



PHOTOS FROM SEED'S LAUNCH

MICHAEL CRICHTON'S

EXCERPT

t first, it was hard to understand what I was seeing-it looked like an enormous glowing octopus rising above me, with glinting, faceted arms extending outward in all directions, throwing complex reflections and bands of color onto the outer walls. Except this octopus had multiple layers of arms. One layer was low, just a foot above the floor. A second was at chest level; the third and fourth layers were higher, above my head. And they all glowed, sparkled brilliantly.

I blinked, dazzled. I began to make out the details. The octo-

pus was contained within an irregular three-story framework built entirely of modular glass cubes. Floors, walls, ceilings, staircases—everything was cubes. But the arrangement was haphazard, as if someone had dumped a mound of giant transparent sugar cubes in the center of the room. Within this cluster of cubes the arms of the octopus snaked off in all directions. The whole thing was held up by a web of black anodized struts and connectors, but they were obscured by the reflections, which is why the octopus seemed to hang in midair. Ricky grinned. "Convergent assembly. The architecture is fractal. Neat, huh?" I nodded slowly. I was seeing more details. What I had seen

these branches, even smaller pipes branched off in turn, and smaller ones still. The smallest of the pipes were pencil-thin. Everything gleamed as if it were mirrored. "Why is it so bright?" "The glass has diamondoid coating," he said. "At the molecular level, glass is like Swiss cheese, full of holes. And of course it's

as an octopus was actually a branching tree structure. A central square conduit ran vertically through the center of the room, with smaller pipes branching off on all sides. From

a liquid, so atoms just pass right through it." Excerpted from the book Prey, a novel by Michael Crichton. Copyright @ 2002 by Michael Crichton. Published by HarperCollins Publishers,

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"Right. Have to."

"So you coat the glass."

Within this shining forest of branching glass, David and Rosie moved, making notes, adjusting valves, consulting handheld computers. I understood that I was looking at a massively parallel assembly line. Small fragments of molecules were introduced into the smallest pipes, and atoms were added to them. When that was finished, they moved into the next largest pipes, where more atoms were added. In this way, molecules moved progressively toward the center of the structure, until assembly was completed, and they were discharged into the central pipe. "Exactly right," Ricky said. "This is just the same as an automobile assembly line, except that it's on a molecular scale.

Molecules start at the ends, and come down the line to the center. We stick on a protein sequence here, a methyl group there, just the way they stick doors and wheels on a car. At the end of the line, off rolls a new, custom-made molecular structure. Built to our specifications." "And the different arms?" "Make different molecules. That's why the arms look different." In several places, the octopus arm passed through a steel tunnel reinforced with heavy bolts, for vacuum ducting.

In other places, a cube was covered with quilted silver insulation, and I saw liquid nitrogen tanks nearby; extremely low temperatures were generated in that section. "Those're our cryogenic rooms," Ricky said. "We don't go very low, maybe -70 Centigrade, max. Come on, I'll show you." He led me through the complex, following glass walkways that threaded among the arms. In some places, a short staircase

enabled us to step over the lowest arms. Ricky chatted continuously about technical details: vacuum-jacketed hoses, metal phase separators, globe check valves. When we reached the insulated cube, he opened the heavy door to reveal a small room, with a second room adjacent. It looked like a pair of meat lockers. Small glass windows were set in each door. At the moment, everything was at room temperature." You can have two different temps here," he said. "Run one from the other, if you want, but it's

I said, "Are we late for an appointment?" "What? No, no. Nothing like that." Nearby two cubes were actually solid metal rooms, with thick electrical cables running inside. I said, "Those your magnet rooms?"

Ricky led me back outside, glancing at his watch as he did so.

usually automated."

"That's right," Ricky said. "We've got pulsed field magnets generating 33 Tesla in the core. That's something like a million times the magnetic field of the earth."

With a grunt, he pushed open the steel door to the nearest magnet room. I saw a large doughnut-shaped object, about six feet in diameter, with a hole in the center about an inch wide. The doughnut was completely encased in tubing and plastic insulation. Heavy steel bolts running from top to bottom held the jacketing in place. "Lot of cooling for this puppy, I can tell you. And a lot of

power: 15 kilovolts. Takes a full-minute load time for the capacitors. And of course we can only pulse it. If we turned it on continuously, it'd explode—ripped apart by the field it generates." He pointed to the base of the magnet, where there was a round push button at knee level. "That's the safety cutoff there," he said. "Just in case. Hit it with your knee if your hands are full." 92 SEED

"Ricky..."

assemb-*

But Ricky had already turned and headed out the door, again glancing at his watch. I hurried after him. "I have more to show you," he said. "We're getting to the end." "Ricky, this is all very impressive," I said, gesturing to the

I said, "So you use high magnetic fields to do part of your

glowing arms. "But most of your assembly line is running at room temperature-no vacuum, no cryo, no mag field." "Right. No special conditions." "How is that possible?" He shrugged. "The assemblers don't need it." "The assemblers?" I said. "Are you telling me you've got

"Yes. Of course." "Assemblers are doing your fabrication for you?" "Of course. I thought you understood that." "No, Ricky," I said, "I didn't understand that at all. And I don't like to be lied to."

He got a wounded look on his face. "I'm not lying."

molecular assemblers on this line?"

But I was certain that he was.

ne of the first things scientists learned about molecular manufacturing was how phenomenally difficult it was to carry out. In 1990, some IBM researchers pushed xenon atoms around on a nickel plate until they formed the letters "IBM" in the shape of the company logo.

The entire logo was one ten-billionth of an inch long and could only be seen through an electron microscope. But it made a striking visual and it got a lot of publicity. IBM allowed people to think it was a proof of concept, the opening of a door to molecular manufacturing. But it was more of a stunt than anything else. Because pushing individual atoms into a specific arrangement was slow, painstaking, and expensive work. It took the IBM researchers a whole day to move 35 atoms. Nobody believed you could create a whole new technology in this way. Instead, most people believed that nanoengineers would eventually find a way to build "assemblers"-miniature

molecular machines that could turn out specific molecules the way a ball-bearing machine turned out ball bearings. The new technology would rely on molecular machines to make molecular products. It was a nice concept, but the practical problems were daunting. Because assemblers were vastly more complicated than the molecules they made, attempts to design and build them had been difficult from the outset. To my knowledge, no laboratory anywhere in the world had actually done it. But now Ricky was telling me, quite casually, that Xymos could build molecular assemblers that were now turning out molecules for the company.

I had worked all my life in technology, and I had developed a feel for what was possible. This kind of giant leap forward just didn't happen. It never did. Technologies were a form of knowledge, and like all knowledge, technologies grew, evolved, and matured. To believe otherwise was to believe that the Wright brothers could build a rocket and fly to the moon instead of flying three hundred feet over sand dunes at Kitty Hawk. Nanotechnology was still at the Kitty Hawk stage.

And I didn't believe him.

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"What fresh bullshit is this? Of course they're important." "Jack," he said, giving me his most winning smile. "Do you really think I'm lying to you?" "Yes, Ricky," I said. "I do." rounded looked up at the octopus arms all around me. Surrounded by glass, I saw my own reflection dozens of times in the surfaces around me. It was confusing, disorienting. Trying

"Come on, Ricky, " I said. "How are you really doing this?"

"The technical details aren't that important, Jack."

to gather my thoughts, I looked down at my feet. And I noticed that even though we had been walking on glass walkways, some sections of the ground floor were glass, as well. One section was nearby. I walked toward it. Through the glass I could see steel ducting and pipes below ground level. One set of pipes caught my eye, because they ran from the storage room to a nearby glass cube, at which point they emerged from the floor and headed upward, branching into That, I assumed, was the feedstock—the slush of raw organic material that would be transformed on the assembly line into finished molecules. Looking back down at the floor, I followed the pipes back-

This junction was glass, too. I could see the curved steel under-

ward to the place where they entered from the adjacent room.

bellies of the big kettles I'd noticed earlier. The tanks that I had thought were a microbrewery. Because that's certainly what it had looked like, a small brewery. Machinery for controlled fermentation, for controlled microbial growth. And then I realized what it really was. I said, "You son of a bitch." Ricky smiled again, and shrugged. "Hey," he said. "It gets the job done."

hose kettles in the next room were indeed tanks for controlled microbial growth. But Ricky wasn't making beer—he was making microbes, and I had no doubt about the reason why. Unable to construct genuine nanoassemblers, Xymos was using bacteria to crank out their molecules.

This was genetic engineering, not nanotechnology.

"Well, not exactly," Ricky said, when I told him what I thought. "But I admit we're using a hybrid technology. Not

much of a surprise in any case, is it?" That was true. For at least ten years, observers had been predicting that genetic engineering, computer programming, and nanotechnology would eventually merge. They were all involved with similar-and interconnected-activities. There wasn't that much difference between using a computer to decode part of a bacterial genome and using a computer to help you insert new genes into the bacteria, to make new proteins. And there wasn't much difference between creating a new bacteria to spit out, say, insulin molecules, and creating a man-made, micromechanical assembler to spit out new molecules. It was all happening at the molecular level. It was all the same challenge of imposing human design on extremely complex systems. And molecular design was nothing if not complicated. You could think of a molecule as a series of atoms snapped together like Lego blocks, one after another. But the image was

together in any arrangement you liked. An inserted atom was subject to powerful local forces-magnetic and chemical-with SEED 95

misleading. Because unlike a Lego set, atoms couldn't be snapped

to make equivalent structures that would work in the desired way. In the face of all this difficulty, it was impossible to ignore the fact that there already existed proven molecular factories capable of turning out large numbers of molecules:they were called cells.

frequently undesirable results. The atom might be kicked out of

its position. It might remain, but at an awkward angle. It might

art of the possible, of substituting atoms and groups of atoms

As a result, molecular manufacturing was an exercise in the

even fold the entire molecule up in knots.

"Unfortunately, cellular manufacturing can take us only so far," Ricky said. "We harvest the substrate molecules-the raw materials-and then we build on them with nanoengineering procedures. So we do a little of both." I pointed down at the tanks. "What cells are you growing?" "Theta-d 5972," he said. "Which is?" "A strain of E. coli."

where in the natural environment, even in the human intestine. I said, "Did anyone think it might not be a good idea to use cells that can live inside human beings?" "Not really," he said. "Frankly that wasn't a consideration. We just wanted a well-studied cell that was fully documented

in the literature. We chose an industry standard."

E. coli was a common bacterium, found pretty much every-

"Uh-huh..." "Anyway," Ricky continued, "I don't think it's a problem, Jack. It won't thrive in the human gut. Theta-d is optimized for a variety of nutrient sources-to make it cheap to grow in the laboratory. In fact, I think it can even grow on garbage." "So that's how you get your molecules. Bacteria make them

We harvest 27 primary molecules. They fit together in relatively high-temperature settings where the atoms are more active and mix quickly." "That's why it's hot in here?" "Yes. Reaction efficiency has a maxima at 147 degrees Fahrenheit, so we work there. That's where we get the fastest combination rate. But these molecules will combine at much lower

"Yes," he said, "that's how we get the primary molecules.

temperatures. Even around 35, 40 degrees Fahrenheit, you'll get a certain amount of molecular combination." "And you don't need other conditions," I said. "Vacuum? Pressure? High magnetic fields?" Ricky shook his head. "No, Jack. We maintain those condi-

tions to speed up assembly, but it's not strictly necessary. The design is really elegant. The component molecules go together "And these component molecules combine to form your final

assembler?" "Which then assembles the molecules we want. Yes." t was a clever solution, creating his assemblers with bacteria. But Ricky was telling me the components assembled

themselves almost automatically, with nothing required but high temperature. What, then, was this complex glass building used for? "Efficiency, and process separation," Ricky said. "We can build as many as nine assemblers simultaneously, in the dif-

ferent arms." "And where do the assemblers make the final molecules?"

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would take several days to make a single camera. We couldn't figure out what the problem was. The late assembly in the arms is done in gas phase. It turned out that the molecular assemblers were heavy, and tended to sink to the bottom. The

I shook my head. I wasn't familiar with the term. "Reapply?"

"It's a little refinement we developed here. We're patenting

You see, our system worked perfectly right from the

start-but our yields were extremely low. We were harvesting

half a gram of finished molecules an hour. At that rate, it

bacteria settled on a layer above them, releasing component molecules that were lighter still, and floated higher. So the assemblers were making very little contact with the molecules they were meant to assemble. We tried mixing technologies but they didn't help." "So you did what?" "We modified the assembler design to provide a lipotrophic base that would attach to the surface of the bacteria. That brought the assemblers into better contact with the component molecules, and immediately our yields jumped five orders "And now your assemblers sit on the bacteria?" "Correct. They attach to the outer cell membrane." At a nearby workstation, Ricky punched up the assembler

design on the flat panel display. The assembler looked like a sort of pinwheel, a series of spiral arms going off in different directions, and a dense knot of atoms in the center. "It's fractal, as I said," he said. "So it looks sort of the same at smaller orders of magnitude." He laughed. "Like the old joke, turtles all the way down." He pressed more keys. "Anyway, here's the

attached configuration." The screen now showed the assembler adhering to a much larger pillshaped object, like a pinwheel attached to a submarine. "That's the Theta-d bacterium," Ricky said. "With the assem-As I watched, several more pinwheels attached themselves. "And these assemblers make the actual camera units?" "Correct." He typed again. I saw a new image. "This is our target micromachine, the final camera. You've seen the bloodstream version. This is the Pentagon version, quite a bit larger and designed to be airborne. What you're looking at is a

"Hasn't got one. The machine uses those little round protrusions you see there, stuck in at angles. Those're motors. The machines actually maneuver by climbing the viscosity of "Climbing the what?"

"Viscosity. Of the air." He smiled. "Micromachine level,

molecular helicopter."

"Where's the propeller?" I said.

remember? It's a whole new world, Jack." wever innovative the design, Ricky was still bound by the Pentagon's engineering specs for the product, and L the product wasn't performing. Yes, they had built a camera that couldn't be shot down, and it transmitted images

very well. Ricky explained it worked perfectly during tests indoors. But outside, even a modest breeze tended to blow it away like the cloud of dust it was. The engineering team at Xymos was attempting to modify the units to increase mobility, but so far without success.

Meanwhile, the Department of Defense decided the design JAN/FEB 03

tion mounted on the wall. There was a sta-

"Vince, lock us down."

down, Ricky."

It was flashing red: PV-90 ENTRY.

"Raise positive pressure."

I said, "What does that mean?"

"Something set off the perimeter

The radio crackled. "We're locked

"It's up five pounds above baseline.

alarms." He unclipped his radio and said,

constraints were unbeatable, and had the walkway, finally stopping beside a big backed away from the whole nano con- air vent, about three feet in diameter, that tus window in the corner of the monitor. cept; the Xymos contract had been can- went into the outer wall.

in another six weeks.

for you."

whole company could go belly up before micro filters arranged in successive layers, to prevent any external contamina-"Unless you fix the units, so they can tion from the facility." work in wind." "Right, right."

celed; DOD was going to pull funding

perate for venture capital, these last few

I said, "That's why Julia was so des-

I said, "Ricky, I'm a programmer. I can't help you with your agent mobility problems. That's an issue of molecular design. It's engineering. It's not my

"Um, I know that." He paused, frowned. "But actually, we think the program code may be involved in the solution." "The code? Involved in the solution to

"Jack, I have to be frank with you. We've made a mistake," he said. "But it's not our fault. I swear to you. It wasn't us. It was the contractors." He started down the stairs. "Come on, I'll show you."

alking briskly, he led me to the far side of the facility, where I saw an open yellow elevator cage mounted on the wall. It was a small

elevator, and I was uncomfortable because it was open; I averted my eyes. Ricky said, "Don't like heights?" "Can't stand them."

"Well, it's better than walking." He

pointed off to one side, where an iron ladder ran up the wall to the ceiling. "When the elevator goes out, we have to climb up that." I shuddered. "Not me." We rode the elevator all the way up to the ceiling, three stories above the ground. Hanging beneath the ceiling was a tangle of ducts and conduits, and a net-

work of mesh walkways to enable work-

ers to service them. I hated the mesh, because I could see through it to the break up, decompose. In a few hours or floor far below. I tried not to look down. days, they're gone. Right?"

We had to duck repeatedly beneath the

low-hanging pipes. Ricky shouted over

pointing in various directions. "Air han-

dlers over there! Water tank for the fire

"Everything's up here!" he yelled,

the roar of the equipment.

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"Unfortunately, the contractor forgot to

"Right," Ricky said. "Frankly, this slots? Those are filter packs. We have

"I see them ... "

install the filters in this particular vent. In fact, they didn't even cut the slots, so the building inspectors never realized anything was missing. They signed off on the building; we started working here. And we vented unfiltered air to the outside environment." "For how long?" Ricky bit his lip. "Three weeks." "And you were at full production?"

"This is vent three," he said, leaning

close to my ear. "It's one of four main

vents that exhausts air to the outside.

Now, you see those slots along the vent,

and the square boxes that sit in the

He nodded. "We figure we vented approximately 25 kilos of contaminants." "And what were the contaminants?" of exactly what."

"A little of everything. We're not sure "So you vented E. coli, assemblers, finished molecules, everything?" proportions." "Do the proportions matter?" "They might. Yes."

"Correct. But we don't know what Ricky was increasingly edgy as he told me all this, biting his lip, scratching his head, avoiding my eyes. I didn't get

it. In the annals of industrial pollution, fifty pounds of contamination was trivial. Fifty pounds of material would

fit comfortably in a gym bag. Unless it was highly toxic or radioactive-and it wasn't-such a small quantity simply didn't matter.

I said, "Ricky, so what? Those particles were scattered by the wind across hundreds of miles of desert. They'll decay from sunlight and cosmic radiation. They'll

Ricky shrugged. "Actually, Jack, that's

It was at that moment that the alarm

not what-"

You want more?" "No. Leave it there. Do we have visualization?" "Not yet." "Shit." Ricky stuck the radio back on his

images from security cameras mounted all

"You see them now," Ricky said. belt, began typing quickly. The workstation screen divided into a half-dozen small

> around the facility. Some showed the surrounding desert from high views, looking down from rooftops. Others were ground views. The cameras panned slowly. I saw nothing. Just desert scrub and

occasional clumps of cactus. "False alarm?" I said. Ricky shook his head. "I wish."

I said, "I don't see anything." "It'll take a minute to find it." "Find what?" "That." He pointed to the monitor, and bit

resaw what appeared to be a small, swirling cloud of dark particles. It Looked like a dust devil, one of those tiny tornado-like clusters that moved over the ground, spun by convection

currents rising from the hot desert floor. Except that this cloud was black, and it had some definition-it seemed

to be pinched in the middle, making it look a bit like an old-fashioned Coke" bottle. But it didn't hold that shape consistently. The appearance kept shifting, transforming.

"I was hoping you'd tell me." "It looks like an agent swarm. Is that your camera swarm?" "No. It's something else." "How do you know?"

"Because we can't control it. It doesn't

"Yes. We've tried to make contact with

"Ricky," I said. "What are we looking at?"

haven't they decayed, or run out of power? And why exactly can't you control them? Because if they have the ability to swarm, then there's some electrically mediated interaction among them. So you should be able to take control of

"Yes."

"Yes."

the swarm-or at least disrupt it." "All true," Ricky said. "Except we can't. And we've tried everything we can think of." He was focused on the screen, watching intently. "That cloud is independent of us. Period." "And so you brought me out here . . ." back," Ricky said. O

"So you have a runaway swarm."

"And this has been going on for . . ."

"Ten days?" I frowned. "How is that

possible, Ricky? The swarm's a collec-

tion of micro-robotic machines. Why

"Acting autonomously."

"Days. About 10 days."

"To help us get the fucking thing The New War (continued from pg 56)

the whereabouts and use of 17 tons still remain unknown in 2002. "The one thing that was never explained to us," Beck insists, "was for what purpose Iraq was buying all this growth media."

UNSCOM felt it had proof that Iraq had manufactured 8,500 liters of anthrax in liquid slurry form, 19,400 liters of concentrated botulinum toxin, 340 liters of Clostridium botulinum bacteria, assorted smaller quantities of viruses, and other bacteria. As for nerve gases, they concluded, Iraq had made a minimum of 2,850 tons of mustard gas, 210 tons of tabun, 750 tons of sarin, and four tons of VX. If properly used, these chemical and biological agents could quite adequately kill the majority of the population of the Middle East.

hat is the history. In December

1997, UNSCOM Chairman

Richard Butler told the UN

Security Council that Iraq was no longer

cooperating with inspection, and would not

allow his staff access to sites it had newly

1998. A year later, the Clinton and Blair

Administrations jointly staged Operation

UNSCOM pulled out of Iraq in early

labeled "Presidential" and "sovereign."

than five percent of the off-limits area. Either Saddam has palatial estates 20

top-of-the-line ballistic missiles.

Butler claims that privately, Iraqi

1997 that all of UNSCOM's suspicions

had been correct, and then some.

Whatever was in fact the case, Butler

knows that his team never even got a

chance to investigate the majority of the

suspicious sites, especially those declared

off limits because they were designated

For years I ignored the question of

"presidential palaces."

homes. I imagined the situation to be roughly equivalent to the UN demanding entry to Camp David. But last fall, Prime Minister Blair released his case for war against Baghdad, entitled "Iraq's Weapons of Mass Destruction: The Assessment of the British Government." It features a satellite photograph of an area deemed off limits by the Iraqis, under the designation "presidential palace." Superimposed on the image,

offering a stark comparison, is a satellite shot of Buckingham Palace, taking up less

"presidential palaces," thinking it some-Baghdad. And, of course, it leaves indihow unseemly that outside inspectors viduals the world over unable to process wished to barge into Saddam's private their own anxieties, or lack thereof. Few adult Americans have forgotten that the nation was suckered in 1990 by Kuwaiti testimony to Congress, in which conservative American and Kuwaiti politicians colluded to give phony claims of rape, torture, and murder carried out methodically in the Iraq-occupied emirates. The CIA has released several reports since 1998, allegedly assessing Iraqi WMD capacity. It is striking that the language in these reports, each ostensibly written a year apart, is nearly word-forword identical, and the "empirical" sense

Foreign Minister Tariq Aziz admitted in to hide. One other "palace" covers an area

of Saddam's capabilities is the same. When data pertinent to a moving target Iraqi soldier stands guard outside the UN headquarters in Baghdad.

times larger than the Royal Family's

manses and grounds, or it has something

five years ago, Beck says, it has been

extremely difficult to determine what

WMD may still be stockpiled there, or

what may have been newly manufac-

tured post-1998. This uncertainty has

prompted highly divergent views on the

necessity of military action against

Since UNSCOM pulled out of Iraq

larger than the District of Columbia.



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It has been extremely difficult to determine what WMD may still be stockpiled in Iraq. This uncertainty has prompted highly divergent views on the necessity of military action against Baghdad. And it leaves individuals the world over unable to

process their own anxieties, or lack thereof.

Desert Fox, a December 1998 air camsprinkler system there! Electrical juncpinging, but it made Ricky jump. He generating an electrical field that we can paign that took out several industrial sites tion boxes there! This is really the center ran down the walkway, feet clanging measure, but for some reason we can't allegedly involved in the manufacture of on the metal, toward a computer workstaof everything!" Ricky continued down interact with it."

respond to our radio signals."

"You've tried?"

rt was a quiet alarm, just a soft, insistent it for almost two weeks," he said. "It's