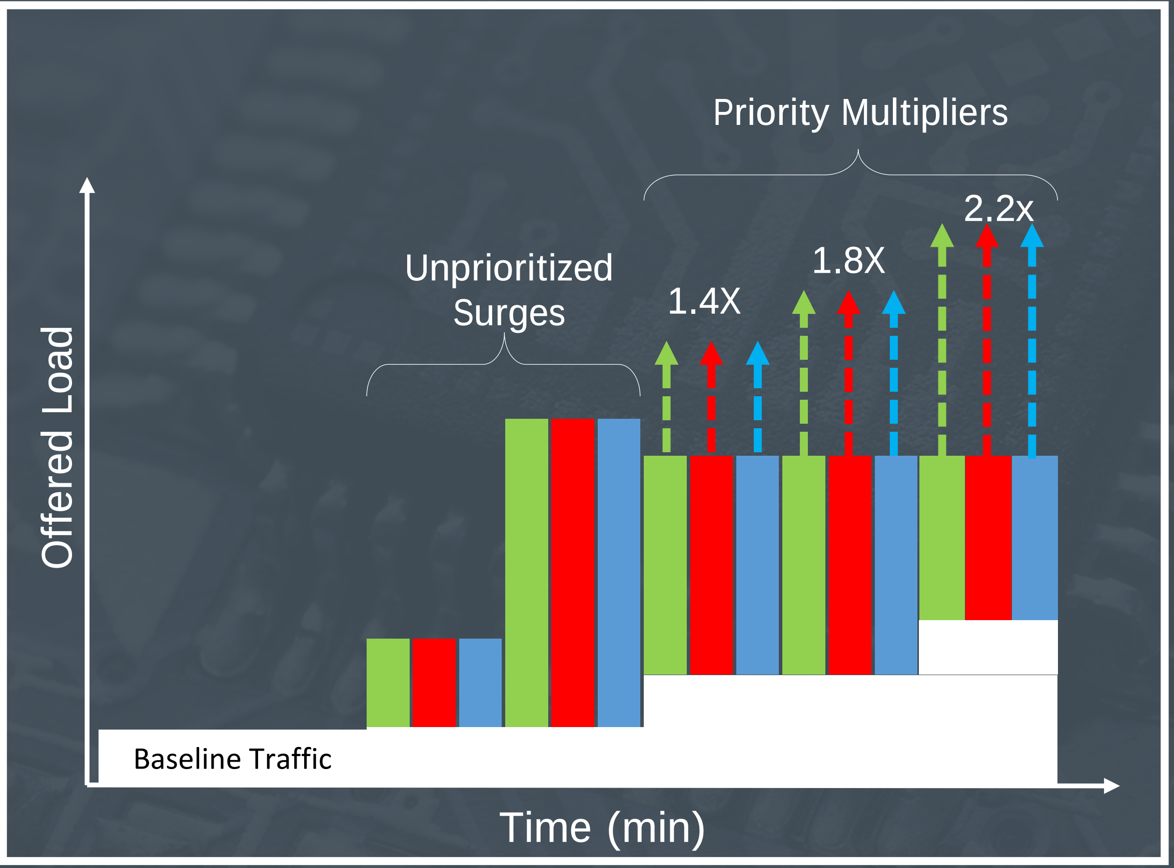
DISTRIBUTION STATEMENT A. Approved for public release. Distribution is unlimited.

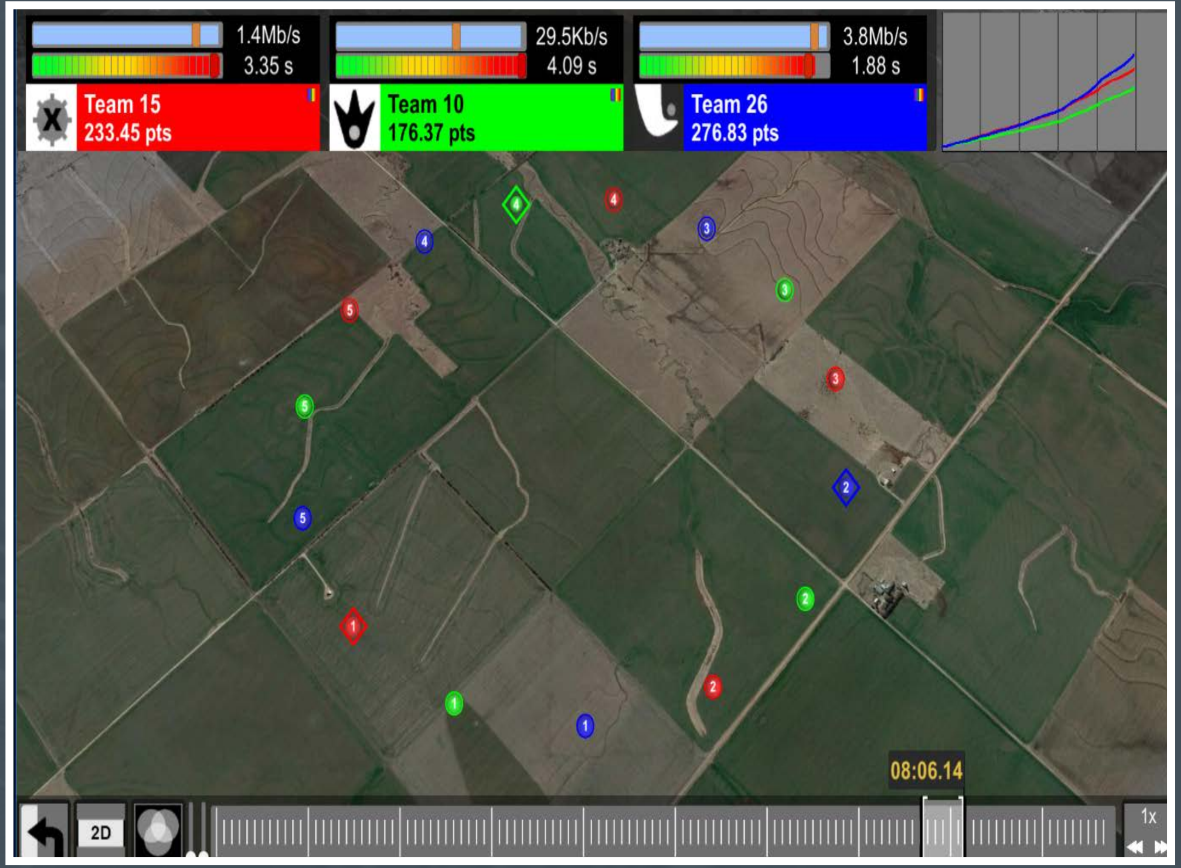
The Good

299.6Kb/s
1.24 s
MarmotE
92.62 pts
1.4Kb/s
2.30 s
Sprite
54.87 pts
145.9Kb/s
1.84 s
Erebus
70.84 pts
Match 411
SanDiegoWildFire
Add New Spectrum
-2.63MHz
1,000.00MHz
+2.63MHz
00:00.29
Spatial Map
3D
20x

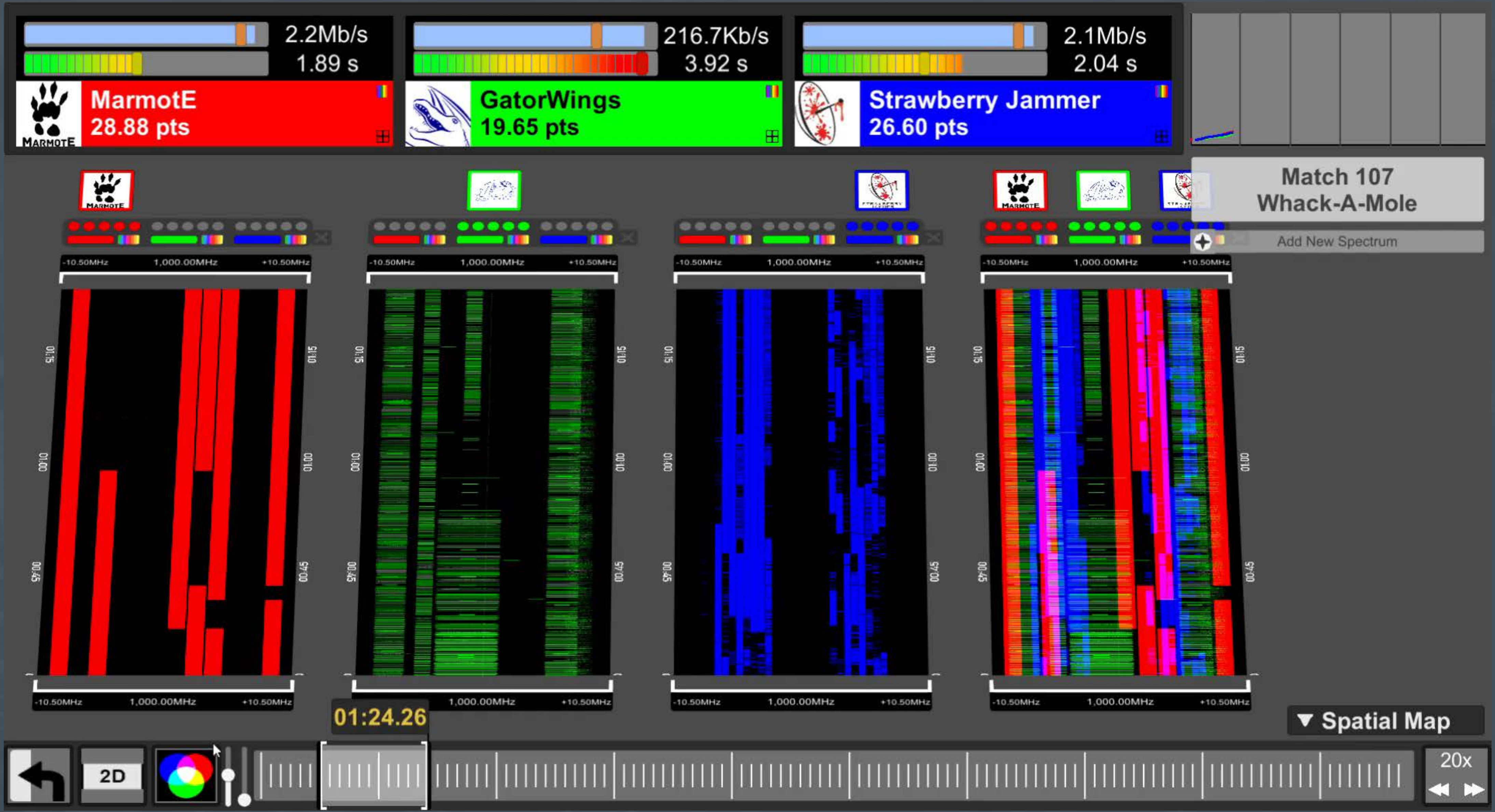
The Role of the Human: San Diego Wildfire

Type	Priority	Rate (kbps)	Timing
Control Traffic	1.8	10	Continuous
VOIP	1.6	32.4	Continuous
Imagery (FTP)	1.4	419.4	Once every 20 seconds
Video Buffer	1.2	83.2	Continuous
Video Stream	1.2	750	Continuous
PLI	1.0	0.4	Continuous


Priority Multipliers
Unprioritized Surges
1.4X
1.8X
2.2x
Offered Load
Baseline Traffic
Time (min)


1.4Mb/s
3.35 s
Team 15
233.45 pts
29.5Kb/s
4.09 s
Team 10
176.37 pts
3.8Mb/s
1.88 s
Team 26
276.83 pts
08:06.14
2D
1x

The Bad


2.2Mb/s
1.89 s
MarmotE
28.88 pts
216.7Kb/s
3.92 s
GatorWings
19.65 pts
2.1Mb/s
2.04 s
Strawberry Jammer
26.60 pts
Match 107
Whack-A-Mole
Add New Spectrum
-10.50MHz
1,000.00MHz
+10.50MHz
01:15
01:00
00:45
01:24.26
Spatial Map
2D
20x

Autonomous Intersection Management (AIM) Project

Department of Computer Sciences
University of Texas at Austin

Project Members:
Prof. Peter Stone
Dr. Guni Sharon
Dr. Michael Albert
Josiah Hanna

Open loop autonomy (requires rules)

OK for light traffic…doesn't scale with congestion/demand

Collaboration and autonomy

Scaling to meet congestion/demand

DARPA investments

Year 1

2000

2018

2004 Grand Challenge

2012

2030

SC2 PE-1 Tournament

Not one team used the available FPGA or GPU successfully as a differentiator

170

THE FUTURE OF COMPUTING PERFORMANCE

Cramming More Components onto Integrated Circuits

GORDON E. MOORE, LIFE FELLOW, IEEE

With unit cost falling as the number of components per circuit rises, by 1975 economics may dictate squeezing as many as 65 000 components on a single silicon chip.

The future of integrated electronics is the future of electronics itself. The advantages of integration will bring about a proliferation of electronics, pushing this science into many new areas.

Integrated circuits will lead to such wonders as home computers—or at least terminals connected to a central computer—automatic controls for automobiles, and personal portable communications equipment. The electronic wristwatch needs only a display to be feasible today.

But the biggest potential lies in the production of large systems. In telephone communications, integrated circuits in digital filters will separate channels on multiplex equipment. Integrated circuits will also switch telephone circuits and perform data processing.

Computers will be more powerful, and will be organized in completely different ways. For example, memories built of integrated electronics may be distributed throughout the machine instead of being concentrated in a central unit. In addition, the improved reliability made possible by integrated circuits will allow the construction of larger processing units. Machines similar to those in existence today will be built at lower costs and with faster turn-around.

I. PRESENT AND FUTURE

By integrated electronics, I mean all the various technologies which are referred to as microelectronics today as well as any additional ones that result in electronics functions supplied to the user as irreducible units. These technologies were first investigated in the late 1950's. The object was to miniaturize electronics equipment to include increasingly complex electronic functions in limited space with minimum weight. Several approaches evolved, including microassembly techniques for individual components, thin-film structures, and semiconductor integrated circuits.

Each approach evolved rapidly and converged so that each borrowed techniques from another. Many researchers believe the way of the future to be a combination of the various approaches.

The advocates of semiconductor integrated circuitry are already using the improved characteristics of thin-film resistors by applying such films directly to an active semiconductor substrate. Those advocating a technology based upon films are developing sophisticated techniques for the attachment of active semiconductor devices to the passive film arrays.

Both approaches have worked well and are being used in equipment today.

II. THE ESTABLISHMENT

Integrated electronics is established today. Its techniques are almost mandatory for new military systems, since the reliability, size, and weight required by some of them is achievable only with integration. Such programs as Apollo, for manned moon flight, have demonstrated the reliability of integrated electronics by showing that complete circuit functions are as free from failure as the best individual transistors.

Most companies in the commercial computer field have machines in design or in early production employing integrated electronics. These machines cost less and perform better than those which use "conventional" electronics.

Instruments of various sorts, especially the rapidly increasing numbers employing digital techniques, are starting to use integration because it cuts costs of both manufacture and design.

The use of linear integrated circuitry is still restricted primarily to the military. Such integrated functions are expensive and not available in the variety required to satisfy a major fraction of linear electronics. But the first applications are beginning to appear in commercial electronics, particularly in equipment which needs low-frequency amplifiers of small size.

III. RELIABILITY COUNTS

In almost every case, integrated electronics has demonstrated high reliability. Even at the present level of pro-

Reprinted from Gordon E. Moore, "Cramming More Components onto Integrated Circuits," *Electronics*, pp. 114–117, April 19, 1965.
Publisher Item Identifier S 0018-9219(98)00753-1.

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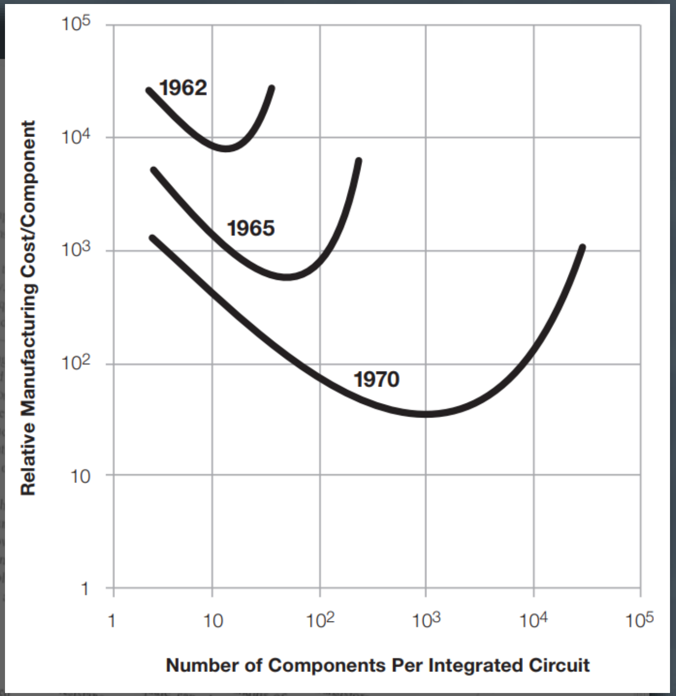
PROCEEDINGS OF THE IEEE, VOL. 86, NO. 1, JANUARY 1998

APPENDIX C



P.3

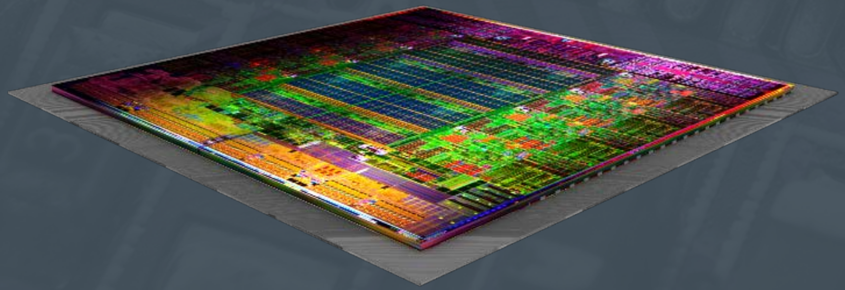
Electronics, April 19, 1965: Cramming More Components onto Integrated Circuits; Gordon Moore

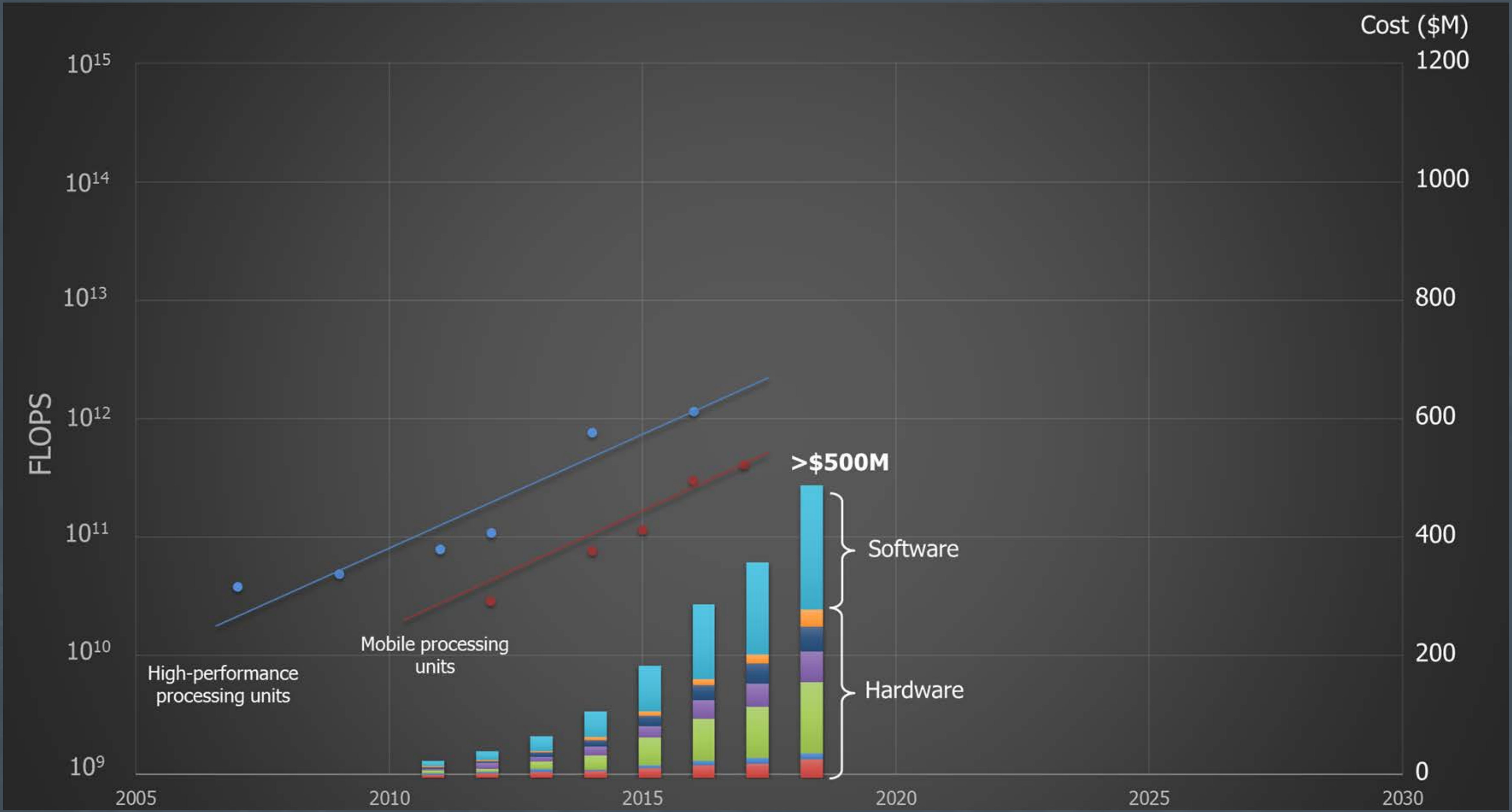
VIII. DAY OF RECKONING

Clearly, we will be able to build such component-crammed equipment. Next, we ask under what circumstances we should do it. The total cost of making a particular system function must be minimized. To do so, we could amortize the engineering over several identical items, or evolve flexible techniques for the engineering of large functions so that no disproportionate expense need be borne by a particular array. Perhaps newly devised design automation procedures could translate from logic diagram to technological realization without any special engineering.

It may prove to be more economical to build large systems out of smaller functions, which are separately packaged and interconnected. The availability of large functions, combined with functional design and construction, should allow the manufacturer of large systems to design and construct a considerable variety of equipment both rapidly and economically.

Today
“component-crammed equipment”





Cost ($M)
FLOPS
10^{15}
10^{14}
10^{13}
10^{12}
10^{11}
10^{10}
10^{9}
1200
1000
800
600
400
200
0
2005
2010
2015
2020
2025
2030
>$500M
Software
Hardware
High-performance processing units
Mobile processing units

COMPLEXITY BIND

Cost

The cost of integrated circuit fabrication, design, and verification is skyrocketing, limiting innovation

Abstraction

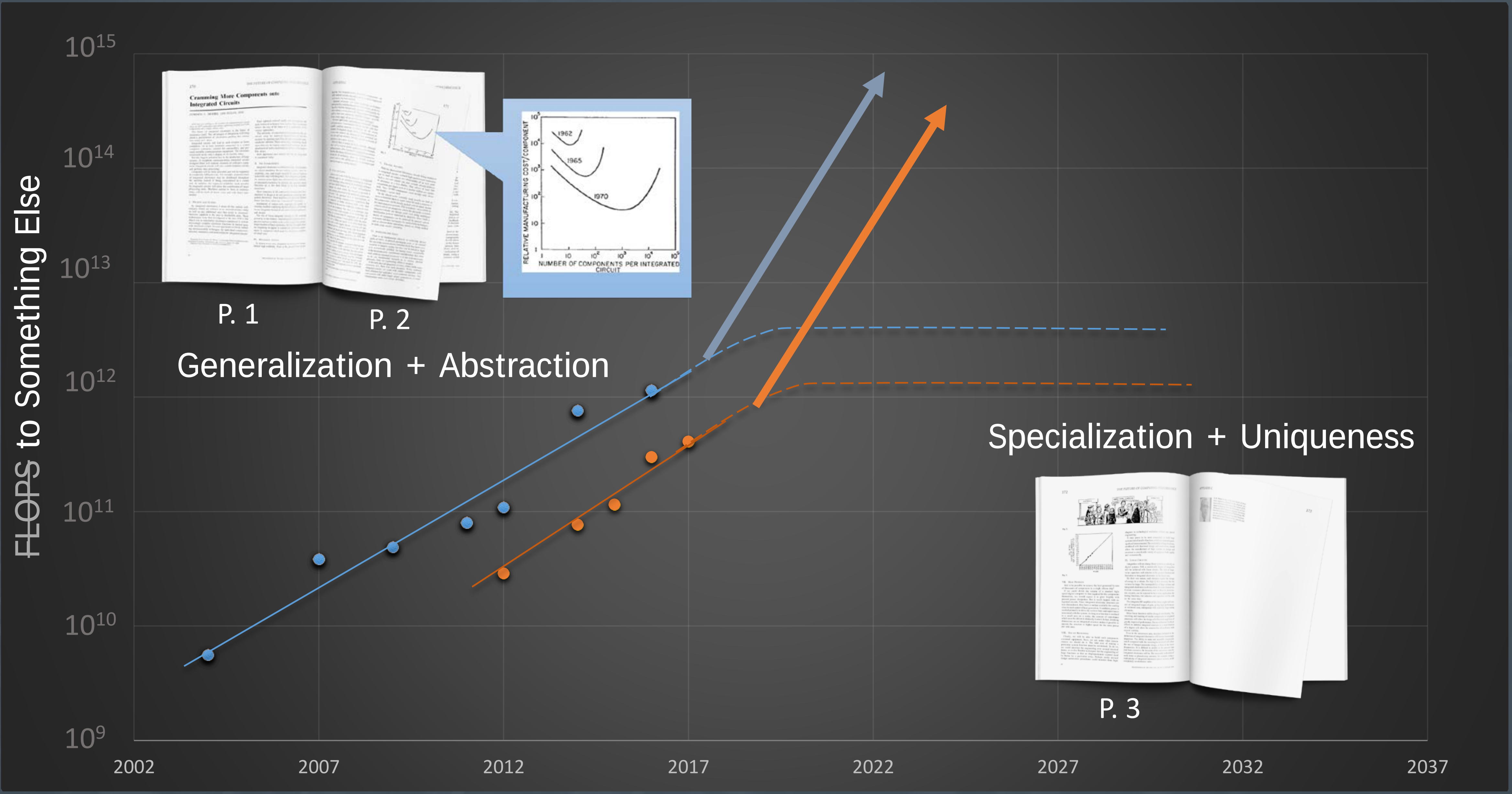
The continued move towards generalization and abstraction is stifling potential gains in hardware

Foreign Investments

Foreign investments are distorting the market and driving a shift outside of the U.S.

Rising Stakes

Digital influence is so pervasive in our society that we can’t afford to have flaws in the digital foundation



~~FLOPS~~ to Something Else
10^{15}
10^{14}
10^{13}
10^{12}
10^{11}
10^{10}
10^{9}
2002
2007
2012
2017
2022
2027
2032
2037
Cramming More Components onto Integrated Circuits
RELATIVE MANUFACTURING COST/COMPONENT
NUMBER OF COMPONENTS PER INTEGRATED CIRCUIT
1962
1965
1970
P. 1
P. 2
Generalization + Abstraction
Specialization + Uniqueness
P. 3

P.3

Electronics, April 19, 1965: Cramming More Components onto Integrated Circuits; Gordon Moore

VIII. DAY OF RECKONING

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It may prove to be more economical to build large systems out of smaller functions, which are separately packaged and interconnected. The availability of large functions, combined with functional design and construction, should allow the manufacturer of large systems to design and construct a considerable variety of equipment both rapidly and economically.

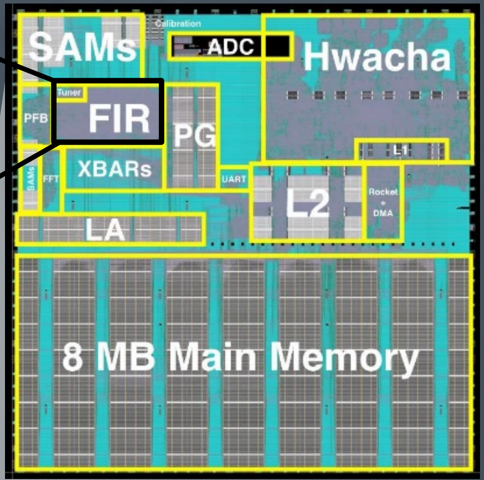
Designs

Quickly enabling specialization

Designs Thrust

```
// calculate products as in * tap
val products = DspContext.withTrimType(dsptools.NoTrim) {
  io.taps.reverse.map { tap => in.map { i =>
    ShiftRegister(i * tap, config.multiplyPipelineDepth)
}}}
```

IDEA



CRAFT

"Perhaps newly devised design automation procedures could translate from logic diagram to technological realization without any special engineering"

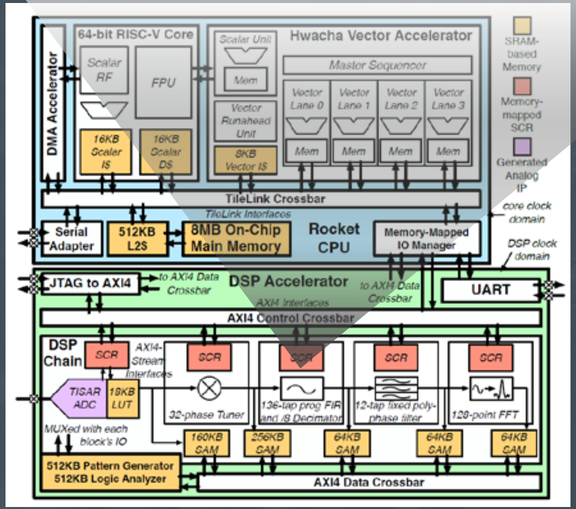
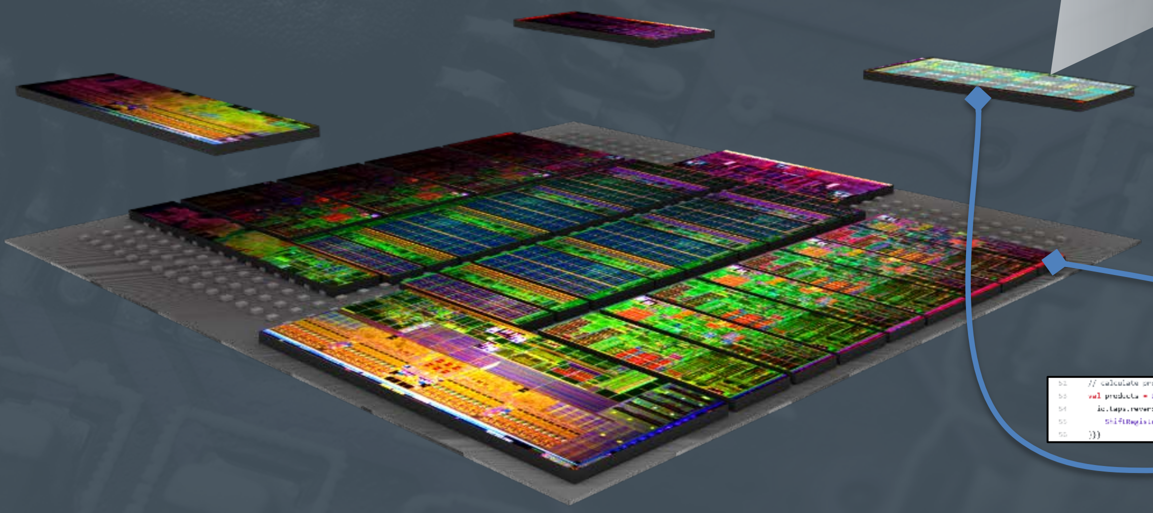


Image: UC Berkeley

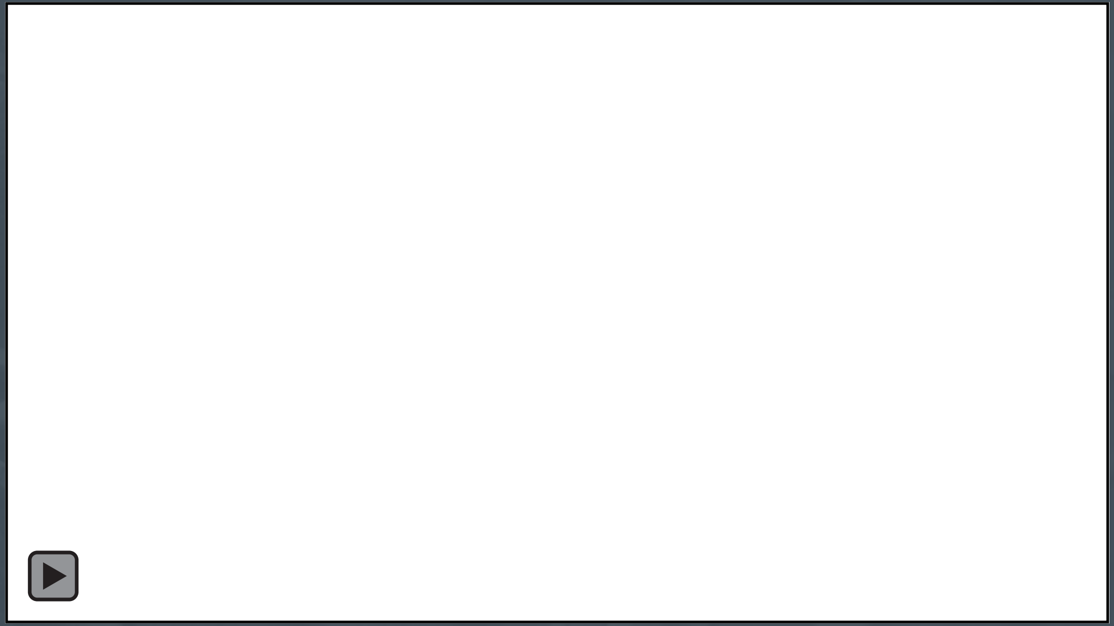
CRAFT



GitHub

POSH

CAPTAIN TSUBASA
Tumblr.com



IAMAG
Published on Nov 14, 2016
More on http://www.iamag.co

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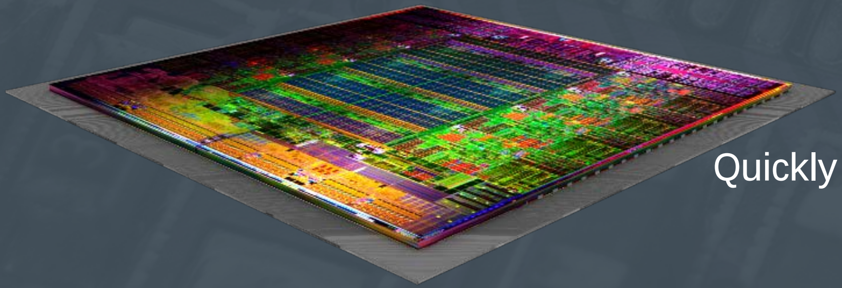
Today
"component-crammed equipment"

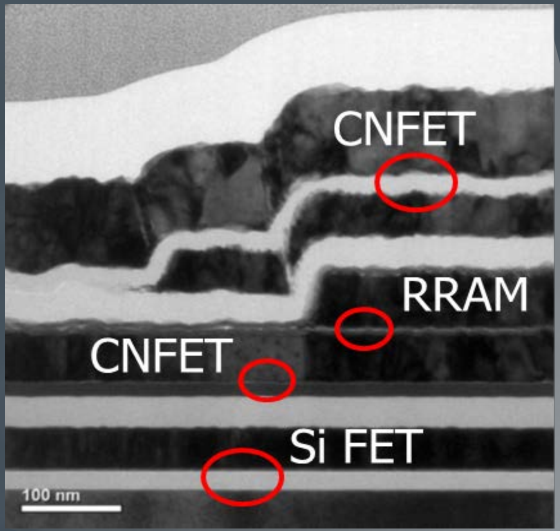


Designs

Quickly enabling specialization

Materials & Integration

Adding separately packaged novel materials and using integration to provide specialized computing



3DSOC

Images: Stanford, MIT

FRANC

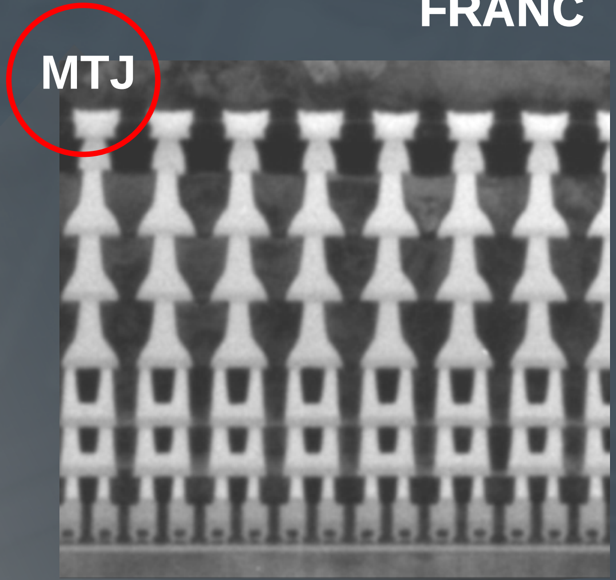
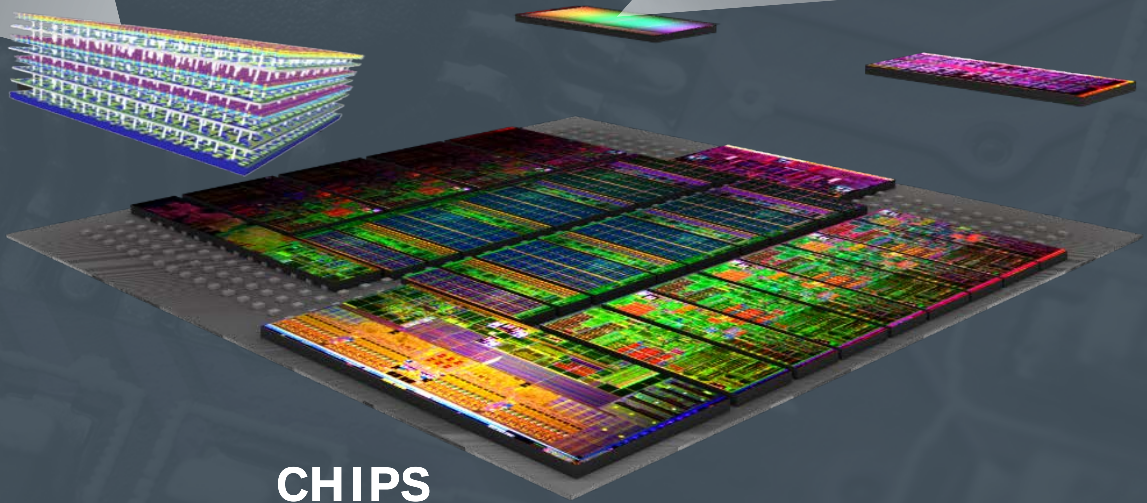


Image: GLOBALFOUNDRIES



CHIPS

P.3

Electronics, April 19, 1965: Cramming More Components onto Integrated Circuits; Gordon Moore

VIII. DAY OF RECKONING

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Architectures

Maximizing specialized functions

Designs

Quickly enabling specialization

Materials & Integration

Adding separately packaged novel materials and using integration to provide specialized computing

Architectures Thrust

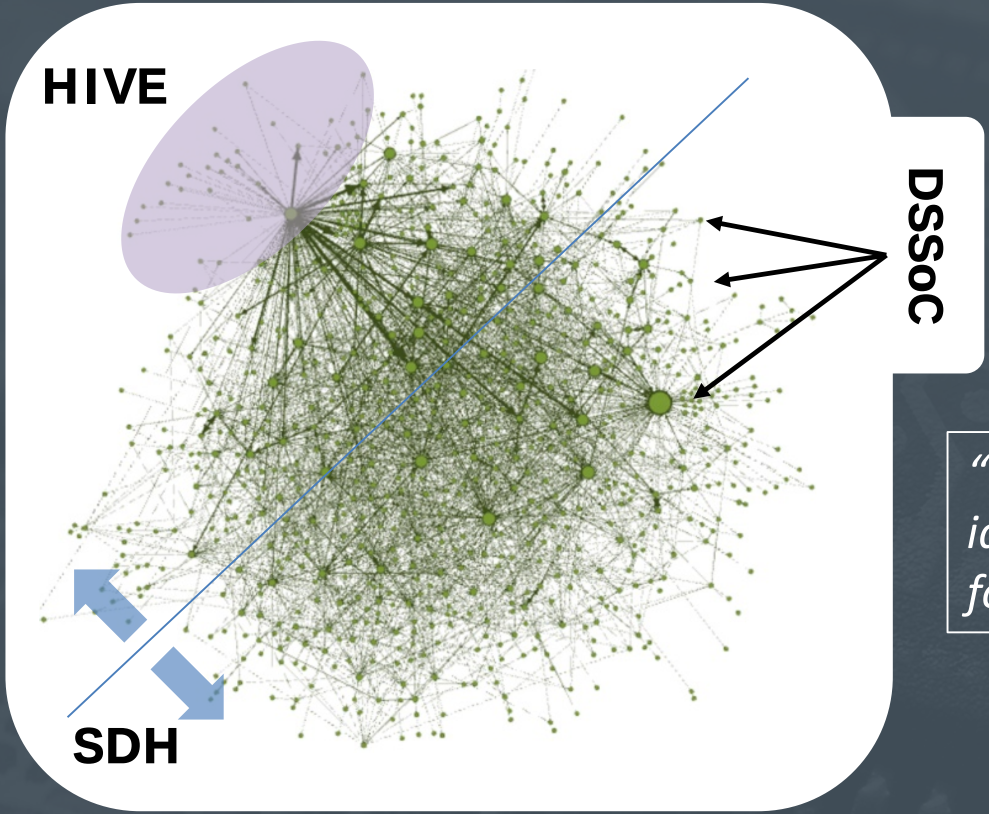
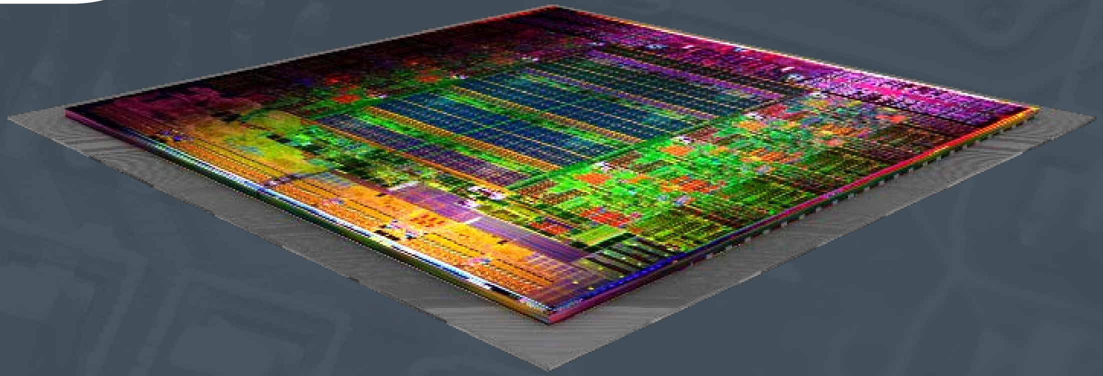


Image: Drexel Univ.

Array of sensors

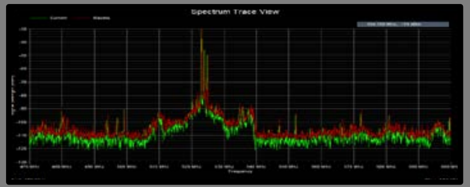
HIVE

"…amortize the engineering over several identical items, or evolve flexible techniques for the engineering of large functions…"

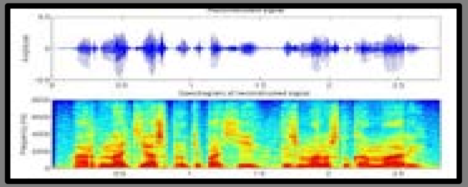


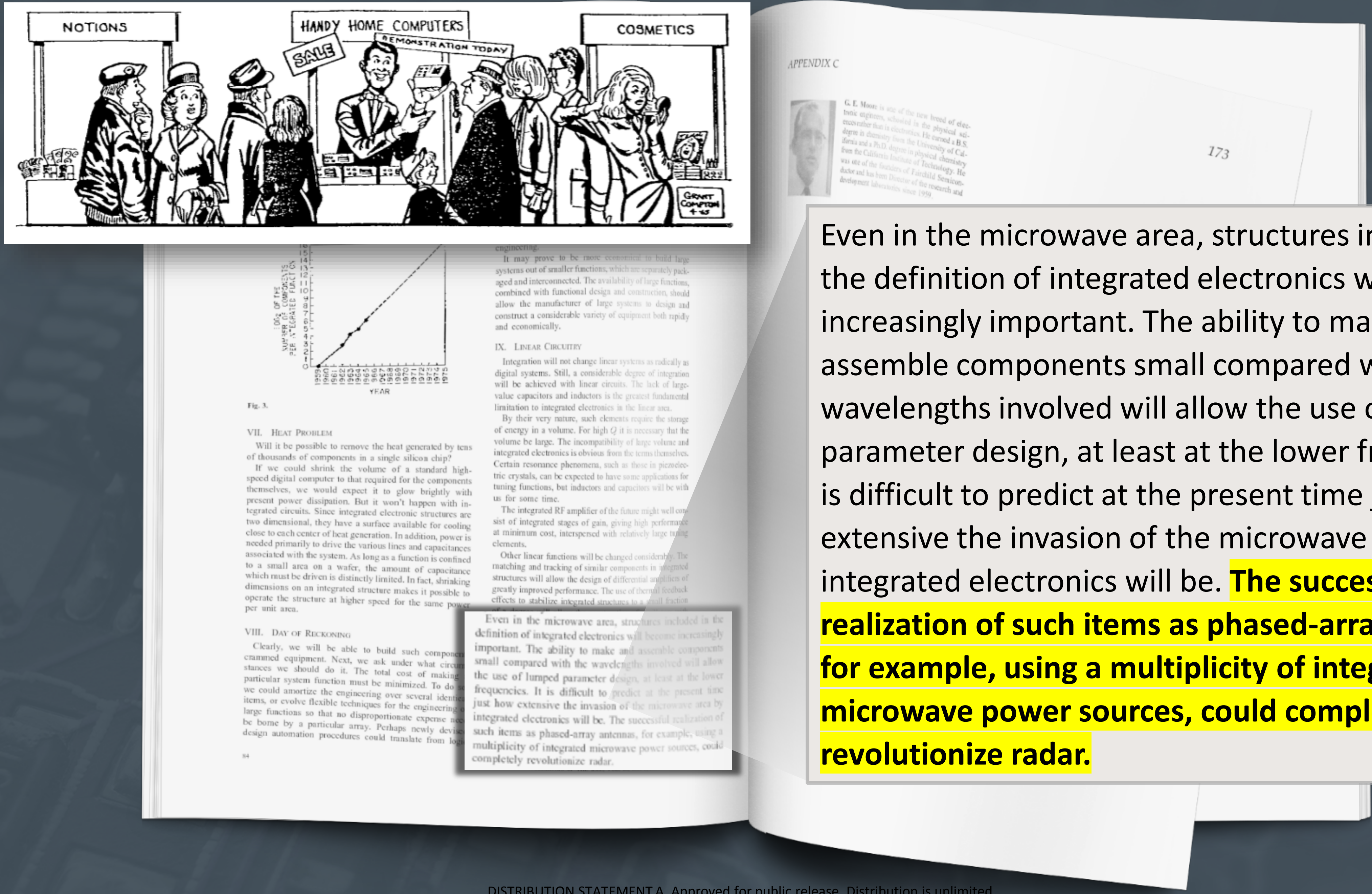
LiDAR

RF



Audio

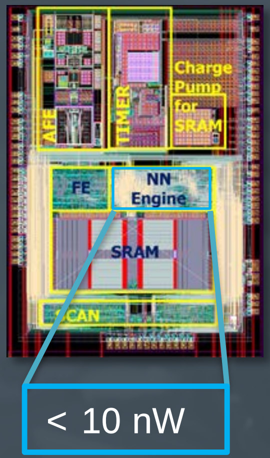




Even in the microwave area, structures included in the definition of integrated electronics will become increasingly important. The ability to make and assemble components small compared with the wavelengths involved will allow the use of lumped parameter design, at least at the lower frequencies. It is difficult to predict at the present time just how extensive the invasion of the microwave area by integrated electronics will be. **The successful realization of such items as phased-array antennas, for example, using a multiplicity of integrated microwave power sources, could completely revolutionize radar.**

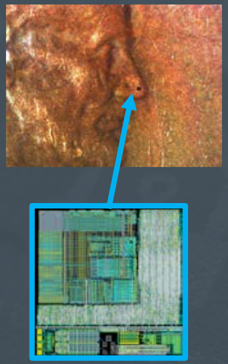
Driving Applications

N-ZERO



No Power Operation

SHIELD



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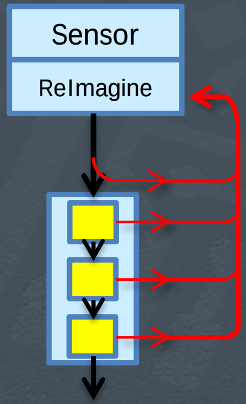
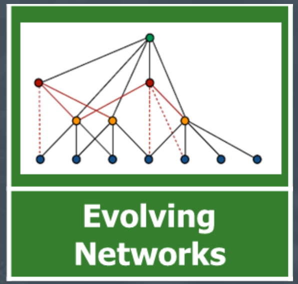
Art of the Small

ReImagine



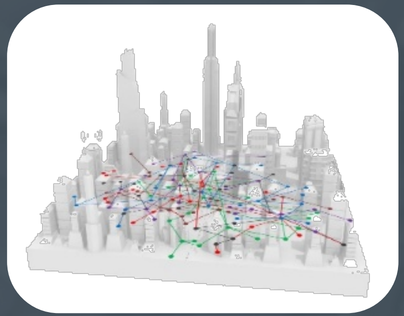
Saliency

L2M



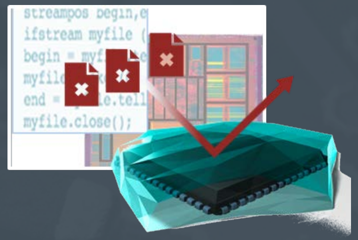
In Field Learning

SC2

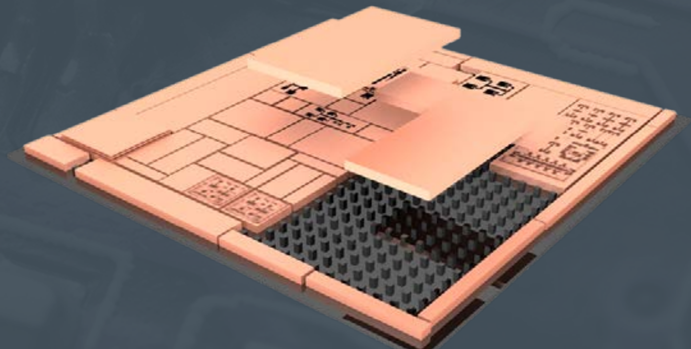


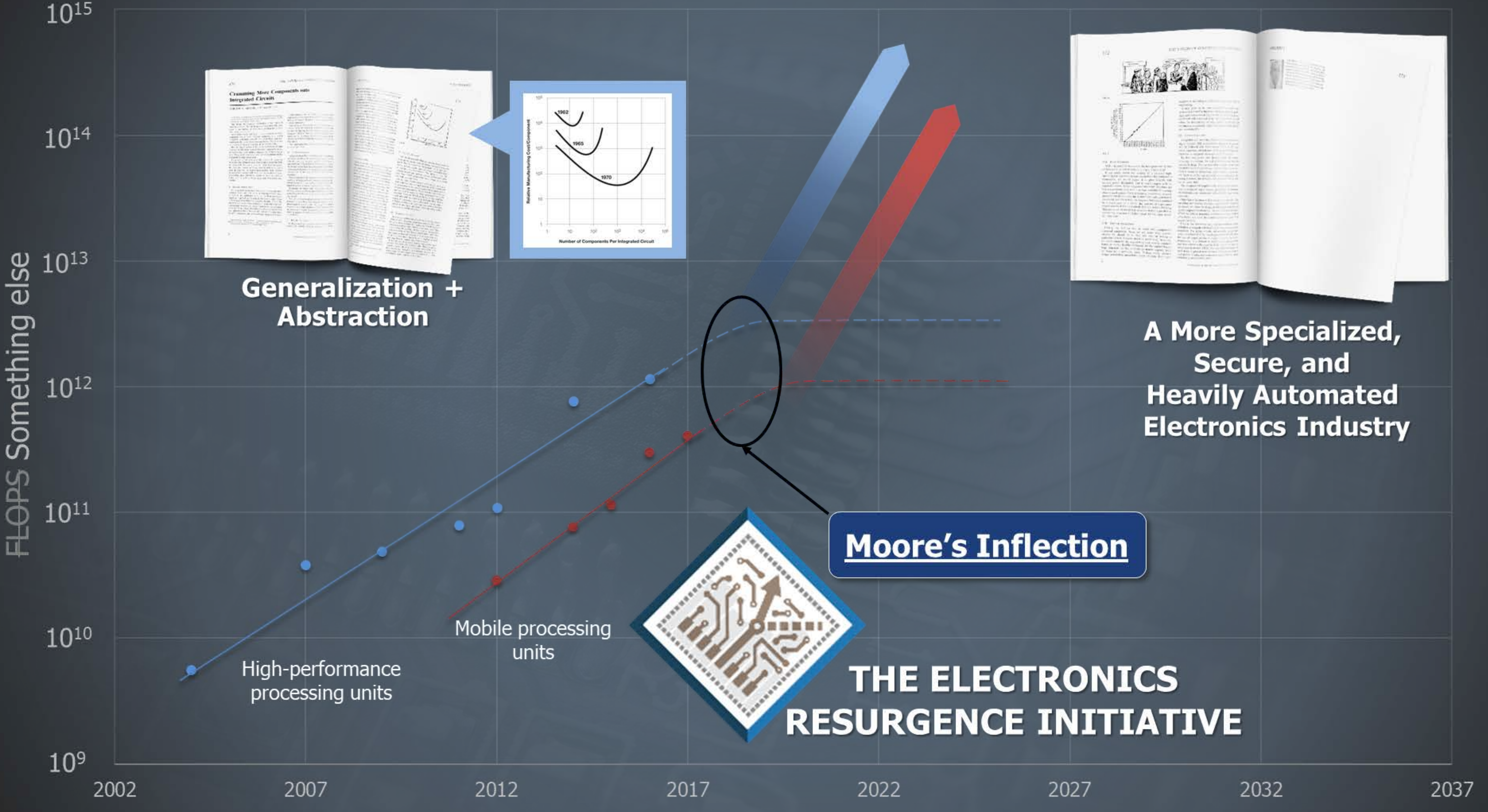
Learning Cooperation through Edge Intelligence

SSITH



Hardware as the Foundation of Security





10^{15}
10^{14}
10^{13}
10^{12}
10^{11}
10^{10}
10^{9}
~~FLOPS~~ Something else
2002
2007
2012
2017
2022
2027
2032
2037
Generalization + Abstraction
A More Specialized, Secure, and Heavily Automated Electronics Industry
Moore's Inflection
High-performance processing units
Mobile processing units
THE ELECTRONICS RESURGENCE INITIATIVE

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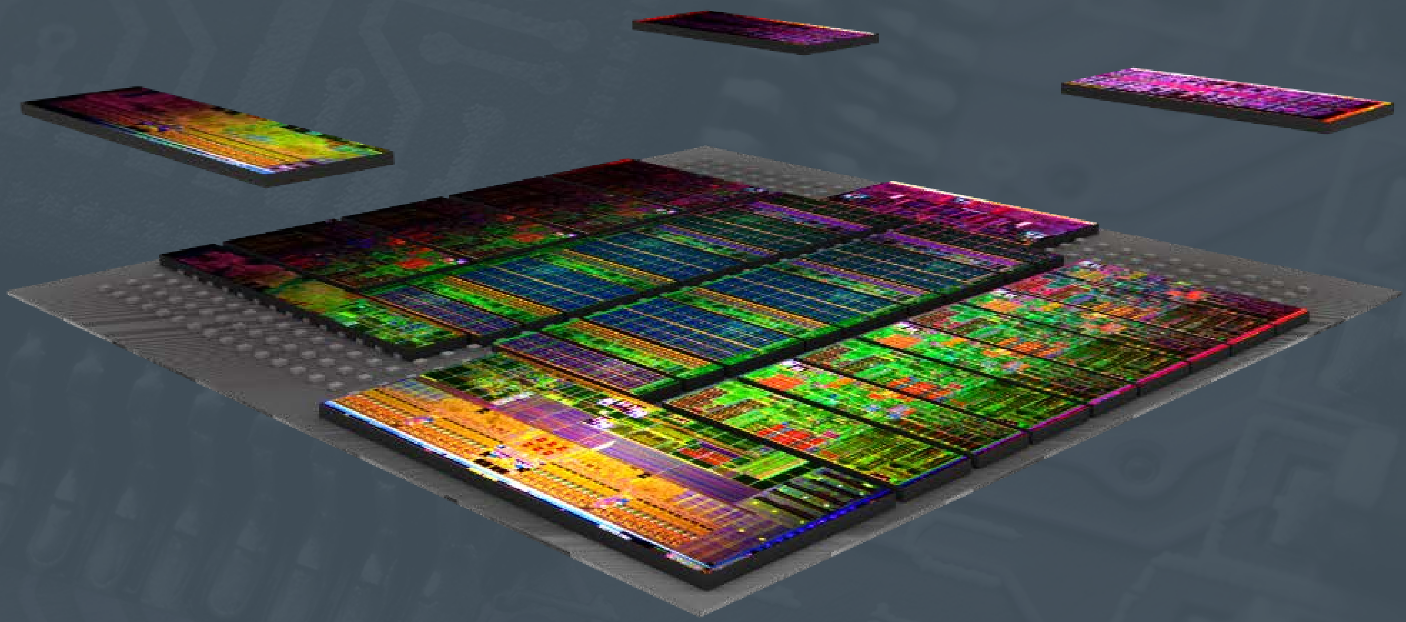
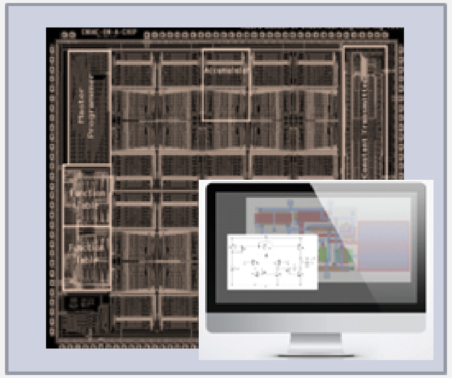


Today: DoD leverages one strategic partner for leading-edge microelectronics



Trusted Design

Sole-source Fabrication below 90nm

Portions of GLOBALFOUNDRIES

Trusted DoD Electronics

Commercial Fabrication

Full access to GLOBALFOUNDRIES	TSMC
Samsung	Intel

Logic Concealment

Hardware Inspection

Component Tagging

Tomorrow: Technology-driven security techniques enable additional options for acquiring state-of-the-art, commercial microelectronics, based on each DoD program's need