The
RADIOSCIENTIST

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VERSIM working group

Mac with NewLife

EDITORIAL STAFF

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COVER: Switching on power on ELBBO-1 immediately before launch at dawn (see story in April issue, 1991)

The Editor's page

Refereeing of papers. As I said in the last issue: "there will be several modifications to policy from time to time over the next few issues." This issue sees the introduction of a refereed *Research Paper*, that by Jim Wait. This is not a reversal of policy since only articles accepted as *Research Papers* describing new results or analyses will be refereed. Why *any* change of policy? Well, a wise editor doesn't turn down a paper by Jim Wait!

There is no intention of competing with *Radio Science* so such *Research Papers* will be strictly limited to four pages including the biography and box containing details of submission, etc. Thus to some degree this part of *the Radioscientist* will act as a "letters" version of *Radio Science* to provide rapid publication of short papers of interest to radioscientists.

Remember, all articles in *the Radioscientist* can be (and have been already) cited. Any announcing a discovery can be cited as evidence of priority. So some of the features of a scientific journal have been included in *the Radioscientist* from the beginning. Some of the journals like *Nature* which were once devoted solely to "learned" works now include news and views.

A feature is that the copyright is held by the author allowing the author to copy the masters provided to make any number of reprints. This will save the cost of mailing parcels of reprints to authors and provide the authors with reprint masters even a few days before publication. There will be no page or reprint charges. Radioscientists lacking the means of making reprints will be catered for.

It is my intention to keep *the Radioscientist* an URSI magazine consisting largely of news, views and reviews, including, but not dominated by, *Research Papers*.

URSI meeting special. The printing and distribution of this issue is being rushed to allow free distribution at two URSI meetings: the North American URSI/AP-S Meeting in London, Ontario, in June and the UK URSI Meeting in July. If you are one of these recipients and want to see future issues of the *Radioscientist*,

tear out the coloured centre fold, fill in the form and hand it to the Registration Desk with your personal cheque or credit card info. It's that easy!

Fast Mail. Subscribers to the *Radioscientist* as well as some of the smaller Member Committees of URSI received their copies of the April issue of the *Radioscientist* by TNT's *MailFast*. This is a form of private airmail where parcels are airfreighted to an agent in the region concerned and then posted by this agent to the addressee. Recipients were asked to return to me the envelope (for post mark) with arrival date noted. Easter occurred just after I sent the April issue (late afternoon on Friday, 22nd March), so the time taken to arrive as measured in working days will vary with the country. There was no data from North America (maybe the answers are still on their way!). The table below shows the elapsed time in NZ working days:

Country (city)	time taken (days)
Australia	2
Belgium	7
Denmark	5
England	7
England (Lond.)	8
Finland	7
France	7
India	2
South Africa	4
Sweden	6
Taiwan	4

Most of the delay was in the post. The two to England were posted in London. One took 4 days just to be delivered across the city. None the less, as a result of this experiment, all future issues will be sent to subscribers this way. Subscribers can expect their copies on or about the first day of the month of issue.

So far, as many copies of the *Radioscientist* are sent to the URSI Member Committees as are sent copies of the URSI *Bulletin*. These are mainly sent by surface parcel post. You may have received your copy via your URSI Member ("National") Committee (or maybe not, since at least one Committee did not post out the copies I sent). If so, it may have arrived two months late. If you want

to get the *Radioscientist* regularly and on time, take out a subscription.

Supermac. In the middle of getting this issue out on my Mac Plus, the upgrade arrived. It was installed in an hour or two but I spent another couple of days getting it to go the way I wanted. In case you get this upgrade too, I thought I would share my experience and solution. The style suggested I put it at the back of the issue.

URSI salaried staff, including that of the *Radioscientist*, numbers one. This one is Inge Heleu, who succeeds Yela Stevanovitch following her retirement at the end of last year after some 30 years of service to URSI.

Inge Heleu was born in Deinze, Belgium in 1963, and lives in the picturesque Baarle Drongen, on the banks of the river Leie, the beauty of which inspired a whole school of Flemish painters. She received a teaching degree in Germanic languages (English, German and Dutch). But, with the birth-rate going down in Belgium, and a new Belgian law called "reaffectation" (giving priority to teachers by seniority), the possibility of becoming an unemployed teacher became a probability. So, while teaching, Inge took exams and was permitted to follow a course in computer programming. Bull trained her as a system manager for DPS4 (Cobol). Later she worked for IBM (System 36 and PC, with loads of software). She joined URSI (and now uses a Mac) after five years of experience as a secretary in an important Belgian firm in the food industry. Inge is engaged to be married early next year to Danny. Her main hobbies are travelling, all kinds of watersports, yoga and cooking. Her photo appears immediately below.

Complex Image Theory — Revisited

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Abstract. A quasi-historical sketch of complex image theory for low frequency electromagnetic fields is presented from a personal perspective. Recent thoughts on the subject are also included.

The Early Days. In the late 1950s and early 1960s, I had a strong commitment to VLF (Very Low Frequency). The motivation was to predict and understand how electromagnetic signals propagate in the waveguide formed by the earth's surface and the lower region of the ionosphere. As a preliminary step in dealing with the eigenvalue or mode equation, it seemed to be prudent to find a simplified representation for the reflection coefficient R at the ionosphere for an upgoing plane wave at a complex angle of incidence θ. As it turned out, the remarkably simple approximation holds:

$$R \approx - \exp(-\alpha\, C) \tag{1}$$

where $C = \cos\theta$ and α is independent of C. This result works best for angles near grazing where, for example, $|C| < 0.15$. But, in general, α is complex so that the downcoming signal appears to emanate from an image source at a complex location even for real values of C. The details of the analytical and the numerical implementation in the context of the earth-ionosphere spherical waveguide are summarized in a review article [1] where many references are given (e.g. to Bremmer, Budden, Bahar, Galejs, Ll.Jones, Pappert, Volland, and others). But this is not the subject of this essay although eqn (1) above contains the key to what follows.

Later On. In the period from 1960 to about 1969, I worked closely, at the National Bureau of Standards in Boulder, Colorado, with A.D.Watt and we conferred on a daily basis on VLF projects even after he moved to Westinghouse. Don Watt had a strong physical insight into both the propagation and the radiation aspects. On one occasion, he posed the problem of how a horizontal insulated cable, grounded at end points, would radiate. He postulated that the system was equivalent to a rectangular loop in the vertical plane which could launch TM (transverse magnetic) modes into the earth-ionosphere waveguide. Don Watt suggested that the depth d_{eff} of the equivalent or effective return conductor was complex and given by $d_{eff} = 1/\gamma$ where γ is the propagation constant of the earth. For VLF, $\gamma = (1 + j)/\delta$ where δ is the electrical skin depth. He arrived at this result by the following argument. Consider a plane wave to arrive at normal incidence onto a homogeneous conducting half-space. From this deduce the effective surface impedance which is then equated to the surface impedance for a conducting plane at a depth d in free space. After some simplifying approximations, valid at VLF, it was found that $d = d_{eff}$ as given above.

My immediate response to Don Watt's inspirational argument was to look at the full blown Sommerfeld theory for a horizontal electric dipole on or just above the conducting half-space model of the earth. Indeed the results seemed to be consistent in so far as predicting the radiated fields. But it seemed desirable to see if a more appealing analytical model might not be developed which showed the image of the source dipole was indeed located at a complex depth.

The Analytical Model. My choice for the basic source was a small vertical axis loop or VMD (vertical magnetic dipole) located in air at an actual height z_0 over the plane interface at $z = 0$ of the half-space of conductivity σ and permittivity ε. The magnetic permeability of the whole space was taken to be the free-space value μ_0. Also note the implied time factor was $\exp(i\omega t)$ for an angular frequency ω. The small loop has an area dA and carries a current I. In the air, for $z > 0$, the fields can be derived rigourously [2] from a z-directed magnetic Hertz potential F given, with reference to a cylindrical coordinate system (ρ,z), by:

$$F = (IdA/4\pi)\,[\exp(-\gamma_0 r_0)/r_0 + P] \tag{2}$$

where

$$r_0 = [\rho^2 + (z + z_0)^2]^{1/2}$$

and

$$P = \int_0^\infty (f/u_0)\, R(f)\, J_0(f\rho)\, \exp[-u_0(z + z_0)]^3\, df \tag{3}$$

and where

$$R(f) = (u_0 - u)/(u_0 + u) \tag{4}$$

$u_0 = (f^2 + \gamma_0^2)^{1/2}$, $u = (f^2 + \gamma^2)^{1/2}$, $\gamma_0 = j\,2\pi/\text{free-space wave-length}$ and

$\gamma = [j\mu_0\omega(\sigma + j\omega\theta)]^{1/2}$. For convenience, we now set $x = u_0/\Delta$ where $\Delta = (\gamma^2 - \gamma_0^2)^{1/2}$. Then from (4) we see that

$$R(f) = R = -1 + 2x - 2x^2 + x^3 - x^5/4 + \ldots \tag{5}$$

provided $|x| < 1$. But a good single term approximation is

$$R \approx -\exp(-2x) \tag{6}$$

which agrees with (5) up to and including the third term. Thus the integral P is approximated by the form

$$P \approx -\int_0^\infty (f/u_0)\, J_0(f\rho)\, \exp[-u_0(z + z_0 + (2/\Delta))]\, df \tag{7}$$

Then (2) is given by

$$F \approx (IdA/4\pi)[\exp(-\gamma_0 r_0)/r_0 - \exp(-\gamma_0 r_2)/r_2] \tag{8}$$

where $r_2 = [\rho^2 + (z + z_0 + (2/\Delta))^2]^{1/2}$. To obtain (8) we have employed the Sommerfeld integral identify given by

$$\int_0^\infty (f/u_0)J_0(f\rho)\, \exp(-u_0 Z)df = \exp(-\gamma_0 r)/r \tag{9}$$

where $r = (\rho^2 + Z^2)^{1/2}$ for Real part of $Z > 0$, where Z is otherwise arbitrary. Clearly the image is located at the complex depth $-[z_0 + (2/\Delta)]$ which is complex. In the quasi-static limit where $\gamma_0 \to 0$, the image is located at $-[z_0 + (2/\gamma)]$. This is the result I published over 20 years ago [3]. There it was also shown that the approximation could be checked against the special known case where the source and observer were in the interface $z = 0$. An exact solution for this configuration was available. Lindell and Alanen [4] refer to this analysis as that "introduced by Watt as reported by Wait"! A further analysis by Wait and Spies [5] extended the solution to the case of a horizontal wire or line source located over a homogeneous half-space. Again the solution was checked against a known exact form when the line source was in the interface.

Subsequent Developments. The implementation and further development was taken up by Peter Bannister who published a major series of papers on the subject. A recent one [6] gives a succinct summary of his accomplishments and their relation to other contributions. But I should also mention the significant and fundamental papers published by Samir Mahmoud and Adel Metwally [7,8]. In their generalizations of the theory, both additional discrete images as well as a continuous line image were introduced. This led to a significant improvement in the accuracy of the field representations without additional computing effort. The extension of the complex image theory to layered substrata is also possible and such representations are useful in applied geophysics [9].

A 'Finnishing' Touch   The analytical advance made by Lindell and Alanen [4] was to exploit the fact that the reflection coefficient could be expressed as a Laplace transform, such that in our context

$$(u_0 - u)/(u_0 + u) = -2\int_0^\infty q^{-1} J_2(\Delta q)\, \exp(-u_0 q)\, dq \tag{10}$$

Then with a change of variable to $p = \Delta q$, it follows from (3) that

$$P = -2\int_0^\infty p^{-1} J_2(p)\, r(p)\, \exp[-\gamma_0 r(p)]\, dp \tag{11}$$

where

$$r(p) = [\rho^2 + (z + z_0 + (p/\Delta))^2]^{1/2} \tag{12}$$

The representation, given for P in (11), is <u>exact</u>. Clearly it can be interpreted as the contribution from a line image beginning at $z = -z_0$ and extending downward to $-[z_0 + \infty \exp(-j \arg \Delta)]$. Now, since the single image location at $-[z_0 + 2/\Delta]$ leads to a 'good' low frequency approximation, it is worthwhile to see if we can obtain a simple correction by working with the 'exact' or Finnish representation. Actually this possibility was also mentioned by Lindell and Alanen [4]. To carry out this task in an explicit manner we expand the function f(p), defined by

$$f(p) = \exp[-\gamma_0\, r(p)]/r(p) \tag{13}$$

into a Taylor series about $p = 2$. That is

$$f(p) = f(2) + (p-2)f'(2) + (p-2)^2\, s^{-1}\, f''(2) + (p-2)^3\, 6^{-1}\, f'''(2) \tag{14}$$

where higher terms are neglected. When we insert this series into (11), we need to evaluate a set of Bessel function integrals that can be deduced from the following known transform [10]:

$$\int_0^\infty e^{-bp}\, p^{-1}\, J_2(p)\, dp = [(b^2 + 1)^{1/2} - b]^{1/2}/2 \tag{15}$$

which is valid for positive b. Successive differentiation with respect to b, followed by imposing the limit $b \to 0$, leads to the following generic form

$$\int_0^\infty p^m\, J_2(p)\, dp = g_m \tag{16}$$

where $g_{-1} = 1/2$, $g_0 = 1$, $g_1 = 2$, $g_2 = 3$ and so on.

Thus, we deduce that

$$\int_0^\infty (p-2)^n\, p^{-1}\, J_2(p)\, dp = 1/2 \text{ for } m = 0$$

$$= 0 \text{ for } m = 1 \text{ and } 2, \text{ and}$$

$$= -1 \text{ for } m = 3 \tag{17}$$

Consequently (11) is given by

$$P \approx -f(2) + (1/3)(1/\Delta)^3\, (\partial^3/\partial z^3)\, f(p)\, \big|_{p=2} \tag{18}$$

where we have noted that $\partial/\partial p = (1/\Delta)\partial/\partial z$.
An equivalent form, which is more explicit, is given by

$$P \approx [-1 + (1/3)(1/\Delta)^3\, (\partial^3/\partial z^3)]\, [r_2^{-1}\, \exp(-\gamma_0 r_2)] \tag{19}$$

where r_2 is as defined in (8). This result suggests that the correction term involving the third derivative is negligible for distances r_0 such that $|\gamma r_0|^3 \gg 1$ which is remarkably non restrictive. It means that r_0 only need be somewhat greater than the skin depth δ of the conducting half-space. This statement is well borne out by the intrepid Peter Bannister [6].

Back to the 1960s. Now it is useful to return to the general form for P as given by (3). Here we follow the original strategy and note that

$$(u_0 - u)/(u_0 + u) \approx -\exp[-2u_0/\Delta]\, [1 - (1/3)\, (u_0/\Delta)^3] \tag{20}$$

where terms involving higher powers of (u_0/Δ) are neglected. Thus, within this approximation

$$P \approx - \int_0^\infty [1 + (1/3)(u_0/\Delta)^3] \exp[-u_0(z + z_0 + (2/\Delta))](f/u_0) J_0(fp) \, df \qquad (21)$$

But

$$\int_0^\infty (f/u_0) \, u_0^3 \exp(-u_0 Z) J_0(fp) \, df = -(\partial^3/\partial Z^3) A \qquad (22)$$

where A is the right hand side of (9). Thus we have very simply recovered (19) which was derived somewhat awkwardly from the "exact" integral form given by (11).

As indicated by Mahmoud, Bannister, and others, the approximate image forms have great utility particularly when dealing with layered substrata and for more complicated source configurations. It is fortunate that, thanks to Ismo Lindell and Esko Alanen, we have exact complex representations which serve as bench marks for the approximate forms.

Acknowledgements
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James R Wait has received BASc., MASc. and PhD degrees from the University of Toronto. From 1955 to 1980, he was a member of the scientific community in Boulder, Colorado. His positions included: Senior Scientist in NOAA, Professor Adjoint in EE at the University of Colorado, Consultant to the Institute for Telecommunications, and Fellow of the Cooperative Institute for Research in Environmental Sciences. In 1980 he became Professor of Electrical Engineering and of Geosciences at the University of Arizona in Tucson. Dr Wait has received numerous awards for his research in electromagnetics and electrical geophysics including: Balth van der Pol Gold Medal presented by URSI in Helsinki in 1978, IEEE Centennial Medal in 1984, IEEE Geoscience and Remote Sensing Achievement Award in 1985, and the IEEE Antennas and Propagation Distinguished Achievement Award in 1990. He is a Fellow of the IEEE and is a member of the (US) National Academy of Engineering. In 1988, Dr Wait was appointed a Regents Professor in the University of Arizona. In 1989, he retired from the university to become a private consultant residing at 2210 East Waverly, Tucson, AZ 85719 (phone 602 325 1005). During his career he has published 8 books and around 800 research papers. (see photo on page 61)

Computing without Programming 2

A Review: Symbol Crunching on *Theorist* version 1.11

In the previous issue of *The Radioscientist* we reviewed two programs; *MathCAD* and *Igor*, which enabled you to read, generate, process and plot *numerical* data. In this issue we review a program which enables you to manipulate expressions in *symbolic* form as well as numerically.

From its name, you might guess that *Theorist,* from Prescience Corporation, is a program oriented towards the theoretical rather than experimental user — and you would be right. Although *Theorist* can produce some good quality graphical output, it is really intended as a tool for providing mathematical insight into a problem together with graphical visualization. (In the next issue of *The Radioscientist* the pendulum will swing back the experimentalists' way with a review of some curve fitting and plotting software for use on IBM PCs).

The startup display on *Theorist* contains the slogan, *"Theorist - Computer mathematics for the rest of us"*. Presumably "the rest of us" means those people who are not able to afford some of the more expensive symbolic algebra and graphics programs which are currently available on personal computers. The list price for *Theorist* of US$399-95 does compare favourably with other products but is *Theorist* as useful and complete as some of the older or more well known packages?

Hardware Requirements

Theorist will run on a Macintosh Plus, SE, II, IIx, IIcx, SE/30, IIci, IIfx or Portable and requires as little as 1Mb RAM to run and 1Mb of disk space to install. *Theorist* is intended to run from a hard disk. However, if your Mac has a high density floppy disk drive then it is possible to install everything you need onto one diskette.

You will also need mac system software version 6.0.2 or later if you own a Plus, SE or II; version 6.0.3 or later for a IIx, IIcx or SE/30; and version 6.0.5 or later if you own a mac IIci, IIfx or portable.

Theorist 1.11 comes on three 720kb diskettes on which you are actually provided with two versions of *Theorist*. One version takes advantage of the math coprocessor chip on your mac SE/30 or mac II. Installation of *Theorist* is very straight forward.

Symbol glut?

A cynic might say that the more traditional numerically-based computer math programs enable you to type in a relatively short mathematical expression and turn it into a long incomprehensible list of numbers. The only way to subsequently get any feeling for the result obtained is to plot or "visualize" the numbers. The same cynic might say that a *symbolic* math program enables you to type in a relatively short mathematical expression and turn it into an equivalent but long incomprehensible *symbolic* expression instead.

It is true that some physicists find their first interaction with a symbolic math program a slightly disappointing experience. Expectations are high that this program can, with one or two clicks of a mouse button, convert the physicists favourite mathematical expression into its simplest possible form while, at the same time, keeping physically meaningful parts of an expression grouped together. Automatic simplification of algebraic expressions is one of the more difficult tasks of a symbolic math program. Partly this is due to the rather subjective decisions involved in deciding which of two equivalent expressions is actually the simplest.

One approach is for the program to automatically try several different algebraic operations on an expression (e.g., factorisation, etc) and choose from among the results the one with the smallest number of parts.

One of the reasons that some symbolic math programs appear to be good at creating large incomprehensible expressions is that they are permanently in "substitute" mode. In other words, when the program displays a symbolic expression it automatically substitutes the values of all previously defined symbols.

Theorist does not work in this way. Instead, substitutions are only performed when explicitly requested or when necessary during an evaluation, but not every time an expression is displayed. *Theorist* therefore tends to keep the size of displayed expressions relatively small.

In general, if you want to perform a task numerically within *Theorist* you enter an expression and choose the **Calculate** option in the **Manipulation** menu. If you want to perform the same operation symbolically you choose the **Simplify** option.

Theorist is in fact, a *very* interactive symbolic math program. You use the mouse to select and move parts of a mathematical equation in order to rearrange it. There *are* built-in automatic simplification features but part of the philosophy behind *Theorist* is to proceed step-by-step through a manipulation making full use of your intuition as you go. *Theorist's* job is to get the algebra right when you shift something in an expression. A mouse-based manipulation system like *Theorist's* is more straight forward to use than a system based on indirect references to parts of an expression in order to simplify them.

Theorist has no built-in symbolic manipulation *operators* like Expand[] or Factor[]. Manipulations like these can only be done by first selecting with the mouse and then choosing the desired action from the **Manipulation** menu.

You make the assumptions.........

Everything you enter into *Theorist* is called an "assumption". It is an equality which you know or "assume" to be true. A *Theorist* file is called a

"notebook" and when you enter an assumption into the notebook, *Theorist* displays it with a open square symbol to its left. An example of an assumption is

$$\square\, z = \sqrt{\dfrac{(1+a)^2\, e^{2y^2} \cos(a^2)}{\sqrt{d^2 - a^2}}}$$

Only *you* are able to create assumptions and it is this step which requires your knowledge of physics rather than mathematics.

Pressing the return key in *Theorist* causes no particular action to be performed. It just sets up room for you to enter a new assumption. If you are used to a symbolic math system which requires a press of the return key after every expression is entered, *Theorist* takes a bit of getting used to.

.........Theorist makes the conclusions

You then use *Theorist* to manipulate these assumptions to derive various "conclusions" that are also true (given that your original assumptions were true that is!). Each conclusion reached by *Theorist* is identified by the open triangle that appears to its left. Only *Theorist* can create conclusions and you're not allowed to edit them while they are conclusions. (So you can't fiddle any of your results! If you do try to edit a conclusion *Theorist* creates a new assumption which you can then modify).

Consider the assumption given above. If you use the mouse to select the square root term in the denominator on the right hand side of that equation, you can drag this term over to the left hand side of the equation. When you release the mouse button, *Theorist* returns the following conclusion

$$\triangle\, \sqrt{-a^2 + d^2}\ z^2 = (a+1)^2\, e^{2y^2} \cos(a^2)$$

which is just a single rearrangement.

A *theory* (according to *Theorist*) consists of one or more propositions and various conclusions.

The basic idea at work here is that given simple known relationships we can use *Theorist* to combine them to create new results. Once you and *Theorist* have obtained a conclusion, you can do a **Get Info** menu command in order to find out all the statements that were used to generate the particular conclusion.

How to enter your assumptions

One of the pleasing aspects of *Theorist*, is the ease with which you can enter mathematical expressions (i.e.,. your assumptions). You can use either a FORTRAN-like notation from the keyboard, or you can use the standard *Theorist* input syntax, or you can use the "function palette" and the "variable palette". Figure 1 is a screen dump during a *Theorist* session showing the main part of a notebook at the bottom with the "function palette" at the top. The "variable palette" is hidden behind the function palette and contains a menu of variables defined so far as well as Greek symbols etc.

A nice feature is the way in which the escape key can be used to "break out" to the next highest level in an input expression without the need for typing in parentheses. For example, by typing in

```
a = 1/x + y   ESC   +   z
```

the following expression builds up dynamically on the screen as you type:

$$\square\, a = \dfrac{1}{x+y} + z$$

Without this special use of the ESC key, the expression would have to be entered as `a = 1/(x + y) + z`.

Documentation

For a program with as many features as *Theorist*, good documentation is essential. The documentation provided with *Theorist* consists of two ring bound folders of manageable size. One is a 240 page Learning Guide, and the other is a 360 page Reference Manual. Both manuals are exceptionally well laid out and the Learning Guide in particular is a good example of what a software manual should be like. The examples start at a very basic level with intermediate steps shown in sufficient detail. The reference manual is very thorough and includes a summary of all the menu options summary, a useful glossary and a comprehensive index.

There is not enough space in this review to cover many of the features of *Theorist* so we will just outline the main structure and illustrate with one or two examples.

The assumptions and conclusions introduced so far are called statements. Statements are just one of the 8 different "propositions" you can have in a *Theorist* notebook:

Propositions:

> Statements
> Comments
> Working Statements
> Case Theories
> Graphs and Plots
> Name Declarations
> Independence Declarations
> Transformation Rules

These are stored in a notebook in a hierarchical manner. This Hierarchical structure is evident in Figure 1 which shows an initial comment (identified by the cartoon-like balloon), followed by an integral expression and various indented conclusions.

Figure 1 demonstrates the use of the symbolic **Integrate by Parts** command. In general, integrals are evaluated symbolically using the **Simplify** menu command. However, in the case shown in the figure, **Simplify** only results in the trivial conclusion on the next line. The subsequent conclusion is obtained by a trivial reordering. This enables the highlighted term to
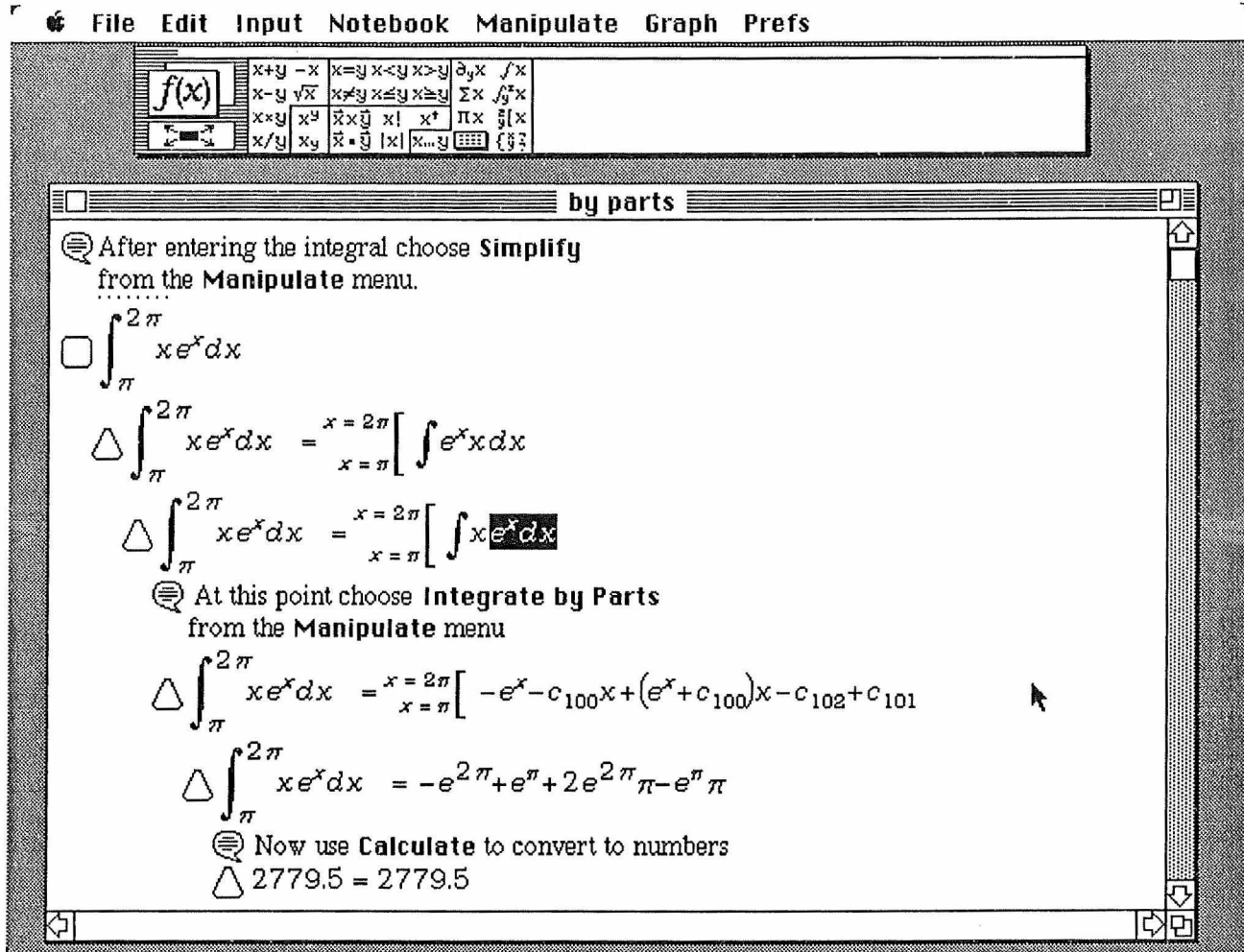
⚬ File Edit Input Notebook Manipulate Graph Prefs

Fig. 1. Screen dump of a Theorist Notebook showing an example of symbolic integration by parts.

The notebook window (titled "by parts") contains:

After entering the integral choose **Simplify** from the **Manipulate** menu.

$$\int_{\pi}^{2\pi} x\,e^x\,dx$$

$$\int_{\pi}^{2\pi} x\,e^x\,dx = {}^{x=2\pi}_{x=\pi}\left[\int e^x x\,dx\right.$$

$$\int_{\pi}^{2\pi} x\,e^x\,dx = {}^{x=2\pi}_{x=\pi}\left[\int x\,e^x\,dx\right.$$

At this point choose **Integrate by Parts** from the **Manipulate** menu

$$\int_{\pi}^{2\pi} x\,e^x\,dx = {}^{x=2\pi}_{x=\pi}\left[-e^x - c_{100}x + \left(e^x + c_{100}\right)x - c_{102} + c_{101}\right.$$

$$\int_{\pi}^{2\pi} x\,e^x\,dx = -e^{2\pi} + e^{\pi} + 2e^{2\pi}\pi - e^{\pi}\pi$$

Now use **Calculate** to convert to numbers

$$2779.5 = 2779.5$$

be selected and then the integral is performed using the **Integration by Parts** menu command. Use of the menu command **Expand** then substitutes the limits into the expression.

The Class system

All objects within Theorist belong to one of five classes:

> Constant
> Variable
> M-Linear Operator
> D-Linear Operator
> Function

M-Linear operators are associative but not commutative under multiplication while D-Linear operators are neither associative nor commutative. Functions can be defined by the user by using so-called "wild card" variables indicated by representing them using the outline font. For example, a function g (x) can be defined using

g (x) = x cos (x)

Note however that *Theorist* functions can only return numerical values.

In *Theorist*, the danger of accidentally confusing a built-in constant (such as the Euler constant e or the imaginary i) with one of your own user-defined variables is greatly reduced. This is because each time you manipulate or plot a new expression a dialogue box pops up asking you to declare any previously undeclared names occurring in the expression. You can choose either the pre-defined meaning of e, for example, or you can declare it as a user-defined name. Once a name is declared, it is added to the list of declarations at the top of every notebook. As new names and functions are declared, they are also added to the "variable" and "function" palettes at the top of the screen. You can subsequently refer to them simply by clicking them on the palette.

Equation Solving

For a single equation you can use **Isolate** command or mouse action to "solve" an equation by shifting the selected variable (or part of an expression) *beyond* the opposite side of an equation. This will work when there is only a single occurrence of the variable (or expression) in the equation. For example, if we return to our original assumption for z above, we can select the "y" variable on the right hand side of the equation and drag it all the way beyond the left hand side. *Theorist* returns the following conclusion:
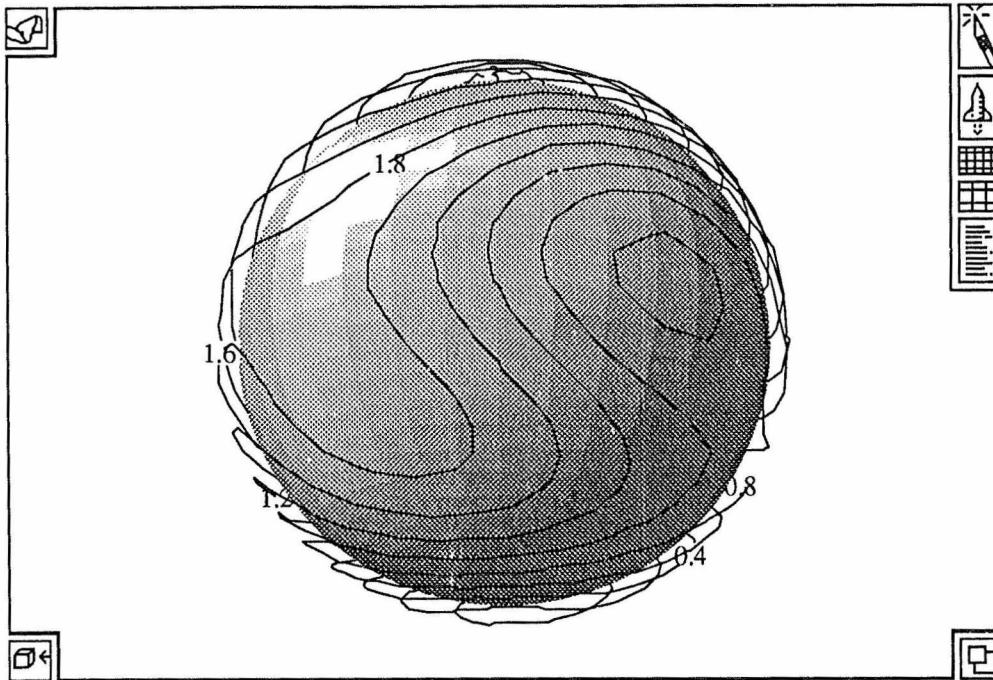
Fig. 2. Example of a contour plot mapped onto a spherical surface.

$$\Delta y = \sqrt{\frac{1}{2}\ln\left(\frac{\sqrt{-a^2+d^2\,z^2}}{[a+1]^2\cos[a^2]}\right)}$$

Linear systems and polynomial are also easily solved. However, nonlinear systems can only be solved numerically for a maximum of two equations using the numerical **FindRoot** command.

One nice feature is how the **FindRoot** command is closely tied to the plot of the function you are trying to find the root(s) of. You use the interactive zooming features of the plotting facility (described below) until you locate a region of the plot where the function crosses the x axis. You then choose the **FindRoot** command from the **Graphs** menu and the numerical value of the root is returned.

Data Files

Importing a numerical array into *Theorist* is easy. You **Copy** a selection of data points out of a data file, then select a matrix or a submatrix and **Paste** the numbers into it. The matrix accepts the pasted numbers as individual elements. Exporting a file is performed using a menu command.

Numerical Accuracy

Theorist does not offer the possibility of arbitrary precision numerical calculations. At most, calculations are performed to 19 digits accuracy, but some of *Theorist's* numerical algorithms return results accurate to only 7 digits. Numerical integration gives answers accurate to

approximately 9 digits and **FindRoot** generally returns answers accurate to 17 digits. It is not possible to specify the accuracy to which a certain *numerical* calculation is performed, only the accuracy to which it is displayed.

Special Math Functions

Theorist is provided with notebooks enabling calculations of various special functions including Bessel functions (J, Y, K, I) and their spherical counterparts, as well as zeta and gamma functions, orthogonal polynomials (P, T, H, L) and spherical harmonics. Mathematical notebooks are also provided on the following topics:

> Finite and Infinite Series
> Integral Tables
> Laplace Transforms
> 3D Calculus
> Re() and Im()
> Statistics
> Units

Declarations, assumptions, etc are not shared between multiple opened notebooks. Therefore to employ the theories provided in these notebooks you must either work in the notebook itself or paste the desired group of propositions into your current notebook.

The notebook Re() and Im() contains various expressions for simplifying and expanding the real and imaginary parts of complex symbolic expressions. *Theorist's* Integral Tables are quite easy to extend by adding your own integrals. Here is an example of how an integral is defined in one of the Integral Table notebooks:

○ Upon $\boxed{\text{Simplify}}$ transform $\displaystyle\int \frac{1}{x\sqrt{x+b}}\,dx$ into

$$\begin{cases} \dfrac{\ln\left(\left|\dfrac{\sqrt{x+b}-\sqrt{b}}{\sqrt{x+b}+\sqrt{b}}\right|\right)}{\sqrt{b}} + \left(\displaystyle\int 0\right) & (b > 0) \\[4ex] 2\,\dfrac{\arctan\left(\sqrt{\dfrac{x+b}{b}}\right)}{\sqrt{|b|}} + \left(\displaystyle\int 0\right) & (b < 0) \end{cases}$$

This is an example of a Transformation Rule. You can define your own transformation rules to change occurrences of any expression you like into another under either the **Transform**, **Simplify** or **Expand** menu commands.

Symbolic computations consume relatively large amounts of memory and processor time. For example, the symbolic inversion of a 5 by 5 matrix, where each element is the sum of two unrelated variables, takes *Theorist* approximately 160 seconds on a mac IIfx. The result returned is not fully expanded, however.

Graphics

The graphical abilities of *Theorist* are truly impressive, and in many aspects excel those of some other more expensive products. The way to generate plots using *Theorist* is highly interactive. To create a plot of a function you use the mouse to select the two variables that you want to plot against each other. You then go to the graph menu and select **y=f(x)** and choose from **Linear**, **SemiLog** or **Polar** options in the submenu.

If *Theorist* is uncertain about which of the two selected variables is to be the dependent one, a dialogue box pops up and asks you to confirm or change. In fact you don't need to select the two variables with the mouse. You can just select a whole equation and *Theorist* will present you with a scroll bar lists of the possible variables to choose for the dependent and independent variables for the plot. You just pick out the ones you want.

Theorist chooses default ranges for both the vertical and horizontal axes and begins to generate the plot immediately. On the right of every *Theorist* plot there are four icons. (These can been seen on the upper right of the 3D plot in Figure 2).
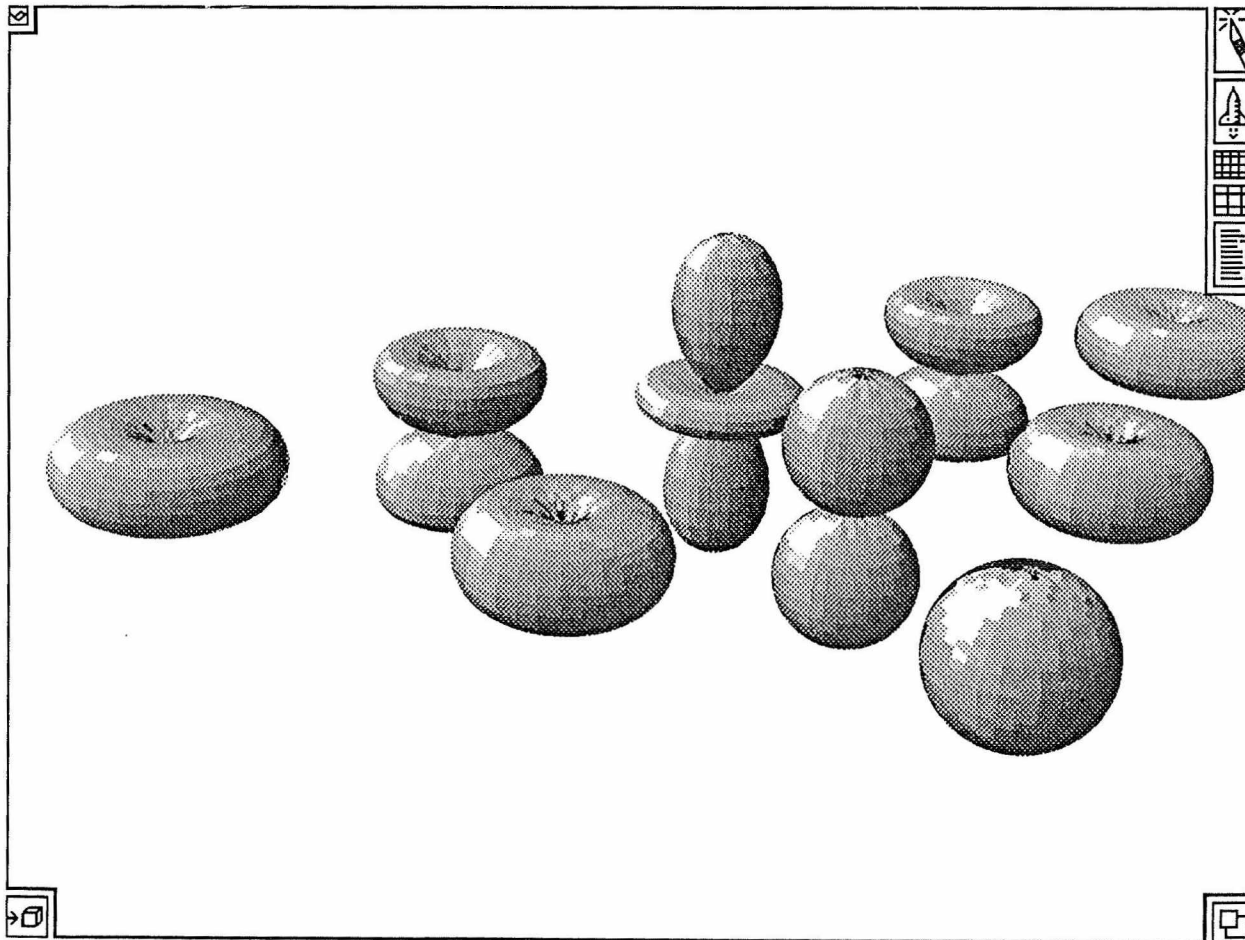

Fig. 3 Plot of a family of spherical harmonics. When plotted in colour, the surface colour represents the phase.
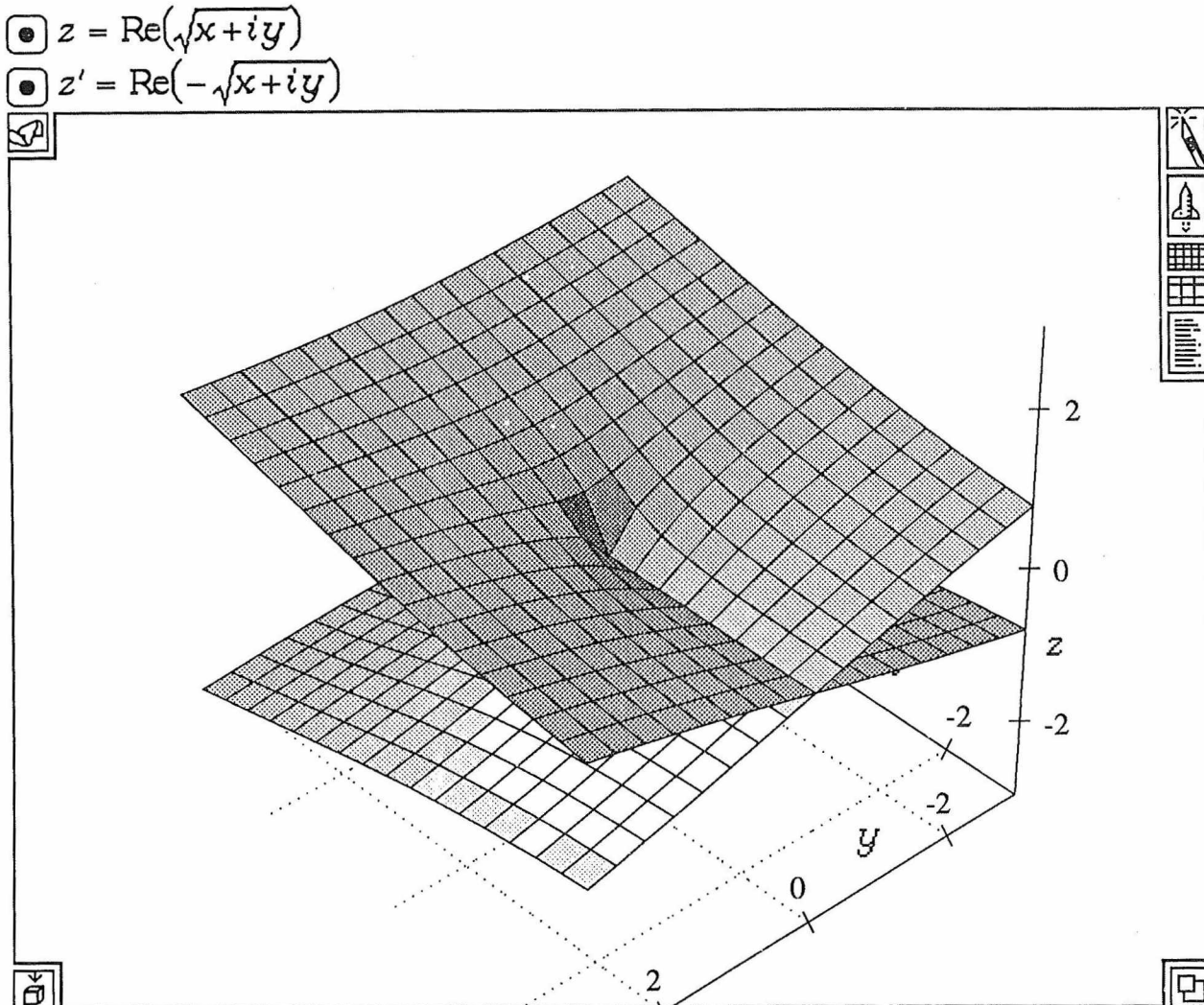
○ $z = \text{Re}\left(\sqrt{x+iy}\right)$

○ $z' = \text{Re}\left(-\sqrt{x+iy}\right)$

Fig. 4. Example of plotting multiple surfaces.

The top icon is a "knife" which enables you to select or "cut out" part of the plot that you wish to be blown up. As soon as you have selected the area of interest, *Theorist* begins to redraw the image on the new scale.

If instead you want to "zoom out" you click the rocket ship icon and the range of both the horizontal and vertical axes is doubled.

The next two grid-shaped icons enable you to change the resolution of the currently displayed plot. This is an excellent feature which enables you to improve the resolution of a plot entirely interactively, without the need to think about step sizes or the number of points to choose (the new number of points is displayed momentarily for you before the plot reappears). If you want to keep the same range of axes but shift to another part of the curve then you just click on the plot itself and the cursor turns into a "hand" which enables you to drag the visible part of the plot in the x or y directions. When you release the mouse button the plot is regenerated.

The lower icon attached to the plot is used to display the "details" associated with each plot. This includes information on plot ranges, axes and grid positioning, and the expressions that are being plotted.

By selecting two dependent variables and one independent variable, you can produce 2D parametric plots by choosing the x=f(t), y=g(t) option from the **Graph** menu.

Three Dimensional Plots

The three dimensional plotting capabilities of *Theorist* are impressive and producing a 3D plot is no more difficult than producing a 2D one. You select the dependent and two independent variables using the mouse, and then choose the option z = f(x,y) from the **Graph** menu. You can choose suboptions for **Density** plot or a **Contour** Plot.

The interactive icons attached to the plot perform similar functions as for 2D plots. The "knife" icon can be actually moved over the surface of the 3D plot to select the part of the surface to zoom in on. Also when you click the mouse on the main body of the surface plot, a box appears around the surface. The edges of the box are aligned with the x,y and z axes and you can use the mouse to rotate this box in real time to choose a better view of the surface. When the mouse button is released, the surface is redrawn from the new point of view.

Figure 3 shows surface plots of a family of spherical harmonics. The whole plot at this resolution takes *Theorist* approximately 75 seconds to calculate on a mac IIfx.

With *Theorist* it is also possible to plot multiple surfaces as a function of two variables. Figure 4 shows an example of a plot of two real functions of two variables.

Another innovative feature in *Theorist* is the option for generating "translucent" surface plots so you can faintly see the shape and colour of "hidden" parts of the surface.

Plotting a single complex function of a single complex variable is a difficult task which most mathematical plotting packages shy away from. *Theorist* however provides an excellent tool for doing exactly that and it is no more difficult than plotting a real function. You select the dependent and independent variable, just as for the real case, but you choose **Complex 3D** from the **Graph** menu. The result is a surface plot drawn as a function of the real and imaginary parts of the independent variable. The height of the surface gives the amplitude of the complex function and the *colour* of each point on the surface gives its phase.

Animations

Theorist also has built-in animation capabilities for both 2D and 3D plots. You simply select the variable to be scanned during the animation and choose **Animate** from the **Graph** menu. An option is provided for the speed of animation play back. It is not possible to set up an "auto reversing" animation however. A useful piece of information provided on the Animate dialogue box is the maximum number of animation frames you can fit in to the currently available memory. Animations can also be played back using an external application called *Projectionist* which is provided on the *Theorist* distribution disks.

One poor feature of *Theorist's* graph plotting is its positioning of axis titles. Often the label for the x or y axis may fall on top of the numerical labels for the tick marks. Although this may be excusable for 3D plots, it even happens for 2D plots when there is plenty of room between the axes and the graphics viewport. I am sure that correction of this problem would make more users consider graphical hardcopy from *Theorist* as publication quality.

When you print from inside *Theorist*, you can only print the whole contents of the notebook. You can't select only a single expression or plot to be printed. When a graph is printed, the interactive icons appear on the side of the graph but there is a menu option for suppressing this during printing.

Conclusion

I was impressed by *Theorist*, particularly the ease at which complicated expressions can be entered and manipulated and the power of its colour graphics and animation facilities.

It may not have some features of the more expensive packages but it is certainly has the most useful ones and is very easy to use. Theorist's menu-driven commands and plain English-like declarations and transformation rules mean that the user doesn't need to remember various symbols to define rules. If you are a specialist who requires certain repetitive manipulations to be *programmed* (rather than used interactively) then *Theorist* is probably not your best choice.

Theorist does have some weak points, such as the not-quite publication quality hardcopy it produces. The lack of explicit control over the accuracy of the internal numerical algorithms is also a point of concern. It is however, brimming with many innovative features for interactive symbolic manipulations which will surely become standard on other packages in the future.

Prescience corporation also produce a package called *Expressionist* which is a scientific equation writing application which can be used in conjunction with *Theorist*. (You get a demonstration copy on the *Theorist* disks — a full version of *Expressionist* costs US$129-95). Combined with *Theorist*, they make a combination that is pretty hard to beat at the price.

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Physics Dept., University of Otago, Dunedin, N.Z.

Product Reviewed:

LETTERS

Lorenz or Lorentz?

The name of the Dutch physicist, Hendrik Antoon Lorentz, is familiar to anybody interested in Electromagnetism. Particularly well-known are his article, "Ueber die Grundgleichungen der Elektrodynamik für bewegter Körper," published in 1890 in the *Annalen der Physik und Chemie*; his extended paper on "La théorie électromagnétique de Maxwell et son application aux corps mouvants," written in 1892 and published in the *Archives néerlandaises des Sciences exactes et naturelles*; and his book on the *Theory of Electrons*, which came out in 1909 (and has been reprinted by Dover Publications). Lorentz was present at the birth of Relativity, and published his famous transformation formulas, which connect the 4-coordinates in an inertial frame to those in another frame, at the turn of the century. Even more familiar are the "Lorentz retarded potentials," based on the "Lorentz condition." In this instance, however, a case of mistaken paternity seems to have taken place. The undersigned was recently glancing through Whittaker's monumental *History of the Theories of Aether and Electricity*, and read with interest, on p.268 of Volume 1, that the paternity for the retarded potentials should really be assigned to L. Lorenz, a Danish physicist who introduced them in three articles written in 1867 (Lorentz was 14 years old at the time). One of the articles, entitled "On the Identity of the Vibrations of Light with Electrical Currents", was written in English, and appeared in Volume XXXIV of the *Philosophical Magazine*. It is most interesting. The author first quotes the Kirchhoff expression for the electric field, viz

$$u = -2k\left(\frac{d\overline{\Omega}}{dx} + \frac{4}{c^2}\frac{d\alpha}{dt}\right),$$

$$v = -2k\left(\frac{d\overline{\Omega}}{dy} + \frac{4}{c^2}\frac{d\beta}{dt}\right),$$

$$w = -2k\left(\frac{d\overline{\Omega}}{dz} + \frac{4}{c^2}\frac{d\gamma}{dt}\right). \tag{1}$$

We nowadays use the more compact form

$$\mathbf{E} = -\mathrm{grad}\phi - \frac{\partial \mathbf{A}}{\partial t} \tag{2}$$

The quantity c in (1) is a given constant. Lorenz then writes the scalar potential as

$$\overline{\Omega} = \iiint \frac{dx'\,dy'\,dz'}{r}\,\varepsilon'\left(t - \frac{r}{a}\right) + \int \frac{ds'}{r}e'\left(t - \frac{r}{a}\right) \tag{3}$$

where ε' and e' stand for the volume and surface charge densities, respectively, and he gives corresponding expressions for the vector potential (α, β, γ). The retardation ef-

fect appears clearly in (3), where the symbol a is the velocity of light. Lorenz assumes that c^2 in (1) is $2a^2$, and mentions that the best value of c known at the time was 284736 miles per second (8% too large as we now know). Towards the end of the article (p 299), he proves that

$$\frac{d\overline{\Omega}}{dt} = -2\left(\frac{d\alpha}{dx} + \frac{d\beta}{dy} + \frac{d\gamma}{dz}\right) \tag{4}$$

which is the gauge erroneously attributed to Lorentz:

$$\mathrm{div}\mathbf{A} + \varepsilon_0\mu_0\frac{\partial\phi}{\partial t} = 0 \tag{5}$$

Lorenz' work is remarkable, since it was performed in parallel with that of Maxwell. The reader will probably agree that the paternity suit must be decided in Lorenz favour. It appears that the various authors of textbooks who sinned against historical accuracy — the undersigned being regretfully one of them — should amend their references in future printings of their books!

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[Ed: The above note is a modified (by Jean Van Bladel) version of that which appeared in the April, 1991, issue of the *IEEE A-P Magazine*. The typesetting (by me) of equations (1), (3) and (4) in this version was made to match as closely as possible that of Lorenz's paper as it appeared in the *Philosophical Magazine* as "translated from Poggendorff's *Annalen*, June 1867" (footnote on p. 287), while the equivalents, equations (2) and (5), are in more familiar form. In view of the mechanical aether models of the time, the concluding remarks of Lorenz (typeset to match the original) are particularly interesting if "sufficient matter" means physical space as an entity with measurable properties as opposed to "vacuum" meaning nothingness:

"In this idea there is scarcely any reason for adhering to the hypothesis of an æther ; for it may well be assumed that in the so-called vacuum there is sufficient matter to form an adequate substratum for the motion.

This hypothesis as to the nature of light and of electrical currents will probably, as science progresses, either assume a new form, or be totally rejected. But the result of the present investigation, that the vibrations of light are electrical currents, has been obtained without the assumption of a physical hypothesis, and will therefore be independent of one."]

Vlasim in need

With the change in the political situation in Czechoslovakia we are looking for opportunities to extend our scien-

tific activity. For several years we have been cooperating with the Solar Section of AAVSO (US) and the British Astronomical Society. Apart from that we are participating in the scientific activity of the Astronomical Institute of Czechoslovak Academy of Sciences Ondrejov and other local centres.

The chief objects of our interest are recording of solar activity (SEA 27 kHz and 38 kHz), the results of which are sent to Boulder, observation of the photosphere, chromospheric flares and corona, and following the active areas by radio interferometer (741 MHz). We are also taking part in predictions of the solar flare activity with the Astronomical Institute Ondrejov and we are carrying out the medical and ecological program 'KARDIOALERT'. We also record meteorological data in cooperation with the Hydrometeorological Institute Prague-Komorany, we look after ecological monitoring, and we organise scientific meetings with foreign participation.

ALL THAT FREE OF CHARGE!

Up till now the totalitarian system in this country did not give us even a single paid employee. Financial support was minimal and our results are entirely the outcome of our enthusiasm and our will.

Today, when the transformation to a market economy in CSFR is in progress and we have the opportunity to open up to the world, we are appealing for your help — financial contributions and donations of instruments that we urgently need such as a PC XT/AT with a printer, gas chromatograph, etc. In return we offer you every cooperation in future ventures.

Jan B. Urban
Observatory Vlasim, Nejedleho 1341, 258 01 Vlasim
Czechoslovakia

[Ed: Jan Urban has raised an important point also raised by Ron Woodman at SCOSTEP: observatories around the world, only some of which are in affluent countries, are expected to provide continuous data for the international community of science in a spirit of cooperation *for free*. This would be fine if there existed an International Science Foundation available to scientists everywhere and with a few billion dollars to distribute each year. But there isn't, and the present trend of small or emerging or desocialising (my speller won't find that!) countries to change to a market economy means that science not seen to have economic benefits is getting less support (so our Eastern European colleagues may have more reason for worry than for hope). The consequence is loss of these observatories. Here in NZ the ionosonde network was closed down to save money. Impassioned motions passed at URSI and SCOSTEP general assemblies have virtually no effect on politicians, so what do we do?]

VERSIM VLF/ELF Remote Sensing of the Ionosphere and Magnetosphere

From VERSIM newsletter No 1. (Dec 1990) Edited and updated 13 April 1991, A.J. Smith

Trimpi networks

There seems at present to be an increasing interest in deploying networks of narrowband, short-time-constant, VLF receivers, tuned to a selection of VLF transmissions, in order to provide a network of crossing paths for use in the detection and imaging of particle precipitation through use of the trimpi effect (e.g. *Helliwell et al.*, J. Geophys. Res. 78, 4679, 1973; *Smith and Cotton*, J. Atmos. Terr. Phys. 52, 341, 1990; *Inan et al.*, J. Geophys. Res. 95, 17217, 1990). The VERSIM working group serves as a means of exchanging information about the current status of such networks, such as receiver sites, frequencies, transmissions recorded, receiver types, operating schedules, etc. Clearly if such networks continue to develop and expand, then given the long subionospheric propagation distances at VLF, there is the scope for truly global measurements and imaging of precipitation, with attendant scientific benefits, provided that the appropriate coordination and interpretation can be achieved. Below is listed the information presently to hand on planned or currently operating networks. If the information is incomplete or incorrect, I should be glad if the investigator concerned would contact me so that a suitable update can be included in the next VERSIM newsletter.

UK — British Antarctic Survey have been operating University of Otago pattern OPAL (Omega Phase and Amplitudes Logger) receivers at Halley and Faraday, Antarctica, since early 1989. These receivers recorded the amplitude and phase, averaged over an Omega segment ~1 s), of all five transmitted frequencies (10.2 kHz, 11.05 kHz, 11.33 kHz, 13.6 kHz, and a unique frequency) for a selected set of four out of the eight Omega transmitters. These were chosen to be Argentina, Liberia, North Dakota and Hawaii at Halley; Argentina, Liberia, Hawaii and Reunion at Faraday.

It was found that the signal-noise ratio was too small for trimpi events of typical size <= 1 degree in phase and <= 0.1 dB in amplitude) to be seen on the weaker transmissions, so in 1990 the OPAL receivers were modified to record amplitude and phase of signals from two Omega transmitters and two MSK transmitters. The data from the latter, being continuous, can be recorded with a choice of averaging times (0.4 s or 1.25 s in the current design). Optionally, the upper and lower frequencies present in each MSK signal can be recorded separately rather than averaged, allowing for the possibility of "group trimpis" being detected (*Dowden and Adams*, J. Geophys. Res. 95, 4135, 1990). Current transmitter selections are at Faraday: Omega Argentina, Omega Hawaii, NAA, and NPM; and at Halley: Omega Argentina, Omega Liberia, NAA, and NSS. A receiver has also been operated intermittently at BAS HQ in Cambridge.

USA — At the Prague URSI meeting, Dr U.S. Inan showed results from the Stanford University trimpi network which uses a variety of paths over North America. Receivers are located at Stanford, Huntsville (Alabama), Arecibo, and Lake Mistissini (Quebec), with a further receiver in the southern hemisphere at Palmer station (Antarctica). Transmitters used include NAA, NSS, NLK, NPM, NAU, and a 48.5 kHz transmitter located in Nebraska. One subset of paths in this network was a line consisting of two transmitters and two receivers (NLK, Nebraska, Huntsville, Arecibo). A case study was presented with a precipitation region on this line near to Huntsville (perpendicular paths, e.g. NAA-Stanford etc. were not perturbed). In one hour of trimpi activity, events were seen up to 15 dB(!) in perturbation amplitude. A detailed study of the sferic to trimpi onset delay time, and the shape of the trimpi rise/fall, could be used to extract information about the precipitation energy profile. An effect in which (for negative amplitude trimpis) a short rise was seen just before the main decrease in amplitude, and which was only seen on the shortest path (Nebraska to Huntsville) at quite low latitudes, was interpreted as being due to very high energy electrons which arrive before those in the main part of the pulse, and penetrate deeper into the atmosphere. A case study of conjugate trimpi events was also described.

New Zealand — The University of Otago (Professor R.L. Dowden and Dr C.D.D. Adams) have deployed their OPAL receivers, and later OMSK receivers (Omega-MSK) at a variety of sites including Dunedin, Macquarie Island, and Campbell Island. They have also used a closely spaced (less than a wavelength) receiver array based on Dunedin, for direction finding on observed trimpi events. An experiment to fly OMSK receivers, as part of a long life balloon payload, is underway in collaboration with the University of Washington (Professor R. Holzworth).

France — Dr Yvonne Corcuff and Professeur Pierre Corcuff (both of the Laboratoire de Signaux et Communication, University of Poitiers) plan to deploy a VLF experiment at Kerguelen early in 1991. This will make amplitude and phase measurements of Omega-Reunion on 10.2 kHz, 11.33 kHz, and 13.6 kHz, and also NWC on 22.3 kHz. The receiver is of the Stanford University design. Broadband measurements and narrowband measurements in 5 bands, of VLF noise, will also be made.

South Africa — The University of Natal group are in the process of joining the international OPAL-MSK net of receivers to monitor Omega and US Navy MSK transmissions in both amplitude and phase. This is a joint project by Dr A.R.W. Hughes and R.H.W. Friedel with Prof R.L. Dowden of the Department of Physics, Otago University, New Zealand and Dr A.J. Smith of BAS, Cambridge, UK. New receivers are being installed at Durban before going to Sanae in 1992 to join the existing BASnet of receivers at Halley and Faraday.

As an extension to the above project, the Durban receivers (SHOMSKI's: Sferics, Hiss, Omega and MSK Instrument) will also be equipped to receive telemetry signals from the ELBBO project (13.45 MHz MSK). This project involves extremely long-life high altitude balloons which will carry a VLF receiver into the trade-winds around Antarctica in an attempt to establish the longitudinal variation of both sferic and hiss VLF activity. This is a joint project with Prof R.L. Dowden of the Department of Physics, Otago University, New Zealand and Prof Robert Holzworth of the Space Sciences Division of the University of Washington, USA.

Brazil — Dr L.R. Piazza (CRAAE, San Paulo) has been operating a modified VLF Tracor receiver at the Brazilian Antarctic station Ferraz since February 1989, in an experiment to detect trimpi events. It is planned to deploy a Stanford type trimpi receiver first in Brazil (L=1.15), then at Ferraz.
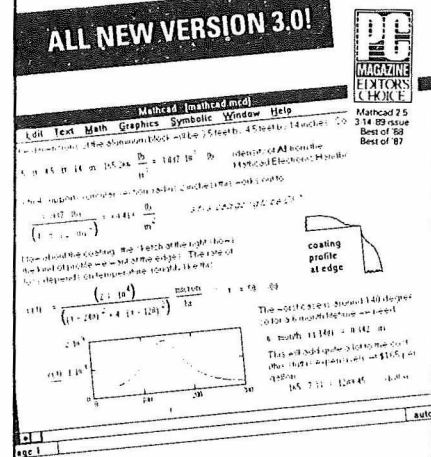
A. J. Smith
Co-chairman of the VERSIM working group
The Radioscientist

[Ed: Andy Smith is now the Regional Editor for UK. His full address, telephone and fax numbers, and his email addresses are found on page 42, the "Editorial Staff" page.]

Hardware review — New life for an old Macintosh Plus

Maybe real radioscientists, or radio engineers at any rate, use PCs, but I use a Macintosh. If you are a PC–only person, don't read any further. It is all in Macintosh jargon anyway. I have an old (1986) Mac Plus with a single internal 800 K disk drive and no hard disk. This is OK for word processing and graphics but far too slow for the applications which Alan McCord has been telling us about in this issue and the previous one. Also, it is becoming harder and harder to make do without a hard disk.

So I got myself a "NewLife" upgrade for around the price of a good hard disk. Not only did I get great speed but also a great substitute for a hard disk.

RAM disk

The "hard disk" is either very hard or very soft, depending on your point of view. It is actually a "crash resistant" RAM disk. My Mac motherboard had, and still has, 4 Mbytes of 110 ns SIMMS. The NewLife board takes a further 4 Mbytes so I filled this with 70 ns SIMMs. The NewLife processor board uses only this. The original 4 Mbytes on the motherboard is used entirely and solely for the "protected" RAM disk. So once having set it up, the RAM disk stays intact as long as the power stays on, even if you reboot.

Just like a hard disk? Well not quite, since you can't boot up on it. If you use the reset on the programmer's switch or either the Restart or Shut Down menu items you will think you have lost your RAM disk. The Mac will wait expectantly (with a flashing "?") for a bootup disk.

Here's where the NewLife manual could have been more helpful. When I set up my first RAM disk and before trying a reboot, I put all the system files into a folder on the RAM disk so that I could add other folders of applications without getting the application files mixed up with the system files. After all, a 4 Mbyte RAM disk is still not big enough to hold all the applications you will ever use. You will need to load and unload (from floppy or via Tops, for example) your less frequently used applications as you need them.

So, how to reboot? I first tried my disk as used to form the RAM disk originally. Unfortunately the Finder on this disk couldn't "see" the system files hidden inside the RAM disk folder. The first attempt produced a box to the effect that the Finder was "damaged" so "try again". I did, and it worked. But the RAM disk now had a double set of System files — those inside the folder and a new set outside it mixed up with my application files! Some of the excess could be put in the Trash, others refused this and had to be put in the system folder which only worked after answering all the consequent dialogue boxes.
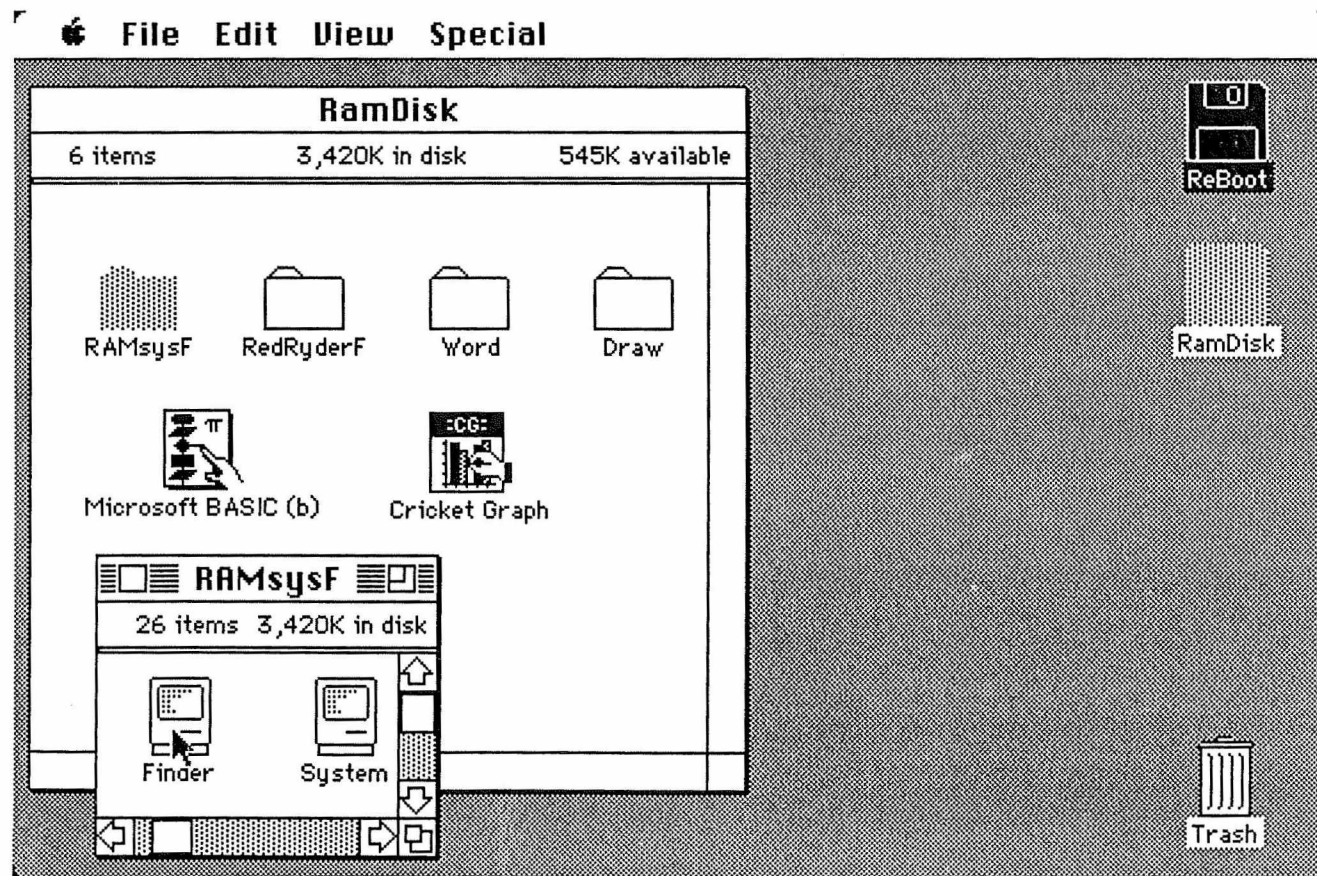
**   File   Edit   View   Special**

Fig. 1. Screen dump immediately after rebooting following a crash or "bomb". The RAMsys Finder is about to be double clicked while holding down the Option and Command keys. This will make "RamDisk" the system disk and allow "ReBoot" to be dragged into the trash can to eject it.

Since I wanted the optimum method of rebooting (e.g., following a "bomb" which gives one no choice) I continued experimenting. Dragging all the system file icons to the far right of the window (a tedious drag-scroll-drag-scroll process) gets them out of sight but "visible" on reboot. Unfortunately, rebooting with the original disk replaces the System file (Mac icon) with a (probably) much leaner version on your boot up disk.

So here is the solution, but first a few points on getting an adequate system on your RAM disk in the first place or after a cold start (from power off). My system (System, Finder and all system files including printer drivers) is well over 1 Mbyte and so cannot fit on an 800 K boot up disk. I first made a "RAM installation" disk. This contains a System file stripped of all non-essential fonts and DAs (desk accessories), but installed with all features like *Tops* which require rebooting to work. This initial bootup was done without the Ramdisk installer file. With the Ramdisk installer file there was just enough room for all the essential system files for Ramdisk installation on next bootup. These essential system files include the files provided by NewLife but not printer drivers which are loaded after bootup. It may not be obvious what files are essential and what can be loaded later. Some experimentation may be needed. All these files non-essential for initial boot up are on a second 800 K disk which includes a DA and font loader and the DA and font files. I call this my "Printer" disk.

Booting up produces a Ramdisk of 4 Mbytes, makes it the system disk and ejects my "RAM installation" disk. I then insert my "printer" disk, load the required files into the Ramdisk, and install all the fonts and DA's I need. This whole system (System and all system files) of 1.2 Mbytes or so is put in a folder ("RAMsysF") with the Finder icon in the top left corner and the window sized so that only the Finder icon needs to show (see Figure 1).

At this stage I made a copy of my "RAM installation" disk, removed the RAM disk installer but left all other system files intact, and named it my "ReBoot" disk. So when I eventually get an application crash — the dreaded "bomb" or a freeze up or a psychodelic screen with sound effects, I just press reset (programmer's switch) or click restart and I am back to the expectant Mac with the slowly flashing "?". I now insert my "ReBoot" disk. After a relatively short time (50 sec) I get the screen just as shown in Figure 1.

There is my "Ramdisk" back and intact but "ReBoot" is the System disk. The system on "ReBoot" is the lean one (pull down the apple menu and see). No matter. I just double click the RAM disk Finder (see mouse arrow in Figure 1) while holding down both "Option" and "Command" keys. All this takes only 60 seconds from reboot and I have my fat Ramdisk system back (pull down the apple menu and see all the DA's). Of course, if I had spent four hours working on the Radioscientist in Word without saving, tough! Note that I can save to Ramdisk (for increased speed) without fear of loss in a crash.

Speed

The *"NewLife 25"* board is almost a replacement motherboard. The 68030 CPU it contains, running at 25 MHz, speeds the Mac Plus by a factor of about six for ordinary tasks like word processing. This is very noticeable in scrolling, spelling checks, sorting and "change all" commands. But the really spectacular speedup (over 100 times!)

shows in tasks which can use the 68882 floating point unit (FPU) co-processor on the *NewLife* board. This means that some tasks taking an hour to complete on the ordinary Mac Plus may now take only 30 seconds.Several speed comparisons between the Mac Plus with *NewLife* (denoted as "Mac + NL"), a Mac II with 40 Mb hard disk and a Mac IIfx with 160 Mb hard disk, were made on *"Speedometer 2.5"*, a shareware product by Scott Berfield (send him $25 if you want a copy). Although *Speedometer* uses built-in data on several Macs from SE to IIci for comparisons, we thought it fairer to run each test on each of the three real Macs in turn (in fact, our real Mac II gave speeds similar to that expected from *Speedometer*)

These tests include the classic benchmarks, *Whetstone* (floating point operations), *Dhrystone* (everything else!), *Sieve of Eratosthenes* (integer arithmetic), and *Savage* (function and inverse calculation). For purposes of comparison, all results are expressed as frequencies or reciprocal times. Speedometer has three further speed tests of *CPU* (memory moves, loops, graphics, etc), *Math* (essentially Whetstone) and *Disk* (repeated reads and writes) all scaled to a standard SE with an Apple HD20 internal SCSI drive.

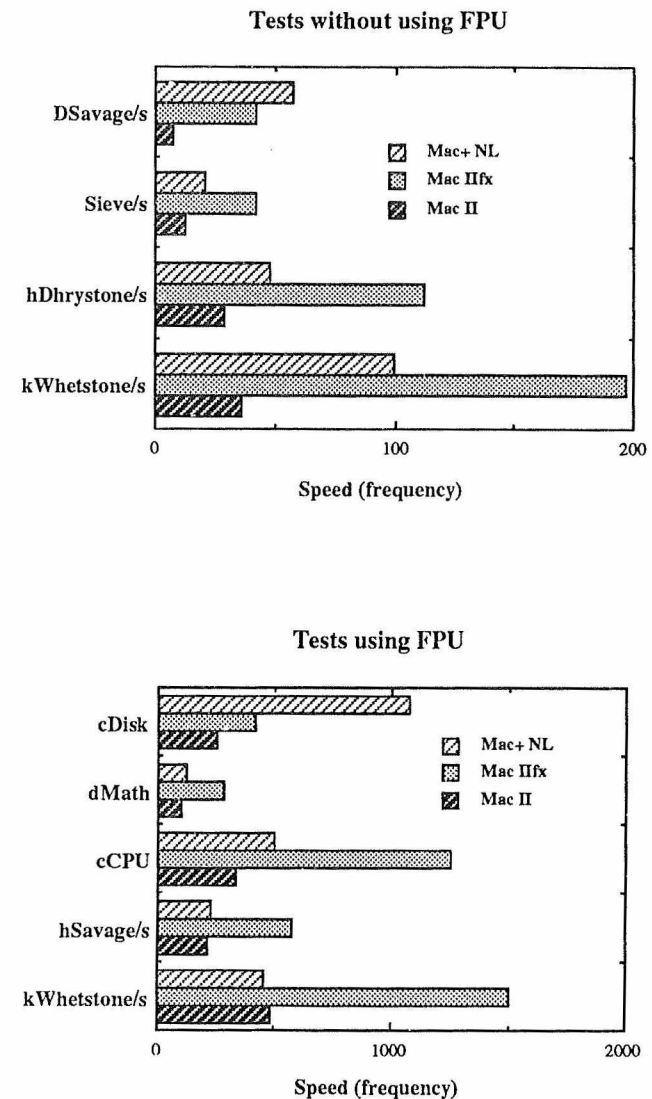All tests were made with and without the FPU, though for

Tests without using FPU

Tests using FPU

Fig. 2. Speed tests with and without the FPU.

some tests (*Dhrystone, Sieve* and *Disk*) the "use" of the FPU makes no difference. For the displayed comparisons above (Figure 2), the various speeds were scaled up or down in factors of ten (denoted by k = kilo, h = hecto, D = deca, d = deci, c = centi) so that all comparisons between the three Macs are visible. Results not shown for use of the FPU are those for which the FPU cannot help.

In most tests the Mac + NL is faster than the Mac II by factors of 1 (when FPU is helpful and both use it) to 8 (*Savage* without FPU) but slower than the IIfx by factors of 2 to 3. The notable exception is in the *Disk* test where the Mac + NL using its 4 Mb RAM disk is 2.5 times the IIfx speed and over 4 times the Mac II speed (both using their hard disks). The *Savage* test is speeded up by the FPU but if the FPU is disabled on all, the Mac + NL is faster than the IIfx! Unless this is the result of faster disk reads (since The Mac + NL uses its Ramdisk), it is hard to understand since the IIfx uses the same 68030 processor but at 40 MHz instead of 25 MHz. My own speed comparison was to run a program in interpreted BASIC (which can't use the FPU even if available) to calculate the radiation pattern of an antenna array. This took 1 minute 40 s on the IIfx, 3 m 19 s on the Mac + NL, 5 m 40 s on the Mac II and 20 minutes on an ordinary Mac Plus. Although not shown in Figure 2, the *CPU, Math* and *Disk* speeds were measured on a Mac Plus by *Speedometer* on 800 K diskette. For these three tests respectively the Mac + NL using its FPU and RAM disk was faster by factors of 6, 120 and 80.

Conclusion

For a cost (including 4 Mb of RAM and a fan) of approximately half that of a Mac SE30 bought on the University (Apple Consortium) discount, the upgrade has indeed given "new life" to my old Mac Plus. It now has the speed of a Mac IIci (approx), a 4 Mbyte "hard" disk and is even more portable than the old Plus configuration since I no longer need an external disk drive. The manual claiming that the upgrade gives "up to 6 times performance improvement" and includes a "crash resistant" RAM disk is surprisingly understated on both counts. The performance improvement is 6 to 120 times. The RAM disk always (so far!) survives a crash (probably due to *Word* or *Igor*, not Ramdisk itself) whereas I abandoned my last hard disk because of its frequent crashing with complete loss of data on it. Even if the RAM disk does ever crash with loss of data this can hardly damage the RAM. One of our ATs has destroyed two hard disks so far. The fan supplied with NewLife is more than adequate (but still reasonably quiet) to keep my Mac cool despite its 8 Mbyte of dynamic RAM and three processors, so I can (and do) leave it powered on permanently.

On the debit side, I had to spend many hours of experimentation to work out how to install the system I needed on the RAM disk and how to reboot quickly. Still, I won't have to do this again and you won't either if you use my solution. The crash proof Ramdisk would be more useful if the Mac could boot up on it as if it was a hard disk. This is because most system parameters requiring modification, and system utilities like *Tops* and *Tops Spooler* requiring installation, require rebooting to take effect. Maybe there is a work around with the present *NewLife* when an 800 K diskette is not big enough to use my solution. If so, the manual should say so, but I can't claim an unbootable Ramdisk as a "debit" if no one else has produced one yet.

When is a Mac not a Mac?

I forgot to say that *NewLife* copies the Mac ROM into the new RAM to speed up access. OK. Suppose the next enterprising guy offers a super upgrade for any old Mac. Installation involves replacing everything inside the case except the power supply and screen (or maybe those too), with the upgrade supplied. Say this results in a "Mac" with twice the speed of a Mac IIfx at half the cost. It has precisely the same look and feel of a Mac. It runs all the same software, but faster. No, it's not a clone, it's like the axe that has been in my family and in continuous use for 100 years. It is still as good as new. Mind you, this axe has had four new handles and three new heads in that time.

R. L. Dowden
The Radioscientist

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603 Kanata
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Canada
Fax   +1 613 592 1320

Speedometer 2.5 by   **Scott Berfield**
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Summit Meeting on Whistler Mountain

URSI President, Edward Jull (left) and URSI medalist (1978), James R. Wait (right, see also p. 47, this issue), discussing the future of URSI (or something!) on Whistler Mountain, Vancouver (16 April, 1991)

International Meeting For Wave Propagation in Random Media (Scintillation)

A meeting on wave propagation in random media, co-chaired by Professors Tatarskii and Ishimaru, will be held August 3-7, 1992, at the University of Washington, Seattle, U.S.A. This meeting of the optical, radio, and acoustical communities will result in an exchange of ideas and new insights for all participants. Only problems of wave propagation in continuous random media will be addressed. Relevant topics include

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The Institute of Physics

International Union of Radio Sciences (URSI)

Optical Society of America

- statistical description of scintillation (PDF, second moment, fourth moment)
- measurements of scintillation statistics
- measurements of turbulence spectra using scintillation
- measurement of velocity using scintillation
- remote sensing using scintillation
- scintillation of waves propagating in random media upon reflection (mirror, phase conjugate mirrors, retro reflector, diffuse target)
- image and focal plane statistics with scintillation
- simulation of scintillation problems
- effects of turbulence profiles on scintillation statistics
- scintillation of beams, incoherent and partially coherent sources
- multifrequency scintillation
- pulse propagation in random media
- adaptive optics and scintillation
- speckle interferometry

Papers are solicited for presentation in a poster format to foster conversations between scientists from the different communities. Invited papers will be presented by internationally recognized experts. If you plan to attend this meeting (or would like to receive the advance program), please complete and return the following section to: Scintillation Meeting, Engineering Continuing Education, University of Washington, 4725 30th NE, GG-13, Seattle, Washington 98195

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