3rd May 2019

On 19 June, we are organizing in Bucharest an event under the Romanian Presidency on the Pathfinder part of the European Innovation Council (including FET Open and FET Proactive).This is part of a bigger 3 days event on EIC and financial instruments.

I would like to invite you to be our keynote speaker of the event, in the session of the event on “From science to future technologies” that will take place from 9:30 to 10:15.

If you accept, you could for example elaborate, from your own experience some of the following topics: the need for having a collaborative research low-TRLs in Europe, how can Europe best foster unpredictable technological breakthroughs? What is at stake for the EU in the on-going global technological race? What are the key factors shaping technological leadership? How scientists from the Eastern Countries are perceiving FET and the opportunities for top-down (FET Proactive) or bottom-up (FET OPEN) research it offers, etc.

I am convinced that your experience from Quantum research in FET will be highly appreciated by our stakeholders.

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6th May 2019

It is relatively easy for us to find another good speaker. However, before taking the decision to do so, I would like to mention that when we thought about you, you were representing in our eyes the "ideal" candidate: An excellent scientist who is very well aware of our FET activities, and in addition who is coming from one of the EU-13 countries. In other terms, we thought you are having all those fine "ingredients" for convincing our attendees in the Bucharest event of 19 June and for sharing your experience with them.

Therefore, I would like to give it a last chance to have you there and let you take a final decision on that, hoping that it will not be too cumbersome and too difficult for you to be with us on the 19th of June (morning) in Bucharest.

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The Art of Science

19.06.2019
Bucharest

Vladimír Bůžek

or

How not fail our future

Science, the Endless Frontier

ROOSEVELT & BUSH

THE WHITE HOUSE Washington, D. C. November 17, 1944

DEAR DR. BUSH: The Office of Scientific Research and Development, of which you are the Director, represents a unique experiment of team-work and cooperation in coordinating scientific research and in applying existing scientific knowledge to the solution of the technical problems paramount in war. Its work has been conducted in the utmost secrecy and carried on without public recognition of any kind; but its tangible results can be found in the communiques coming in from the battlefronts all over the world. Some day the full story of its achievements can be told.

There is, however, no reason why the lessons to be found in this experiment cannot be profitably employed in times of peace

FOUR QUESTIONS

1) What can be done, consistent with military security, and with the prior approval of the military authorities, to make known to the world as soon as possible the contributions which have been made during our war effort to scientific knowledge?
2) With particular reference to the war of science against disease, what can be done now to organize a program for continuing in the future the work which has been done in medicine and related sciences?
3) What can the Government do now and in the future to aid research activities by public and private organizations?
4) Can an effective program be proposed for discovering and developing scientific talent in American youth so that the continuing future of scientific research in this country may be assured on a level comparable to what has been done during the war?

VANNEVAR BUSH
PATRON SAINT OF US SCIENCE

- A leading figure in the development of the military-industrial complex and the military funding of science in the United States, Bush was a prominent policymaker and public intellectual during World War II and the ensuing Cold War and was in effect the first presidential science advisor.
- In 1922, Bush and L.K.Marshall - the S-tube. - Raytheon
- Starting from 1927, Bush constructed a *Differential Analyser*, an analog computer that could solve differential equations
- The Memex
- Bush became vice-president and dean of engineering at MIT from 1932–38.
- In 1941 - the Office of Scientific Research and Development (OSRD) with Bush as director, which controlled the Manhattan Project until 1943
- He recommended the creation of what would eventually become in 1950 the National Science Foundation (NSF),
- Students: Claude Shannon and Frederick Terman (the father of the "Silicon Valley")

FROM THE BUSH REPORT
(Science: The Endless Frontier)

- The simplest and most effective way in which the Government can strengthen industrial research is to support basic research and to develop scientific talent
- The basic research is pacemaker of technological progress
- The most important single factor in scientific work is the quality of personnel employed
- New products and new processes do not appear full grown. They are funded on new principles which in turn are painstakingly developed by research in the purest realm of science
- Scientific progress results from the free play of free intellects.
- Basic scientific research is scientific capital.
- Scientific progress is one essential key to our security, to our better health, to more jobs, to higher ling standards, and to our cultural progress
- We have to have national policy for science.

BASIC PRINCIPLE

The pioneer spirit is still vigorous within this nation. Science offers a largely unexplored hinterland for the pioneer who has the tools for his task. The rewards of such exploration both for the Nation and the individual are great. Scientific progress is one essential key to our security as a nation, to our better health, to more jobs, to a higher standard of living, and to our cultural progress.

BASIC RESEARCH I.

- Basic research is performed without thought of practical ends. It results in general knowledge and an understanding of nature and its laws. This general knowledge provides the means of answering a large number of important practical problems, though it may not give a complete specific answer to any one of them. The function of applied research is to provide such complete answers. The scientist doing basic research may not be at all interested in the practical applications of his work, yet the further progress of industrial development would eventually stagnate if basic scientific research were long neglected.
- One of the peculiarities of basic science is the variety of paths which lead to productive advance. Many of the most important discoveries have come as a result of experiments undertaken with very different purposes in mind. Statistically it is certain that important and highly useful discoveries will result from some fraction of the undertakings in basic science; but the results of any one particular investigation cannot be predicted with accuracy.

BASIC RESEARCH II.

- Basic research leads to new knowledge. It provides scientific capital. It creates the fund from which the practical applications of knowledge must be drawn. New products and new processes do not appear full-grown. They are founded on new principles and new conceptions, which in turn are painstakingly developed by research in the purest realms of science.
- Today, it is truer than ever that basic research is the pacemaker of technological progress. In the nineteenth century, Yankee mechanical ingenuity, building largely upon the basic discoveries of European scientists, could greatly advance the technical arts. Now the situation is different.
- A nation which depends upon others for its new basic scientific knowledge will be slow in its industrial progress and weak in its competitive position in world trade, regardless of its mechanical skill.

YOUNG TALENTS & TRAINING

"If we were all-knowing and all-wise we might, but we think probably not, write you a plan whereby there might be selected for training, which they otherwise would not get, those who, 20 years hence, would be scientific leaders, and we might not bother about any lesser manifestations of scientific ability. But in the present state of knowledge a plan cannot be made which will select, and assist, only those young men and women who will give the top future leadership to science. To get top leadership there must be a relatively large base of high ability selected for development and then successive skimmings of the cream of ability at successive times and at higher levels. No one can select from the bottom those who will be the leaders at the top because unmeasured and unknown factors enter into scientific, or any, leadership. There are brains and character, strength and health, happiness and spiritual vitality, interest and motivation, and no one knows what else, that must needs enter into this supra-mathematical calculus.

FIVE FUNDAMENTALS

1) Whatever the extent of support may be, there must be stability of funds over a period of years so that long-range programs may be undertaken.
2) The agency to administer such funds should be composed of citizens selected only on the basis of their interest in and capacity to promote the work of the agency.
3) The agency should promote research through contracts or grants to organizations outside the Federal Government. It should not operate any laboratories of its own.
4) Support of basic research in the public and private colleges, universities, and research institutes must leave the internal control of policy, personnel, and the method and scope of the research to the institutions themselves. This is of the utmost importance.
5) While assuring complete independence and freedom for the nature, scope, and methodology of research carried on in the institutions receiving public funds, and while retaining discretion in the allocation of funds among such institutions, the Foundation proposed herein must be responsible to the President and the Congress. Only through such responsibility can we maintain the proper relationship between science and other aspects of a democratic system.

Science takes time

A BRIEF HISTORY OF LIGO

- 100 years ago A Einstein predicted the existence of gravitational waves – he thought these waves seemed too weak ever to be ever detected
- In the 1960s, Joseph Weber pioneered the effort to build detectors for gravitational waves, using large cylinders of aluminum that vibrate in response to a passing wave,
- Laser interferometry to monitor the relative motion of freely hanging mirrors, was proposed in 1962 by Michael Gertsenshtein and Vladislav Pustovoit
- In 1968, Kip Thorne and Vladimir Braginsky recognized that advanced gravitational wave interferometers would operate in an entirely new technological regime, in which heavy mirrors behave like quantum particles
- In 1980 the NSF funded the construction of a Drever- Whitcomb 40 meter prototype interferometer at Caltech and Weiss's 1.5 meter prototype at MIT.
- In 1990 the National Science Board, approved LIGO construction, and in 1991 Congress appropriated LIGO's first year of funding.
- Starting from 1994 Barry Barish (Caltex) organized LIGO's construction phase, then oversaw construction of its facilities (1994-1998) and then the installation and commissioning of LIGO's initial interferometers (1999-2002) and its first few gravitational wave searches (2002-2005).
- In 2005-2010 the initial LIGO searches placed astrophysically interesting limits on gravitational wave sources, but did not find any waves.

A BRIEF HISTORY OF LIGO

On September 14, 2015, shortly before the beginning of Advanced LIGO's first official gravitational wave search and nearly 100 years after Einstein first postulated gravitational waves, LIGO's two interferometers achieved their first detection of a gravitational wave: a detection with a large signal to noise ratio, 24. The measured waveform matched the predictions of Einstein's general relativity for waves from two black holes spiraling together, colliding and merging. A few days later there appeared in both detectors a weaker second signal consistent with the merger of two lower mass black holes.

https://www.ligo.caltech.edu/system/media_files/binaries/313/original/LIGOHistory.pdf

Science is expensive

Tycho Brahe and Uranienborg

- Uraniborg was a Danish astronomical observatory and alchemy laboratory established and operated by Tycho Brahe. It was built c. 1576 – c. 1580 on Hven island which was part of Denmark at the time.
- Tycho Brahe has been described as "*the first competent mind in modern astronomy to feel ardently the passion for exact empirical facts*." His observations were some five times more accurate than the best available observations at the time.
- King Frederick II granted Tycho an estate on the island of Hven and the funding to build Uraniborg, an early research institute, where he built large astronomical instruments and took many careful measurements, and later Stjerneborg, underground, when he discovered that his instruments in Uraniborg were not sufficiently steady.
- ***Uraniborg was an extremely expensive project. It is estimated that it cost about 1% of the entire state budget during construction.***
- After disagreements with the new Danish king, Christian IV, in 1597, he went into exile, and was invited by the Bohemian king and Holy Roman Emperor Rudolph II to Prague, where he became the official imperial astronomer. He built an observatory at Benátky nad Jizerou. There, from 1600 until his death in 1601, he was assisted by Johannes Kepler, who later used Tycho's astronomical data to develop his three laws of planetary motion.

Science is unpredictable

STORY OF A TRANSISTOR

- The Bell Labs work on the transistor emerged from war-time efforts to produce extremely pure germanium "crystal" mixer diodes. Walter Brattain and H. R. Moore made a demonstration to several of their colleagues and managers at Bell Labs on the afternoon of 23 December 1947.
- In 1956 John Bardeen, Walter Houser Brattain, and William Bradford Shockley were honored with the Nobel Prize in Physics "for their researches on semiconductors and their discovery of the transistor effect”
- The world's first commercial transistor production line was at the Western Electric plant on Union Boulevard in Allentown, Pennsylvania. Production began on Oct. 1, 1951 with the point contact germanium transistor.
- By 1953, the transistor was being used in some products, such as hearing aids and telephone exchanges, but there were still significant issues preventing its broader application, such as sensitivity to moisture and the fragility of the wires attached to germanium crystals. Donald G. Fink, Philco's director of research, summarized the status of the transistor's commercial potential with an analogy: ***"Is it a pimpled adolescent, now awkward, but promising future vigor? Or has it arrived at maturity, full of languor, surrounded by disappointments?"***

Science is not “democratic”

The Harnack Principle

The fundamental principle (of the Max Planck Society) to allow ***outstandingly creative*** scientists, who think in interdisciplinary terms, scope for independent scientific development.

Science leads to knowledge

Knowledge must precede application

Max Planck

1st Quantum Revolution

Quantum physics & industry

Transistor: Nobel Prize**1956** – J. Bardeen, W. Brattain & W. Shockley ; semicondurcot heterostructures and integrated circuits (**2000**) – Z. Alferov, H. Kroemer & J. Kilby.

Laser: Nobel Prize **1964** - Ch. Townes, N. Basov & A. Prokhorov,; holography (**1971**) – D. Gabor, laser spectroscopy (**1981**) – N. Bloembergen, A. Schawlow & K. Siegbahn, photochemistry (**1999**) – A. Zewail ; quantum optics (**2005**) – R. Glauber, J. Hall &T. Haensch.

Superconductivity: Nobel Prize **1913** – H. Kamerlingh-Onnes ; BEC theory **1972** – J. Bardeen, L. Cooper & J. Schrieffer; tunneling effects **1973** – L. Esaki, I. Giaever & B. Josephson, high-temperature superconductivity **1987** – J. Bednorz & K.A. Mueller; theory of superconductivity and superfluidity **2003**– A. Abrikosov, V. Ginsburg & A. Leggett.

Gigantic magnetoresistance (GMR): Nobel Prize 2007 – A. Fert & P.Gruenberg

2^{nd} Quantum Revolution

MANIPULATIONS WITH INDIVIDUAL Q-SYSTEMS

In the first place it is fair to state that ***we are not experimenting with single particles***, any more than we can raise Ichthyosauria in the zoo. We are scrutinizing records of events long after they have happened.

E. Schrödinger, 1952

Nobel Prize 2012

Serge Haroche and David J. Wineland have independently invented and developed ***methods for measuring and manipulating individual particles*** while preserving their quantum-mechanical nature, in ways that were previously thought unattainable.

From Helsinki Sept 1998 to…

QUANTUM EUROPE 2016

(Amsterdam 17th May, 2016)

EU Commissioner for Digital Economy and Society, Günther Oettinger, announced the ***investment of one billion Euro*** *in a new* ***Flagship*** *on quantum technologies. "Building on the strong support for the Quantum Manifesto, we aim to launch an ambitious, large-scale Flagship initiative to unlock the full potential of quantum technologies, accelerate its development and bring commercial products to the consumer marketplace."*

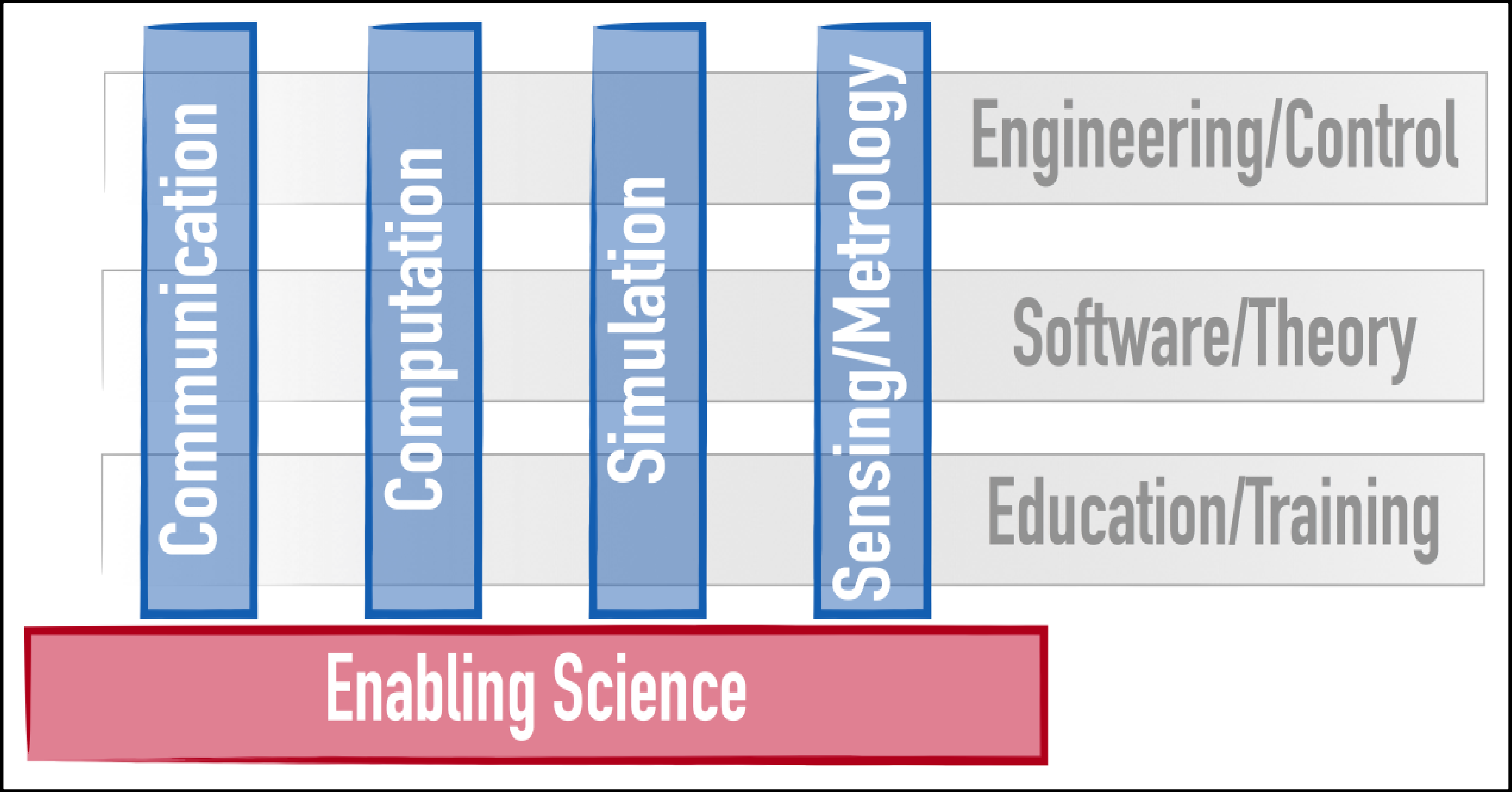
Quantum Manifesto

The [Quantum Manifesto](#) was written by the European quantum community and is endorsed by over [3400 supporters](#): industries, research institutes and scientists in Europe. It is a call to develop Europe's capabilities in quantum technologies creating a lucrative knowledge-based industry, leading to economic, scientific and societal benefits. It paved the way for the European Flagship.

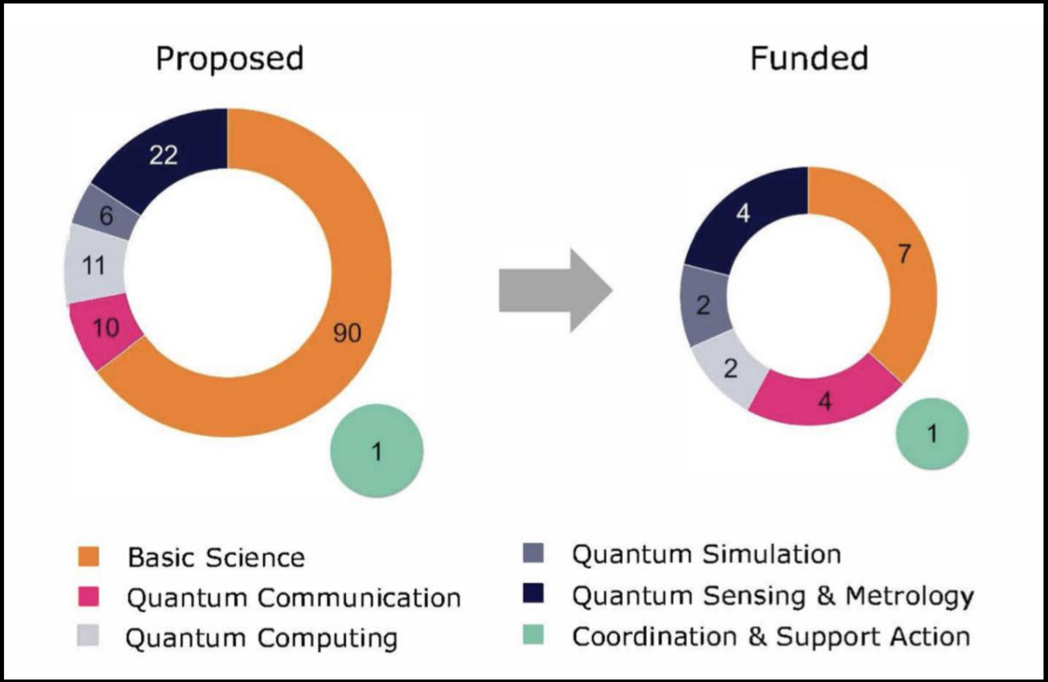
Quantum Flagship

The Flagship will fund over 5,000 of Europe's leading quantum technologies researchers over the next ten years and aims to place Europe at the forefront of the second quantum revolution. Its long term vision is to develop in Europe a so-called quantum web, where quantum computers, simulators and sensors are interconnected via quantum communication networks. This will help kick-starting a competitive European quantum industry making research results available as commercial applications and disruptive technologies. The Flagship will initially fund 20 projects with a total of €132 million via the Horizon 2020 programme, and from 2021 onwards it is expected to fund a further 130 projects. Its total budget is expected to reach €1 billion, providing funding for the entire quantum value chain in Europe, from basic research to industrialisation, and bringing together researchers and the quantum technologies industry.

Strategic Research Agenda



EU funded projects on QuTe



140 submitted **20 funded**

https://cordis.europa.eu

FET has done an excellent job!

Quantum Communications

CiViQ - The vision of CiViQ is to develop quantum-enhanced physcial layer security services that can be combined with modern cryptographic techniques, to enable unparalleled applications and services.

Quantum Internet Alliance - The project aims at building a Quantum Internet that enables quantum communication applications between any two points on Earth.

QRANGE - The project wants to push the quantum range number generagion (QRNG) technology further, allowing for a wide range of commercial applications of QRNG.

UNIQORN - The project aims at revolutionising the Quantum Ecosystem from Fabrication to Application.

Quantum Simulations

Qombs – The project is a quantum simulator platform made of ultracold atoms for engineering quantum cascade laser frequency combs.

PASQunS - The project will develop next generation Quantum Simulation platforms that will be pushed far beyond both the state-of-the-art and the reach of classical computation.

Quantum Sensing and Metrology

iqClock - The project aims to boost the development of optical clocks using quantum technology to be ultra precise and affordable. These clocks will improve technological developments and scientific applications that are beneficial to the society.

MetaboliQs - The project is working to leverage room-temperature diamond quantum dynamics to enable safe multimodal cardiac imaging which can help better diagnosis of Cardiovascular Diseases.

macQsimal - The project aims to develop quantum-enabled sensors which measure physical observables which will benefit many areas like autonomous driving, medical imaging and more.

ASTERIQS - The project is developing precise sensors made from diamonds to measure quantities such as magnetic field, electric field, temperature or pressure..

Quantum Computing

OpenSuperQ - The project aims to enable European citizens to be able to use the final machine and learn about quantum computer programming in a guided way.

AQTION - The project will realise a scalable European quantum computer that is based on the manipulation of single-charged atoms.

QuTe Basic Science

2D·SIPC - The project explores new quantum device concepts based on 2D materials which have enhanced quantum properties and can bring new functionalities.

S2QUIP - The project is developing quantum integrated photonic circuits, which will provide the end user on-demand with carriers of quantum information to share with other users via quantum communication channels.

QMiCS - The QMiCS project aims to set up quantum architechture to implement quantum communication protocols.

SQUARE - The results of the SQUARE project will contribute to strengthen the European high-tech industry as it aims to establish a new platform for quantum computing, quantum networking and quantum communication.

PhoG - The goal of PhoGs is to deliver a compact, versatile, deterministic source of quantum light based on integrated waveguide networks with engineered loss, and to develop its applications in metrology and other quantum technology tasks.

PhoQuS - The project aims to understand the photonic quantum fluids and to develop a new platform for quantum simulation.

MicroQC - The project will build a scalable quantum computer which outperforms the best classical computers in certain computational tasks.

Coordination Support Action

QFLAG – the project will build upon the work of the Quantum Support Action (QSA), supporting the governance of the Quantum Flagship and monitoring its progress while coordinating the stakeholders to set conditions to foster innovation, education and training, and increase awareness of QT in Europe.

Houston we have a problem!

EU funded projects on QuTe

CiViQ	(ES, 21, 1)	OpenSuperQ	(D, 10, 0)
QIA	(NL, 23, 0)	AQTION	(AT, 9, 0)
QRANGE.	(CH, 9, 0)	2D·SIPC	(ES, 5, 0)
UNIQORN	(AT, 17, 0)	S2QUIP	(S, 8, 0)
Qombs	(I, 11, 0)	QMiCS	(D, 8, 0)
PASQuanS	(D, 15, 0)	SQUARE	(D, 8, 0)
iqClock.	(NL, 12 ,1)	PhoG	(UK, 5, 1*)
MetaboliQs	(D, 7 ,0)	PhoQuS	(F, 9, 0)
macQsimal	(CH, 14, 0)	MicroQC	(BG, 5, 1)
ASTERIQS	(F, 23, 2)	QFLAG	(D, 7, 0)

Out of 226 partners there are 4 from new MS

TOTAL:	**€ 131 570 892**
New MS:	**€ 1 427 845**

1,085%

Not everything that can be counted counts, and not everything that counts can be counted.

Albert Einstein

Where is a problem?

We have to do our homework!

Some tasks (following VB)

- Scientific progress is one essential key to our security as a nation, to our better health, to more jobs, to a higher standard of living, environmental protection and to our cultural progress.
- The simplest and most effective way in which the Government can strengthen industrial research is to support basic research and to develop scientific talent.
- Clear national policy for science.
- A nation which depends upon others for its new basic scientific knowledge will be slow in its industrial progress and weak in its competitive position in world trade, regardless of its mechanical skill.
- Stability of funds.
- **Regional scientific collaboration (joint institutes)**

To be continued…

CENTERS OF BASIC RESEARCH

- Colleges and universities are uniquely qualified by tradition and by their special characteristics to carry on basic research. They are charged with the responsibility of conserving the knowledge accumulated by the past, imparting that knowledge to students, and contributing new knowledge of all kinds. It is chiefly in these institutions that scientists may work in an atmosphere which is relatively free from the adverse pressure of convention, prejudice, or commercial necessity. At their best they provide the scientific worker with a strong sense of solidarity and security, as well as a substantial degree of personal intellectual freedom. All of these factors are of great importance in the development of new knowledge, since much of new knowledge is certain to arouse opposition because of its tendency to challenge current beliefs or practice.
- It is rarely possible to match the universities in respect to the freedom which is so important to scientific discovery.

THE IDEA FACTORY

- The Bell Labs

Government Chief Scientific Advisers

Science as Liberal Art

Science as a Liberal Art
Steven Weinberg

(Washington College, Chestertown, 19th May1985)

- I am convinced that without great research universities we in the United States would have to support ourselves by growing soybeans and showing the Grand Canyon to tourists from Germany and Japan.
- But research universities are generally not institutions that focus on the role of science education. I don’t say that no one in these universities cares about education, but it is research and not education that drives our most important decisions.
- I can say that I’ve never seen any physicist hired because he or she was a good teacher rather than a good researcher.

S.Weinberg: *Facing Up* (Harward University Press, 2001)

BARROW & NEWTON

In 1663 was Isaac Barrow selected as the first occupier of the Lucasian chair at Cambridge. In 1669 he resigned in favour of his pupil, Isaac Newton who was long considered his only superior among English mathematicians.

LESSONS TO LEARN

- Identification of excellence
- Timescale on which excellence in science is created and maintained