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US OFFICE PRODUCTS

Exhibit A to CICATS Comments
Advanced Television Systems and
Their Impact on Existing Television Broadcast Service
Fifth Further Notice of Proposed Rule Making, MM Dkt. No. 87-268
(submitted July 11, 1996)

Technical Flaws with the ACATS Standard

In addition to the enormous burdens imposed by the ACATS standard's complex slate of video formats, the standard contains several individual elements that are technologically flawed: interlaced scanning, non-square pixel spacing, and computer-unfriendly picture rates. In addition, the ACATS standard lacks a bit error correction mechanism that is sufficiently reliable for computer applications. Each of these flaws is described in detail below.

1. Interlaced Scanning.

The specific flaws of interlaced scanning are legion. They were briefly recounted by the Commission in the Notice of Inquiry in this proceeding,[1] and include:

- interline flicker, *i.e.*, flickering of horizontal lines and borders, which the Commission characterized as "generally irritating to the eye";[2]
- line crawl, where lines appear to move upward or downward, which causes the viewer to perceive the picture in a lower resolution;[3]
- vertical aliasing, or unnatural cluttering of certain patterns;[4]

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[1] *Advanced Television Systems and Their Impact on the Existing Television Broadcast Service*, MM Dkt. No. 87-268, Notice of Inquiry, 2 FCC Rcd 5125 (released August 20, 1987) ("NOI") at ¶¶ 9-14.

[2] NOI at ¶ 9.

[3] NOI at ¶ 10.

[4] NOI at ¶ 11.

- large area picture flickering;[5]

- "static raster," or the ability of some viewers to see individual scan lines, which the Commission noted is "objectionable to some viewers";[6] and

- temporal aliasing, which lowers the resolution of moving objects and makes the scanning process more visible.[7]

It is axiomatic that interlaced scanning is totally anathema to computer applications. Even the Grand Alliance has admitted that "progressive scan is the better mode for text and graphics."[8]

The problems caused by interlaced scanning are amplified if the picture is viewed from a closer distance than the typical TV viewing distance (as when one is working on a PC), and they intensify with time One of the tangible physical consequences of using interlaced scanning for computer applications is notable eye fatigue, a problem the Commission has recognized.[9]

The exclusive use of progressive scanning is not only feasible, it would not entail any "significant economic penalty to anyone."[10] The Grand Alliance

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5 NOI at ¶ 12.

6 NOI at ¶ 13.

7 NOI at ¶ 14.

8 Reply Comments of the Grand Alliance in the Fourth Further Notice of Proposed Rule Making, MM Docket No. 87-268 (filed January 22, 1996) ("Grand Alliance Reply") at 41.

9 NOI at ¶ 9.

10 William F. Schreiber (Professor of Electrical Engineering, Emeritus, MIT), Comments on Fifth Further Notice of Proposed Rule Making, MM Docket No. 87-268 (submitted June 24, 1996) ("Schreiber Comments") at 6.

has self-righteously scorned the computer industry for seeking to foster computer compatibility by eliminating entirely interlaced scanning -- even going so far as to quote the New Testament! in support of its position.[11] But the wholesale abandonment of interlaced scanning would be preferable to retaining video formats that incorporate it.[12]

MIT Professor Emeritus William F. Schreiber stated in Comments filed in response to the Fifth NPRM:[13]

> The imminence of a new set of television broadcasting standards presents a rare opportunity to make a quantum advance in spectrum efficiency, image quality, and interoperability. Actually achieving this highly desirable set of potential improvements requires the *exclusive use* of progressive-scan (P) formats for transmission. Not only are interlaced formats (I) deficient in these characteristics, their use will inhibit any migration to progressive scan, which is agreed by all parties to be the final objective. *The use of interlaced transmission will effectively eliminate the possibility for the system to be improved over time in a manner that does not make unusable much of the first-deployed equipment, especially receivers in the hands of the public.*
>
> *[N]o advantage, economic or otherwise, is gained from the use of interlace by any stakeholder in the television industry. . . . The Commission is urged to include only progressive formats in the new standards for HDTV (high definition) and SDTV (standard definition).*

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[11] Grand Alliance Reply at 44-45.

[12] William F. Schreiber (Professor of Electrical Engineering, Emeritus, MIT), Informal Reply Comments to the Fourth Further Notice of Proposed Rule Making, MM Docket 87-268 (filed March 11, 1996) ("Schreiber Reply") at 9.

[13] Schreiber Comments at 1-2.

The elimination of interlaced scanning from the DTV standard would not burden owners of interlaced receivers or broadcasters. To the contrary, as noted above, converting a progressive signal for display on an interlaced receiver is significantly less costly than converting an interlaced signal for display on a progressive receiver. And the cost to broadcasters of converting programming produced by existing interlaced studio equipment to a progressive signal at the transmitter would be relatively modest.[14] In any event, the aggregate cost to broadcasters of de-interlacing at the transmission end would be far less than the aggregate cost to consumers of de-interlacing at the receiving end.[15]

Furthermore, Polaroid Corporation has introduced the world's first progressively scanned HDTV camera, which features 720 vertical lines and 1280 horizontal pixels (square pixel spacing), and a picture rate of 60 Hz, the performance of which has been rated highly -- indeed, superior to the 1080-line interlaced HDTV format in the ACATS standard.[16] At the National Association of Broadcasters annual conference held in Las Vegas in May of this year, the camera was voted "Best In Show." The camera, which was developed in cooperation with Philips Broadcast Television Systems of the Netherlands, and

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[14] *Id.* at 6.

[15] Assuming that there are 1500 local television stations, and each installs a top-of-the-line de-interlacer (cost: $180,000), the aggregate cost to broadcasters would be $270,000,000. But if every American television in use had to incorporate a quality de-interlacer (cost: $400), the aggregate cost to consumers would be **$85,600,000,000**, assuming that 214,000,000 televisions are in use.

[16] Schreiber Comments at 1; S.M. Spitzer, J. Toker, A. Moelands, *et al.*, "Design and Implementation of a 3-CCD, State of the Art, 750-line HDTV Progressive Scan Broadcast Camera."

with support from the federal government's Advanced Research Projects Agency and MIT scientists, negates the Grand Alliance's claim that an interlaced format is necessary for high quality HDTV.

It is critical that interlaced scanning be *completely excluded* from any standard that may be adopted. The inclusion of progressive scanning in the DTV standard -- as in the ACATS proposal -- will not remedy the interlaced problems. If the standard includes even one format with interlaced scanning, the problems caused by interlaced scanning will continue to proliferate, primarily for two reasons.

First, the long-standing use of interlaced scanning in NTSC broadcasting will create inertia among broadcasters and a reluctance to transmit programming in a relatively unfamiliar format, *i.e.*, progressively scanned. The problems with interlaced scanning will persist. One researcher has observed in this regard:[17]

> The move of the broadcasting world from interlaced to progressive scanning is unavoidable in the medium/long term. It is however strongly slowed down by the dominance of the interlaced format both in studio and consumer equipment. This situation should be recognized and duly taken into account . . . . Excessively sticking to the interlaced format will limit the added value of digitization for the broadcasting industry and it will be a source of increased costs for the user in a medium/long term.

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[17] P. Delogne, "Comparison Between Interlaced and Progressive Scanning Formats," (Laboratorie de Telecommunications et Teledetection, Universite Catholique de Louvain, Louvain-la-Neuve, Belgium) ("Delogne Study") at § 6. Similarly, Prof. Schreiber has written that "the presence of any interlaced format is likely to result in the death of all the [progressive] formats," and that "[f]ailure to adopt . . . precautions [he recommends] will preclude any transition from interlaced to progressive scan transmission in the future. The interlaced format will then become the only format, and maximum efficiency in the use of spectrum will never be achieved." Schreiber Reply Comments at 8, 4.

> The end result may well be a greater attraction of telecom distributed services compared to classical broadcasting.

Second, any interlaced transmissions will be incompatible with computer applications. If interlaced scanning is even one option for broadcasters, all receiving equipment will have to be capable of converting interlaced signals to progressive-scanned displays to allow computer interaction, adding unnecessary and avoidable equipment costs for consumers -- as much as $400 per unit for an acceptable quality de-interlacer. Equipment that is incapable of such conversions would be less expensive, but it would deny its owner the benefits and services of computer compatibility, at least with respect to any interlaced transmission.

2. Non-Square Pixel Spacing

Another component of the ACATS standard that interferes with computer interoperability is the non-square pixel spacing of the two 704 x 480 SDTV video formats.[18] It is widely acknowledged that the display of computer-generated material requires square pixel spacing, as explained in more detail in Exhibit B hereto. Two hundred million computers are in use; all assume square pixel spacing and lack the software to do the necessary conversion.[19]

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[18] Comments of Microsoft Corporation on the Fourth NPRM, MM Dkt. No. 87-268 (filed December 12, 1995) ("Microsoft Comments on Fourth NPRM") at 5.

[19] "CICATS Technical Details." Exhibit B to CICATS Comments (filed July 11, 1996) at 6, 15.

The Grand Alliance has admitted that square pixel spacing is "important . . . for facilitating interoperability with computers "[20] Indeed, the ACATS Final Report states that the square pixel spacing in some of the standard's video formats was "a critical component" because it facilitates computer compatibility.[21]

Although it is possible for receivers to convert material transmitted in non-square pixel format, the conversion entails added costs and degrades picture quality.[22] Products and services merging computers and DTV will thus be more costly and have less-than-optimal quality if they must include the ability to convert DTV transmissions to square pixel spacing in order to combine it with computer applications. That may be good news for set manufacturers, but it is bad news for consumers and those who would like to see demand for convergent products take off.

As with interlaced scanning, if even one prescribed video format incorporates non-square pixel spacing, receiving equipment will have to be capable of converting that format to square pixel spacing for any programming delivered in that format to be interoperable with computer applications. If this can reasonably be avoided -- and it can -- it should be.

If the DTV standard requires all transmissions to incorporate square pixel spacing, existing material in non-square pixel format will have to be converted at

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20 Grand Alliance Reply at 40.

21 ACATS Final Report at 16.

22 Microsoft Comments on the Fourth NPRM at 5

the head-end. Such a conversion is not only possible, it can be accomplished at a cost to broadcasters that would be insignificant relative to the cost of going digital, and, in the aggregate, would be far less than the aggregate cost to consumers if all DTV receivers required the ability to convert material to square pixel spacing. And broadcasters will incur such conversion costs *even if* the ACATS standard is adopted, if they choose to transmit existing non-square pixel material using any of the standard's square pixel video formats.

There is no good reason to prescribe formats with non-square pixels. It appears that one reason such formats were included in the ACATS standard was to accommodate the installed base of broadcaster production equipment, most of which has been designed for non-square pixel spacing for at least 10 years.[23] As with the inclusion of interlaced scanning, equipment manufacturers' existing production standards may well have influenced the decision to include formats that, while enormously suboptimal, have the advantage of preserving the value of existing plant investments, even if that meant creating difficulties for the computer and software industries and raising consumer costs.

Any DTV standard the Commission adopts should provide only for square pixel spacing.

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[23] *See* Memo from Paul Misener (ACATS) to Fiona Branton (ITI) (August 18, 1995) (cited at Fifth NPRM at note 44) at 6.

3. Picture Rates

The term "picture rate" describes the number of video pictures transmitted or displayed each second. A picture rate of 24 Hz -- the rate at which all motion pictures and most prime time programming are produced -- indicates that an image is being created at the rate of 24 pictures per second.[24] All display devices, including television receivers and computer monitors, have their own "native" picture rates. U.S. and Japanese NTSC televisions have rates of 60 Hz; computer monitors have faster rates. Receiver costs increase as display picture rate increases.[25]

Programming is produced in a variety of picture rates, and any rate that is not identical to that of a display device must be converted to the display's native rate. Transmission rates do not dictate display rates, but the difficulty of converting a transmission rate for display will directly affect receiver cost and picture quality.[26] A transmission rate that is evenly divisible into the native display rate is simple to convert by multiplying the number of incoming pictures; however, it is far more difficult -- and costly -- to convert a 60 Hz transmission rate for display on a 72 Hz monitor, which is common in the computer industry.[27]

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[24] CICATS Technical Details at 12.

[25] Grand Alliance Reply at 44.

[26] CICATS Technical Details at 7.

[27] CICATS Technical Details at 7.

Some of the picture rates prescribed by the ACATS standard -- 60 Hz and 30 Hz -- are difficult to convert to faster rates required to display computer applications. Although the ACATS standard does not permit transmission picture rates above 60 Hz, display of computer applications requires faster rates to eliminate disturbing large area flicker, which is exaggerated at close viewing distances. Human perception of flicker is reduced at greater distances, such as the average TV viewing distance of American audiences -- six times the height of the screen.[28] Because NTSC receivers have 60 Hz displays, picture rates of 60 Hz and 30 Hz, as included in the ACATS standards, are not problematic for television programming. But such rates create conversion problems for display with computer applications, and their inclusion in a DTV standard would inhibit computer compatibility.

This is because of the added processing power and artificial manipulation that is required to convert transmissions in rates not easily multiplied to achieve the faster display rate used with computer applications.[29] These added abilities in the receiver increase consumer costs; but without them, the quality of computer applications would be unacceptable when combined with transmissions having incompatible picture rates

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[28] CICATS Technical Details at 12-13; Schreiber Reply at 6-7

[29] CICATS Technical Details at 7. For example a rate of 60 Hz is not evenly divisible into the 72 Hz rate that many computer monitors use, whereas a rate of 24 Hz is, making it easy to convert without adding excessive processing power and cost.

The ACATS standard's three prescribed picture rates limit broadcasters' options and consequently restrict display options By not permitting broadcasters to transmit at rates above 60 Hz. the ACATS standard guarantees that every DTV broadcast will have to be converted in computer-compatible displays, all but the oldest of which have faster rates.

The ACATS standard apparently includes formats with 60 Hz picture rates because existing NTSC receivers in this country and Japan have picture rates of 60 Hz.[30] Again, it appears that existing manufacturing standards may have influenced the Grand Alliance's selection of components for the ACATS standard.

The Grand Alliance has argued that increasing the picture rate above 60 Hz would impair the picture quality of certain programming,[31] but Prof. Schreiber has characterized these claims as "pure speculation."[32] The Commission should not adopt a standard incorporating computer-unfriendly frame rates which would impose burdens on the computer and software industries -- and ultimately, consumers -- without a compelling justification. So far, no adequate justification has been advanced.

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30 Grand Alliance Reply at 44.

31 *Id.* at 44.

32 Schreiber Reply at 7

4. Improved Bit Error Correction

An additional failing of the ACATS standard that will impair compatibility with computer applications is its lack of a bit error correction mechanism reliable enough for computer data. The Grand Alliance has not denied that the ACATS standard's error correction mechanism is inadequate for computers, but it has argued that the Commission need not modify the standard to incorporate such a mechanism because industry will voluntarily address the issue.[33]

If the Commission decides to adopt a standard for DTV, CICATS would not advocate that adoption or implementation be delayed until the standard's bit error correction mechanism is improved CICATS would, however, *strongly* urge the Commission to reopen this proceeding to incorporate reliable data correction in the standard as soon as industry has developed a proposed mechanism for that purpose.

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[33] Grand Alliance Reply at 44, n.64.

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Technical Details of the Proposed Base-Line Format of the Computer Industry Coalition on Advanced Television Service (CICATS)[1]

July 10, 1996

Overview

The CICATS[2] technical proposal for the US digital TV standard is briefly this

- **Adopt ACATS Low Levels**: That the FCC adopt all ACATS proposals for modulation, error correction[3], data packetization, and compression for the new digital TV channels.
- **No Video Format**: That the FCC not specify a video data format.

In other words, adopt all low-level ACATS standardization proposals, where low-level means all levels except the video data level, which is not to be standardized by the FCC.

CICATS understands that the FCC may find it impossible to honor the second point above (No Video Format), in which case we propose an alternative second point:

- **One Required Video Format (Alternative)**: That the FCC specify a single 480-line (nominal), progressive-scan video format with square pixel spacing, utilizing a base-layer technology concept. Others could be implemented but only one would be required.

As will be explained below, CICATS actually couches this alternative as follows:

- **One Required Video Format (Alternative):** That the FCC specify the CICATS Reference Decoder.

This is as opposed to the ACATS proposal of 18 video formats that do not use a base-layer concept and that include interlaced formats. The CICATS alternative

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[1] Prepared by Dr Alvy Ray Smith, Graphics Fellow, Microsoft Corp., Redmond, WA, with technical assistance from Gary Demos of DemoGraFX and Apple and Steve Gabriel, Dr James Blinn, and Dr Brian Guenter of Microsoft.

[2] See attached Glossary for expansion of all acronyms and definitions of technical terms.

[3] There is one caveat: The error correction capability of the digital channel, when used for non-video data, may need to be increased. See further discussion below

proposal is cost-effective for consumers, immediately gives them higher resolution video, ensures smooth and true interoperability with computers, and is ready for improvements—such as even higher resolutions—as digital component costs drop.

On Point 1: Adopt ACATS Low Levels

The ACATS proposal (formerly the Grand Alliance proposal) has much to recommend it. At its most fundamental level, it proposes a completely digital standard, and we applaud this. Eight or nine years ago, when ACATS began its deliberations, analog systems were still being contemplated.

ACATS has invested much effort in testing the radio frequency and transmission system[4] of its proposal. We recommend, in particular, that its vestigial sideband (VSB) modulation subsystem be adopted. This is the subsystem that takes a digital stream of bits and modulates the radio frequency transmission carrier with it. The most time-consuming tests of the ACATS proposal were those that eliminated all other contenders for this level (the physical level) of standardization.

CICATS further supports these ACATS protocols and technologies: Trellis coding, Reed-Solomon error correction with interleaving, and Dolby AC-3 audio.

ACATS also proposes the use of the MPEG2 transport stream system for packetization of the bit stream. CICATS endorses this packetization level proposal from ACATS, to within the caveat on error-correction of non-video data already mentioned and further discussed below.

CICATS proposes that MPEG2 error correction be adopted for video data, as per the ACATS proposal.

On the Error-Correction Caveat to Point 1

The most general view of a digital channel, and one which CICATS highly encourages, is that it is a communications medium for arbitrary digital data. In this view, video data is simply one type of digital data that can be carried in the new digital channels.

CICATS proposes adoption of the ACATS error correction technology for video data, but the error-correction level may be too low for use by the new digital TV channels for transmission of many types of non-video digital data. The ACATS error correction level is sufficient for transmission of pictorial data (e.g., video) but not for general data. For example, if a new channel were used to download a program, then loss of data generally could not be tolerated. This is especially true in the headers for the transmitted data.

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[4] The "RF/Transmission System" of the ACATS proposal.

CICATS proposes that the FCC endorse the ACATS position on the low-level protocol but with the addition of a mandate to determine what needs to be done to the standard to increase its error-correction capabilities. This could take the form of an FCC specified committee to report on the problem and suggested solutions to it within one year from propagation of the initial digital TV standard. We believe it is important to officially pursue the problem with a time limit.

It is important to understand, however, that by delaying this study, a solution to the problem may be precluded. It may be that the structure of MPEG2 transport headers do not permit a sufficiently robust solution, and that a reasonable solution would require changes to the MPEG2 standard. If this standard has already been mandated and placed into use, then it cannot be changed.

Point 2: No Video Format

The computer industry is well aware of the astonishing rate of change in its underlying digital technology. It prospers because of it. It knows that it is difficult, if not impossible, to predict order-of-magnitude phenomena that happen regularly every five years in the high-technology sector (the Moore's Law phenomenon, see Glossary). So the CICATS position is that the FCC specify the fundamental protocols for its new digital TV channels but refrain from overly restricting what forms the data in those channels may take.

The most recent success in high technology, based on a similar strategy, is the Internet. Only two years ago it would have been impossible to predict today's businesses and world-wide impact of the data applications built atop the fundamental protocols of the Internet. We believe the inventiveness that industry would bring to bear on the new digital TV communications channels, to be mandated by the FCC, would be phenomenal and do not want to see any formats—specified now in the infancy of the digital world—hinder that innovation.

Hence the CICATS proposal is that the FCC not specify any video formats in particular but let market forces and economic considerations dictate how the channels get used. It is conceivable that the TV and PC industries would decide to proceed with the ACATS video formats, but we believe that the standards that would actually arise would be considerably different.

We can support the ACATS standard in many areas, as described above: VSB modulation, trellis coding, Reed-Solomon error correction with interleaving, MPEG2 transport and packet protocol, Dolby AC-3 audio and, most importantly, MPEG2 video compression. In the best of all possible worlds, we would revisit the adoption of MPEG2 itself (the real meaning of no video format), but in this proposal we are accepting the ACATS choice. Where we diverge is that we see

no need for the artificial restriction of the flexibility inherent in MPEG2 to a fixed set of resolutions.

Table 3 of section 5.1.2 in Annex A of the ATSC standard[5] is the heart of our problem. It constrains the vertical and horizontal size values to specific numbers instead of simply allowing anything under a maximum value, as MPEG2 does. ACATS tries to put display constraints *in the transmission standard*, where they don't belong. When these constraints are removed, then any aspect ratio image can be sent through the channel. It would then be up to the receiver to display what it can by either pan-and-scan or letterboxing, or a combination of the two. This would satisfy the objections of the film industry, since there would be no difficulty sending 1.85:1 or 2.37:1 or any of the other film aspect ratios as long as the horizontal and vertical sizes stayed below defined limits.

We address below the possibility that the FCC is under so much pressure from video broadcast manufacturers that it is unwilling to trust the market pressures as we propose. Hence we provide our alternative second point.

Alternative Point 2. One Required Video Format

Should the FCC feel it needs to specify a video data format, then CICATS proposes that it be as simple and extensible as possible, while displaying an immediate quality advantage over the current analog TV broadcast familiar to all US citizens. Furthermore, we propose a single format that is fully compatible with modern computer technology, without the quality or cost compromises intrinsic to the ACATS proposal.

The format we propose is a base-layer concept (see the Glossary), which means by definition that it is extensible to higher resolutions and better quality. We differ from the ACATS proposal in that we do not require that higher resolutions be standardized at this time. We feel that it is premature to do so, and that the market does not yet support higher resolutions such as the interlaced 1920x1080 ACATS format. We do believe, however, that in a few years, the inexorable Moore's Law phenomenon will make the higher resolutions cost effective, and want a base-layer technology in place so that logical extensions of it to higher resolutions are possible when the costs drop sufficiently—should the market then demand it.

In order not to slow down the FCC decision process, we propose a single format that is easily within today's capabilities and has been demonstrated so.

Furthermore, we are very desirous that PCs and TVs become tightly coupled devices, sharing data and even computing on each other's data—true

[5] Doc. A/53.

interoperability, not simply side-by-side display. Any video data format should encourage this possibility, not discourage it or make it costly.

Hence CICATS proposes a video format, by way of a *Reference Decoder* (see Glossary), that

- Has 480 lines (nominal) of vertical resolution
- Is progressively scanned
- Has square pixel spacing
- Employs a base-layer design for future, logical, cost-effective extensions to higher resolutions.

(See resolution, progressive, interlace, square pixel spacing, and layering in the Glossary.)

The 480 lines is numerically the same as today's analog TV standard but, because the lines are progressively scanned rather than interlaced, the quality level is immediately higher than today's analog TV. It takes about 768 lines of interlaced video to equal the same perceived quality level of 480 progressive lines.

The base-layer concept guarantees that no digital TV set will ever go dark as newer and better extension layers are built atop it—a set bought honoring the initial standard will always continue to work even as the extension layers are added in the future. Any future TV broadcast at higher resolution would still display at the base-layer resolution on any initial set. This is because the higher resolution would consist of the base layer resolution plus an enhancement layer that is added to it to form the higher resolution. The base layer would simply be stripped off by the older set and displayed. The newer set would combine the two layers and display the higher resolution picture.

One of the advantages of the CICATS proposal is that 4-5 times less memory is required in a CICATS receiver than in an ACATS receiver that must decode all 18 ACATS formats, including high-resolution formats that are prohibitively expensive for most people today. They would have to buy a receiver with all the memory despite the fact that they needed far less. And they would have to pay for it. We believe this is an unnecessary burden on the consumer. Our base-layer concept gives higher-resolution to the consumer when the costs for it have dropped substantially in about 5 years—while increasing the quality of TV even at the base layer initially offered.

All computer displays are progressively scanned, so CICATS believes it is essential to rid the national standard of old-fashioned interlaced scanning formats. Unfortunately, the ACATS proposal includes several interlaced formats. If even one is allowed then all receivers (including all PCs) would have to provide for the conversions. These conversions are unnecessary and are difficult

to do with quality. Cost pressures would dictate that they would be done at low quality.

Furthermore, all computer displays have square pixel spacing (see Glossary) and therefore so does the CICATS video format The ACATS proposal includes several formats with non-square pixel spacing. Again, if even one is allowed then all receivers (including all PCs) would have to provide for the conversion.

Two further specifications are required to fully describe the CICATS single video format: horizontal resolution and temporal resolution (frame rate). The format should have:

- **Spatial Resolution**: A ***spatial base layer*** with horizontal resolution determined by the CICATS requirement for square pixel spacing. For example, a TV set with an aspect ratio of 4 3 and 480 lines of vertical resolution would have 640 pixels horizontally.
- **Temporal Resolution**: A ***temporal base layer*** supporting 24, 36, and 72 Hz frame rates.

The notion of a temporal base layer is a new one to these FCC-related discussions and needs some explanation. For example, it might appear that we are proposing three video formats here, one each at 24, 36, and 72 Hz. This is not the case and here's why:

In case of three separate formats, the broadcaster selects one of the three to transmit and the receiver detects which one is sent and converts, if necessary, to its local frame rate. Frame rate conversions are the most difficult, of all the conversions implied by the ACATS proposal, to do with quality at a low price.

In the case of a temporal base layer, all sets would implement the base layer (by definition of a base layer), hence all three frame rates would be implemented. Regardless of transmitted frame rate, a set receiving the proposed temporal base layer signal would operate at 72 Hz frame rate. It would select and decode the appropriate MPEG2 frames (I, P, and B frames in MPEG2 terminology) to form the 72 Hz display. The base layer technology makes this simple to do. It is a *selection* process rather than a *conversion* process.

It is important to note that the CICATS temporal base layer does not support 30 Hz or 60Hz. 30 Hz is a relic of interlaced scanning so is not needed in the progressively scanned future. The PC market has determined that 60 Hz is insufficient so it is not included in the CICATS temporal base layer.

But CICATS, again, understands that the FCC might have to support 60 Hz under pressure from the old analog world. In this case, we propose an alternative to the temporal base layer:

- **Temporal Resolution (Alternative)**: 24, 60, and 72 Hz frame rates. Not a temporal base layer

This alternative does extend the CICATS proposal to three video formats, but the three differ only in frame rate. Although we offer this alternative, we want the FCC to understand that it implies conversion hardware and more memory in the receiver, hence more cost to the consumer. Furthermore, the conversions between 60 and 72 Hz are particularly prone to poor quality. Nevertheless, 60 Hz display displayed on 60 Hz sets and 72 Hz displayed on 72 Hz sets would suffer no quality loss.

Spatial Resolution. Reference Decoder

One way to look at the CICATS proposal is that it severs the decision to go digital from the decision to go high-resolution (or "high-definition"). We believe that going digital is the fundamental revolutionary step. We want to concentrate on doing it right. We believe that adding high resolution is straightforward if the groundwork is in place. We encourage adoption of a posture that allows this to happen when Moore's Law makes it more economically feasible than now, in about 5 years. We re-emphasize, however, that the CICATS base layer alone has higher perceived resolution than today's TV

The preferred way to think of the CICATS proposal is in terms of a reference decoder. The CICATS Reference Decoder has a memory capable of supporting 1024 horizontal by 512 vertical pixels. This plus the requirement for square pixel spacing implies that the Reference Decoder is capable of decoding any resolution up to and including 1024x512. The following table shows several examples supported by the Reference Decoder on TV displays of various aspect ratios:

Aspect	Horizontal	Vertical	Remarks
1.33:1 (4:3)	640	480	Current TV format
1.78:1	854	480	Approximately the ACATS 16:9 format
1.85:1	944	512	Most popular Hollywood format
2:1	960	480	Acceptable to Hollywood
2:1	1024	512	Acceptable to Hollywood
2.37:1	1024	432	Popular widescreen Hollywood format

Rather than propose a single video format, CICATS proposes that the FCC mandate the Reference Decoder. Then the choice of horizontal resolution becomes a secondary choice. This choice would be left to industry – that is, to market demand.

The CICATS Reference Decoder is a way of specifying a class of video formats acceptable to the computer industry. It is a hardware specification to the same degree that an ACATS video format is a hardware specification. That is, it puts requirements on the hardware but does not specify the implementation that satisfies them. Following are some example uses of the Reference Decoder.

There are arguments for the choice to transmit 640x480 pixels: It is consistent with today's capabilities. Progressively-scanned 640x480 systems have already been demonstrated. The costs and demands for this resolution are well known. The aspect ratio of 4:3 is the current one for which CRT (cathode-ray tube) technology is already well-suited and cost effective. Computer displays are as comfortable with this format as are TV displays. The cost of a converter for one of today's analog sets to receive the new digital signal is minimal for this resolution. CICATS believes this format to be the one most likely to appeal pricewise to consumers now, encouraging them to convert to the new digital standard and thereby release the old analog spectrum.

There are, however, good arguments for other choices within the set allowed by the the Reference Decoder. Consider, for example, 1024 by 512 pixels, the maximum allowed by the Reference Decoder (base layer only). The vertical resolution would be higher than today's analog TV because 512 is greater than 480, but more importantly because progressive 512 lines is equivalent to about 780 interlaced lines. And the horizontal resolution (on a TV set with aspect ratio 2:1) would be very much higher than today's analog TV, as well as spread out much wider. 2:1 aspect is considered desirable by Hollywood. Enhancement later (with an enhancement layer added to the base layer) to a nominal 2048x1024 resolution would be straightforward.

But there are serious counterarguments against the 1024 by 512 choice. The most serious is that displays for such an aspect ratio have not been demonstrated. Even if they were, they would probably be exorbitantly expensive at this time. So the same argument we levy against the expensive ACATS array of formats holds against this format too: Only the wealthy would be able to afford it at first. Sets that displayed in the old 4:3 aspect would either have to letter-box the wide aspect ratio, or pan-and-scan in it, or both (MPEG2 supports all of these choices). Both of these are familiar practices in widescreen films broadcast on TV today. All sets would implement the Reference Decoder but only those capable of 2:1 aspect would get full benefit of the signal.

Notice that a format with approximately 16:9 aspect could be chosen within the parameters of the CICATS Reference Decoder. This is one of the ACATS proposed aspect ratios. This aspect ratio has some of the same problems as just discussed for the 2:1 aspect ratio. In particular, sets to display at that ratio are too expensive for the average consumer. It is not an interesting aspect ratio for Hollywood. On the other hand, CRTs of that aspect have been demonstrated.

Pan-and-scan or letterboxing would be required for satisfactory display on sets of smaller aspect ratio, as discussed above for the 2:1 ratio.

In any case, the new digital TV sets would implement the Reference Decoder. They would need 4-5 times less memory than the equivalent ACATS-compliant set so would be optimally cost effective for consumers—*and at no loss in quality* implied by the conversions required between the 18 ACATS formats at the receiver. The CICATS proposal would be cheaper and better. Over time the cost differential between the two types of sets would diminish (with Moore's Law again) but in the meantime, US consumers would have paid many billions of dollars for unnecessary conversion and suffered unnecessary loss of quality as well.

Spatial Resolution: Enhancement Layers

Since the submissions to the FCC so far have confused the change to digital with the change to high resolution, it is important that the CICATS proposal not be interpreted as sacrificing the push toward higher resolution. Higher resolution is desirable to all members of CICATS and to all consumers. We argue that most consumers will not be interested *so long as the price tag is in the thousands of dollars per set,* as it is today. We believe that high resolution will certainly arrive, as costs drop with Moore's Law, and hence are proposing a base-layer / enhancement-layer technology that paves the way (see layering in the Glossary).

We propose that the FCC suggest—as a *recommended practice*—how enhancement layers might be used atop the standardized base layer to reach higher resolutions immediately, if certain market sectors wish to pursue it now. We emphasize that this should not be mandated.

More important than a specific enhancement layer is a *process* for adding enhancement layers and how they work. Following is one of many possibilities[6]:

Suppose that the 1024x512 resolution discussed above has been chosen with the framework of the Reference Decoder. Suppose further that memory prices have dropped substantially so that now a memory of 2048x1024 pixels is as cheap as 1024x512 pixels is today. Moore's Law tells us this will happen in a few years. At that time the PC and TV industries might decide—or the FCC might decide—that it is time to add an enhancement layer to the base layer already in place in the national digital TV standard. An example enhancement layer that would work in this case is this:

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[6] See comments of DemoGraFX, Appendix K, for details on several of these possibilities. The one used here is Resolution Enhancement Mode 4.

The base layer is expanded by 3/2 to get a resolution of 1536x768 pixels. The difference is sent in an enhancement layer. 3/2 is a straightforward multiplication factor for digital images[7]. Notice that 768 lines, progressively scanned, is perceptually equivalent to about 1180 lines interlaced, greater than the 1080 lines interlaced in the ACATS highest proposed resolution.

CICATS has determined, from the work of Gary Demos of DemoGraFX, that all of this fits into a given 6-megaHz digital TV channel using MPEG2 compression technology.

Temporal Resolution: Temporal Base Layer

This is an example of another new idea that goes beyond simply digitizing the analog video world as currently understood (the idea of a reference decoder being the other). The notion is to apply the base-layer / enhancement-layer concept in the time dimension as well as in the space dimension. The receiver of a digital TV signal would select among the various entities provided by the MPEG2 bitstream.

DemoGraFX[8] has proposed a temporal base layer that supports either 24 Hz or 36 Hz frame rates and a temporal enhancement layer that goes up to 72 Hz. Since CICATS proposes 24, 36, and 72 Hz frame rates, it is convenient to think of the DemoGraFX temporal base layer and enhancement layer to 72 Hz as a single CICATS temporal base layer.

As explained above, regardless of transmitted frame rate, a set receiving the CICATS temporal base layer signal would operate at 72 Hz frame rate. The Reference Decoder, which incorporates the CICATS temporal base layer, would select and decode the appropriate MPEG2 frames (I, P, and B) to form the 72 Hz display.

This technology has been demonstrated by Gary Demos of DemoGraFX and formally reported to the SMPTE (Society of Motion Picture and Television Engineers)[9]. Displays capable of 72 Hz are commonplace today in computers.

Just as the Reference Decoder supports many more spatial formats than will actually be used, it also supports more temporal formats than will probably be used. For example, the 36 Hz format might not typically be used, but it comes "for free" with the CICATS Reference Decoder (just as the other spatial formats do).

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[7] op cit. (DemoGraFX)

[8] See comments of DemoGraFX, Appendix I

[9] See comments of DemoGraFX, Appendix I

Temporal Alternative: 3 Frame Rates

CICATS understands that there is immense pressure from the existing analog TV industry to maintain the current frame rate of 60 Hz. CICATS would prefer to see new and legacy material at this frame rate converted, at high quality, at the head-end before transmission over the new digital channels. However, we are willing to expand our one simple format (expressed in terms of the Reference Decoder) into three formats that differ only in frame rates: 24, 60, and 72 Hz. This does not have near the elegance of the temporal base layer proposal but it does allow continued use of 60 Hz.

Use of three formats requires interconversion. Interconversions have been our argument against the ACATS proposal because they typically imply loss of quality in order to meet realistic consumer price expectations. However, the very difficult conversions between interlace and progressive scan are not asked for in this alternative 3-format proposal, and spatial conversions are not required either. Only temporal conversions are required

The most tricky conversions are between 60 and 72 Hz because they are relatively so near one another. Conversions tend to show artifacts related to the 12 Hz difference, a very visible frequency for the human eye.

Furthermore, conversions imply more machinery and hence higher costs.

Finally, the three-format scenario is not a base layer concept so there is no clear enhancement path to higher frame rates in the future.

Nevertheless CICATS would compromise to three video formats differing only in frame rate so long as the FCC understood the interconversion problem and its consequences.

Summary

CICATS proposes that the FCC mandate the ACATS low-level protocols for the new national digital TV broadcast channels

CICATS proposes that the FCC not mandate video data formats for the new digital channels.

CICATS proposes that the FCC institute a study group chartered to return a finding within one year on how to improve the low-level digital TV protocols by several orders of magnitude to accommodate error-free transmission of non-video or non-pictorial data. It is understood that a satisfactory solution might be precluded by proceeding with the low-level protocols before this study is made

CICATS recognizes certain political realities that may cause the FCC trouble in pursuing the proposals above. The following alternative proposals are aimed at alleviating these problems, so long as it is understood that CICATS believes them to be inferior positions.