Broadcast

A pure broadcast service does not have any return path to the program source. Everything that is displayed or used at the receiver must be transmitted without the source having any real feedback on the state of the destination(s). In order for ACC to provide the envisioned sophisticated locally-interactive services, it is necessary for the receiver to have a **powerful processor, a substantial amount of memory** (e.g., from 16 to 64 MB of RAM), and very **robust software**. The viability of the first has already been proven by demonstration of the 3DO system. The economic trend of the second is highly predictable and it will easily be viable within the required time frame. The third will result from many factors (beyond the scope of this paper) now ongoing in the personal computer industry plus proprietary techniques specifically developed for this project.

A large number of locally-interactive capabilities will be available to enhance or extend standard TV programming and marketing techniques. For example, advertising can be customized according to accumulated statistics in the receiver and the particular demographics. Choices can be provided and selected individuals may be eligible for prizes, discounts, and other marketing techniques. Even the inclusion of little treasures like animations of jokes within ads could be provided. These capabilities can be overlaid on standard programming. They are conceptually simple but require the use of fairly sophisticated and intelligent software modules downloaded to the receiver.

ACC's DIBS is unique in that it is the first and probably only broadcasting system based on the principals of Object Oriented Programming (OOP). This technique has its origins in the field of computer software and is also the basis of several upcoming computer operating systems. Through proper OOP extensions and supported by the distribution system design, ACE's DIBS applies this powerful software concept to create a radically new type of broadcast medium. Although DIBS uses a combination of seemingly diverse and previously unrelated techniques, it is in fact a true synthesis, i.e., a unification through incorporation and modification producing a synergism resulting in a whole that is much greater than the sum of its constituent parts. It is not entirely straightforward and requires dealing with issues that are foreign to both the broadcasting and computer industries.

Return Path

The main situations where a live return path may be desirable are distance learning and home shopping. DBS itself is inherently a one-way medium. However, that does not preclude its use in conjunction with other communications paths.

The first question is "Do we really need a two-way or return path?" The answer is "yes", "no", "maybe", "often", "sometimes", "occasionally", "always", and "never".

The second question , assuming we decide we need a return path, is "Return path to where? The program originator? A regional teacher's aid?" The answer is "anywhere we can get help".

The third question is "What do we need to send by return path? Voice? Voice-mail? E-mail? Data?" The answer is "yes".

As can be seen, the answers are a varied as the situations. The real answer is "anything we can, and whatever is available and makes sense".

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ACE's DIBS has a distinct advantage over anything that has ever existed for distance learning — the receiver has a **powerful, locally interactive, intelligent processor with a substantial amount of memory**. Many situations can be anticipated, especially after running the course a few times, and optional material can be included to deal with the vast majority of problems and questions. Thus, the need for direct contact back to the source can be greatly diminished and the instructors numerical student reach can be extended. Also, regional aids can be available, extending the reach of a master teacher even farther. E-mail allows communications to continue off-line and can have much faster response than waiting for the next class.

Another advantage of an intelligent receiver is that the means of providing the return path can be transparent to the student. It is not necessary for the student to know anything about the means of getting E-mail messages delivered. Intelligent software agents can provide the connection via whatever means is available. Some of the return path possibilities are discussed.

Telephone Voice

This is presently the only return path available to the vast majority of distance learning students. Each receiver station usually has one or more portable phones that can be passed around the classroom. The connection is made via long-distance phone call to the instructor. No data transmission capability is usually included.

Telephone Modems

With a computer-based receiver or even with a separate computer, a telephone modem can be used to send questions, homework, or completed exams to the instructor or teacher's aid. The advantage of the computer-based receiver is that this entire process can be setup and prompted through the broadcast link when desired.

ISDN

If a higher-rate (basic) ISDN link is available it can be used in lieu of the telephone modem. If an ISDN link is available, the question might arise as to why we don't just use it for everything instead of the satellite link? The answer is has been partly discussed previously, but it comes down to two factors: 1) Basic ISDN can't deliver anywhere near the bit rate that can be done by dynamically multiplexed DBS delivery. 2) Cost. i.e., it's a lot less expensive via ACE's DIBS, especially when many classroom locations are involved. Using DIBS, the ISDN return link would only receive occasional usage rather than the continuous usage required if it were the primary delivery means.

Data Network

Local access numbers to national data services such as Compuserve and America On Line are available in most parts of the country. This can provide an alternative to long-distance calls for voice-mail or E-mail. (Note that this short burst-mode is far less expensive than continuous on-line connection.)

There are actually some University groups that are offering for-credit courses entirely via modem or data networks. One such organization is the University of Phoenix. There is no real lecture capability, so it works somewhat like a correspondence course, but with much faster response. Combining this type of on-line capability with an ACE DIBS type of nationwide broadcasting capability is certainly possible.

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Fiber Optics

Of course the big hope is fiber optics. It's great stuff if you can get it. But it is going to be **very expensive** and take many years to reach significant portions of the population. We would love to have a fiber optic system available. It would provide an easy solution to one of our uplink problems that we partially addressed by our unique multiple-uplink capability. We could use fiber systems to concentrate more live courses into a single uplink, thus saving costs and operating more efficiently.

Fiber, if available, would provide a means to return wide-band input from individual classrooms to the source. An example might be a QuickTime movie production done by students. It could then be broadcast to each participating classroom.

VSAT

Relatively inexpensive two-way satellite terminals are used by many distributed businesses, one example being WalMart. From one location in Bentonville, Arkansas WalMart monitors transactions and inventory on a daily and even hourly basis in every one of their stores nationwide.

VSAT terminals are typically relatively low date rate, in the range of 9600 bps or 19.2 kbps. Antennas sizes are in the range of 4 ft. Multiple access and control of interference to other services is provided by using spread spectrum transmission through a satellite transponder that is not operated in the saturated mode that most satellite services use.

Although relatively inexpensive, VSAT terminals and service are still expensive compared to using telephone line modems for similar data-rate communications when only occasional usage is required, which is the likely mode of operation with distance learning.

PBS is presently installing VSAT terminals in many locations to provide return path hubs to their serving areas. If such service is locally available, we may be able to use it.

4. DBS — The Only Full-Coverage National System

DBS will be the **only** nationwide broadcasting system. All other delivery systems subject subscribers to the whims of local powers over which they have little or no control. Cable systems are notorious for only carrying what they wish to offer, regardless of what local subscriber groups would like. This issue has become particularly acute with the recent confusing cable reregulation bill.

The DBS service was established by international agreement as a high-power (approx. 120 to 240 Watts per transponder) service broadcasting from geosynchronous[1] orbit and assigned (in the western hemisphere) an exclusive frequency band with minimum satellite spacing of 9 degrees which permits receiving antennas as small as 14". Each orbital position can have 32 transponders.

---

1 Geosynchronous means that the orbit is circular, in the plane of the Earth's equator, at an altitude of approximately 23,000 miles, and traveling in the direction of the Earth's rotation. This results in an orbital period of 24 hours and allows the satellite to appear to be stationary from a point on the Earth.

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DBS will provide universal access and will provide for a nationwide market from the very beginning of service, not dependent on development of local distribution capabilities and markets. It has extremely low per-subscriber distribution cost and has only one physical distribution plant to install, pay for, and maintain. Possibly most important, it totally bypasses today's squabbling and infighting over the various terrestrial links, thus allowing its resources to be focused on providing useful services to its customers.

For many of the envisioned services for ACC's DBS, the importance of this unique universal-access feature should not be underestimated. For example, if a professional organization or a government agency wants to run a nationwide course or seminar on public health or emergency procedures, DBS is the only means by which access in all areas can be inexpensively and quickly implemented.

5. ACE's DIBS — The Only System Designed for the Digital Age

Most others in the satellite broadcasting industry are just now beginning to think about capabilities of ACE's DIBS which have been in planning for years. The digital age blindsided them and is being mostly treated as simply another means to transmit the same type of programming they have always provided. By contrast, ACE long has recognized this as a fundamentally new medium, and designed its transmission operating system accordingly.

The ACE-designed Digital Integrated Broadcasting System (DIBS) uses a flexible video compression format based on what are becoming standard algorithms. It has the ability of combining a variety of transmission bit rates, quality levels, and specified screen video regions. It will likely be the only DBS transmission system taking advantage of dynamic multiplexing.

ACE's DIBS is designed to be the only DBS transmission system with total reallocation flexibility and being capable of multiple uplinks into the same transponder. In the past, this last point was moot because only one analog video could be carried in a transponder. With ACE's object-based design and ACC's commitment to educational course broadcasting with large numbers of courses in each transponder, multiple uplink capability into a transponder is an important capability.

ACE's DIBS also is unique by being the first and probably only broadcasting system based on the principles of Object Oriented Programming (OOP) — a concept with origins in the field of computer software. Through proper OOP extensions and supported by the distribution system design, ACE's DIBS applies this powerful software concept to create a radically new type of broadcast medium.

Local interactivity is attained by including a inexpensive but powerful processor in the receiver, and providing enough memory and software intelligence for the receiver to operate somewhat autonomously, while under the general direction of received commands using received data and live decompressed video and audio.

By treating video and audio as simply another data type (with real-time delivery constraints), ACE's DIBS can carry all of today's usual types of broadcast services plus future types such as wide-screen and HDTV. In addition, it can include just about anything conceivable in the way of video, audio, data, locally-interactive multimedia, executable code resources, data bases with customizable filters, intelligent agents, messaging, and even some virtual reality programming.

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6. ACC's DBS — The Only Operator With These Capabilities

ACE's DIBS is being designed primarily to operate on ACC's Direct Broadcast Satellites. Although a number of DBS orbital slots are assigned to the U.S., they were originally intended and assigned for East/West split operation. Today, the most interest is in covering the entire U.S. from the same satellites. Receiver performance has continued to improve over the years and it is obviously less expensive to operate half as many satellites as that required for the East/West split. There are only two good orbital locations available for full CONUS coverage, 101 deg. West and 110 deg. West. ACC is FCC licensed for launch and operation of 27 of the 32 transponders at 110 deg. West, making it one of the two main DBS licensees. It also has an application pending for the remaining 5 transponders.

7. Comparisons

The Utility Factor — Comparing Capabilities

The advantages of digital, compressed video transmission have now been recognized by most of the industry. Educational course broadcasts can especially benefit because the dynamics of the video are usually less demanding than entertainment broadcasting. ACE's DIBS will provide the capability for ACC to go far beyond compression, using combinations of video and advanced software techniques to cut nationwide course broadcast cost by at least an additional factor of ten or twenty. At the same time, sophisticated interactive capabilities will be provided in order to get students (and consumers) actively involved rather than passively watching presentations.

The possibility of 200 or more services being simultaneously delivered through one satellite transponder, where previously only one was possible, significantly changes both the economics and the operation of the system. For example, ACE's dynamic multiplexing is particularly advantageous with this volatile mix of data rates. ACE's DIBS uses its own proprietary means of allowing flexible capacity re-assignment to multiple uplinks within the same transponder. This is especially useful for educational broadcasting and is a unique capability.

The Crucial Time Factor — Operational Within 3 yr.

It is generally agreed by those that have studied the problem that building the required infrastructure and replacing coaxial cable with fiber optic cable will take 25 to 30 years. Even then, it will not provide anywhere near 100% accessibility. In contrast, the ACC DBS system can be in place within less than **three** years and will be instantly accessible to almost 100% of the population. Because ACC's instantaneous potential market is the entire country, its subscriber service ramp-up will be very rapid. The vast number of educational courses and services envisioned by the Foundation for Educational Advancement Today's (FEAT) underwritten Your Educational Services (YES) Networks can be up and operational immediately once the first satellite is in place.

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The Critical Cost Factor — Extremely Cost Effective

The cost of building the required infrastructure and replacing coaxial cable with fiber optic cable has been estimated to be in the range of tens to hundreds of Billions of dollars. Again, even then, it will not provide anywhere near 100% accessibility. In contrast, the ACC DBS system can be in place within less than three years, be instantly accessible to almost 100% of the population, and **cost 1000 times less than the fiber alternative.**

The vast number of educational courses and services envisioned by the YES Networks can be available immediately for a tiny fraction of the cost of alternatives. ACE's unique OOP-based educational broadcasts capabilities on ACC's satellites will cut educational course delivery cost by at least an additional order of magnitude (even compared with systems using only compressed video) while providing new interactive multimedia and simulation capabilities that have never before been possible by any other means.

8. Conclusion

The advanced on-line interactive services that may eventually be available via various land-line systems (e.g., cable, wire pairs, fiber) are worthy goals to pursue. However, they will at best serve some of the more affluent areas by the end of the millennium. In the poorer, rural, and more remote areas, they will lose at least an entire generation or more. The ACE/ACC DBS system can fill the need almost immediately, making full access possible to sophisticated locally-interactive educational programs, courses, and services in all areas without regard to financial status or pressure from special interest.

Whether or not we decide we can afford hundreds of billions of dollars for the alternatives, we can still invest in the ACE/ACC DBS system which will only entail a few hundred million dollars, yet will immediately, upon launch, provide a similar level of services to that envisioned a generation from now with the vastly-more-expensive alternatives. And it will be available to virtually everyone.

We have shown that DBS is the only medium that can actually reach the entire population. The ACE/ACC combination is also unique in the DBS arena and provides many capabilities not envisioned by other DBS operators. Thus, especially for education and training, it is the only system which can make these services available to everyone and do it in a timely manner.

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The YES* Networks:

A High-Capacity, Interactive, Direct Broadcast Satellite System for Education

(*Your Educational Services)

August 27, 1992

Foundation for Educational Advancement Today

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Summary

Reaching America's goals in education by the year 2000 will require motivation, training, communication, distribution, innovation and mobilization on a scale not seen since W.W.II. And the stakes are of similar magnitude. Through the YES Networks, FEAT is planning a highly efficient but extremely effective national educational broadcasting system that will be able to simultaneously offer hundreds of interactive courses and seminars that can be received anywhere using an inexpensive 18-inch antenna and digital receiver. The system can be operational in less than three years at a tiny fraction of the cost of alternatives. Using ACE's innovative DIIBS (Digital Interactive Integrated Broadcast System) on ACC's Direct Broadcast Satellites (using transmission capacity donated to FEAT by ACC), educators will for the first time be able to provide universal access to master teachers, high-quality interactive courses, educational computer software, teacher training, job training, and more.

by
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I. The Situation Today

No truly-nationwide, universal-access broadcasting system currently exists, and especially not for desperately-needed educational courses, teacher training, job training, and related services.

At present, "broadcasting" means either local radio or local television. The public's access to programming is decided on a case-by-case basis by individual local broadcasters, cable companies, and other distributors. Frequency spectrum for additional services, such as educational broadcasting, is limited and expensive. Very few educational courses are available. Cable systems, which serve only a portion of the population, cannot be counted on to universally carry any specific programming.

Though large amounts of educational programming may eventually be delivered to many locations by fiber optic systems, the best estimates are that it will be phased-in over several decades, beginning with the most affluent areas that already have access to relatively high-quality educational resources, and will cost at a minimum several hundred billion dollars.

Use of existing satellites for TV course broadcasts is slowly increasing. However, it is limited to those that can both afford 8-10 foot antennas and get necessary local zoning approval. Today's satellite systems are also limited in both quantity (channels) and in much needed capabilities such as data delivery and interactivity.

The problems facing the educational system in the United States are legion. You don't "teach" students anything. You provide guidance, motivation, access to information, assistance, a stable environment, and generally **make it possible for students to learn.** One of the best methods to motivate students is by guided interactive involvement, allowing them some level of control and a means to build up their sense of accomplishment and self esteem.

There is a rapidly growing repertoire of innovative interactive personal computer courseware available for use by individuals or instructors. However, there is no common economical means of distributing this software for short-term use by a large number of students. What is needed is the ability to integrate such materials into the broadcast course, letting the students interact with them in real-time both cooperatively and individually.

Large scale broadcasting of math and hard-science courses is simply not economically feasible using current capabilities.

According to Bob Grady, deputy director of the White House's Office of Management and Budget, "every classroom should have in it technology that would allow it to access a hugely expanded universe of data, learning tools, and educators."[1] We don't need more couch-potatoes. Neither do we need Nintendo education. In order to reach America's goal of its students being tops in math and science by the year 2000, we need a distribution system to extend the reach of educators and "master teachers" to the largest possible audience.

II. The YES Networks Solution

The YES Networks is a low-cost, nationwide educational broadcast system that will allow educators to bring the nation's most potent educational resources within reach of every school,

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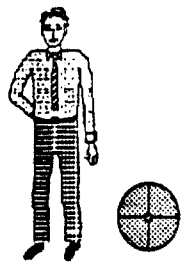
1 Crocker, Will, "The Official Word", *MacWorld*, September, 1992, p. 233.

home, and business. It will use high-power satellites to transmit audio, video, and interactive multimedia educational programming and software to low-cost, mass-produced receivers equipped with antennas only 18 inches in diameter. Today's TV sets, tomorrow's HDTV sets, as well as personal computers, will all be able to receive and use YES educational programming.



Because YES will, for the first time in history, provide every American community — including all remote rural areas — with access to the nation's best instructors and courseware, it is a uniquely powerful tool with which to achieve America's ambitious educational goals. The YES Networks approach has compelling advantages over other alternatives. Unlike the decades-long phase-in of fiber optics, YES — scheduled to launch in just three years — will provide **universal access from day one at a fraction of the cost.** In this time of urgent educational needs but also of limited resources, YES is clearly the right solution at the right time.

Technologically, YES will build on areas in which the U.S. remains the world leader, drawing on expertise that has kept the U.S. in the forefront of military-aerospace technology. It will help revitalize and refocus our high-tech economic sector as we confront the challenges and opportunities of the post-Cold War era. A related benefit will be the creation of hardware and software exports as other countries endeavor to copy the YES model.

The YES Networks is possible because of several factors:

1) Advanced Communications Corp.'s (ACC) Direct Broadcast Satellites;
2) Advanced Communications Engineering's (ACE) revolutionary Digital Interactive Integrated Broadcast System (DIIBS);
3) The **Foundation for Educational Advancement Today** (FEAT), a 501(c)3 public charity, formed to underwrite the YES Networks and encourage this new type of educational broadcasting, primarily utilizing DBS;
4) **The provided one billion dollar plus infrastructure** (consisting of a free receiver for all of America's schools and libraries and the value of the hundreds of channels that will be available to FEAT on the satellites).

This combination of factors can provide a **hundredfold** or more improvement in spectral efficiency and economy for some types of programs. In addition, the flexibility of the digital transmission format and a video-computer-receiver will enable new types of capabilities and greatly enhanced educational services not possible by other means. YES will be an "open" system, thus encouraging teachers, students, and programmers to design and develop innovative interactive software and courseware. Distance-learning courseware authoring tools are presently being developed to empower program originators and "master teachers" to create and integrate their own course materials and interactive capabilities.

The National Education Association (NEA)[2] and other national educational organizations have expressed substantial interest and support for the concepts of the YES Networks. By allowing daily contact between students and teachers, by making the talents of Master Teachers available to all regardless of location or economic status, and by widely distributing the best interactive learning materials possible, educators' effectiveness will be multiplied and performance will be elevated nationwide.

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2 National Education Association Special Committee on Telecommunications, July, 1992.

type of broadcasting system. It can carry traditional programming such as TV, radio, and HDTV when available. It can also carry an extremely large number of new, not-previously-possible broadcast services. Educational courses, emphasizing interactive video presentation materials, can be transmitted very efficiently. Two hundred or more courses can be delivered through one satellite transponder compared to one using standard methods, and about ten using video compression alone. Therefore, the satellite-use cost per course is extremely small.

At the same time, the video quality of displayed presentation materials will be vastly superior to that of standard video, rivaling HDTV if a personal computer screen is used at the receiver rather than a standard TV. With today's broadcasting systems, received information vanishes within milliseconds. One presentation chart, if discussed for 6 minutes, must be re-transmitted 10,000 times. That made sense 50 years ago. Today, it waste valuable radio/TV spectrum and transmission capacity. The memory in the basic YES receiver (and optional expansion) allows sophisticated locally-interactive capabilities, such as realistic interactive laboratory simulations that can span a substantial time period, from seconds to days.

YES will provide universal access within three years at a tiny fraction of the cost of alternatives. The benefit-to-cost ratio is a few hundred times better than existing or proposed alternatives.

The YES educational DBS system will also work in conjunction with the fiber optic systems that will be phased into the higher-population areas over the next 25 years. However, YES will provide universal access from day one — approximately three years from now — at a tiny fraction of the cost of alternatives, e.g., less than a few hundred million dollars compared to estimates of several hundred billion dollars for optical fiber.[7]

V. The Education Revolution:

"I hear and I forget....I see and I remember..I do and I understand"

The means of broadcasting and the business of broadcasting are both undergoing a total revolution. The integration of personal computers and video is now underway. Broadcasting is no longer just about stereo audio and NTSC video. A significant benefactor will be education. IBM, Apple Computer, Microsoft, and others are rapidly gearing up for interconnectivity and digital multimedia. Interactivity adds a new dimension to broadcasting that has not existed before. Used appropriately, it will encourage the student to take the initiative and explore options — a very effective learning tool.

Consider a program like Mr. Roger's Neighborhood or Sesame Street that could have an independent interactive component which is overlaid on the video and not seen or heard by other viewers. Variations could be used to teach counting, arithmetic, and algebra at very early ages. For higher-level math and science programming, a lecture consisting of live-annotated slides, animations, and some video, could be augmented by an interactive sophisticated software physics-lab simulation that is downloaded through the satellite into each receiver, demonstrated remotely by the instructor, and then handed-off to the students for individual experimentation. Educators will undoubtedly discover unlimited innovative uses for interactivity. All they need is the proper medium, which previously has not existed.

---

7 Johnson, L. and D. Castleman, *Direct Broadcast Satellites — A Competitive Alternative to Cable Television?*, RAND, 1991.

Interactive video instruction can improve achievement by an average of 38 percent (50 percent in higher education) while reducing time to competency by 31 percent and is less costly.

Another area made possible by the YES system is teacher training and computer literacy for both teachers and students. The system will span a very wide range of users from a technophobe teacher who's afraid to touch a computer, to the "computer nerd" who lives and breathes it. Having nationwide interactive capabilities, an after-hours incentive programs could be launched for students and teachers. Participants would be able to accumulate points that can be redeemed for commercial products or accumulated towards financing college or continuing education.

Within only the last two years, the advantages of digital transmission and compression have become obvious to all. However, for the most part, the existing broadcast industry has not yet grasp the implications of the computer as, or in, a broadcast receiver. The digital interactive multimedia broadcast concept is presently at the acceptance stage that "digital" was two or three years ago. That will change by the time ACC's DBS system is in place.

VI. The Process

Capability to support education should be designed-in initially.

A broadcast system designed to use built-in educational capabilities requires presentation management software, requiring custom development. The initial design costs for the hardware, software, and system must all be considered. Moreover, this software must be capable of independent use, and with already-available, off-the-shelf, application software packages. Not all of the features need to be implemented initially. However, systems design engineering is required to make sure that the "hooks" are present for eventual implementation. The more features that are initially implemented, the more useful the system will be. Many involve control-processor software that should be started soon. Software cannot easily be rushed. It is important to fully staff these efforts as soon as possible to pace the project correctly.

VII. Conclusion

There may not be another chance to provide so much to so many for so little.

By using high-power satellites, digital processors, video-compression techniques and computer software — all areas of U.S. dominance — the YES Networks' educational initiative provides the ideal framework to substantially improve access to quality education for all Americans and strengthen the United States' competitive position in the global economy.

The YES Networks is uniquely positioned to offer new, innovative, interactive educational services. It has the potential of establishing the most revolutionary educational broadcasting system and riding one of the biggest technology-transition waves in history. The time is now, we must seize the moment. There will likely not be another opportunity in our lifetimes with so vast a potential to provide so much to so many for so little.

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Attachment A: Early Tasks

The following are some of the major categories of endeavors that need to be addressed in the near future in order to lay the proper foundation and ensure that the described educational broadcasting services will be available to all:

- DBS receivers and related system issues;
- Educational demonstration systems;
- Distance-learning software authoring tools;
- Integration with education;
- Teacher training;
- A coordination of organizations.

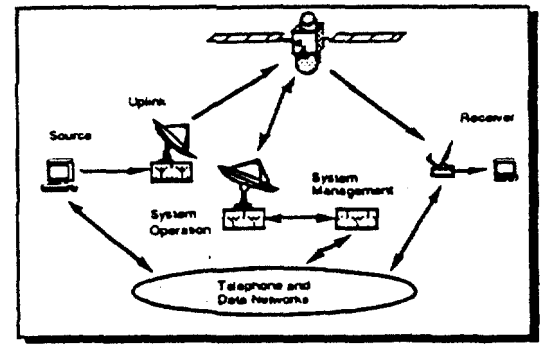

Figure A.1 Major System Components

The top-level planning diagram in Figure A.2 is based on the needs expressed and on the engineering, educational, and organizational efforts necessary to reach the desired goals. The estimated duration from start to finish is 30 months.

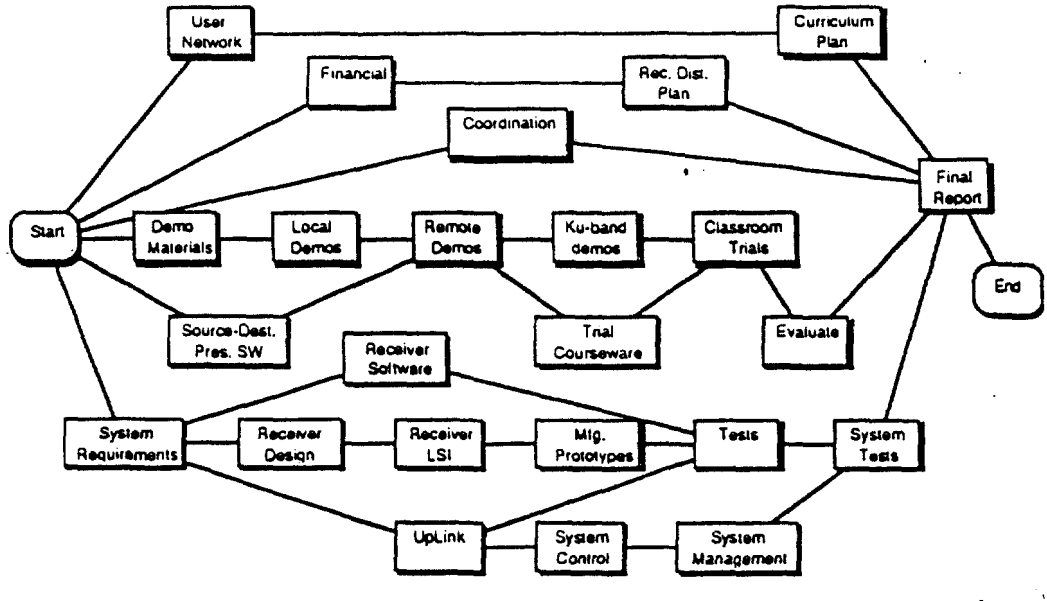

Figure A.2 Top-Level Sub-Project Relationships

Multi-Purpose, Digital Broadcast Satellite System for Military Operation, Training and Simulation

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May 9, 1991

Abstract

A universal digital satellite broadcast system is described which can give the U.S Armed Forces a flexible capability for both domestic and foreign use for a wide variety of purposes. The system's emphasis can be adapted to the needs of the moment and can be synergistically combined with other new technologies. It can be used with equal ease by receivers connected to hand-held computers and displays or by high-resolution displays connected to powerful computer systems. It provides total integration of multi-media and object oriented programming techniques and allows use of sophisticated simulation objects. It can be used in war time or peace, and can provide the most economical and effective means ever devised for military technical training, general education, and deployment readiness.

The system can easily be used for the training of Reserves and National Guard. Field service maintenance could be greatly enhanced. A high-resolution medical imagery network could be established for military hospitals which would insure the highest level of training, operational preparedness, consultation, and effective war-time capability.

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Introduction

Convergence of Technologies

Information acquisition, transmission, processing, and high-resolution displays are becoming essential elements of military systems and operations. The extremely high flexibility of the described broadcasting system will allow direct interface into complex systems with high resolution graphics such as command and control, battle management, training and simulation, intelligence analysis, weapons systems, and others. It can also be used for training and recertification for Reserves and National Guard either at training centers, or even in their own homes or normal workplace. A worldwide military network could be implemented by using capacity on domestic DBS or Ku-band satellites, North Atlantic satellites, or other commercial and military satellites operating in different locations and frequency bands, including EHF.

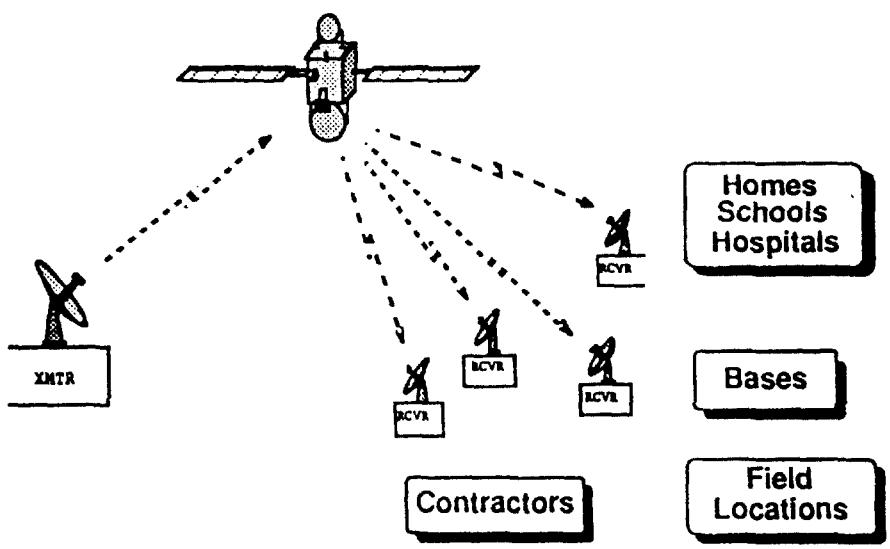


Figure ??? Universal Distribution

U.S. companies are establishing the first **universal** broadcasting system — satellites using a totally flexible, dynamically reconfigurable digital format. A high-rate bit stream will be directly accessible to **small, inexpensive** but sophisticated, microprocessor-controlled receivers, fixed or transportable, anywhere in the nation. The system will deliver normal and high resolution video, digital audio, data, educational services, electronic hypermedia publications, and a variety of other new services. All of these will be **hard-encrypted,** and will provide a wide range of selectable data rates. Various degrees of secure access will be provided within the system and additional encryption can be overlaid as needed.

From its initial concept, this system has been designed to be totally **flexible**, allowing an amalgamation of services, the mix of which can be adjusted at will to constantly-varying needs. It is **dynamically** allocated, providing utility far beyond what its transmitted data rate suggests even without considering planned **compression** techniques.

The system exploits the convergence of computing, communications and video technologies. In addition to various types of data compression (appropriately and transparently applied), the system is based on extending the tenets of object oriented programming (OOP) to dynamic linking of persistent objects of varying lifetimes. Strong encapsulation, such as that provided in the Ada programming language or for "private" members and member functions in C++, is also an essential element.

Instead of requiring a full transponder, a single application can use a fraction of a transponder and may therefore incur only a fraction of its total cost. Trainees can watch a lecture or presentation on a standard TV, high resolution screen, or any of a variety of other high resolution imaging devices. Low-cost, but highly effective, high-resolution animation, graphics, video, and interactive materials will be used. Printouts can be included and computer disks can be downloaded with interactive materials.

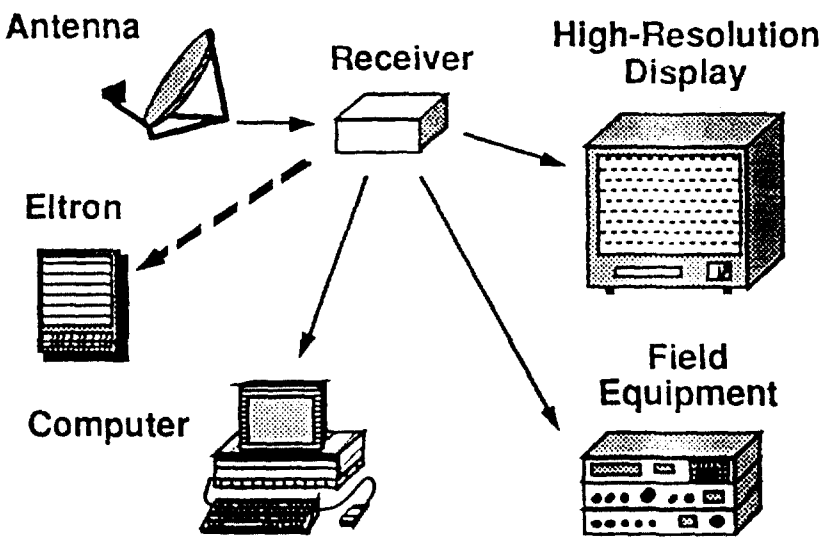


Figure ??? Types of Receivers

Benefits to the Military

The system's unique combination of features provides a new, very efficient type of distribution resource which can also be used by the military on this and/or other systems. Military personnel could also have access to conventional training and could avail themselves of a traditional education without regard to physical station or interruption by relocation. Training

could include very realistic transmitted interactive simulations of military equipment and situations. This capability will be greatly enhanced when inexpensive high resolution systems become available.

This revolutionary system already has a long lineage and deep roots in high technology originally developed for Defense. The high-speed A/Ds, digital demodulation, data compression, signal processing, and integrated circuits necessary for this mainly-commercial system may not have been possible without the original groundwork laid by Defense needs. One of the first block-transform coders was designed and mostly built by one of the team members on a NASA grant. The need for secure voice processing (e.g., ANDVT, and programs for Ft. Meade) spurred development of TRW's parallel multiplier chips, and TI's DSP series. Techniques developed for VHSIC and MILSTAR have influenced system design and engineering. Receivers may also benefit from GaAs, HEMT, and MMIC technologies.

A Broadly Enabling Technology

The needs of the military and the potential of communications systems are both rapidly changing and will likely continue to do so in the foreseeable future. Military systems are becoming more dependent upon technology and highly-trained personnel. As the cost of electronic capabilities declines, it becomes increasingly apparent that increased use of electronics, computers, and communications can decrease total costs while increasing capabilities. The system described herein is a totally-digital, highly-flexible, reconfigurable, robust, multi-purpose broadcast system which can meet a very large number of military needs, both at home and abroad, during peacetime and war.

Applicable Technologies

Displays

The display technology itself is not a main object of discussion in this paper. However, it is an essential element of the system and strongly effects the overall applicability and utility of the system in many specific instances.

CRT

The Cathode Ray Tube (CRT) is still the mainstay of the video and graphics industries and will likely be so for some time to come in spite of substantial inroads by flat panel displays for portable computers. The most common displays for video and computer screens have approximately 500 scan lines and 600-700 pixels per line. Computer displays are typically sequentially scanned (60-80 Hz frame rate) and in contrast to television sets have full chrominance bandwidth equal to that of the luminance whereas video displays (TV) are normally interlace scanned and have substantially reduced chrominance bandwidth relative to luminance, making the latter subject to artifacts such as flicker.

High Definition CRT

High definition displays are becoming more important in both the military and commercial worlds. These have 1000-2000 or more scan lines and at least as many pixels per line. The displays themselves usually have full chrominance bandwidth and interface as analog RGB. These types of displays are essential for graphics work, reconnaissance, display of large amounts of data, and large area displays (e.g., air traffic control, AWACs, etc.). As commercial availability of high resolution displays increases, they will become an ideal means of enhanced multi-media presentation and of simulation displays of other equipment.

Flat Panel

The flat panel (mostly LCD) display is becoming prominent in certain classes of equipment, both commercial and military. They can typically operate at low power for reasonable duration from batteries. They are also small and lightweight and can easily be carried by a soldier when necessary. Color and greyscale versions are becoming available and are at least functional as a video screen although not nearly as good as a CRT.

It is widely recognized that soon it will be possible to have an entire computer built into the back of a flat display. When attached to a small CD-ROM player, this device will be the

equivalent of hundreds of books, except that it will be far more useful due to interactivity, animated graphics, and actively linked information. Such a device could also be connected to a digital receiver for live reception of many types of information. Later we refer to this device as the "Eltron" although it has had many incarnations under other names (e.g., Dynabook).

Projection

Projection screens come in a variety of types. The TV or multisync data projectors are typically expensive, usually have three (RGB) CRTs, and require extensive adjustments when set up. They cannot be even slightly moved before the presentation.

Liquid Crystal Display (LCD) overlays for overhead projectors are becoming popular for computer presentations. A few show a reasonable number of colors. Unfortunately, these displays usually have an extremely slow response time which makes them almost unusable with a cursor or with animation or video. Recently, in-line RGB LCD projectors have started to appear and have reasonable resolution (close to standard video or computer screen) and much faster response time. The big advantage is that they have only a single focus lens which avoids reconvergence adjustments every time they are set up.

Virtual Screen

There are several ways to provide a virtual screen. Heads-up displays and visors have been used by the military in some applications for a number of years. One recent display is a very small, lightweight unit which clips on a pair of glasses and has an actual viewing area less than a square inch. It is focused for normal viewing distance so it looks similar to a normal screen except that only one eye is used while the other still looks past it. The image is formed by a linear LED array and a vibrating mirror. This could be extremely useful in a battle field environment because normal vision through the other eye is not impaired. Presently, these units are monochrome and have low to medium resolution. However, there is no inherent reason why a color high-resolution image could not be done in a similar manner.

Virtual Reality

Using two of the above virtual screens and some remote imagery or 3D-rendered computer graphics the user is projected into a virtual environment. This could be used for computer interaction, familiarization training, or robotic telepresence such as exploring enemy territory or entering a possibly booby-trapped bunker.

Audio

Audio can be be made available in a variety of quality levels including stereo high-fidelity and surround-sound. The latter might be appropriate for a virtual reality environment.

Source Coding

One of the main innovation of this system is its source coding. What we call "source coding" actually covers a considerably larger range of topics than what is usually associated with that term. However, we believe the term is appropriate if one considers the ultimate source which is the individual who controls the transmission and determines its content. These are simply means of representing and encapsulating information for conveyance to others.

Compression

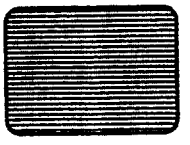
"Compression" refers to an attempt to efficiently represent a signal such as an image or a sound or other type of data within a smaller bandwidth or using fewer bits. In the case of normal television, this means efficiently encoding images or sounds without regard to their origin. As we shall see later, one can actually do much better if more is known about what generated the image in the first place. In many situations today that is in fact the case.

"Lossless" encoding refers to any representation which perfectly preserves and allows reconstruction of the original representation. Examples commonly used today are entropy coding techniques such as Huffman coding and Lemple-Ziv-Welch coding which exploit the frequency of occurrence of sequences of a bit stream. Another commonly used technique is run-length coding where a simple code indicates the distance (in pixels) to the next change. The latter is particularly useful in document storage and transmission. Both of these types of coding are also useful in some aspects of video compression.

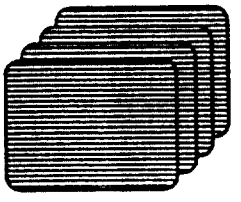
"Intra-Frame" coding works on single images and does not exploit redundancy in the time domain. It is an attempt to represent a single image with the fewest bits possible without degrading its functional or esthetic properties. There are many algorithms available which are based on a wide variety of techniques. These include one- and two-dimensional prediction, subsampling and interpolation, wavelets, fractals, vector quantization, and a many types of transforms. Of these, the 8x8 Discrete Cosine Transform (DCT) has strong analytical and psycho-visual bases, has been widely adopted, and is included in standards such as JPEG (Joint Photographic Experts Group) and the CCITT's h.261.

Most transform-coded natural images are judged to be indistinguishable from the original (possibly 24-bits per pixel) when squeezed to 1 or 2 bits per pixel (average). This process

usually makes use of the DCT transform, coefficient quantization, and Huffman coding. Some proprietary schemes also include vector quantization. However, vector quantization can be a highly computationally-intensive technique that is expensive to implement in real time. JPEG will likely find much use in individual-image storage and transmission and in frame-accurate video editing, laser disks, and other random-access applications.



- **Intra-Frame Techniques**
  - **Prediction**
  - **Estimation**
  - **Transforms**
  - **Quantization**
  - **Entropy**



- **Inter-Frame Techniques**
  - **Prediction**
  - **Subsampling**
  - **Conditional Replenishment**
  - **Motion Compensation**

Figure ??? Video Compression

"Inter-Frame" coding exploits the high degree of redundancy between successive frames of most video images. The simplest method is that of frame differentials and conditional replenishment. This requires that a copy of the previous frame be stored for comparison purposes and that the receiver also have a frame store for rebuilding a complete image. Change areas can be thresholded and flagged for further intra-frame coding. Run-length or region-flag techniques can be used to indicate where changes have occurred. Frame differential techniques are very effective but result in a highly varying data rate which must be smoothed by channel-rate buffering and interactive control of image quality (and thus data rate) as a function of buffer fill. When multiple sources share a broadcast system, the statistical properties of this data rate fluctuation can be exploited for further gain. (More on that later.)

"Motion compensation" attempts to determine areas which can be identified as moving and determines their velocity. The translated partial image can then be used in the frame differential reconstruction, thus giving a far better basis of prediction, which then may need little or no additional updating. With proper filtering, fractional-pixel image translation can be accomplished.

In transform-based systems, one can transmit the differences of transform coefficients or can compute the transform of the frame differentials. The latter is more amenable to a broadcast system because it minimizes the computational burden on the receiver. In either case, finding the

translation vectors is an extremely computationally-intensive task for the encoder and is expensive to do in real time. These techniques are used in the evolving (almost final) MPEG (Motion Picture Experts Group) standard which is primarily intended for video on CDs (Compact Disks), operating at rates below 1.5 Mbps and where off-line, non-real-time encoding can be used.

Related schemes are being proposed by C-Cubed, JVC, Phillips, and others for broadcast video standards in the 5-10 Mbps range for what will likely be known as "MPEG-II." It will also likely be further extended for high definition systems.

This system's receiver will include all of the functions necessary to implement the upcoming standards and will also include other proprietary techniques. More important, the algorithm will be controllable and reconfigurable at the instant of reception by transmitting instructions and parameter tables to the main receiver processor.

Immediate Drawing Primitives

One thing that has changed radically over the past few years is that few people draw anything by hand anymore. It is all done on computers. This is true for both documentation and presentation materials. It is also true for dynamic materials such as animation. The recent movie "Roger Rabbit" will likely be the last of the major hand-drawn animations. Let us ignore for the moment the computational process of 3-D image rendering and image composition techniques. The process of placing a computer-generated image on the computer screen is almost universally done using some type of drawing "primitives." These are the procedures which draw a line or stretch a rectangle between specified points, determine the line thickness, color, and pattern, and fill-patterns, colors, gradients, etc. They are what actually composite the screen image in electronic form so that it can be raster-scanned onto the physical display.

A computer-screen image is usually created by executing a sequence of drawing primitives. In fact, some file formats (e.g., Macintosh "PICT") are simply created by "bottlenecking" such command primitives and capturing them to memory. The captured sequence of commands can later be played back from memory to generate the image. A reasonably intelligent operating system can work in conjunction with such a list of drawing primitives to efficiently update an "invalidated" portion of the screen when necessary (e.g., when an overlapping window is closed or moved).

The drawing commands which update the computer screen could just as easily be forwarded through a transmission system to another remote computer screen (of course, itself having the intelligence to interpret such drawing commands). Such systems are practical and are in use in

screen-sharing software today such as Farallon's "Timbuktu" which allows a remote consultant to see a client's screen and control his computer. Similar techniques will allow efficient information-lossless broadcast of all, or a portion of, a computer-generated standard or high resolution screen.

We describe this as "immediate drawing primitives" because the commands are transmitted and implemented immediately when generated and do not involve any storage of commands at the receiver. Whenever a change is required in the displayed image, new drawing commands must be transmitted. The system can be designed to use Display Postscript, QuickDraw, or any of a number of other screen drawing systems.

Local Software

Another way to draw presentation screens is to use software and data files at the receiver which are controlled by the broadcaster through low-data-rate commands. The software and/or data files may be downloaded through the transmission system prior to utilization or may be locally resident on other media such as magnetic or optical computer disks, tapes, or CD ROMs.

The software will run on an imbedded processor which will create the display screens including automatic updates of invalidated areas. The presentation sequence of images can be completely and very efficiently controlled through the broadcast link, even including animation. The local software package can be very sophisticated if desired, including 3-D rendering if enough processing power is available. Alternatively, a less capable receiver might show the same information, but without photo-realistic image rendering.

Transmitted Objects

A new broadcasting capability that we are designing is that of transmitted software objects. Objects are encapsulated units of data and software behavior. Their data structure and behavior may be inherited in part or entirely from other objects. (To be technically correct, such terms actually apply to the object "classes" rather than instantiated "objects".) "Dynamic linking" and "late binding" of objects are necessary elements in this concept.

Due to the continuous-running nature of this software, sophisticated memory management and automatic garbage collection are critical elements. "Handle-based" objects will prevent a Swiss cheese memory space (i.e., full of mostly unusable holes) by allowing heap compaction when necessary. Memory leaks caused by erroneous (or non-existent) disposal methods will hopefully be at least contained by automatic garbage collection. In any case, the transmitter should be able to monitor expected receiver processor heap behavior (by even using a colocated

receiver, if necessary) and take appropriate remedial action when necessary. Object life control will be implemented with expected lifetimes and prioritization established to determine when objects and other resources can be purged from memory.

Software objects may or may not be related to drawings on the screen. However, chances are that any visible object will be drawn and supported by one or more software objects. Complex screen objects can be formed by hierarchical groupings of simpler objects (commonly done with the "group" command in drawing programs) thus allowing a building-block approach. Software objects also have the ability of being cloned and manipulated (usually through "command" objects). It is this ability of objects to be cloned and controlled through external "messages" which allows such great transmission efficiency in a broadcast system. Once the basic object exists in receiver memory, it can be told "draw yourself" on the screen. It can also be told to rotate or distort itself, or move across the screen at a given direction and rate, or attach itself to another object at a specified distance and position and with a given coupling spring constant. The possibilities are limited only by the originator's imagination.

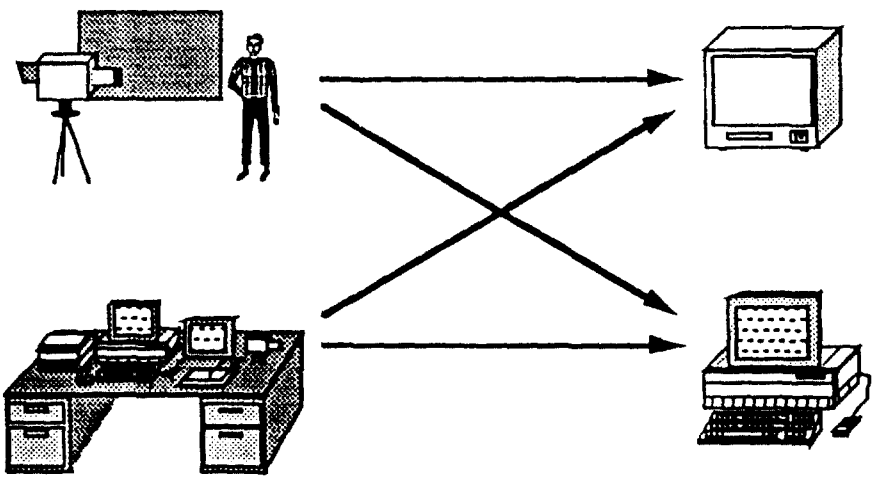


Figure ??? New Types of Offerings — New Kinds of Reception

Integrated Multi-Media

It is easy to see that the concept of transmitted objects can be used to integrate a multi-media system. Transmitted video can be one type of object, or at least can be manipulated by an object to control its method of appearance, screen location, size, clipping, transition effects, and extraction of freeze frames. Local video from laser disks and CDs can be afforded even more control because they can be accessed directly from the source and are not dependent upon what comes down the pipe. Background screens, image sequences, animation, video, sound, and other external devices can all be controlled through the same basic object oriented control software.