

Lunar Lander and the GT40

Moonlander, February 1973
50th Anniversary

Scott Swazey & Fritz Mueller

Lunar Lander Game

- Apollo 11 landed on the moon July 20, 1969.
- The first Lunar Lander game was a text-based game published under many names, including the Lunar Landing Game, written in the FOCAL programming language for the Digital Equipment Corporation (DEC) PDP-8 minicomputer by Jim Storer while a high school student in the fall of 1969.
- The original Lunar Landing Game was converted to BASIC by David H. Ahl, who included three versions in his 1973 book 101 BASIC Computer Games. By the end of the decade, this type of game was collectively known as a "lunar lander" game.

BASIC Program Instructions

LUNAR
CREATIVE COMPUTING MORRISTOWN, NEW JERSEY

THIS IS A COMPUTER SIMULATION OF AN APOLLO LUNAR
LANDING CAPSULE.

THE ON-BOARD COMPUTER HAS FAILED
SO YOU HAVE TO LAND THE CAPSULE MANUALLY.

SET BURN RATE OF RETRO ROCKETS TO ANY VALUE BETWEEN
0 (FREE FALL) AND 200 (MAXIMUM BURN) POUNDS PER SECOND.
SET NEW BURN RATE EVERY 10 SECONDS.

CAPSULE WEIGHT 32,500 LBS; FUEL WEIGHT 14,500 LBS.

BASIC Program output

SEC	HI + FT	MPH	LB FUEL	BURN RATE
0	120 0	3600	16500	? 0
10	109 5015	3636	16500	? 0
20	99 4223	3672	16500	? 0
30	89 2903	3708	16500	? 0
40	79 1055	3744	16500	? 0
50	68 3959	3780	16500	? 0
60	58 1055	3816	16500	? 0
70	47 2903	3852	16500	? 200
80	37 1883	3882.87	14500	? 200
90	28 1191	3086.71	12500	? 200
100	20 1251	2659.65	10500	? 200
110	13 2549	2196.95	8500	? 200
120	8 370	1692.63	6500	? 100
130	3 3778	1440.59	5500	? 75

ON MOON AT 139.926 SECONDS - IMPACT VELOCITY 1253.25 MPH
SORRY THERE WERE NO SURVIVORS. YOU BLEW IT!
IN FACT, YOU BLASTED A NEW LUNAR CRATER 347.15 FEET DEEP!

TRY AGAIN??

Low Cost Graphic Terminal

A minicomputer-based graphics terminal priced under \$11,000 (\$79,000 today) was announced by Digital Equipment Corporation in **October 1972**.

- The intelligent terminal, designated the GT40, links Digital's new PDP-11/10 minicomputer with 8 Kbytes of core memory, to a specially designed, hard-wired display processor and a 12-inch diagonal refresh scope.
- A light pen, full ASCII keyboard and character set, a serial communications interface and 31 special mathematical and scientific symbols are standard on the GT40. The GT40 may be used either as a stand-alone graphics system or as a remote terminal interacting with various types of host computers.

DEC GT40 Terminal



Source: <https://serious.gameclassification.com/EN/machines/117-DEC-GT40/index.html>

GT40 Moonlander

- On February 25th, 1973, DEC commissioned the creation of a real-time, graphical version of Lunar Lander, which was intended to demonstrate the capabilities of their new DEC GT40 graphics terminals. The game, written by Jack Burness and named *Moonlander*, was distributed with DEC computers and displayed at trade shows.
- Unlike the previous turn-based, textual games, *Moonlander* is a real-time graphical game. The lander's thrust and rotation were controlled using the light pen.
- The game showcased the advanced features of the terminal such as *italic text*, hardware based dot/dashed line drawing, multiple intensity graphics and a light pen interface.

GT40 running Moonlander



Source: https://commons.wikimedia.org/wiki/File:GT40_Lunar_Lander.jpg

Controlling the lander with the light pen



1630 FUEL LEFT

-15 DISTANCE

-100 PER VOL

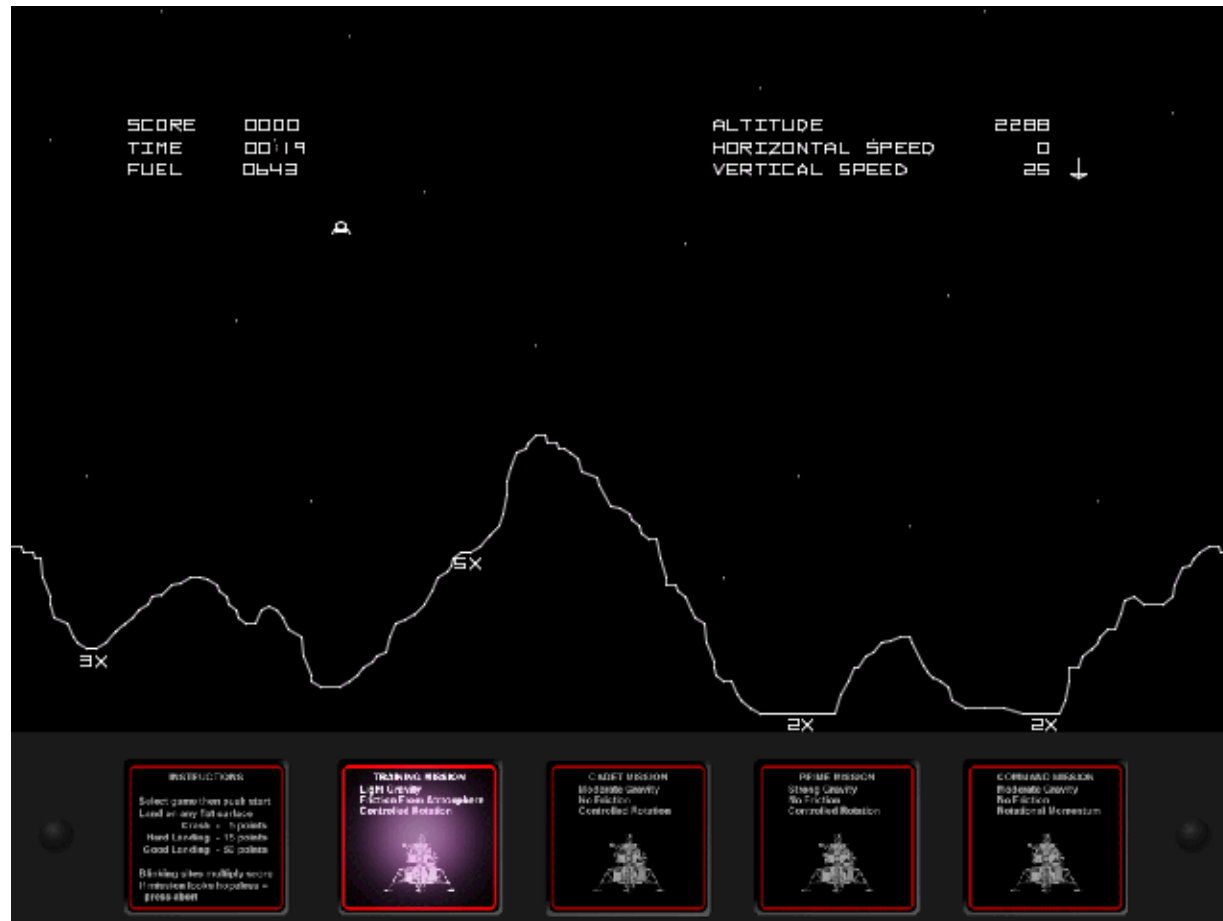
25 000 PER



Atari Version of Lunar Lander

- Released 1979
- 6502A CPU, 2.25K RAM, 12.5K ROM
- Copied GT40 vector generator
- Analog throttle for thrust
- Buttons for Left/Right Rotation

Atari Lunar Lander



Source: <https://www.arcade-museum.com/images/118/118124212765.png>



Analog Thruster



GT40 Restoration

Goal:

Restore GT40 and present the working Lunar Lander game at California Extreme 2023, August 18th 2023

Our GT40



Screen Rot



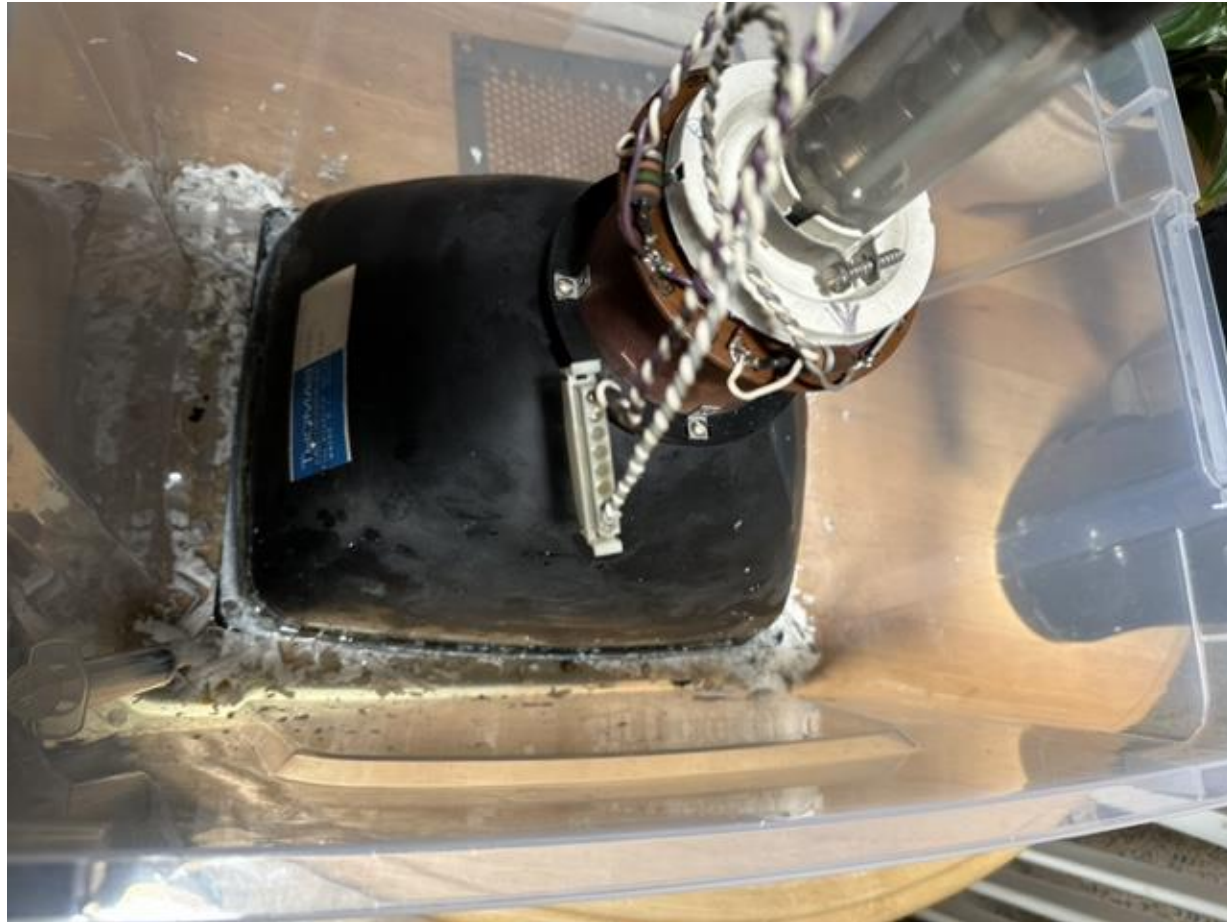
Remove CRT



Silicone Digester



Remove Digested Silicone



One week later...Success



But we still need an
implosion shield



Too Hot, too long



CRT reinstalled, but will it work?



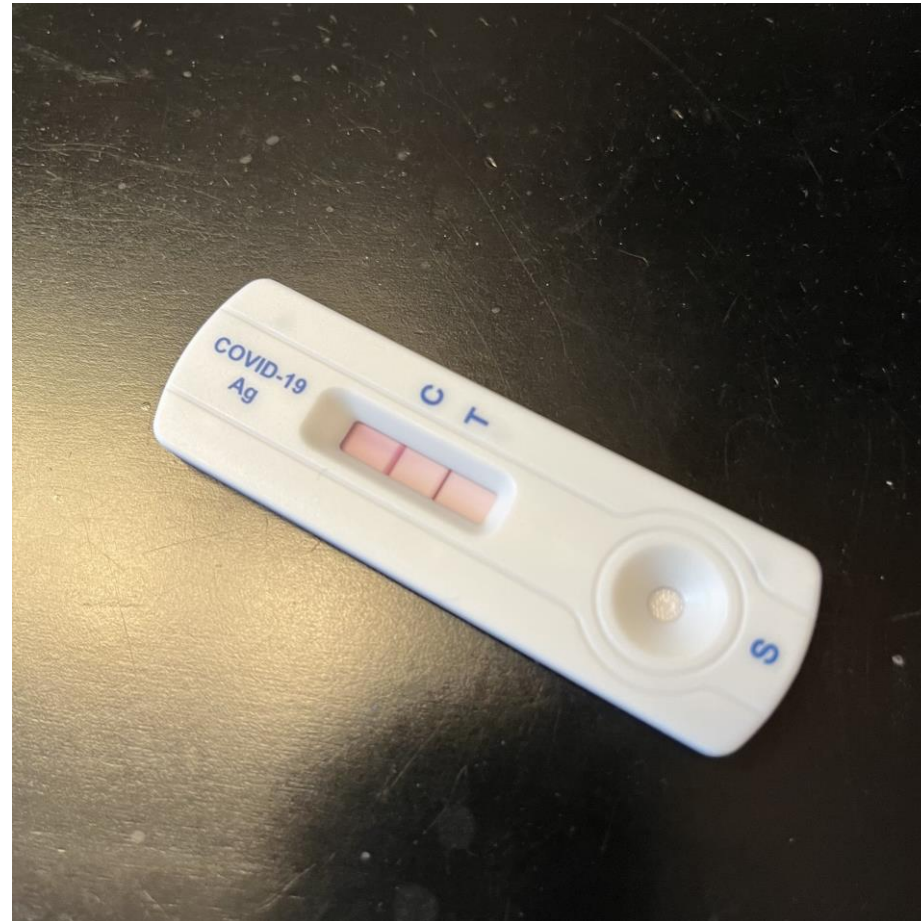
Vector monitor works!



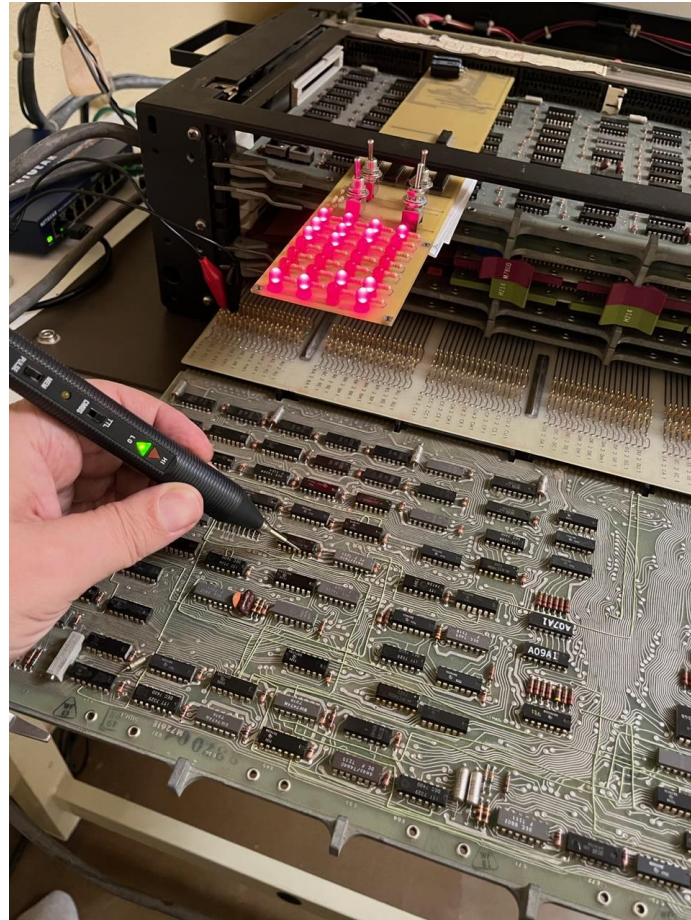
Diagnosing the GT40



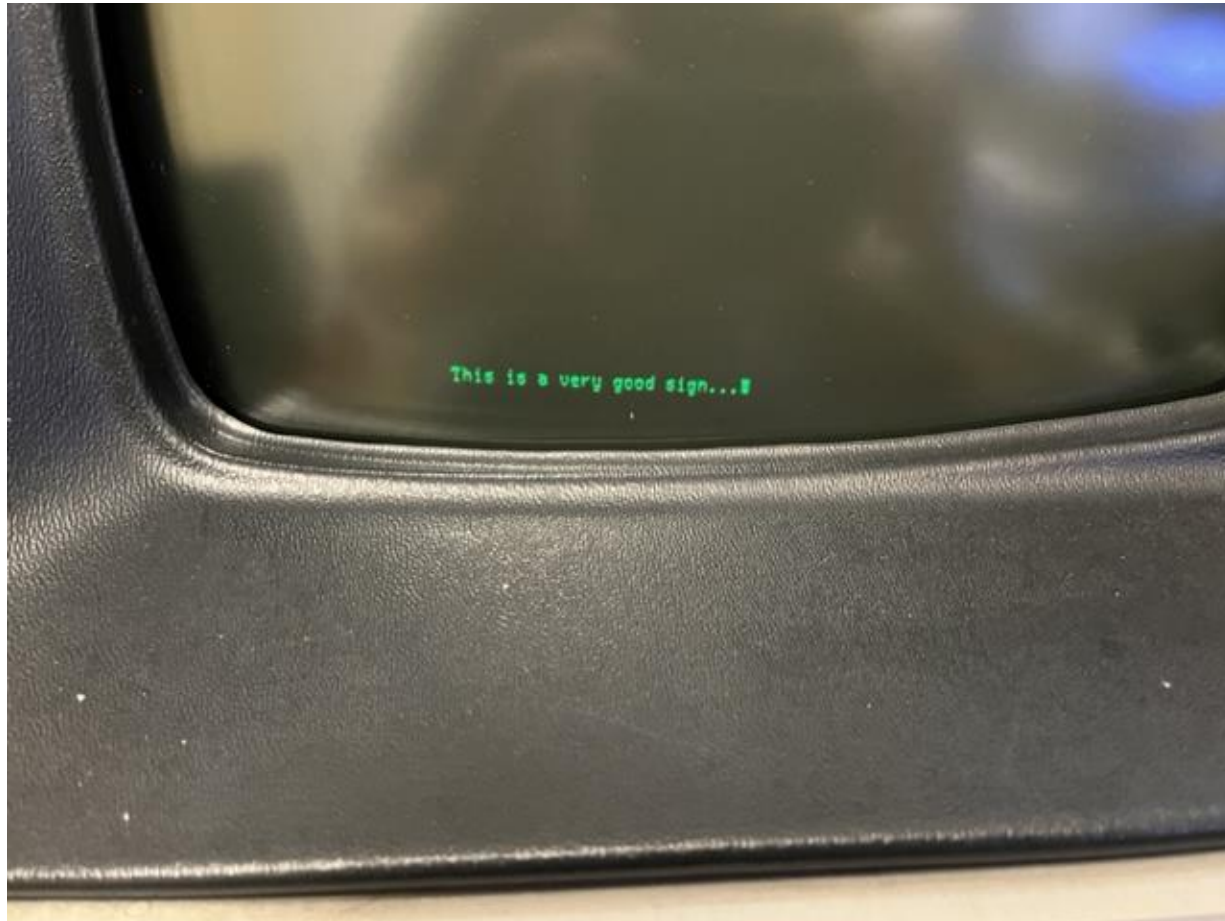
Doh!



Back to Debugging...



This is a very good sign...



Can we draw a box?



Friday August 18th, 6pm

CPU micro code PROM failure



See you at CAX2024

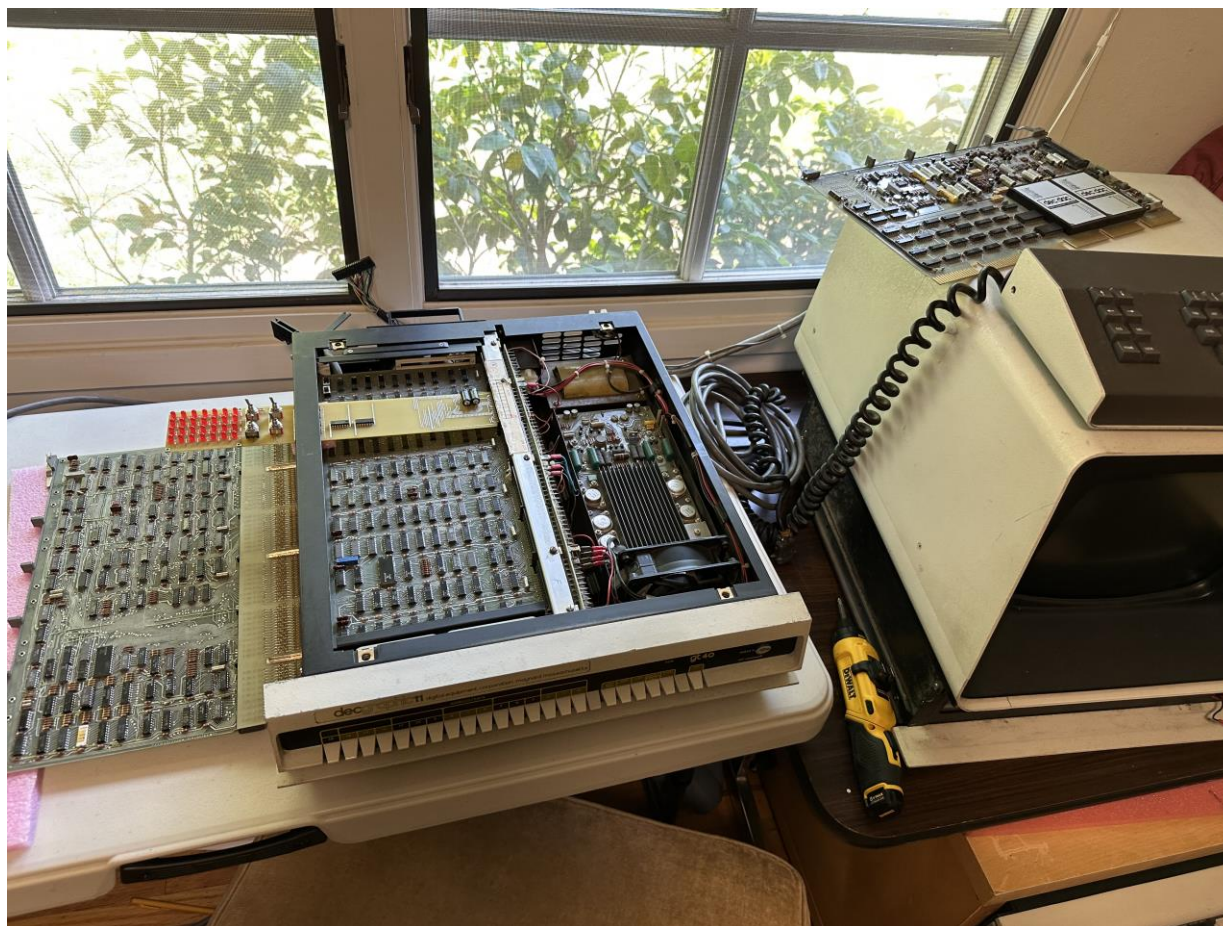
Santa Clara, CA

- Working GT40 with Demos
- Play Moonlander with the light pen
- Side by side with Atari Lunar Lander
- Additional info about the restoration process
- Follow <http://fritzm.GitHub.io>
- Follow <http://TattlerSolutions.com/gt40>

New Goal

- Complete GT40 restoration in time for VCF Midwest on September 9th, 2023

Pickup the GT40 from Fritz



Where to Start?

- Let's program the PROM...

KD=11B MICROPROGRAM BINARY LISTING REV, A

27 JUL 72

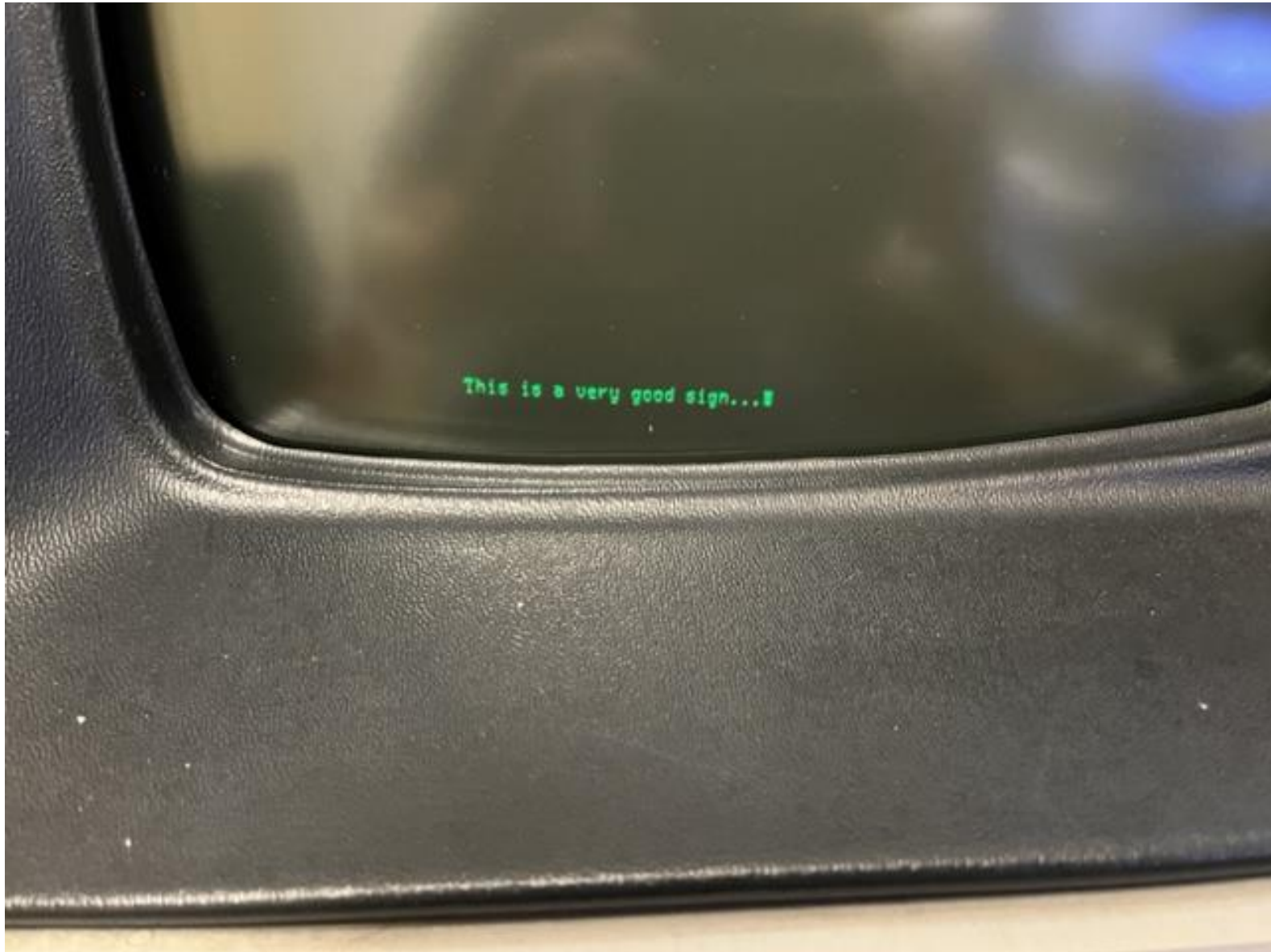
PAGE 2 OF 7

N A M	L O C	N X T	A L U	C F A R S U I H X	P S S D S P P I W 1 3 P	S S S B M P M B 0 0 1 T	B B S S A T P P R P F 2	C A T K B N O T S	A B L R G G	B U T
A145	145	0000	0000	0000	0 0 1 0	0 0 0 0	1 0 1 0	0 1 0 0	0 0 0 0	0 0 0 0
B#1	015	1001	1000	1100	0 0 1 1	1 0 0 1	1 0 1 1	1 1 1 0	1 1 1 1	1 1 0 0
B#2	147	1001	1001	0110	0 0 1 1	1 1 0 1	1 1 1 1	1 1 1 1	1 1 1 1	1 1 1 1
B#3	146	1101	1111	0101	1 0 1 1	1 1 0 1	1 1 1 1	1 1 0 1	1 1 1 1	1 1 0 0
B2#2	305	1101	1111	0000	1 0 1 1	1 0 0 1	1 0 1 1	1 1 1 0	1 1 1 1	1 1 0 0
B2#2	333	1101	1111	0000	1 0 1 1	1 0 0 1	1 0 1 1	1 1 1 0	1 1 1 1	1 1 0 0
B2#2	335	1101	1111	0000	1 0 1 1	1 0 0 1	1 0 1 1	1 1 1 0	1 1 1 1	1 1 0 0
B2#2	343	1101	1111	0000	1 0 1 1	1 0 0 1	1 0 1 1	1 1 1 0	1 1 1 1	1 1 0 0
B2#2	013	1101	1111	0000	1 0 1 1	1 0 0 1	1 0 1 1	1 1 1 0	1 1 1 1	1 1 0 0
BG#1	040	0011	1010	0000	1 0 1 1	1 0 0 1	1 0 1 1	1 1 1 0	1 1 1 1	1 1 0 0
BT#1	045	1101	1010	0000	1 0 1 1	1 1 0 1	1 0 1 1	1 1 0 0	1 1 1 1	1 0 1 1
CC#1	112	1101	1111	0010	1 0 1 1	0 0 0 1	1 0 1 1	1 1 1 0	1 1 1 1	0 0 0 0
CCM#	151	0001	0111	0001	1 0 1 1	1 0 0 1	1 1 1 1	1 1 0 0	1 1 1 1	1 0 1 1
CCM#	350	1011	0101	0000	1 0 1 1	1 0 0 1	1 0 1 1	1 1 1 0	1 1 1 1	1 1 0 0
CCS#	316	0100	0001	0000	1 0 1 1	1 1 0 1	1 1 1 1	1 1 1 1	1 1 1 1	1 1 1 1
CCS#	276	0100	0111	0000	1 0 1 1	1 0 0 1	1 0 1 1	1 1 1 0	1 1 1 1	1 1 0 0

Rule Number One

Don't Trust Anyone!

Success! Now what?



Let's Load A Diagnostic

← → ↻ ⚠ Not secure | brouhaha.com/~eric/retrocomputing/dec/gt40/

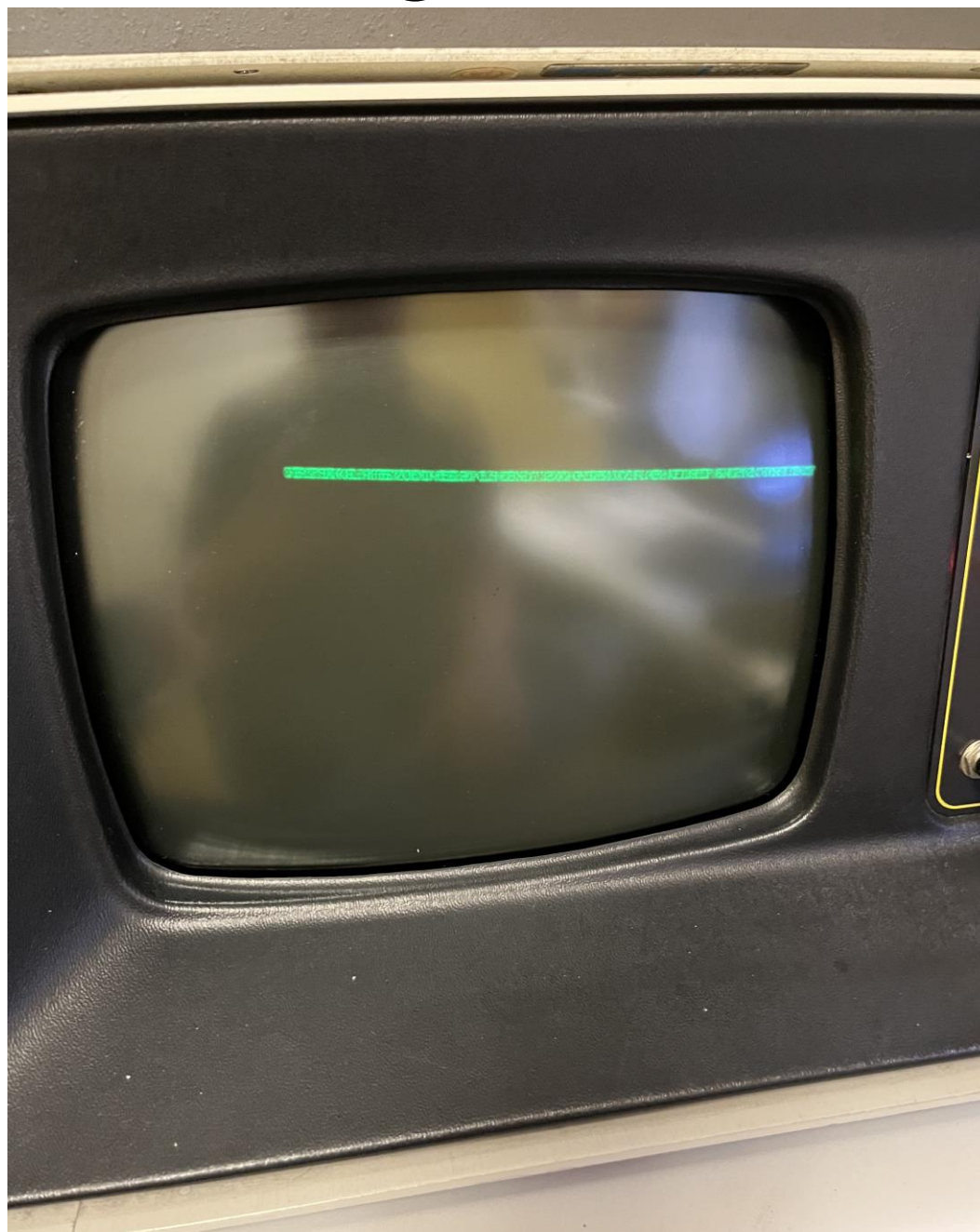
Diagnostics

Diagnostics in GT40 bootstrap loader format, supplied by John Holden:

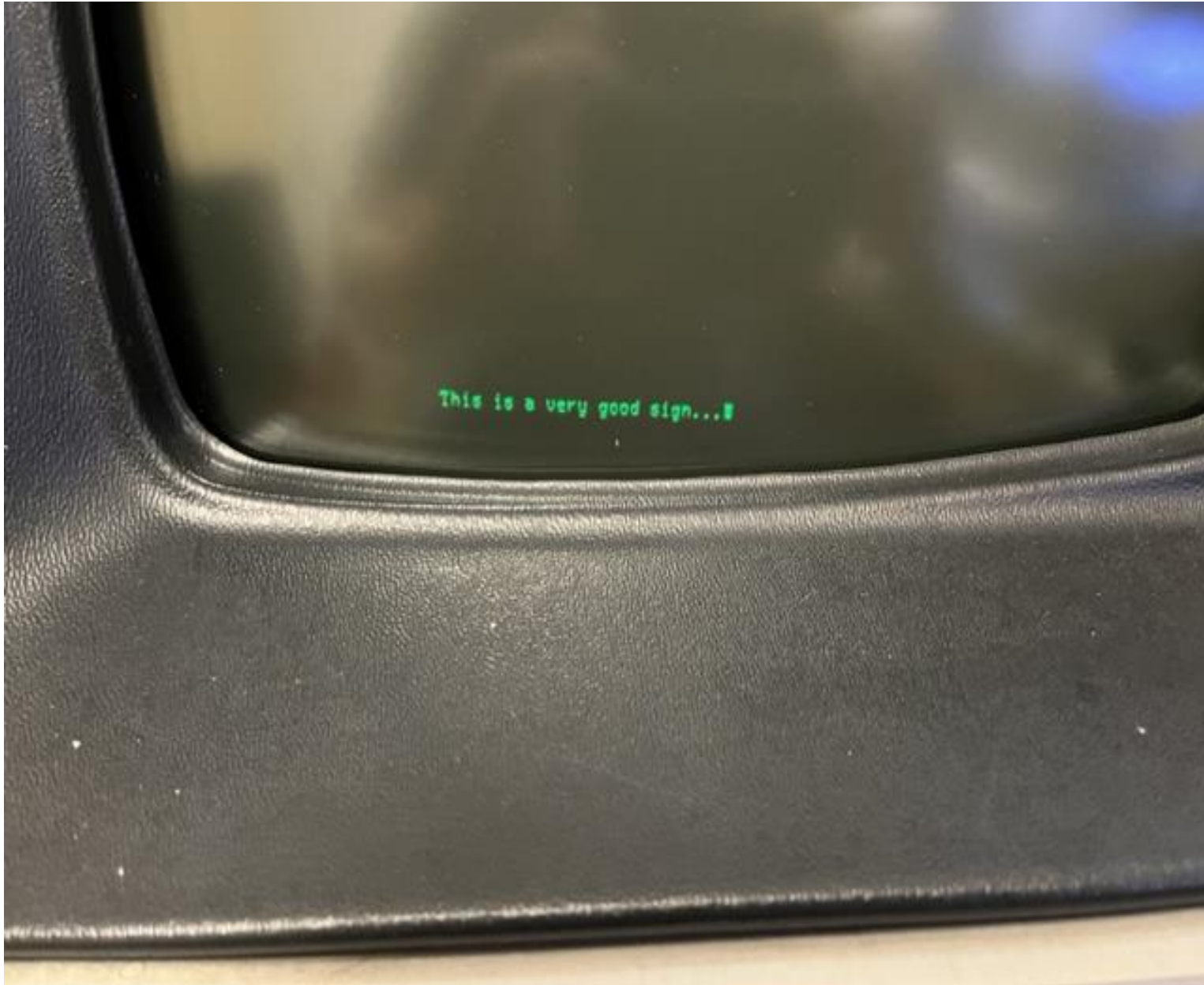
Listed in Maintenance Manual		Available Here
Title	Part Number	
GT40 Quick Verify	MAINDEC-11-DDGTE-A	dgtec0.gt (10K)
GT40 Instruction Test 1	MAINDEC-11-DDGTA-A	dgtad1.gt (9.5K)
GT40 Instruction Test 2	MAINDEC-11-DDGTB-A	dgtbd0.gt (8.0K)
GT40 Visual Display Test	MAINDEC-11-DDGTC-A	dgtcc0.gt (7.3K)
DL11-E, C/D Off-Line Test	MAINDEC-11-DZDLA	
ROM Bootstrap Loader Test	MAINDEC-11-DDGTD-A-D	dgtdc0.gt (10K)
GT40/GTP Overlay Program	MAINDEC-11-DDGTF	
not listed		dgtgb0.gt (7.3K)

Source: <http://www.brouhaha.com/~eric/retrocomputing/dec/gt40/>

Loading Aborted...



Linefeed Character Hangs GT40



Single Step Through Bootloader

SCROLLING ROM BOOTSTRAP FOR THE GT40
BOOT.T15 VT05 SIMULATOR

MACDLX 622(622)-1 26-JUN-73 16:11 PAGE 1-6

313						
314	166256	012705	000040	FFI	MOV	#NUMLIN,COUNTR
315						
316	166262	012706	000012	FFLOOP1	MOV	#12,CHAR
317	166266	004737	166304		JSR	PC,LFSUB
318	166272	005305			DEC	COUNTR
319	166274	003372			BGT	FFLOOP
320	166276	000715			BR	NXTCHR
321						
322						
323	166300	012746	166132	LFI	MOV	#NXTCHR,=(SP)
324						
325						
326	166304	013703	007012	LFSUB1	MOV	JMPADD,SCAN
327						
328	166310	12230E		LFSUB1	CMPI	(SCAN)+,CHAR
329	166312	001406			REQ	LFOUND
330	166314	020327	007000		CMPI	SCAN,#BLIMIT
331	166320	103773			RLO	LFSUB1
332	166322	012703	001000		MOV	#BSTART,SCAN
333	166326	000770			BR	LFSUB1
334						

IFORM FEED IS DONE BY INSERTING LF'S;

MAKE THE CHARACTER A LINEFEED,
DO A LINEFEED;

IDONE?

INOPE, KEEP SENDING THEM,

YES, NOW RETURN, DO NOT FALL THROUGH;

RETURN TO NXTCHR AFTER PROCESSING
THE LF BY FAKING A JSR,

GET POINTER TO FIRST CHAR ON SCREEN

AND LOOK FOR A LINEFEED,

IF GOT IT, SEARCH HAS ENDED,

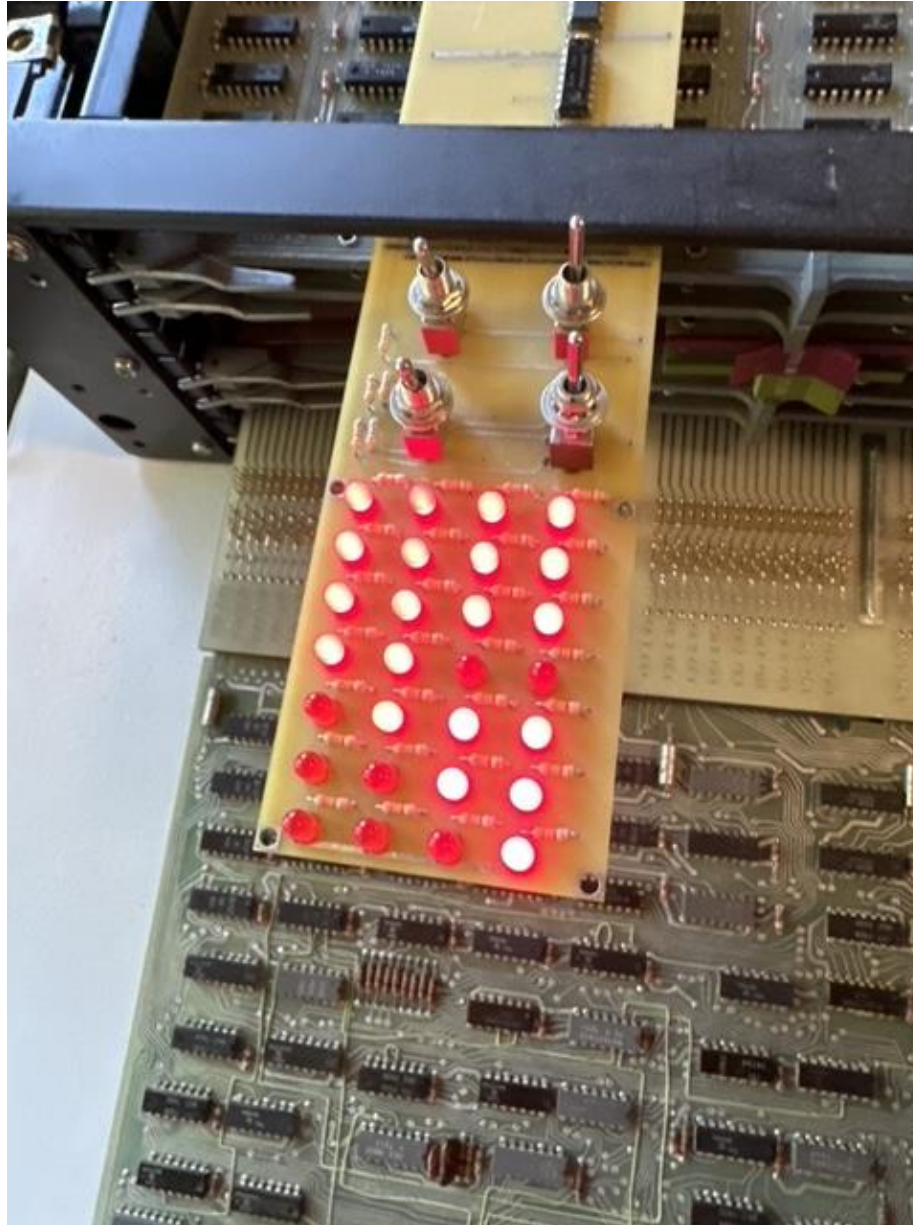
ARE WE AT END OF BUFFER?

INOPE, KEEP ON LOOKING;

IF AT TOP, RESET TO BOTTOM OF BUFFER

AND KEEP ON LOOKING,

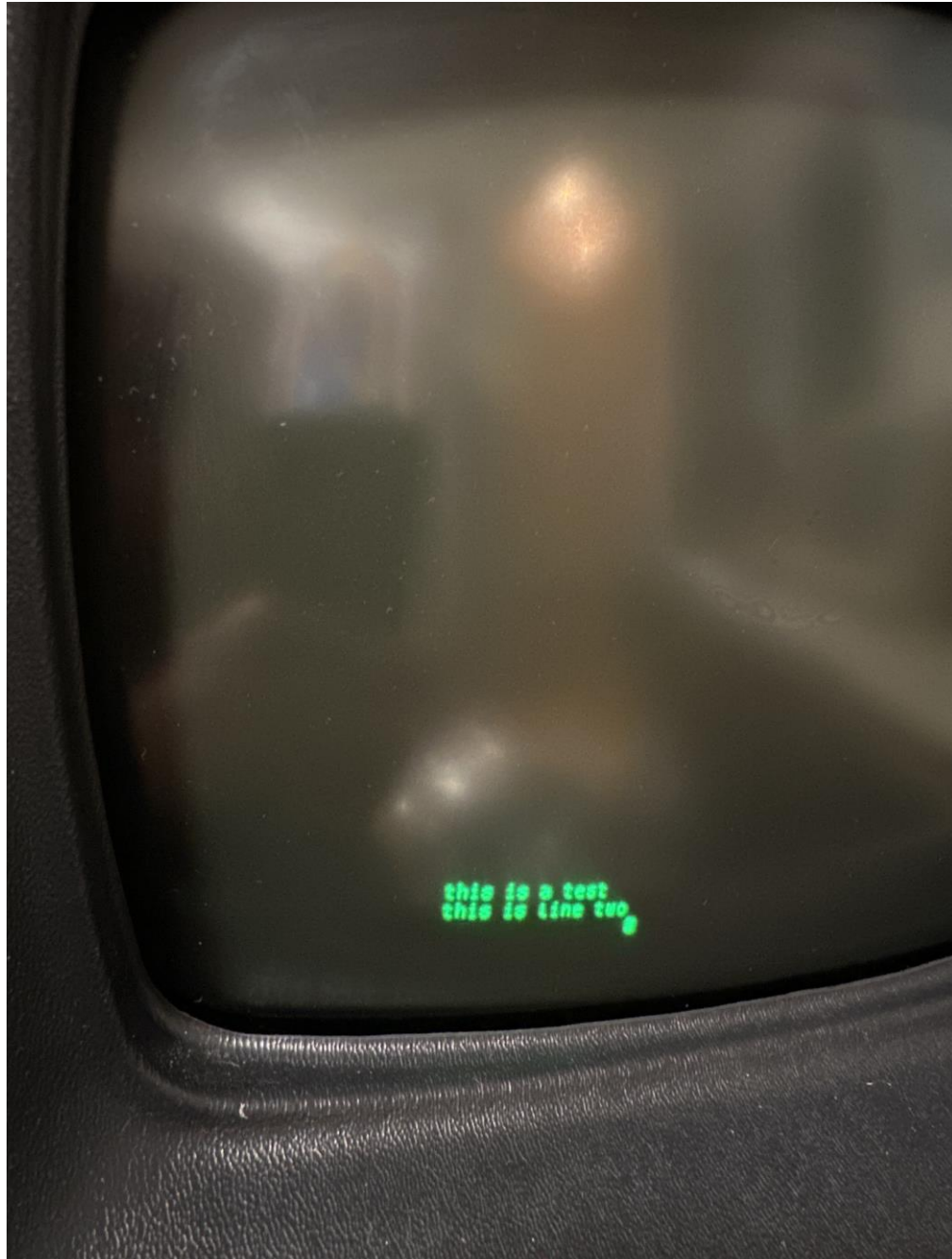
Single step the Microcode



Compare High Byte by Shifting to Low Byte

```
LOC  NXT  * SOURCE BYTE ODD
      / GETE TO SBO#1 FROM S1#2 VIA BUF BYTE
067   346  SBO#1  SHIFT B RIGHT; F SHIFT
346   324  SBO#2  SHIFT B RIGHT; F SHIFT
324   340  SBO#3  SHIFT B RIGHT; F SHIFT
340   361  SBO#4  SHIFT B RIGHT; F SHIFT
361   050  SBO#5  SHIFT B RIGHT; F SHIFT
050   020  SBO#6  SHFIT B RIGHT; F SHIFT
020   052  SBO#7  SHIFT B RIGHT; F SHIFT
052   047  SBO#8  SHIFT B RIGHT; GOTO SBE#1
```

Replaced Bad 74194 4-Bit Shifter



Load Diagnostics...

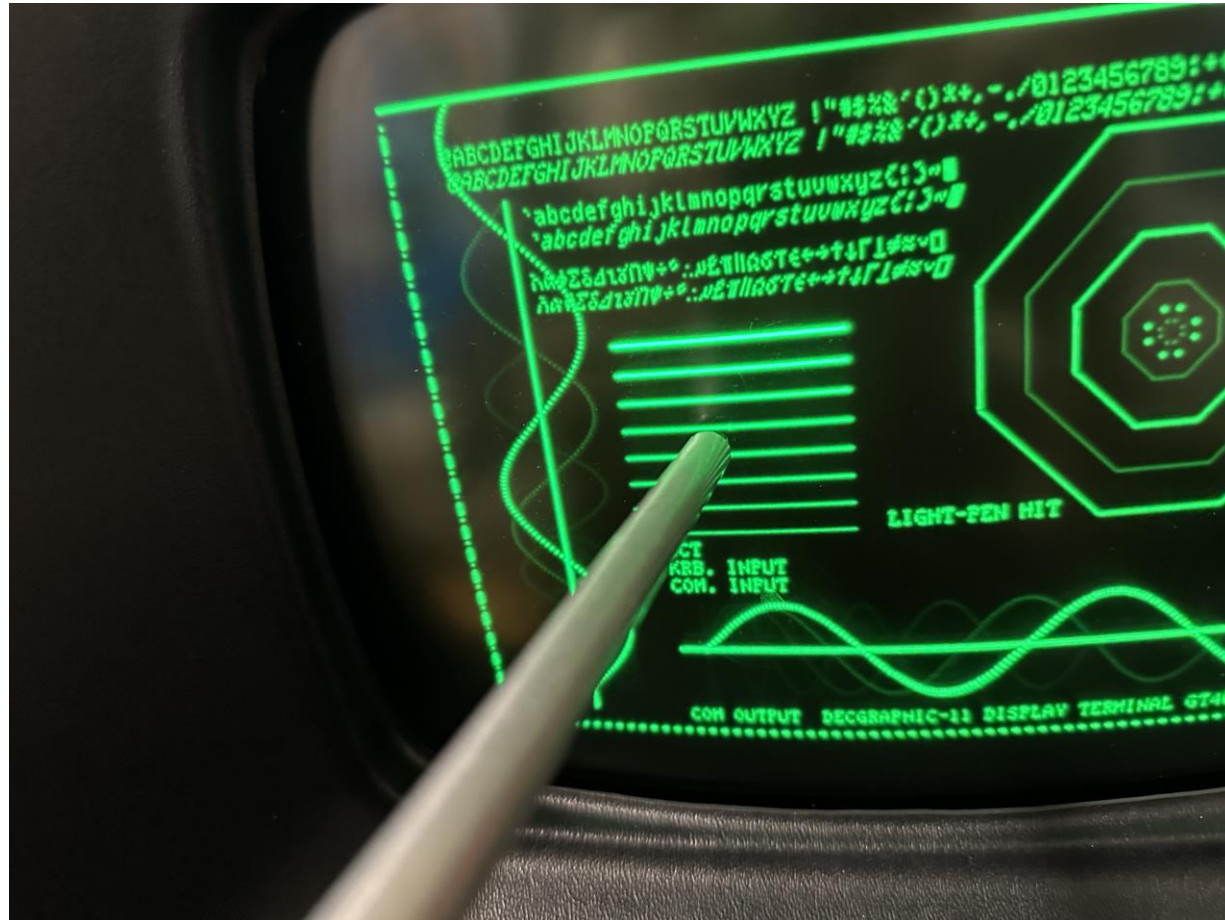
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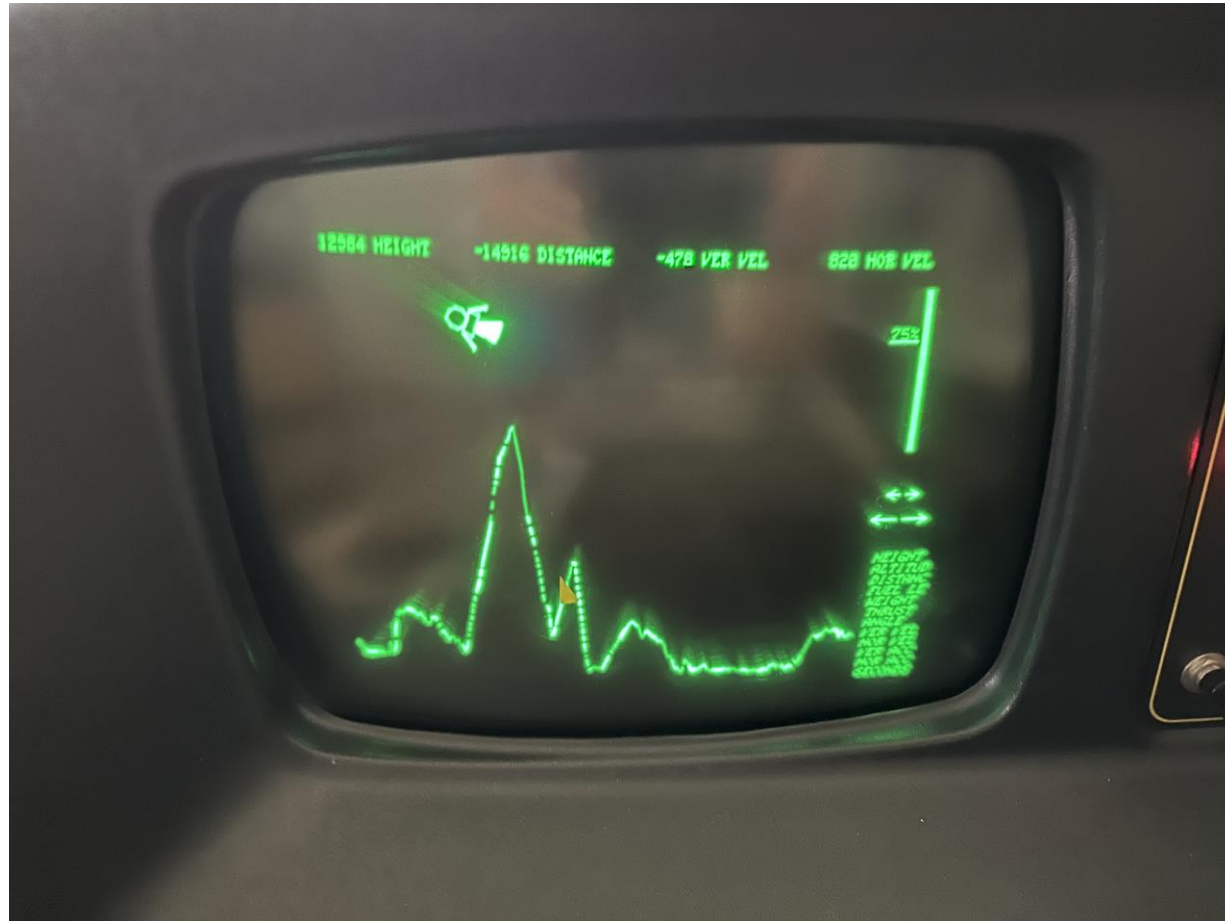
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not listed		dgtgb0.gt (7.3K)

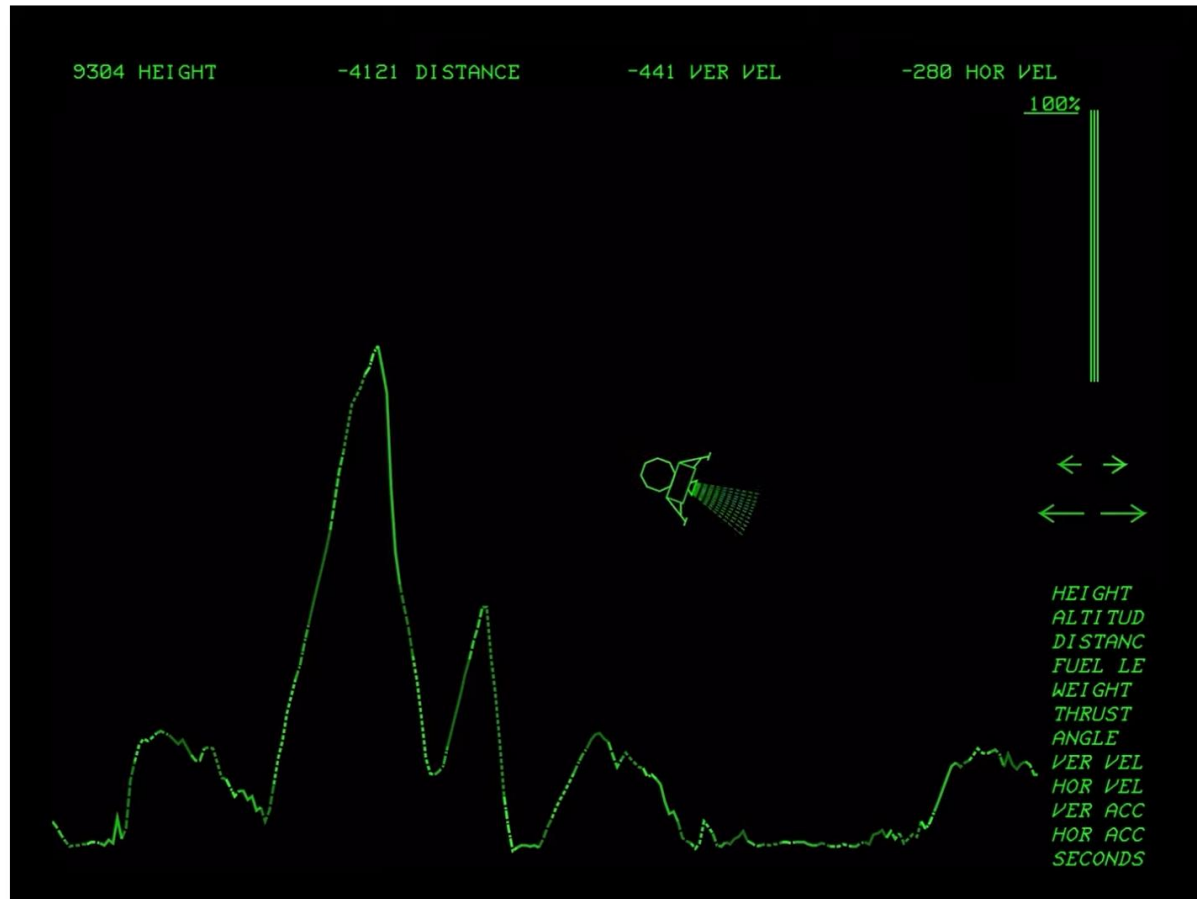
Success



Let's Load Lunar Lander...

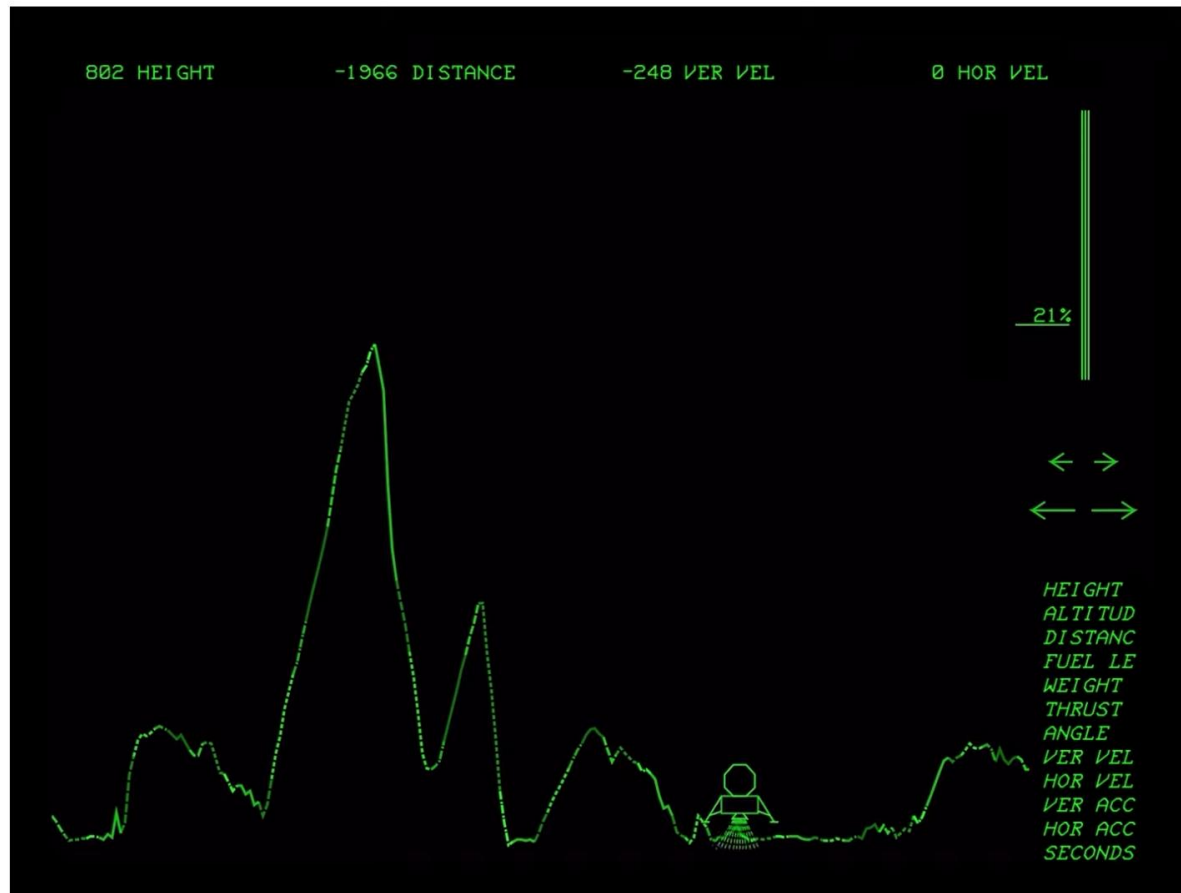


Height 9304 Feet



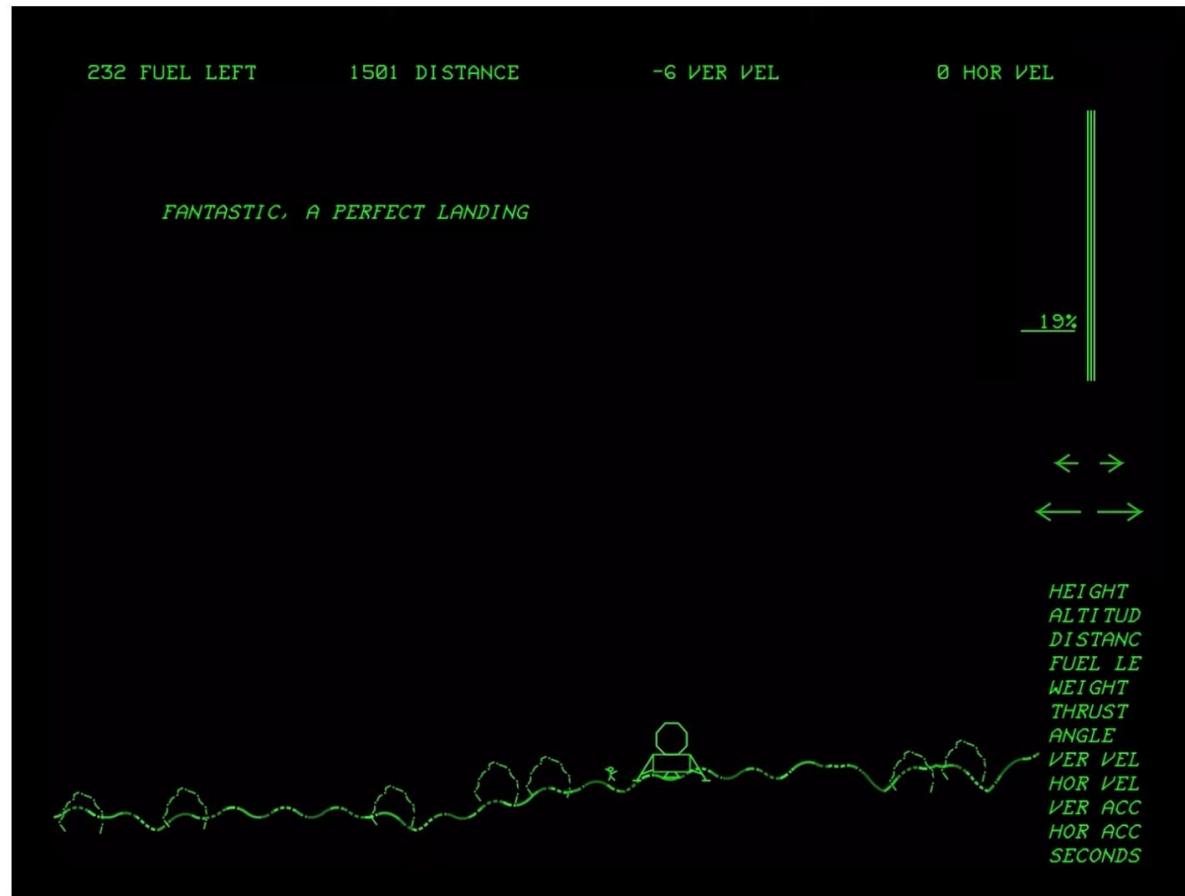
Source: <https://www.youtube.com/watch?v=z97TfAhDKGk>

Height 802 Feet...



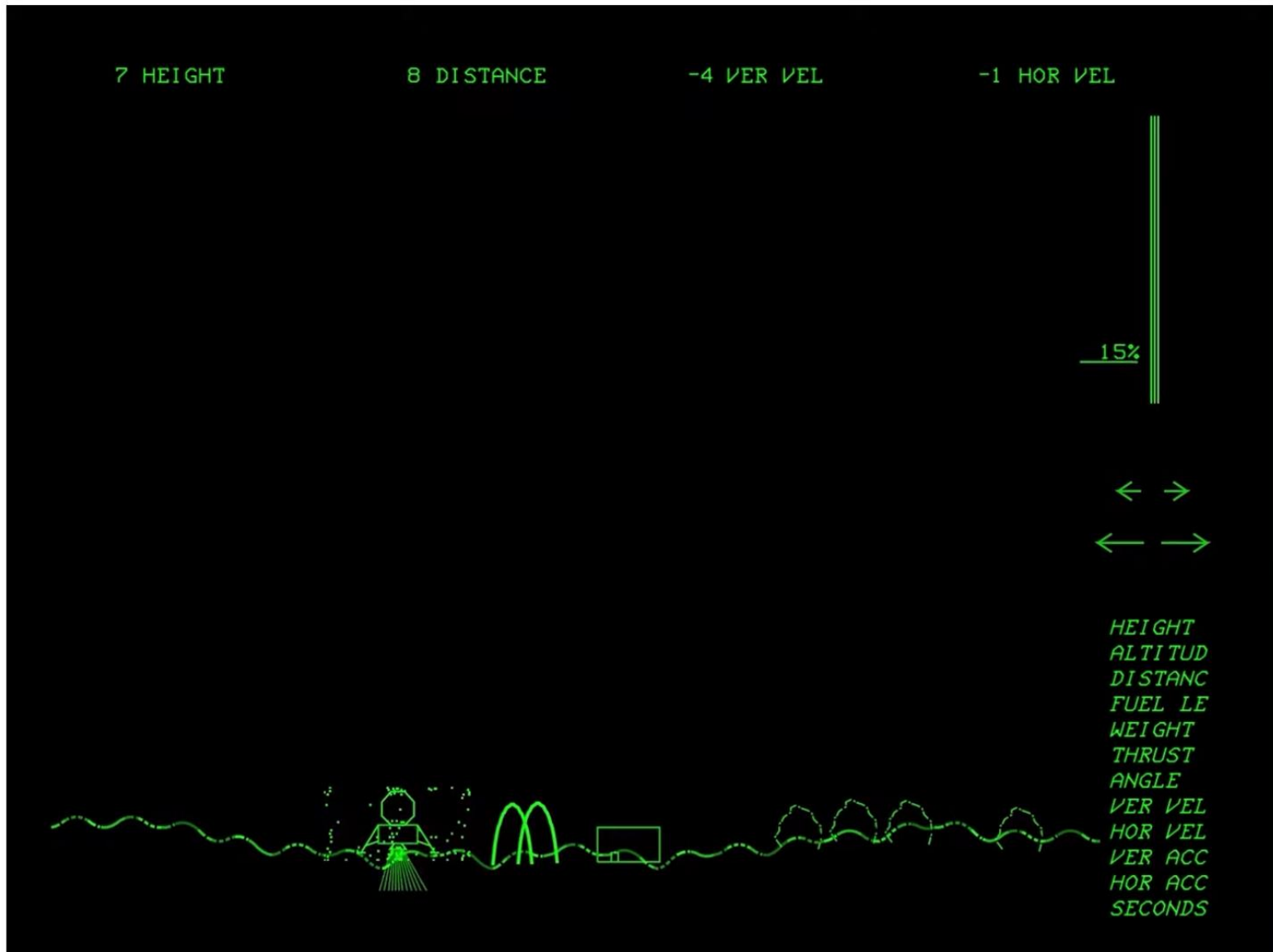
Source: <https://www.youtube.com/watch?v=z97TfAhDKGk>

One Small Step...



Source: <https://www.youtube.com/watch?v=z97TfAhDKGk>

The First Easter Egg



Source: <https://www.youtube.com/watch?v=z97TfAhDKGk>

Two Cheeseburgers and a Big Mac to Go...

