Memory) or similar technology. It is also important to keep watch over the process to make sure that no unauthorized production runs take place. These devices can be built with a means of "burning your bridges behind you," i.e., a security gate which, once blown, prevents external access to the internal information. It is important that all cryptographic processes be integrated into this single device. (Lack of integration was one weakness of the original VideoCipher, which, although encapsulated, could be easily opened to get access to vital information.) With fusible-link devices it is even possible to pry the lid from an IC and visually read the code from the obviously blown fuses. EPROMs (Electrically...) should be a substantial improvement in this regard.

Each device must have a readable serial number so that it can be matched with its (secret) internal code during service authorization. This also requires tracking the receiver serial number in order to know who has which security device.

The individual code (key) is used for private communication between the authorization center and a particular receiver. The sales people do not have access to it — they simply have (or the customer gives them) a receiver serial number. The "vault" in the authorization center has the list which maps box serial numbers to individual code keys. The authorized service key is encrypted with the individual key and sent via the satellite, phone line, (mailed) card, or smart card.

The "vault" becomes the most valuable resource and must be backed up at several locations to make sure it is available in spite of catastrophes. However, this also makes it more vulnerable to theft or bribery. Therefore, it is probably desirable to also encrypt the lists with multiple keys so that no individual person can access it, i.e., similar to procedures with nuclear warheads.

Multi-tiered access control today is done by using a common service key and setting or clearing "authorization" bits which enable or disable descrambling for a particular sub-service. Once the basic service is authorized, this feature can easily be defeated to gain access to all tiers. The main reason that it is done this way today is the limited addressability capability of the VideoCipher control channel.

If the necessary hardware can be obtained or built , then all it requires is one legitimate access code to build an unlimited number of clones of a legitimate unit, or simply clone the access chip and modify an otherwise legitimate unit, all of which can then receive the same services while only one actually pays for it. (This actually happened with VideoCipher and was quite rampant for a while.) However, once a cloned unit is found, then its access code can be disabled, thereby simultaneously terminating service to all sibling clones.

Other than taking steps such as making the authorization chip expensive and technically difficult to physically clone, watching the production line like a hawk, making key readout as difficult as

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possible, and placing armed guards at the "key" vaults, the next line of defense requires some type of physical or location-specific delivery of additional authorization codes to the subscriber. This authorization should also be ID-specific for the intended box and should be required in addition to the over-the-air (conditional) authorization. Some of the possible methods are:

- Telephone connection in response to satellite command (telephone ANI[1] verification may not specifically be required but would be useful);
- Physically carry the receiver (or security module) to a service center;
- Periodically mail out individual magnetic or optically readable cards;
- Require use of a "smart card".

Of these, use of the telephone line is probably the least hassle from everyone's viewpoint. Telephone modems are a single inexpensive chip today and will also allow many enhanced services such as home shopping. A re-call algorithm must also be included in case the phone is not available or connection is unsuccessful. The box must be required to call the authorization center, not vice-versa. It is not possible to ring a phone and hope that a TV receiver box will answer and the customer won't. A minor shortcoming is that some alternative must also be provided for subscribers without ready access to a phone, e.g., someone touring in a Winnebago.

Mailing out magnetic or optically readable cards for additional service verification is very economical and provides a significant increase in security. However, it is still vulnerable to piracy networks which could reproduce them and forward the cloned cards to those in a network. Even so, the additional security may well be worth it. Many people who would make a one-time purchase of a cloned unit in a back alley or a dark room might still be apprehensive about long-term overt association with a service-piracy ring. (A few well publicized anti-piracy campaigns with public floggings might help — just kidding, really.)

Physically carrying the unit or it's authorization module into a service center may not be practical and certainly is not desirable. However, the "smart card" approach may prove to be the best overall. It is not easily cloned and has the ability to interact with the subscriber's unit is such a manner that **Impulse Pay Per View (IPPV)** purchases can be properly registered before further credit authorization.

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1 David A. Woodcock and Larry K. Moreland, "Launching a Statewide ANI Passing Impulse PPV System," NCTA Technical Papers, 1988, p. 4.

Access Control

As indicated previously, a critical factor is the available control channel capacity. These messages must originate from the control computer at the uplink site because it is the only system having the detailed program schedule and attribute database. However, the data channel originating from that computer, which in turn is broadcast to all decoders, contains many other messages which need to be inserted into the transmission channel. Some of these messages are related to:[1,2]

- Current Program Key (encrypted under several Category Keys, and thus repeated);
- Next Program Key (encrypted under several Category Keys, and thus repeated);
- Current program name strings;
- Next program name strings;
- Time remaining for current program;
- Current Program Attributes: Program Rating, IPPV mode, Program Cost, Audio mode;
- Next Program Attributes: Program Rating, IPPV mode, Program Cost, Audio mode;
- Tier Messages.

As can be seen, the rate at which essentially all of the above messages are transmitted directly affects the speed with which a receiver tuning in the channel can obtain the necessary information to acquire and decode the signal.

ACC's Digital DBS

ACC's uniquely flexible multiplexing architecture allows far more efficient utilization of the available bit stream than is possible with the fixed-rate-service architectures that others have advocated. Access to this bit stream will be prioritized so that basic TV services always get the maximum available capacity whenever needed. However, video compression studies have shown that on the average one third to one half of the bit stream can be available for lower-priority use without degrading the basic television service simultaneously being provided. (A comparable situation simply does not exists in analog systems.) This means that on the average, at least 10 Mbps of capacity is available for other data services. If necessary, the authorization center could take over this entire bit rate for a short period of time for a complete system rekey. It is also available for heavy temporary use by IPPV authorization requests.

---

1 Mark F. Medress, "Satellite Television Scrambling with VideoCipher", Communications Technology, September 1985, p 82.

2 Mark F. Medress, "How Will VideoCipher Affect the TVRO Picture?", TVRO Technology, October 1985, p 20.

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This available authorization bit rate is over one thousand times that available presently in today's systems. To put this in perspective, if 256 bits are used to rekey one subscriber, a total rekey for 10 million subscribers could be done in about **four minutes** through ACC's Digital DBS system, **compared to about three days** using present techniques.

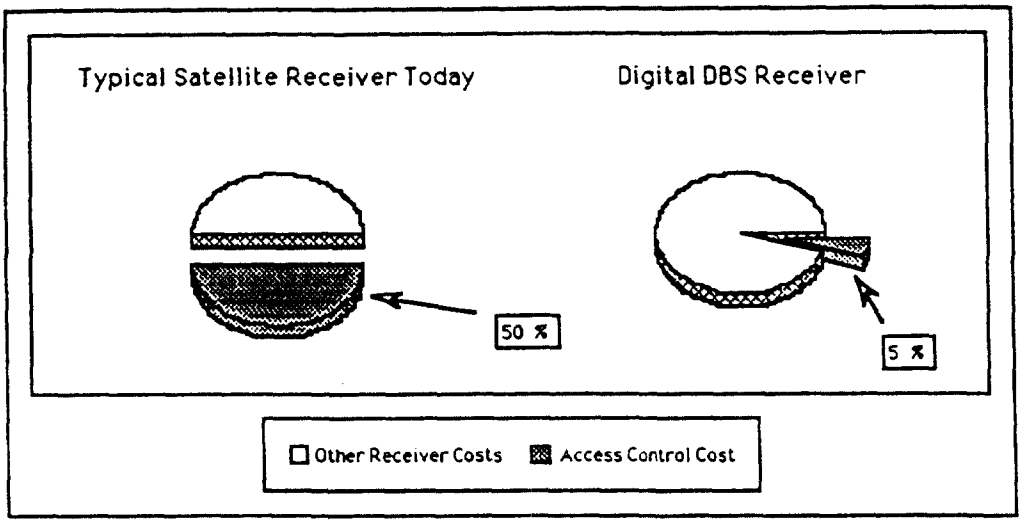

Figure 1 Portion of Receiver Cost Due to Access Control

The cost of the Access Control module is approximately 50 % of a typical satellite receiver today, largely due to the special processing necessary for even this modicum of protection. A digital DBS receiver, on the other hand, requires no processing in the actual encryption process because it deals only with a single digital bit of information at a time. The bit is flipped (0→1 or 1→0) or it is not flipped (0→0 or 1→1) according to the binary state (0 or 1) of an appropriate cipher bit. This results in a seemingly completely random bit stream containing no usable information without the appropriate key to regenerate the cipher stream.

The cost of providing the high-speed DES cipher generation and storing the necessary crypto keys continues to decrease with each generation of LSI. We estimate the entire **Access Control** function to be less than 5 % of the cost of a digital DBS receiver. This will include full authorization for individual **multi-tiered access** and **IPPV**. Figure 1 illustrates the difference in relative cost for this function between todays VideoCipher receivers and ACC's Digital DBS receivers.

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Comparison

As can be seen from the previous discussions, there are many differences between the security level that has been possible previously with analog transmission systems, and what can be achieved today with digital transmission. In order to facilitate a better comparison, Table 1 provides a summary of contrasting characteristics for these systems.

	Present Analog Techniques	Digital DBS
Signal Descrambling Process.	Requires much video processing and many IC chips.	Uses a single logic gate (ExOr) — about 1/100,000 of an LSI chip.
Relative Access Control Cost.	High — Doubles the cost of the receiver.	Low — Adds only about 5 % to receiver cost.
Video Security.	Can and has been defeated — even without access to the key.	Hard encrypted — Virtually impossible to defeat without key.
Control Data Rate.	Low — 9600 bps.	Very high — 10,000,000 bps when needed (no resulting degradation).
Time to Update 10,000,000 Subs.	3 days.	4 minutes.
Multi-tiered access control.	Done by setting single control bits — Not very secure.	Full individual service encryption — Very secure.
Impulse Pay Per View.	Difficult to provide and only for a very limited number of events.	Relatively easy due to fast authorization capability.
Security Breach Re-key Response.	Difficult, due to long update time.	Easy, due to fast update time.
Handling of Many Low Rate Services.	Limited to a very few low rate services.	Extremely large number of low and medium rate services.
Channel Overhead for Authorization.	Not huge — but significant.	Virtually none — due to flexible prioritized multiplexing.
Degradation due to scrambling.	Significant.	None.

Table 1 Comparison of Access Control Techniques

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Conclusion

ACC's Digital DBS system will provide a **Access Control** system with a level of security that is decidedly superior to any system available today. **Hard encryption** of the digital signal and **extremely fast rekey capability** make transmission security much easier to attain than with analog systems. Physical device "key" security is much improved due to the ability to totally encapsulate the digital decryption process in a one-chip device. However, "key" protection and reverification must still be provided through other means such as telephone lines, mail, or "smart cards."

Tiered Access is fully protected by complete individual service encryption. Fast authorization and "smart card" or telephone line access also allow **Impulse Pay Per View** to become practical for a large number of services. The system will also support a large number of low and medium rate subscription services.

Appendix A Vita

Dr. G. Gordon Apple - President, Advanced Communications Engineering, Inc. Dr. Apple was principal investigator and project manager for a joint effort with CBS Television to develop data compression for High Definition Television (HDTV) using digital transmission via Direct Broadcast Satellites. He also served as assistant Program Manager for VHSIC (Very High Speed Integrated Circuit) ground terminals for the MILSTAR satellite system—by far the most sophisticated communications satellite ever built. This was a pioneering program which was the first to incorporate the most powerful and advanced digital signal processor ever designed. He was then principal investigator for IRAD (Internal Research and Development) programs for small, light-weight EHF (Extremely High Frequency) terminals. He developed a system design for an ultra-small VHSIC Phase II (wafer-scale integrated circuit) EHF satellite communications terminal and proposed (to NSA) a unified cryptographic integrated circuit design for use by the Air Force.

In recent years Dr. Apple has devoted his efforts toward concept development, system design, and promotion of digital transmission for DBS broadcasting of television, HDTV, educational services (e.g., the YES Networks), and other services. In particular, he pioneered the concept of using personal computers to (digitally) broadcast services directly to televisions and personal computers using a flexible combination of data compression, file transfer and control, and transmission of drawing primitives. He has also been actively engaged in extending the concept of

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"object oriented programming" across boundaries between multiple diverse processors and dedicated hardware, particularly between personal computers and embedded signal processors.

While at Purdue, Dr. Apple developed a transform-coding digital filter for NASA on a research contract. He then worked at Bell Telephone Laboratories on digital-interframe-coding video-compression techniques for PicturePhone® transmission. At North Electric he headed a department which developed transmission, synchronization and multiplexing systems for a new digital telephone switching system. He then was Director of Engineering for Automation Products Company. At TRW, Dr. Apple was a project manager for many digital communication system projects including satellites, modems, and data compression systems. He served as system engineer on the Space Shuttle's primary communications system (for which he received award recognition from NASA) and served as system engineer on a number of satellite programs including an Intelsat VII proposal, partly in Toulouse, France, jointly with MATRA.

Dr. Apple was a system engineer for development of a secure-voice terminal (for Ft. Meade) and developed the KDC (Key Distribution Center) protocols and signal formats used for exchanging crypto-keys in this system. He was the system engineer for a project that developed a television satellite transmission scrambling system.

Dr. Apple received his BSEE degree from the University of Arkansas in 1966 and an MSEE and PhD from Purdue University in 1967 and 1970 respectively. He has over 25 years experience in digital communications spanning the telephone, computer, space, and defense industries. Dr. Apple has patents in the fields of error correction coding, digital transmission, synchronization, and video data compression. He also has various publications and has made many presentations (including internationally) on these subjects. Dr. Apple is a Senior Member of IEEE, a member of Sigma Xi (research society), Eta Kappa Nu, Tau Beta Pi, Pi Mu Epsilon, and the Society of Motion Picture and Television Engineers. He is a Registered Professional Engineer and an instrument rated pilot.

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Appendix B Data Encryption Standard (DES)

On July 15, 1977, the National Bureau of Standards (NBS) Data Encryption Standard (DES) became effective.[1] This is a cipher which maps a 64-bit plaintext block into a 64-bit ciphertext block, and vice-versa, by using a 56-bit cryptographic key. Although the choice of such a relatively short key has been vehemently criticized in the literature by Hellman,[2] its vulnerability is only evident in extremely-high-motivation situations where someone can monopolize a "Cray" super-computer for weeks at a time, hardly an economically worthwhile endeavor to obtain a transmission key for a movie.

The DES algorithm can be implemented in sixteen stages which are identical in form but differ in the small permutation sets at each stage. Encryption and Decryption both work the same way. If each stage is allocated 4 clock cycles (assuming a parallel hardware implementation), the output cipher stream will produce precisely the correct number of cipher bits to equal a data stream at the same clock rate. Therefore, a data stream of 30 Mbps would require a cipher processing clock rate of 30 MHz. This can be easily implemented today as one portion of an IC chip.

Usually, the output cipher stream is combined with the system clock and fed back to the input to produce the succeeding cipher block. The cipher generator runs independently from the data stream and is simply "exclusive-ored" with the data stream. Thus, the cipher stream is a highly non-linear type of Pseudo-Noise (PN) sequence. Doing this, rather than running the encrypted data through the cipher, prevents single channel errors from multiplying into error bursts each having an average of 32 errors. Single channel errors remain single errors. It also allows the generator to be periodically re-started fresh from the system clock, if desired.

The same crypto processor can be used for (non-feedback) block decryption of individual service keys and crypto-sync information. If a higher level of security is desired, then it is also possible to use a double encryption method using two separate crypto keys.

Each provided service could have its own individual crypto key which could also be updated at frequent intervals, e.g., once per week. The theoretical number of keys using 56 bits is $2^{56} \approx$ 64,000,000,000,000,000.

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1 Meyer, Carl H., and Stephen M. Matyas, *A New Dimension in Computer Security Cryptography*, John Wiley & Sons, 1982.

2 Hellman, M., R. Merkle, R. Schroeppel, L. Washington, W. Diffie, S. Pohlig, and P. Schweitzer, *Results of an Initial Attempt to Cryptoanalyze the NBS Data Encryption Standard*, Information Systems Laboratory Report, Stanford University (September 9, 1976) (Revised November 10, 1976).

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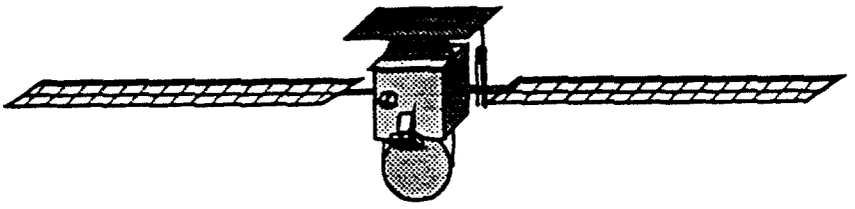

The YES* Networks:
Distance Learning via Digital Direct Broadcast Satellites

(* Your Educational Services)

July 2, 1990

G. Gordon Apple, PhD

For: Foundation for Educational Advancement Today (FEAT)

Advisors:

National Education Association
American Federation of Teachers
National School Boards Association
American Association of School Administrators
National Aeronautics and Space Administration
Advanced Communications Corporation
Public Service Satellite Consortium

For further information: **Daniel H. Garner** (see p. 9)

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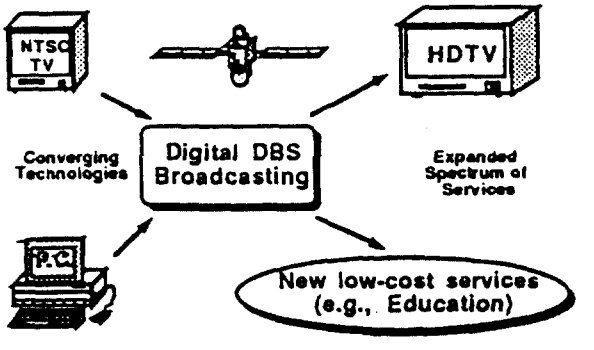
Summary

Your Educational Services (YES) Networks is a totally new concept in satellite distance learning. Class lecture services, equivalent to what is being offered by satellite distance learning today, will be **much cheaper and easier to use.** In addition, it will deliver many **new types of educational services which are vastly superior in both technical quality and utility to what is now possible.** High-powered digital DBS (Direct Broadcast Satellite) signals, received by small antennas (1.5 ft. square), used with microcomputers, offer perhaps the most impressive application of technology yet introduced to the classroom. Add to this the fact that 100 or more courses can be simultaneously offered in one satellite channel, compared with only one today, and the economics and potential extent of applications is readily apparent. The YES Networks is developing the future of distance learning today.

The YES Networks

Education, and particularly distance learning, is rapidly approaching crossroads of historical proportions.[1] Decisions made and directions taken in the next few years will set the course for decades to come. The famous statement, "the medium is the message," could not ring truer than when applied to storage, propagation and delivery of information, and to educational access.

The YES Networks is being developed for the purpose of simultaneously providing a large number and variety of educational services using digital transmission through high-power satellites. These services will be received by relatively inexpensive, easy-to-install receivers in schools, libraries, hospitals, and homes — virtually anywhere needed. It combines a variety of existing technologies[23] to very efficiently send voice, video, computer files, control, and configuration information. Subscriber access can range anywhere from completely open access up to the highest levels of government security at the discretion of the individual program originator. The YES Networks will provide to anyone in the nation a wide-band data pipe for access to many educational and other services.



The enabling event will be the advent of digital satellite broadcasting combined with the widespread use of personal computers for education, work and recreation. Within only a few years anyone will be able to receive television, HDTV,[4] digital stereo radio, electronic publications,[5] and educational courses[6] by using a DBS receiver and a television and/or a personal computer.

Its Capabilities

Educational course broadcasts will be enhanced in the following areas:

Capacity - The YES Networks will insure that adequate satellite course transmission capacity will be available to meet the needs of today and tomorrow for all types

Foundation for Educational Advancement Today

FEAT is a 501(c)3 public charity which has the use of four high-power DBS transponders on-board ACC's DBS system for the YES Networks. In addition, the Foundation will offer a free antenna-receiver to each of approx. 125,000 public and private schools and libraries across the USA by 1993-94 -- a combined value in the mid nine figures.

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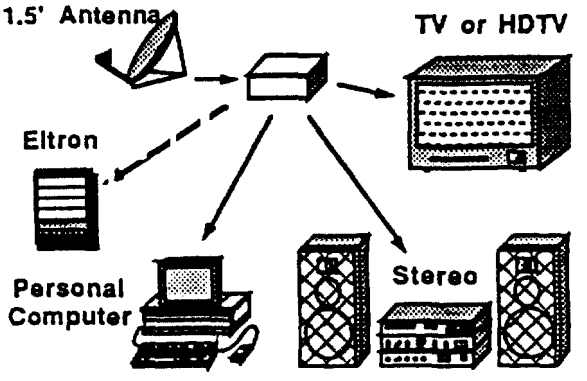
application of knowledge, and state-of-the-art "hypermedia" techniques for obtaining and sharing information.



Why It's Needed

The needed growth of distance learning may soon be stymied by high delivery costs, lack of related capabilities (little or no capability to down-load supplementary materials, limited interactivity) and especially a coming **shortage of affordable satellite transponders.**[8] Current analog transmission and reception techniques are capable of carrying only one or two TV courses per transponder. There is an obvious need to increase this capability and improve efficiency in current and future satellites to ensure that each transponder can simultaneously broadcast many services.

The relevance of digital DBS to distance learning cannot be overemphasized. It will bring unparalleled flexibility, efficiency and **economy of operation** to educational course broadcasting. It will allow introduction of a vast number of **new educational services never before possible**—all received with antennas convenient to install because they are not much larger than a student's opened notebook. The system under development by the YES Networks **will assure the future economic availability of adequate satellite delivery capacity** for traditional-type distance learning for the entire nation.

Satellite Transponders

A "transponder" is a basic communications relay unit of a satellite of which there are usually up to 24 (active) plus switchable spare components. Each transponder consists of a receiver operating at one frequency, a transmitter operating at a different frequency, and a frequency translator between. Each normally carries one TV signal (or equivalent).

Distance learning has been proven effective[9] and is growing at a rapid pace. As noted by Dr. Frank Withrow of the U.S. Dept. of Ed., "It is possible to use these technologies to reach very isolated students, i.e., handicapped homebound students, students in prisons, students on Indian reservations and even students who are in the workplace....Distance learning in this country dates back to the 1890's, when correspondence schools evolved to meet the needs of people who did not have access to certain types of education. Later, in the 1930's, educational radio was a viable resource in certain parts of the nation....In 1974, NASA, NIE, NSF and the Office of Education participated in experiments on video-satellite education, using the ATS-6 satellite."[10]

But students need more than audio/video lectures. They need real-time interaction and off-line study aids which can only be effectively delivered by a digital broadcast medium. Some of today's satellite distance learning systems have a low data-rate digital capability which allows text to be printed at remote sites. Much higher data-rate capabilities than now available are required to allow downloading of computer-interactive course materials for use during and outside the class.

Research is clearly demonstrating that American school children at all grade levels perform poorly in math and science on achievement tests in comparison to students from other industrialized nations. In addressing this problem, the NCTM developed its "Math Framework"[11] to provide a cohesive national plan for upgrading math education. However, there is a shortage of teachers possessing master teaching competencies in mathematics and science, particularly in rural or small school districts. Several barriers exist to implementing the needed changes. These include: teachers being poorly prepared to provide science and math instruction; current text and workbooks not containing sufficient material to allow students to develop and

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practice higher-order thinking; and computers primarily being used only to provide drill and practice of basic facts.

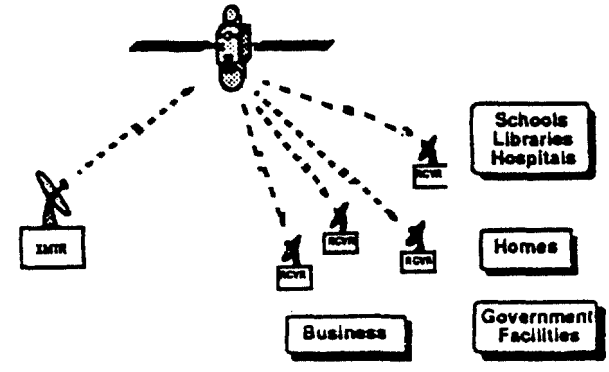
Reports such as *The Governors' 1991 Report on Education, A Time for Results* - Task Force on Technology; and the National School Boards' Association, *A National Imperative: Education for the 21st Century*, made clear the concerns of many educators regarding the need to introduce new methodologies and technologies into education. More recently, U.S. Congress Office of Technology Assessment has completed its description and evaluation of technologies that are available for classroom use today: *Linking for Learning — a New Course for Education*;[12] and *Power On — Tools for Teaching and Learning*.[13] Explicitly evident is the consensus that **if the costs can be reduced,** technology as a tool can and should be used to transform the classroom environment and the learning experience in revolutionary ways.

What is Needed

According to Ewell,[14] one solution is to use distance-teaching technologies to share master teachers among many schools and classrooms. These specialists would exhibit exceptional teaching strategies, superior motivation and communication skills, sound curriculum knowledge, interpersonal competence and classroom management proficiencies. This can provide an effective alternative to traditional instruction in terms of student satisfaction, content mastery and cost effectiveness.

The advent of digital broadcasting satellites will allow the development of totally new services and completely new industries that do not even exist today. Electronic publications and digital delivery of these publications will revolutionize the dissemination of information as we know it.

In addition to telecommunication technologies, microcomputers have revolutionized distance education in virtually every area. Used alone, microcomputers can provide students and teachers with a wide range of instructional activities and productivity tools. When connected to local or distant networks, microcomputers can facilitate communications between students and teachers providing access to vast storehouses of information.



Who Will Benefit

The public benefits to be derived from meeting the need for improved access to instructional and informational materials are legion. One might compare today's access to educational resources enjoyed by most schools and the potential for an effectively-administered, digital-based satellite communications network with the increased access to information created by Gutenburg with "movable type." With Gutenburg's invention, costs fell, the dissemination of ideas expanded, and learning was made available to a vastly broader segment of the population. Similarly today, while technology cannot replace the human resource in the classroom, it can greatly expand teachers' inventory of educational materials and their effectiveness with students.

Following are only a few of the more obvious educational services and programs which would benefit the public as a result of implementing the YES Networks:

- Satellite educational programming to all public and private elementary and secondary schools in America;
- Much improved access of rural schools to educational programming;
- In-service training to teachers;
- Information data streams to all libraries in America;

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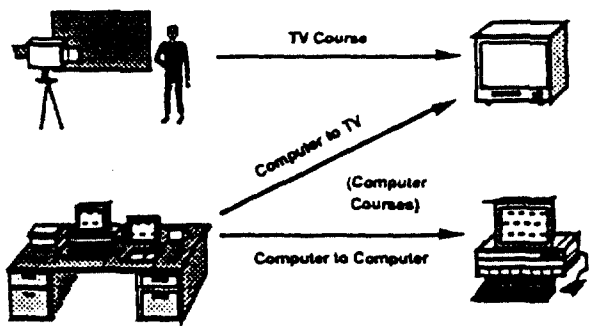
- Transmission of informational and innovative materials to/for schools, PTAs, school boards, administrators, teachers, their national associations, and the U.S. Dept. of Ed.;
- Specialized programs for vocational-technical schools;
- Drug prevention and rehabilitation education;
- Specialized programs for disadvantaged, gifted, talented youth;
- Training and educational advancement programs for businesses and industries;
- Lifelong education, including graduate studies through the University of America;
- Educational programming to all child-care centers in America;
- Emergency Broadcast System to schools (tornados, earthquakes, floods, fires and other catastrophes);
- Adult literacy;
- Student remedial programs;
- Senior citizen learning opportunities;
- Support of the Job Corps and other federal programs;
- Professional re-qualification as required by state laws;
- Medical information interchange among medical facilities;
- Education and data transmission to support migrant students;
- Assist prison inmates rehabilitation programs;
- Relay of educational programming to Department of Defense-operated schools;
- Professional training and informational services (legal, accounting, financial, medical, engineering, etc.);
- Parent education in home or school.

During after-school and evening hours the YES Networks will implement a student incentive program delivered via DBS to homes. It will provide student and teacher assistance including "point" accumulation for a variety of rewards for participation, ranging from commercial products to a college education. The Foundation's underwritten YES Networks concept has received the endorsement of NEA, AFT, NASB and AASA, among others.

Once such a system is created and implemented through a network of users, there will be little reason for any school to be deprived of access to an extraordinary inventory of educational programming far in excess of that now available only to the wealthier districts. This advance in educational access would be possible not only by introducing new hardware, but also through the pooling of resources in a user network.

The demonstration of feasibility of using digital-based communications in education and the lower per service costs and increase capability of such a system will be the most persuasive argument for creating a network of users founded in public and private schools and libraries.



How It Works

Two basic types of services will be offered. One is a **TV Course** service which is functionally similar to that being offered today, but is far more transmission-efficient, far less expensive and has the flexibility of including additional services such as printed output and high-quality, on-screen graphics. The other is a **Computer Course** service which is even more efficient and less expensive than TV courses. However, it still can include live TV

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images on the computer screen. The Computer Course also has vast additional capabilities that cannot be offered by any of today's TV course transmissions. It can also be displayed on multiple TV monitors or a projector.

Hypermedia makes new forms of educational experiences possible and more powerful. This is particularly important for reaching students at risk, and "visual learners" who have extensive experience watching television, videos, and playing computer games. It provides extremely powerful tools for teachers to provide information in a wide variety of formats and to answer virtually any question "on the fly". In addition to integration tools, teachers can conduct immediate searches of computerized data resources. This will enable teachers to provide superior instructional opportunities for all students.

Hypermedia control software gives instructional developers extremely powerful tools for creating high quality multimedia-based instruction and the capabilities to modify the instruction virtually instantaneously to meet the needs of specific individuals or groups. It includes the ability to connect text, graphics, animation, relational databases, motion video, and sound into a single environment, coupled with the ability to jump as needed from place to place in an intuitive manner. Information can be "spoken" by the computer or presented in a written form in any language desired.

Analog or Digital?

All television broadcasting systems today (including satellites) use analog transmission. In the western world the predominant system is known as NTSC[15]— a standard now over 40 years old. It is extremely inefficient in transmitting images which change infrequently (e.g., business conferences and classroom lectures). Much work has been done over the last 20 years to improve the efficiency of transmitting such images. From the beginning, these efforts have used digital techniques.

Until recently, most DBS operators had planned to use analog TV transmission—the method that is presently used exclusively for standard television on today's domestic low-power satellites. Advanced Communications Corporation's leadership[16] in promoting digital DBS[17] has now been validated by a virtually complete industry turnabout. For example, the Hughes-Murdoch-NBC-CableVision group followed ACC's lead by announcing in February of 1990 that it would be transmitting digitally over its DBS satellites.

The advantages of digital transmission are well known to NASA and the space communications community. Indeed, deep space probes would have been impossible without it. Digital transmission allows system design flexibility and a reliability of fidelity that cannot be attained otherwise. Telephone distance transmission and switching are rapidly becoming all-digital and the digital local (ISDN) telephone loop is not far behind. Introducing a digital format to the DBS transmission capability will open vast new applications of technology for both public and private user services and especially computer users. The difference is as important as that between the analog and digital computers, and between analog vinyl records and digital compact disks.

TV Course

The YES Networks TV Course system will use a combination of techniques that will allow very high quality video to be delivered to relatively inexpensive receivers while using a small fraction of the total digital transmission capacity of a single DBS transponder. The video compression techniques have been chosen to be compatible with that which is planned for digital transmission of commercial television programming, in order to assure lowest cost from mass production.

Much of a DBS receiver is basically the same for either analog or digital transmission. Part of it requires specialized digital signal processing, which is now becoming relatively inexpensive. Another portion is beginning to be remarkably similar to the output of a personal computer. This includes a video "frame store" (a digital electronic version of the screen image), scan and sync circuits, and digital-to-analog converters. Any DBS receiver will include a general-purpose control processor equivalent to that already in personal computers. This will also allow inclusion of

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Comparison	Present Systems	YES Networks
Recipients of Services	Schools, Businesses	Schools, Businesses, Homes (also mobile), Hospitals, Libraries
Receiver Antenna Size	8 to 12 ft. diameter	1.5 ft. Square Plate
Local Zoning for Antenna	Very Restrictive	Not Restricted (Preempted by FCC)
Installation	Construction, Pedestal, Sometimes Needs Fencing	No Construction or Pedestal, Set up Indoors Through Window or Skylight
Types of Services	TV Lectures	TV Lectures, Computer Lectures, Written Materials, Teacher Aids, Remedial/Advanced Programmed Learning, Interactive HyperMedia
Simultaneous Courses in One Satellite Channel	One (Possibly Two)	100 (Estimated)
Satellite Transmission cost of one Course	100% (Reference)	1% to 5% (of Reference)
Flexibility of Service	Very Limited	Extremely Flexible
Support for Interactivity	Only by Telephone Line	Classroom System Interactivity, Both During Broadcasts and Off-Line, using HyperMedia
Origination Facilities	TV Studio and Crew (Relatively Expensive)	YES Networks Studio or Instructor's Office (No Studio or Crew Required)

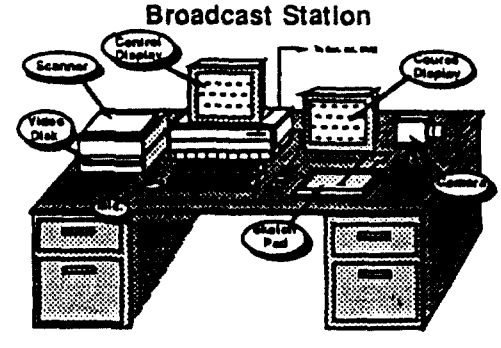
computer graphics and other services. (The TV is starting to look remarkably like a computer.)

Computer Course

The means of presenting visual materials in classrooms and business is rapidly undergoing a revolution of its own. The ubiquitous transparencies used on overhead projectors are giving way to output directly from the personal computer to TV monitors and/or projectors. In many cases, static slide presentations are giving way to dynamic animated presentations created with relatively inexpensive personal computer programs. Special effects keep the presentation visually stimulating and highly effective. Study aids created with these interactive programs can be downloaded for off-line study.

Image scanners and TV frame grabbers are relatively inexpensive and in common use today. Sketch pads are also being used by instructors as an electronic blackboard and for pointing to or annotating items on the screen. High-quality voice transmission (and music, when desired) will be provided by digital encoding. Once prepared on the computer, the course (or segment thereof) can be presented entirely in real-time or stored (in computer format) for playback using a recordable CD (Compact Disc) or DAT (Digital Audio Tape).

Broadcast Station



Using inexpensive computer cards now available, it is relatively easy to insert a live TV image of an instructor, or a video segment illustrating a concept, into a portion of the computer screen. Full-color display capability is rapidly becoming standard on new PCs and will support high-quality TV images, i.e., the computer is starting to look like a TV.

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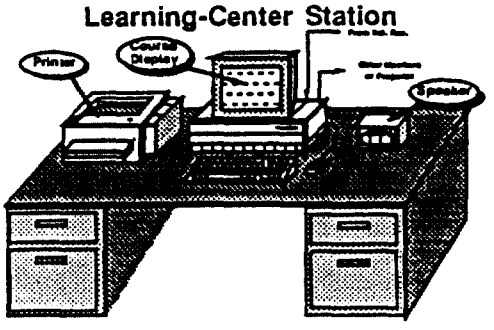
Inclusion of a printer will allow written materials to simultaneously be sent to the classroom. Teacher aids and learning aids will also be transmitted through the computer. For example, examinations will be downloaded while still allowing the local teacher to select questions or customize the exam. Grading can also be highly automated and impartial. Programmed learning will be provided for off-line remedial or advanced study.



Training And Installation

The TV Courses will not require special training of either the course originator or the classroom users. However, optimal use may require training (e.g., a seminar or reception of a short training sequence, itself delivered through the satellite). For basic Computer Course reception and for many of the supplementary services, no special training or computer literacy is required. Self-running tutorials will prompt the user to perform any necessary actions.

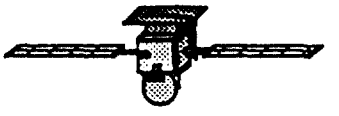
Some of the more advanced features, e.g., customizing downloaded exams, will require interaction between the local teacher (or assistant) and the computer. User-friendly, interactive animated computer media are increasingly being used for training, some spanning more than one computer family.

No installation crew or training program is necessary at the school site. Installing the DBS antenna is easier than installing a standard TV antenna. The 1.5 ft. antenna even can be located indoors and pointed through a window or a skylight.

Conclusion

It is difficult at best to introduce new technologies and unique ideas - no matter how innovative and efficient they may be. This must be done if educational resources are to be distributed uniformly with the greatest benefits. **The YES Networks can multiply the effectiveness of each school dollar spent for distance learning by a factor of more than twenty.** Imagine a classroom where the student operates in a world of color, sound, and animation — a world where master teachers are made equally available to children in the smallest rural or largest urban schools alike.

Technology has changed the world forever. The future belongs to those who can master it. The place to begin is the schools of America — with the **YES Networks** digital-based satellite broadcasts.



Dr. Apple is President of Advanced Communications Engineering, Inc. His previous experience (e.g., Bell Labs and TRW) includes PicturePhone®, digital telephone switching, Space Shuttle communications, high-speed digital signal processing, and HDTV video compression (for CBS). He pioneered the concept of using personal computers to send digital DBS services directly to televisions and PCs and is actively engaged in extending "object-oriented programming" to embedded signal processors. He is a Senior Member of IEEE, a member of Sigma Xi (research society) and SMPTE. He is an instrument rated pilot and a developer of hardware and software for personal computers.

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References

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Organizations Involved

Foundation for Educational Advancement Today (FEAT): A 501(c)3 public charity formed to hold transponder (2) broadcasting rights on board ACC's DBS system, acquire and donate miniature digital receiving antennas for every public and private school and library in the U.S., and to assist the YES Networks in its programming activities.

Advanced Communications Corporation (ACC): A Federal Communications Commission licensed DBS permittee with authority to construct, launch, and operate two (and up to four) high-powered 16-transponder satellites covering the U.S. ACC has contracted with the General Electric Company to construct these satellites.

Advanced Communications Engineering, Inc. (ACE): Technical design and development of transmission and reception capabilities for digital TV, HDTV, and related educational initiatives among other services for broadcast through ACC's DBS system.

YES Networks, Inc. (YES): Operation and programming for comprehensive national educational and informational services.

Associated Individuals

The Honorable Wilbur D. Mills: Chairman and Trustee, FEAT; Chairman Emeritus, ACC; former Chairman, United States House of Representatives Committee on Ways and Means.

Mr. Daniel H. Garner, Jr.: President and Board Member, ACC; Sec./Treas. and Board Member, ACE; Trustee, YES; former broadcasting and investment banking executive.

Mr. James M. Beggs: Chairman, ACE; Senior Advisor, ACC; former NASA Administrator; Chairman, Spacehab, Inc.

Mr. Donald K. Dement: Senior Vice President and Board Member, ACC; Vice Chairman, ACE; Senior Advisor, YES; former Director, NASA Communications Programs.

Dr. G. Gordon Apple: President, ACE; Vice President, ACC; Senior Advisor, YES; former TRW Senior Engineer and Bell Labs Engineer; Mgr. of digital HDTV project for CBS (1982-1983).

Mr. Wayne Wells: Vice Chairman and Trustee, FEAT; Senior Financial Advisor, ACC; former Treasurer and Board Member, General Dynamics Company.

Mr. Gary S. Coe: Sec./Treas. and Trustee, FEAT; Senior Advisor, YES ; over 30 years in broadcasting and communications.

Mr. Jackson T. Stephens, Jr.: Founding Board Member and Senior Financial Advisor, ACC; Senior Advisor, YES; CEO, Stephens Enterprises and related activities.

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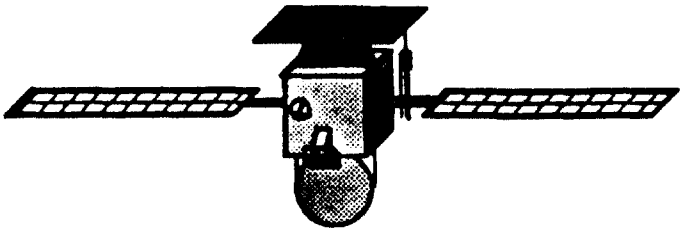

GUTENBERG II:
Tomorrow's Revolution in Educational Services Today

Submitted May 16, 1990 to:

The United States Department of Education

Star Schools Program (CFDA 84.203)

Washington, D.C.

By: The YES* Networks Partnership

(* Your Educational Services)

The Foundation for Educational Advancement Today
Advanced Communications Engineering, Inc.
National Association of State Coordinators of Compensatory Education
The Arkansas State Department of Education
The University of Arkansas at Little Rock
Massachusetts Department of Education
Massachusetts Institute of Technology

Donald K. Dement — **Project Director**

G. Gordon Apple, Ph.D. — **Co-Investigator for Technology**

Alan VanBiervliet, Ph.D. — **Co-Investigator for Education**

Wilbur D. Mills
CHAIRMAN
FOUNDATION FOR EDUCATIONAL ADVANCEMENT TODAY

May 16, 1990

U.S. Department of Education
400 Maryland Ave., S.W.
Application Control Center - Rm. 3633
Washington, D.C. 20202-4725
ATTN: CFDA #84.203, "Star Schools Program"

RE: STAR SCHOOLS PROPOSAL

Gentlemen:

On behalf of the Foundation for Educational Advancement Today and the Yes Networks Partnership, I am pleased to transmit an original and two (2) copies of the partnership's application for a grant under the Star Schools Program.

The partnership, assisted by the Executive Advisory Board (EAB), represents diverse educational, governmental, and industrial interests. It proposes a unique, innovative, and timely solution to remove a major impediment to the distribution of quality video, computer, and other distance learning to America's schools, namely the high costs and inaccessibility of satellite transponder time and the requisite receiving equipment. This project will ultimately benefit all Chapter 1 schools and serve many other educational applications by making high quality programming available at dramatically reduced costs.

With the successful conclusion of this project, the Foundation will take two major actions: (1) It will make available to a national educational network two high-powered, Direct Broadcast Satellite (DBS) transponders for a fifteen-year period. With digital-based signal processing equipment of the type to be demonstrated through this Star Schools project, the volume of programming which can be made available to schools throughout the United States will increase dramatically, while transmission costs will be greatly reduced - an enormous gain for our educational resource base and (2) The Foundation will implement its plan to place a satellite receiver in each of America's 125,000 public and

private schools and libraries - a combined value approaching $400,000,000. With this national educational infrastructure in place, the Foundation will inaugurate the YES Networks.

Our project is national in scope, with partners in Arkansas and Massachusetts, the National Association of State Coordinators of Compensatory Education, and a nation of participants. In accord with the directives of the Star Schools program, it is designed to demonstrate a system of delivery of quality mathematics and science-based curriculum programming superior to any presently available or foreseen. The Foundation, a 501(c)3 public charity, will act as the managing entity and fiscal agent for the partnership. The Project Director for the project is Mr. Donald K. Dement. The Foundation's accountants are Peat Marwick Main and Co.

We appreciate your consideration of our application, and look forward to working with you to bring to fruition a project which will contribute so much in support of the revolution in education programming that our nation needs to regain technological leadership. Should you have any questions pertaining to this submission, please call Donald K. Dement at (301) 858-5702.

Sincerely,

W.D. Mills

Wilbur D. Mills
Chairman
The Foundation for Educational
Advancement Today
3105 South St., N.W.
Washington, D.C. 20007

OMB Approval No. 0348-0043

APPLICATION FOR FEDERAL ASSISTANCE

2. DATE SUBMITTED: 5/16/90

Applicant Identifier:

1. TYPE OF SUBMISSION:
Application: ☐ Construction ☒ Non-Construction
Preapplication: ☐ Construction ☐ Non-Construction

3. DATE RECEIVED BY STATE:

State Application Identifier:

4. DATE RECEIVED BY FEDERAL AGENCY:

Federal Identifier:

5. APPLICANT INFORMATION

Legal Name: Foundation for Educational Advancement Today

Organizational Unit:

Address (give city, county, state, and zip code): 3105 South St., N.W.
Washington, D.C. 20007

Name and telephone number of the person to be contacted on matters involving this application (give area code): Donald K. Dement
(301) 858-5702

6. EMPLOYER IDENTIFICATION NUMBER (EIN): 5 2 – 1 5 9 9 8 0 5

7. TYPE OF APPLICANT: (enter appropriate letter in box) ☐
A State
B County
C Municipal
D Township
E Interstate
F Intermunicipal
G Special District
H Independent School Dist.
I State Controlled Institution of Higher Learning
J Private University
K Indian Tribe
L Individual
M Profit Organization
N Other (Specify): Public Charity 501 (c) 3

8. TYPE OF APPLICATION:
☒ New ☐ Continuation ☐ Revision

If Revision, enter appropriate letter(s) in box(es): ☐ ☐
A Increase Award B Decrease Award C Increase Duration
D Decrease Duration Other (specify):

9. NAME OF FEDERAL AGENCY: U.S. Department of Education

10. CATALOG OF FEDERAL DOMESTIC ASSISTANCE NUMBER: 8 4 . 2 0 3

TITLE: STAR SCHOOLS PROGRAM

11. DESCRIPTIVE TITLE OF APPLICANT'S PROJECT: Gutenberg II: Tomorrow's Revolution in Educational Services Today - A Star Schools Proposal

12. AREAS AFFECTED BY PROJECT (cities, counties, states, etc.): Arkansas
Massachusetts

13. PROPOSED PROJECT:

Start Date	Ending Date
9-1-90	8-31-91

14. CONGRESSIONAL DISTRICTS OF:
a. Applicant: Washington, D.C.
b. Project: Arkansas Total
Massachusetts Total

15. ESTIMATED FUNDING:

a. Federal	$ 3,647,844 .00
b. Applicant	$ 1,401,000 .00
c. State	$ .00
d. Local	$ .00
e. Other	$ .00
f. Program Income	$ .00
g. TOTAL	$ 5,048,844 .00

16. IS APPLICATION SUBJECT TO REVIEW BY STATE EXECUTIVE ORDER 12372 PROCESS?
a. YES THIS PREAPPLICATION/APPLICATION WAS MADE AVAILABLE TO THE STATE EXECUTIVE ORDER 12372 PROCESS FOR REVIEW ON
DATE _____
b. NO ☒ PROGRAM IS NOT COVERED BY E.O. 12372
☐ OR PROGRAM HAS NOT BEEN SELECTED BY STATE FOR REVIEW

17. IS THE APPLICANT DELINQUENT ON ANY FEDERAL DEBT?
☐ Yes If "Yes," attach an explanation. ☒ No

18. TO THE BEST OF MY KNOWLEDGE AND BELIEF, ALL DATA IN THIS APPLICATION/PREAPPLICATION ARE TRUE AND CORRECT. THE DOCUMENT HAS BEEN DULY AUTHORIZED BY THE GOVERNING BODY OF THE APPLICANT AND THE APPLICANT WILL COMPLY WITH THE ATTACHED ASSURANCES IF THE ASSISTANCE IS AWARDED

a. Typed Name of Authorized Representative: Donald K. Dement
b. Title: Project Director
c. Telephone number: (301) 858-5702
d. Signature of Authorized Representative: [signature]
e. Date Signed: 5/16/90

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PART II

BUDGET INFORMATION

Section A - Budget Catagories For Program Years FY 90 FY91

1..	Salary and wages	$ 1,998,334
2.	Fringe Benefits	395,446
3.	Travel	171,572
4.	Equipment	312,643
5.	Supplies	18,301
6.	Contractual Services	704,974
7.	Other	210,393
8.	Total Direct Costs (lines 1 to 7)	3,811,663
9.	Total Indirect Costs	1,237,181
10,	Total Project Costs (lines 8 + 9)	5,048,844

Section B = Cost Sharing

1.	Program Income	$ 0
2.	Non-Federal Funds (State, Local, Private)	
3.	In-Kind Contributions	1,401,000

Section C - Estimate of Funding Needs

1.	First Fiscal Year (FY 90)	$ 3,647,844
2.	Second Fiscal Year (FY 91)	3,953,616

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