

Usefulness of useless science

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youtube: Fiore scienza inutile

If the scientific results financed by taxpayer money are “public goods”, is it useful or even ethical to spend billions Euros/\$ to search for an elementary particle? Or to visit a Jupiter satellite and look for water on Mars? Or to observe a galaxy at the edge of the Universe?

Competition has become one of the major driving forces for research. But are we sure that the competition-driven science model is truly the best one to make *useful* science?

More, is the very concept of knowledge changing today? The scientific method introduced by Galileo more than 400 years ago resisted at least three industrial revolutions. Are we sure it is still valid and applicable today, in the midst of the fourth industrial revolution?

Founded during the
'30s the Princeton
Institute for
Advanced Studies

The Usefulness of Useless Knowledge

— *Abraham Flexner*



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1939: "Scientists without teaching or administrative duties, so that they can concentrate on deep thoughts, as far as possible from contingent problems and practical applications."

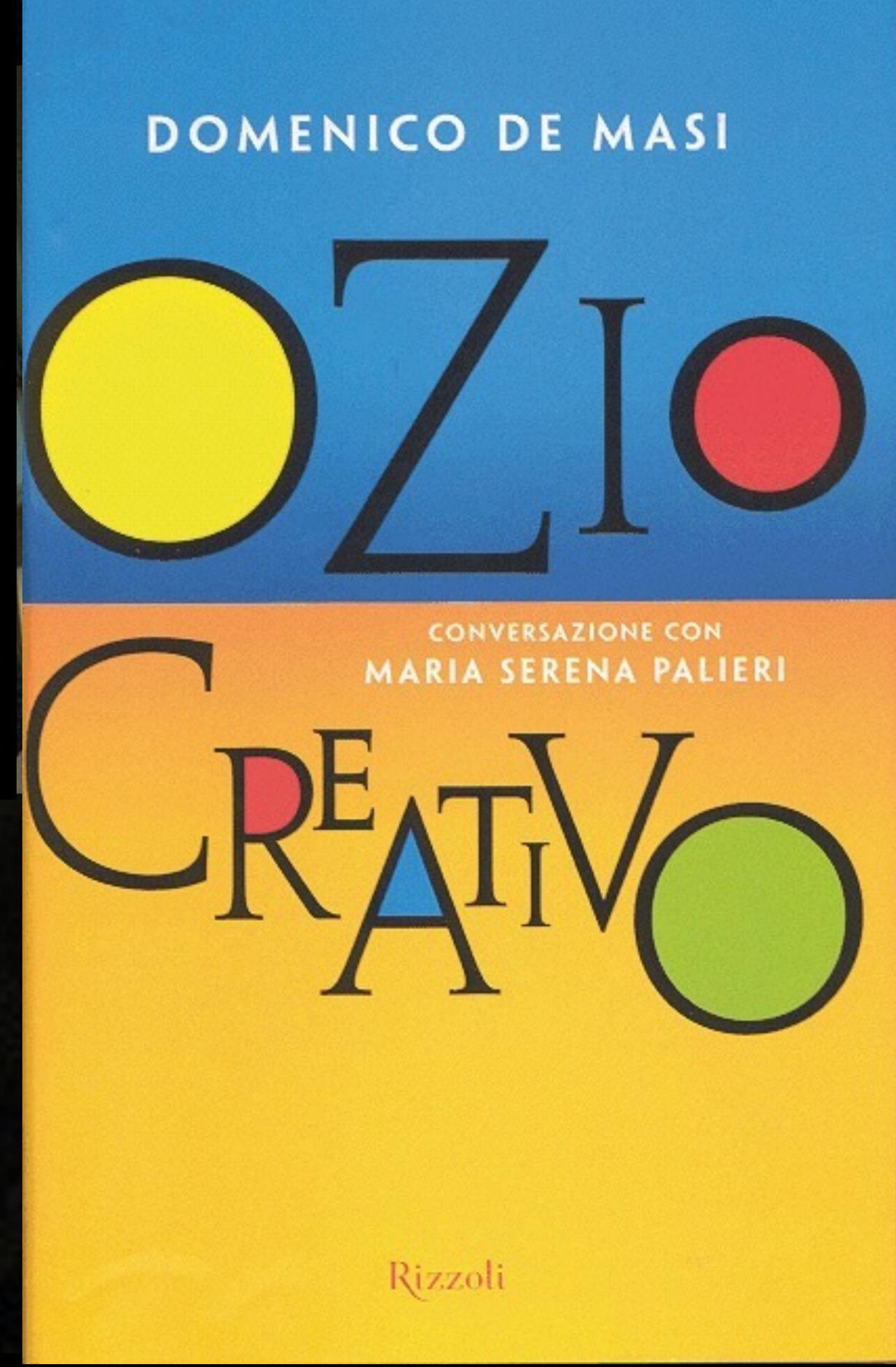


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*“When work to produce wealth,
the study to produce knowledge,
the game to produce well-being
they hybridize and get confused allowing the
creative act”*

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duties, so that they can concentrate on deep
thoughts, as far as possible from contingent
problems and practical applications.”*



Institute of Advanced Studies

Einstein

letter to President Roosevelt

Oppeneimer

Director of the Manhattan project

Godel, Turing, von Neumann:

*I am thinking at something much
more important than bombs:
computers*



Porter: applied research and research not yet applied

It may take decades, if not centuries, to find applications of profound theories. Examples:

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DNA 1953 —> Insuline from genetic engineering 1982

Obvious conclusion

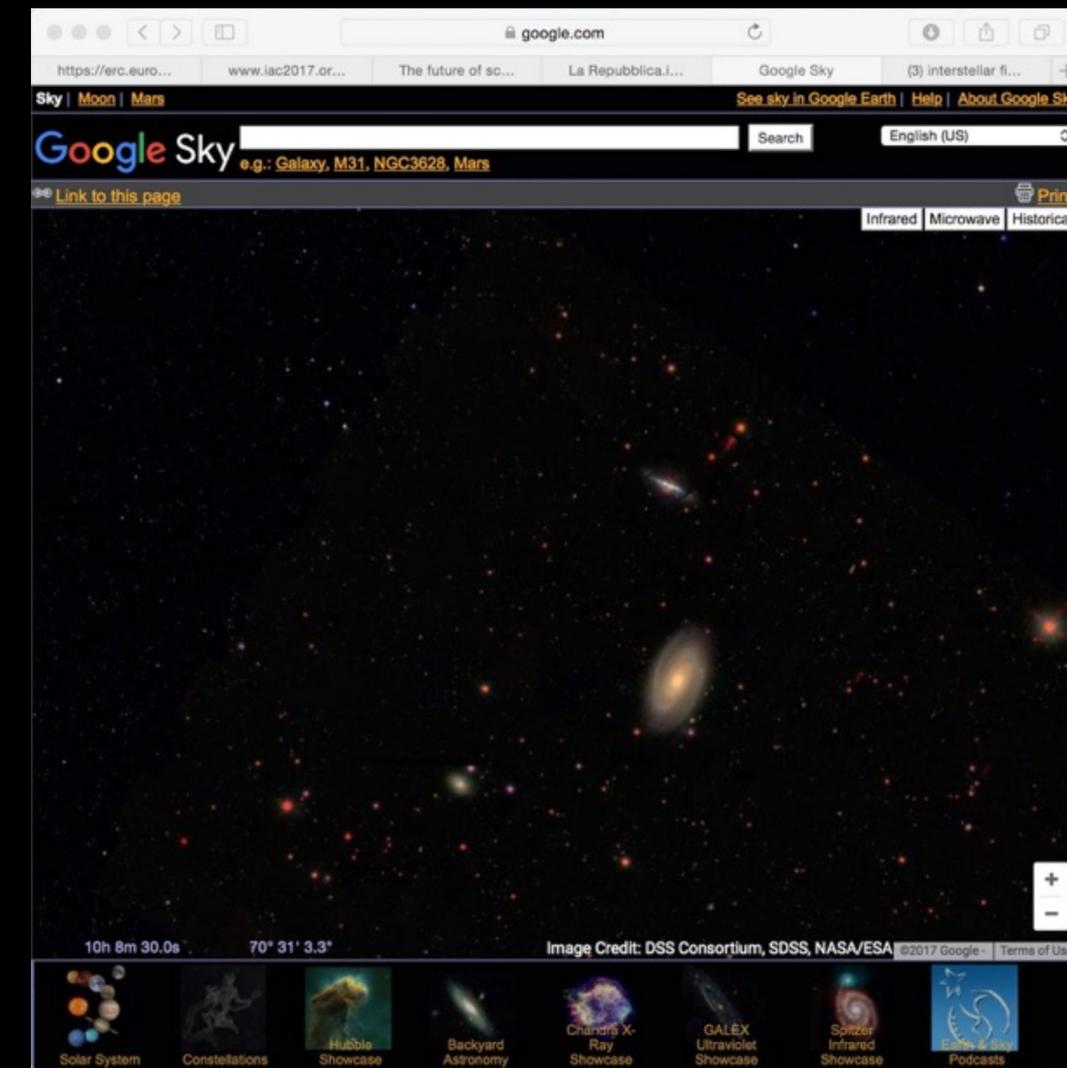
Certainly yes, useless science, Maxwell's equations, special and general relativity, quantum mechanics, etc. are more than useful, without them the world in which we live would be completely different.

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Perhaps in 100 years the world can not do without quantum gravity.

Observations of Gaia will be at the base of the galactic googlemap ..



So obvious that...

In the world, spending on pure, basic research grew exponentially at the turn of the Second World War, during the Cold War and until the fall of the Berlin Wall.

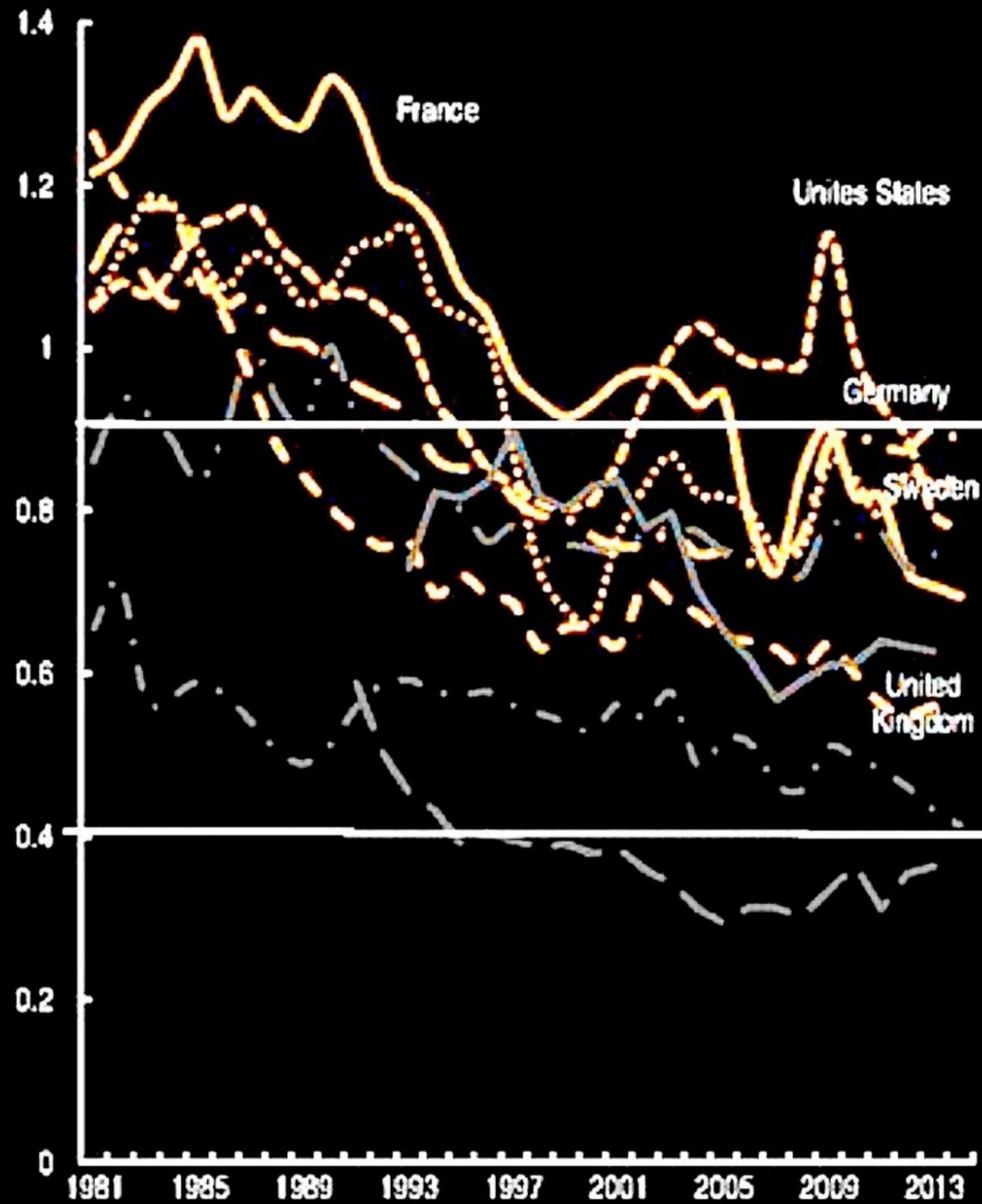
World War II: radio / radar / nuclear / rockets

Cold war: nuclear / rockets

Sputnik/Gagarin: space race, NASA, Apollo project (> 3000 scientific articles, vs. 500 Martian rovers, 1400 ISS, 4000 Cassini)

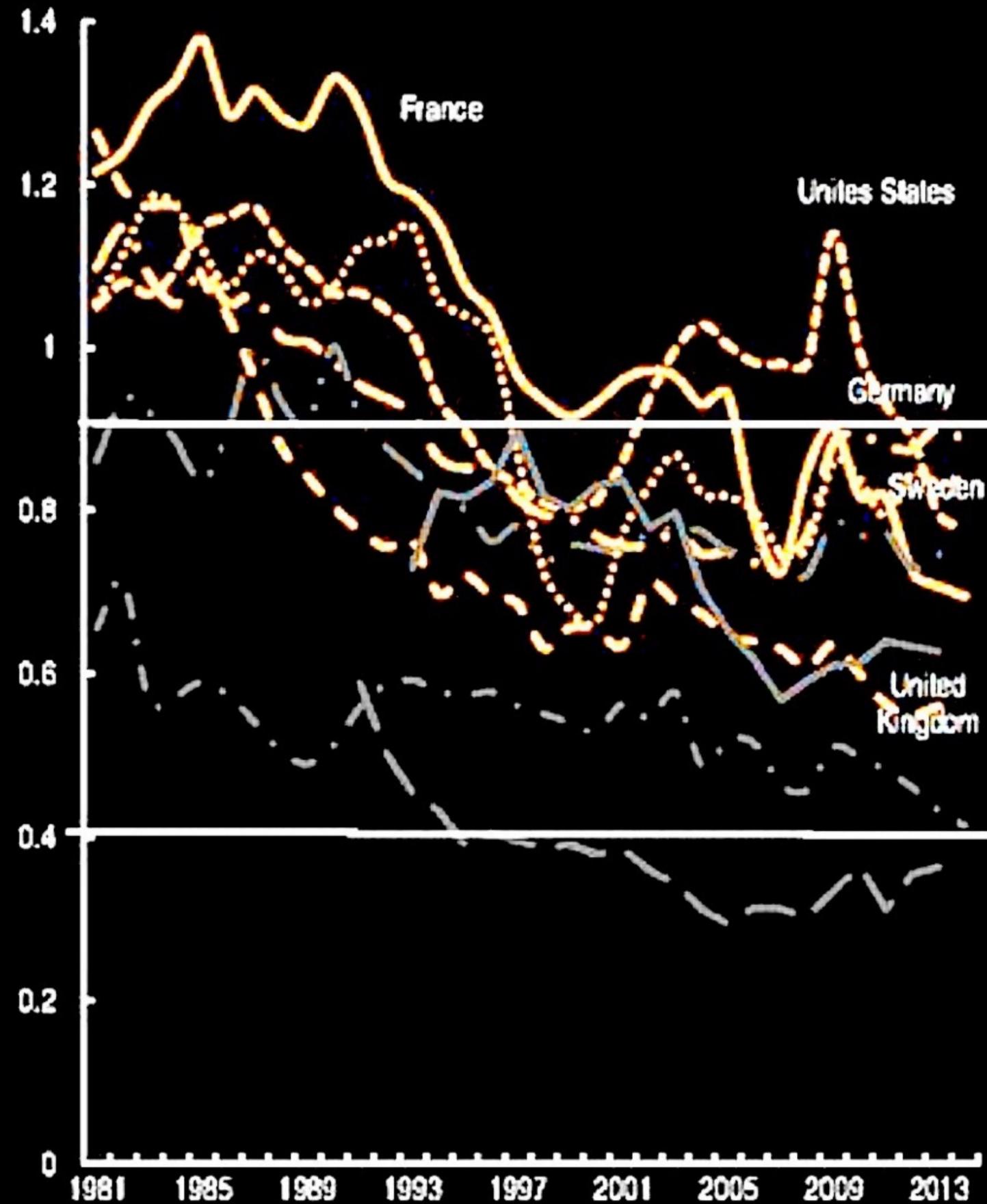
Startup: Silicon Valley (Stanford, Berkeley) , Boston Area (MIT e Harvard)

But...



But...

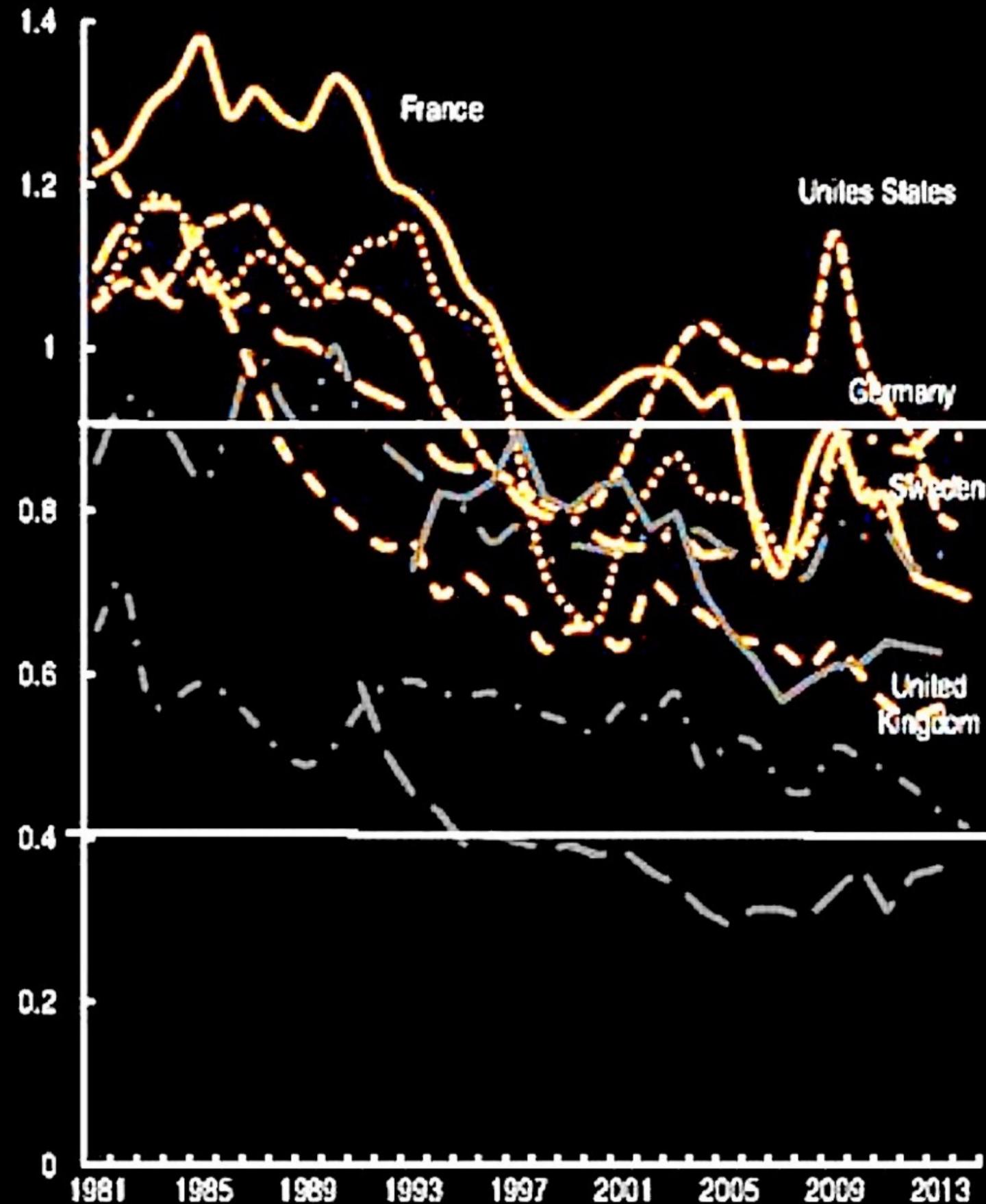
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USA ~ 2% GDP in the 60s, today 0.85% (half for defense research)

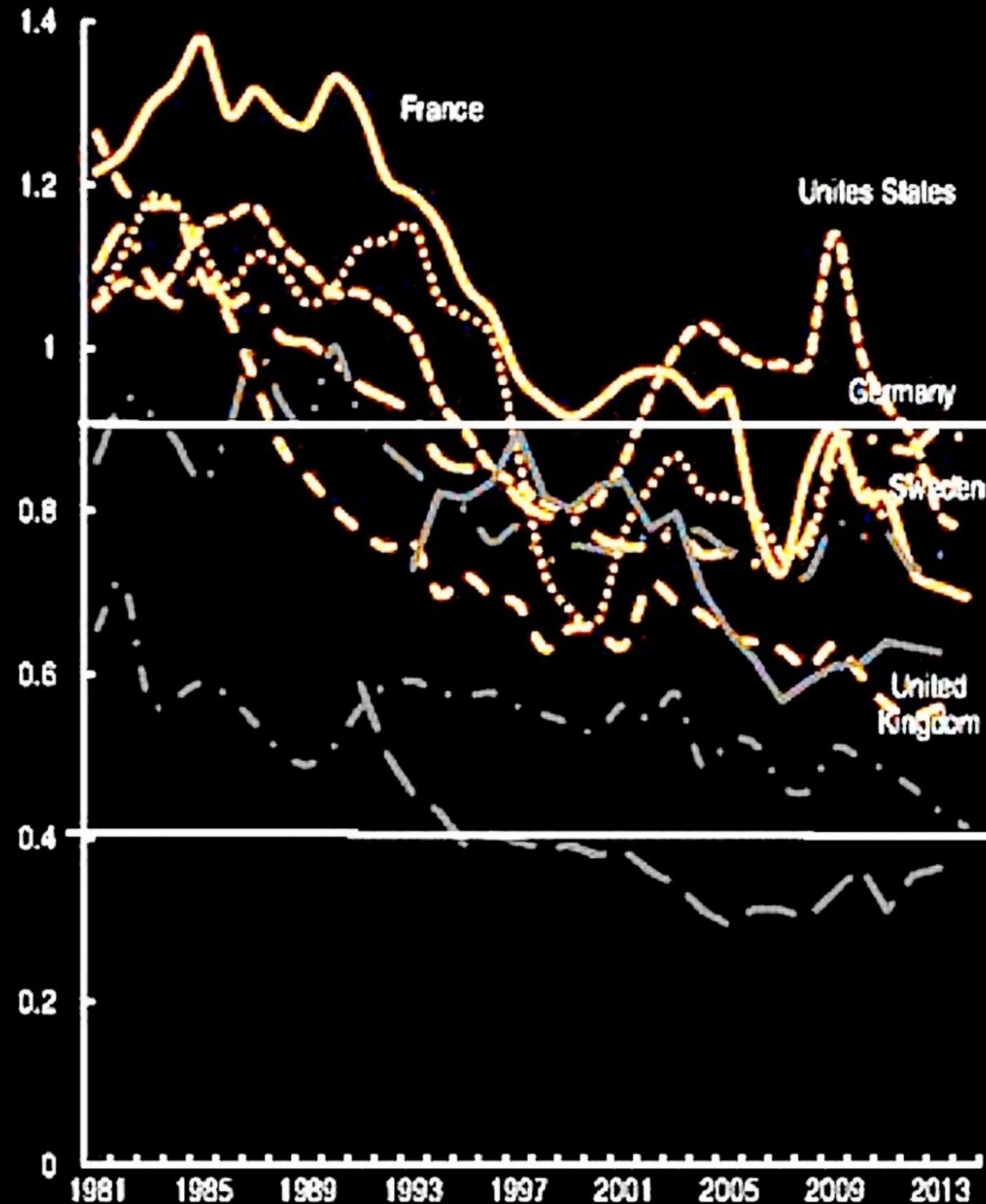


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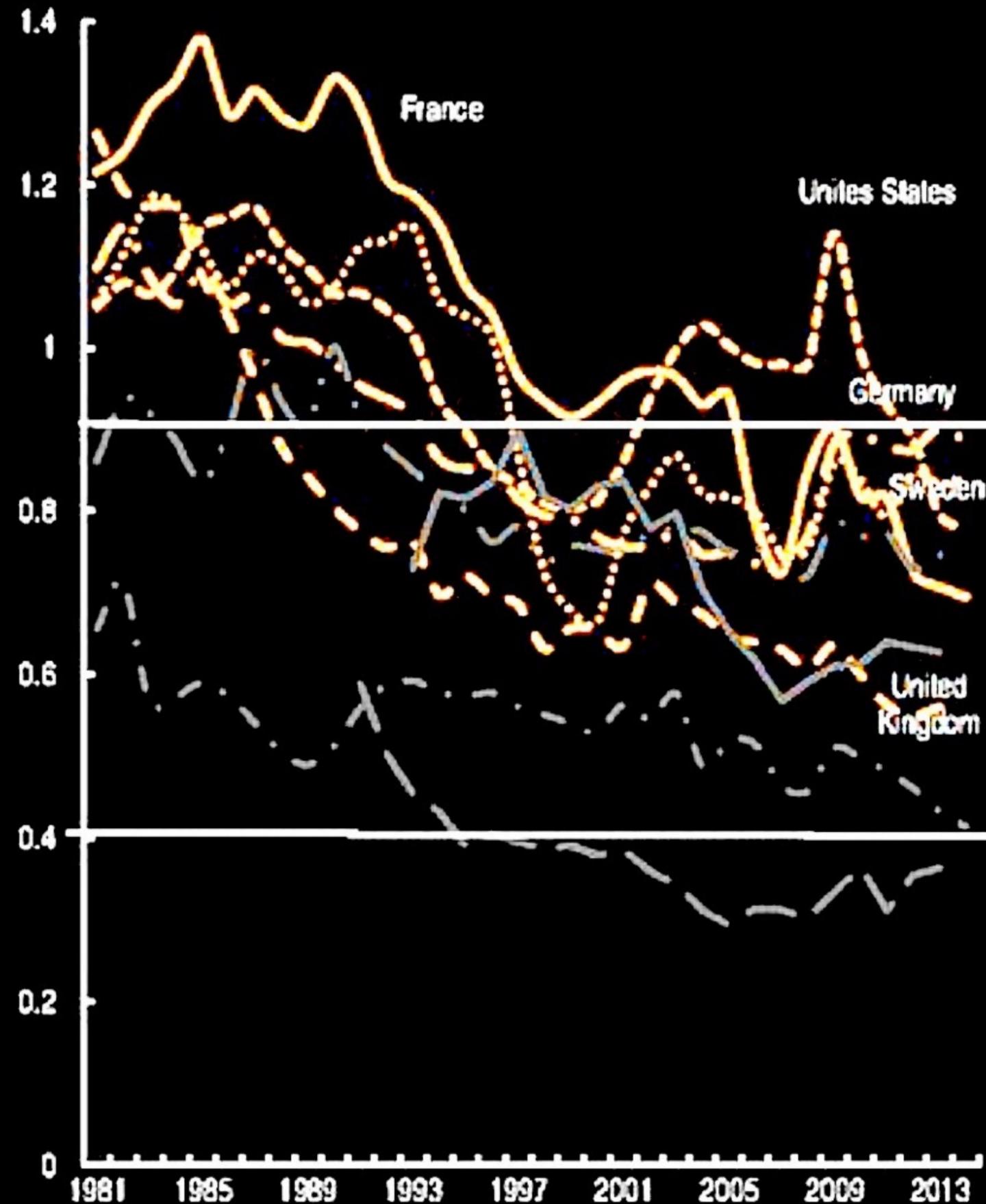
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The fraction of investment in basic research compared to applied research decreases



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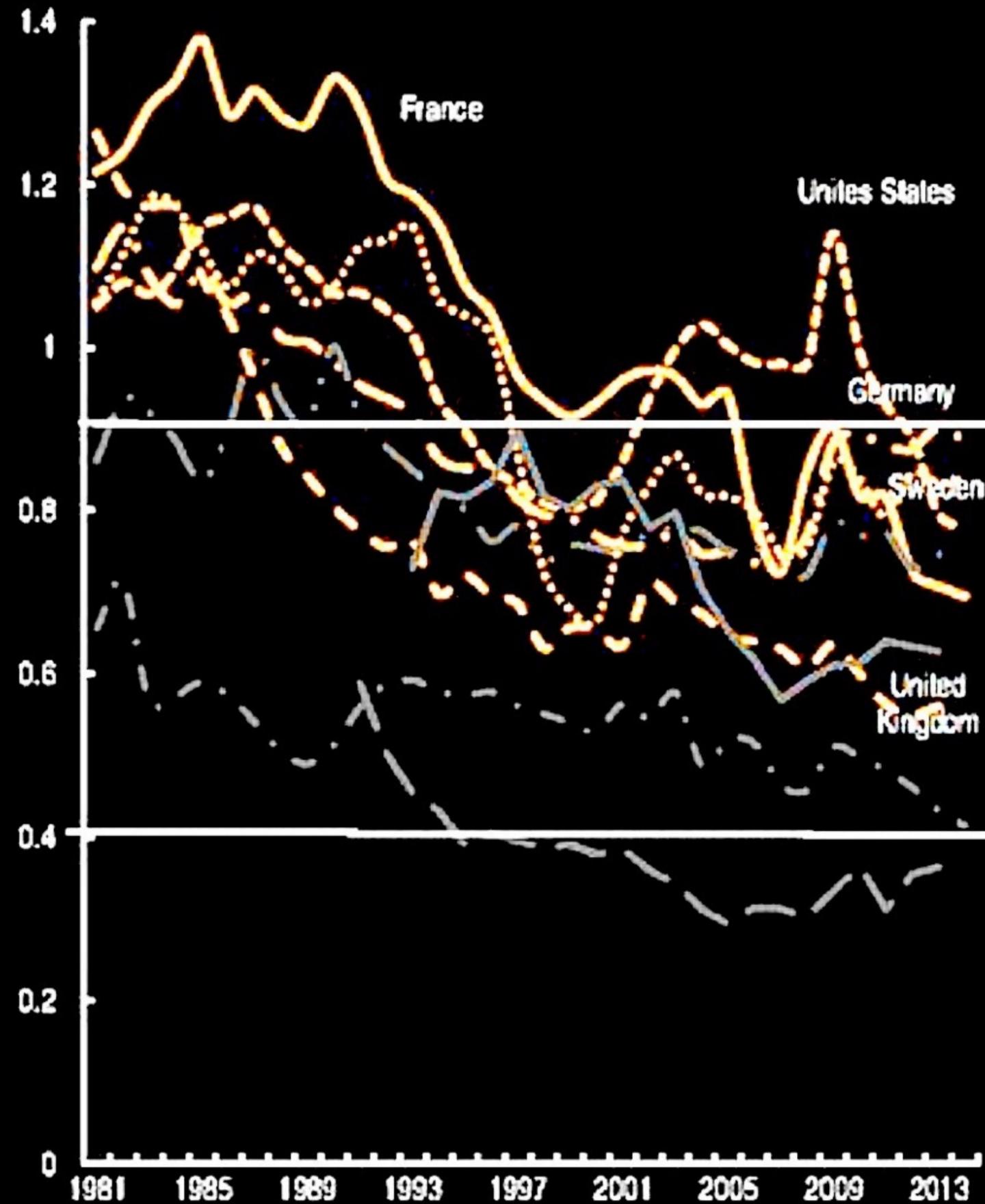
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Private sector invests less and less in basic research: USA 6% of the total. Example of Bell Lab (8 Nobel laureates) today impractical

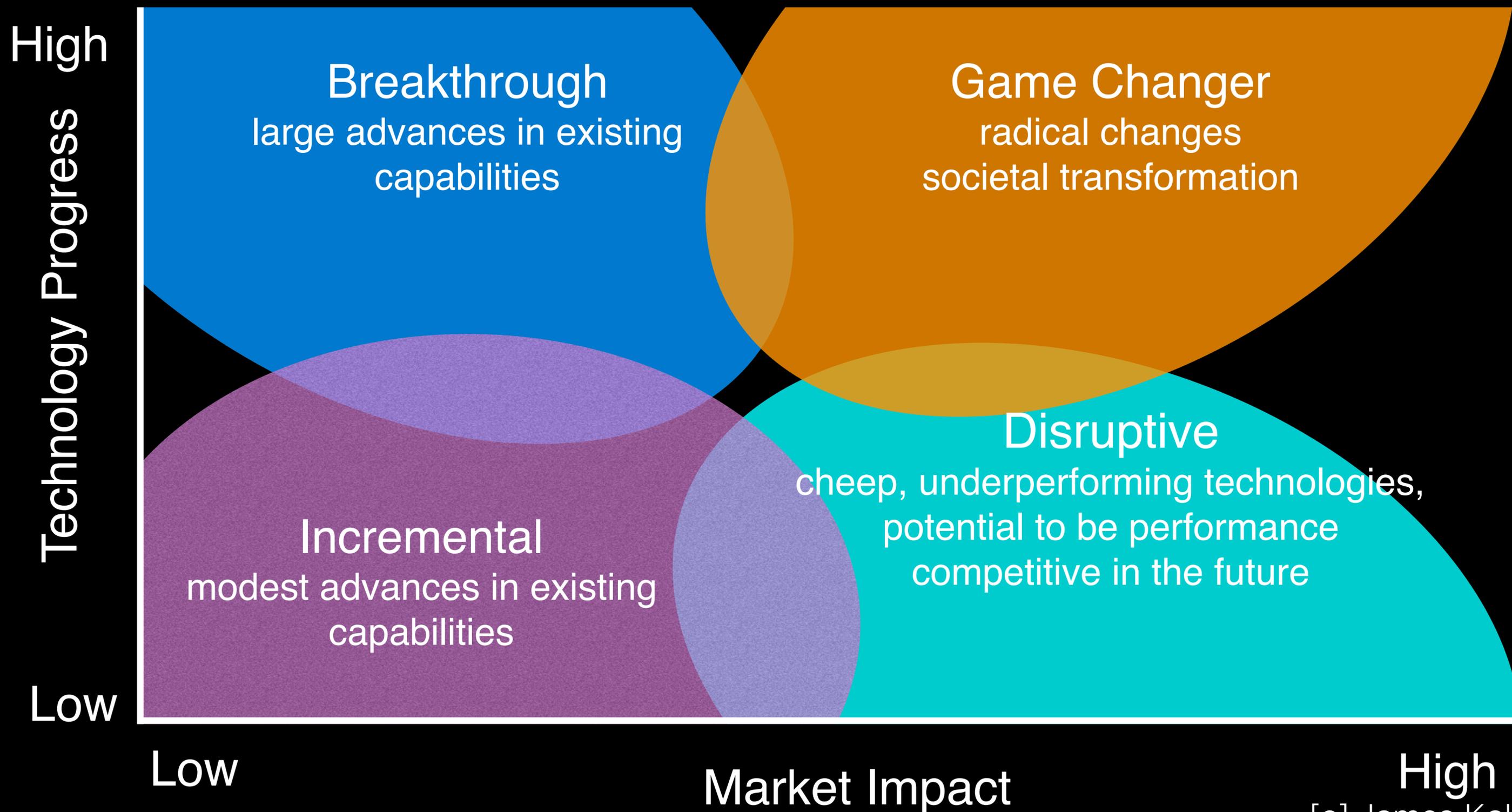


Investments in research 2014

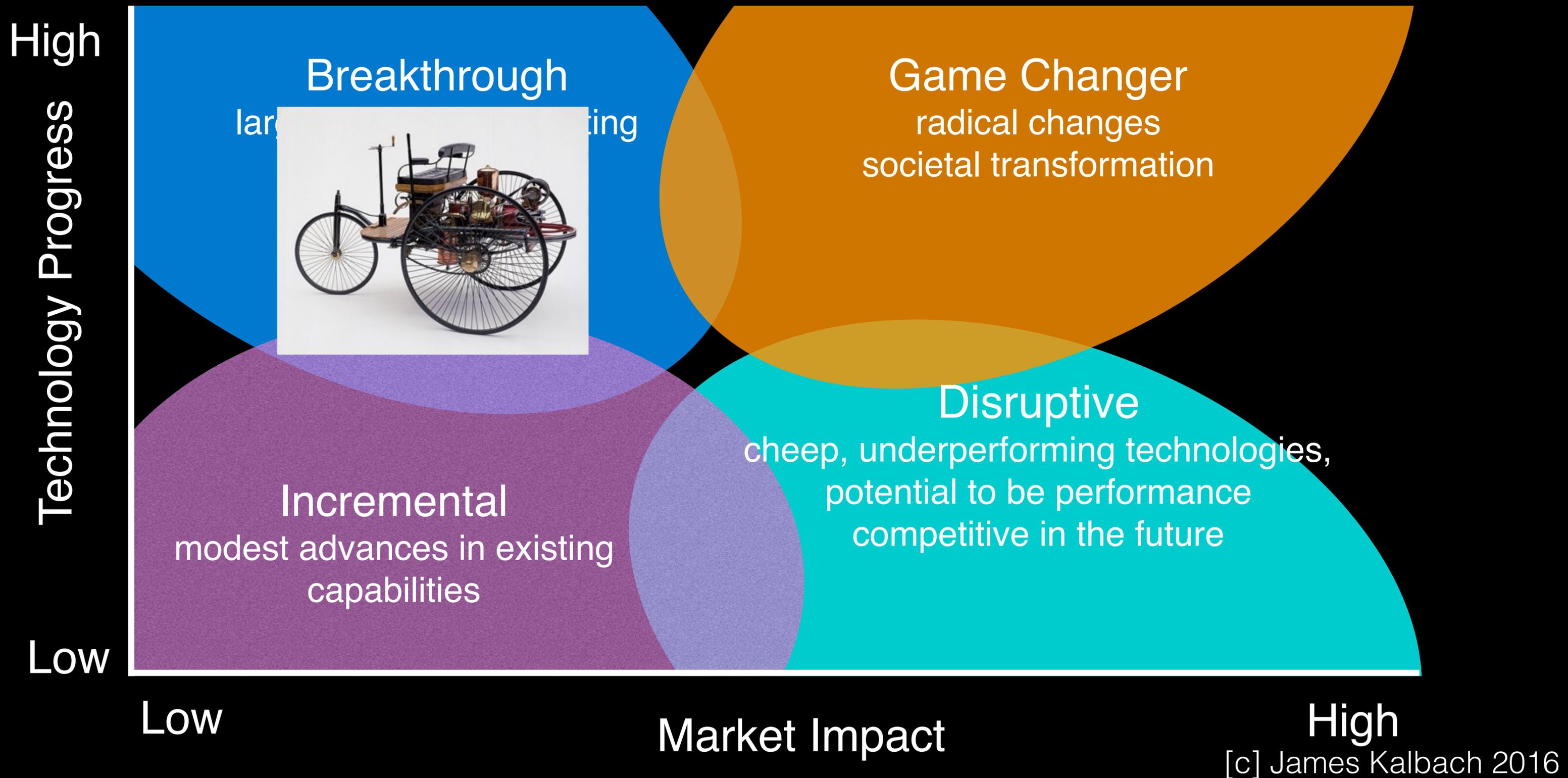
In the world, on average, the public sector invests in research ~ 25% of the total

Country	Public GDP fraction	Total	Abroad	Total G\$	Basic research
Italia	0.56%	1.2%	0.07%	27.7	50%
Francia	0.8%	2.2%	0.26%	58.7	55%
UK	0.5%	1.7%	0.42%	44.2	35%
GER	0.8%	2.0%	0.20%	108.8	
EU	0.67%	2.0%		365.8	
USA	0.85%	2.75%	0.08%	457.0	
China	0.8%	2.0%	-	368.7	25%
Japan	0.8%	3.6%	-	166.9	
Korea	1.0%	4.3%	-	72.3	

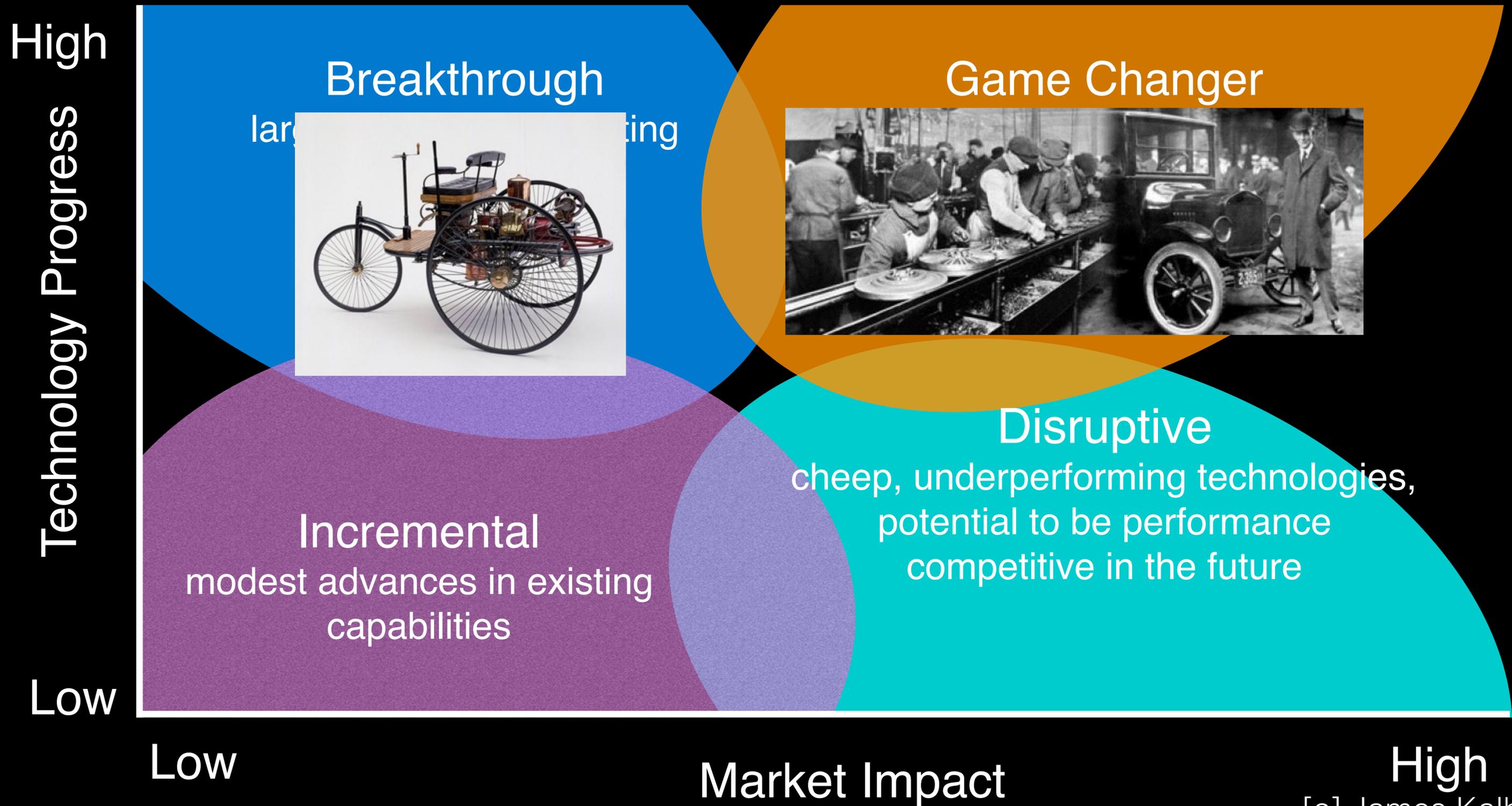
Which research?



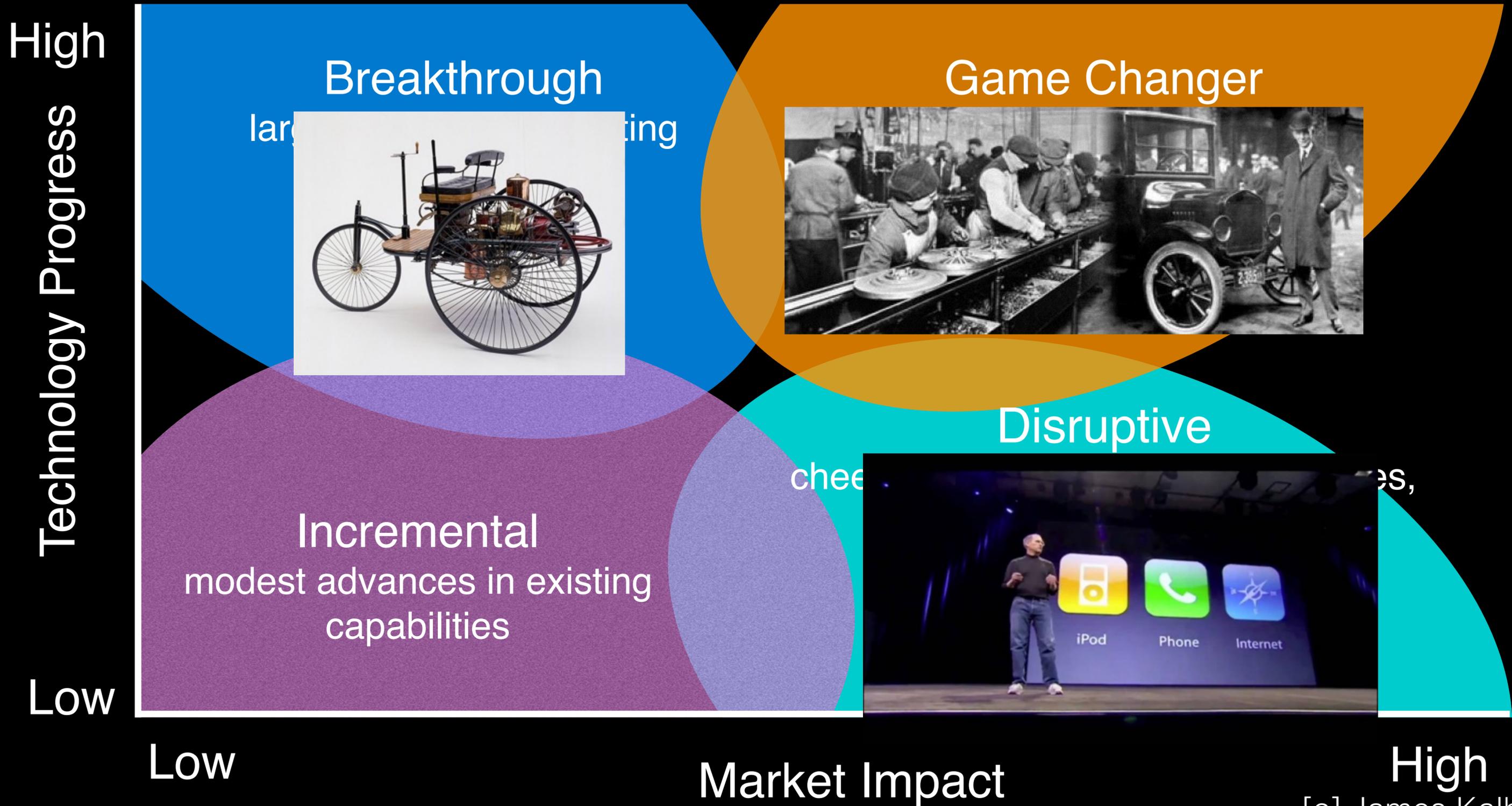
Which research?



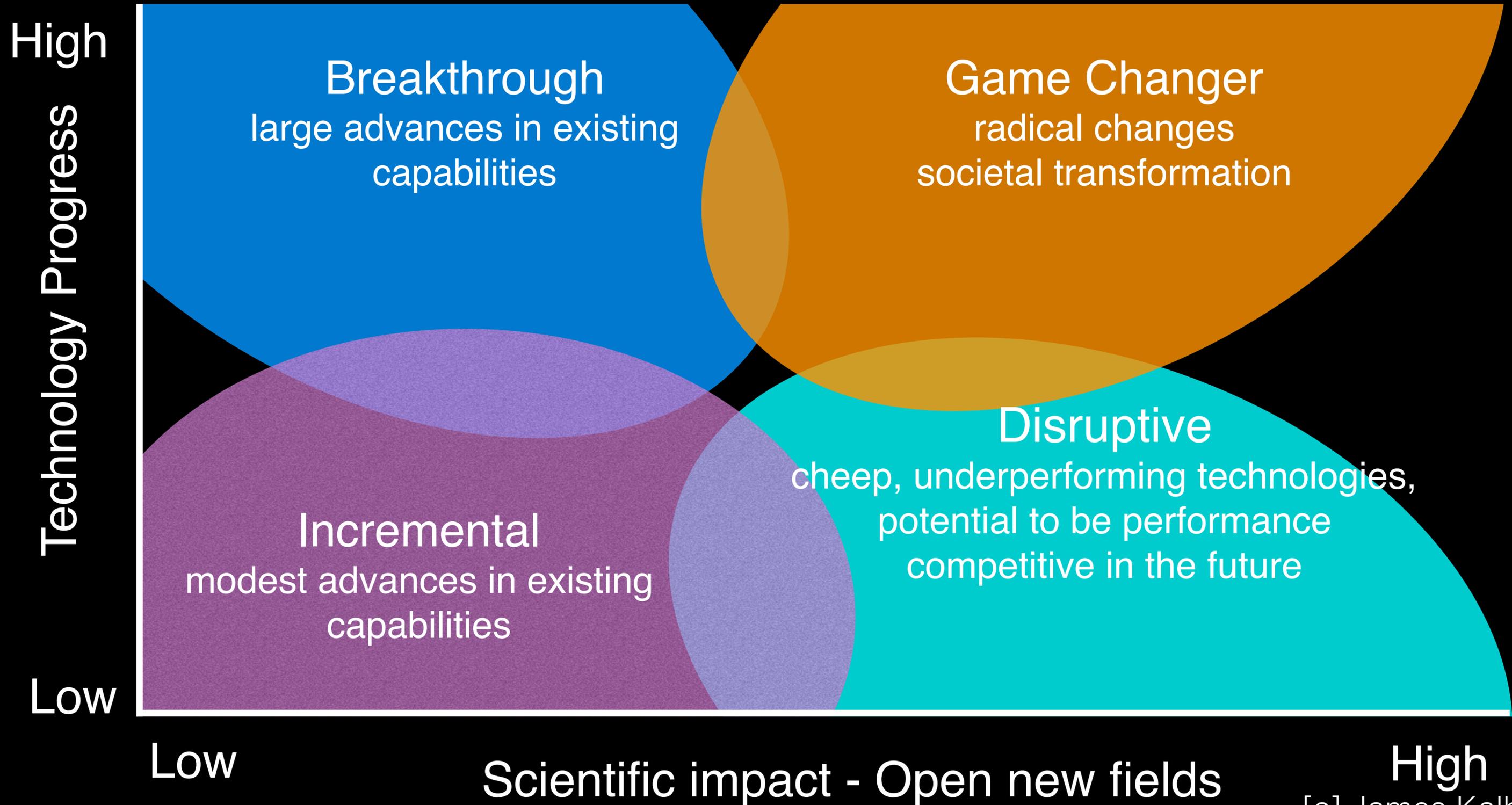
Which research?



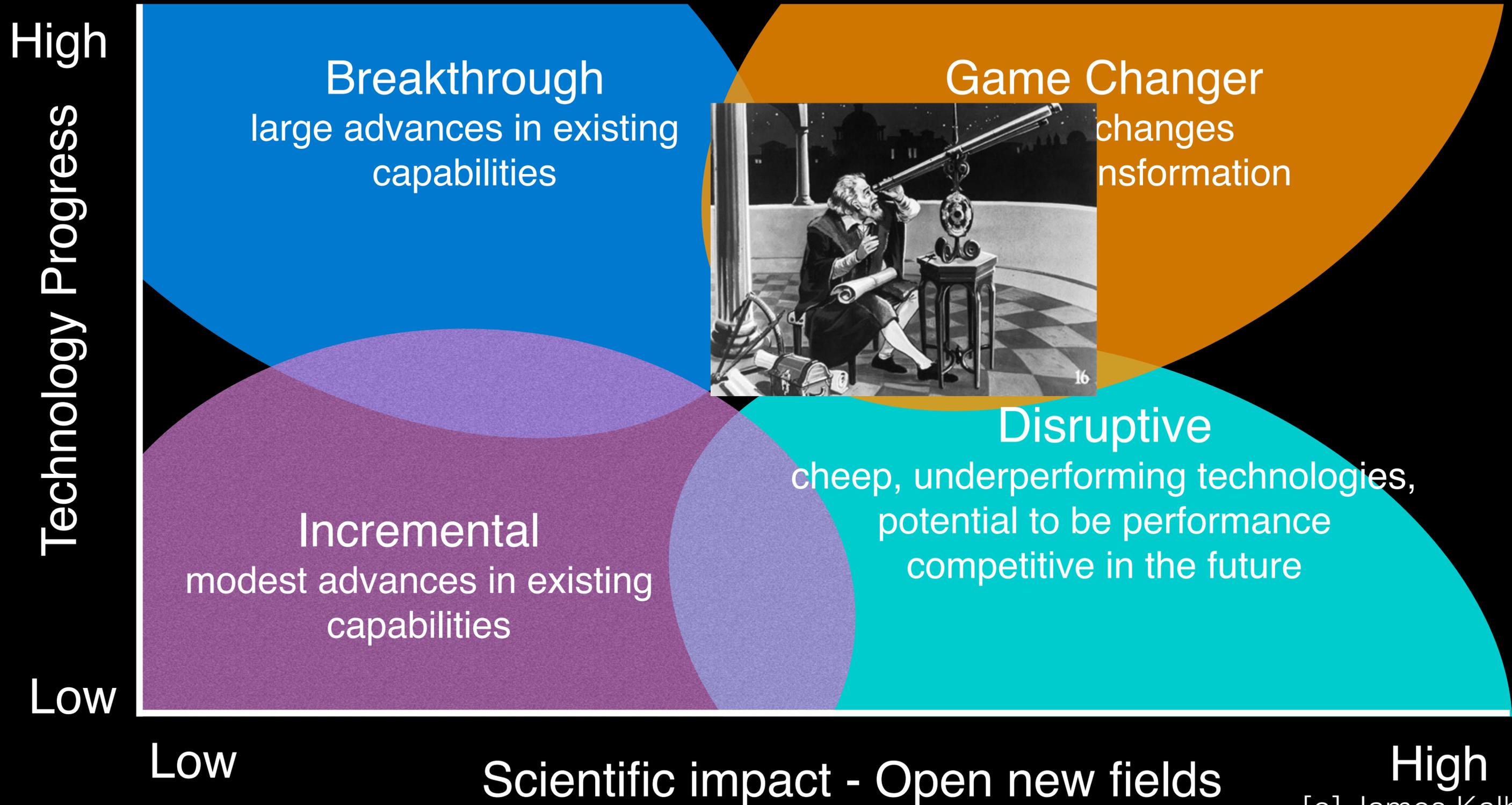
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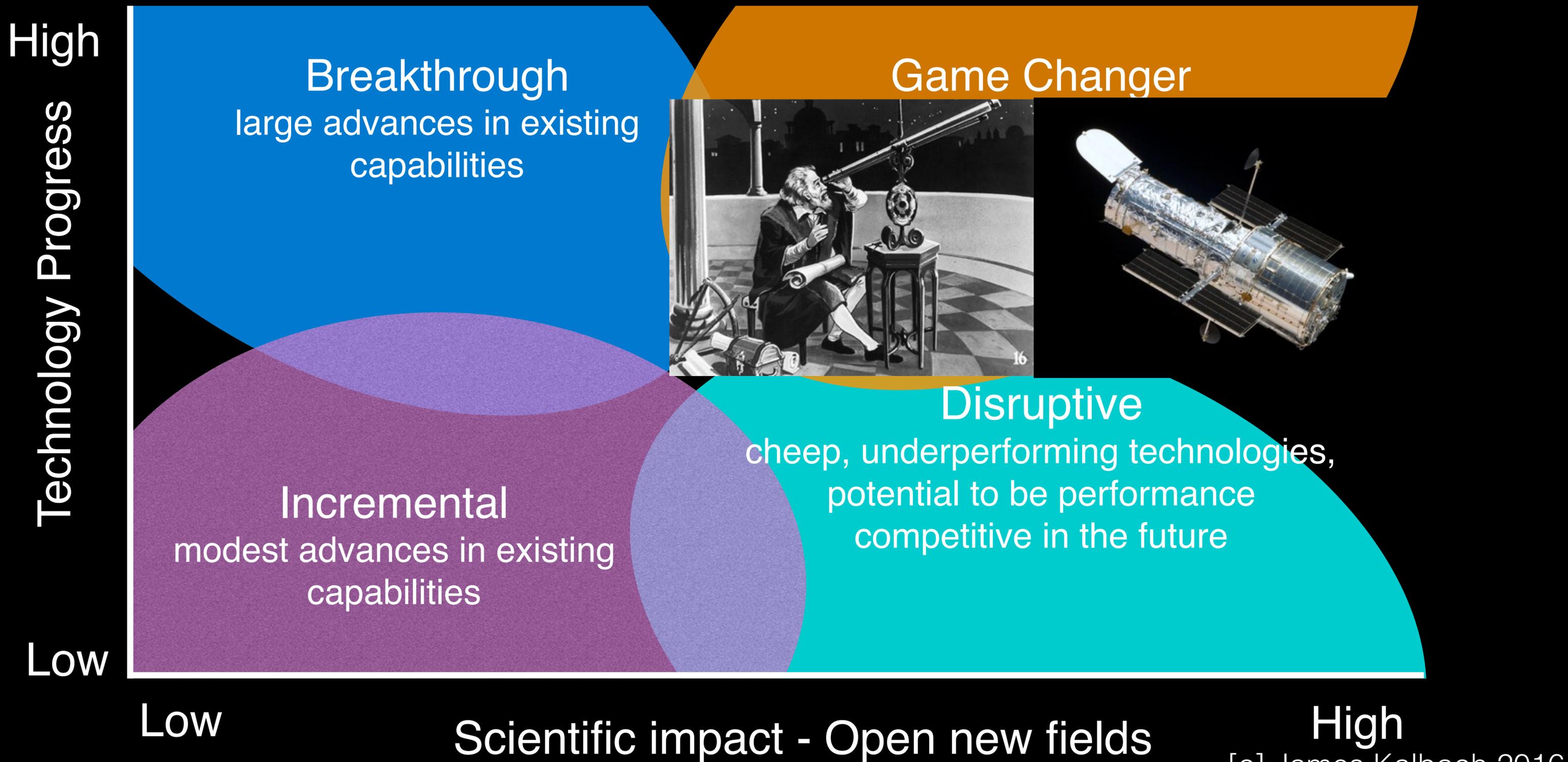
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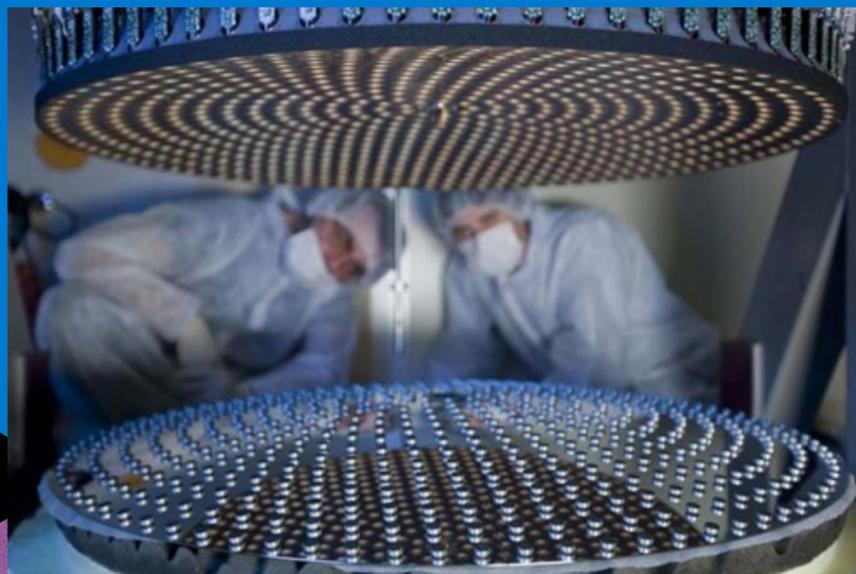
Which research?

High

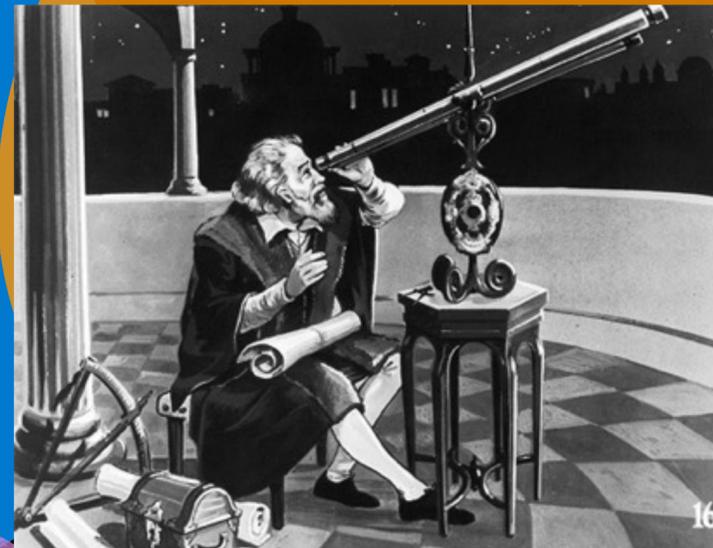
Technology Progress

Low

Breakthrough



Game Changer



Disruptive

cheap, underperforming technologies,
potential to be performance
competitive in the future

Incremental
modest advances in existing
capabilities

Low

Scientific impact - Open new fields

High

[c] James Kalbach 2016

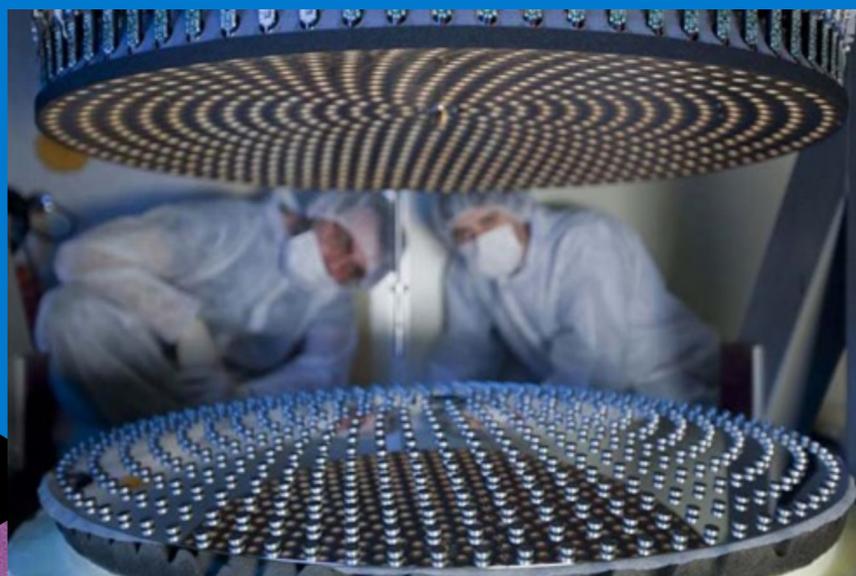
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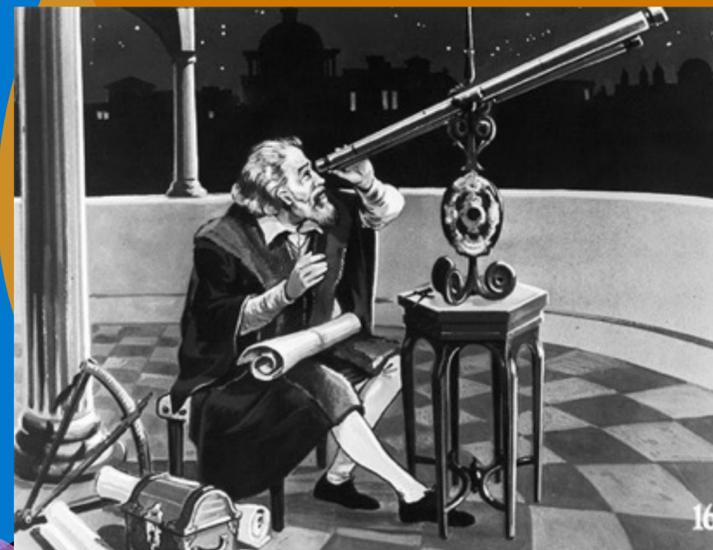
Technology Progress

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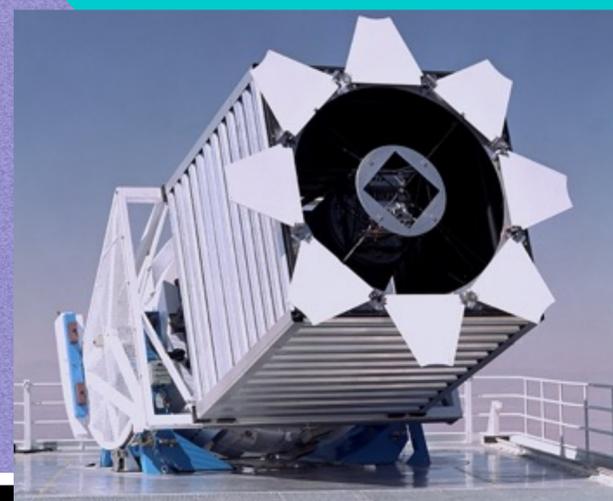


Game Changer



Disruptive

arming technologies,
e performance
in the future



Incremental
modest advances in existing
capabilities

Low

Scientific impact - Open new fields

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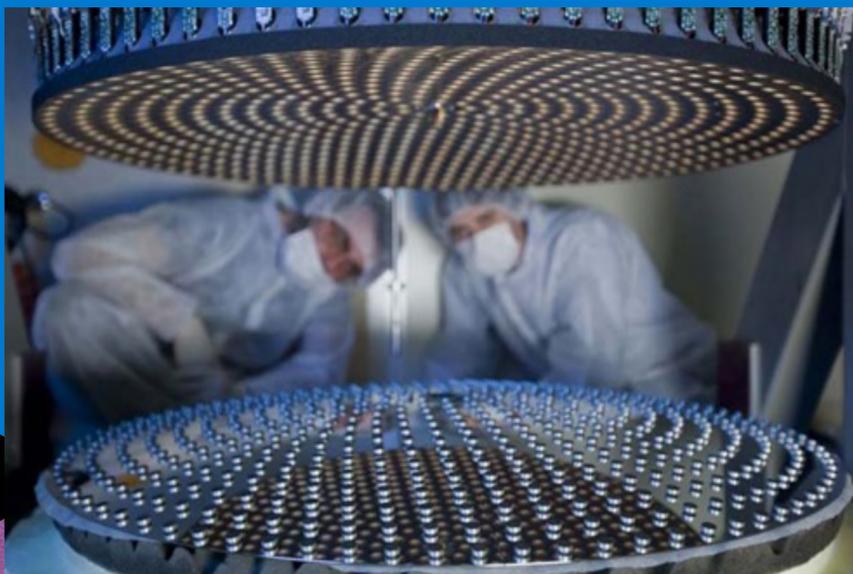
Which research?

High

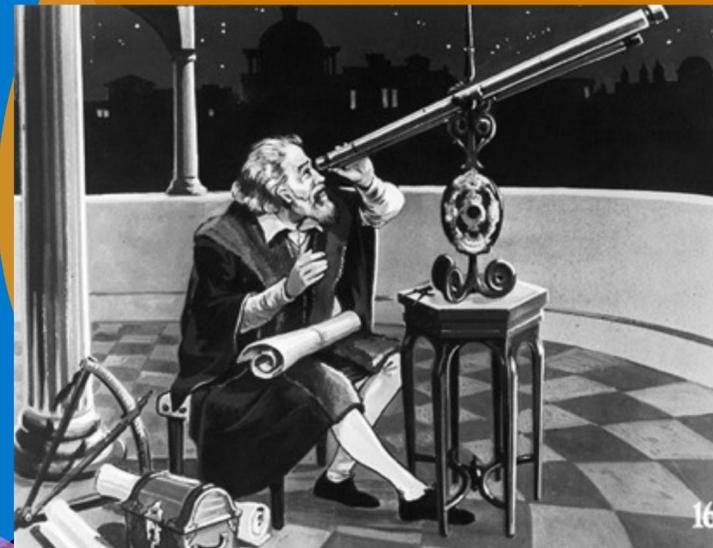
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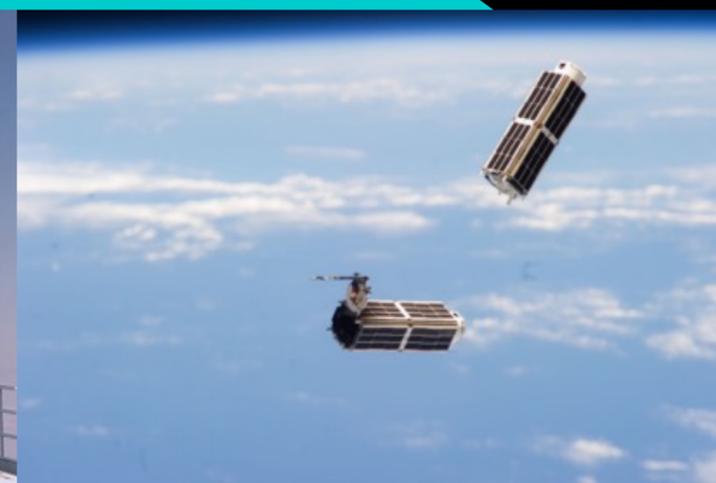


Game Changer



Disruptive

Incremental
modest advances in existing
capabilities



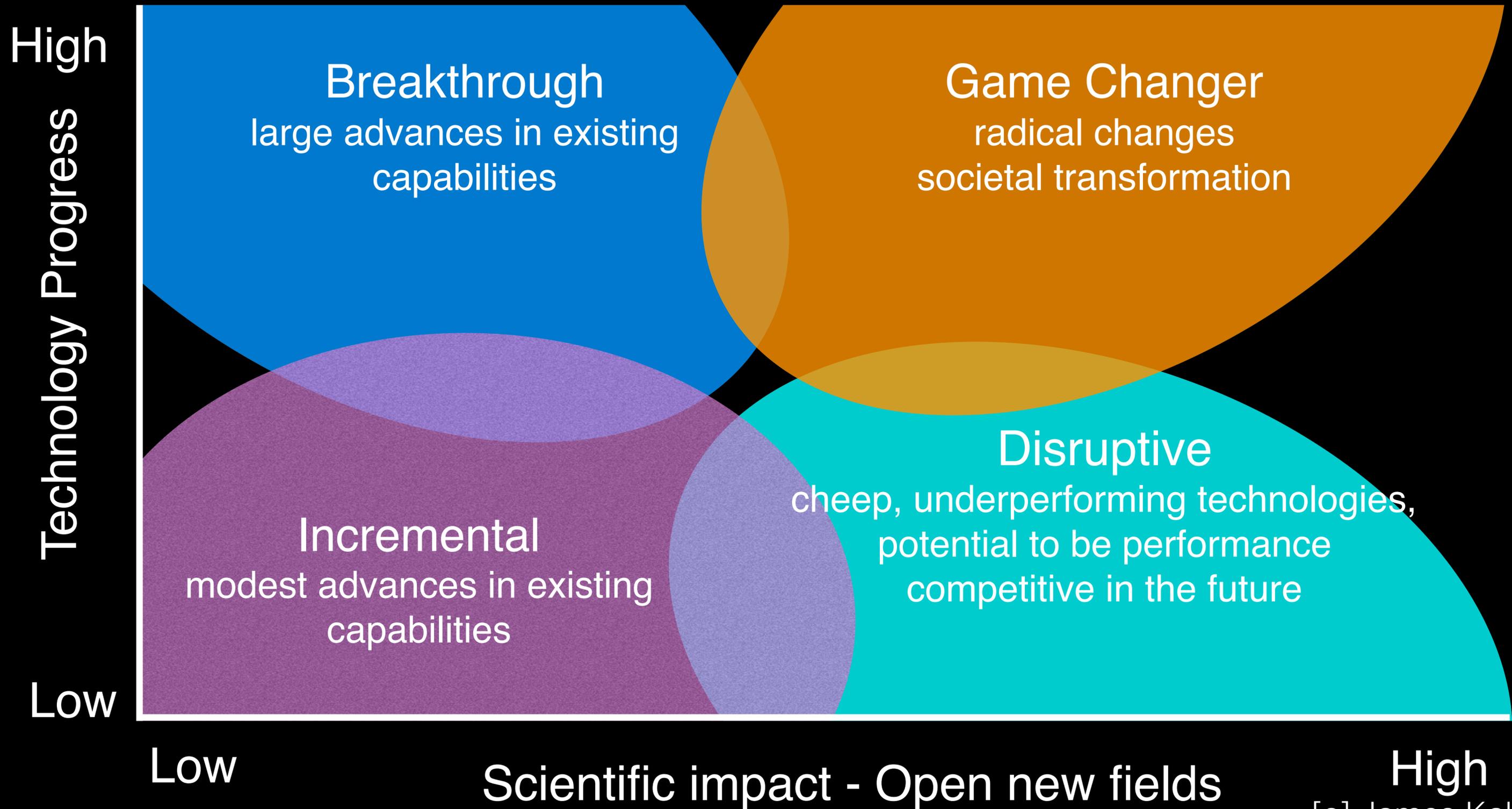
Low

Scientific impact - Open new fields

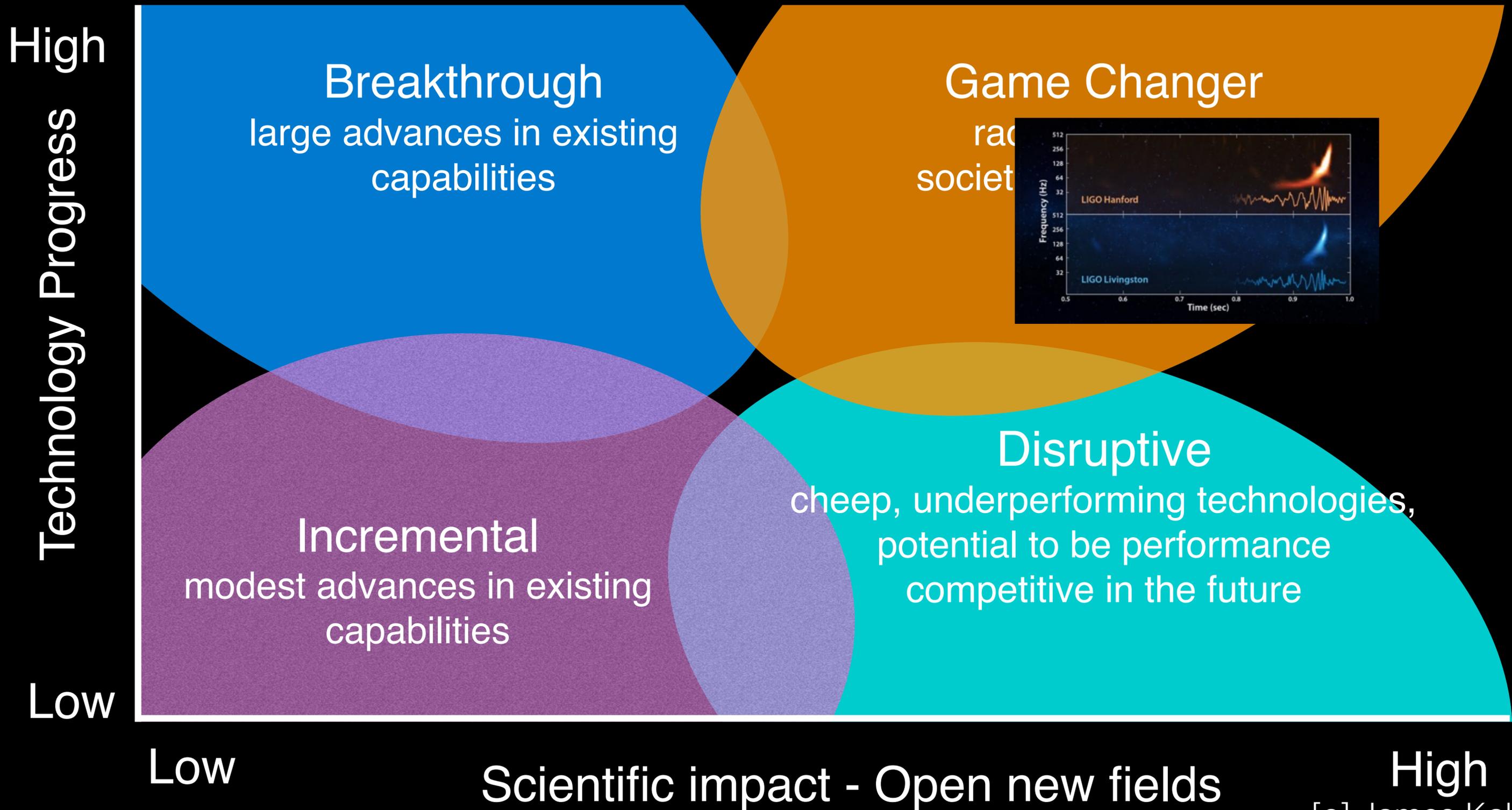
High

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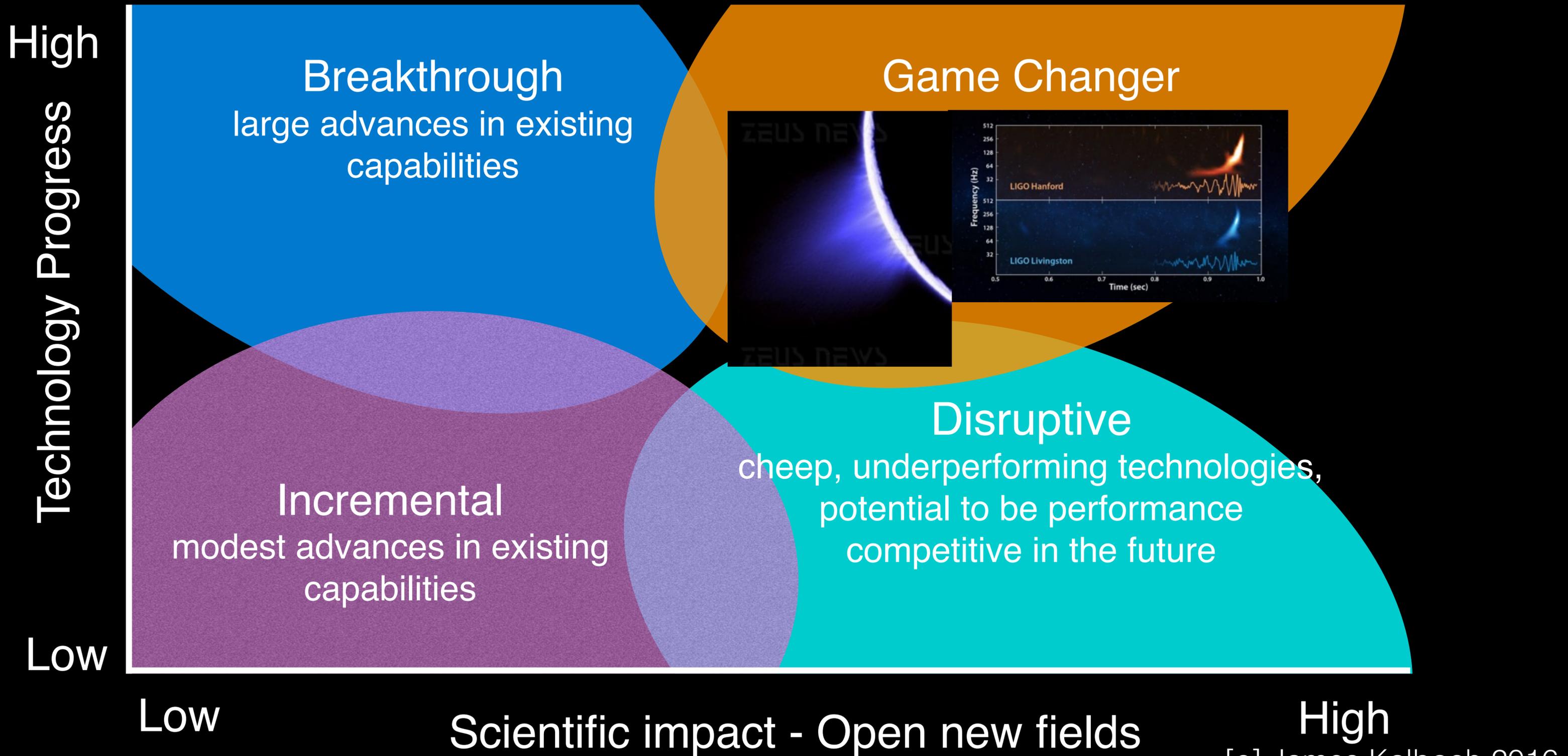
Which research?



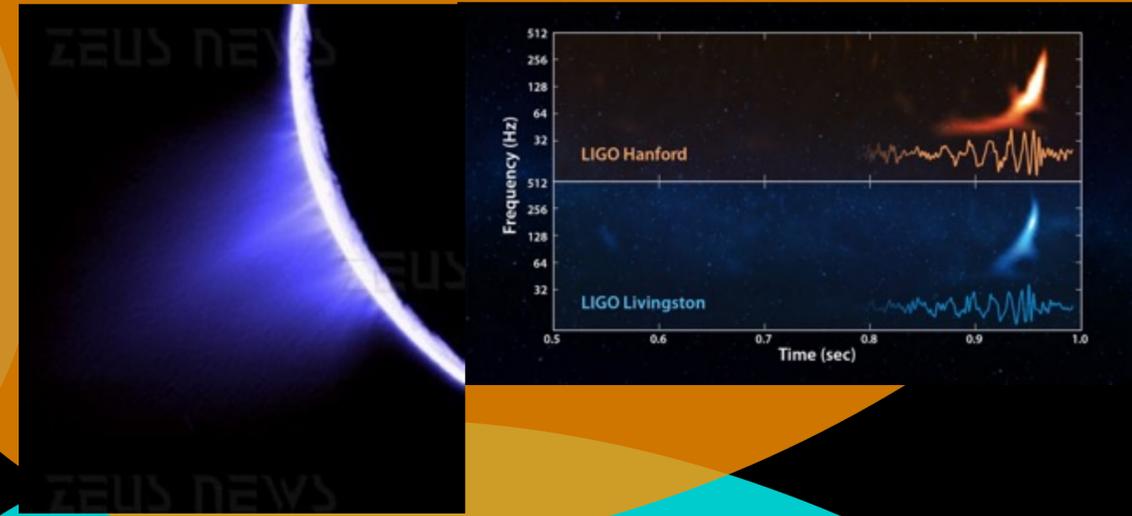
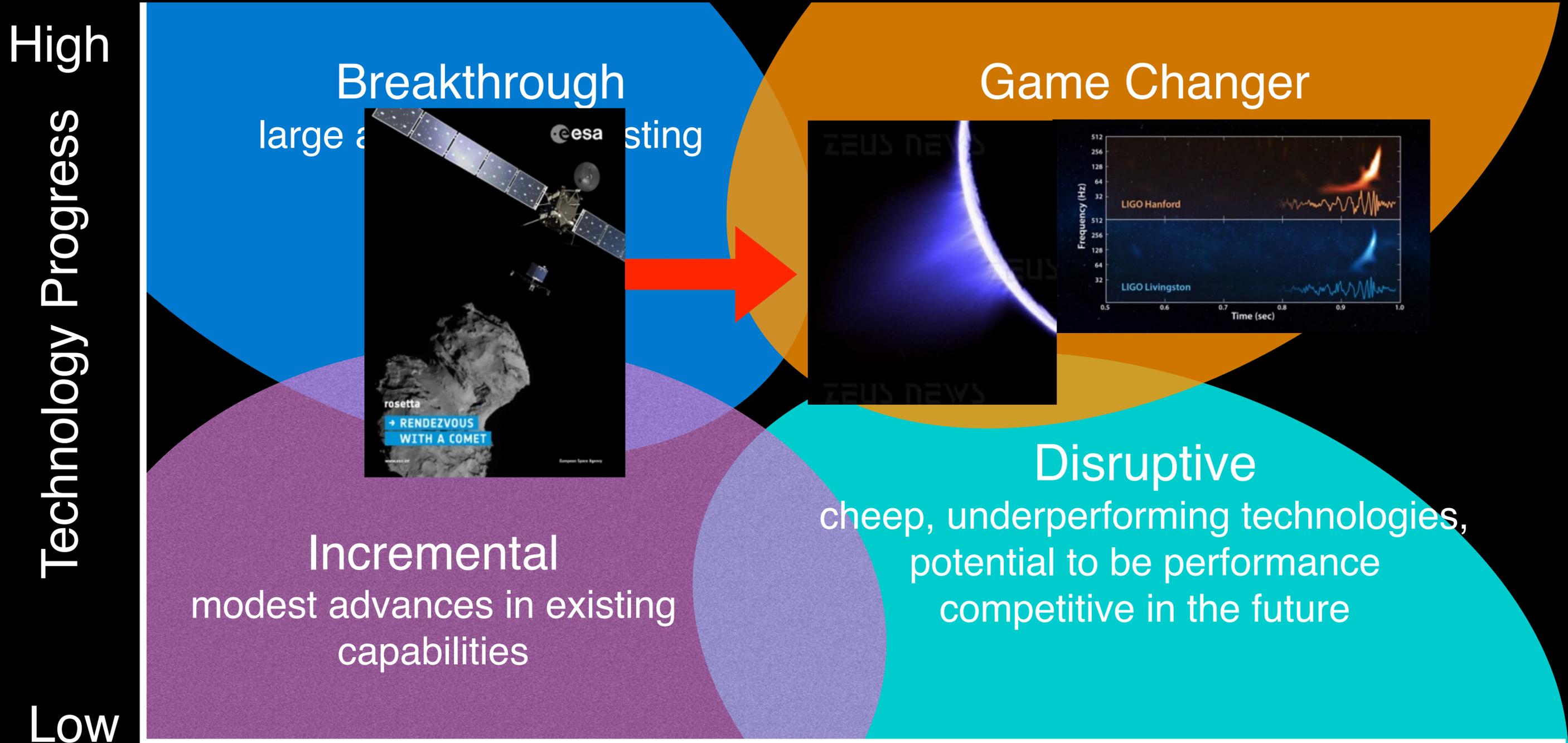
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Technology Progress

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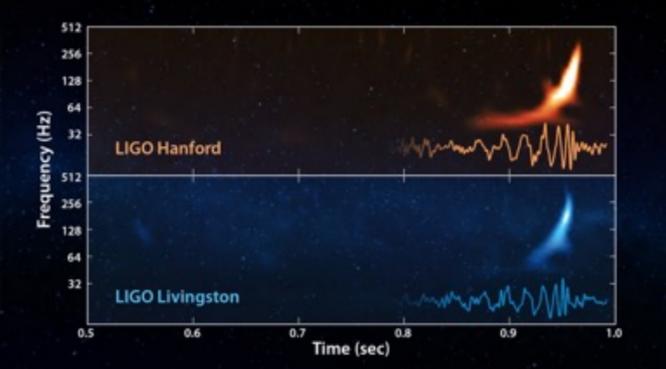
Breakthrough
large advances in existing capabilities



rosetta
→ RENDEZVOUS WITH A COMET

Incremental
modest advances in existing capabilities

Game Changer



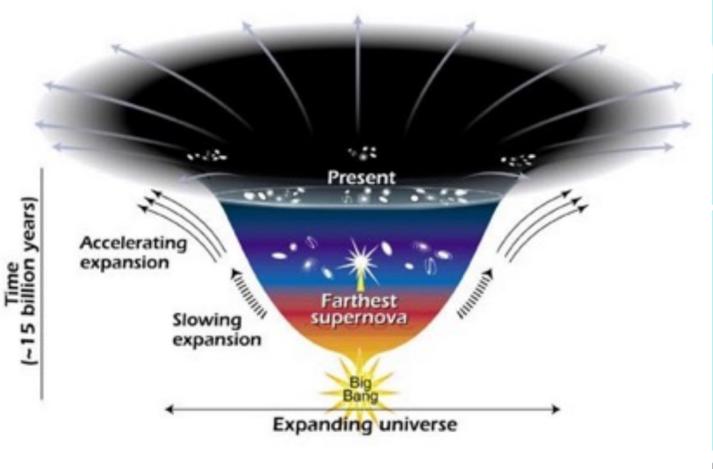
Frequency (Hz)

Time (sec)

LIGO Hanford

LIGO Livingston

Disruptive



Time (~15 billion years)

Present

Accelerating expansion

Slowing expansion

Farthest supernova

Big Bang

Expanding universe



Low

Scientific impact - Open new fields

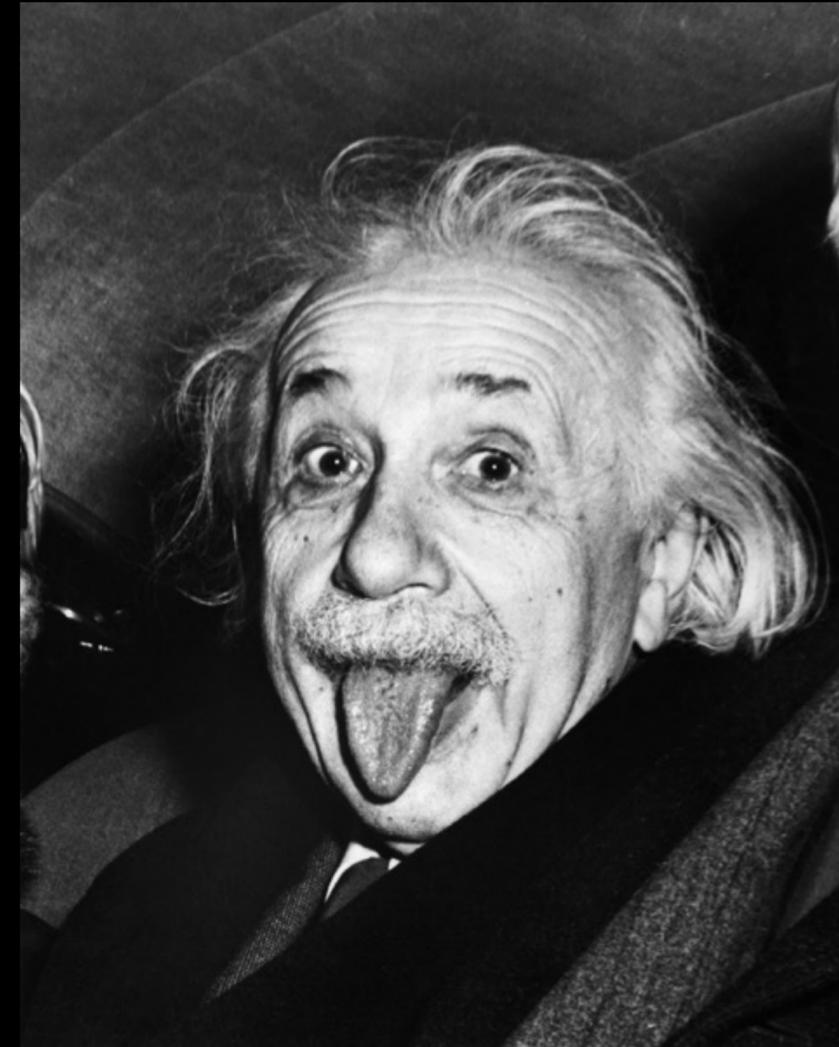
High

[c] James Kalbach 2016

Propulsive forces for basic research

Propulsive forces for basic research

Imagination is more important than knowledge

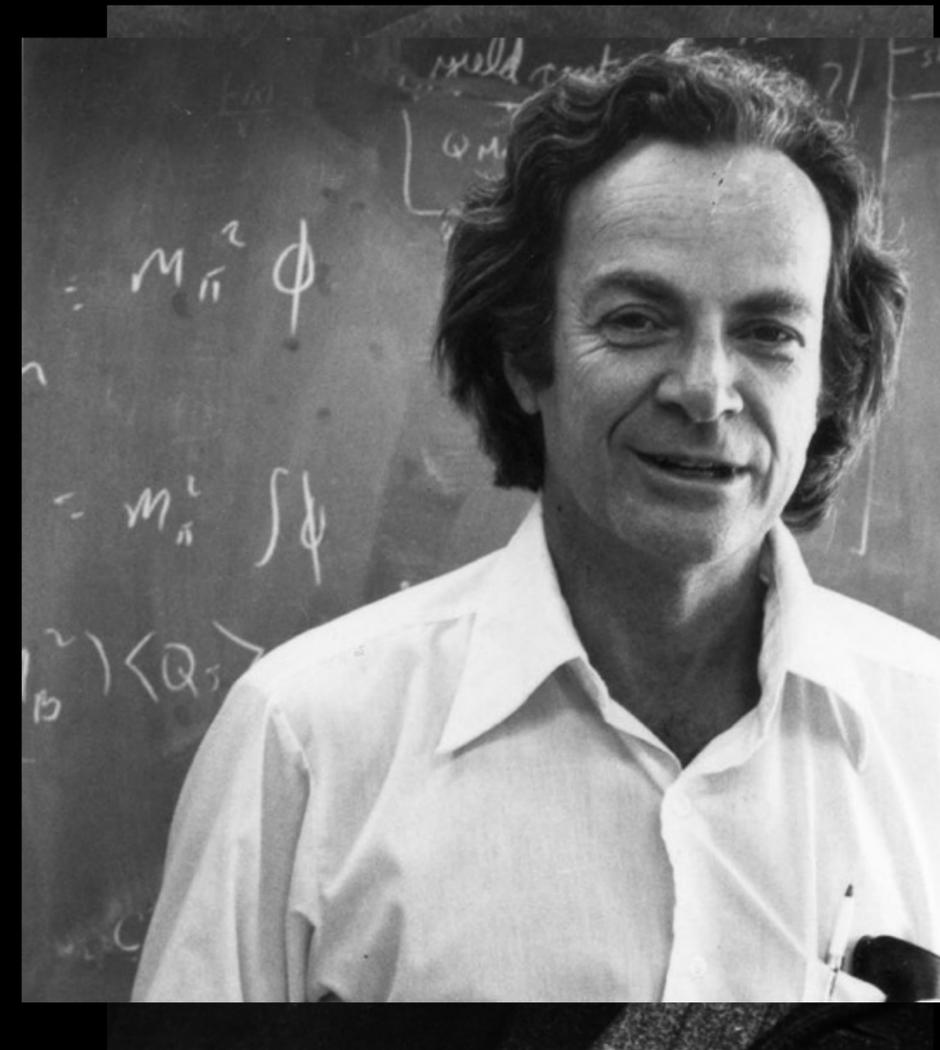


Imagination

Propulsive forces for basic research

Imagination is more important than knowledge

Scientific creativity is *imagination* in a straitjacket



Imagination

Propulsive forces for basic research

Imagination is more important than knowledge

Scientific creativity is *imagination* in a straitjacket

But the fool on the hill

Sees the sun going down

And the eyes in his head

See the world spinning round

Imagination

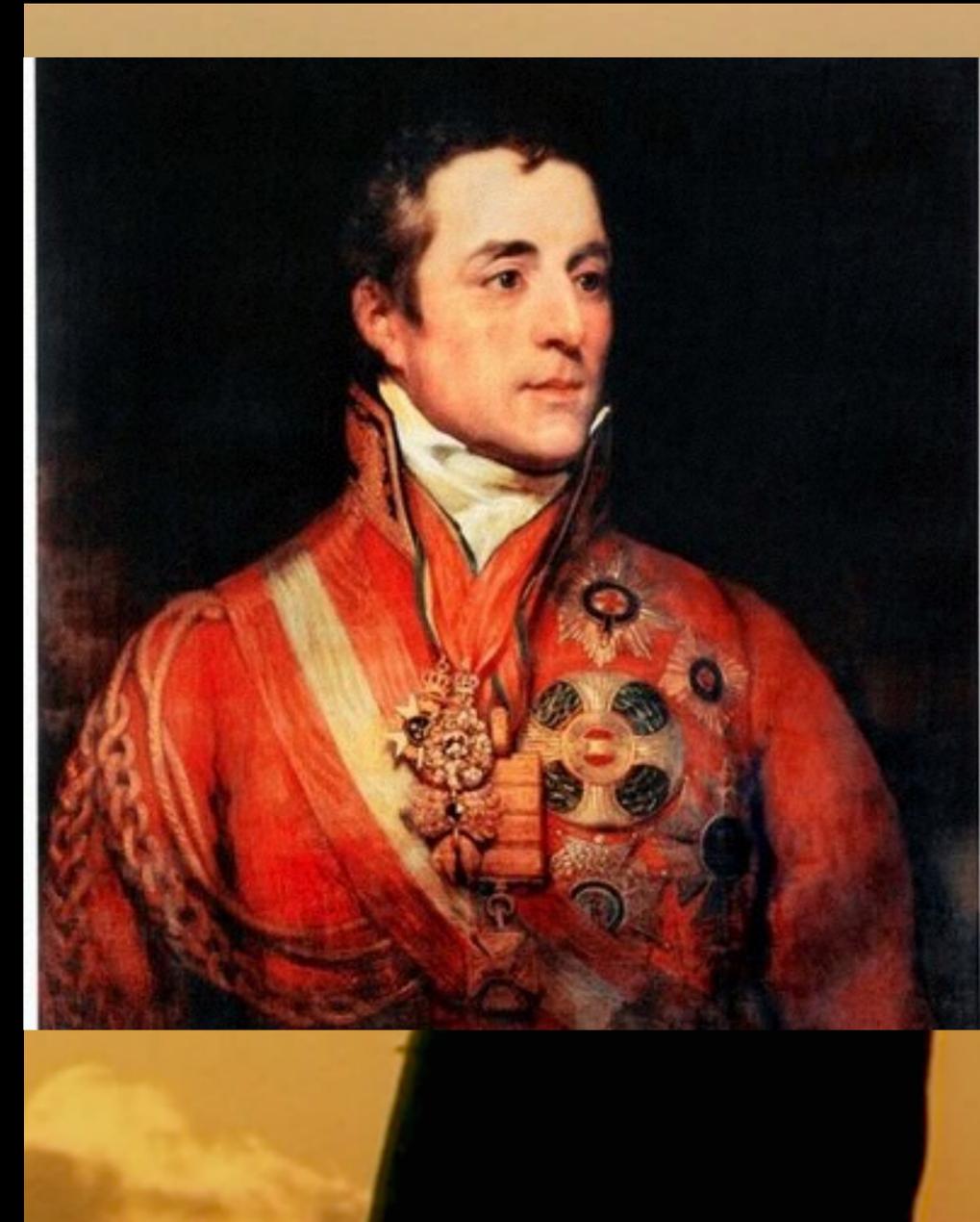


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What is on the other side of the hill



Imagination

Curiosity

Propulsive forces for basic research

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What is on the other side of the hill

Ambition leads me not only farther than any other man has been before me, but as far as I think it possible for man to go.



Imagination

Curiosity

Ambition

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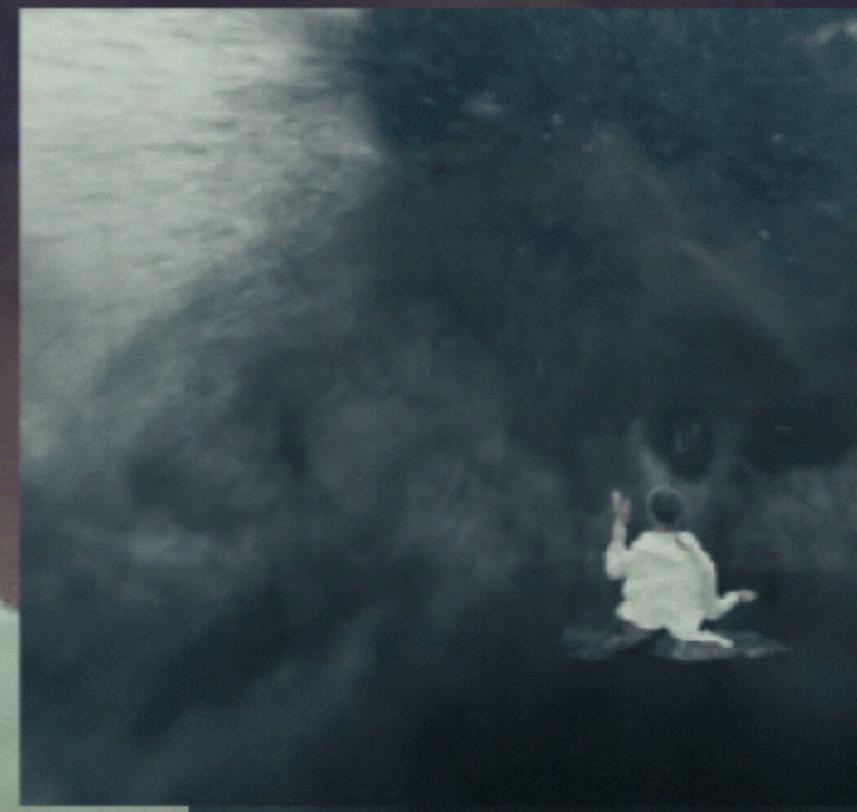
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Curiosity

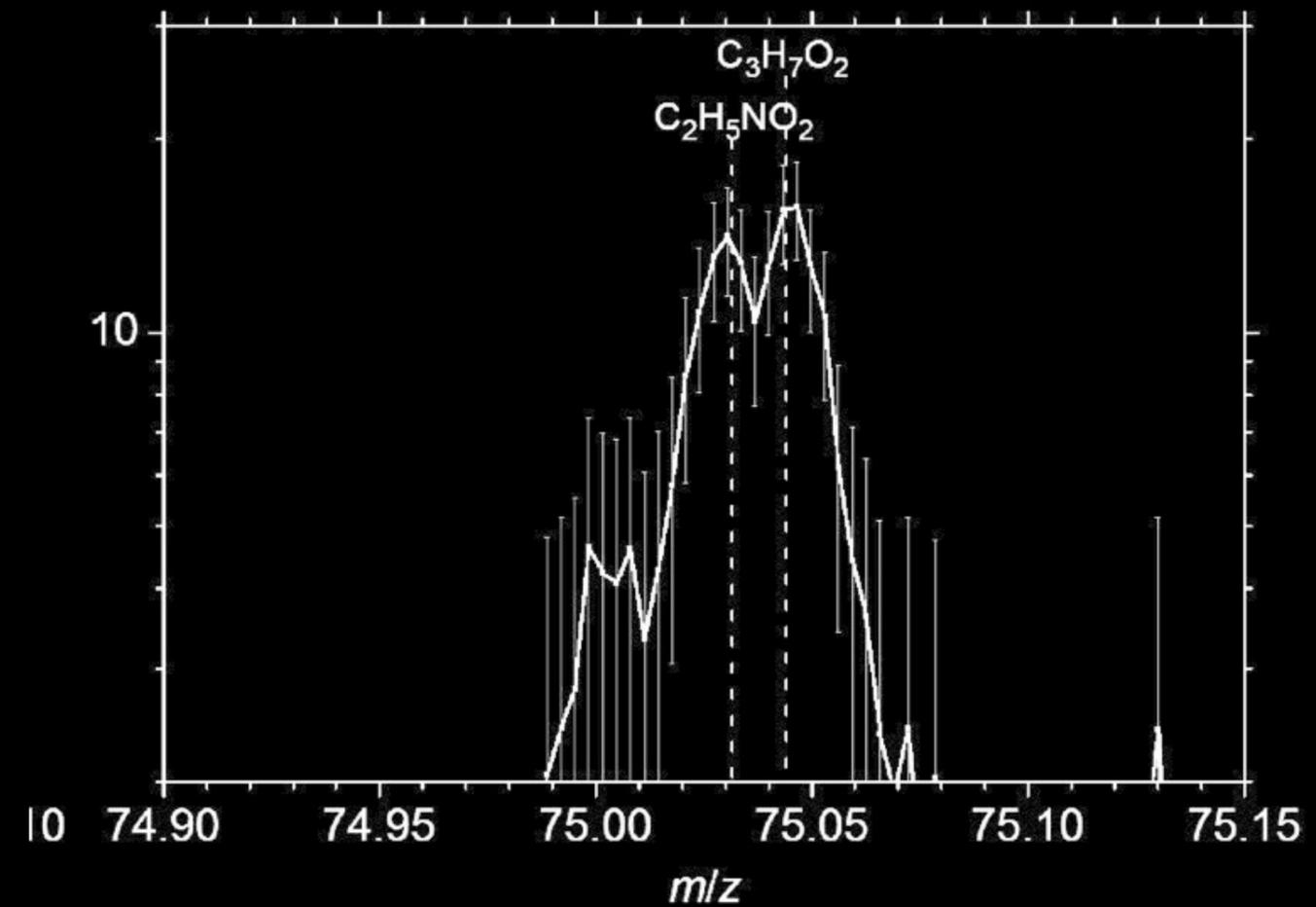
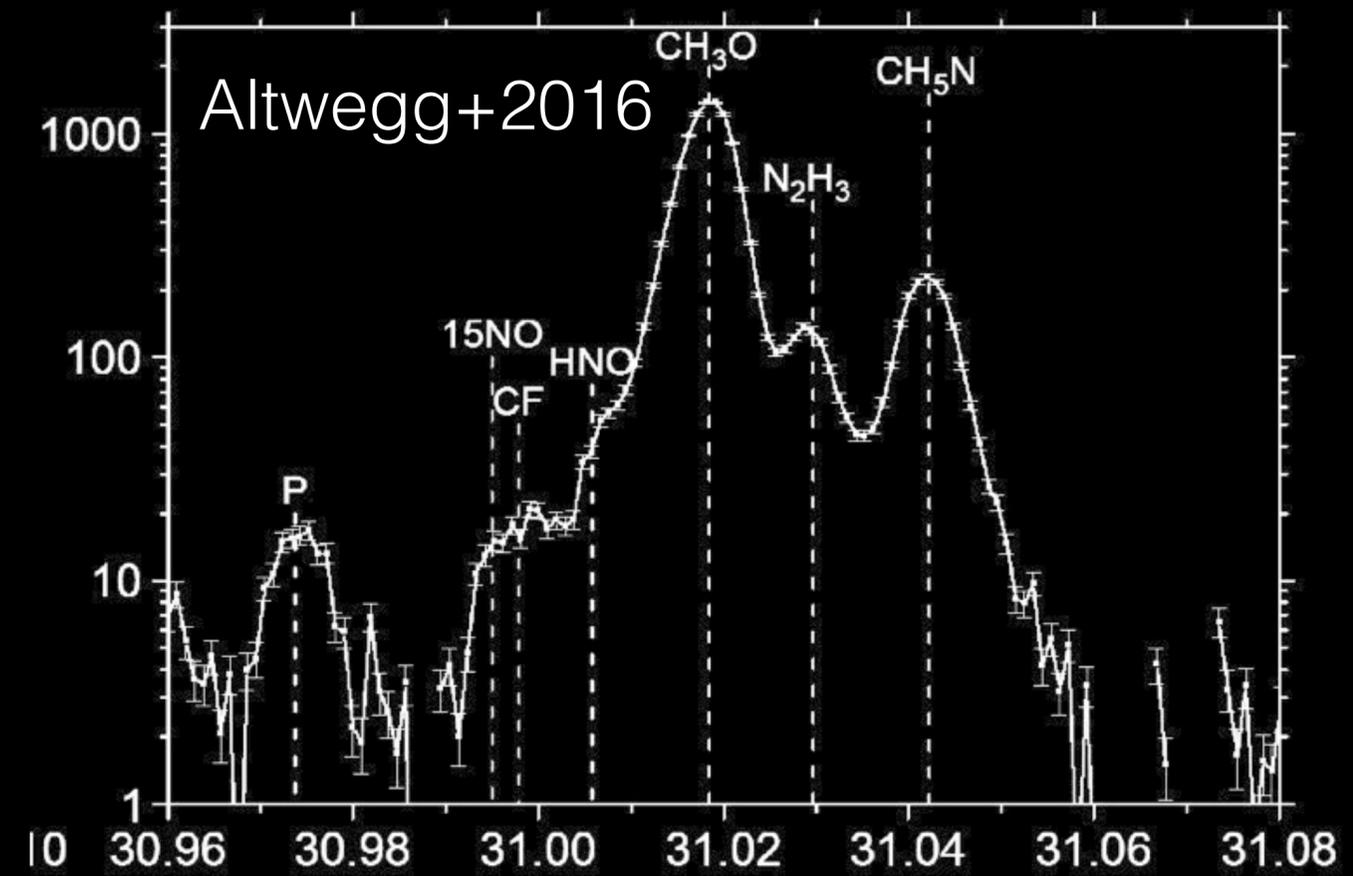
Ambition



Rosetta
Human
AMBITION

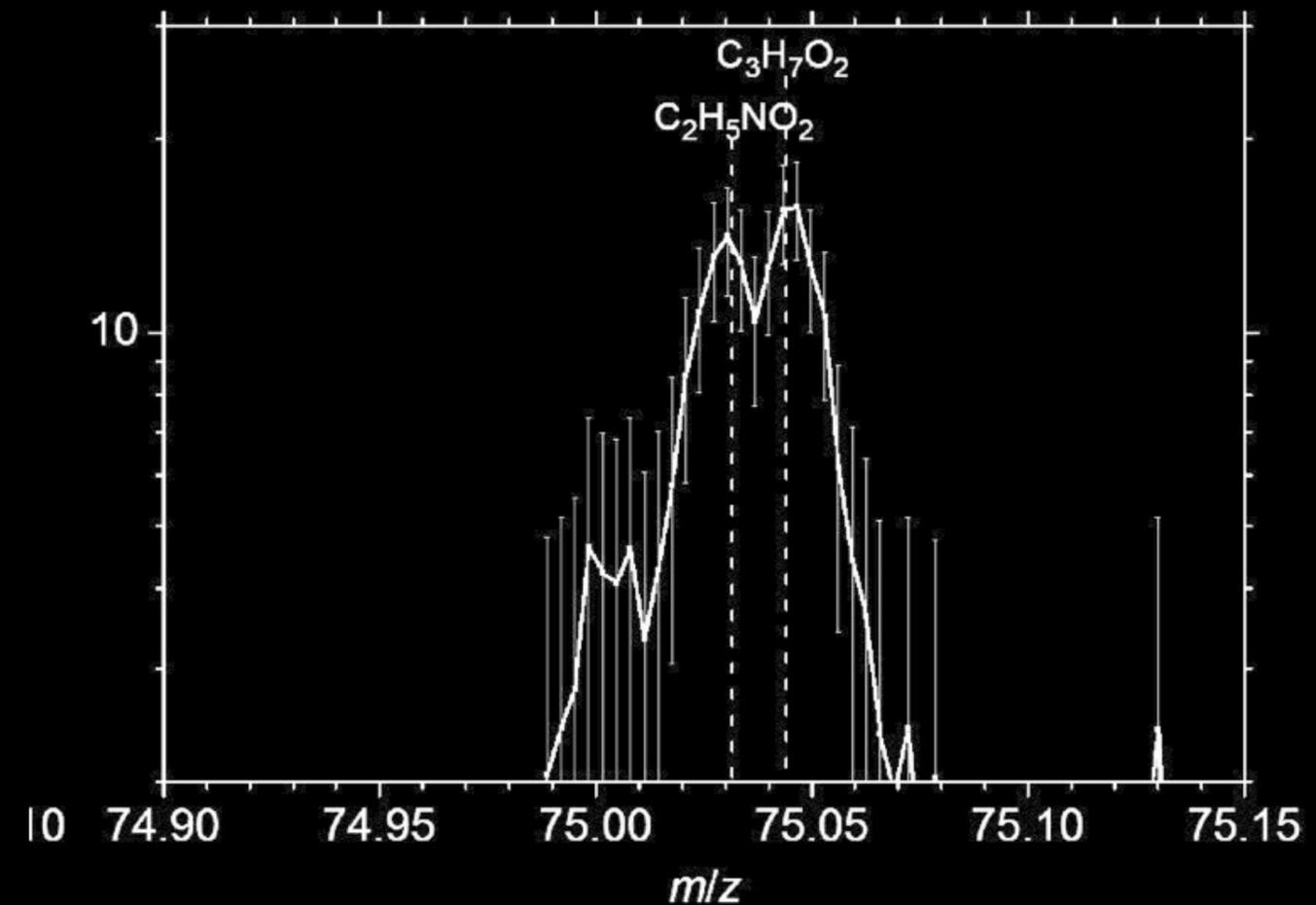
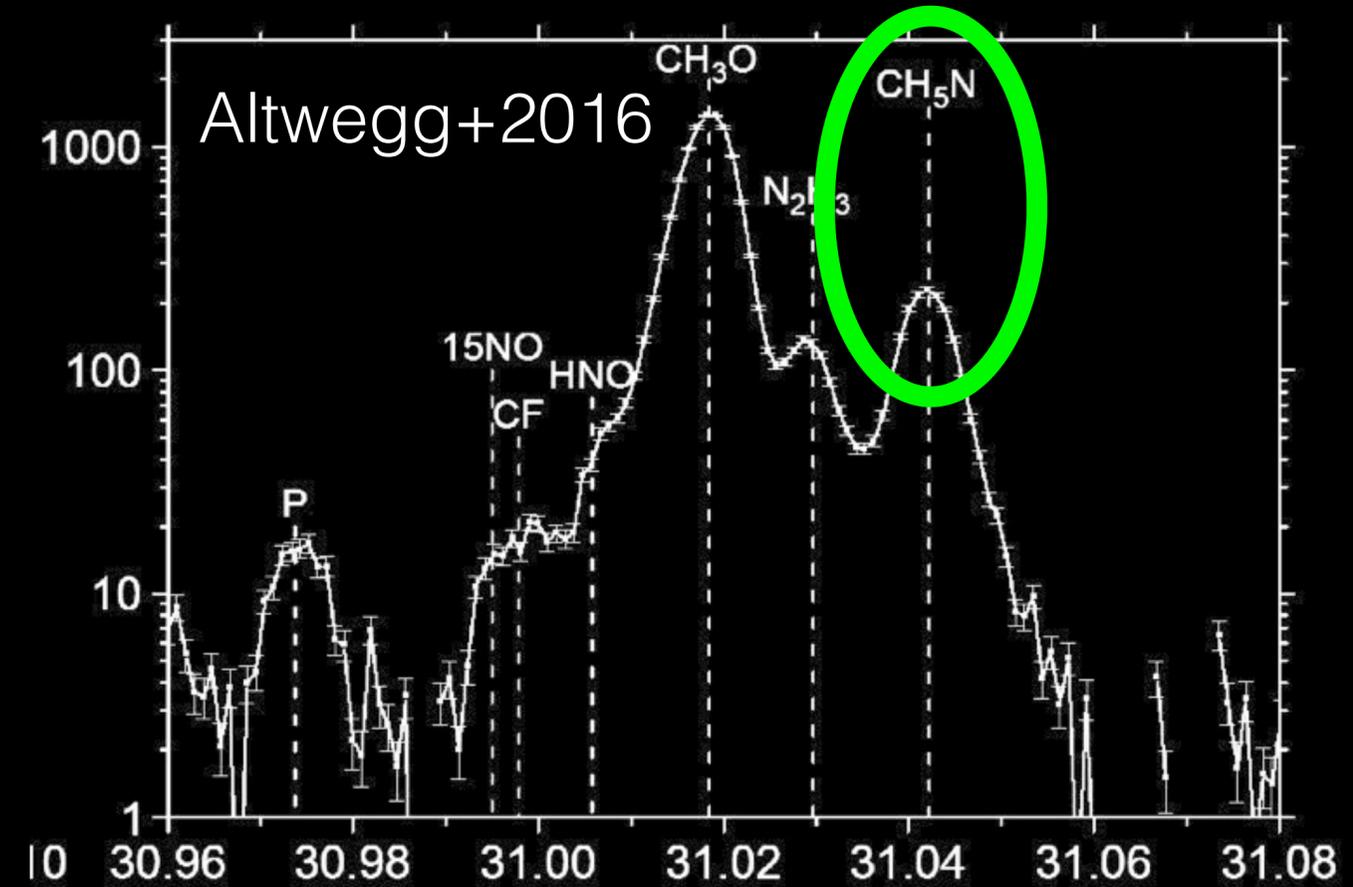


Rosetta: ambition-driven research



Rosetta: ambition-driven research

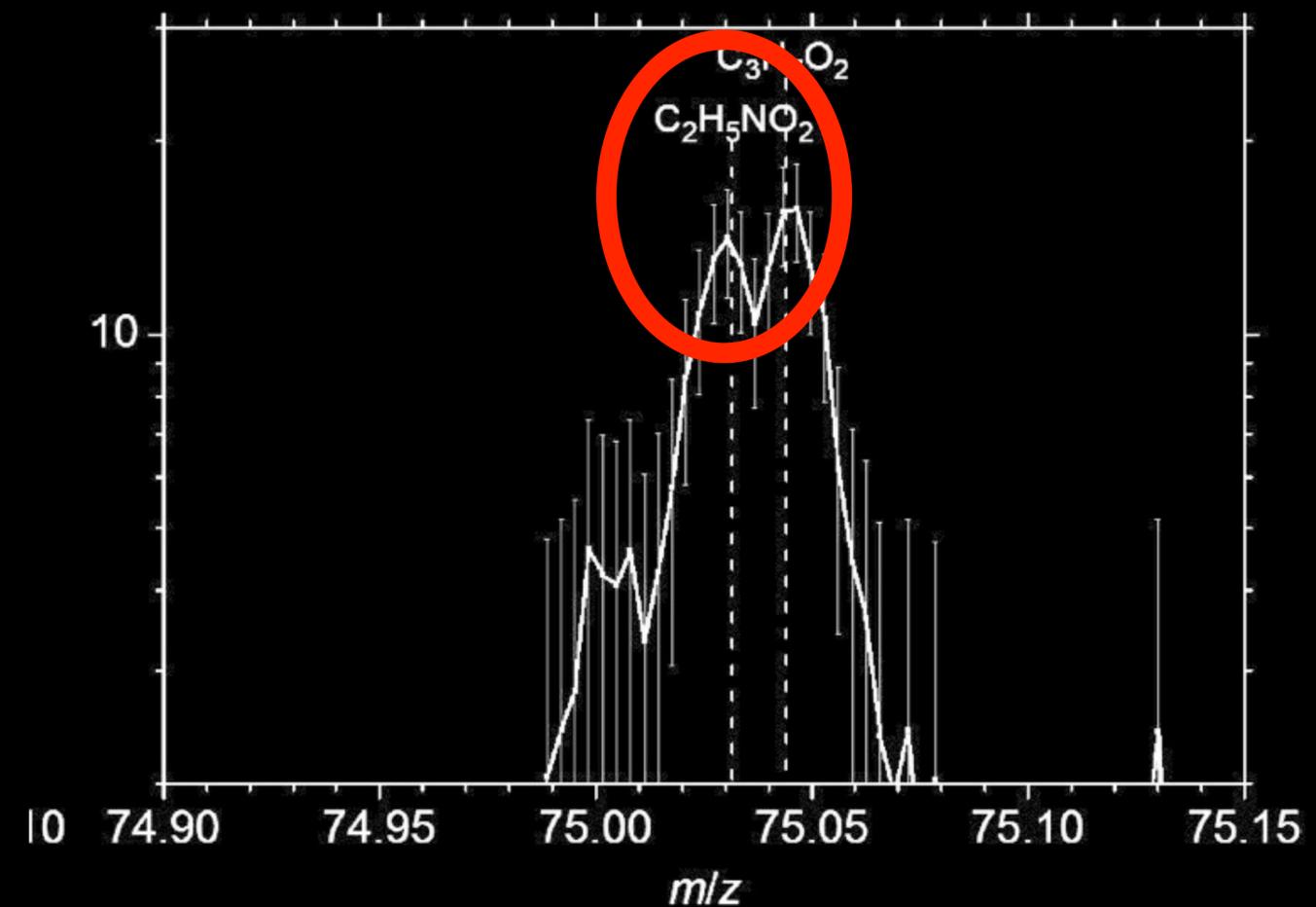
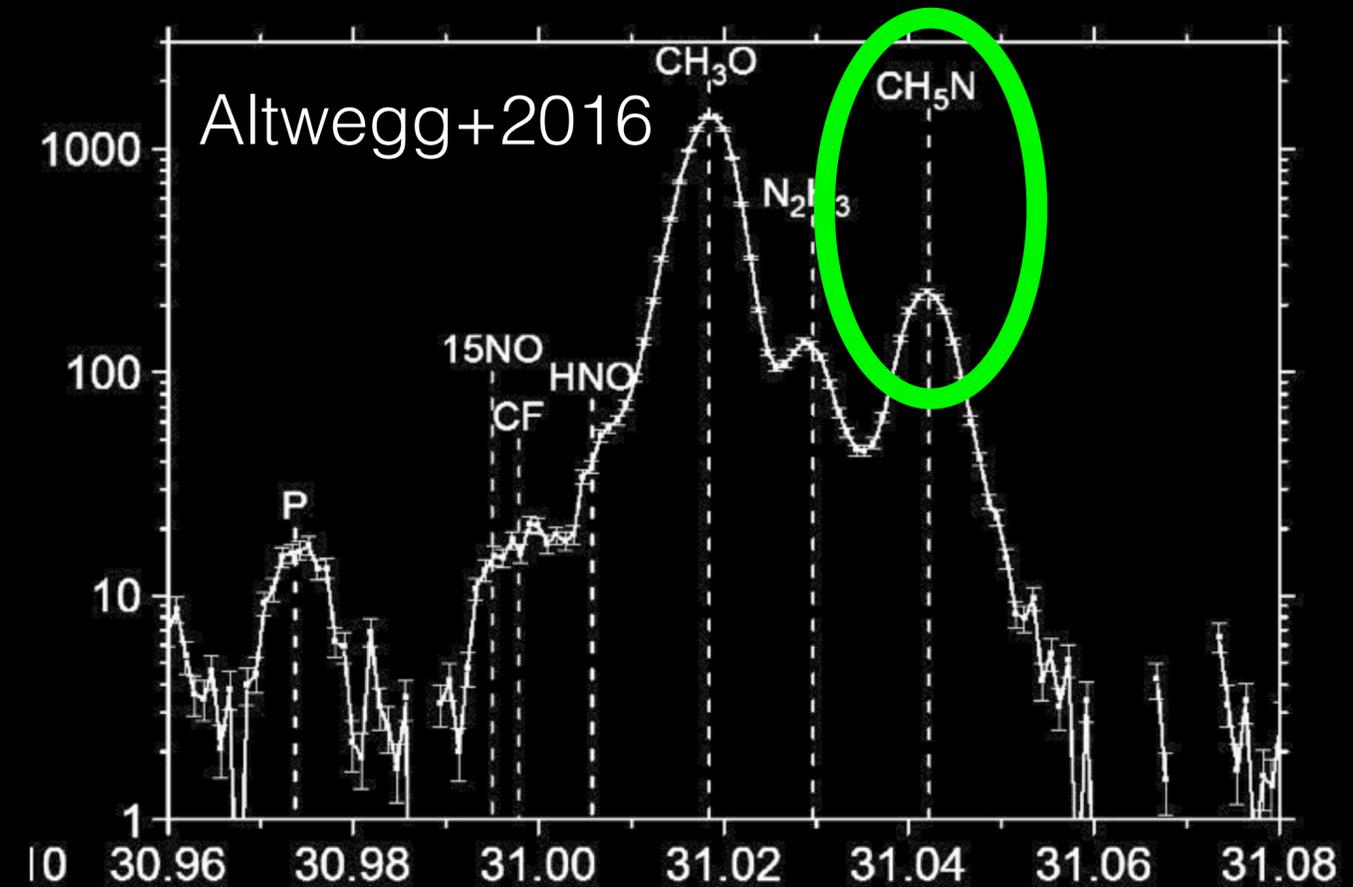
Volatile Methylamine ethylamine



Rosetta: ambition-driven research

Volatile Methylamine ethylamine

Volatile Glycine

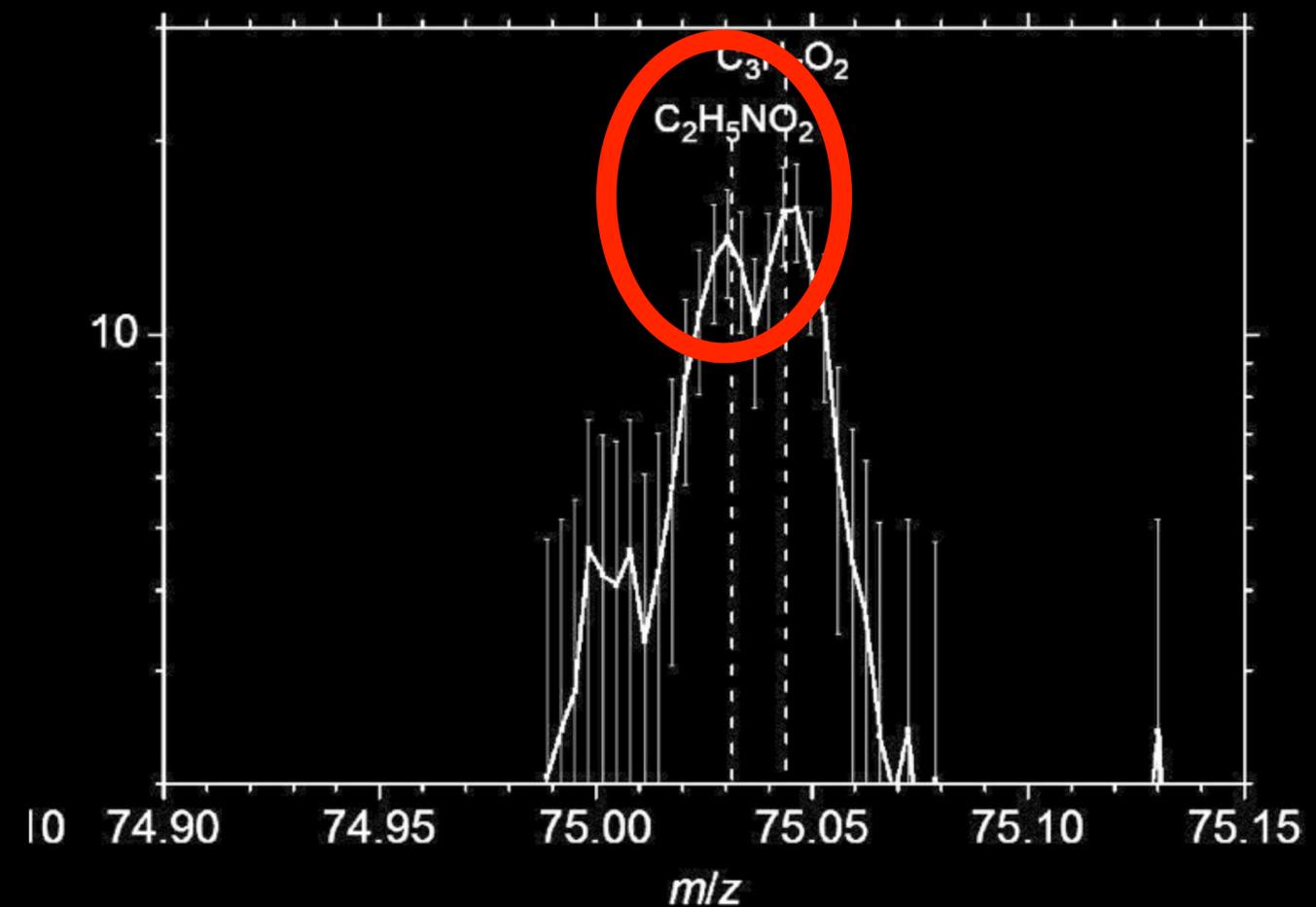
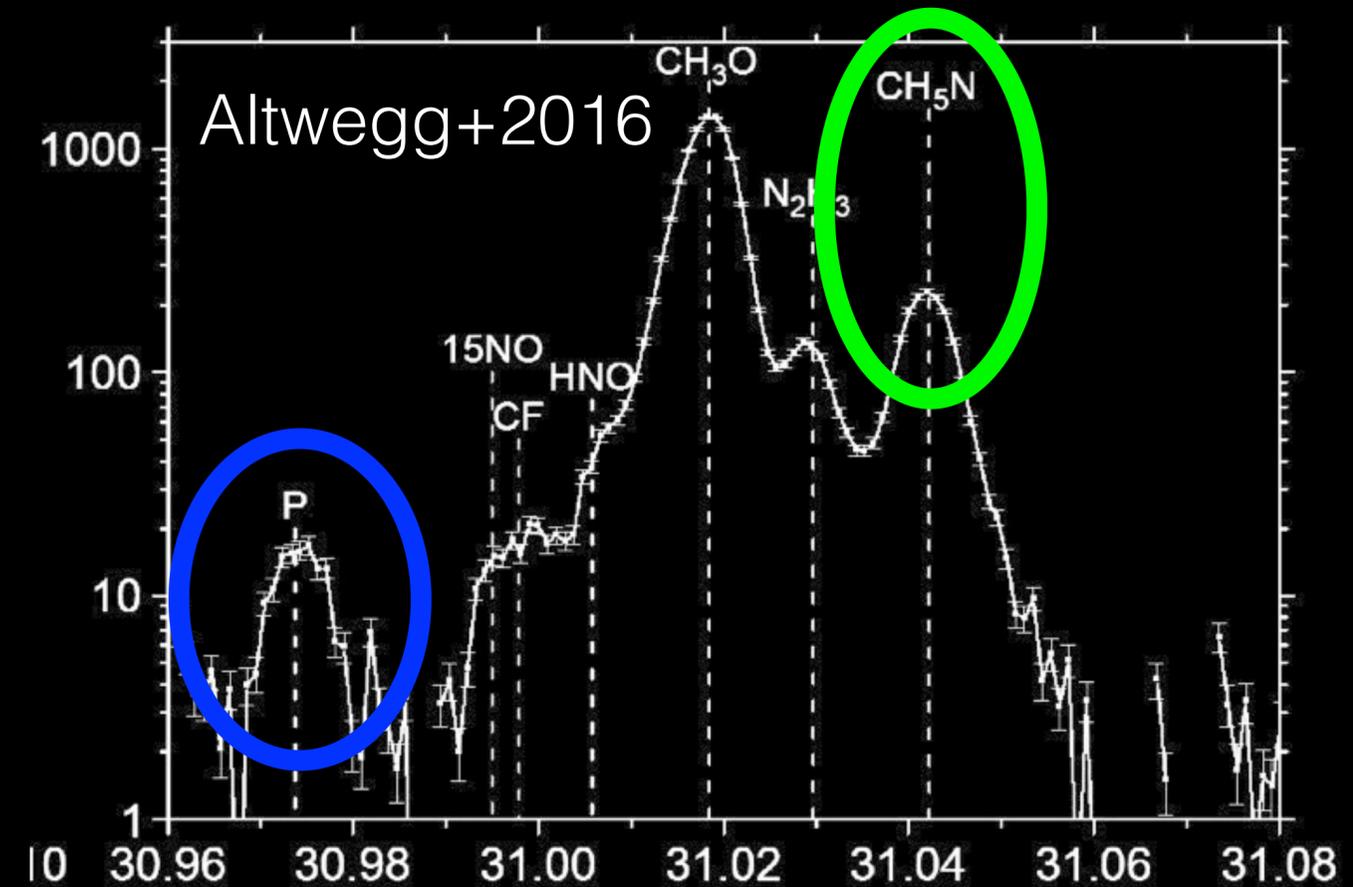


Rosetta: ambition-driven research

Volatile Methylamine ethylamine

Volatile Glycine

Volatile Phosphorus



Rosetta: ambition-driven research

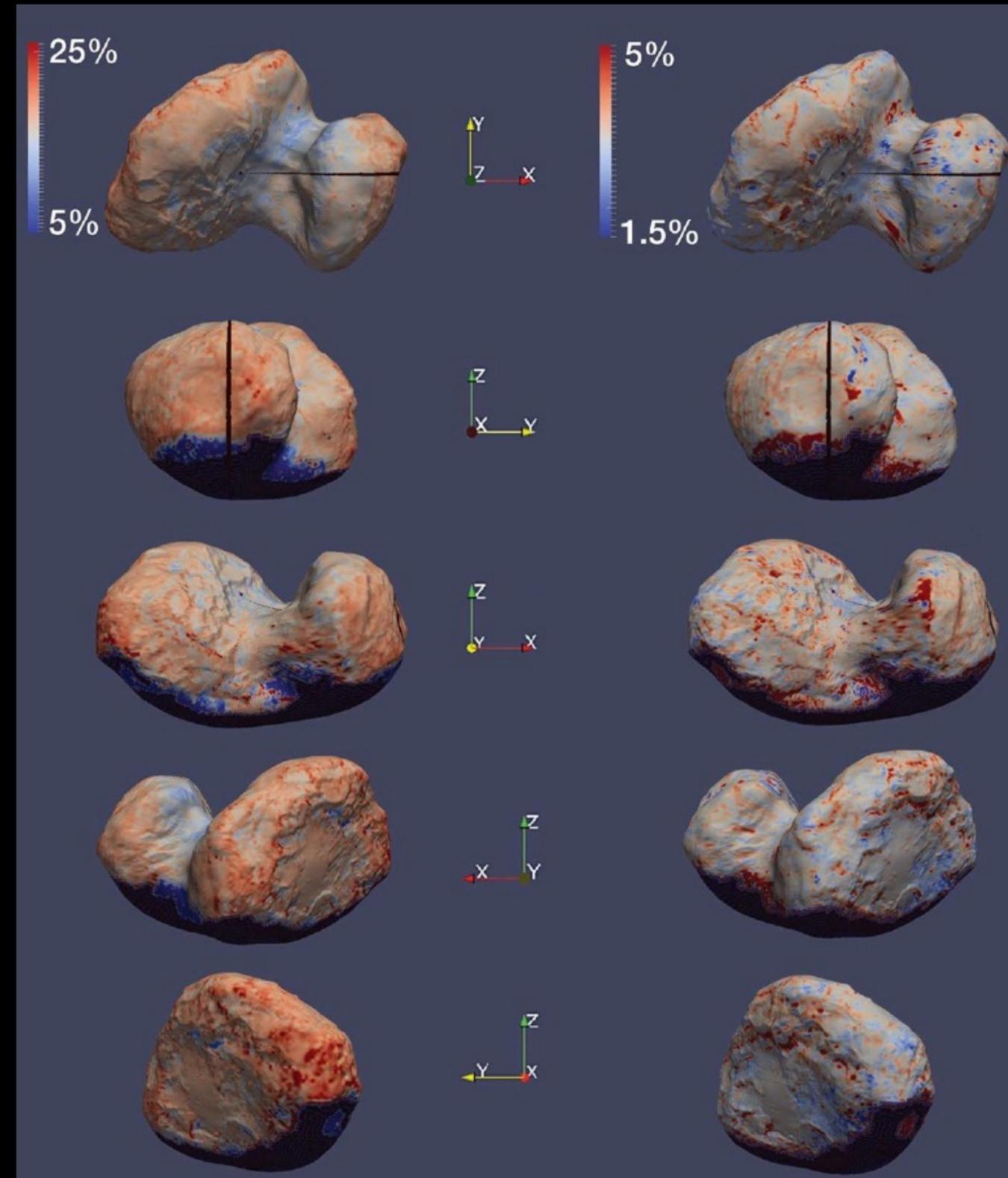
Capaccioni+2015

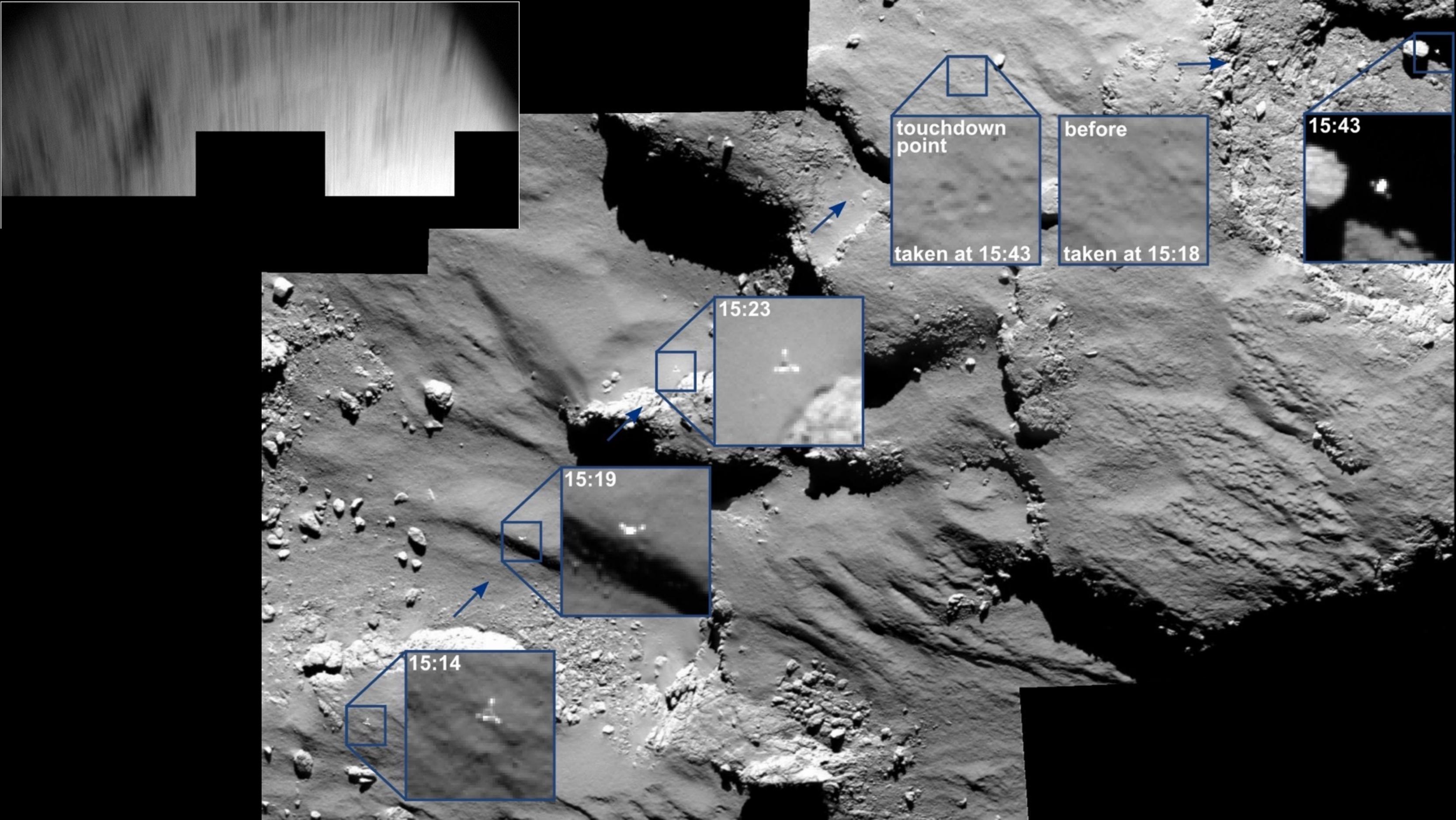
Volatile Methylamine ethylamine

Volatile Glycine

Volatile Phosphorus

Comet is completely covered by
organic macromolecules
base C-H, O-H





touchdown
point
taken at 15:43

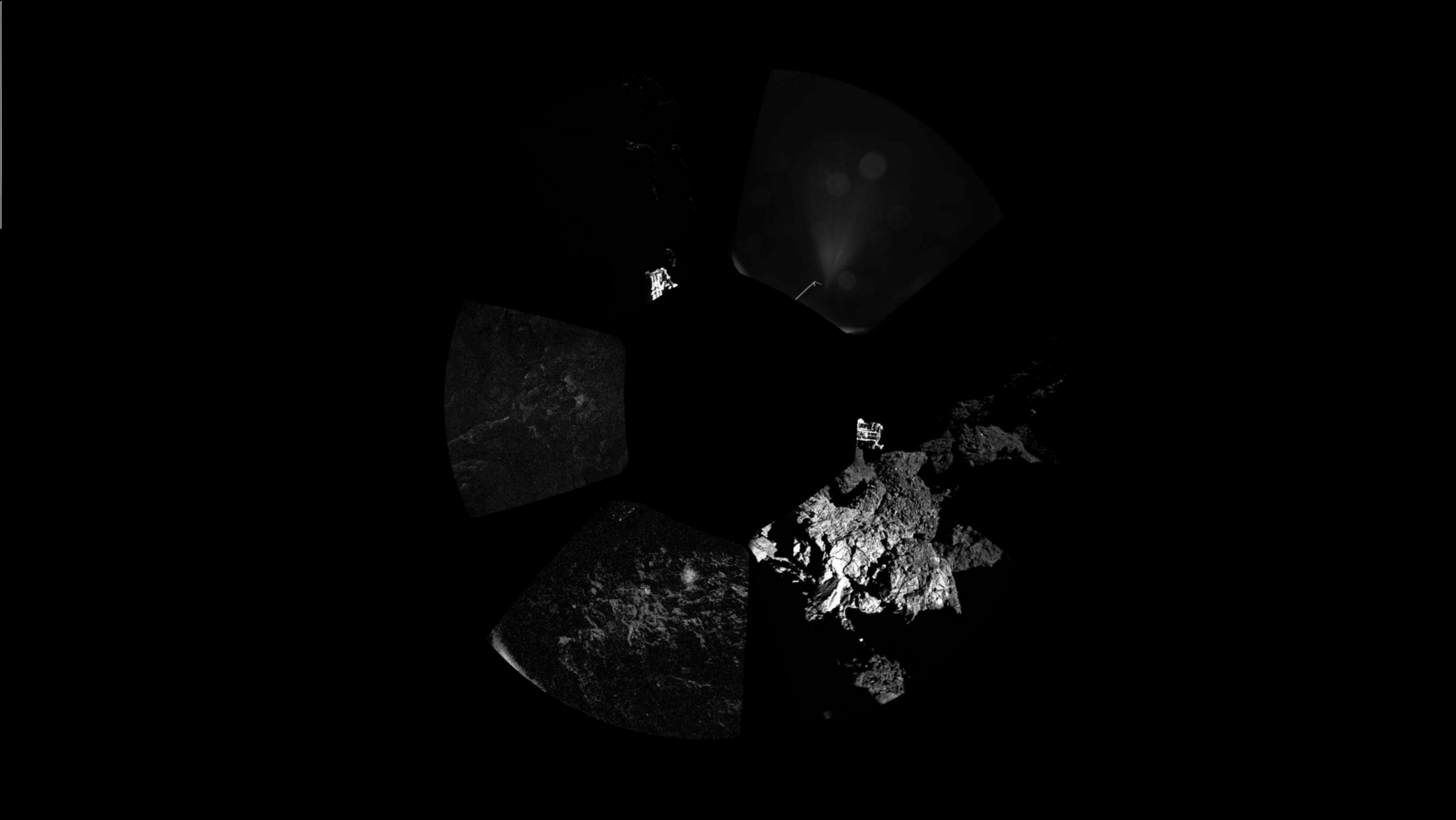
before
taken at 15:18

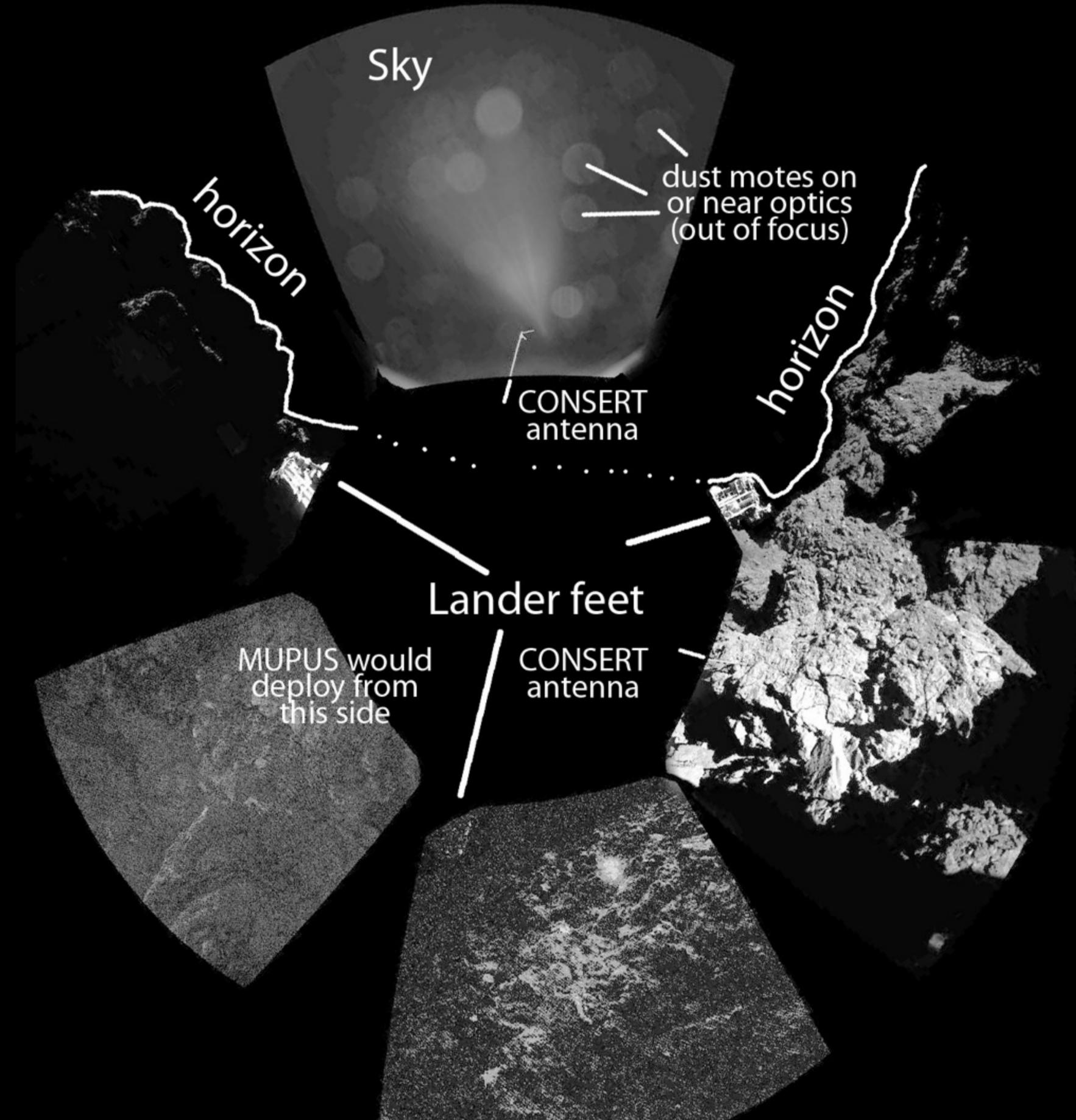
15:43

15:23

15:19

15:14





Sky

dust motes on
or near optics
(out of focus)

horizon

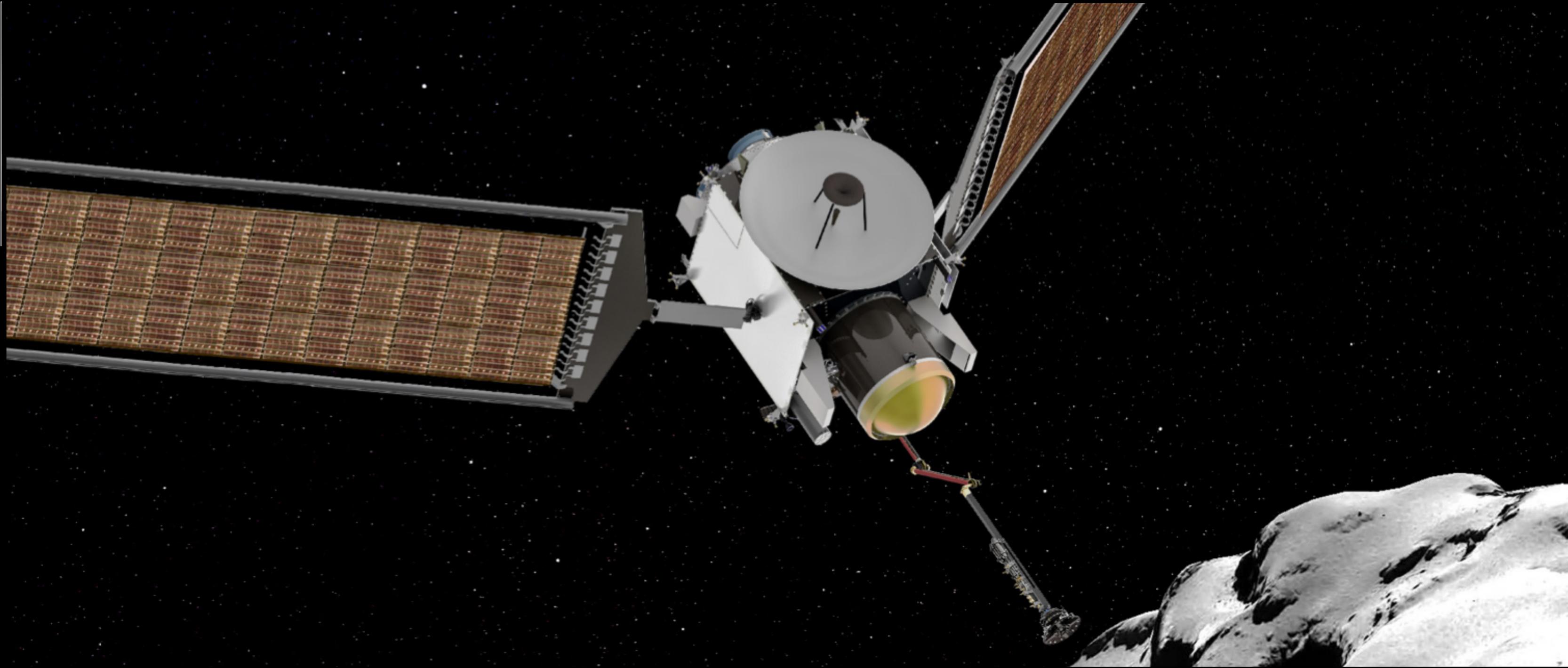
horizon

CONCERT
antenna

Lander feet

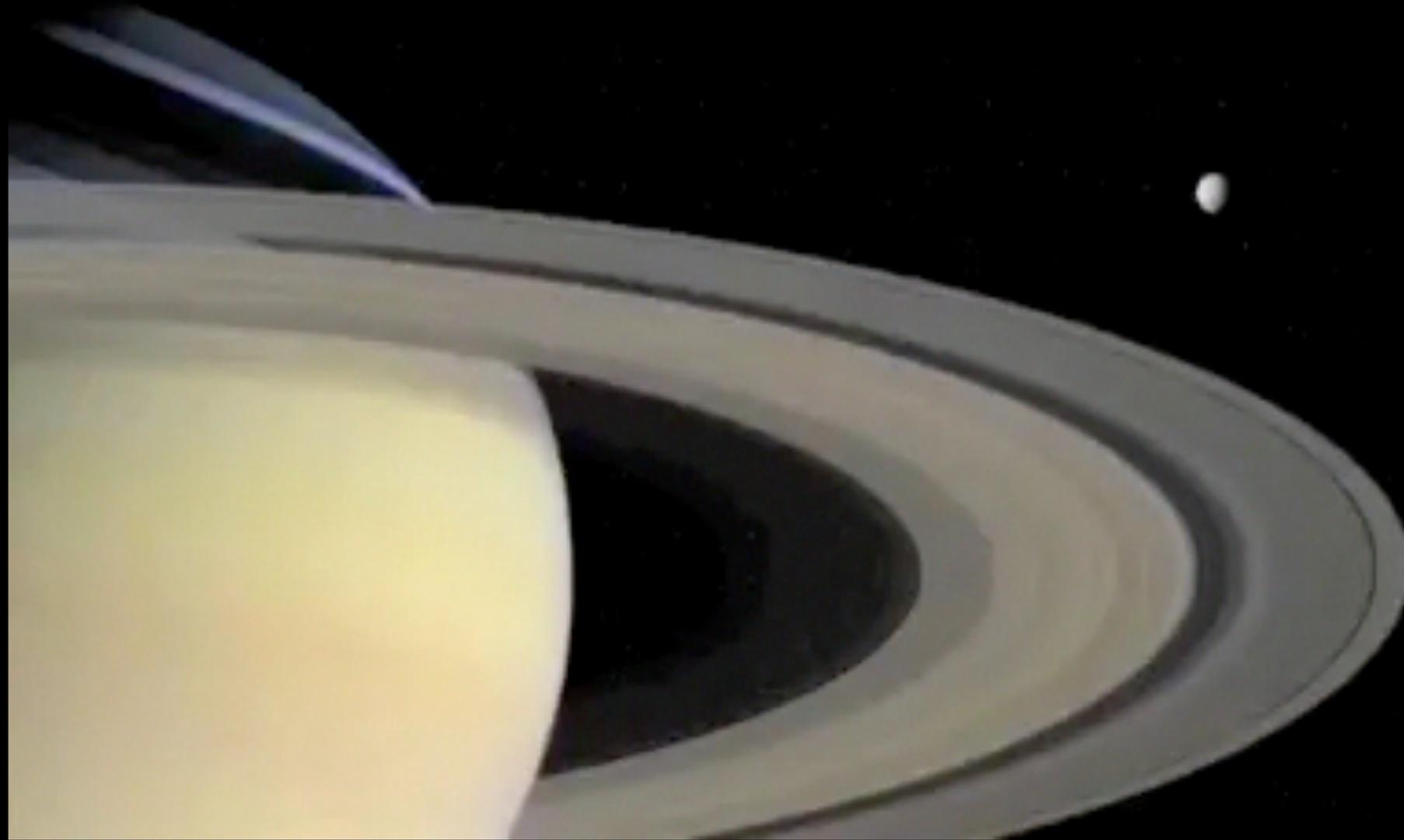
MUPUS would
deploy from
this side

CONCERT
antenna

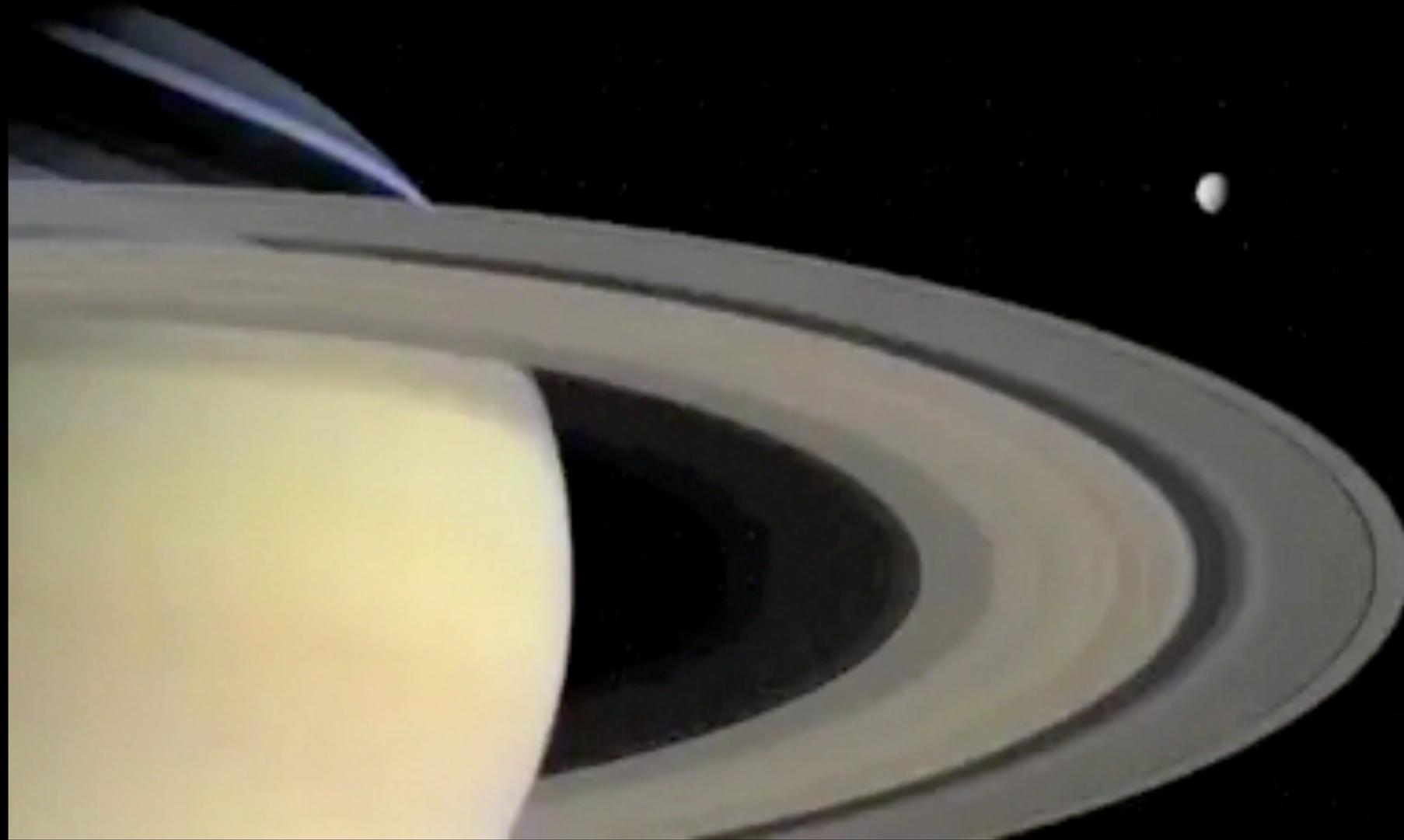


NASA CAESAR mission to Churyumov-Gerasimenko

Icy moons: Encelado



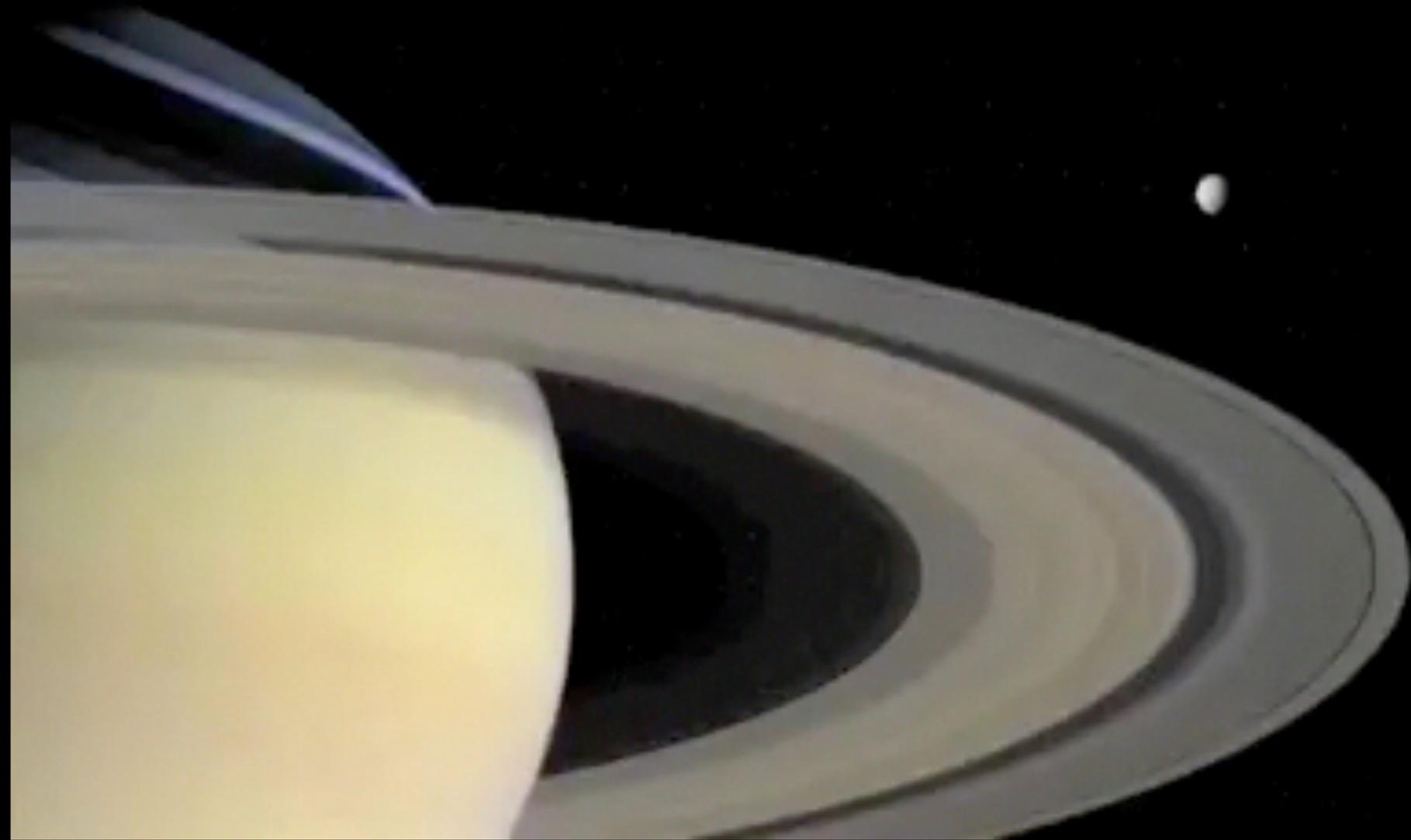
Icy moons: Encelado



Icy moons: Encelado

500km diameter

T ~ -200 C

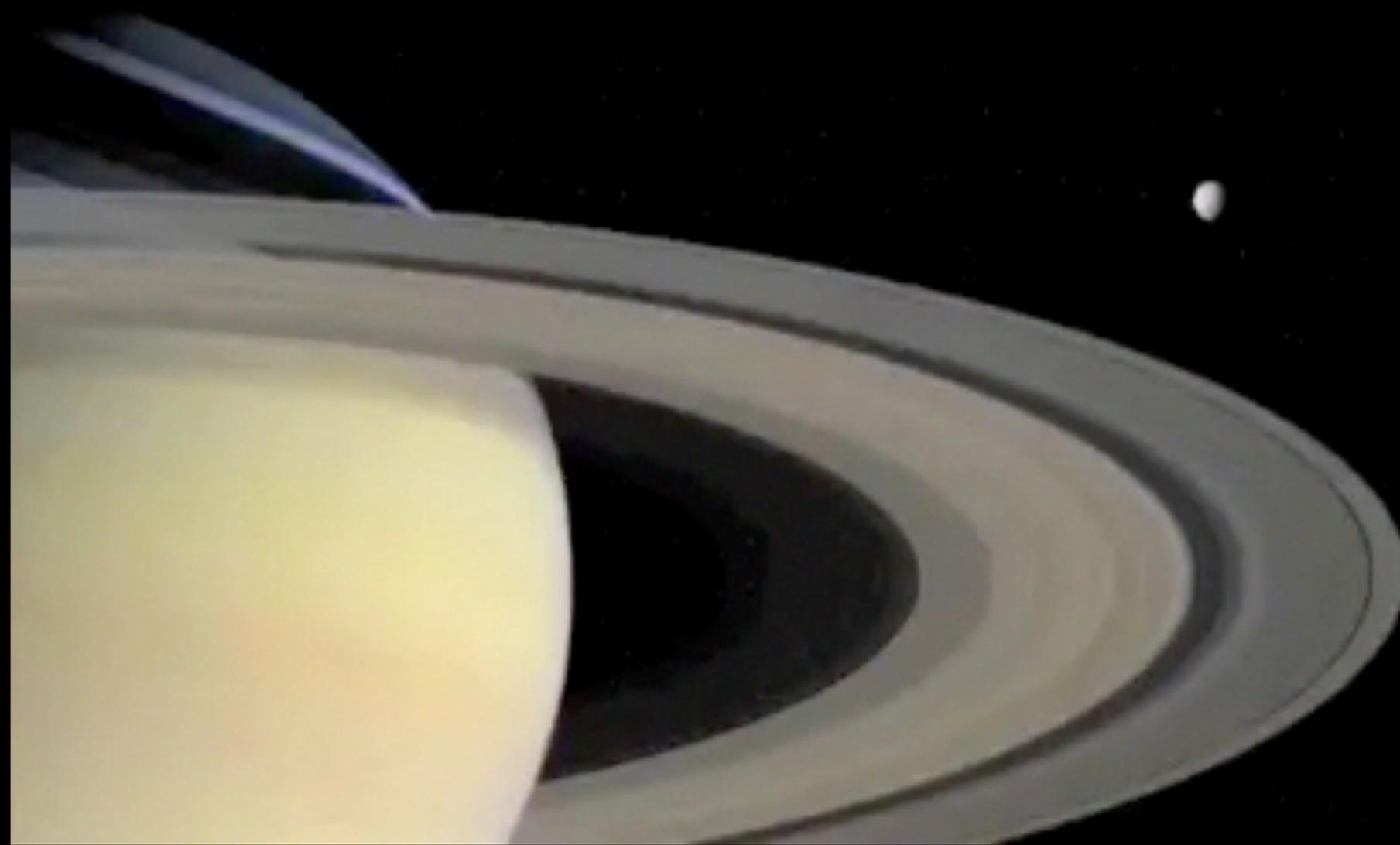


Icy moons: Encelado

500km diameter

T ~ -200 C

Spectacular
geysers at the
south pole!



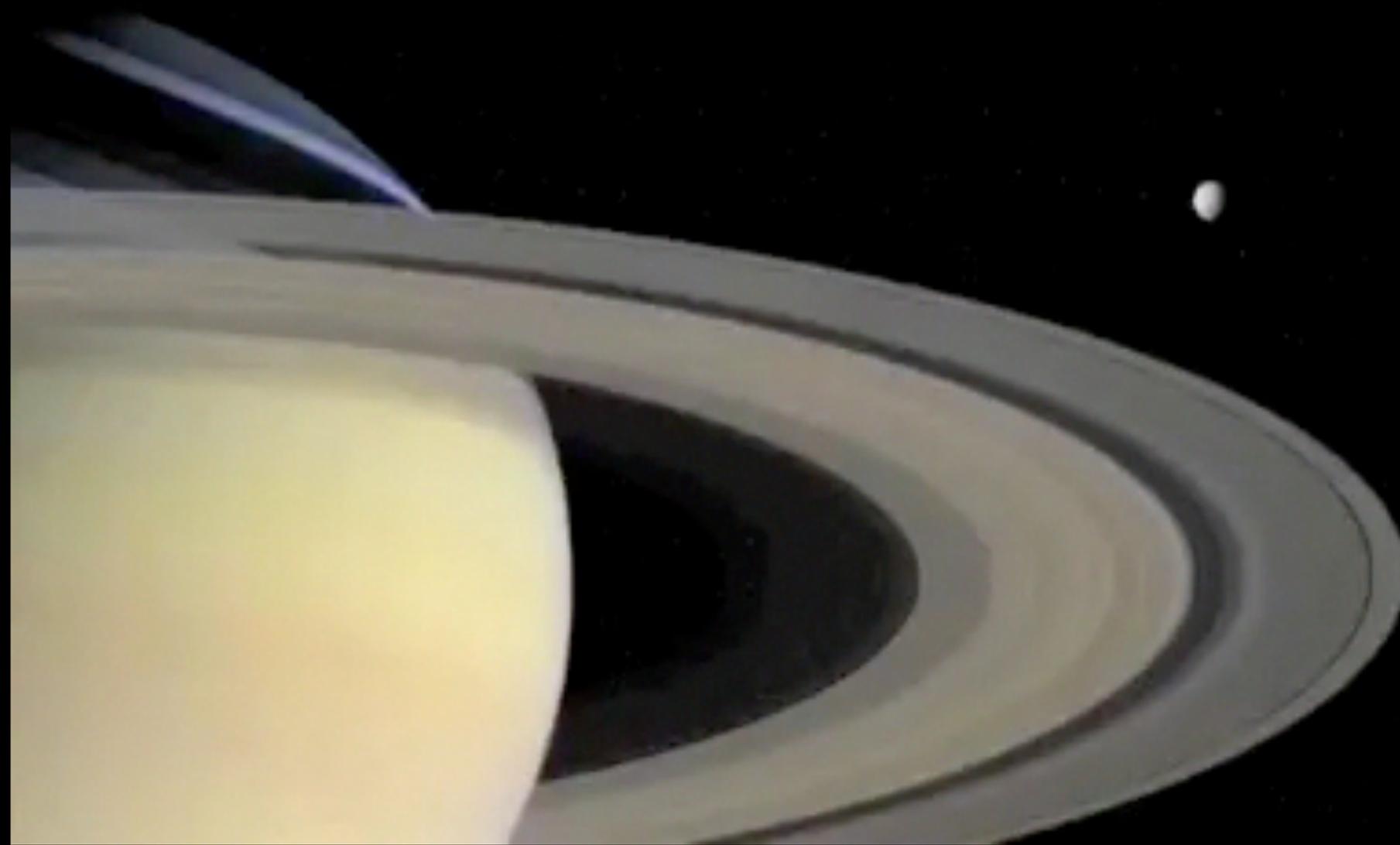
Icy moons: Encelado

500km diameter

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Spectacular
gaisers at the
south pole!

Sprays of ice
and water vapor
thousands of km
high.



Icy moons: Encelado

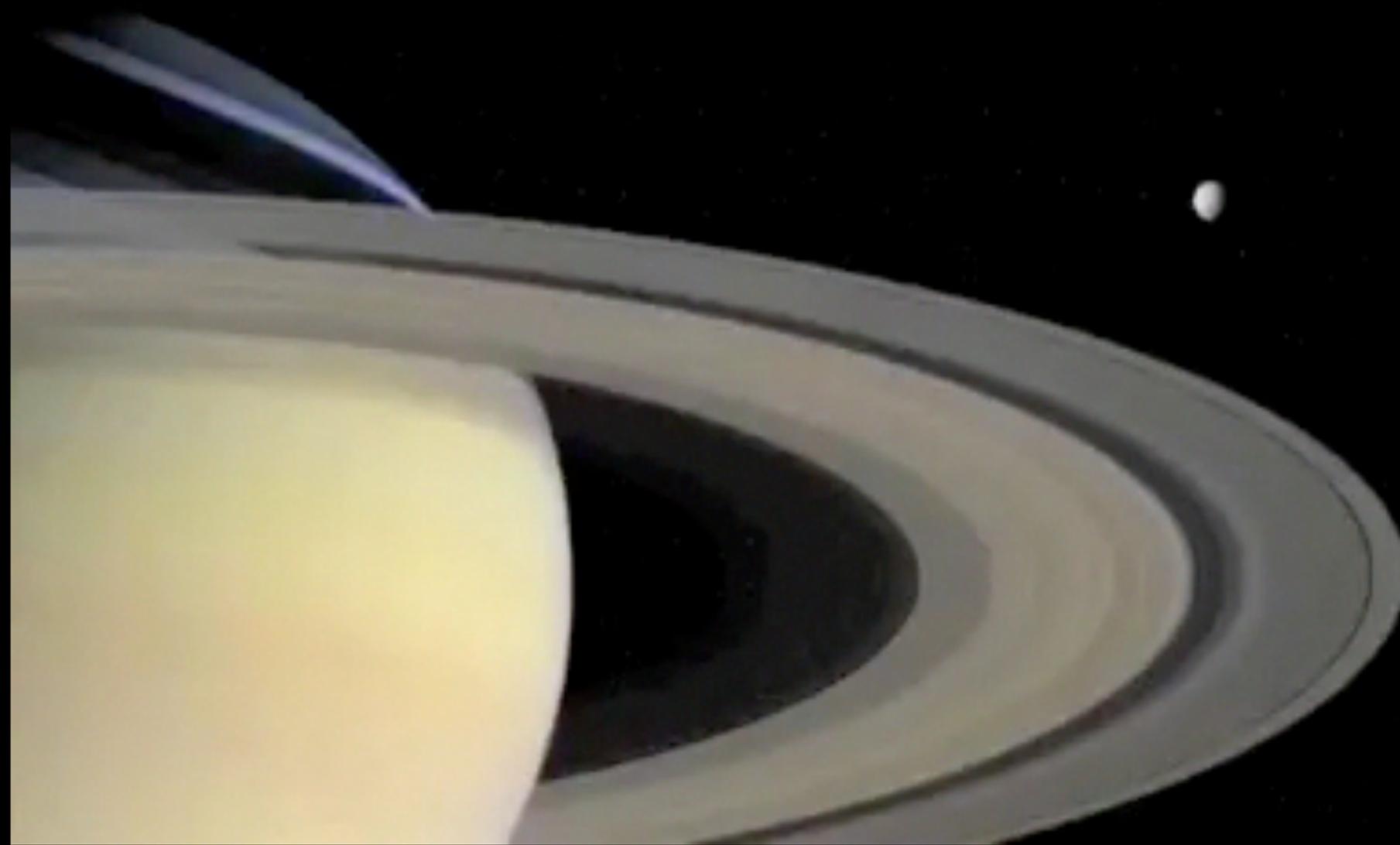
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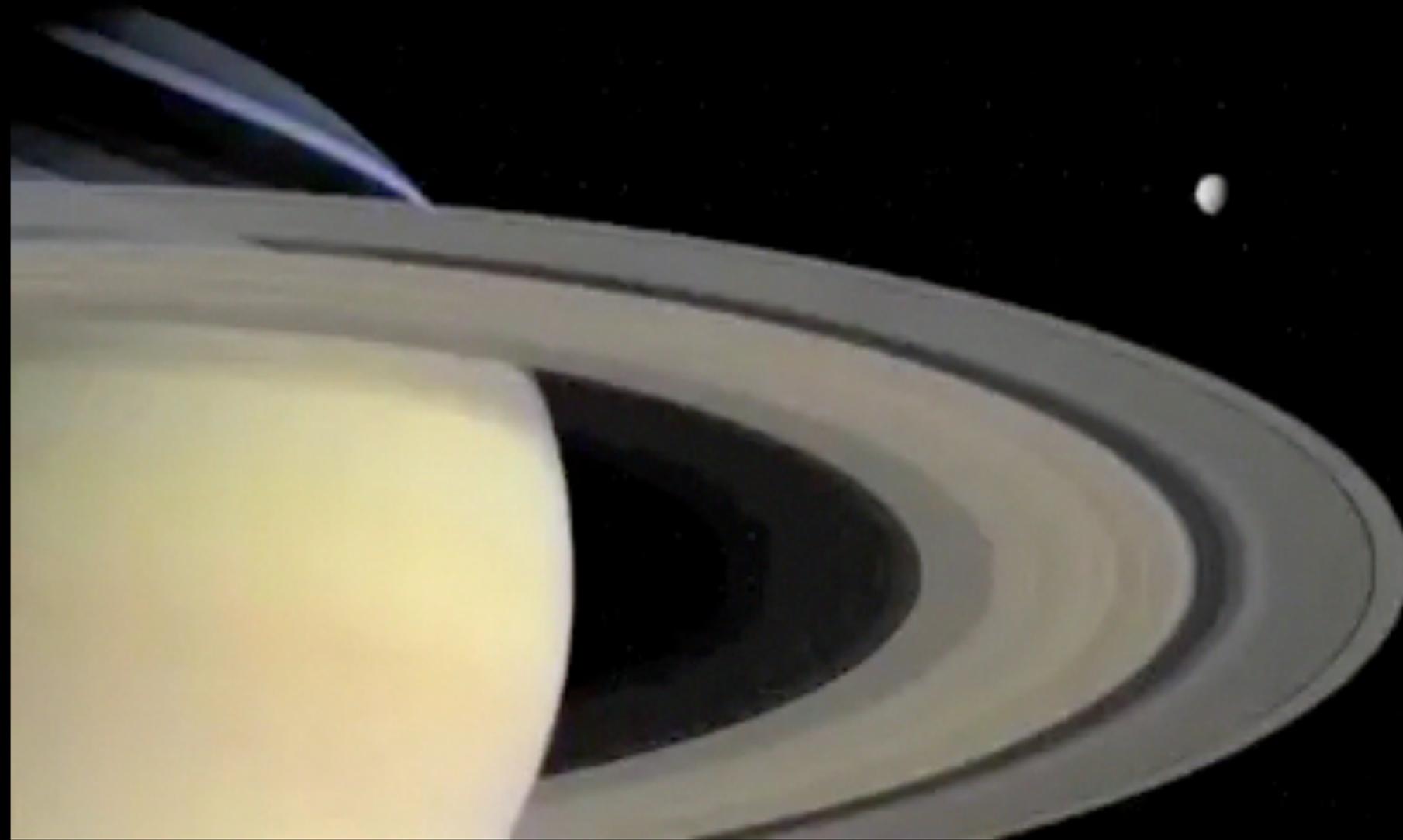
Sprays of ice
and water vapor
thousands of km
high.

Form Saturn
external rings



Icy moons: Encelado

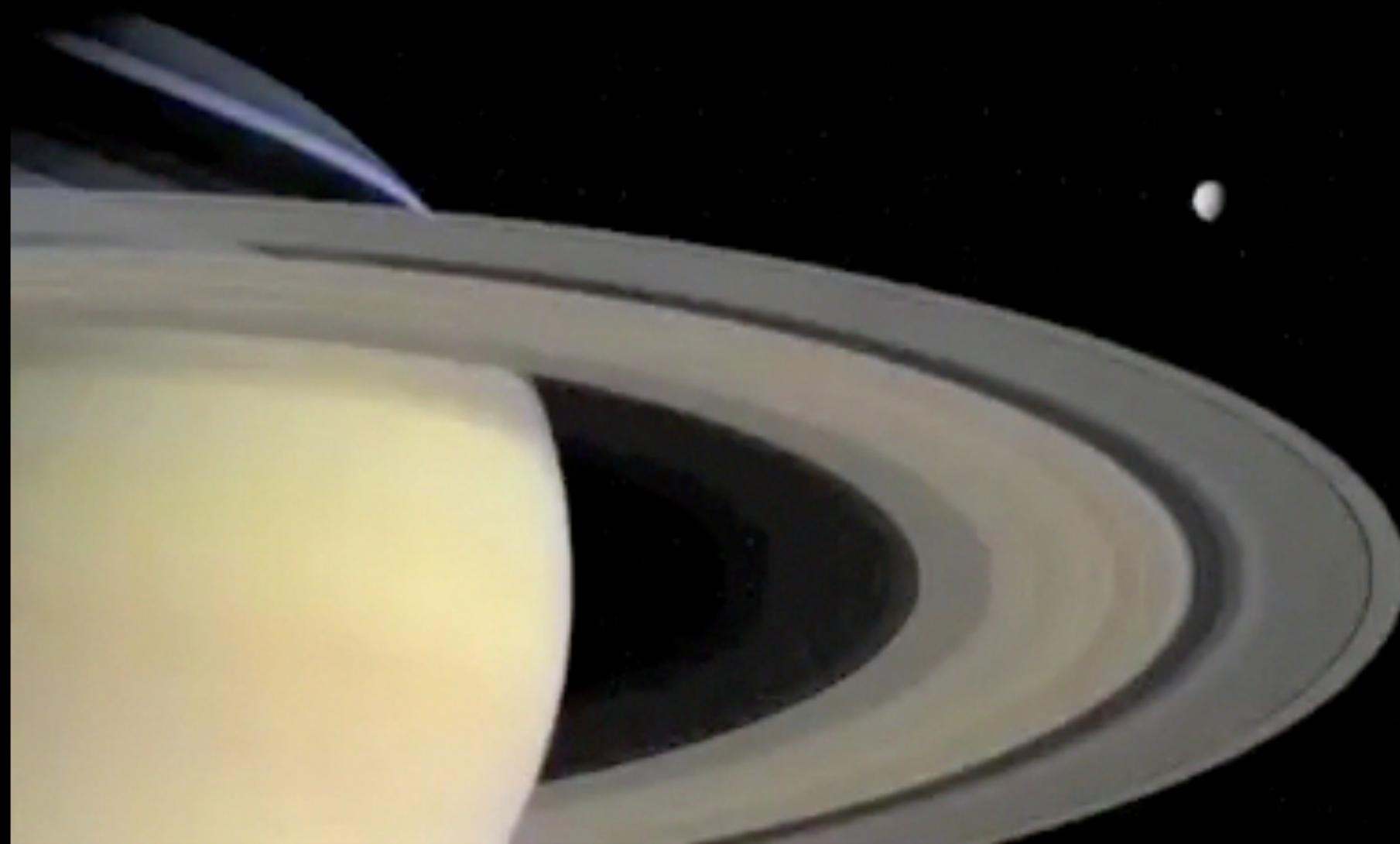
Young fractures.
High T near
fractures (-100 C).



Icy moons: Encelado

Young fractures.
High T near
fractures (-100 C).

Organic molecules

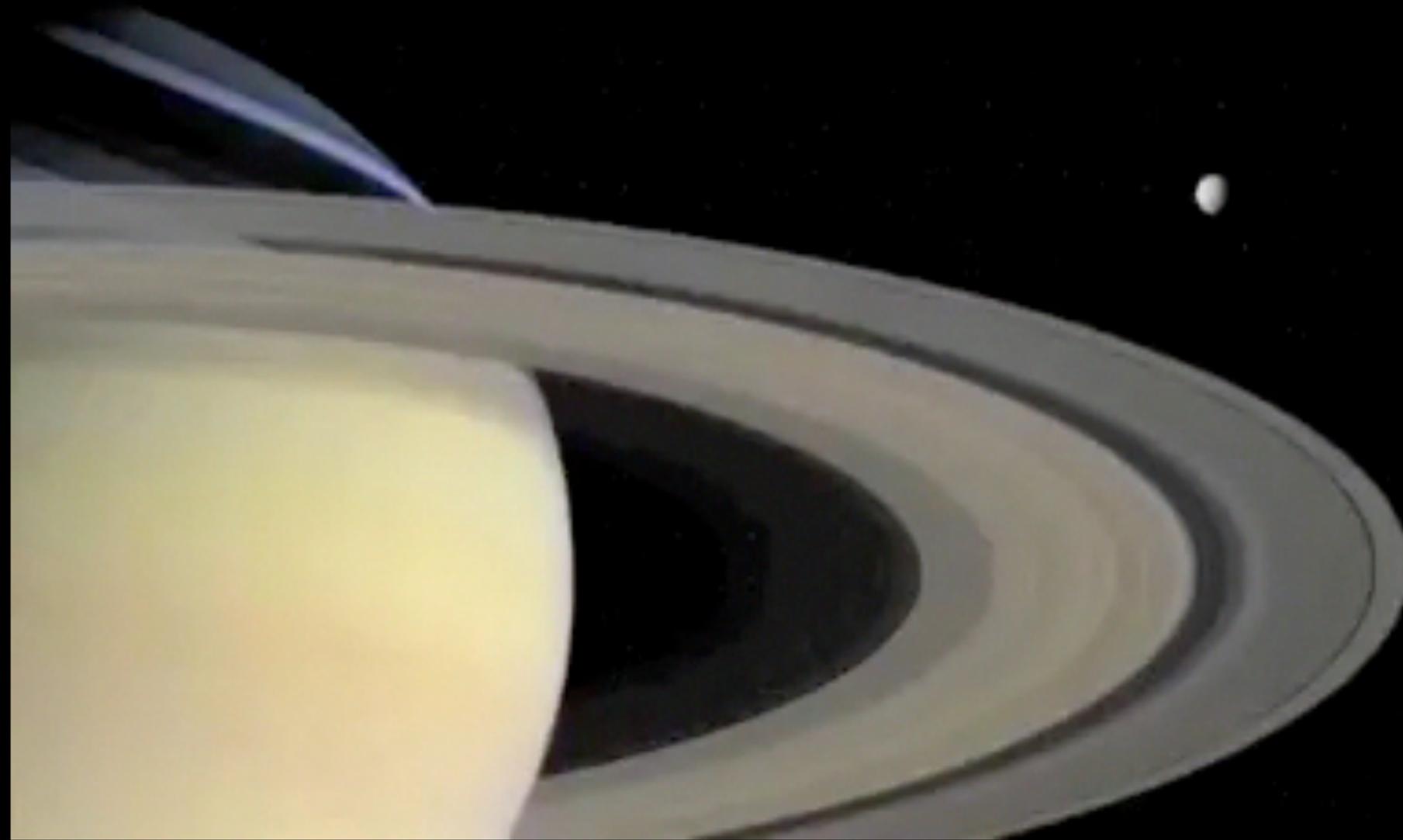


Icy moons: Encelado

Young fractures.
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Organic molecules

H₂



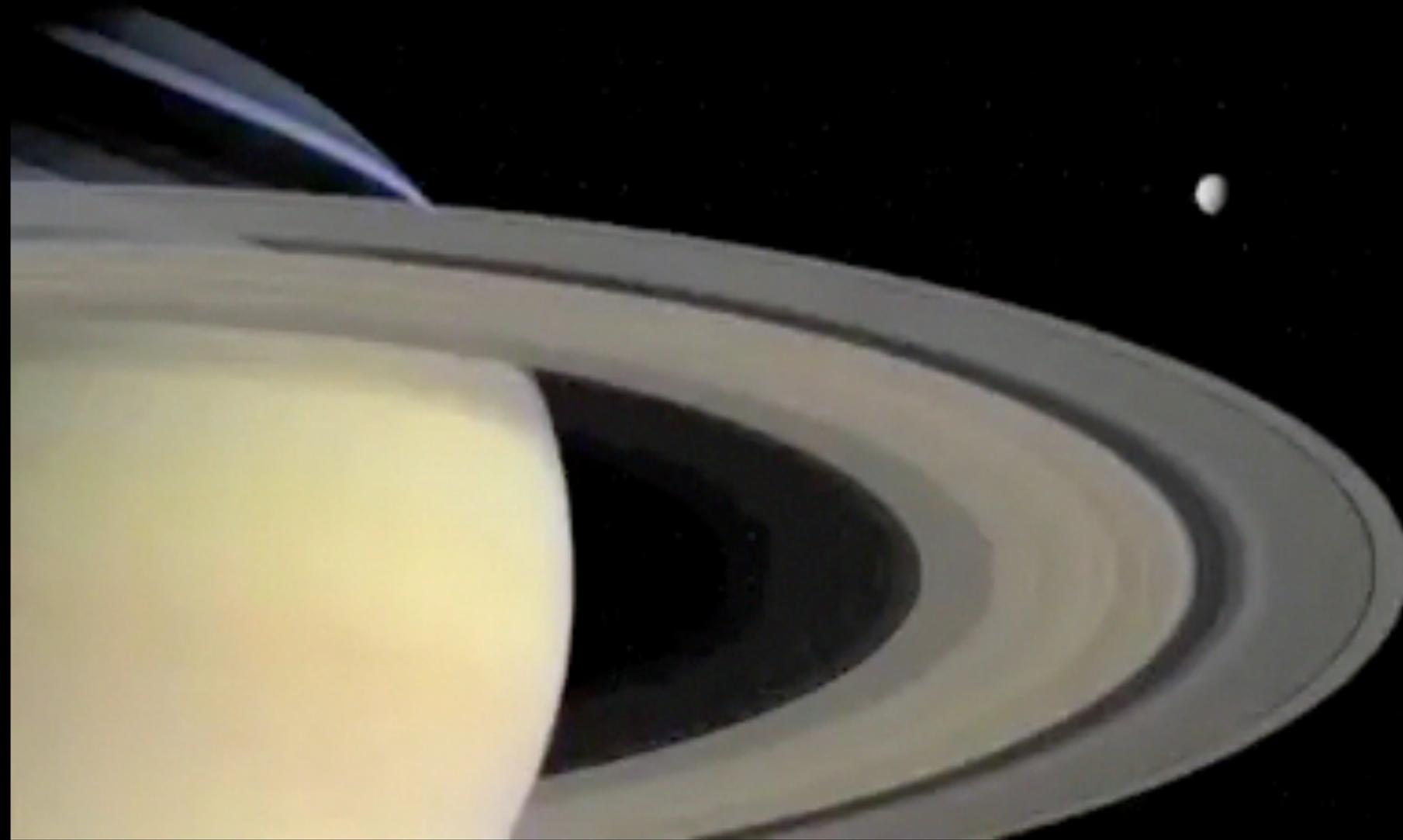
Icy moons: Encelado

Young fractures.
High T near
fractures (-100 C).

Organic molecules

H₂

Prebiotic conditions



Icy moons: Encelado

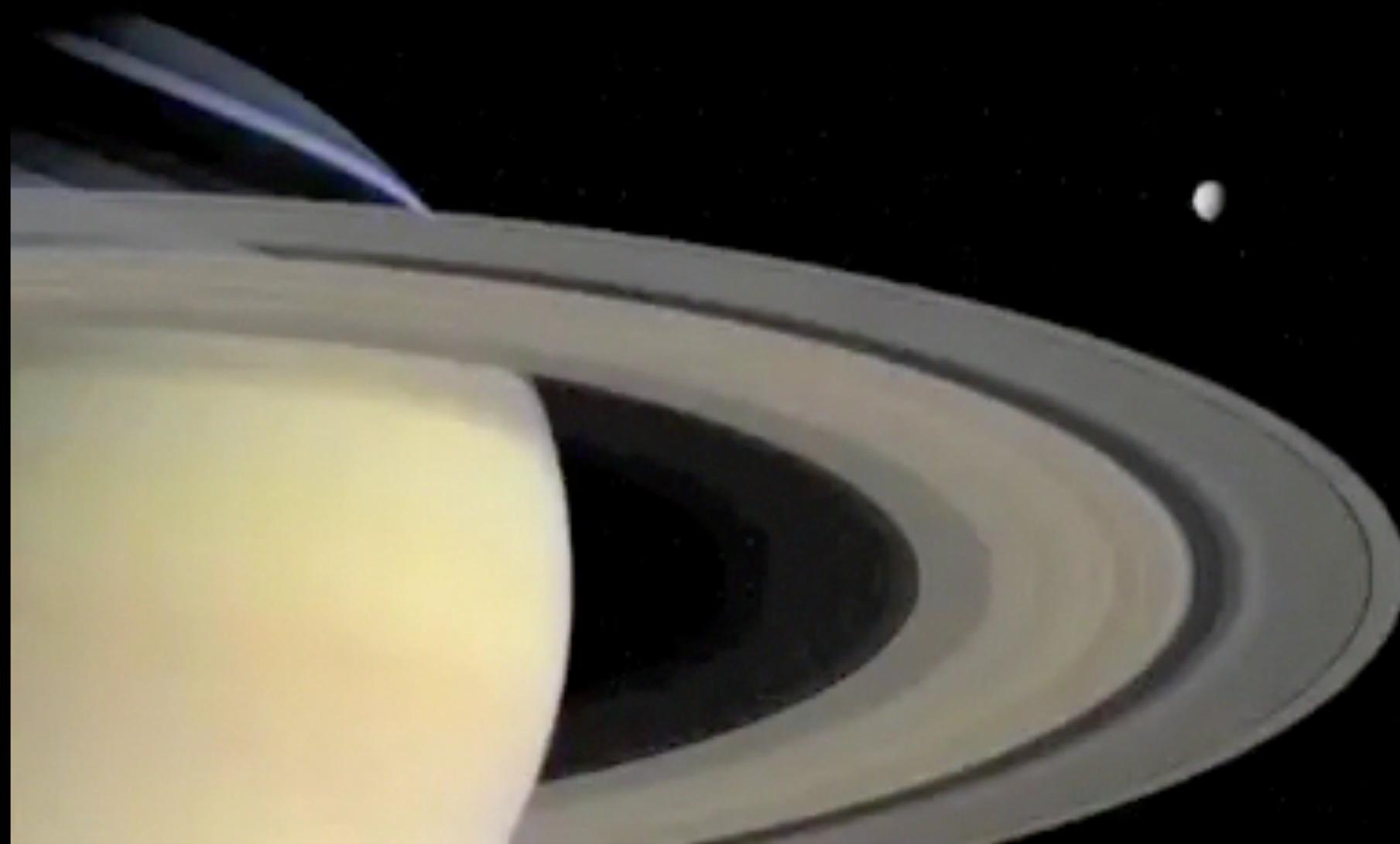
Young fractures.
High T near
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Organic molecules

H₂

Prebiotic conditions

Global oceans
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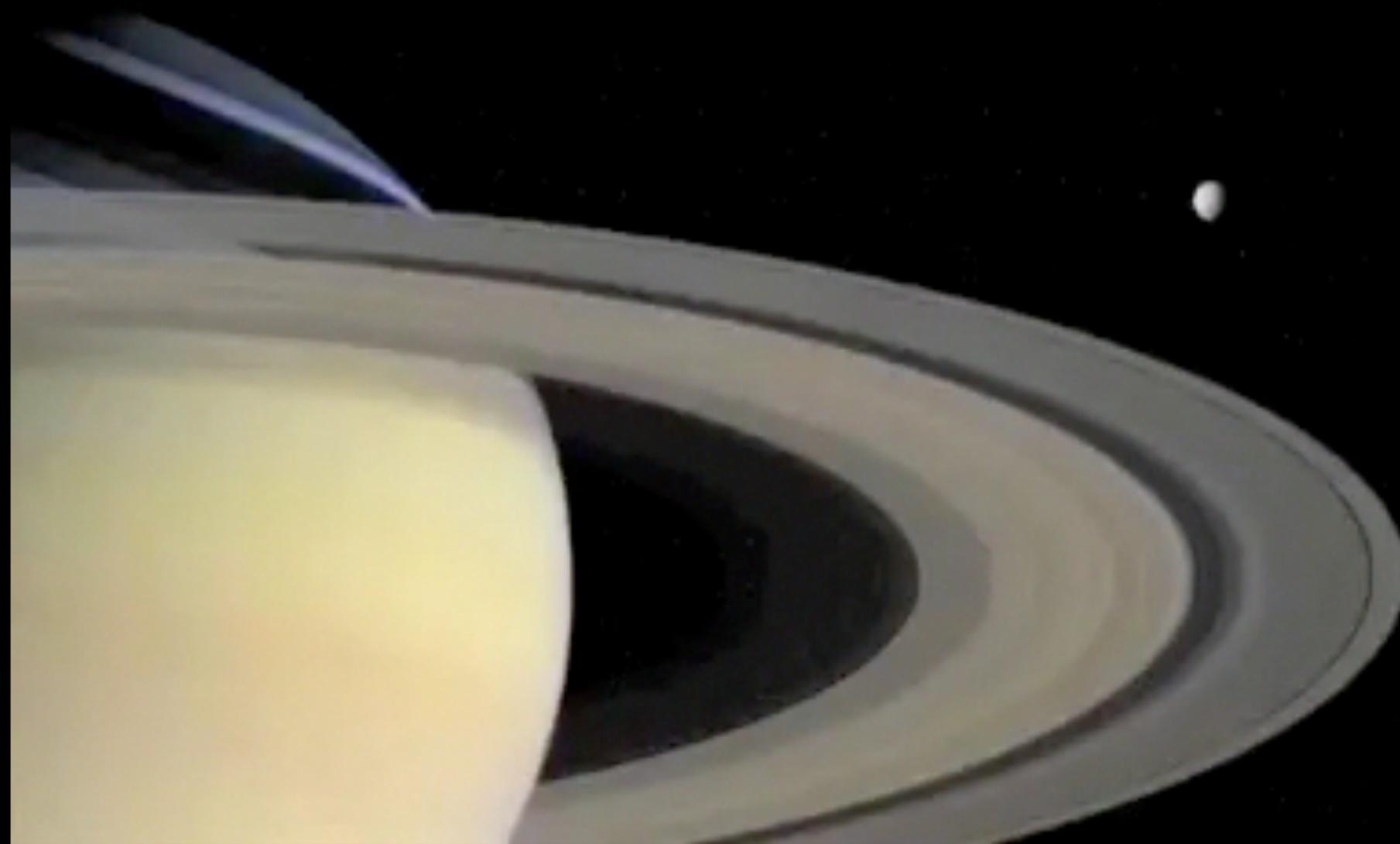
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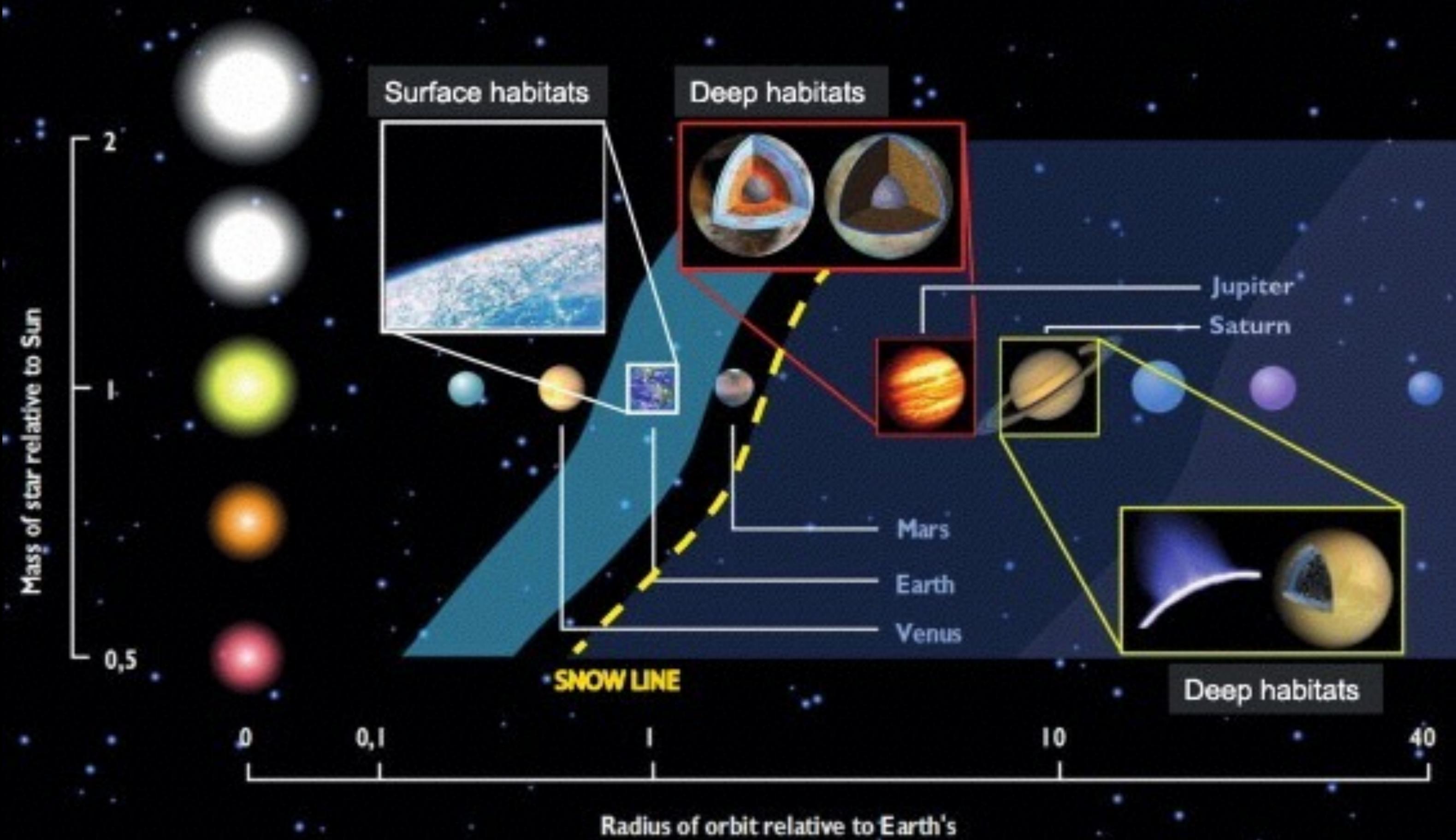
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Prebiotic conditions

Global oceans
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Heating caused by
tidal forces

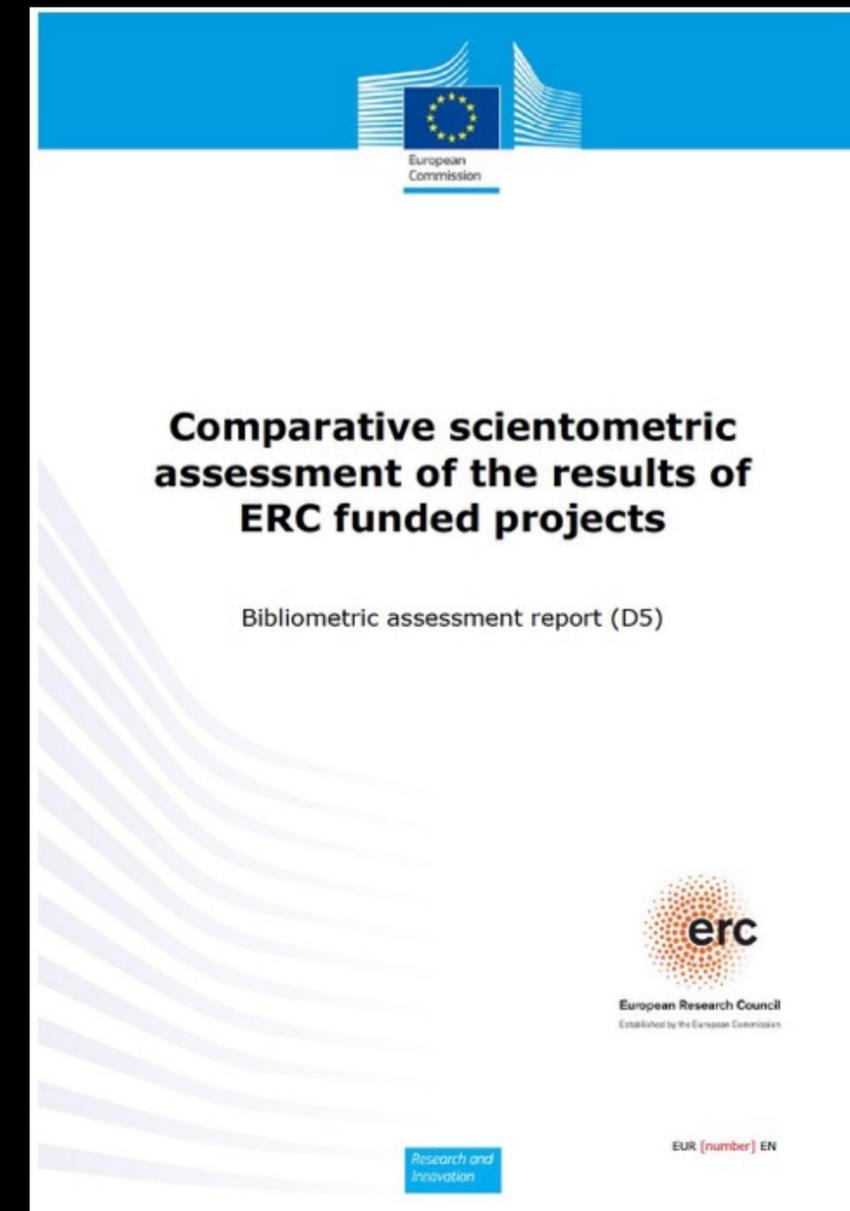




A new driving force for research:
competition

Competition-driven science

The balance between science driven by competition and science driven by curiosity / ambition has changed in the last 30 years, in favor of the former. Example: the ERC system, 13.1 BEuro 2014-2020

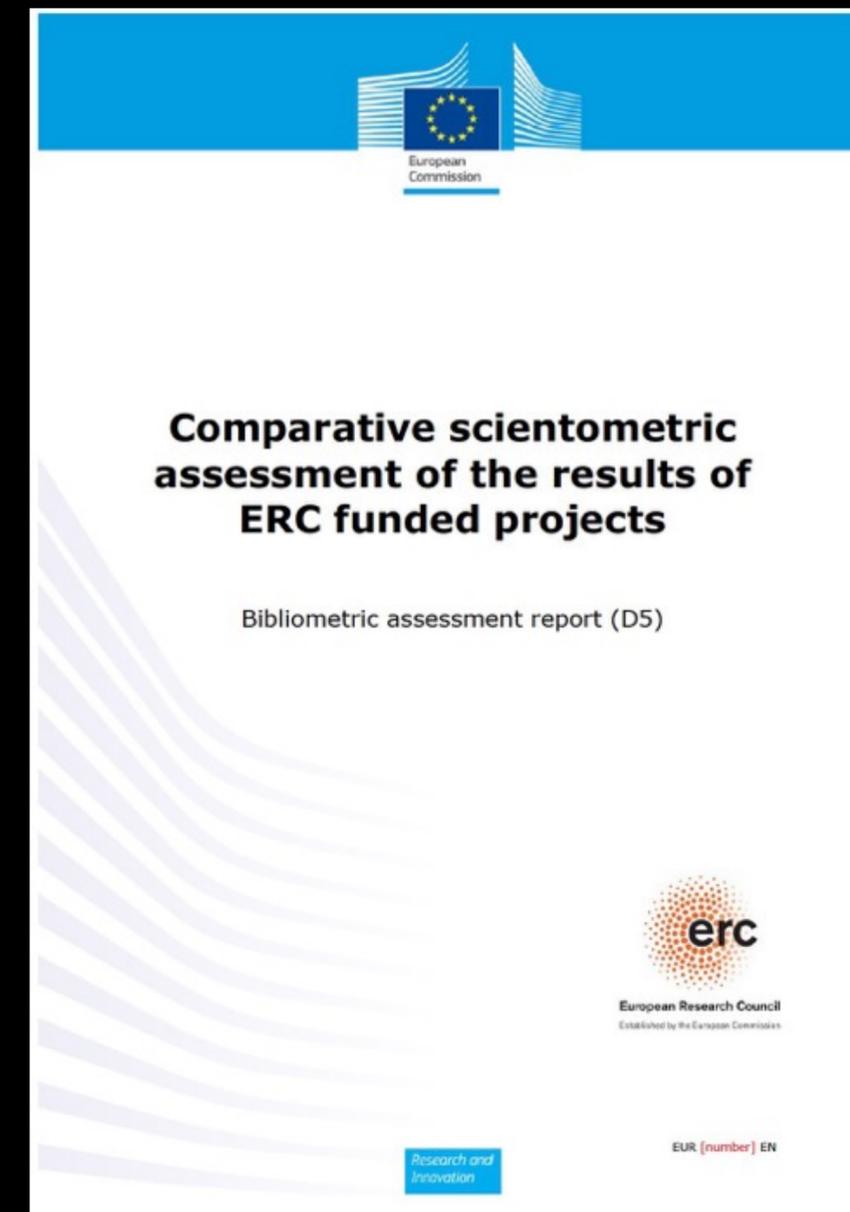


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Extremely competitive: 1 proposal out of 10 financed

How many breakthroughs and how much advancement of science does it produce?



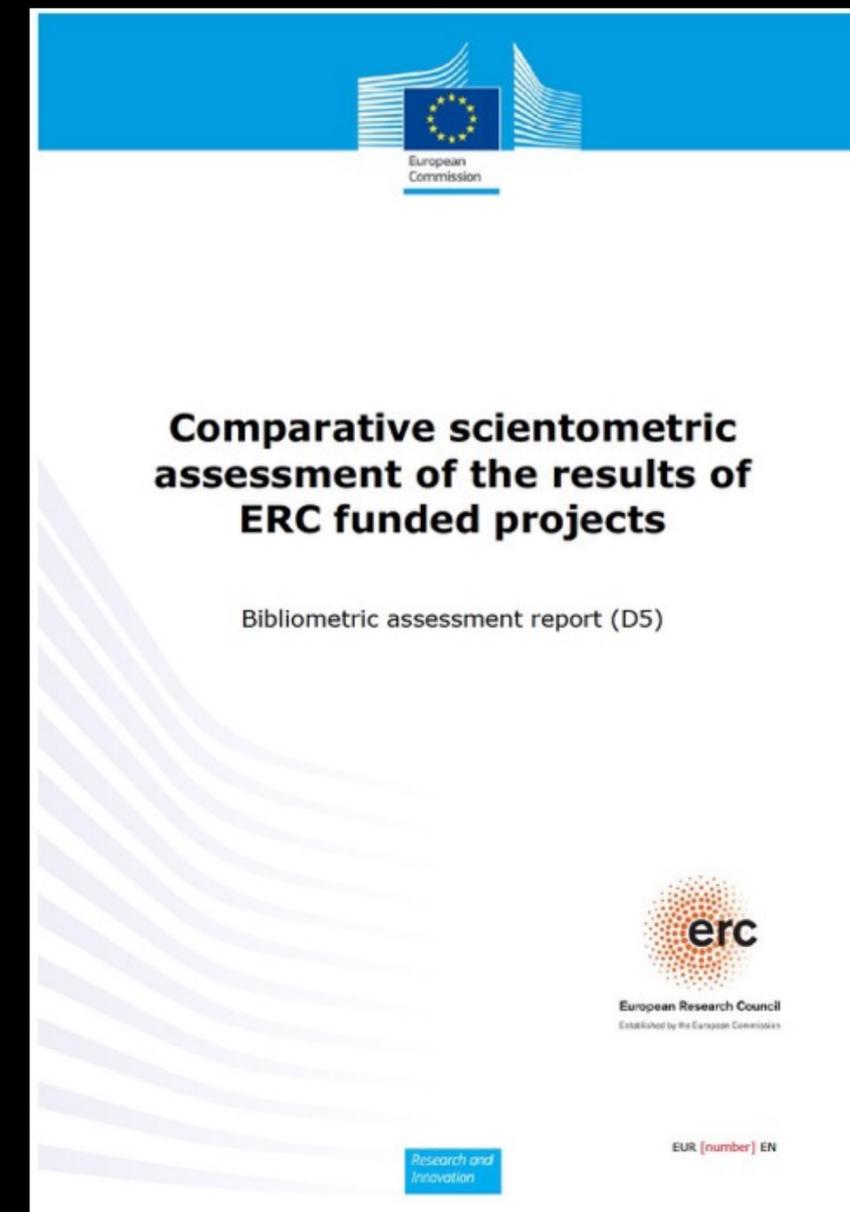
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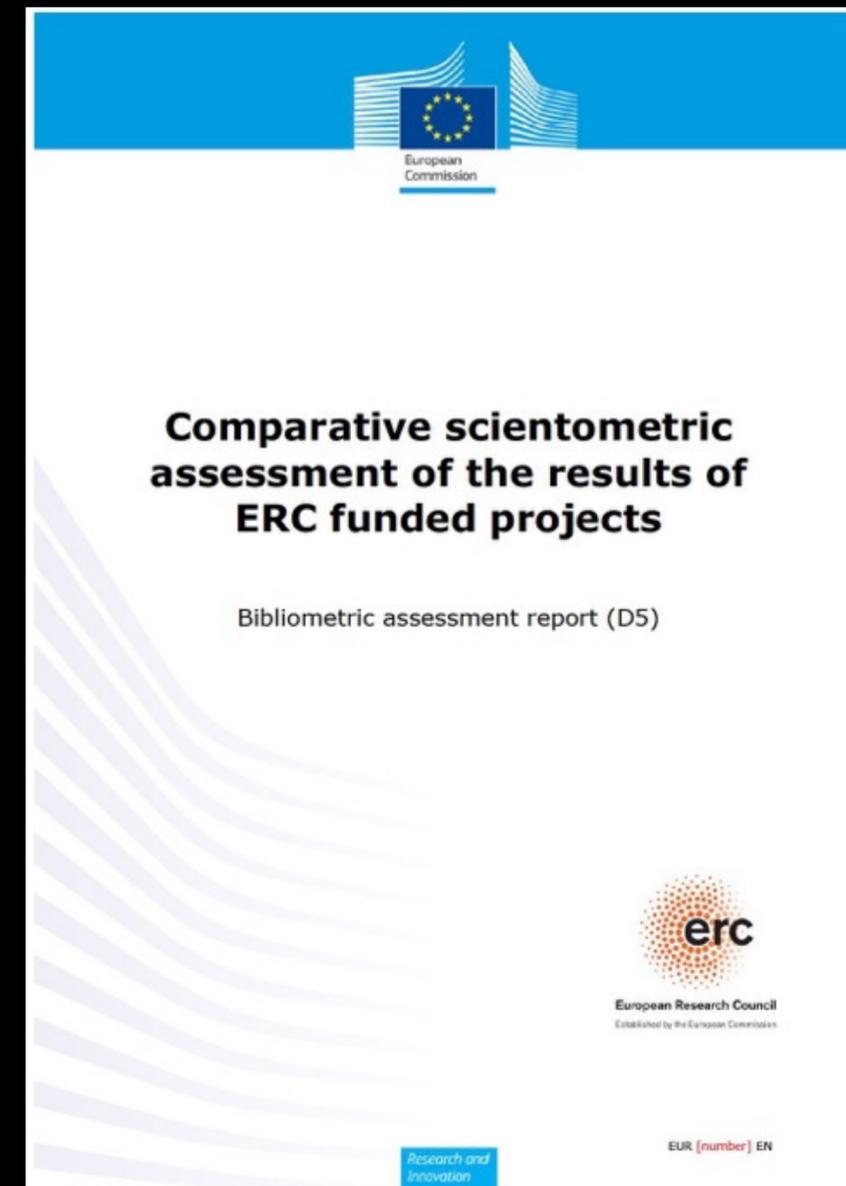
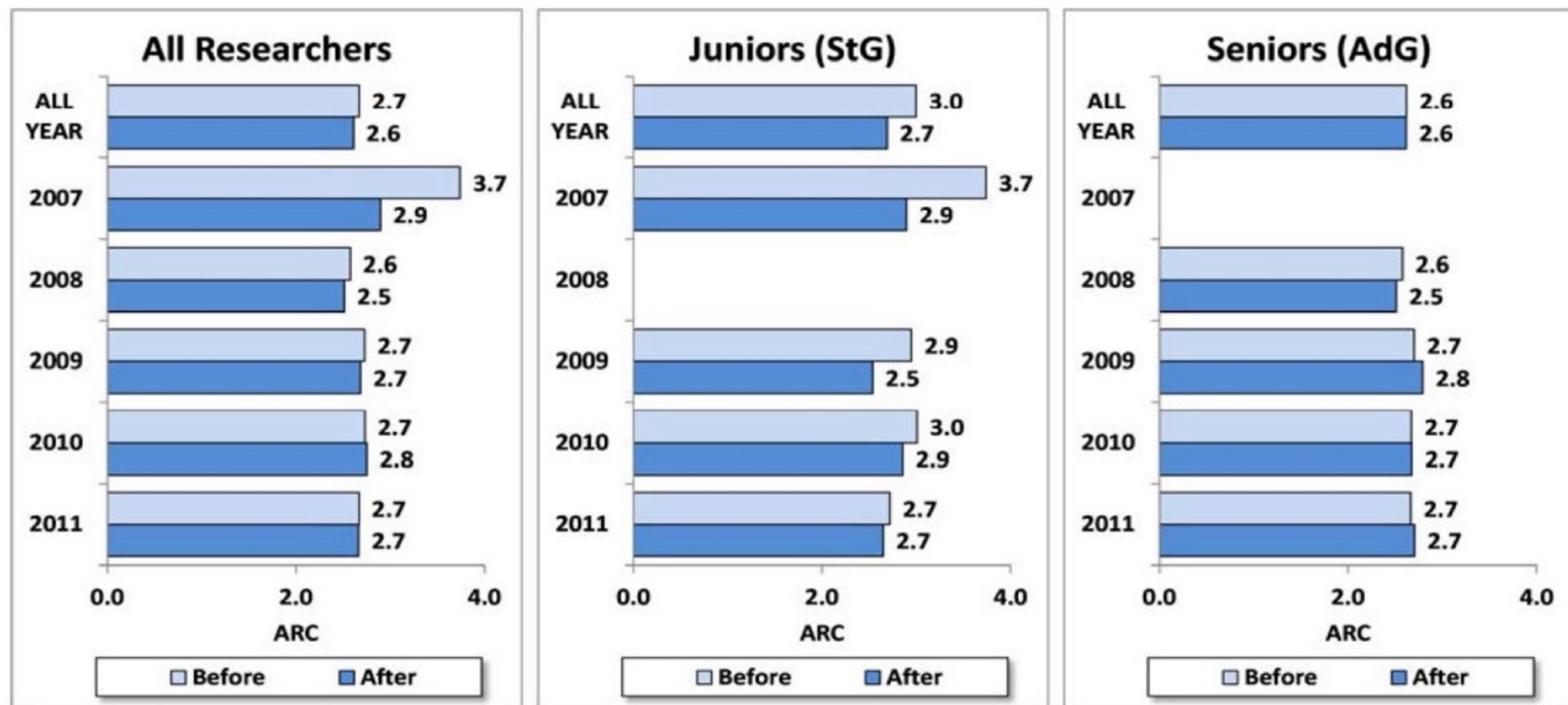
- Does productivity increase with funding?
- Are the winners really the most competitive researchers?



Competition-driven science

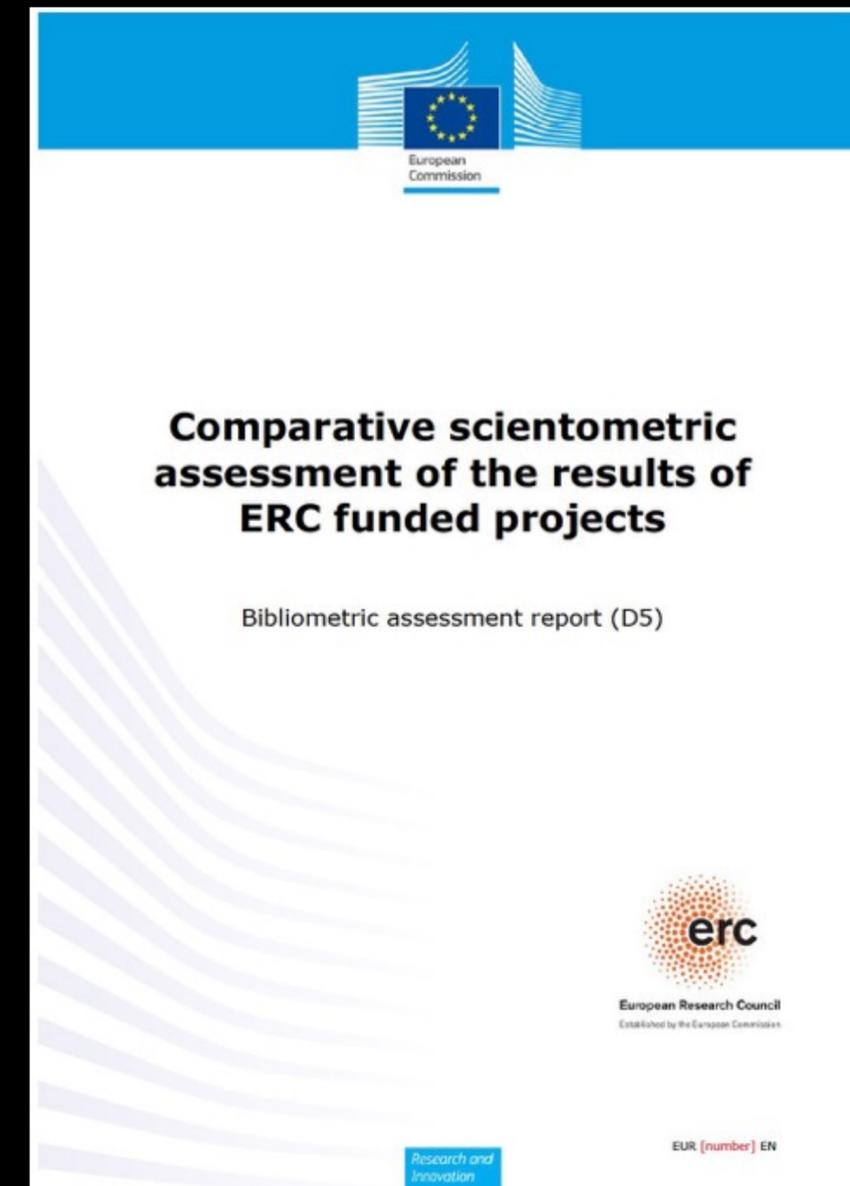
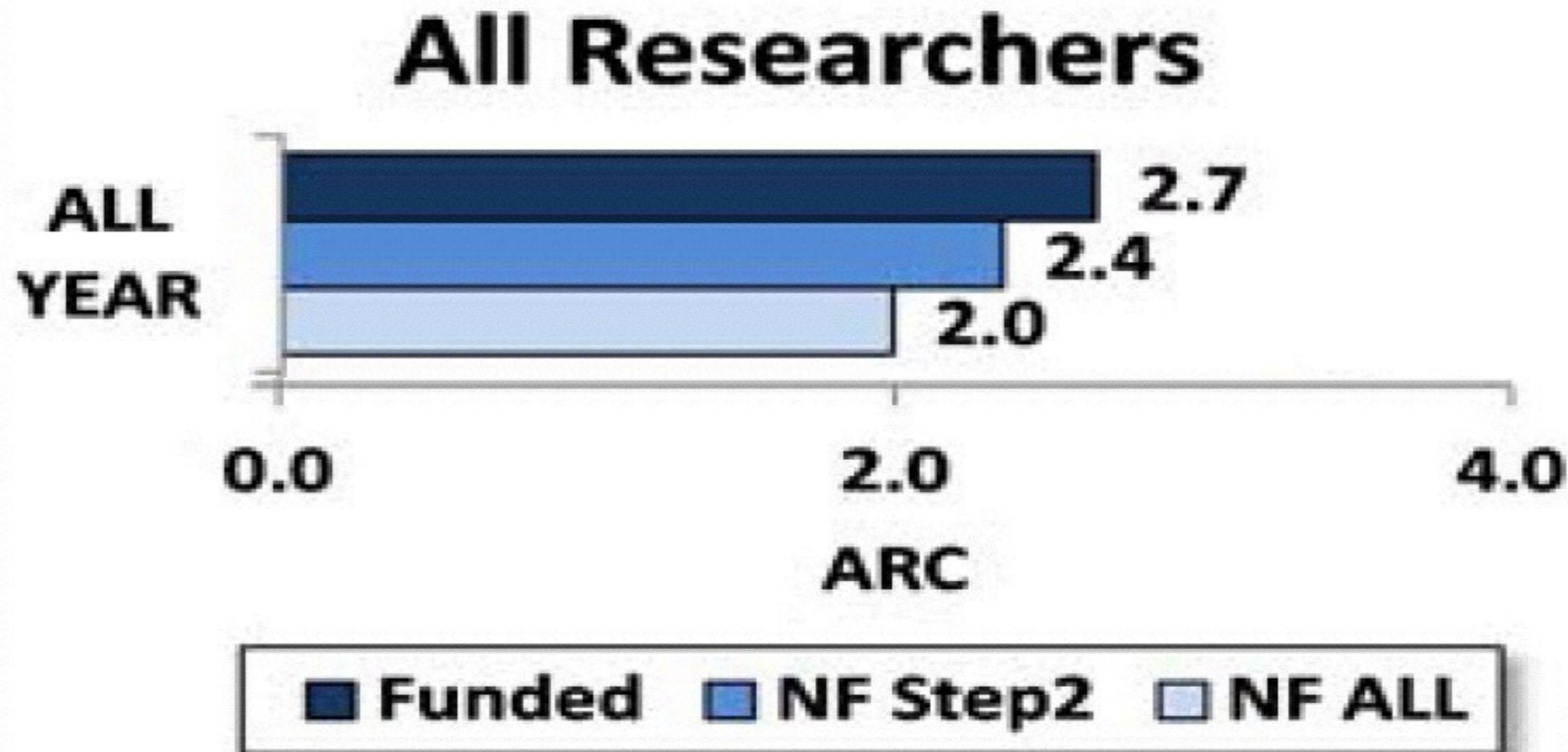
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Figure 3-19. Average of Relative Citations (ARC) of ERC Funded Researcher Before and After the Grant Start Year by Seniority and Competition Year



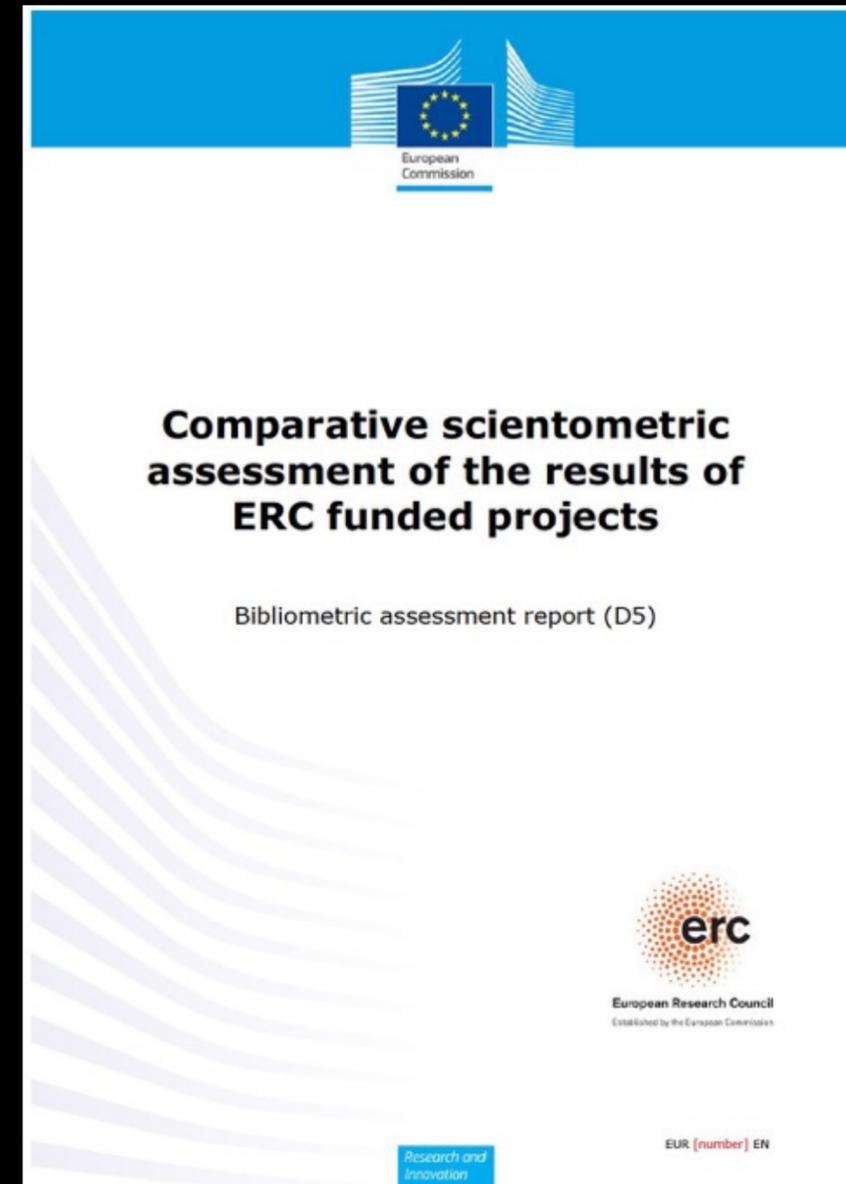
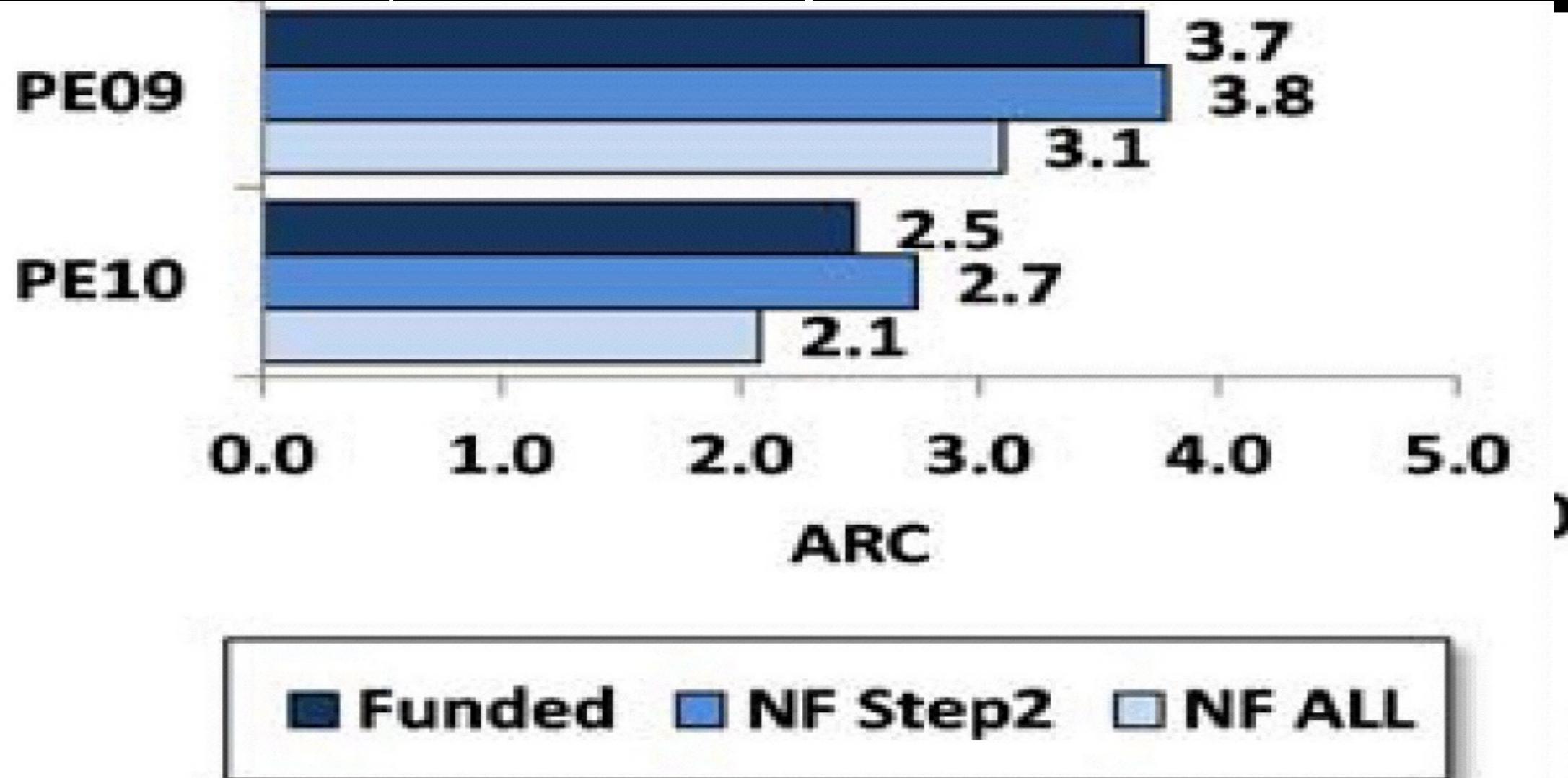
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Competition-driven science often produces incremental results

A new driving force for research:
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Competition-driven science: short-term, project-based funding. Implication:
a) incremental results; b) demand of short term positions cheap and mobile.
Dual labor market.

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Thorne: “Today it would not be easy to convince the government to finance a project like LIGO, politics no longer wants to risk big scientific adventures”

Historical trends: scientific production

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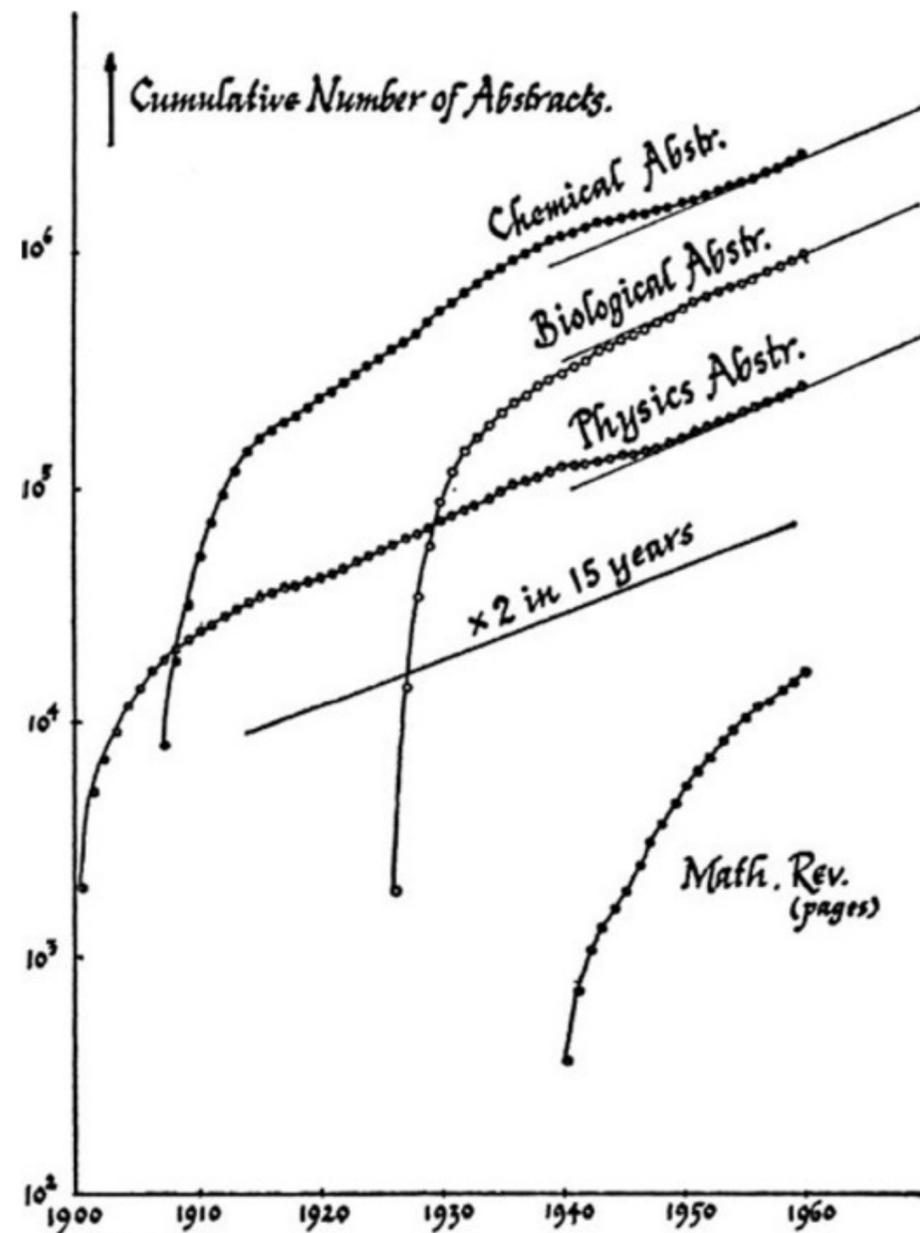


Fig. 2. CUMULATIVE NUMBER OF ABSTRACTS IN VARIOUS SCIENTIFIC FIELDS, FROM THE BEGINNING OF THE ABSTRACT SERVICE TO GIVEN DATE

It will be noted that after an initial period of rapid expansion to a stable growth rate, the number of abstracts increases exponentially, doubling in approximately 15 years.

Historical trends: scientific production

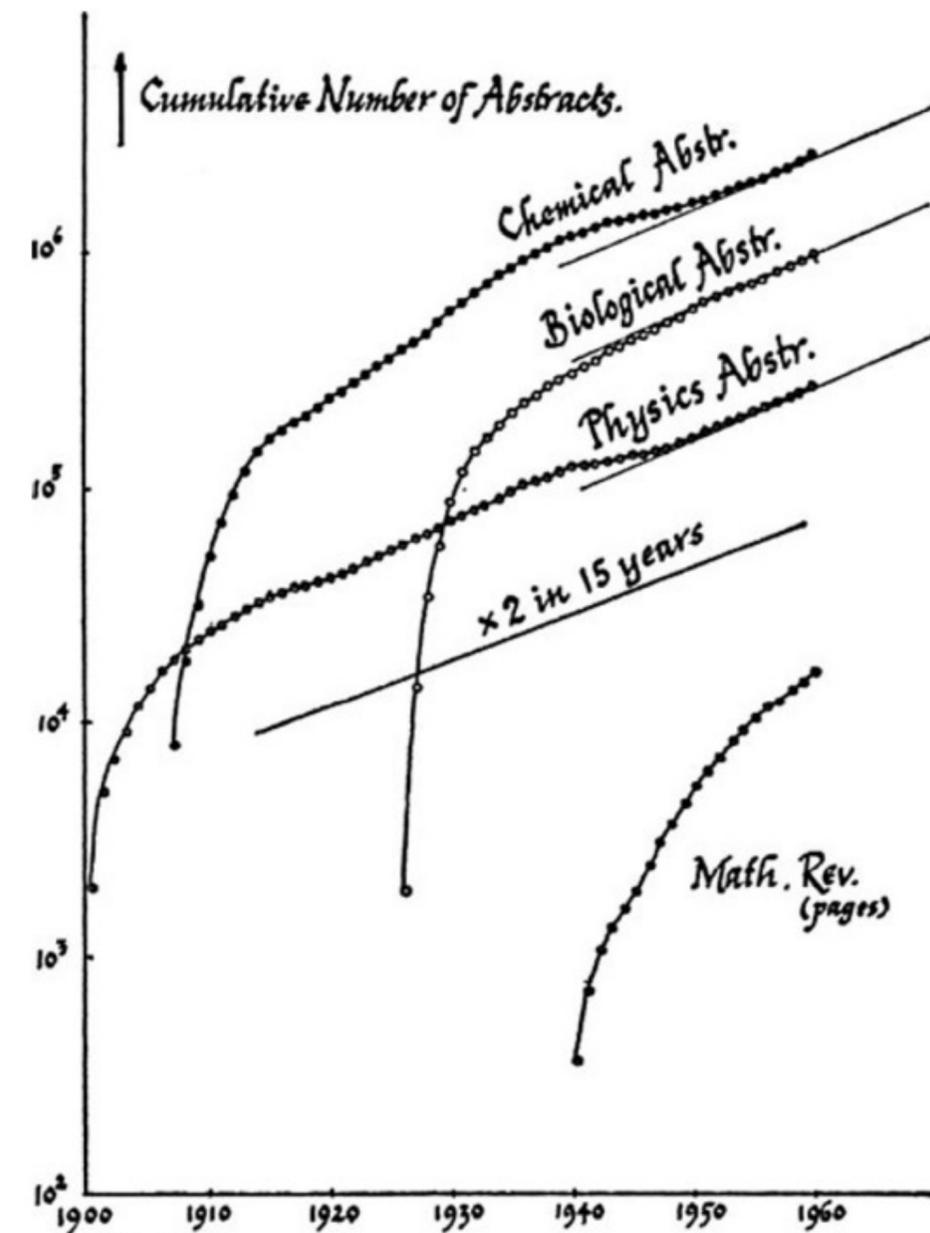
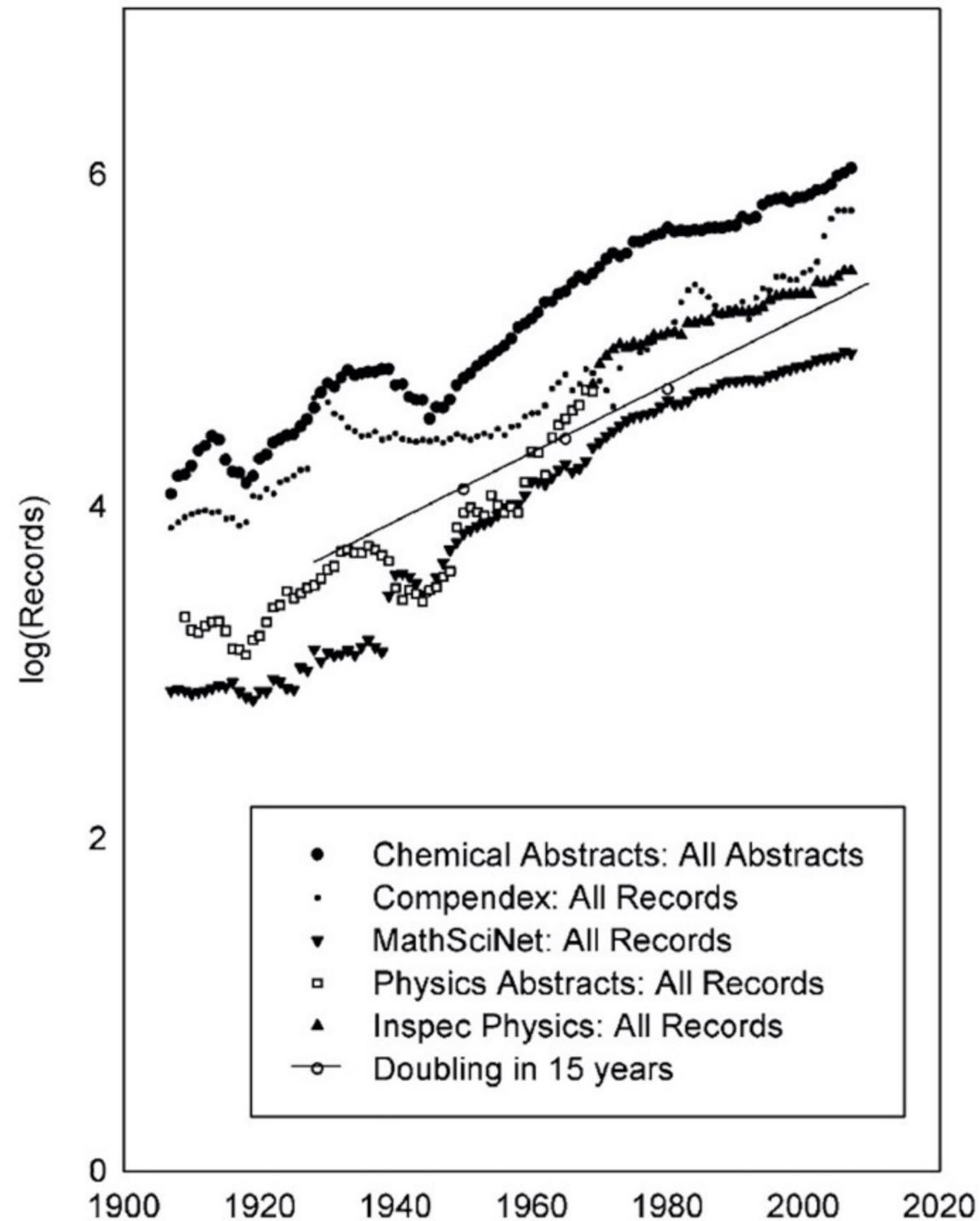
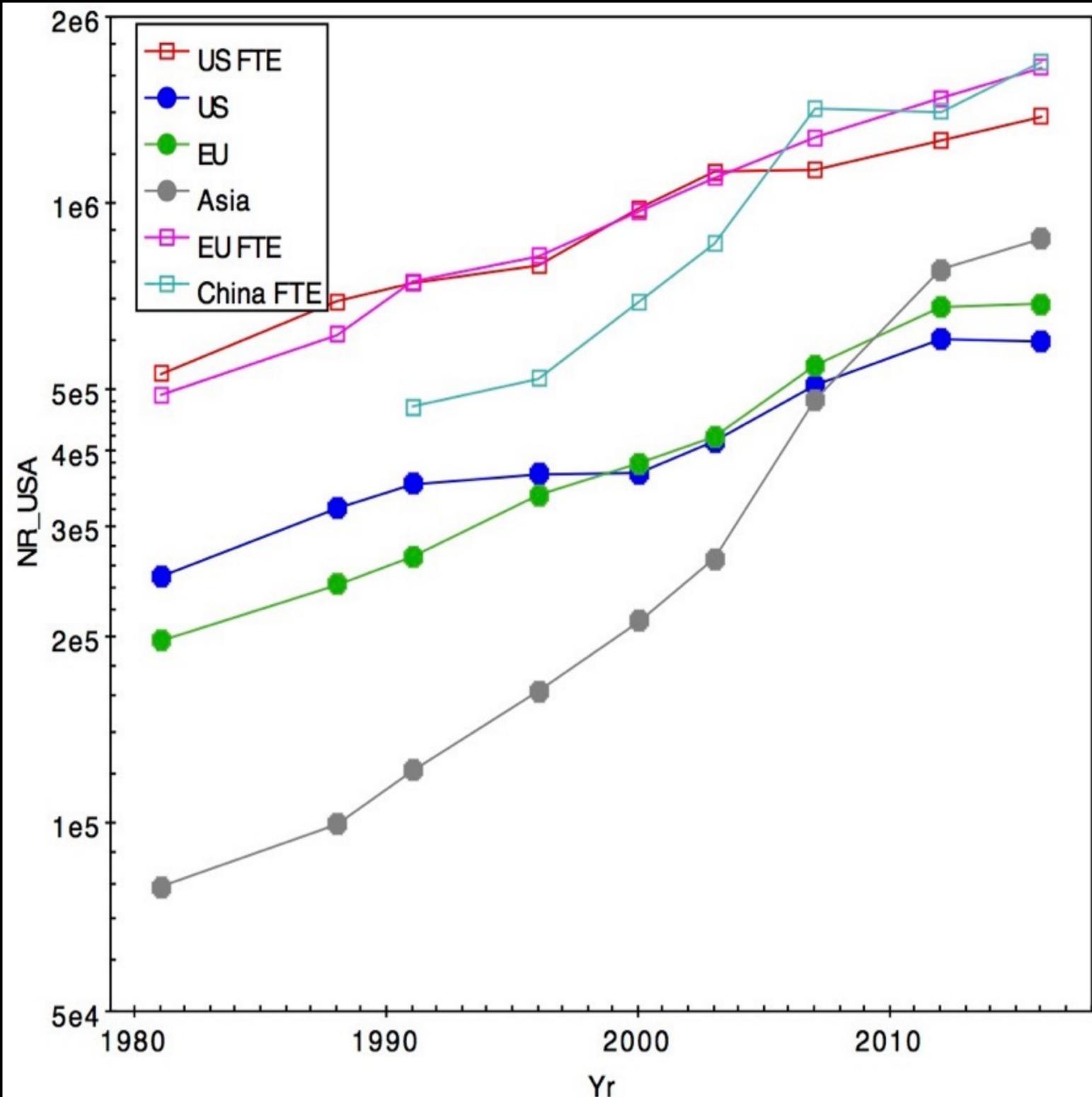
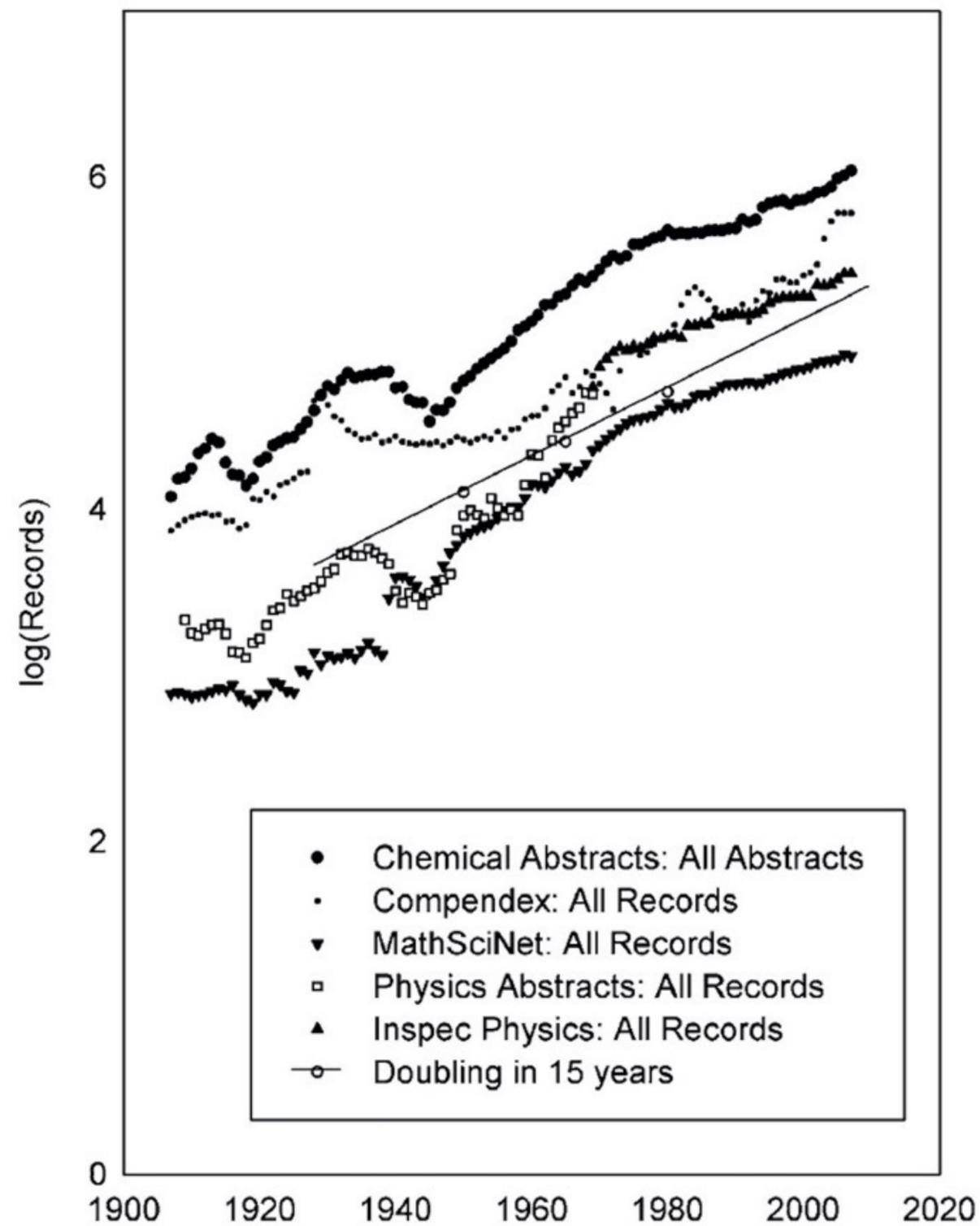


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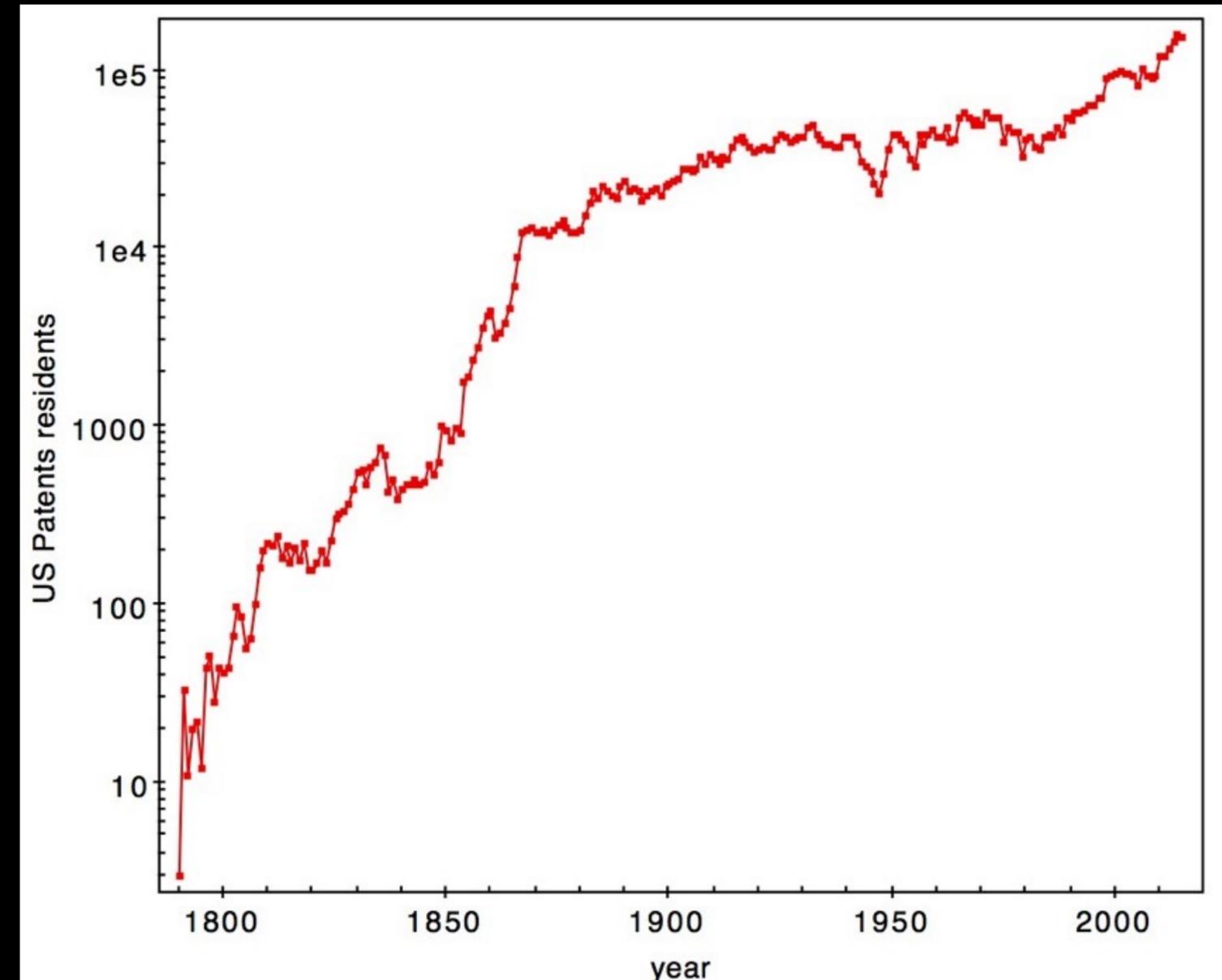
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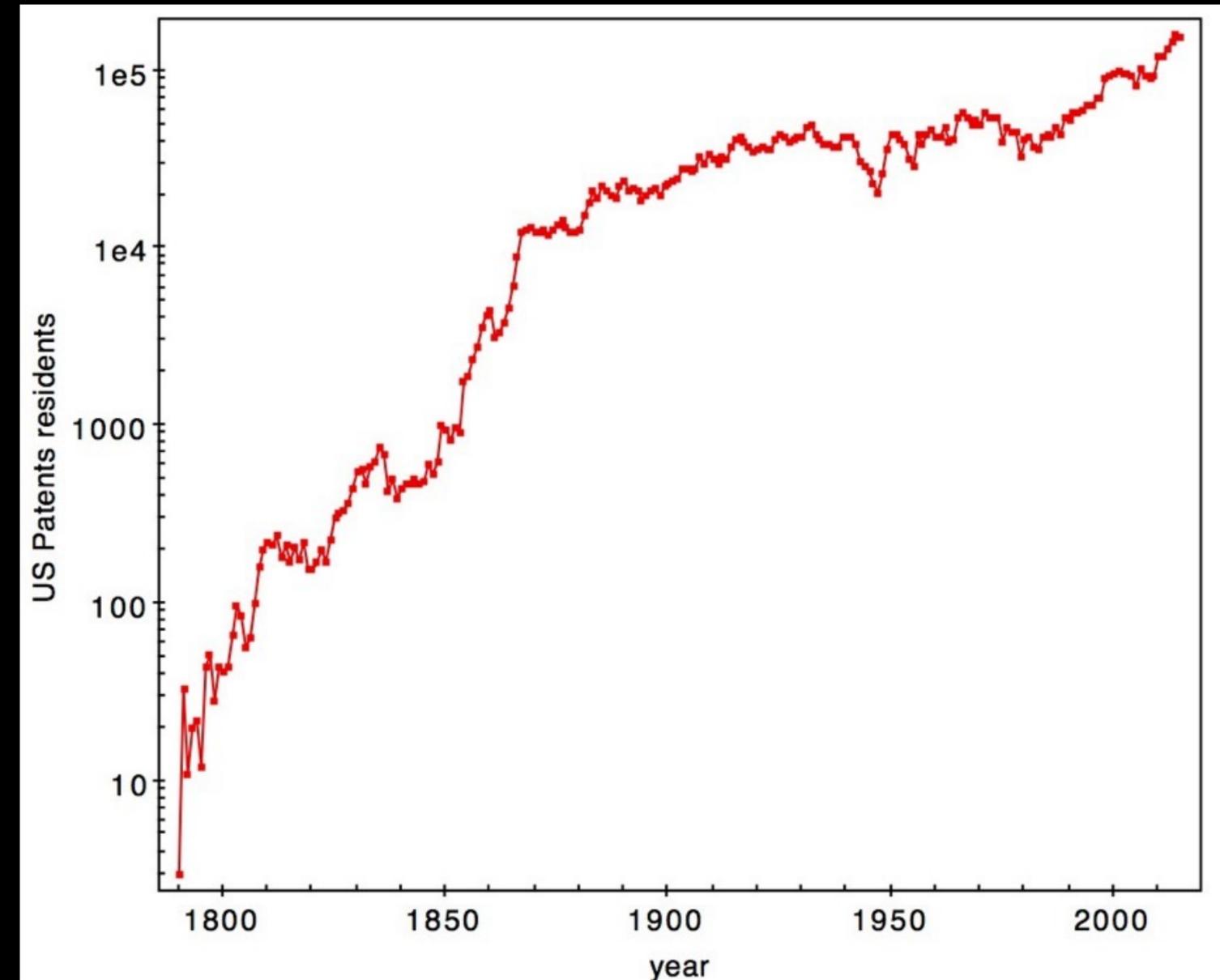
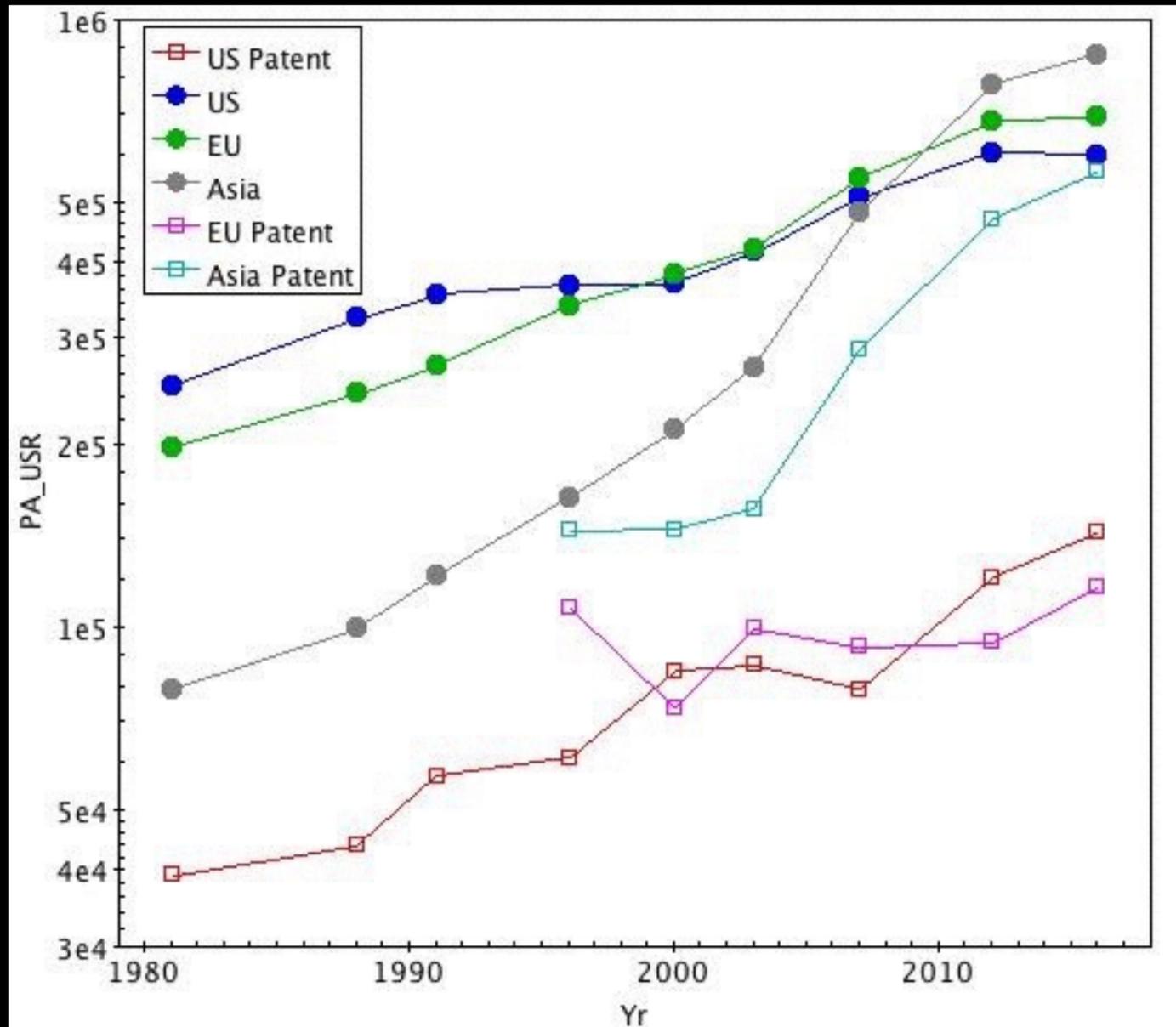


Historical trends: Transfer Knowledge

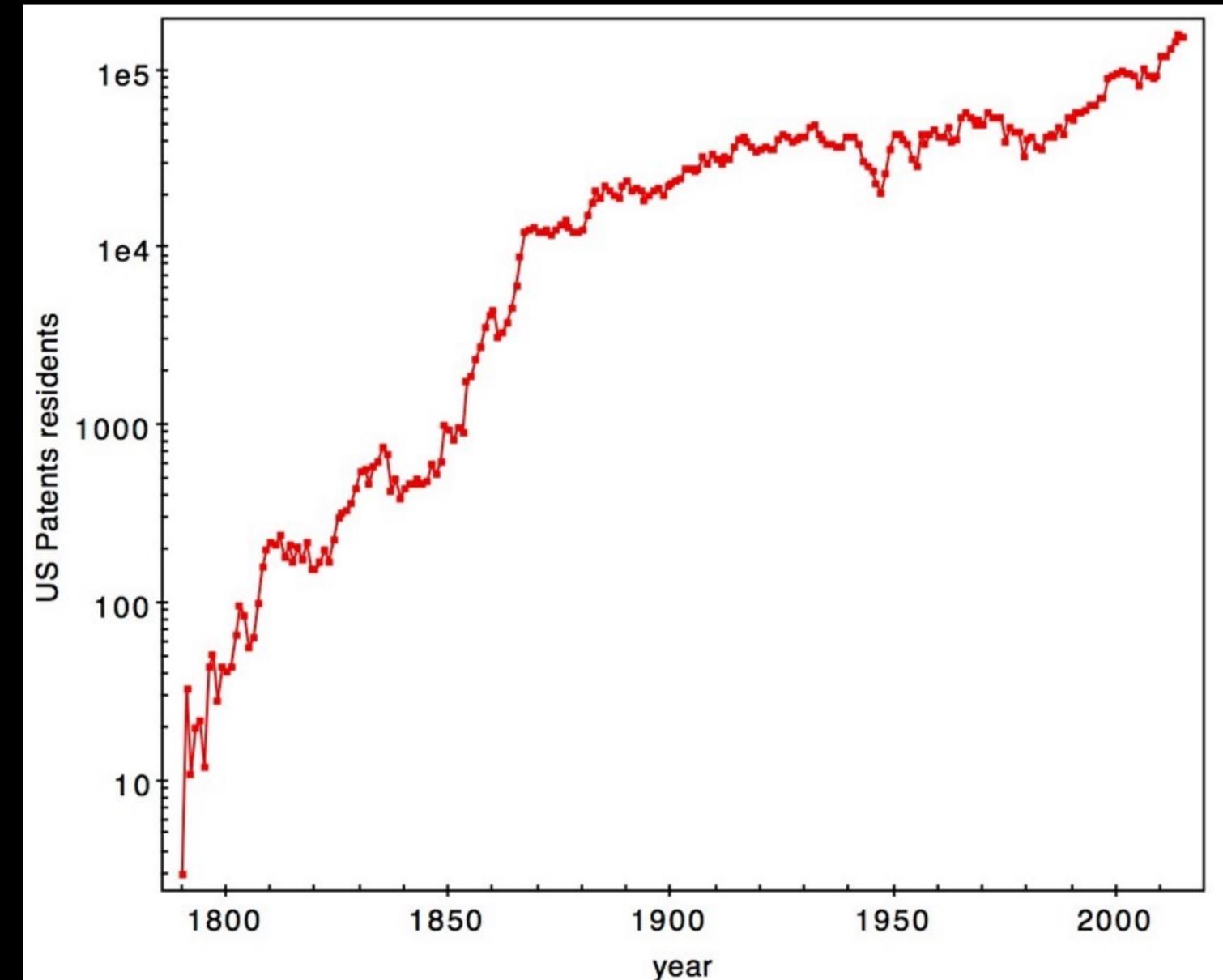
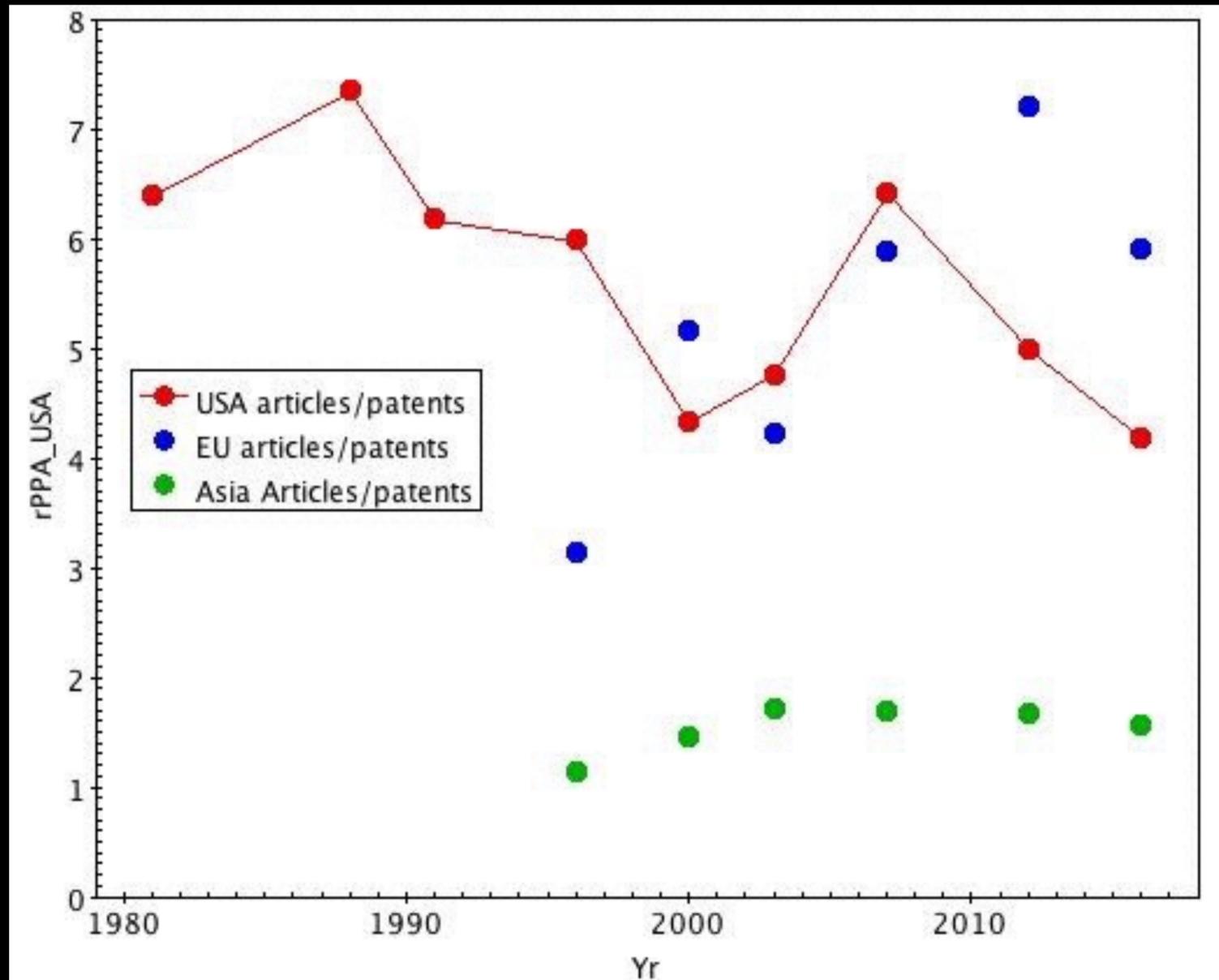
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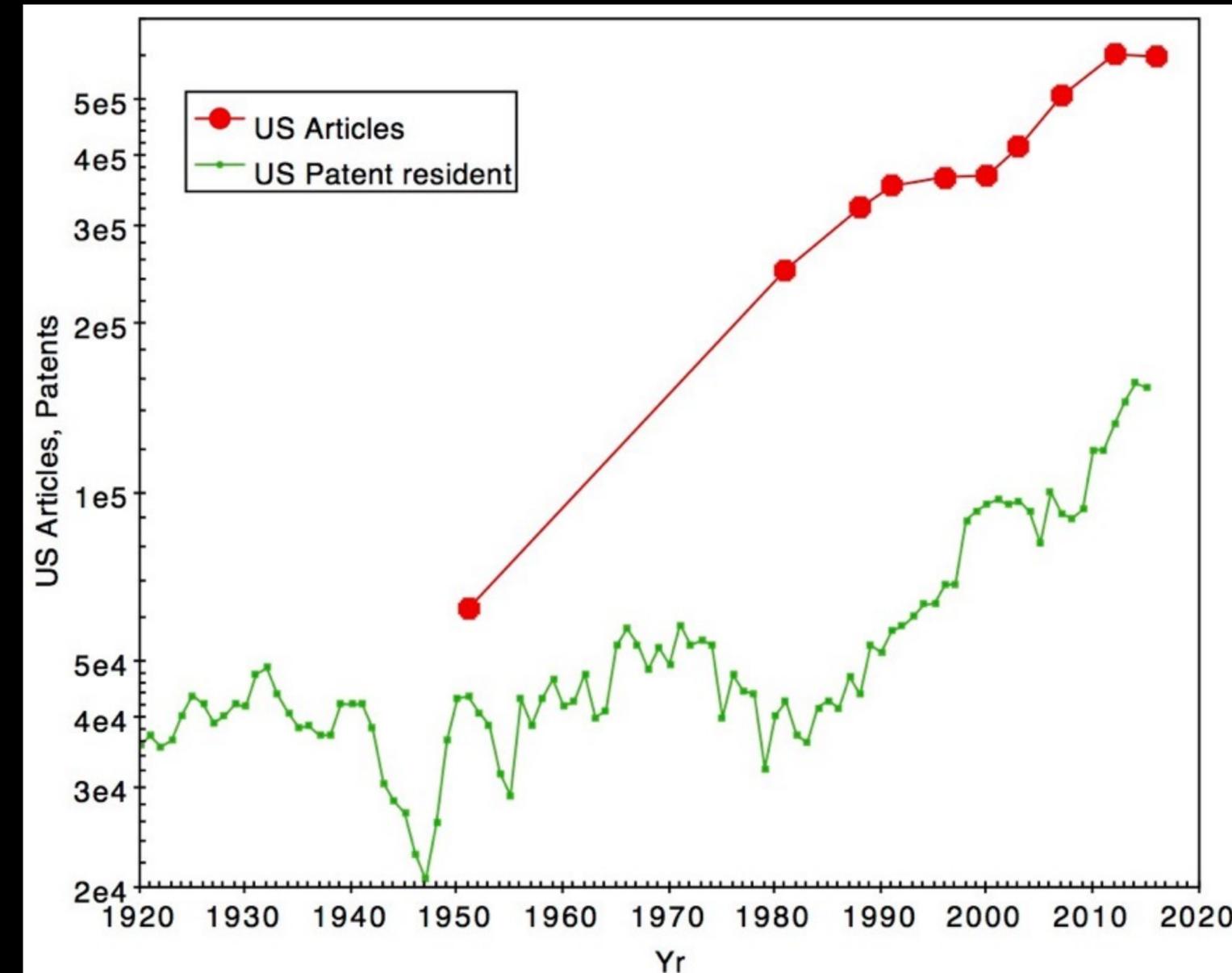
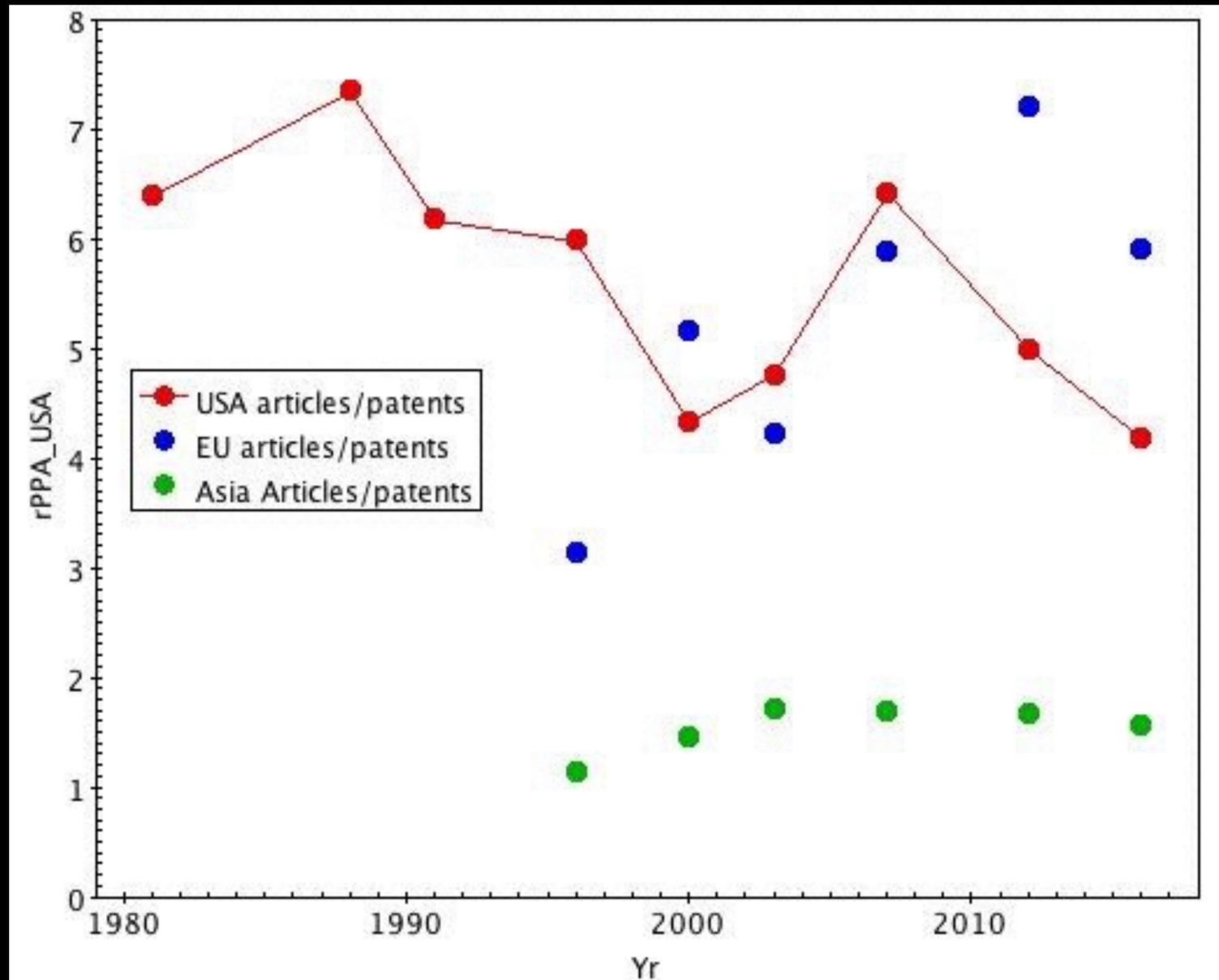
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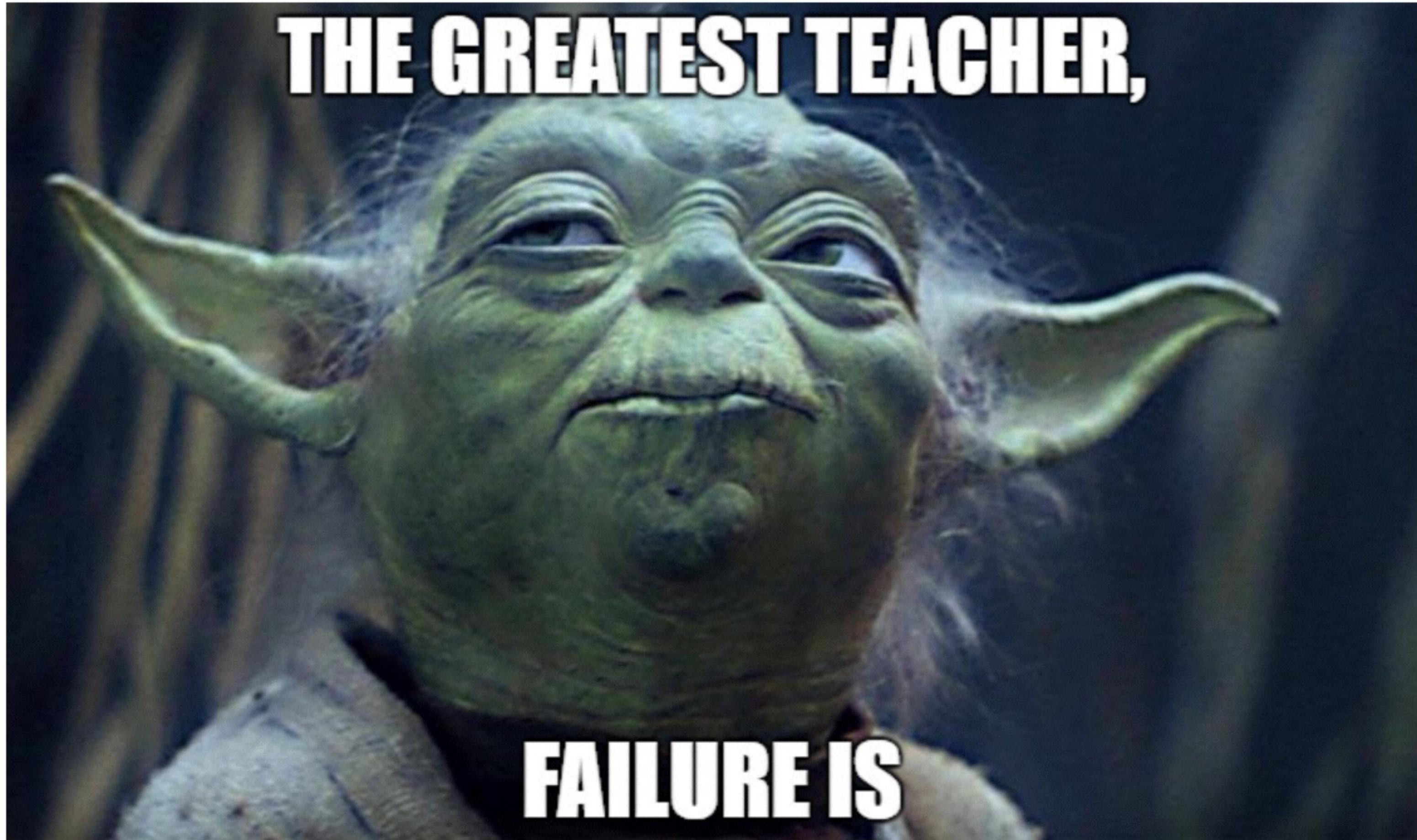


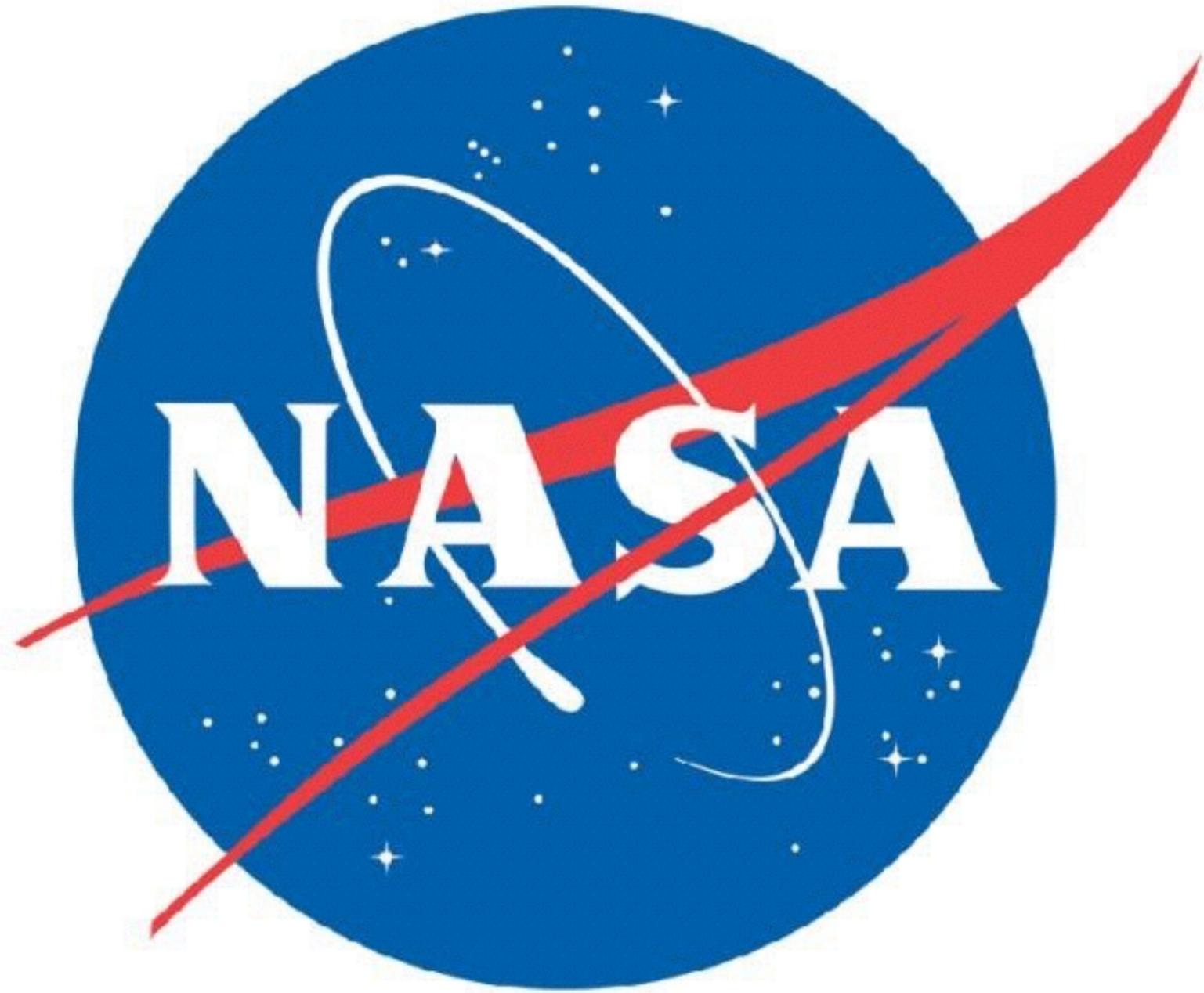
Science is a risky business

Is still Science a risky business?

THE GREATEST TEACHER,

FAILURE IS





Failure is not an option

Conclusion

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Reverse the trend:

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Return to public institutions the ability 'to make ambitious science and therefore ambitious choices.

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Rebalance the relationship between ambition-driven science and competition-driven science in favour of the former.

Reduce the short-term, cheap position: drive the recruitment through tenure tracks

Collaborate with private sector who want to invest in ambitious projects

But, how to do science?

The scientific method was invented by Galileo 400 years ago, and has resisted at least three industrial revolutions:

1750 - The first industrial revolution in UK

1900 - Ford and the assembly line

1950 - von Neumann dream: computers

>2000 - Is resisting to the fourth? (Big data, IoT, AI)

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Model confirmed, model rejected

One method, no method, 100 methods

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However, theoretical ideas influence the choice of the experiment and the interpretation of data ...

Feyerabend: The experiments that may contradict the dominant vision come from rival theories. Scientists should never agree. **No method**, in times of crisis, scientists proceed by violating the rules

One method, no method, 100 methods

100 methods: the essence of science is to draw conclusions from incomplete information. Great chance of error. Science requires correction mechanisms, a collection of practical activities to unmask errors.

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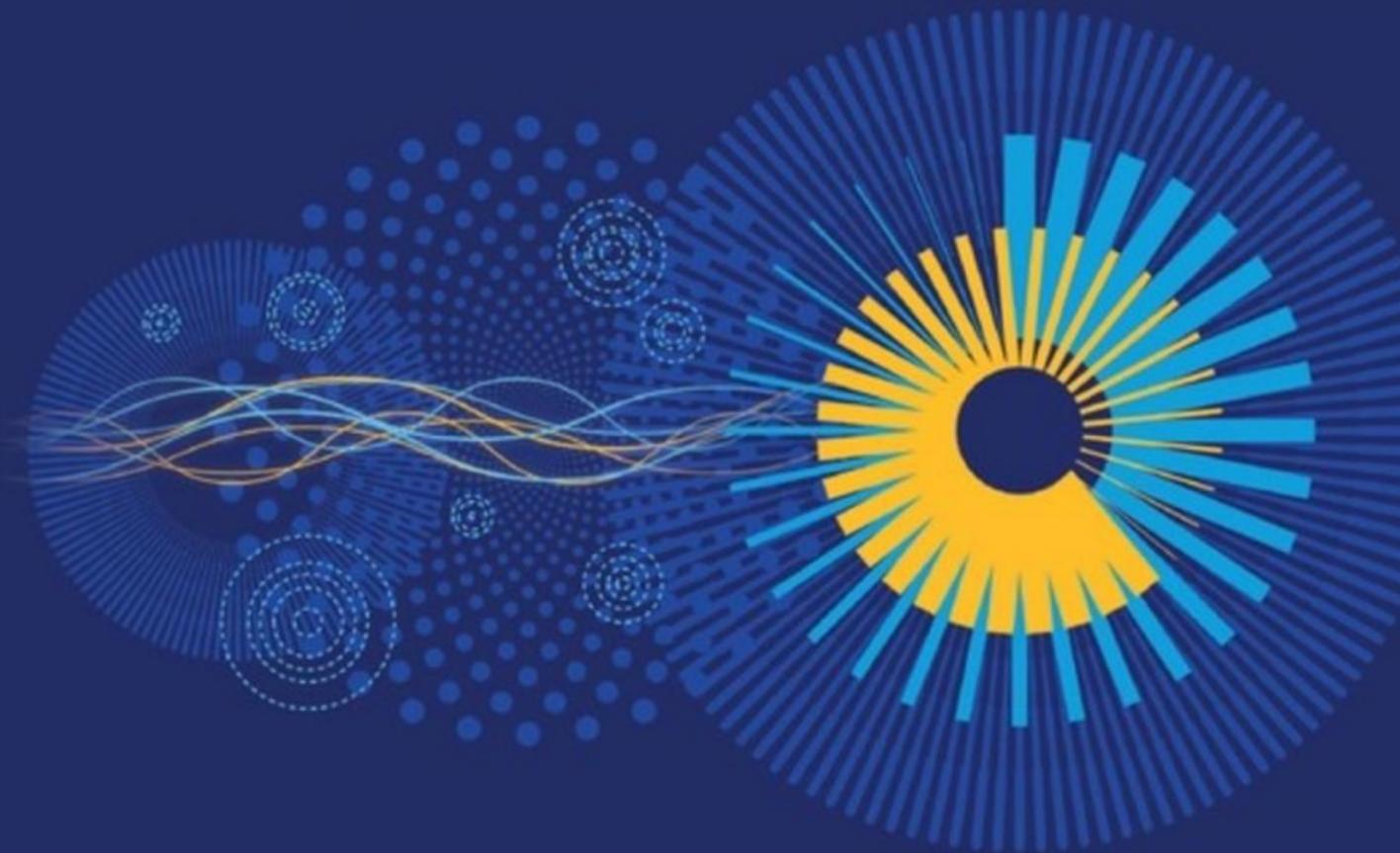
Feynmann: Science is organized skepticism towards the reliability of experts' opinion

The fourth industrial revolution

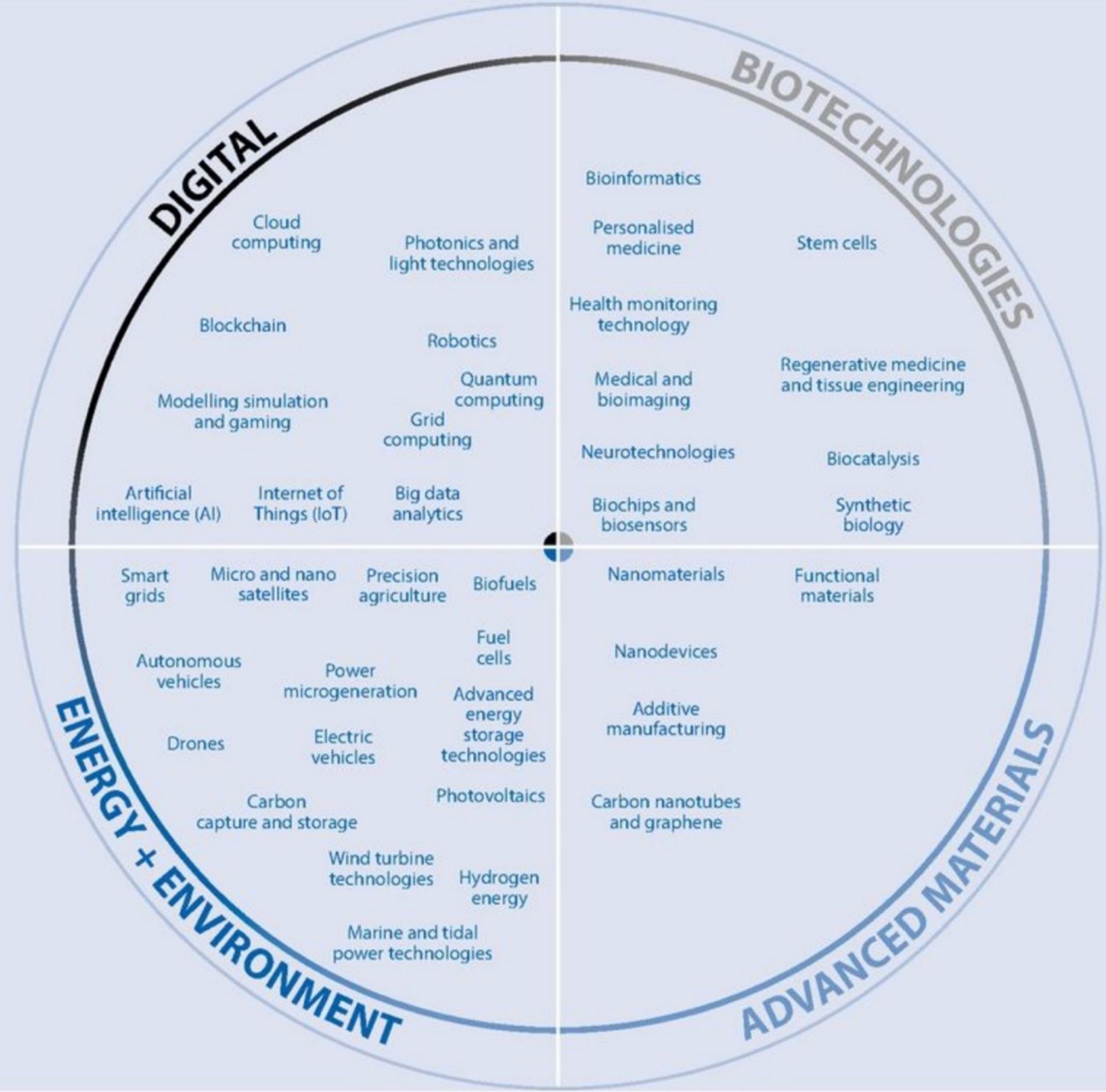
Organisation for Economic Cooperation and Development



OECD Science, Technology and Innovation Outlook 2016



The fourth industrial revolution



The fourth industrial revolution

Internet of Things

Big data

Artificial Intelligence

Neurotechnologies

Nano/micro satellites

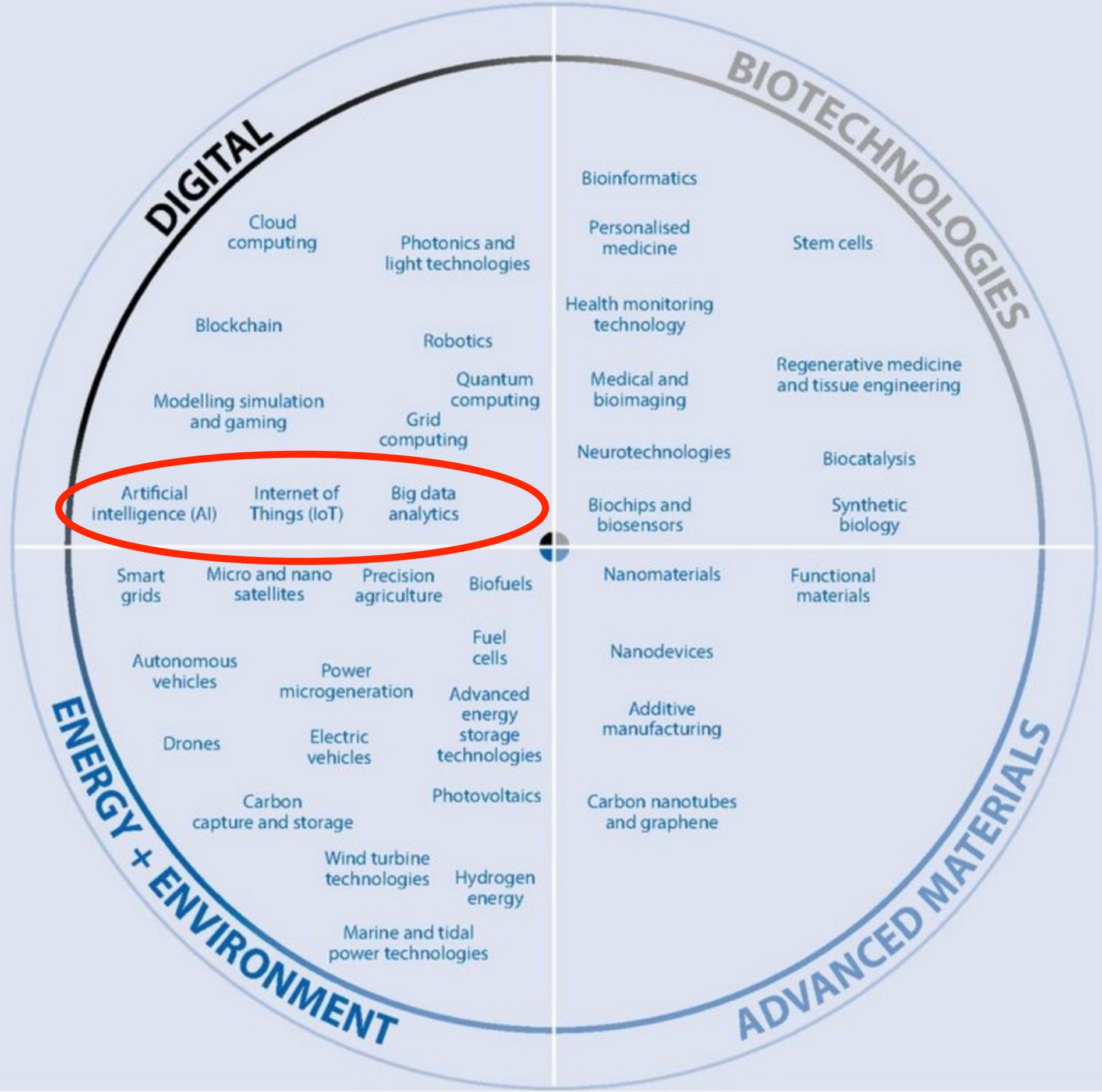
Nanomaterials

Additive manufacturing (3D printing)

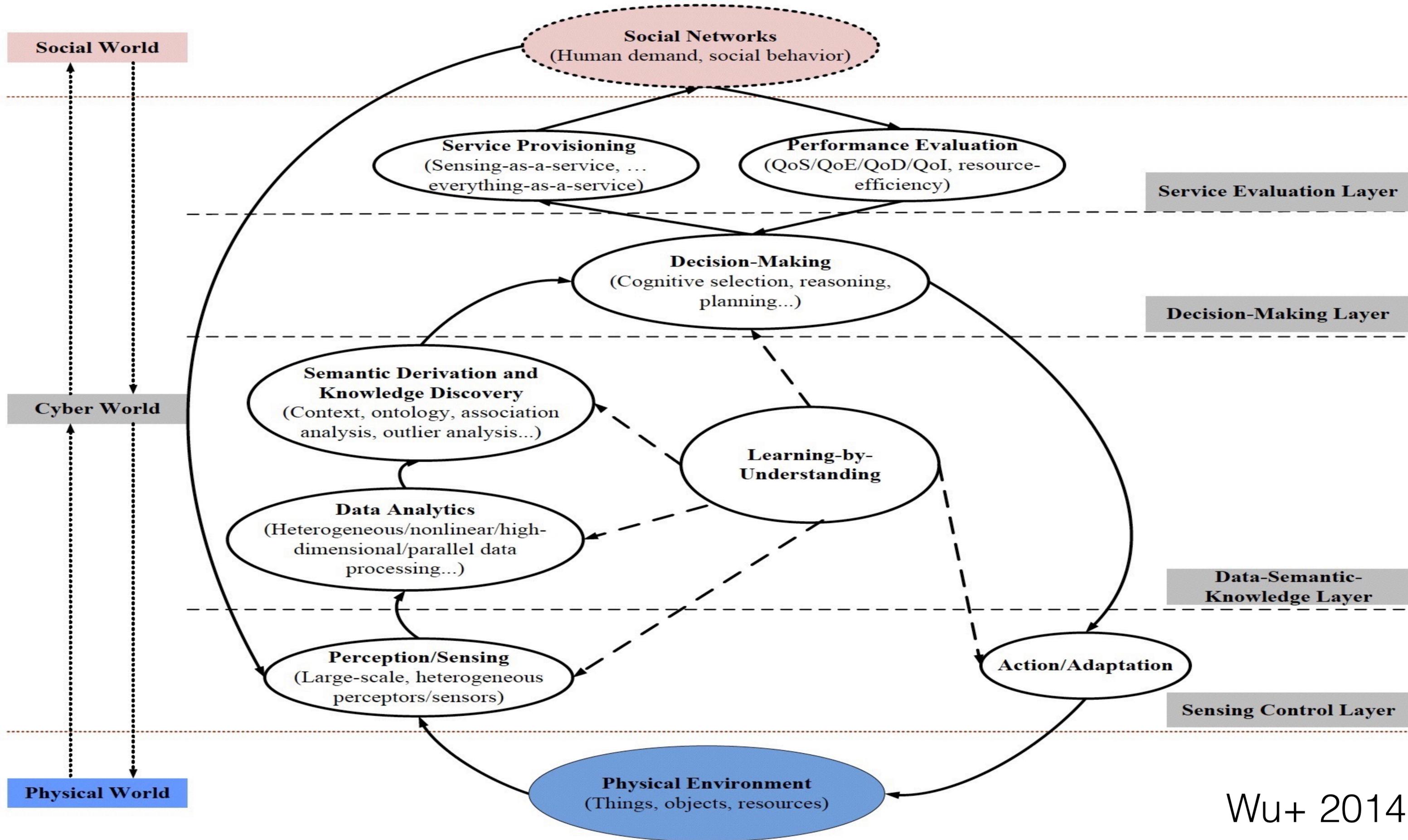
Energy storage

Synthetic biology

Blockchain



IoT+AI+Big data analytics =
Cognitive IoT





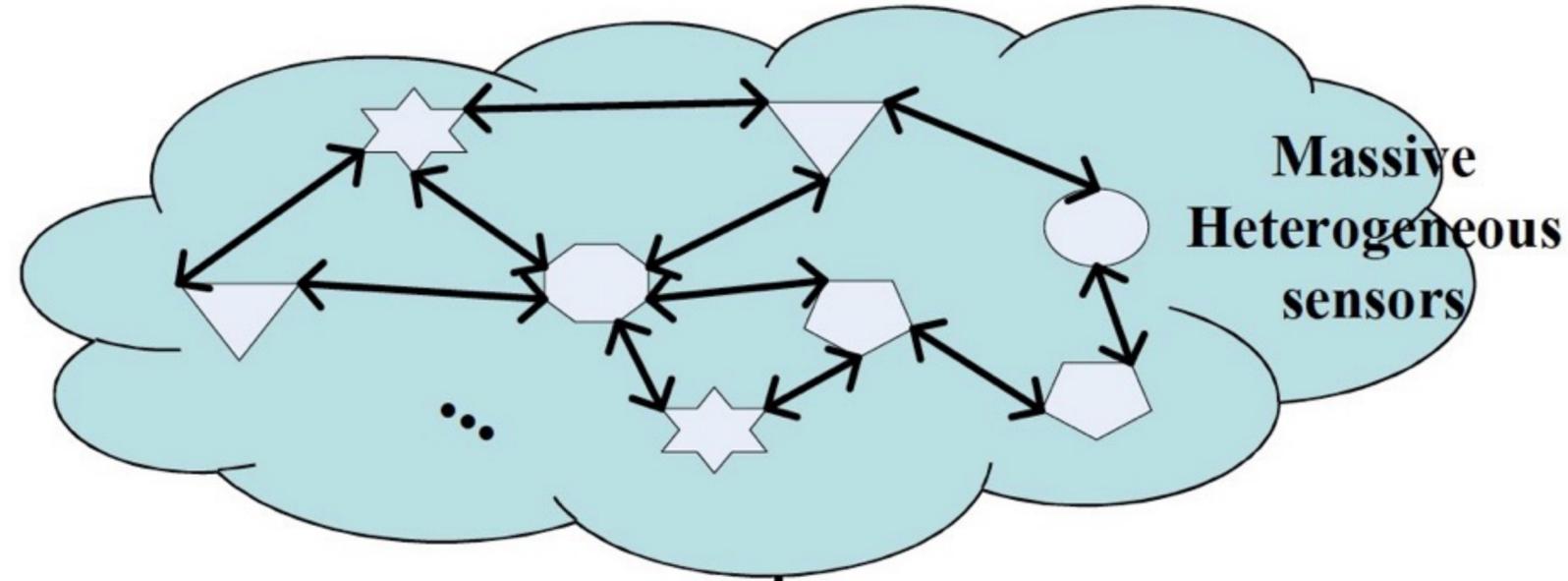




Kyle Reese to Sarah Connor

*Defense network computer, new, powerful, **hooked into everything**, trusted to run it all. They say it got smart, **a new order of intelligence**. Then it saw all people as a threat, not just the ones on the other side. Decided our fate in a microsecond: extermination.*





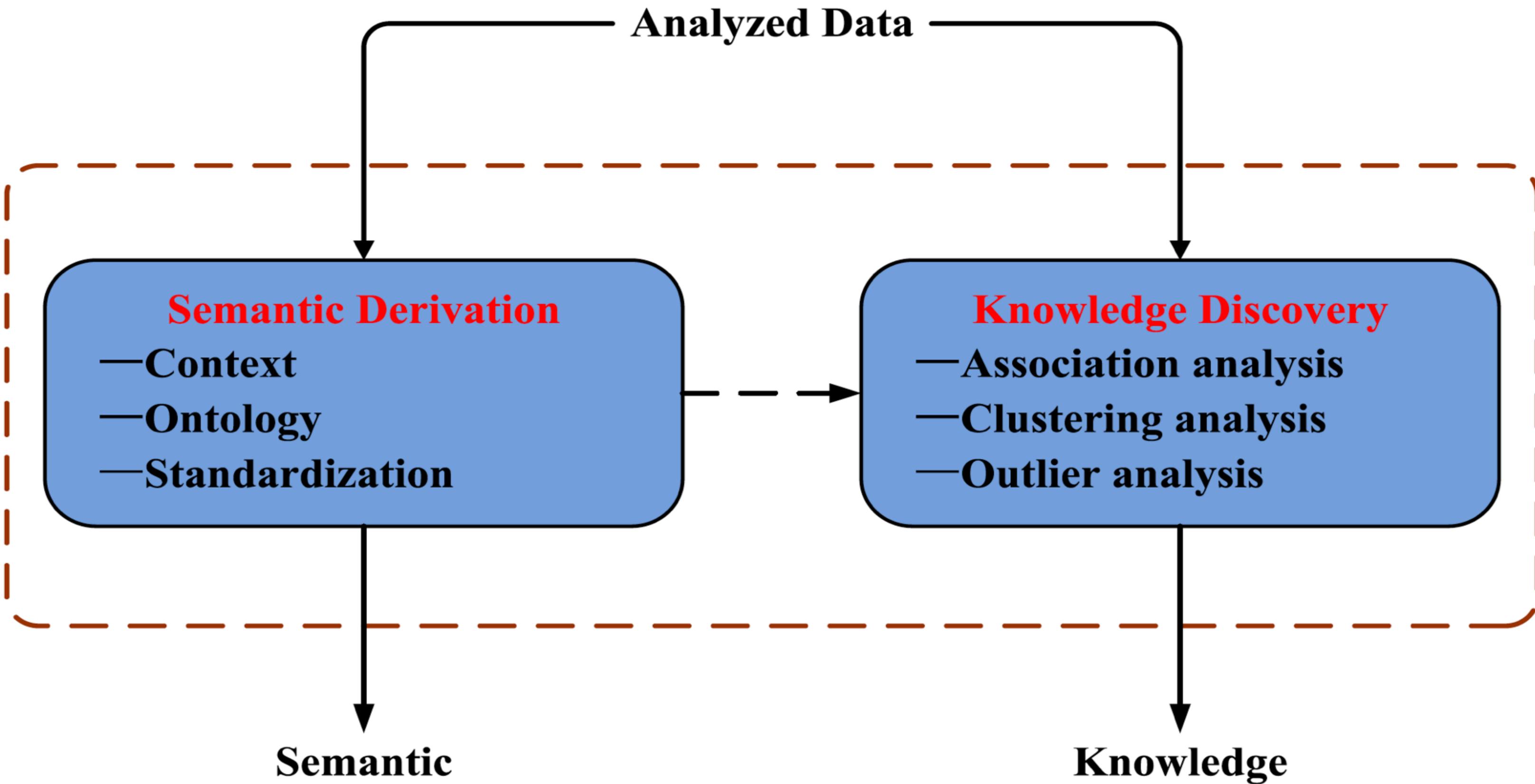
Raw Sensing Data

Massive, noisy, corrupted, heterogeneous, high-dimensional, and nonlinear separable...

Massive Data Analytics

- Heterogeneous data processing
- Nonlinear data processing
- High-dimensional data processing
- Distributed and parallel data processing

Organized Data



Science driven by testing of computer generated hypotheses based on patterns extracted from massive datasets.

Data will increasingly precede the research idea.

The process and utility of model development will change because the data will contain all objects of interest.

Data will be comprehensive, not representative.

Scientific method

First observation

Model/theory

Experiment

Model confirmation/rejection

Prediction



Cognitive IoT

Observations

Data analysis

Extrapolation



Knowledge

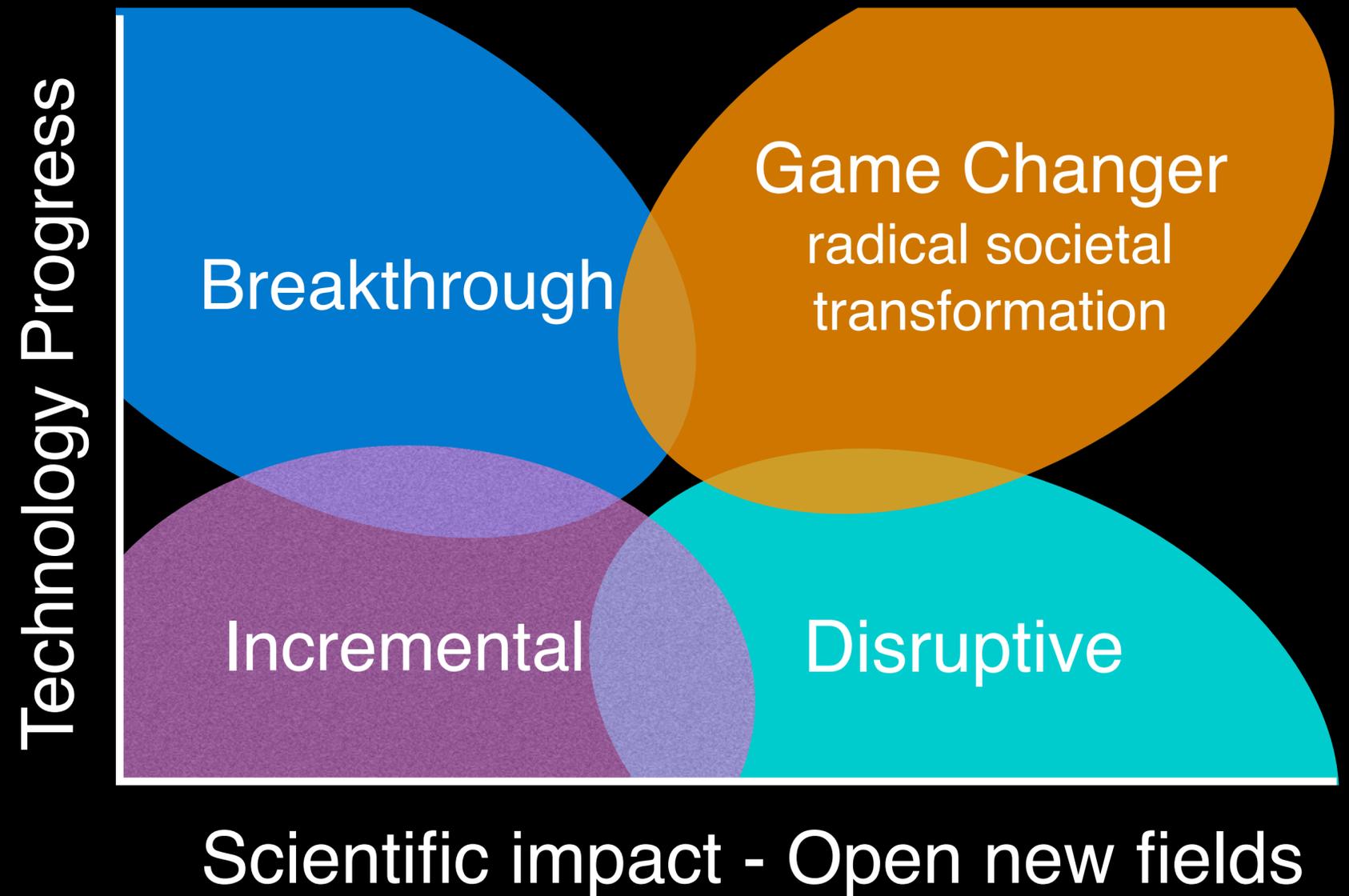
data will contain all
objects of interest

A (weak) reply

Sensors, computers, robots, software could not exist without strong theories that allowed their development (in particular quantum mechanics and relativity)

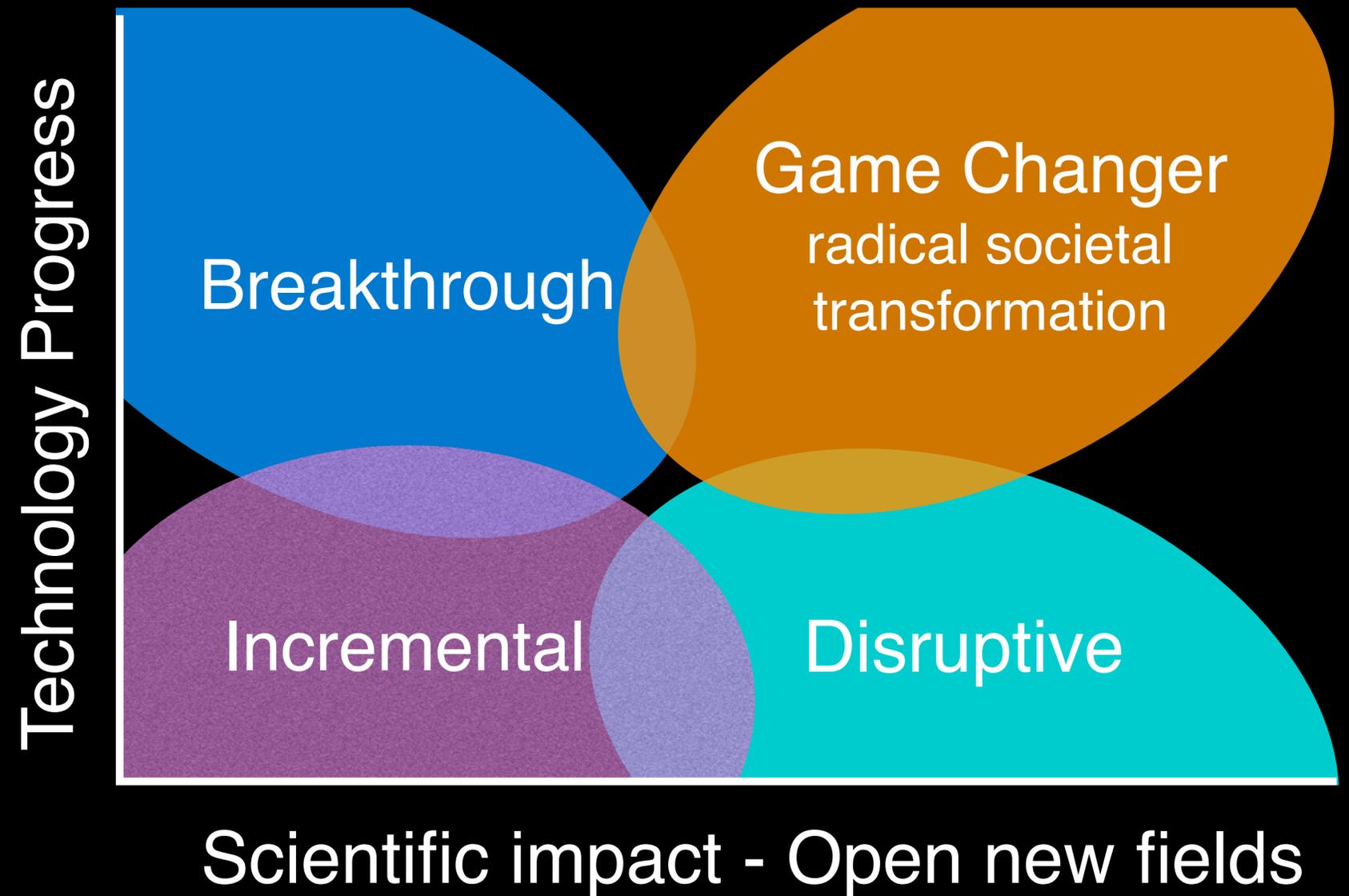
A CloT proto-system already exist: Google

Is there a way out?



Is there a way out?

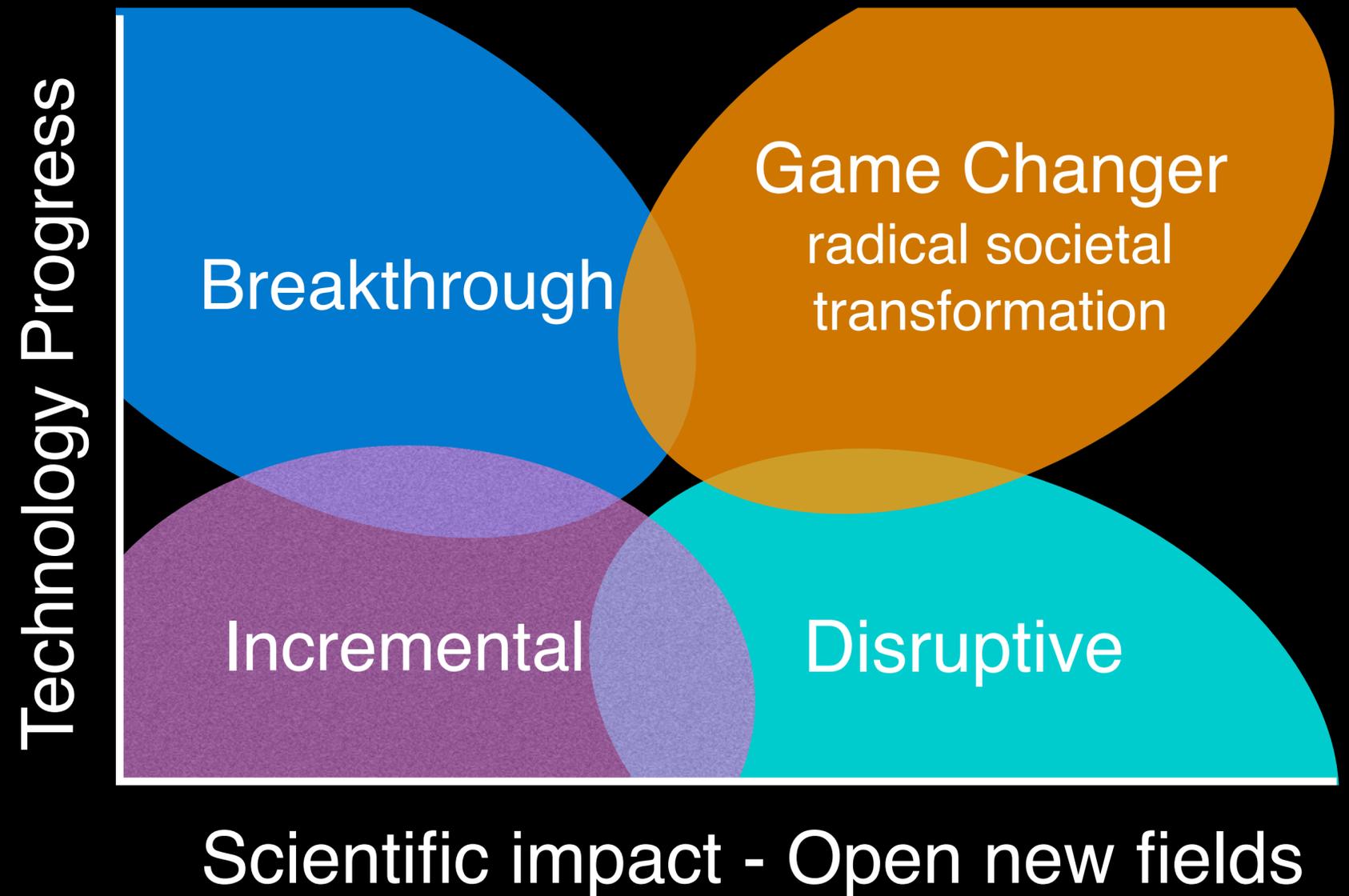
Incremental knowledge: there is no match: CloT (or even google) win easy



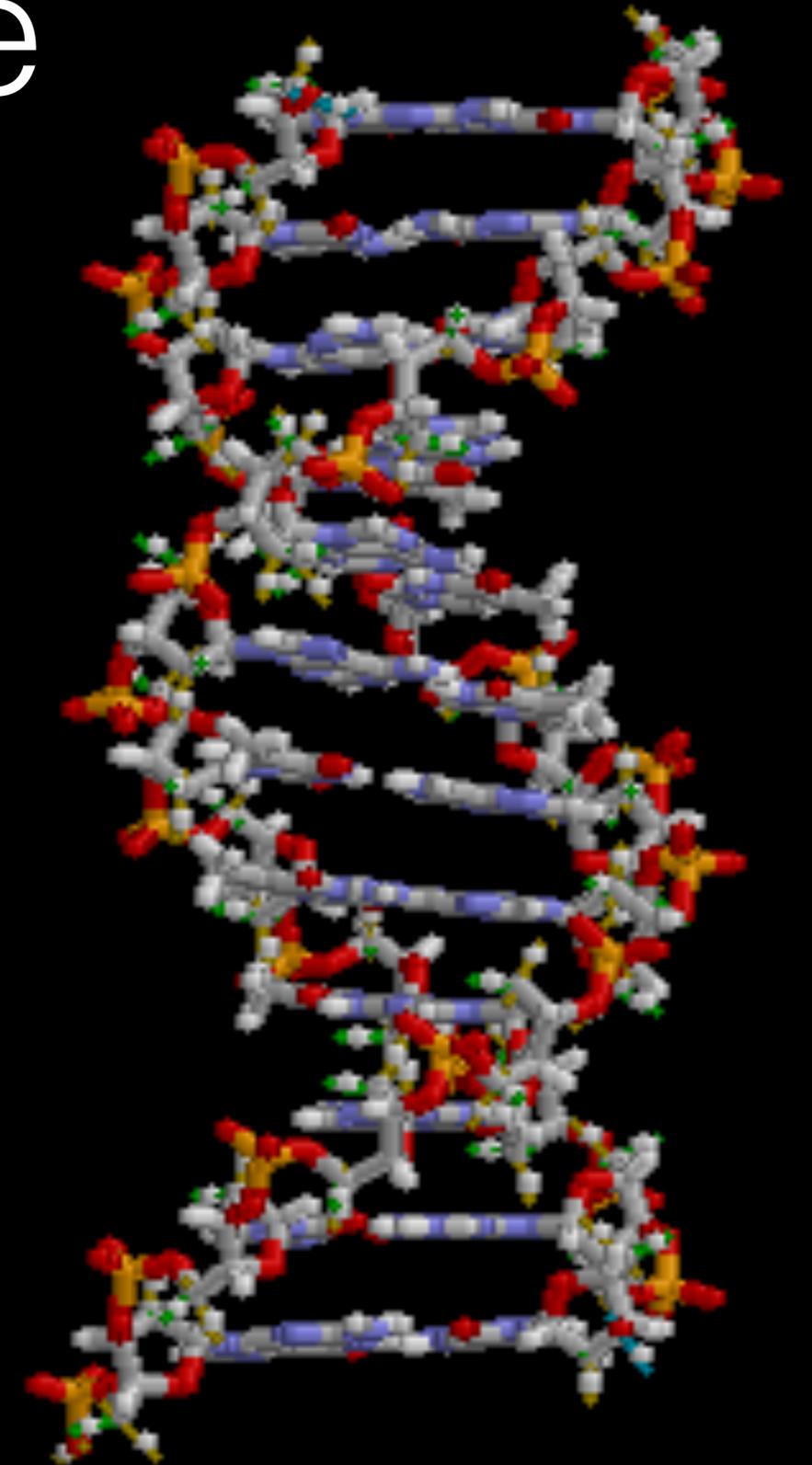
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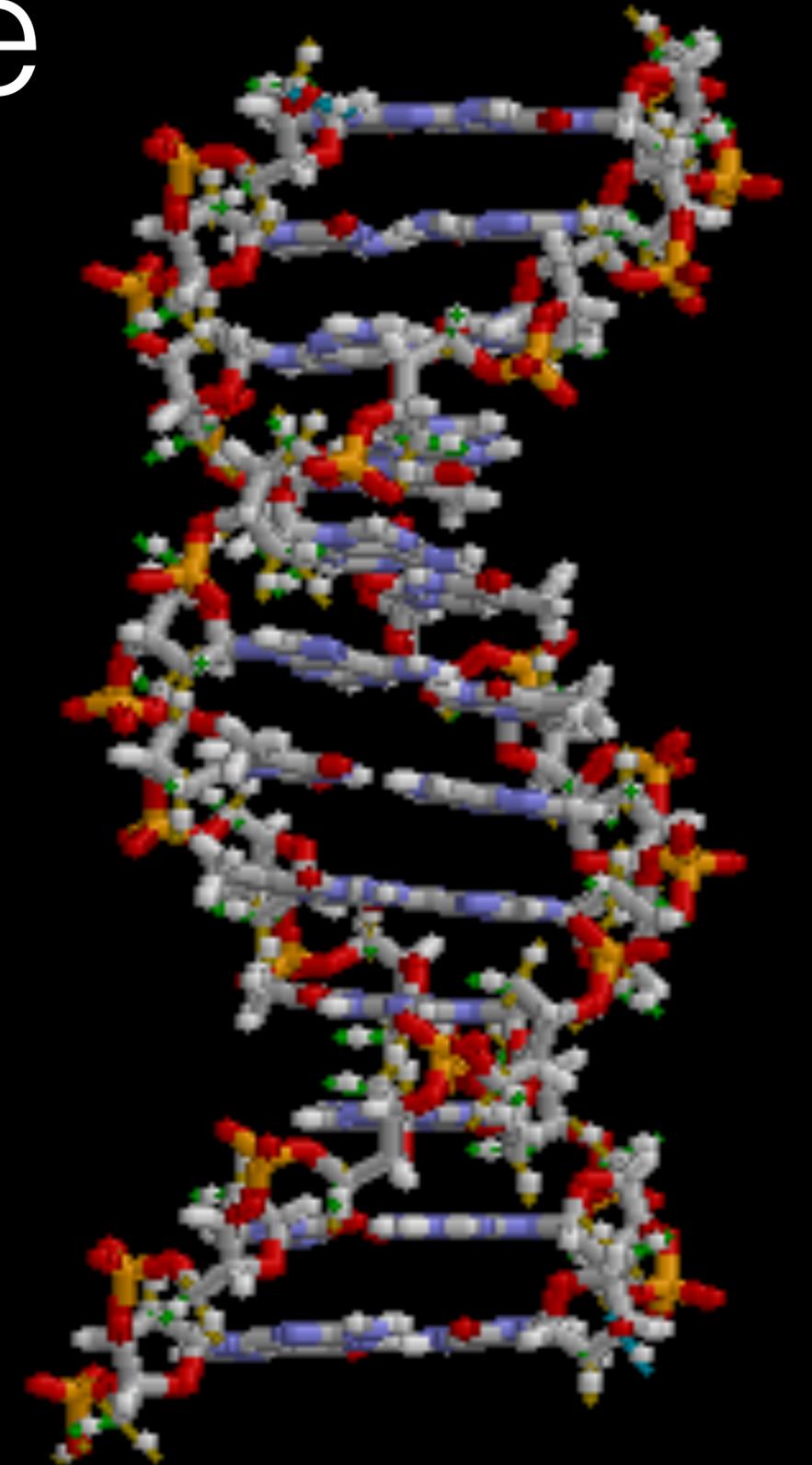
But are CloT and Google able to produce scientific results truly Game Changer? Those causing radical changes in the society?



The origin of Life



The origin of Life

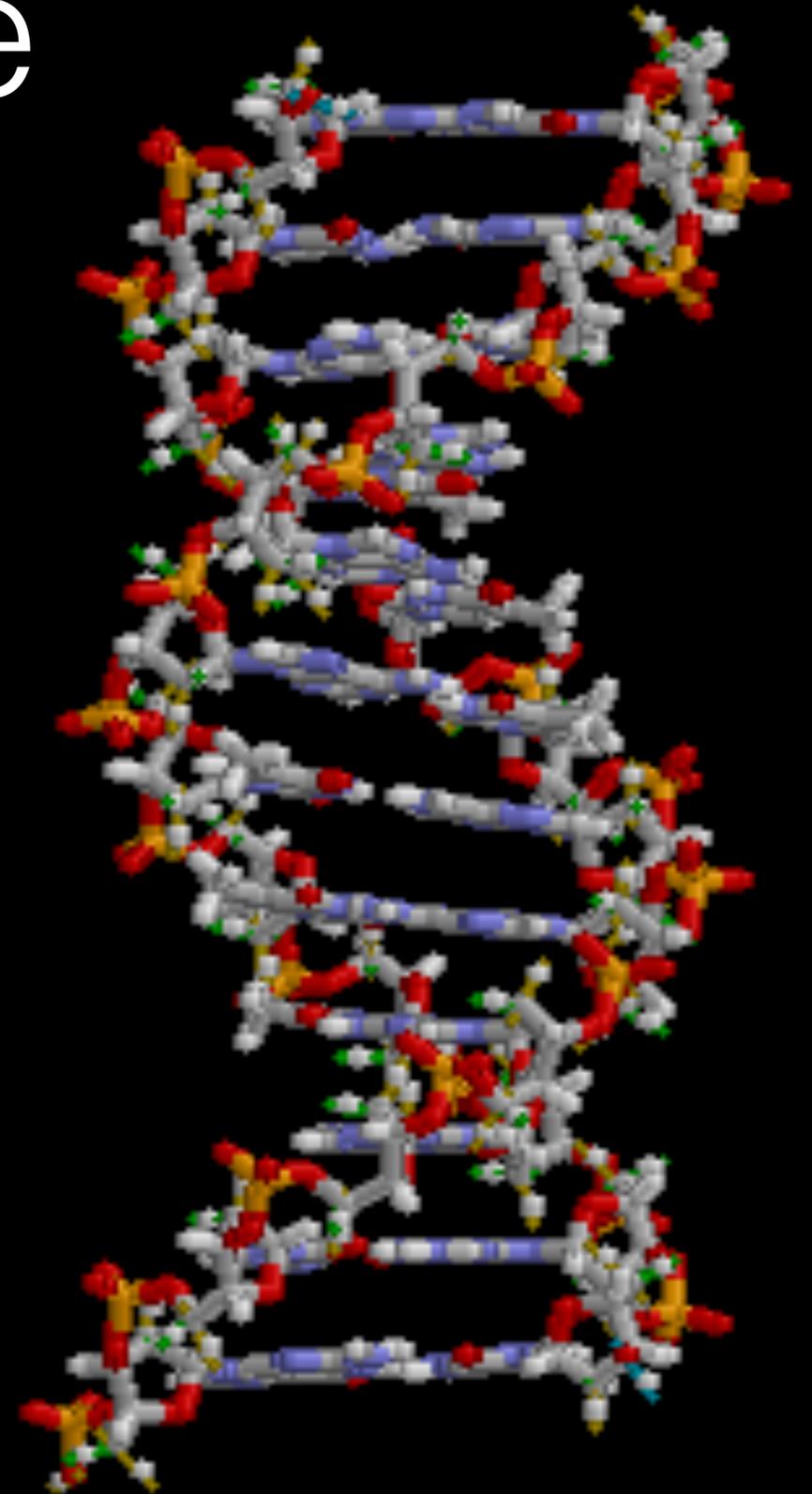


The origin of Life

Origin of Life

The first principles

Research in the laboratory, the lego of life



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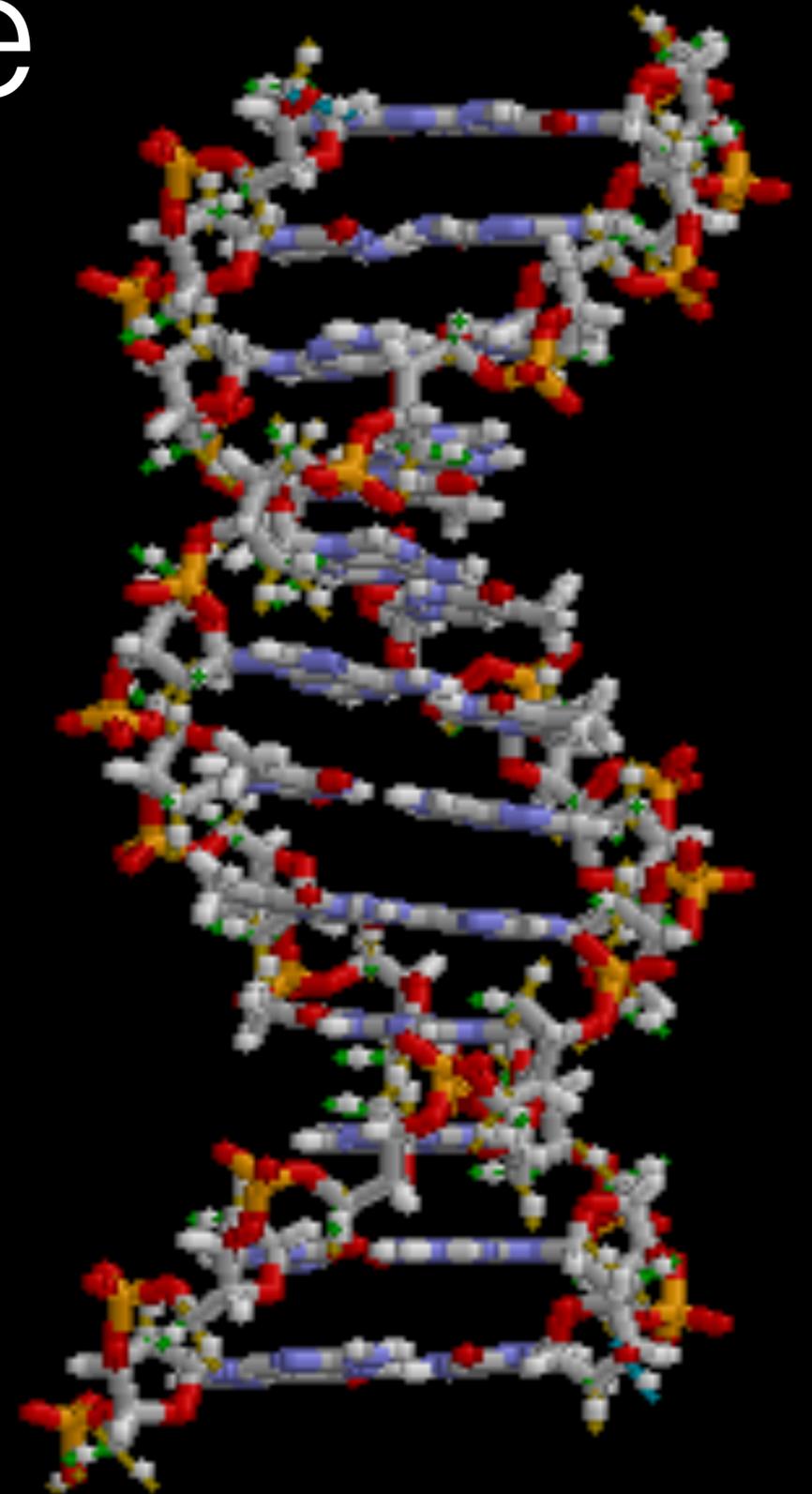
The search for an alien life

Solar system

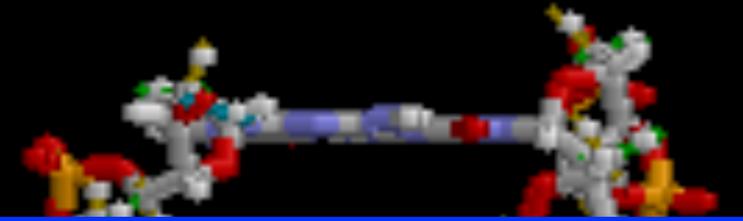
Mars, comets, frozen moons

Exoplanets

SETI



The origin of Life



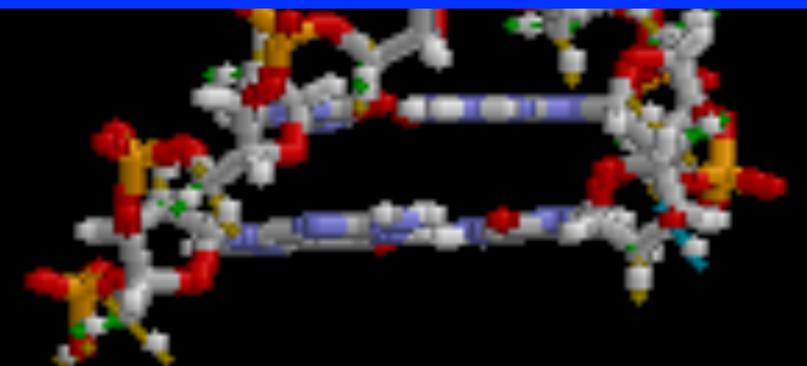
Imagination

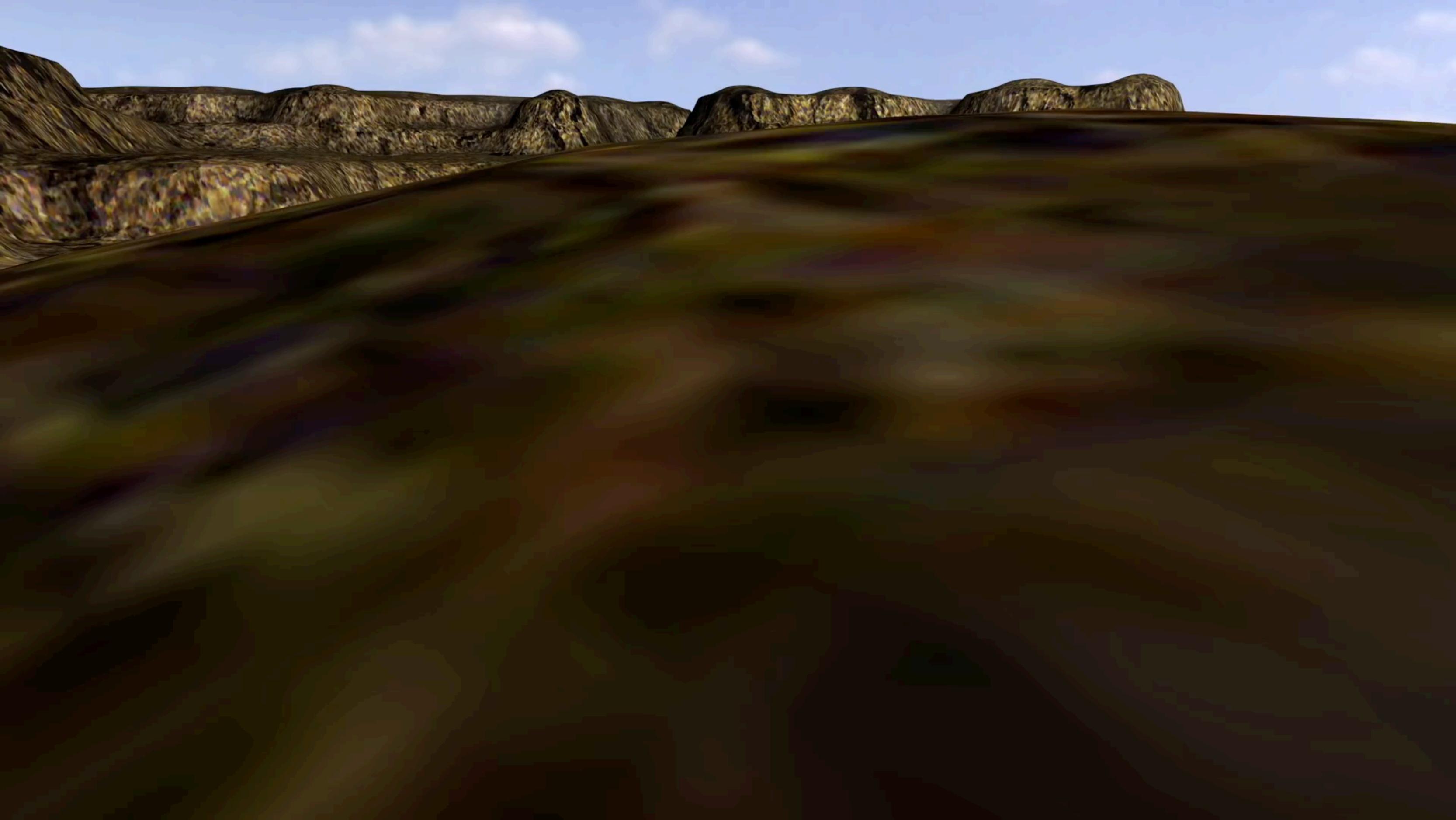
vs

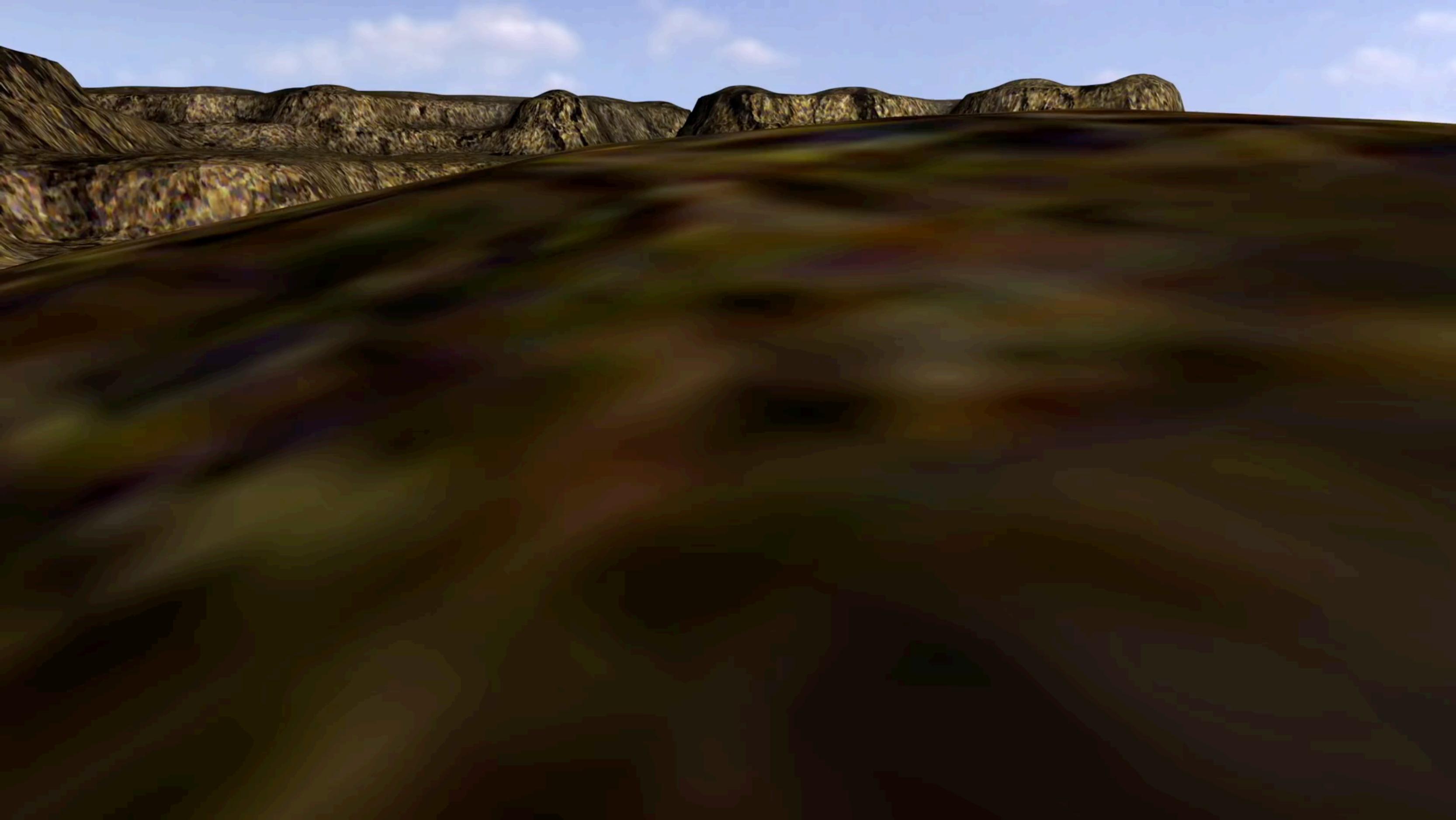
computing

Exoplanets

SETI



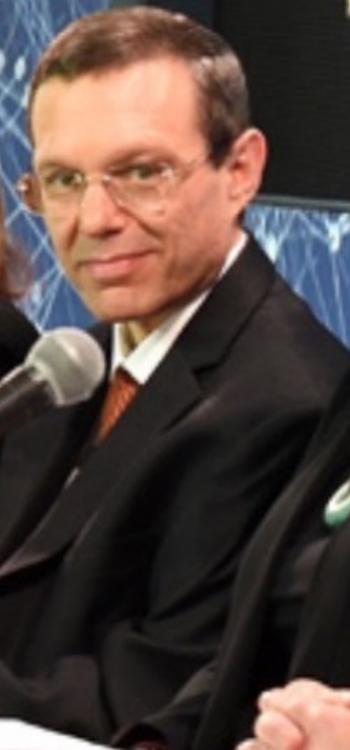




BREAKTHROUGH STARSHOT

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INITIATIVES BREAKTHROUGH INITIATIVES BREAKTHROUGH INITIATIVES BREAKTHROUGH INITIATIVES

BREAKTHROUGH
STARSHOT



BREAKTHROUGH
Starshot



SIX MEMOS
FOR THE NEXT MILLENNIUM

John Calvin

- 1 - Lightness
- 2 - Quickness
- 3 - Exactitude
- 4 - Visibility
- 5 - Multiplicity
- 6 - Consistency

Reclutamento

Modello Italiano (Francese)

Reclutamento

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Definire aree di ricerca strategiche

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Esempio —> 500 ricercatori indispensabili

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Impostare il reclutamento per soddisfare questo requisito

Esempio —> 500 ricercatori indispensabili

~30 nuove assunzioni ogni anno

Reclutamento

Modello Italiano (Francese)

Definire aree di ricerca strategiche

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50-70 primi post doc (AR)

~30 tenure track (equivalenti TD-B)

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~30 tenute track (equivalenti TD-B)

~10 posizioni TI aperte, concorso nazionale, vince il migliore e sceglie la sede

Reclutamento

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~30 tenute track (equivalenti TD-B)

~10 posizioni TI aperte, concorso nazionale, vince il migliore e sceglie la sede

~100 posizioni su progetto (equivalenti TD-A)