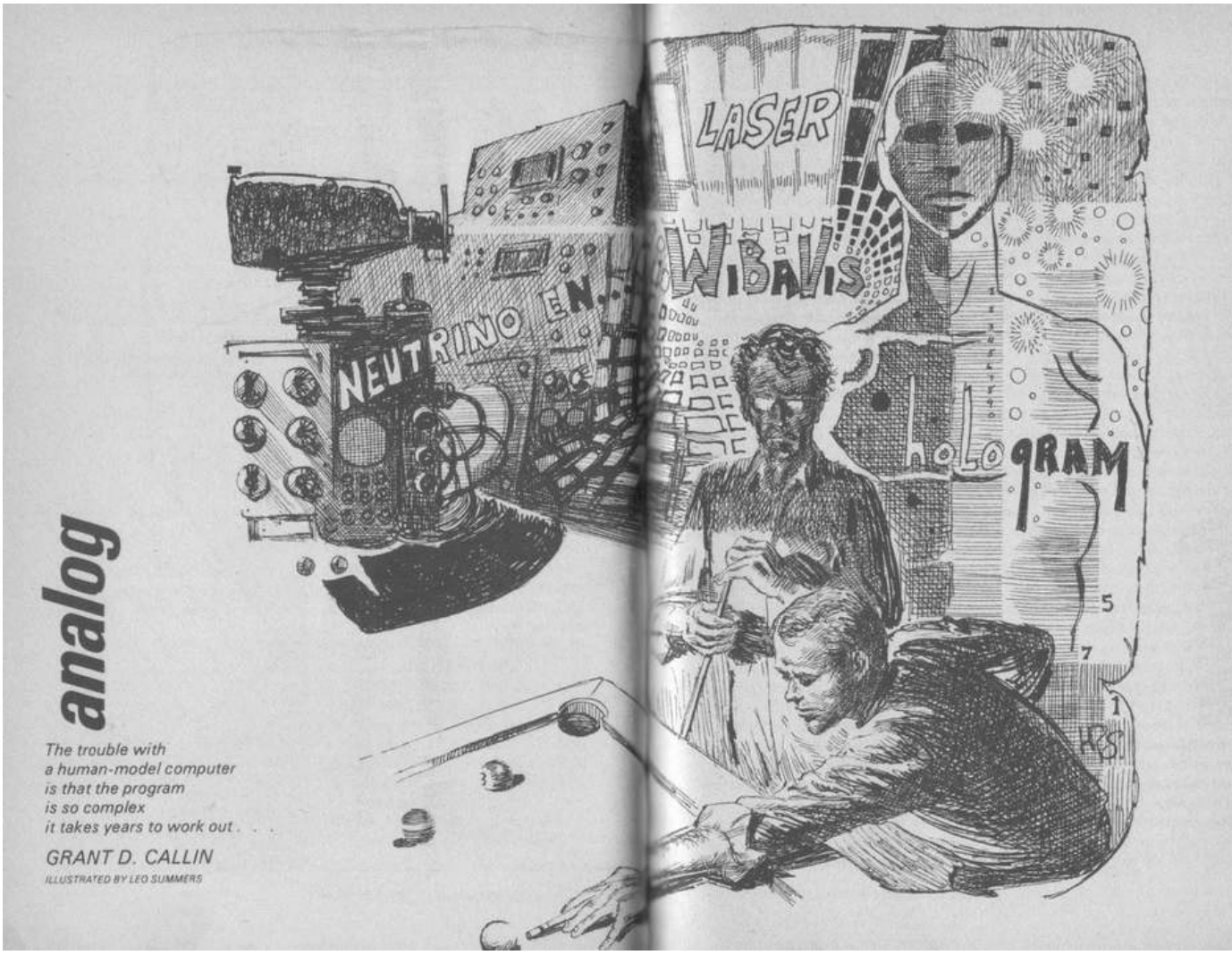

ANALOG
Grant D. Callin

PROLOG: CATALOG

The Director of Research of the Library of Congress was a good computer man in his younger days, but his real flair was for politicking; he had climbed up the civil service ladder with relative ease to his present post, and promised to go further. Nevertheless, he kept up with the literature of his old field, and he still retained a sweeping imagination.

The man facing him across the desk was his opposite in many respects—brilliant researcher, Huxley Laureate in neurophysiology, and entirely out of his element in the nation's capital. But he, too, was a man of imagination, and had been a friend of the director since their college days. At the moment his fair features were screwed up in mild puzzlement; he was wondering why the director had called him down from the Federation meetings at Atlantic City, apparently to expound on the elementary principles of library information dissemination.

"… Essence, the catalog is simplicity in itself, which you know, Hank. Every time an author submits a scientific paper for publication, he's required to place it in one of our 8,400 main categories, in at least one sub and three sub-subs, and is further encouraged to fit it into as many more as he can. Then when a researcher wants to explore the literature with respect to a particular type of experiment or technique, he simply contacts one of our thousand or so outlets and requests a printout of the categories in which he's interested. A beautiful system, right?"

"Well…"

"Exactly: it stinks and we both know it. There's a frightening loss of information in the semantic chain involved. And frankly, it's getting worse all the time with 5,000 titles a day coming in, and the rate accelerating. Last spring at the LS conference Shalot showed by statistical sampling that the rate of needless experimental duplication is up to ten percent, and will increase during the next generation to almost forty percent before it begins to level off." He switched his tone of voice. "When's the last time you used the LC computer for researching a piece of work you wanted to do?"

The neurophysiologist hunched his small body up on the edge of the chair, and thought for a moment "Let's see, it was about three years ago. I wanted to find out what had been done in the way of using IR microlasers for selective destruction of cortical motoneurones. I went into the computer with 'Microlasers,' sub 'Infrared,' sub-sub 'Biological use of,' which was as close as I could get." He smiled ruefully. "The print out was a list of fourteen hundred odd articles, twenty-seven book and seven monographs; and after half a month of weeding, I finally got down to five articles which were of some value. Guess I was lucky a that; my research fell into only one possible sub-sub."

"Don't kid yourself, my friend. The catalog system runs on Finagle's Second Law; odds are a hundred to one that, buried somewhere in the other half a million sub-subs, there were at least ten more titles of direct interest. Which brings me to the next point. What're we gonna do about it?"

"Well…"

"Never mind. The library science people have beat their heads against that wall for years. They say that a really good system is impossible, and that it would cost about half a GNP to come up with even a mildly significant improvement. Let me ask you something else instead: postulating that he could take in all the information somehow, could a man with total recall hold all the facts now in the Library of Congress?"

"Easily. He wouldn't begin to strain."

"And if I were to ask him about possible new techniques in underwater basket-weaving, would he be able to tell me to look at Whatsitsname's paper on the art of liver surgery because of its discussion of sewing in a viscous medium?"

"If he were reasonably intelligent, and trained in cross-correlation techniques, yes."

"Hah! In that case, Dr. Henry D. Hoffman, I have a proposal to make: let's build a computer for this library which duplicates—at a much higher speed—the associative processes of the human mind, and thereby completely eliminate the semantic gap!"

The neurophysiologist caused his face to go amusedly wry. "Don't forget to implant the three laws of robotics."

"Huh?"

"Oh, come off it, Bob. You've been hung up on Asimov's stories ever since we took that course in-Classics of SF together twenty years ago."

The director blushed, but held his ground. "The time to do this thing must come eventually. Why not now? How many neural synapses in the human brain—somewhere around ten billion?"

"No, that's the number of neurons. The number of synapses is more like 10^{13}."

"Even so, with the new self-breeding circuits Bell developed a couple of years ago a specialized computer with 1013 bits is not only feasible, but the core and its talk circuits could fit into the bathroom of an average-sized condom. What's the sweat?"

Hoffman smiled gently, "Bob, the human brain is not a digital logic machine. It's an analog device with probably thousands, possibly millions, of action potentials generated to form one small thought-chain."

"So? Digital analog simulation has been around for decades."

"Yes, but to duplicate higher brain function by sequential logic processes would probably take too long for what you have in mind. I don't think we could use a DAS any faster than about ten or twenty times biological speed."

"Hm-m-m… what kind of fast-memory core you get in your lab?"

"A Packard-Bell 6240."

"Let's see… that means your machine takes about a tenth of a microsec to go in and grab a bite from core. No wonder you're biased; you have the old wafer/cube system. Fast enough for most work, and dirt cheap, but it can't hold a candle to the new five-molecule layer stuff. Hell, man, the biggest lag in that

system is the wiring length; time through a gate is of the order of that of a few electrons jumping orbitals. Core conversation time is determined strictly by the 'nanosec-a-foot' rule. So we can get speeds about fifty times those you're used to, and if that's not enough we can use parallel operation; cores are cheap. Besides," he finished confidently, "we don't want to duplicate the whole brain, just the part that does the coding and association of incoming information."

Hoffman laughed. "Bob, you just encompassed not only the whole brain, but the entire afferent and much of the efferent nervous system, including all the spinal ganglia and the twelve cranial nerves."

"I did?"

"You did. Information coming from any one of the thirty-odd senses is coded logarithmically almost right at the site of stimulation; it's re-coded at the spine according to a power function. And then, depending on the input pathway, it's re-coded again and again and mixed with other signals—including feed-back from commands going out to the periphery—all before it ever gets to the brain! Most information reaching as high as the brainstem appears diffused and garbled almost beyond our comprehension. And virtually all neurons in the higher centers are laced up with hundreds or thousands of synaptic boutons, none of which is capable of independently firing the cell; the brain is really an enormous collection of coincidence detectors.

"In fact, current theory has it that the process of 'thinking' involves largely the raising and lowering of neuronal tone, and that it evolved from anticipating and changing act about to be performed reflexively. Which is beside the point. Fact is what you're asking your computer to do is duplicate coding which is constantly occurring at a huge number of sites over a vast network. Would you be willing to undertake a task of that magnitude?"

"Yes. Even if it took twenty years it would be worth it."

"I agree, but your estimate is no even of the right order of magnitude. Now, I admit that I've complicated the picture a little for dramatic effect; with present knowledge a transmitter action, receptor sites, and nerve fiber geometry, we could probably build a decent analog of an neural pathway. But to know absolutely that we'd duplicate the associative powers of the human brain we'd have to build an exact anatomical analog of an entire nervous system down to the spinal level." Hoffman began tapping his finger on the director's desk to emphasize his points. "All those stories you read about throwing a bunch of 'synapse circuits' together and creating a super-brain are poppycock.

"Anyway, with present slice-and-trace techniques a person can build a full model of a single neuron in about two working weeks. Now assuming that we could do this for each cell in the brainstem without destroying any of the others, we come to the depressing conclusion that the time required for the task would come to four or five hundred million man-years!"

The director held up his hand, a frown coming to his face. "Please! You sound like a conservative editorial of some kind. The people who developed WiBAViS solved that class of problem over ten years ago."

"Hm-m-m… wiring by automatic visual scanning? I never thought of that; those systems are so expensive only the government can afford them. I've never seen one in operation."

"You should. It's an education. Say, don't you remember those two guys about five years ago that used a WiBAViS to build an electric analog of a monkey's kidney? And they did it pretty fast, too, using laser-sliced electron microscope slides. The job only took 'em a couple of weeks, once they got the programming done."

"Yes, I do remember, now that you mention it." Hoffman's face was beginning to light up a little. "It was Ross and Barney, at the Mayo Clinic. And the model worked pretty well, as I recall. Hm-m-m…" A look of speculation began to dominate his face; he began muttering sub-audibly, oblivious to his friend for the moment.

The director smiled to himself; he'd finally got Hoffman thinking seriously about the problem. The bright fall day drew his eyes toward the window, where he saw the denuded cherry trees silhouetted against the bay. They brought to his mind a row of inverted organizational charts, lacking only the neat labels at the branch tips to tag the departmental levels… He focused his ears as the neurophysiologist

began talking again.

"… Suming that WiBAViS is sophisticated enough to handle the job—"

"It is, believe me. All you need is an imaginative programmer."

"Well, assuming that, anyway, there's still one insurmountable difficulty. Neurons exhibit two types of activity, depending on the type of synapse: either excitatory or inhibitory. Now when the brain is alive, we can differentiate between these two types by a slight variation of the anatomical geometry; but when we preserve a brain for detailed study, our perfusions also destroy this differentiation. And, of course, anything like X-ray holography is out of the question; it would certainly destroy any live brain on which we used it extensively."

The director frowned a moment, as if trying to remember something, then suddenly began to laugh.

"What's so funny?"

"Y'know, Hank, I got so wrapped up in arguing this project from the computer standpoint I completely forgot what gave me the idea in the first place!" He walked to his bookshelf, pulled out the latest edition of *Scientific American*. "Read this yet?"

"No. My copy must have arrived after I left for the Federation meetings."

"Take a look at the cover story."

He handed the magazine to Hoffman. On the front was a picture of a multitude of tiny units composed of triple spheres; its caption read: "Water Molecules Frozen in Their Thermal Dance." The story was entitled "Neutrino 'Holograms' Defy Heisenberg Uncertainty." Without a word, Hoffman thumbed slowly through the article, stopping from time to time to read a paragraph and mutter to himself. Finally he looked up and spoke, his eyes beginning to fill with wonder. "Why, this instrument could scan a live brain without destroying a single cell. It just might be possible. It just might."

The director reached for his phone, punched a number.

"Hi, Carol, this is Bob Macpherson. The boss in? O.K., I'll wait." He turned his attention back to the neurophysiologist. "If you were going to attempt a project like this, how much time and money do you think you'd need?"

Hoffman suddenly had a suspicion that the conversation was getting out of control. He replied slowly; "Oh, I don't know… maybe about four or five years. But I'm sure the money's out of sight. Probably over 500 megabucks, not even counting the neutrino—"

"Hello, Glenn? BobbyMac. Remember the idea we talked about Thursday night?… Yeah. Well, I've got him here now, and he thinks he can do it—"

Hoffman panicked. "Hey, wait a minute; I didn't say—"

Macpherson shushed him with an impatient hand, continued talking; "Right. About a five-year gigabuck… Uh-hunh, yeah… O.K., I'll take your word for it, and we'll get started on this end right away… Sure… Thanks a lot, buddy. See you tomorrow at the CC… 12:30, right. Bye."

Hoffman was dumbfounded at the acceleration of events; he was certain that the person to whom the director was talking was Glenn Johnson, the Cabinet Secretary for Research and Technology. He finally found his voice after Macpherson disconnected:

"Hold on now, Bob; all we've done is speculate. There're thousands of smaller problems I haven't even touched on—and any one of them could invalidate everything I just said. And where am I going to find a CS man willing to undertake the computer development? And how do we know this Meneely-or-whatever-his-name-is will be willing to loan us this neutrino thing and show us how to use it? Damn it, I haven't even told you *I'd* do it. I've got my own job at the University, research projects of my own—"

"Nonsense. Of course you'll do it. And you'll solve the problems, too. Man, this'll probably be the biggest thing since Armstrong's 'one small step.' Leave that snug little academic life behind; I'll even let you pick the location of your lab."

"Well, I don't know; I'd still have to break my contract with the University, and if they got nasty they could stick me for a stiff—"

"I'll give you a flat salary of two megabucks, and all the spending money you want for equipment and hiring."

Hoffman grinned. "Sounds like fun. You have someone in mind to do the computer work?"

"Hm-m-m… tell you what. Let me make one phone call, then we'll go to dinner and talk about it."

As the director finished up his business for the day, the neurophysiologist gazed idly out the window. The naked cherry trees brought a vivid picture to mind: a row of Purkinje cells, with their dendrites standing up into the cerebellar cortex…

INTERLOG: BIOLOG

Dr. Henry Daniel Hoffman approached the office of Dr. Clinton Tucker Meneely with some trepidation. He'd never even talked to the man personally; all his explanations and appointment-making had been done by correspondence, and phone conversations with a secretary. From what he could gather, Meneely was something of a social and professional recluse; his attitude toward the project had been totally noncommittal. Finally—and this was something Hoffman didn't realize on a conscious level—he held the bio-science man's indefinable feeling of awe toward the hard-core physicist.

He walked into the office, and was awarded a polite "Yes?" by the secretary.

"I'm Dr. Hoffman. I believe Dr. Meneely is expecting me."

"Oh, yes, certainly, sir. He's in the lab across the hall; please go right in."

He thanked the girl, stepped quickly across the hall, and opened the opaque plastic door to the physicist's laboratory.

Inside, his eyes were overwhelmed by a shambles of oscilloscopes, commercial and home-built lasers, recording gear of all descriptions, and literally tons of equipment he didn't recognize at all. From somewhere to his left he heard a muttering, and simultaneously became aware of the odor of burning resin-core solder. He carefully picked his way towards the sound/smell, coughing loudly to advertise his presence.

Abruptly the muttering stopped. From behind a bench popped a head, then neck, shoulders, torso in distinct jerks, as if there were sequential time delays for each part of the body to realize the presence of a stranger. Finally the man had straightened out and stood, continuing to stare at Hoffman for a full five seconds. During that uneasy silence, Hoffman burned the physicist into his memory. Meneely was tall and rangy, with narrow face and unkempt hair; but dominating his appearance was a pair of extraordinarily thick glasses in which the neurophysiologist could see only the reflection of the overhead glow-panels. He had time for one wild thought—*must be too thick for contacts—before* the physicist finally spoke.

"Oh, yes, you must be Dr. Hoffman." His voice was high, nasal, monotonically formal. "Please sit down." He picked up a pile of books and papers from a chair, and put them on an already impossibly cluttered workbench. "I'm intrigued by your letters; I'd be very interested in hearing the exact manner in which you'd like to use the neutrino phaser."

Hoffman had no clues about how to act, but sensed he had to sell both his idea and himself at the same time. He decided on the side of humanity, smiling warmly into his reply: "I sure hope so, Dr. Meneely, because that's why I'm here. We'd like to build a rather unique kind of computer…

"… So we need a completely benign method of internally scanning a live human to build the electric analog. Oh. And one last thing, if you're interested. I've been authorized to offer you a salary of one megabuck if we can use your instrument and services."

Hoffman had talked for fifteen minutes without a sign of life from Meneely. Now the physicist spoke:

"Dr. Hoffman, since I demonstrated the phaser for the first time several months ago, I've had a multitude of requirements, requests, and demands presented me for its immediate employment. None of them interested me more than my current study, so I ignored them as best I could. But what you want to do is both interesting and worthwhile. I'm inclined very much to… say, do you play billiards?"

Hoffman, startled, focused his eyes on the physicist's face. Miraculously, it was engaged in an embarrassed grin. In a flash of insight, the physiologist realized that Meneely was one of those rare people who lacked the ability to shade his relationships with others; he was either completely formal or completed friendly, depending on some mysterious decision circuit in his head. He thought fleetingly that the physicist must have been hurt enough times so that he was usually slow to offer friendship.

Considering himself lucky, he smiled.

"Matter of fact, I used to play quite a bit. Out of practice, though."

Meneely somehow looked relieved and eager at the same time. "Come on. I know a place that has tables with real slate beds instead of plastic hardpack. We can talk between innings." He shrugged off his lab coat, seeming to doff about twenty years in the process. Hoffman happily walked out the held-open door.

"… Cause of overlapping surface effects, the single lattice-layers of the new styrometals emit mono-energetic, unidirectional betas along one axis, and likewise neutrinos along another, if you hit them with a uniform magfield and laser pulse at the same time." Meneely was speaking as he lined up the break shot. "What I found out was that you could turn around and make an inferential detector out of the same kind of setup." He pushed his cue ball smoothly with top right english; both men watched as it began its long journey to the red ball, into the left corner, back against the right rail and squarely into Hoffman's ball with a soft click. He was already in Position for the next shot. "The only trick was to set up the computer to analyze the magfield changes in speed-of-light space, then make the coordinate transformations back to our-space quantum mechanics to deduce exactly where the neutrinos are when they pass through the target."

"Good stroke," Hoffman murmured half to himself, then, louder, "Speed-of-light space? What the Devil is that?"

"Huh? Why, I guess you'd call it a convenient mathematics. Some of the theoretical geniuses at Cal Tech dreamed it up about ten years ago to work meaningfully with the so-called massless particles. Gives 'em analogous wavelengths, Pauli numbers, Heisenberg uncertainty, and so forth. Say, I thought physiologists had to have a good background in physics." He missed his fourth billiard by millimeters. "Your shot."

Hoffman wry-grinned. "I thought I *did* have a good background; but frankly, I couldn't work my way past the 'what-it's-going-to-do-for-science' section of the SA article." He cautiously smoothed a corner-to-corner four-railer, making the billiard with a glancing kiss.

Meneely politely banged the butt of his cue against the floor. "Nice stroke. O.K., forgetting about theory, the instrument consists basically of this neutrino emitter and a couple of detectors. A neutrino pulse goes through the first detector, target, and second detector; and the outputs of the two detectors are compared, using that special SOL mathematics I was talking about. Then by quantum-mechanical 'back-dating,' so to speak, you can deduce the euclidian coordinates of objects the neutrinos went 'near.' " Meneely began to look put. "Its only limits are the bounds of your imagination!"

Dr. Jerome J. Kale gathered his notes together and stepped back from the podium amidst enthusiastic applause from the collected members of the American Association of Scientific Businessmen.

Hoffman, waiting for him in the wings, was still amazed by the duality of the computer scientist. He looked nearly subhuman—short, extremely broad, with low, slanting forehead and thick, dark features. His voice was raspy and his social language—in the short time during the day that Hoffman had had to judge—could be coarse at times. But the man could also be incredibly erudite, and was considered brilliant in his chosen discipline; he held PhDs in electrical engineering and computer science, was the author of a host of papers, owner of several patents, past president of CSAA, an FRS (honorary), ad infinitum. As Kale entered the wings, Hoffman greeted him.

"Pretty good speech."

"You really think so? I can't tell anymore; I give the same talk ten times a year with minor variations. Ready to go?"

"Any time, Jay."

"You're talking my language. I've been excited as a kid ever since I got that phone call from Mac a couple of months ago. Been waiting two years for a good excuse to quit that paper-pushing, butt-spreading vice presidency at General Software, and I'm happy to say that the last word of that speech was my final instant of employment." He forced his massive shoulders into a topcoat. "Meneely

still planning to get on the plane in Denver?"

"No; I got a call from him about three hours ago. He had a last-minute job to take care of, so he'll catch a commercial flight to Seattle and meet us there tomorrow." The neurophysiologist glanced at his watch. "In the meantime, our bird leaves in about forty-five minutes.

Let's go."

During the flight Kale snored quietly, victim of the soporific whispering of the ramjet. Hoffman sat unmoving, eyes open, dreaming in that peculiarly self-aware fashion of the complex mind. Kale awoke as the jet changed modes for the descent, and glanced out the window.

"Hey, aren't we pretty far north for the approach to Sea-Tac?"

"Huh?" Hoffman broke out of his reverie. "Oh, didn't I tell you? The airstrip at the laboratory is finished now. We're going directly in to Whidbey Island.

"Oh." The computer scientist yawned, stretched. "How 'bout our condoms. How're they coming along?"

"All ready. You can send for you family and furniture any time. In fact, Meneely's bringing his wife with him so she can buy new furniture in Seattle." Hoffman picked up the yawn from Kale, used it to pop his ears. "Some of the technicians and machinists have already moved in."

"Say, what's this guy Meneely really like? I've heard conflicting stories."

Hoffman smiled, remembering the thoroughly enjoyable week he'd spent with the Meneelys. "A really brilliant man, but a little slow, socially; he takes a while to make friends, sometimes, so go easy on him at first. But you won't have to hold back on shop talk—in fact, I think he's already got some ideas of his own about the phaser-WiBAViS interface." He buckled his seatbelt. "And he shoots a damned good stick of billiards."

As he approached the door to his office, Hoffman reflected that if the hecticity of the three days since his landing on Whidbey were any indication, he'd be a sorry person by the end of the five-year project. He opened the door to find Meneely and Kale each occupying a corner of his desk.

"… A standard algorithm interface modified with a Dibiase splitter to sample in two dimensions."

"Yes, but you see, I'm already using Gestalt algorithms in my interpretive output circuits. Now it might be possible to shortcut directly into the breeder command circuits by—" Meneely looked up, waved casually. "Morning, Hank. Are we finally ready?"

"Hi, Clint, Jay. I hope so. You guys both got your notes warmed up? Good, let's run it." He strode around the desk, sat down, and took a sheaf of notes from the top drawer. "Have a seat, fellas, this is gonna take a while." He reached over to a panel on the side of the desk, flipped a switch, cleared his throat, and began talking in the overloud tone of the novice using a tape:

"Official report. From: Associative Computer Research Project, Whidbey Island, Washington. To: Dr. Robert Macpherson, Director of Research, Library of Congress, Washington, D.C. Subject: Organizational and first progress report of ACRP. Reporting: Dr. Henry D. Hoffman, Project Director and Chief of Physiological Division, Dr. Jerome J. Kale, Chief of Computer Division, and Dr. Clinton T. Meneely, Chief of Bioinstrumentation Division. The report of the Project Director follows…"

An hour later Hoffman flipped the recorder off, leaned back in his chair, and sighed gratefully. Well, that does it for six months. Now the fun begins. You've both done a fine job of luring good people out here to work on the project." He grinned devilishly. "Being able to offer long contracts at exorbitantly high wages has its advantages. Now. How long do you think it'll take you to set up that self-breeding core, Jay?"

"Well, it appears that we don't have to make any radical design changes, except to modify the WiBAViS to work in the five-molecule matrix. And we have a break with Clint's phaser; the interface looks like it'll be a snap. Our only real problem is to design an efficient setup to take care of the sheer number of core elements involved." He scratched his mop of black hair. "Let's see, I've got Tilsen coming out here from Bell labs in about six months, and I figure it'll be seven or eight months after that we'll be ready to go. Call it fifteen months to be safe."

Hoffman looked doubtful. "Only fifteen months. Are you sure? Nobody's ever tried to set up something this comprehensive before, have they?"

"Don't worry, Hank," Kale said confidently, "the obstacles aren't technological, only adaptive," he smiled; "and, you know, computer men have a long history of adapting creations to novel ends."

"Good," Hoffman said. "Then you'll have time to set up the WiBAViS to do the initial statistical work on the internal and peripheral receptors. Before we can even begin to design the indicator circuits we have to get distribution and density functions for every type of motor and autonomic nerve ending in every part of the body. Our big board is going to be crowded enough even with a five thousand-to-one reduction in the receptor/effector network; and to do that reduction I've *got* to have those statistics. Now, Clint, when will your brainchild be ready for scanning? I need it as soon as possible."

"For single-volume scans, I'll have it ready just as soon as I get it unpacked and aligned." He took off his glasses, and inspected them myopically. "Call it a couple of weeks. But as for trying to build a picture out of two or more volume shots, we've got to wait until we can come up with that clamp. And the final model, integrated into WiBAViS, will probably be a couple of years in the building."

Hoffman nodded, musing half out loud. "And I'll probably need at least twenty months myself to classify the unknown…" He stopped and thought intently for two minutes, then began again:

"O.K., the way I see it, we'll attack the problems this way…"

Robert Macpherson seated himself comfortably in the easy chair in Hoffman's office, and gazed briefly out the window at the brown and green definition of Whidbey Island in early winter. Hoffman was just beginning to speak.

"… Begin to tell you how grateful we all are at being given a free hand here, Bob. When I told you to give me the money and leave me alone for a couple of years, we were both giggling drunk; I had no ideal you'd take me literally."

Macpherson chuckled. "You've got some old-fashioned ideas about how research administrators operate these days, Hankboy. By the time the first Secretary of Research and Technology was sworn into the Cabinet, the government had learned quite a bit about the science of science, and we've continued to learn. With the Ecological Balance Program under tight control and almost licked, we get more and more money each year allotted to pure research. We're perfectly willing to give modest sums to bright lads with good ideas; and for substantial grants like yours we look at the basic concept, and the reputation and past work of the head man involved, then let him have his head. It's worked beautifully—you ought to see the size of the spin-off patent file from 1980-to-present. Why, even if the associative computer is a complete flop, the whole project will probably pay for itself in medical technology advances alone." He smiled. "But knowing you, I don't think it'll flop."

Hoffman mirrored his smile. "Hope you're right; it's been increasingly harder during the past couple of years to see the forest. But I think we'll be ready in six months or so to start putting it all together." He stood up. "Well, ready for the two-bit tour?"

"Lead on."

Hoffman stepped to the door, opened it, and motioned Macpherson out. "To the left; we'll visit the bioinstrumentation lab first." He checked his watch. "Clint Meneely should still be there; I'll let him tell you about his setup."

They walked into Meneely's laboratory; as always, it was a visual assault. Papers, scopes, and instrument racks abounded in apparently thoughtless disorder. Hoffman looked at the director's face, laughed softly. "It used to affect me that way, too, but I got over it. It's the only kind of environmeat Clint feels at home in. He—" Meneely's face popped up from behind a small core-talk unit "Speak of the devils Hi, Clint. Meet Bob Macpherson."

Meneely came around to the front of the console, wiping his hand on his lab coveralls. "How do you do, sir." They shook hands rather warmly while Hoffman looked on thankfully. He liked them both, and had done as much verbal groundwork as possible to make the physicist feel at home with Macpherson.

Meneely spoke shyly: "Welcome to the 'rat's nest,' Dr. Macpherson."

"It's a pleasure to meet you, Clint. Understand you shoot a good stick."

Meneely's eyes lit up. "Well, my game's been going downhill the past couple of years." He looked

slyly at Hoffman. "No competition, you know."

Macpherson hooked his thumb at the neurophysiologist. "If he's the only guy you have to play with, I don't blame you. I tried to teach him the game in college, but he couldn't do much more than soak up the rudiments."

Hoffman, laughing, broke into the conversation. "Please, fellows, my poor ego! Besides, we've only got half an hour till luncheon—then we'll see who sniggers at whom."

"You're on," said Macpherson, grinning. Then, turning to the physicist, "Say, I understand you've got a tourist attraction around here, somewhere."

"You mean the phaser setup? It's right in the next room. Come on, I'll show it to you."

As Meneely opened the door for the Director, Hoffman followed, really understanding for the first time the reason for Macpherson's success in the human hustle of the nation's capital. The man honestly enjoyed people; others felt that enjoyment, and responded to it.

The appearance of the "examining room," as it was called by the staff, was a neat visual opposite of Meneely's private lab—attesting to the essential orderliness of the technicians who worked there. Its dominating feature was a high, man-sized table in the center, ringed by six pieces of apparatus that looked disturbingly like laser slicers. The left-hand wall was completely occupied by several special-purpose computers, and the right wall contained a long rack on which hung half a dozen milk-colored plastic creations. They looked like human-shaped cocoons, the front halves of which had been sliced away. On the wall directly in front of the three men were arranged a multitude of recording instruments set in racks. High up on the left, a thigh-thick cable ran through a hole from the adjoining room to disappear behind the computers on the left wall. From the ceiling were suspended several movable hooks which supported cables running in all directions.

Meneely paused quietly for a moment at the entrance, as if sensing the need of a stranger to orient himself, then spoke to Macpherson: "I assume you know how the phaser works."

"Hm-m-m? Oh, yeah. Hank here gave me a layman's version last night to cover the points I didn't get from the tapes." He continued to soak in the room.

Meneely grinned. "But he didn't prepare you for a grade B movie set, I bet. Come on over to the table." He indicated the entire layout with a sweeping gesture. "This is our second-generation apparatus; we're in the middle of final checkout right now. Poor Hank had to do eighteen months of exploratory experiments with a crude version we worked up in the first few weeks of the project. But no more." He pointed overhead to one of the neutrino sources. "You can see that these each move freely in two dimensions. Each detector pair—for instance this one and its twin under the table—move as one unit, and the three units are computer-controlled so we can scan any given volume element in a body lying on the table. The output is mathematically calculated and holographically displayed in the tank over there," he indicated a standard Holovistor set on the wall behind them, "and at the same time is coded algorithmically and sent to Jay's WiBAViS next door."

"Neat," Macpherson murmured; then, "What are those suits hanging on the wall over there?"

"Those are Hoffman's creations. He calls them biological clamps; people who have to wear 'em have less polite names. I'll let Hank tell you about them."

Hoffman looked a little rueful. "I'm sorry nobody likes them, but they're an absolute necessity—due to one of those little problems that came up and threatened to turn into a nightmare until we finally worked it out. You see, it's a matter of micromovements—those automatic posturing adjustments that go on continuously within the muscular framework of the conscious body. Now Clint's phaser can handle micromovements, all right, but when the WiBAViS tries to fit two volume elements together by anatomical recognition patterns, relative movements of objects within each element can't be any greater than about five microns between one scan and the next.

"We've finally evolved two methods of movement control which we use in conjunction to bring the errors down to where the Gestalt algorithms can handle them." He walked over to the rack of half-suits. "First thing is to have a subject fitted for one of these; they're made by contract with the Hard-pack factory over in Seattle—and it's quite an epic just to see how one of these things is molded to a skin-tight

fit." He walked back to the table. "Now, when a man is going, to be a subject, we take his suit and fix it rigidly to the table with these retractable pins, here; then he strips and lies down in the clamp. For most of the work I've done to date with the old phaser setup—analyzing receptor and effector distributions, determining transmitter effects, timing events by slow motion holography, and so on—the clamp is enough by itself. "But for piecing together a sizable portion of the anatomy, we have to call in the hypnotherapist to put the subject in a light trance. Relaxant drugs would work splendidly, but they're out of the question, of course; they all have nonnatural effects on the nervous system."

Macpherson frowned thoughtfully. "But doesn't the subject have to breathe?"

Hoffman waved his hand deprecatingly. "Oh, we take other steps, too, like having a subject stop breathing for a moment while we take a 'picture,' timing the heart cycle so we always shoot at end-diastole, and so on. Gets pretty hairy sometimes, shooting in the torso during trance, when the subject can't control his breathing pattern. Now when we get Nelson in here for the big run in about eight months, we plan to do the whole thing all at once, in about a six-hour sitting; he'll be catheterized and given a compensating IV for on-line replacement of body fluids."

"Nelson? That name rings a bell, but I can't quite place it."

"He's our model. Age 42, IQ 140, lots of common sense, a liking for money and a willingness to serve. And he's got total recall."

The trio moved into the adjoining laboratory. Three of the walls were taken up by large computers and computer components; the fourth, which they were facing as they walked in, was almost completely covered by thousands of tiny knobs and galvanometers. It was sectioned by white lines, and large irregular areas of the plastic facing were painted different colors; in addition, all the knobs were color-pattern coded. Each of the tiny readout meters was labeled in fine print contrasting with the background color.

Hoffman glanced at the library director, who was frankly gaping.

"Kinda gets you, doesn't it?"

Macpherson let out his breath. "That's probably the understatement of the year." He walked mechanically toward the wall, drawn by the hypnotic force of the swirling color patterns. "This, I take it, is the Big Board?"

"None other." Hoffman allowed himself to beam a little. "An electronic analog of the entire human body—or it will be after the final wiring—as complete as we can make it after eighteen months of study with the world's greatest physiological investigator." He made a mock bow towards Meneely, who returned it in good humor. "The only things we haven't finished yet are the analogs for the three special input-output devices of the head—ears, eyes, and vocal apparatus."

Macpherson looked bewildered. "How in the world do you keep track of it all? How can you tell if some part is malfunctioning?"

"See the row of lights on top? There's one light for each column of meters on the board. Now, the meters indicate nervous activity; when the activity of any of the meters in a column rises or falls to malfunction levels, the warning light over that column will come on.

"As for interpreting the board, it's not too complicated once you get used to it. It's laid out with respect to functional anatomy. The fifty-three sections outlined in broad white lines are logical anatomic divisions of the body, and each division is sectioned with fine white lines, with everything labeled. Here, for instance, is the heart analog, subdivided into atria, ventricles, and coronary blood vessels. Now the background colors represent major physiological control systems, which overlap not only the-white lines, but each other." He pointed to an area painted in small green and blue checks.

Macpherson, still looking bewildered, asked: "Exactly what do the knobs and meters represent?"

"The meters are readouts of the electric analogs of nerve effector activity—the final outputs of the body control systems. The knobs allow us to create an electronic analog of internal and external environment by adjusting the input firing rates of the sensors. You can see that the meters are labeled; the knobs are distinguishable by what anatomic section they're located in, and their color pattern. We have patterns for each of the thirty-eight functionally different types of receptors we've classified in our studies.

"Frankly, we plan never to touch most of the knobs after we set them at initial tonic levels; you see, they can also be controlled internally by feedback circuitry, all except for the peripheral receptors. That way, when the brain core sends out a 'command,' it'll be 'fooled' into thinking that the 'body' has obeyed."

Macpherson continued to study the board for several minutes. Finally he shook his head. "*Whew*! I give up. It's just too much." He turned to Hoffman. "Now, you were speaking of the brain core—?"

Hoffman grinned. "I can take a hint; if you will direct your attention to the left wall, sir. Since Jay's in Chicago with his two top men, I'll let Clint explain the big computers. He can give you a much better snow job than I could, since you're an old computer man yourself."

The director waved a hand. "I don't think you'll need to do too much explaining, Clint. Jay's been to see me twice in D.C. and I've read both the papers he and his assistants have published in ACSJ since they began here." He scrutinized the machinery against the left wall. "However, I must admit I'm surprised at the size of the core and WiBAViS unit, since they're both using five-molecule core and talk circuits." He walked over to the brain core, fondled it.

"You can blame Hoffman for part of that," said the physicist, "since he required us to build a multispeed analog. The brain core is about three times the size of what it would have been for single-mode operation. And as for the WiBAViS, it'll get even bigger before we're done. We found out early that the only way to do the thing practically would be to first store and correlate the entire anatomic contents of the body, then wire according to program." Meneely took off his glasses, absently rubbed them against his dirty coveralls. "Unfortunately, we also had to find a way around the sheer numerical monstrosity of the operation. Nelson is a big man—masses about a hundred kilos—so we'll require about 100,000 shots with the phaser; multiply that by 109 coordinate points per shot, each requiring three spatial references, each reference requiring ten bits, and so on—you know the routine—and we would have had a mess trying to use normal core notation."

Macpherson nodded. "So I gathered from talking with Jerome."

"Of course, the solution was to store the algorithms themselves, spatially coding with a one-for-one correspondence with body volume coordinates, then slice and wire at leisure." Meneely put his dirtied glasses back on, looked surprised for a moment, took them off again and began repolishing them with a handkerchief. "Even so, it took a memory of 1014 bits; you can see it's about twice the size of a standard unit. Its functional twin is in the next room, spread out thin and plastered up against the backside of the Big Board, ready to breed and wire it into the brain core. We're using laser hookups for intercommunications, of course; nothing else is feasible." He inspected his glasses. "What else? Oh, yes. The saga of the poor programmers; I couldn't begin to do it justice. Hank and his boys," he pointed accusingly, "have hit them with more than seven hundred different recognition sequences, each one requiring a different wiring delay, synapse interaction coding formula, and God knows what else. And then he has the gall to demand an error figure of 106!" He put his glasses on again, and looked at his watch. "And now, as I recall, there was a matter of lunch and billiards."

Macpherson stopped by Hoffman's lab a few minutes before his departure for Washington, D.C.

"Hi, Hankboy. Just wanted to say good-bye."

Hoffman rose from the micro-hologram he'd been studying. "Hi, Mac. I still wish you'd let me see you to the airstrip."

"Nothin' doing. When you told me you were humping to meet a deadline for the Federation meetings, I felt guilty about coming here in the first place; you should have told me two days ago. Before I go, though, tell me something confidentially: do you really need all those controls on the Big Board, or was that part of a plan to suck in some good physiological research talent? Not that I'd do any differently, you understand."

Hoffman chuckled. "I'd hate to have an investigating committee pin me down on that one, Bob, because I'm not sure, myself, any more. We could probably do without some of them, but I couldn't guarantee it. We have to program the computer so it'll 'learn' associative techniques and the psychologists contend that an environment analog is absolutely necessary for the machine to communicate effectively with humans. So I ended up by throwing in everything, to be absolutely certain that our final product will

have full recall and associative abilities." His smile broadened. "So by the time I had the thing fully designed, it promised to be the greatest physiological research model ever built. Naturally there were a few people anxious to be associated with the project."

Macpherson smiled wryly. "Nice answer. You ever thought of taking up politics?"

"Not a chance. Even this job's driving me batty."

The two shook hands warmly, and Macpherson departed. The neurophysiologist sat back down at his table and quickly lost himself in his work…

Summer lay lushly on Whidbey Island, creating a serpentine emerald dropped across the headwaters of Puget Sound. But the several hundred beings in the main building of the ACRP complex had closed their minds to the beauties of the Pacific Northwest. For the moment, they had eyes only for the Holovistor monitors; their field was centered on a man named Nelson, who lay nude in trance, half in a white cocoon on the table of the examining room. The several beings privileged to view Nelson in the flesh were tense with quiet fatigue; they had been attending his body and its monitors for nearly six hours, as silently as possible so as not to disturb the trance state of the man. The only sound in the room was the monotonous muted clicking of the phaser as its probing, invisible pulses shifted their attentions from section to section at the steady rate of ten times per second.

In the adjoining computer room silence was not necessary, but the tension remained. Dr. Jerome Kale sat at the WiBAViS console, attended by colleagues and technicians, watching the phaser's progress in coded digital readouts. Hoffman entered from the examining room, closing the door silently behind him. "How's it going, Jay?"

"Smooth enough," the computer scientist grunted, "but I see we're almost to the ears, now. Won't be too long until slowdown."

Hoffman nodded. "That's why I came in here; I'm considered 'nonessential personnel' for the time being." He took out a handkerchief, mopped his forehead. "I thought we'd never make it through the, torso; four and a half hours of off-and-on shooting is enough, to drive anybody up the wall. Boy, when this is over—"

"Here we go," interrupted Kale.

Hoffman looked up at the digital readout of the current total of volume elements stored in WiBAViS. The far-right position had stopped its frantic changing and was now jerking sedately once every second. In the examining room, he knew, the remaining people were constrained to absolute silence; and the phaser had slowed to allow its own sound to be damped out before taking each scan.

After about thirty seconds a red light flashed on the panel in front of Kale, indicating a movement too large for anatomic correlation with the adjoining sections. He swore softly, then stopped abruptly as the light went out again; WiBAViS had ordered a re-scanning of the troublesome volume element, and found the second image acceptable. The phaser in the next room continued its steady journey to the top of Nelson's head.

Kale laughed softly, without humor, and said to Hoffman; "I don't know why I get so nervous every time we have to retake; it happened one hundred sixty-seven times in the heart-lung area. But it still makes me jumpy; deep down, I probably lack faith in all the last-minute jury rigs we've made in the past month."

Hoffman was sympathetic. "I'll probably feel the same way when it comes time to turn on the Big Board for the first time."

During the next five minutes, there were two more red flashes, but each time they persisted only a second. Finally the digital indicator began its lightning pace again. Kale sighed, then spoke loudly to the whole room: "Two minutes!"

During the final minute Hoffman stood immobile, his hand on Kale's shoulder, hypnotized by the decimal dance of the volume readout. The far right position was an almost continuous blur as it raced through its cycle, ten numbers every second, over and over. The neurophysiologist noticed absentmindedly that his eyes seemed to catch different numbers, and hold them in afterimage in an unpredictable sequence. His glance moved to the next position on the left, whose one change per second

seemed a snail's pace. He had just moved his eyes to the third column when the readout suddenly stopped changing. He took in the whole display. It announced 1 1 4 8 5 7. Abruptly Hoffman realized that that was a figure he recognized from many reports and conference sessions. The run had ended.

Kale came to life, called out crisply: "Micropunch?"

"Taped, sir," answered a technician; "15.47636 kilometers. No parity error."

"Core memory?"

"Locked in, Doc. Emergency back-up power on line. We won't lose this one!"

The computer scientist turned to Hoffman, his neanderthal features spread in a wide grin. "Your model's in the books, Hank. Go give 'em the good word."

Hoffman strode into the adjoining room, smiling and holding up his thumb. Facing the front pickup of the closed-circuit holovision, he announced in a serious voice: "Ladies and gentlemen. You've worked mightily, with hardly a break, for nearly three years. Today, in this past six hours, we've seen an important culmination of that labor. For those of you who will be leaving us now, I can't begin to thank you for your devotion to the task. For those who will be staying on for the eighteen months of wiring and final six months of programming, I thank you also for your untiring efforts, and hereby proclaim a month of leave for everyone!"

As cheers went up from every part of the building, Hoffman walked over to a grinning Clint Meneely, and warmly took his hand. Kale joined them, and the three walked slowly out of the examining room.

POSTLOG: PROLOG

Whidbey Island was shrouded in its habitual midwinter cloud-cover. But inside the main building of the ACRP coinplex, warm walls and glowing ceilings pushed out the gray drizzle. In the computer room Hoffman, Meneely, Kale and Macpherson stood facing the Big Board. The room was crowded with technicians and scientists making last-minute triple-checks of level settings and status indicators. Hoffman was talking to Macpherson.

"… Three modes of operation are designed simply as slow, intermediate, and fast. The slow mode is what we call biological speed.' We'll use it for a lot of the initial oral programming, and to get the feel of correct operational sequencing before we switch over to intermediate in a month or so. When we finally deliver the computer to you in Washington, the entire software for initial programming will be on fast mode tapes, so the operation can be done at 1,000 times biological speed."

Macpherson stepped over to the brain-core. "And you say this is the principal input/output?" He indicated a small speaker set into the console of a small auxiliary computer. Also on the console were a pair of sonic receivers, and still another pair of wide-angle photoreceptors mounted on gimbaled controls.

"Essentially, yes," Kale answered the question, "but, of course, the external I/O systems you see there will be used only in slow mode. For intermediate and fast speeds, the input system is wired in parallel directly to electronic talk-circuits. But the oral output in all modes is the movement of air molecules initiated by the vocal cord analog; we'll tape directly, of course. For written output, Hank suggested we wire seventy of the skeletal muscle effectors into the key-activators of a speedwriter; it's on the right side of the Big Board, over there. Matter of fact, we just finished the programming for that output mode."

While they had been talking, the technicians had one by one finished their inspections and stepped back from the Big Board and brain core. Kale looked around, glanced at his watch, and sang out to the room:

"Status report! Parity?"

"Parity O.K., Jay."

"Initial input levels?"

"All nominal at tonic values."

"Speedwriter?"

"Switched in, Doc."

"Special senses I/O?"

"In circuit, sir. Slow mode."

"Core status?"

"Core running on full standby, Jay. Slow mode. Consumption 130 watts."

"Laser intercoms?" Kale asked.

"All hot, sir."

"Oral programmer?" Kale turned to a man on his left. "Go ahead and take your place, Sam." The man to whom he had spoken detached himself from the group in the center, and went over to stand by the sonic receptors. He cleared his throat selfconsciously.

The computer scientist turned to Hoffman, said with formality: "I believe the honor should be yours, sir."

Hoffman nodded, stepped to the main console, and placed his hand over a switch labeled CORE/PERIPHERY INTER-CONNECT. He flipped it perfunctorily and stepped back from the console, noting that the power consumption indicator had swung abruptly to three hundred watts. He turned to the right, eyes sweeping the Big Board; almost every one of the thousands of readouts was displaying motion of some kind. He nodded to Kale.

Kale said: "O.K., Sam, start the initial in—"

He was suddenly interrupted by a sporadic clattering from the right side of the Big Board; the

speed-writer had suddenly come to life. Kale held up a hand, a startled look on his face. "Wait a minute, Sam." He walked over to the instrument. It was printing out random symbols. "What the hell—"

Again he was interrupted, this time by the oral output speaker. It had burst into a wailing ululation, filling the room with its weird sound. Hoffman, who had just looked back to the Big Board from the speedwriter, suddenly froze, vision blurring as realization struck him. In a daze he walked over to the division on the board marked "Stomach," searched briefly, found a section labeled "fundus." He reached up and slowly turned one of the knobs until the speaker stopped its screeching. Turning to Kale, who was looking at him questioningly, he smiled idiotically, and said: "Hungry."

As if in confirmation, the unmistakable sound of a belch burst from the output speaker, followed almost immediately by a contented gurgling noise.

As comprehension swept the computer room, the scientists and technicians fell silent, listening in fascination to the speaker's unintelligent but utterly meaningful output. Hoffman stood completely lost in thought as the gurgling slowly subsided; the speedwriter stopped its rapid clicking, leveled off to an occasional burst.

Finally the neurophysiologist seemed to make a silent decision within himself. He sighed, straightened out his slumped shoulders. Life returned to his eyes and voice. He spoke to Macpherson. "Bob, our delivery schedule is going to be somewhat delayed—maybe by years. Maybe even forever." Then, turning to Kale, "Jay, I'm calling a meeting in my office in half an hour. Bring your section chiefs and all your programmers; I want to see the staff psychologist, too. Oh, and have somebody make an announcement that I'd like the attendance of all personnel who have children less than five years old.

He stopped and cocked an ear toward the speaker. It was now emitting a soft, rhythmic rasping noise. Hoffman smiled, walked over to the console, and turned a knob marked "Oral Input Intensity Level" all the way counterclockwise. Turning back around, he explained: "Wouldn't want to wake him."

He spoke once again to the computer scientist. "Before you come, Jay, slap a permanent cover over the core/periphery interconnect—the spinal shock would be serious if someone accidentally turned it off. And put two emergency power backups into the core circuit; we have some serious thinking to do about the legal and moral implications of a power failure.

He strode toward the door, gathering up the still-dazed Macpherson. As they walked out together, Hoffman was talking: "… Know you have a pretty good latch on the Secretary. Now the grant we'll need won't have to be large, but must be guaranteed for several years; I figure eventually, though, we'll be getting plenty of contributions from interested…"

The door shut on the two men.

The computer continued to snore contentedly.