Science & Technology Facilities Council

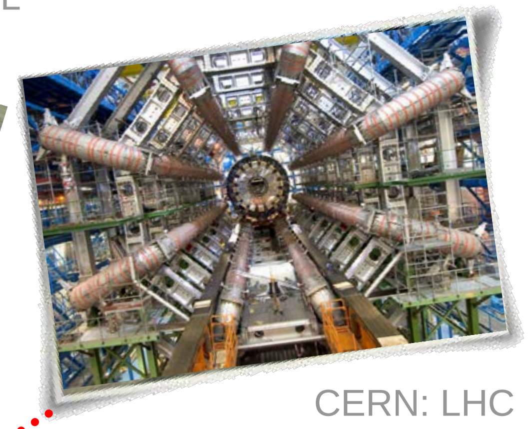
Impact of the Tevatron on Technology and Innovation

John Womersley
Chief Executive, STFC
11 June 2012

The Science & Technology Facilities Council

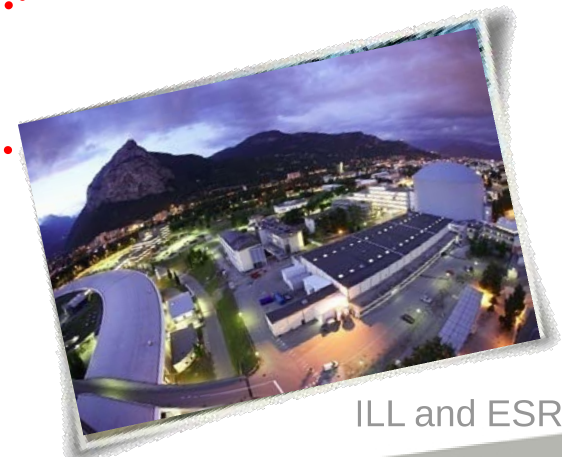
JCMT Telescope

Research in UK universities,
RAL and DL



CERN: LHC

ESA: Top Sat



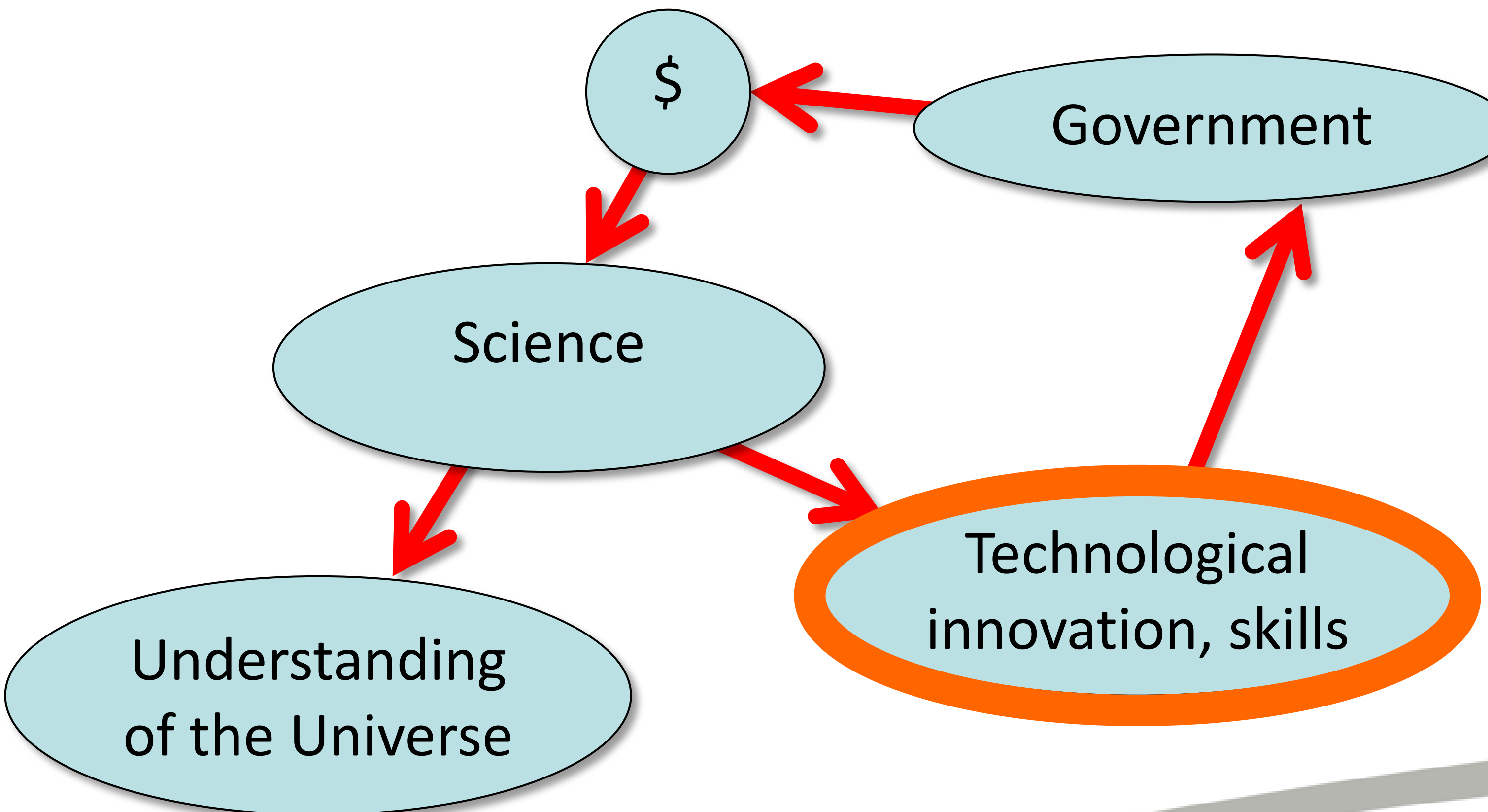
ILL and ESRF

ESO: Alma Array

Science & Technology
Facilities Council


10

Why do governments support science?



Science & Technology Facilities Council

Impacts

- Can we try to measure the payoff from the investment made in the Tevatron?
  - At least in the UK, case studies and examples are not enough: quantitative arguments are needed

- Focus on three particular areas
  - PhD students
  - Impact on SC magnet technology
  - Impact on Computing technology

Health Warnings

- Hand Waving

- Back of envelopes

Science & Technology Facilities Council

Debits

What did the Tevatron cost?

- Tevatron accelerator
  - $120M (1983) = $277M (2012 $)
- Main Injector project
  - $290M (1994) = $450M (2012 $)
- Detectors and upgrades
  - Guess: 2 x $500M (collider detectors) + $300M (FT)
- Operations
  - Say 20 years at $100M/year = $2 billion
- Total cost = **$4 billion**

Science & Technology Facilities Council

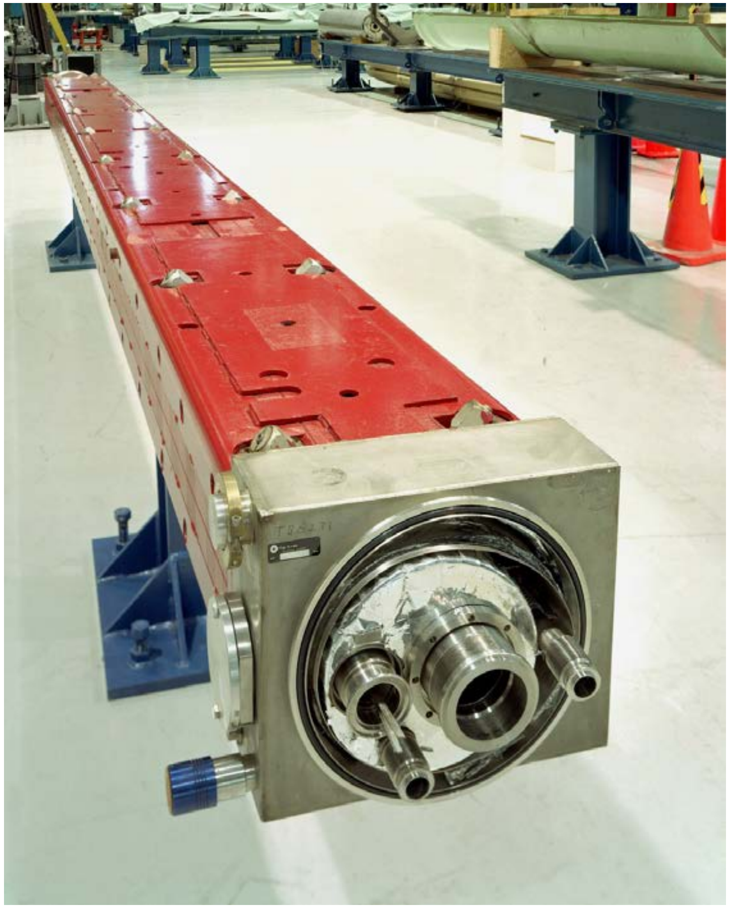
Credits

PhD Student Training

- Value of a PhD student
  - $2.2M (US Census Bureau, 2002) = $2.8M (2012 $)
- Number of students trained at the Tevatron
  - 904 (CDF + DØ)
  - 492 (Fixed Target)
  - 18 (Smaller Collider experiments)
  - 1414 total
- Financial Impact = **$3.96 billion**

Science & Technology Facilities Council

Superconducting Magnets



- Tevatron was the first installation of mass-produced superconducting magnets on an industrial scale

Superconducting Magnets

- National medal of Technology (1989)

- Historic engineering landmark (1993)

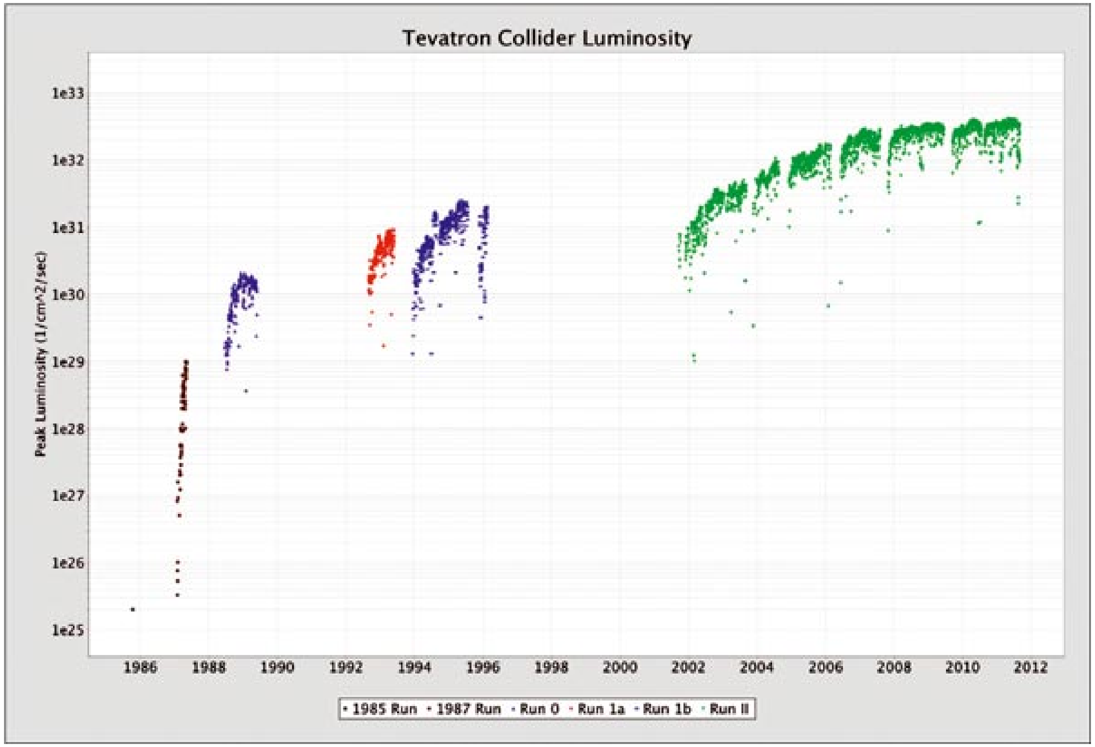
Science & Technology Facilities Council

Superconducting Magnets

- Current value of SC Magnet Industry
  - $1.5 Billion p.a.
- Value of MRI industry (major customer for SC magnets)
  - $5 Billion p.a.
- This industry would probably have succeeded anyway – what we can realistically claim is that the large scale investment in this technology at the Tevatron significantly *accelerated* its development
  - Guess – one to two years faster than otherwise?
- Financial Impact = **$5-10 billion**

Science & Technology Facilities Council

Computing



- Increases in luminosity – driven by physics – created the challenge of processing ever larger datasets

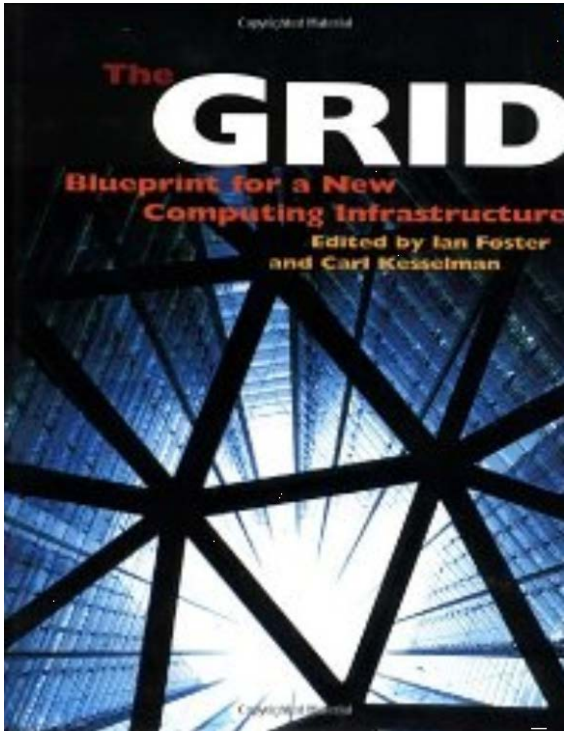
Computing – Linux PC farms

- MicroVAXes
- Unix Farms in Run I
- Computing requirements for Run II led to pioneering adoption of PC Farms running Linux for large scale data handling
  - Fermilab PC Farm Exhibit in Supercomputing Conference SC 1997
  - Linux Torvalds and Red Hat CEO Robert Young visit Fermilab; Fermi Linux released 1998
- More than 90% of the world's supercomputers now use Linux

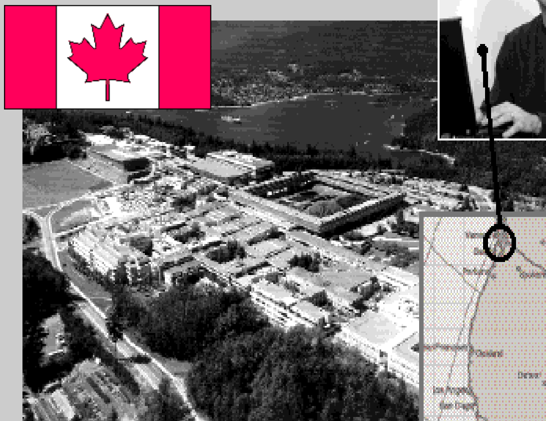
Science & Technology Facilities Council

Distributed Computing

- Concept of Computing as a Utility
  - "The Grid" (1998)
- Grid resources used for Monte Carlo generation and large scale reprocessing of Run II data
  - DØ data shipped over the internet to Canada, France, Germany, Netherlands UK, and US universities, and processed data shipped back



DZero

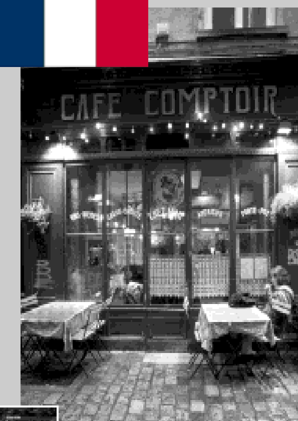


SFU campus on Burnaby Mountain, Vancouver

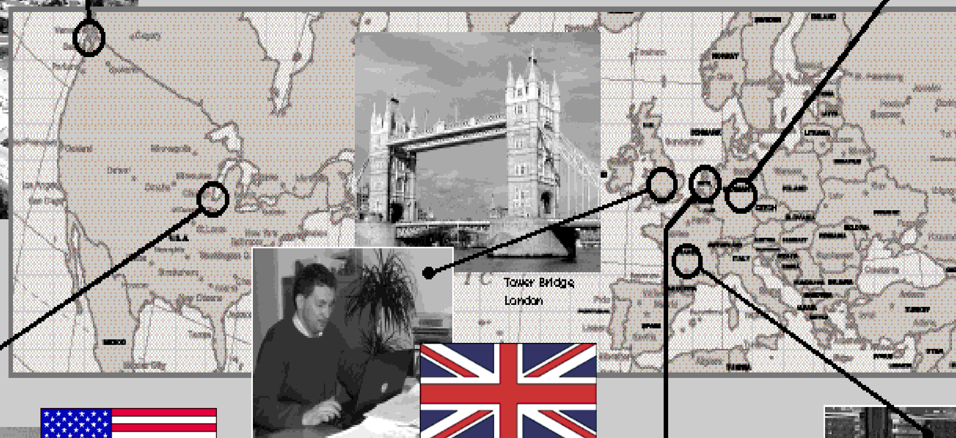
"You can't make the Grid work without motivation. It's one thing to have a vision, and it is another thing to stay up to three in the morning to make things work because they need to get done. DZero is a real application. We need to get the physics results out."
– Dugan O'Neil, Simon Fraser University, Canada

Wuppertal's landmark, the elevated train line

"In the past, particle physics collaborations have used remote computing sites to carry out Monte Carlo simulations. We are now one of the first experiments to process real data at remote sites. The effort has opened up many new computing resources. The evaluation of our experience will provide valuable input to the Grid development."
– Daniel Wicke, University of Wuppertal, Germany



Street scene in Lyon



Tower Bridge, London

"The machines at Imperial College, for example, are shared across the whole college, so it takes grid software to keep it all running smoothly." – Gavin Davies, Imperial College London, UK

"We've participated in large-scale Monte Carlo production in the past, but data reprocessing involves large volumes of data to be transferred in both directions on a scale that was simply unthinkable a few years ago. It will open new possibilities that we are only beginning to explore."
– Patrice Lebrun (right), with Tibor Kurca, CCIN2P3, Lyon, France

"With the SAM software developed by the Fermilab Computing Division and DZero, a user doesn't know whether the data is stored on tape or on disk, whether it is located at Fermilab or at Karlsruhe."
– Wyatt Merritt (left), with Mike Diesburg and Amber Boehnlein, Fermilab, U.S.A.

Chicago skyline

Amsterdam, famous for its canals

"The re-processing was a major milestone for DZero. For us it is also important that we have been able to show that we can really use the LHC Computing Grid for DZero processing. We saw jobs submitted from Wuppertal being executed on our CPUs, and we executed jobs in Karlsruhe, at Rutherford Appleton Laboratory and a few more places."
– Kors Bos (front row, second from left) and the Scientific Computing team at NIKHEF, Amsterdam, Netherlands

Ferminews 2004

Cloud Computing

- Remotely accessible Linux farms are now a commercial service
  - Amazon etc.

Cloud Computing

- Value of Cloud Computing Industry today
  - $150 Billion p.a. (Gartner)
- This industry would definitely have succeeded anyway – but let's assume that the stimulus given by the Tevatron experiments, work with Red Hat etc. gave just a *3 month* speed-up to its development
- Financial Impact = **$40 billion**

Balance sheet

- 20 year investment in Tevatron ~ $4B
- Students $4B
- Magnets and MRI $5-10B } ~ $50B total
- Computing $40B

Very rough calculation – but confirms our gut feeling that investment in fundamental science pays off

I think there is an opportunity for someone to repeat this exercise more rigorously

cf. STFC study of SRS Impact

www.stfc.ac.uk/About+STFC/19005.aspx

Science & Technology Facilities Council

Global collaboration in HEP

- Tevatron experiments were also pioneers in establishing a genuine partnership between US, Japan and Europe
- We need this approach again now
  - CERN Council European Strategy Process
  - US community process
  - Japanese roadmap under development

- Breakthrough discoveries coming
  - opportunity to shape a **science-driven** strategy

Global collaboration in HEP

- Needs to be a **global** strategy
  - Complementary pathways through a common landscape
  - CERN's focus will be on energy frontier at LHC
  - Main questions: how (and where) to progress neutrino physics, precision measurements and astroparticle physics?

- I hope other regions will see the scientific logic and political importance of supporting a strong US program in these areas

Conclusions

- Especially in tough economic times, the non-science impacts of major projects are an important part of the case we must make
  - "What will it do for jobs and economic growth?"
- Impacts tend to be long term and unpredictable – so one way to make the case for future investments is to look back at the benefits from past examples
- Here I've tried to make a plausible case that the Tevatron has returned its investment roughly **tenfold** over its life
  - A more detailed study along these lines may well be worthwhile