April 21, 1972

Prof. Edward Fredkin
M.I.T. Project MAC
545 Technology Square
Cambridge, Massachusetts   02139

Dear Prof. Fredkin:

        Systems Concepts, Inc. is pleased to
submit the enclosed proposal for a Graphic Terminal
System for Project MAC.

        If you have any questions or wish to
discuss this proposal further, please do not hesitate
to call us.

                            Yours truly,

                            Peter R. Samson
                            Director of Marketing

PRS/ea

Enclosures

PROPOSAL

TO

M.I.T. PROJECT MAC

FOR

A GRAPHIC TERMINAL SYSTEM

APRIL 21, 1972

INTRODUCTION

Systems Concepts proposes a system of up to 32 remote inter-active display terminals, capable of a wide range of alphanumeric and graphic displays and accepting user input from keyboard, light pen, foot pedal and joystick. The terminals proposed are SC-4 computers, each with an SC Δ-4 display; each sends and receives data through a twisted pair (one per terminal) to a central SC-4 which performs data switching and supervision functions, and which communicates through a multiplexor channel with the main G.E. com-puter.

SYSTEM CONFIGURATION

Figure 1 is a block diagram of the system.

Supervisor SC-4

An SC-4 computer is used to supervise data flow to and from the terminals. It has 16K words of semiconductor memory, used largely for buffering data between the terminals and the main G.E. computer. The SC-4 is an 18-bit machine with a memory cycle time of 750 nanoseconds. Further details are in the description of ter-minals, below; see also the enclosed preliminary draft of the SC-4 Reference Manual. A teletype ASR-33 is supplied with the supervisor SC-4.

Multiplexor Channel Interface

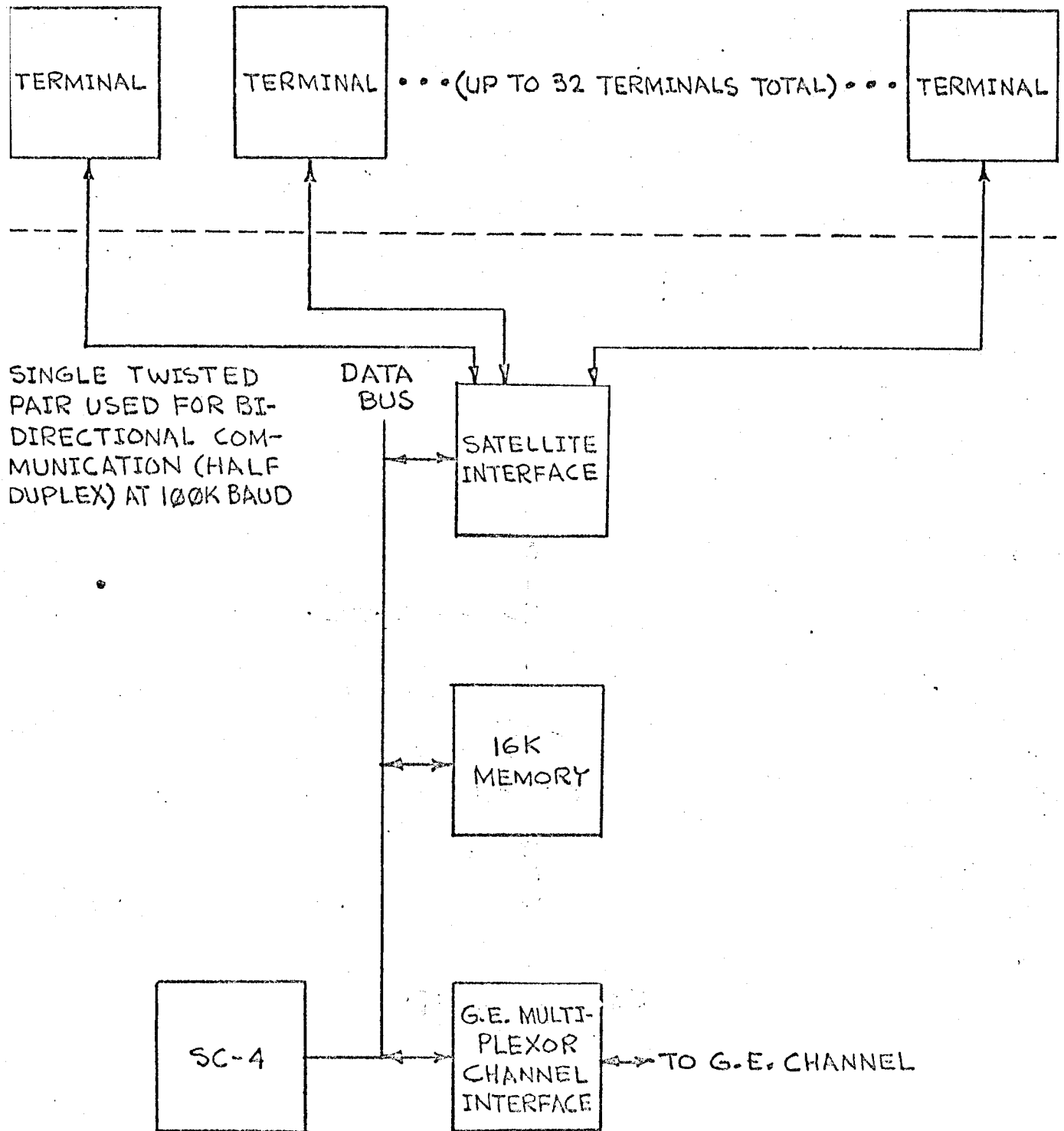Principal data path between the supervisor SC-4 and the G.E.

FIGURE 1. SYSTEM BLOCK DIAGRAM

computer is a Multiplexor Channel Interface. This is proposed to
be a direct memory-to-memory block transfer unit, run by the SC-4
in accordance with software data descriptors supplied by the G.E.
machine.

Satellite Interface

Attached to the supervisor SC-4 is a Satellite Interface to
communicate with up to 32 remote terminals. For each terminal,
this interface has separate input and output pointers into super-
visor memory, so it can autonomously receive or send arbitrary
blocks of data from or to each console, in effect simultaneously.
The supervisor can also command it to send out a polling query, or
other specially flagged one-word messages.

Lines

Communication between the Satellite Interface and a given
terminal is accomplished over a single twisted pair. A differen-
tial transmitter and receiver are at each end. Data is sent
serially, in one direction at a time, at 100 kilobaud. A "word"
consists of a start bit ("space"), a flag bit, eighteen data bits,
a parity bit, and a stop bit ("mark"). The flag bit is off
("space") for data words, and on ("mark") for words requiring
special functions. These special functions include word count,
starting address for following data, and requests for data from
the terminal. (Systems Concepts does not propose to supply the
twisted pair. Standard telephone cable can be used up to a
distance of 3000 feet.)

Protocol

Normally the supervisor is set to transmit, and the terminal
to receive. Periodically for typein, and on demand from the G.E.

machine for joystick, light pen, and foot pedal information, the
supervisor sends a request for data. (Supervisor software makes
sure that data blocks to the terminal are in small enough pieces
to allow frequent polling for typein.) Such requests are distin-
guished by the sign bit of the 18-bit data, and cause the termi-
nal's line interface to change from receiving to transmitting.
After sending the request, the supervisor's Satellite Interface
ceases transmitting on the line; and after a delay (about 20 micro-
seconds) starts receiving. Upon receiving the request, the termi-
nal's line interface stops receiving and starts transmitting "mark".
The terminal then delays (about 40 microseconds) before sending the
requested data, ended with a flagged word that causes transmitting
and receiving ends to be changed back again.

TERMINAL CONFIGURATION

A block diagram of a terminal is shown in Figure 2. It con-
sists of an SC-4 computer, 4K words of memory, and various peri-
pherals.

•

SC-4 Computer

This is an two's-complement 18-bit machine, with 16 general
registers and a 16 level priority interrupt system. Its program-
ming aspects are explained in great detail in the SC-4 Reference
Manual, of which a draft is enclosed. Below are times for some
typical instructions.

Add word on stack (not top word) to general register	1.5 us
Multiply general register by memory word (indexed 2-word instruction) (36-bit product)	6.2 us
Jump	750 ns
Push and Jump	1.5 us
Compare Immediate	750 ns

DATA BUS

BIDIREC-
TIONAL
SERIAL
INTERFACE

TWISTED PAIR TO
SUPERVISOR SC-4

JOYSTICK

FOOT PEDAL

KEYBOARD

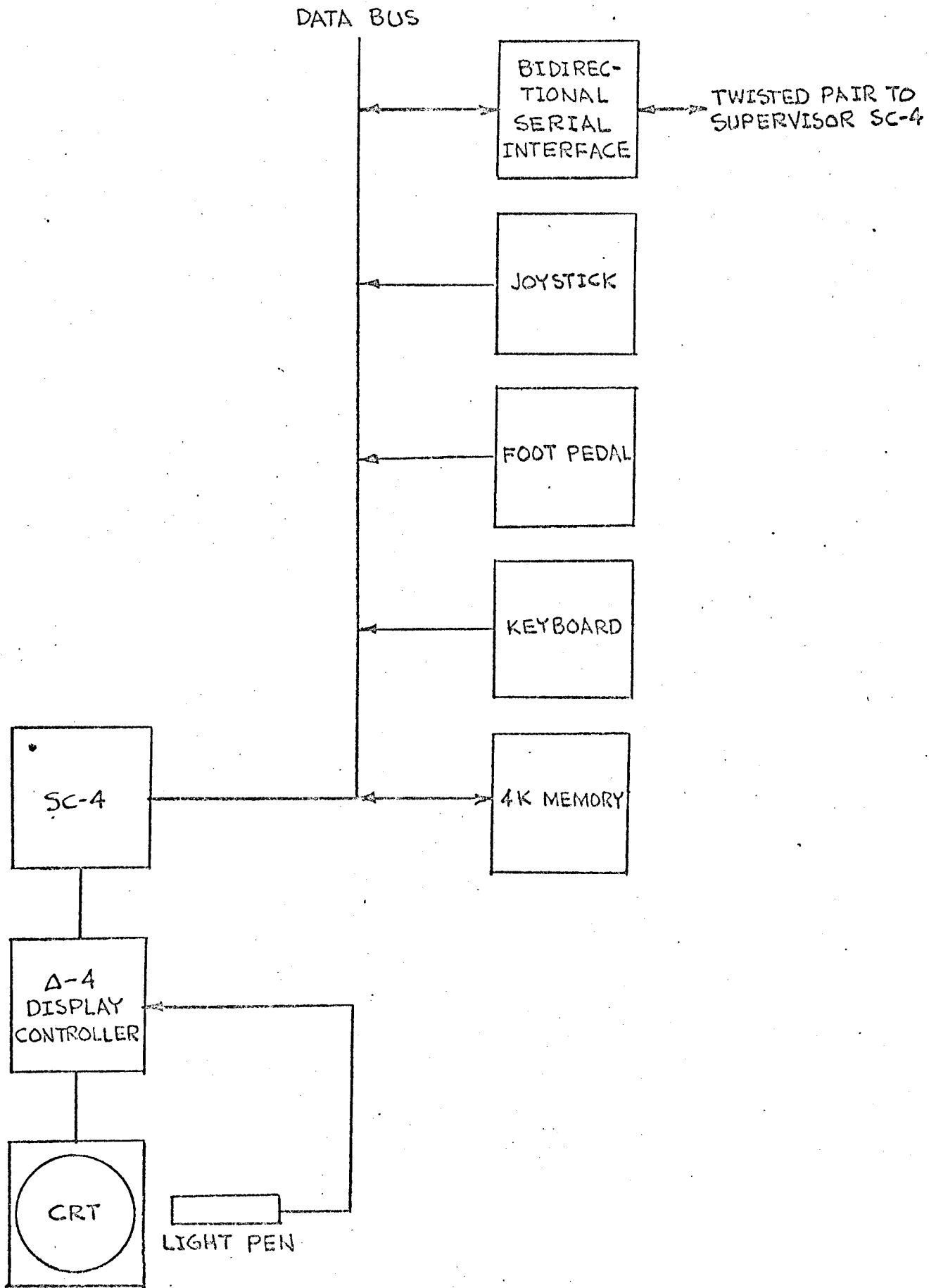SC-4

4K MEMORY

Δ-4
DISPLAY
CONTROLLER

CRT

LIGHT PEN

FIGURE 2. TERMINAL BLOCK DIAGRAM

A portion of SC-4 memory is reserved for a read-only bootstrap, configured according to available input/output devices, to initially load a general-purpose loader or utility program. In these terminals it is proposed to have it load a program from the supervisor SC-4 by way of the line between them.

Δ-4 Display

The Δ-4 is a refresh-type CRT display which uses much of the hardware of the SC-4 CPU. A screen area of approximately 12½ inches square is addressed by 11-bit X and Y coordinates. A twelfth high-order bit is kept for each coordinate, but the display is normally blanked when either of these bits is on. It is possible to override this blanking to take advantage of the non-square face of the tube and display several lines of text (for example) below the 11-bit square area. Programming aspects of the Δ-4 are treated in detail in the enclosed draft of the SC-4 Reference Manual.

The Δ-4 proposed will draw the average character (small size, 8 direction changes, 33 units of stroke length) in 15 microseconds. Vector setup takes 10 microseconds and the vector drawing rate is 20 microseconds per inch (250 microseconds full screen) on the major axis.

A choice of P31 or P39 phosphor is available.

Memory

A 4K-word semiconductor memory is proposed for each terminal. After character tables and program, approximately 2K is left for display lists. Cycle time is 750 nanoseconds; access time is 350 nanoseconds. Memory is on plug-in cards that are interchangeable with those of other terminals or the supervisor SC-4.

Keyboard

A microswitch 61SW12-1 Keyboard is proposed. This is an n-key rollover, MOS-encoded keyboard with Hall-effect switches. All 7-bit ASCII characters can be generated, and an eighth bit is also encoded for parity checking. Optionally the parity feature can be removed and a "Function" key added, to enable generation of a full 8-bit code.

Light Pen, Joystick, Foot Pedal

The light pen causes an interrupt as soon as the Δ-4 finishes the vector, point or character that the pen saw. Then the SC-4 can note the current X and Y coordinates, and the address in the display list. On subsequent polling by the supervisor, these data would be passed along.

The two-axis spring-centered joystick gives two 7-bit coordinates, and the foot pedal yields one bit of status. These are passed to the supervisor when explicitly requested.

Serial Interface

This both receives and transmits data to and from the supervisor SC-4. When the supervisor sends a word, the start bit causes the terminal's interface to request an interrupt. Sufficient buffering is provided in the interface to ensure that data is not lost. (The SC-4 may be drawing a full-screen vector, which is uninterruptable for about 260 microseconds. One data word, with start and stop bits, is transmitted in 220 microseconds.) The Serial Interface checks parity on received words and sets an error flag if bad parity is detected. This flag is checked by the bootstrap in read-only memory; checking it on data transfers is the responsibility of software. The "flag bit" sent as a 19th data bit, and the 18-bit data word, can be read by software when assembled.

If the word received is one specially flagged to request data
from the terminal, the Serial Interface will "turn the line around"
with the appropriate delays, after which the program can write one
word of data at a time; the last word is written in a special way
that sets the flag bit and causes the Serial Interface to revert to
receiving. Correct parity is transmitted for a check by the super-
visor.

SYSTEM EXPANSION CAPABILITIES

The system can be connected to other time-sharing computers
in addition to the G.E. machine. The only change would be to add
an appropriate interface to the supervisor SC-4, and to modify
its software to deal with that interface and switch data to or from
it. No modifications to the terminals are needed, and no additional
lines to them are involved.

Memory on the supervisor or any terminal SC-4 can be extended
(subject to chassis space) up to 256K (32K is directly addressable).

To expand above 32 terminals, it would be necessary to essential-
ly duplicate the system with another supervisor SC-4, Multiplexor
Channel Interface, 16K memory, and Satellite Interface.

SUPPORT

Documentation

Full documentation will be provided. This includes the finished
version of the SC-4 Reference Manual, complete logic drawings, tech-
nical description of the hardware, and signal glossary.

Programs

Maintenance programs, and the bootstrap loaders for the terminals

and the supervisor will be provided. Systems Concepts is interested in negotiating additional software for this system.

Training

A two-week training course covering operation and maintenance of all the proposed equipment will be given for up to four persons at our San Francisco location.

Warranty

The unconditional 90-day Systems Concepts Warranty, parts and labor included, will apply to all units shipped in this system.

DELIVERY

If an order were received now, delivery of the supervisor and the first terminals could be late in August, 1972. Any orders received before this one would naturally mean a later date. Once delivery began, terminals would be delivered at a rate of four per month (a higher rate could be negotiated). Systems Concepts personnel would install the initial system; it is believed that installation of additional terminals, as received, would pose no problem to Project MAC.

PRICES

Undiscounted Unit-Quantity Prices

SC-4 CPU with 4K x 18 memory and an ASR-33, but
   without floating point, map, time-sharing
   or display features $12,500.00

SC Δ-4 including SC-4 CPU as above, 4K x 18 memory,
   21-inch CRT monitor, keyboard, joystick, and
   foot pedal (no ASR-33) 17,500.00

Light Pen for Δ-4 . . . .   750.00

Serial Interface for Terminal SC-4 . . . .   500.00

G. E. Multiplexor Channel Interface for Supervisor
   SC-4 . . . .   25,000.00

Satellite Interface for Supervisor SC-4 to handle
   as many as 32 terminals 18,500.00

Additional 4K x 18 memory 3,000.00
   (3 needed for Supervisor)

Quantity Discounts

The following quantity discounts apply individually to each item priced above.

Quantity ordered	Percentage discount
1	(net)
3	5%
5	10%
10	15%
15	19%
20	22%
30	25%
40	28%
50	30%
75	32%
100	34%

Software Discount

The price arrived at after quantity discounting may be discounted itself by 20% if Systems Concepts is given the right to use and distribute any software developed by Project MAC for this system.