

One Day

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High performance computing (HPC) affects the lives of Canadians every day. We can best explain this by telling you a simple story. It's about an ordinary family on an ordinary day: Russ, Susan, and Ceri Sheppard. They live on a farm 15 kilometres outside Wyoming, Ontario. The land first produced oil, and now it yields milk; and that's just fine locally.

Their day - Thursday, May 29, 2003 - begins at 4:30 a.m. when the alarm goes off. A busy day. Susan Zhong-Sheppard will fly to Toronto to see her father, Wu Zhong, at Toronto General Hospital; he's very sick from a stroke. She takes a quick shower and packs a day bag for her 6 a.m. flight from Sarnia's Chris Hadfield Airport. Russ Sheppard will stay home at their dairy farm, but his day always starts early. Their young daughter Ceri can sleep three more hours until school.

Waiting, Russ looks outside and thinks, *It's been a dryish spring. Where's the rain?*

In their farmhouse kitchen on a family-sized table sits a PC with a high-speed Internet line. He logs on and finds the Farmer Daily site. He then chooses the Environment Canada link, clicks on Ontario, and scans down for Sarnia-Lambton. Good, as he hoped:

Periods of morning rain. Risk of a thunderstorm.

Wind south 30 km/h gusting to 50 diminishing to 20 in the afternoon. Sunny periods. High 14

One of a million who check that site every week, Russ uses HPC, although he doesn't know he does. Two decades ago, Russ found Environment Canada reliable only two days ahead. Now, the forecasting works pretty well for a week.

Russ thinks, *They've got some smart people at our Meteorological Service.*

But Russ worries. The farming Sheppards go back four generations to the thirties, times of hunger in the evening. A picture in the hall landing reminds him of 'those days'.

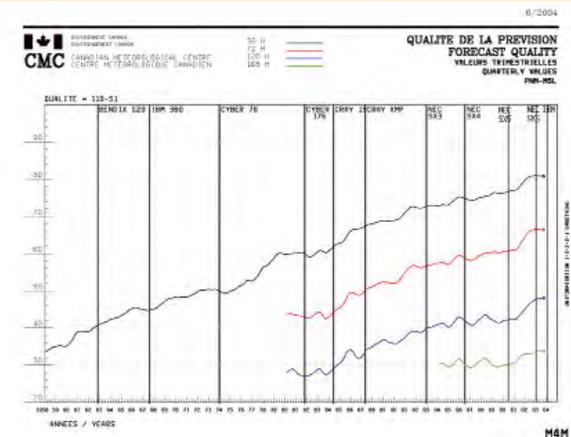
He sits a while, staring at the screen. Ten days ago Russ felt his world shake. BSE, bovine spongiform encephalopathy, appeared in one cow in Wanham, Alberta, and now seven countries have banned our beef. Russ gets tired thinking about this because he can do nothing about it.

What would he and Susan do if their cows had to be destroyed? And now there's her father, and he can't burden her with what he thinks.

Russ calls up www.google.ca and enters "bse alberta". The news describes the slaughter of a thousand suspect Alberta livestock. But an article from last March details BSE testing in the Animal Health

Weather Prediction

The accuracy of a five-day forecast in the year 2003 was equivalent to that of a 36-hour forecast in 1963 [REF 1]. The quality of daily forecasts has risen sharply by roughly one day per decade of research and advances in HPC hardware and software. Accurate forecasts transform into billions of dollars saved annually in agriculture and in natural disaster costs. Using a model developed by Dr. Keith Thompson at Dalhousie University, the Meteorological Service of Canada has recently been able to predict coastal flooding in Atlantic Canada early enough for the residents to take preventative action.

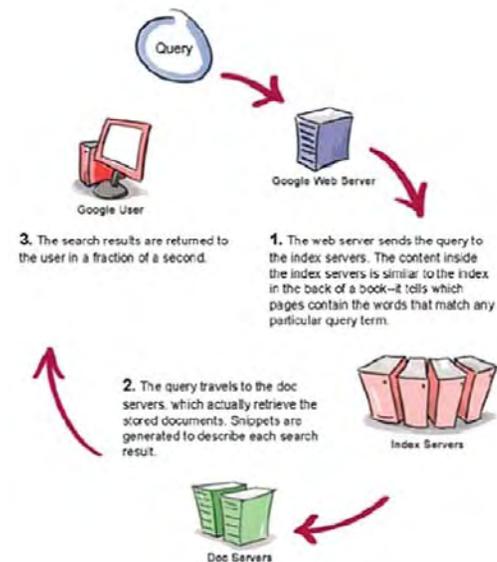


The figure charts the steadily increasing quality of weather prediction

Web Searching

Google [REF 2] is powered by over 30,000 PCs performing smart computer mathematics, and has three distinct HPC components which allow it to find and organize news, science and much else:

- Googlebot, a web crawler that finds and fetches web pages.
 - An indexer that sorts every word on every found web page in a huge database.
 - A query processor, which compares your search query to the index and extracts relevant documents.
- Twenty-four hours a day, Google typically responds to a query in less than a second - thanks to HPC.



Laboratory at the University of Guelph: no positives at all in 2002. A few tissue samples from dead animals went to a Canadian Food Inspection Agency lab in Winnipeg. He locates the CFIA site and its news release from yesterday. They're taking samples for BSE testing now in Saskatchewan, and a CFIA lab in Lethbridge is doing DNA analysis to trace that infected cow. These biohazard researchers rely on HPC, just as Russ unknowingly does in using Google.

Russ says to himself, *Ok, things are happening!* and then he calls out, "Susan, ready to go?" Russ clicks the programmable keyless entry system for his new SUV.

The drive to Sarnia's Chris Hadfield airport takes twenty minutes, and an EDR (event data recorder) in the driver's airbag tracks their SUV velocity, engine speed, and the status of their brakes. Russ taps the car's electronic compass. Susan gets out her cell phone to check departure time. After his "Give my best to Dad," a peck, a hug, and her "Pick me up at one, and don't let Ceri sleep in again!", Susan is out of the car and through the gates.

Belting herself into the 18-seater Air Georgian Beech 1900H, she thinks, *Oh my. The life of an only child, wife, and mother!* Outside the window, it's raining. Susan peers up at the air traffic control tower as the plane taxis out. She crosses her fingers. Since rising, she and Russ, in their rural world, have used three massive HPC-based systems.

Now she places her life in the tender mercies of another. The same company that built the Beech 1900H airplane, Raytheon, also made CAATS, the Canadian Automated Air Traffic System headquartered in Moncton. None of Susan's fellow passengers knows that NavCanada's flight data processing system ranks as the world's best. If anyone told them, most wouldn't be surprised.

A Canadian-made prop engine lifts Susan 20,000 feet into the sky. This Pratt & Whitney PT6A engine has been in continuous demand and development for over forty years. If you've been in an Otis elevator, you've been lifted up by yet another Pratt & Whitney product. The approach of Susan's flight to Toronto's Pearson Airport takes her over the offices of the HPC company that helps keep her airborne.

CATS brings Susan down safely into what her friends are grimly calling "plague city" these days. Born in oil-rich Calgary, Susan heard Dad grumble about eastern Canada in the 1970s, but now he's an Easterner and she thinks, *Life's like that, isn't it? It takes you to strange places.* Like Russ, she worries, although not about an Alberta cow but about a new virus from China that rode the skies into Pearson Airport two months ago. Wu Zhong's an innocent in the thick of SARS (Sudden Acute Respiratory Syndrome). Last Monday, the World Health Organization listed Toronto as a city that had recently transmitted SARS locally, a blow to a big town already reeling in isolation.

Susan comes anyway. She has to talk to the doctor.

The plane taxis up to Terminal 2, and Susan walks down the stairs and across the tarmac in the rain. The (area code) 905ers were already heading *en masse* into downtown using the two huge highways, 401 and 427, that border on Pearson. The late spring pollution billows past, and Susan's throat catches. Asthmatic since childhood, she takes out her inhaler. The first puff of the day and her watch says barely 6:55.

Things look worse when Susan sits down at a Tim Horton's on the Terminal 2 Departures level. She buys a rimless coffee and looks at the morning's papers abandoned at her table. Yesterday, Toronto placed 1700 students and staff at Markham's Father Michael McGivney Catholic Academy in home quarantine until June 3, because just one student with SARS symptoms attended school last week. His mother works at North York General Hospital, one of the affected hospitals. Worse, the papers describe how Chinese Canadians, labelled as SARS carriers, along with their businesses and their children have been suffering from racism, boycotting and shunning. "This is ridiculous. What am I doing here?" Susan says to herself. And from the next table comes a voice, "Just what I was wondering, dear. . . . No one wants a person *like you* deplaning from SARS headquarters today, do they?" Susan answers, "What do you mean by that? I'm from Sarnia, not Toronto or China!" But the voice per-

sists, "Oh, are you? . . . Well, if I were you, dear, I'd watch my step today."

With as much dignity as she can muster, Susan gets up and hurries down the terminal concourse, looking for the city buses bound downtown. *Right enough*, she thinks, *where are the frequent fliers today?* A few persons with rigid expressions walk briskly by, pointedly keeping their distance from her. Outside the automatic doors, a Toronto Transit bus waits. Susan gets on, pays, and goes right to the back.

Sometimes, as at 7:25 a.m., when Susan's bus joins the 427 southwards highway, Toronto roads flow like refrigerated peanut butter. At other times, they are speedways. Drivers generally know what to expect according to when they drive, and that predictability, a function of Toronto's regulated traffic system, calms them. In mid-July of 1999, when a switchboard panel exploded at a Bell Canada building, traffic lights at 550 Toronto intersections failed. . . . This was a hint of what lays in store for this town on August 14, 2003, when all power will cease on the eastern seaboard. But this morning everything's OK; an HPC system, fed with information from magnetic sensors and fibre optic cables, controls the city's traffic lights.

Susan watches the city go by as the bus turns east onto the Gardiner Expressway and exits at Bay Street. A big yellow billboard with a large arrow pointing upward, advertising the Weather

Designing An Airplane

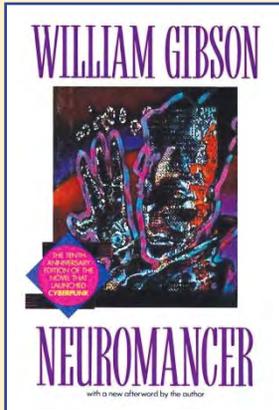
After Pratt & Whitney added HPC to its tools - a single computer grid governing 15,000 computers in North America - its products were engineered in half the time and cost. Platform Computing, the HPC firm that Pratt & Whitney hired, has its headquarters in Markham and offices in 15 cities from Boston to Beijing. Computational fluid dynamics research predicts how the Pratt & Whitney gas turbine engine burns fuel and so allows improvements in its engineering. [REF 3]



"Wingmating" - wing making in the Bombardier CRJ900

Canada's leading science fiction writer, William Gibson, coined the word "cyberspace" in his novel "Neuromancer" which won the Hugo, Nebula, and Philip K. Dick awards in 1984–85. "Unthinkable complexity. Lines of light ranged in the nonspace of the mind, clusters and constellations of data. Like city light . . ."

[REF 4]



William Reeves, Technical Director of Pixar Animation Studios, studied in Waterloo and Toronto, getting a B.S. in math and an M.A. and a Ph.D. in computer science. In 1980, he joined Lucasfilm and invented an image-synthesis technique called Particle Systems. It generates complex and detailed images through many (normally) simple geometric particles changing stochastically over time. After working on films like *The Empire Strikes Back*, Reeves and two partners created Pixar. Today his technique, taught everywhere in film courses, powers many of Pixar's groundbreaking animated films. As supervising Technical Director on *Toy Story*, the first feature film created entirely by computer animation, Reeves won four technical Academy Awards. Another Canadian, Darwyn Peachey (BSc and MSc from Saskatchewan), has played a key technical role with Pixar, receiving a technical Oscar in 1995 for his part in the development of *RenderMan*.

Patrick Coleman and Karan Singh, from the Dynamic Graphics Project, the University of Toronto research group of which Reeves is an alumnus, developed nonlinear projection software for Chris Landreth's "Ryan", which received the Academy Award for Best Animated Short film of 2004. The Canada Council for the Arts participated in the development of "Ryan". [REF 5]



Ryan, a victim of drug addiction and alcoholism, experiences states of mind that affect his perception of the space around him. Computer animation software normally uses the rules of linear perspective, but to show how characters like Ryan see their world, those rules had to be modified. The nonlinear projection system used to create Ryan allows animators to combine multiple points of view in various ways to achieve effects that distort linear perspective.

Pixlet (Pitxar + wavelet) is the first studio-grade algorithm for filmmakers. Pixlet provides 20-25:1 compression, allowing a 75 Megabytes/sec series of frames to be delivered in a 3 Megabytes/sec movie, similar to DV Data.

Network, has the caption, "(We told you so.)" It was right again. A wet bus pulls up to the Royal York Hotel. "Good for the farmers," the bus driver observes evenly, as Susan gets off. She enters the hotel and quickly steps downstairs to the underground walkway. It's 8 a.m. and 75 minutes until she meets with her father's doctor. Susan wants a gift for Ceri, so she'll browse in what Toronto says is the world's biggest subterranean complex, 27 kilometres of halls with a thousand shops. At an early-opening CD shop in the underground city she picks out *Finding Nemo* because Ceri liked *Toy Story*, another Pixar animation. Didn't a Canadian win an Oscar for that? Susan doesn't remember Bill Reeves' name and has no idea that Pixar uses eight super-computing clusters and sixty terabytes of disk space, called a "RenderFarm", to make entertainment for folks on farms like hers. There's no reason she should remember. If digital processors were pixels on a North American screen, Toronto's underground city and the Bay Street markets above it would shine out like a beacon. But like most Canadians, Susan never sees the cyberspace world all around her.

At 9 a.m. Susan exits the underground at City Hall, turns west to University Avenue, and finds that Toronto General Hospital is in sight. In ten minutes, she's at the Peter Munk Cardiac Centre's entrance on Gerrard Street.

She meets a sign: "Patients Infectious Disease Screening." "Two gowned and masked nurses block

Susan's way. They give her a mask, squirt some anti-bacterial soap on her hands, and tell her to rub them well. Susan is still outside the door. Then one nurse asks, "Who are you and why are you here?" "I'm Susan Zhong-Sheppard from Wyoming near Sarnia, and I've an appointment with Dr. Christopher Andres in Neurosurgery about my father, Wu Zhong. He's a patient here." The nurse firmly says, "Didn't you read this sign? We have an emergency situation here! You can't visit your father. Don't you know about SARS?" "I'd hoped . . ." Susan says weakly. The other nurse consults an appointment sheet and says, "You're not listed here. Well, take a seat over there and we'll see."

Susan joins some silent, masked people seated just inside the door. Orderlies send most away. Forty-five minutes pass. Her return flight is scheduled to leave at noon, and she frets. At 10 a.m. a nurse tells her to come down the hall. She sits next to a computer and another gowned, masked nurse kindly asks, "Do you have a cough, fever, headache, muscle pains, or shortness of breath?" At this, Susan's asthma acts up, and the nurse becomes quieter. "No? Please, Mrs. Zhong-Sheppard, step into this room so that we can examine you." Researchers further east on highway 401, at Queen's University, use HPC to simulate how inhalers work so that people like Susan will get more effective relief. She could use that relief today.

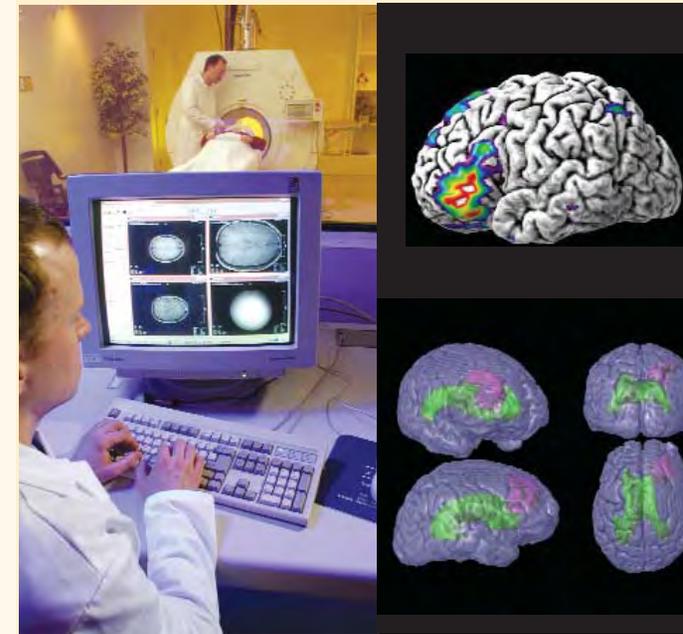
Susan shows the intern her inhaler. He takes her temperature and asks more questions. Twenty minutes later, a shaken Susan is sent out. The nurse at the computer workstation says, "I'm sorry, but this is the new normal. We've checked and Dr. Andres will see you now. Take this sheet and get everyone you meet to sign it. When you leave, hand in the sheet. Do you understand?"

Susan makes her way to a fourth-floor waiting room in the west wing. A quiet masked nurse signs her sheet. Ten minutes later, the nurse accompanies her to a small consulting room. Dr. Andres walks in, masked. "I'm sorry you find us this way, Susan, but I'm glad you came. Did you make an appointment?" Susan says, "Yes I did, really." "Well, all that matters is you're here now. Your father is stable, but he still can't talk. Susan, I need you to let us create dynamic pictures of his left hemisphere. They're called functional magnetic resonance images. We're well set up to analyze them . . . have you heard of our Functional Imaging Research Network?"

"Dr. Miner sent my father here. Please, Dr. Andres, whatever's best for Dad." "Susan, we work with the Heart and Stroke Foundation and the Universities of Ottawa and Toronto, and we can design a good therapeutic strategy for Mr. Zhong." Susan doesn't know what to say. She wants to take her father home *now*.

Medical Imaging

Modern HPC imaging techniques (such as PET using 'positrons' and SPECT using 'photons') provide non-invasive two- and three-dimensional real-time dynamic images for the brain, heart, kidney and other organs. They are revolutionizing research, surgery and disease management. A one-minute three-dimensional reconstruction requires enormous computing power to generate these images. [REF 6]



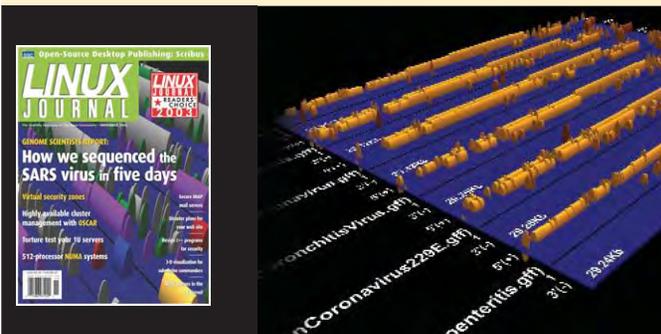
Sequencing SARS

"The rapid dissemination of the SARS genomic sequence through the Internet allowed groups all around the world to participate in the computational analysis of the genome and the 3D modeling of the protein sequences, ultimately resulting in an unprecedented number of scientific publications and vaccine initiatives just over one year after the discovery of this emerging disease. Such initiatives have typically taken many years."

Dr. Steven Jones

Head, Bioinformatics

Genome Sciences Centre, BC



The image shows a genomic (BLASTX) analysis of the protein complement of the *Nidovirales* family against build 7.4 of the SARS-suspected virus sequenced at Canada's Michael Smith Genome Sciences Centre. [REF 7]

He understands. "We can't move patients around these days. We're under siege here. I'll let you know soon, ok? But I've really got to go now, Susan. Are you all right?" She reaches for her inhaler but she nods. "Good. I'll call you next week, ok? I'm sorry . . . I am out of time!" Dr. Andres signs Susan's sheet and leaves her there.

When Susan reaches the Gerrard Street exit, it is 11:20 a.m. A masked orderly squirts disinfecting soap on her hands, tells her to put her mask in the bin, and takes her sheet. It has two signatures. Then she is escorted out the door. She pauses . . . a moment. Her face is wet, and not with rain.

She can't understand why no one knew of her appointment (aren't there computers?), why they all looked at her that way (I'm just from Sarnia, aren't I?), and why she had to wait so long. That morning, HPC and cyberspace failed Susan. But they were going to help her father. She believes that now, and she thinks, *Dad's going to get better.*

Susan uses her cell phone to call Air Canada. It forgives her the missed flight, but has cancelled all later flights to Sarnia. The new normal sinks in. She walks south under a clearing sky down University Avenue to Union Station. The only VIA train leaves at 5:40 p.m. and arrives in Sarnia at 9:40 that evening. Susan withdraws some cash from one of her bank's 4400 ATMs, buys her VIA ticket, and calls Russ on her cell.

Susan's and Russ' voices are converted to pulses and then transmitted, thanks to a hidden HPC infrastructure, 160 miles in less than a heartbeat. "I'll be at the Green Street station to meet you," Russ says. She's unknowingly hitched a ride on a global HPC-powered bank network to buy her way home. Not even the new normal of SARS prevents the bank from recognizing Susan Zhong-Sheppard, even without an appointment.

Six weeks earlier, on April 12, the DNA sequence for the new SARS coronavirus had been published by the Genome Sciences Centre working with the British Columbia Centre for Disease Control and the National Microbiology Laboratory in Winnipeg. Two days before that, scientists at the Hospital for Sick Children in Toronto published the completely sequenced human chromosome 7, including landmarks for diseases like cystic fibrosis, leukemia, and autism. Both projects heavily used HPC resources.

Outside in downtown Toronto, on the afternoon of May 29, no one wears masks, and Torontonians go pretty much where they want to. Many carry day bags like Susan's. She visits a big bookstore and wanders through the Eaton Centre. No one asks her what her business is. No one looks at her bag with interest. This is Canada, and today is the International Day of United Nations Peacekeepers. Yet electronically, whenever Susan steps into cyberspace to do banking or charge purchases, her avatar grows, date-stamped with events. Two hundred

years from today, archivists will know she visited Toronto, bought a CD in the underground city, saw Dr. Andres, made a phone call home, and bought a VIA rail ticket. They will also know she stops at an Internet café at 3:45 p.m. and writes Ceri:

I can't be home tonight to tuck you in bed Ceri but tomorrow I've got something for you ok so DO do your homework tonight oh are you getting along at school all right? hugs and kisses xxx mom

Twenty minutes later Ceri checks her email and picks up the note. Digitally at least, the "Susan" avatar might be, well, anyone because anyone can send e-mail that appears to be from her address. So yes, maybe an HPC security system is listening in, although why bother listening to unencrypted, non-image texts such as Ceri receives? Canadian firms like Entrust in Ottawa and Certicom in Waterloo sell encryption tools that are now fundamental to secure bank transactions and much else.

Ceri arrives home from school by bus at 4:15 p.m. Her health teacher asked her to explain to class tomorrow why her father doesn't let her drink raw milk from the cows. So Ceri asks her father. Russ explains that until milk is pasteurized, or quickly heated and cooled, it can be contaminated by bacteria from the milking. They send their milk to a plant to be pasteurized. Ceri asks, "What bacteria?" and Russ says, "It's called *E. Coli*. Check out the stack of *Scientific American* magazines or look online."

Ceri sits down at the big kitchen table and searches the Web for mentions of *E. Coli*. At a University of Alberta website, she finds Project CyberCell, which simulates an *E. Coli* bacterium as a virtual cell. By using HPC to discover how proteins interact in a virtual cell, scientists can help biopharmaceutical companies tailor-make drugs for individual patients.

Ceri calls out, "Dad, they look like hot dogs!" Ceri stares at the HPC-simulated cells, twisting in their strange world. In ten minutes, she learns that real *E. Coli* cells live in her own intestines.

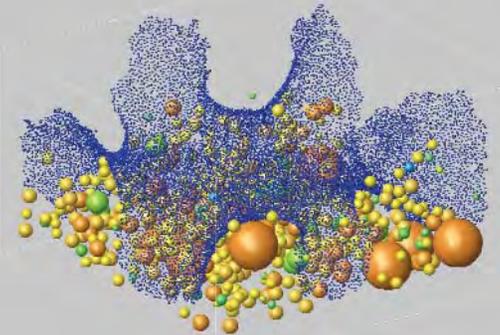
She calls out, "Dad, why can't I drink our milk if we already got *E. Coli* in us?" Russ patiently answers. "Ceri, it's a mutation of the normal bacteria that's bad. Search some more." And so she finds a *Nature* website image of *E. coli* 0157:H7 and its sinister flagella, and descriptions of bloody diarrhea and kidney failure. She gets up, glad that she doesn't drink raw milk.

Once on the train, Susan falls asleep, to dream of windswept springtime grasslands that make no one with asthma sick, of fields where cheering faces a lot like Ceri's throw their inhalers up into the antigen-rich Canadian rain.

When Susan steps off the train in Sarnia, Russ is there, smiling. Outside the station, they look up at a new moon and a shockingly starry sky. High in the south is Mars, bright and orange-coloured. She

Project Cybercell

Project Cybercell [REF 8] aims to model "the structures of almost all of the 4,000 *E. coli* proteins and then to simulate their interactions and functions in a computer," says Dr. Michael James, a member of the research team. James says once the *E. coli* proteins are "defined" and stored digitally, researchers can virtually interact with their digital versions and see how they would interact with antibiotic molecules. CyberCell, a huge cross-country project, will "take a long time to achieve - perhaps 20 years - but with more HPC resources this time could be significantly reduced."



Simulation of the dynamic interplay between a cell's interior and its environment through the plasma membrane.

OECD/OCDE

In Paris on January 30, 2004, 34 governments (including Canada, China, the European Community, the Russian Federation, and the United States) from the Organisation for Economic Co-operation and Development (OECD) agreed to establish ways to give the public open access to all publicly-funded digital research. [REF 9]



wondered if Chris Hadfield, who lent his name to the airport where Susan took off 16 hours before, was looking up too. He grew up in Sarnia and was the first Canadian ever to float freely in space. He also served on the crew of the Space Shuttle Endeavour that two years ago installed the Canadarm 2. Susan says to Russ, “Will we ever see families like ours on Mars, do you think? Will Ceri’s children?”

And will there be cows on Mars too? Looking up, Russ wonders, *Are we the only part of this universe that is conscious of itself?* “Well, love, if they can

simulate the first minutes of the life of the universe, getting to Mars can’t be so hard, can it?”

Quietly, Russ and Susan drive home together. They find Ceri still up and waiting at her window, singing to herself:

“Star light, star bright,
First star I see tonight,
I wish I may, I wish I might,
Have the wish I wish tonight.”
. . . and what *was* Ceri’s wish that night?

Susan and Russ know, but only much later, long after a biographer has combed through their family papers, will others know . . . others like a mother younger than Susan, and a daughter taller than Ceri, who both will one day ask that same question.

“Selay,” says the mother yet unborn to her ten-year-old, “have you found her yet? Your homework’s due tomorrow, isn’t it?”

“The Library’s looking, Mom,” the girl answers, standing before a hovering plasma image. Her teacher had given her a strange question to answer: “What made a famous 21st-century woman from Ontario named Ceri Zhong-Sheppard want to become a scientist?” Selay turns to her constant friend, the online Library.

It shows her Ceri’s bio, a few pictures, and then a record from the online science archive. The screen dissolves into

2020.05.06:12:06 K.Z-S@IntSpaceStation2 to zhong-sheppard@sympatico.ca

Dad! . . . you can see our satellite in the NW sky about 23.30 your time. We’re in space monitoring Pacific carbon uptake and phytoplankton distribution now that the deep-ocean ‘mote field’s in place — those remotes feed us a quarter-petabyte a minute! What a far cry from our wee kitchen PC! love Ceri

“Do you understand, Selay? Ceri was helping save our oceans.” But Selay asks, “What’s a wee kitchen PC, Mom?”

Her mother answers, “I think . . . yes . . . it was a little computer. It couldn’t listen, like the Library, but it knew things.” The plasma then resolves into an antique facsimile image of a real-paper printout.

2003.05.29:15:51 zhong-sheppard@sympatico.ca to zhong-sheppard@sympatico.ca

mom are you there

I got PC pictures of ecoli that’s why we cant drink milk from the barn! can I make pictures like those when I grow up
xxx Ceri

Selay stands quietly a few moments before what Ceri’s mother, long ago, had secreted in her bedroom drawer.

“Mom, her PC at home . . . that made Ceri want to be a scientist!”

“Little one, wishes can come true.”

