17. *Engineering Empires: Chaps 1–2*

1. **Cultural History of Technology**

*Whig history*

"...the history of the winning side, valuing the past only where it matches, or approaches, the present, and all but ignoring the 'failures', 'dead-ends' or paths not taken, except where they stand as salutary reminders of the extent of human folly, nurtured by arrogance or fashion". (MS05, pg. viii.)

"A central aim of our book... is to highlight the cultural contingencies which shaped the varied technologies of empire in the long 19th century [~1760–WWII]." (MS05, pg. ix.)
Types of history of technology:

(i) Popularized accounts: "...the inexorable march of material technological progress; the individual triumph over adversity and the forces of conservatism; and the moralized life of the engineering 'visionary', outside—and yet ahead of—his (always his) time."

(ii) Economic accounts: quantitative analyses of technologies based on "economic impact".

(iii) Antiquarian accounts: "Internal", detail-specific accounts, as opposed to "external" accounts of broader meanings or patterns of use.

Cultural history = "the study of the construction (or production) and the dissemination (or reproduction) of meanings in varying historical and cultural settings."
Is there a distinction between "technology" and "culture"?

- Does technology produce culture, or does culture produce technology?

"...we might instead prefer to see 'technology' and 'culture' in simultaneous reciprocal transformation—each involved in the other's production and each conferring meaning on the other." (MS05, pg. 5.)

"We accept, therefore, historical contingency rather than assuming the inevitable success of certain projects or technologies, especially those subsequently found to have been 'successful', in some sense, in the long term." (MS05, pg. 5.)

Interpretive flexibility = the idea that different social groups interpret a technology differently according to their own local needs and demands.

"The eventual stabilization of a technology in one particular form, and with one particular meaning, is as much a social event as a material one." (MS05, pg. 5.)
**Technological system** = network of societal, cultural, political, and material relations surrounding the design and deployment of a technology.

"...we gain interrogative purchase and narrative power, as historians, by considering technologies as complex systems of heterogeneous elements, given collective meaning by and within their social milieus." (MS05, pg. 8.)

"Our study, then, attempts to penetrate the black boxes of 'steam-power', 'steamship', 'railroad' and 'telegraph' to see each of those 'tools of empire', not simply as a fixed product with a given role, but also as a dynamic system, formed according to the contexts of exhibitions, experiments, standardization and so on, for varied and specific ends including empire—but not limited to it." (MS05, pg. 11.)
2. Exploration, Mapping and Measurement

- **Cultural background in Great Britain**

  "...a gentlemanly culture which found expression in the Whig party and its adherents, in metropolitan learned societies, and, increasingly, in provincial literary and philosophical societies."  (MS05, pg. 13.)

- Cultural values of the scientific revolution (17th century):
  - "experiment, reliably undertaken and properly communicated by men of status; trust in observation".
  - *Royal Society of London (1660)*
  - *Royal Observatory at Greenwich (1675)*

- Cultural values of the enlightenment (18th century):
  As typified by the Whig party:

  "...they consolidated a moderate Anglican theology at the core of the Church and State and regarded a knowledge of God's creation as a foundation of social and political order, a bastion against any return to the disorder of the earlier Civil War and the religious enthusiasm of much of the 16th and 17th centuries throughout Europe."  (MS05, pg. 13.)
Standards and cultures of measurement:
Techniques by which systems of societal, cultural, political, and material relations associated with a given technology are built, stabilized and maintained.

**Example 1: Greenwich Mean Time (GMT).**

- 1884 International Meridian Conference: Establishes GMT as the international standard for time-keeping.
  - Accepted basis of the world's time zones.
  - 72% of world's commercial shipping used Greenwich as the first meridian.

- Why Greenwich?
  - 1673. Committee to investigate proposals for measuring longitude at sea.
  - 1674. Royal Commission for longitude.
  - 1675. Greenwich Observatory built.
How to determine longitude with an accurate clock:
1. Determine local noon (by position of the sun) and record GMT (by ship's clock).
2. Calculate time difference in hours: \( \Delta t = \text{GMT} - 12:00 \) (local time).
3. Translate into spatial difference in degrees of longitude \( \ell \):
\[
\ell = (\Delta t \text{hr}) \times \frac{360^\circ}{24\text{hr}}, \text{ east(−) or west (+) of Prime Meridian.}
\]

How to synchronize clock with GMT:
1. 1830s. Anchor ship in the Thames and wait for Time Ball to drop at 1pm!
3. 1840's onward. Construction of land and sea telegraph lines makes possible the near instantaneous transmission of Greenwich Time beyond the Thames.

This new culture of time discipline in Britain "marked a radical shift from traditional task-orientation such as harvesting...to timed labor...that is, a shift from a rural economy to industrial capitalism."

"I, as Senior Wrangler, was led up first to receive the degree, and rarely has the Senate House rung with such applause as then filled it. For many minutes, after I was brought in front of the Vice-Chancellor, it was impossible to proceed with the ceremony on account of the uproar."
Example 2: Chartism.


- 19th century spin-offs:
  - 1807. Geological Society
  - 1820. Astronomical Society
  - 1831. British Association for the Advancement of Science (BAAS).

- BAAS "House of Commons" to Royal Society "House of Lords".

But still hierarchical
- Section A: Mathematics and physical science
- Section B: Chemistry
- Section C: Geology
- Section D: Zoology
- Section E: Anatomy
- Section F: Statistics
- Section G: Mechanical science

"At the lowest end of the hierarch, Section G ('Mechanical Science') occupied a subservient position, professing to apply laws and theories of Section A while simultaneously using that strategy to distance itself from the mechanical arts of the practical engineer." (MS05, pg. 22.)
Chartism = "the orderly mapping not only of land and sea but of terrestrial magnetism, tidal flows, meterological phenomena and of the health and diseases of the body politic..."

- Typical mode of presentation at BAAS meetings.
- Becomes "...defining characteristic of British science in a period threatened by increasing political chaos."
- Emphasis on quantification as an enlightenment ideal.

• "Objects of national importance": tidal charts, meterology, terrestrial magnetism.

Terrestrial magnetism:
- 1830s. Problems with employing magnetic compasses on iron-hulled steam-ships.
- 1838. Airy's fixed magnets and iron correctors. Requires expert to make precise adjustments.
- 1854. William Scoresby (former whaling captain, Anglican preacher) criticizes iron-hulls at Liverpool meeting of BAAS Section G.
- 1870s. William Thomson's modified compass for iron-hulls. System allows ship-master to use without need for experts.
• **Issue of trust:** Are steam-driven iron hulls to be trusted over sails and wooden hulls?
  - 1854. Loss of iron-hulled Tayleur and 290 lives.

• **Issue of BAAS authority:**
  - *Elite mathematicians of Section A* (Airy, Thomson) versus *practical-minded members of Section G* (Scoresby).
  - *Liberal Presbyterians versus conservative Anglicans:*

  "[Scoresby's Anglican] evangelical perspective interpreted nature, especially the sea, as expressing the infinite power of Providence...In contrast, liberal Presbyterians and Unitarians had no reservations about 'consulting' and even 'cross-examining' nature through experiment with a view to 'imitating Providence' through the harmony of human artefacts with nature's mechanisms."  (MS05, pg. 30.)

• **Legitimatization of mechanical science (engineering):**
  - *Engineering projects as "experiments"* (ships, railways, telegraphs).
  - *Section G advocates appeal to the authority of science and view them as scientific and progressive.*
  - *Critics sceptical of untested experimental schemes that challenge tried and tested practices and traditions.*
3. Steam Culture

• **Background:** 18th century Scottish Enlightenment.
  - Productive labor (marketable goods) versus non-productive labor (servents in employ of aristocratic gentleman).
  - Calvinist distinction between moral value of work and sinful nature of idleness and waste.

**Ex. 1:** Adam Smith's (1776) *Wealth of Nations.*
  - Labor theory of value: Value of a commodity = the labor required to produce it.

**Ex. 2:** John Smeaton's (1759) analysis of efficiency of waterwheels:
  - Ideal waterwheel pumps same amount of water used to drive it.
  - Ratio of water pumped (multiplied by height pumped) to water used up gives simple measure of efficiency.
  - 1771. Helps found "Society of Civil Engineers".
Events in the historical development of the steam engine

- 17th century demonstrations by Robert Hooke and Denis Papin: vessels filled with steam, quickly cooled, create vacuum. Atmospheric pressure delivers power.
- 1698. Thomas Savery obtains patent on steam-driven pump.
- 1712. Thomas Newcomen's steam engine.
- 1757. James Watt becomes instrument maker at Glasgow College.
- 1759. Glasgow student John Robison urges Watt to think about steam engines.
- 1763-64. Watt repairs Glasgow College's Newcomen steam engine.
- 1769. Watt obtains patent for modified Newcomen engine, with backing of financier John Roebuck.

- 1770. Roebuck goes bankrupt; Watt refashions himself as canal surveyor.
- 1774. Watt moves to Birmingham to get back into steam engine business with Lunar Society fellow-member Matthew Boulton.

- 1775. Boulton and Watt partnership extends Watt's patent to the end of the century.

- 1784. Albion Flour Mill in London as a public display of steam culture.

- 1780s-90s. Boulton & Watt go after patent infringers.

"The irony here is that by blocking innovation in engine design... the men popularly held responsible for the engine that powered the industrial revolution may have promoted atrophy in mechanical engineering." (MS05, pg. 63.)
Was steam inevitable?

1. Gaz ($CO_2$) engine:
   - 1823. Michael Faraday liquifies $CO_2$.
   - 1825. Marc Isambard Brunel patents "differential machine".

   **Advantages over steam:**
   - Less heat needed to transform liquid $CO_2$ into gas.
   - Greater pressure differential.

   - 1825-33. Isambard Kingdom Brunel attempts to perfect gaz engine (one of many grand projects).

     - Backing of Faraday and Royal Institution.
     - 1832. Royal Admiralty commissions study.

   - **But:**
     "no sufficient advantage [over steam] on the score of economy can be obtained. All the time and expense, both enormous, devoted to this thing for nearly 10 years are therefore wated...It must therefore die and with it all my fine hopes—crash—gone—well, well, it can't be helped." (1833)
2. Atmospheric (air) engines:
- 1816. Robert Stirling patents atmospheric engine with "economizer".
- 1833. John Ericsson patents "caloric engine" with "regenerator".


Ericsson champions "caloric engine"
- More efficient.
- Easier to use: no need for "steam experts".
- Safer: operates at lower pressure.
- Working fluid (air) easier to handle.

Set backs:
- 1853. Caloric-powered ship Ericsson sinks.
- Claims about regenerator are questioned by developments in the theory of heat engines.

But: 1840s-50s. Theoreticians (Rankine, Thomson, Joule) see air engines as successors to steam.

* "The heat which is required to give motion to the engine at the commencement, is returned by a peculiar process of transfer, and thereby made to act over and over again, instead of being, as in the Steam Engine, thrown into a condenser, or into the atmosphere as so much waste fuel." (1833)*

* "If the practical difficulty in the construction of an efficient Air Engine can ever be removed to nearly the same extent as already has been done in the case of the Steam Engine, a much greater amount of mechanical effect would be obtained by the consumption of a given quantity of fuel." (1847)*
3. **Electro-magnetic engines:**

- 1820. Oersted's current-carrying wire with magnetic effect.
- 1824-25. William Sturgeon's "electro-magnet".
- 1834. Thomas Davenport's rotary motor.
- 1830s-40s. Toy models and mock-ups of electric carriages, trains, boats.
- 1840. Hermann von Jacobi addresses 10th meeting of BAAS:

  "I must, on the present occasion, confess frankly and without reserve, that hitherto the construction of electro-magnetic machines has been regulated in a great measure by mere trials; that even the machines constructed according to the indisputable laws established with regard to the statical effects of electro-magnetics, have been found inefficient, as soon as we came to deal with motion."

- **But:** 1841. James Joule, "On a new Class of Magnetic Forces", *Annals of Electricity.*

  "This comparison is so very unfavorable that I confess I almost despair of the success of electromagnetic attractions as an economical source of power; for although my machine is by no means perfect, I do not see how the arrangement of its parts could be improved so far as to make the duty per lb. of zinc superior to the duty of the best steam-engines per lb. of coal."
"Steam's hardiness came from constant innovation within steam culture, often in conflict with the principles of caution, necessary to maintain business confidence, adhered to by Watt after his frenzy of invention in the early 1780s." (MS05, pg. 81.)

- 1804. Arthur Woolf patents the compound steam engine.
- 1850s-60s. Compound steam engine adopted for steamships.

"One aspect, then, of the failure of the challengers to steam was that particular steam engines were themselves superseded—by others more suited, through economy or durability or a host of other factors, to developing environments." (MS05, pg. 82.)
• Icons of Steam

Fifty Pounds

Leeds

Manchester

Glasgow

Birmingham

Greenock

Edinburgh

Westminster Abbey
• Watt and the steam kettle (Newton and the apple).

"His aunt Mrs Muirhead, sitting with him one evening at the tea-table, said, 'James, I never saw such an idle boy! Take a book or employ yourself usefully. For the last half hour you have not spoken a word, but taken off the lid of that kettle and put it on again, holding now a cup and now a silver spoon over the steam; watching how it rises from the spout, and catching and counting the drops of water formed by condensation.'"*