C O N F I D E N T I A L
PROPOSAL TO WALT DISNEY PRODUCTIONS

Computer Division
Lucasfilm Ltd.
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SUMMARY

A proposal for a 2-dimensional computer animation software system for Walt Disney Productions is presented by the Computer Division of Lucasfilm Ltd. The Computer Division is in the process of spinning out as a separate company, called for our purposes here GFX Inc., which will be partially owned by Lucasfilm Ltd. The work proposed here would be performed by the new company.

The cost of the proposed system to Disney would be $X million. The time required for completion would be two years.

The proposed system would consist of seven subsystems, one for each of seven workstations:

- Digitizing Camera Workstation
- Clean-up Workstation
- Paint Workstation
- Background Painting Workstation
- Color Models Workstation
- Scene Planning Workstation
- Image Composite/Final Check Workstation

For the most part, these names are taken from a Disney document "Animation Production System Proposal" (APS Proposal), dated October, 1984. One exception is the Background Painting Workstation which is listed as an outside purchase in the APS Proposal. Another is the Image Composite/Final Check Workstation which incorporates the image compositing function of the so-called Central Facility into the Final Check Workstation of the APS Proposal.

This is a software proposal only. A condition of the proposed work is that it be designed for particular hardware configurations. The cost of the hardware and its maintenance is not included in this proposal. (See Appendix A for estimated hardware costs associated with this proposal.) Furthermore, the proposed software would be designed to run under the Unix 4.2 operating system. The cost of Unix is also not included in this proposal. (See Appendix B for estimated Unix costs associated with this proposal.)

SYSTEM OBJECTIVES

Following is a list of objectives the proposed system is designed to meet:

- To maximize throughput.
- To minimize down time.
- To keep cost/performance ratio down.
- To minimize any wait time at any point in the production process.
- To keep supervisors informed at all times fo the status of any task.
- To minimize errors.
- To meet union requirements.
- To permit simple expansion.

SYSTEM DESCRIPTION

Figures 1 and 2 show the proposed system software and hardware architectures, respectively. The software system is conceived of as a logistics management system, called the Disney Animation Logistics System (DALS), which communicates with each workstation subsystem. The hardware system would consist of workstations doubly linked with two communications channels - two Ethernets - one reserved just for picture transmissions. The proposed system would communicate directly with the Central Facility, referred to in the APS Proposal, via Ethernet. DALS would reside in the Central Facility and be written by Disney. It is intimately dependent on the logistics fed to it from each workstation, written by GFX. The Central Facility and DALS itself are not included in this proposal, but the logistics fed to DALS from each workstation clearly are.

The workstations described below are each assumed to be controlled by cpu's running the Unix 4.2 operating system and linked together by Ethernet. There are many computers that meet these two popular standards. We propose either the Sun or Microvax II. An extended file system for Unix 4.2 and Ethernet is also assumed. This permits simple intermachine file access by making the entire network appear to a user to be a single machine. An extended file system designed by GFX personnel and used very successfully for years at Lucasfilm is proposed.

Several framebuffers are listed. We assume Pixar2 framebuffers which feature a very powerful programmable picture processor, called the Chap (Channel Processor). Many of the software routines listed would be programmed in microcode into the Chap to utilize its exceptionally high performance (40 million instructions per second), an order of magnitude faster than most commercially available general-purpose computers. GFX will program 3-dimensional graphics routines into the Chap. Although not discussed in this proposal, we believe Disney will be interested in this package as a way for obtaining cost-effective computational power required for 3-dimensional rendering.

DISNEY ANIMATION LOGISTICS SYSTEM (DALS)

We believe that logistics and its management is a key component of the proposed system. By logistics we include the following:

- Task assignments
- Workstation status
- Scene, shot, frame, and level status and corresponding file locations
- Error reports and handling
- Exposure sheet generation and management
- Backups and archival storage
- Intermachine communications
- Production pipeline staging, control, and monitoring

The Scene Planning Workstation would provide one means of marshalling some of this data into a standard Disney exposure sheet format. The remainder of the logistics management would be the responsibility of DALS. It would be implemented by Disney personnel in close conjunction with GFX personnel who would see to it that the proposed workstations fed DALS all necessary information in the required forms. The design of DALS and the logistics management functions of each workstation would require the closest cooperation between Disney and GFX.

SOFTWARE IMPLEMENTATION STRATEGY

There are several packages of software routines which would be needed for all of the proposed workstations: menu control, tablet control, framebuffer driver, picture coding/decoding, and logistics management control. Unix 4.2 and the extended file system would be installed first. Then these packages would be installed. Then each station would be specialized to its particular function by customizing the menu display, installing special equipment drivers, and installing the software peculiar to each station.

The packages would be integrated at the subsystem level and then finally at the system level. In particular, the logistics management system would require system-wide integration with DALS.

HARDWARE IMPLEMENTATION STRATEGY

Because the software is highly dependent on the hardware selected, we would require that the intended hardware configuration for each workstation be installed at GFX for software installation and integration. Since the workstations are similar in required hardware, the proposed strategy is that two workstation cores (cpu, tablet, bitmap display, framebuffer, color monitor, disk) be installed at GFX and two at Disney. Two is the required number to locally test system networking. As each workstation were completed at GFX, its software system would be forwarded to Disney for installation there. This would provide Disney early experience with each workstation and permit Disney personnel to make suggested modifications before freezing the system design.

There are two stations which depart somewhat from the workstation core described above. The Digitizing Camera Workstation has a scanner and associated hardware (scanning platform with movements and illumination) in addition to the core. The Scene Planning Workstation has a printer in addition. We would use our printer but require that Disney have the scanner and associated hardware installed at GFX. Furthermore, we would require that the hardware integration of the scanner and its associated hardware be performed by Disney.

COOPERATION STRATEGY

It is clear that there will have to be a close relationship between GFX and Disney during the execution of the proposed work. This takes the following explicit forms:

1. The hardware configurations required for this proposal would be ordered by Disney. The systems delivered to GFX would be installed by GFX.
2. Disney would agree to commit a knowledgeable person or persons to the system planning stage. Disney would agree to give GFX the necessary logistics information required to make a complete workstation of each proposed type. In particular, Disney would write the DALS system in close conjuction with GFX which would write the logistics subsystems feeding input to DALS. The Scene Planning Workstation specification would also require specific Disney information, especially as regards its exposure sheet formats, before it could be completed.
3. GFX would expect and make changes in the workstation software of each workstation after its delivery to Disney. The intention is to respond to improvements deemed necessary by Disney personnel during the period between workstation delivery and final system acceptance.
4. GFX would give Disney all sources so that Disney could add their own modules (e.g., the IMI vector display to the Scene Planning Workstation).

RIGHTS

1. Source and Binary Rights

Sources and binaries for all software in the proposed system would be given to Disney as part of the proposed system up to the limits set forth in the section below. The software could not be sold or passed to third parties, and Disney would have to take due precautions to ensure that such would be the case. The protections of the Unix source license are intended here.

2. Fixed Limit on Workstations

The source and binary licenses implied in the section above are to apply to a fixed number of each type of workstation. The intention is to fix a limit within which Disney easily fits during the next several years but which is nevertheless not an unbounded limit. We propose that the limits be software licenses for at most

- 5 Digitizing Camera Workstations
- 5 Clean-up Workstations
- 25 Painting Workstations
- 5 Background Painting Workstations
- 5 Color Models Workstations
- 5 Scene Planning Workstations
- 5 Image Composite/Final Check Workstations

3. Modifications

Disney would be free to modify all software. We would remain responsible only for what we supplied. So long as a system contains any of our software, it could not be sold or passed to a third party. Again, we use the Unix license as a model here.

SOFTWARE MAINTENANCE

Since Disney will have all sources, all software may be modified in-house.

Since Unix 4.2 is a popular operating system and Ethernet is a popular networking system, a great deal of workstation code is readily transferrable to other computers so long as they handle these two standards. However, this does not include the user interface, menu display, and tablet control functions which are very device dependent nor does it include Pixar2 microcode which is of course dependent on the Pixar2. Unfortunately, device-independent code runs entirely too slowly to be attractive to Disney, we believe, regardless of the manufacturer of the equipment.

The Ethernet workstation system architecture permits simple additions to the system of copies of workstations or of workstations for entirely different functions. It also permits the proposed system to be easily attached to a larger system planned by Disney (including, for example, the Central Facility of the Disney APS Proposal).

DOCUMENTATION

Each main program and each library of subroutines used in the proposed system would be documented in the Unix style. GFX would provide all technical documentation. Disney would write all user-oriented documentation.

TRAINING

There would be a one-week intensive training course for key Disney personnel after final test and acceptance. The purpose would be to train the managing personnel who would then train the actual production personnel.

SUBSYSTEM DESCRIPTIONS

4. *Digitizing Camera Workstation*

4.1. Description

This station would cause artwork to be digitized for entry into the computer animation system. The artwork is assumed to be black-and-white line drawings (pencil or ink) on standard Disney animation paper and standard Disney color background paintings, in general designed for panning. The background paintings might lie on several levels for multiplaning. The output of the workstation would be digital disk files for storage in a central disk pool for transfer to the Clean-up Workstation.

The user of this workstation would mount the artwork and adjust the illumination. He would make several scans while adjusting the controls of the scanner until satisfactory digitizations were accomplished. Since film resolution is higher than a video monitor can display, the user would roam around a high-resolution image in the framebuffer with a video-resolution window, or he would average the picture down to displayable resolution to see it in its entirety. He would also digitize a flat field consisting of a piece of animation paper with no lines on it, for flat-field correction. Once he had a satisfactory scan for one frame, remaining digitizations in a shot would proceed rapidly. Each digitization would be saved in dumped mode (pixel by pixel) or in a compressed mode using a nondestructive compression technique to save file space.

In case of fields larger than one frame, as in a background painting designed for a pan, the digitization would proceed in adjacent pieces which would then be pieced together in the stored digital file. Alternatively, the concatenation of pieces could be reserved for the Clean-up Workstation described below.

4.2. Hardware

- Color scanner and digitizer for large format reflecting artwork
- Scanning platform, platten, Disney pegboard, panning movements
- Illuminating lamps
- Small controlling cpu with bitmap display and keyboard
- Small tablet for menu control
- Framebuffer to hold one frame at desired resolution
- Color monitor

4.3. Software

- Scanner/digitizer driver
- Digital control of analog scanner parameters
- Framebuffer driver
- Picture file storage, dump mode
- Picture concatenation
- Menu display and control
- Tablet control
- Logistics management (scene number, shot number, frame number, element or level number, status, responsible person, disk pack where stored, location of corresponding flat field, etc.).

5. *Clean-up Workstation*

5.1. Description

The raw scans from a Digitizing Camera Workstation are retrieved by this station. These are flat-field corrected, have their dynamic ranges expanded, color corrected, if necessary, and their edges sharpened using a filtering operation. Cleaned-up frames would be saved with a picture encoding scheme to save disk space. If not done so at the Digitizing Camera Workstation, pan backgrounds are pieced together at this station.

A matte (transparency mask) is created for each frame at this step for compositing at a later step.

5.2. Hardware

- Framebuffer to hold one frame at desired resolution
- Color monitor
- Small controlling cpu with bitmap display and keyboard
- Small tablet for menu control

5.3. Software

- Flat-field correction
- Edge sharpening
- Color balancing
- Thresholding
- Histogramming and dynamic range expansion
- Matte creation
- Menu display and control
- Logistics management
- Picture concatenation (if not included in Digitizing Camera Workstation)
- Picture compression (runlength encoding) and storage
- Tablet control

6. *Paint Workstation*

6.1. Description

The Paint Workstation is the station where black-and-white input scans are painted, or opaqued. The scans are cleaned-up scans from the Clean-up Workstation, received indirectly from the disk pool via Ethernet. Lines may be colored to colors other than black. Areas may be filled, or flooded, with arbitrary colors selected from a palette (which is created at the Color Models Workstation described below). Since "leaks" may occur where an area is not completely enclosed with lines, provision is made for their repair. Simple touchup painting for difficult to fill areas is provided with magnification. Mattes are extended to include filled areas.

Since high-resolution frames cannot be displayed entirely on a color monitor, a roaming facility would be provided. Alternatively, an averaging technique would be provided for viewing the entire frame at a lower resolution.

6.2. Hardware

- Framebuffer to hold one frame at desired resolution
- Color monitor
- Small controlling cpu with bitmap display and keyboard
- Small tablet for menu control

6.3. Software

- Antialiased area fill, with matte creation
- Simple touchup paint
- Line coloring
- Leak recovery
- Menu display and control
- Logistics management
- Picture compression (runlength encoding) and storage
- Tablet control

7. *Background Painting Workstation*

7.1. Description

A digital painting program can be used to create backgrounds, including pan backgrounds and multilevel backgrounds for multiplaning. It can also be used for texture map generation for 3-dimensional computer graphics. The Background Painting Workstation digital painting program would be designed for painting on large pictures for panning and with transparency (via a matte channel) for multiplaning. The program would include brushes of different sizes and shapes, different styles of painting, splines, lines, area clears and fills, palette control, picture storage and retrieval, cut-and-paste, magnification (video and computed), and cursor control.

7.2. Hardware

- Large framebuffer to hold panning backgrounds or several levels of multiplaned background
- Color monitor
- Small controlling cpu with bitmap display and keyboard
- Large tablet for menu control and painting

7.3. Software

- Digital paint program (see description above)
- Menu display and control
- Logistics management
- Large picture management
- Tablet control

8. *Color Models Workstation*

8.1. Description

The Color Models Workstation is used to design palettes for the Paint Workstation and the Background Painting Workstation. Individual colors can be mixed from the primaries (red, green, and blue) or from the so-called perceptual parameters (hue, saturation, and value). Palettes are designed by assigning desired colors to desired locations in the palette.

This workstation is also used for visual checks of foreground characters over backgrounds to see if the colors selected for the foreground read well over the background. The character might be translated over the background to check the colors over different parts of the background. Repainting of foregrounds, if necessary, is assumed to occur only at Paint Workstations.

8.2. Hardware

- Small framebuffer
- Color monitor
- Small controlling cpu with bitmap display and keyboard
- Small tablet

8.3. Software

- Color mixing (RGB and HSV, or HSL)
- Palette design and color assignment
- Foreground over background compositing and translation
- Menu display and control
- Logistics management
- Tablet control

9. *Scene Planning Workstation*

9.1. Description

Logistics information from the other workstations is fed to this workstation for construction and updates of exposure sheets. Multiplaning is implemented here with controls for individual level resizing, rotation, and translation. A framebuffer is used for experiments to verify exposure sheet instructions. Results are recorded in an exposure sheet which is passed to the Image Composite/Final Check Workstation, described below, for final assembly and checking prior to filming or videotaping.

9.2. Hardware

- Small cpu with bitmap display and keyboard
- Small framebuffer
- Color monitor
- Output printer (for exposure sheet hardcopy)
- Small tablet for menu control

9.3. Software

- Compositing control
- Multiplaning control
- Individual level scale, translate, and rotate control

- Exposure sheet generation and editing
- Menu display and control
- Logistics management
- Tablet control

10. *Image Composite/Final Check Workstation*

10.1. Description

Compositing of many elements is handled at this station, including partial transparencies and multiplaning. Wipes, pans, trucks, cross-dissolves, and fades are implemented here. All these are driven by the exposure sheet generated at the Scene Planning Station. As each composite is completed, a checker inspects it for correctness. If the composite is successful, it is passed on to the film printer or videotape recorder workstation. The checker either roams around a full resolution composite image or averages it down to monitor resolution to inspect it.

10.2. Hardware

- Small cpu with bitmap display and keyboard
- Film resolution Pixar2
- Color monitor
- Small tablet for menu control

10.3. Software

- Compositing code
- Individual level scale, translate, and rotate
- Exposure sheet interpreter
- Menu display and control
- Logistics management
- Tablet control

TIME SCHEDULE

Following is a list detailing the proposed schedule for software system development, installation, testing, and acceptance. All times are relative the installation of the required hardware at GFX. The total time required is 2 years.

1. *System-wide Software (8 Weeks)*

1.1. Planning

System planning sessions and work assignments.

1.2. Unix

Berkeley Unix 4.2 with GFX efs (extended file system) is installed in all cpu's and tested along an Ethernet.

1.3. Microcode

Pixar2 microcode libraries installed in all cpu's and tested in all Pixar2's.

1.4. Ethernet

Ethernet protocol code for picture file passing installed in all cpu's and tested along a Ethernet between all Pixar2's.

1.5. Menus

Menu controllers installed in all cpu's.

1.6. Tablets

Tablet controllers installed in all cpu's and tested.

1.7. Picture Compression

Picture coding/decoding in dump and runlength modes installed on all relevant Pixar2's and tested.

2. *Digitizing Camera Workstation (DCW) (10 Weeks)*

2.1. Scanner driver

DCW scanner/digitizer driver installed and tested.

2.2. Analog driver

DCW black-and-white and color parameter controls installed and tested.

2.3. Picture Concatenation

DCW color scan picture concatenation code installed and tested.

2.4. Logistics

DCW logistics management system installed and tested.

2.5. Menu

DCW menu display installed and tested.

2.6. Integration

DCW system integration and test.

3. *Clean-up Workstation (CUW) (11 Weeks)*

3.1. Filtering/Contrast Enhancement

Flat-field correction, Edge sharpening, Color balancing, Thresholding, Histogramming and dynamic range expansion routines installed and tested.

3.2. Mattes

Matte creation routine installed and tested.

3.3. Logistics

CUW logistics management system installed and tested.

3.4. Menu

CUW menu display installed and tested.

3.5. Integration

CUW system integration and test.

4. *Paint Workstation (PW) (11 Weeks)*

4.1. Fill

Antialiased area fill program, with matte creation and leak recovery, installed and tested.

4.2. Touchup

Simple touchup paint program, with magnification, line closure, and simple area clearing, installed and tested.

4.3. Line Coloring

Line coloring routines installed and tested.

4.4. Logistics

PW logistics management system installed and tested.

4.5. Menu

PW menu display installed and tested.

4.6. Integration

PW system integration and test.

5. *Background Painting Workstation (BPW) (16 Weeks)*

5.1. Paint

The Background Painting Workstation (BPW) digital painting program installed and tested. This includes windowing, levels with transparency, brush design and selection, palette control and color selection, several different styles of painting, splines and lines, area clears, cut-and-paste, and cursor control. Other components of the paint program are included in software work elsewhere in this proposal.

5.2. Logistics

BPW logistics management system installed and tested.

5.3. Menu

BPW menu display installed and tested.

5.4. Big Pictures

BPW big picture management system installed and tested.

5.5. Integration

BPW system integration and test.

6. *Color Models Workstation (CMW) (7 Weeks)*

6.1. Color Mixing

CMW color mixing (RGB and HSV, or HSL) routines installed and tested.

6.2. Palettes

Palette design and color assignment routines installed and tested.

6.3. Simple Composites

Foreground over background test composite control (with translation) installed and tested.

6.4. Logistics

CMW logistics management system installed and tested.

6.5. Menu

CMW menu display installed and tested.

6.6. Integration

CMW system integration and test.

7. *Scene Planning Workstation (SPW) (10 Weeks)*

7.1. Compositing Control

SPW compositing control code installed and tested.

7.2. Multiplane Control

SPW multiplaning control code installed and tested.

7.3. Transformation Control

SPW controlling routines for scale, translate, and rotate on individual levels installed and tested.

7.4. Exposure Sheet Editing

Exposure sheet generation and editing installed and tested.

7.5. Logistics

SPW logistics management system installed and tested.

7.6. Menu

SPW menu display installed and tested.

7.7. Integration

SPW system integration and test.

8. *Image Composite/Final Check Workstation (IC/FCW) (11 Weeks)*

8.1. Exposure Sheet Interpreter

Exposure sheet interpreter installed and tested.

8.2. Matting/Merging

Matting and merging programs installed and tested.

8.3. Transformations

Scaling, translation, and rotation programs installed and tested.

8.4. Opticals

Fades, cross-dissolves, wipes installed and tested.

8.5. Logistics

IC/FCW logistics management system installed and tested.

8.6. Menu

IC/FCW menu display installed and tested.

8.7. Integration

IC/FCW system integration and test.

9. ***System Integration and Test (3 Weeks)***

10. ***Documentation and Manuals (8 Weeks)***

11. ***Disney System Installation, Test, and Acceptance (4 Weeks)***

12. ***Disney Training (1 Week)***

PAYMENT SCHEDULE

The proposed payment schedule is as follows:

- An initial payment of $X would be made at the delivery of the first workstation to Disney.
- An additional $X each would be made upon delivery of the other six workstations to Disney.
- The final $X would be due upon acceptance of the entire proposed system at Disney.

Thus the system total would be $X

APPENDIX A: HARDWARE

RECOMMENDED HARDWARE COMPONENTS

The following major components of the proposed system are suggested. A rough estimate of each cost is also provided.

- Digitizing Scanner: Eikonix ($X).
- Scanning platform, platten, pegboard, illumination: ($X). It is assumed that this would probably be a modification of existing Disney equipment, so the cost is very approximate.
- Framebuffer: Pixar2 ($X). The Chap 40 mip processor is included in each Pixar2. The cost depends on the amount of memory required per Pixar2. The cost listed here assumes 2Kx2K pixels.
- Controlling cpu with keyboard and bitmap display: Sun ($X). We do not yet recommend a specific model of Sun. An alternative might be the Microvax II from Digital Equipment Corporation which is faster than the Sun. We are not yet certain of the cost of the Microvax II.
- Disk: Fujitsu ($X). This is a 150-megabyte Winchester type disk for Unix.
- Color monitor: Barco ($X). There are several other monitors which might serve equally well.
- Tablet: Hitachi ($X). There are several other tablets which might serve equally well.
- Printer: Imagen ($X).
- Ethernet controller/transceiver: 3Com ($X).

ESTIMATED SUBSYSTEM HARDWARE COSTS

The estimates above are used to calculate the following subsystem hardware costs. There is one small system disk (150 megabytes) per cpu assumed, but a disk pool of large disks and a large central computer are not included. Each cpu is assumed to come with two Ethernet controller/tranceivers, one included in the cpu cost but the other not included.

- Digitizing Camera Workstation: $X.
- Clean-up Workstation: $X.
- Paint Workstation: $X.
- Background Painting Workstation: $X. This assumes a very large Pixar2 for wide or tall background paintings ($X).
- Color Models Workstation: $X.
- Scene Planning Workstation: $X.
- Image Composite/Final Check Workstation: $X.

ESTIMATED SYSTEM HARDWARE COSTS

The hardware system costs for the proposed system may be estimated as follows:

- Subsystem subtotal: $X
- Maintenance charge: 1% of purchase price per month
- Tax: 6% of purchase price
- Shipping: 1.5% of purchase price

In addition there would be a shipping charge for those systems at GFX which would be moved to Disney.

APPENDIX B: UNIX

A Unix 4.2 source license is about $X. This is a one-time charge per type of machine (e.g., Sun). Each additional machine of the same type requires a binary license of about $X. So the Unix system costs for the proposed system is $X.