The Death of Innovation?

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Competition will only drive technological advances if telecom carriers commit to expensive network upgrades.

On October 31, 1996, a fundamental change occurred within the telecommunications industry: AT&T spun off Lucent Technologies—and with it Bell Labs, arguably the most famous research lab in the history of the world. Bell Labs had been the source of innovations like the induction coil, the coaxial cable, the transistor, fiber optics and cellular telephony. Seven of its researchers have won four Nobel prizes.

Anyone who believes "if it ain't broke, don't fix it," can't help but wonder what effect the Bell Labs spin-off will have on innovation. If the marriage of the Labs (R&D), Western Electric (manufacturing) and the Bell System (telecom services) led to many—if not most—of the telecom innovations we've enjoyed over the past 80 years, how will dismantling this engine lead to ever-more-capable functionality at ever-lower prices?

Or is the Labs/Western/Bell triad an idea whose time has passed? Will the world be characterized by Silicon Valley startups funded by venture capitalists? In short, should we be merely nostalgic about the passing of the old order or deeply concerned about the future?

The splitting off of Bell Labs from AT&T is not the only reason to wonder about the fate of telecom innovation—there is also the growth of deregulation in the U.S. and world markets, assuming we take the recent World Trade Organization agreement at face value. Ideologically, we are all in favor of using competition to drive costs down and improve services. But having slogged through the 100 or so pages of the Telecom Act and the 2,000+ plus pages of post-Telecom Act FCC Orders, NPRMs and Joint Board Recommended Decisions, we believe that legislators and regulators have erred: They've focused on competition, without paying much attention to the impact of these changes on innovation or taking actions to directly foster innovation.

These issues aren't trivial. The combined effect of deregulation and the final Bell System split-up raises fundamental questions about the ability of the U.S. telecom industry to maintain a high rate of innovation. Given that the regulatory process is still under way, we think it useful to consider how regulators can foster accelerating innovation.

Déjà vu All over Again

Economists have been studying which industry structure(s) best foster innovation for some time. In 1942, Joseph Schumpeter's classic work, *Capitalism, Socialism and Democracy,* argued that oligopolists (like the Bell System) have distinct advantages in fostering technological innovation:

- Their large, secure cashflows enables them to fund both pure research and applied engineering.
- They can afford to pursue multiple innovation pathways and take greater risks.
- They can maintain interdisciplinary teams with greater capabilities than smaller firms can afford.
- They have greater ability to commercialize innovations, particularly if they already control the downstream market.

Professor Schumpeter, if he were alive today, might deem the Bell System breakup a catastrophe that will stifle telecom industry innovation.

…Or maybe not. There have been many changes since 1942. Perhaps Professor Schumpeter, fresh from a visit to Sand Hill Road in Menlo Park or Qualcomm in San Diego, would conclude that vigorous competition and entrepreneurial startups foster innovation better in today's economy. Indeed, modern economists, many of whom recognize merit in Schumpeter's thesis, use microeconomic theory and empirical observation to argue that this is precisely the case.

While there is no clear-cut answer, we decided to examine where some recent innovations came from. Did they emerge out of large integrated companies like the old AT&T, or from other sources—government, universities, large focused companies and/or small startups? We developed a list of 20 innovations since 1960 (Table 1), which range from traditional analog, hierarchical, copper-based wireline networks to digital, broadband, nonhierarchical packetized systems that run in-

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Innovation goes beyond merely *developing* new technology

TABLE 1 Fundamental Telecommunication Advances, 1960–Now

Advances	Conceptual Originator	Leading-Edge Commercialization
Transmission—Wireline:		
1. Laser	Bell Labs	SDL, Lasertron
2. Optical Fiber	Corning	Corning, AT&T
3. Optical Amplifier	Polaroid, Univ Southampton (UK)	Pirelli, Corning
4. Optical Amplifier	Bellcore, Bell Labs	Ciena, Pirelli, Lucent, Nortel
Transmission—Wireless:		
5. Cellular	Bell Labs	Ericsson, Motorola
6. Spread Spectrum	UK Military, MIT Lincoln Labs	Qualcomm
7. Satellite Transmission	Bell Labs	Hughes
Transmission—Digital Signal Processing:		
8. xDSL	Bellcore	PairGain
9. Video Compression	Bell Labs	PictureTel
Switching—Circuit:		
10. Time Slot Interchanger	Collins, NTT	Rolm, Mitel, Intecom, Nortel
Switching—Packet:		
11. SNA	IBM	IBM
12. TCP/IP	DARPA	Sun, Cisco Systems
13. Ethernet	Xerox	3Com, Bay Networks, Cabletron, Cisco
14. Frame Relay	Bell Labs	Cascade
15. ATM	Carnegie Mellon	Fore Systems
16. Multiprotocol Router	Stanford Univ	Cisco Systems
17. World Wide Web	CERN, Univ of Illinois	Netscape, Sun
Control:		
18. Operating System: Unix	Bell Labs	Sun, Hewlett-Packard
19. Language: C, C++	Bell Labs	Borland, Sun, Microsoft
20. Language: Java	Sun	Sun

Legend:
- Large Integrated Equipment/Network Provider
- University
- Government
- Large Equipment/Software Company
- Network Provider
- Small Entrepreneurial Company

TABLE 2 Eight Important Integrated Network Innovations: 1960–Now

Successfully Implemented	Not Successfully Implemented
4 CATV Network	4 ISDN
4 Cellular Networks	4 Residential Fiber/ Hybrid Fiber Coax (HFC)/ Switched Digital Video (SDV) Networks
4 LD Fiber Networks	
4 CAP Fiber Networks	
4 Internet Backbone	
4 Direct Broadcast Satellite (DBS)	

creasingly over non-copper facilities—i.e., fiber and wireless. For each, we considered who was responsible for both the initial conceptual breakthrough and the initial commercialization.

Because we believe innovation means not simply *developing* new technology but also *installing* this equipment into new networks, we also developed a list of eight prospective network innovations (see Table 2)—some of which (e.g., the CATV network and the Internet) have been widely installed, some of which (i.e., ISDN and residential fiber) have not. By considering the underlying factors in market acceptance/nonacceptance, we believe we can reach conclusions about the factors in the industry structure that promote or retard deployment of new technology. From there, we may consider whether pending telecom regulations in U.S. will advance or inhibit innovation.

Historical Sources of Innovation

Table 1 shows that Bell Labs and its offspring, Bellcore, were important in originating nine of 20 major advances. While the percentage is significant—45 percent—most came from other sources. In short, while the Labs and Bellcore have been central to new technology evolution, they have not been the sole source. It is also important to note

TABLE 3 Two Tiers of Innovation

Tier 1: Established Companies—Lab-Based Innovation	Tier 2: Venture-Capital-Funded Startups
Alcatel	Ascend
Ericsson	Bay Networks
IBM	Cabletron
Intel	Cascade
Lucent	Ciena
Microsoft	Cisco
Motorola	Netscape
NEC	Qualcomm
Nortel	3Com & US Robotics

TABLE 4 R&D Expenditures of Eight U.S. Telecom Companies (in billions of dollars)

	1985	1995	Percentage of Eight-Company Total (1995)	CAGR %
AT&T:				
Lucent	2.0	2.6	19%	1.3%
New AT&T/Other	0.3	1.5	11%	15.0%
AT&T Total	**2.3**	**4.1**	**30%**	**6.0%**
RBOC: Bellcore	**0.8**	**1.0**	**7%**	**0.4%**
Five Mfrs:				
Ericsson	0.3	2.3	17%	22.6%
Motorola	0.5	2.2	16%	16.0%
Nortel	0.4	1.6	12%	14.9%
Cisco	0.0	0.3	2%	57.2%
Alcatel	0.6	2.2	16%	13.9%
Five Mfrs Total	**1.8**	**8.6**	**63%**	**16.9%**
Total: Telecom	**4.9**	**13.7**	**100%**	**10.8%**

Source: Annual Reports, Business Strategies LLC

that many Bell Labs innovations (i.e., lasers, cellular, satellite, compression and operating systems) date back to the '60s; its recent role in innovation is much smaller.

The answer to the second question—AT&T's role in commercializing innovations—is unambiguous: not a significant player. In seven areas where Bell Labs innovated, AT&T is absent in the commercialization column. Only in optical fiber, which was pioneered by Corning, did AT&T establish a leading commercialization role.

Over the past 35 years, large public- and private-sector organizations—equipment manufacturers, universities and government—have played a significant role in telecom innovation. Interestingly, none of the conceptual innovations came from small startups—they have tended to function as commercializers (in nine of the 20 examples in Table 1) rather than conceptualizers.

Also, conceptual innovations have *not* emerged from *telecom* equipment manufacturers (Collins being a quasi-exception); instead, important contributions have come from computer manufacturers, defense electronics and the glass/optics industry. A good deal of what we call "telecom innovation" is more the result of the convergence of telecom and industries like computers and optics, rather than from telephony itself.

In sum, the evidence suggests a mixed view of telecom innovation, in which the integrator (Bell Labs) was responsible for innovations but generally failed to commercialize anything important. Indeed, costly failures like the Picturephone and TrueVoice come to mind more quickly than success stories. Most commercialization has come from nonintegrated companies—large and small—that produce new products sold to operators of enterprise and commercial networks.

Given the convergence between telecom and computing, the emerging model looks much like the computer industry's familiar two-tiered structure: The first tier comprises major technical labs owned by computer vendors, and the second tier consists of venture capital–funded startups (see Table 3). The major labs support both basic and applied research, as well as exploratory and ongoing product development. The startups support both exploratory and ongoing product development.

It's important to note that many of the startups were founded by individuals who had previously worked within the labs of large companies. After watching their employers reduce expenditures for R&D as part of a decade of corporate downsizing, many of these researcher/entrepreneurs decided to go off on their own.

What We Are *Not* Worried About

Given this emerging two-tiered structure, Dr. Schumpeter's model can rest in peace. We may miss the glory days of Bell Labs, but on balance we prefer the dynamic picture of free-market competition—although universities will become more critical as a source of pure research advances with the diminishing role of Bell Labs in pure science. Government agencies could also play an important role, although in an era of military downsizing this will become more problematic (remember that spread spectrum came directly out of the military, and the Internet was funded by DARPA, whose first initial stands for "Defense").

One possible concern is whether the hardware/software companies that are assuming a leadership role in telecom innovation (one of which will be Lucent) will be able to maintain and grow the aggregate innovation level by continued spending for R&D. On further examination, however, the picture seems relatively bright.

Since the AT&T breakup, telecom R&D spending has been relatively healthy, growing at

There has been a fundamental change in the way innovation is funded

TABLE 5 Venture Capital Funding for Computer Communications: 1985 & 1995

Level of Venture Funding:	
1985	$1.2B
1995	$5.2B
CAGR	15.8%
Number of Transactions:	
1985	173
1995	414
Percentage of All Venture Funding:	
1985	15.1%
1995	27.3%

Source: VentureOne, Coopers and Lybrand, Price Waterhouse, Business Strategies LLC

TABLE 6 1995 Valuation of Venture-Capital-Funded Computer Communications Companies Funded 1985–1995

Number of Companies Examined	23
Total Funding through 1995	$478.2M
Valuation in 1995	$46.1B
Valuation/Funding	96.5×

Source: NYSE, AMEX, NASDAQ, Business Strategies LLC

10.8 percent per year, based on the eight-company sample shown in Table 4. While AT&T's spending rose at only 6 percent (and Lucent-equivalent spending rose at 1.3 percent—less than inflation), this was offset by an 16.9 percent annual spending increase by five nonintegrated manufacturers. So, to the extent that the components of the former Bell system cut back on spending, the slack (and then some) appears to have been taken up by others. (Note: This ignores possible diseconomies of scale due to duplication. However, the substantial overall growth rate, well in excess of inflation, makes this of less concern).

What about financing innovations? Here again, we probably don't need to worry. Venture capital funding for computer and communications applications has increased 16 percent per year over the past five years and is now at $5.2 billion annually (Table 5). At the same time, the average capital outlay required to start a technical business has dropped dramatically, because of declining costs for personal computer hardware and software, and because more open standards make it more cost effective to integrate third-party components into new products.

Furthermore, the total market valuation of a sample of 23 venture-capital-funded companies was 96.5 times the initial investment (Table 6). With this level of interest and returns, financing innovation will not be a problem.

What *Does* Worry Us

However, a nagging problem is that a fundamental change in how innovation is funded makes continued growth more problematic.

The old Bell System's earnings stream was relatively secure. But it was not profits from Western Electric or, more recently, AT&T Network Systems that funded Bell Labs; the cash-flow surpluses came from the telephone network—that was the old AT&T's "cash cow." It didn't matter that Network Systems didn't make much money in 1985–1995—cumulative losses for 1991–1995 were $5 billion—as long as AT&T's management was prepared to continue funding.

The Lucent spin-off extinguished that linkage. Although AT&T continues to spend on R&D via the new AT&T Labs (witness the recent announcement of a new proprietary fixed-wireless system), R&D spending generally is not funded by network service providers—the RBOCs have been relatively paltry spenders.

Instead, R&D now comes from equipment manufacturers. This makes funding much more problematic, because it now takes *equipment orders* to fund R&D, rather than more predictable/assured cash flows from telephony. Moreover, the key equipment orders will have to come from facilities-based network operators. Unless new networks are built or old networks upgraded, total industry sales will fall, which will hamper R&D budgets.

One way to look at this issue is to review historical capital investment trends by LECs, IXCs, CATV and wireless networks. As shown in Table 7, there has been a steady but relatively slow growth rate of 3.5% per year during 1985–1995.

In this context, maybe we've been fortunate that the eight-company R&D budget increased by 10.8 percent per year over the past decade. However, industry capital expenditures eventually must increase; unless network service providers buy equipment, the manufacturers won't have profits with which to fund R&D.

Theoretically, this shouldn't be a problem. The Telecom Act lets new entrants into local and interLATA telephony, as well as CATV. The Internet is growing at a phenomenal pace, and there will be new PCS and DBS entrants. The RBOCs and the CATV MSOs need to replace existing systems. It should be a great time to be an equipment manufacturer. Wall Street evidently thinks so. Just look at the increase in Lucent market value since the spin-off.

But we don't live in a theoretical world. The track record for installing innovative networks has been mixed. Just as we developed a list of the 20 important technical innovations since 1960, we have prepared a list of eight important integrated network innovations (Table 2). Numerically, the track record looks fairly good: six of eight successes. Looking closer, however, the successes have tended to be new networks at the margin of the core local loop network—where the bulk of telecom assets are deployed. Often, the new elements were successful because they:

- Provided important new functionality (e.g., mobility, multichannel TV entertainment with R-rated movies, data networking).
- Did not require wholesale replacement of the existing network (in the case of the CATV and cellular networks).
- Enjoyed density of traffic that facilitated new installation and even replacement of existing assets (long distance networks, undersea cables, business CAPs).
- Were supported by regulations facilitating investment (e.g., regulations allowing CATV entrants protection against LEC competition and the right of pole attachment at cost).
- Were supported by regulations requiring network investments (e.g., cellular buildout requirements).

In contrast, the failures deal with unwillingness of incumbents and new entrants to invest heavily in the local loop. While some CAPs have invested in facilities to connect relatively few large buildings in major commercial districts, the lack of new investment is particularly noticeable for residential and low-density business markets.

The implication is clear: To see major growth in capital spending (to fund more R&D and hence innovation), we need more investment in core local loop assets. Remember that with an average RBOC gross investment per access line of around $1,600 and 150 million access lines in the U.S., we are talking about a gross capital investment by RBOCs/LECs of $240 billion for the familiar (and aging) copper-based network that serves us today.

While vendors such as Cisco and Cascade have done well selling innovative equipment into the enterprise and ISP markets, that "edge" play gets one only so far. Ultimately, to support new generations of CPE development, more advanced network functionality is needed that can work in tandem with the new CPE. It is one thing for US Robotics to sell 28.8-kbps modems, but the market for broadband xDSL and/or cable modems will be much larger once the requisite network functionality exists.

The Role of Regulation

Which brings us to regulation's role in innovation. The Telecom Act, by reducing legal barriers to entry in the local loop, IXC and CATV markets, could spur a major increase in spending and thus in innovation. But consider whether tangible incentives exist to invest in these opportunities.

To its credit, Congress inserted Section 706 into the Telecom Act, which explicitly discusses the need to deploy advanced equipment. If, within 30 months following enactment—August 1998—the FCC finds that advanced technology is not being installed, the Act orders proceedings to reduce "barriers to infrastructure investment."

TABLE 7 Historical Industry Capital Expenditure Levels: 1985–1995 (in billions of dollars)

	1985	1995	CAGR%
"Big 3" IXCs:			
AT&T	$4.178	$6.411	4.4%
MCI	1.000	2.866	11.1%
Sprint	1.060	1.857	5.8%
Big 3 IXC Total	**$6.238**	**$11.134**	**6.0%**
RBOCs/GTE:			
Ameritech	$1.991	$2.120	0.6%
Bell Atlantic	2.121	2.627	2.2%
BellSouth	2.624	4.203	4.8%
GTE	3.553	4.034	1.3%
Nynex	2.088	3.188	4.3%
Pacific Telesis	2.196	2.002	-0.9%
SBC Communications	2.036	2.336	1.4%
US West	1.998	2.462	2.1%
Total RBOCs and GTE	**$18.607**	**$22.972**	**2.1%**
New Carriers:			
MFS Communications	N/A	$0.507	N/A
Teleport Communications	N/A	0.140	N/A
Worldcomm Inc.	$0.14356	N/A	N/A
Total New Carriers	**$0.14**	**$1.002**	**N/A**
Grand Total	**$24.985**	**$35.108**	**3.5%**

But after more than a year, absolutely nothing has happened relative to Section 706. Instead, the FCC's focus has been on rules for local competition, access reform and universal service reform. At this point, progress on all three issues is either incomplete or being challenged in court.

Conclusion

Because so little of the Telecom Act's agenda is finalized, the jury is still out. But we can't escape the feeling that the goal of fostering innovation is taking a back seat to other considerations.

While obviously it is important to establish rules for network interconnection, unbundling and pricing, RBOC entry into long distance, access and universal service reform, these issues also have important implications for technology innovation. Take the issue of pricing unbundled network elements at TELRIC (Total Element Long-Run Incremental Cost). The FCC's actions will address one important policy goal—increasing local-loop competition in the near term—but if the price of unbundled elements drops below a certain point, new entrants might decide against investing in their own facilities. That would reduce the overall level of industry investment and therefore the cashflow available to fund R&D.

That is but one example of how complex issues—fostering technical innovation and creating a more competitive marketplace—intersect.Unless the goal of fostering innovation becomes a more explicit objective in the FCC's regulatory calculus, the future for our industry may not be as promising as we've all hoped□