IOP Publishing

Commercialising Fusion Energy
How small businesses are transforming big science
William J Nuttall, Satoshi Konishi, Shutaro Takeda and David Webbe-Wood

Chapter 13

Conclusions

William J Nuttall, Satoshi Konishi, Shutaro Takeda and David Webbe-Wood

In this book, we have seen that the field of fusion science and technology is in the midst of profound change. This change has several dimensions, including: the increased involvement of the private sector in fusion development; that large publicly-funded projects are actively being prepared in anticipation of commercial technology demand; and that the energy industry has started to consider a role for fusion as part of their own transition to a low-carbon economy.

Fusion has tended to see technology requirements as presenting challenges in the decades' long journey from fusion science to fusion engineering. However, technology is increasingly finding a role as an enabler, whether that is the materials science of high-temperature superconductivity facilitating the development of high field tokamak devices or the use of computer vision and rapid digital control for the precise positioning of targets in inertial confinement fusion systems. Another shift underway is visible in investors' attitudes, be they wealthy individuals concerned for the climate emergency or financial institutions conscious of the fiduciary duties to mitigate risks related to our energy future. Finally, we are seeing a shift in individual enthusiasm. Increasingly young researchers and technologists are attracted to the sheer technical difficulty of fusion. Once the realization dawns that fusion may not be as difficult as it was once perceived to be, then their motivations start to shift from bold ambition to quiet confidence.

As one enters the development labs emphasized in the pages of this book, one does not encounter researchers working on decades-long projects destined for success in the distant future; rather, one has a sense of immediacy concerning the challenges and the opportunity.

We trust that this book has managed to make the case that the third decade of the 21st century has the prospect of seeing genuine progress in fusion commercialization. It seems probable that any such progress will be based upon fundamental physics that has been known for more than 50 years but was impossible to engineer until recently. Reading through this book, readers may find key enabling

doi:10.1088/978-0-7503-2719-0ch13

technological innovations that could be relevant to fusion commercialization including, but not restricted to:

- Practical high-temperature superconductors;
- For experiments: high-speed data processing and responsive instrumentation;
- For theory: affordable high-powered computing for modelling;
- Computer-aided design and manufacture;
- Advanced materials for hostile environments.

It would be wrong, however, to conclude that the emergence of commercial fusion enterprises has simply been a consequence of new materials and technologies. We suggest that the timing is not accidental and hence we posit that the following historical trends have been important.

- The early 1990s saw the end of the Cold War and the winding down of much of the military-industrial complex. This combined with a wave of economic liberalization that saw the privatization of many state-owned industries and the closure of many national laboratories, especially in the energy sector.
- The late 1990s were known for the emergence of a range of internet companies in the 'dot-com' boom. These companies absorbed investment capital, but much was lost as the boom became a bubble, and then it burst. Russia, once a superpower, was having a difficult time.
- The period 2000–2010 saw the 9/11 terrorist attacks on the United States and the subsequent 'War on Terror.' Despite the conflicts and tension, western economic growth was strong, and there was growing pressure on energy resources. China started to emerge as a major global economy and source of energy demand. The threats to the global climate were becoming clear to policy-makers.
- The decade 2010–2020 started with a severe global economic shock following the collapse of Lehman Brothers in the US. The banking bailouts were expensive, and austerity took hold in many major economies. We posit that public R&D, already a shadow of its former self, now hunkered down into defensive conservatism. Private capital was still available, but orthodox returns on investment were poor. Those who were 50 years old in 2015 had been amongst the youngest to see Neil Armstrong and Buzz Aldrin walk on the Moon in 1969. They had expected a world of bold, scientific endeavour based on large machines such as space-ships and fusion power plants. Many of this generation had become rich in the innovations that did occur in bio-medicine, mobile communications, software, and e-commerce. This reality extended below the famous billionaires now known for pioneering commercial space flight, but it also includes millions of millionaires curious about bold initiatives that somehow did not happen in the period 1990–2020.

We posit that there is now money available ready to absorb the extreme risks of a fusion energy proposition. We note the 2020 coronavirus pandemic and agree it will shape thinking for years to come, but we hope that rather than heralding a major economic collapse, it will merely be another future concern alongside climate

change, terrorism, and cybersecurity. Fundamentally the new bold climate for innovation will be maintained. Noting the uncertainties facing the world, we expect that clean, safe, local and affordable fusion energy will remain a most attractive investment proposition for those with money, a desire to make a difference and an acceptance of risk. Noting the convergence of technology with an enthusiastic investment culture bodes well for fusion commercialization in the 2020s.

We close the book with an observation and a related question. Professor Ian Chapman of the UKAEA Culham Laboratory has described fusion energy research with the words: 'Fusion is probably the most collaborative field of science in the entire world' [1]. By way of illustration, he adds:

> It [ITER] is the most collaborative science project ever undertaken by humankind and it will demonstrate, we hope, that fusion really works on a commercial scale and can produce a lot more energy out than you have to put in to get the reaction going in the first place [1].

This culture of international openness and collaboration has been a major strength of the publicly-funded global fusion community. Indeed, the ITER experiment highlighted by Professor Chapman first arose as a result of a high-level political agreement between the leaders of the two superpowers of the Cold War. President Ronald Reagan of the United States and Premier Mikhael Gorbachev of the Soviet Union initiated the ITER programme at the Geneva Superpower Summit held in November 1985 [2]. If the USA and USSR could work together on high technology nuclear research and in this way nucleate the global collaboration we see today, then fusion has found a central place in the history of scientific co-operation.

Thirty-five years after the Geneva summit, we are now far closer to commercial development. The spirit of open and generous collaboration (with, for example, completely open intellectual property availability) is now starting to transition to the more competitive landscape of the commercial energy business. The start-up companies of the early 21st century are identifying key aspects of intellectual property, such as in high-temperature superconductors or in digital system monitoring and control. They are keen to realise the value of these innovations outside the fusion sector. Fusion needs these high technology innovations but it will not be the only sector needing these innovations and with a willingness to pay for them.

Finally, as we have seen in this book, the fossil fuel energy industry in transition is truly waking up to the potential of fusion with a sense of purpose not seen previously. We note the comments of the energy industry, including [3]:

- 'We see fusion technology as a promising, low-carbon future energy source,' Barbara Burger, president of Chevron Technology Ventures, 2020
- '(We are investing in fusion and a fusion start-up) because we believe in the technology and the company, and we remain committed to providing energy to the world, now and in a low-carbon future,' Sophie Hildebrand, Equinor's Chief Technology Officer, 2018

This book focuses on the fusion energy research and development sector in transition. That transition sits in the broader context of an energy transition where energy experts now see the beneficial attributes of fusion. For fusion, a key observation is perhaps that the greatest opportunities come from fixing other people's problems. Decarbonizing mobility, heat, and IT services represent a global challenge that provides nothing but opportunity for those seeking the commercialization of fusion energy.

References

[1] Lamont A 2020 *BP Technology Outlook Nuclear Fusion – Technology Special* (London: BP) (https://bp.com/en/global/corporate/what-we-do/technology-at-bp/technology-outlook.html)

[2] ITER Organization 2020 *The ITER History* (France: St. Paul-lez-Durance) (https://iter.org/proj/ITERHistory)

[3] Deign J 2020 Why are oil and gas companies investing in nuclear fusion? (https://greentechmedia.com/articles/read/why-are-oil-and-gas-companies-investing-in-nuclear-fusion)