Want to predict what the next technological revolution will be (e.g., cryptocurrency, artificial intelligence, CRISPR, VR/AR), and how it will unfold? Want to envision the most valuable applications, startups, and business opportunities to arise in this new paradigm?

One way to get better at predicting the future is to study history and people who accurately predicted the future. In 1996, Bill Gates published The Road Ahead, his manifesto on how the Internet and PC will pervasively transform our lives and major industries.

To control for hindsight bias, remember that in the mid-90s:

- the web was used only by a small minority niche - 0.4% of the world population, compared to 54% today
- computers were glacial by modern standards, connected to the Internet by 28k/56k modems capable of transmitting 3-6kB/s (0.1% of a typical connection in 2018)
- many critics felt the Internet was just a gimmick or a simple tool, incapable of upending people’s well-established habits

Within this context in The Road Ahead, Bill Gates is optimistic and remarkably prescient about how important the Internet will be. He predicts that the Internet is a revolutionary paradigm change in zero-cost information handling, that this will spur development of groundbreaking applications, and that virtuous cycles will kick off revolutions in many industries. Bill Gates predicts elements of today’s largest tech companies - Facebook, Netflix, Amazon - and top applications - mobile phones, social networking, ecommerce - years and even decades before they fully materialized.
In this summary of The Road Ahead, I’ll summarize major elements of Bill Gates’s vision for the future. I try to build a framework for evaluating a new technological paradigm and how it will transform our lives and industry. I also discuss where Gates’s predictions fell short and possible patterns to misprediction.

Note: quotes in this The Road Ahead summary are often paraphrased for conciseness, but do not materially change the author’s sentiment.

Summary of Themes in The Road Ahead

- The Internet + PC brings a new paradigm of costless information storage, transfer, recall, and manipulation. The marginal cost of information handling is effectively zero.
- This is paradigm changing, allowing access to infinite information and content on demand, from anywhere connected to the Internet.
- This in turn will enable:
  - Personalization and customization, instead of mass homogeneity
  - Productivity improvements
  - Interactive applications
  - Expansion of social communities
  - More efficient economic transactions (since money and prices are information)
- How a new technological paradigm takes root
  - Technology that offers cost or performance advantages
  - A killer app to build an early userbase
  - A virtuous cycle of: more users creating larger markets drawing more development
    creating more applications drawing in more users
- To consider how an industry will be changed by a paradigm like the Internet, consider how it can be made more effective or cheaper with the new paradigm.
  - For the Internet, consider how any industry’s operations can be made into digital data, and how that will make life better/things cheaper.
  - Eg shopping - finding products (an infinite catalogue), more product information and reviews, surfaced custom recommendations based on past buying behavior
  - Eg media - all text, pictures, videos, sound can be digital. This means it can be accessed on demand at any time, with the bottleneck being viewer time and attention
  - Eg brokerages - industries dependent on proprietary access to information will be endangered. So travel agents, stockbrokers became obsolete
- Similarly, consider what people do on a day to day, week to week basis, and consider how activities will fit the new paradigm.
- People will continue doing what they’ve done in the past to a lesser degree. The new paradigm will just increase consumption of the original behavior in a new way
  - “A large part of the money you’ll spend on network services will be money you already spend today for the same services in other forms.”
  - Eg with Facebook, people still see their friends in person, but they interact with people
virtually much more than they used to, and this probably displaces in-person interaction and calls a bit

- As prescient as Bill Gates was about the ubiquity of computers and the power of the Internet, he underestimated the spread and utility of mobile phones with wireless Internet. He was wired-centric, imagining large displays in homes and homes connected to Internet by cable. It was probably quite difficult to imagine that consumers would quickly embrace the tiny form factor of a phone.

## The Internet Revolution

The focus of Bill Gates’s The Road Ahead is on the enabling power of the Internet and its implications on consumer habits and practices.

In this The Road Ahead summary, we’ll

- cover his general beliefs about the Internet
- detail his predictions of how the Internet will change our home lives, commerce, and business operations
- explore where his predictions fell short of reality and why

## Beliefs about the Internet

- During the 1980s, he was surprised that online services weren’t very popular. What combination of bandwidth and content would it take to become mainstream?
- In the 1980s, Gates treated the Internet with some initial skepticism
  - Game theory - how much value can be assigned when more than one person has it?
    - Doesn’t accessibility undermine its value?
  - Nonsensical conversations: “how much information do you have?” “The US is strong because of all the information they have there!”
- But he realized the revolution was unprecedentedly inexpensive communication. “What if communicating were free?” Information that was once difficult to retrieve will be easier to find
  - Eg Is my bus running on time? Are there accidents on the route I take to the office? Does anyone want to trade his Thursday theater tickets for my Wednesday tickets? What’s a good recipe for halibut? Which store, anywhere, can deliver by tomorrow for the lowest price a wristwatch? How is the hole in a needle manufactured? What are symptoms of a heart attack? What does the Eiffel Tower look like right now? Where was I at 9:02PM last Thursday? [Broad but prophetic]
  - “What sets this period in history apart is the ability to manipulate and change information, and the speed at which we can handle information. Almost all information will be digital. Once digital information is stored, anybody with permission and access can recall, compare, and refashion it.”
• “The internet will be the ultimate market. We social animals will meet here to buy, sell, trade, invest, haggle, pick stuff up, argue, meet new people, and hang out.”
• “The information superhighway metaphor isn’t quite right - it suggests everyone’s taking the same fixed route, when the network is country roads that everyone can take in whatever direction they want. The highway emphasizes the infrastructure rather than its applications.”
• In 1994, MS started betting on the Internet, but they didn’t expect that within 2 years it would captivate the whole industry and the public. They suspected videoconferencing and high-bandwidth apps like video on demand were needed (in addition to security, privacy, reliability)
• In 1996 in the book: “we’re experiencing the early days of a revolution in communications that will be long-lived and widespread.” “The revolution will take place over several decades and will be driven by new applications, new tools often meeting needs we don’t even foresee now.”
• “What I’ve said that turned out to be right will be considered obvious and what was wrong will be humorous”
  o [It’s better to be optimistic than pessimistic probably - you don’t want to be the one to say “the iPhone is going to be a total failure” - but it’s OK to say that VR was going to revolutionize our everyday lives in 1995]
• “I’m still thrilled by the feeling that I’m catching that first revealing hint of revolutionary possibilities. I first experienced this particular kind of euphoria as a teenager” with microprocessors and microcomputers.
• In the early days of Microsoft, “I was afraid other companies would scoop us; today I know thousands of companies already share our vision of interactive networks. Millions of people are trying to take advantage. Thousands of innovative companies will be founded to exploit the coming changes.” “Microsoft was fortunate in its early years in that the established players ignored personal computing.”
• “The pace of the Internet’s evolution is so fast that a description of the Internet as it existed a year ago might be seriously out of date now.”
• “The PC wasn’t perfect. Aspects of it were arbitrary or even inferior technologically. Despite its shortcomings, its popularity grew to the point that the PC became the standard hardware for a which applications were developed. Companies that tried to fight the PC standard failed because so many other companies were invested in continuing to improve the PC.”
• Broadband “won’t be available to the majority of US homes for at least a decade” where broadband = 2Mbps
  o This is based on overpromises of telecom to wire millions of households with broadband by 2000, but they realized the costs were higher than expected ($1200 per household and $120 billion for US in total), with few applications for it.
  o Marketing tests suggested video-on-demand would generate only a little more revenue than cheaper systems showing popular movies frequently.
  o [This suffers from the underpredicted market size analogy, similar to how some thought Uber could never be bigger than the entire taxi industry. Could telecom have predicted the large industries possible and made the investment in broadband, collecting more rent later, maybe even starting their own Internet arms? Yet This is far outside their core competency.]
• Bill Gates thought the killer apps of the Internet would be on-demand video and photos, but low-bandwidth 56k connections were too low to service this killer app. He was caught off-guard by the willingness of people to use it for communication, information, and commerce.
  o Conventional wisdom: killer app would be video on demand. TV looked like obvious
device for delivering services since TVs were cheaper and more common

- Telecom rushed to get interactive TV going, which in some implementations was just someone loading a VCR across town for one customer.
  - [He may not have been a social enough guy to foresee chat, the same way Bezos didn’t foresee music.]
  - At MS they believed a wide range of apps would need to be available from the beginning for Internet to succeed, so they spent time on a software architecture platform to support myriad applications (with compatibility with the TV) and created applications themselves.
    - They wanted to control the standards, avoiding the IBM mistake, as did AT&T, IBM, Oracle, all expecting telecom would choose one platform for their customers.
    - This likely made them a bit slower to Internet applications.
  - It became clear that the Internet would be built around the PC and later around the TV.
  - “Millions of people were demonstrating their enthusiasm for interactivity on maddeningly slow narrowband connections.” Interactive information services became the first rather than the last of killer applications.

- “It costs no more for a user to request data from a server thousands of miles away than from a server a mile away. This pricing model has already done serious damage to the notion that communication has to be paid for by time and distance, just as PC computing did away with hourly rates for computer time-sharing.”
  - “There will be local, less expensive kinds of wireless networks available inside businesses and most homes. You can connect to the highway without paying time charges so long as you’re within a geographical range.”
  - Bill Gates is excited about ADSL, which bypasses the voice network by using an altogether different, higher frequency part of the spectrum and offers far more bandwidth as a result.
  - Gates was impressed with Germany’s Deutsche Telekom, which lowered the price of ISDN service in 1995 to increase users connecting PCs, promoting development of applications that will speed up adoption of broadband and kick off a virtuous cycle of users.
  - In the future, hundreds of low-orbit inexpensive satellites by Teledesic will provide global fiber-quality Internet. [Though this company failed, now Facebook and SpaceX are taking this up.]

- “The competition we saw in the PC software industry in the 1980s is underway again, this time to determine which software components will become standard on the evolving Internet.”
  - Browsers: MS and Netscape fought to define the web standards, each trying to stimulate development of applications and the ecosystem while also building their own moat.
    - Netscape aimed to make Windows and MacOS irrelevant by developing Navigator into a full-featured OS [like ChromeOS]. It would be a de facto software platform sitting on top of Windows, MacOS, or Unix.
  - Powerful PC vs powerful servers and dumb terminals
    - Sun/Oracle believed in the latter, essentially a precursor to slow PCs connected to cloud applications
    - Gates: “the future lies in balanced client/server computing in which both the client and server are quite capable and cooperate in running software. I don’t see much reason to dumb down the desktop machine. People don’t want to settle for outdated features or performance.”
• “It’s important that expectations don’t get cranked too high. The total number of users of the Internet is still a small part of the population. And the attrition rate is high - many subscribers drop off, disappointed, after less than a year.”
  ◦ It’s too much to expect PCs and the Internet to solve all human problems. In Gutenberg’s age, did people ask if this press will feed people or overcome illness? With time, it did, but it was hard to tell.
• “Firsthand experiences are unmediated - no one will take away from you in the name of progress the experience of lying on a beach. But firsthand experiences aren’t always so rewarding. Waiting in line is a firsthand experience, but we have been trying to invent ways to avoid it ever since we first queued up.”
• “Some believe major software apps are already so capable and feature-rich there will never be a need for newer versions. But there were people who thought the same thing about software 5 and 10 years ago.”
  ◦ [MS Word hasn’t changed all that much. But Dropbox and Google Docs did.]
  ◦ “Web pages circa 1996 are not rich enough to suit publishers’ and ultimately consumers’ expectations.”
    ▪ [How can you tell this, rather than falsely believing the current paradigm is good enough? You imagine an application and realize it’s super hard to build?]
• “We can no more imagine what the broadband information highway will carry in 25 years than a Stone Age man using a crude knife could have envisioned Ghiberti’s Baptistery doors in Florence. Only as the Internet evolves will all of the possibilities be understood.”
  ◦ Possibly the predictions int this book would be a bit disappointing if they account for most of the really valuable companies? Gates might have wished for more than Amazon, Facebook, Netflix.
• On the “height of information highway mania” in 1994/5:
  ◦ A gold rush atmosphere caused companies to lay claim to tech and content they hoped would pay off. It seemed to be motivated by companies’ wanting to stay ahead of other companies than by an understanding of the economics.
  ◦ “In retrospect it’s clear the gold lay deeper and in different places than the would-be prospectors realized. Most...had been fixated on video-on-demand” and ignored the PC.
  ◦ “People in a gold rush dream of quick riches and overinvest in the obvious areas, ignoring subtler or longer-term opportunities.” Few fortunes were made in the gold rush actually mining gold, though Bill Gates cites Levi’s as a “selling shovels” approach.
    ▪ Similarly, in the PC revolution, PC companies seemed like a good investment, but many failed. But less obvious - Intel provided microprocessors, Microsoft supplied software, H-P manufactured printers.
  ◦ “Every major limitation of the Internet, from its questionable security to its chaotic content, has spawned dozens of companies working to solve the problem. Lots of money will be lost along the way. What seem to be lucrative niches today may wind up as highly competitive markets with low margins, or simply not popular.”
  ◦ “If a company had announced back in 1994 that it would soon release a software program that was many times better than anything already on the market, most people would have been skeptical. But two years later somebody making the same announcement, but with “…for the Internet” would encounter a surprising open-mindedness: “10x better, and for the Internet? Wow!”
    ▪ [Cue similarities to blockchain]
“For every large existing company that succeeds with a new application of service, ten startups will flourish and 50 more will flash into existence and momentary glory before slipping into obscurity.”

- Although the TV revolution generated some profits for TV set manufacturers, the biggest winners were the companies that used the new medium to deliver content: entertainment, news, sports, advertising. We’ll see a similar dynamic for the Internet.
- Many communications companies “want a financial interest in some of the bits being shipped.” They want to move up the food chain rather than just delivering bits. So cable companies are working with Hollywood studios and television.
- But “it’s almost impossible to do everything well.”

- “I think it will be many decades before robots are practical [in the home]. It takes a great deal of visual intelligence and dexterity to prepare food or change diapers. It’s very hard to design a machine that can recognize and respond to all of the contingencies that come up.”

- Bill Gates suggests balance between reining in the Internet and letting it be completely open and free.
  - “The Internet is precious. It’s the first medium that allows worldwide publication of information at no marginal cost. If governments squeeze it too hard, it will suffocate.”
  - “People who insist that interactive networks should be wide open and a self-governed world apart, in which copyright, libel, confidentiality laws don’t apply. This is naive. The Web is mainstream now, and its days as a lawless backwater are over.”
  - [Connect to cryptocurrency]

- “You’ll know that the Internet has become part of your life when you begin to resent it if information isn’t available to you via the Internet.” eg a bicycle manual that’s a paper document and not available online
  - “It’s tough to achieve a huge success with a middleware strategy when the most popular OS’s are embracing the same features that the middleware promotes.”
  - “It’s a little scary to contemplate the historical truism that there’s never been a leader from one computer technology era who was also a leader in the next.”
    - “The difference with IBM is that Microsoft is focused intently on the Internet. If we don’t adapt well, it will be because we misexecuted, not because we focused on the wrong objective.”
    - **Success is a lousy teacher. It seduces smart people into thinking they can’t lose.**
      - “It’s important to acknowledge mistakes and draw the right lessons from them. It’s also important to make sure nobody avoids trying something new because he thinks he’ll be penalized if it doesn’t work out. Almost no single mistake is fatal.”
      - [And so has come true of Microsoft and mobile/cloud.]

**Predictions of Internet applications and the future**

The meat of The Road Ahead is Bill Gates's vision for the future and the applications/behaviors we will be using in this new paradigm.
General Changes

- When speech- and handwriting-recognition become accurate enough, another big change in operating systems will come.
- Digital cash - this is just digital financial information after all.
- Terminals and kiosks specifically for browsing (like phone booths)
  - LAN cafes were the short intermediary between this and ubiquitous mobile phones.
- Speech recognition will get better, but because they’ll read your lips
  - Maybe in future; right now ML applied to audio is good enough, and the bottleneck is now NLP
- Cameras for gesture input
- Handwriting instructions to computers
- Digital whiteboard, large wall-mounted screen
  - Convert handwriting into text.
- Smaller laptops until they’re the size of a tablet of paper.
- Already here: games, e-mail, banking.
- Pass through security gate with your phone automatically connecting to airport computers
- Hum a tune and play it back to hear it fully orchestrated
- Healthcare
  - Use app to find hospital who would accept patient; register electronically while driving there; match injury to doctor and retrieve medical records from net; store X rays digitally for access anywhere in world; look at X rays from home.
- Communications will involve more video (eg Skype)
  - Many calls will be asymmetric, only one-way video, like customer service
  - Synthetic faces showing your best self.
- Broadcast communications (Usenet, BBS) made super cheap relative to mass mails or group telephone
  - [Gates didn’t scale far beyond this into things like Reddit and Twitter.]
- Quality of service guarantees
  - “To achieve its full potential, Internet needs the ability to reserve bandwidth with a quality of service guarantee” - by introducing payments to traffic handling. Without this, everybody would request a QoS guarantee, which won’t work.
  - [This has panned out a bit, with QoS in reserving servers and bulk reservations of bandwidth through Internet subscription plans. But this has not been necessary from the customer’s standpoint, possibly because the pipes are now fat enough that everyone can get done what they want done.]
- Electronic documents going back and forth in an instant.
  - Corrections, annotations, indications of who made them showing up alongside original text
  - Two parties able to talk to each other while they edit together
- How to find information
  - Queries
    - Difficult questions like “Which of my relatives have I been out of touch with for >3 months?” or “Which major city has the greatest % of people who watch rock videos?”
On current search engines like AltaVista: “It’s frustrating to use because it has no editorial judgment...search for ‘Friends’ and 100,000 sites come back in no particular order - map to Cambridge Friends School, a jewelry store called Gems for Friends.”

“Most questions are likely to have been asked before and answers will have been computed and stored.” (not quite: long tail keywords account for 70% of searches, 20% searches are brand new).

[Google isn’t quite as general purpose as this, but individual applications do let you do this. Partially because of data siloed in paid applications and no incentive to share some data publicly.]

- Filters
  - Check on all data coming in to see if it qualifies the rule

- Spatial Navigation
  - Modeled on physical way we locate information today. Go to bank app by pointing at a drawing of a bank, or find bus schedule by pointing at bus terminal. Buy a lawn mower by going into garage to see tools, and click on lawn mower.
  - “Spatial navigation will be particularly important for interacting with televisions and small, portable PCs, which are unlikely to have conventional keyboards.”
    - [He couldn’t predict tiny keyboard on Blackberry, and general purpose touchscreens. Also, skeumorphism became quickly unnecessary - I think people got accustomed to software faster than people expected. Possibly Bill Gates was scarred by the time it took to get GUI OS’s adopted.]

- Links
  - See a newscast with unfamiliar person, point at person. Read more about her.
  - [This is a pretty neat idea actually - machine vision to detect objects.]

- Agents
  - These are meant to help the average user remember how to use features. The agent will remember past activities and predict future activities. Gates calls this “softer software” ie less rigid than deterministic software.
  - E.g. Agent could scan every project schedule at MS and alert Gates to what were real issues vs what can be ignored.
  - This will be difficult, as with human assistant, to find balance between initiative and routine.
  - Program will behave to some degree like a person. Some find humanized computers creepy, but people like anthropomorphizing things.
    - [See Siri, Alexa.]

**Home and Consumer**

- General-purpose devices
  - General-purpose devices as new versions of familiar tools (books, newspapers, music, telephones)
    - These will obviate specific-purpose devices like CDs, stereoes, reference books, file drawers, fax machines.
● The computer will interconnect entertainment, communications, and productivity. It will be “as standard a piece of equipment as the telephone.” It will rarely be turned off.

● Wallet PC
  ● Functions as credit card, checkbook, address book, appointment book, notepad, something to read, camera, cell phone, concert tickets, map, calculator, photographs, entry card, games, email, fax, GPS, navigation.
  ● PDAs were the first precursors of these.
  ● “A really sophisticated wallet PC might cost what an elaborate camera does now, $1,000 or more.”

● Phones will have small screens and tiny cameras - but “they’ll look more or less like today’s phones.”
  ● Kitchens will continue to have wall phones that conserve counter space.
  ● [Mispredicted how everything would go into general-purpose mobile devices, and that would be sufficient.]

● Television connected to the Internet via a general-purpose computer

● HDTV
  ● Already in Japan, but not funded by advertisers because it doesn’t make ads measurably more effective

● Asynchronous television, movies, music. Watch/listen to what you want whenever, at whatever speed, how many times you want.

● Social interaction
  ● The phone and automobile broadened our community from immediate neighbors to people locally and (expensively) worldwide, synchronously. The Internet broadens your community to people worldwide, cheaply, asynchronously or on demand.
  ● Communities bound by interest. Members can share rich information about their interests (eg skiers with up-to-date info about weather conditions and equipment, photos of races, instructional videos, group meetups for training)
  ● Political movements and groups will be easier to organize.
  ● Multiplayer games, with avatars
  ● Staying in touch with friends remotely. Finding out what they’re doing and interested in
  ● Finding new friends in new ways - dating, interests, location - a general “people filter” that lets you find people who are a good match for what you want
  ● The full power of broadband won’t be apparent until a large share of people in developing countries are on the Internet.
  ● Will this be overwhelming?
    ● No more than being overwhelmed by the number of entries in a telephone book - the Internet will select for segments that are relevant to you
    ● Further, any communications can be filtered, prioritized, and delayed based on relevance and criteria

● Interactive media
  ● TV shows that ask for input from the audience, eg an interactive Jeopardy [prescient of live broadcasting like Twitch and HQTrivia]
  ● Gambling
  ● Watch Gone with the Wind with your own face and voice replacing Clark Gable’s
    ● [Recently prescient with deepfakes!]

● Rich simulations
VR for heart surgeon, play drums at rock concert

- Home management
  - When on trip, automatically turn down heat, ask post office to hold mail, cycle indoor lighting, pay bills
  - In Gates’s home, people have ID tags that customize whatever room they’re in to their preferences. Music and lights follow them as they walk around; designs on screens adjust to the person.
  - Any innovation needs to work a high percentage of time, because gain in convenience needs to be balanced with reliability/sensitivity.
- Sharing of screen to be viewed by two or more people at different locations.
- E-book with display for text, pictures, video; flip pages with your finger.
- Create virtual spaces
  - Your own museum curation

Content and Media

- Form factor
  - For centuries, the bulk of knowledge has been paper docs. From now, digital docs will dominate because they will help us in new ways.
  - Digital docs are easier to store, transmit, and manipulate.
    - Consider Boeing moving away from blueprints and physical mockups toward digital docs and 3-D models. Everyone could track progress in any component, annotate design, and make changes that would be impossible with paper. [Are companies usually first to exploit a new more efficient technology?]
  - Digital docs can have different media, like photos, video, audio, animations, interactivity. “The first documents that achieve widespread use will offer new functionality rather than simply duplicate the older medium.”
    - Much as a TV is not a duplicated book or magazine; it has less resolution and is larger/more expensive, but it offers video.
    - “Magazine publishers took text already created for paper editions and simply shoved it online. This was interesting but couldn’t compete with the richer forms of information in our lives. Now most online content includes lots of graphics, photos, and links to related information.”
  - Content will hyperlink to each other, be searchable.
    - Unlike encyclopedias that list items in alphabetical order and require flipping to pages, with Encarta you can pull up related articles and updates instantaneously.
  - This will be redefinition of a document itself, which also changes what we consider to be author, publisher, textbook.
- Content examples
  - Interactivity - games and movies can be interactive.
  - Multimedia emails - drag in weather forecast into email.
  - Image libraries with images on anything you can find (art, nature)
  - Automatic photo albums.
  - Virtual reality
- Already had 747 simulators back then.
- Will have light, cheap goggles with high resolution and latency.
- Will have haptic bodysuits - 10 million tactels, 100 tactels per inch, 256 levels of pressure per tactel. “The amount of computation needed is between 1-10x required for a current video display. This really isn’t a lot of computer power.”
  - Sex will be big, as it was for VCR, CD-ROMs, and Web. But it will shrink as the markets grow.
  - What we have today is “a synthesis of current media. Over time we’ll start to create new forms and formats that go significantly beyond what we’re able to do now.” New technology will offer people new means with which to express themselves.
    - [Has this happened? Seems we still consume text, photos, and videos the most.]
- Ease of Use
  - “In the past information has been hard to locate. It’s been almost impossible and very time-consuming to find all the best information on a specific topic. If you wanted to read biographies of all the recent Nobel Prize laureates, compiling them could take an entire day.”
  - Motion video and resolution need to be improved. “If you compare postage-stamp-size video images earlier in the 90s with video quality in 1996, the progress is remarkable. The size and quality of images will improve with faster processors and better compression, and eventually images on the PC will be far better than today’s television picture.”
  - “To edit video right now you have to be a professional with expensive equipment. This will change.” Desktop publishing has progressed to the point that consumers and professionals use the same tools. The same will happen to video. “The difference will be one of talent and craft rather than access to tools.”
- Cost
  - “The Internet is a publishing medium with entry barriers lower than any we’ve ever seen.”
  - Hard drives cost $0.15 per MB, holding 700 pages, so $0.00021 per page, compared to $0.05 per page. But you’re actually renting time since you can rewrite storage, so price per page per year is actually $0.00007.
  - A film takes up 4GB, or $1,600 in hard drive space, comparable to 20x $80 for VHS. But this can only service 20 customers a day - one digital copy can serve thousands of customers at once.
  - Cost of distribution will drive down. Much of a book’s cost goes into the actual paper, preprinting to get economies of scale, and to pay for distribution. This in turn causes risk for publishers, so not everything gets produced. The Internet will allow friction-free publishing; more money will go to authors.
    - [In short term, this was true; in long term, aggregators like Google/Facebook take much of the pie.]
  - Historically, the printing press made mass dissemination of information easy (but not practical for small-scale spreading of niche information). Xerox allowed the latter.
  - “The cost is so low that nobody thinks about the cost of sending am essage” - on BBS, mailing list, etc.
    - [Lowering the friction even further - psychological - led to Snapchat.]
- Monetization
  - “It’s hard to imagine the Internet thriving as a publishing medium unless content providers are paid for their work.” “Content development has been held back somewhat
because the simple, secure mechanisms authors need for charging users or advertisers are just beginning to appear.”
- But “advertisers usually hesitate to move into a new medium.”
- “It’s not practical to charge or pay small amounts” like 3 cents per news article.
  - [Content is so free nowadays that this is still true - just as people don’t like paying for free apps, they don’t like paying piecemeal for free content, even though they happily pay for Starbucks.]
  - [Exception is journal articles, which nominally charge say $40 per article, but prob most money still made through flat institutional subscriptions.]
- “New billing options - monthly subscriptions, hourly rates, charges per item accessed, advertising payments.”
  - [Some worked, others didn’t. Why? People may have gotten too used to free information, and advertising is just disguised free.]

Business Operations

- Greater interworker efficiency through intranets
  - Already at 10-100Mbps ethernet connections, limited less than home connections
  - Sharing docs and viewing data
    - Memos, announcements, reports, documentation, meetings, financial statements, sales, product development, brainstorming, phone directories
    - MS made financials available only on computers, not on paper (dogfooding)
    - Collaborative documents where shared editing can happen live [wow!]
    - Finding files is still a challenge.
      - Future folders will be viewed as a web page. [Not really panned out]
  - Videoconferencing will limit need for travel
    - Previous analogy: videoconferences on news show
  - Meetings will decrease with emails and shared documents
  - Email
    - Instant broadcasting of information to anyone
  - Document creation, spreadsheets are already in place but will be extended
  - All this will empower remote workers and leisure travel
  - Easier communication means less middle management
  - More automated hiring of employees and contractors, screening out their resumes.
- Greater intra-worker efficiency
  - Software does automatic calculations (accountant), designs virtually (architect), formats text (screenwriter)
  - Having more data more easily accessible and sliceable leads to new insights
    - Eg Pivot tables
    - No more need to wait for central IT to generate a new report
  - Internet lets people check facts (journalist)
  - Decreasing cost of software means higher production values (illustration, video, journalism)
Telecommuting

- Call-centric workers will have as much info as in the office - telemarketers, customer support
- “A decade from now advertisements for jobs will list how many hours a week are expected in an office”
- New productivity monitoring methods will have to come
- Desks in offices may be shared and customized depending on who’s coming in that day
- This will cause a dispersion of talent away from cities

Equalizing the playing field with small companies

- Previous functions like accounting, sales analytics, publishing can now be done by PC

Better services

- Customers can order directly from websites
- Customers can find much more detailed product information
- Customer service can now pull up all data about the customer and her products
- Customer service can happen over video chat, or asynchronously over email
- Consulting can happen over email and video chat (lawyers, accountants). The market will become very competitive, and unqualified people will be automatically filtered out.
  - “You’ll rely on it to find baby-sitters and people to cut your lawn.”
  - Get a specialist somewhere else in the country, rather than relying on your local generalist.
- Billing is electronic

Commerce

Efficient marketplaces

- Instantaneous information about worldwide supply, demand, prices
  - Pricing anomalies will disappear
- Automated haggling with computers of sellers. Servers will coordinate bids and handle transactions.
- The only middlemen who survive will be those who add real value, and they will thrive since the Internet will make them accessible worldwide.
  - Middlemen who offer specialized access to information will need to add value in new ways.
    - Travel agents will need to customize your trip to your preferences.
    - Travel agents might actually specialize in trips to his local hometown, rather than to hometown people who want to visit other places. [True of airbnb, Vayable!]
  - Example: Amazon. Value in fulfillment operations (leading to cheap, fast shipping), refund handling, reviews, other Prime benefits.
- Example: Kayak for price comparison

Customer services

- More product information from vendors, richer media in video, audio.
  - “Advertising will evolve into a hybrid, a combination of today’s television
commercials and infomercials, magazine ads, and detailed sales brochures.”

- [Predicted content marketing! Which I guess might just be infomercials.]
- No more printing of millions of pages of data sheets
  - Independent reviews online from third parties and communities
    - “You’ll get into the habit of checking online before you make any significant purchase.”
    - “Companies who don’t serve their customers well will see their reputations and their sales decline.”
    - Communities and forums suffer from voluble bad actors, but are self-moderating
  - Sales and retail will be widespread
    - Do you let all agents sell nationwide? How do you define sales territories?
      - [State regulations often defined local boundaries.]
- Personalization
  - Automated software to analyze your requirements and make suggestions
  - Consultants who can help you make better purchasing decisions at low cost, if Consumer Reports is too broad for you
  - Customization of clothes to your exact specifications
    - Your measurements registered electronically, to find ready-made clothes that will fit or place custom orders
    - Computerized machines that will custom-make clothes based on your fit
  - Personalized media
    - Journalism that doesn’t repeat info and context - you can explore deeply as much as you want
    - Media that gathers information about your interests and compete with each other to service your views and needs
    - Whatever news you care about, instantaneously (don’t wait for next hour)
    - New payment models for media - per view, per day,
    - What about serendipidity? Software will provide “calculated surprise” based on your viewing history and updating your profile.
      - [This is Facebook in spades, as well as Amazon and other recommenders]
  - Personalized banking
    - Banks will gather data from your accounts, spending patterns, tax liabilities, investments - then offer the best services
    - Mutual funds and other instruments will be available to consumers who aren’t Wall St insiders. Stockbrokers will be obsolete
    - Middlemen will aggregate small customers efficiently to get them the low interest rates that only large depositors can get [interesting!]
- Customer convenience
  - Won’t need to go into store
    - “Neighborhood video rental stores and music stores will face a dwindling market”
  - Much broader variety of products and services
  - Unlike TV home shopping networks, Internet is asynchronous and much wider variety
  - Media you can fact check and read source material
  - See what you ordered in clear detail
    - Hotel room before you book. Bouquet as it’s being made.
- Marketing
Product placement in videos/movies that let you find and buy any product in it
Experts can publish recommendations, products, services
- [Twitter, blogs]
New advertising models
- Traditional advertising-supported media will continue.
  - Advertisers spend more than $20/mo subsidizing broadcast and cable TV
- See grouped commercials
- Advertising that is granular down to the individual - not just by special interest (e.g. fishing magazine or sports game).
  - [Strong prediction!]
- Local advertising within city blocks
- Pay for your attention
  - People can bid for your attention: $5 to watch a Ferrari ad if you’re rich, $0.01 to a 16 year old kid.
Classified ads
- Get alerted whenever something new matches your criteria
- Put your own ads up with much more media - photos, video, floor plans
- “At some point word-of-mouth from satisfied customers will draw more and more users to the best of the network’s classified ad services. A positive feedback loop will be created” drawing more buyers and more sellers.
  - [Craigslist won! And out of simplicity and being largely free for most postings. eBay too. Can OfferUp etc beat it]
- “Much of the newspaper advertising base could be in jeopardy.”
New models for payment
- Digital media offer new complications of free copying, free transmission, infinite plays.
  - Charge for fixed number of plays.
  - Free for certain number of plays before you have to pay.
  - Like hardcover $30 -> paperback $10, digital media may charge $30 for first day pay, then $5 for later pay.
  - [ Piracy largely prevented this]
- Copyright: having a copy of a media work gives you the right to consume it, not ownership of the actual content.
  - Lending policy: can you share content with other people at light speed, if you’re not listening to an album?
  - Answer was no, copyright holders nixed this with licensing agreements with iTunes.

Education
- Free, hyperlinked, rich-media, instantaneous, interactive information
  - The very nature of education is devoted to information - how to acquire, organize, evaluate, use it. So PCs and the Internet are a natural fit
  - Being curious about something an dfailing to find it is discouraging and suppresses the impulse to learn more. The Internet will reverse this into an opposite virtuous cycle
  - The Internet will enable instantaneous deep learning on any topic
Curious about oil? Learn how oil is drilled, transported and refined; learn difference between automobile and aviation fuel; understand internal combustion engine vs jet turbines; learn molecular structure of gasoline and hydrocarbons.

For teachers, “it will take only minutes to pull together a visual show that would require days of work to organize now”

- Children naturally like interactivity, and PCs are eminently responsive and feedback-providing
  - Computers are endlessly patient: “Ask a thousand questions, get a thousand answers.’
  - Homework and tests give instant feedback, lowering the fear of tests and the defensive responsive that “since I’m not good at testing I’m just going to learn to not care about them”

- People can access the best teacher in the world on a subject. Teachers can access the best lesson plans
- Cross-disciplinary learning is available, with information being linked more readily than between textbooks
  - Check a historical fact while studying psychology, or get a math refresher during a physics lesson
- Students can get info live on ongoing events and interact with people they’re learning about (eg talk to an Inuit)
- Games and simulations will teach concepts in more compelling ways

**Personalization**

- PCs and the Internet will move the focus of education from the institution to the individual
- Own learning speed
- Own learning style
  - Linear vs organic
  - Reading vs manipulating models
  - Tailor analogies to the student’s strengths
- Computers will adapt the lesson to what the student already knows and is good/weak at

**Amplification of human teachers**

- Students will spend most of their time learning on computers. Teachers will conduct 1-on-1 sessions for more personal attention
- Teachers will still be important for understanding individual student behaviors and knowing when to stimulate or observe
- Software will replace textbooks, workbooks, tests, homework, grading, student progress
- Class sizes may rise to help pay for technology

**Computers should be made widely accessible in all schools**

- [no doubt ideally running Windows]
- School purchasing model is buy once, use forever - causing outdated PCs that aren’t upgraded

**History**

- Gates argues that education is capable of change. In the 1890s mass media exploded, causing many to realize they needed new skills to stay competitive. People pulled for standardization of curricula, and more students stayed later in school
- A similar wave is happening today, where parents are insecure about the schism between high-paid knowledge workers and low-paid service workers
Managing increasing enrollments from the children of baby-boomers is going to require cost-competitive innovations, like online distance learning

Predictions that Fell Short

In The Road Ahead, Bill Gates makes hundreds of predictions about how the world with Internet will develop. Remarkably, many more of his predictions came to pass than not.

The predictions that fell short surely sounded reasonable back then (many of them are still compelling). Here I attempt to understand patterns to why predictions failed.

- Became obsolete/unnecessary
  - Spatial navigation of data has been unnecessary as people got comfortable enough not to need real world metaphors (like going to the shed)

- Insufficient software
  - Real-time face mimic in video chat (eg talk as Hugh Grant)
  - Replacing faces in movies with your own
  - In 2018 all of these have progressed to a practical point. So betting on software to get more powerful is usually safe, even if you’re off by years

- Insufficient hardware
  - VR
  - Customization of clothes to your exact specifications. Your measurements registered electronically, to find ready-made clothes that will fit or place custom orders.
    - Making custom clothes is still really expensive. Robotics cost hasn’t gone down as fast as software
    - It’s not easy to get a 3D scan of your body yet.
    - Fit is quite subjective. Some skinny jeans are too baggy for others.
    - Logistics are so much better now, it’s easier just to order a ton of ready made clothes and return everything that doesn’t fit. The base clothes are cheaper and returns are easier than custom made clothes.

- Insufficient consumer want
  - Asymmetric calls, one-way video chat with customer service rep
  - Automatic calendar cross-scheduling
  - Finder of consultant services with reviews and qualification info (baby sitters, lawn care)
    - Angie’s List and Thumbtack come close, but other applications are niche - DogVacay. Insufficient demand and frequency means disintermediation
  - Automated haggling with computers of sellers. Servers will coordinate bids and handle transactions.
    - Why didn’t automated price discrimination come into practice? You can produce 1000 units and auction it off to capture the most value, so the people who want it
first pay more.

- A competitor might just do flat pricing avoiding customer wait.
  - Amazon became larger than eBay. Consistent immediate price is what matters. Amazon does use automated pricing though.
  - Consultants who help you make custom purchasing decisions at low cost, saving you time and lowering price
    - Consensus Amazon reviews may be enough. We have homogeneous-enough preferences that a 4.5 star review of a knife is fine.
    - Consultants may still not know enough about you for the hardest, highly subjective and high-variance decisions (eg whether a mattress or shoe feels good)
    - The rise of the Internet also means good hourly wages that keep labor expensive
  - Product placement in videos/movies that let you find and buy any product in it
    - Not enough demand to make the annotation worth it?
    - Dislike of explicitly too-commercial artistic works (eg movies)
  - Micropayments for media
    - The friction from paying $0 to $0.01 for content is very high, possibly much higher than that of paying $0.01 to $0.10
    - Thus consumers will prefer free information subsidized by ads to very-low-cost information without ads.
  - Always-on video
    - Gates predicted video that would read lips to make voice recognition better
    - Privacy concerns may have reversed this trend; now people actively shutter webcams
  - Paying for your ad attention. Why has no network been created that pays people for their attention?
    - This does happen with paying for timeshare vacations. This has to be somewhat profitable.
    - Adverse selection - the people who want to get paid most are the least valuable to point ads to
    - It’s been far more effective to market to people with search intent or retargeting (at least so far, with the data we have) than indiscriminate ads. The ad rates for a pay-for-attention market eventually fall below search intent, so companies would rather put their marketing budget there.
      - Though Facebook lookalike is close in concept
    - Customers have been fine with free information subsidized by ads. They understand this deal and haven’t clamored to be paid for their attention yet - they’d rather get the free info than spend their time on ads
    - Customers have a limited capacity to spend, which is already maxed out by ads. You can’t get them to spend more just by showing them more ads, which lowers the ROI possible.
  - Corporate inertia/moats
    - More telecommuting work
      - Thus many people still live in cities (though companies like Google have many local headquarters). Gates predicted a positive feedback loop where talent disperses, causing employers to relax their location requirements.
      - Cities may themselves be entrenched, given the many amenities.
Shared offices that can morph depending on who’s coming in that day

Obviating brokers due to direct marketplaces
- Has come true for stocks, travel. Where the item purchased is a commodity
- Insider knowledge is hard to develop for infrequent transactions: real estate, mergers and acquisitions

Most of his education predictions haven’t come true, aside from pilots in charter schools. What he was hoping would come true in 1996 is still being bandied as the future of edtech in 2018
- “If someone who dropped out of society 20 years ago walked into an office today, she’d be surprised by the new workplace...but if she walked into an American classroom, she’d find little that was unfamiliar.” Still true today.
- Why hasn’t education changed more toward the individualized model?
  - Aggregating content into a customization platform is still not trivial
  - Possible that teachers still resist handing off education to computers
  - Regulation around teaching styles and curricula in public schools
  - Lack of strong efficacy results - customization might not be enough to overcome differences in behavior and early childhood influences
  - The Internet has offered more enticing/addictive applications than free information, neutralizing its hoped-for educational advantages

Escape mechanisms defeated
- Like hardcover $30 -> paperback $10, digital media may charge $30 for first day pay, then $5 for later pay.
  - Piracy probably prevented this.

Where the benefit provided was too small to overcome another bottleneck, which was not relieved by Internet/software.
- More automated hiring of employees and contractors, screening out their resumes.
  - Why doesn’t Indeed have a resume form with selections for schools, companies, skills? And automated tests?
  - The entrenchment of Craigslist through network effects might actually be a detriment to efficiency and technological ability.
  - Too easy for applicants to cheat?
  - Hard data too fuzzy - has to go through manual layer soon after, which is where most of the cost is anyway? I don’t reject people from mid-tier schools by faith. And I do reject very quickly. Only takes 30 seconds each.

Big things Gates didn’t explicitly predict/discuss
- Adwords - advertising based on search intent
- The virtuous cycle of more consumer adoption of Internet -> more commerce -> more valuable for vendors to buy ads -> stimulation of media
- Physical personal goods exchanged on the market - Uber, Airbnb
- [To be fair, Internet usage up to 2000 was so niche that some business models wouldn’t clearly have been possible. Then the dotcom crash came, tech was in winter for a few years, and then the new business models they came pretty quickly after that.]
Concerns, Critical Issues, and Counterarguments

In The Road Ahead, Gates spends more time imagining the future than addressing the arguments of naysayers. The final chapter does deal with major concerns people have about the Internet - I share those here.

- What will happen to jobs?
  - New professions and industries will flourish as others fade. The majority of 501 job categories in 1990 by the US Census Bureau didn’t exist 50 years ago.
  - There is not a finite number of jobs in the world. When people lose jobs, resources are freed up to work on something more productive.
  - Advancing productivity leads to broad benefits that may cause some to suffer temporarily (eg eliminating middlemen from commerce)
  - People will need to reinvent themselves. In general, seek to acquire new interests and skills throughout your life.
  - Education needs to focus on general problem solving and facility with computers. The beauty is that the extra cost of educational material access is zero.
    - [This turns inequality less about information access and more about inequality in genetics, parenting, behavior, motivation.]

- What if Internet access and facility is unevenly distributed?
  - A computer connected to the Internet must be available to every citizen, not just the elite, for the Internet to be fully integrated into society.
  - The question of universal access arises only if the Internet is immensely successful - “more successful than many commentators expect it to be. Some of the same critics who complain that the network will be so popular it will cause all kinds of problems also complain dismissively that it won’t be popular at all.”
  - The Internet needs to be a mass phenomenon, or it is nothing. “There are fixed costs to authoring content, and a large audience is required to make it affordable.”

- Will AI destroy humans?
  - Every prediction about major advances in AI has proved to be overly optimistic. “Today even simple learning tasks are well beyond the world’s most capable computer.”
  - Eventually there will be programs that will recreate some elements of human intelligence, but “I don’t think it’s likely to happen in my lifetime.”
  - But when computers achieve true intelligence, this will “raise issues of who is in control and what the whole purpose of our species is.”

- Connecting the world and effacing cultures
  - Some cultures may feel under assault as people pay more attention to global issues and cultures and less to traditional local ones
  - “The fact that the same ad appeals to someone in New York and in Africa does not prove those situations alike - it’s merely evidence that people have a few feelings in common.”
  - People want to belong to multiple communities and share national/global experience,s like the Super Bowl, the OJ Simpson car chase, or SpaceX rocket launches.

- Overindulgence and overreliance on the Internet
The Internet will be pervasive and life and replace much of our current experiences. This makes a failure of the network worrying. Cryptography breaking would be disastrous.

- Breaking RSA - Paul Kocher carefully timed how long it took the system to decrypt them, which gave enough information to find the private key.
  - [Interesting indirect attack, much like Spectre used CPU response time to figure out what was in memory.]
- Loss of privacy and information collected about everything can be abused. All your activity will be recorded and your Wallet PC will measure many things. Should insurance be able to see what you eat at home? Should an employer see what you watch on Netflix? It’s a question of balance of accepting restrictions in exchange for security.
- Overwhelming of information
  - Information overload won’t be a problem, the same way no one gets overwhelmed when visiting a library or looking at the phone book. Navigational aids will point us to information relevant to us.

**Principles**

Here I organize some of the main general principles of *The Road Ahead*. These are meant to apply to any possible technological paradigm, even though they fit very well for the PC + Internet revolution.

- Small players disrupt because they have to - the incumbent has raised the barrier of entry too high so small players have to start low cost (eg PCs vs mainframes). Of these disruptors, some of them win because they’re on the right side of customer needs and enjoy positive feedback loops.
- The new tech paradigm looks scary or foreign at first, but it’ll work if it makes your life easier.
  - Making things easier pretty much guarantees it will be done more often.
  - The old paradigm won’t totally disappear, but the new one will dominate.
  - Over time, the new machine finds a place in our everyday lives because it offers convenience, saves labor, and inspires us to new creative heights. Goods and services and new jobs arise. It assumes a trusted place besides our other tools. A new generation grows up with it, changing and humanizing it, playing with it.
  - Once you get used to it, you’ll wonder how you got along before it.
- The first documents that achieve widespread use will offer new functionality rather than simply duplicate the older medium. Content needs to be specially authored with the medium in mind.
  - Is this true of more than just content/documents?
- It is impossible to do everything well. Companies do well by picking a narrow slice of the pie and focusing on it.
- The free market allows rapid innovation on many fronts in parallel, with most being failures but all contributing to shared learning and rapid progress. The marketplace decides which approaches win and lose, getting to the right solution faster than with central planning.
  - Thus government should stay out of creating technology standards. By mandating complete compatibility with past machines (eg mandating PCs compatible with
mainframes), they can stifle innovation and progression to new standards.

- Killer app - a use of technology so attractive to consumers it fuels market forces and makes the underlying invention indispensable.
  - Lighting for electricity
  - Web for Internet
  - VisiCalc for Apple II
  - Word processing for PCs
  - What is the killer app for the Internet? It’s hard to tell when it’s so pervasive, but one can look to developing countries to see why they adopt it.
  - Social networks/communication. Banking.

- Abstractions - people don’t need to know how it works, nor do they care.
  - The web abstracted away messy server connections, commands, and code.
  - The browser and https abstract away RSA
  - Similarly, crypto needs to make the blockchain invisible - users get only the benefit.

- The trend in hardware was from specific to general purpose, enabled by software.
  - VCR -> software on hardware connected to Internet

- The new technology needs to solve identified problems. It’s not a panacea.
  - “I’m losing money, I’d better get some computers” = failing strategy
  - Automation amplifies whatever efficiency/inefficiency is already there.
  - For the Internet, think - how should information move?

- New communication modes bring their own sort of etiquette
  - Before phones, meetings happened face to face, likely with a meal and hours long visit.
  - With phones, short calls were enabled. “hello?” “good bye”
  - With emails, even shorter, asynchronous communication. Consider like lines in a conversation, not like letters. Reply-all, CC had their own etiquette.
  - With texts, tweets, Snapchats, even more etiquette (emoji, read but not responded).

- Explaining the flexibility and ease of use is difficult to a “nonuser”

- “It’s almost impossible to guess the secondary effects of the changes we can foresee, let alone those we can’t. You might have warned your friends at the Acme Buggy Whip Company to polish up their resumes and learn something about engines, but would you have known to invest in real estate for strip malls?”

- To learn a new technology or paradigm, try to use it to solve a personal problem or do something you find fun.
  - Like Warren Buffett avoiding computers until Gates showed him how to play bridge online.

- Some late adopters and developing areas will skip a step and move directly into the new paradigm, avoiding others’ mistakes.
  - (like China moving from no telephone to wireless without needing copper cables)

- People often overestimate what will happen in the next two years and underestimate what will happen in ten.

- The gold lays deeper and in different places than prospectors realize. People in a gold rush dream of quick riches and overinvest in the obvious areas, ignoring subtler or longer-term opportunities.
Virtuous Cycles

- A de facto standard emerges when one way of doing something gets a slight advantage over competing ways. It’s most likely to happen with a high-tech product made in great volume at small marginal cost and derives some value from compatibility.
- The greater the number of software applications available for a platform -> the more valuable the machine to the consumer -> the more machines consumers buy -> the more applications software developers create for it -> the more desire there is to be part of the network that everyone else belongs to.
  - VHS vs Betamax: It’s said that VHS won even though Beta was technically better, but Beta recorded only for an hour, while consumers wanted longer recordings. So VHS marginally won out, which led to more VHS players, more VHS tapes in rental stores, making VHS fundamentally more useful, kicking off more VHS sales.
  - For the IBM PC and MS-DOS: thousands of software applications appeared like Lotus 1-2-3; companies began making compatible accessory card add-ons extending the hardware (like floppy disk drives, memory expansion). This makes the IBM PC more valuable than the Apple II, which recruits more people to the IBM PC.
  - Gates argues that once the standard is set, sales skyrocket - though this may just be coincident with momentum identifying a winner, rather than the consumer certainty of a known standard causing more sales.
  - [How do you model the turning point when this happens?]
  - [See VR, crypto as not having broken critical mass yet]

- The web: cheaper cost of production and distribution -> more content -> more value in Internet -> more users and longer retention -> bigger markets -> more infrastructure development -> cheaper cost of production
  - Also bigger markets -> more advertisers -> more content
- “Death can come swiftly to a market leader. By the time you’re thrown out of the positive-feedback cycle, it can be too late to change what you’ve been doing, and a negative spiral can come into play.”

Counter-forces

- Telephone companies arguing to regulate and tax Internet as long-distance services. Their high margin long-distance service has subsidized underpriced local service, given in the name of universal service. They argue the Internet will be overwhelmed by traffic.
  - “This will be a passing problem because the investments in Internet infrastructure are heavy and the bandwidth is increasing rapidly. There’s no fundamental roadblock that’s going to stop the Internet from flourishing.”

History of Computing and Disruption

In The Road Ahead, Bill Gates spends the first few chapters on the history of computing and tech companies in the industry, his early personal history with computing, and the environment in which
Microsoft started.

Bill Gates and Computers

- Early on, Gates was thrilled with immediate feedback from whether program works or not. Started in BASIC
- The PDP-8 and Intel 8088 inspired Bill Gates and Paul Allen to be certain that computers would be cheap and everywhere. If it was cheap, people would find all kinds of new applications, and software is the key to delivering on the full potential of the machines. Even the industry at the time didn’t see that a microprocessor could grow up to be a general-purpose computer.
- “One reason I was so determined to help develop the PC is that I wanted one myself.”
- “We asked, what if computing were nearly free?”
- “A computer on every desk and in every home” - MS’s corporate mission
- “A great deal of a general-purpose computer’s value to its user depends on the quality and variety of the application software available for it.”
  - This could be said about any hardware product (VR/AR) or platform (blockchain).
- “Many manufacturers use a tie between their hardware and their software to distinguish their systems.” This will “play out again in the Internet marketplace.”
- “Microsoft is not unstoppable. We have to earn our leadership position every day. If we miss the next big turn in the industry’s road, we’ll lose out.”
  - See: Windows phone failure to capture mobile

A Brief History of Computing

- Over time, the new machine finds a place in our everyday lives because it offers convenience, saves labor, and inspires us to new creative heights. Goods and services and new jobs arise. It assumes a trusted place besides our other tools. A new generation grows up with it, changing and humanizing it, playing with it.
  - The printing press was the first mass medium. For the first time knowledge, experiences, opinions could be passed on in a portable, durable form. A population’s reach became far beyond the village. Literacy was a significant skill that revolutionized education.
  - The phone was once seen as a nuisance, a mechanical invader in the house. Eventually, they realized this was a new kind of communication. It wasn’t as long and as formal as face to face. You didn’t need to visit and have a meal, and spend a full afternoon or evening.
- In the 1830s, Babbage saw that information could be manipulated if the information were converted into numbers first. A general purpose machine running software could replace countless special-purpose machines like cotton gins.
- In 1930s, Claude Shannon saw that computer circuits could perform logical operations with 1 and 0.
Moths attracted to vacuum tubes with heat and light, causing short circuits. Hence giving rise to “bugs.”

In 1945, von Neumann architecture avoided having to reconfigure 6,000 cables to change the computer function.

- Analogy: the airplane propeller got perfected and reached a plateau until the jet came along (from Ben Evans). Similarly, vacuum tubes got super powerful until the transistor came along.

1960: DEC created the PDP-1, the first small minicomputer for $120,000.
- DEC later failed to see the personal computer. “He was brilliant at seeing new ways of doing things, and then he missed a big bend in the road.”

1965: Gordon Moore predicted capacity of computer chip would double every year. Over 3 decades it held up, every 18 months.
- Gates said in 1996: “it’s likely to hold for another 20 years.” This was pretty accurate - how did they know? Were they able to estimate the limits of physics?

Mid 1960s: IBM created scalable architecture with the System/360 OS - all models (crossing a 50x range in performance) would run the same OS and use the same set of instructions. Software, peripherals would be compatible between models.
- Customers invested big in 360, confident their training and software wouldn’t be wasted if they later moved to a larger machine.

1970: Amdahl created hardware that ran the same 360/370 OS and applications. Soon many clones followed.
- [Why isn’t this possible today with OSX? Is it just far too expensive to build an OSX compatible OS? Some also argue OSX is tuned to Mac hardware.]

1970s: Wang Laboratories, previously dominant in electronic calculators, switched to word processing machines as low-cost calculators came in.
- But in the 1980s he didn’t see the opportunity for software for general-purpose personal computers. They kept the software tied to their hardware.

1977: Bob Noyce comparing microprocessor to ENIAC: “It is 20x faster, has a larger memory, is thousands of times more reliable, consumes the power of a lightbulb rather than a locomotive, occupies 1/30,000 the volume and costs 1/10,000 as much.”
- Thus marketing can illuminate the possibilities.

Microsoft
- In 1972, Allen and Gates tried to write BASIC on the DEC PDP-8, but it didn’t have enough transistors. They first built Traf-O-Data to process data traffic tapes.
- In spring 1974, Intel’s 8080 chip had 10x the power of the 8008 for under $200. “If a tiny chip could get so much more powerful inside two years, the end of mainframes was at hand.”
- After trying to get clients for a BASIC to no avail, in December they see the Altair 8800 for $397 with no software. “Oh no! It’s happening without us! People are going to go write real software for the chip.”
- Gates left school in spring 1975 for Albuquerque, where MITS (making the Altair 8800) was located. MS built software for it until MITS was acquired. After this, Gates vowed to always have enough cash on hand to run the company for a year with no income.
- 1977: Apple, Commodore, Radio Shack produced PCs; MS provided BASIC for most early PCs. Despite charging $50-100k, this was cheaper than the company
creating its own programming language.

- MS sold to computer manufacturers because it feared piracy.

**1979:** MS moves to Seattle. Their main business is writing programs for the new machines appearing as the PC industry takes off. Gates recruits Steve Ballmer.

- They license software at low prices to earn on volume. They didn’t want to give anybody a chance to look elsewhere - “we wanted choosing Microsoft software to be a no-brainer.”
- Virtually every PC manufacturer licenses a programming language from MS. They want to advertise that their machines are compatible with the growing MS BASIC standard.
- The big fear is that a major computer manufacturer would take software for larger machines and scale it down to run on microprocessor-based computers. This happens too late - IBM and DEC don’t really believe in personal computers and don’t push the product.
- MS knows that a general-purpose PC’s value depends on the application software available to it.

**1980:** IBM approaches MS to discuss a PC IBM might build.

- At the time it has 80% of mainframe market, mainly B2B. It wants to partner with outsiders to sell little machines to individuals since it’s outside its competency.
- IBM wants to create a PC in less than a year; this urgent timing forces it to abandon its tradition of creating all hardware and software itself. It has to build from off-the-shelf components, meaning it’s an open architecture, meaning manufacturers like Compaq can create IBM clones.
- So IBM licenses the OS from MS, what will become MS-DOS.
- MS pushes for 16-bit chips (Intel 8088) to increase up to 1MB of memory, but IBM wants to save money and uses an 8-bit bus and 16kB of memory.
- “IBM had a real chance to create a new, broad standard in personal computing. We wanted to be a part of it.”
- IBM PC ships in August 1981 with 3 OS’s - PC-DOS, Digital Research’s CP/M-86, and UCSD Pascal P-system. MS knows only one will become the standard. Modeling their strategy after the VHS, they see three ways to compete:
  - Make MS-DOS the best product
  - Help other software companies write MS-DOS based software
  - Make MS-DOS inexpensive to license

- They give IBM a great deal - a one-time fee of $80k granting IBM the royalty-free, non-exclusive right to use MS-DOS forever. This gives IBM an incentive to push MS-DOS.
  - The UCSD system sold for $450, CP/M-86 for $175, and MS-DOS for $60.
  - MS’s goal is to make money not from IBM but from computer companies who wanted to make machines compatible with the IBM PC.
  - Surely IBM’s perception of the PC market as likely to be perpetually small made it cut corners in negotiating and controlling
its territory. [Perhaps why Jeff Bezos negotiates hard on everything.]

- [At the time, rivals Apple, Tandy, Commodore have >50% of the PC market, distribution networks, and software. Jobs finds the IBM PC inadequate and places the famous “Welcome, IBM. Seriously” ad in 1981.]
- The IBM PC is immediately successful. IBM customers who were reluctant to buy Apples are happy to buy from their traditional supplier. Many software developers switch over to the IBM PC when announced. Peripherals make up for initial hardware limitations.
- “IBM undertook a lot of projects whose goal was to eliminate any dependence on Microsoft. It was only by staying ahead of IBM technically that we maintained the relationship.”

- **1982:** Third-party software developers start producing applications to run on the IBM PC, powering the virtuous cycle.
  - Lotus 1-2-3 is an early example, beating VisiCalc on the Apple II through its expanded memory and larger screen, yet retaining the menu structure and user experience so VisiCalc users could migrate to 1-2-3. [Even in 1984 it’s startlingly close to how Excel works today.] VisiCalc’s sales quickly drop, having been released only in 1979 and declining in 1983.

- **1983:** MS develops the software for a small laptop, the Model 100/NEC PC-8200.
  - [What did they do with this computer? It was popular with reporters, who could type stories on the field and send it to HQ via an acoustic coupler.]
  - [Also: “The used-car market is six times bigger than the new-car market,” says Clive Smith, NewDeal’s CEO. "When the used-computer economy emerges, it will be a bigger business than the new-computer economy. The sheer scale of x86 retirements dwarfs any other platform base in history.”]

- **Example Basic program for a BBS**

- **1983:** Bill Gates believes MS should develop a graphical OS, and they announce Windows (after the Apple Lisa, before Macintosh).
  - Windows work has started in 1981.
  - MS-DOS requires users to type obscure commands. If they want computers on every desk and in every home, then PCs have to be made easier to use.
  - Xerox Star and Apple Lisa are already available with graphics. But “Xerox did a poor job of taking commercial advantage of this groundbreaking idea because its machines were expensive and didn’t use standard microprocessors.” Also, they’re built on proprietary hardware and other companies can’t license the Xerox/Apple OS’s to build compatible computers. So neither platform attracted software developers to build applications.
  - On Xerox PARC: “Translating great research into products that sell is still a big problem for many companies.”
  - MS wants to create an open standard, bringing graphical capabilities to any computer with MS-DOS.

- **1984:** the Macintosh is released, with the first widely used GUI and desktop metaphor, licensed from Xerox PARC.
  - Microsoft wants the Macintosh to sell well because MS had created
applications for it and because they want the public to accept graphical computing.

- For years major software companies (eg Lotus, WordPerfect) ignore the Macintosh and Windows, believing graphics gets in the way of usage without offering big benefits for power users. This is eventually their mistake.

- “Steve has a keen instinct for engineering and design as well as an ability to motivate people that is world class.”
- “The Macintosh had great system software, but Apple refused (until 1995) to let anybody else make computer hardware that would run it. This was traditional hardware company thinking: If you wanted to use the software, you had to buy Apple computers.”

- **1984:** IBM sets record for profit at $6.6 billion.
  - It introduces the PC AT, built around Intel’s 80286 (the 286) and 3x faster than the original IBM PC.

- **Mid 1980s:** IBM is the standard for PCs. Only Apple II and Macintosh remain.
  - HP, DEC, Texas Instruments, and Xerox all fail because their machines weren’t compatible with IBM’s and didn’t offer enough improvements over the IBM architecture to encourage a shift.
  - Startups like Eagle and Northstar produce hardware they think is slightly better and think they’ll win, but “they were wrong” - the ecosystem of software and peripherals is too large. People want the same system people they knew and worked with had.
  - IBM becomes the central force in the PC industry with its open architecture, but **its lead is tenuous, “more like that of the leading runner in a marathon” than the impenetrable giant it was in the mainframe business, where its large sales force and R&D were difficult to match.** In the lower-cost, volatile PC business, with rapid virtuous cycles, low barrier to entry, and evolving consumer preferences, the leader has to run fast or the rest of the field will pass by.
  - In mainframes, IBM could limit the price/performance ratio, release hardware that requires the new OS, or release an OS that requires new hardware. This doesn’t work in PC. “The world had discovered that lots of companies made IBM-compatible hardware and that, **if IBM couldn’t deliver the right value, someone would.**”
    - This is partly due to IBM’s lack of IP control over its OS’s and lack of proprietary hardware (using off the shelf parts, due to wanting to speed up its entry). Unlike Apple, **it has no patents on the components,** allowing “clean room” reverse engineering of the BIOS. Manufacturers could then license MS-DOS.
    - Example: Compaq is founded in 1982 by three former Texas Instruments managers and makes the first IBM PC compatible computers. Then in 1986 they beat IBM to the punch by releasing a 386-based computer before IBM, which pulls back to protect sales of its low-end minicomputers
IBM holds back on PC development to avoid PC sales cannibalizing its higher-end products.

- 1987: IBM releases Personal System/2 (PS/2), meant to be the “clone-killer,” with proprietary hardware, software, and architecture.
  - The intent is to own proprietary hardware architecture (Micro Channel) that is incompatible with the IBM PC and AT. The new Systems Application Architecture will be compatible across its entire suite of computers, from mainframe to PC. They believe this will be irresistible to corporate customers. They also plan to release their own office suite, OfficeVision.
  - IBM holds strong patents on Micro Channel and requires manufacturers to pay license fees.
  - IBM doesn’t properly weigh that mainframes are a declining market and will influence buying decisions less.
  - IBM also believes Micro Channel’s faster bus than PC AT’s will win the day, but it turns out this was not really a bottleneck, and it’s incompatible with add-in cards.
  - IBM takes a more active role in developing OS/2, engaging with MS, but the requirement to be compatible with mainframes leads to a rift in design philosophy.
    - Example: it takes 3 minutes for OS/2 to boot, which is not a big deal to them since mainframes could take 15 minutes to boot.
    - They are stymied by need for consensus, with mainframe product managers requesting handicaps to the PC product to make it compatible with IBM mainframe printers.
  - In response, manufacturers (the Gang of Nine, including Compaq, HP, NEC) agree on the Extended Industry Standard Architecture (EISA), which is compatible with the PC AT bus and all its peripheries.
    - Customers reject Micro Channel in favor of this new standard.
  - “IBM was such a great company. Why did it have so much trouble with PC software development?”

- 1988: The Open Software Foundation tries to rally manufacturers (IBM, DEC) to unify UNIX, which has splintered across manufacturers leading to cross-incompatibilities.
  - This is a reaction to the threat of AT&T and Sun merging.
  - Gates believes it fails because the competing vendors try to promote the benefits of their particular versions of UNIX and want to tie-in customers.
  - This points out the difficulty of maintaining cartels with competing companies.
    - “Any company that wants to create a standard has to price its products very reasonably, or the standard won’t be adopted. The market effectively chooses a standard whose products are reasonably priced and replaces it when its products are obsolete or too expensive.”
    - Consider audiocassettes, VHS tapes, CDs, televisions, cell phones - all technologies made by private companies that receive royalties from people
making the equipment.

- “Microsoft has been able to provide compatibility because hardware manufacturers have agreed not to allow modifications to our software that would introduce incompatibility.”
  - [Also see Android, Example compatibility requirements]

1. 1990: MS tries to reach agreement for IBM to license Windows 3.0 on its PCs. IBM refuses.
2. 1991: Apple and IBM put aside their rivalry and create Taligent and Kaleida Labs. The goals respectively are to produce an OS to eclipse Windows and to get market leadership in multimedia technology. These shut down by 1995.
3. 1992: IBM and MS stop joint development of OS/2, letting IBM keep the joint work the two companies had done.
   - “It was the scariest threat to Microsoft’s future ever. We had to compete against the largest company in the computer industry, which was fighting us with OS software we had helped develop.”
   - OfficeVision is eventually canceled.

- “During the PC industry’s infancy, the mass media paid little attention...we were hardly what you’d call trendy.” vs the information superhighway.
  - Why? Were the applications of the Internet more obvious?

**Brainstorming Notes**

**Checklist of Industries**

Make a list of every industry, and use as a checklist for how a new tech paradigm can change it. I imagine that for The Road Ahead, Bill Gates used a somewhat similar strategy to consider all the pervasive changed the Internet would bring.

- Finance
  - Consumer transactions
  - Trading instruments
  - Consumer banking
  - Investment banking
  - Lending
  - Insurance
- Retail
- Media
  - News
  - Entertainment
- Services
  - Accounting
  - Consulting
Questions to Overcome

Here’s a set of questions inspired by The Road Ahead to push your thinking forward past your biases toward the present. Each question has historical examples for illustration.

- What happens if this is literally costless? Even if it’s quite low cost already.
  - Storing and transmitting a page cost $0.05 with Xerox. But it can be $0.00002.
  - Printing press reduced page from $20 (?) To $0.1.
- What quantitative trend is being mapped out today? What happens if you extend this continuously for 10-20 more years - what does the world look like, and what is enabled? What if this accelerates?
  - Moore’s Law
  - Cost of sending a packet
- What can make adopting this easier for consumers?
  - Video editing with desktop software. Document prep with desktop software.
  - Web easier than terminal commands to connect to usenets
  - GUI easier than terminal commands
  - Asynchronous sending emails vs letters or synchronous telephone. Also, psychological - Snapchat vs emails or Facebook posts.
- What happens if usage increases dramatically, because things are way easier?
  - Eg Microsoft’s company financials viewed far more frequently when put on intra-web.
  - Reading more content on web means more impressions for ads than newspapers ever had.
- How will life improve in the enterprise and workplace?
  - Authoring documents and communicating made far easier with publishing software and
Easier communication means less middle management

- What current bottlenecks/delays is this going to prevent?
  - Eg spreadsheet software obviates waiting for IT to generate a new data report
- Simulate the ecosystem to its logical conclusion. How will industry structures change?
  - For content, take the first step to knowing frictions to publishing are super low, meaning more work will be created. Then imagine that discovery of all this widely varying content will be very hard. Then realize that a middleman will need to allow discovery and also service relationships at scale with advertisers. Then picture this middleman will have immense leverage over publishers.
- What paradigm changes in interactivity, engagement, consumption are allowed through this new technology?
  - Magazines provided good enough niches. But Web allowed for much more media - videos, audio, more photos - and linking.
- What are the structural barriers preventing the vision from unfolding?
  - Five forces - if consumers don’t have enough pull to force a change. If incentives don’t push for new tech.
  - Costs don’t lower as fast as expected (3d modeling for VR)
  - The improvement diff is not enough to make life better for customer (VR over 2D gaming in 2017).
  - Consumer habits and emotion are usually not a barrier, if the improvement is good enough.
    - Browsing bookstores vs Amazon
    - Going to movie theater vs Netflix
  - If the industry hasn’t changed for 20+ years - why would it change now?
    - Eg Education from 1976 to 1996, then to 2018.
- What are pessimistic questions that need to be broken past?
  - This is already good enough. Why do we need anything better?
    - Standard TV broadcasts are great. Libraries already have all the info we need. Why do I need it personalized to me?
      - Counter: Imagine a dedicated personal assistant who read the entire world’s news and gave you only what you wanted to hear. In a 30 minute broadcast, how often are you bored? 20 minutes? What if we reduce that to 0?
      - Counter: Tell me how much time it took you to find a good plumber. What if instead of an hour calling, it took you 2 minutes?
    - (In film print days) I already take and print as many photos as I want. I don’t have enough space for photos. I like being judicious with taking photos.
      - Counter: What if you had infinite film? Instead of 500 photos, what if you had 50,000? What if you had video cameras recording your baby 24/7? Would you like this?
    - I already get my niche information through magazines. I don’t need more magazines.
      - What if you could have 100x more volume, searchable, whenever you want?
      - Web can get you audio, video. And linking to more relevant info.
    - I can buy CDs at the store already.
      - Counter: You don’t need to go to the store - your device at home can access
any album ever produced. You can buy songs, instead of the album. You can carry this library anywhere you go.

- [I faced this myself when trying to find Sibelius concerto - only one violinist was available.]

○ Experts don’t need this.
- Would Winston Churchill or Shakespeare really have produced better work with MS Word?
  - It’s hard to predict for the elites, but raising the ability of the masses of average people substantially will lead to improvements across the board.
- Good accountants don’t make mistakes that take time to retabulate. Why do we need spreadsheet software?
  - Similarly, “people don’t need Dropbox because you could roll your own in Linux.”
  - Similarly, “the iPad is terrible. It’s underpowered, screen is way too big, can’t run Flash.”
  - Don’t let your ego/expertise get in the way of appreciating how massive improvements can make something much more pervasive.

○ This won’t fix problem X.
- The new technology isn’t a panacea. The Internet and computer don’t fix broken businesses.

Open Questions

- Wars have been really helpful for innovation - there is no motivation like dying and being conquered. Similar between companies.
  - Have governments ever induced fake wars for progress?
- Can anything break the compression limit per Shannon? Would this need an entirely new paradigm of coding information?
- Why did it take so long for Innovator’s Dilemma concepts to arise? There must have been disruptions in the past.
- When is hardware a competitive advantage, and when is it a commodity?
  - When tied into software, like Apple
- If IBM had started work on the PC earlier in 1980, and created proprietary hardware/architectaure, would that have prevented its decline? Or would an upstart have created a low-cost entrant that became pervasive?
- Why did Windows phone fail?
  - MS grew too fat on Windows and Office, making mobile a distant priority. Google and Apple had it at its core for various reasons - Google to extend search and ads, Apple to sell hardware.
  - Mobile devices, with focus on touch, simplified interfaces, and ARM, were nothing like PCs. Everyone had to start from scratch, which means MS didn’t have any advantage. They were out-executed.
  - MS wanted to license an OS for profit. Android killed this model since Google made its
money from search and gave away Android, making it hard for anyone trying to extract rent for a competitive product. “They want market share, but they don’t need economics.”

- Leveraging Windows and Office didn’t work, since people don’t want Office on the phone; apps consumers want are being written for the web, not for Windows; and free software like Google Drive eats into need for Windows.
- It failed to grab a virtuous cycle in platform - developers - software - users, while Android/iOS took it instead (Android by being pervasive and cheap; iOS by being early, with a good UX and hardware).

- Will kids one day think of mobile phones not as phones but general purpose computers?
- Why didn’t MS develop a search engine earlier?
  - They did - MSN Search
- Bill Gates was spot on with the extrapolation of progress and usage patterns. How did MS choose which opportunities to work on?
  - “Microsoft’s competence is in building great software products and the information services that go with them. We won’t become a bank of a conventional store.”
- The predictions that worked are admirable but maybe “too easy” if they merely extended what was already happening. What are patterns to predictions that were either slow to come (VR) or off base (wall phones)
  - VR: Still high cost of 3D modeling, computing power, only recently fixed the latency issue
- Ev Williams: “We often think the Internet enables you to do new things - but people just want to do the same things they’ve always done.”
  - If secular stagnation is true, is this why IT didn’t lead to massive growth? Consumption increased, but also got cheaper, and it was just redistribution of wealth (from Sears to Amazon, from newspapers to Google).
- Compared to just 20 years ago, instant gratification is more serviceable than ever before.
- Is it usually the case that enterprises take up the new paradigm first to solve business cases? And this is also where the money is?
  - True for computing and mainframes, maybe Internet and email? False for the PC and web.
- How could you predict early in the Internet that it would lead to widespread economic growth?
  - Taken simplistically, accessing more information more quickly - like “it would take all day to find biographies of the recent Nobel Prize laureates” - how do you connect this to GDP growth?
    - More consumption of cheaper, more personalized content? Better education?
      Better, more creative ideas? More efficient trade (removing brokers)? Elimination of inefficiencies in communication? Lowering barrier for small companies to compete, allowing more testable ideas?
    - In 2011, McKinsey: Internet is responsible for 20% of GDP growth in developed countries; raised real GDP per capita by $500, compared to 50 years for Industrial Revolution to do this.
      - Maybe it’s not a matter of going from 2% to 20% - but 2% to 5%. This is “really fast growth” in national terms.
- Did most of the predictions end up being executed by the starting major players (Google, Facebook, Amazon, Netflix)?
  - Eg customization of media
- The limitations of information as copyrighted.
  - Is DNA for designer animals and babies going to be copyrightable? Can you copyright
your own genome? What if a nation creates a GMO apple, and you can export this DNA on a flash drive?

○ Is Chrome blocking malicious sites impeding free speech, similar to requiring ISPs to regulate the bits that flow through their network?

• Read this Infoworld 1982