



Dario Gill

SVP IBM Research

EAGLE KEYNOTE [15 MINS]



“Eagle” Presentation for Quantum Summit

Dario Gil, SVP, IBM Research (November 2021)

**ORGANISING ELEMENTS
TO INCLUDE IN THE STORY**



“Eagle” Presentation for Quantum Summit

Dario Gil, SVP, IBM Research (November 2021)

IDEAS, CASE STUDIES & POTENTIAL TALKING POINTS??

QUANTUM COULD DRIVE UP

QUANTUM COULD DRIVE DOWN

ExxonMobil seek sustainable growth by shipping natural gas instead of coal, to solve the energy crisis, as a result of population growth. Quantum is finding optimal shipping routes for 500 LNG ships that classical computers can't.

IBM Research has the largest fleet of 20+ of the most powerful quantum systems in the world, IBM is aiming to turn the world's most challenging problems into valuable opportunities – environmentally & commercially.

The bigger IBM Quantum story helps to attract and retain both talented executive hires and new client opportunities. This is one area where **IBM** is genuinely leading the world, and the pride it creates is impacting IBM's 8% growth YoY (Q2, FY22)

CERN's partnership with IBM Quantum seeks new ways of finding patterns in Large Hadron Collider data (1 Petabyte per second) – to spot connections beyond the power of classical computers – shedding light on hidden features of the universe.

Revenue & Profit

Market Share

Retention

Positive Change

MONEY

MARKET

EXPOSURE

SUSTAINABILITY

Costs

Time to Market

Risk

Environmental Impact

Mitsubishi Chemical, Japan is conducting battery R&D to make lighter and more sustainable batteries. Lithium-oxygen (instead of Lithium-ion) batteries will help create a more sustainable future, environmentally & economically.

Mercedes-Benz is using Quantum to help with simulations and design better batteries and new battery technology (Lithium Sulfur). This will give them a competitive advantage + reduce the size and charging times of batteries.

JPMorgan Chase & Co. are researching how computing can improve trading strategies, enhance client portfolios, and reduce financial risk (improving option pricing, fraud detection, portfolio optimization)

IBM Quantum leads the world in quantum computing. This nascent technology is widely expected to solve valuable problems that today's most powerful classical supercomputers cannot solve and never will.

"Eagle" Presentation for Quantum Summit

Dario Gil, SVP, IBM Research (November 2021)

POTENTIAL STORY
STRUCTURE & FLOW?

1. A CHARACTER

What do they want?

[OPENING QUOTE?]

"... A lot of people said building a hundred plus quantum computer was just a pipe dream. We wouldn't get there until decades from now. And here we are. Out of the crazy ideas of quantum mechanics, this real thing, in just 10 years. Such a fantastic example of the scientific method..."

Charlie Bennett and Rolf Landauer got us all started on this. Asking things like, "Is there a fundamental limit to the efficiency of computing?" and "Is information processing thermodynamically reversible?" Only the kinds of things that a physicist would ask..."

2. WITH A PROBLEM

Internal, External & Philosophical

- What did the first lab look like?
- How much risk was involved?
- How did the team collaborate around this huge unsolved problem?
- Can the "Scientific Method" help business leaders to be more successful?
- The world is facing unprecedented challenges which we can't solve on our own with classical computers. There are easy problems and there are hard problems...

"I remember going to see our first quantum lab and the modesty of what the lab environment looked like.

BUT the enormous level of risk and difficulty of what was behind the scenes in that modest laboratory..."

3. MEETS A GUIDE WHO UNDERSTANDS THEIR FEARS

Empathy & Authority

- IBM has the world's largest & most powerful Quantum fleet, but this is *not* about IBM – this is about how we can help solve problems for our clients and the planet.

"Today I am **excited** to present to you the first commercial quantum processor to break the qubit barrier. Meet "**Eagle**", the new 127 qubit chip.

For the first time in history we've entered the realm where a classical super computer can no longer fully simulate the behaviour of a quantum chip. Eagle will let **us** explore truly uncharted computational territory..."

4. AND GIVES THEM A PLAN

Summary?

- **2019**: Falcon (27-qubit) which allowed us to reduce errors caused by interference.
- **2020**: Hummingbird (65 qubit) "*multiplexing...*"
- **2022** Osprey (433 qubit)
- **2023**: Condor (1,121 qubit) will allow us to explore error correction and dive deeper into "*quantum advantage*".

BUT developing this larger system poses a challenge. We believe that Eagle is the last processor that will fit inside of our IBM Quantum System One. And so, we are **excited** to unveil a concept for the future of scalable quantum computation: the IBM Quantum System Two. System Two is a bridge to the future of quantum computing.

5. THAT CALLS THEM TO ACTION

Call to action?

The past 10 years have shown how fundamental scientific research has created a potentially paradigm shifting advance in computing. But what do the next 10 years have in store?

We dream of a future with frictionless quantum computing, where users can code a quantum computer without having to know about the intricacies of the quantum processor. We envision developers across all levels of the quantum computing stack relying upon our advances hardware with a cloud-based API, working seamlessly with high-performance computing resources to push the limits.

BUT developing this larger system poses a challenge..."

6. SUCCESS

Result

Performance metrics to measure results & future progress of quantum Advantage: Eagle represents improvements that will allow us to press forward on all 3 of our performance metrics: **scale, quality and speed.**

By following this roadmap, we think that by 2030 companies and users will be running a trillion quantum circuits a day, providing real world benefits and hopefully solving some of the world's most important problems.

[CLOSE]

Thank you (attendees & users of IBM Quantum Network) for joining us over the past 10 years. "We hope that you'll stay with us for the next 10 years and beyond as we continue to transform computing **together**".

“Eagle” Presentation for Quantum Summit

Dario Gil, SVP, IBM Research (November 2021)

Mission: IBMers have always believed in progress and the scientific method. That the application of intelligence, reason and science can improve business, society and the human condition.

- IBM Quantum System One >> System Two!
- Scalable & Flexible - **“A true quantum data center”**
- 2030 → Trillion quantum circuits a day
- Solving world’s most important problems
- Thank you – Global community & Quantum network
- Last 10 years → Next 10 years...

Transformation Vision

- Time travel quote *“Memories are like time travel to the past...”*
- **“In just 10 years... such a fantastic example of the scientific method...”**
- *“There’s so much history in these Qubits...”*
- Charlie Bennett & Rolf Landauer: **Eccosorb story** (10X better)
- Showing people it was real...
- Quantum community **“trolls!”**
- The **“Perfect Quantum Computer”**.

Your Hero

- The past 10 years have shown how fundamental scientific research has created a potentially paradigm shifting advance in computing
- **But... what do the next 10 years have in store?**
- We dream of a future with frictionless quantum computing
- Users can code a quantum computer without having to know about the intricacies of the quantum processor.
- We envision developers across all levels of the quantum computing stack relying upon our advances hardware with a cloud-based API, working seamlessly with high-performance computing resources to push the limits.

What **Success** Looks Like

What’s their **Problem?**

- Perfect machine but small & noisy
- How can we “benefit” from them?
- **RABI data story**
- 127-Qubits >> “It’s alive!”

Your **Plan** for a Safe Journey

Why Should I **Trust** You or **Care?**

So what can we expect from this step into uncharted computational territory? We hope to use Eagle to explore the realm of quantum advantage, where quantum computers can tackle problems faster and with fewer resources than classical computers. And quantum advantage might be coming sooner than you think.

- Announce 1st commercial processor to break the quantum barrier
- “Eagle. “For the first time in history....”
- Falcon (27q) >> Hummingbird (65q) >> Eagle (127q) >> Osprey (433) >> Condor (1,121q)
- Integration into business workflows: Libraries (Finance, ML, Chemistry)

“Eagle” Presentation for Quantum Summit (15 mins)

Dario Gil, SVP, IBM Research (November 2021)

ACT I: DEVELOPMENT – “The Scientific Method”

[1:00] Someone said “Memories are like time travel to the past and dreams are time travel into the future”. Well, we have definitely travelled into the future. A lot of people said building a hundred plus quantum computer was just a pipe dream. We wouldn’t get there until decades from now. And here we are. Out of the crazy ideas of quantum mechanics, this real thing, in just 10 years. Such a fantastic example of the scientific method.

[2:00] Hypothesizing, testing, inventing, experimenting, with all the ways to make qubits, how they could work and how they could look. And also how often you’re gonna get stuck. There’s so much history in these qubits. Charlie Bennett and Rolf Landauer got us all started on this. Asking things like, “Is there a fundamental limit to the efficiency of computing?” and “Is information processing thermodynamically reversible?” Only the kinds of things that a physicist would ask. I remember going to see our first quantum laboratory and the modesty of what the laboratory environment looked like.

[3:00] But the enormous level of risk and difficulty of what was behind the scenes in that modest laboratory. Our first quantum device, quantum system, and the basis of all our future quantum computers. “Certainly I’d say one of my fondest memories involves studying this one, actually a single qubit system that we had back then”. “The effective temperature that this device exhibited was far higher than what the fridge temperature said it was. And we’ve tried numerous experiments over the years to try to address this, but nothing seemed to work very well. The community started to get a sense that maybe there is some other radiation, black body radiation that might be causing this.” “We took this idea back and we shared it with one of our engineers, Jim Rosen, and he didn’t believe it at all. He actually just said, “I’m going to prove to you that this is baloney.”

[4:00] “So he did something really, really drastic. He took the entire package and he bricked it into this, what we call Ecosorb material. It’s made out of the same absorptive material that you find on stealth fighters. It’s literally a one or two pound almost looks like a paperweight, almost, a very heavy object and said, “OK, cool this down and see how it looks.” Amazingly it was 10 times better than what we had before. Went from 500 nanoseconds to five microseconds. Easily the highest coherence time we’d ever measured at IBM. I remember calling at the time, our group lead, Mark Ketchen on the phone, we were blasting loud music in the lab just really, really excited that we saw this and we told Jim, “Hey, look, we proved you exactly wrong.” The engineer said, “I’ve never been more glad to be wrong.” Jay and Jerry’s idea to put our quantum computer in the cloud was brilliant.

[5:00] It showed people it was real. The boldness of saying what felt like a laboratory experiment is going to be available to all of you now. “I think it started by realising that our colleagues needed this tool to do their research.” “What we learned was that there was a huge appetite for accessing cloud deployed systems. I mean within the first few weeks there were people running algorithms. That first year we started to see exactly how much research was starting to be generated, what the community was bubbling into. You know that was fun itself. You know, finding the first like, quantum trolls on our little community forum. But it’s basically where we saw that this has so much legs in terms of expanse and who wants to use this. And who wants to learn from this. It changed how we looked at things completely. The field was enormously focused about what we could do when we had the so called “perfect quantum computer”.

← **EXCITE**
05:00
(653 Words) →

ACT II: PRODUCTION – “What we’ve done/why you should care”.

[6:00] But now, we had generation after generation of new capabilities. “You had remarkable algorithms but all of those were designed with this perfect machine in mind. But now we had these devices that were being made available. They were smaller. They were noisy. So how can we benefit from them? That was the time when the team did the simulation of beryllium hydride, which back then was the largest chemistry simulation, which back then was the largest chemistry simulation that was ever done on a quantum computer. It taught us about the promise for scaling and it really opened the door for exploring more applications in chemistry and more applications for physics. You know, it’s the saying, “Necessity is the mother of invention.” We are so bound by how we see the world and how we experience the world.

[7:00] But how many people realise that when they’re using a quantum computer, they’re going into extra dimensions. Extra dimensions are always presented as such a science fiction-y thing. But the mathematics of quantum mechanics is very clearly multi-dimensional. This abstraction in mathematics is how nature operates. It sounds like science fiction but it’s not. It’s just science. “All right, we’re starting to get our RABI data, let’s take a look, see if we see any that look... we did? Yeah they’re all looking about right here.” Everything so far you could have done with a classical computer. We already knew the outcome of every experiment.

[8:00] But now, we actually can’t predict what the Eagle will find. “Let’s take a look. Yep. Most of them look pretty well lined, so we’re all good.” “Hey,” “Appearances are looking pretty good too.” “So, is it alive?” “Looks like all 127 qubits are alive.” “All right, congratulations.” If you want to understand what these quantum computers with more than a hundred qubits can do, the only way is to use them.

[9:00] Today I am excited to present to you the first commercial quantum processor to break the qubit barrier. Meet Eagle, the new 127 qubit chip. For the first time in history we’ve entered the realm where a classical super computer can no longer fully simulate the behaviour of a quantum chip. Eagle will let us explore truly uncharted computational territory. 2019 brought the 27 qubit Falcon processor, which introduced a heavy hex qubit arrangement, arranging qubits on the edges and corners of hexagons allowed us to reduce errors caused by interference between qubits. In 2020 we were able to build Hummingbird our 65 qubit device, thanks to multiplexing.

[10:00] That’s the ability to read out multiple qubits with a single wire, which greatly reduced the number of components that needed to inside of the fridge. Eagle incorporates multiple qubits with a single wire which greatly reduced the number of components that need to go inside of the fridge. Eagle incorporates both of these advances and also takes advantage of IBM’s deep expertise in chip manufacturing and packaging to set the stage for scalable quantum computing. Even the quantum processors packaging is important for scaling. Quantum chips typically require a tangle of wires that have to be directed outward to the edge of the chip. But state of the art research allowed us to incorporate 3D integration into Eagle. This allowed us to put chip components and wiring on multiple physical levels, that make the path toward a 1000 qubit quantum computer possible. Next year, the IBM quantum team plans to release a 433 qubit processor called Osprey.

[11:00] And in 2023 they plan on debuting Condor, a 1,121 qubit processor. Condor will be an inflection point. It will allow us to explore error correction and dive deeper into the realm of quantum advantage. Everyone always talks about the number of qubits which is definitely important for running more complex calculations.

← **DISTURB**
06:00
(640 Words) →

ACT III: APPLICATION – “What’s next...?”

But qubit count, scale, is just one facet of the way we measure a quantum processors performance. Eagle represents improvements that will allow us to press forward on all 3 of our performance metrics: scale, quality and speed. For improved quality Eagle uses the latest advances in qubit fabrication, control electronics and software that will help us to maximise its quantum volume.

[12:00] For increased speed Eagle will seamlessly integrate with classical computing workflows using Qiskit Runtime and other improvements to maximise the number of quantum circuits it can run per second. It’s important to continue to develop the software systems to match the hardware advances. The OpenQASM 3 assembly language is already allowing developers to run circuits incorporating both classical and quantum instructions. We plan on developing new circuit libraries tailored to fields like finance, machine learning and chemistry. Making it easier than ever for developers to incorporate quantum into business workflows. So what can we expect from this step into uncharted computational territory? We hope to use Eagle to explore the realm of quantum advantage, where quantum computers can tackle problems faster and with fewer resources than classical computers. And quantum advantage might be coming sooner than you think.

[13:00] By integrating quantum with our classical high-performance computing resources, we will have a powerful combination that will open an entirely new path to study physics, chemistry and machine learning. The past 10 years have shown how fundamental scientific research has created a potentially paradigm shifting advance in computing. But what do the next 10 years have in store? We dream of a future with frictionless quantum computing, where users can code a quantum computer without having to know about the intricacies of the quantum processor. We envision developers across all levels of the quantum computing stack relying upon our advances hardware with a cloud-based API, working seamlessly with high-performance computing resources to push the limits.

[14:00] But developing this larger system poses a challenge. We believe that Eagle is the last processor that will fit inside of our IBM Quantum System One. System Two takes a hexagonal form. The scalable modern structure will allow us to bring fridges close together. It will give flexibility to design even larger quantum systems by linking processors together. System Two represents a glimpse into what the future of quantum computing looks like. A true quantum data centre. By following this roadmap, we think that by 2030 companies and users will be running a trillion quantum circuits a day. And we hope that quantum computers will be providing real world benefits, solving some of the world’s most important problems. I want to thank you, IBM Summit attendees for joining us on this journey over the past 10 years. We have made tremendous advances thanks to you, our global community of users and the IBM Quantum Network. We hope that you’ll stay with us for the next 10 years and beyond as we continue to transform computing together.

← **ASSURE**
04:00
(496 Words) →

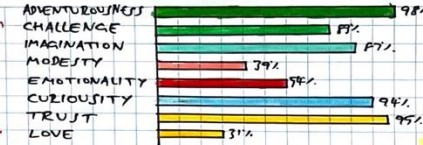


“Eagle can do things no other supercomputer is capable of....
It would take a billion times longer than this.”

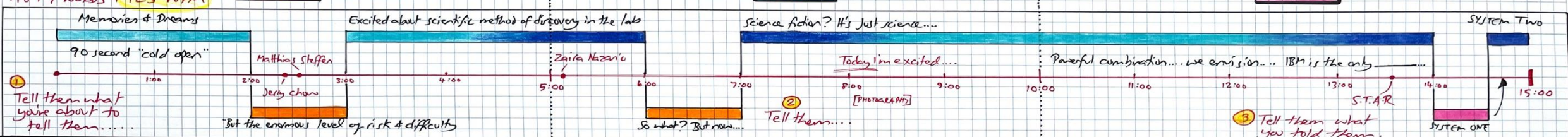
It would take a computer bigger than this planet to do what Eagle can do!

ARVIND KRISHNA

Perceived audience reaction based upon personality profiling of the speaker



THE RELATIONSHIP BETWEEN TECHNOLOGY & BUSINESS IS AT A CROSSROADS. MOORE'S LAW IS ENDING. A POWERFUL NEW APPROACH TO COMPUTING IS EMERGING. IF YOU THINK COMPUTERS HAVE DRAMATICALLY CHANGED THE WORLD SO FAR, WAIT UNTIL YOU SEE WHAT'S NEXT....



ACT I: DEVELOPMENT (IBM Q)
"The Scientific Method"

Act II: PRODUCTION
"What we've done & WHY you should care"

ACT III: APPLICATION & IMPACT

"What's next & how can it help you gain a (quantitative) advantage?"

[1:00] Someone said "Memories are like time travel to the past and dreams are time travel into the future". Well, we have definitely travelled into the future. A lot of people said building a hundred plus quantum computer was just a pipe dream. We wouldn't get there until decades from now. And here we are. Out of the crazy ideas of quantum mechanics, this real thing, in just 10 years. Such a fantastic example of the scientific method. ref: wild ducks / crazies PATHOS Build on SMUGA

[2:00] Hypothesizing, testing, inventing, experimenting, with all the ways to make qubits, how they could work and how they could look. And also how often you're gonna get stuck. There's so much history in these qubits. Charlie Bennett and Rolf Landauer got us all started on this. Asking things like, "Is there a fundamental limit to how efficiently you can store information?" and "Is information thermodynamically reversible?" or "What of things that a physicist would ask. I remember going to see our first quantum laboratory and the modesty of what the laboratory environment looked like. Time2 ETH 01

Hypothesis not yet theory. Inventing tech that doesn't exist yet. TEN YEARS

[6:00] But now, we had generation after generation of new capabilities. "You had remarkable algorithms but all of those were designed with this perfect machine in mind. But now we had these devices that were being made available. They were smaller. They were noisy. So how can we benefit from them?" That was the time when the team did the simulation of beryllium hydride, which back then was the largest chemistry simulation, which back then was the largest chemistry simulation that was ever done on a quantum computer. It taught us about the promise for scaling and it really opened the door for exploring more applications in chemistry and more applications for physics. You know, it's the saying, "Necessity is the mother of invention." We are so bound by how we see the world and how we experience the world. [PATHOS]

[7:00] But how many people realise that when they're using a quantum computer, they're going into extra dimensions. Extra dimensions are always presented as such a science fiction-y thing. But the mathematics of quantum mechanics make it a very real thing. It's a very real phenomenon. It's not something that's native on the

[11:00] And in 2023 they plan on debuting Condor, a 1,121 qubit processor. Condor will be an inflection point. It will allow us to explore error correction and dive deeper into the realm of quantum advantage. Everyone always talks about the number of qubits which is definitely important for running more complex calculations. But qubit count, scale, is just one facet of the way we measure a quantum processor's performance. Eagle represents improvements that will allow us to press forward on all 3 of our performance metrics: scale, quality and speed. For improved quality Eagle uses the latest advances in qubit fabrication, control electronics and software that will help us to maximise its quantum volume. Triple KPI's: Scale/Quality/Speed
"Survival of the fittest"

[12:00] For increased speed Eagle will seamlessly integrate with classical computing workflows using Qiskit Runtime and other improvements to maximise the number of quantum circuits it can run per second. It's important to continue to develop the software systems to match the hardware advances. The OpenQASM 3

[3:00] But the enormous level of risk and difficulty of what was behind the scenes in this modest laboratory. Our first quantum device, quantum system, and the basis of all our future quantum computers. "Certainly I'd say one of my fondest memories involves studying this one, actually a single qubit system that we had back then." The effective temperature that this device exhibited was far higher than what the fridge temperature stated it was. And we've tried numerous experiments over the years to try to address that. But nothing seemed to work very well. The quantum community started to get a sense that maybe this was some other radiation, black body radiation that might be causing this." We took this idea back and we shared it with one of our engineers, Jim Rosen, and he didn't believe it at all. He actually just said, "I'm going to prove to you that this is baloney."

[4:00] "So he did something really, really drastic. He took the entire package and he bricked it into this, what we call Eccosorb material. It's made out of the same absorptive material that you find on stealth fighters. It's literally a one or two pound almost looks like a paperweight, almost, a very heavy object and said, "OK, cool

It sounds like science fiction, but it's not. It's just science. "All right, we're starting to get our R&D data, let's take a look, see if we see any that look... we did? Yeah they're all looking about right here." Everything so far you could have done with a classical computer. We already knew the outcome of every experiment.

[8:00] But now, we actually can't predict what the Eagle will find. "Let's take a look. Yep. Most of them look pretty well lined, so we're all good." "Hey," "Appearances are looking pretty good too." "So, is it alive?" "Looks like all 127 qubits are alive." All right, congratulations. "If you want to understand what these quantum computers with more than a hundred qubits can do, it's the only way to use them."

KARLO + ETHIO

[9:00] Today I'm excited to present to you the first commercial quantum processor to break the qubit barrier. Meet Eagle, the new 127 qubit chip. For the first time in history we've entered the realm where a classical super computer can no longer fully simulate the behaviour of a quantum chip. Eagle will let us explore truly uncharted computational territory. 2019 brought the 27 qubit Falcon processor, which introduced a heavy

Don't need to understand quantum to leverage it's advantage

instructions. We plan on developing new circuit libraries tailored to fields like finance, machine learning and chemistry. Making it easier than ever for developers to incorporate quantum into business workflows. So what can we expect from this step into uncharted computational territory? We hope to use Eagle to explore the realm of quantum advantage, where quantum computers can tackle problems faster and with fewer resources than classical computers. And quantum advantage might be coming sooner than you think. **KAISO**

Ref: Daimler to Competitive advantage

[13:00] By integrating quantum with our classical high-performance computing resources, we will have a powerful combination that will open and entirely new possibilities to enable our machine learning. The past 10 years have shown how fundamental scientific research has created a potentially paradigm shifting advance in computing. But what do the next 10 years have in store? We dream of a future with frictionless quantum computing, where users can do next-generation computing without having to know about the intricacies of the quantum processor. We envision developers across all levels of the quantum computing stack relying upon our advances hardware with a cloud-based API, working seamlessly with high-performance computing

this down and see how it looks. Amazingly it was 10 time better than what we had before. Went from some nanoseconds to five microseconds. Easily the highest performance time we'd ever measured at IBM. I remember calling it the "grand old Mark 1 machine". We were blasting pop music in the lab just really, really excited that we saw this and we told Jim, "hey look, we proved you exactly wrong." The engineer said, "I've never been more glad to be wrong." Jay and Jerry's idea to put our quantum computer in the cloud was brilliant.

[5:00] It showed people it was real. The boldness of saying what felt like a laboratory experiment is going to be available to all of you now. "I think it started by realising that our colleagues needed this tool to do their research." "What we learned was that there was a huge appetite for accessing cloud deployed systems. I mean within the first few weeks there were people running algorithms. That first year we started to see exactly how much research was starting to be generated, what the community was bubbling into. You know that was fun for itself. You know, finding the first like, quantum troll on our little community forum. But it's basically where we saw that this has so much legs in terms of expansion and who wants to use. And who wants to learn from this. It changed the way we thought about things completely. The field was enormously focused about what we could do. And we had this so-called "perfect quantum computer".

hex qubit arrangement, arranging qubits on the edges and corners of hexagons allowed us to reduce errors caused by interference between qubits. In 2022 we were able to build Hummingbird our 65 qubit device, thanks to multiplexing.

(Lucas) Educate & Inform... **Rebecca ETHUS @ CM**

[10:00] That's the ability to read out multiple qubits with a single wire, which greatly reduced the number of components that needed to be inside of the fridge. Eagle incorporates multiple qubits with a single wire which greatly reduced the number of components that need to go inside of the fridge. Eagle incorporates both of these advances and also takes advantage of IBM's deep expertise in chip manufacturing and packaging to set the stage for scalable quantum computing. Even the quantum processors packaging is important for scaling. Quantum chips typically require a tangle of wires that have to be directed outward to the edge of the chip. But state of the art research allowed us to incorporate 3D integration into Eagle. This allowed us to put chip components and wiring on multiple physical levels, that make the path toward a 1000 qubit quantum computer possible. **Next year**, the IBM quantum team plans to release a 433 qubit processor called Osprey.

CHALLENGE - VM QUE POW

BREVITY

IBM's unique packaging

why should we care?

resources to push the limits.

[14:00] But developing this larger system poses a challenge. We believe that Eagle is the last processor that will fit inside of our IBM Quantum System One. And so, we are excited to unveil a concept for a new line of scalable quantum computation: the IBM Quantum System Two. System Two is a bridge to the future of quantum computing. IBM Quantum engineers took a holistic approach that will be capable of housing the upcoming 400 and 1,000 qubit processors. And even processors we haven't begun to develop yet. System Two takes a hexagonal form. The scalable modern structure will allow us to bring fridges close together. It will give flexibility to design even larger quantum systems by linking processors together. System Two represents a glimpse into what the future of quantum computing looks like. A true quantum data centre. By following this roadmap, we think that by 2030 companies and users will be running a trillion quantum circuits a day. And we hope that quantum computers will be providing real world benefits, solving some of the world's most important problems. I want to thank you, IBM Summit attendees for joining us on this journey over the past 10 years. We have made tremendous advances thanks to you, our global community of users and the IBM Quantum Network. We can't wait that you'll stay with us for the next 10 years and beyond as we continue to transform computing together.

← setup "System Two" (WHAT IF....)

set up tangible gains: Question advantage in year
high by 2003

PATHOS. Ref: "Accelerate Together" + BELIEVE + HOPE

BRIEF

SOLUTION

CHARITY IBM BELIEVES IN PROGRESS. THAT THE APPLICATION OF INTELLIGENCE, REASON & SCIENCE CAN IMPROVE

- TELL AN ENGAGING STORY ABOUT IBM QUANTUM RESEARCH
- SHOWCASE THE SCIENTIFIC METHOD (BUT DON'T BE BORING)
- KEEP THE LANGUAGE SIMPLE & ACCESSIBLE
- CREATE A DRAMATIC STORY WITH CONTRAST (NOT "CONFLICT")
- MAKE IT SHORT & AVOID DEATH-BY-POWERPOINT
- HAVE A S.T.A.R. MOMENT (SOMETHING THEY'LL ALWAYS REMEMBER)
- ACKNOWLEDGE THE UNCERTAINTY, CHALLENGES, POTENTIAL & QUANTUM

- USE A 3 ACT STRUCTURE LIKE A MOVIE: "EXCITE / DISTURB / ASSURE" OVERLAIN WITH
- FEATURE STORY AROUND IBM'S SCIENTIFIC METHOD **SMUBA**: SEE "MENTIONED GX / MAP
- GUNNING FOG INDEX 12.12! "HIGH SCHOOL STUDENT" (UNUSUALLY 16+ GRAD) → SHORT S
- APPLY JAPANESE METHOD OF STORYTELLING (NO SPECIFIC VILLAINS) = "KISHOTEN K
- INSPIRED BY BRYAN STEVENSON'S 3 ACT TED TALK (3x5 MIN.) "LONGEST EVER S
- WORLD'S FIRST QUANTUM DATA CENTRE - UNVEIL "IBM SYSTEM TWO" TO
- DEMONSTRATING TECH WITH LITTLE APPLICATION BUT 100% AVAILABLE MA

"THE HERO'S JOURNEY" BUTLER, SOCIETY & THE HUMAN CONDITION

"ROADMAP" / "UNDERSTANDING" x 1 / "BELIEVE" x 2 / "ACTION" - LIBRARIES NOW / SDG 2030

SENTENCE STRUCTURE + 30% LESS 3 SYLLABLE WORDS (ONLY 291 = 1:16)

ETSV" ~~CONFLICT~~ CONTRAST = BUT MENTIONED 14x (1:132)

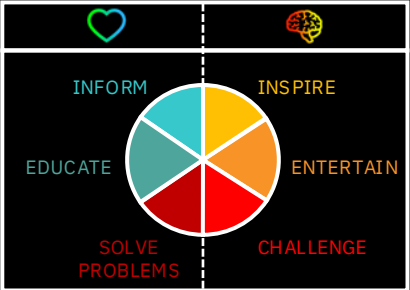
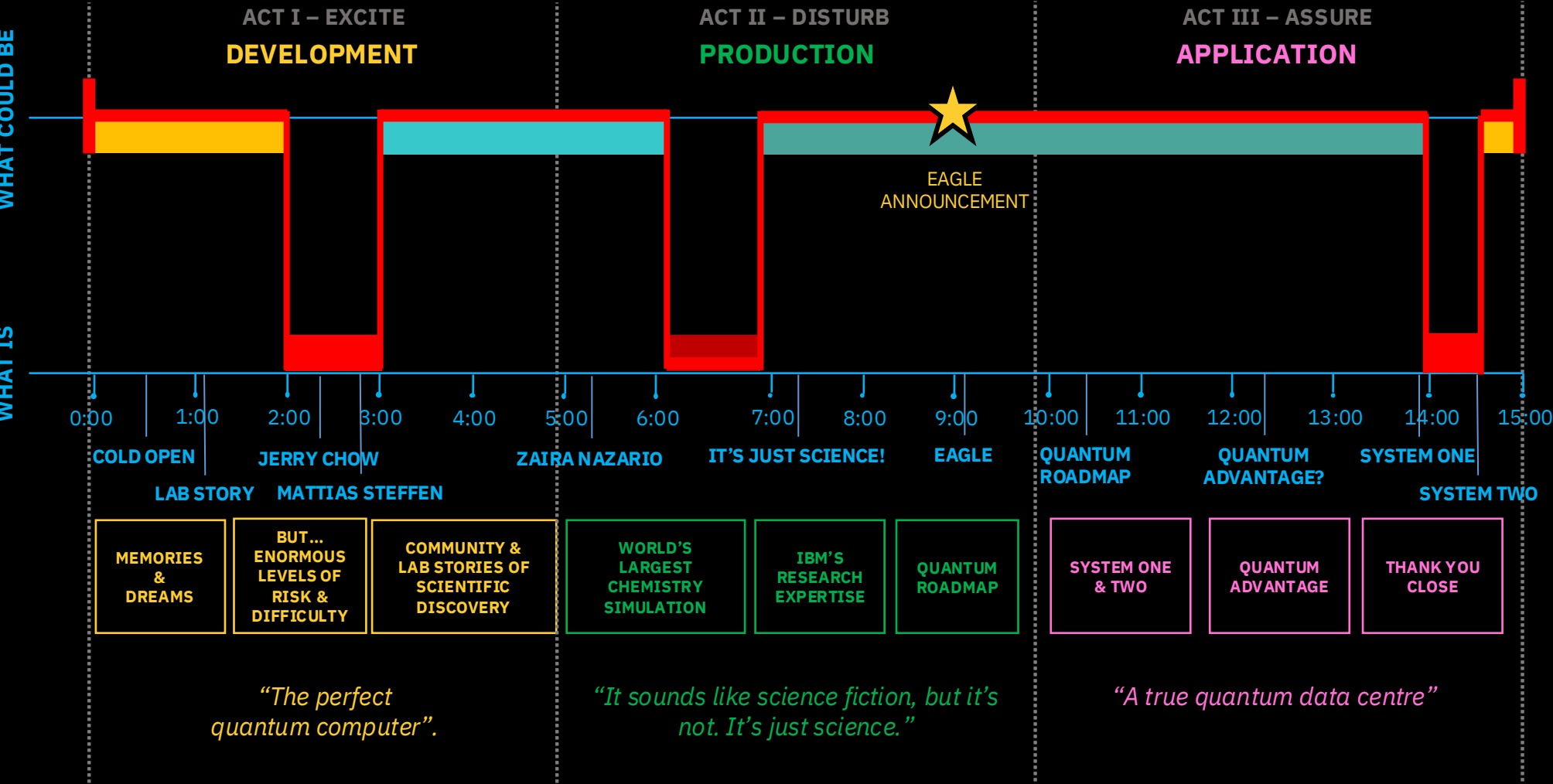
HANDING OVATION CTED" + STUNNING PHOTOGRAPHY/VIDEO + ONLY 5 SLIDE

SCALE ABOVE 1,000 QUITS - CURRENTLY IMPOSSIBLE

+ POTENTIAL TO SOLVE WORLD'S BIGGEST PROBLEMS BY 2030 - SDG:



“Eagle” Presentation for Quantum Summit (15 mins)



DARIO GIL, SVP IBM RESEARCH

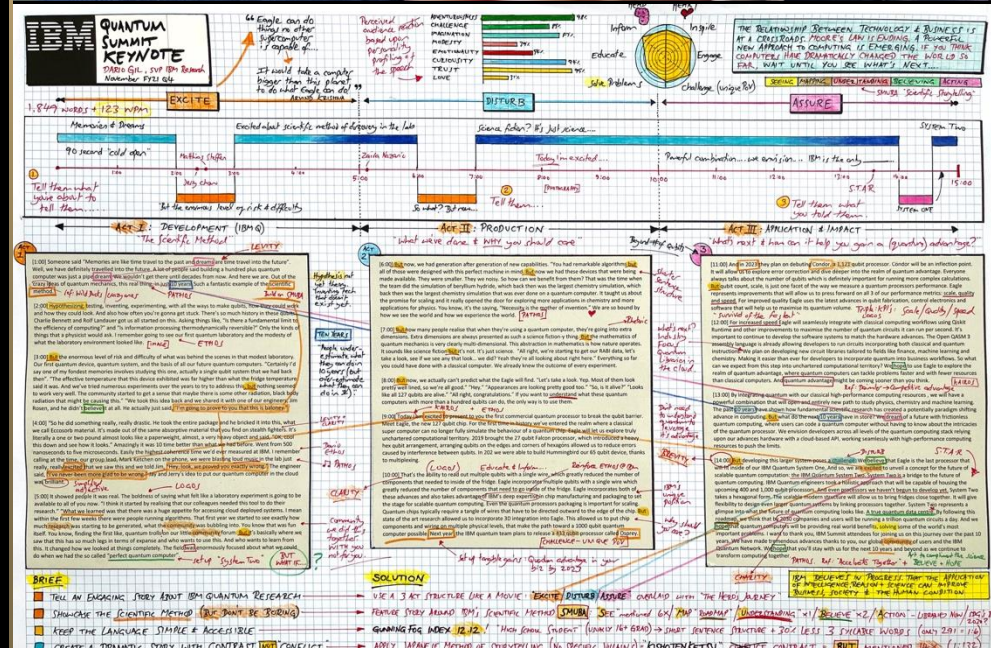


15 min video presentation

- A complicated speech presented in a simple 3-act structure
 - Act I: **DEVELOPMENT** – *The Scientific Method*
 - Act II: **PRODUCTION** – *What it means to you*
 - Act III: **IMPACT** – *Applications today & in the future*

- 15 mins** (Inspired by the top TED Talks)
- 120+ Words/Minute** = Thoughtful words & slower pace
- Memories & Dreams** = 90 Second personal “cold open”
- Props:** Quantum processors bring the story to life
- Language:** CXO-friendly but doesn’t compromise academically
- SMUBA** References (SEEING / MAPPING / UNDERSTANDING / BELIEVING / ACTING)
- BUT** mentioned 14X = **CONTRAST NOT conflict**
- 5 Slides** + 3 soundbites to alternate pace and keep attention
- Gunning Fog Index** “readability score” of 12.12 (Usually 16+)
- S.T.A.R. moment** = Quantum Data Center x IBM System Two

Darío Gil, Ph.D.
Senior Vice President and Director
of Research | IBM





Dario Gill

KEYNOTE ANALYSIS

The Quantum Era of Accelerated Discovery

Dario Gil, Ph.D.
Director of IBM Research



IBM Quantum



Premium ^{GB}

Communications Masterclass



Dario Gil: Cognitive systems and the future of expertise

26,868 views • 22 Dec 2014

150

4

SHARE

SAVE



TED Institute
54.2K subscribers

SUBSCRIBE

we have - the world of bits

You've got 3 minutes to win an audience.

Jerry Seinfeld

COLD OPEN
25 Title - no cred.

3 BIG NUMBERS

4:00 QUANTUM AFFORDS US

③ SUPER POWERS
superposition
interference
entanglement

WHY DOES THIS MATTER?

IBM Q
Hummingbird
5628 qubits
No bogging
make 'em go
"Wow!"

A Quantum Circuit is the unit of value for your business

2:00 Use Case

TOUR D CLOSURE

Easy IBM cloud program in your favorite language like C++

New metric
"Quantum Volume"
How we manage
scaling
+ progress

EDU

we are witnessing the most exciting development in computing for 60 years.

BITS/QUBITS/NEURONS

③

building

Arg

The convergence of happening with science itself
with the rate at which perform acceleration
Whole new mission critical in intelligent

"AND THEN WHAT HAPPENS?"
No. 1 Gainer

INTENTION & OBSTACLE
from left

TRIPLE

Implications for
SCIENCE
BUSINESS
BIOLOGY
at LARGE

COVID-19
"villain"

Technical breakthrough of QUBITS v 0.2
Elegant design

"BUT... we have a special trick"

THE POWER OF EXPERIMENTAL
more than...
atoms in universe
if each atom
shook 1.0"

Mother Nature is an example of an experimental problem

"EASY PROBLEMS + HARD PROBLEMS"
"villain"
we can't solve.

figure not exploiting classical those quantum you'll never get there

LET'S GO
TAKE A LOOK
AT A FEW
SO YOU CAN
SEE WHAT
THEY
LOOK LIKE

ACT III

This is one of the very first quantum computational centers to have ever been created.

ACT II

ACT I

9

Tech

4000 words

(28 MINUTES = approx. 4000 words)

10

4000?

WHAT

INFORM INSPIRE

EDU ENT

SR CHALL

WHY & HOW

9 x 150 = 1350

BUT IMAGINE THAT WE CAN MANIPULATE THOSE BITS.

PARADIGM PROFILE

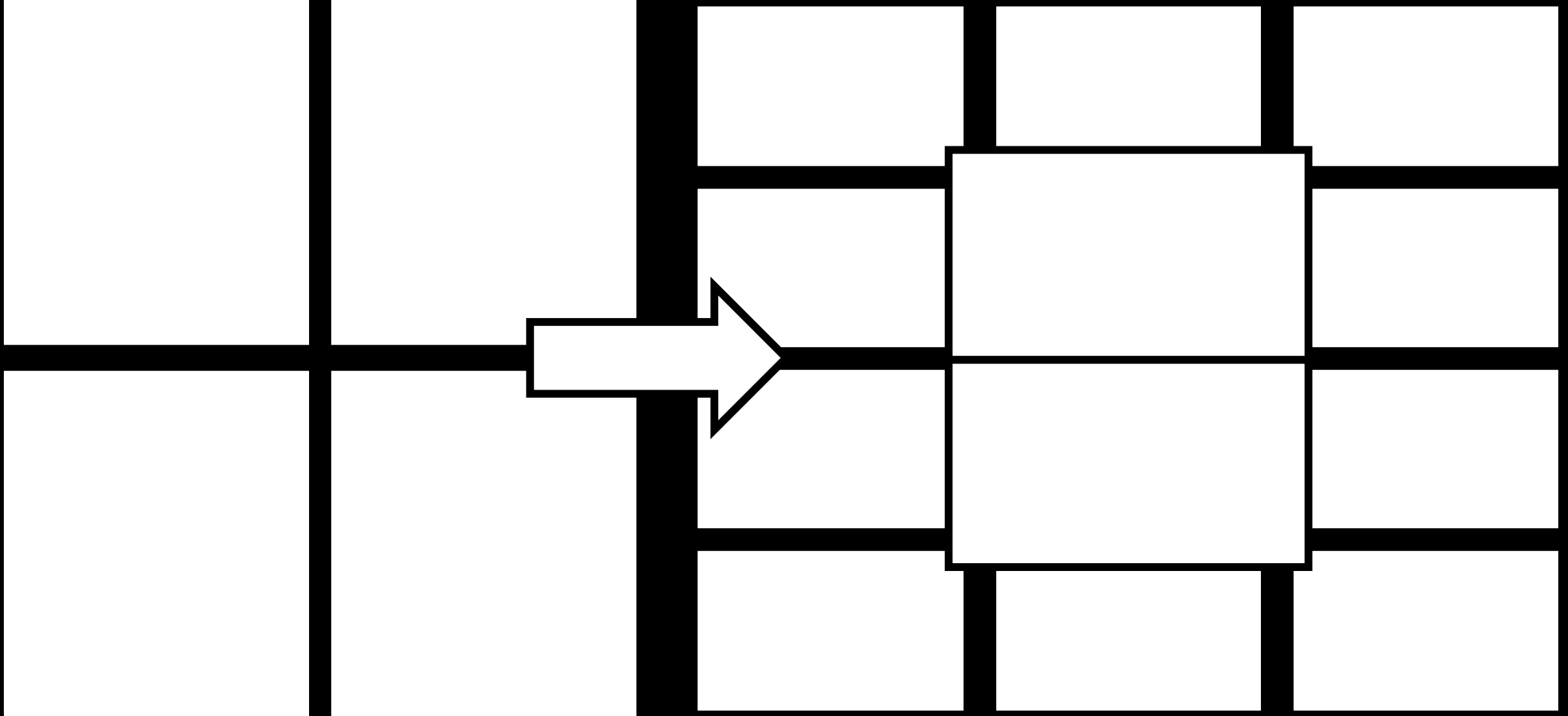
- VALUES - Drive change
- BIG 5 - Trust/Innovation/Endogeneity
- NEEDS - Resiliency/stability/structure

Regulation



Commercial Story Board

Who, What, Why, Where & When?





Commercial Story Board

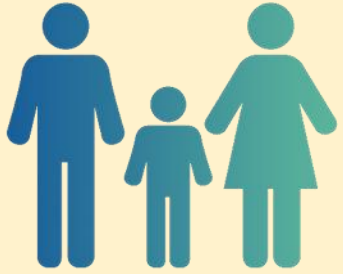
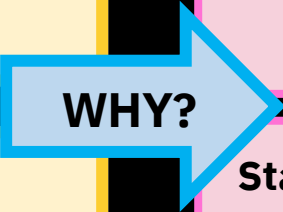
Who, What, Why, Where & When?

What?	For Who?	Topic	Conflict	Unique Value Proposition
In Competition With?	Different From?	Heroes	Point of View	Today's World
		Stage	Mission	History
		Internal Stories	User stories	Magic Facts
YOUR MESSAGE		YOUR AUDIENCE		



PERSONAL Story Board

Who, What, Why, Where & When?

What You LOVE 	What You Get Paid For 	Topic	Conflict	Unique Value Proposition
What You're Good At 	What The World Needs 	Heroes	Point of View	Today's World
WHY? 		Stage	Mission	History
		Internal Stories	User stories	Magic Facts
YOUR MESSAGE		YOUR AUDIENCE		



Dario Gill

The Quantum Era of Accelerated Discovery

What?

- IBM THINK
- May 2020
- 30 minute pre-recorded virtual presentation
- Quantum 101
- No Q&A

For Who?

30,000 online audience with an estimated 3-5% in this breakout.

General audience but mostly IT, tech leaders & innovators.

In Competition With?

- Netflix?
- YouTube?
- Email?
- Traditional Thinking?
- Relevance (to me?)

Different From?

- Google Quantum AI Lab
- Accenture & 1QBit
- Amazon Bracket
- Intel Labs
- Microsoft Azure Quantum

WHY?

Why?

In moments of crisis we need to come together & solve complex problems differently.

Topic

“The Quantum Era of Accelerated Discovery”

Conflict

We can’t solve some of the world’s biggest problems via classical computers.

UVP

We can give you access to the world’s largest & most powerful fleet of Quantum computers.

Point of View

There are profound implications for Bits, Neurons & Qubits converging through hybrid-cloud & AI-assisted programming.

Today’s World

IBM has a fundamentally different way of computing that can transform businesses & societies.

Heroes

- You. Together with...
- IBM Research
- (Sergey Bravyi?)

Stage

- Office
- Media Studio
- Yorktown Labs

Mission

To HELP YOU be among the first to explore, define, and benefit from the rapidly approaching age of quantum computing.

History

The most exciting time in computing for 60 years. A revolution driven by exponential computing power.

Internal Stories

COVID-19 Computing Consortium (30+ members)
Scaling IBM Q 2X YoY
NEW KPI: Quantum Volume

User stories

- Daimler
- ExxonMobil
- JPMorgan Chase & Co.

Magic Facts

180 billion quantum circuits executed by IBM Q via IBM Cloud. 230,000 users worldwide. 18 quantum systems available to YOU.

Your **Mission:** To **help you** be among the first to explore, define, and benefit from the rapidly approaching age of quantum computing.

This is not just aspirational. We are doing this today. We are committed to doubling our computing power every year and we want you to access quantum technology to leverage the opportunities within the most exciting time in computing in the last 60 years.

Transformation Vision

The world is facing some unprecedented challenges which **we can't solve on our own.** We are inviting you to collaborate with us, so that together we can solve some of the biggest problems facing science and industry today.

Your Hero

There are easy problems and there are hard problems. With **COVID-19** Mother Nature has given us an example of an exponential problem that classical computers can't solve.

What's their Problem?

Why Should I Trust You & Why Should I Care?

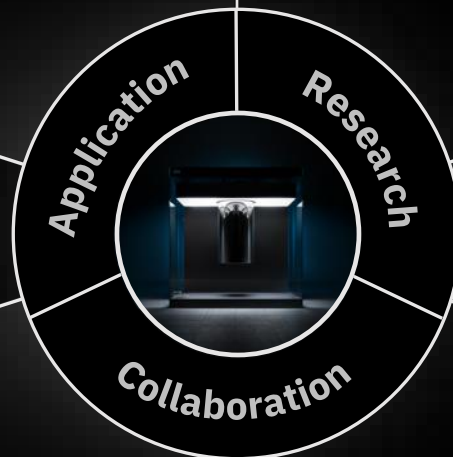
IBM have built **the world's first** integrated universal approximate quantum computing system designed for scientific and commercial use with **YOU can access via IBM Cloud.**

Your Plan for a Safe Journey

IBM's Quantum computing team which includes some of the best minds in the world (including leading quantum theorist Sergey Bravyi) are already **building libraries for you to use.**

What Success Looks Like

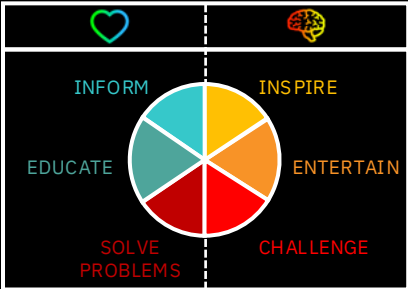
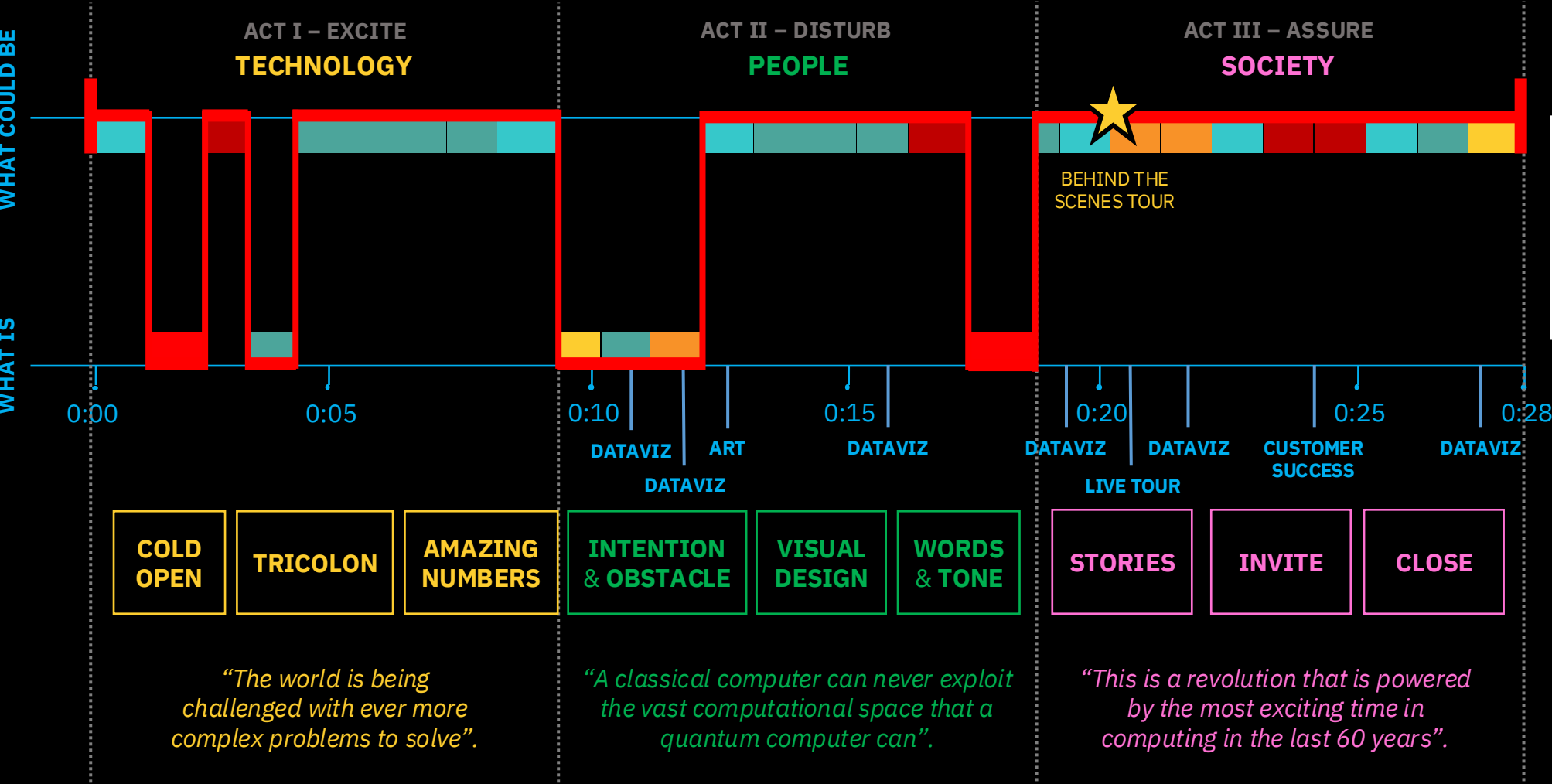
Combining the best of classical computing systems with quantum is helping companies such as Daimler, ExxonMobile and JPMorgan Chase & Co. solve some of these complex problems while gaining a **competitive advantage.**





The Quantum Era of Accelerated Discovery

Dario Gill, THINK, May 2020



The Quantum Era of Accelerated Discovery

Dario Gil, Ph.D.

Director of IBM Research



Cold Open

Establish Empathy & Authority by Informing & Inspiring

- First 75 seconds is critical (Av. Attention span B2B exec)
- *“If you’re worth \$1Bn you get 3 minutes”*
- *Inspire, Inform & Create Urgency*

00:00 – 00:23

Open (*Inform*)

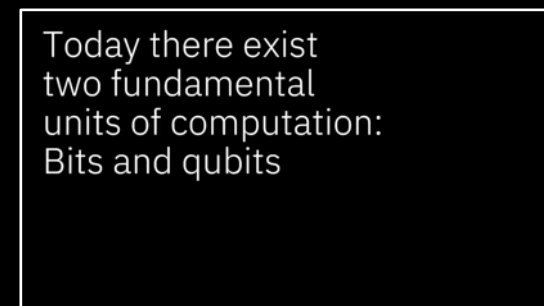
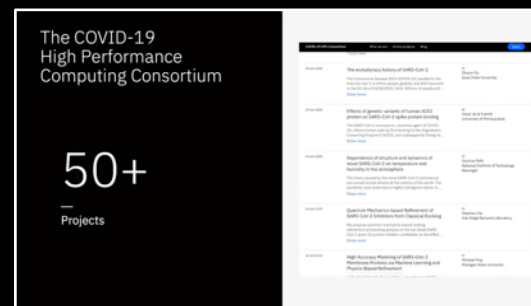
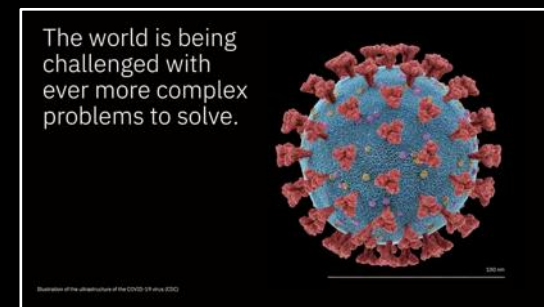
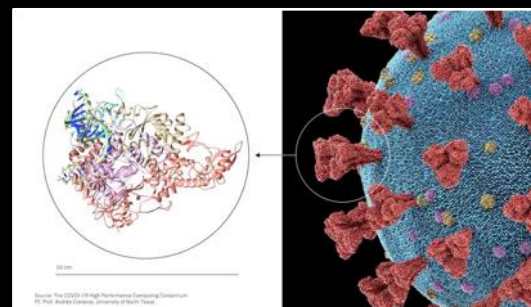
00:23 – 02:23

COVID-19 (*“Collaborate”*)

02:23 – 02:58

“What this tells us...”

- ✓ Tell them what you’re about to tell them.
- ✓ Tell them.
- ✓ Tell them what you told them.





Tricolon

Use the power of 3 to guide your audience

A **tricolon** is a rhetorical device that employs a series of three parallel words or phrases. The word derives from Greek tri (“three”) + colon (“section of a sentence”).

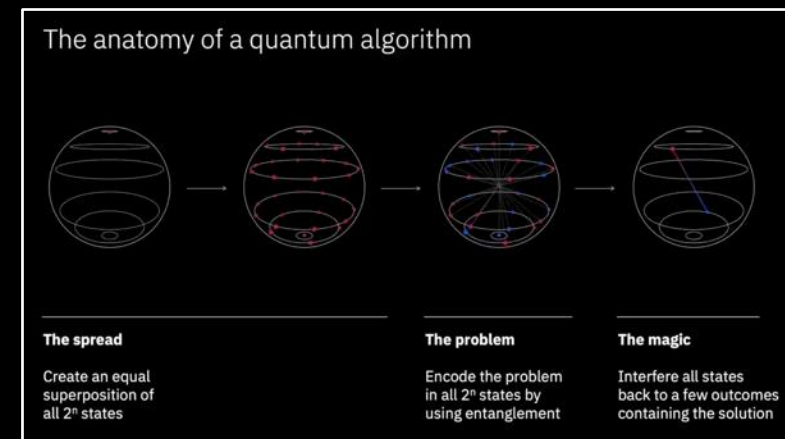
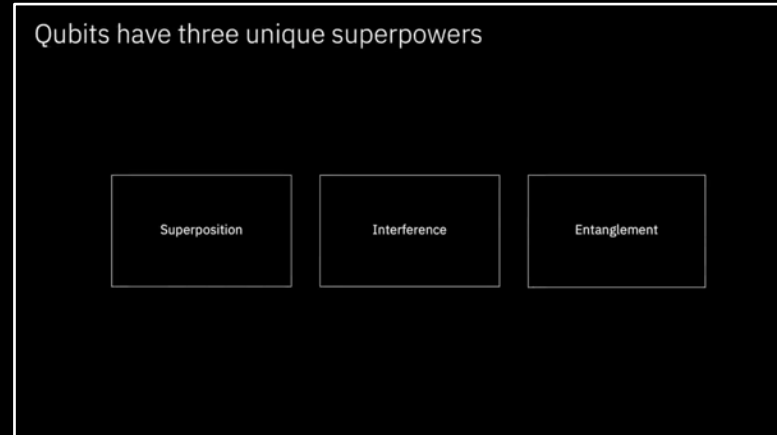
00:23 *“Quantum era.. and the implications it will have for **science, discovery and business**”.*

04:04 *“Quantum affords us three unique superpowers: **Superposition, Interference & Entanglement.**”*

07:26 *“The spread, the problem and the magic...”*

*“Any sufficiently advanced technology is indistinguishable from **magic**”.*

ARTHUR C. CLARKE





Amazing Numbers

Bring data to life by comparing to real-world examples

Example: If digital transformation has an 85% failure rate, a 15% success rate is only 2% higher than the odds of gambling in a casino!

09:00 *“Here’s an **amazing number**: By the time you have 100 perfect Qubits that are entangled with one another, if you needed to describe them using 0’s and 1’s, you would need to devote every atom of planet earth to store those 0’s and 1’s.*

“Oh, the stories data would tell, if there were a teller to tell them well.”

NANCY DUARTE

The power of exponential	
Qubits	Classical bits required to represent an entangled state
2	512 bits
3	1,024 bits
10	16 kilobytes
16	1 megabyte
20	17 megabytes
30	17 gigabyte
35	550 gigabytes
100	More than all the atoms of planet earth
280	More than all the atoms in the universe

380	More than all the atoms in the universe
100	More than all the atoms of planet earth
32	220 kilobytes



Intention & Obstacle

Tell more compelling stories by introducing conflicts & villains

- 00:53** *“**We’re struggling** to figure out ways how to deactivate the functioning of the virus.”*
- 02:42** *“Today we’re fighting within the context of the computational paradigm we have... **BUT** there’s another computational paradigm that is emerging...”*
- 03:49** ***BUT** imagine if we can manipulate those bits...*
- 17:35** *“Not all circuits have equal value... because if you’re not exploiting that computational space... you don’t get there”. [FOMO – 4/5 ‘overwhelmed’]*

*“The story doesn’t begin until you use the words ‘**BUT**’ or ‘**AND THEN**’.”*

AARON SORKIN

Not all circuits
have equal value.

Communications Thinking™ Masterclass | Lesson 3

Pixar Story Structure

Journeys, Heroes, Villains, Conflicts & Obstacles.



Once upon a time _____. Every day _____.

One day _____. Because of that _____.

Because of that _____. Until finally _____.

“Art challenges technology. Technology challenges the art”. John Lasseter



Visual Design

Simplicity, Elegance & 6 Objects Per Slide*

The world is being challenged with ever more complex problems to solve.

The COVID-19 High Performance Computing Consortium

Bringing together the Federal government, industry, and academic leaders to provide access to the world's most powerful high-performance computing resources in support of COVID-19 research.

30+ Members 400+ Petaflops 100k+ Nodes

Today there exist two fundamental units of computation: Bits and qubits

The power of exponential

Qubits	Classical bits required to represent an entangled state
2	112 bits
3	1,024 bits
10	1A kilobyte
16	1 megabyte
20	17 megabytes
30	17 gigabytes
35	500 gigabytes
100	More than all the atoms in planet earth
280	More than all the atoms in the universe

Easy problems and hard problems

Inside an IBM Quantum superconducting quantum processor

Chemistry

Exploring when the automotive and transportation industry will leverage quantum computing.

Energy of binary crystalline materials circuit.

Scaling quantum volume by at least 2x/year

The world is being challenged with ever more complex problems to solve.

100 nm

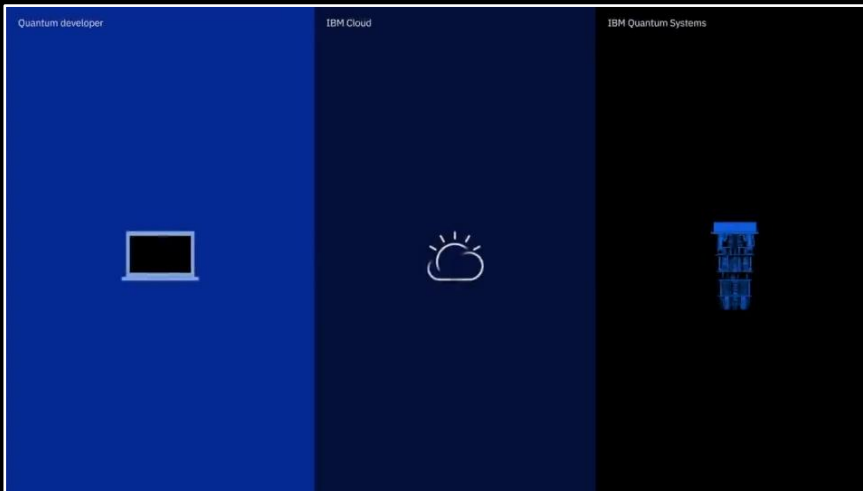
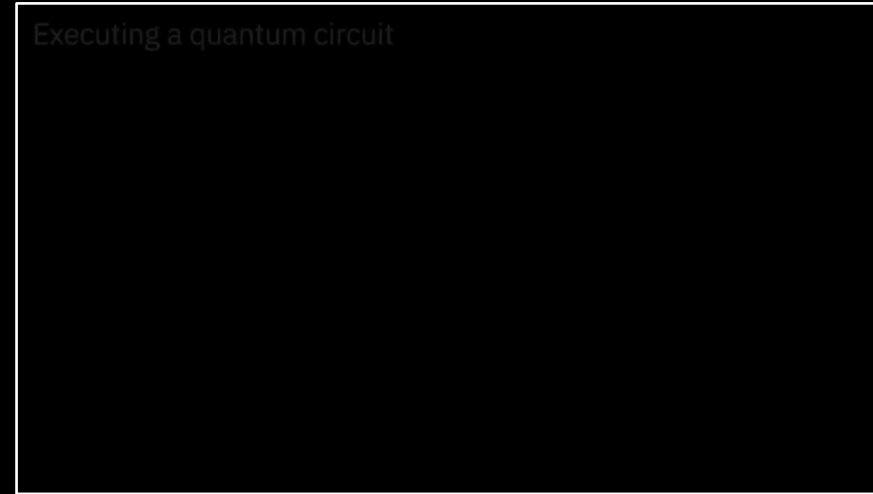
Illustration of the ultrastructure of the COVID-19 virus (CDC)

* The amount of slides is never the problem, the amount of objects on the slide is always the problem.



Visual Design

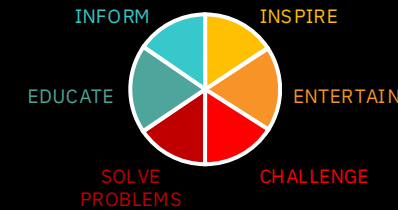
Animations educate faster & build stronger stories



Words & Tone

Remember the 7/38/55 Rule

In 1967 UCLA Professor **Albert Mehrabian** wrote a paper on the relative impact of **words** (7%), **tone of voice** (38%) and **body language** (55%) in communication. His conclusion was that tonality is 5X more important than the words spoken.



*"We're very **fortunate** that some of the best minds in the world are thinking really hard about what are the classes of circuits that give us a path to quantum **advantage**".*

*"In moments of crisis, it is particularly important that we all come **together**. The world is being challenged with ever more complex problems to solve."*

*"What this tells us is something very **profound**..."*

*We are witnessing the most **exciting** development in computing for 60 years".*

*"This is not **aspiration**, we are doing this today".*

***beautiful** machines... **gorgeous** pieces of engineering & science".*

*We're very **excited**... the best of classical programming with the best of quantum power.*

*"Let me close with a reflection on the **urgency** of tackling some of the world's most complex problems".*



Customer Success Stories

One Sentence Elevator Pitches

Chemistry

Daimler AG

Exploring ways the automotive and transportation industry can leverage quantum computing.

Energy of binary crystalline materials circuit.



Daimler
28 seconds

Exploring Quantum to invent new battery technologies & highlight manufacturing defect inspections

Chemistry

ExxonMobil

Exploring how quantum computing can help develop the next generation of energy solutions.

Accurate thermodynamic observables calculation circuit



ExxonMobil
29 seconds

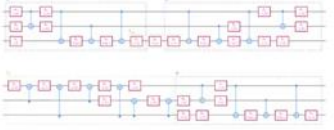
Modeling thermodynamic in collaboration with several partners to develop new energy solutions.

Optimization

JPMorgan Chase & Co.

Researching how quantum computing can improve trading strategies, enhance client portfolios, and better analyze financial risk.

European derivative pricing circuit



JPMorgan Chase & Co.
26 seconds

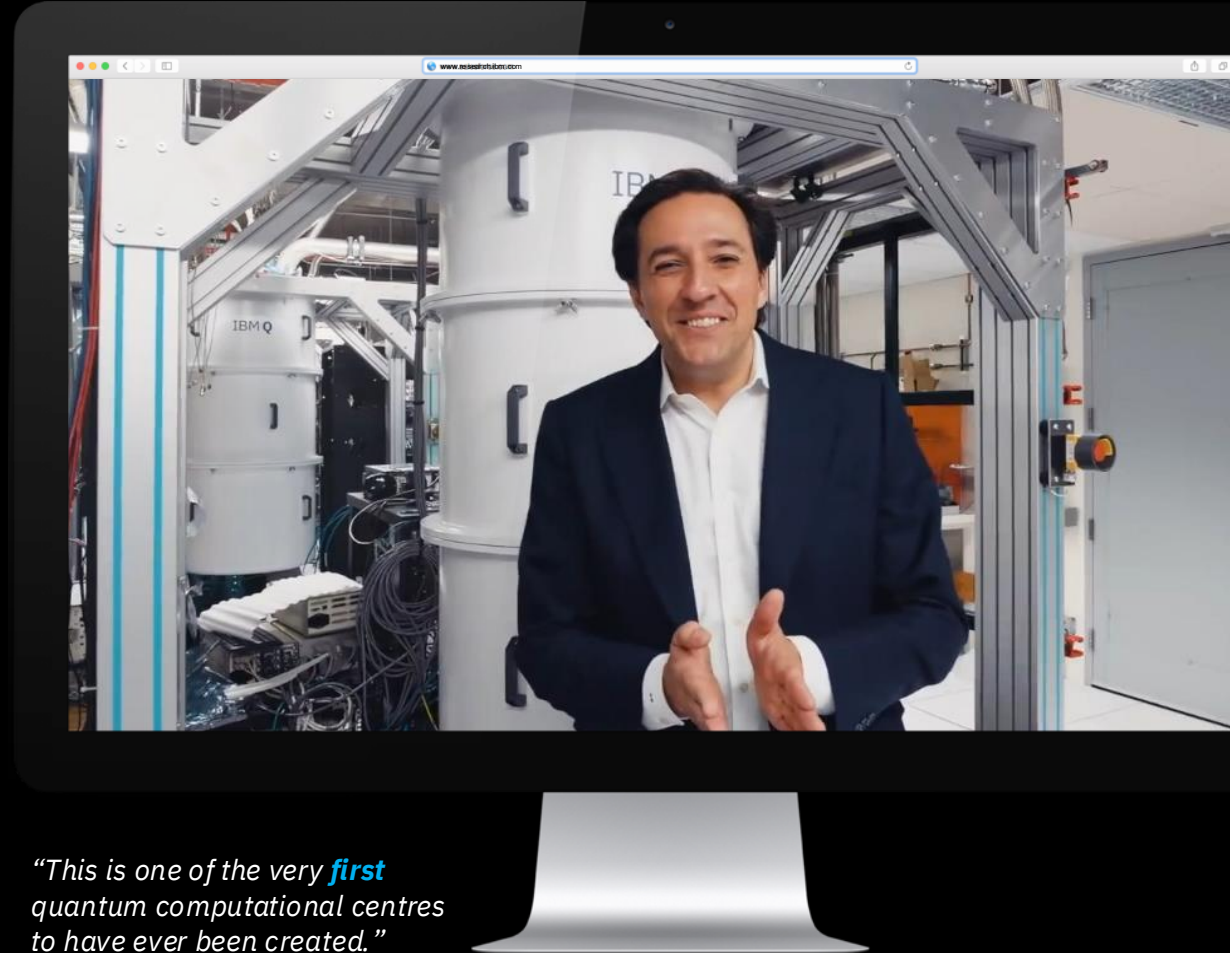
Looking at the potential to find solutions to portfolio optimization or fraud detection that classical computers are not capable of.



Invitation

Engage the audience on a journey. Literally.

- B2B attention spans are 75-90 secs.
- Dario's tour of the IBM Q labs took **93 secs**.
- Dario engages the camera directly.
- *"Let's listen to the sound of a quantum computer"*.
- Positive body language with hand gestures to look behind behind the scenes mirrors the mission of the story that **"we need to come together"**.





Close

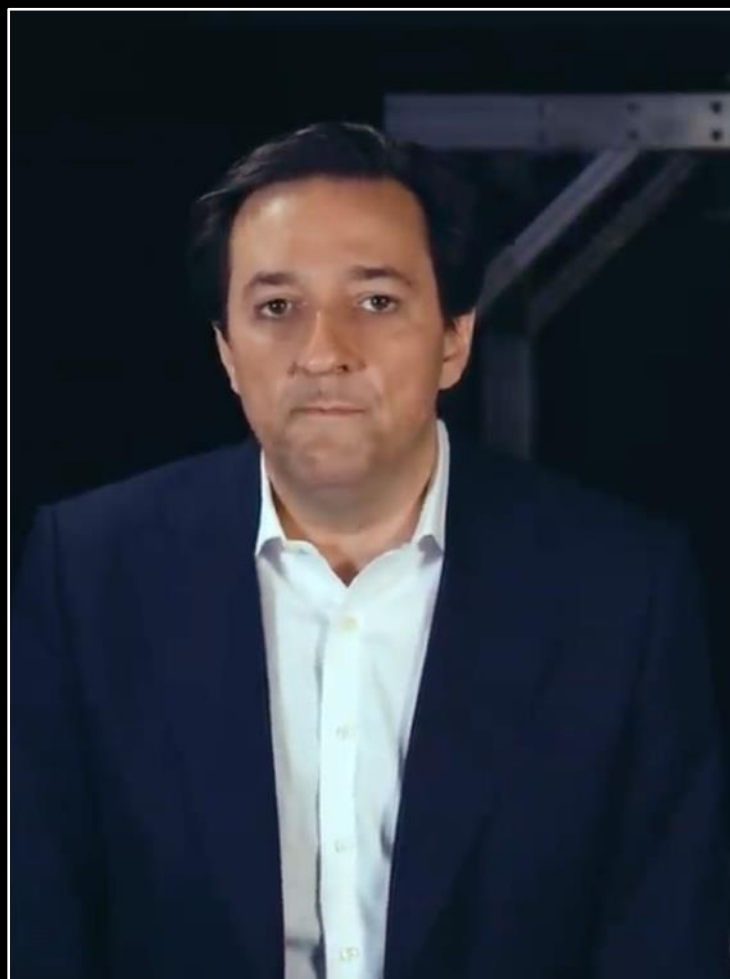
Create a compelling call to action

“Let me close with a reflection on the urgency of science. The urgency of tackling some of the most complex problems in the world.

And that reflection is that a revolution in discovery is going to be powered by the most exciting time in computing in 60 years.

It is not that one will eat the other, the most profound implication is the convergence of bits, neurons and qubits.”

- ✓ Tell them what you’re about to tell them
- ✓ Tell them
- ✓ Tell them what you told them



Communications Thinking™ Masterclass | Lesson 2

Aristotle's Rhetoric
The Pillars of Communication to Inspire, Persuade & Influence

Pathos. Logos. Ethos. Kairos.

[STORM] **EXCITE** – Emotions & Values (Dopamine) • **DISTURB** – Logic & Evidence (Endorphins) • **ASSURE** Credibility & Trust (Oxytocin)

Communications Thinking™ Masterclass | Lesson 2

Contract. Clock. Crucible.

“Story Begins With The 3 C’s.” Dan Brown

- **CONTRACT:** An implied promise you make to your audience
- **CLOCK:** Adding time pressure creates more interest & “Kairos”
- **CRUCIBLE:** A box that contains your characters, offers no escape & forces them to act.



Scaling Your Message

Dario Gil: A New Quantum Era of Accelerated Discovery

By Larry Greenemeier

May 6, 2020



Explore an IBM quantum computing center with Director of IBM Research Dario Gil

Computing power and collaboration.

Exponential advances in computing, along with global collaboration, can help us confront world crises like the COVID-19 pandemic, as well as other big societal challenges, Dario Gil, Director of IBM Research, said Wednesday.

Gil, addressing the IBM [Think Digital](#) conference, noted that the emerging field of quantum computing will complement today's supercomputers and other classical computers to accelerate scientific discovery and technical innovation.

→ [Watch a replay of Dario Gil's complete Think Digital session](#)



Build Awareness

Dario created a whitepaper to amplify IBM Research's differentiated PoV

Look Inside: A Quantum Computer

Harnessing the power of a quantum processor requires achieving constant temperatures near absolute zero. Here's a look at how a dilution refrigerator, made from more than 2,000 components, exploits the mixing properties of two helium isotopes to create such an environment.

A Field Guide to the Age of Quantum Computing

- I. OVERVIEW**
A New Style of Computing
Classical computing built our world, but it has inherent constraints. If we want to tackle intractable problems and reveal potentially huge opportunities, we need to embrace a new computing paradigm.
- II. QUANTUM AT WORK AT IBM**
It takes brilliant scientists and cutting-edge infrastructure to create a quantum computer. The IBM Q Lab has both. A behind-the-scenes look at our facilities in Yorktown Heights, New York.
- III. LEARN**
Harnessing the Forces of Nature
Quantum computing may be inspired by actual behavior in nature – but that doesn't mean it's easy to harness. Here's an exploration of how we leverage the laws of quantum mechanics in a laboratory environment.
- IV. TRAVEL**
Quantum: Past, Present & Future
Quantum computing may seem like a new phenomena, but scientists at IBM and elsewhere have been exploring and testing its underlying properties and principles for more than a century.
- V. CREATE**
A Truly Quantum Experience
Interested in seeing an actual quantum computer do its thing? Be our guest! Our IBM Q experience is served over the IBM Q Cloud and accessible to all. Take it for a spin!
- VI. PREPARE**
How to Get Quantum Ready
If you could go back to 1993 and better prepare yourself for the Internet, would you? That's the opportunity that exists now with quantum computing. Dario Gil, VP of IBM Research, explains how to get going.

What makes some problems so difficult to solve?

Simply put, for certain types of problems, the number of possible solutions doubles every time you add another component into the equation. And that makes it exponentially more difficult to compute. But what does that really mean? There's a classic fable that demonstrates the nature of exponential growth. It goes like this. There once was a craftsman who invented the game that we now know as chess. He brought his creation to the emperor as a gift, who was so pleased that he told the craftsman to name his reward. The craftsman made a seemingly modest request: some rice, to be delivered over 64 days, representing the 64 squares on the chess board. On the first day, he would receive a single grain. On each subsequent day, the amount would double. The emperor considered this a bargain and delivered that single grain on day one. The next day, he doubled it. On day three, the craftsman received four grains and then eight grains, and so on. After a week, the craftsman had collected a total of 127 grains of rice, not even enough to fill a teaspoon. But within a month, thanks to the power of exponential growth, it was becoming clear that the craftsman's request wasn't so modest after all. On the 10th day, the craftsman was due more than a billion grains. To keep his bargain on the 64th day, the emperor would have to surrender 133 billion metric tons of rice. That's a pile the size of Mt. Everest – and more than a thousand times the total amount of rice produced in the world in 2016!

Some problems work like this, too. When they're small, with just a few components to consider, they're analogous to the tiny quantities of rice during the first few days of the craftsman's reward. But adding one new component can double the number of possible solutions to consider, which means it takes twice as long to solve. Nearly every adult has experienced problems like these. Think about the last time you hosted a dinner party of a dozen people. To create the most memorable evening, you considered the personalities, interests, and backgrounds of each guest, and then arranged them at the table to facilitate conversation. In other words, you optimized the evening for maximum happiness. If you were to add one more guest, there wouldn't be just one new configuration to consider; it might totally change your entire

Which Way to a Fault-Tolerant Universal Quantum Computer?

Today's quantum researchers are following one of two development paths. We believe only one will lead to highly generalizable quantum computers capable of solving great problems. The other path is very limited.

PATH 1: VERY LIMITED	PATH 2: THE WAY FORWARD
Quantum Annealing Computer	Approximate Universal Quantum Computer
DIFFICULTY LEVEL: ●○○○○○○○○	DIFFICULTY LEVEL: ●●●●○○○○○○
NO PATH TO UNIVERSAL CONVENTIONAL POWER: Similar to a classical computer GENERALITY: Restricted APPLICATIONS: Optimization problems	THE GOAL: Fault-Tolerant Universal Quantum Computer DIFFICULTY LEVEL: ●●●●○○○○○○ CONVENTIONAL POWER: Very high GENERALITY: Computer APPLICATIONS: Quantum chemistry, Quantum simulation, Cryptography, Sampling

Depicting the Positions of Bits and Qubits

Qubit behavior is dynamic and complex. Visualizations can help.

BITS: A Classical System

The limitations of bits: They can only be 0 or 1

Classical computing is based on the binary system, where the fundamental unit of information is a bit. A bit can take on one of two values: 0 or 1. All information is stored and read as a sequence of bits and 1s.

Classical computers are powered by these bits, which are manipulated by transistors. The speed of the computer is directly proportional to the number of transistors. The more bits a circuit has, the more complex it can be. A circuit with 1 billion bits can perform 1 billion operations per second.

QUBITS: A Quantum System

The magic of a single qubit: It can be both 0 and 1

Unlike bits, qubits can be a superposition of 0 and 1, enabling them to store different types of information. Superposition and entanglement are two fundamental properties of quantum systems. The ability to manipulate these properties is what gives quantum algorithms their power.

The Bloch sphere (below) is a visualization used to show the state of a single qubit. When the qubit is in the 0 state, it is represented by a vector pointing to the top of the sphere. When the qubit is in the 1 state, the vector points to the bottom of the sphere. When the qubit is in a superposition of 0 and 1, the vector points along a different direction.

The extreme magic of multiple qubits: They offer exponential states of 0s and 1s

To visualize the state of a multi-qubit system, we use the QSphere. The QSphere for a 3-qubit system has six vertices, representing all possible combinations of 0s and 1s. The top vertex represents 000, the bottom vertex represents 111, and the other four vertices represent 001, 010, 100, and 101. Each vertex represents a possible outcome of the system. There are 2^3 = 8 possible outcomes for a 3-qubit system.

Next to doing the right thing, you need to tell people that you're doing the right thing...