Why invest in space exploration?

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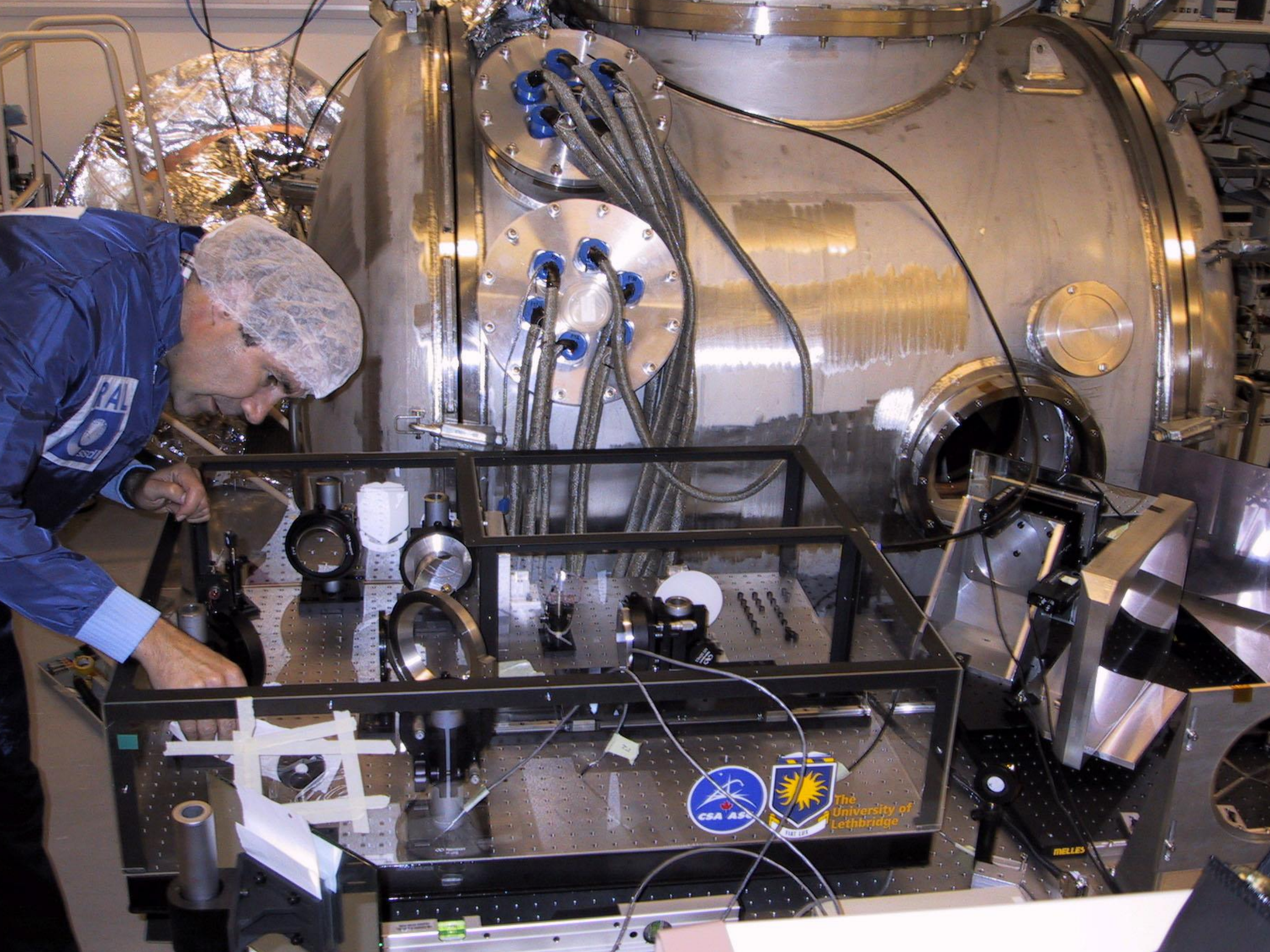

RAL
CSA ASC
The University of Lethbridge

“Why should we spend money on space exploration when there are so many problems here on Earth?”

1. Philosophical reasons to invest in space exploration
2. Space faring nations
3. Spin-offs from NASA program
4. Canada space program
5. Spin-offs closer to home

1. Philosophical reasons to invest in space exploration

Inspiration

The Apollo missions inspired an entire generation of students to pursue math and science careers. As we become an increasingly more technology-dependent society it is important that our citizens become scientifically literate so that they can make informed decisions on the inevitable challenges that will face us.

Few disciplines evoke inspiration as space exploration.

Exploration

To be human is to be an explorer. It is part of who we are: since the first tribes left the African savanna and spread into Europe and Asia, we have had the need to explore the unknown. Now humans have visited or settled every corner of the globe. The instinct to explore is still active. It may be an old cliche, but Star Trek had it right:

Space is the final frontier, and it calls to the explorer in all of us.

Economy

Space agencies do not launch cash into space. The majority of the money spent on space exploration goes toward the salaries of thousands of skilled workers around the world.

New Technology

These skilled workers, coming from many different fields, work on some very challenging problems. This not only leads to scientific breakthroughs, but numerous inventions and serendipitous applications.

Appreciating and protecting our planet

Studying other worlds like Venus and Mars provide sobering examples of how the climates of planets can change and develop tools for analyzing this change. Helping us to better appreciate the earth and protect it.

International Collaboration

Large space exploration projects are almost always the result of international cooperation. The International Space Station is the most obvious example. As NASA gears up to return to the moon, precursor missions from China, India, Japan and Russia are already in orbit or are under construction. Future human Mars missions will almost certainly involve multiple space agencies to spread the cost among several nations.

The SPIRE Consortium

Canada France Italy Spain Sweden UK USA

- Cardiff University, UK
- CEA Service d’Astrophysique, Saclay, France
- Institut d’Astrophysique Spatiale, Orsay, France
- Imperial College, London, UK
- Instituto de Astrofisica de Canarias, Tenerife, Spain
- Istituto di Fisica dello Spazio Interplanetario, Rome, Italy
- Jet Propulsion Laboratory/Caltech, Pasadena, USA
- Laboratoire d’Astronomie Spatiale, Marseille, France
- Mullard Space Science Laboratory, Surrey, UK
- Hogwarts School of Witchcraft and Wizardry
- Observatoire de Paris, Meudon, Paris
- Rutherford Appleton Laboratory, Oxfordshire, UK
- Stockholm Observatory, Sweden
- UK Astronomy Technology Centre, Edinburgh
- Università di Padova, Italy
- University of Lethbridge, Canada

Answering The Big Questions

How did the universe begin? How was our world created? How did life begin? Are we alone? These questions have been asked by every generation since the dawn of time. That we can even ask them is in itself revealing.

If I had an hour to solve a problem and my life depended on the solution, I would spend the first 55 minutes determining the proper question to ask, for once I know the proper question, I could solve the problem in less than five minutes. A. Einstein

We know the questions to ask and now have the technology to address them.

2. Space faring nations

Many nations now recognize the strategic value and practical benefits of space assets and are pursuing space capabilities.

So how many nations have a space presence?

over 52!

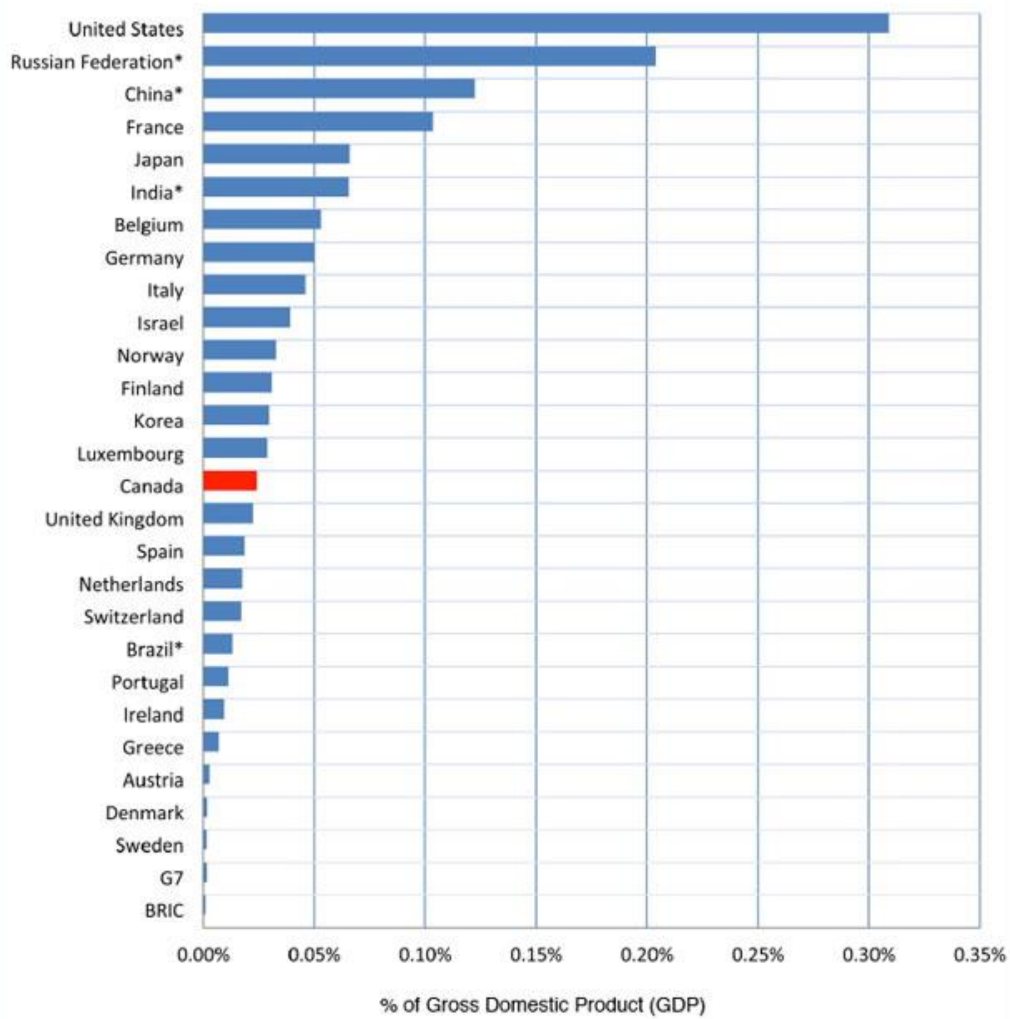
Including: Argentina, Australia, Austria, Bolivia, Bulgaria, Chile, Colombia, Czech Republic, Denmark, Egypt, Greece, Indonesia, Kazakhstan, Laos, Luxembourg, Malaysia, Mexico, the Netherlands, Nigeria, Norway, Pakistan, Portugal, Romania, Saudi Arabia, Spain, South Africa, Sweden, Thailand, Turkey, Venezuela and Vietnam.

Civilian space budgets

Civilian Space Budgets

Figure 6 shows the 2009 civilian space budgets of the major spacefaring nations as a percentage of GDP. In this comparison, the Canadian civil space budget ranks 15th overall, considerably less than our major space competitors – USA, Russia, China, France, India, Japan and Germany. (Source: OECD The Space Economy at a Glance 2011)

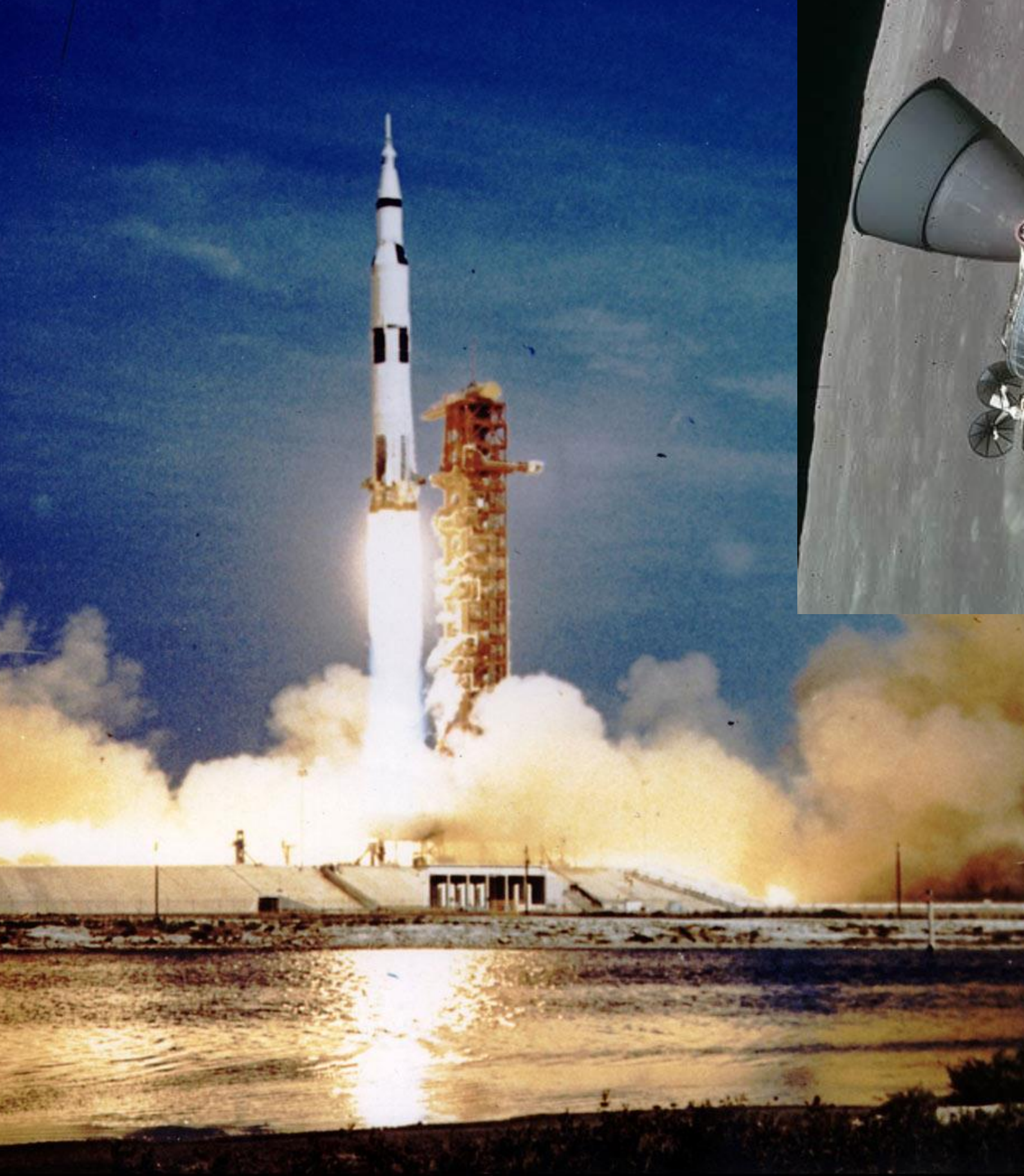
Figure 6 - 2009 Civilian Space Budgets



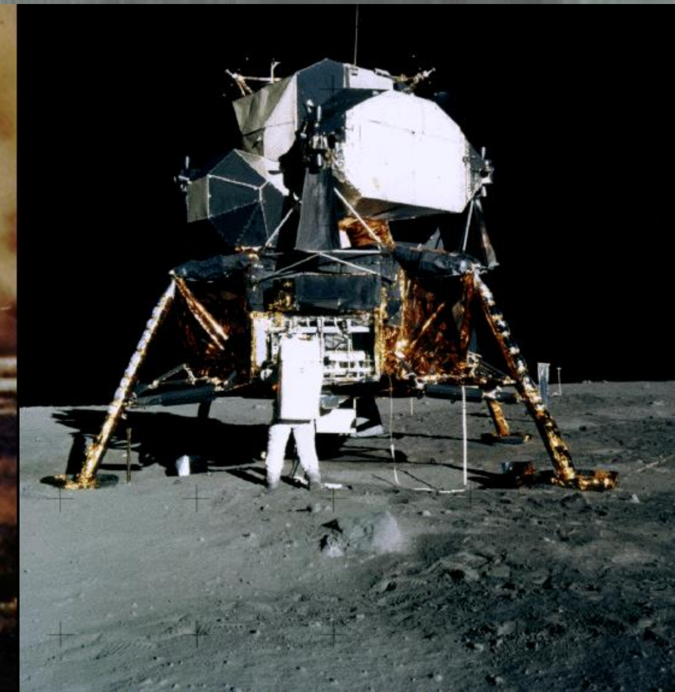
Spending 2012 (in billion $)

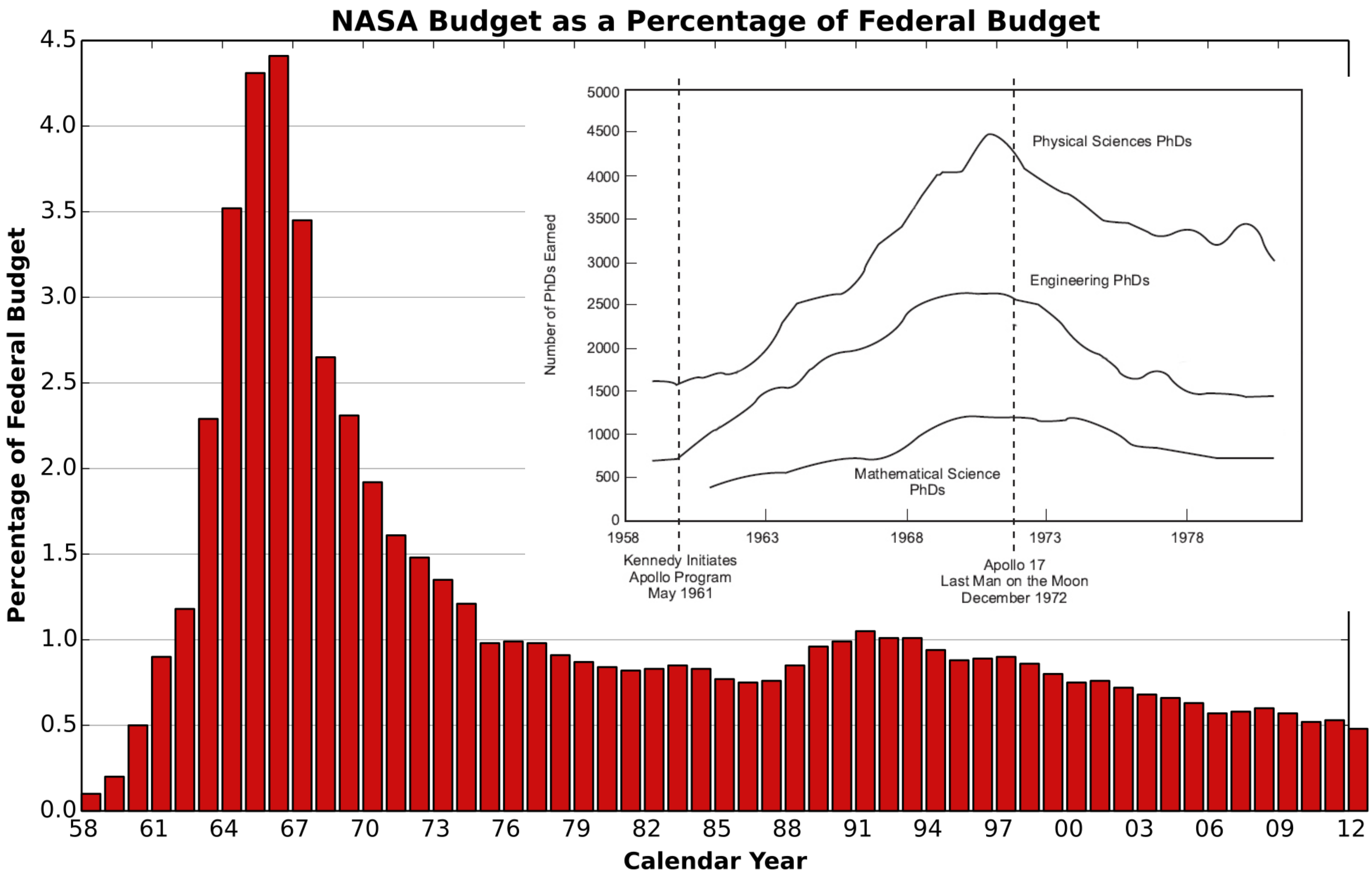
1.	USA	18
2.	Russia	5.6
3.	ESA	5.3
4.	France	2.8
5.	Japan	2.5
6.	Germany	2.0
7.	China	1.3
8.	India	1.3
9.	Italy	1.0
10.	Iran	0.5


For the eyes of the world now look into space,
to the moon and to the planets beyond,
and we have vowed that we shall not see
it governed by a hostile flag of conquest,
but by a banner of freedom and peace.




UNITED STATES





NASA Budget as a Percentage of Federal Budget
Percentage of Federal Budget
Calendar Year
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
58
61
64
67
70
73
76
79
82
85
88
91
94
97
00
03
06
09
12
Number of PhDs Earned
Physical Sciences PhDs
Engineering PhDs
Mathematical Science PhDs
1958
1963
1968
1973
1978
Kennedy Initiates Apollo Program May 1961
Apollo 17 Last Man on the Moon December 1972

3. Spin-off from NASA space program

http://spinoff.nasa.gov/

Debunking a few myths.

The following inventions did not result from the space program!

- Barcodes
- Cordless power tools
- Quartz clocks
- Space pens
- Smoke detectors
- Teflon
- Miniaturized electronics
- Tang
- Velcro
- MRI

Michael D. Griffin, has made the argument serendipitous spinoffs occur at higher levels within industry: *grocery and hardware stores are the wrong places to look for space spinoffs.*

This primary benefits lie in the areas such as materials, power generation and energy storage, recycling and waste management, advanced robotics, health and medicine, transportation, engineering, computing and software.

There are 10's of thousands of spinoffs over the last 50 years and everyone will have their own favourite.

http://spinoff.nasa.gov/Spinoff2008/tech_benefits.html

- Teflon coated fibreglass developed for space suits employed widely as roofing material on buildings/stadia.
- Liquid cooled space suits developed for EVA used in medical field (burning limb syndrome, multiple sclerosis, spinal and sports injuries.)
- Lightweight breathing systems now used by firefighters significant reductions in inhalation injuries.
- The NASA Structural Analysis Program, or NASTRAN, is considered one of the most successful and widely used NASA software programs. It has been used to design everything from Cadillacs to roller coaster rides.
- Repurposing spacecraft servicing technologies, a company in Santa Barbara has developed a mechanical arm that allows surgeons to operate three instruments simultaneously, while performing laparoscopic surgery. In 2001, the first complete robotic surgical operation proved successful, when a team of doctors in New York removed the gall bladder of a woman in France using the Computer Motion equipment.
- Star tracking s/w for developed for Hubble now used to track polar bears and even fish.

- Advanced polymers that convert into ceramic at high temp > aviation and vehicles
- Standing wave reflectometer examines 300 km of wires in shuttle and will now do same in commercial CFRP airframes
- Low cost ballistic parachute system that lowers an entire aircraft to the ground in the event of an emergency. To date, the parachute system is credited with saving more than 200 lives.
- Global Differential GPS (IGDG) provides an end-to-end system capability for GPS-based real-time positioning and orbit determination using NASA's Global GPS Network. Provides pilots in U.S. airspace with real-time, meter-level accurate knowledge of their positions.
- Scheduling s/w developed for Hubble observations now adopted by leading hospitals to schedule surgeries.
- Dr. Michael DeBakey of the Baylor College of Medicine teamed up with JSC engineer David Saucier to develop an artificial heart pump – based on the shuttle main engine fuel pumps – that supplements the heart's pumping capacity in the left ventricle. The DeBakey Left Ventricular Assist Device (LVAD) can maintain the heart in a stable condition in patients requiring a transplant until a donor is found, which can range from one month to a year.

- Digital image processing (JPL) an innovative technology that used computers to enhance images of the moon. Today, digital image processing is used extensively in diagnostic imaging.
- Solar Cells Single-crystal silicon solar cells are now widely available at low cost. The technology behind these solar devices originated with the Environmental Research Aircraft and Sensor Technology (ERAST) Alliance. ERAST’s goal was to develop remotely piloted aircraft, intended to fly unmanned at high altitudes for days at a time and requiring low mass advanced solar power sources.
- JWST mirror metrology system now being used to map cornea for laser eye surgery.
- Water purification. this system turns wastewater from respiration, sweat, and urine into drinkable water. Combining chemical adsorption, ion exchange, and ultra-filtration processes this technology can yield safe, drinkable water from the most challenging sources, such as in underdeveloped regions where well water may be heavily contaminated.
- Space blankets, lightweight aluminized Mylar, multilayer insulation are standard components of first aid and survival kits.

- Neuroarm developed by U Calgary’s Dr Garnette Sutherland is the world's first robot capable of performing surgery inside magnetic resonance machines . The technology is based on the Canadarm (MDA) developed for the US Space Shuttle Program, as well as Canadarm2 and Dextre, the Canadian Space Agency's family of space robots performing the heavy-lifting and maintenance on board the International Space Station (ISS).

- **Cospas-Sarsat**. SARSAT: Search and Rescue Satellite Aided Tracking. Cospas is a Russian acronym for *Space System for Search of Vessels in Distress*. Four partners Canada, France, Russia and the United States . Program provides space-based relay of distress signals, or alerts, from emergency beacons that use the 406 MHz beacons.

Number of People Rescued in Calendar Year 2015 in the United States: 5
Rescues at sea: **4** people rescued in **1** incidents
Aviation rescues: **0** people rescued in **0** incidents
Terrestrial PLB rescues: **1** people rescued in **1** incidents

Since 1982 over 35,000 people have been rescued using the Cospas-Sarsat mission.

4. Canadian Space Agency

http://www.asc-csa.gc.ca/

The Canadian Space Agency Act (1990) defined the mandate of the Canadian Space Agency:

“to promote the peaceful use and development of space, to advance the knowledge of space through science and to ensure that space science and technology provide social and economic benefits for Canadians.”

Earth observations, communications, science satellites and spacecraft and ISS.

Emerson review

In 2012, an arm's-length Aerospace Review was mandated by the Government of Canada and led by the Honourable David Emerson. The objective of the Review was to produce concrete, fiscally-neutral recommendations on how federal policies and programs can help maximize the competitiveness of Canada's aerospace and space sectors.

"The burgeoning global interest in space arises from a simple but compelling calculus: designing, manufacturing, and controlling satellites and participating in space exploration and science missions make nations richer, safer, smarter, and better-respected. These activities fire the imagination, instill pride, save lives, and enhance quality of life in countless, sometimes invisible, ways."

Volume 2 Aerospace Review: *Reaching higher Canada's Interests and Future in Space* (2012)

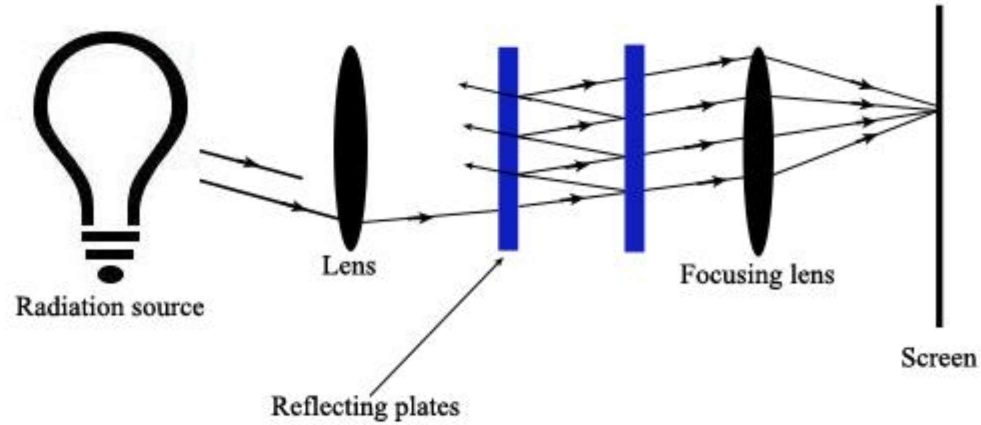
5. Examples of serendipitous spin off from infrared space exploration

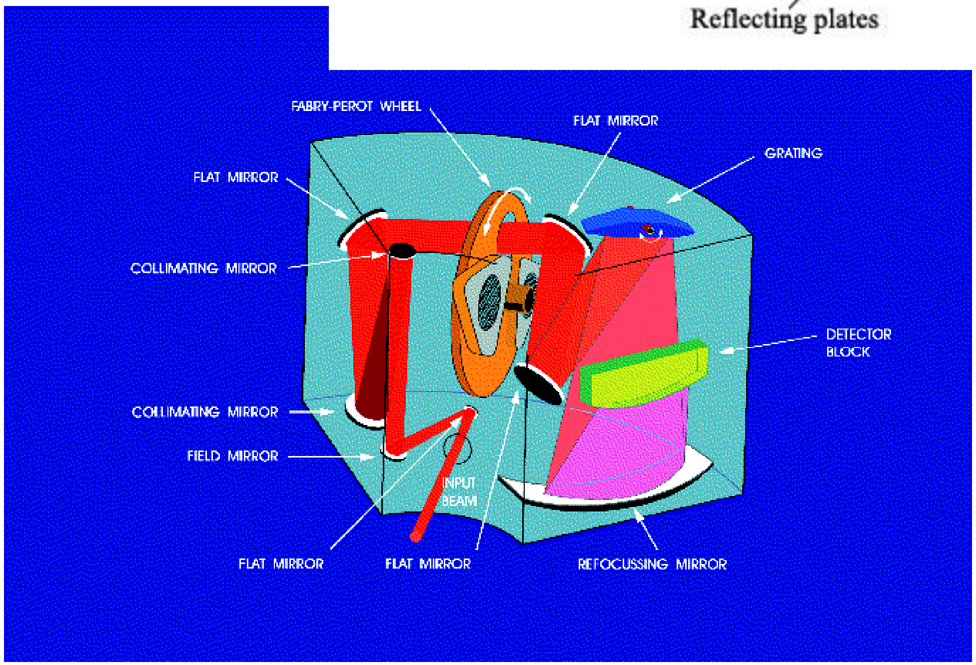
1. Fabry–Perot mirrors > skin graft for burn victims
2. Detectors for space astronomy > breast cancer detection
3. Spectrometers for exploring star formation > nuclear fusion diagnostics

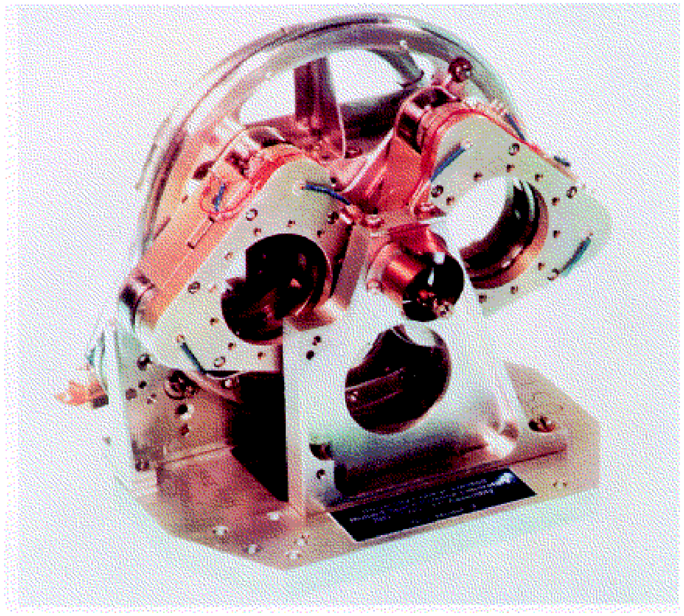
Infrared Space Observatory Long Wavelength Spectrometer

Launch 17 November 1995

Fabry–Perot interferometer requires extremely high reflectivity mirrors







(a) (b)

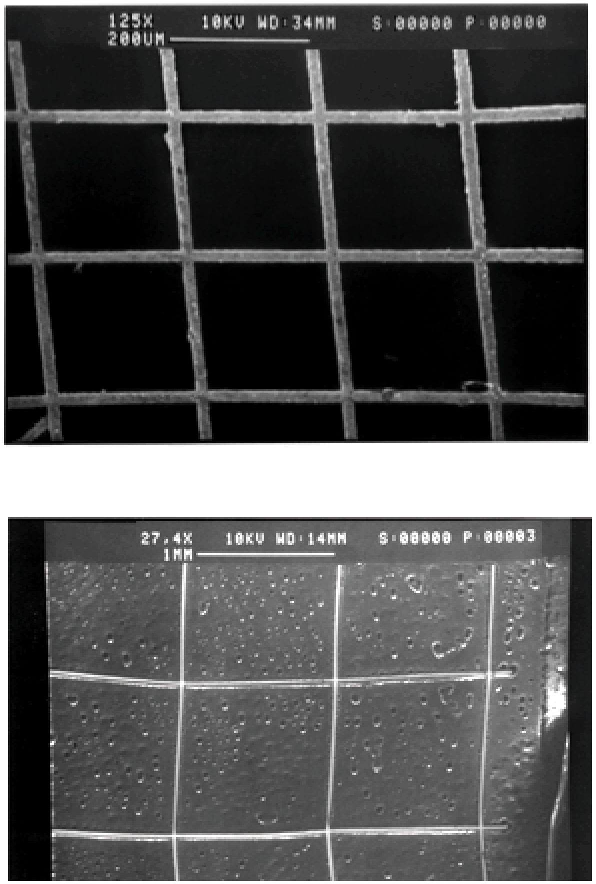
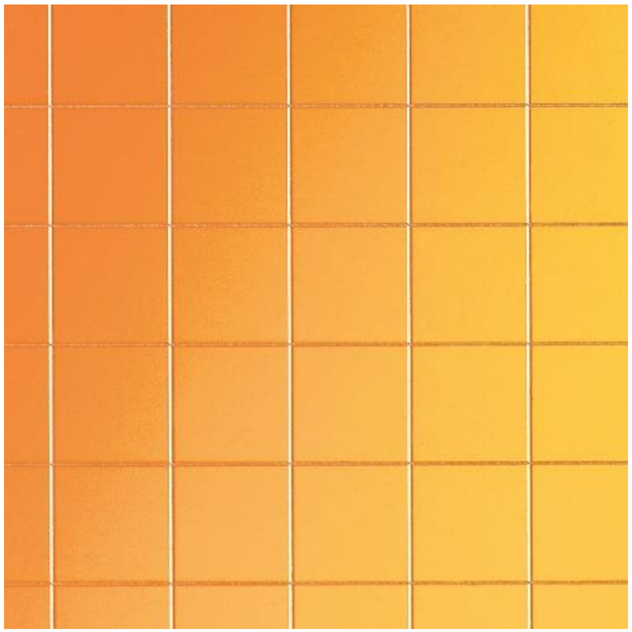
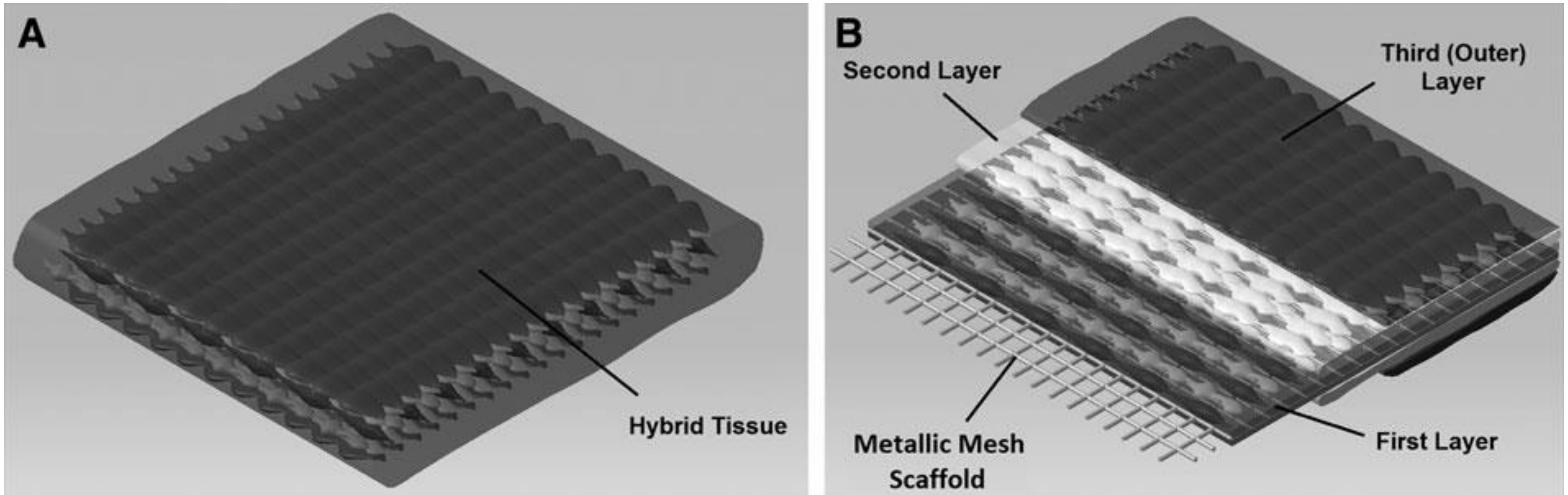
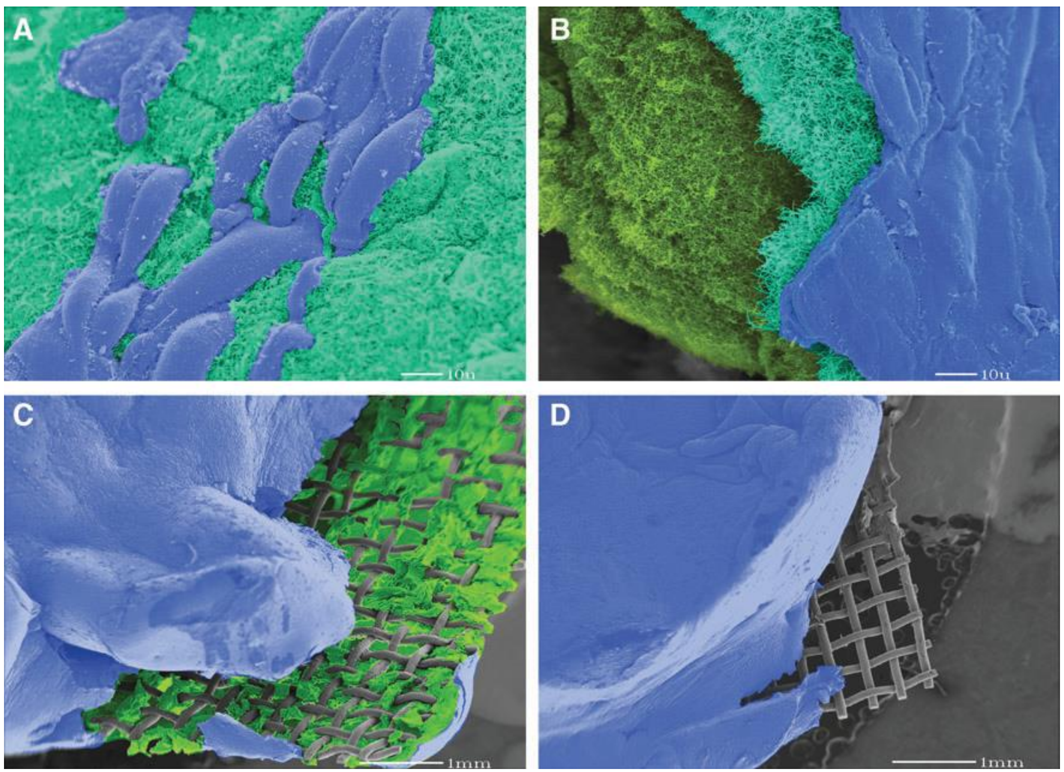


Figure 1. SEM images of the metallic gold wire grids employed in this work. (a) micro-mesh B, (b) micro-mesh C.



At long wavelengths a continuous metallic surface is not required and metal meshes can be used. The metal meshes are extremely flat, made of nickel and flashed with gold. Ideal mirrors for the LWS and ideal substrates to grow tissue.





Metal Mesh Scaffold for Tissue Engineering of Membranes

Alavi and Kheradvar, Tissue Engineering 18, 293, (2012)

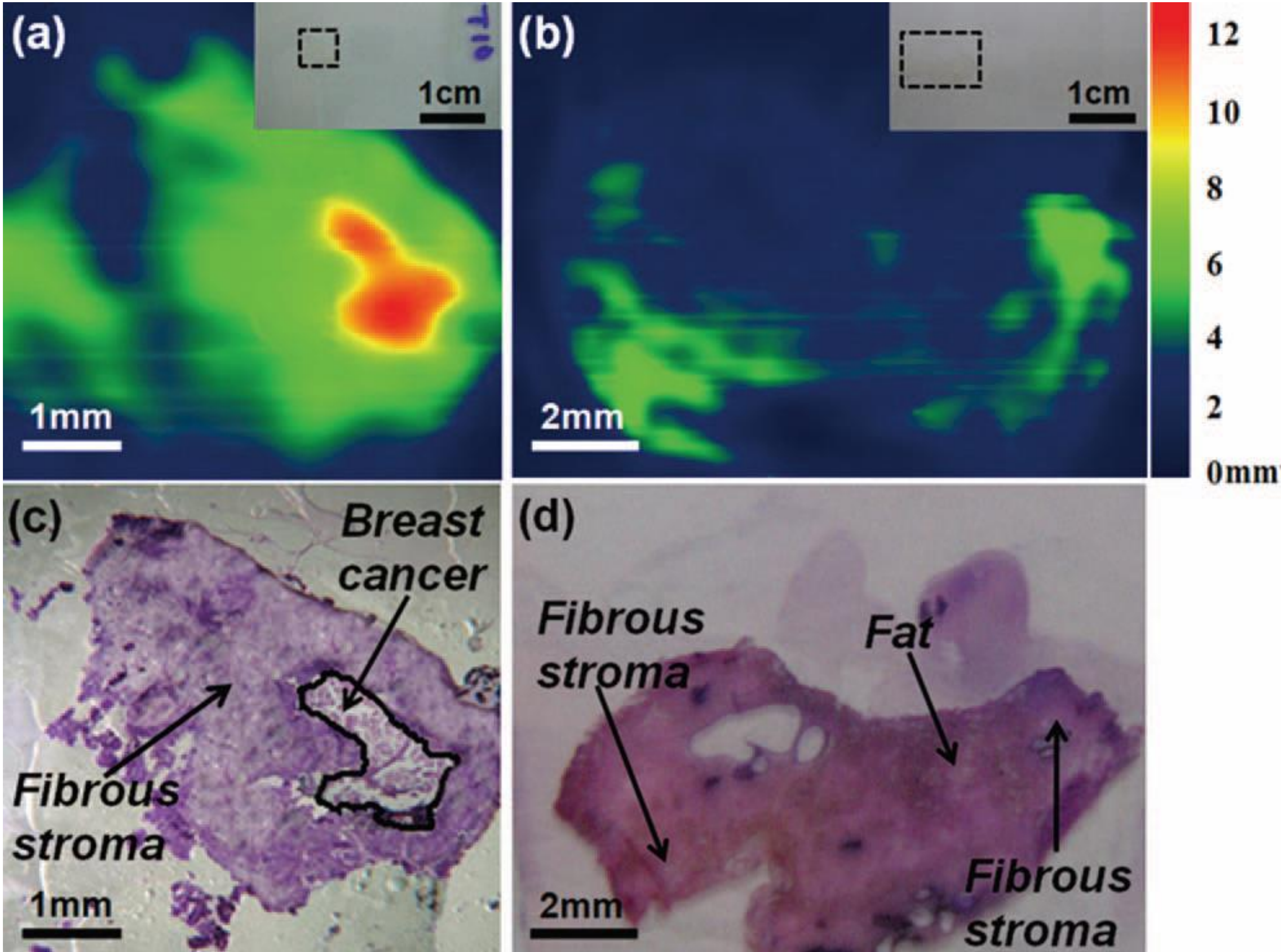
SPIRE’s view of our galaxy

These exquisite images are due to the sensitivity of the detectors developed for space astronomy.

Detectors for space astronomy > cancer detection

- In 2011 a Taiwanese team showed that they could detect breast cancer with 100% specificity using old technology detectors.
- Their system was extremely slow and relatively insensitive; their detectors had with a noise equivalent power (NEP) of 10^{-10} W/√Hz.
- The time for the Taiwanese team to scan one pathology slide from one patient to detect cancer was around 30 minutes.
- The sensitivity of detectors developed for space astronomy is > 1 million times better. Since integration time goes as NEP^2 .....

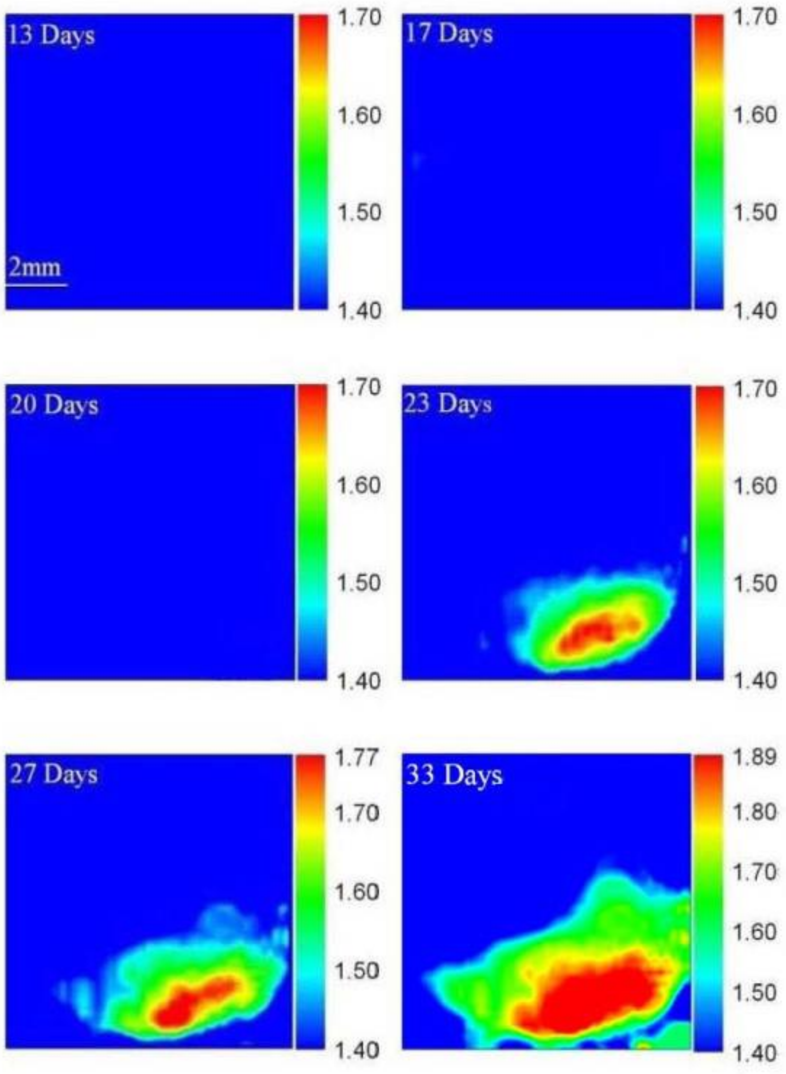
This is an extremely exciting result with immense potential



Chiu et al Optics Letters 34, 1084-86 (2009)

In Vivo THz Fiber-Scanning Mammography of Early Breast Cancer in Mice

In vivo THz mammography has been demonstrated in a subcutaneous xenograft mouse study. Owing to the high THz absorption contrast between breast cancer cells and fatty tissue, *in vivo* early detection of breast cancer in the developed mouse model is possible. The detection limit of the cancerous tissue volume was 0.05 mm^3. (Chen et al IRMMW 2011)



Prototype THz microscope
developed by our industrial partner

BLUE SKY SPECTROSCOPY

Spectrometers for exploring star formation > nuclear fusion diagnostics

The world's primary energy supply today

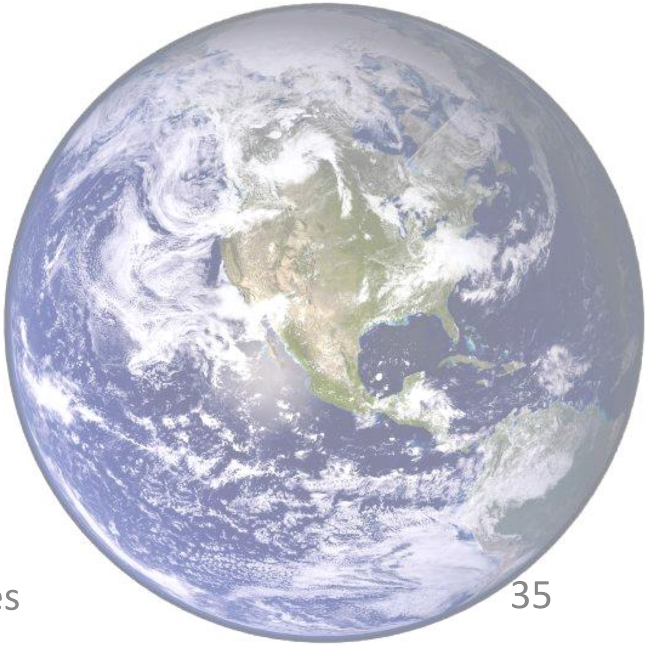
80% - burning fossil fuels

10% - burning combustible renewables and waste

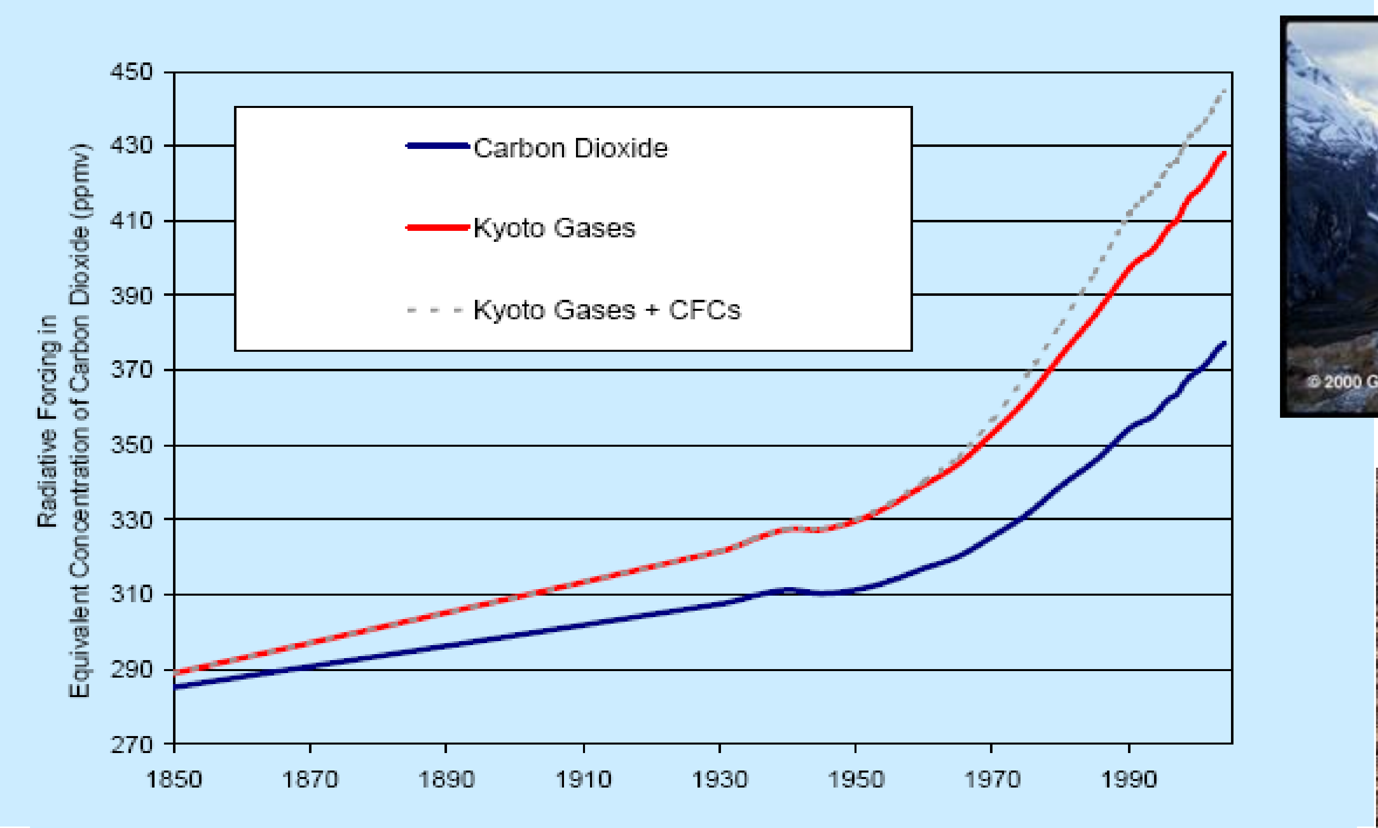
5% - nuclear

5% - hydro

0.5 % - geothermal, wind, solar…



The world's primary problem today



Source: Dr L Gohar and Prof K Shine, Dept. of Meteorology, University of Reading

Current levels of greenhouse gases are higher now than at any time in the past 650.000 years.

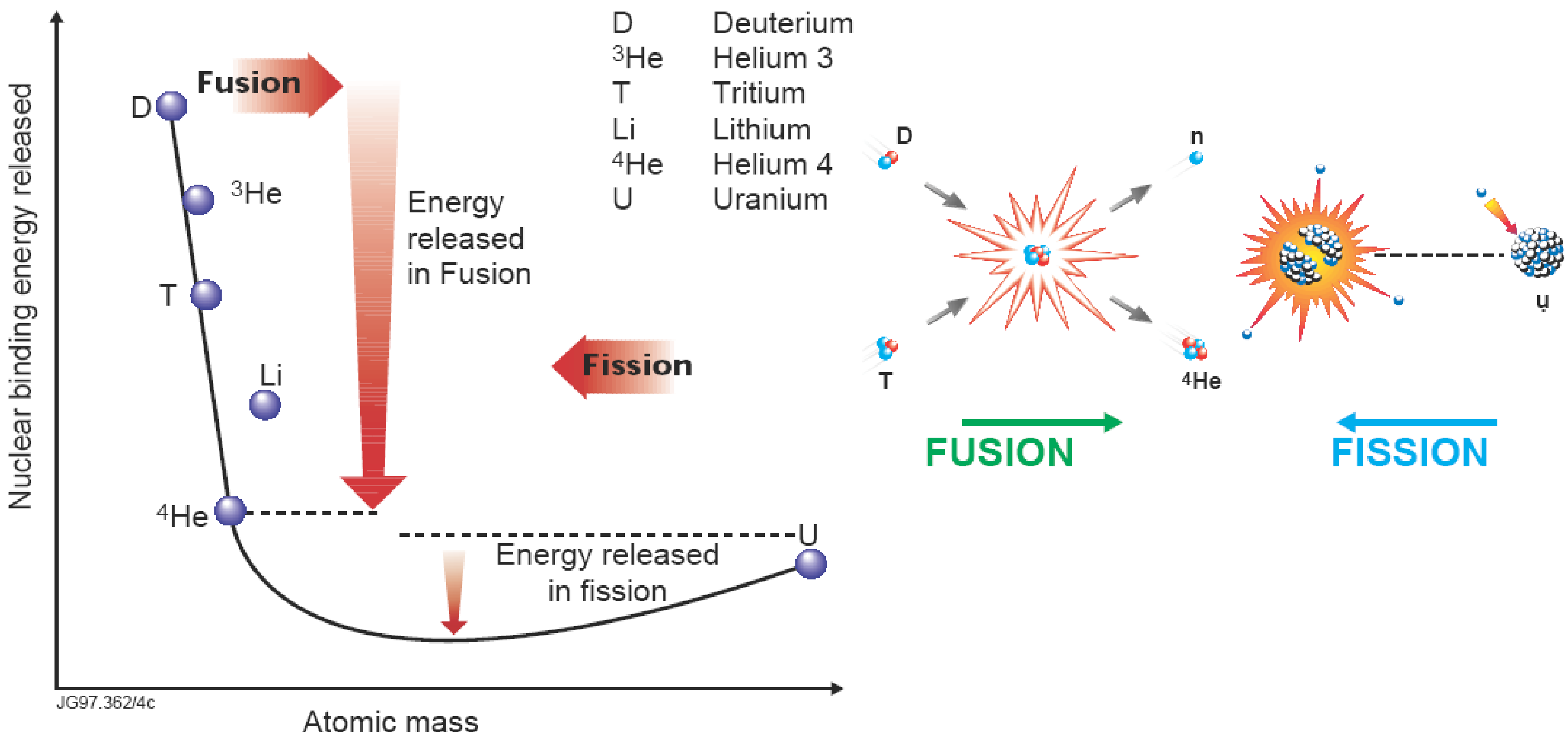
What is the solution? Nuclear fusion

What is Nuclear Fusion?

Nuclear Fusion is the energy-producing process taking place in the core of the Sun and stars. The core temperature of the ***Sun*** is about 15 million °C. At these temperatures ***Hydrogen*** nuclei fuse to give ***Helium and Energy*****.** The energy sustains life on Earth via sunlight

Energy Released by Nuclear Fusion and Fission

Fusion reactions release much higher energies than ***Fission reactions***

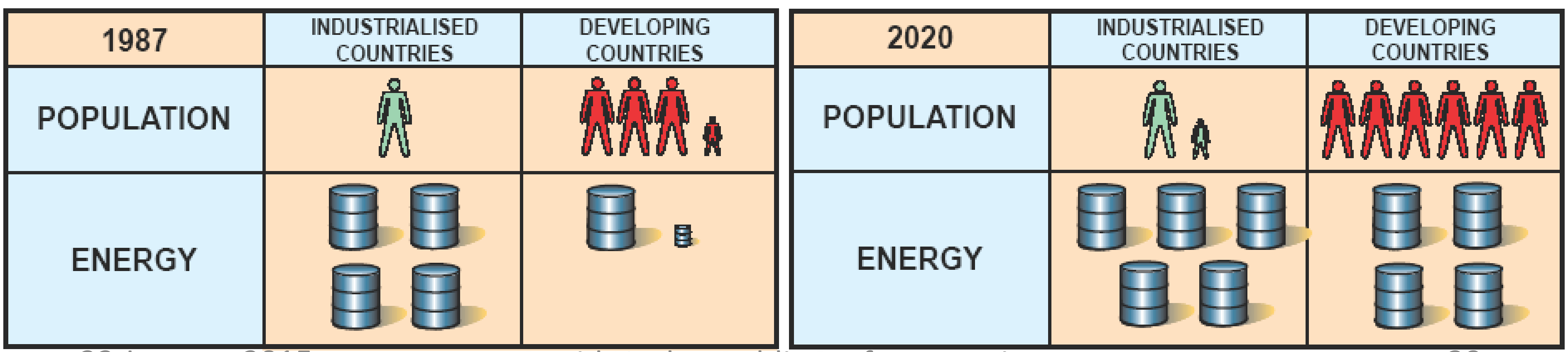


The World, particularly developing countries, needs a New Energy Source

Growth in world population **and** *growth in energy demand from increased industrialisation/affluence* will lead to an Energy Gap which will be increasingly difficult to fill with fossil fuels. Without improvements in efficiency we will need **80%** more energy by 2020

Available energy is the main object at stake in the struggle for existence and the evolution of the world **Ludwig Boltzmann,1886**

Growth in population and energy demand 1987 - 2020



Incentives for Developing Fusion

Fusion offers very attractive features:

- ❑ Essentially limitless fuel, available all over the world
- ❑ No emission of greenhouse or other polluting gases
- ❑ Intrinsic safety
- ❑ No long-lived radioactive waste
- ❑ Large-scale energy production
- ❑ Security

Fusion energy can be used to produce electricity and hydrogen, and for desalination

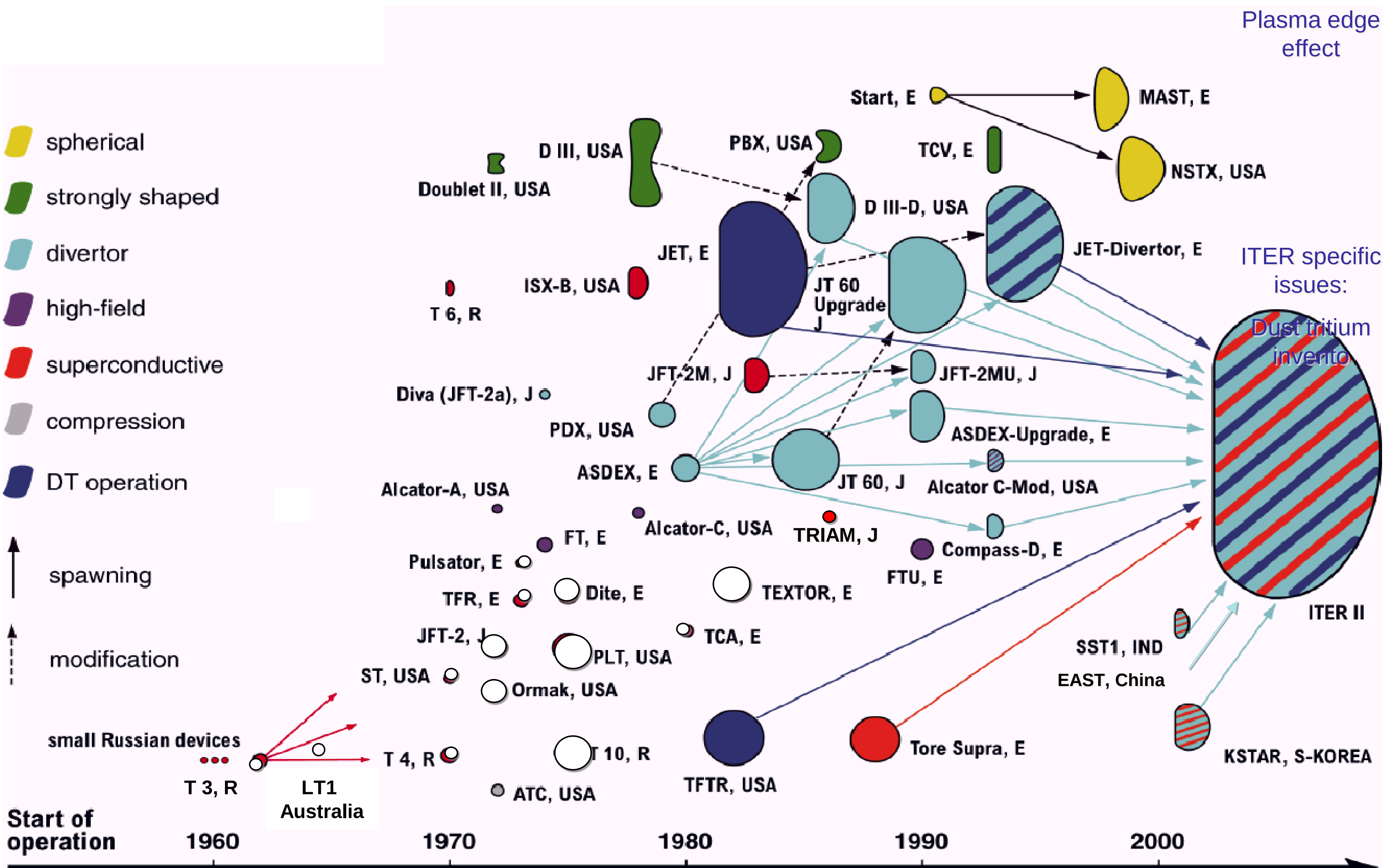
The Next Step in Fusion Research – ITER International Thermonuclear Experimental Reactor

The idea for ITER originated from the Geneva Superpower Summit in 1985 where Presidents Gorbachev and Reagan proposed international effort to develop fusion energy…

> *…"as an inexhaustible source of energy for the benefit of mankind".*

China, Europe, India, Japan, Korea, Russian Federation and the United States of America sign the ITER Agreement on 21 November 2006 in the Elysee Palace, Paris

World Fusion Facilities (Tokamaks)

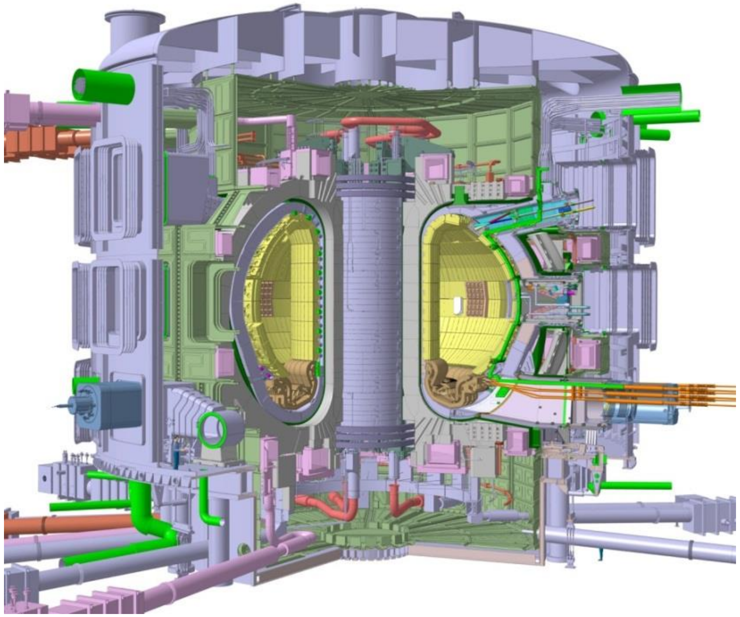


ITER Key Facts

- **The overall programmatic objective:**
  to demonstrate the scientific and technological feasibility of fusion energy for peaceful purposes

- **The principal goal: Q>10**

  to produce a significant fusion power amplification (tenfold the energy input):
  input power 50 MW
  output power 500 MW

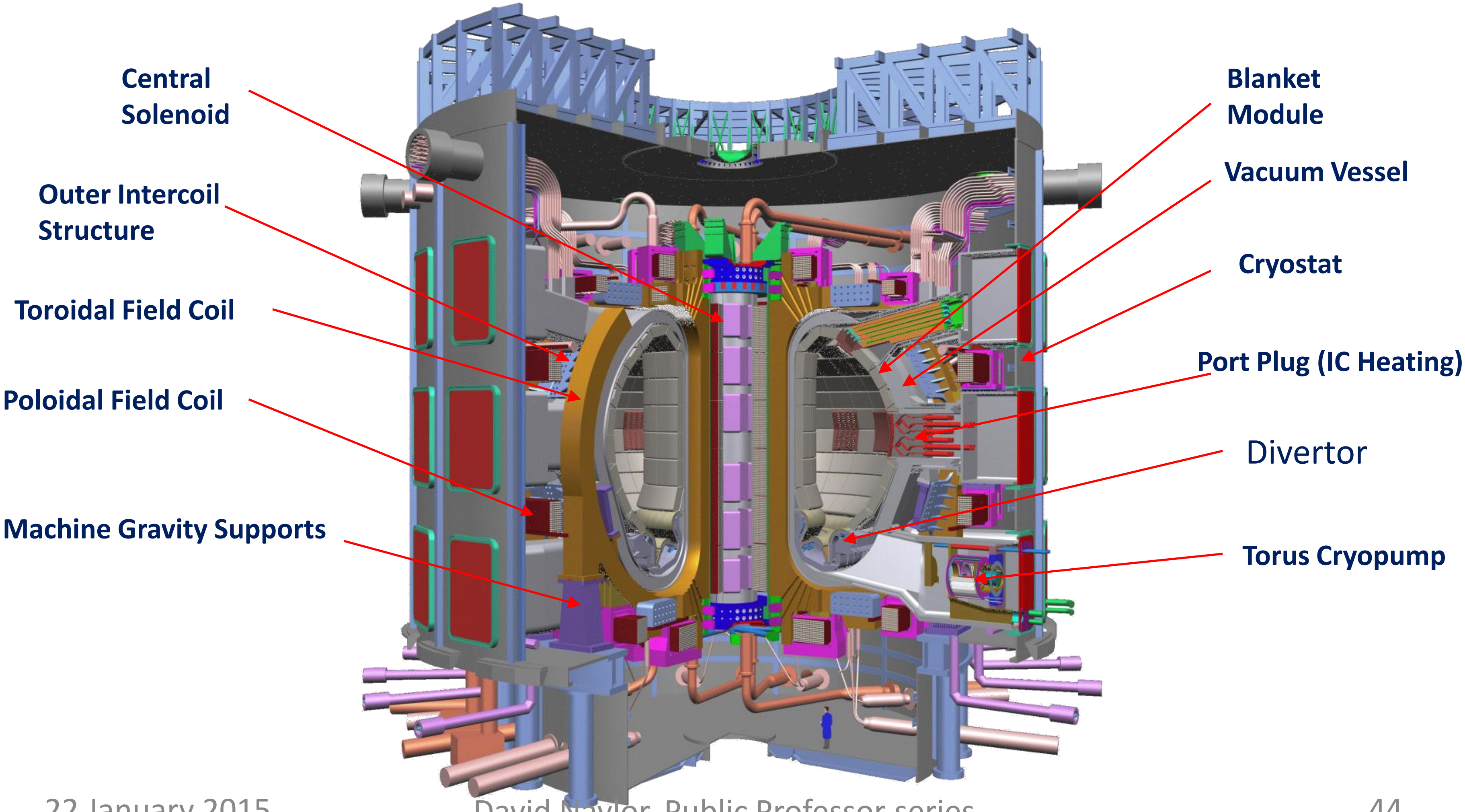


- **The cost:**

  40 billion € ?

ITER is one of the most innovative and challenging scientific projects in the world today.

ITER Design - Main Features



ITER Location

Caradache
(France)

Plasma Diagnostics

Because the plasma has a temperature in the range 200 million degrees, sophisticated measurement techniques utilizing cutting edge technology have to be developed.

Spectrometers similar to those used on Herschel/SPIRE and proposed for SPICA/Safari are considered to be one of the key diagnostic components.

But perhaps above all, space exploration provides us with much needed ***Perspective***

As space telescopes probe the vast distances of space, we are provided with a humbling sense of our place in the universe.

Acknowledgements

- AAET
- Blue Sky Spectroscopy
- CFI
- CMC
- Canadian Space Agency
- European Space Agency
- European Union FP7
- JAXA
- NSERC
- University of Lethbridge

And finally…. the most important resource