An Analysis of Noise Aggregation from Multiple Distributed RF Emitters

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Abstract

The purpose of this technical note is to explore the aggregate noise generated by a large number of distributed radio emitters. There have been concerns that the widespread and ubiquitous use of ultra-wide-band (UWB) devices might increase the ambient noise levels beyond today's conditions. There are particular concerns regarding aircraft safety due to substantial line-of-sight propagation through the air.

Both the theoretical analysis [1] and past experiences with actual, spatially reused, radio systems are related to this theoretical model and *strongly indicate that substantial noise build-up does not and will not occur.*

From our derivations, it becomes clear that problems cannot come from an aggregation of emitters within a 45 degree cone below the victim receiver. On the other hand, the effects of an aggregation of emitters near the horizon are controlled by either of the curvature of the Earth or damping at ground level near the emitters.

The developed model applies equally to all radio emitters, addressing spatial reuse of AM and FM radio, spread spectrum, and UWB sources alike. The density of the emitters is not an issue, only the spatial reuse. The longstanding observation of non-aggregation of noise of such emitters as AM and FM radio and cellular systems speaks to the effectiveness of damping and the finite Earth in mitigating the effects of an aggregation of emitters on the horizon.

1. Aggregation Model

We consider the aggregate power at the apex of a solid cone resulting from the aggregate power emitted by the disk forming the base of the cone (Fig. 1). We will eventually apply this model with the base of the cone on the surface of the Earth and the apex at some height above the surface. We take the radius of the disk to be r and the height of the apex above the ground plane to be h. The areal power density in the base disk is P. Using the inverse square law we can integrate in cylindrical coordinates over the base disk and arrive at P_{apex}, the apex receiver power density per unit area of apex receiver antenna (x is the radius from the base of the cone):

$$\begin{aligned} P_{apex} &= \int_0^x P \frac{2\pi x_*}{h^2 + x_*^2} dx_* = \pi P \int_0^x \frac{d\left(h^2 + x_*^2\right)}{h^2 + x_*^2} = \\ &= \pi P \ln\left(h^2 + x_*^2\right)\Big|_{x_* = 0}^{x_* = x} = \pi P \ln\left(\frac{h^2 + x^2}{h^2}\right) = \pi P \ln\left(\sin^{-2}(\theta)\right) \end{aligned} \tag{1}$$

If $\theta = \pi/4$ then the power density at the apex is

$$P_{apex,\theta=\pi/4} = \pi P \ln\left(\sin^{-2}(\pi/4)\right) = \pi P \ln(2) = 2.178P \tag{2}$$

This is not a very big increase.

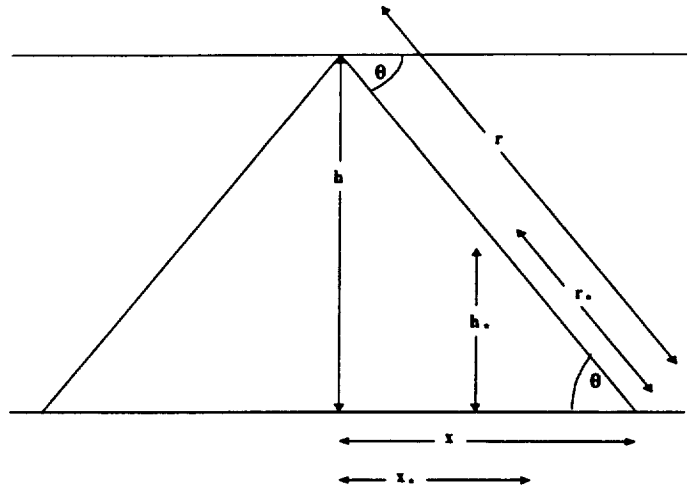

Fig 1 – Setup Geometry

Beyond $\theta = \pi/4$ we are ultimately limited by the radius of the Earth R_E =6,375,000 m, whose effect is not negligable. For $h << R_E$ (true for any altitude in the atmosphere) we have $hR_E = x_H^2$ where x_H is the distance from directly below the apex to the horizon.

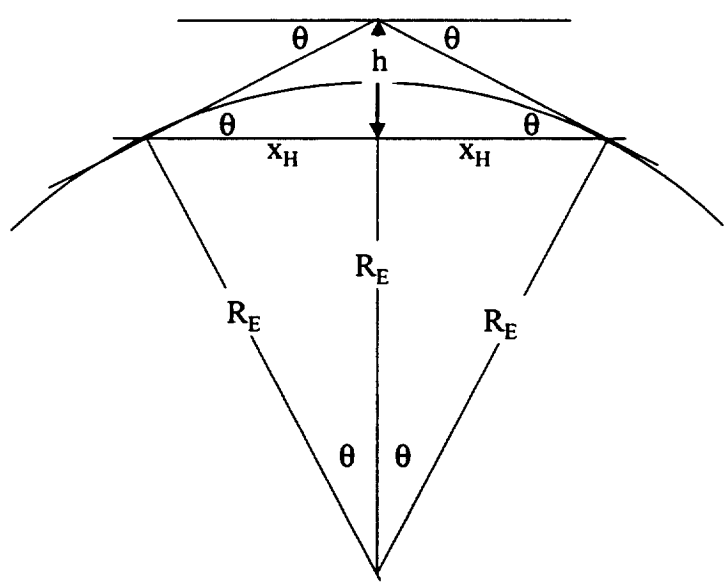

Fig 2 – Earth Curvature

Then we have

$$P_{apex\ to\ horizon} = \int_0^{\sqrt{hR_E}} P \frac{2\pi x_*}{h^2 + x_*^2} dx_* = \pi P \ln\left(1 + \frac{R_E}{h}\right)$$
$$= \pi P \ln\left(\sin^{-2}\left(\theta_H(h)\right)\right) \approx 2\pi P \ln\left(1/\theta_H(h)\right) \tag{3}$$

As an example, if the apex height h is 100 m we will have

$$P_{apex,\ h=100m} = \pi P \ln\left(1 + \frac{6{,}375{,}000}{100}\right) = 34.75P \tag{4}$$

2. Electromagnetic Damping

There are only two possible dispositions for emitted photons. They may either be lost to space or they may be absorbed here on Earth. Such absorption in this context is referred to as *damping*. Interaction with matter which is neither perfectly conducting nor perfectly insulating (i.e., most materials) will result in a non-zero proportion of the photons being absorbed. Damp materials found close to the surface of the Earth are particularly effective in absorption. Moreover, the complex natural and man-made geometry near the surface of the Earth causes many reflections and other changes of course to the photons, resulting in increased interaction with absorbing materials.

We therefore need to modify the above derivation to take damping into account.

Damping is characterized by an absorption coefficient b_* which describes the proportion of photons absorbed in traversing a unit length of a given material. We will not assume that the absorption coefficient is a constant, but rather that it varies widely for different materials. In our context we will assume that it varies with the distance from the apex and with the height h_* above the surface of the Earth. (Do not confuse h_*, the height of a photon in propagation, with h, the height of the apex.) We expect the height to be the parameter causing the largest variations.

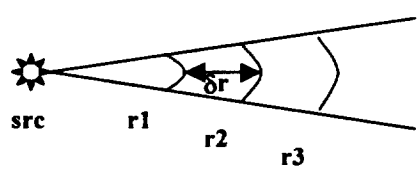

Fig 3 – Signal Propagation

The signal power degrades as it travels farther away from the source (Fig. 3). If the signal strength at the distance *r1* is *P(r1)*, then, with the inverse quadratic law, the signal strength at the distance *r2* can be described by the following equation.

$$P(r_2) = \frac{r_1^2}{(r_1 + \delta r)^2}(1 - b_*(h_*(r_2), r_2)\delta r)P(r_1) \tag{5}$$

This process is repeated and thus at a distance of r_n, the signal strength is the following:

$$\begin{aligned} P(r_n) &= \prod_{i=1}^{r_n/r_0} \frac{r_i^2}{(r_i + \delta r)^2}(1 - b_*(h_*(r_i), r_i)\delta r)P(r_1) \\ \ln(P(r_n)/P(r_0)) &= \ln\left(\frac{r_0^2}{(R + \delta r)^2}\right) + \sum_{i=1}^{r_n/r_0} \ln(1 - b_*(h_*(r_i), r_i)\delta r) \\ &\approx \ln\left(\frac{r_0^2}{r_n^2}\right) - \sum_{i=1}^{r_n/r_0} b_*(h_*(r_i), r_i)\delta r \approx \ln\left(\frac{r_0^2}{r_n^2}\right) - \int_{r_0}^{r_n} b_*(h_*(r_*), r_*)dr_* \end{aligned} \tag{6}$$

In the limit as $\delta r \to 0$ we have

$$P(r_n)/P(r_0) = \frac{r_0^2}{r_n^2} e^{-\int_{r_0}^{r_n} b_*(h_*(r_*), r_*)dr_*} \tag{7}$$

Equation (1) is then generalized to

$$P_{apex} = \int_0^r P \frac{2\pi x e^{-\int_0^{\sqrt{h^2+x^2}} b_*(h_*(r_*), r_*)dr_*}}{h^2 + x^2} dx \tag{8}$$

In the case where b_* is a function of h_* alone the value of b_* will be noticeably greater than zero for small h_* (near the Earth's surface) and negligibly small for larger h_* where the propagation path is "line-of-sight" through the air. The integral of b_* along a ray is still definitely greater than zero. Notice that in the geometry of Fig. 1 that $h_* = \sin(\theta)r_*$

$$\begin{aligned} & b_*(h_*(r_*), r_*) = b_*(h_*(r_*)) \Rightarrow \\ & \int_{r_*=0}^{r_*=\sqrt{h^2+x^2}} b_*(h_*(r_*), r_*)dr_* = \csc(\theta)\int_{h_*=0}^{h_*=h} b_*(h_*)dh_* = r\frac{1}{h}\int_0^h b_*(h_*)dh_* = br \end{aligned} \tag{9}$$

where we define

$$b = \frac{1}{h}\int_0^h b_*(h_*)dh_* \tag{10}$$

Therefore, in this case, the damping integral is still O(r). The aggregated signal power at the apex, considering damping, is

$$P_{apex,damped} = \int_0^{\sqrt{hR_E}} P\frac{2\pi x_* e^{-br}}{h^2+x_*^2}dx_* = \int_0^{\sqrt{hR_E}} P\frac{2\pi x_* e^{-b\sqrt{h^2+x_*^2}}}{h^2+x_*^2}dx_* =$$

$$= \int_0^{\sqrt{hR_E}} P\frac{\pi e^{-b\sqrt{h^2+x_*^2}}}{h^2+x_*^2}d\left(h^2+x_*^2\right) = \int_h^{h\sqrt{1+\frac{R_E}{h}}} P\frac{\pi e^{-bu}}{u^2}du^2 = \int_{bh}^{bh\sqrt{1+\frac{R_E}{h}}} P\frac{2\pi e^{-v}}{v}dv = \tag{11}$$

$$= 2\pi\left(\exp\mathrm{int}(bh) - \exp\mathrm{int}\left(bh\sqrt{1+\frac{R_E}{h}}\right)\right)P$$

It's not so clear what happens when the damping coefficient b is very small. If $bh\sqrt{1+\frac{R_E}{h}} << 1$ we obtain

$$P_{apex,damped,b\ small} = \int_{bh}^{bh\sqrt{1+\frac{R_E}{h}}} P\frac{2\pi e^{-v}}{v}dv \approx \int_{bh}^{bh\sqrt{1+\frac{R_E}{h}}} P\frac{2\pi}{v}dv =$$

$$= 2\pi\left(\ln\left(bh\sqrt{1+\frac{R_E}{h}}\right) - \ln(bh)\right)P = 2\pi\ln\left(\sqrt{1+\frac{R_E}{h}}\right)P = \pi P\ln\left(1+\frac{R_E}{h}\right) \tag{12}$$

so that the aggregation is bounded even if b is zero (as in eq. 3) so long as h is not.

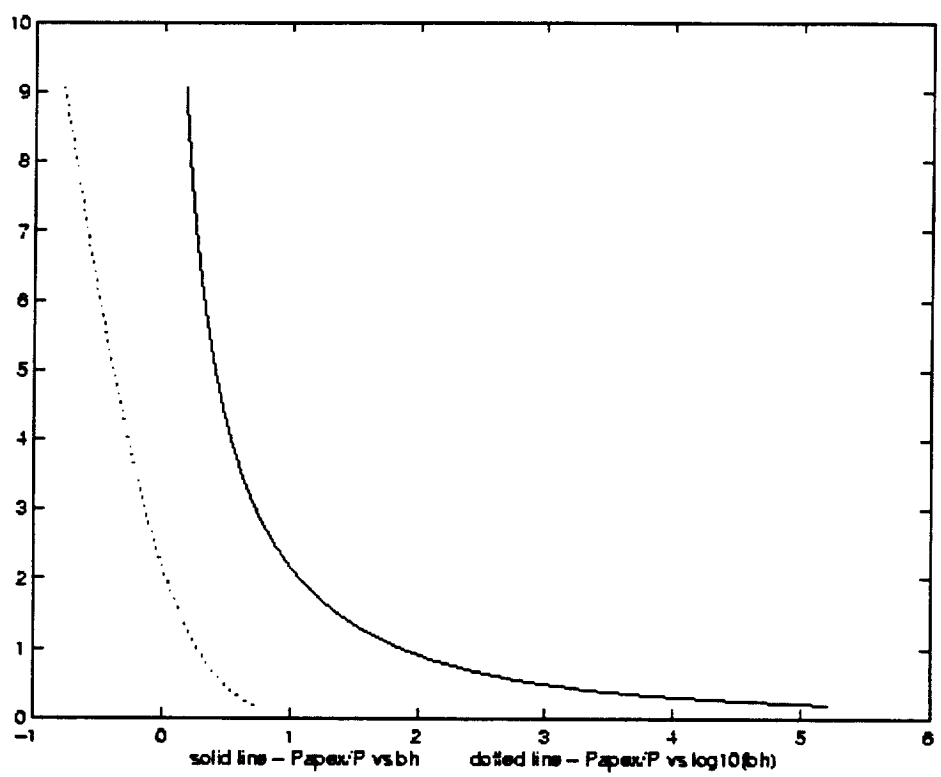

Figure 4 – Relative apex power vs. scale height

Thus this integral is finite for all positive values of h. Rather than speculate on the values of b, we'll shortly address the question qualitatively. A similar computation shows that the apex aggregate power is finite even if the damping integral increases as slowly as $O(\ln(r))$.

Thus it is clear that very small amounts of damping prevent the aggregate power from growing large.

Figure 4 graphs the aggregation factor as a function of the *scale height bh* and also of the $\log_{10}$ of the scale height.

3. Application to Spacially Reused Radio

An examination of the preceding arguments reveals that the model depends neither on the bandwidth nor on the modulation of the signal. The arguments depend only on the spatial reuse of the frequencies to the extent that a continuous emitting source plane is a good approximation. However, as any aggregate is linear in the power density, that aggregate will be finite if both the height and damping are positive (non-zero) and remains so as long as the power density has an upper bound (surely so if there are a finite number of transmitters).

Conversely, if the analysis given above is faulty we would conclude that we would observe unbounded aggregate power levels from the many contemporary RF sources that are spatially divided. Such sources include cellular phone systems, FM radios and even AM radio stations. *No such aggregation is observed.*

4. Conclusions

A theoretical analysis for the noise aggregation of spatially reused radio systems has been developed. Both this analysis and past experience with actual spatially reused radio systems related to this model *strongly indicate that substantial noise build-up does not and will not occur.*

From our analysis, it is clear that noise buildup from an aggregation of emitters within a 45 degree cone below an airborne victim receiver is very limited (approximately a factor of two).

Aggregation of noise from emitters near the horizon is controlled by either of the curvature of the Earth or damping at ground level near the emitters. . Such radiation departs its source essentially parallel to the plane (clearly not perpendicular to it). Damping of these plane parallel rays is significant as described in the next section.

The developed model applies equally to all radio emitters, addressing spatial reuse of AM and FM radio, spread spectrum, and UWB sources alike. The density of the emitters is not an issue, only the spatial reuse. The longstanding observation of non-aggregation of noise of such emitters as AM and FM radio and cellular systems speaks to the effectiveness of damping in controlling horizontal aggregation.

References

[1] T. Shepard, "*Decentralized Channel Management in Scalable Multihop Spread-Spectrum Packet Radio Networks*", Ph.D. Thesis, MIT/LCS/TR-670, July 1995.

[2] M. Rofheart, J. McCorkle, "*Short Analysis on the Effects of a Large Number of UWB Systems*", OC Technologies Inc. Technical Report, 1998.

Appendix A – Numerical Approximation and Simulation

Alternative to an analytic solution of the problem stated, one might be tempted to numerically approximate the problem. However, as we will show in the following, it is extremely difficult to numerically calculate large RF aggregations accurately without inadvertently introducing the equivalent of some damping. To illustrate this, consider the numerical summation of $\sum_{i=0}^{\infty} \frac{1}{i}$

The obvious way of calculating the (divergent) summation is to set a running sum to zero and then add terms in the order of indexing until convergence is obtained. Numerical convergence generally will be obtained and we can approximate the converged value. Suppose that the calculation is performed with single precision IEEE arithmetic, with 24 bits of mantissa. Eventually the running sum will become 2^24 times the running sum and further additions will not increase it.

Let this happen after N terms. Then the running sum will be about ln(N) so we need ln(N) ~ 2^24/N. Solving for N we obtain 1,198,700. So "convergence" is obtained after a million terms and the running sum is ln(N) = 14, approximately! In effect the terms that are 2^24 times smaller are "damped" to zero.

Such series are well known to be difficult to sum. Since the terms are positive, any convergence will be absolute so that the sum can be calculated in any order. If, say, 3.25x10^6 = 1.2*e terms are summed from smallest to largest the running sum will increase from 14 to 15 and we can get the sum to 16 by summing 1.2*e^2 terms. Double precision with 56 bits of precision will converge with 2*10^15 terms yielding a summation value of just 35.

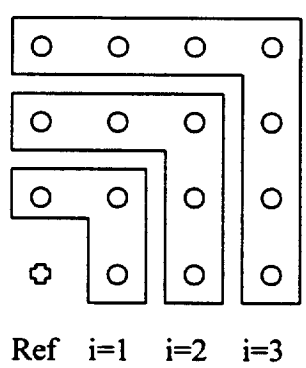

Fig 5 – Field of Emitters

Even worse, it is clear that any absolute or any relative convergence criteria will eventually be met, even with very high precision arithmetic. In essence, we must know that the series diverges in order to program the calculation correctly!

A double summation of the form $\sum_{j>0,k>0} \frac{1}{j^2+k^2}$, is closely related to the integral in section 1 and diverges in the same way. A divergent lower bound can also be calculated in layers as Fig. 5 illustrates.

$$\sum_{j>0,k>0} \frac{1}{j^2+k^2} > \frac{3}{1^2}+\frac{5}{2^2}+\frac{7}{3^2}+\ldots$$

yields the corresponding lower bound series.

$$\sum_{j>0,k>0} \frac{1}{j^2+k^2} > \sum_{i=1}^{\infty} \frac{2i+1}{i^2} > 2\sum_{i=1}^{\infty} \frac{1}{i} > 2\int_1^{\infty} \frac{dx}{x} = \ln(x)\Big|_1^{\infty} = \ln(\infty) \tag{14}$$

a slowly diverging one that goes to infinity.

Appendix B – Estimating the Damping

Empirical studies have often fit their data with a propagation law that is not inverse square ($\frac{1}{r^2}$), but rather a higher power ($\frac{1}{r^{2+\varepsilon}}$).Any positive, non-zero value of ε leads to finite aggregate power [1] for all values of *bh*, including zero. These studies [1] generally have found $2.4 \le 2+\varepsilon \le 4$.

There is a particular form for the damping $b(h(r),r)$ that reconciles this empirical form with the earlier analysis. From equation (8) we have

$$P_{apex} = \int_0^r P \frac{2\pi x e^{-\int_0^{h^2+x^2} b(h(r),r)dr}}{h^2+x^2} dx = \int_0^{\infty} P \frac{2\pi x}{\sqrt{h^2+x^2}^{2+\varepsilon}} dx \tag{15}$$

and this will be satisfied if

$$e^{-\int_0^{h^2+x^2} b(h(r),r)dr} = \sqrt{h^2+x^2}^{-\varepsilon} \tag{16}$$

Taking the log and the differentiating each side

$$\begin{aligned} -\int_0^{h^2+x^2} b(h(r),r)dr &= \ln\left(\sqrt{h^2+x^2}^{-\varepsilon}\right) = -\frac{\varepsilon}{2}\ln\left(h^2+x^2\right) \\ \frac{d\left(\int_0^{h^2+x^2} b(h(r),r)dr\right)}{d\left(h^2+x^2\right)} &= \frac{\varepsilon}{2}\frac{d\left(\ln\left(h^2+x^2\right)\right)}{d\left(h^2+x^2\right)} \end{aligned} \tag{17}$$

we end up with

$$b(h(x),x) = \frac{\varepsilon/2}{h^2 + x^2} \tag{18}$$

This damping function decreases rapidly with distance but is still sufficient to limit aggregation. Physically, it is consistent with a "foamy" propagation medium where the matrix is lossy and where there is a suitable "long-tailed" distribution of void sizes. Such a propagation environment seems consistent with the interiors of buildings. It also seems consistent with the tangent plane out-of-doors where the role of the lossy matrix is played by vegetation and tree canopies, structures, and terrain relief.

Appendix C – Matlab Code for Figure 4

```
for i = 24:-1:1,
   x(i) = exp(0.15*(12-i));
   y(i) = WhiteSky(x(i));
end;
hold off;
plot(x, y, 'b');
hold on;
plot(log(x)/log(10), y, ':r');
xlabel('solid line - Papex/P vs bh        dotted line - Papex/P vs log10(bh)');
print -dbmp256 'C:\WINDOWS\Desktop\WhiteSky.bmp';

function v = WhiteSky(H);

global bh;
if  H > 1/10^8,
   bh=H;
   A=1;
   v = quad8('Integrand', A, 14); % the range of integration must be split
   while A > H/1000,              %   in order to avoid excessive recursion depth
      A=A/8;                      %   errors in quad8
      v = v+quad8('Integrand', A, 8*A);
   end;
   v = v+quad8('Integrand', 0, A);
   v = 2*pi*v;
   % disp(v);
else
   v = 2*pi*(log(1/H)+log(10^-4)+expint(10^-4));
   %    2*pi*(log(10^-4)+expint(10^-4))= -3.6269;
end

function u = Integrand(t)

global bh;
u = t.*exp(-t)./(bh*bh+t.*t);
```

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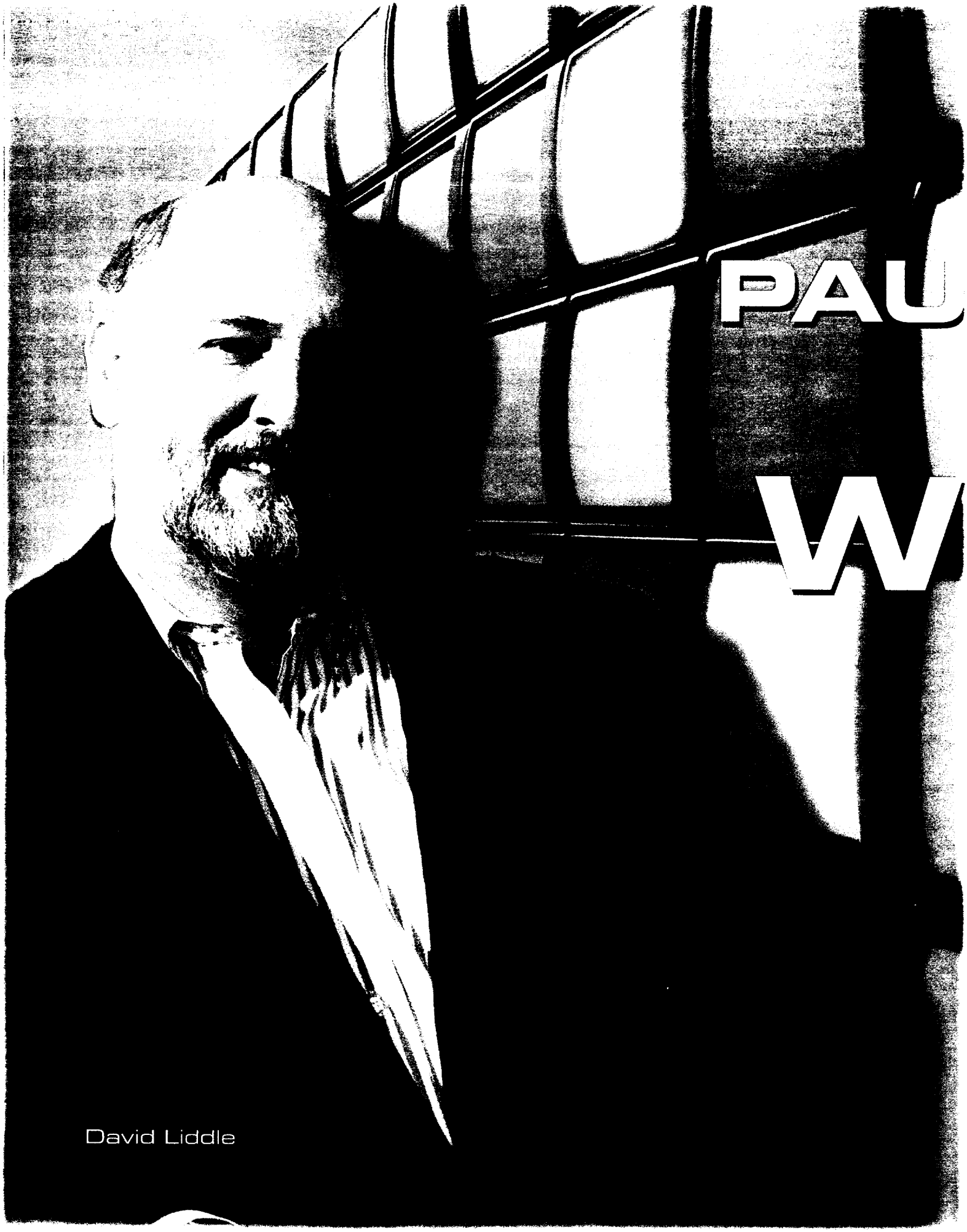
David Liddle
of Interval Research

PAUL ALLEN'S SECRET WEAPON

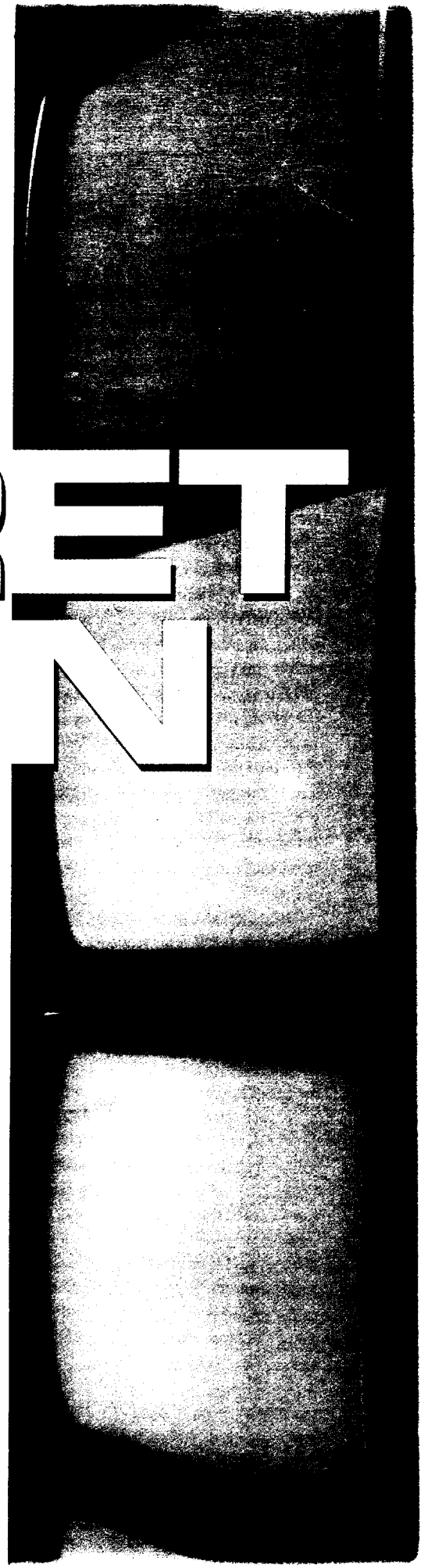
His name is David Liddle, and he's creating the future in a Silicon Valley lab no outsider has ever seen —until now



David Liddle

ALLEN'S SECRET WEAPON

■ BY TOM KERVER



They say the only difference between men and boys is the size of their toys. If that's true, then Paul Allen is having fun playing with the sort of digital toys that only someone of his immense wealth can afford.

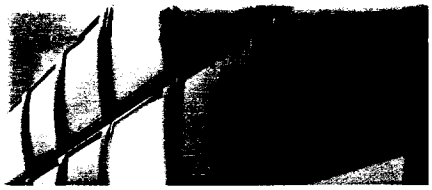
In Palo Alto, Calif., down the street from Hewlett-Packard's world headquarters and in the shadow of Stanford University, Allen's funding supports the efforts of his colleague, Dr. David Liddle (pronounced Li-DELL), who oversees a research team of 200 of Silicon Valley's best and brightest.

These individuals, many holding doctoral degrees from academia's finest bastions of learning and research, come from diverse disciplines. They're united by a communion with Allen's digital dreams. Their "baggage" consists largely of a dedication to bringing these dreams to fulfillment. Their collective goal is to create digital-based applications that will enrich and perhaps even enthrall the American consumer.

Not surprisingly, such dreams sometimes incorporate concepts such as 3D and so-called "virtual reality."

But Interval Research pushes these concepts well beyond what often passes for technology research.

Mind you, technology is unquestionably very important at Interval. But it's only one aspect of a broader effort. Another major piece of the puzzles being manipulated and assembled there—one not often visible in research laboratories of this genre—is the potential customer.



"Paul [Allen] recognized 16 years ago that almost all the research efforts with a digital bent were focused on commercial applications, explains Liddle, who's Interval's president/CEO. "He knew even then that what companies like Xerox and IBM were doing to improve the flow of commerce had to spill over to the consumer side. He and I saw it much the same way. So, with the consumer in mind, we started Interval in 1992."

Free Form, Free Flow

The outward appearance and sparse interior furnishings of Interval's three-story building belie much of what's going on inside. At any given moment, a couple of dozen free-form research projects—varying in scope from digital dubbing of human voices and facial expressions to morphing sounds, from creating interactive children's games to repackaging television news programs—are undergoing intense inquisition. Much of this is the kind of work that many major corporations and academic institutions can only wish that their restricted budgets would permit.

Allen doesn't skimp when it comes to providing the funds. If a team seeks to travel to West Africa or the Middle East to bring to three-dimensional life some of the world's most sacred and hallowed sites, so be it. If someone thinks it's important to morph the sound of one word into the sound of a very different word with a very different meaning, the opportunity is available.

Unlike some other research labs—including highly touted ones at Massachusetts Institute of Technology and nearby Stanford—Interval, says Liddle, "tries to approach each challenge on a business basis. Everything we do, even blue-sky projects, is required from the start to gear itself toward potential consumer applications." Hence, he says, "We combine deep, fundamental engineering with exploration of what users in the marketplace will tolerate and perhaps embrace."

Still, Interval doesn't function in a vacuum. It has ongoing collaborative projects with the MIT Media Lab (see page 46), Stanford, New York University and even London's Royal College of Art. Artists, journalists, architects, economists, musicians, psychologists, filmmakers and other creators converge within Interval's work force. Quite intentionally, only about 125 of the 200 positions are considered permanent.

"Creative people don't want to be permanently ensconced in a research environment," Liddle explains. "They have other interests to pursue. Yet they bring so much to the process, and we're very anxious to get their contributions." Each year about 40 newcomers replace 40 departees. "It helps recharge the intellectual gene pool and keeps everybody from getting stagnant," he adds.

Liddle is convinced that "If you want to develop interesting products for real people, you need to mix creative thought and artistic talent with technical expertise."

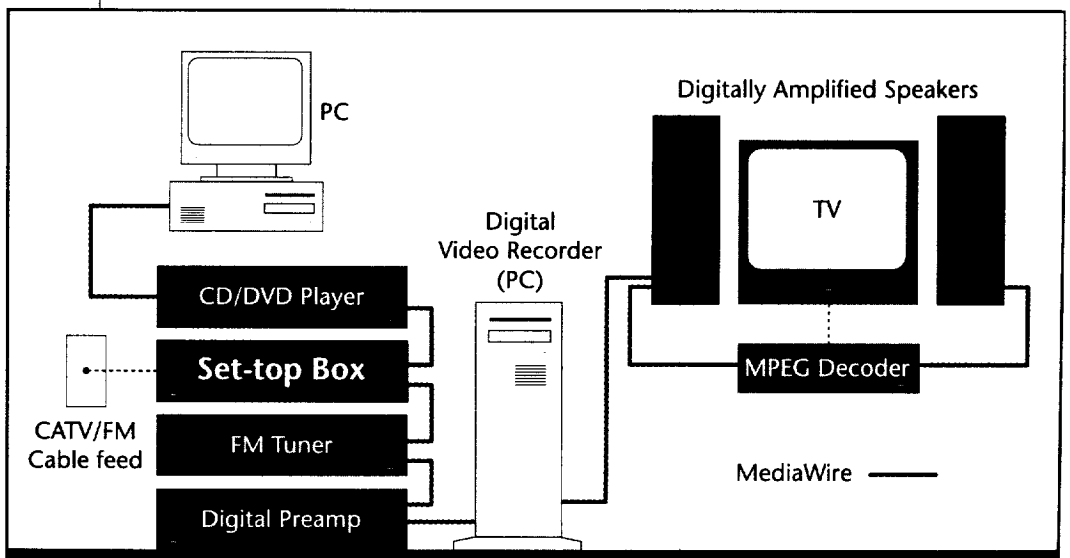
Avio Digital: Wiring the Future

Down the street from Interval Research, birthing pains are readily apparent at the company's newest spin-off, Avio Digital—as the staff struggles to unpack boxes and set up shop. Time is of the essence, because Avio is slated to debut its MediaWire Home Network at this week's Western Cable Show in Anaheim, at the Scientific-Atlanta booth.

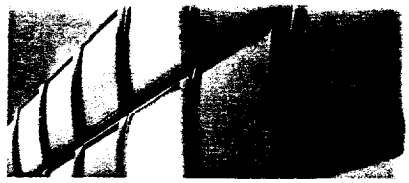
Acting CEO Michele DiLorenzo explains that MediaWire emanated from three years of work at Interval. It empowers a mini-network within the home, using existing in-house (copper) wiring, to carry digital signals from room to room and device to device.

A single "OpenCable" digital set-top device could be a home-automation control center, feeding high-capacity digital input to television sets, personal computers, telephones and other household appliances. The output feeds would be linked and directed via MediaWire's simple plug-in connectors. Digital signals would move through existing twisted-pair (Category III) copper within the walls of the home.

In theory, Avio's MediaWire network could



A simple MediaWire™ home network



The Allen Factor

Liddle seems to enjoy Allen's wholehearted support. "Paul never dictates or directs what we do. He doesn't get involved in management issues. Instead, he supports us in many ways that go well beyond providing the funds. When he's here, he brainstorms with us and helps us review projects. Off hand, I can think of at least eight projects that directly resulted from his input," Liddle says.

Nonetheless, Allen's financial backing could be his most critical contribution. The broad mix of talent at Interval doesn't come cheap, especially in Silicon Valley, where the cost of living (and, therefore, of salaries for bright, creative thinkers) is stratospheric.

It cost Allen about $100 million to start Interval in 1992. Maintaining its research projects (especially in the absence of income to this point) has cost untold millions more (probably at least an additional $100 million). Liddle won't discuss finances, other than to say that Interval ultimately expects to begin showing some revenues from start-up companies it seeds. "We're designed as a for-profit business. However, we're still only part-way there. It takes at least 10 years in this environment before we know whether something works," he says.

He likens Interval to a pipeline. "At any given time, around 25 ongoing research projects sit at the fat end of the pipeline. As these projects progress, perhaps five to seven of them will be singled out for advanced development. From that group of five to seven, maybe two will emerge each year as start-up companies."

The first start-ups, which produce digital products for education and entertainment of young people, emerged from Interval's pipeline in 1996. This year, coincident with Allen's $7.3 billion (so far) investment in cable distribution plant, witnessed the birth of Interval's first cable-related start-up, Avio Digital (see page 32).

Real-World Focus

Like all of Interval's start-ups, Avio was hatched only after extensive consumer research suggested its products would serve a useful real-world need.

But the research Interval conducts is often far different from the normal focus-group approach that most companies pursue (see page 36). Says Dr. Bonnie Johnson, who oversees much of this effort: "We're looking for answers that go beyond just what people tell us in focus groups. We use a variety of techniques in the hopes of getting deeper meaning from their answers."

For example, Johnson likes to employ hidden video cameras during focus-group sessions to record facial expressions and other body language. Often those details reveal more about what a consumer really thinks than his spoken words. Sometimes, Johnson's staff even track consumers into their homes (with permission) or watch them at play as they attend concerts or other entertainment.

One stereotype she dismisses as outmoded is the way households interact with their TV sets. "The image of a family sitting down together to watch a pro-

---

simultaneously distribute as many as four digital video streams, eight telephone calls, 16 digital audio streams and more than 3 megabits/second of data. But though the research and advanced development are finished, much remains to be done before MediaWire can integrate with "OpenCable" set-top technology to create a digital network within the home.

Says a somewhat skeptical Steve Effros, president of the Cable Telecommunications Association (CATA): "Cable operators have learned the hard way that copper wiring inside a home's walls may not be as good as advertised. If Category III wiring is to carry digital signals, it must be well-shielded and tightly wrapped. That's not always the case, and it's one reason why ADSL technology is proving far more challenging to the phone companies than they had expected."

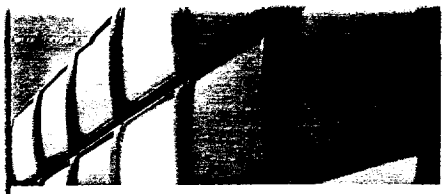
Effros feels a wireless solution—several of which are under development in direct competition with Avio's wire-based approach—may have some strong advantages. "The wired approach may be satisfactory in relatively new single family dwellings, but it could be highly suspect in older homes and multiple-dwelling units," he suggests.

But such skepticism isn't deterring DiLorenzo and her Avio colleagues. "Our experience tells us that, using average Category III wiring, we can transfer signals point-to-point up to 100 feet between specific devices," says Roger Meike, one of Avio's senior executives. "Moreover, we can create a total network within the walls of the home that would stretch out to a distance of 2.5 miles."

Meike holds equity in Avio, which is an interesting aspect of the new company. Ownership is shared—not in equal proportion—by three entities: Interval Research (Paul Allen and David Liddle), Avio management (principally DiLorenzo, Meike and chief technology officer Glenn Edens) and Vulcan Northwest (Allen's investment company, which also controls Charter Communications and Marcus Cable). That structure immediately suggests two things:

- Allen strongly believes in Avio's potential, because he has a dual investment track—through Interval and through Vulcan.
- Charter/Marcus will probably be testing Avio technology in some upgraded systems in the very near future.

Since Charter CEO Barry Babcock is also chairman of CATA (theoretically, therefore, Effros' boss), Effros seems to realize that he might be skating on thin ice were he to sound excessively skeptical about Avio's potential in the cable environment. "If Avio can create a wired network within the digital home, it will be great day for cable," he says—with seemingly sincere enthusiasm.—*T.K.*



gram is woefully obsolete. Lives are changing; people are talked out at the end of the day. Many prefer to be alone with the company of a TV set that doesn't talk back to them," she says. That is precisely the kind of conclusion that will be incorporated into future Interval products.

The Broadband Factor

Because they come (as does Allen) from a computer-focused background,

Let's Do the Time-Shift Again

Though supposedly immersed in scientific objectivity, research can also be a labor of love.

So it is with Interval's Paul Freiberger, a technical journalist and news junkie turned researcher on a project called "News Browser." Like Discovery Communications' now latent Your Choice TV, News Browser is a time-shifting concept (i.e., like videotaping your favorite daytime soap to watch at night) whose real-world usefulness may have been displaced, unfortunately, by the very technology it employs.

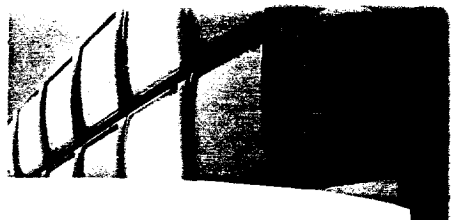
Paul Freiberger

Unlike Your Choice and other time-shifting efforts, Freiberger's project is PC-based. Television news broadcasts are downloaded and stored in a PC, with color codes and icons used to help the user call them up by topic. Thus, for example, the business segment of a Headline News replay can be instantly accessed. "This puts all control over content into the user's hands," Freiberger explains.

Freiberger thinks the PC might be the appropriate tool to make time-shifting of news and information attractive, even though the concept hasn't interested television viewers. "People who use the PC are more receptive to learning on it," he says. But the dynamic and often perishable nature of news and information can make a morning-after (or even hour-after) viewing of any news broadcast look like ancient history. Worse yet, Web sites operated by wire services, networks and newspapers all provide a more current version of what Tom Brokaw or Dan Rather was saying earlier in the day.

Perhaps the concept would work better on TV newsmagazines like *60 Minutes*, which look behind the stories and cover issues in depth. Or perhaps even talk shows have a place in this kind of realm. The jury's still out on those things, so Freiberger continues his research in the advanced-development mode.

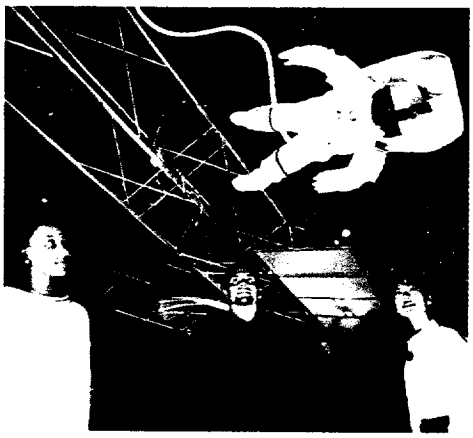
Soon, however, "It will be up to the business gurus to determine whether this project proceeds any further," Freiberger says. He's nervously awaiting their verdict.—*T.K.*



Liddle, Johnson and many others at Interval still have much to learn about the television side of "convergence." But as Johnson's research is starting to attest, they're learning fast. They'd better. As Allen begins to lay a foundation for a wired future on a TV-focused platform, he and his colleagues will need to reorient themselves to take full advantage of that platform's potential.

Liddle says he's very much aware of that. Avio is only the first of what promises to be a plethora of ventures with direct cable relevance. Already in Interval's pipeline are projects focusing on new applications for high-speed data that will be pushed through cable modems.

Under close scrutiny, for example, is the concept of transferring digitally delivered data into electronic books and catalogs. Johnson's consumer research has convinced her that "people don't want to read on their PCs." So the idea—already being unleashed by others in somewhat crude formats—is to create electronic books that people can read at their leisure without disturbing others around them. The content would be downloaded and refreshed as needed via broadband into a portable, battery-powered device.



At the Tech Museum's Exploration Gallery, visitors can take a virtual trip to Mars.

This and similar concepts now have a real-world testing laboratory in the form of Allen-owned cable systems. "Knowing we now have access to a cable plant will make a big difference for us as we plan our research priorities for next year and the years beyond," Liddle says.

This shift toward broadband-oriented research could be seismic from Interval's perspective. "It's not something out on the horizon," Liddle maintains. "More so than in the past, you'll see us starting to shift toward a cable orientation right away. It will happen in 1999."

Even in a place where earthquakes are commonplace, Paul Allen's secret weapon is set to shake things up in a big way. •

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INFORMATION TECHNOLOGY GUIDE — AND MORE

JULY 11, 1994

$4.50

FORTUNE

Managing in a WIRED WORLD

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A LOOK INSIDE ALLEN'S THINK TANK

FORTUNE'S GUIDE TO INFORMATION TECHNOLOGY

THIS WAY TO THE I-WAY

With $100 million to spend, this research center has hired the best to find out what the information highway will need by way of goods and services. ■ **by David Kirkpatrick**

WHAT LOOK LIKE madcap frolics on these pages actually represent some pretty serious research. With the help of a hefty complement of eminent software developers and electrical engineers, some of the very best anthropologists, psychologists, videographers, virtual-reality designers, musicians, artists, and writers are trying to identify the goods and services that will be profitable once the information highway really gets going. In fact, and as is often the way in science, by play-acting hypothetical scenarios of the wired future and building prototype devices, staffers at Paul Allen's Interval Research have already stumbled on five prospective products they weren't even looking for. Just as typically, the center won't reveal any details.

In a large sense, Allen is re-creating Xerox PARC (Palo Alto Research Center), which so fed his head and those of Bill Gates and other makers of PC hardware and software when those industries were in their infancy. Allen says he wants Interval to do "pure research." He hopes Interval will have the kind of influence on the new wired consumer universe that PARC had on PCs when it invented local area networks, the mouse, and laser printing.

To run the research center as its president, Allen turned to David Liddle, 49, one of the most respected names in computerdom. Liddle spent ten years at Xerox PARC before leaving to start Metaphor, a business software company. IBM bought the company in 1991, and Liddle became a millionaire. Liddle, quite a visionary himself, took the job at Interval after a long conversation with Allen from which, he says, he came away awed: "Paul was really taking the long view. He gave me some papers he'd written years before. I realized how parallel our views were."

REPORTER ASSOCIATE *John Wyatt*

David Liddle was hired to think about everybody's future worries.

Liddle symbolically selected a site half a mile from PARC as Interval's home. The center plans to become self-supporting within ten years, probably through licensing fees paid for its discoveries and spinoff companies that will develop products. Interval also will feed ideas to other Allen companies. Liddle says having artists on his staff is critical: "In the first five minutes with a piece of technology, artists push it to the edge of what's possible. That is how you find out what *is* possible. You need unreasonable people doing things for reasons they can't verbalize."

Interval devotes a huge amount of time and money to studying real people and how the I-way may affect them. Teams of employees spend days on end with insurance salesmen in home offices, retirees in a nursing home, even a hair stylist in her salon. The teams take copious notes and videotape everything. Then, back at the office, they engage in role-plays they call "informances," meaning informative performances. Allen sometimes sits in the bleachers as researchers ask such questions as: Would the hair stylist want a digital communicator in this situation? The point is to try to live the electronic future as staffers imagine it in order to ferret out inconsistencies and unexpected opportunities.

Much of Interval's work is directed toward how individuals can use technology creatively—to make consumer electronics more active than passive.

Liddle won't elaborate much on Interval's work, but he says that among the more than 20 projects under way are a study of entertainment electronics; development of wearable devices; research into the potential perils that computer viruses may pose for the info highway; a study of how men and women, and boys and girls, will differ in their use of upcoming technologies; and a project that examines how to skim through so-called serial media like video.

PHOTOGRAPHS BY LOUIS PSIHOYOS—MATRIX

"LIVE THE FUTURE BEFORE YOU SPEND MONEY MAKING IT HAPPEN"

So says Interval President Liddle. He might have said, "Draw it." That's how these researchers created this future kitchen and living room, where they act out imagined electronic futures. They model their behavior on real people they've studied. One afternoon they planned a Moroccan dinner by videophone. The dog, Junior, is real.

WHAT'S IT LIKE TO BE LIVE?

Here's how video may intrude in the future: The fanciful red light signals that a camera or microphone has zeroed in on the man at left. In the experiment above, a passerby and a colleague enjoy an electronic hallway encounter.

IF I WERE A CARPENTER, WOULD I NEED A PC?

Masks help engineers and technicians learn to get out of their own mind-set so they can convincingly act out the roles of real people in imagined futures.

WRIST COMPUTERS

From the role-playing come ideas for prototype devices like these.

WORKING TOWARD THE DAY WHEN YOU'LL REALLY FEEL YOU'RE THERE

An Interval filmmaker records the surrounding landscape on twin movie cameras. Film advances as the cart's wheels turn. He stores the stereoscopic views on videodisks as part of a research project on the uses of virtual reality.

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CORPORATE SUMMARY
INTERVAL RESEARCH CORPORATION

Interval imagines how technology will impact individuals and then experiments with how and whether to make it happen.

Founded in 1992 by David Liddle and Paul Allen, the company emphasizes long-term studies in a number of pre-competitive technologies requiring deeper research than is typical today in determining commercial potential. The hope is that its research ideas will become the source of new ideas to drive an industry and provide opportunities for entrepreneurs.

Typical research areas upon which Interval focuses include audio spaces, media skimming, field ethnography, adaptive algorithms, portables/wearables, interactive entertainment, on-line societies, games and kids, collaborative displays, movie maps, on-line journalism, autonomous agents and image/audio compression.

To bring a fresh and real-world perspective to creating the future, Interval has gathered a broad range of people to make up its research staff, including film makers, clothes designers, musicians, cognitive psychologists, artists, computer scientists journalists, entrepreneurs and software developers. The company also collaborates with other research groups and university laboratories, including the Royal College of Art, the MIT Media Lab, the Santa Fe Institute, Stanford University, UCSD, and Electronic Cafe.

Technology will change the way we perceive our world. Interval will change the way people feel about technology.

Interval believes that the emergence of high-capacity, low-cost ubiquitous communications during the coming decade will profoundly change the opportunities for creative use of information and stimulate new approaches to organizing knowledge and human interactions with information-rich products and services.

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David E. Liddle
Biographical Data

David E. Liddle is co-founder, president and CEO of Interval Research Corporation, a high-technology research lab studying technologies that will be meaningful to people in the future. Interval performs research and advanced development in more than 20 technology areas, including network cultures, interactive entertainment, fashionable technology and signal computation.

Liddle heard his calling at an early age. It was 1955, and Liddle's father, an engineer, took his 10-year-old son on a trip to check out a client's computer. The mammoth piece of machinery was two stories high. Its memory was a maze of wires and vacuum tubes. By today's standards, the device was crude. But Liddle saw its promise. Riding home with his dad, Liddle remembers saying, "This programming thing is going to be big - really big."

During and after his education (B.S., E.E., University of Michigan; Ph.D , Computer Science, University of Toledo, Ohio), Liddle has spent his professional career developing technologies for interaction and communication between people and computers, in activities spanning research, development, management and entrepreneurship. First, he spent ten years at the Xerox Palo Alto Research Center and the Xerox Information Products Group where he was responsible for the first commercial implementation of the Graphical User Interface and local area networking. He then founded Metaphor Computer Systems whose technology was adopted by IBM and the company ultimately acquired by IBM in 1991. In 1992, Liddle co-founded Interval Research with Paul Allen, and in 1996, the company announced the formation of three start-up companies based on the research conducted at Interval.

Liddle is a consulting professor of Computer Science at Stanford University. He is chairman of the board of trustees of the Santa Fe Institute. He has served as a director at Sybase, Broderbund Software, Starwave and Ticketmaster. He currently serves as a director at Metricom, Inc. He was honored as a distinguished alumnus from the University of Michigan and is a member of the national Advisory committee at the College of Engineering from that University. He is also a member of the advisory committee of the school of Engineering at Stanford University. He has been elected a Senior Fellow of the Royal College of Art.

San Jose Mercury News

WEST, page 6 | Serving Northern California Since 1851 | SUNDAY, NOVEMBER 3, 1996

INNOVATIONS

The Future of Literature?

By BOB FROST

HELEN CHO of Oakland just wanted a nice home page on the World Wide Web.

She didn't expect that her site would win a big international art competition or that people would hail her for expressing the artistic potential of the personal computer. She certainly didn't expect to win $5,000. But she did.

Cho, 27, began creating her Web page last May. Over the summer she heard about an interesting-sounding contest for digital art.

She entered, largely because her friends suggested it, and then more or less forgot about it.

In October, one of the sections on her home page, called "Quiet Foxes," was awarded one of three top prizes in the "New Voices, New Visions" digital media competition. The annual contest is co-sponsored by Interval Research Corp., a technology think tank based in Palo Alto (funded by Microsoft co-founder Paul Allen), and by Voyager, a New York publisher of interactive media.

This year's competition drew some 430 entries from around the world. Each qualified entry was a digital piece that could be presented on a personal computer—works included Web pages, films, animation, musical pieces, typography, stories, and compilations of photographs. Most of the entries were interactive. The judges, including performance artist Laurie Anderson, leaned toward pieces that were "fresh and experimental" and "expressed the potential of the medium."

A fine-arts high gloss was not necessary, according to Carol Moran of Interval Research. "This is a contest that taps into the folk art of the digital art world," she says.

Cho's Web page is a complicated (or baffling) combination of text and graphical images. "It's an exploration," she says, "of the nature of confession." Subthemes include identity, pleasure, secrecy, shame and fame. The judges said, " 'Quiet Foxes' brings hypertext and art together in a more intriguing and fluid fashion.... It combines luminous imagery, evocative text, and typographic elegance to create compelling literature for a new medium."

Cho earns her living as a free-lance graphics designer. After graduating from Princeton in 1990, she won a Century Fellowship to study English literature at the University of Chicago. She decided she didn't like the program, went to South Korea where she wrote and performed on a children's TV show, and in 1993 won one of 10 annual Wallace Stegner Fellowships in Creative Writing at Stanford, which she did like, very much. She would not mind at all, she suggests, writing a Great American Hypertext Novel.

"Proust and Joyce," she says, "would have *loved* hypertext."

Cho's page is at **www.quiet-time.com** . The "New Voices, New Visions" site is **www.nvnv.org** . ❑

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THE NEW YORKER

LETTER FROM SILICON VALLEY

THE NEXT BIG IDEA

BY JOHN HEILEMANN

Special Reprint

THE NEW YORKER SPECIAL REPRINT

LETTER FROM SILICON VALLEY

THE NEXT BIG IDEA

Why everyone wants to know what's going on at Interval Research.

BY JOHN HEILEMANN

SEVEN years ago, Paul Allen, the co-founder of Microsoft, began to entertain one of those fantasies that, for a billionaire, are automatically more than fantasy. Allen believed that the high-tech industry was in a rut. The Web hadn't yet been born, and although the P.C. revolution that he'd helped instigate was chugging along, its progress was incremental—more of the same, only faster and cheaper. "It was a fallow period," he told me recently, "where the last flurry of innovation was still being digested and you couldn't see where the next flurry was going to come from." What would be interesting, Allen mused, would be to create an institution dedicated to ginning up that next flurry—a new research lab, situated in Silicon Valley and stocked with the best brains in computing, all formulating "ideas and opportunities" suited to what he liked to call "the wired world."

Allen had a model in mind for his project: Xerox's Palo Alto Research Center. By the nineties, Xerox PARC had become a solid, if conventional, corporate R. & D. outfit, but back in the seventies it developed a remarkable number of the technologies that the P.C. industry was built on. The graphical user interface, with its windows and icons and pull-down menus, and also the laser printer, the local area network, the word processor, and the P.C. itself had their roots in PARC. Yet, in one of Silicon Valley's most famous missed opportunities, it wasn't Xerox that commercialized most of these inventions but firms such as Apple and Microsoft, whose founders had visited PARC and then imitated its breakthroughs. Allen himself was one of the plunderers. When he paid a call on PARC in the early eighties, he was "blown away" by what he saw. "I said, 'We gotta have this on the P.C., and this, and this—all of it!' " he told me. A decade later, Allen wanted to found a PARC for the nineties, and to make sure that, this time, the innovators (and their financier) would reap the rewards.

Allen asked David Liddle, who was a well-respected figure in the Valley, to run his think tank. A gifted scientist, Liddle had been a researcher at PARC and had then gone on to head his own software company, Metaphor, which I.B.M. had recently bought when Allen approached him, in the fall of 1991. They agreed that the new lab should devote itself exclusively to technology for consumers, not businesses, and that it should tackle hard problems on a long time line instead of "taking little details from the baroque to the rococo," as Liddle put it. Allen pledged to invest a hundred million dollars in the lab over ten years. It was initially

incorporated under the name Valhalla, but Liddle pointed out that, strictly speaking, Valhalla was where warriors were consigned to relive their deaths again and again. A new name was chosen, which was less mythical but more forward-looking: Interval Research.

In March of 1992, Interval opened its doors, then promptly slammed them shut. Ever since, Allen and Liddle have been obsessively secretive about what their researchers are up to. As a result, Interval has become a subject of intense speculation and skepticism in the Valley—sentiments that have been only heightened by vague leaks about exotic projects ("wearable computing") and by the lab's rare public forays, such as its sponsorship of a funky multimedia exhibit, called the "Electric Carnival," on the 1994 Lollapalooza tour. "Nobody wants to be mean, because David Liddle is such a nice guy," a leading ven-ture capitalist told me. "But the consensus is that what Interval is doing is either irrelevant or just goofy."

Last fall, Liddle invited me to spend a few days at Interval and judge for myself. The lab had spun off three start-ups to take some of its inventions to market, and Liddle and Allen would be deciding imminently whether to spin off several more. Interval was, as the politicos say, ready to show a little leg. And Liddle said that, while there would be certain projects that I couldn't see, and some that I could see but not write about, I'd still get a sense that, far from working on "head-in-the-clouds, tree-full-of-owls stuff," Interval was doing what he and Allen had always said it would do: taking "long strides." However, with the rise of the Internet, Silicon Valley is flush with cash and alive with innovation. At a moment like this, the question isn't simply whether Interval is taking long strides but whether it's taking them quickly enough to avoid getting left in the dust.

SINCE Paul Allen resigned from Microsoft, in 1983—he had Hodgkin's disease but is now considered cured—his net worth has grown to more than fourteen billion dollars. For him, the attempt to re-create Xerox PARC at its zenith may be an act of nostalgia or idealism or idle recreation. For David Liddle, though, it is deeply personal. Liddle, at fifty-three, is a big, bearish man with a bald head and a white beard and clear blue eyes. He talks with his hands, in a genial, professorial manner that belies a cutting wit, a thin skin, and an ambition as fierce as any in Silicon Valley. Ruthann Quindlen, who is Liddle's wife and a prominent venture capitalist, told me, "With Interval, David is trying to correct what happened at PARC."

Xerox had established its lab in Palo Alto, near Stanford University, in 1970, in the hope of profiting from, as opposed to being destroyed by, the incursion of computers into the office. Presiding over PARC's computer-science wing was Bob Taylor, a former administrator in the federal Advanced Research Projects Agency. In the late sixties, at ARPA, he had funded the ARPANet—which later evolved into the Internet—and also much of the serious research on information technology going on at the time. Taylor knew all the brightest young stars of computer science and set about recruiting them to PARC. In 1972, Liddle, a Detroit native who had worked on an ARPA-funded project as a grad student at the University of Toledo, got his Ph.D., and moved West to join the élite team that Taylor had assembled. "It was definitely 'Welcome to the N.F.L.,'" Liddle said.

When Liddle arrived at PARC, Silicon Valley was still known as the South Bay, and computers were machines that typically filled up entire rooms. But Taylor's people had a radical idea about technology. They called it "personal-distributed computing," and around it they built a system of hardware and software which was a decade ahead of its time. They created, in effect, the first P.C.—a workstation called the Alto, which featured a mouse and point-and-click graphics. They tied the Altos together with a high-speed network known as Ethernet, connected them to the outside world through the ARPANet, and equipped them with programs like E-mail and the first WYSIWYG (what you see is what you get) word processor. Liddle recalled, "People in the field whom you respected would show up and just gasp." Even more impressive was the reaction of nonspecialists. "You'd see the spouses of researchers coming in at night to use the system for things like P.T.A. reports," I was told by Charles Simonyi, who had devised PARC's word processor and, later, Microsoft Word. "These were normal people—civilians—using computers for normal stuff. This was unheard-of."

There were early signs that Xerox, with its buttoned-down East Coast culture, didn't appreciate what PARC was up to. A 1972 article in *Rolling Stone* praising the lab irritated the top executives: they hated Xerox's being touted in a "drug magazine" and recoiled from Annie Leibowitz's photographs, which revealed a certain similarity between hackers and hippies. In 1977, at a Xerox senior-management conference, in Boca Raton, the PARC team demonstrated its system and let the executives and their spouses give it a try. "All the wives came forward and sat down and oohed and ahed, because a lot of them had done clerical work and could see how wonderful this was," Bob Taylor told me. "But in those days there was an ethos that an executive didn't type, so all the men stood in the background. The executives wouldn't touch the Altos, just wouldn't come near them." Taylor frowned. "That should have been the handwriting on the wall."

No one felt Xerox's indifference more acutely than Liddle did. In the mid-seventies, he was put in charge of a division that was supposed to turn PARC's research into products, but Xerox didn't enter the blossoming P.C. market until 1981, with an advanced version of the Alto called the Star. Featuring the first full-blown graphical user interface, the Star was impressive; it was also slow and, at around sixteen thousand dollars a box, pricey. The Star bombed. And Xerox, facing severe competition in its core copying business, abandoned its efforts to get into the P.C. business.

For Liddle, the decision was a harsh one. A couple of years earlier, Steve Jobs had toured PARC and come away inspired by the Alto. Jobs's first stab at a graphical machine, the Lisa, had been

introduced just after the Star, and it suffered from many of the same maladies. If Xerox had let Liddle refine the Star, he might have come up with something like Jobs did on his second try—the Macintosh. Instead, Liddle resigned in frustration and joined a long line of PARC refugees who went on to found their own companies, such as 3Com, Adobe, and, in Liddle's case, Metaphor.

For some PARC veterans, Liddle not least among them, pride over having created technology that changed the world is tinged with bitterness over having failed to bring it triumphantly to market. But after some "soul-searching," Liddle said, he came to the view that Xerox's decision—to focus on defending its copier franchise instead of wading deeper into the uncharted waters of the computer business—was inevitable. "I call it the Silicon Paradox," he said. "The only companies that can afford to do research are those with a huge share of a multibillion-dollar market—A.T. & T., I.B.M., Xerox, G.M., DuPont. But the paradox is that the very circumstances that let you do research keep you from taking advantage of it. Meaning that if you already have a big, profitable business it probably makes more sense to focus on feeding that bulldog instead of going into the new businesses your research points to." If a research lab was going to prosper, Liddle concluded, it would need to be free of corporate parentage. It would need to be, in his phrase, "a PARC without a Xerox." Luckily, this was a luxury that Paul Allen could afford.

It is hard to imagine a more comfortable place to invent the future than Interval. Allen and Liddle's lab occupies several buildings on some of Silicon Valley's sweetest real estate, not far from the foothills on the western edge of Palo Alto. Inside, the halls are peaceful, the colors are soothing shades of gray and lavender, and every researcher has a private office—a major perk in a culture of cubicles. Outside, a tree-filled garden and a pond with a fountain present a pleasingly low-tech tableau.

Interval's campus is a half mile from PARC's. A handful of Interval's grand old men were Liddle's contemporaries there. More than a few PARCisms—"Build what you use, and use what you build," for instance—are part of the Interval vernacular. Yet in many respects Interval bears little resemblance to the PARC of the seventies. Whereas PARC made computers for the office, Interval is interested in products for the home; whereas PARC devised the whole architecture surrounding the desktop P.C., Interval wants to go beyond that architecture, which Liddle calls a "scorched desert." Interval's researchers foresee a world in which computing is ubiquitous and the purpose of it is no longer just to enhance productivity. "When you're making stuff for consumers, it's about how you fit into this person's life—whether you're aligning with the kind of person they want to be," Liddle said. "But technology companies don't know much about consumers. And companies that do things for consumers aren't very good at technology. For us, that's an interesting gap." Liddle has culled a "wide gene pool" of a hundred and twenty permanent researchers—among them many computer scientists and engineers, of course, but also artists, designers, musicians, videographers, social scientists, cognitive psychologists, and even journalists—in the hope of fostering "hardy, inquisitive, mongrel projects" rather than "deeper, narrower, nervous thoroughbreds."

Interval has more than twenty projects under way at any given time, and they encompass a diversity of topics—from "electro-optic and mechatronic design" to computers that do in fact live in your clothes. A few of these projects fall under the heading of the "D." in R. & D., meaning that they're being pursued with a particular product in mind. But the vast majority are pure research. Liddle wants his researchers to be free to "follow a good idea wherever it goes." He knows that much of the research won't lead directly to a product, and that some of it might seem, at a glance, to be a waste of time. The reigning catechism in Silicon Valley is that speed counts and that urgency is the mother of invention. But at Interval, where scientists speak of the pleasures of having "unfettered money to do whatever you want," the average research project lasts a leisurely thirty months. One afternoon at lunch, I began to ask Liddle about how Interval could compete with the Internet businesses that are charging ahead so frantically, and I mentioned Netscape.

"O.K., let's talk about Netscape," Liddle said, and he then observed, correctly, that its browser technology had sprung out of government-funded research at the University of Illinois which cost millions of dollars and took more than three years to complete. The point, Liddle went on, is that most great companies build off research done somewhere else—in universities or in labs such as Bell Labs and PARC—and that research is unavoidably costly and time-consuming. "People often think of research as a form of development—that it's about doing exactly what you planned, doing it on time, and doing it with the resources that you said you'd use," he explained. "But, if you're going to do that, you have to know what you're doing, and, if you know what you're doing, it isn't really research."

The first researcher I met was Michael Naimark, a forty-five-year-old "media artist," who described his work at Interval, which consists of two 3-D art installations, as "classically a-entrepreneurial." He explained that although it had produced two patents, this had been "totally unintentional." Naimark led me to a room where a group of researchers demo'd the Magic Morphin' Mirror, which comprised a set of computers equipped with video cameras that capture your face and then distort it (in a Jim Carrey sort of way) on a nearby TV. The Mirror's creators told me that tracking a face as it moves in real time is a particularly hard challenge in giving computers "vision"—the ability to "look" at you, just as you look at them. "The average Japanese urinal is more perceptive than your P.C.," a researcher said. "As it is, the P.C. doesn't know if you've left the room or not, but, if it did, it could do different things in different cases"—shut itself down, for instance, if you had gone for the day.

Making technology more intimate—and more commonplace—is a central concern at Interval. "There's this third

wave of computing coming that's all about microprocessors that are embedded in all sorts of everyday devices, and this plays right into the hands of industrial designers," Colin Burns, a Scotsman and an industrial designer, told me. Burns talked about how the designers at Interval had built a "cartoon house" out of foam core to help them brainstorm about ways that computers could be seamlessly integrated into a domestic environment. He cited the Valley company named WebTV, which has designed a system to put the Net on television, as an example of the trend away from the notion of "computers being this gray thing that sits on a desk in the spare room." Burns imagines them in the walls, in the furniture, in the bathroom, and in the bedroom—and looking stylish in all those places.

Burns's mentor, Bill Verplank, oversees Interval's "haptics" lab, which studies the ways that people use their hands. Verplank is interested in making computer interfaces that are dynamically tactile. He sat me down in front of the Phantom, a "force feedback" device that is used for experiments in creating illusions of touch. As I held a pen suspended from a hinged arm on the Phantom, Verplank used a P.C. to create a range of sensations. Though the pen touched nothing, it felt as if it were sticking to a gooey surface, then plucking the string of an instrument, then rubbing against sandpaper. Verplank talked about enabling users not just to look at 3-D images on computer screens but to "feel in 3-D."

Verplank is one of Interval's elder statesmen, a group that includes Glenn Edens, who designed the world's first laptop and is now working on a new kind of multimedia network; Jim Boyden, who invented the ink-jet printer and is now focussed on wearable computers; and Bonnie Johnson, who runs a wing of the lab which conducts in-depth studies of consumer habits and life styles among various demographic groups, from teen-agers (hence the Lollapalooza tour) to senior citizens. At the other end of the spectrum are the younger researchers, like Tom Ngo, a fresh-faced expert in algorithm development. One day in his office I asked Ngo how old he was, and he said, "I'm eleven thousand nine hundred and ninety-eight days old. I'm two days from turning twelve thousand—I have that in my calendar, because I enjoy round numbers." He added, "In human-speak, I'm thirty-two."

Ngo demo'd a technique by which a P.C. disentangled two voices talking over each other—a trick that human beings routinely perform at cocktail parties but computers have found nearly impossible to master. The next day, I visited Malcolm Slaney, a specialist in signal computation. Slaney showed me a way of manipulating sound so that voices can be played at twice normal speed and not sound like chipmunks, and a program that let a P.C. "hear" the differences in agitation in your voice. And he demo'd Video Rewrite, a process that uses digital animation to achieve automatically and inexpensively the sort of lip-synching effects created at great cost in "Forrest Gump." (At the end of the presentation, there was footage of President Kennedy declaring in someone else's voice, "I never met Forrest Gump. I did not inhale. Read my lips.") Slaney noted that Video Rewrite could put an end to the horrendous dubbing that afflicts so many cheap foreign films. "No more 'Godzilla syndrome,'" he said.

THERE are plenty of projects at Interval, like Video Rewrite, whose commercial potential is obvious, if untested. Various researchers are working on applying browser technology to the watching of TV news; on devising tools and systems that let people with no musical training make music and people with no filmmaking skills produce simple movies; on building a virtual-reality system that overcomes the worst of that technology's nausea-inducing glitches; and on putting together a home-media system that would weave everything electronic in your house into a seamless network.

Nevertheless, doubts about Interval remain pervasive in Silicon Valley. Liddle's wife, the venture capitalist Ruthann Quindlen, said, "The entrepreneurial community is very results-oriented, and results in the Valley are measured by one metric: the creation of firms that create huge value. To the extent that Interval hasn't yet done that, the community thinks there are cool things going on there but it's still unsure about what the payoff will be."

In November of 1996, Interval took its first steps toward a payoff by spinning off its first start-ups. Today, two of the three—Electric Planet, which is developing a computer-vision system that lets kids play games on a P.C. without using a keyboard, and Carnelian, which makes software to help publishers make money on the Web—have yet to hit the market, but the third, an entertainment-software firm called Purple Moon, is off and running.

The idea for Purple Moon was planted in 1992, when Liddle and Brenda Laurel, an Interval computer-design expert, pondered an anomaly that seemed to cry out for study. Computer games were a six-billion-dollar business that catered almost exclusively to boys. Why had the industry failed to appeal to girls? Laurel is a self-styled "interface cowboy" and "equity feminist." She had ideas about why girls weren't responding, and Liddle had quite different ones. "But we shook hands and laid our agendas at the door," she told me. "Our goal was to figure out how to get girls to put their hands on computers and have fun. If that meant the box had to be pink, we'd make it pink. Luckily, it didn't."

Over five years, Laurel led a project exploring gender differences and play patterns among kids aged from seven to twelve—the "post-doll, pre-makeup era" for girls, she said. Researchers interviewed eleven hundred children. At one point, they gave them "gender-bent toys," which they had created by taking traditional toys for boys and girls and giving them a cross-gender tweak. (A Tonka truck was covered with fuzzy pink material; a diary was marked with bloodstains and bullet holes and labelled a "secret journal.") The goal was to see "what overrides what in the vocabulary of gender," Laurel said. "Fuzzy pinkness overrides truckness—a fuzzy pink truck isn't for a boy at all. Bullet holes and blood did

not override diaryness. But when we took Echo the Dolphin, from a gentle video game popular with girls, and gave it bloody fangs, we immediately regendered the game." Laurel handed me a Barbie doll as G.I. Joe. "This was a toy nobody wanted. The blond hair turned the boys off, and the uniform turned the girls off. Competing gender signals cancelled out the value of the toy completely."

Eventually, Laurel's team came up with a "design heuristic." Their research concluded that, contrary to the conventional wisdom, the reason that girls don't like computer games isn't that they're too violent but that they're too boring. "In most games, you just do the same idiotic thing over and over," she said. Boys are interested in beating the clock, in beating each other, in seeing their initials on the high-scorers list of an arcade console. Girls want covert competition, narrative complexity, and characters they can relate to. To meet those demands, Purple Moon designed two quite different games. Rockett's New School is what Laurel calls a "when-I-grow-up fantasy," in which the player helps the heroine, a redheaded girl named Rockett, traverse the unimaginably complex social hierarchies of junior high school. In Secret Paths in the Forest, characters from Rockett's school meet in a tree house, explore lush sylvan landscapes ("magic gardens, magic mountains, magic forests, magic clouds—that's where all this misty, dreamy, inner-life stuff comes out," according to Laurel), and talk about their troubles.

Purple Moon is the first Interval project to play out fully—going from concept to research to development to spinoff to product to the store shelves. The CD-ROMs of Rockett's New School and Secret Paths were big sellers at Christmas, and a Web site is flourishing. When Interval spun off Purple Moon, Ruthann Quindlen persuaded her partners in the venture-capital firm I.V.P. to invest four million dollars in the company. (Another investor was Herb Allen, of Allen & Company.) At I.V.P., potential investments are put into one of two categories: "faster, better, cheaper," where the risks are relatively low but so are the rewards, and "brave new world," where the opposite is true. Quindlen said her partners believe that Purple Moon is clearly in the second category—a company that, if and when it goes public, could be worth as much as a billion dollars.

For Liddle, who often likens Interval itself to a venture-capital fund, which places an array of bets in the hope that a few will hit big, such an outcome would be satisfying on more than one level. Five years into Interval's life, he acknowledges that Paul Allen, who is referred to affectionately around the lab as "our shareholder," has already put up close to the hundred million dollars that he initially pledged. If Purple Moon should make a splash in the stock market, it could return Allen's investment several times over. Moreover, it would provide a plausible riposte to those in Silicon Valley who believe that Interval, far from being the new PARC, is, as one executive put it, "the clearest sign yet that Paul Allen has more money than he knows what to do with."

FOR now, however, Allen and Liddle remain in the awkward, if self-imposed, position of having raised expectations high while being unwilling to say much about Interval's endeavors. "It was the same way with PARC," Liddle said. "The reaction of the industry to what we were doing was that it was all irrelevant and excessively eggheaded and intellectual. But people didn't really have a good idea of what we were doing at PARC, and they don't have a good idea of what we're doing here at Interval. Pretty soon, they will."

As more and more of Interval's work becomes public, either through further spinoffs or just through a more open policy, the skepticism about it is bound to fade. Much (if not all) of the research and development going on there is firmly in synch with commercial reality—so much so, in fact, that many of its ideas are likely to encounter furious competition in the marketplace. When Allen started Interval, he was pining for the Next Big Thing. Now the Internet is playing that role, stirring up a swarm of innovation reminiscent of the early days of the P.C. industry. Both start-ups and established firms, such as I.B.M. and Sun Microsystems, are making important breakthroughs, such as Java, the Sun programming language that is rapidly becoming a lingua franca for the Net and could also play a critical part in letting small, ubiquitous, networked computers talk to one another. At Microsoft, Allen's old partner Bill Gates has assembled a research squad twice the size of Interval's with much the same aim. And Xerox PARC itself is forging ahead; it has, for example, come up with a "hyperbolic browser," which lets you navigate the Internet through a system of branches rather than overlapping windows. In an environment as fertile as this, Interval may well succeed. But there is little chance that it, or any other institution, will occupy the intellectual position that PARC enjoyed in the seventies.

Liddle says he hopes simply to produce a reasonable return on Allen's investment and to "change the way people look at or think about information technology for ordinary people." His optimism is evident. Until recently, Interval's visitor's badges bore the dates "1992-2002," an allusion to Allen's ten-year commitment to fund the lab, but then Liddle had the end date removed. "I had a job candidate who said, 'Gee, I was surprised that you were hiring so close to your expiration date,'" he said. "I had to explain that 2002 was just the time when we'd know if we were making progress—it's not a 'sell by' date."

Allen agrees. "I'd like to see Interval have an ongoing experience beyond 2002, but you make judgments as you go along," he said. "You know, paradigm-shifting ideas don't grow on trees." ♦

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COMPUTERS

Ambitious Start For a Computer Research Group

By PAUL B. CARROLL
Staff Reporter of THE WALL STREET JOURNAL

Microsoft Corp. co-founder Paul Allen and a software executive, David Liddle, said they founded what promises to be an ambitious computer research effort.

Mr. Allen said he will provide nearly $100 million to the group in the next 10 years. Mr. Liddle, a former vice president of **International Business Machines** Corp., will run the group and hire about 100 researchers to tackle some of the fuzziest technical problems facing the computer industry.

The group, **Interval Research** Corp., will focus on technologies that probably won't be commercially viable for five or 10 years. For instance, the group will try to figure out ways for software applications to take better advantage of the huge increases in the speed of data communications. It will also try to puzzle out new definitions of data, so that data bases can become flexible enough to incorporate video and sound, which are starting to be used more often on computers.

In many ways, Messrs. Allen and Liddle are attempting to recreate the phenomenal creativity that existed at Xerox PARC, where a group of researchers, including Mr. Liddle, laid the foundation in the late 1970s and early 1980s for most of what has since happened in the personal-computer business. While such commercial labs as PARC are directing their research more carefully, to fit with their corporate parents' development plans, Interval Research will be free to tackle whatever problems appear to be interesting, much as PARC once did.

Interval, to be based in Palo Alto, Calif., will also try to correct some of the problems PARC had in commercializing the technology it developed. Because Interval doesn't have a particular commercial vision, it will be able to license its technology to others or to spawn startups that will use the technology. Interval will also be free to get corporate labs or university groups involved.

There certainly is no guarantee of success. Interval is tackling hard problems, and research efforts established in recent years by groups of private companies have found the going rough. But Bobby Inman, the former head of one of those groups, Microelectronics & Computer Technology Corp., said he is "very enthusiastic" about Interval. "As long as Mr. Allen doesn't lose his interest or enthusiasm and can provide a long-term spur," Mr. Inman said, "the prospect of attracting absolutely first-rate researchers is very high."

Mr. Inman, who is also a former chairman of a private-sector task force on competitiveness, said this sort of heavy investment in basic research also addresses the task force's fear that the U.S. could lose its dominance in software. "If this is done right," he said, "this could help ensure that the U.S. keeps its lead."

While Mr. Allen's co-founder at Microsoft, Bill Gates, has drawn tremendous attention in recent years as the fast-growing company's chairman, the 39-year-old Mr. Allen has been relatively unnoticed. He dropped out of day-to-day activities at Microsoft in the early 1980s, when he learned he had Hodgkin's disease. Even after he beat the disease, he decided to pursue other interests, which have included buying the Portland Trail Blazers basketball team. Mr. Allen also founded a small software company, Asymetrix, and said he has been considering a research venture for some time.

"Obviously, I've benefited incredibly from my involvement with Microsoft, and this is a way of returning some of that by doing pure research," he said.

Mr. Allen said he approached Mr. Liddle last fall to ask his advice on how to set up the venture, and it simply happened that Mr. Liddle was interested in running it himself. Mr. Liddle, 47, found himself a vice president in IBM's personal-computer business after IBM bought Metaphor Computer Systems Inc., a software company that Mr. Liddle co-founded after leaving Xerox PARC. But IBM had recently canceled a software project that Mr. Liddle was running because the company's joint venture with Apple Computer Inc. superseded it, and Mr. Liddle was losing interest in the possibility of running the successor project.

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Business News : Friday, July 09, 1999

Paul Allen is wiring together an empire

by Helen Jung
Seattle Times technology reporter

A billionaire can indulge his whims.

Paul Allen

Paul Allen the movie buff, renovated the Cinerama Theater. **Paul Allen**, the Jimi Hendrix fan, is building a museum as a tribute to the musician. **Paul Allen**, owner of a professional football team, is spending millions on a new stadium.

But then there's **Paul Allen**, investor, who lately has been spending billions, buying something every week or so, from Internet sites featuring Oprah Winfrey to cable companies in Georgia.

What is the man once derided as an "Accidental Zillionaire" doing with his money?

Following through with a decades-old idea, his supporters say.

Internet link by Internet link, cable network by cable network, the Microsoft co-founder is assembling the building blocks of an electronic **empire**. If his hunches are right, he stands to create a global realm more influential than any of his projects that edge the Seattle skyline.

In Allen's futuristic "wired world," fast Internet connections plus easy-to-use technology and cheap computer devices will deliver a simple and universal way for people to shop, enjoy

entertainment and communicate. People will call up "Seinfeld" reruns at will, buy a compact disc after watching a music video on TV, and send pictures to family members by punching a remote control.

But so far, that wired world is one-third vision, two-thirds money.

Lots of money.

Since January, through his cable company, Charter Communications, and his investment firm, Vulcan Ventures, **Allen** has embarked on a $12 billion-plus spending spree, buying or investing in more than 20 Internet, cable and technology properties.

With other challengers emerging on the national scene, **Allen** and his team are making an ambitious push to convert the sketches of his dream into hard-wired connections to a future with no certain arrival date.

"More than anyone else I've met in this industry, he has the greatest vision for what, ultimately, the user experience is going to represent," said Russell Horowitz, chief executive officer of Seattle-based Go2Net, in which **Allen** owns a controlling interest.

"He's had the vision for years and has been waiting for the rest of the world to catch up."

Earlier effort flopped

Allen has had to wait a long time.

The man who persuaded high-school friend Bill Gates to drop out of Harvard University and get into the software-writing business has had the idea of a wired world for decades.

The fuzzy notion gained definition in the early 1990s, with roots grounded in one of Allen's biggest failures.

Allen, already rich from his Microsoft holdings, invested millions in 1991 in a Kent company called SkyPix. The venture sought to broadcast pay-per-view movies and other entertainment to homes via satellite, a technological novelty at that time.

The company flopped.

"It was a disaster," said Bill Savoy, who headed up Allen's investment in SkyPix. "It took 90 days to lose all the money."

Despite its demise, SkyPix gave shape to Allen's dream of a wired world.

Allen was fascinated by the ability to send information to an individual instead of mass broadcasts, said Savoy, who now heads Allen's Vulcan Ventures investment arm. **Allen** declined requests to be interviewed.

Savoy said **Allen** recognized that connecting low-cost computers to a network represented not only a major shift in the computer world, but also in the way people could communicate with one another.

He wasn't sure, however, which technology would be the best way to string **together** the planet. So he invested in several communications companies, including Metricom, which transmits data using wireless technology. He also devoted cash to entertainment properties such as DreamWorks, a programming venture with Steven Spielberg.

But a number of setbacks, including SkyPix and his buckshot approach to investing, had contributed to a portrait of **Allen** as an "Accidental Zillionaire," as Wired magazine characterized him in 1994. The World Wide Web was in its earliest days then. Amazon.com, the Internet-retailing powerhouse based in Seattle, had not yet been founded.

Today, Allen's vision is taking on definition with each purchase, said Adam Schoenfeld, vice president and senior analyst for new-media firm Jupiter Communications. "There is a design behind it," he said.

With the fast growth of the World Wide Web, the widespread embrace of e-mail, and such popular trends as buying books over the Internet, labels such as "Accidental Zillionaire" are fading. Meanwhile, Allen's course has remained the same, Savoy said.

"The only thing that's changed is (that) the marketplace and technology community now understands what **Paul** was talking about," he said. "People flung a lot of arrows at our backs because they didn't understand."

Cable as growth industry

The first step for stringing **together** a wired world is choosing the wire.

In April 1998, **Allen** chose cable. He bought Dallas-based Marcus Communications, the 10th-largest cable operator in the country.

Three months later, he folded Marcus into his newest purchase, St. Louis-based Charter Communications. Then the deals started to fly.

Since January, Allen's cable **empire** has leapfrogged to the fourth-largest operator in the country - once all pending acquisitions are completed. In the past six months, **Allen** has snapped up 11 cable companies with networks from California to Massachusetts, bringing Charter's total subscriber base to 6.2 million.

But the company isn't planning to stop its spending spree as **Allen** competes with major players such as AT&T and Time Warner in a race to build massive cable networks. And AT&T and Time Warner, with even deeper pockets than **Allen**, the world's third-richest man, are devoting billions to build their array of Internet and communications holdings.

Cable television itself is a profitable business. Add the possible sales from offering telephone service over the lines and tapping television-top boxes as a "personal computer in disguise," Savoy said, and you've got a wealth of opportunities.

The thick cable lines that are already installed in many homes offer a way to carry more information via the Internet than thin phone lines allow. This "broad band" connection to homes is becoming an increasingly valuable channel to deliver retail services, movies-on-demand and other entertainment to consumers.

But cable by itself is just a "dumb pipe," said Horowitz, the Go2Net executive. It needs to carry something - programs, services, information - to the consumer. That's where his business and other Internet companies join the wired world.

Going for Go2Net

At 2:30 a.m. Monday, March 15, Vulcan chief Savoy finally had nailed the deal.

He and Go2Net executives had worked round-the-clock to seal an investment partnership that made **Allen** the biggest shareholder of Go2Net and gave the young company $426 million.

But the early morning negotiations aren't uncommon these days for Savoy, who has been crisscrossing continents in his quest for Internet sites to add to the **Allen** family of Web sites.

"If we lived in a vacuum, we could take a break," he said. But rumors leak, stock prices change and other competitors are eyeing the same or similar properties. "The right thing to do is lock yourself in a room and get things done."

Similar to Yahoo!, Go2Net is a destination for Web users, combining popular stock, business, entertainment and informational Internet links in a common Web site. Go2Net would become a strategic part of the wired world as a stepping-off point into cyberspace - a navigational index to sift through and search for all the services and entertainment available on the Internet.

And although the Go2Net name was virtually unknown a year ago, the company has climbed in popularity in recent months. Go2Net's rapidly expanding family of Web sites most recently ranked 15th among the most-visited networks on the Internet.

It is also a rarity in the Internet world. It makes a profit through advertising and membership fees on some of its sites.

Go2Net is now working on a "broad-band portal" - an information-rich site or stepping-off point that helps users navigate the online world.

The effort is more than a tinkering with Go2Net's current Web site. It will take advantage of the high-data capacity of Allen's cable networks, Horowitz said.

Besides Go2Net, **Allen**, through Vulcan Ventures, has financed other Internet information or program-oriented sites, such as Oxygen Media, which is developing programming geared to women. That company also has backing from television host Oprah Winfrey and others.

Investing `on the cheap'

A third corner of the wired world involves the retail sector. Vulcan has developed or invested in Internet-commerce sites that seek to expand ways of shopping online.

For example, Mercata, a Bellevue company funded by Vulcan, allows multiple customers of the same products to band **together** and secure a lower price per item than they could as individual customers. The more people who buy an item, the less it costs.

"He (**Allen**) looks at technology as a foundation to deliver value," said Maggie Wilderotter of Wink Communications, another Vulcan-backed company, which allows television users to request information and order products by simply clicking buttons. "It's a bold strategy and it's a great strategy."

Money isn't Allen's only asset, said Tom Van Horn, the Mercata chief executive. Vision often means more.

And others noted that the investment selections themselves were smart buys. Instead of buying Yahoo!, **Allen** focused on the similar but less expensive Go2Net.

"**Paul Allen** is very shrewdly putting **together** on the cheap a bunch of different assets that could rival anything that AT&T or Microsoft or Time Warner puts **together**," said Schoenfeld, of Jupiter Communications. "I think, if you went dollar for dollar, he's strung **together** his assets for much less. . . . He has as much chance of winning as anybody else."

And although the race may seem to be accelerating, it's far from over, said Horowitz of Go2Net.

"Right now feels like more of a beginning than ever before," Horowitz said. "This is all preseason for everything else. The real game is about to be played."

Helen Jung's phone-message number is 206-464-2742.

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E-PLANET

Electric Planet Debuts to Catalyze a New Generation of Interaction by People With Computers

E-Planet announced that G. Scott France has joined the company as president and CEO.

- E-PLANET raises more then $6 million in recent investments

E-PLANET RAISES MORE THAN $6 MILLION IN RECENT INVESTMENTS

Interval Research Spin-Off Secures New Investors

PALO ALTO, Calif., December 10, 1998 - E-Planet announced today that it has raised in excess of $6 million in recent financing from Intel Corporation and from Interval Research, a leading Silicon Valley R&D center founded by computer visionaries Paul Allen and David Liddle. Specific terms of each investment were not disclosed. E-Planet, which was formally introduced this week, is pioneering vision technologies for consumer applications.

" We are very pleased with the company's progress and with the tremendous promise of vision technology for the home PC and digital consumer electronics," said David Liddle, president and CEO of Interval Research."

"Intel believes that vision technology represents a new way for consumers to interact with applications on PCs in the home," said Avram Miller, vice president, Corporate Business Development, Intel Corporation. "Technology like E-Planet's can enable the creation of new types of applications and create new uses for personal computers."

With E-Planet's vision technology, digital video cameras enable home computers to "see" into the real world, make sense of what they see and act accordingly. Consumers will be able to manipulate their on-screen worlds by moving physically and naturally, just as they do in real-world movements. Eventually, this vision technology is expected to supplement existing computer input devices, such as keyboards, mice and joysticks.

"E-Planet's goal is to bring vision first to the home PC, and eventually to a full range of other home digital devices, such as set-top boxes," said Scott France, E-Planet's president and CEO. "This new infusion of capital will help enable us to complete our goals of bringing

vision technology to the mass market."

E-Planet has numerous patents pending for its vision technologies, as well as for technological advancements in graphics and computer interaction. The company's goal is to create new genres of interactive entertainment and content that showcases its vision technology for sale to partners and developers.

The company's latest investments will be used to support technology and product development; to find and secure marketing and distribution partners for the interactive entertainment and toy market segments; and to pursue opportunities for vision technologies beyond these initial market segments.

About E-Planet
Using vision technologies, E-Planet works to humanize and simplify people's interactions with computers. It is developing software products based on vision technologies that allow a computer to "see" the same world as the user, and to communicate (non-verbally) and react accordingly. Initially, E-Planet is focusing on developing immersive software applications that let kids, in particular, experience and explore the digital world in much the same ways they experience and explore the physical world: by moving their bodies through a personalized digital world, filled with characters and environments of their own creation.

The privately funded E-Planet maintains its corporate offices in Palo Alto, California. E-Planet's world-class management team and staff include members from MIT, Xerox PARC, Stanford University, Cornell, Royal College of Art, UC Berkeley, Sony, Sega and MAXIS. For more information on E-Planet contact Kristin Thomson at (310) 785-9002 or kthomson@shandwick.com.

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Avio Digital and Cadence Announce Agreement to Develop Next-Generation Home Networking Silicon

San Jose, CA – June 1, 1999 -- Avio Digital, Inc. (San Carlos, CA), developers of the high-performance MediaWire™ home network technology, today announced a strategic relationship with Cadence Design Systems, Inc. (NYSE:CDN), the world's leading supplier of electronic design software and services -- to facilitate the design and manufacture of the MediaWire chipset.

The bandwidth of the MediaWire home network (up to 100 Mbps in the first-generation product) enables a single telephone line to simultaneously deliver sixteen 24-bit audio channels, four MPEG2 video channels (6 Mbps each), eight phone or ISDN lines and over 6 Mbps of serial control or TCP/IP (Internet) data. Using MediaWire home network technology, one connector provides all these services. Avio Digital plans to broadly license the MediaWire home network technology to consumer electronics, cable/telco, and PC manufacturers and develop MediaWire-enhanced products. Customer delivery of silicon is expected in the 4th quarter of 1999 at an anticipated price of under $15 (in volume).

"Cadence is pleased to leverage our world-class design expertise to help Avio Digital tackle its sophisticated MediaWire chipset challenge and accelerate the chipset's time-to-market," said Bob Wiederhold, corporate vice president of Design Services at Cadence. "We are excited to be working with Avio Digital on a project that could be of great interest to a wide range of consumer electronics manufacturers, cable set-top, and PC vendors."

"Avio Digital selected Cadence as our design partner for a simple reason – they have proven themselves in some of the most demanding projects for ASIC design and have consistently delivered on-time solutions to their partners," said Eugene Van Bergen, CEO of Avio Digital. "The successful relationship between Avio Digital and Cadence is the first step to delivering MediaWire as a packaged chip solution for our customers and licensees."

About MediaWire

MediaWire was originally conceived at Interval Research Corporation (Palo Alto, CA) – Avio Digital is an Interval spin-out company chartered with the ongoing development, deployment and marketing of the MediaWire technology.

Digital media is distributed by the MediaWire home network at speeds of up to 100 million bits per second in the first-generation product (the speed of 2nd generation corporate networks) with a range of 33 meters (over 100 feet) between devices using standard Category 3 telephone wiring. The bandwidth of the MediaWire home network enables a single telephone line to simultaneously deliver sixteen 24-bit audio channels, four MPEG2 video channels (6 Mbps each), eight phone or ISDN lines and over 6 Mbps of serial control or TCP/IP (Internet) data. With up to 100 devices of different types, the MediaWire home network is capable of supporting a total cable length of more than 4,000 meters (about 2.5 miles).

About Cadence

Cadence provides comprehensive services and technology for the product development requirements of the world's leading electronics companies. Cadence is the largest supplier of software tools and professional services used to accelerate and manage the design of semiconductors, computer systems, networking and telecommunications equipment, consumer electronics, and a variety of other electronic-based products. With more than 4,000 employees

and annual sales of $1.2 billion in 1998, Cadence has sales offices, design centers, and research facilities around the world. The company is headquartered in San Jose, Calif., and is traded on the New York Stock Exchange under the symbol CDN. More information about the company and its products and services may be obtained from the World Wide Web at http://www.cadence.com.

About Avio Digital

An independent start-up based in San Carlos, Calif., Avio Digital is funded by seed investments from Vulcan Northwest Corp. Ventures Inc. and Interval Research Corp.; both are owned by financier Paul G. Allen.

-30-

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Avio Digital and Apogee Technology Announce Partnership to Develop Digital Audio Home Network

Companies cross-license technology to integrate MediaWire and Apogee's DDX Digital Amplification Technology for PC multimedia and Consumer Electronics

San Carlos, CA – July 19, 1999 -- Avio Digital, Inc. (San Carlos, CA), developers of the high-performance MediaWire™ home network technology, today announced a strategic alliance with Apogee Technology, Inc. (Norwood, MA) (NASDAQ:APGT) to jointly develop and cross-license technologies for integrating MediaWire and Apogee's DDX digital amplification silicon. The goal of this alliance is to enable an end-to-end pure digital music network for the home.

The bandwidth of the MediaWire home network (up to 100 Mbps in the first-generation product) enables a single telephone line to simultaneously deliver sixteen 24-bit audio channels, four MPEG2 video channels (6 Mbps each), eight phone or ISDN lines and over 6 Mbps of serial control or TCP/IP (Internet) data. Using MediaWire home network technology, one connector provides all these services. Avio Digital plans to broadly license the MediaWire home network technology to consumer electronics, cable/telco, and PC manufacturers and develop MediaWire-enhanced products. Customer delivery of silicon is expected in the 1st quarter of 2000 at an anticipated volume price of under $15.

DDX is a high-efficiency audio amplifier chipset that maintains the audio signal in a pure digital form, eliminating analog signal corruption and enabling digital audio sources such as CDs and DVDs to remain digital from source to speakers. Products that can benefit from DDX technology include digital TV, digital speakers, PC multimedia, surround sound systems and car audio.

"Avio Digital is convinced that Apogee's DDX silicon represents the next step in digital audio technology," said Keith Crosley, MediaWire product manager at Avio Digital, Inc. "The combination of DDX with our MediaWire technology will enable consumers to enjoy the best-quality digital audio - whether from CD or the new DVD audio standard – anywhere in their home. As MediaWire-enhanced audio products become available next year, Apogee technology will play an integral part in establishing MediaWire as the audiophile standard for the Wired World."

"Apogee has evaluated a number of home networking technologies and we firmly believe that only MediaWire has the capability for making it as an audio/video solution," said David Meyers, Director of Business Development at Apogee Technology, Inc. "Our strategic alliance with Avio Digital is the first step in establishing our DDX technology as the essential standard in digital audio amplification and we look forward to working with them to jointly bring about music networking for the home."

About DDX

Direct Digital Amplification (DDX) is a high efficiency amplifier technology that converts digital audio directly into power without the need of an analog to digital conversion (DAC). DDX uses embedded signal processing and is intended for digital audio components such as AC/DC'97, surround sound decoders and digital receivers enhanced with the MediaWire interface. A surface mount DDX chipset will be available for portable and moderate power applications; significantly reducing the size and power draw of traditional bulky amplification devices.

The primary difference between DDX and other amplifiers is that DDX provides an all-digital design and has much

higher efficiency. Current digital audio systems use Class A/B amplifiers to amplify analog signals produced by a DAC. Analog designs have low efficiencies because of the power consumed in the active components as a result of the voltage difference between the amplifier's output and its power supply. This results in peak efficiencies of about 50%. As a result, large power supplies and heat sinks are required.

Class D switching amplifiers were developed to overcome this problem by discretely connecting the load to the power supply. Higher efficiency is achieved, but Class D is still essentially an analog solution because it utilizes an analog interface and control. Apogee's approach was to develop a new Class D amplifier that utilized digital control. This approach enables lower cost through digital integration and eliminates performance degradation due to analog component variations.

About MediaWire

MediaWire was originally conceived at Interval Research Corporation (Palo Alto, CA) – Avio Digital is an Interval spin-out company chartered with the ongoing development, deployment and marketing of the MediaWire technology.

Digital media is distributed by the MediaWire home network at speeds of up to 100 million bits per second in the first-generation product (the speed of 2nd generation corporate networks) with a range of 33 meters (over 100 feet) between devices using standard Category 3 telephone wiring. The bandwidth of the MediaWire home network enables a single telephone line to simultaneously deliver sixteen 24-bit audio channels, four MPEG2 video channels (6 Mbps each), eight phone or ISDN lines and over 6 Mbps of serial control or TCP/IP (Internet) data. With up to 100 devices of different types, the MediaWire home network is capable of supporting a total cable length of more than 4,000 meters (about 2.5 miles).

Apogee Technology, Inc.

Apogee Technology, Inc. (NASDAQ:APGT) is a research and development company providing design leadership in high-efficiency amplification through its DDX silicon solutions for the PC multimedia, automotive, home audio and communications markets. The company's audiophile heritage includes the development of the acclaimed Apogee Acoustics' ribbon loudspeakers – a product whose design and performance was so revolutionary that a pair are on display at the Smithsonian Museum. More information on Apogee and DDX may be found at the company's Website at http://www.apogeeddx.com.

Avio Digital, Inc.

An independent start-up based in San Carlos, Calif., Avio Digital is funded by seed investments from Vulcan Northwest Corp. Ventures Inc. and Interval Research Corp.; both are owned by financier Paul G. Allen.

-30-

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Zowie Intertainment, Inc

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ZOWIE INTERTAINMENT TO JOIN KNOWLEDGE KIDS

Creating a Powerhouse in the High-growth Smart Toys And Kids Interactive Entertainment Market

E3 Show LOS ANGELES, May 14, 1999 – Zowie Intertainment, Inc. announced today that it has entered an agreement in principle to merge its operations into Knowledge Kids Enterprises, Inc. The transaction involves a multi-million dollar co-investment by Interval Research Corporation, Vulcan Ventures and Knowledge Kids.

With finalization anticipated within 60 days, Zowie will join LeapFrog and Explore Technologies as independent divisions of Knowledge Kids. Zowie will continue to market and develop its brand of products, and Zowie's Smart Toy technology is expected to be implemented in the products of the other Knowledge Kids companies.

Zowie designs and develops smart toys and other technology-based entertainment products. The company has a portfolio of sensing and recognition technologies called Zowie Power™. These technologies combine off-line play with on-screen activities, enhancing play rather than directing it. The first two product offerings from the company, which will debut this fall, are **Redbeard's Pirate Quest™** and **Ellie's Enchanted Garden™**. Next year, the Zowie Power technologies will be integrated with the Internet to create the next generation of kids' entertainment.

"After the industry's spectacular response to our introduction at Toy Fair, we knew we had the products and technology that would allow us to define the Smart Toy category," said Teymour Boutros-Ghali, CEO of Zowie Intertainment. "The merger with Knowledge Kids gives us the ability to rapidly explore ways of bringing Zowie Power to a broader array of PC and non-PC related products as well as reaching millions more consumers."

"Zowie represents a great example of the commercialization of consumer and technology research," said David Liddle, chairman and CEO of Interval Research. "As we look at broadening our impact, merging Zowie into Knowledge Kids makes eminent sense."

Knowledge Kids focuses on building companies that serve the educational needs of young children and is the leading developer of interactive educational products, toys and books.

"Knowledge Kids' dedication to kids' education and entertainment through technology is unparalleled," said Tom Kalinske, CEO of Knowledge Kids. "We believe that combining our expertise with Zowie, the leading innovator in the Smart Toy category, will result in the perfect marriage of companies, technologies and management teams."

"We are particularly impressed with the caliber of the entire Zowie team" added Mike Wood, president of Knowledge Kids. "Their passion and commitment to providing children and their parents with the highest quality experiences fits perfectly with our culture."

Zowie management will remain in place as part of Knowledge Kids' philosophy of looking at companies both for their innovative products and technology as well as their solid management team.

About Zowie Intertainment, Inc.
Zowie Intertainment, Inc. designs and develops smart toys and other technology-based entertainment products. Headquartered in the Silicon Valley, Zowie Intertainment, Inc. has a portfolio of proprietary technologies that allow children to play and control on-screen activities through traditional play. The portfolio of Zowie Power™ technologies and the company's first products, Zowie PlayZones™, are the results of years of research from Interval Research Corporation.

About Knowledge Kids
Knowledge Kids Enterprises, Inc. is a subsidiary of Knowledge Universe, a lifelong learning company dedicated to building businesses that help individuals realize their full potential throughout their lives. Knowledge Kids is committed to building companies that serve the educational needs of young people. Knowledge Kids, through its LeapFrog division and Explore subsidiary, is a leading developer of interactive toys and books.

About Interval Research
Founded in 1992 by computer visionaries, Paul Allen and David Liddle, Interval is a high technology research laboratory based in Palo Alto, California. The lab studies new market opportunities at the intersection of technology, consumers and popular culture.

About Vulcan Ventures
Vulcan Ventures Inc. of Bellevue, Washington was founded by Paul G. Allen in 1986 to research and implement his investments. Allen's investments through Vulcan Ventures are long-term, as his goals enable him to take above-average risks and a long-term view. Through Vulcan Ventures, Allen invests in companies, which offer products, services or technologies that fit his wired world strategy, and can contribute to or benefit from the technology and strategy of other Paul Allen companies. William D. Savoy is president of Vulcan Ventures and represents Allen in his professional and personal financial transactions as well as managing the Vulcan analysts who investigate and secure investment opportunities.

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back

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