51898

Distr.
LIMITED

E/CN.14/CART/309
19 October 1972

Original: ENGLISH

UNITED NATIONS

ECONOMIC AND SOCIAL COUNCIL

ECONOMIC COMMISSION FOR AFRICA

Third Regional Cartographic Conference
for Africa

Addis Ababa (Ethiopia) 30 October - 10 November 1972
Provisional agenda item 7 (a)

THE PROGRAMMABLE CALCULATOR AND THE GEODESIST*

Submitted by the Government of the United States of America

The geodesist has, in past years, developed formulas of classical geodesy whereby logarithmic and trigonometric function tables were the main feature in computational techniques. With today's advance technology in electronics, the scientist has been given the opportunity to eliminate table look up of various kinds, and bridge the gap between large computers with the programmable calculator. The geodesist no longer needs to use specialized tables or even a slide rule to check computations to see if they are within specifications. The accuracy and speed of the programmable calculator allows the exact formulas to be programmed instead of algorithms, therefore more time can be spent analyzing the problem and if necessary, solve the problem from a different approach.

The programmable calculator is the modern tool of computation and its limitations are almost unlimited compared to the old system of computing. To compare the programmable calculator with the large computer would be to take a segmented program for the programmable calculator and program it to be a one-step operation for the large computer. The large computer is designed for masses of data manipulation on a large scale, but the programmable calculator is shortening the gap by providing modular devices, such as mathematical function blocks, magnetic tape cassettes, plotters, paper tape and marked-sensed card readers, typewriters, digitizer, and other interfacing capabilities.

The National Geodetic Survey has developed a library of programs for the Hewlett-Packard programmable calculator. These programs were designed to help the geodesist solve many problems without using the regular desk calculator or large computer. The following list of programs indicated by the ** are being translated from the Hewlett-Packard (H-P) 9100 to the H-P 9810. All the programs in the library are available from National Geodetic Survey, Rockville, Md., 20852 except for the programs being converted.

---

* By Robert D. Cappell, Geodesist, National Geodetic Survey.

Geodetic Surveying Program Library
for Programmable Desktop Calculators

* Hewlett-Packard 9100A
B Hewlett-Packard 9100B
** Hewlett-Packard 9810

*	70037	Solution of 2-4 Equations.
**	74004	3 Point Fix (Plane Co-ordinates).
*	74040	Direct Geographic Position Computation.
*	74040A	Direct Geographic Position Computation Short Lines.
*	74041	Inverse Geographic Position Computation.
*	74041A	Inverses from a Fixed Point.
B**	74042	Lambert - Geographic Position to Plane Co-ordinates.
B**	74043	Lambert - Plane Co-ordinates to Geographic Position.
**	74044	Transverse Mercator - Geographic Position to Plane Co-ordinates.
**	74045	Transverse Mercator - Plane Co-ordinates to Geographic Position.
*	74046	Alaska Zone 1 - Geographic Position to Plane Co-ordinates.
*	74047	Alaska Zone 1 - Plane Co-ordinates to Geographic Position.
*	74048	Alaska Zone 2-9 - Geographic Position to Plane Co-ordinates.
*	74049	Alaska Zone 2-9 - Plane Co-ordinates to Geographic Position.
B*	74050	Local Co-ordinates to State Co-ordinates.
*	74051	Plane Co-ordinate Inverse with 2nd Term.
*	74052	Plane Co-ordinate Traverse - Loop Projection.
*	74053	Lambert Grid Azimuth Computation.
*	74054	Transverse Mercator Grid Azimuth Computation.
*	74055	Preliminary Determination of Geodimeter Distance and Difference Between Sides of △'s Composing Diamond Figures in Transcontinental Traverse.

**	74056	Geodimeter Measurement Reduction.
*	74057	Tellurometer and Electro-Tape Reduction.
*	74058	Astronomical Azimuth - Direction Method.
**	74059	Elevations from Reciprocal and Non-Reciprocal Vertical Angles Using Slope and Geodetic Distance Respectively.
**	74060	Triangle Computations.
**	74061	Side and Length Equations.
*	74062	Observation Equations for Direction, Azimuth, and Length.
*	74063	Intersection Adjustment from Predetermined Coefficients.
*	74064	Standard Error of Observations.
*	74065	Andoyer-Lambert Inverse Position Computation.
*	74066	Helmert's Direct Geographic Position Computation.
**	74067	Helmert's Inverse Geographic Position Computation.
*	74068	Transformation of Rectangular Space Co-ordinates.
*	74069	Polyconic Projection.
*	74070	Strain Ellipses.
*	74071	Laplace Azimuth.
*	74072	UTM GP to PC.
*	74073	UTM PC to GP.
*	74074	Meridional Arc Constants - A, B, C, & D.
*	74075	Error Ellipse Computation.
B**	74076	Hirvonen - Foot Point Formula - Direct Geographic Position Computation.
B**	74077	Hirvonen - Foot Point Formula - Inverse Geographic Position Computation.
*	74078	Tape Correction - Two Point Support - Table.
*	74079	Sun Azimuth Computation.

Programs numbered 74042-74049 and 74054 are designed for the USA State Grid Co-ordinate System. The programs are formulated from Special Publication 62-4.

Program 74060, Triangle Computations, provides for the following possible solution:

1. Solution of a triangle given the three observed angles and the side opposite the first vertex-angles given in clockwise order - computes the other two sides using the law of sines.

2. Solution of a triangle given any two sides and the included angle.

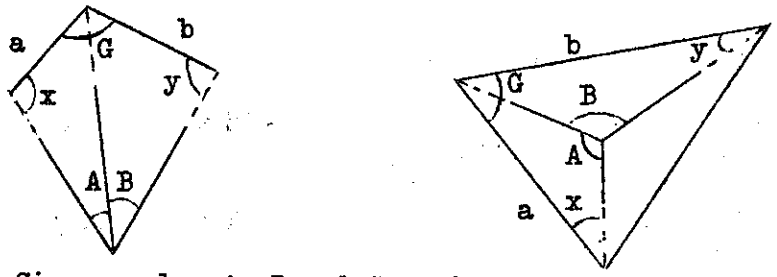
3. Solution of a triangle given three sides. Plane or spherical using law of cosines or tan 1/2 angle formulae.

4. Oblique triangle computation, given two sides and the angles opposite using the law of cosines which projects the two sides onto the third side.

5. The Eccentric station triangle computation or two sides and an angle, wherein a vertex has an angle observed at and a distance to second vertex, and from this vertex to the third point (vertex) the distance given. The angle computed will be the angle opposite the first distance given.

6. A version of number 1 above has been developed for intersection stations. The angle of vertex 1 is not given but concluded. Since the other angles are observed - plane angles computation method is used - the spherical excess is computed, and angles are reduced for the computation.

7. The three point triangle computation involves the general case where one station is occupied and three known points are observed. The distance between these known points and the angle formed at the known intersection is given. The angles computed are illustrated in the following.



Given angles A, B and G, and distances a and b computes angles X and y.

The majority of the triangle computations given above take in account the spherical excess and use plane angle triangle computation since angles used are co puted from observed dir ctions to the different points (vertecies).

The H-P 9810 options used are 111 storage registers, 2036 program steps, printer alpha, math and typewriter control blocks. The programs being converted have a restriction of 500 program steps excluding the program steps required to operate the typewriter and any other peripheral unit that may be used. The conversion or direct translation of a H-P 9100 program to the H-P 9810 is very simple. The major difference is in the storage register names that can be equated very easily. The only known problem that is inherent in the 9810 is with the math function block and the square root of the x register; caution should be taken in programming to save the contents of the z register. In translating, this may be a problem. The following subroutine has been developed and used in the 9810 to save and retrieve the contents of the z register:

ØØØØ	GTO	44	ØØ1Ø	Ø	ØØ
ØØØ1	1	Ø1	ØØ11	GTO	44
ØØØ2	9	11	ØØ12	1	Ø1
ØØØ3	RUP	22	ØØ13	6	Ø6
ØØØ4	IFG	43	ØØ14	XFR	67
ØØØ5	Ø	ØØ	ØØ15	Ø	ØØ
ØØØ6	Ø	ØØ	ØØ16	RUP	22
ØØØ7	1	Ø1	ØØ17	RUP	22
ØØØ8	4	Ø4	ØØ18	S/R	77
ØØØ9	XTO	23			

Subroutine labeled 3 is the starting address of the subroutine (address number 3). To call for the value of z to be stored, the instructions would be GTO S/R 3 when the flag is not set (cleared). To return the value previously stored in this case, register Ø was used for the temporary storage, SFL GTO S/R 3 will return the value to the z register. This routine is found very useful when using the math function block or square root functions. In geodetic programs written for the H-P 9100, the z register in many cases was used temporarily when using the mathematical functions several times and in a direct translation of these programs, this subroutine solved the problem.

Universal Transverse Mercator Grid Co-ordinates

The adopted notation is as follows:

Z	Zone number
ϕ	Latitude
λ	Longitude west + and east -
E	Grid Northing
CM	Central Meridian
a_2	Semi-major axis
e_2	Square of first eccentricity
e_1	Square of second eccentricity

$r = a/(1-e^2 \sin \phi)^{\frac{1}{2}}$ Radius of curvature in the prime vertical

S True meridional distance on the spheroid from the equator (meridional arc)

k_o Center scale factor, $k_o = 0.9996$

ϕ' Latitude of the foot of the perpendicular from the point to the Central Meridian

ϕ_r Latitude in radians

The formulae for computing grid co-ordinates from geographic positions are:

$$E = 500{,}000 + E'$$

$$E' = r\, b\, k_o\, (1 + b^2((1-\tan^2\phi + e_1^2 \cos^2\phi)/6 + b^2(5+\tan^2\phi(-18+\tan^2\phi) +2e_1^2(7-36\sin^2\phi))/120))$$

$$b = (P \sin 1'' \cos \phi)\, 10^4$$

$$P = 0.36\, \Delta\lambda^\circ$$

$$\Delta\lambda^\circ = (CM)^\circ - \lambda^\circ$$

$$(CM)^\circ = 183^\circ - 6\, Z$$

$$N = S\, k_o + 1/2\, r\, b\, d\, k_o\, (1 + b^2\, (5-\tan^2\phi + e_1^2 \cos^2\phi\, (9 + 4e_1^2 \cos^2\phi) + b^2\, (61 + \tan^2\phi (-58 + \tan^2\phi) + 30e_1^2\, (9-20\sin^2\phi))/30)/12)$$

$$S = a\,(1-e^2)\,(A\, \phi_r - 1/2\, B \sin 2\phi + 1/4\, C \sin 4\phi - 1/6\, D \sin 6\phi)$$

$$d = (P \sin\phi \sin 1'')\, 10^4$$

$$A = 1 + \frac{3}{4}e^2 + \frac{45}{64}e^4 + \frac{175}{256}e^6 + \frac{11025}{16384}e^8 + \frac{43659}{65536}e^{10}$$

$$B = \frac{3}{4}e^2 + \frac{15}{16}e^4 + \frac{525}{512}e^6 + \frac{2205}{2048}e^8 + \frac{72765}{65536}e^{10}$$

$$C = \frac{15}{64}e^4 + \frac{105}{256}e^6 \quad \frac{2205}{4096}e^8 \quad \frac{10395}{16384}e^{10}$$

$$D = \frac{35}{512}e^6 + \frac{315}{2048}e^8 + \frac{31185}{131072}e^{10}$$

The formulae for computing geographic positions from grid co-ordinates are:

$$\phi^\circ = (\phi')^\circ + 90f^2 \tan\phi'(-(1 + e_1^2 \cos^2\phi') + f^2\, (5 + 3\tan^2\phi' + 3e_1^2\, (2-e_1^2\cos^2\phi')\, (1-2\sin^2\phi') - f^2\, (61 + 45 \tan^2\phi'\, (\tan^2\phi + 2) + e_1^2\, (107 - \sin^2\phi\, (45 \tan^2\phi' + 269)))/30)/12)/\pi$$

$$f = q \times 10^{-6}/r\, k_o$$

$$q = E' \times 10^{-6}$$

$$E' = E - 500{,}000$$

$$r = a/(1-e^2\sin^2\phi')^{\frac{1}{2}}$$

To compute ϕ'

$$(\phi'_n)^\circ = 180^\circ\ N/A\ (1-e^2)\ A\ k_o\ \pi$$

is the first approximation and the formulae for iteration is

$$(\phi'_{n+1})^\circ = 180^\circ\ (N/A\ (1-e^2)\ A\ k_o - (-1/2\ B \sin 2\phi'_n$$

$$+ 1/4\ C \sin 4\phi'_n - 1/6\ D \sin 6\phi'_n)/A)/\pi$$

when $\phi'_{n+1} = \phi_n$ ϕ' will have been computed

$$\lambda^\circ = (CM)^\circ - \Delta\lambda^\circ$$

$$(CM)^\circ = 183^\circ - 6\ Z$$

$$\Delta\lambda^\circ = 180^\circ F\ (1-f^2\ (1+2\tan^2\phi' + e^2\cos^2\phi' - f^2(5$$

$$+ 2e_1^2\ (3 + \sin^2\phi') + 4\tan^2\phi'\ (7 + 6\tan^2\phi'))/20)/6)/\pi \cos\phi'$$

The Universal Transverse Mercator Grid system, where 60 zones of 6 degree bands numbered from the international date line eastward around the world, is used frequently by the geodesist. Programs numbered 74072-74073 provide a solution to the system. A program is provided for transformation of grid co-ordinates to geographic position and geographic position to grid co-ordinates. The grid co-ordinates units are expressed in meters and the referenced ellipsoid may be chosen by substituting the proper ellipsoidal constants.

The H-P 9100 was selected for solving our geodetic problems because it provided automatic trigonometric functions. These trigonometric functions did not have to be programmed and were not available on any other programmable calculator at the time of purchase. The machine has a capacity of 196 programming steps, 19 storage registers; 5 of these registers cannot contain program steps. This means that programming takes away from the storage registers by a factor of 14 steps per register. The H-P 9810 which is being used presently does not have this problem; the programming steps are independent of the storage registers. The H-P 9100 has since, cosine, tangent and their inverse functions, to polar and to rectangular conversion, logarithmic functions, and conditional branching. All these functions have been compressed into an optional math function block for the H-P 9810. The use of the printer was a demand for us, because in some cases the computation had to be documented and preserved.

The documentation of the programs for the Universal Transverse Mercator Grid system for the H-P 9100, and the formulas used follow. It may be noted that A, B, C and D used in computing meridional arc were pre-computed using the proper ellipsoid constant and stored as constants in the program.

HEWLETT-PACKARD
74072
Operating Procedures
Universal Transverse Mercator Grid Co-ordinates
From Geographic Position

1.	Set: Degrees, Fixed, On, Run & Decimal Wheel 5 (x,y,z on printer)	
2.	Insert side A of Card 1	
3.	Press: END, ENTER & CONTINUE	
		Z Temporary
		Y accumulator
4.	Enter: Z zone number in keyboard	Z X keyboard
5.	Touch: CONTINUE	
		Z Z temporary
6.	Display:	$(CM)^{o}$ Y accumulator
		7 X keyboard
7.	Enter: ∅ Deg. in keyboard touch CONTINUE	Deg. Z temporary
8.	∅ Min. in keyboard touch CONTINUE	Min. Y accumulator
9.	∅ Sec. in keyboard touch	Sec. X keyboard
10.	Touch: CONTINUE	
11.	Repeat steps 7-10 for λ	
12.	Insert side B of Card 1	
13.	Press: END, ENTER & CONTINUE	
14.	Insert side A of Card 2	
15.	Press: END, ENTER & CONTINUE	
		Z temporary
16.	Display:	N Y accumulator
		E X keyboard

To change ellipsoid constants

		Constants	Program Step
1.	Press: GO TO DO CONTINUE	1/4C	1d-28
2.	Enter: $-e^2$ touch CONTINUE	1/6D	33-39
3.	Enter: a_2 touch CONTINUE	1/2B	46-54
4.	Enter: e_1 touch CONTINUE	A	62-70

Sample using Clarke 1866 spheroid

Zone No.	14.
(CM)	99.
	7.
	34.
∅	15.
	34.742
	96.
λ	2.
	43.158
	0.
N	3794702.172
E	772075.812

UNIVERSAL TRANSVERSE MERCATOR.
Geographic Position to Grid Coordinates

STEP		KEY	CODE
0	0	CLR	20
	1	4	04
	2	STP	41
	3	UP	27
	4	1	01
	5	8	10
	6	8	03
	7	UP	27
	8	6	06
	9	RUP	22
	a	X	36
	b	RDN	31
	c	-	34
	d	7	07
1	0	PRT	45
	1	PRT	45
	2	YTO	40
	3	d	17
	4	STP	41
	5	UP	27
	6	STP	41
	7	UP	27
	8	STP	41
	9	PRT	45
	a	PRT	45
	b	XTO	23
	c	f	15
	d	6	06
2	0	0	00
	1	DIV	35
	2	RDN	31
	3	+	33
	4	f	15
	5	RUP	22
	6	DIV	35
	7	DIV	35
	8	DN	25
	9	+	33
	a	IFG	43
	b	3	03
	c	9	11
	d	YE	24

STEP		KEY	CODE
3	0	e	12
	1	SFL	54
	2	CLX	37
	3	UP	27
	4	UP	27
	5	7	07
	6	GTO	44
	7	1	01
	8	4	04
	9	d	17
	a	-	34
	b	.	21
	c	3	03
	d	6	06
4	0	CHS	32
	1	X	36
	2	1	01
	3		27
	4	3	03
	5	6	06
	6	0	00
	7	0	00
	8	DIV	35
	9	DN	25
	a	SIN	70
	b	X	36
	c	EEX	26
	d	4	04
5	0	X	36
	1	e	12
	2	SIN	70
	3	UP	27
	4	e	12
	5	COS	73
	6	RUP	22
	7	X	36
	8	YTO	40
	9	b	14
	a	RUP	22
	b	X	36
	c	YTO	40
	d	d	17

STEP		KEY	CODE
6	0	UP	27
	1	X	36
	2	3	03
	3	6	06
	4	X	36
	5	7	07
	6	-	34
	7	C	16
	8	X	36
	9	2	02
	a	X	36
	b	e	12
	c	TAN	71
	d	UP	27
7	0	X	36
	1	1	01
	2	8	10
	3	XEY	30
	4	÷	34
	5	X	36
	6	5	05
	7	-	34
	8	DN	25
	9	+	33
	a	b	14
	b	X	36
	c	X	36
	d	1	01
8	0	2	02
	1	0	00
	2	DIV	35
	3	YTO	40
	4	f	15
	5	e	12
	6	COS	73
	7	DN	27
	8	X	36
	9	C	16
	a	X	36
	b	2	02
	c	STP	41
	d	STP	41

STEP		KEY	CODE
9	0	7	07
	1	9	11
	2	9	11
	3	7	07
	4	5	05
	5	6	06
	6	8	10
	7	6	06
	8	7	07
	9	EEX	26
	a	3	03
	b	CLR	20
	c	9	11
	d	2	02
a	0	0	00
	1	0	00
	2	4	04
	3	6	06
	4	0	00
	5	2	02
	6	8	10
	7	7	07
	8	3	03
	9	6	06
	a	6	06
	b	0	00
	c	0	00
	d	0	00
b	0	0	00
	1	0	00
	2	0	00
	3	0	00
	4	0	00
	5	0	00
	6	0	00
	7	0	00
	8	0	00
	9	0	00
	a	0	00
	b	0	00
	c	0	00
	d	0	00

STEP		KEY	CODE
C	0	5	05
	1	4	04
	2	9	11
	3	4	04
	4	8	10
	5	7	07
	6	4	04
	7	1	01
	8	8	10
	9	6	06
	a	3	03
	b	CLR	20
	c	2	02
	d	9	11
D	0	CLR	20
	1	a	13
	2	STP	41
	3	XTO	23
	4	a	13
	5	UP	27
	6	STP	41
	7	XTO	23
	8	9	11
	9	UP	27
	a	STP	41
	b	XTO	23
	c	c	16
	d	END	46

		x	y	z
0	2	z		
1	8	S	M	D
9	0	-	9	d
	=	-	e^2	
a	o	-	a	d
	=	a		
C	0	-	C	d
	=	e_1^2		

UNIVERSAL TRANSVERSE MERCATOR
Geographic Position to Grid Coordinates

STEP		KEY	CODE	STEP		KEY	CODE	STEP		KEY	CODE	STEP		KEY	CODE	STEP		KEY	CODE
0	0	e	12	3	0	X	36	6	0	UP	27		0				0		
	1	TAN	71		1	1	01		1	X	36		1				1		
	2	UP	27		2	RUP	22		2	5	05		2				2		
	3	X	36		3	+	33		3	8	10		3				3		
	4	DN	25		4	a	13		4	CHS	32		4				4		
	5	–	34		5	X	36		5	XEY	30		5				5		
	6	1	01		6	YTO	40		6	+	33		6				6		
	7	+	33		7	a	13		7	X	36		7				7		
	8	6	06		8	DN	25		8	DN	25		8				8		
	9	DIV	35		9	f	15		9	+	33		9				9		
	a	f	15		a	X	36		a	6	06		a				a		
	b	–	34		b	5	05		b	1	01		b				b		
	c	b	14		c	EEX	26		c	+	33		c				c		
	d	X	36		d	5	05		d	b	14		d				d		
1	0	X	36	4	0	+	33	7	0	X	36		0				0		
	1	1	01		1	YTO	40		1	X	36		1				1		
	2	+	33		2	f	15		2	3	03		2				2		
	3	b	14		3	d	17		3	0	00		3				3		
	4	X	36		4	RUP	22		4	DIV	35		4				4		
	5	YTO	40		5	X	36		5	e	12		5				5		
	6	f	15		6	2	02		6	COS	73		6				6		
	7	YE	24		7	DIV	35		7	UP	27		7				7		
	8	9	11		8	YTO	40		8	X	36		8				8		
	9	e	12		9	d	17		9	c	16		9				9		
	a	SIN	70		a	9	11		a	X	36		a				a		
	b	UP	27		b	UP	27		b	4	04		b				b		
	c	X	36		c	e	12		c	X	36		c				c		
	d	DN	25		d	SIN	70		d	9	11		d				d		
2	0	X	36	5	0	UP	27	8	0	+	33		0						
	1	1	01		1	X	36		1	e	12		1						
	2	+	33		2	2	02		2	COS	73		2						
	3	a	13		3	0	00		3	X	36		3						
	4	RDN	31		4	X	36		4	X	36		4						
	5	SRT	76		5	DN	25		5	c	16		5						
	6	RUP	22		6	–	34		6	X	36		6						
	7	XEY	30		7	c	16		7	DN	25		7						
	8	DIV	35		8	X	36		8	+	33		8						
	9	•	21		9	3	03		9	5	05		9						
	a	9	11		a	0	00		a	+	33		a						
	b	9	11		b	X	36		b	3	03		b						
	c	9	11		c	e	12		c	END	46		c						
	d	6	06		d	TAN	71		d				d						

UNIVERSAL TRANSVERSE MERCATOR
Geographic Position to Grid Coordinates

STEP		KEY	CODE
0	0	e	12
	1	TAN	71
	2	UP	27
	3	X	36
	4	DN	25
	5	-	34
	6	b	14
	7	X	36
	8	X	36
	9	1	01
	a	2	02
	b	DIV	35
	c	1	01
	d	+	33
1	0	b	14
	1	X	36
	2	d	17
	3	X	36
	4	YTO	40
	5	d	17
	6	e	12
	7	UP	27
	8	4	04
	9	X	36
	a	DN	25
	b	SIN	70
	c	UP	27
	d	2	02
2	0	7	07
	1	1	01
	2	6	06
	3	5	05
	4	3	03
	5	9	11
	6	EEX	26
	7	6	06
	8	CHS	32
	9	X	36
	a	e	12
	b	UP	27
	c	6	06
	d	X	36

STEP		KEY	CODE
3	0	DN	25
	1	SIN	70
	2	UP	27
	3	3	03
	4	5	05
	5	8	10
	6	7	07
	7	EEX	26
	8	9	11
	9	CHS	32
	a	X	36
	b	DN	25
	c	-	34
	d	e	12
4	0	UP	27
	1	2	02
	2	X	36
	3	DN	25
	4	SIN	70
	5	UP	27
	6	.	21
	7	0	00
	8	0	00
	9	2	02
	a	5	05
	b	5	05
	c	9	11
	d	8	10
5	0	8	10
	1	2	02
	2	5	05
	3	3	03
	4	1	01
	5	X	36
	6	DN	25
	7	-	34
	8	e	12
	9	UP	27
	a	1	01
	b	8	10
	c	0	00
	d	DIV	35

STEP		KEY	CODE
6	0	PI	56
	1	X	36
	2	1	01
	3	.	21
	4	0	00
	5	0	00
	6	5	05
	7	1	01
	8	0	00
	9	8	10
	a	9	11
	b	2	02
	c	0	00
	d	3	03
7	0	9	11
	1	X	36
	2	DN	25
	3	+	33
	4	a	13
	5	X	36
	6	.	21
	7	9	11
	8	9	11
	9	9	11
	a	6	06
	b	X	36
	c	d	17
	d	+	33
8	0	f	15
	1	UP	27
	2	CLX	37
	3	RDN	31
	4	PRT	45
	5	PRT	45
	6	PRT	45
	7	PRT	45
	8	END	46
	9		
	a		
	b		
	c		
	d		

STEP		KEY	CODE
	0		
	1		
	2		
	3		
	4		
	5		
	6		
	7		
	8		
	9		
	a		
	b		
	c		
	d		

STEP		KEY	CODE
	0		
	1		
	2		
	3		
	4		
	5		
	6		
	7		
	8		
	9		
	a		
	b		
	c		
	d		

		x	y	z
8	4	E	N	
1	d	-	2	8
	=	C	/	4
3	3	-	3	9
	=	D	/	6
4	6	-	5	4
	=	B	/	2
6	2	-	7	0
	=	A		

HEWLETT-PACKARD
Operating Procedures
74073
Universal Transverse Mercator Grid Co-ordinates To
Geographic Position

1.	Set: Degrees, Fixed, On, Run & Decimal Wheel 5 (x,y,z on printer)		
2.	Insert side A of Card 1		
3.	Press: END, ENTER & CONTINUE		Z temporary
			Y accumulator
4.	Enter: Z zone number in keyboard	Z	X keyboard
5.	Touch: CONTINUE		
		Z	Z temporary
6.	Display:	(CM)°	Y accumulator
		7	X keyboard
		(CM)°	Z temporary
7.	Enter: N in keyboard touch CONTINUE	N	Y accumulator
8.	E in keyboard	E	X keyboard
9.	Touch: CONTINUE		
10.	Insert side B of Card 1		
11.	Press: END, ENTER & CONTINUE		
12.	Insert side A of Card 2		
13.	Press: END, ENTER & CONTINUE	Deg.	Z temporary
		Min.	Y accumulator
14.	Display: ϕ	Sec.	X keyboard
15.	Touch: CONTINUE display in 14 will be λ		

to change ellipsoid constants

		Constant	Program Step
1.	Press: GO TO DO CONTINUE	$1/4Cx10^{12}$	43-49
2.	Enter: $-e^2$ touch CONTINUE	$1/6Dx10^{12}$	53-57
3.	Enter: a_2 touch CONTINUE	$1/2Bx10^{12}$	64-6d
4.	Enter: e_1 touch CONTINUE	A	register b

Sample using Clarke 1866 spheroid

Zone No.	14.
(CM)	99.
	7.
	99.
N	3794702.172
E	772075.812
	34.
ϕ	15.
	34.74199
	96.
λ	2.
	43.15801

UNIVERSAL TRANSVERSE MERCATOR
Grid Coordinates to Geographic Position

STEP		KEY	CODE
0	0	CLR	20
	1	4	04
	2	STP	41
	3	UP	27
	4	1	01
	5	8	10
	6	3	03
	7	UP	27
	8	6	06
	9	RUP	22
	a	X	36
	b	RDN	31
	c	-	34
	d	7	07
1	0	PRT	45
	1	PRT	45
	2	YTO	40
	3	d	17
	4	STP	41
	5	UP	27
	6	STP	41
	7	PRT	45
	8	PRT	45
	9	AC+	60
	a	1	01
	b	8	10
	c	0	00
	d	X	36
2	0	PF	56
	1	DIV	35
	2	.	21
	3	9	11
	4	9	11
	5	9	11
	6	6	06
	7	DIV	35
	8	a	13
	9	DIV	35
	a	b	14
	b	DIV	35
	c	1	01
	d	RDN	31

STEP		KEY	CODE
3	0	YE	24
	1	9	11
	2	YTO	40
	3	9	11
	4	RDN	31
	5	+	33
	6	DN	25
	7	DIV	35
	8	YTO	40
	9	0	00
	a	YTO	40
	b	E	12
	c	4	04
	d	X	36
4	0	DN	25
	1	SIN	70
	2	UP	27
	3	2	02
	4	7	07
	5	1	01
	6	6	06
	7	5	05
	8	3	03
	9	9	11
	a	x	36
	b	e	12
	c	UP	27
	d	6	06
5	0	X	36
	1	DN	25
	2	SIN	70
	3	UP	27
	4	3	03
	5	5	05
	6	8	10
	7	7	07
	8	x	36
	9	DN	25
	a	-	34
	b	e	12
	c	UP	27
	d	2	02

STEP		KEY	CODE
6	0	X	36
	1	DN	25
	2	SIN	70
	3	UP	27
	4	2	02
	5	5	05
	6	5	05
	7	9	11
	8	8	10
	9	8	10
	a	2	02
	b	5	05
	c	3	03
	d	1	01
7	0	X	36
	1	DN	25
	2	-	34
	3	EEX	26
	4	1	01
	5	2	02
	6	DIV	35
	7	b	14
	8	DIV	35
	9	1	01
	a	8	10
	b	0	00
	c	X	36
	d	PI	56
8	0	DIV	35
	1	DN	25
	2	YE	24
	3	0	00
	4	YTO	40
	5	0	00
	6	-	34
	7	e	12
	8	x=y	50
	9	8	10
	a	STP	41
	b	GTO	44
	c	3	03
	d	a	13

STEP		KEY	CODE
9	0	7	07
	1	9	11
	2	9	11
	3	7	07
	4	5	05
	5	6	06
	6	8	10
	7	6	06
	8	7	07
	9	EEX	26
	a	3	03
	b	CLR	20
	c	9	11
	d	2	02
a	0	0	00
	1	0	00
	2	4	04
	3	6	06
	4	0	00
	5	2	02
	6	8	10
	7	7	07
	8	3	03
	9	6	06
	a	6	06
	b	0	00
	c	0	00
	d	0	00
6	0	0	00
	1	2	02
	2	9	11
	3	8	10
	4	0	00
	5	1	01
	6	5	05
	7	0	00
	8	0	00
	9	1	01
	a	0	00
	b	0	00
	c	9	11
	d	3	03

STEP		KEY	CODE
C	0	5	05
	1	4	04
	2	9	11
	3	4	04
	4	8	10
	5	7	07
	6	4	04
	7	1	01
	8	8	10
	9	6	06
	a	3	03
	b	CLR	20
	c	2	02
	d	9	11
d	0	CLX	20
	1	a	13
	2	STP	41
	3	XTO	23
	4	a	13
	5	UP	27
	6	STP	41
	7	XTO	23
	8	9	11
	9	UP	27
	a	STP	41
	b	XTO	23
	c	C	16
	d	END	46

		x	y	z
0	2	z		
1	6	E	N	

42-4 9= C/4
54-5 7= D/6
64-6 d=13/2
above X10^12
90-9 $d=-e^2$
ao-ad =a
bo-bd =A
co-cd=e^2

UNIVERSAL TRANSVERSE MERCATOR
Grid Coordinates to Geographic Position

STEP		KEY	ECOM
0	0	TAN	71
	1	UP	27
	2	X	36
	3	4	04
	4	5	05
	5	X	36
	6	2	02
	7	6	06
	8	9	11
	9	+	33
	a	e	12
	b	SIN	70
	c	X	36
	d	X	36
1	0	1	01
	1	0	00
	2	7	07
	3	-	34
	4	C	16
	5	x	36
	6	e	12
	7	TAN	71
	8	UP	27
	9	X	36
	a	2	02
	b	XEY	30
	c	+	33
	d	X	36
2	0	4	04
	1	5	05
	2	X	36
	3	DN	25
	4	-	34
	5	6	06
	6	1	01
	7	-	34
	8	3	03
	9	0	00
	a	DIV	35
	b	YE	24
	c	f	15
	d	5	05

STEP		KEY	ECOM
3	0	EEX	26
	1	5	05
	2	-	34
	3	.	21
	4	9	11
	5	9	11
	6	9	11
	7	6	06
	8	DIV	35
	9	e	12
	a	SIN	70
	b	UP	27
	c	X	36
	d	RUP	22
4	0	YE	24
	1	9	11
	2	RDN	31
	3	X	36
	4	I	01
	5	+	33
	6	DN	25
	7	SQR	76
	8	X	36
	9	a	13
	a	DIV	35
	b	YE	24
	c	f	15
	d	f	15
5	0	X	36
	1	X	36
	2	YTO	40
	3	b	14
	4	e	12
	5	SIN	70
	6	UP	27
	7	X	36
	8	2	02
	9	X	36
	a	1	01
	b	-	34
	c	e	12
	d	COS	73

STEP		KEY	ECOM
6	0	UP	27
	1	X	36
	2	c	16
	3	X	36
	4	2	02
	5	-	34
	6	DN	25
	7	X	36
	8	c	16
	9	X	36
	a	3	03
	b	x	36
	c	e	12
	d	TAN	71
7	0	UP	27
	1	X	36
	2	3	03
	3	X	36
	4	DN	25
	5	+	33
	6	b	14
	7	+	33
	8	5	05
	9	+	33
	a	f	15
	b	X	36
	c	X	36
	d	1	01
8	0	2	02
	1	DIV	35
	2	e	12
	3	COS	73
	4	UP	27
	5	X	36
	6	c	16
	7	X	36
	8	1	01
	9	+	33
	a	DN	25
	b	-	34
	c	3	03
	d	END	46

STEP		KEY	ECOM
	0		
	1		
	2		
	3		
	4		
	5		
	6		
	7		
	8		
	9		
	a		
	b		
	c		
	d		

STEP		KEY	ECOM
	0		
	1		
	2		
	3		
	4		
	5		
	6		
	7		
	8		
	9		
	a		
	b		
	c		
	d		

UNIVERSAL TRANSVERSE MERCATOR

Grid Coordinates to Geographic Position

STEP		KEY	CODE
0	0	e	12
	1	TAN	71
	2	X	36
	3	f	15
	4	X	36
	5	X	36
	6	9	11
	7	0	00
	8	X	36
	9	PI	56
	a	DIV	35
	b	e	12
	c	+	33
	d	YTO	40
1	0	a	13
	1	TAN	71
	2	UP	27
	3	X	36
	4	6	06
	5	X	36
	6	7	07
	7	+	33
	8	e	12
	9	TAN	71
	a	X	36
	b	X	36
	c	4	04
	d	X	36
2	0	E	12
	1	SIN	70
	2	UP	27
	3	X	36
	4	3	03
	5	+	33
	6	C	16
	7	X	36
	8	2	02
	9	X	36
	a	DN	25
	b	+	33
	c	5	05
	d	+	33

STEP		KEY	CODE
3	0	f	15
	1	X	36
	2	X	36
	3	2	02
	4	0	00
	5	DIV	35
	6	e	12
	7	COS	73
	8	UP	27
	9	X	36
	a	C	16
	b	X	36
	c	DN	25
	d	-	34
4	0	e	12
	1	TAN	71
	2	UP	27
	3	X	36
	4	2	02
	5	X	36
	6	DN	25
	7	-	34
	8	1	01
	9	-	34
	a	f	15
	b	X	36
	c	X	36
	d	6	06
5	0	DIV	35
	1	1	01
	2	+	33
	3	f	15
	4	X	36
	5	1	01
	6	8	10
	7	0	00
	8	X	36
	9	PI	56
	a	DIV	35
	b	E	12
	c	COS	73
	d	DIV	35

STEP		KEY	CODE
6	0	d	17
	1	XEY	30
	2	-	34
	3	YE	24
	4	a	13
	5	DN	25
	6	UP	27
	7	INT	64
	8	XTO	23
	9	d	17
	a	-	34
	b	6	06
	c	0	00
	d	X	36
7	0	XEY	30
	1	UP	27
	2	INT	64
	3	-	34
	4	RDN	31
	5	X	36
	6	d	17
	7	RDN	31
	8	PRT	45
	9	PRT	45
	a	STP	41
	b	GTO	44
	c	6	06
	d	3	03
8	0	END	46
	1		
	2		
	3		
	4		
	5		
	6		
	7		
	8		
	9		
	a		
	b		
	c		
	d		

STEP		KEY	CODE
	0		
	1		
	2		
	3		
	4		
	5		
	6		
	7		
	8		
	9		
	a		
	b		
	c		
	d		

STEP		KEY	CODE
	0		
	1		
	2		
	3		
	4		
	5		
	6		
	7		
	8		
	9		
	a		
	b		
	c		
	d		

		x	y	z
7	a	S	M	D

Bibliography

1. Hirvonen, R.A., 1970, THE USE OF SUBROUTINES IN GEODETIC COMPUTATION, Teknillner Korkeakoulu, Helsinki, Finlande.

2. Fury, Rudolf J., 1970, SELECTING ELECTRONIC CALCULATORS OR MINI-COMPUTERS FOR SURVEYOR'S NEED, Wolf Research and Development Corporation, Riverdale, Maryland.

3. Claire, Charles N., 1968, STATE PLANE CO-ORDINATES BY AUTOMATIC DATA PROCESSING, Publication 62-4, US Government Printing Office, Washington, D.C.

4. Corps of Engineers, UNIVERSAL TRANSVERSE MERCATOR GRID, US Department of Army, Washington, D.C.

5. Chappell, Robert D., 1970, CONSIDERATIONS IN EVALUATING DESKTOP COMPUTERS, Surveying and Mapping Paper 70-299.

6. Chappell, Robert D., 1969, INVERSE GEOGRAPHIC POSITION COMPUTATIONS, Hewlett-Packard Keyboard, Summer 1969.