Walk around a consumer electronics store and look at all the different kinds of high-definition televisions. Flat-panel LCDs, plasma displays, DLP and LCoS Projection TVs abound, while receivers with cathode ray tube (CRT) displays are becoming increasingly scarce.

Receiver labels proclaim “HDTV-ready,” “built-in ATSC decoder,” and “EDTV.” Display specifications tout resolutions of $1366 \times 1080$, $1024 \times 720$ and formats of $1080i$, $720p$ or $1080p$. How many different kinds of HDTV are there? What does it all mean?

As difficult as it is for the consumer, it is significantly worse for television professionals. Veteran broadcast engineers have to learn a new kind of television, one based predominantly on digital technologies. Each digital subsystem of a broadcast infrastructure is now an area of expertise that technology professionals have spent a lifetime pursuing competence in.

It may be even more of a challenge for experienced broadcast industry professionals—who don’t have engineering or computer science degrees—to understand the obscure jargon and technical complexity of modern digital broadcast systems. In the past, operational experience was usually sufficient to specify production systems. This first-hand knowledge enabled a production or operational oriented viewpoint to guide the underlying infrastructure design and facilitated the inclusion of required capabilities and desired features.
Analog broadcast systems consisted of mostly stand-alone components interconnected by real-time audio and video signals. When something went wrong, “divide and conquer” trouble-shooting techniques could be used to quickly isolate the problem and take corrective action.

All this has changed. Digital broadcasting, and its merging of broadcast engineering and information technology, has created a networked environment where every piece of equipment is interconnected.

**Analog and Digital TV Compared**

In analog television systems, audio and video are transmitted as one complete “composite” signal. But with digital TV, audio and video are separately processed and transmitted as discrete packets. When processing streams of digital content, there must be a way to differentiate groups of bits and bytes into program elements.

The transmission must include information that identifies which bits are video and which are audio. Assembly instructions for these components are also included in the transmission, so the digital television receiver knows how to combine the audio and video pieces into a complete program for presentation. Other data provides information for the electronic program guide, closed captions and other features.

All this is enabled by metadata, data that is not the actual audio or video content of a program but provides organizational and descriptive information which is now just as important as audio or video. Metadata is discussed in greater depth in Chapter 5.

**Analog versus digital quality**

Until the advent of high quality digital encoding techniques, analog audio and video was considered more aesthetically pleasing than a digital representation of the same content. So when CD technology was invented, many audiophiles argued that it was inferior to analog sound recording because the act of digitizing the audio creates steps or discrete units that approximately represent the sound, whereas sound in nature, and when represented in analog form, is a smooth, continuous wave. But digitization of sound works because these steps are so small that the auditory system perceives the sound as continuous.
An important advantage of digitization is noise immunity. For example, if electronic noise contaminates an analog audio signal, the fidelity of the sound is diminished and eventually too much noise becomes annoying. With digitized sound, a “1” is a one and a “0” is a zero, well past the annoying analog noise threshold. In other words, the same amount of noise that makes an analog signal unpleasant has no effect at all on a digital representation of the same sound.

Perception is at the core of digital processing of visual and aural information. Reduction of audio and video data is facilitated by an understanding of the physiology, neurology and psychology of sensory stimulation. Psychovisual and psychoaural algorithmic models are applied to audio and video source material to reduce the amount of data necessary for apparent perfect fidelity. In this way, unperceived sensory information is discarded.

Data compression techniques, when properly applied to digitized audio and video, permit the transfer of high quality content over broadcast facility production networks and transmission channels. In the consumer environment, compressed media enables content transfer and consumption in a digital home media network. The explosion of MP3 audio and the rapid emergence of video downloads over the Internet is an example of how compression is an enabling technology for new content distribution business models.

Analog Television

In the U.S., the National Television System Committee (NTSC) black-and-white television standard was established in 1940. Regular over the air (OTA) broadcasts began on July 1, 1941. The aspect ratio of the display was set at 4:3 (horizontal by vertical), with 525 lines of vertical resolution, about 480 of which are active and display an image 30 times per second. In the horizontal direction, cathode ray tube technology facilitated a continuous trace and an absence of discrete picture elements, resulting in the intensity of portions of the line being varied.

In 1953, National Television Systems Committee II (NTSC II) defined the color television broadcasting technical standard. Color television broadcasts had to be compatible with NTSC I so black-and-white sets could receive and properly decode an NTSC II signal. The frame rate was altered to yield about 29.97 fps to avoid color dot-crawl effects and audio distortion.

TV engineering developed a numerical measure of the equivalent number of picture elements (“pixels”) for analog displays. However, the bandwidth of the NTSC signal reduces the number of vertical resolution elements and the number of horizontal resolution elements. The result is that an analog NTSC 4:3 display can be said to have a resolution of $340 \times 330$ pixels. In the computer display world this is about the same as the CGA display mode.
Digital Television

Digital television, or DTV, presents a conceptual shift for creation production, distribution and consumption of television programs. With the advent of digital cameras, digital tape machines, compression, microprocessors, computer networks, packetized data transport and digital modulation, DTV is the consummation of communications engineering, computer science and information technologies developed in the twentieth century. In effect, DTV is a bit pipe into a receiving device. In addition to audio and video, this allows data delivery features and applications.

Digital data compression techniques, combined with error correction, facilitate “squeezing” a picture and sound into a standard broadcast channel. Although, in principle, many levels of DTV resolution are available, high definition (HD) and standard definition (SD) are the two general descriptions of the level of visual detail. HDTV, when viewed on a display that supports full resolution and adequate bit rates, is close enough to reality to provide an experience of immersion, particularly if multi-channel surround sound is included in the broadcast. SDTV is similar to analog television as seen in a broadcast studio but the digital signal processing provides a superior picture in the home compared to any deliverable via NTSC.

Today, digital broadcasters have the option to “multicast.” That is, they can choose to transmit a mix of more than one HD or SD program and include data services over their delivery channel. Contemporary compression equipment can usually facilitate the transmission of one HD program and another SD program of low-resolution, slow-moving content (like weather radar) over a broadcast channel. Emerging advanced compression encoder/decoder technologies will enable delivery of even more programs and services in a broadcast channel.

Digital, expressed in its most fundamental meaning in electrical engineering, is the use of discrete voltage levels as contrasted with continuous variation of an analog voltage to represent a signal. Figure 1.1 shows the same signal in analog and digital form. This simple analog 0.0 to 1.0 Volt “ramp,” when converted to digital,
can be represented by a series of numbers, i.e. 0, 1, 2... up to a defined number. In this example this is 255. This creates 256 discrete voltage levels. Generally, exponential powers are used, creating 2, 4, 8, 16 distinct voltage levels and so on.

One primary advantage of using digital technology is that digital signals are more resistant to noise than analog signals. As shown in Figure 1.2, for a digital signal as long as the voltage level is above the 0.75 V threshold, the signal will be interpreted as a digital “1”. Similarly, if the voltage level is below the 0.25 V threshold, it will be interpreted as a digital “0”. Hence, the 0.2 V of noise riding on a digital signal has no effect on the data value. The picture, sound and data will be perfectly reconstructed.

However, in the analog domain, if the actual value of the voltage at the 0.5 V point on a ramp signal that is corrupted by 0.2 V of noise is measured, it will vary between 0.4 and 0.6 V. Hence, this analog signal value is significantly less precise than a digital “1” or “0”. In fact the noise will be annoyingly visible on a display.

Another important distinction between analog and digital television, as mentioned earlier, is the composition of a horizontal scan line. As illustrated in Figure 1.3, analog NTSC display lines are presented as a continuous trace on a display. DTV lines consist of discrete, individual pixels. With the migration away from CRTs towards LCD, DLP and plasma display technologies, the concept of lines and pixels is
implemented as a matrix-like structure, often referred to as a pixel grid. These modern displays now have one native resolution, whereas a CRT could inherently display many different combinations of numbers of lines and pixels.

**Standard Definition**

SD is only associated with digital television—it does not apply to conventional analog TV. This is an important distinction, though people in the industry loosely exchange the two terms. Standard definition television (SDTV) has the same 4:3 aspect ratio as NTSC. While the exact number of active NTSC lines (480, 483 or 486) can vary, for ATSC SD transmission the picture always contains 480 active lines. For SD resolution with 4:3 aspect ratio, the source content has 720 pixels per line and the transmitted picture frame normally has the center 704 of these pixels. However, all 720 pixels may be sent as well.

The number of active lines for NSTC and has been described as 480, 483 and 486 lines depending on which “standards” document is referenced. However for SDTV the number is fixed at 480 in the ATSC standard.

The distinction between 720 and 704 horizontal pixels for an SD line is based on the technology used in digital displays or for analog CRT displays respectively.

SD content has been stretched to fill a 16:9 display. This results in a loss of horizontal resolution and the picture looks distorted.

Enhanced definition television (EDTV) is the term used to indicate widescreen, high frame rate, progressive scanning. These standards are extensions of SD and (similar to SD) define 960 and 968 samples per active line for 16:9 aspect ratio pictures.
High Definition

By now, everyone has become familiar with widescreen television displays. In the U.S., they are synonymous with HD content. Yet in Europe, widescreen TV has, until recently, offered no more resolution (just more pixels horizontally) than conventional analog television. As will be discussed in Chapter 2, the development of HDTV was a global technological battlefield, and Europe’s lack of support for HDTV in light of historical events was understandable. Until recently, European broadcasters and consumer electronics manufacturers felt that consumers were satisfied with widescreen SD and weren’t concerned about image resolution. To influence acceptance of HDTV, the World Cup 2006 broadcasts were an HD showcase in Europe and around the world.

HDTV is digital and defined as double (at a minimum) the resolution of conventional analog TV in both the horizontal and vertical directions. Pixel resolution can be either $1920 \times 1080$ or $1280 \times 720$. The geometry of the display is always in a 16:9 widescreen aspect ratio, more like a movie screen and closer to the natural field of vision. Image scanning for each picture is either progressive (line after line) or interlaced (odd lines then even lines). The number of pictures sent per second can vary as well. Audio is CD-quality multi-channel, cinema surround sound.

Chapter 3 will delve deeply into the fundamentals of DTV technology. For now, it is sufficient (but very important) to realize that the HD, SD and analog television formats are three different things.

Going HiDef

The starting gun in the global race to develop HDTV standards is generally attributed to efforts by NHK in the 1970s to gain worldwide acceptance for its Hi-Vision analog HDTV system. In the U.S., it would be fair to say that it began with the creation of the Advanced Television Systems Committee (ATSC) in 1982 and reached “official status” in 1987 when the FCC created the Advisory Committee for Advanced Television Systems (ACATS).

A decade later, “The Advanced Television Systems Committee Digital Television Standard” was formally adopted by the FCC. The motivation to develop HDTV in the U.S. was varied, and depending on viewpoint, was to:

- Replace antiquated NTSC technology
- Quell the threat of losing TV spectrum to mobile services
• Provide a stimulus to U.S. consumer electronics manufacturing
• Prevent a Japanese or European system from setting the U.S. standard
• Keep over-the-air broadcasting competitive and slow the loss of viewers to cable

NHK’s efforts to establish an analog HD production standard rather than garner a consensus and create a global HD production standard as intended, ignited a war. Many participants in the European and U.S. television industry, content creators, broadcasters and consumer electronics manufactures became concerned about the Japanese HDTV threat. Chapter 2 will go into more detail about the history of HD standards development and the implementation of DTV.

A classic catch-22 scenario that included production, transmission and consumption issues has contributed to the length of the transition to digital broadcasting. Stakeholders can be grouped into content distributors, content producers and consumer equipment manufacturers. The delay can be attributed to the following factors:

• Broadcasters were not rushing to convert to digital transmission capabilities and installation of an HD production infrastructure in 1998 when the first broadcasts took place. HD production equipment was scarce and when available, expensive. If there was little hope of attracting advertisers without viewers, why invest considerable sums to convert to HD?

• Independent content producers and TV production houses shied away from HD production. HD video tape recorders and cameras, especially lenses, were expensive. And why produce something that will not be widely broadcast and if it is, few will see in all its HD, 5.1 surround sound glory?

• When the first HD broadcasts began in late 1998, few consumers had HDTV receivers. The first sets were projection TVs, large, heavy and expensive, from $3,000 to $10,000. If there was little or no HD programming available, why build receivers that are virtually useless and very few will buy?

And so it progressed, with some forward-looking broadcasters steadily increasing HDTV content, gradually educating others about the experience, with others waiting to see.

A decade has passed since the transition to digital broadcasting began and only in 2006 have the sales of DTV receivers finally exceeded sales of analog TVs. Though that may seem like a slow adoption rate, DTV consumer uptake has actually outpaced the introduction of color television, VCR’s and personal computers.
Modern broadcast operation centers are in many ways huge data processing centers. As a result, along with the media industry transition to HDTV and digital technology, a new engineering discipline is evolving. It is the consummation of the marriage of broadcast engineering and information technology. This new technology discipline, “media systems engineering,” encompasses the creation, assembly, distribution and consumption of digital content. It includes traditional broadcast engineering and has added network and storage technology, computer platforms, software applications and security.

In this book, generally, a reference to information technology or IT will also include all aspects of computer science, networking/storage and security. The individual terms will be used when discussing topics specific to a particular discipline.

The union of these technologies is somewhat like the mixing of oil and water. Broadcast engineering and information technology cultures and business models are fundamentally different.

For example, in the consumer space, televisions are purchased with the intent that they will last seven or more years. They are expected to be reliable, turn on like an appliance, rarely break and never require system upgrades. However, when compared with a personal computer, PC hardware is usually out dated after a year and a half. Operating systems are upgraded regularly. Programs freeze up and sometimes crash. The “blue screen of death” is not a welcome sight.

Differences between Broadcast Engineering and Information Technology

Jargon

Terms used in a broadcast engineering context do not always have exactly the same meaning when used in IT. A “port” in broadcast engineering is an audio, video or control connection. In IT, “port” means a network connection. This distinction is particularly confusing when discussing media servers, since they have both kinds of ports!
For many years, analog audio and video have been converted to digital signals and distributed around a facility as serial data. For example, audio, video and graphics processing systems convert analog signals to digital, process the signals, distribute them throughout the infrastructure and eventually convert them back to analog for NTSC transmission.

With the compression of audio and video required for digital transmission, the capability of transferring appropriately sized media files over a network can be implemented in broadcast operation centers. File-based media can now be stored economically on servers rather than on video tape. This leads to non-linear workflows, where more than one production process can access a clip simultaneously. Time is saved and more can be done with the same amount of personnel.

As digital media infrastructures grow in size and complexity and integrate diverse technologies, the design, deployment and support of these systems becomes
increasingly difficult. Facing the reality that expertise in all technologies integral to media systems engineering cannot be mastered by any one individual, coordination of departmental competencies is critically important.

**Media System Technologies**

Dividing the role and relationship of various technologies and areas of expertise in a complex infrastructure aids in conceptualizing and understanding the relationship among the various subsystems. In broad terms, digital media systems and broadcast operations centers can be characterized as consisting of four layers: physical, media network, application and security.

At the physical layer, media is in a real-time state. Responsibilities in a digital facility continue to include transmission, network traffic, systems engineering and other traditional engineering departments.

The use of networks and storage throughout a facility in a media network that transfers and stores compressed data is an area of expertise that is growing in importance in a Broadcast Operations Center (BOC).

Software applications run on various computer platforms that control playout, ingest and graphics automation will be installed, configured and tested. The need for security requires a highly skilled and knowledgeable group of IT security experts.

Each of these four layers requires the expertise of experienced professionals. Successful media systems engineering demands that these varied systems and the technologists who design and support them, work together as a cohesive unit.

**Communication**

As broadcast infrastructures become more complicated and system resources more interdependent, the amount of communication necessary to design, install, commission and support them is becoming virtually infinite. In the analog past, with a single technical department responsible for a system, the communication channel was innate and wide enough to get the job done. Today, with numerous technical department involvement and the large amount of detailed information to be conveyed, sufficient technical communication has become increasingly difficult.

Ad hoc procedures may be developed that circumvent established communication channels in order to get a system operational or to stay on the air. Silos of information and expertise inhibit a full scale system overview and make infrastructure design and support difficult.
Consider the graphics program control room infrastructure in Figure 1.4. Traditional broadcast system engineers are experts when it comes to production switchers and audio and video routing. Similarly, the broadcast applications experts are a programming group. In between is a new technical domain, Broadcast IT Systems, a place where both IT and broadcast engineering are used.

If there is a malfunction somewhere in this graphics infrastructure, neither the broadcast systems engineering, network engineering or broadcast applications departments individually possess all the required expertise to solve a system problem. It will require competencies from more than one technology department and a coordinated team effort. Support problems can arise if an application programmer tries to debug a network routing problem or if a systems engineer tries to troubleshoot an application problem. Therefore, communication and teamwork are essential.

**Team Building**

To focus only on the technology—and not on the organizational impact the transition has in a broadcast organization—would be to ignore a potential source of long
term problems. This new era, where no one person can master all technologies sufficiently, has intensified the need for coordinated technology teamwork.

A team of people who are probably unfamiliar with working together will be assembled for projects crucial to the facility’s digital transition. Teams composed of people who can see the opportunities in the future and who embrace change will transfer much needed enthusiasm to all personnel on the project team.

The best teams are generally built by careful selection of personnel, have worked together in the past and have clearly defined roles and goals. For example, the DTV transmission standard was the culmination of a decade of effort by engineering teams that had been working together at developing HDTV, first as teams within their own organizations, then, in the first round of ATSC testing, as members of competing consortiums, and finally, as one cohesive engineering team, the Grand Alliance.

With so many different experts involved in interdepartmental teams, it can be difficult to coordinate all the available knowledge. There will be a mix of “experts” in each discipline. Experts have a tendency to emphasize what they know and not admit to what that they don’t know. But even if an expert knows 90 percent about something, there is still 10 percent of their area of expertise that they are ignorant about.

Experts from different fields may be working on a problem that requires expertise from all of their specialties. If each are 90 percent knowledgeable but are lacking in communication skills, maybe only 75 percent of the knowledge required to successfully attain a goal may be pooled. This can compromise the potential for success.

The challenge is to create a collaborative environment such that these four experts can work together to attain 100 percent of the required knowledge to get the job done.

To help open communication channels, there is a need to include all stakeholders, systems designers, consultants, system integrators, implementation teams, support personnel and users in the design process while systems and workflows are still in the conceptual stage. An organization should strive to migrate from a reactive, fireman, hero culture and evolve to a proactive, team-oriented, long-term vision. This process can be aided by using a technology and organizational strategic roadmap.
A Media Business Technology Strategy Map

“Strategy Maps,” by Kaplan and Norton (Harvard Business School Books), describes how an organization can develop a strategic capabilities roadmap that evaluates personnel expertise and plans a way to migrate the organization to the desired competencies necessary to navigate a technology disruption. This analytic methodology can be applied to the transition to digital broadcasting.

Figure 1.5 is a strategy map that charts specific actions to take, how they interrelate and how they help an organization attain its business goals. There are two motivating opportunities for increased revenue with the transition to digital broadcasting. Clearly defining an approach will help in attaining this goal.

On the one hand, reducing operational expenses will impact the bottom line. Increases in production efficiency, streamlined workflows and tight integration of infrastructure with operational processes will lead to the ability to create more content in less time. This reduces costs and increases ROI in production infrastructure.

The other side of the business equation is to increase revenue. Income is directly proportional to “consumption” (the act of watching a program), increased market share and higher advertising rates. Unique features and graphics create a noticeably higher quality product and can differentiate one broadcaster’s brand from another.

Using the strategy map approach, management can evaluate the organization’s technical capabilities and identify areas that need strengthening to support present and future technology based initiatives.

Digital Workflows

As broadcasting evolves to a digital infrastructure and media systems engineering, the changes in technology are so fundamental that there is an opportunity to coordinate the numerous processes, resources and workflows that comprise broadcasting under one enterprise-wide conceptual paradigm. Because the digital transition has exponentially increased the complexity of a broadcast infrastructure, the workflows and methodologies of the analog past will not suffice.

Workflow and technology improvements implemented during the transition to digital, can enable more efficient production processes. This is especially important
More Sophisticated GFX & Animations
Support More Shows
Faster Time to Air
Reduce Costs
Increase Revenues
Sell Ad Time for More $$$
Increase Ratings
Get More Viewers
Produce Unique GFX
Install Cost Effective GFX Infrastructure
Maximize Output of GFX Personnel
Win Artistic GFX EMMYs
Win Technical GFX EMMYs

Financial Perspective
What Do Shareholders Expect?
Markets/Customer
What Do Our Customers Value?
Internal Process
What Processes Must We Excel at to Deliver Value to Our Customer and Meet Financial Objectives?
People
What People and Environment Must We Have to Achieve Our Objectives?

Business Strategy
More Sophisticated GFX & Animations
Support More Shows
Faster Time to Air

Organizational Strategy
Personnel Scheduling (HUDDLE)
Map Workflows
Appoint GFX Program Coordinator
Establish User Groups

Creative Strategy
Establish Creative R & D
Establish Applications Working Groups

Technology Strategy
Establish Engineering R & D
Map Infrastructure
Engineering Analysis of Color Space
Establish Technical Working Groups

Personnel Strategy
Career Path
Technical Training
Develop GFX Programming Expertise
Communication

FIGURE 1.5 Strategy Map

Increased Profits

Monday, January 10, 2005
with the increasing need to repurpose content for multi-platform delivery over the Internet and to cell phones. Production efficiency can maximize the use of production personnel and resources. Besides resulting in an increased ROI, these improvements will help reduce organizational stress during the transition. The transition can be exciting rather than threatening.

**Summary**

- Digital television is not just better television, but fundamentally different than analog television.
- Many of the problems inherent with analog TV, such as cross color, ghosts and noise, are eliminated with the use of digital technology.
- The term “SD” and “analog” are not interchangeable.
- The transition to digital is occurring in three broad categories: production, distribution and consumption (consumer electronics).
- A natural impact of the transition may be to precipitate organizational evolution.
- Broadcast engineering is still about real-time audio, video and control signal distribution and assembly of program elements but now has added network and storage technology, computer platforms, software applications and security.
- Media systems engineering addresses the integration of traditional broadcast engineering with information technologies.
- Rapidly increasing broadcast system complexity necessitates continual enhancement of expertise by all technical personnel.
- A cultural evolution and migration to a digital mentality is underway.