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The Little Reactor That Could?

As the United States and other nations consider their next steps in nuclear energy, a new movement to support small modular reactors is coming to the forefront. But how are we to envision these technologies and their role in a post-Fukushima era?

A week before Halloween 2009, John R. Deal, an entrepreneur who goes almost exclusively by "Grizz," took the stage at the Denver Art Museum to deliver the headline talk at an evening seminar titled "The Truth About Nuclear Energy." Though slightly less bearded, barrel-chested, and commanding than his nickname suggests, Deal's style was exceedingly casual. A long-sleeved, amply pocketed khaki shirt included a shoulder patch with his company's logo, eliciting an association somewhere between park ranger and scoutmaster—both of which match his cheerful, disarming demeanor. Before launching into the benefits of his company's miniature nuclear reactor, he began with a joke.

"It turns out that most of the . . . mishaps [in nuclear plants] actually involve humans. So we were thinking today, what do we do to create a power plant control system to minimize that kind of impact? We came up with the following. The power plant of the future will have three control devices: a computer, a dog, and a guy. The computer runs the power plant because, as I said, most power plant mishaps happen because of human interaction. The dog keeps people away from the computer. And the guy is just there to feed the dog."

After lingering on the title slide a moment longer—"New. Clear. Energy." in yellow letters—he advanced the screen and gave his opening line, a message he would revisit throughout his talk. "It's more of a battery metaphor."

As the co-founder and president of Hyperion Power Generation, Deal was referring to his company's starring product, which he believes will represent a radical revolution for nuclear power. He has also described the Hyperion Power Module (HPM), which is only a few feet wide and not much taller, as the iPhone of nuclear power: a compact, technologically elegant device that will be a worldwide sensation for its portability, ease of use, and applications. These first moments of a normal overview presentation contain two of Hyperion's prominent talking points: a piece of imagery and a problem solved. HPMs are batteries that eliminate nuclear energy's obstacles related to human error and expertise. For the latter point, his Denver talk and many others refer to the goal of taking Homer Simpson out of the equation.

When Sonja Schmid and I set out to capture the story of small modular reactors, it quickly became clear that this technological coming-of-age tale is really, at least for now, a story about stories—the imagery industry leaders use to both envision their designs and communicate them to policymakers and the public. Behind the technical fact sheets, and in the years that remain before designs become physical machinery, small reactors are a movement of metaphors.

On many topics, imagery doesn't carry substantive weight. It is added for flavor, to simplify, clarify, or restate content in more vivid terms. But in the house of small nuclear reactors, metaphors seem to be weight-bearing walls. They also come in the context of a debate that couldn't have higher stakes. On one hand, our world must quickly scale up new sources of carbon-neutral energy. On the other, the nuclear accident in Fukushima, Japan, reminded us that our attempts to do so in the nuclear sector may result in unforeseen complications that can spiral into disasters. In today's proposals for a new nuclear approach, presentation matters. But how much does corporate imagery reveal about the technology itself and its implications, and how accurate are the pictures the industry paints?

Is small beautiful?

Overall, the emerging vision of small modular reactors is a major downshift from the custom-built giants of yesteryear to new railcar-ready, factory-manufactured, standardized machines with an electricity output in the range of 25 to 200 megawatts (MW), rather than the 1,000 or more MW that is typical in today's commercial reactors. A growing faction of promoters believes that these small reactors can provide solid answers to the myriad risks nuclear energy continues to face: safety, weapons proliferation, waste management, and initial capital cost. Each small reactor design offers a unique narrative of how it will remove or reduce these risks. Recurring themes include built-in capsule-like containment, passive cooling features, pledges for more effective disposal or recycling of waste, and a kind of inverse "economies of scale": advantages offered by small capital investment, standardization, and mass production.

Because none of these small designs has yet been licensed by the Nuclear Regulatory Commission (NRC), and all of them are still several years from market deployment in even the most optimistic scenarios, they make a convenient canvas on which to paint metaphors. In the case of radically advanced reactor designs and deployment strategies, both corporations and journalists readily put vivid colors to use. Others are cast in more muted, evolutionary tones: They are miniature versions of the world's tried-and-true light-water reactors, with substantially improved safety features. Leading revolutionary approaches in fuel, moderation, and cooling include reactors by Hyperion, Toshiba, and GE Hitachi, whereas efforts in favor of a more incremental design change include NuScale, Westinghouse, and Babcock & Wilcox.

All leading small reactors create a modular option, which allows them to be pieced together like LEGO blocks to build up a customized power supply. Customers could potentially receive their prepackaged mini-reactors anywhere in the world, as long as the site is accessible by boat, truck, or rail.

Judging by a rising emphasis on small modular reactors within President Obama's past two budget requests, not to mention Energy Secretary Steven Chu's outspoken affection for the technology, small reactors are increasingly being considered a highly exportable clean energy innovation and therefore prime candidates to implement the administration's "win the future" message.

Returning to Hyperion, the way they present their technology shows that subtlety is not a priority. In some sense, there is a space for this; the small reactor market is already revolutionary in that it allows room for entrepreneurs to join the nuclear energy ranks alongside giant, buttoned-up corporations. And some entrepreneurs have a habit of making big, bold claims—early and often.

Most recently, a February 2011 *Time* magazine article titled "Nuclear Batteries" prominently features the "tanned and enthusiastic" Grizz Deal. Curiously, the author of the piece uses the phrase "nuclear battery" throughout, not as a metaphor but as the default label for Hyperion's small reactor. Along the way, Deal outlines his goals for the HPM, a commercialized design that is based on work performed at Los Alamos National Laboratory. By the end of the article, he is quoted offering to "take care" of much of the world's nuclear fuel, precluding the need for new nations to pursue enrichment or reprocessing programs, because these countries will presumably rely entirely on leasing Hyperion's product.

The *Time* article is not an outlier. In dozens of trade and popular press articles, interviews, and blog posts, the character of Grizz and his imagery shine through. In November 2008, he was quoted in the *Guardian* on Hyperion's safety and nonproliferation features: "You could never have a Chernobyl-type event; there are no moving parts," said Deal. "You would need nation-state resources in order to enrich our uranium. Temperature-wise it's too hot to handle. It would be like stealing a barbecue with your bare hands."

Seeking out the origins of the venture helped us fill in some of the history behind the enthusiasm. It began with an initial shared motivation, which was recounted to us in an interview with Deborah Deal-Blackwell, Deal's sister and cofounder of Hyperion. "My brother and I—neither of us have kids," she said. "About five years ago, we started asking, what can we do to leave a legacy in the world? After some searching, we found that clean water was the answer."

Deal-Blackwell explained the leap from clean water to nuclear reactors. She and Deal had quickly found that providing clean water on large scales, such as through desalination, can be quite energy-intensive. So they began to explore options. After briefly looking into renewable energy sources, they decided on a nuclear solution to pursue their clean water mission. Deal had worked at Los Alamos as an entrepreneur in residence, and he knew of an advanced reactor design by the lab's Otis Peterson that he thought would be perfect to commercialize. The HPM concept was born.

Peterson's design was technically intriguing to say the least. It would use uranium hydride, a novel nuclear fuel with unique self-regulating features that control the core's temperature. But in 2009, foreseeing licensing delays with such a revolutionary approach, Hyperion decided on an entirely different design Los Alamos had produced: a uranium nitride–fueled fast reactor cooled by molten lead-bismuth. In other words, instead of forcing the NRC to create a new classification, Hyperion intends, for now, to fit its reactor within the somewhat more familiar, but still far from commercial, Generation IV category. Interestingly, the only previous application of a lead-bismuth cooled reactor was in the Alfa-class Soviet submarines developed in the 1960s.

The HPM is also revolutionary in its size and its approach to spent fuel. The smallest of the leading design proposals, each unit would produce 25 MW of electricity, enough to power 20,000 U.S. homes—or considerably more homes in any other nation. Also unique is the approach of providing a factory-sealed unit that would be removed completely for refueling and waste removal every 5 to 10 years, alleviating proliferation concerns related to sensitive material accumulated in spent fuel. This is a clear innovation that, if successful, would be a positive step forward from traditional practice. As a result, the approach offers an advantage over other small reactor designs, which do not seem to contain substantively new solutions for dealing with the on-site accumulation of spent fuel.

However, returning to the notion of human expertise reveals a clear weakness. Deal-Blackwell also told a version of the "feed the dog" joke during our interview, a repetition that implies that, in Hyperion's view, human expertise is best handled by sealing it inside an automated technology. Although concerns about human error are legitimate, neither the public nor government regulators are ready to accept that scenario. Emerging technologies such as Hyperion's call for a new and robust regulatory plan to determine what kind of human expertise is necessary for their safe operation, as well as how relevant knowledge can be created and maintained, transferred when appropriate (such as during export), and secured from illicit applications.

For three years, the "battery" metaphor has been the centerpiece of Hyperion's identity. Although some of this language seems to have been scrubbed from the company's Web site, former statements are easy to find on other sites devoted to the leading edge of nuclear technology. One example, from an early Hyperion Web page, began with the text "Hyperion is different. Think Big Battery . . ." and ended with, "Think battery, with the benefits of nuclear power. Think Hyperion." With this direct exhortation to nontechnical audiences on exactly how they should think about a small reactor, Hyperion is unmatched in its brazen communications. And as the *Time* article shows, the image has stuck.

The question is whether it fits. In one way, it does. The HPM is envisioned as a self-contained sealed unit, delivered and used until its fuel has depleted, then carefully returned to a proper facility. But the comparison doesn't hold much further than procedural similarities. A battery is a static device that converts stored chemical energy to electrical energy. It arguably does not belong in the same conversation as harnessing a nuclear chain reaction, the results of which include highly radioactive materials. Images on Hyperion's Web site of buried, unattended nuclear reactors would make sense if they were merely batteries, but they are not. For this reason, more than one of the nuclear energy experts we interviewed used the term "fantasy" in reference to such scenarios that deploy "walk-away-safe" nuclear reactors.

In the middle of Deal's talk in Denver, he began flipping through some artist-drawn images. The most striking of all shows a small nuclear reactor, buried and unattended at what looked to be less than 15 feet below the surface. Two simple tubes snake upward from the reactor, drawing the eye to a pair of gray above-ground tanks, with the words "Potable Water" stamped on the side. The setting? An impoverished African village complete with about a dozen mud-constructed, thatch-roofed huts. A handful of people were drawn into the image, all of them walking to or from the clean water source, which is apparently powered by a $50 million HPM.

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Although the humanitarian goals that launched Hyperion are admirable, this quaint portrait of a Third-world problem goes beyond vivid jokes, iPods, batteries, and barbecues to reveal a full savior narrative that casts Hyperion's small reactor as a solution to some of humanity's direst needs. And the message is reinforced again and again. A recent news article in South Carolina's *Aiken Standard* led with the following sentence: "Nuclear power is the only thing that can save the human race, Hyperion Power Generation CEO John 'Grizz' Deal told a crowd of more than 150 in Augusta on Wednesday."

A utopian narrative is not without precedent in the history of nuclear power. In fact, it harkens back to the early 1950s, when the American public first heard rumors that "atoms for peace" would soon yield "electricity too cheap to meter." Early in our search for the story of small reactors, we began to notice something familiar: The shift to small modular reactors has the nuclear industry playing out the plot of *The Little Engine That Could*, a slice of mid–20th-century Americana that became a hallmark of children's self-esteem building. Where the large have failed to try, or tried and failed, the Little Reactor will come along and prevail, pulling the heavy load of toys and goodies over the mountain. Or at least the Little Reactor thinks he can.

An emphasis on evolution

The Little Reactor character appears in many forms, most of which are far less colorful than Hyperion's version. We spoke to Bruce Landrey, chief marketing officer at NuScale Power, a small-reactor startup based in Corvallis, Oregon. Landrey has spent his career communicating information about nuclear reactors for various companies. The story of his experiences, at its end, harmonizes well with his current employer's approach.

When Landrey graduated from the University of Oregon in the mid-1970s, he didn't have a job, and he wasn't necessarily looking to go into the energy sector. But soon his father was paired on the golf course with a stranger from an electric company that happened to be seeking new communications talent for the rollout of a new nuclear power plant. Eighteen holes later, Landrey's father had positioned him, without his knowledge, as a prime candidate for the job. He applied, and was hired.

"I was thrown into the deep end," he said, remembering how little he knew about nuclear power. He also encountered an odd phenomenon related to public perception in his region. "We had a lot of protesters and demonstrations at the plant, people chaining themselves to the fence and so on," he remembers. "But it was ironic, because the protesters were the same people I was drinking beer with the previous year at the university. But here I was, on the other side of the issue."

Landrey decided that if he would be earning his living speaking in favor of nuclear power, he would use his first six months on the job to learn everything he possibly could about the technology and its implications. He did so, becoming immersed in the technical side of nuclear reactors enough to make him confident discussing them from an environmental and safety perspective.

"But what I was never comfortable with was the tremendous business risk a large nuclear power plant poses to an electric company, its customers, and its shareholders," he said. And over the next several years, he had a front-row seat to the downsides of this risk. "The company I worked for tried to build two additional nuclear plants, which became caught up in licensing delays. Then, after the Three Mile Island accident, they were finally just abandoned."

Three decades later, Landrey still finds himself speaking up for nuclear energy, but now for NuScale. He is as risk-averse as ever when it comes to the financial challenges presented by nuclear power. So is NuScale, and this perspective guides both its technical approach and its communications. As the company sees it, their strategy builds on proven market-ready technology, familiar to regulators and the community of existing experts. Compared to revolutionaries such as Hyperion, the essence of NuScale's metaphor is much less splashy: Our small reactor is really an improved version of the reactor down the road. It is a light-water de-

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sign, which means it uses normal water as its coolant, and it shares this feature, along with standard fuel rods, with the majority of active nuclear power reactors in the world.

Landrey explained some differences between NuScale and its larger predecessors, while also evoking a metaphor: a Thermos. Rather than a large concrete containment building, each reactor module comes inside its own steel vessel, which performs the containment's safety purposes while also forming a Thermos-like vacuum between the vessel and the reactor module. This enables the reactor's passive cooling feature, which uses natural circulation by a convection process, eliminating the need for a normal light-water reactor's mechanical equipment or backup power generation to cool the reactor. Of course, backup power generation was the key failure that set off the Fukushima disaster and is the Achilles heel of all existing nuclear power plants.

When we asked about Hyperion and other small reactor designs, Landrey was quick to draw a line in the sand between NuScale and a less traditional approach. "You have to be very careful with small modular reactors," he said, "to distinguish what goes in the near-term commercialization category and what continues to remain a concept in a laboratory someplace. There is a big gulf—it's really apples and oranges."

He also mentioned key differences on the topic of human expertise. Rather than automation, Landrey spoke of the importance of education and training in any context that will use NuScale reactors. The company's plans call for an expert staff to operate the facility. For example, the top image on the company's "Our Technology" Web page is an overhead view not of a reactor itself, but of the control room and user interfaces for plant operators.

For Landrey, the evolution-versus-revolution question is a central issue to explore when looking into small reactors: Which designs, or aspects of the design, grow out of widely used commercial power reactors, and which represent completely new attempts? The unstated perspective is that the evolutionaries represent realistic near-term solutions, whereas the revolutionaries are still far more futuristic than their promoters will admit.

Dusting off a design

Also quick to emphasize this gulf is Babcock & Wilcox, one of the world's preeminent suppliers of nuclear reactors. B&W is now partnering with engineering and construction giant Bechtel to develop and produce the "mPower," a compact new light-water reactor similar in many ways to the NuScale design. Last summer, Christofer Mowry, president of B&W, told the *Wall Street Journal*, "Bechtel doesn't get involved in science projects. This [agreement] is a confidence builder that the promise of this small reactor is going to materialize." Of course, as with Landrey's comment, such a quote cleverly forces the question into the reader's mouth: Which of today's small reactors should be dismissed as mere "science projects"?

Although the mPower is certainly an advanced project, its first draft has been around for quite a while; our interviewees spoke of their small-reactor effort beginning by "dusting off a technology from the early eighties." Compared to a conventional pressurized water reactor, the mPower reactor has the distinction of integrating the entire primary system (the reactor vessel, the steam generator, and the pressurizer) in one containment structure, which, according to one of the B&W engineers, "gives us a lot of inherent safety features that the large reactors don't have."

The tendency to look backward before moving forward arose not only from B&W's vast experience with light-water designs. First, it was a conscious response to its perception of the market. Many potential mPower customers are utilities that run today's fossil fuel plants (not exactly the most venturesome bunch), who will perhaps one day need to turn their turbines using a carbon-neutral technology. Hypothetically, a significant number of these utilities that would be priced out of a large reactor would, in fact, be interested in a more manageably sized, and priced, option. This thinking was the result of an executive saying flatly "show me a customer" when the company's technical leaders approached him with their idea about a small-sized, budget reactor. But a related and perhaps greater motivation for B&W's design conservatism is the current regulatory gatekeeper.

"The Nuclear Regulatory Commission... is a light water reactor regulatory agency," one of our B&W interviewees said. "It takes a very long time to come up with a regulatory framework to be able to license another type of technology, and we wanted to get the technology to market as quickly as we could."

Another interjected, "The idea was to come up with a design that capitalizes on the tremendous knowledge base that surrounds light water reactors, and then make some evolutionary changes. But when you get into revolutionary changes, the market isn't looking for that right now."

The design includes a plan to bury the mPower underground. Although this feature is widely shared across the small-reactor industry, B&W offered an interesting reason when we asked why. They first referred to aesthetics; their initial rationale had been to avoid the stigma associated with the physical appearance of a nuclear power plant. The typical cooling towers and containment structures have acquired almost emblematic status among opponents of nuclear energy. Only after having volunteered these reasons did they add that the underground placement also earned them safety advantages with regard to earthquakes and missile impact.

Like Mowry's reference to "science projects," B&W's presentation is subtle but quick to make use of the public's associations. Rather than taking a direct approach to force positive associations through imagery, B&W and others find the negative associations we already hold, and offer just the opposite. As they do so, the message comes back to their historical credentials, familiar technology, and the inclusion of credible players such as Bechtel. And the continuity of mPower's design sends its loudest message to the regulatory community: This is a well-known, mastered technology, but upgraded to add significant improvements.

The appeal to history

Our foray into the light-water approaches coalesced in one question: Does inertia trump innovation in the U.S. nuclear industry? It would seem so, at least judging by NuScale's and B&W's carefully chosen paths. To some extent, even Hyperion's shift in reactor fuel for its initial small reactor sends a similar signal. A familiar picture emerges, where the very entities that serve as the guarantor of safety also represent an obstacle to new, potentially better ideas. Perhaps unintentionally, they provide incentives for companies to continue down the well-trodden path, in exchange for faster licensing approval and shorter time to market.

In terms of accounting for human expertise, evolutionary approaches do have a marked advantage. They do not seek a technical fix that eliminates the operator's crucial role and ignores organizational and educational structures. On the downside, however, slow incremental innovations tend to neglect nuclear energy's historical problems. The known hurdles with traditional light-water reactors, including low efficiency and unresolved waste management concerns, will arguably continue to live on for another generation, and if their industrial promoters get their way, these problems will be mass-produced and widely exported.

Other potentially valuable lessons from history are also ignored; for example, why there is so little commercial experience with small nuclear reactors. In the past, small reactors have been used in research settings, for naval propulsion, and, rarely, to power research or industrial facilities at remote locations. But until recently, most small reactors for research and on submarines and icebreakers operated on highly enriched uranium, material that in sufficient quantities could be used to produce a nuclear weapon. When converted to fuel with lower enrichment, these reactors require more frequent refueling. Furthermore, the United States abandoned small reactors altogether in the 1970s to take advantage of the anticipated economies of scale to be achieved with larger power reactors. As the story has gone, in many cases the word "economy" hasn't proven to apply.

In the 1970s and 1980s, the U.S. nuclear industry was embroiled in a debate over the safety of scaling up. Would substantially increasing the size of nuclear reactors allow extrapolation from existing safety protocols, or would it in fact produce qualitatively new problems? Similar questions should be asked in today's opposite scenario. It is far from self-evident that a compressed scale automatically produces smaller risks or that the data gathered from similarly fueled and cooled large reactors transfers down.

And if the evolutionary approach does lower the risk of a given small modular reactor, who can say whether reduced risks in individual power plants are outweighed by an overall global risk of dispersing a much greater number of nuclear reactors across the planet? The Fukushima disaster has inconveniently shown a problem inherent to installing multiple reactors at one plant. After a scenario of unique failures within several reactors at once, is the prospect of a dozen or more interrelated small modular reactors on one site still as attractive?

An overarching question is whether any of these risks are significantly curbed by an approach that offers familiarity, or whether this would encourage complacency. Pyotr Neporozhni, who served as the Soviet minister of energy and electrification for three decades, is reported to have dismissed concerns about nuclear safety with the quip: "A nuclear reactor is just another boiler." Neporozhni retired in

1985, one year before Chernobyl. Although it is true that the end task is to boil water, it would be a mistake to ignore the intricate, wholly new ways in which small modular reactors will attempt to go about that task, even if widely known materials are used. A small design is not "just another light water-reactor."

Even if, as one B&W representative said, the NRC has traditionally been a "light-water–reactor agency," its leadership does not seem to be glossing over the novel questions small modular reactors are raising. During a summer 2010 keynote address at a conference devoted to small reactors, William Ostendorff, a current member of the NRC, indicated that the question is open regarding how much history counts toward confidence about new small reactors.

"There are substantial differences between the proposed concepts for SMRs [small modular reactors] and the large, light-water reactors that the NRC's regulations were based upon," he said. "How will prototype reactors be licensed? How will risk insights be used? How do SMRs fit into the Price-Anderson nuclear liability framework? Questions like these are not easy ones to answer."

Mixing metaphors

During her dissertation research on the Soviet nuclear industry, Schmid spent a year in Moscow, mostly penned inside musty archival reading rooms. But with a single tape recorder and without a quiet office at her disposal, she also set out to preserve a primary resource that was, and is, dying out. Former dons of the Soviet-era nuclear power program spoke with her on trains and buses, in homes and coffee shops, and over sometimes-obligatory shots of vodka. One of these interviews yielded an image that stuck with her, a counterweight to the simplifying metaphors we had encountered.

Like her other interviewees, "Yuri" had been eager to speak to Schmid, but visibly relieved when she offered not to use his real name. For an elderly Russian nuclear engineer whose Cold War career had comprised stints in both military and civilian reactors, secrecy fell somewhere between a reflex and a superstition.

After two terse hours with her microphone on a desk between them, they shared a cigarette break. They stood in a stairwell, holding cigarettes over the public ashtray, a large metal trash bin painted, rather sternly, the same gray as the walls. Then, in two sentences separated by a narrow downward stream of smoke, Yuri abandoned his technical talking points.

"The reactors are like children; each one is different," he said, as if suddenly remembering something he had forgotten, the central point. "You come to know their peculiarities by spending time with them; you begin to feel how each reactor breathes."

The large traditional reactors he had operated during his career were supposedly identical in design, but as he said, their personalities were quite distinct, as if there was something immeasurably complex happening beyond the components of these machines, something relational.

Historically, nuclear energy has been entangled in one of the most polarizing debates in this country. Promoters and adversaries of nuclear power alike have accused the other side of oversimplification and exaggeration. For today's industry, reassuring a wary public and nervous government regulators that small reactors are completely safe might not be the most promising strategy. People may not remember much history, but they usually do remember who let them down before. It would make more sense to admit that nuclear power is an inherently risky technology, with enormous benefits that might justify taking these risks. So instead of framing small reactors as qualitatively different and "passively safe," why not address the risks involved head-on? This would require that the industry not only invite the public to ask questions, but also that they respond, even—or perhaps especially—when these questions cross preestablished boundaries. Relevant historical experience with small compact reactors in military submarines, for example, should not be off limits, just because information about them has traditionally been classified.

The examples we discussed show that metaphors always simplify the complex technical calculations underlying nuclear technologies. Vivid illustrations often obscure as much as they clarify. Small reactors are not yet a reality, and the images chosen to represent them are often more advertisement than explanation. What information do we need to navigate among the images we are presented with?

Clearly, some comparisons are based more on wishful thinking than on experience. A retrievable underground battery and a relationship with a child, for example, invoke quite different degrees of complexity. Carefully scrutinized, the selection of metaphors often reveals the values that go into the design of these new reactors: why one approach is safer than another, which level of risk is acceptable, and whom we should trust.

Ultimately, the images offered by our interviewees are based on projections. Although it may make intuitive sense that smaller plants will be easier to manage, nuclear power involves non-nuclear, and even nontechnical, complexities that will not disappear with smaller size, increased automation, or factory-assembled nuclear components. For instance, nuclear reactors, and by extension nuclear power plants, need reliable organizations to train experts, provide everyday operation and maintenance, address problems competently when they arise, and interact effectively with the public in case of an emergency. This is not a trivial list even for high-tech nations like the United States, and it presents an even larger challenge for prospective importers of small modular reactors, particularly the developing countries with no domestic nuclear infrastructure that are clearly a major target of Hyperion's efforts.

The same goes for the projected cost of small reactors. If there are any numbers publicized at this point at all, they tend to increase monthly, not least because of the recent events in Japan. The nuclear industry may need to rethink nuclear safety issues, revisiting problems it had considered long resolved. Small modular reactors do not offer easy solutions to multiple point failure. In fact, the modular arrangement of multiple cores at one site might increase this particular risk. These questions remain, regardless of whether a new reactor follows an evolutionary or a revolutionary track.

Whether the "nuclear battery" or the "just another light-water reactor" message appeals to us, we would be well advised to keep in mind the connotations of familiarity and controllability they offer in the face of unpredictable novelty. That should make us suspicious. Is what we are being sold as advantageous in fact the biggest vulnerability of these small designs? Easy transportability may look less like an asset when considered from the standpoint of proliferation. Multiple small cores might not necessarily turn out to be safer than one large one. We may remember that taking apart a machine, looking inside, and trying to figure out what is wrong ourselves can be more appealing than a machine that, like an iPod, needs to be shipped back to the factory for repair. Distributed generation sounds like a good idea when we talk about solar roof panels, but may not be as attractive when it requires highly trained expertise and accumulates radioactive waste.

We don't know all the answers yet, but we should avoid being drawn in too quickly by these metaphors, even those that are more muted than Hyperion's. Yuri's realization that reactors are like children, an image based on profound experience and devoid of any marketing bias, presents a different and competing picture. Rather than simplifying, Yuri's image goes in the opposite direction. Thinking of small reactors as more like children offers a lesson in humility in the face of complexities, both technical and nontechnical. Reactors, like children, may come with their own complicated personality; they can be quite unpredictable, but they also hold the promise of a better future.

Today's small-reactor narrative isn't a children's story but an immensely complex novel, rife with layers of context, relationships, and flawed characters. But even children's literature can temper itself against its own oversimplifications, as we are urging the nuclear industry to do. In 1974, Shel Silverstein published his reaction to *The Little Engine That Could*, flipping the empowerment narrative to a cautionary tale. The last stanza of his poem "The Little Blue Engine" warns against allowing confidence and optimism to become hubris:

> He was almost there, when — CRASH! SMASH! BASH!
> He slid down and mashed into engine hash
> On the rocks below . . . which goes to show
> If the track is tough and the hill is rough,
> THINKING you can just ain't enough!

For the small-reactor movement to truly come of age, the metaphors we use to describe it must also mature. Convenient images, save-the-day narratives, and a we-think-we-can reliance on a purely technical fix must be balanced by a broader examination of a full range of metaphors, the complexities they capture or ignore, and the social, political, and organizational contexts in which these machines will ultimately be used.

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