SOLVIT
An HP-41 Program to Solve Multiple-Variable Equations for Arbitrary Unknowns

by
Ted W. Beers

y = slope x + intercept
y = 9.5, x = 5, intercept = 2
slope = ?

x = \(v_0\) t - \(\frac{1}{2}g\) t^2 + x_0
x = 0, v_0 = 50, x_0 = 10
t = ?

slope = 1.5
t = 10.4

includes:
Introduction
Detailed Instructions
Instruction Table
Examples
Technical Details
Annotated Program Listings
Program Barcode

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HP-41 SOLVIT Software Support

As the author of SOLVIT, An HP-41 Program to Solve Multiple-Variable Equations for Arbitary Unknowns, I wish to support this software at a level appropriate to the complexity and customer cost of the package. To this end, I invite you to write to me directly if you discover problems with the software or the manual. I also welcome any comments you may have on the quality and usability of HP-41 SOLVIT. My address is:

Ted W. Beers
3947 NW Tamarack Dr.
Corvallis, OR 97330

Included with this Software Support sheet is a Purchase Registration form. Please fill it out and send it to me so that I can notify you if there are any revisions to the software or the manual.

I will try to respond to letters regarding HP-41 SOLVIT, but because of the range of applications of SOLVIT and the number of potential customers, I can not guarantee to answer all requests. Please enclose a self-addressed, stamped envelope with all correspondence.
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**KEYSTROKE NOTATION**

<table>
<thead>
<tr>
<th>Keystroke Example</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>[]</td>
<td>The gold shift key.</td>
</tr>
<tr>
<td>[XEQ]</td>
<td>A key labelled in white on the face of the key.</td>
</tr>
<tr>
<td>[] [GTO]</td>
<td>A shifted key labelled in gold letters above a key.</td>
</tr>
<tr>
<td>['Y']</td>
<td>A top row key located under the character(s) in the display above.</td>
</tr>
<tr>
<td>[] [] X []</td>
<td>A shifted top row key located under the character(s) in the display above.</td>
</tr>
<tr>
<td>123</td>
<td>Numeric digit keys.</td>
</tr>
<tr>
<td>ABC</td>
<td>Alpha mode keys labelled in blue letters on the slanted faces of the keys.</td>
</tr>
</tbody>
</table>
The HP-41 is well known for its ability to tackle complicated calculations with ease. The new HP-18C Business Consultant is appreciated for its formula solver that produces fast solutions to an endless variety of financial and business problems. SOLVIT, an HP-41 program to solve multiple-variable equations for arbitrary unknowns, provides the best of both these powerful calculators: the rich function set of the HP-41 combined with an equation solver styled after the HP-18C formula solver.

SOLVIT works with an equation containing any number of variables that you enter in the familiar HP-41 RPN format. Based on names that you assign to the variables in the equation, SOLVIT creates a custom menu that labels the keys used to input data and calculate solutions. Using the custom menu, you can assign known values to variables and have SOLVIT calculate the unknown value of any variable in the equation. The flexibility of this solution method encourages "what if" investigations into interesting equations that are too difficult to manipulate on paper.

These instructions start with the basics: the equipment you'll need to use SOLVIT. Then, a simple example is explained in detail to illustrate how SOLVIT assigns known data and calculates results. Subsequent sections cover all aspects of SOLVIT: DETAILED INSTRUCTIONS FOR SOLVIT explains SOLVIT's features completely; EXAMPLES demonstrates further how SOLVIT simplifies a difficult problem; TECHNICAL DETAILS describes the more technical aspects of SOLVIT that will help you understand how SOLVIT works; The APPENDIX introduces supplementary programs you can use to save and recall frequently-used equations; and REFERENCES, PROGRAM LISTINGS, and PROGRAM BARCODE are provided in the last three sections.

Equipment Needed

To use SOLVIT, the following HP-41 configuration and software is required:

- HP-41C with two Memory Modules
  or
- HP-41C with one Quad Memory Module
  or
- HP-41CV
  or
- HP-41CX

- HP-41 Advantage Advanced Solutions Pac

The SOLVIT program must be in HP-41 main memory.
For information regarding inserting HP-41 modules and loading the SOLVIT program, refer to your HP-41 Owner's Manual. Program barcode for SOLVIT is printed in the PROGRAM BARCODE section. Throughout the rest of these instructions, it is assumed that you have the SOLVIT program in main memory and that the Advantage Module is inserted.

**Example 1**

SOLVIT works with equations that you program in the same RPN format that the HP-41 uses for keyboard calculations. Once an equation has been entered, you specify the name of each variable in the equation, then, given values for all variables but one, SOLVIT is ready to solve for the unknown variable. To see how this works, try the following example. Don't worry about the details of each step; they will be explained later. For this example to work properly, the HP-41's top row keys must not have any User key assignments. If necessary, clear any User key assignments before proceeding. Refer to your HP-41 Owner's Manual for details.

The Problem: Find the slope of the straight line in the figure below. The line intercepts the y-axis at y = 2, and one point on the line is located at x = 5, y = 9.5.

![Graph of a straight line](image)

The Solution: The straight line equation is

\[ y = \text{slope} \times x + \text{intercept} \]

There are four variables in this equation, which we'll call \( Y \), \( \text{SLOPE} \), \( X \), and \( \text{INTER} \).
This equation is entered into HP-41 memory as a program called LINE with the following procedure; the first two steps assure that you have enough memory for the example.

Keystrokes

<table>
<thead>
<tr>
<th>[XEQ]</th>
<th>[ALPHA] SIZE</th>
</tr>
</thead>
<tbody>
<tr>
<td>[ALPHA]</td>
<td>010</td>
</tr>
<tr>
<td>[GTO]</td>
<td>[.]</td>
</tr>
<tr>
<td>[LBL]</td>
<td>[ALPHA]</td>
</tr>
<tr>
<td>[ALPHA]</td>
<td></td>
</tr>
<tr>
<td>[RCL]</td>
<td>02</td>
</tr>
<tr>
<td>[RCL]</td>
<td>03</td>
</tr>
<tr>
<td>[+]</td>
<td></td>
</tr>
<tr>
<td>[RCL]</td>
<td>04</td>
</tr>
<tr>
<td>[+]</td>
<td></td>
</tr>
<tr>
<td>[RCL]</td>
<td>01</td>
</tr>
<tr>
<td>[-]</td>
<td></td>
</tr>
<tr>
<td>[PRGM]</td>
<td>[GTO]</td>
</tr>
</tbody>
</table>

Display

| X register + |
| 00 REG nnn + |
| 01 LBL LINE |
| 02 RCL 02 |
| 03 RCL 03 |
| 04 * |
| 05 RCL 04 |
| 06 + |
| 07 RCL 01 |
| 08 - |

+ If the HP-41 displays PACKING, then TRY AGAIN, clear one or more programs and repeat this step.
+ If nnn < 016, clear one or more programs and repeat this step.

SOLVIT is initialized to solve the straight line equation in the following manner:

Keystrokes

| [F] | [FIX] | 2 |
| [XEQ] | [ALPHA] | SOLVIT | [ALPHA] |
| LINE | [R/S] |
| 4 | [R/S] |
| Y | [R/S] |
| SLOPE | [R/S] |
| X | [R/S] |
| INTER | [R/S] |

Display

| X register |
| EQUATION? |
| NO. OF VARS=7 |
| NAME, VAR 1? |
| NAME, VAR 2? |
| NAME, VAR 3? |
| NAME, VAR 4? |
| LINE |
| Y S X 1 |

The last display is the menu for the straight line equation, which labels the HP-41's top row keys. When labelled in this manner, the top row keys are called menu keys. Note that the menu contains only the first character of each variable name. In general, a menu can contain the first one or two characters of a variable name.
The example can now be solved by first providing the known values for \( Y, X, \) and \( \text{INTER} \), and then solving for \( \text{SLOPE} \).

<table>
<thead>
<tr>
<th>Keystrokes</th>
<th>Display</th>
</tr>
</thead>
<tbody>
<tr>
<td>9.5 ( \downarrow ) Y ( \downarrow ) ( \downarrow ) +</td>
<td>Y S X I</td>
</tr>
<tr>
<td>5 ( \downarrow ) X ( \downarrow )</td>
<td>Y S X I</td>
</tr>
<tr>
<td>2 ( \downarrow ) ( \downarrow )</td>
<td>Y S X I</td>
</tr>
<tr>
<td>1 ( \downarrow )</td>
<td><em>WORKING</em></td>
</tr>
<tr>
<td></td>
<td>SLOPE=1.50</td>
</tr>
<tr>
<td></td>
<td>Y S X I</td>
</tr>
</tbody>
</table>

\( \langle \text{m} \rangle \) is menu key \( \text{m} \), the top row key under the character(s) \( \text{m} \). If necessary, press \( \text{R/S} \) before \( \langle \text{m} \rangle \) to see which key to press.

The solution to this example is a slope of 1.5.

Of course, this simple example could probably be solved more quickly by just rearranging the equation to the form

\[
\text{slope} = \frac{(y - \text{intercept})}{x}
\]

However, while some useful equations can be manipulated this easily, many cannot. But no matter how complicated the equation, SOLVIT can always provide the friendly user interface illustrated above.
Rewriting an Equation in the SOLVIT Format

Equations are usually written in algebraic form (also known as infix form, because operators are placed between their operands). SOLVIT requires equations to be programmed in an RPN form (also known as postfix form, because operators come after their operands). The conversion from an equation in algebraic form to SOLVIT's RPN form is very straightforward (examples below are excerpted from Example 1):

1. Write the equation in algebraic form.
   (Example: $y = \text{slope} \cdot x + \text{intercept}$)

2. Rearrange the equation from the form $\text{left side} = \text{right side}$ to the form $\text{right side} - \text{left side} = 0$ or $\text{left side} - \text{right side} = 0$
   (Example: $\text{slope} \cdot x + \text{intercept} - y = 0$)

3. Disregard the "= 0" portion of the equation and rewrite the left side of the equation in RPN form.
   (Example: $\text{slope} \cdot x + \text{intercept} + y$)

4. Replace each variable with an HP-41 RCL nn statement, where $nn = 01, 02, 03, \ldots$, up to the number of variables in the equation. Variables that appear more than once in an equation are assigned the same RCL nn statement.
   (Example: RCL 02 RCL 03 * RCL 04 + RCL 01 -)

The nn in each RCL nn statement must be remembered to initialize SOLVIT later. Each nn determines the position in the display where the corresponding variable name will appear as a label. In this example, $Y$ will be first, followed by SLOPE, $X$, and INTER. Although the order of register assignment can be arbitrary, it seems reasonable (as done here) to assign registers to variables as they appear from left to right in the algebraic form of the equation.

Programming an Equation

Once written in the proper format as described above, an equation is entered into program memory just like any other program. Each RCL nn statement, operator, or special instruction becomes one
program step. More specifically, a good approach to programming an equation is as follows:

1. Press \([\text{\{\text{STO}\} . . }]\). The HP-41 will display PACKING, then the X register. This step packs main memory to make room for the equation and positions the program pointer to an area of program memory where the equation can be entered.

2. Press \([\text{PRGM}]\) to enter Program mode. The HP-41 will display the PRGM annunciator.

3. Enter a name for the equation in the form of a global label statement. Press \([\text{\{\text{LBL}\} \text{ALPHA}\text{name} \text{ALPHA}]}\), where \text{name} is the name to be associated with the equation (up to six characters). The name should be meaningful for the equation.

4. Enter each program step exactly as written in the SOLVIT format described above. If there are not enough program registers, the HP-41 will display PACKING, then TRY AGAIN, as it attempts to free more registers. If you still can't enter program steps, reduce the SIZE or clear key assignments or alarms, then try again to continue. If this fails, clear one or more programs from main memory, then go back to the last line entered and continue.

5. Press \([\text{PRGM}]\) to exit Program mode.

6. Press \([\text{\{\text{STO}\} . . }]\) to pack program memory and to add an END statement to the equation program. Your equation program will remain in main memory until explicitly cleared with the CLP command or a similar operation.

Following this approach for the straight line example will produce the LINE program described in Example 1.

All of the HP-41's functions, including tests and branching, can be used to customize an equation. In addition, SOLVIT provides a special optional feature, described in Equation Program Techniques, that may be useful in some equation programs.

**Initializing SOLVIT**

Before SOLVIT can work with an equation, it must know the equation's name and the name of each variable. The process of providing these items is called initialization, accomplished as follows (examples below are excerpted from Example 1):

1. Start the SOLVIT program. Press \([\text{\{XEQ\} \text{ALPHA}\text{SOLVIT}}\) \text{ALPHA} or press a key in User mode to which SOLVIT has been assigned.
2. At the prompt EQUATION?, key in the name (that is, the
global label) of the equation program in main memory to be
solved and press [R/S]. Do not press [ALPHA] before or
after keying in the equation name. Note: A previously-
initialized equation can be restarted by just pressing [R/S]
at the EQUATION? prompt. Refer to Restarting SOLVIT.
(Example: LINE [R/S])

3. At the prompt NO. OF VARS=?, key in the number of
variables in the equation and press [R/S].
(Example: 4 [R/S])

SOLVIT requires a minimum SIZE of \(2 \cdot (\text{NO. OF VARS}) + 2\). If
the current SIZE is too low, the HP-41 will prompt
SIZE=\(\text{nnn}\), where \(\text{nnn}\) is the minimum SIZE needed. To
increase the SIZE, press [XEQ] [ALPHA] SIZE [ALPHA] \(\text{nnn}\),
then press [R/S] to continue. If the HP-41 displays
PACKING, then TRY AGAIN, clear key assignments or alarms,
then try to increase the SIZE again. If this doesn’t work,
clear one or more programs from main memory, then try again
to initialize SOLVIT, starting at step 1.

4. For each variable in the equation, the HP-41 will prompt
NAME, VAR \(\text{nn}\)?, where \(\text{nn} = 1, 2, 3, \ldots \), up to NO. OF VARS.
For each prompt, key in the full name (up to six characters)
of the variable corresponding to the RCL \(\text{nn}\) statement in the
equation program and press [R/S]. Do not press [ALPHA]
before or after keying in each variable’s name.
(Example: Y [R/S] SLOPE [R/S] X [R/S] INTER [R/S])

5. After all variable names have been keyed in, the HP-41
will display the equation name as it checks main memory for
the 13 free registers required by the SOLVE function. If
there are not enough free registers, the HP-41 will display
NO ROOM. If possible, reduce the SIZE (but not below the
minimum specified in step 3), clear key assignments or
alarms, then press [R/S] to continue. If this fails, clear
one or more programs from main memory, then restart SOLVIT
as described in Restarting SOLVIT.

6. When SOLVIT has been completely initialized, the first
menu (described below) will be displayed. The
initialization process need not be repeated each time SOLVIT
is used; the data will remain intact until the data
registers used to store parameters for SOLVIT are altered.

SOLVIT is now ready to solve your equation using the techniques
described next.

**Basic Use of SOLVIT**

Each menu used by SOLVIT consists of the first one or two
characters of a variable’s name positioned over one of the
HP-41’s five top row keys. When labelled this way, the top row
DETAILED INSTRUCTIONS

keys are called menu keys, because their use changes with the menu above. Throughout these instructions, | m | means menu key m, the top row key under the character(s) m. If the equation has more than five variables, the menu key to the right of the last variable in the menu is labelled with | tt |, indicating that pressing it will cause the next menu, containing more variable names, to be displayed. When a menu shows the last set of variables, pressing | t? | causes the menu with the first set of variables to be displayed.

For SOLVIT to operate properly, the top row keys (and all other keys you press to use SOLVIT) must not have any User key assignments. If necessary, use ASN to clear assignments from the necessary keys. Refer to your HP-41 Owner's Manual for details.

While using SOLVIT, you can exit User mode temporarily to access the top row key functions. You must enter User mode again before attempting to use a SOLVIT menu.

Solving an equation for any unknown variable with SOLVIT is basically a two-step process (examples below are excerpted from Example 1):

1. Assign all known values to their corresponding variables by keying in the value and pressing the variable's menu key. If necessary, press | t? | one or more times first to display the appropriate menu. To restore the menu after keying in a number (if you need to see which menu key to press), press [R/S]; the appropriate menu key can then be pressed to assign the value.
   (Example: 9.5 | Y | 5 | X | 2 | I |)

2. Press the menu key of the variable for which a solution is desired (the "unknown", or solve variable). The HP-41 will display *WORKING* as it solves for the variable. If found, the solution will be displayed for approximately four seconds, then the menu will be restored. If no solution is found, the HP-41 will display NO SOLUTION.
   (Example: | S |)
Instruction Table for SOLVIT

SOLVIT has many features that expand the basic capability described in Basic Use of SOLVIT. Most of the features are summarized in the Instruction Table below, and all are described in detail afterwards. Remember that while SOLVIT is busy (that is, while the PRGM annunciator is on), you should not press any keys unless you intend to interrupt the program.

<table>
<thead>
<tr>
<th>Instructions</th>
<th>Keystrokes</th>
<th>Display</th>
</tr>
</thead>
<tbody>
<tr>
<td>Set display format</td>
<td>[ ] [FIX] n</td>
<td>X register</td>
</tr>
<tr>
<td></td>
<td>or</td>
<td></td>
</tr>
<tr>
<td></td>
<td>[ ] [SCI] n</td>
<td></td>
</tr>
<tr>
<td></td>
<td>or</td>
<td></td>
</tr>
<tr>
<td></td>
<td>[ ] [ENG] n</td>
<td></td>
</tr>
<tr>
<td>Set all variables to value</td>
<td>value [XEQ] [J]</td>
<td>menu</td>
</tr>
<tr>
<td>Clear (set to zero) all variables</td>
<td>[XEQ] [J]</td>
<td>menu</td>
</tr>
<tr>
<td>Restore current menu</td>
<td>[R/S]</td>
<td>menu</td>
</tr>
<tr>
<td></td>
<td>or</td>
<td></td>
</tr>
<tr>
<td></td>
<td>[J]</td>
<td>menu</td>
</tr>
<tr>
<td>Display next menu</td>
<td>1 1 1</td>
<td>next menu</td>
</tr>
<tr>
<td>Assign value to variable m</td>
<td>value 1 m 1</td>
<td>menu</td>
</tr>
<tr>
<td>View full name and value of</td>
<td>[ ] 1 m 1</td>
<td>varnam=value</td>
</tr>
<tr>
<td>variable m</td>
<td></td>
<td>menu</td>
</tr>
<tr>
<td>Recall value of variable m</td>
<td>[XEQ] 1 m 1</td>
<td>value</td>
</tr>
<tr>
<td></td>
<td>or</td>
<td></td>
</tr>
<tr>
<td></td>
<td>[RCL] 1 m 1</td>
<td>value</td>
</tr>
<tr>
<td>View/Recall value of last</td>
<td>[&lt;]</td>
<td>value</td>
</tr>
<tr>
<td>solve variable</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Solve for variable m</td>
<td>1 m 1</td>
<td>^WORKING^ varnam=value</td>
</tr>
<tr>
<td></td>
<td>or</td>
<td>menu</td>
</tr>
<tr>
<td></td>
<td>^WORKING^ NO SOLUTION</td>
<td></td>
</tr>
<tr>
<td></td>
<td>varnam=NO SOL</td>
<td></td>
</tr>
<tr>
<td></td>
<td>menu</td>
<td></td>
</tr>
</tbody>
</table>

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Menu Format

SOLVIT works with variable names of up to six characters. To create a menu of up to five variables, each variable name is abbreviated to its first one or two characters, depending on the variable's position in the display. SOLVIT builds and displays a menu in the format

\[ aa \ b \ cc \ d \ ee \]

where

\[ aa, \ cc, \text{ and } ee = \text{the first two characters of the first, third, and fifth variables in the menu, and} \]

\[ b \text{ and } d = \text{the first characters of the second and fourth variables in the menu.} \]

Each variable is represented in the menu by the first one or two characters in its name. This display restriction is necessary because of the HP-41's 12-character display.

As an example, the figure below shows the HP-41 display and top row keys corresponding to the menu for an equation with the variables DISTAN, VELOC, TIME, ACCEL, and COLOR.

If the equation has more than five variables, the menu key to the right of the last variable in the menu is defined as \[ | tt | \], indicating that pressing it will cause the next menu, containing more variables, to be displayed.

Any menu keys not currently assigned to variables are left blank in the menu display.

Setting the Display Format

SOLVIT displays all results using the current display format (for example, FIX 2). You can change the display format any time.

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a menu is displayed. To restore the menu after changing the display format, press [R/S].

**Setting or Clearing all Variables**

All variables of an equation can be set simultaneously to any one value by keying in the desired value and pressing [XEQ] [J]. Alternatively, all variables can be cleared (set to zero) by just pressing [XEQ] [J].

SOLVIT distinguishes between the two options by noting whether or not you key in a number before pressing [XEQ] [J].

**Restoring the Menu**

The current menu can be restored after keying in a number (or any time the display has been cleared) by pressing [R/S]. This does not affect subsequent operation of SOLVIT.

Occasionally (for example, when the ALPHA register has been changed or the program pointer has been repositioned), pressing [R/S] will not restore the menu. When this happens, press [J] to recreate the menu and then display it. If this fails, refer to Restarting SOLVIT.

**Displaying the Next Menu**

When an equation contains six or more variables, SOLVIT can't display a menu containing them all. Instead, SOLVIT creates multiple menus, each displaying up to four menu key labels and the label \( \text{II} \). The order in which labels are displayed in the menu structure corresponds to the order in which variable names are keyed in when SOLVIT is initialized. Pressing menu key \( \text{II} \) causes the next menu, containing the next set of menu key labels, to be displayed. At the last menu, pressing \( \text{II} \) causes the first set of labels to be displayed. All unlabelled (blank) menu keys operate like \( \text{II} \).

**Assigning Values to Variables**

To assign a value to a variable, key in the desired value and press the menu key corresponding to that variable. Alternatively, you can calculate the value for a variable (for example, \( 45 \text{ SIN} \)) and then press its menu key. However, SOLVIT won't recognize that you want to assign the value unless a number has been keyed in. If necessary, perform some operation like [1] [*] before pressing the menu key.

**Recalling Values of Variables**

To display the full name of a variable and its value, press [ ]
and then the variable's menu key. The HP-41 will display the variable's full name (\texttt{vnam}) and current value (\texttt{valve}), according to the display format, in the format

\texttt{vnam=valve}

After approximately four seconds, the menu will be restored.

To recall to the X register the value of a variable, press \texttt{[XEQ]} and then the variable's menu key. If there are five or fewer variables in the equation, a quicker alternative is to press \texttt{[RCL]} and then the variable's menu key.

To view the current value of the variable last solved for (which is always in the X register when a menu is first displayed), press \texttt{[<-]}. If no variable has been solved for yet, the X register will contain the equation control value (see Data Register Usage).

**Solving for a Variable**

To solve the equation for a specific variable (the solve variable), press the variable's menu key without first keying in a number. The HP-41 will display \texttt{*WORKING*} for up to several minutes as it solves the equation. If a solution is found, the solve variable's full name (\texttt{vnam}) and the solution value (\texttt{valve}) will be displayed, according to the display format, in the format

\texttt{vnam=valve}

After approximately four seconds, the menu will be restored. The solution value is automatically assigned to the solve variable.

Optionally, an initial estimate for the solution can be supplied by assigning the desired initial estimate to the solve variable before solving (see Assigning Values to Variables). SOLVIT always uses the current value of the solve variable as the initial estimate of its solution, with one exception: if the current value is ALPHA data, SOLVIT uses zero as the initial estimate.

The solution SOLVIT calculates is one of perhaps several. If you suspect there may be other solutions, you can assign a new initial estimate and solve for the desired variable again.

**When No Solution Is Found**

For some complicated equations or bad initial estimates, SOLVIT may not be able to find a solution to the equation. When this happens, the HP-41 will display \texttt{NO SOLUTION}. After approximately one second, the HP-41 will indicate that no solution was found for variable \texttt{vnam} by displaying \texttt{vnam=NO SOL}. After
approximately four seconds, the menu will be restored. The ALPHA
data value "NO SOL" will be assigned to solve variable varnam.

It may be possible to find a solution to the equation by choosing
another initial estimate. Refer to Solving for a Variable.

Interrupting SOLVIT

During the time that SOLVIT is attempting to solve for a variable
(while «WORKING» is displayed), SOLVIT can be stopped by pressing
[R/S]. Because SOLVIT repeatedly executes the equation program,
it is possible that the program pointer may not be in SOLVIT
when [R/S] is pressed. Therefore, restoring the menu after
interrupting SOLVIT can be a one- or two-step operation. First,
press [J] to attempt to restore the menu. If the menu is not
restored, refer to Restarting SOLVIT, described next.

Restarting SOLVIT

If the SOLVIT program has been exited temporarily to do other
calculations, you may resume work with the same equation without
reinitializing SOLVIT, but only if the data registers used to
store parameters for SOLVIT have not been altered. To restart
SOLVIT, start SOLVIT as instructed in Initializing SOLVIT, but
instead of keying in the equation name at the EQUATION? prompt,
just press [R/S]. SOLVIT will continue at step 5 of the
initialization process.
Example 1

Refer to the INTRODUCTION and DETAILED INSTRUCTIONS FOR SOLVIT, where this example is examined in detail.

Example 2

The Problem: If a ball is thrown from a balcony 10 meters above the ground with an upward velocity of 50 meters per second, how long will it take the ball to hit the ground?

The Solution: The equation describing the vertical motion of the ball is

\[ x = v_0 \cdot t - 0.5 \cdot g \cdot t^2 + x_0 \]

where

- \( x \) = the height of the ball,
- \( v_0 \) = the initial velocity of the ball,
- \( t \) = the time the ball spends traveling in each direction,
- \( g \) = the acceleration due to gravity (9.8 m/s^2),
- \( x_0 \) = the initial height of the ball.

Since \( g \) is a constant, this equation really has only four variables.

Programming:

Enter the equation program MOTION, below. Note that the expression \( 0.5 \cdot g \cdot t^2 \) has been simplified to \( 4.9 \cdot t^2 \).

\[
\begin{align*}
01 & \text{LBL "MOTION"} \\
02 & \text{RCL 01} \\
03 & \text{RCL 02} \\
04 & \ast \\
05 & 4.9 \\
06 & \text{RCL 02} \\
07 & \text{X} \cdot \text{X} \\
08 & \ast \\
09 & \text{-} \\
10 & \text{RCL 03} \\
11 & + \\
12 & \text{RCL 04} \\
13 & \text{-} \\
14 & \text{END}
\end{align*}
\]

In the equation program, register numbers for \( v_0 \) and \( x_0 \) have been chosen to insure both characters in their names will appear in the menu. This is a justifiable transgression from the order guideline suggested in Rewriting an Equation in the SOLVIT Format.
### Initialization:

**Keystrokes** | **Display**
---|---
[ ] [FIX] 2 | X register
[ ] [XEQ] [ALPHA] SOLVIT [ALPHA] | EQUATION?
MOTION [R/S] | NO. OF VARS=7
4 [R/S] | NAME, VAR 17
V₀ [R/S] | NAME, VAR 27
T [R/S] | NAME, VAR 37
X₀ [R/S] | NAME, VAR 47
X [R/S] | MOTION

### Solving:

A solution for \( T \) is desired when the ball reaches the ground \((X=0)\). The initial velocity and height are given in the problem statement.

To illustrate a point, the variables in the equation will be cleared by \([XEQ][J]\) before assigning values and solving for \( T \). After clearing all variables, it isn't necessary to assign a value to \( X \), since zero is the desired value.

**Keystrokes** | **Display**
---|---
[ ] [XEQ][J] | V₀ T X₀ X
50 | V₀ T X₀ X
10 | V₀ T X₀ X
1 | T | *WORKING*
1 | T | T=10.40
1 | T | V₀ T X₀ X

This obviously isn't the value for \( T \) expected. However, the "error" is explained easily. Pressing \([XEQ][J]\) cleared all variables. Therefore, when \( T \) was solved for, its initial estimate was zero, which caused SOLVIT to find a solution, near zero, that corresponds to the time it takes for ball to go from the ground to the balcony with an initial velocity greater than 50 m/s. The positive solution for \( T \) can be found by choosing a better initial estimate:

**Keystrokes** | **Display**
---|---
10 | V₀ T X₀ X
1 | T | *WORKING*
1 | T | T=10.40
1 | T | V₀ T X₀ X

The ball remains in the air for 10.4 seconds.
How SOLVIT Solves It

The computation power of SOLVIT is derived from the HP-41 Advantage Module function SOLVE. Like SOLVIT, SOLVE repeatedly executes a program until it finds a value that causes the program to return zero, thereby solving for a variable in the equation. But SOLVE is limited because it can only solve an equation containing one variable; every other number within the equation program must be a constant.

SOLVIT extends the power of SOLVE in two major ways:

- SOLVIT solves an equation program containing any number of variables.
- SOLVIT provides a very simple method for inputting data and getting results.

SOLVIT leverages the power of SOLVE by having SOLVE always solve the same special program, called SURTN. SURTN takes the current estimate passed by each iteration of SOLVE and stores it in the data register corresponding to the solve variable. Then SURTN passes execution to the equation program, which really treats all other variables as constants, since their data registers aren't changed. However, since SURTN updates the solve variable's data register with each iteration, SOLVE eventually finds a value in that data register that solves the equation -- and therefore is the value of the solve variable.

For a comprehensive description of the algorithm used by SOLVE to calculate a solution, refer to the HP-15C Advanced Functions Handbook (Hewlett-Packard, 1982).

Equation Program Techniques

- SOLVIT sets user flag 05 before executing the equation program the first time. Since the equation program is usually executed many times (while *WORKING* is displayed) before a solution is found, this feature makes possible special procedures within an equation program to handle unique circumstances that may arise only occasionally. To use this option in an equation program, follow these guidelines:

  - Include a flag 05 test to check if the special condition is in effect.
  - If the special condition is in effect, perform any necessary steps based on the condition.
When the special condition has been resolved, clear flag 05 to speed subsequent equation program execution.

For example, suppose you would like the LINE equation program described in Example 1 to insure that SLOPE input is never zero; instead, a default slope of 1 is desired. The LINE program could be changed to check the slope every time it's executed, replacing zero with 1 as necessary, but this method has two problems:

1. In most cases, you will assign a non-zero slope. Therefore, the LINE program will usually be wasting time checking if the slope is zero.
2. If you are solving for SLOPE, the equation program will continually thwart SOLVIT's efforts to attempt a solution of zero slope.

By adapting the LINE program to check for a zero slope only once, when the equation program is first executed, both these problems are eliminated. By this method, the beginning of the LINE program can be changed to the following:

```
01 LBL "LINE"
02 FC?C 05
03 GTO 00
04 RCL 02
05 X=0?
06 1
07 STO 02
08 LBL 00
```

If you would like to observe how SOLVIT converges on a solution for an equation, insert a VIEW X instruction at the beginning of the equation program. This will cause the HP-41 to display the current estimate of the solve variable with each execution of the equation program.

Almost any HP-41, module, or peripheral function can be included in an equation program. The exceptions are the functions AK, PASN, PSIZE, all card reader functions, and any other functions that alter the HP-41's size, key assignments, or alarms.
**Flag Usage**

SOLVIT uses two user flags and two system flags during its operation, as described in the following table.

### SOLVIT Flag Usage

<table>
<thead>
<tr>
<th>Flag</th>
<th>Use</th>
</tr>
</thead>
</table>
| 05   | Used during menu formatting.  
      | Set before solving for a variable.  
      | May be left set by SOLVIT. |
| 06   | Set if NO. OF VARS is greater than five; cleared otherwise. |
| 21   | Cleared to display (but not print) *WORKING*, then matched to flag 55 (printer present). |
| 27   | Set to enter User mode. |

**Data Register Usage**

For an equation with nn variables, SOLVIT uses data registers 00 through (2 * nn) + 1. Thus, SOLVIT requires a SIZE of at least (2 * nn) + 2. SOLVIT uses data registers as described in the table below.

### SOLVIT Data Register Usage

<table>
<thead>
<tr>
<th>Data Register</th>
<th>Use</th>
</tr>
</thead>
</table>
| 00           | equation control value iiii.nnnn.nnnss | iiii = index to current menu number (1, 2, ...),  
              | value of variable 1                       |
| 01           | value of variable 2                       |
| ...          | ...                                        |
| nn-1         | value of variable nn-1                    |
| nn           | value of variable nn                      |
| nn+1         | name of variable 1                        |
| nn+2         | name of variable 2                        |
| ...          | ...                                        |
| 2*nn-1       | name of variable nn-1                     |
| 2*nn         | name of variable nn                       |
| 2*nn+1       | name of equation program                  |

nnn = number of variables in equation, and  
ss = register number of last solve variable, or zero.
Stack Register Usage

Many of SOLVIT's features manipulate values in the stack. The following table describes the state of the stack after each action indicated.

<table>
<thead>
<tr>
<th>Keystrokes</th>
<th>Stack Registers After +</th>
</tr>
</thead>
<tbody>
<tr>
<td>value [XEQ] [J] to set all variables to value</td>
<td>X - Y - -</td>
</tr>
<tr>
<td>[XEQ] [J] to clear variables</td>
<td>- - Y - -</td>
</tr>
<tr>
<td>[R/S] to restore menu</td>
<td>X Y Z T L</td>
</tr>
<tr>
<td>[J] to restore menu</td>
<td>- - - - -</td>
</tr>
<tr>
<td>1 [I] to display next menu</td>
<td>- - - - -</td>
</tr>
<tr>
<td>1 [m] 1 to assign value to variable</td>
<td>X - - - -</td>
</tr>
<tr>
<td>[I] [m] 1 to view name and value of variable</td>
<td>- - - - -</td>
</tr>
<tr>
<td>[XEQ] 1 [m] 1 to recall value (v) of variable</td>
<td>v X - - -</td>
</tr>
<tr>
<td>[RCL] 1 [m] 1 to recall value (v) of variable</td>
<td>v X Y Z L</td>
</tr>
<tr>
<td>[&lt;] 1 to view/recall value of last solve variable</td>
<td>X Y Z T L</td>
</tr>
<tr>
<td>1 [m] 1 to solve for variable</td>
<td>- - - - -</td>
</tr>
</tbody>
</table>

* The stack register name entries in the table indicate where the contents of each register are located after the operation. "-" indicates the contents are not meaningful.
APPENDIX: STORING AND RECALLING EQUATIONS

When using SOLVIT with a number of different equations, the advantage of saving the equation program and its menu structure as one unit becomes apparent. Programs and functions already exist to conveniently store programs and data registers in extended memory or on mass storage (Beers and Beers, 1985), but not to link the equation program with its menu structure (a new concept motivated by the SOLVIT menu interface).

The programs explained below provide the capability to store and recall, within the SOLVIT environment, equation programs and their menu structure. Each program works by accessing two similarly-named files in extended memory or mass storage. To use these programs, all you need in addition to the basic SOLVIT essentials is the appropriate module (either Extended Memory or HP-IL) to access the storage medium. (RCLMS requires both modules.) Program barcode for these programs is provided in the PROGRAM BARCODE section.

STOXM and STOMS (STOre equation, eXtended Memory/Mass Storage)

STOXM and STOMS can be executed any time a SOLVIT menu is displayed (or outside of SOLVIT, if no data registers have been altered). STOXM and STOMS are non-prompting programs. When either is executed, the HP-41 will display *WORKING* as STOXM or STOMS takes data directly from the data registers and creates two files in extended memory or mass storage:

- A data file, containing the equation menu structure, with the name ?name, where name is the name of the equation program.

- A program file, containing the equation program, with the same name as the equation program.

If either file already exists, it is replaced.

When STOXM or STOMS is completed, SOLVIT is restarted automatically at step 5 of the initialization process.

RCLXM and RCLMS (ReCall eQuation, eXtended Memory/Mass Storage)

RCLXM and RCLMS can be executed when a SOLVIT menu is displayed or outside of SOLVIT in order to initialize and start SOLVIT. At the prompt, EQUATION?, key in the name of the equation you wish to recall and press [R/S]. If you can't remember the name of the desired equation, just press [R/S], and the HP-41 will display a directory of extended memory or mass storage, then prompt again for the equation name. If the directory listing is interrupted by [R/S], the HP-41 will prompt R/S, indicating that you should
press [R/S] to prompt again for the equation name. The HP-41 will display *WORKING* as RCLXM or RCLMS recalls information from extended memory or mass storage in the same two files stored by STOXM or STOMS. If a program by the same name as the equation program already exists in main memory, it is not replaced.

When RCLXM or RCLMS is completed, SOLVIT is started or restarted automatically at step 5 of the initialization process, ready to solve the selected equation.
REFERENCES


Start of SOLVIT.
Skip EQUATION? prompt if executed from another program.
Prompt for equation program name.
Skip NO. OF VARS=? prompt if EQUATION? prompt not answered.
Prompt for number of variables in equation.
Check for minimum SIZE.
Calculate and store equation control value.
Prompt for full name of each variable in equation.
Initialize user and system flags.
Check for 13 free registers required by SOLVE. SIRTN is a no-op program in the HP-41 Advantage Module.
[J]: Initialize values to build menu.
Add | %t | for more than five variables.
Display menu.
136¢LBL 10
RCL 00 1 E3 * INT
1 E3 / X<>Y FC?C 22
CLX

146¢LBL 08
STO IND Y ISG Y GTO 08
GTO 15

151¢LBL A
0 GTO 09

154¢LBL B
1 GTO 09

157¢LBL C
2 GTO 09

160¢LBL D
3 GTO 09

163¢LBL E
FS? 06 GTO 10 4

167¢LBL 09
RCL 00 INT + RCL 00
FRG 1 E3 * INT X<>Y?
GTO 10 FC?C 22 GTO 11
RCL Z STO IND Z GTO 15

183¢LBL 10
FC? 06 GTO 15 4
ST+ 00 RCL 00 INT
LASTX FRG 1 E3 * INT
X<>Y X<=Y? GTO J
RCL 00 FRG 1 +
STO 00 GTO J

204¢LBL 11
CF 21 "*WORKING*"
AVIEW FS? 55 SF 21
SF 05 RCL IND Y RCL 2
1 E3 / RCL 00 1 E3 *
INT + 1 E3 / STO 00
RDIN SIGN X#0? LASTX
ENTER "SVRTN" SOLVE
GTO 12 "NO SOLUTION"
AVIEW ATO X

234¢LBL 12
RCL 00 FRG 1 E3 *
FRG LASTX FRG 1 E3 *
+ CLA ARCL IND X "=*
ARCL Y AVIEW LASTX
RCL Z STO IND Y GTO J

[XEQ] [J]: Initialize values to set or
clear all variables.

Set or clear all variables.

I n i t : Initialize values to set or
solve for variable m, or display next
menu.

Determine whether to display next menu
(GTO 10), solve (GTO 11), or set a
variable.

Initialize values to display next menu.

Solve for a variable.

Update equation control value to contain
solve variable register number.

Solve SURTN, which executes equation
program.

Display solution.
\[
254\text{LBL a} \\
\text{0 GTO 13}
\]

\[
257\text{LBL b} \\
\text{1 GTO 13}
\]

\[
260\text{LBL c} \\
\text{2 GTO 13} \quad [\text{m}] \; \text{l\: Initialize values to display full name and value of variable m.}
\]

\[
263\text{LBL d} \\
\text{3 GTO 13}
\]

\[
266\text{LBL e} \\
\text{FS? 06 GTO 15 4}
\]

\[
270\text{LBL 13} \\
\text{RCL 00 INT LASTX FRC 1 E3 * INT X<> Y + STO Z XY? LASTX 2 * X<>Y? GTO 15 CLA ARCL IND Y "r=" ARCL IND Z AVIEW GTO J}
\]

\[
294\text{LBL 01} \\
\text{0 GTO 14}
\]

\[
297\text{LBL 02} \\
\text{1 GTO 14}
\]

\[
300\text{LBL 03} \\
\text{2 GTO 14} \quad [\text{XEQ}] \; \text{l\: Initialize values to recall variable m.}
\]

\[
303\text{LBL 04} \\
\text{3 GTO 14}
\]

\[
306\text{LBL 05} \\
\text{FS? 06 GTO 15 4}
\]

\[
310\text{LBL 14} \\
\text{RCL 00 INT + RCL 00 FRC 1 E3 * INT X<>Y? GTO 15 RDW RDW RCL IND T GTO 15}
\]

\[
325\text{LBL "SVRTN"} \\
\text{RCL 00 FRC 1 E3 * INT LASTX FRC 1 E3 * XY? 2 * 1 + RCL IND X X<>Y Z RT STO IND Y GTO IND T END}
\]

\[
\text{HP-41 SOLVIT} \; \text{- 25 -} \; \text{HP-41 SOLVIT}
\]
HP-41 Program Listing: STOXM, STOMS, RCLXM, RCLMS

01+LBL "STOXM"
SF 06 GTO 00

Start of STOXM.

04+LBL "STOMS"
CF 06

Start of STOMS.

06+LBL 00
XEQ 05 2 RCL 00 FRC
1 E3 * INT * ISG X
AOFF "?" ARCL IND X
SF 25 FS? 06 PURFL
FC? 06 PURGE FC?C 25
XEQ 05 "?" ARCL IND X
LASTX 2 + FS? 06
CRFLD FC? 06 CREATE 0
FS? 06 SAVERX FC? 06
SEEKR FC? 06 WRTXR
RDN BYE X XOY 1 E3
/ + FS? 06 SAVERX
FC? 06 WRTXR ATOX
FS? 06 SAVEP FC? 06
WRTP FC?C 06 VERIFY
GTO 15

Build data file name ?name.

Purge existing data file.

Create data file.

Store equation control value.

Store variable and equation program names.

Store equation program.

Restart SOLVIT.

60+LBL "RCLXM"
SF 06 GTO 01

Start of RCLXM.

63+LBL "RCLMS"
CF 06

Start of RCLMS.

65+LBL 01
CF 23 "EQUATION?" AON
PROMPT AOFF FS?C 23
GTO 02 "R/S" ATO X
FS? 06 EMDIR FC? 06
DIR GTO 01

Prompt for equation program name.

Display extended memory or mass storage directory if EQUATION? prompt not answered.
88+LBL 02
ASTO X XEQ 05 "?"
ARCL X CLX FS? 06
SEEKPTA FC? 06 SEEKR
FS? 06 GETRX FC? 06
READRX ATOX 2 RCL 00
FRC 1 E3 * INT *
LASTX 1 + X<Y 2 +
ASTO Z XROM "SZ?"
FC?C 25 PROMPT FC? 50
XEQ 05 R÷ 1 E3 / +
FS? 06 GETRX FC? 06
READRX CLA ARCL Y 11
SF 25 PASH FS?C 25
GTO 03 XEQ 05 CLA
ARCL Z FS? 06 GETSUB
FC? 06 READSUB

136+LBL 03
CF 06 CLA PASH

140+LBL 15
GTO "SOLVIT"

142+LBL 05
"*WORKING*" CF 21
AVIEW FS? 55 SF 21
END

Build data file name ?name.
Recall equation control value.
Check for minimum SIZE.
Recall variable and equation program names.
Check for existing equation program.
Recall equation program, if necessary.
Clear key assignment made by check for existing equation program.
Restart SOLVIT.
Display, but not print, *WORKING*.
SOLVIT
PROGRAM

ROW 1: LINES 1-3

ROW 2: LINES 3-6

ROW 3: LINES 7-11

ROW 4: LINES 11-15

ROW 5: LINES 16-25

ROW 6: LINES 25-33

ROW 7: LINES 34-36

ROW 8: LINES 36-42

ROW 9: LINES 43-51

ROW 10: LINES 51-61

ROW 11: LINES 61-66

ROW 12: LINES 67-77
SOLVIT PROGRAM

ROW 25: LINES 164-173

ROW 26: LINES 174-181

ROW 27: LINES 182-188

ROW 28: LINES 189-197

ROW 29: LINES 198-206

ROW 30: LINES 206-209

ROW 31: LINES 209-216

ROW 32: LINES 216-225

ROW 33: LINES 226-231

ROW 34: LINES 231-233

ROW 35: LINES 233-242

ROW 36: LINES 242-250
<table>
<thead>
<tr>
<th>Row</th>
<th>Lines</th>
</tr>
</thead>
<tbody>
<tr>
<td>13</td>
<td>67-73</td>
</tr>
<tr>
<td>14</td>
<td>74-80</td>
</tr>
<tr>
<td>15</td>
<td>81-87</td>
</tr>
<tr>
<td>16</td>
<td>87-93</td>
</tr>
<tr>
<td>17</td>
<td>94-103</td>
</tr>
<tr>
<td>18</td>
<td>104-112</td>
</tr>
<tr>
<td>19</td>
<td>113-119</td>
</tr>
<tr>
<td>20</td>
<td>120-126</td>
</tr>
<tr>
<td>21</td>
<td>127-133</td>
</tr>
<tr>
<td>22</td>
<td>133-140</td>
</tr>
<tr>
<td>23</td>
<td>141-143</td>
</tr>
<tr>
<td>24</td>
<td>143-147</td>
</tr>
</tbody>
</table>
STOXM
PROGRAM

ROW 25: LINES 147-148