- Competition expanding telephones, independents vital & growing
- Fish (?) sees need for capital, need to acquire major independents, compete in all markets nationally. A man, a plan, a system, …
- Enter NY banks, Vail: A man, a plan, a system
- Vail strategy: One system…
- Finance & management
- Regulation, states, DoJ, Congress; the "scam"(?)
- WW I, the monopoly

Chapter 1

*Chapter 1 tells the story of the **creation** of the electronic communications industries from 1900 to the early 1930s - the formation of the AT&T monopoly to eliminate telephone competition, and the birth of broadcasting in a competitive flurry that quickly settled into a monopoly of three radio broadcast networks.*

Theodore Vail and the Creation of the Bell System

As the Twentieth Century began, there were three national network industries in the United States – railroad, telegraph, and telephone – all built on strands of steel. [1] [2] The railroads were by far the largest with XXXX miles of track, dwarfing the XXXX miles of telegraph lines, and XXXX miles of telephone lines.[3] Western Union had tried but given up on competing in the telephone business, but the two electric communications industries were still seen – by bankers at least – as candidates for consolidation.

The well-established telegraph industry was dominated by two large telegraph companies in 1900, Western Union and Postal Telegraph. In the telephone industry, however, Alexander Graham Bell's telephone patents that had once given the old Bell Company[4] a nationwide monopoly had expired in 1894[5],, and the telephone industry of the new century had become vibrantly – and chaotically[6] and doggedly - competitive. Bell remade itself into the new American Telephone & Telegraph[7] company to deal with the new competitive era of the Twentieth Century.

The telegraph was still [by far?] the largest electrical communications business, with $XXX million in revenue, while the telephone industry had revenues of only $XX million[8]. But competition was changing the telephone from a service for business

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[1] Need footnote to doc steel?

[2] Need footnote that acknowledges water and gas, but dismisses as local utilities. Also that electricity was also regulated by state commissions, with minimal intercity lines. Is this accurate? See Water and Power pp 81-82. Also note that electric lines were primarily copper – see *Water & Power* p33 and refs starred in footnote 45 there.

[3] Miles may not be applicable in all three cases.

[4] Is this the correct name? it changed names several times. We should pick a representative name (like "the Bell Company") to use prior to 1900 when it becomes AT&T. maybe we should list the prominent colloquial names – Bell, American company, ... See FCC 1939 Section 1.

[5] It was actually 1893-94 for a series of patents.

[6] This is a key word – is there a better one to describe competition in 1900 and 2000???

[7] Need to explain, probably in a footnote, where the "Telegraph" came from.

[8] AT&T revenue in 1900 was $41 million: Walker Report page 56. table 1885-1935. Need$ for independents.

executives and elites into an everyday reality in a more and more American homes and businesses. Entrepreneurs and business groups had started hundreds of new "independent" telephone companies, providing service in the smaller towns Bell had ignored and competing head-to-head in larger towns and cities where Bell's high prices had kept penetration low.[9] New manufacturing companies made and sold improved telephones and switching equipment. The number of telephones in the country had quadrupled in the first six[10] years of competition to over a million, customer growth was accelerating, and the independent companies were catching up with Bell.[11]

[1,2,3 paragraphs on role of phone in US business and social life at turn of century.]

While it was growing rapidly, the telephone "industry" was anything but what we would today characterize as an industry. Until its patents expired, the Bell Company had been a small Boston-based company that manufactured telephones and leased them to affiliated regional operating companies owned by local investors.[12]

This section is too boring for here. Where does it go? Is there a two-sentence version for here? Is it needed?

Bell: [had it been profitable?] [Brief description of Board, management, Boston culture, …]

[Brief paragraph on regional operating companies, ownership, financial ties to Bell, own finance, management,]

[Brief paragraph on standards, Western Electric, toll, long distance.]

[Brief paragraph on independents, finance, suppliers, farmers, company-ops, …]

With the advent of competition, Bell – and later AT&T - continued that basic business model, allowing its regional service companies to use only Bell-manufactured telephones and switching equipment on their wires.[13] Thus was born the business model for most of the Twentieth Century, that AT&T's telephone service was an end-to-end package provided over the "Bell System" that included the basic black Bell telephone on both ends of every telephone call.[14] It was not until [19XX that AT&T offered a telephone with a handset and cradle instead of the separate microphone and earpiece, and not until] 19XX that AT&T offered its customers any choice even in the color of the

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[9] I want as often as possible to put sentences in the active voice. People did things, things didn't just "happen". So maybe we can rewrite this sentence, or maybe it is one of those that is better the way it is.

[10] ?

[11] Quantify this. Some sources (FCC seem to say 40% ±) some say almost equal. Look in Mueller or some other book for table with my calculations showing how % accelerated.

[12] Is this true as of 1900?? Bell had some minority investments; maybe this could be a footnote.

[13] Bell also refused to sell its phones to other telcos.

[14] Bell contracted with Western Electric and other manufacturers to actually build its phones, and later bought Western Electric and concentrated all its manufacturing in that subsidiary.

telephones. [15]

Because of this policy, Bell's competitors had to build their own networks of wires and switchboards and buy telephones from non-Bell manufacturers, and many companies, large and small, sprang up to do just that. Bell had built most of its business in cities where affluent residents and large companies that could afford Bell's prices were concentrated, but by 1900, the independents had built systems and brought service to many mid-size and small towns not served by Bell [16] and were stringing their own wires alongside Bell's wires to compete in the larger towns to compete head to head with Bell. Farmers formed cooperatives to build their own systems. Larger independents built toll[17] lines to connect larger towns with surrounding smaller towns that made up regional trading centers. Public pay phones spread rapidly, so that many more people were telephone users than the number of homes connected would suggest.

Faced with being left behind in a competitive flurry, the staid Boston company had struggled to find ways to maintain its dominance in the industry. Reflecting its origins as a patent licensing business,[18] Bell had filed numerous [Thierer says 600] patent infringement suits that imposed heavy costs on many small independent phone companies and equipment manufacturers and put some out of business altogether.[19] But Bell's chief tools for competing with its rivals, or preferably putting them out of business, were economic –expanding into markets it had previously ignored either to discourage entry by an independent or to undercut an established independent with predatory price reductions[20].[21] Both of these tactics required construction of extensive new facilities, and the price wars took a major toll on revenues and profits. By the time Bell became AT&T in 1900, it was losing the battle with the independents[22] and in need of rapidly escalating capital infusions.

Bell had tried various ways of dealing with competition in the years leading up to 1900There was more innovation and growth in independents because in some ways they had better access to capital, but small amounts of capital for small company needs. AT&T was woefully undercapitalized to compete with them. It was set up at that time as a national entity that raised its capital for its entire industry in Massachusetts.

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[15] It could be argued that the country would have been better off if they had been required to license the patents to others to encourage technical and entrepreneurial growth as happened after the patents expired. But it could be counter-argued that this could have fragmented the telephone service industry into incompatible patterns.

[16] Put a note here, or later, about mutual companies serving small towns and farms.

[17] As a rule, "toll" lines were considered to connect towns up to 50 miles, while "long distance" lines were longer than 50 miles. This terminology arose in part because the independents had the technology for the shorter lines whereas AT&T had superior quality for the longer lines. While the "toll" and "long distance" distinction persisted for decades, it has little meaning in the larger sweep of the telephone business, and this book will not dwell on the distinctions.

[18] Bell licensed manufacturers, leased phones to regional affiliates.

[19] Ref?

[20] Need a footnote to deal briefly with definition "predatory" and to cite.

[21] Same tools rivals used to enter the market.

[22] Data

Massachusetts governor vetoed bill to allow Bell to raise capital. Massachusetts law prohibited majority ownership of operating companies. Bell needed reliable sources of accelerating capital needs and needed organization.

Bell needed much more capital to keep from losing its predominant position in the American telephone business.

Massachusetts state restrictions on raising capital, control of operating companies[23] Consideration of move to NY as early as 1896[24] fewer restrictions, larger amounts of capital.

Decision and announcement consolidate incorporation in NY[25]. Change from a Boston based company to a New York City based company with better access to the much larger and more open New York capital markets. Bell is no longer Bell, but AT&T[26]. This recognition of the company's capital needs and reorganization to remain the predominant national telephone company marked the beginning of the telephone business as a true industry.[27]

As it happened, John Hudson[28], the president of AT&T who led the company through the first years of competition, died in 1900[29], and the job was offered to Theodore Vail[30]. Vail had turned 65[31] in 1900. He knew the company well, having been the first General Manager of the old Bell Company from 1878 to 1885[32], [33] and he kept his home in Boston and kept up his contacts inside the company. Vail resigned in part because he had not been made President[34] had hoped to return one day as President of the company[35], and although he was financially well off from the Bell shares he had acquired in his early years at the company, he elected to decline the offer and continue the business ventures he had started in the US and South America.[36] [37]

Vail continued to follow the company. He kept his home in Boston, where the company still maintained its headquarters. Some of his key people from his days as GM

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[23] Stehman 40-41,59-63

[24] Garnet 106. based on memos by EJ Hall

[25] The Bell system reorganized itself Dec. 31, 1899 with AT&T as the parent company and … details…

[26] Where did the "Telegraph" come from? Must go back to original 1883(?) formation. Was that part of Vail's idea of a combined telephone/telegraph electric communications company?

[27] Can we add some weight to this statement? Do we want to put this flag here or on Vail's arrival?

[28] Could introduce Hudson earlier, let him lead the fight against competition.

[29] Garnet, p 91

[30]

[31] ??

[32] Garnet 31

[33] Vail apparently worked in NYC july-dec 1878 and then moved to Boston. Paine 146 & preceding.

[34] Did someone else get the job around this time?

[35] Paine 227

[36] Cite Paine, other?

[37] Do I have the timing right on the business ventures? Maybe they were not profitable until 1906.

of the old Bell company were now in important positions – Hall, Hibbing(?)[38]. others. He knew important bankers in Boston and New York because of the business stature gained in his years at the old Bell Company and in pursuing his business projects[39]. Fish was brought in to be President [40]as competition intensified.[41] As AT&T struggled to deal with the increasing competition it became clear that the move to the NY capital markets had been wise – the company would need increasingly large amounts of capital every year. The expansion into the many cities and towns where the independents were growing required capital to build many new phone systems. The large price cuts to cripple or force independents out of business drained revenue and profits, requiring still more capital infusions. Competition was not only thriving, but accelerating[42]. More and more businesses and homes were getting phone service at lower prices, but the competition was painful for the executives AT&T who hoped to reverse the tide.

As was his wont, Vail took the long run view. A few months[43] after turning down the presidency he had wanted 16 years earlier, Vail wrote a detailed memo to Senator W. M. Crane[44] in July, 1901 laying out his views on the policy that should govern the company at this critical time.

Vail sent his 1901 memo to W. M. Crane and to XXX Coolidge. Not clear if memo was intended to guide him if he accepted the presidency or it was aimed at Fish. Crane had been a long-time investor in AT&T[45]. His was on the board when AT&T was formed in 1899(?). Coolidge was president (chairman?) of Old Colony Trust Company. Coolidge and Old Colony had been early(?) investors in the Bell Company and were major shareholders of AT&T(?).

Vail's view of AT&T in 1901 was not good, particularly in the financial realm. After recounting a general assessment of the policies that were needed, he concluded:

> The existing hand-to-mouth policy results wholly from a dread that the mgrs of the company had of acknowledging either to themselves or to the public, the full requirements of the business, and the responsibilities of the company for these requirements. … Many things that are important and necessary have been and are postponed until further postponement is absolutely impossible, or are abandoned, to the real detriment of the company's interest, for fear of some unfavourable[46] temporary results. All this is wrong.

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[38] Hall was at first AT&T. Hibbing? Who else?

[39] Cite? Paine?

[40] From where?

[41] Somewhere I annotated a table to quantify the "velocity" of the competition growth.

[42] See footnote 39.

[4343] Date of refusal is unclear – try Paine. Date of memo to Crane July 1, 1901 FCC exhibit xxx footnote 305

[44] Who he then? Need more on him in text?

[45] Document.

[46] sic

The thrust of Vail's view of what the company needed in '01 was "control." AT&T should stop the independents, achieve as much control of the telephone business as possible, consolidate the regional operating companies and the Western Electric manufacturing operation into a single, centrally managed company, and establish a solid financial plan that would for provide stable sources of capital to fund the strategy.

> *Monopoly*: "The Company, having a tendency toward and desire for a monopoly should be abundantly prepared to assume the obligations, and discharge the responsibilities of its position.[47]
>
> *Control*: "In all these cases [of dealing with the competition from the independents], care should be take that a maximum of control be obtained by a minimum of concession.
>
> *Consolidation*: "All the Bell Telephone interest should be as soon as possible consolidated into [a single] operating company."
>
> *Planning for capital needs*: "The worst of the opposition (i.e. competition) has come from the lack of facilities afforded by our companies, -- that is, either no service, or poor service. … To meet these increasing demands, increasing amounts of money will be needed each year. A low estimate for the next five years would be $200,000,000 – every probability points to a larger sum."
>
> *Predictability*: "The knowledge that $250,000,000 would be required in the natural development of our business in the next five years … would not affect the shares of the company half so unfavourably[48] as an unexpected issue of $10,000,000 each year."

This 1901 memo would hold up well for his strategy when he later did become the President of AT&T in 1907. After Vail turned down the presidency in 1901, he directly involved himself in the strategy and financial control of the company.

The years 1901-1903 (check these dates) were pivotal for AT&T. The independents continued to expand rapidly and to reduce AT&T's share of the telephone market.

The Rockefeller and Morgan financial groups joined in 1901 to form TTCC to compete with AT&T in Boston and NY, to acquire independent telephone companies in the northeast and midwest, and to establish a long distance company to help independent companies compete with AT&T. But the Morgan interests withdraw[49], AT&T acquires control of Erie, the major independent in the TTCC plan, causing stalemate because Morgan interests control stock of Erie subsidiaries. Morgan interests and AT&T negotiate deal 1902 whereby AT&T gets control of Erie, the proposed competition in

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[47] Memo to Crane op.cit.

[48] sic

[49] Why?

Boston and NY exchanges disappears as does the proposed long distance company[50].

Vail worked with Coolidge, Baker(?), and ??? on the financing needs of AT&T. He no doubt worked with executives he knew, some of whom he hired in his earlier tenure as general manager of Bell. Especially Hall, Hibbard(?), and Carty(?). Dates of contacts 1896-1902. involvement in strategizing to move incorporation from Mass to NY.

In 1902, Morgan… AT&T…

Immediately thereafter, Waterbury, Baker, and Vail[51] were elected to the AT&T board.[52] Waterbury and Baker are allowed to buy 50,000 shares of AT&T stock worth $9 million.[53] This is the first[54] time bankers are on board and first non-Boston members.[55]

Morgan interests[56] pursue a consolidation of the electric telecommunications businesses telephone and telegraph businesses. This may have been Morgan's idea stemming from his experience in railroads to achieve economies by weeding out "wasteful competition", but it also was a Vail idea, stemming from his views when he was at Bell that Bell and Western Union should be merged.[57]??? [Need more drama in confluence of Morgan and Vail ideas and their coming together.]

At the same time they were moving to get control of AT&T, the Morgan interests began negotiating with Postal Telegraph about a merger[58] of AT&T and Postal to gain control of electric telecommunications businesses[59]. This effort falls apart, but presages later, 1909, AT&T takeover of Western Union.

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Competition intensifies. Independents thrive. AT&T struggles to keep up. As predicted by Vail, needs more and more capital. Various financing arrangements 1902-

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[50] Did the Rockefeller Stillman group continue to pursue the long distance company idea?

[51] There must be SOME evidence that Vail came on as part of an arrangement between AT&T and Morgan interests. Or maybe it was to get him involved after he declined the presidency. Fish had not been president very long – maybe HE wanted Vail's involvement.

[52] Need a lot of fact checking and documentation here.

[53] What % of the company was this? Stock price based on Stehman avg for 1902 p 326

[54] ?

[55] ?

[56] I probably use "Morgan" and "Morgan interests" interchangeably, but at some point we will need to be more precise. It would be good to have a footnote that lays out who the bankers are in the Boston and Morgan camps. Is Coolidge of Old Colony a bridge?

[57] Or that Bell should acquire WU?

[58] Was it really a merger they sought or something else? Probably a merger between Postal and AT&T that they would control, regardless of whether Postal or AT&T took over the other? Maybe they wanted Vail on the AT&T board to run the combined telephone/telegraph company.

[59] Why not Western Union? Gould?

1906.[60] Major bond offering planned in 1906. AT&T board faces question of how to place this major issue. Should it be a competitive bidding process between the Boston and New York bankers? Should the bonds be convertible into common stock? Convertibility potentially would give bankers control or near-control of company.

Major decision: Bond placement is given to Morgan interests without competition and the bonds are convertible.[61]

Bankers have difficulty placing bonds. Price is cut, but almost no takers[62]. Why? Seems like they could/should have priced them at market. AT&T needs the money. 1907 financial panic. Bankers got what they wished for, now needed Vail to come in to rescue them.[63] Fish resigns or is forced out.[64] Vail becomes President of AT&T date, 1907, the job he had wanted for two decades. He is 67 years old.[65] The independents as many phone customers as AT&T.[66]

Theodore Vail

The telephone business in the first 20 years of the century is mostly about Theodore Vail. Until 1907 he worked behind the scene with AT&T executives and bankers. Then as president of AT&T, he began an incredibly shrewd and effective strategy of business, political, and public relations tactics [changes] that killed off competition, reestablished the telephone as a monopoly service with AT&T controlling most of the country and all the long distance service.

Brief bio of Vail.[67]

Born in 1845 and retiring from AT&T in 1919 at the age of 74, Vail's life and career spanned two centuries, life in the rural midwest and in the power centers of the east, and four major transformations of American business Vail not only saw these business transformations of the 19th and 20th centuries, he helped shape and integrate them.

National operating companies: railroads, telegraph, steel (or was this local/regional?), oil, other?

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[60] What were they?

[61] What documentation do we have for why this decision was reached? Who, besides Baker and Waterbury on board would have favored this? Vail?

[62] Date?

[63] Need to make sure this is a supportable assertion.

[64] Somewhere there is the suggestion that he was under a lot of stress – understandable – and/or had health problems.

[65] Born July 16, 1845 paine 7.

[66] Need to document this. Census seems to be best source.

[67] Will have to draw from various sources to get the key points for us.

Capital intensive industry: railroads, telegraph, oil(?), electricity, water, gas, (weren't public utilities mostly local?) other?

Systematic management: Express mail, railroads(?),Taylor, where else applied?

Monopoly, antitrust, and regulation: Need a concise timeline and summary of monopolistic industries and emergence of "trusts", public concern, antitrust legislation and enforcement. Then the implementation of regulation by federal and state legislation and ICC and state commissions.

Vail saw the emergence of national operating companies in the spread of the railroads and the link of the east and west coasts in 1869. His experience as telegraph operator and director of ??? at the headquarters of the Post Office Department in Washington gave him a first hand knowledge of national operations and the need for systematic management. He no doubt read the works of the scientific management writers like Frederick Taylor. In his work as General Manager of the Bell Company, he installed there and improved upon many of these principles of national organization and systematic management he had earlier learned. (Was capital an issue in his years there?) He probably participated with Forbes and Hall and ???" beginning in 1896[68] in setting the stage for the reincorporation in NY under AT&T, and certainly in 1901 saw the necessity of capital. He undoubtedly followed the antitrust movement in the 18?? – 19?? years[69] He was a major shaper (if not the major shaper) of regulation as the balance to monopoly.[70]

Business Vail was a systematizer. He believed in tight organization. Every regional operating company should use the same kind of facilities, equipment and operating practices. Every engineer should have the same training and use the same standards everywhere across the country. [Other examples of tight organization would be useful] Decisions to expand were done in light of consistency. [What does this sentence mean?] Long distance connections should work the same way between all cities and regions. Equipment manufacturing should be standardized and centralized nationally in one AT&T subsidiary – Western Electric. Hubbard had been moving the company in this direction, often against the practices and desire for independence among the regional operating companies, but Vail forcefully completed the transformation of the company and its facilities into the Bell System.[71]

Vail created the Bell system and made it a bureaucracy run by bureaucrats and enabled the company to deliver good service very well and become a very powerful entity. [How did his reorganization allow AT&T to become powerful? One doesn't necessarily flow from the other] AT&T basically provided better telephone service.

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[68] We have a reference to this somewhere.

[69] Do the seminal or dramatic years match up with Vail before 1907? Surely.

[70] Was there someone earlier? Any academic or political precursors?

[71] Note that the expression *Bell system* had been used much earlier.

They used that position to get the government to grant it preferential powers [such as?], which lead to the consolidation of their monopoly. So the telephone business is for the first 20 years substantially T. Vail.

Vail built AT&T into the Bell system, turning the company into a national organization that was centrally managed. He was able to buy and build equipment with large economies of scale and build uniform practices, pay schedules and rates on a national basis.

Vail also created the regulatory framework,[72] first in the states and then nationally and ultimately at the FCC. This was a really successful political and intellectual scam. When encouraging and arguing for a regulatory scheme in a state, Vail insisted that the telephone business was inherently a monopoly business. It was naturally a monopoly and as such it had to be regulated because competition really wasn't feasible in the phone business and you had to have regulation to serve the public interest. That line he began articulating in the annual reports of AT&T in about '07 / '08. In the 20s, while Vail is building AT&T on this monopoly framework, the independent phone companies became more forceful, and Vail began arguing that the monopoly of the phone company was a good thing for society. Because of the good things that AT&T did and could do because of its monopoly, Vail asserted, regulation was needed to protect AT&T from competition. But those two ideas are fundamentally incompatible. A natural monopoly is an industry where competition isn't feasible. If you're a natural monopoly, why do you need protection from competitors?[73] Nonetheless, this idea continued until the 70s when the Nixon Administration's Office of Telecommunications Policy worked to undermine that rationale.

Vail's mantra – one system, one policy, universal service – was aimed at the switchboard problem. When Vail coined the term "universal service," he meant that everyone should be on the same system, a nice word for monopoly. The phrase later came to mean that everyone in the country should have a telephone.[74] Vail thought that there should be one monopoly phone company because he believed that was the best way to develop a robust phone system in US.

Vail concern with capital 1901. worse in 1907. Monopoly as alternative to capital demands of competition. Regulation as publicly acceptable way to sanction monopoly over competition. AT&T could not overtake the competition to "save" the "Bell System" as the predominant telephone company under the dual service competition that was thriving. So, he switched gears. It was

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[72] Did he also coin public interest, convenience, and necessity?

[73] Bruce Owen's recollection was different -- Tom doesn't remember exactly, but it had to do with the time Vail said something.

[74] This happened around time of 34 Communications Act.

masterful and successful.

Now go to buying of Western Union, his earlier interest in that, possible earlier common cause with Morgan, carrying the intercommunicating idea to all electrical communications.

Need to develop the original AT&T long distance mission, reference to it in the 1901 memo, reliance on it after 1907 in argument for nationwide intercommunicating monopoly dictated by technology and nation's needs and customer service. Short-haul (or "toll") vs long-haul (or "long lines").[75]

Now buying up of independents. Independents fight. Antitrust suits all over.[76] Burleson proposal for Post Office ownership. Vail adds argument that monopoly must be protected from competition.

The shift to regulation as partner to monopoly and not "wasteful competition. >> This is important to get dates and arguments right. Start with annual reports, look for other primary source references in books we have. <<

Antitrust suit – which administration? Which AG? Kingsbury Commitment – negotiating parties, independents.

Kingsbury Commitment substance. 50 miles. Other – be careful of exact provisions vis-a-vis subsequent interpretations and enforcement agreement. Why a win for AT&T. Subsequent interpretations to allow killing off dual service.[77] Success of Vail's drive to eliminate competition by substituting regulation. A BIG deal to pull off in such a short time, especially in the climate against trusts.[78] Competition worked! Vail killed it. AT&T now "the largest corporation in the world?

Technology policy. Carty. Patent rights. Vacuum tube rights for long distance repeaters. Importance to coast-coast long distance circuits. Interest in, or lack of interest in, wireless. "Bell System"[79]

Concerns about government ownership, Burleson again, ww1, government takeover. Impact of demands on system, long distance, capital. Raising of rates to provide capital and make stock more saleable.

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[75] See McDougall paper on long distance. Need to adopt a terminology here. Maybe "short-haul toll" vs "long distance".

[76] See McDougall paper on long distance.

[77] Need an earlier description of dual service competition.

[78] See McDougall long distance paper for material on this, on picture with Rockefeller and Morgan, on meetings with Morgan and Rockefeller and others regarding hostile climate against big business, on Rockefeller praise for Vail success in PR campaign.

[79] McDougall again?

Need somewhere to refer to government ownership model for telephone systems in other parts of the world. Footnote on Canada as hybrid.

This should take us to ww1.

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And then after WWI, Vail's successor Gifford consolidates the natural monopoly structure that Vail had promulgated and makes some peace with the independents.

Quotes from *Bodies, Ideas, And Dynamics: Historical Perspectives On Systems Thinking In Engineering* by David A. Mindell, emphasis added by CTW for use in book.

Edison and electric power

Echoing the pattern of the railroads, electric power grew up on a similar model, though more consciously planned as systems. **Thomas Edison is hailed as a genius inventor for creating the light bulb, and indeed the light bulb has become a symbol for invention. But Edison's electric light succeeded because he designed not only light bulbs, but also a system that included generators and transmission lines.** When developing his system in the late 1870s, Edison explicitly compared it to the competitor he intended to replace: gas lighting. Edison designed light fixtures to resemble gaslights. An economic analysis of the cost basis of electric versus gas lighting led him to concentrate on a high-resistance filament, which required less current and hence smaller transmission lines than the lower resistance model his rivals were pursuing. **Edison described his invention in the physiological sense, as connected elements with current flowing between them. It was, in his words, "a system based on different inventions or discoveries, some of which have been made years before the others." 14** Edison also organized invention in the philosophical sense, initiating many of the features of a modern industrial R&D laboratory, especially an organization devoted to a "systematic" attack on technical problems. During design, Edison clearly understood how the components of his electric lighting system interacted with each other. He was less clear, however, on the dynamics of the system, or how those relationships affected each other during operations.[15] Indeed, Edison's early systems had stability problems, which his engineers solved with cut and try methods, not according to any overall model of their dynamics. For example, when the generators at the Pearl Street Station began to oscillate, the only solution was to replace them with newer ones, not to detune the system to avoid the resonance.[16] **This approach worked well when the systems were simple, and even up to moderate size, and up through the 1920s,**

engineers conceptualized electric power systems in the physiological sense, as sets of interconnected elements like generators, motors, traction loads, or transmission lines, each of which could be designed and analyzed independently and then combined. As local networks, engineers could treat them as hierarchical and centrally controlled, with all power emanating from a central station. [Chap 2?]

14 Edison to Butler, February 1879, quoted in Paul Israel, 1998. *Edison: A Life of Invention* (New York: Wiley), 189.
15 Hughes, *Networks of Power*, 31.
16 Nathan Cohen, "Recollections of the Evolution of Realtime Control Applications to Electric Power Systems," *Automatica* 20 (2, 1984), 145-62.

In the 1920s, local or regional power networks connected into national "grids" or "superpower" systems. Hughes has pointed out the importance of "load factor," as electric power systems expanded to equalize their average and peak demand.[18] No longer could individual systems be considered only as the power emanating from the station in the center of town. Now a system might incorporate a varied residential and industrial loads, coal- fired plant, and a hydroelectric station miles away – and connect to similar networks over a long transmission and tie lines. These new networks began to exhibit behaviors that could only be understood by looking at the system as a whole.[19] Stability problems with large, interregional electric power networks drove engineers to study the characteristics of large-scale power networks as complete entities, and to conceptualize them as systems in the dynamic sense.

This new approach was exemplified by a young electrical engineering professor at MIT, Vannevar Bush, who sought to bring a variety of systems under a single quantitative model. In his 1929 book, *Operational Circuit Analysis* Bush applied Heaviside's operational calculus to model systems of varying types. Bush noted that across fields in engineering like hydraulics,

17 Ronald Kline, *Steinmetz: Engineer and Socialist* (Baltimore: Johns Hopkins University Press, 1992). ughes, *American Genesis*, 161-175. While Steinmetz had the vision, G.E.'s research laboratory was headed by Ilis R. Whitney, a chemist, and focused primarily on physical chemical problems related to electric lighting.
18 Hughes, *Networks of Power*, 218-21.
19 See Committee on Power Transmission and Distribution, "Annual Report," *Trans. A.I.E.E.* 46 (June, 1927). For a general review of the subject of power system stability, see C.L. Fortescue, "Transmission Stability: Analytical Discussion of Some Factors Entering into the Problem," *Trans. A.I.E.E.* 26 (February, 1927), 984-994 and discussion 994-1003. Frederick Terman, "The Characteristics and Stability of Transmis sion Systems" (Sc.D. diss., MIT, 1924). Vannevar Bush, "Power System Transients," *AIEE Trans.* 44 (1925), 229-30. C. L. Fortescue, discussion of Bush and Booth, "Power System Transients," *Trans. AIEE* 44 (February, 1925), 97-103. This discussion, from six commentators, provides a good overview of the state of the stability problem in 1925.

In the other new large technical system of the early twentieth century, the telephone network, engineers used the language of systems more explicitly than in electric power. AT&T chief Theodore Vail's famous motto "One policy, one system, universal service," captured the company's totalizing view, though its network was composed of vast numbers of small, interconnected units. Within AT&T, engineers referred to their national network as "the System," and beginning in the 1920s the company had job titles for "System Engineers" and a "Systems Development" department. Yet these were not systems engineers in the modern sense; they did not have an abstract view of the system, nor did they manage a variety of subsystems. Rather, system engineers at AT&T concentrated on the concrete manifestations of the networks: the equipment layouts, power systems, and wiring diagrams for local substations.[23] The system was physiological, a thing, emanating from central switching stations.

[20] Vannevar Bush *Operational Circuit Analysis* (New York: J. Wiley & Sons Inc.: 1929), 1-2. John Carson, *Electric Circuit Theory and the Operational Calculus* (New York: McGraw-Hill: 1926).
[21] For more detail, see David Mindell, *Between Human and Machine: Feedback, Control, and Computing Before Cybernetics* (Baltimore: Johns Hopkins: 2002), Chapter 5.
[22] Bernard Carlson, "Academic Entrepreneurship and Engineering Education," and Alex Soojunk-Kim Pang, "Edward Bowles and radio engineering at MIT, 1920-1940," *Hist. Stud. Phys. Bio. Sciences* 20 (no. 2, 199), 313- 337. Christian Lecuyer, "The making of a science based technological university: Karl Compton, James Killian, and the Reform of MIT, 1930-1957," *Historical Studies in the Physical* Sciences 23 (1), 1992, 153-80. Larry Owens, "MIT and the Federal 'Angel:' Academic R&D and Federal-Private Cooperation Before World War II," *Isis* 81

As Bell Labs founder Frank Jewett told the National Academy of Sciences in 1935, **"We are prone to think and, what is worse, to act in terms of telegraphy, telephony, radio broadcasting, telephotography, or television, as though they were things apart. When they are merely variant parts of a common applied science. One and all, they depend for the functioning and utility on the transmission to a distance of some form of electrical energy whose proper manipulation makes possible substantially instantaneous transfer of intelligence."[26]**

[26] Frank B. Jewett, "Electrical Communication, Past, Present, and Future," Speech to the National Academy of Sciences April, 1935, reprinted in *Bell Telephone Quarterly* 14 (July, 1935): 167-99.