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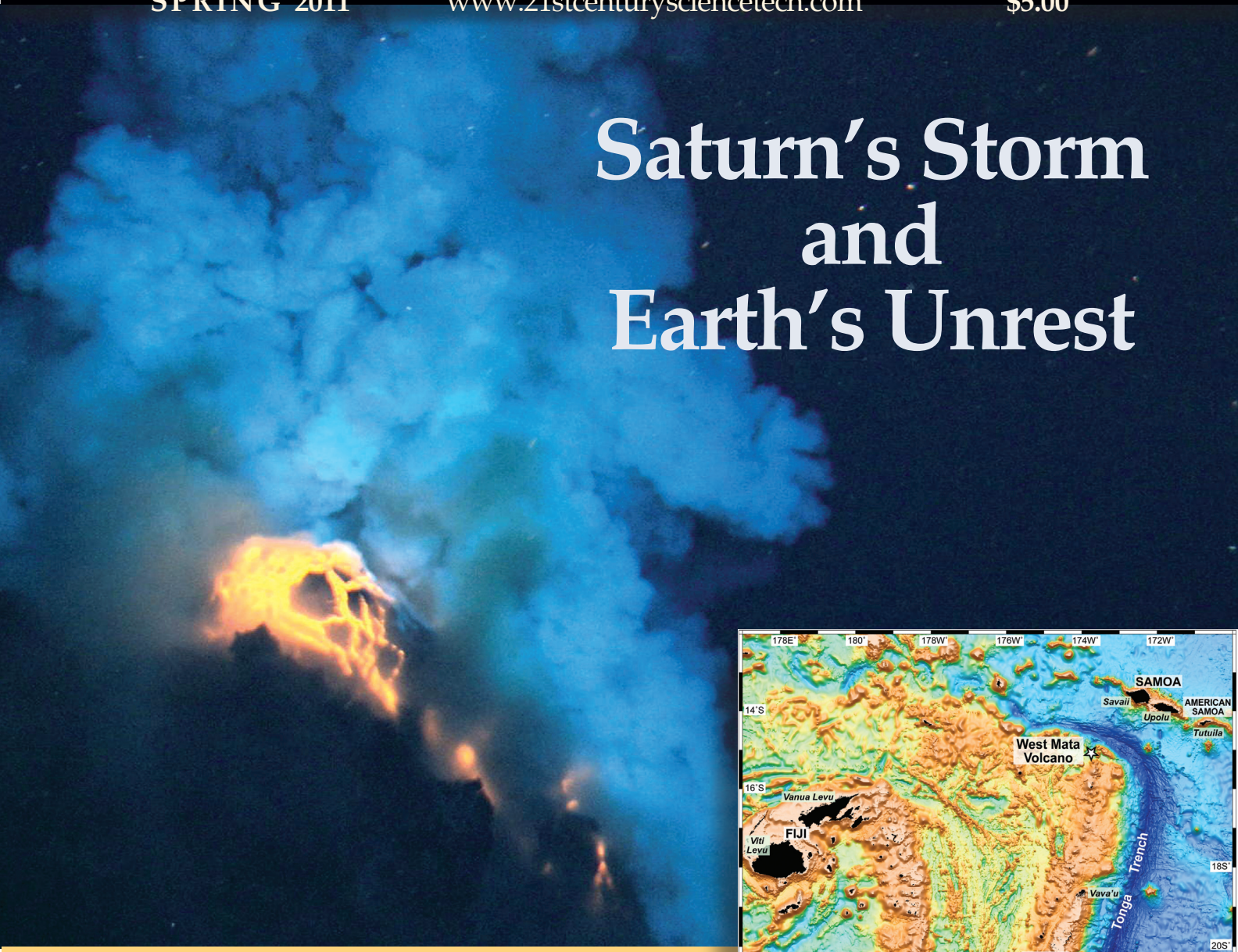

Saturn's Storm and Earth's Unrest

- **NAWAPA, Geophysics, and Nuclear Power**
- **Former NRC Head on Reprocessing**
- **Humboldt's Legacy**

21st CENTURY SCIENCE & TECHNOLOGY

Vol. 24, No. 1 Spring 2011

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On the Cover: Sea-floor image of molten lava erupting at the West Mata volcano in the southwest Pacific, as captured by cameras on a remotely operated vehicle. Inset: NOAA map showing location of the West Mata volcano. The islands (black) are the only areas above water. Photo courtesy of NSF and NOAA; cover design by Alan Yue.

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Saturn's Storm, Earth's Unrest … And Science's Silence

By itself, the great storm spanning 30 degrees of latitude across Saturn's northern hemisphere, first detected in December 2010, is not a significant trend. Events such as these, traditionally called Great White Spots, have been noted approximately every 29 years since 1876. The unexpected appearance of this year's storm only 21 years after the last, raises questions about the prevailing theory that such storms are caused by return of the orbit to Summer solstitial position. Yet it is surely not, by itself, any cause for alarm.

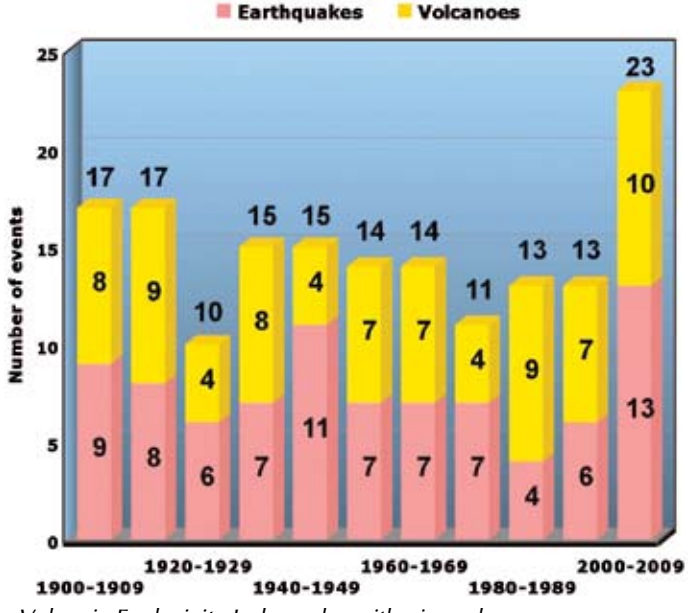
Neither is the shocking rise in frequency of earthquakes of magnitude greater than 8.0 over the last decade, significant in itself. The 13 great earthquakes from 2000 to 2009, surpassed any previous decade since measurements became available. Subsumed within this was an unprecedented spate of mega-quakes, defined as 8.6 or greater, beginning with the magnitude 9.0 earthquake/tsunami off the coast of northern Sumatra in 2004.[1] Nor is the increased occurrence of cataclysmic volcanoes measuring 4 or greater on the Volcanic Explosivity Index, which began to show itself in the first decade of this century, and continues through the second, by itself of significance (Figure 1).

Nor is the dramatic increase in severe tornadoes experienced so far this year in the continental United States, of any significance by itself. As of May 24, the

1. C.G. Bufe and D.M. Perkins, "The 2011 Tohoku Earthquake: Resumption of Temporal Clustering of Earths Megaquakes," April 14 poster session, Seismological Society of America annual meeting (2011).

"We now have, within 6.3 years, four M 8.6 and greater events in the ongoing global cluster, including two megaquakes of M 9 and larger. Given the nearly 40 years of relative quiescence preceding the present cluster, this represents a very significant change in global moment release rate. These two clusters of M 9.0 and above since 1900 have a probability of less than 2 percent of having occurred randomly."

Figure 1
EARTHQUAKES MAGNITUDE 8.0+ AND VOLCANOES VEI 4+



VEI = Volcanic Explosivity Index, a logarithmic scale.

number of severe F4 and F5 tornadoes already equals or exceeds the entire yearly count of all but three previous years in the past 61 years since modern record-keeping began. (Figure 2).

By itself, no one of these events could be assumed to be anything more than an aberration in an astronomical, seismic, or meteorological process which is not perfectly understood. Yet taken together, we see indications of an Earth and a Solar System in a state of unusual ferment.

Taken together—that is the key point. Conventional scientific prejudice, which reflects the methodological sickness that has taken over modern science since the late 1920s Solvay conferences, militates against this standpoint. Now, the time has come to cure the illness. Not only for the good of science, but for the very survival of humanity itself. We have no assurance that the just-described effects are not a sign of worse to come. We don't know that they are. But neither do we know they are not. We do not know that another extinction event, of the sort recorded in the sedimentary record, is not in progress or about to happen.

There is hesitancy to accept that. For some, the reasons are mixed. Thirty years of apocalypse-mongering over global warming has taught many of us to be wary of alleged frightening trends, invoked to manipulate us into a panic that always turns out to be motivated by the desire to stop industrial progress and reduce world population.[2] It scarcely needs stating here, that we have been and remain opposed to that piece of genocidal mockery. We speak rather of a real threat to mankind, which requires, not austerity, but a vast increase in our scientific and physical economic capabilities to deal with.

Contrary to widespread propaganda and pessimism, we now possess, or are on the verge of possessing, the capability to forecast many of these events, and thus to take preventive action to save lives. Take the case of earthquakes, the most devastating of the cataclysms presently threatening. As Prof. Sergei Pulinets and collaborators have documented, retrospective analysis of the March 11 Tohoku earthquake in Japan has demonstrated once again that certain known transient atmospheric anomalies are present in the period leading up to an earthquake.[3]

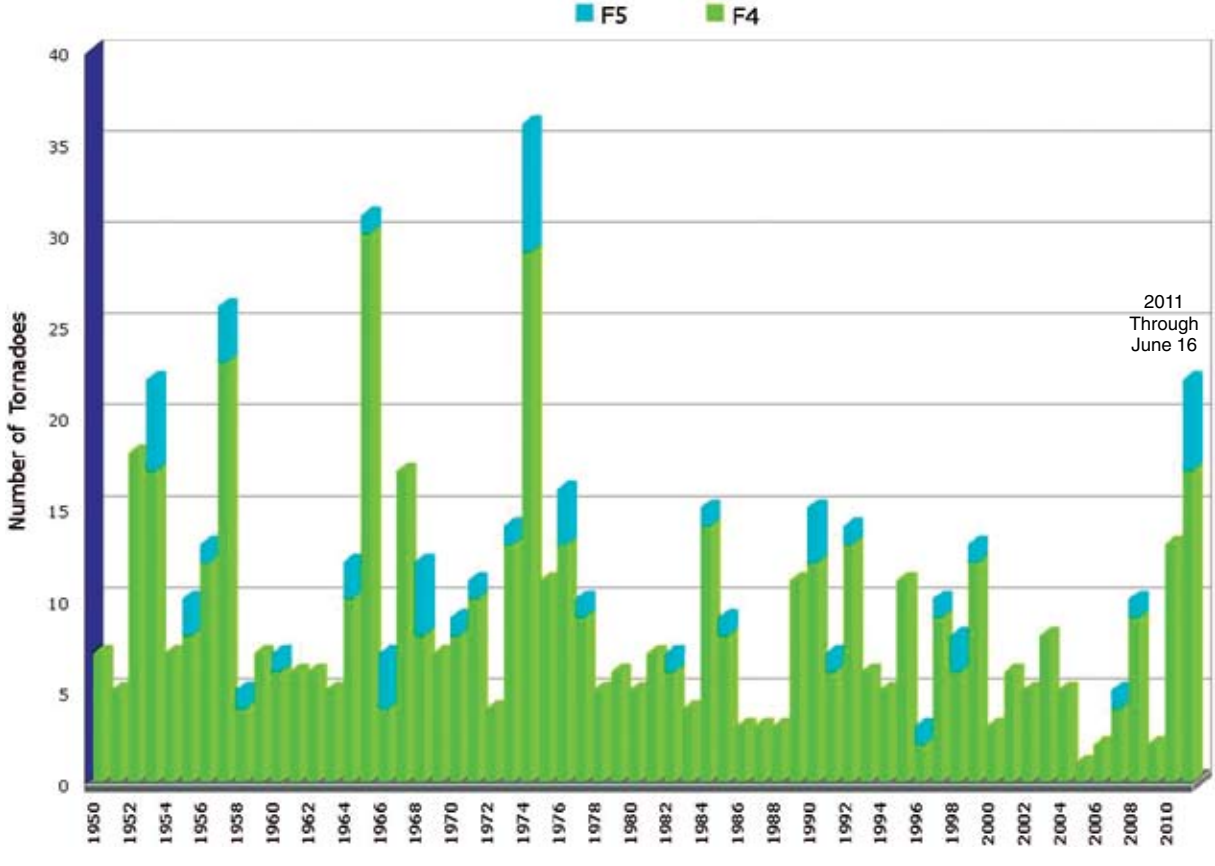
In the case of the Japan quake on March 8, a rapid increase of emitted in-

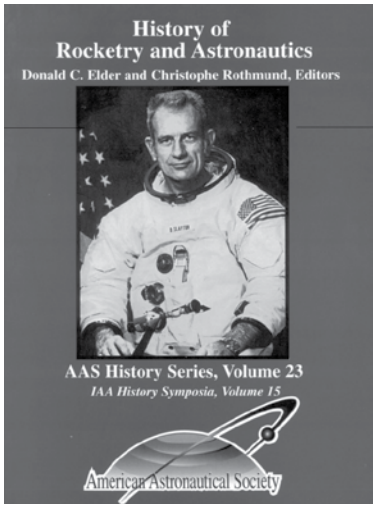
2. Marjorie Mazel Hecht, "Where the Global Warming Hoax Was Born," *21st Century,* Fall 2007, pp. 64-68. http://www.21stcenturysciencetech.com/Articles%202007/GWHoaxBorn.pdf

3. Dimitar Ouzonov, Sergey Pulinets, et al., "Atmosphere-Ionosphere Response to the M9 Tohoku Earthquake Revealed by Joined Satellite and Ground Observations. Preliminary Results" (2011) http://arxiv.org/ftp/arxiv/papers/1105/1105.2841.pdf

An interview with Professor Pulinets from April 11, 2011 can be seen at http://www.larouchepac.com/node/17944?page=2&lid=0-0-2

Figure 2
SEVERE U.S. TORNADOES F4 AND F5, 1950-2010





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frared radiation was observed in the satellite data and an anomaly developed near the epicenter. The Total Electron Count (TEC) data obtained by processing data from the GPS system showed an increase and variation in electron density also reaching a maximum value, also on March 8, three days before the quake.

An abnormal variation in the Total Electron Count was confirmed on this day over the epicenter. From March 3 to 11, a large increase in electron concentration was recorded at all four Japanese ground ionosonde stations in Japan, which returned to normal after the main earthquake. Data were also taken from the Low Earth Orbiting satellites of the COSMOS system, and from the ground-based vertical sounding network in Japan. Ionospheric tomography, and observation of the variation in the critical frequency (foF2) for ionospheric transparency also play a role.

Taken together, these and other measurements form the basis of what Pulinets emphasizes is a multi-parameter approach to forecasting. The theory of causation is based on observations of numerous earthquakes going back many decades. The outflow of radon from the Earth, in the period of two weeks to a few days before the seismic shock, is thought to play a leading role in production of the precursor effects. The radon produces detectable surface thermal anomalies, humidity variations, and changes in the atmospheric ionization.[4]

Among the other sorts of earthquake precursors are ground deformations, gravitational anomalies, planetary positions, crustal stress, ground water levels, earthquake clouds, foreshocks, microseisms, changes in animal behavior, and variations in earth resistivity. All of these can be taken account of in a full-scale multi-parameter approach.

It is not true that we can do nothing in the face of natural disasters. We can do many things. But, first must be a change of attitude from the widespread and prevailing pessimism infecting all pores of society.

Second, we need a beefing up of our science capabilities, in both applied and fundamental research. New satellite systems, most of them right now on the budgetary chopping block, can add to our detection capabilities for both short-term forecasting and for the accumulation of observations crucial to the formation of new hypotheses.[5]

The sort of pessimism, repeated by our President on recent visits to Joplin, Missouri, and to flooded regions of the South, is worse than unacceptable. It is pure lying in service of a foreign power. It is the same lying which has prevented crucial action on Glass-Steagall reform of the financial system, and for the same reasons, the most essential of which is the commitment to reduce world population. There is no commitment to fight for progress and growth, except in words. There is only a commitment to defend London and Wall Street banking interests, and the spending habits of a First Lady fantasizing about royalty on the family's now-frequent visits to Buckingham Palace.

Science Must Change Fundamentally

Science itself must change fundamentally. A return to an optimistic spirit that can only result from a fundamental change in national policy is a prerequisite. On that score, either we implement the Glass-Steagall reorganization prescribed by Lyndon LaRouche, or there is no national survival. Kiss your future and that of your family goodbye.

At the same time, nothing stops any thinking person from joining with the rapidly maturing movement led by the LaRouche "Basement" team to bring about a scientific renaissance. The shift in thinking from a particle-based conception to that of cosmic radiation, proved the conceptual turning point in this renaissance. Not empty space with self-evident particles interacting according to certain laws, but a completely filled and self-developing universe which is not defined by, but defines its own space-time, different at every instant.

Not an outer world of phenomena and an inner world of interpretation of the sensory impressions conveyed by them, but a continuously creative universe, knowable only by the act of creation of the individual creative mind.

—Laurence Hecht

4. See Dimitar Ouzounov, "Recent Research in Monitoring Earthquakes Using Multisensor Satellite and Ground Data" (2007) http://www.gwu.edu/~spi/assets/ docs/Ouzounov%20-%20Recent%20Research%20in% 20Monitoring%20Earthquakes%20by%20using% 20multisenssor%20satellite%20and%20ground%20 data%20-%20a%20preliminary%20report.pdf

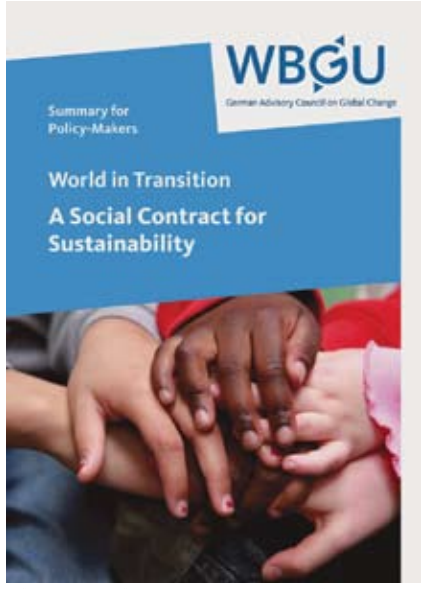
5. See the video "Japan Quake Precursors" http://www.larouchepac.com/node/18298

SIGN THE PETITION TO STOP GLOBAL ECO-FASCISM!

The WBGU (German Advisory Council on Global Change) has called for decarbonization—an end to all fossil fuels—and an end to nuclear power and fusion research: In short, a program to send us back to a Dark Age and kill 5-6 billion people in the process. The full story and supporting material appear on our website. The petition is here.

Related items include:

- the WBGU document,
- Helga Zepp-LaRouche's on-the-scene report of the situation,
- A report on the intervention of our colleagues in Sweden against WBGU head Hans Joachim Schellnhuber and his failure to convince a meeting of Nobel Laureates to endorse his call for an end to nuclear and to fossil fuels,
- Video footage of the Stockholm event, included in this report,
- More background on Schellnhuber.



This "social contract" may look sweet in the photo, but it is designed to kill off 5 billion of the world population, and send those who live into a New Dark Age.

NASA'S FERMI SPOTS 'SUPERFLARES' IN THE CRAB NEBULA

The Crab Nebula supernova remnant erupted in an enormous flare, detected on April 12, which challenges all existing hypotheses about the highly anomalous process known as the Crab Nebula. The flare, detected by NASA's Fermi Gamma-ray Space Telescope, was five times more powerful than any other flare previously seen from the object. On April 16, an even brighter flare erupted, but within a couple of days, the unusual activity completely faded out. In all, the outburst lasted six days.

"These superflares are the most intense outbursts we've seen to date, and they are all extremely puzzling events," said Alice Harding at NASA's Goddard Space Flight Center in Greenbelt, Md. "We think they are caused by sudden rearrangements of the magnetic field not far from the neutron star, but exactly where that's happening remains a mystery."

IN MEMORIAM: JACK TRESSIDER (1920-2010)

Most people in Ontario, New York, Michigan, and Minnesota do not know that they owe the 19 per cent of the electricity generated by Ontario, Canada, from which they benefit, to an unsung hero of the Labor Movement, Jack "Blackie" Tressider, who passed away on October 19, 2010, just six months shy of his 90th birthday.

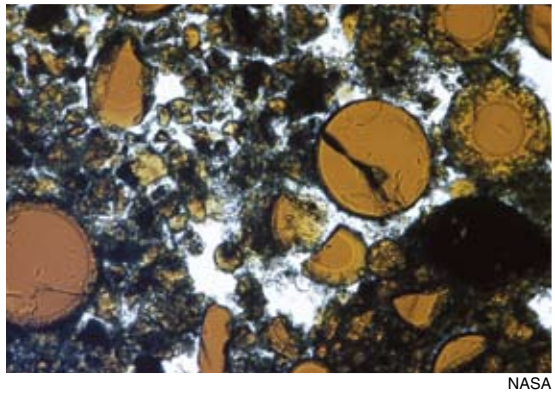
After the Three-Mile Island incident in 1979, Jack, who at the time was the Business Manager of Ironworkers Local 721, was the main sparkplug in the Toronto metropolitan area for the push to build the Darlington nuclear plant (four units with a total output of 3,512 MWe), then on the drawing boards. After meetings and discussions with LaRouche co-thinkers in Canada (including a visit from scientists from the Fusion Energy Foundation in New York), Jack organized the Building Trades to hold a large labor demonstration near the plant site. Jack was not much for bragging; he just did things. The message got through and the plant was built, from which people still benefit today. Many years after his retirement, Jack urged his old Ironworkers local to support NAWAPA, the North America Water and Power Alliance.

LUNAR MAGMA WATER CONTENT FOUND TO BE 100 TIMES HIGHER

A team of NASA-funded researchers for the first time has measured water from the Moon in the form of tiny globules of molten rock, which have turned to glass-like material trapped within crystals. These newly discovered lunar melt inclusions were found in lunar sample 74220, which is high-titanium "orange glass soil" collected during the 1972 Apollo 17 mission. Indications are that the water content of lunar magma is 100 times higher than previous studies suggested.

The inclusions were formed during explosive eruptions on the Moon, approximately 3.7 billion years ago. To measure the water content of the inclusions, scientists used an ion microprobe instrument. The results raise questions about the "giant

Below: Whole spheres and fragments of orange volcanic glass, of the type from which the lunar melt inclusions were recovered. The largest sphere in the center is 0.2 millimeters across. At left is an optical photograph of a lunar melt inclusion (30 microns in diameter) from Apollo 17 sample 74220, enclosed within an olivine crystal.



NASA

impact theory" of how the Moon was created, which had predicted very low water content of lunar rock because of catastrophic degassing during the collision of Earth with a Mars-sized body very early in its history. For more information, click here.

A family now under attack: Arthur Robinson and his children in 2008. From left: Robinson, Matthew, Noah, Bethany, Zachary, Arynne, and Joshua with his wife, Fama.

NASTY POLITICAL OPERATION TARGETS ART ROBINSON AND CHILDREN

Arthur Robinson, Ph.D., a research professor of chemistry and co-founder of the Oregon Institute of Science and Medicine, has made public a shocking report on the political harassment against three of his children, all graduate students at Oregon State University in nuclear engineering. After he ran for Congress against incumbent Democrat Peter DeFazio in 2010, gaining 43.6 percent of the vote, OSU faculty administrators, Robinson wrote, "initiated an attack on my three children—Joshua, Bethany, and Matthew—for the purpose of throwing them all out of the OSU graduate school, despite their outstanding academic and research accomplishments. OSU is a liberal socialist Democrat stronghold in Oregon that received a reported $27 million in earmark funding from my opponent, Peter DeFazio, and his Democrat colleagues during the last legislative session."

Robinson, who directed the Petition Project that collected signatures of more than 31,000 scientists who opposed the "human-caused global warming" hypothesis, wrote a detailed article on the harassment, which appeared on the WorldNetDaily website. (www.wnd.com/index.php?fa=PAGE.view&pageId=271753). Readers can follow the links at the end of the article to contact the university in support of Robinson, his children, and the nuclear engineering professor who blew the whistle on the faculty smear campaign. The Robinsons also have a website (www.oregonstateoutrage.com/) where Robinson has a detailed overview of the situation, and where supporters can report feedback on actions they have taken in support.

NASA

The International Space Station and the docked Space Shuttle Endeavour, photographed at an altitude of about 220 miles by crew member Paolo Nespoli, who was returning to Earth in the Russian Soyuz.

HASTINGS CENTER BIOETHICISTS PLAN TO KILL MORE ELDERLY

Two octogenarian bioethicists at the Hastings Center, Daniel Callahan and Sherwin Nuland, want to accelerate the killing of America's elderly, by making age 80 the cut-off point for medical treatment. "The real problem," they write in a feature article in *The New Republic,* "is that we have medicine excessively driven by progress, which aims to rid us of death and disease and treats them as the targets of unlimited medical warfare."

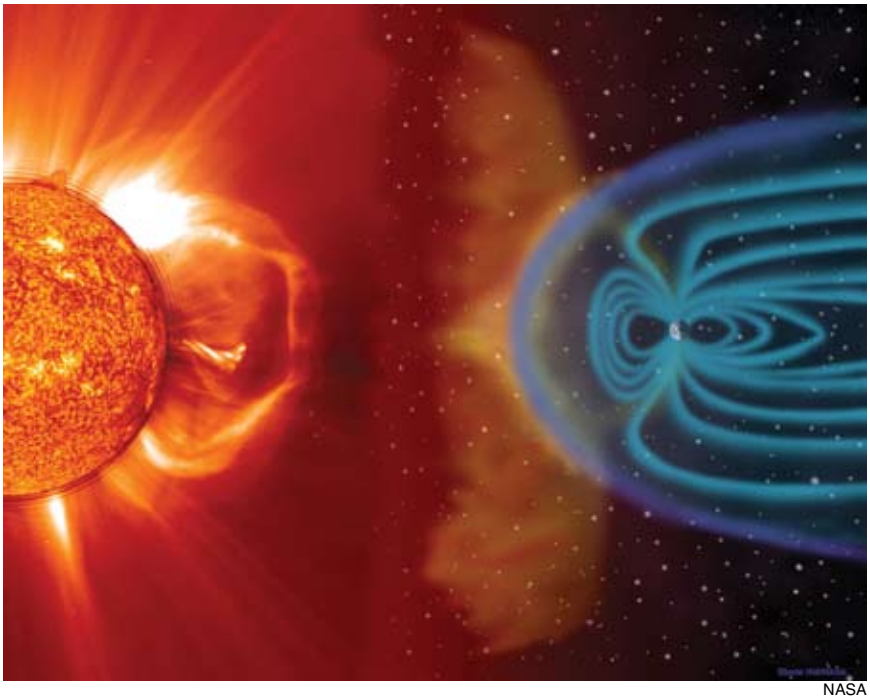
The solution of this death duo is to give only palliative care to those over the limit. We can't afford to do more, just as we can't afford space exploration, they write.

NEW FREE ELECTRON LASER PRODUCES ITS FIRST BEAM OF LASER LIGHT

RIKEN and the Japan Synchrotron Radiation Research Institute in June successfully produced a first beam of X-ray laser light with a wavelength of 1.2 angstroms, using SACLA, a cutting-edge X-ray Free Electron Laser facility that opened in February in Harima, Japan. SACLA provides much shorter wavelengths and higher intensities than other lasers, enabling researchers to observe and manipulate objects on an unrivalled scale, and for the first time to directly observe individual atoms and molecules.

UNIQUE 'PORTRAIT' OF SHUTTLE ENDEAVOUR AND THE SPACE STATION

European Space Agency astronaut Paolo Nespoli captured the first photos of the Space Shuttle docked to the International Space Station, taken from the perspective of a Russian Soyuz spacecraft. The Soyuz was about 600 feet from the station on May 23, when Nespoli took digital photos and film. NASA and the Russian space agency, Roscosmos, then processed the imagery. Images can be viewed on NASA's website: http://go.nasa.gov/stationportrait.



NASA

A coronal mass ejection (CME) blast and, at right, a depiction (not to scale) of the subsequent impact at Earth, two to four days later, when the CME cloud strikes and begins to be mostly deflected around the Earth's magnetosphere. The blue paths emanating from the Earth's poles represent some of its magnetic field lines. The magnetic cloud of plasma can extend to 30 million miles wide by the time it reaches Earth.

The Solar Storm Threat To America's Power Grid

by Laurence Hecht

A known and cataclysmic threat to the U.S. electric power grid is being largely ignored by the President and Congress. Warning events in 1859, 1921, 1989, and 2003 showed the danger that solar activity can pose to electrical power and distribution systems. Now, as we move into another solar maximum, with increased vulnerabilities built into our electrical grid, the danger again looms large. In the worst case, there is the possibility of no electricity for 130 million Americans for a year or longer. The warnings have been issued, but have gone unheeded.

The greatest danger is to the more than 300 extra-high-voltage (EVH) transformers located at power substations along the routes of major transmission lines. An eruptive event on the Sun, known as a coronal mass ejection (CME), sends a powerful flux of charged particles, protons and electrons, into the surrounding space. If the Earth is on a line with the eruption, the charged particles interact with the Earth's radiation belts and geomagnetic field to produce currents in the ionosphere. The power lines which make up the electrical transmission grid act as antennae, to couple these ionospheric currents to the installed transformers which step up the voltage for long-distance transmission.

High-voltage transmission lines in Washington state. Higher voltage lines are more susceptible to geomagnetic storm damage.

The ionospheric or auroral currents produced by a powerful solar storm induce strong fluctuating direct currents in the power lines. Known as geomagnetically induced currents (GIC), when they reach the transformers, they piggyback on to the strong alternating current already flowing, and cause the iron cores of the transformers to saturate and overheat from hysteresis and reactive resonance effects in the transmission line. This can cause network-wide voltage regulation problems leading to blackouts, or complete transformer burnout.

Transformer Failure

The consequences of a transformer failure are catastrophic, as there is a lack of manufacturing capacity for extra high-voltage transformers in the U.S.A. and worldwide. According to a study by the Metatech Corporation, commissioned under Executive Order 13407 for assessment of vulnerability to geomagnetic storms, manufacturers presently have a backlog of nearly three years for all extra high-voltage transformers (230 kilovolts and above).

Only one plant exists in the U.S.A. capable of manufacturing a transformer up to 345 kV. There is no manufacturing capability in the U.S.A. for 500 kV and 765 kV transformers, which represent the largest group of at-risk transformers in the U.S. power grid. The 500 and 765 kV transformers are the backbone of the grid that extends into regions that contain nearly 80 percent of the U.S. population,

Courtesy of J. Kappenman, Metatech Corp.

Transformer damage at Salem Nuclear Plant in New Jersey from overcurrent and stray flux heating during the 1989 geomagnetic storm.

according to John Kappenman of Storm Analysis Consultants and Metatech Corp.

Thus, as summarized by space physicist Daniel N. Baker, who chaired the National Research Council panel on Severe Space Weather Events, and NASA director of Planetary Sciences James L. Green, writing in the February 2011 *Sky & Telescope*: "Large areas of our nation could be without electricity for *months or years*, as power companies struggle to purchase and replace damaged hardware."

Because the solar storm threat is greatest to the low-resistance power lines carrying the highest current densities, some of the most vulnerable areas are also those of highest population concentration. Metatech estimates that more than 130 million people in the U.S.A. are at high risk for such an event. The highest risk areas are the northern states from the Atlantic seaboard to the Mississippi; coastal states as far south as Georgia; and the northwestern states of Washington, Oregon, and Idaho.

A prolonged lack of electricity in any of these areas would reduce the population to Dark Age-like conditions. Drinking water supply would break down for lack of pumping, and sewage service would cease shortly thereafter. For lack of refrigeration, the food chain would collapse, and medical supplies would be lost. Fuel could not be pumped, and thus transportation would break down. Heating and air conditioning systems would cease functioning.

Communication would be crippled by the lack of electricity as well as from the direct damage to satellites and sensitive electronics which a solar storm produces—perhaps no Internet and no cell phones. Modern life would come to an end, and a population and economic infrastructure unprepared for a return to pre-electricity conditions could descend into chaos.

The Remedies

Three means of mitigating the threat of severe geomagnetic storms and electromagnetic pulse damage are available:

- Provisions for replacement equipment, including spare transformers, circuit breakers, etc.
- Low-ohmic, neutral-to-ground resistors to reduce induced current levels at the transformer.
- Blocking devices to prevent the flow of geomagnetically induced currents.

Some combination of all three measures is urgently required. Maintaining reserve transformers on site, especially near critical metropolitan bottlenecks, is a must. But this would require the restoration of EHV transformer manufacturing capability in the U.S.A. and worldwide. The present backlog in production makes this option not available for the short term.

Immediate installation of supplemental transformer-neutral ground resistors can produce a 60 to 70 percent reduction of geomagnetically induced currents for storms of all sizes, according to Metatech. The EMP (Electromagnetic Pulse) Commission, established by Congress in 2001, estimated the cost of hardening the U.S. power grid with this first level of defense at $150 million.

There also exist conceptual designs for blocking devices, to shut down direct current flows from geomagnetically induced currents, while permitting normal AC flow on the power line. In one such design by Advanced Fusion Systems of New York, known as a Neutral Capacitor Bypass Device (NCBD), a high-power electron tube known as a Bi-Tron™ is utilized for fast bypass of induced currents, within a fraction of an alternating current cycle. The design envisions a modification and scaling of the 4275 Bi-Tron™ tube, originally developed for high-power military microwave applications, which has significantly faster switching capability than power transistors.

Without these measures, the power grid remains vulnerable to a catastrophic failure. Although satellites can provide warning of impending hits to Earth from solar coronal mass ejections, there are no viable options if preventive equipment and replacement transformers are not in place. Shutting down what might be thought to be the most vulnerable points in the grid, increases the risk of transformer saturation at other points by increasing the flow of power, in addition to the human and economic cost of a partial blackout in some areas.

Also, as noted by Metatech, the expansion of renewable energy greatly increases the threat posed by solar storms.

NASA

Technicians check the GOES-M satellite before its launch. GOES-M provides weather imagery and quantitative sounding data used to support weather forecasting, severe storm tracking, and meteorological research. It is one of a system of satellites that needs to be maintained if we are to have advance warning of superstorms.

To supply power from "wind farms," requires the construction of an extensive network of 765-kV transmission lines to bring the power from Midwestern states to the major metropolitan areas of the East and West coasts. "This could result in a seven-fold increase of the existing U.S. 765-kilovolt transmission network infrastructure," according to Kappenman, "and it would greatly escalate the vulnerability of the U.S. to geomagnetic storms, as higher voltage transformers are more vulnerable."

The Solar Storms

Solar coronal mass ejections, which produce the greatest known threat to Earth, are frequent but presently unpredictable events. The most powerful known storm occurred in 1859, at the beginning of the electrical age. It became known as the Carrington Event, after the British astronomer who observed "two patches of intensely bright and white light" from a group of sunspots near the center of the solar disk. The next day, a powerful geomagnetic storm occurred. American telegraph operators suffered damage to their equipment, and some reported a persisting signal on the line without any current being applied. Displays of Northern Lights were observed at low latitudes, lasting for a full week.

Another powerful geomagnetic superstorm was recorded in 1921. At that time, and up until the satellite era, the magnetic activity was associated with solar flares, which referred to the bright light observed in the eyepiece of a solar telescope. The magnetic effects could be detected by the global network of magnetic observatories, which dates back to the Göttingen Magnetic Union, founded by Carl Gauss and Wilhelm Weber in 1834.

The connection of geomagnetic storms to solar sunspot activity had been recognized since studies in the 1860s, after the Carrington event. But it was not until the 1970s that it was recognized that the coronal mass ejections, rather than the flare itself, were the cause of the geomagnetic storms. The solar flares are now recognized as intense eruptions from the Sun's visible surface, producing X-rays, radio emissions, and bursts of energetic particles, all of which can cause damage on Earth, and danger to humans in Earth orbit.

The 1991 eruption of Mt. Pinatubo was preceded for two weeks by some of the most intense X-class solar flares ever measured, although the causal connection of the events remains unknown. Since 1977, a continuous record of X-ray emission from solar flares has been re-

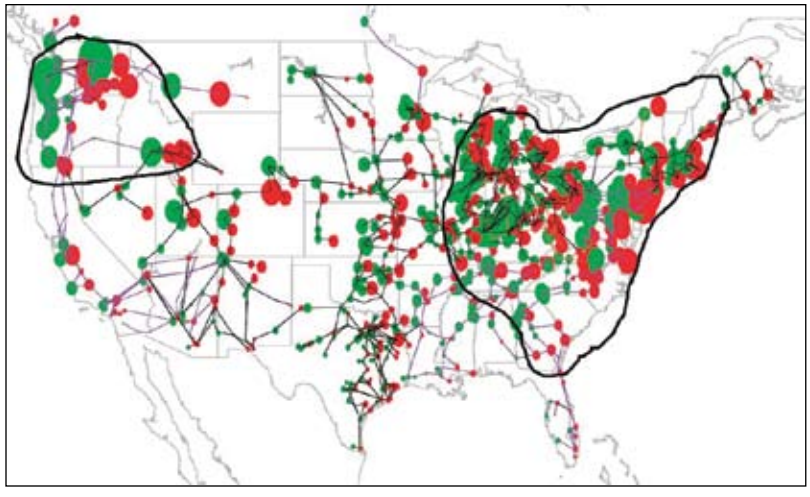


Figure 1
POSSIBLE EFFECTS OF A GEOMAGNETIC DISTURBANCE ON THE U.S. POWER GRID

The regions outlined are susceptible to system collapse, affecting more than 130 million people.

Source: J. Kappenman, Metatech Corp.

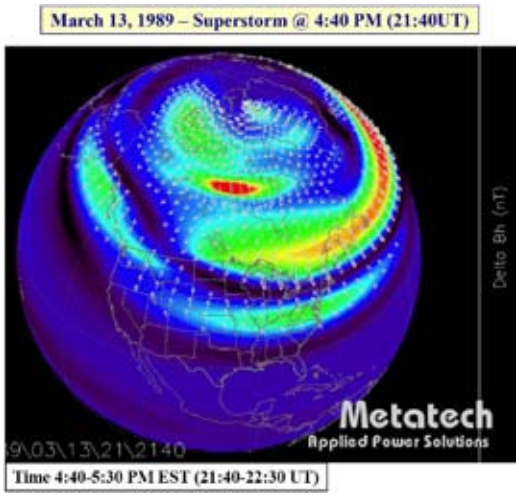


Figure 2

The geomagnetic superstorm, March 13, 1989, which caused a blackout in Quebec.

Source: J. Kappenman, Metatech Corp.

corded by the Earth-orbiting satellites of the GOES system.

Coronal mass ejections, which may or may not follow a solar flare, are eruptions of plasma, moving charged particles carrying with them a self-generated magnetic field, from the solar corona. A large coronal mass ejection can contain 10 billion tons or more of such material travelling at about 1 percent the speed of light. It is these charged particles, mostly protons and some electrons, which, when aimed at the Earth, produce the ionospheric currents which, in turn, can induce dangerous currents in the electric power grid.

Advanced Fusion Systems

The Bi-Tron™, devised by Advanced Fusion Systems of New York, is designed for fast bypass of induced currents, within a fraction of an alternating current cycle.

The Worst Recent Strike

The worst strike in modern times came on March 13, 1989, when currents induced by a coronal mass ejection tripped circuit breakers in the Hydro-Quebec network, leaving 6 million people without electricity for 9 hours to several days. Experts have described it as largely good fortune that a Northeast-wide power outage did not follow.

A more powerful CME accompanied by a solar flare occurred in November 2003, but was not aimed directly at Earth. According to experts, a direct hit by a CME of that magnitude would likely have produced a Carrington-level event, but with far worse consequences to a vastly more electricity-dependent planet. In that case, as in some others, the solar storm occurred, not in a period of peak activity, but during a solar minimum. However the threat of eruptive activity increases with the onset of the maximum in the 11-year cycle of solar activity. We are now approaching such a maximum in the current Solar Cycle 24, which commenced in December 2008.

Thanks to satellite systems, we now have sometimes up to a day or two of warning from the time the eruptive event is witnessed on the Sun's surface to the arrival of the charged particle flux which carries most of the known danger. But, as noted, it is not sufficient to know it is coming. Preventive devices and back-up equipment must be in place to avert a catastrophic consequence.

Remedies Not Taken

The warnings and required remedial measures reported here were delivered in repeated congressional testimony and compiled in a 2008 report by the National Academy of Sciences entitled, "Severe Space Weather Events—Understanding Societal and Economic Impacts." In the words of Dr. Baker, the chairman of the commission which produced the report, "It's difficult to fathom how damaging an 1859-type event might be in today's world." Yet, so far, no effective action has been taken to implement the necessary defenses.

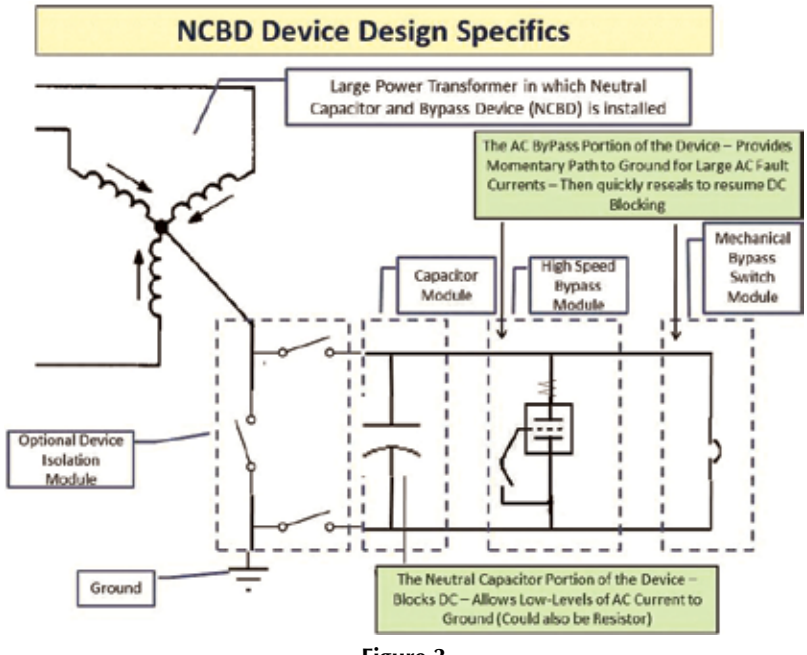


Figure 3

NEUTRAL CAPACITOR AND BYPASS DEVICE

Source: J. Kappenman, Metatech Corp.

The Importance of NAWAPA For Geophysical Research

by Peter Martinson

April 23, 2011

Bert punched out and headed home from work. These days, everybody had jobs. There weren't enough people to fill them! They had been watching the Copper Reservoir fill behind the colossal 1,753-foot-high Chitina Dam for the past several months, keeping an eye on the dam for structural problems. So far, so good, so Bert headed home.

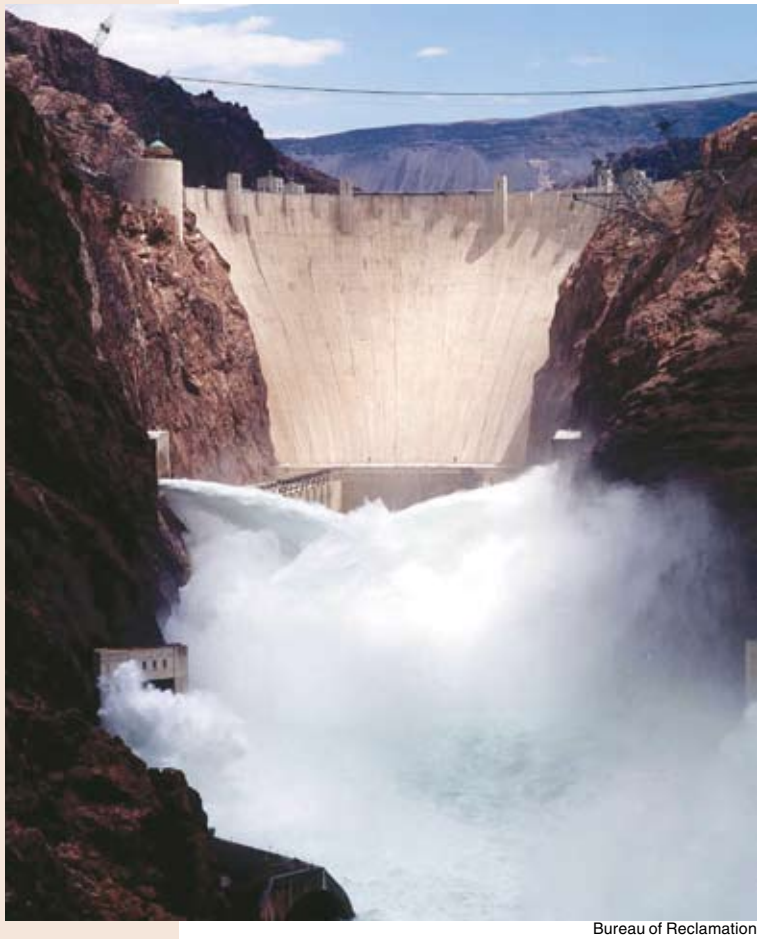
As he walked to his car, he heard some rustling just next to him, like an animal in the bushes, or someone crumpling up some cellophane. But, upon looking around, he saw nothing in the bushes. As he looked up, he then saw the source of the sound: a magnificent display of the northern lights! He and many other people up here near the Arctic can hear them, and the Eskimos have all these legends about the sound. Just then, a meteor streaked across the sky, which Bert also heard as a crackle.

Bert got into his car and drove home. When he pulled up, he saw that his dog, Katyusha, was already waiting at the window for him, as she always does—even though Bert works odd hours. He walked in, said hi to Katyusha and his two cats, Ivan and Sascha, and began making dinner. Just as he finished cooking, he heard some commotion in the living room, and went in to scold his pets. His dog was running in very tight circles, while his two cats bolted out of sight. Then his dog took off up the stairs. Bert had seen this behavior before, and he immediately dove under his heavy oak desk, and held on tight. Within moments, the ground began to shake. Up and down, books flying off shelves, cookware hitting the wall. As Bert would find out later, Chitina was now getting hit by a magnitude 4.5 earthquake, whose epicenter was about 2 kilometers beneath the huge Copper Reservoir. Within seconds, which seemed like minutes to Bert, the shaking stopped.

When he thought it was safe, Bert scrambled from under his desk, and dug out his phone to call the base. "Come on, Bert!" said the voice on the other end, "this dam has handled worse than that in the past few months! It was built to withstand an atomic bomb blast!" Bert hung up, let out his breath, and said to his cats, who had come out of hiding, "So, have you come back to your senses?"[1]

1. http://www.larouchepac.com/node/17172

Accepted geology today is about as objective as modern climatology. All phenomena are assumed to be derivable from a few accepted doctrines, and all observations that cannot be explained with these doctrines as the primitive causes must be ruled out as "superstition." Several of the doctrines are attributed to valid, even perhaps heroic, hypotheses of past scientists, such as Alfred Wegener and Tuzo Wilson, but they have been turned into the



Bureau of Reclamation

The dams and tunnels built under NAWAPA will provide ample freshwater, and at the same time act as a laboratory for understanding how the Earth works. Here, Hoover Dam releases water from its jet-flow gates.

USGS

A collapsed bridge over the Copper River, after Alaska's March 27, 1964 earthquake, magnitude 9.2. This was the largest measured earthquake in American history, and NAWAPA's proposed Chitina Dam, about 100 miles east of the 1964 quake site, will have to be engineered to withstand a magnitude 10 or 11 earthquake.

chains that bind scientists to a limited universe. Real hypotheses are never the ending points from which scientists are relegated to deriving implications; they are always transition points to higher discoveries that improve Man's mastery over his universe, while posing more profound questions. The relationship between earthquakes and the North American Water and Power Alliance (NAWAPA) can help us break these chains.

It has been known for some time that the impoundment of water into man-made reservoirs causes seismic activity. Tremors can occur immediately upon initiation of impoundment, or appear after several seasons of filling cycles, or both. The seismic activity is typically related not to the actual level of water, but appears to correspond to change in the water level. When the water level becomes stabilized, the tremors usually die down. The theory is that the added weight, and possibly the entrance of water into fault cracks, can cause an already stressed fault to snap. Scientists like Pradeep Talwani,[1] director of the South Carolina Seismic Network, try to use these reservoir-induced seismic tremors as models to understand how natural earthquakes occur, but, as we will see, there is almost certainly a sharp distinction between the two phenomena.

The NAWAPA plan includes the impoundment of hundreds of millions of acre-feet of water along areas that are quite close to the North American section of the Pacific Rim of Fire, from Alaska down through the Rocky Mountain Trench fault line, to the Rocky Mountains and Cascadia. The largest measured earthquake in American history occurred about a hundred miles west of the largest proposed dam in the system, the 1,700-ft Chitina Dam in Alaska, which will hold back a reservoir of more than 1,000 million acre-feet of water. The construction of such a dam, with the capability of withstanding a magnitude 10 or 11 earthquake will present large engineering challenges, but nothing that is beyond the future ability of Man.

Will the water impounded cause a huge earthquake? It is not clear. There are some that claim a causal relationship, like the scientists at the *Wall Street Journal*,[2] who claim that a reservoir impounded by the Zipingpu Dam in Sichuan, China, caused a devastating 7.9 magnitude earthquake in 2008. What is clear, is that there has been an ongoing effort by the British Empire to stop the advancement of Man's control over both the biosphere and the lithosphere, and also an effort to retard the understanding of how the Earth works.

What I'll just sketch in this short report, is that the tremors generated by human impoundment of water are a different species of phenomenon from real earthquakes.

Real Earthquakes

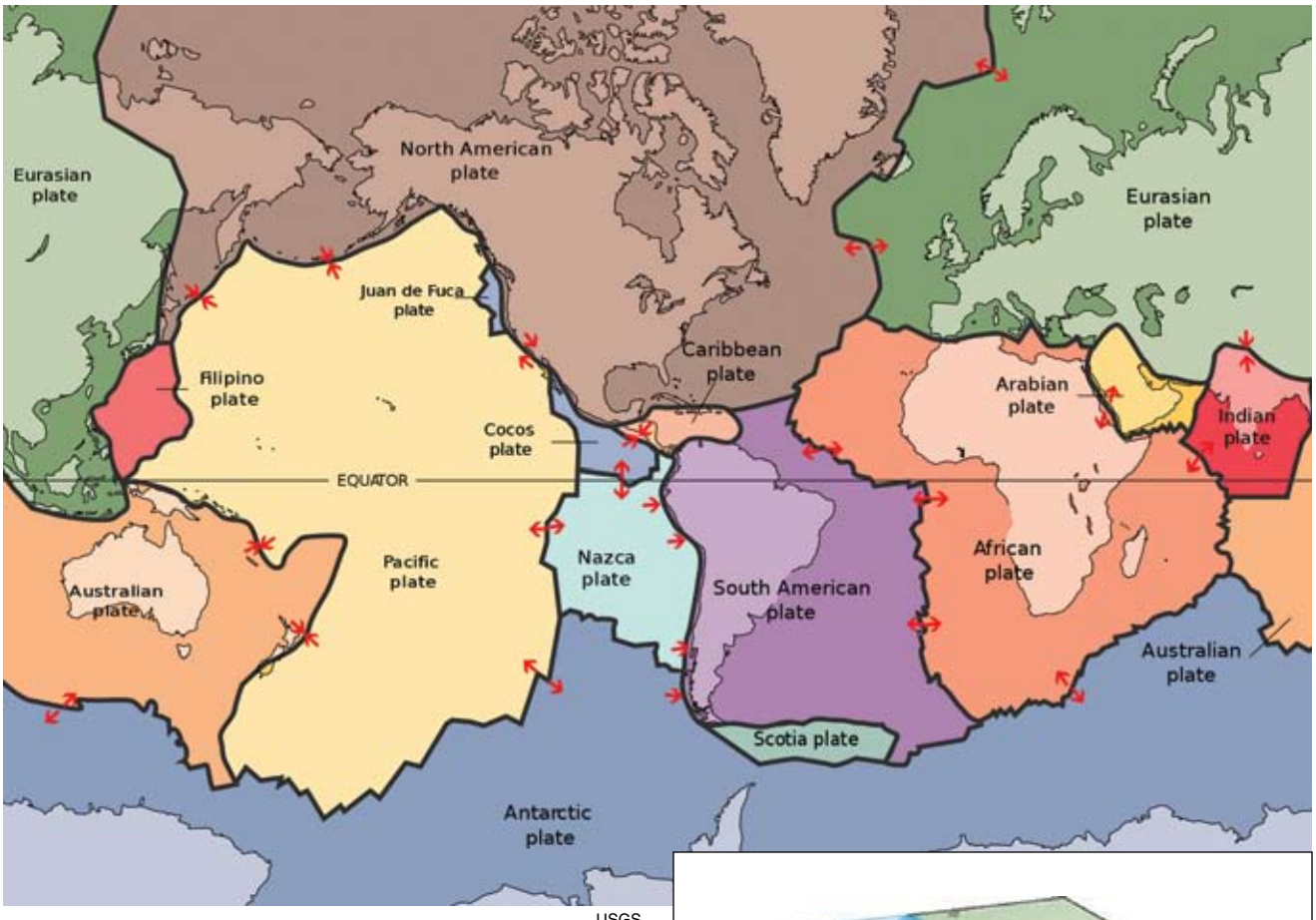
Geology is dominated by the theory of tectonic plates and subduction. In summary, underneath the crust of the Earth is a bunch of hot, plastic rock which undergoes convection. This rock emerges from the depths at mid-ocean ridges and forms new, basaltic plate material. The surface of the Earth is composed of several of these large basaltic plates, whose creation at mid-ocean ridges is compensated for by destruction at subduction zones, almost like a conveyor belt.

Earthquakes and volcanoes typically occur at areas designated as subduction zones, where the plates are bent dramatically downwards and pushed underneath, usually, granitic

2. http://online.wsj.com/article/SB123391567210056475.html

Anti-development activists claim that the reservoir impounded by the Zipingpu Dam in Sichuan, China, caused the devastating 7.9 magnitude earthquake in 2008? But tremors associated with reservoir impoundment and earthquakes are two different species of phenomena.

1. http://www.geol.sc.edu/talwani.htm



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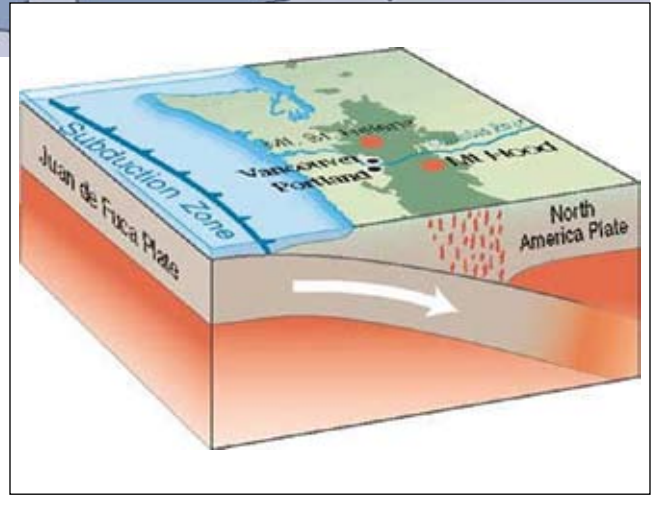


Traditional geological theory holds that the Earth's crust is composed of distinct tectonic plates, the largest of which are shown here. Earthquakes and volcanoes are said to occur at subduction zones (see inset), where the plates are bent down and pushed underneath.

continental crust. That subducted plate sucks water down with it, melts when it reaches the asthenosphere, and the melted material rises and pops out at volcanoes. As the plate gets pushed downwards, the continental crust on top gets buckled back and upwards, the strain growing until such point that the crust gives way and collapses back down in an earthquake.

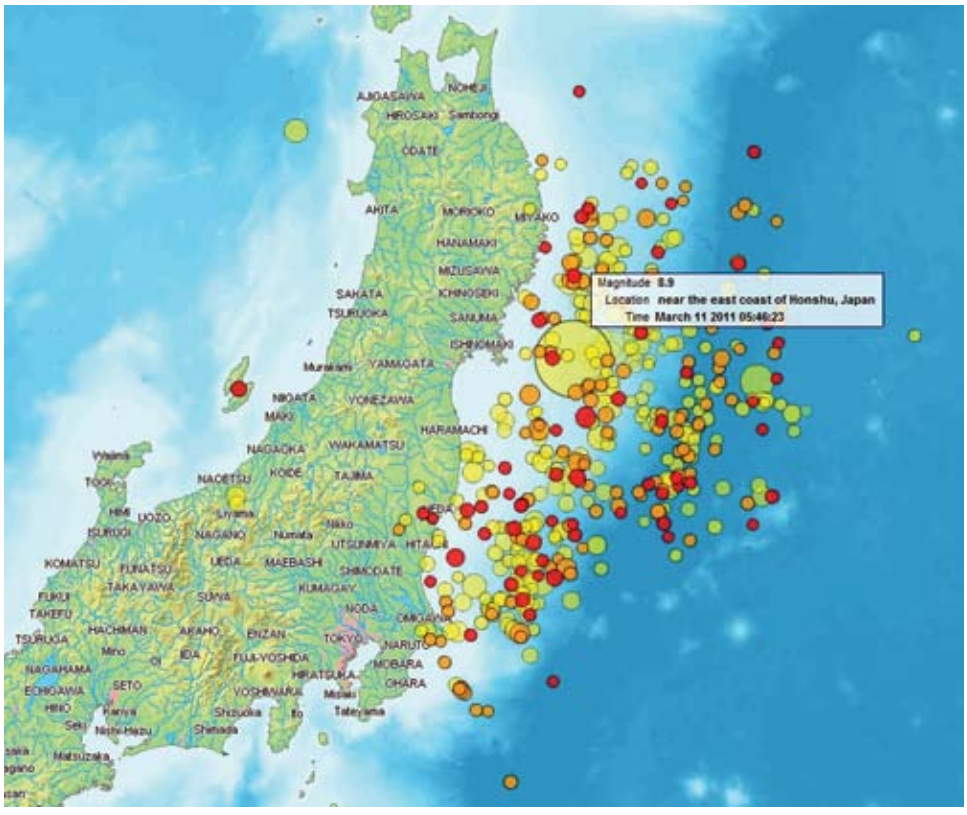
Ignoring for now the fact that bending a several-kilometer-thick section of very dense rock at a sharp angle, and then pushing it down hundreds of kilometers, would require enormous stresses that are simply not observed, a large body of evidence is now piling up that indicates that these merely kinetic and thermodynamic mechanisms are not the real story. There is something else going on down there.

According to the kinetic model of seismic waves, the epicenters of large earthquakes are usually quite deep in the crust. For example, the seismic waves sent out by the main March 11, 2011, Japanese earthquake lead back to a spot about 32 kilometers beneath the floor of the ocean. After this event, the many aftershocks, several of which were over M7, and continue to this day, have ranged from near the surface to about 200 kilometers deep.

For comparison, the deepest hole ever dug by man, the Kola Superdeep Borehole project in Russia, is a little over 12 kilometers deep. Based on seismic data, conjured by British statistician Harold Jeffreys, an opponent of Wegener's continental drift theory, the Russians expected to reach a boundary between 3 and 6 kilometers down, where the granite continental rock would transition into basaltic basement rock, which carries seismic waves much faster. Instead, they ran into a quite different species of rock, gneiss (a metamorphosed granite), which was saturated with water that could not have trickled down from the surface. They never reached basalt. Eventually, they had to give up the project because of funding, but also be-

cause the rock was twice as hot (~200°F) as they had expected (~100°F), and had entered into a new, plastic phase that kept destroying drill bits and closing up.

The foundations of geophysics had thus been demonstrated as wrong a mere 3 to 6 kilometers down, while most earthquakes originate at depths several times this. Can it really be assumed that we know what causes earthquakes?



Map of the Sendai Earthquake in March 2011 and aftershocks until March 14, 2011. The size of the circles is a function of magnitude, and the color indicates the date: light green: March 11; yellow: March 12; orange: March 13; red: March 14. The seismic waves sent out by the earthquake lead back to a spot about 32 kilometers beneath the floor of the ocean.

The New Madrid Seismic Zone

Let's look at an example of a real earthquake, here in the United States. Quakes are generally relegated to the so-called plate boundaries, until one happens in the middle of a plate. This is represented in northern Arkansas as the New Madrid Seismic Zone. Between 1811 and 1812, within about three months, this was the site of three or four quakes estimated to be larger than magnitude 8. Descriptions of this event are rife with imagery that is absolutely inconsistent with simple, or even complex, rock kinetics.

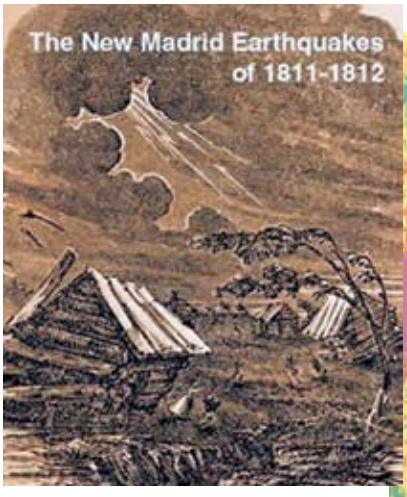
The series of quakes tore open huge chasms that belched forth noxious fumes, created round mounds that apparently burnt trees to cinders, and shook the land like waves on the ocean. Parts of the Mississippi River reversed direction for a while, lakes disappeared, and new lakes emerged and filled with hot, stinky water. This area then suffered "aftershocks" for the next 200 years.

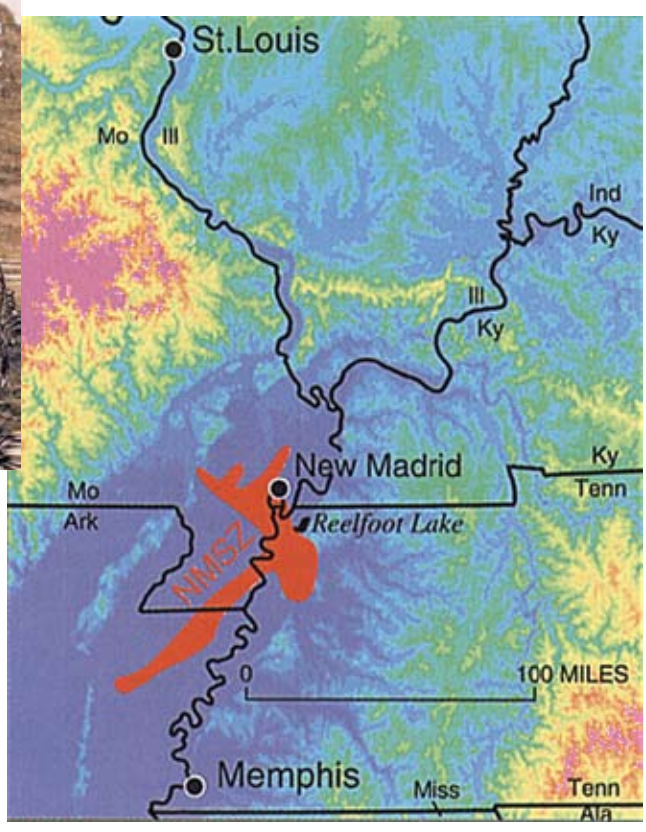
There is no observed plate boundary or fault line around the New Madrid Seismic Zone, although seismologists have mapped out where one could be, based on the seismic data. They call this thing the "Reelfoot Rift," which was created when North America threatened to break into two parts, but then stopped.

There is now a developing situation in Nevada, far from any known fault line, where there have been well over a thousand

The deepest man-made hole, the Kola Superdeep Borehole in Russia, is just over 12 kilometers deep.

The conventional, statistically based theory holds that drilling 3 to 6 kilometers down, there would be a transition into basaltic basement rock (left). But the Kola borehole never reached basalt; they found gneiss (right), which was so hot that it destroyed drill bits.





Between 1811 and 1812, a series of magnitude 8-plus earthquakes hit the New Madrid Seismic Zone, shaking the land like waves on the ocean, with aftershocks that continued for 200 years. Although there is no plate boundary or fault observed there, seismologists mapped out where one could be, based on the seismic data, called the "Reelfoot Rift" (see map). Reelfoot Lake supposedly covers the rift.

earthquakes, reaching up to M 4.0, in the past two weeks. Seismologists are now scrambling to describe the existence of a "previously unknown fault" underneath this area. Perhaps, earthquakes actually create the faults, rather than vice versa!

Now, look at the observations and measurements both leading up to earthquakes and during them. Since antiquity, people have described various precursor phenomena, such as anomalous animal activity, the smelling of "noxious gases," and strange weather before an earthquake strikes. Recently, with the advent of satellite technology, other phenomena have been observed days to weeks before an earthquake, such as changes in the ionosphere, ultra-low frequency magnetic variations, infrared anomalies, increased air conductivity, and other electromagnetic and chemical phenomena. During the earthquake, people have described seeing strange lights and fires near rifting areas.

The processes deep in the Earth's crust responsible for building up this potential are currently unknown. Thomas Gold[3] has proposed, based on these and other anomalies, that earthquakes and other tectonic events are caused in large part by the exhalation of gases from deep below the Earth's crust. This gaseous discharge then results in many of the precursors seen by people (and animals). Russian academician Sergey Pulinets[4] suggests that radon from radioactive decay of uranium is released near the time and location of earthquakes, which then causes a cascade of events generating the various precursors.

NASA scientist Friede-

3. http://books.google.com/books?id= PEyYSUO6hgYC&printsec=frontcover&dq=intitle: deepintitle:hotintitle:biosphere&hl=en&ei= qAezTdyTIcTqgQf368zGCw&sa=X&oi=book_result& ct=result&resnum=1&ved=0CDYQ6AEwAA

4. http://www.larouchepac.com/node/17944

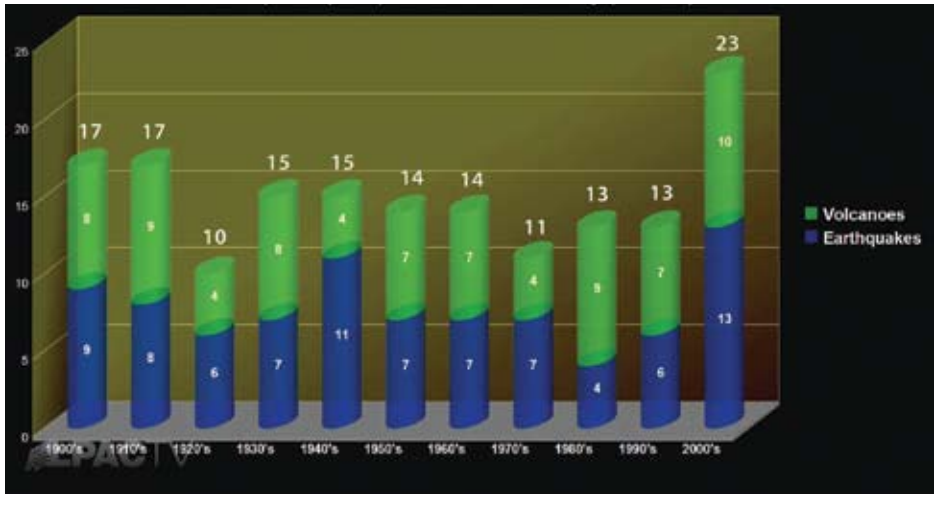
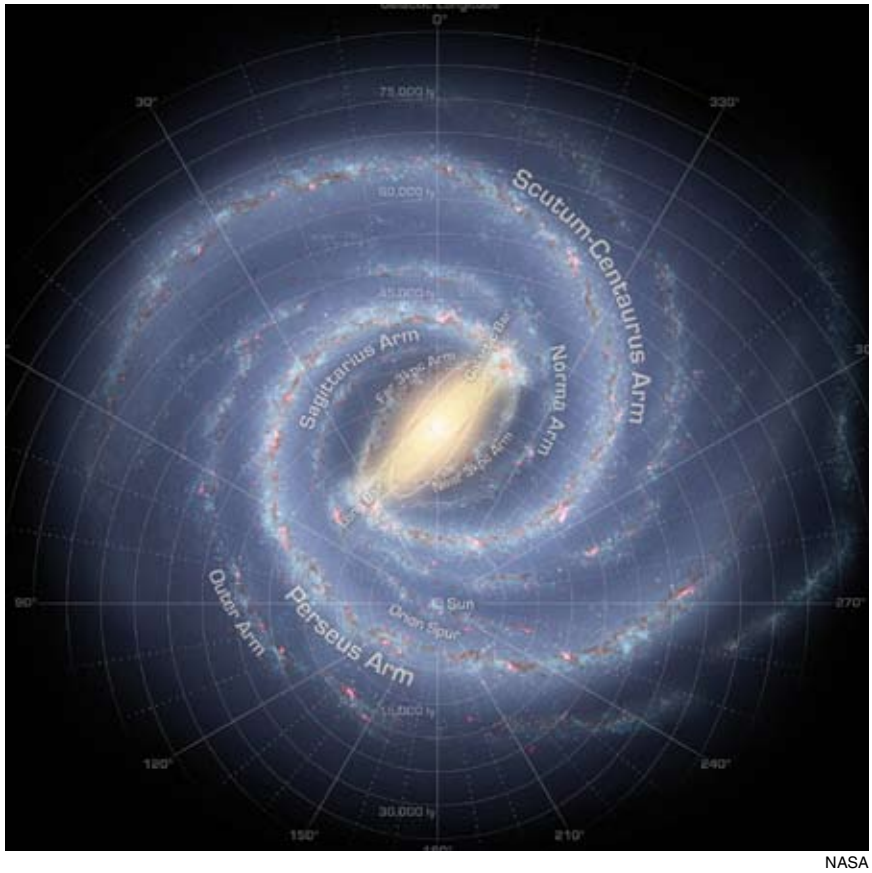


Figure 1
TOTAL GREAT EARTHQUAKE (M8+) AND VOLCANIC ACTIVITY (VEI-4+), 1900-2009
There is a correspondence between the increase in solar activity and that of great earthquakes and volcanoes (as pictured here). These images are from the LPAC-TV video, "The Shocking Rise in Great Quakes," www.larouchepac.com/node/17916.

mann Freund[5] has demonstrated that compression of rock will generate various electric currents that could cause several of the observed phenomena. All of these hypotheses are testable, and may play a role, but everything adds up to a picture that leaves the usual geophysics dogmas in the dust.

Although the result of the earthquake is the movement of a large mass of rock, the movement of rock cannot be held to be the cause of the earthquake. Whatever moves the rock, must be built up as potential, which then begins to "burn" some time, leading up to the actual explosion. It appears that some change in the environment around the quake zone causes the fuse to be lit, which will then be followed some time soon after by the actual quake. It is likely, because large quakes also coincide closely with solar flare events from the Sun, that the trigger is formed by an interaction with the environment far off the surface of the Earth.

The moral of this story is that this immense transformation of energy is not caused by the weight on top of the rock, and certainly not by man-made reservoirs. The shakes created by these reservoirs are surface shakes. The idea that the pressure of the water will generate large earthquakes is rooted in the typical geophysics dogma, that rubbing rocks together will give you a quake. It is reminiscent of the old trick of squeezing water out of a buffalo nickel. Constructing reservoirs along NAWAPA may help us sound out existing stresses built up in the crust, and may indeed be useful in relieving some of those stresses, but, as we will see in the next section of this report, there is another factor involved with large quakes that cannot, at this moment, be touched by Man.



NASA

Artist's conception of the spiral structure of the Milky Way, with two major stellar arms and a central bar. Infrared data from NASA's Spitzer Space Telescope, indicate that the Milky Way's spiral structure is dominated by two arms that wrap off the ends of a central bar of stars. Our Sun lies near a small, partial arm called the Orion Arm, or Orion Spur, located between the Sagittarius and Perseus arms.

Paleotectonics

Scientists from all over the world have demonstrated that there is a close correspondence between large earthquakes and solar cycles. For example, Gerald Duma[6] has taken the catalog of all earthquakes in four parts of the planet over the entire 20th Century, and categorized them based on time of occurrence during the day. In all four places, he found a clear increase of quake activity during the local night, versus the local day. He also found that increases in seismic energy release tend to follow increases of solar activity, in an 11-year cycle.

Examining the number of earthquakes of magnitude 8.0 or greater, and later also 7.9 and greater, Laurence Hecht found a shocking rise over all previous decades back to 1900 in the decade 2000 to 2009 (see editorial).[7] Although powerful earthquakes could occur during weak solar cycles, Hecht pointed out that the two most powerful earthquakes recorded on seismometers, the 1960 magnitude 9.5 in Chile and the 1964 magnitude 9.2 in Alaska, followed the solar maximum of 1960, which exhibited the highest recorded maximum monthly sunspot number (SSN = 201.3) since records began in 1755.

Our planet is an integral part of the Solar System. As such, it shows clear resonances with processes in the Sun, and with other planets. The whole system is also part of a galactic system, along with the Crab Nebula, which itself is part of a greater local group of intergalactic spacetime, which includes over 30 galaxies, and beyond that, supergroups and superclusters. What is emerging from the research into earthquake precursors, and correspondences with other phenomena of our galaxy, is a scientific revolution.

Study of the last 550 million years of our planet's fossil record reveals a cyclic change over a period of about 62 million years, give or take a few million. This cycle appears as a growing and shrinking of the number of distinct types of organisms, which

5. http://earthquake.usgs.gov/regional/nca/seminars/2009-02-04/

6. http://meetingorganizer.copernicus.org/EGU2011/ EGU2011-5987.pdf

7. http://www.larouchepac.com/node/17916

Mark A. Wilson

Sedimentary rock in southwestern Utah. Sedimentary layers usually form underwater, and so most of the fossils in the layers are of ocean creatures. There are several methods of dating the layers, including dating of the discontinuities, where contiguous layers may have been deposited millions of years apart in time.

grows and shrinks in an apparently regular tempo. Some of the most severe dips in the numbers are what we call "mass extinctions," but those statistical variations ignore the overall anti-entropic development of the biosphere. After each so-called dip, there is a resurgence of life on the planet, always including advances that can be measured in energy flux density. Hence, there is an overall growth of both number, and intensity, of life in the biosphere, which is punctuated by something that reduces, sometimes catastrophically, the number in a rather regular rhythm.

According to best current estimates and models, Medvedev and Melott (2007)[8] have noted that the 62-million-year cycle of biodiversity coincides with the path of our Solar System up and down through the plane of the Milky Way galaxy. Melott and Bambach (2009)[9] later also note another cycle, which is more intriguing, and bears on our study of earthquakes and other Earth-shaking processes. The picture that emerges, is that our planet pulses, in continental uplift and collapse. This pulse produces massive volcanic outflows and earthquakes, and coincides with the periodic extinctions of life on the planet.

There are several pieces of this puzzle, which assemble into a strange new phenomenon touching upon our discussion of earthquakes.

The record of life on the Earth is preserved in sedimentary rocks. It is well known that sedimentary rock rarely forms on continents, but rather underwater. The vast majority of animal fossils are thus of ocean creatures. The rock layers which contain dinosaur or other land animal bones typically represent an area that used to be downriver, or some kind of sinkhole that the animals fell into as they were dying, or perhaps an area that was catastrophically flooded at some point. In fact, much of the vast sedimentary rock beds found in the central United States were laid down during several episodes of "epeiric" seas, which divide North America into two separate continents, East and West.

Imagine an area of land that is under a few hundred feet of water. This area will be undergoing sedimentation, and thus will be represented some day as sedimentary rock. Now, imagine that some unknown process makes the ocean depth shrink to nothing. This could happen either by lowering the ocean levels as a whole (as when water gets locked up in polar icecaps), or by raising the level of the land, so-called continental uplift. If this area remains dry for a few million years, and then gets resubmerged, sediments will resume piling up on the floor, and there will thus be a gap in the sedimentary record, called a discontinuity.

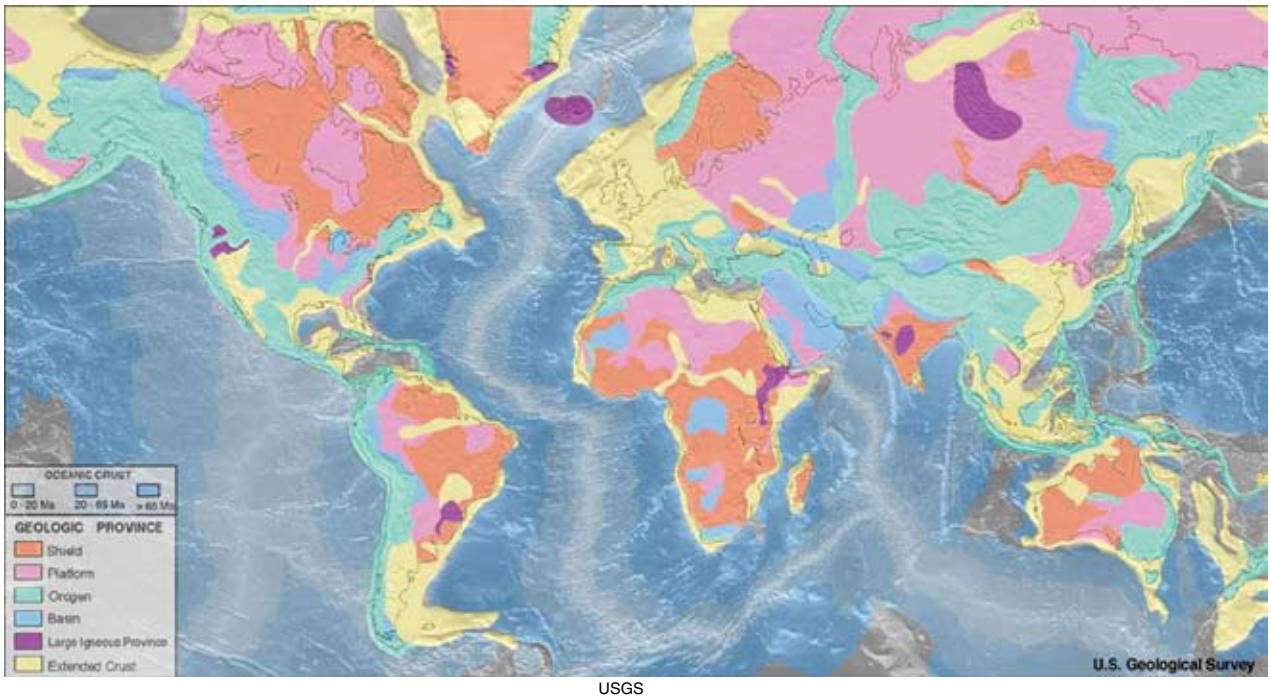
The problem for us is that, as one follows the layers of rock upwards in a rock face, there may be a point where one layer of sedimentary rock is followed immediately by another layer of sedimentary rock that was put down millions of years later. In other words, there may have been a gap of several million years in which no sediments were laid down, followed by a period of renewed sedimentation. Some scientists, such as Shanan Peters,[10] have

Much of the sedimentary rock beds in the central United States were laid down during several episodes of epeiric seas, which divided North America into two separated continents, as shown here. This image, titled "Paleogeography of North America during the late Campanian Stage of the Late Cretaceous," is from Scott D. Sampson, Mark A. Loewen, Andrew A. Farke, Eric M. Roberts, Catherine A. Forster, Joshua A. Smith, and Alan L. Titus (2010). "New Horned Dinosaurs from Utah Provide Evidence for Intracontinental Dinosaur Endemism," PLoS ONE, Vol. 5, No. 9.

8. http://arxiv.org/PS_cache/astro-ph/pdf/0602/0602092v3.pdf

9. http://arxiv.org/ftp/arxiv/papers/1011/1011.4496.pdf

10. http://strata.geology.wisc.edu/vita/reprints/Peters2008.pdf



USGS

A few of the largest Large Igneous Provinces are shown (dark purple areas) on this geological map. The LIPS are massive structures of mafic igneous rock, created when lava poured onto the surface of the Earth over millions of years.

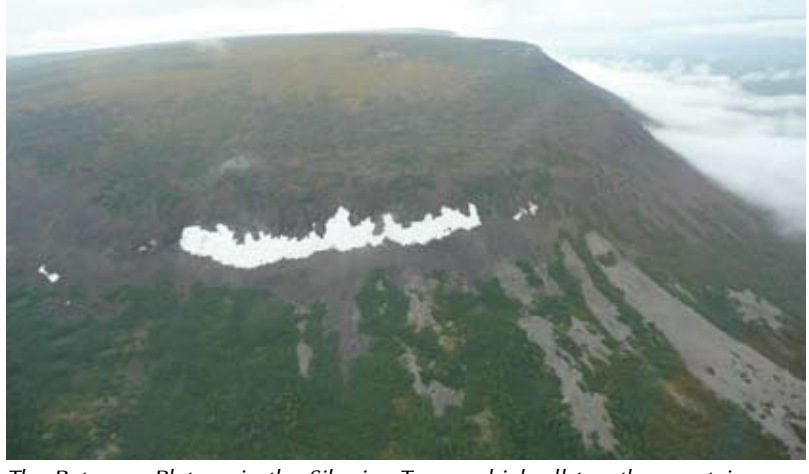
found that it is possible to recognize when sedimentation rates are slowing down, as a gap is approached, and that these periods of slowing sedimentation recur on an approximately 60-million-year cycle. Indeed, Melott and Bambach note that it is during these periods, when rates of sedimentation begin to slow, that low points of biodiversity are reached (including the mass extinctions).

Another piece of the puzzle is shown by ancient ocean composition. Aspects of this record is preserved in the sedimentary rocks. Geochemists can look at the weights of various elements in the rock, and based on how these weights vary, can get some sense of what must have been in the ocean water. One particular element observed to vary is strontium, element 38. Strontium found in ocean sediment is typically lighter than that found in continental rock. If ocean sediments are found to contain somewhat heavier strontium than usual, it is a sign that either the production of ocean water at hydrothermal vents went down at that time, or that heavier strontium was being delivered to those sediments by increased erosion of continental rock by rivers. More rapid delivery of heavier strontium would then mean that the river water was more rapidly eroding the continental rock, either because there were more rivers, or because the rivers were originating at higher altitudes, and thus the water moved much faster.

Melott and Bambach show that strontium in the sedimentary record changes weight with a

California State University at Long Beach

An example of mafic sills that form the Large Igneous Provinces.



The Putorana Plateau in the Siberian Traps, which all together contain more than 2 million cubic kilometers of basalt.

ESO

Earth must be studied as an integral manifestation of processes of the galaxy as a whole. Here, an early morning view of the Milky Way, captured by the Very Large Telescope array in the European Space Organization's Paranal observatory in Chile. Four telescopes work together, allowing astronomers to see details up to 25 times finer than with the individual telescopes. The Moon is just rising and the zodiacal light shines above it, while the Milky Way stretches across the sky opposite the observatory.

roughly 60-million-year period, such that the weight goes down as sediment deposition goes up, and the weight goes up as deposition goes down. In other words, more continental erosion took place as sedimentation rates went down, and as biodiversity plummeted, but the erosion slowed while sedimentation rates went up and the biosphere recovered.

The last piece of Melott and Bambach's puzzle is volcanic. At several places on the surface of the Earth, we find what are called Large Igneous Provinces (LIPs). A LIP is a typically massive structure of mafic igneous rock (usually basalts) that was created when loads of lava poured out onto the surface of the Earth over a period as long as several million years. One of the most interesting LIPs is known as the Siberian Traps, a set of four distinct structures in Siberia which collectively contain well over 2 million cubic kilometers of basalt. The outflow of lava began around 251 million years ago, and lasted about 2 million years. This event is widely believed to be at least part of the reason that about 98 percent of all types of creatures disappeared in the so-called Permian-Triassic extinction, about four 62 million year cycles before the dinosaurs became extinct.

LIPs represent the building up of pressure under the crust, and the bursting forth of enormous quantities of liquid rock. The earliest strata of rock contain evidence of LIP events, and several scientists, such as Prokoph, et al. (2004),[11] have noted that there are several frequencies of occurrence through time. If one only looks at LIPs that occurred on continental crust, one will get a clear signal of increasing and decreasing amounts of such liquid rock floods over a period of about 60 million years, which tend to coincide with increasing strontium weights and decreasing sedimentation rates.

What does all this mean? Each of these points of evidence—sedimentation rates, strontium weight, and LIP occurrence—point to the fact that the crust of the Earth, particularly that covered by continental rock, pulses in uplift and collapse, with a period of about 60 million years, and that each of these uplifts is accompanied by a corresponding decrease in the number of types of organisms on the planet. As uplift transitions into collapse, the organisms quickly rebound to higher-than-previous diversities, and higher states of organization.

A Revolution in Science

Currently, there is no adequate explanation of this apparent "Heartbeat of the Earth." Most of the attempts at finding a cause revert back to the usual mechanism of mantle convection, which supposedly drives the tectonic plate conveyor belt. As we have seen, this model is not very interesting, or truthful. By combining the cycles with the earthquake precursors, we begin to see that a scientific revolution is afoot.

Perhaps changes within the Earth will find their cause in cosmic radiation. It is well known that our climate is almost completely driven by the dynamic between the Sun and galactic cosmic rays (see Svensmark 2007[12]). It has also been recently shown that the eruptions of volcanoes could also be triggered by increasing cosmic ray storms (Ebisuzaki, et al. 2010[13]). We also know that the highest energy cosmic rays, those produced in locations such as the Crab nebula and emitted from other galaxies, are capable of passing through the core of the Earth. Perhaps the very deepest reaches of our planet are in intimate discussion with the rest of the galaxy, in real time.

What is clear, is that this picture is of an Earth which does not generate its internal activity all by its lonesome. Thus, it cannot be studied as an object unto itself, a closed system, but instead must be studied as an integral manifestation of processes of the galaxy as a whole. Understanding how the insides of the Earth function must thus be viewed as a branch of true astrophysics, and as a laboratory that we have access to, if

11. http://www.geofys.dk/waveletcourse/articles/8%20-%20Time-Series%20Analysis%20of%20Large%20Igneous%20Provinces.pdf

12. http://www.space.dtu.dk/upload/institutter/space/forskning/05_afdelinger/sun-climate/full_text_publications/svensmark_2007cosmoclimatology.pdf

13. http://tiny.cc/f1is0

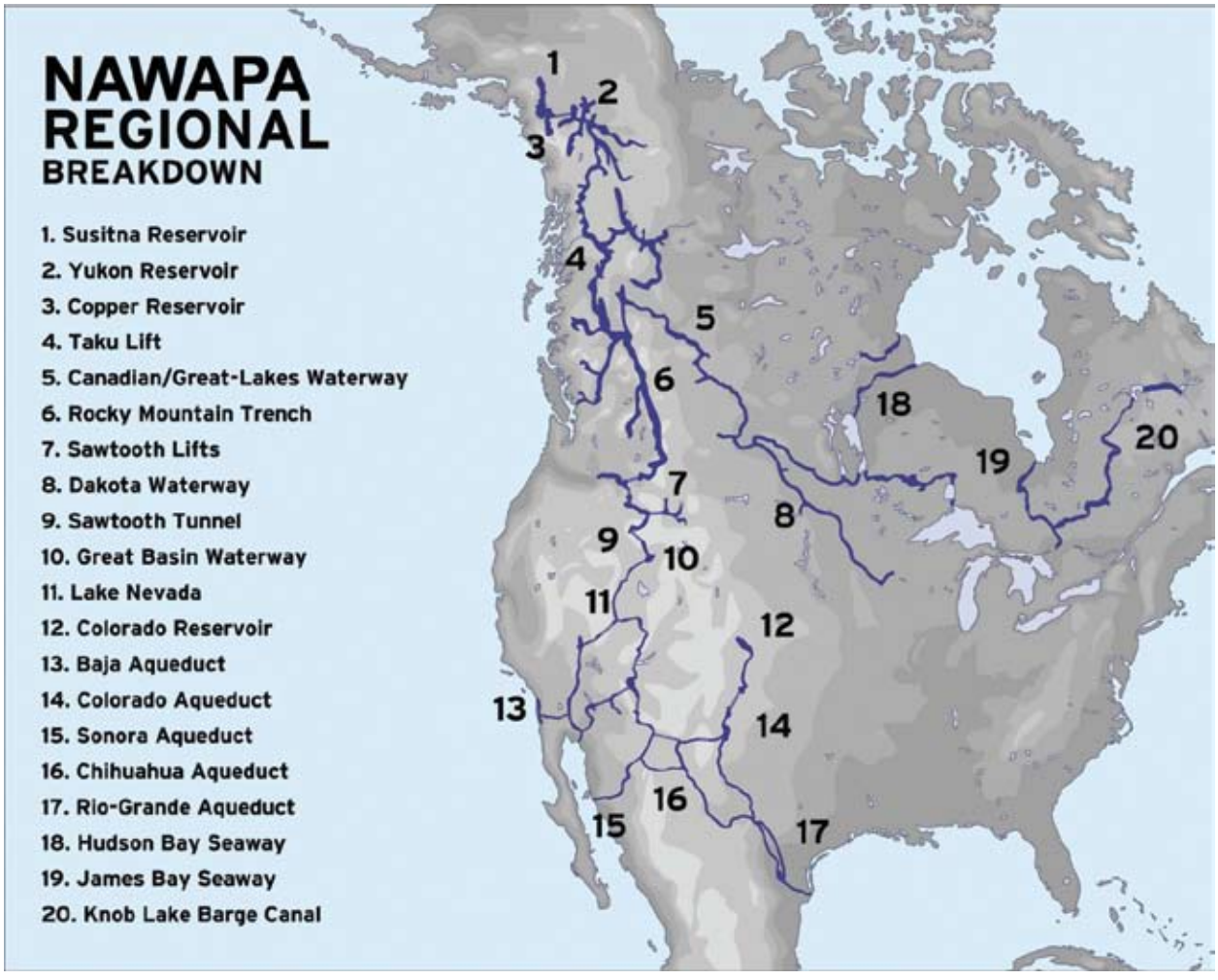


Figure 2
NAWAPA PROJECT OVERVIEW

The North American Water and Power Alliance, first proposed in the 1960s, will capture 20 percent of the 800 million acre feet of water that runs off yearly into the Pacific and Arctic Oceans, and route it into the dry and barren areas of the western half of the continent.

NAWAPA will build strategically placed dams and tunnels, creating a collection system of major new reservoirs and canals, taking advantage of the natural topography of the Rocky Mountain Chain, and effecting a distribution of 160 million acre feet of water per year to parched lands and strategic water ways.

Of this total, 22 million acre feet would go to the Canadian Prairie Provinces, 69 million acre feet to U.S. states, and 21 million acre feet to Northern Mexico. This will irrigate 86,000 square miles of land, doubling the current irrigable acreage west of the Mississippi. It will replace the increasingly inefficient and limited sources of well water with a permanent source from gravity flow, relieving agriculture of pumping costs and restoring its productivity.

For more information, see http://www.larouchepac.com/infrastructure.

we build the technology needed in order to plumb the depths. Hence, NAWAPA.

The reservoirs we construct with NAWAPA are really a method of tuning the region where the Galaxy meets the Earth. By adjusting water levels, we may learn more about how and why the crust shakes, but we will also provide the water to agriculture, which will increase the moisture content in the air, and provide a more dynamic electric circuit between the ground and atmosphere. At the same time, the transport routes of water, through deep tunnels, indicate the advances in drilling technology that will have to be made, which might allow us to actually dream of drilling down to several hundred kilometers, to see what is really down there. NAWAPA will not only be a boon to geophysics, but will be a laboratory for developing an experimental understanding of how the Creator's universe works.

Nuclear Power and NAWAPA: What Will It Take?

by DeWitt Moss

The North American Water and Power Alliance, proposed in the 1960s, is a program to truly green the United States, and uplift the nation and world in the process. For a brief video overview of the project, see www.larouchepac.com/node/15570. Other NAWAPA maps, videos, and interviews are available at www.larouchepac.com.

DeWitt Moss is a retired nuclear engineer and former director of the National Water Resources Association (NWRA) for Idaho. He also was involved with the fuel selection and testing of the Fast Flux Test Facility at Hanford, Washington. His article also includes excerpts transcribed from his interviews on the subject.

The North American Water and Power Alliance (NAWAPA) is a very impressive, almost overwhelming project: It would take 17 percent of the nearly 800 million acre/feet of runoff water out of northern Canada and Alaska, and bring it south, distributing it across some of the plains provinces of Canada, and much of it down through Idaho, Montana, other Western states, and Mexico.

In the course of recent discussions and technical news, I have reflected on the monumental task confronting us with the NAWAPA program. The concerns may be surmountable and solved with extensive and expert management, but we should be aware of the issues in order to address them in the NAWAPA context.

Since NAWAPA was first conceived in the early 1960s, and

relooked at in the 1980s, the United States has gone from 160 million people to 311 million people today. There is not one state in the Western part of the United States that is not struggling for water—for agriculture, for fish and wildlife, for hydropower, and communities. To the extent that there can be a feasible way to get this water down, without the destruction of the wild and scenic areas and critical habitat, through Canada and through the northern part of the Montana-Idaho region of the United States, there is probably nothing more valuable to the nation than getting water into Utah, Nevada, Idaho, New Mexico, Texas, California, and so on, and also Mexico.

Mexico would be allocated almost 20 million acre-feet under NAWAPA. Right now, Mexico is getting just 1.5 million acre-feet from the Colorado River, but that water is inherently salty, because of runoff, and is probably too saline to use in producing crops. The addition of 20 million acre-feet will give Mexico adequate water at enough dilution for agricultural production.

In California, the upper San Joaquin Valley and the westlands irrigation district had to idle upwards of 500,000 acres last year, and NAWAPA would provide an alternate source of water for these people. When you move farther on down into the Central Valley, the number I read 20 years ago, is that some of that land in the middle of the valley had subsided 20 to 50 feet because of the overpumping of ground water. So, there is an opportunity in that area to provide new water and use the excess water for aquifer recharge.

The same is the case in the state of Idaho. We are not desperate in Idaho, but we are gradually depleting our 200-400 million acre-feet Snake River aquifer, by pumping out of it. Our aquifer in Idaho is probably 50 percent of what it was just 40 years ago. We can tell that exactly—it's not a mystery: This water comes out through the canyon walls of the Snake River, and it's measured. At one time it was 7,000 cubic feet per second, and it's now getting down to 4,000 to 5,000 cubic feet per second. We are pumping it out to irrigate more agricultural land.

In the Tucson/Yuma/Blythe area of Arizona, the ground water there has been pumped out to the point that it's uneconomical to pump any more. There, 300,000 to 400,000 acres are idled; the water is now down too deep. In the Central Arizona Project and those areas, the water from NAWAPA would supplement the water supply and any extra could be put back into the aquifer. This would be an absolute boon.

Probably the picture doesn't differ at any major U.S. aquifer that you look at, which services agriculture and municipalities. Industry can generally get by with river-type water—industry generally doesn't need that pure type of water. But because industry needs so much water, it heats up the streams, and then you get the problems for fish and wildlife that come with that reduced flow, heat pollution, and algae.

If we talk about 50 million acre-feet of water coming south, down through the mountain states area, it has the potential to provide adequate water for 50 million additional people. If it takes an average of 5 or 6 acre-feet of

The Rio Grande at White Rock, N.M. The United States and Mexico share the water of the river, but there is now not enough river water to supply all the users—a condition that NAWAPA will alleviate.

City of Jerome

The Northside Canal Company canal in Jerome, Idaho. Idaho, like other Western states, is depleting its underground aquifer.

FAO

A farmer works on an irrigation canal in Mexico. NAWAPA would provide 20 million acre-feet of usable water to Mexico.

water to irrigate an acre of land to grow one crop, or two crops a year, we would have the ability to grow 8 to 10 million more acres of land.

I know the Western water problems relatively well. I was a director for the Northside Canal Company, which manages 165,000 acres of surface-irrigated water. We were changing then from gravity irrigation to sprinkler systems, which are much more efficient: Sprinkler systems only put the amount of water on the crop that it needs, and there is not much percolation down to the underground aquifer. The sprinkler system uses about 2 acre feet per acre, compared to 4 to 5 acre feet of water per acre used by a gravity system.

As part of this program, I was involved with the National Water Resource Association. I served on that for approximately 10 or 12 years, which gave me the opportunity to see many of the water issues throughout the Western states.

NNSA

Yellowcake, the milled uranium ore used to produce uranium fuel for nuclear reactors. We have enough uranium for now, but to provide adequate fuel for the numbers of new nuclear reactors required, we need to reprocess spent nuclear fuel, not bury it. The spent fuel from one 1,000-MW reactor over 40 years would yield the equivalent of 5 billion gallons of oil.

Somewhere around 80 percent of the rural and small city population rely on groundwater for their municipal water supplies, so NAWAPA would directly impact them. There is another aspect to this also. It is typical of rural America today that there are few industries, few challenging jobs, so the young people move away when they grow up, because there is no work for them. This is now the most difficult time in the last many decades for a young person to get a job, and develop a profession. It's one of the most difficult times I ever envisioned. You can get an education, and you still can't get a job. NAWAPA can change this.

NAWAPA's Power Requirements

The NAWAPA program, as presented by the Parsons Engineering Company in the 1960s, will require copious quantities of power to provide for pumping, railways, cities and communities, resource and infrastructure development, and other related needs. Nuclear and hydropower are viewed as the most environmentally preferred and readily available to minimize the carbon impact of the energy required. The hydro contribution should be incorporated where the water quantities and head justify such use—but the opportunities may have their limits.

In some instances of unpopulated and remote areas, natural gas may be an option, if it is readily available to a given area. However, natural gas power plants still have a carbon impact to the atmosphere, about one-half that of a coal-fired plant. A policy decision will need to be made regarding that carbon impact versus the cost of a power transmission line connecting to a larger proposed nuclear complex. Natural gas plants could also be considered, as required, for back-up power supply during normal nuclear outages for maintenance and repairs.

Let us consider the following: NAWAPA may require 30 or more nuclear stations to be operable, some as early as 10 to 15 years from the start and others up to 10 to 15 years later. These reactors will average out at 600 to 1,200 megawatts electric. Add to this nuclear plant requirement the projections that the United States will need 46 or more new nuclear plants by 2030 to meet U.S. power demand and Washington's target for reducing greenhouse gases. The question is, does this country have the industrial infrastructure, including the manufacturing-fabrication capacity, to do this?

In my assessment, probably not, without a Manhattan Project-type of commitment from the U.S. government and industry, in addition to cost guarantees to utilities.

Proven and tested technical expertise, quality assurance and control practices, material standards, operating and maintenance procedures, reliable equipment, operations and safety procedures and systems are paramount. These plants are massive, complex, and expensive, requiring demonstrated proven technology. In the case of new untested concepts, such as the PRISM, LMFBR, or IFR, discussed below, a demonstration plant is definitely in order.

Another question is, does the United States have the available uranium and plutonium to fuel a planned 70 to 80 nuclear reactors in a 20-year period, or do we have to consider reprocessing some existing inventory of spent fuel? Reprocessing facilities or new fuel enrichment facilities may be required. We possibly have weapons-grade material that could be blended for fuel. Also, the French company Areva plans to start building an enrichment plant in Idaho Falls in 2012.

In addition to the above-mentioned manufacturing capability, do we have in this country the necessary and qualified engineering talent to assure that these plants are built to the rigid required standard, on schedule and within the required costs? If not, we need to develop this expertise via training and education.

The cost burden of nuclear plants is definitely impacted by the recent surge of building material commodity prices. I quote from the *Global Energy Reporter* of Jan. 16, 2011. "In 2009,

The Sawtooth Lift

A crucial inflection point in the 1964 NAWAPA design of the Ralph M. Parsons Co. is the transfer function, where flows from the collection function exiting the Rocky Mountain Trench are transferred from the Columbia Basin up into the Great Basin and on through the distribution network. This transfer function hinges on the Sawtooth Lift, consisting of six pump lifts, for a total of 2,450 feet, with a flow rate of 85,500 cubic feet per second.

This would require 26 gigawatts of power. Powering this 26-GW pumping system with the most advanced nuclear power plants can serve as a trigger for a long-awaited nuclear renaissance in the United States.

—*Michael Kirsch,*

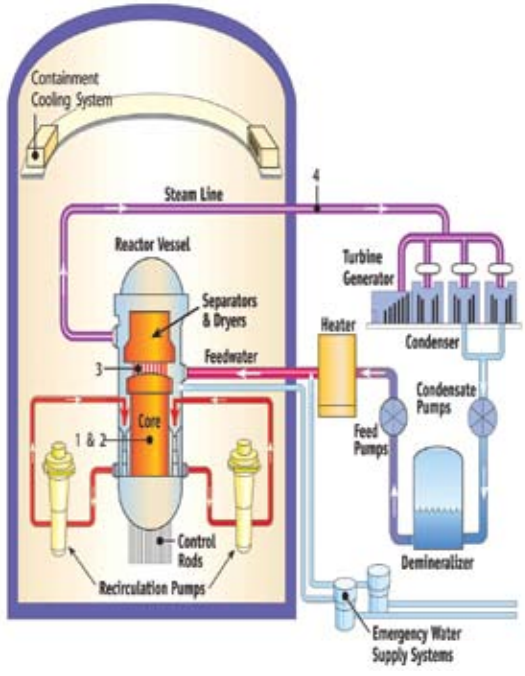


Figure 1
BOILING WATER REACTOR

The Boiling Water Reactor is the second most common commercial reactor type. In the BWR, water circulates through the reactor core, where the fission process heats it to boiling, converting it to steam. Steam separators remove water droplets from the steam, and the steam then goes to the turbine generator, which produces electricity. After it passes through the turbine, the steam goes to the condenser, where it is condensed into water. The cooled water is pumped from the condenser and sent back to the reactor core to begin the cycle again. The BWR has only two loops: the first one, which goes from the reactor core to the generator, and a second loop from the condenser to the cooling tower.

The control rods in the BWR come up from the bottom, instead of from the top. There is also a Torus or Suppression Pool below the reactor, which is used to remove heat in an emergency.

Source: NRC

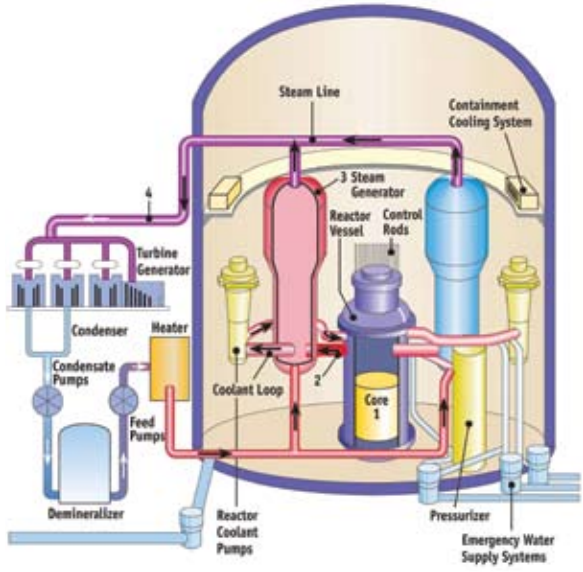


Figure 2
PRESSURIZED WATER REACTOR

The Pressurized Water Reactor is the most common commercial reactor type, and is similar to the BWR. The fission process in the reactor core heats pressurized water in a primary loop, which carries the heat to the steam generator. There it is vaporized and moves into a secondary coolant loop, where the resulting steam turns the turbine generators. The unused steam passes to a condenser, and is recycled back to the reactor core. A third loop, between the condenser and a cooling tower, cools the water in the condenser. High pressure keeps the water from boiling.

Source: NRC

MIT doubled its forecasted construction costs of new nuclear plants, while the U.S. Information Administration increased its 2009 estimate by 37 percent just this past December. All cost estimates have a huge amount of uncertainty—there is a big unknown in how reliable the contractors are going to be in coming through with their estimated costs. And similarly, how good they'll be at constructing them on time."

These are some of the major issues and obstacles that will confront NAWAPA tomorrow and into the foreseeable years to come. They probably are resolvable with adequate program planning and resources applied. It won't be simple, but with expert leadership, it is doable!

The Nuclear Options for NAWAPA

There are many nuclear power options to be considered. It is recognized that some of the concepts, discussed briefly here, will require an in-depth, independent evaluation, together with policy considerations to determine the preferred concept. Three engineering firms come to mind: Bechtel, Battelle Memorial Institute, and Fluor; there may be others.

The status of the nuclear and materials technology, availability of demonstrated fabrication expertise, safety and license approval, waste generated and disposal, economy of size and numbers of plants, capital and operating costs, and any required R&D will all need to be considered in choosing the preferred nuclear concept to be employed. Rigid quality assurance and quality control must be demonstrated through all phases of construction, equipment, materials, and operations. The significant number of plants involved may elicit some development and financial assistance from the chosen nuclear plant vendors.

Here are some of the nuclear power concepts available:

BWR—Boiling Water Reactor. The technology and operating experience are well proven for these light-water-cooled reactors, in sizes from 60 megawatts-electric to more than 1,000 megawatts-electric. Spent fuel is stored at reactor sites, as is the case for any operating U.S. nuclear power plant. Ad-

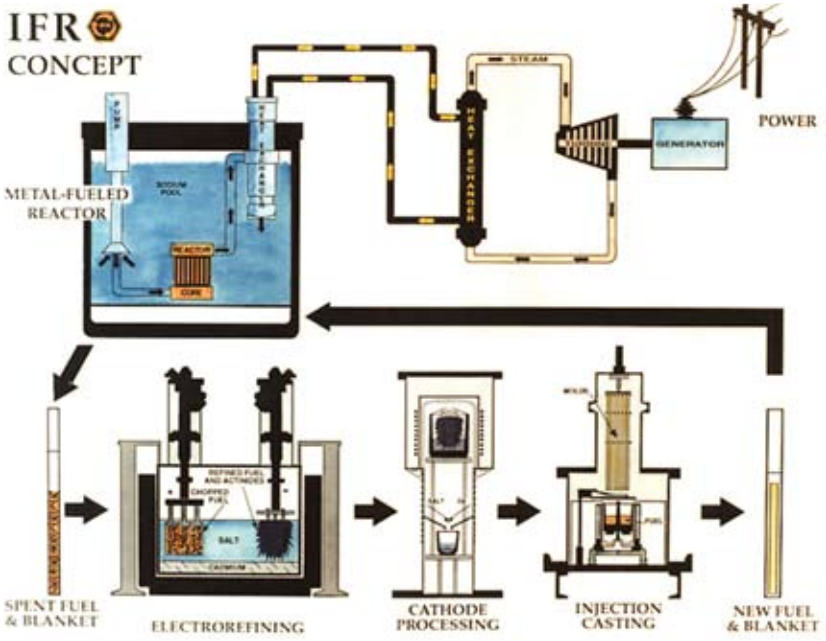


Figure 3
INTEGRAL FAST REACTOR

The Integral Fast Reactor uses fast neutrons (there is no moderator) to breed new fuel in a blanket. It completes the nuclear fuel cycle at the reactor site, reprocessing its spent fuel using electrorefining, and reusing it. The coolant is liquid sodium and the fuel is metallic. Developed at Argonne National Laboratory in the 1980s, the IFR was based on prior research with the EBR-II. The concept was cancelled in 1994, under pressure led by Energy Secretary Hazel O'Leary and Sen. John Kerry, allegedly for reasons of "proliferation."

Source: ANL

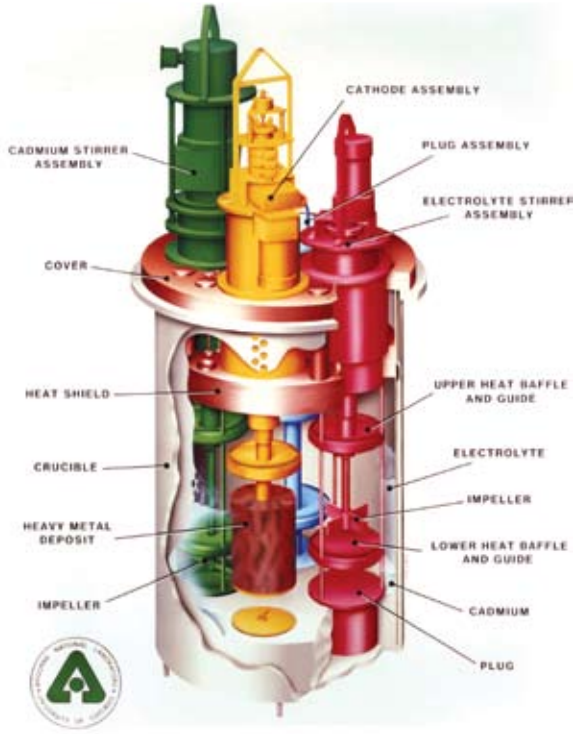


Figure 4
IFR ELECTROREFINER

The unique feature of the IFR concept is its electrorefiner (shown here in an artist's concept), which recycles its spent fuel, returning the long-lived "wastes" to the reactor to be burned up.

Source: DOE

vanced designs provide safer, long-lived mechanically improved plants.

Because thermal reactors produce small amounts of plutonium as a by-product of fission in uranium dioxide, any conventional-chemical reprocessing that separates the plutonium is cause for proliferation concerns. Also, it is an inefficient burner of its 4-6 percent enriched uranium, as is the Pressurized Water Reactor described below. High capital costs and lengthy construction times are a factor, similar for any nuclear concept.

PWR—Pressurized Water Reactor. Approximately 70 percent of the operating nuclear power reactors in the world are the PWR concept. The operating mode, plant equipment, and reactor component materials are similar to those of the BWR. France currently supplies 80 percent of its electrical needs, primarily with PWRs. The experience of PWR successful operation is bolstered by the fact that more than 100 nuclear naval submarines employ the PWR concept.

IFR—Integral Fast Reactor. The IFR concept is a sodium-cooled, pool-type, fast reactor with a closed fuel cycle employing uranium and/or plutonium metal fuel. The EBR-II (Experimental Breeder Reactor-II), a similar concept, was operated successfully for about 20 years. With the proper core and blanket design, the IFR can be configured to breed new fuel. With an attached fuel reprocessing cell, only chemical wastes are generated; plutonium is never outside the hot-cell reactor complex and is, therefore, unavailable for proliferation.

The IFR's design with metal fuel and pool sodium coolant makes it very safe in all modes of operation. Double-walled heat-exchanger tubing is generally used to avoid sodium-water contact, adding to its capital cost. The IFR can be designed to have a high power density, which requires smaller cores to produce a given amount of electricity, when compared to PWRs and BWRs. Because of its lower operating pressure, containment structures are less massive. Operating temperatures are

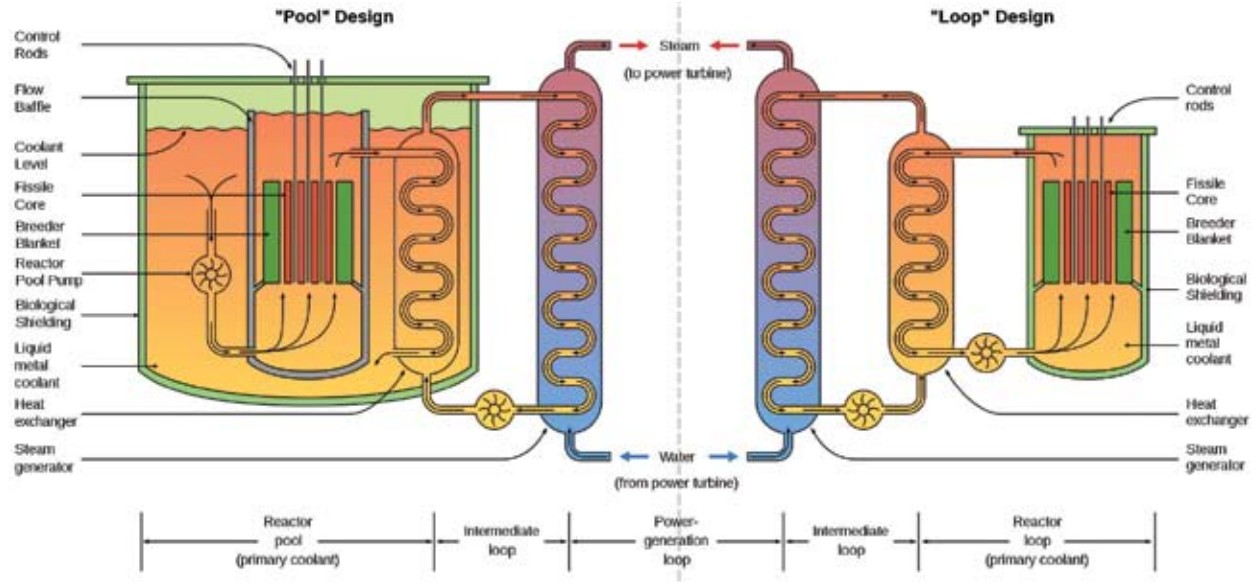


Figure 5
LIQUID METAL FAST BREEDER REACTORS

Liquid metal reactors usually use liquid sodium as the primary coolant that transfers heat from the reactor core to steam, which then is used to power a turbine to generate electricity. In the pool-type reactor (left), the primary heat exchangers and pumps are located inside the reactor tank. The loop-type reactor circulates the primary coolant through heat exchangers located outside the reactor tank. The LMFBR can be operated at much lower pressures and higher temperatures, because of the heat transfer properties of the liquid metal. The U.S. shut down its fast breeder program in the 1970s, for political reasons.

very nominal for the fuels and materials used.

Sodium melts at 208 degrees F and boils at 1,621 degrees F, while the metal-fueled core operates between 640 and 905 degrees F.

LMFBR—Liquid Metal Fast Breeder Reactor. The LMFBR concept is a sodium-cooled, mixed-oxide-fueled (generally) fast flux facility. Alternately, it could be a metal-fueled core. Demonstration plants exist in England, France, Japan, and Russia. Many have been in operation 10 years or so, and most experience is reportedly positive.

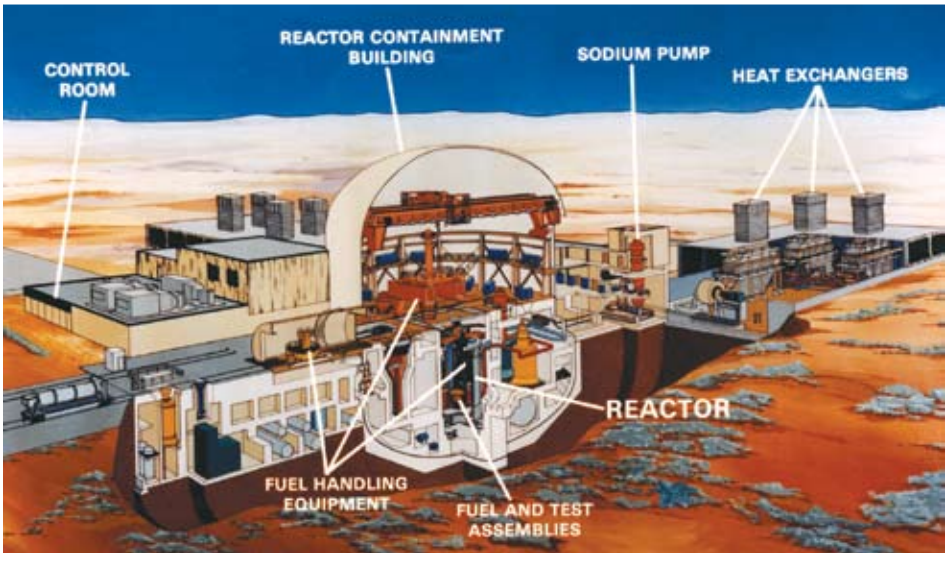


Figure 6
SCHEMATIC OF THE FAST FLUX TEST FACILITY

The FFTF at the Hanford Site in Washington state is a 400-MW sodium-cooled reactor that was designed to test breeder reactor fuels, materials, and components, and also to produce medical isotopes. The reactor was started up in 1980, and despite its very successful operation, political forces shut it down. The FFTF is now in limbo, but could be restarted.

Source: DOE

The largest fast breeder reactor was built in France, the 1,200-megawatt-electric Superphénix. It was shut down in 1998, for political reasons.

The concept was developed to breed plutonium, in order to use it as new fuel, which would extend our uranium resources for hundreds of years. Plutonium fissioning produces more neutrons per fission than uranium, resulting in a better output of energy. It's a fantastic resource. If we didn't ever find another pound of uranium, we could last another 1,000 years!

In my view, we stopped our breeder program when we were the leader in the world. We stopped, and every major country in the world proceeded, based on our developed technology..

The materials technology and nuclear characteristics are well established. In a closed cycle, like the IFR above, plutonium concentration for proliferation would not be a problem; it is recycled into new fuel for the reactor(s).

Metal fuel lends itself to the closed cycle, but the refabrication of irradiated, mixed oxides in a hot-cell complex is relatively undemonstrated. It would be a new concept to license, hence time-consuming and expensive. The United States had a design and construction under way at Clinch River, Tenn. for a demonstration LMFBR plant, but this was cancelled in the early 1980s, for political and economical reasons, and the perceived "lack of need" for a breeder reactor at that particular time.

The FFTF (Fast Flux Test Facility), a sodium-cooled fast flux test facility was built in the late 1970s-early 1980s at Hanford, Wash. It was fueled with mixed oxides of uranium and plutonium to test and evaluate materials, operating characteristics of the equipment and core, and reliability of equipment and other related purposes of a new concept. Although it operated successfully for several years, it is shut down now—but could be restarted.

PRISM—Power Reactor Innovative Small Module. A new concept with significant attributes, the PRISM is a pool-type sodium-cooled fast reactor with four components: a reactor core and associated pumps and heat exchanger, a hot cell to fabricate fuel, an Advanced Recycling Center (ARC) to recycle spent nuclear reactor fuel, and an electrical steam generator producing 622 megawatts-electric. As proposed, one nuclear site would have one, two, or three generators.

The reactor core is fueled with a metallic alloy of uranium, plutonium, and zirconium, which are easily fabricated in an attached hot cell. The proposed reactor core design and shutdown mechanisms make the reactor super safe.

Probably the most innovative and attractive attribute is the ARC. The Advanced Recycling Center would take spent nuclear fuel, now stored at the 100 or so operating nuclear power plants, and expose it to a molten lithium-chloride pool, with an adjacent electroplate anode. The uranium-based fuel would be dissolved, deposited and collected on the anode, and made into new metallic fuel.

If employed, the ARC could extract and burn up 90 percent of the uranium, compared with the 1-2 percent burn-up in light water reactors. Proliferation of uranium and plutonium are nonexistent in this concept because the fuel never leaves the reactor, hot cell, and ARC complex.

In the United States, 100 nuclear power plants produce 20 tons of spent fuel per plant per year for a 60-year lifetime, a total accumulation of 120,000 tons of spent fuel. Twenty-six PRISM-ARC plants can consume 120,000 tons of spent fuel, while producing 50,000 megawatts-electric—thus avoiding the emission of 400,000,000 tons of carbon dioxide every year. It would, also, consume our spent fuel inventory, avoiding expensive and time-sensitive storage. Only small quantities of radioactive "waste" would need storage at a site such as Yucca Mountain.

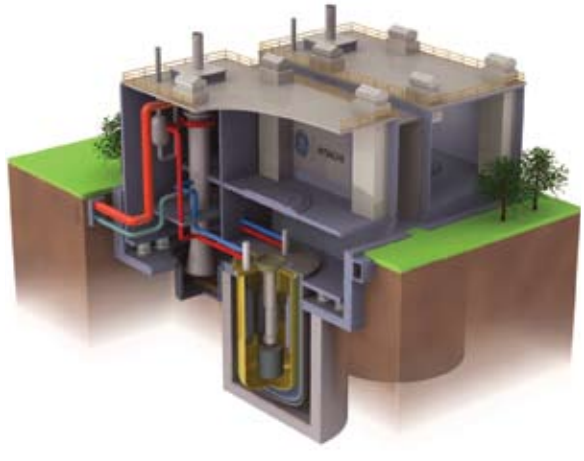


Figure 7
PRISM

The PRISM (Power Reactor Innovative Small Module) is a GE-Hitachi design similar to the IFR concept. It is a liquid-metal-cooled fast breeder, located below ground, which has an Advanced Recycling Center on site.

GE-Hitachi has initiated preliminary licensing steps for a single reactor and a 50 ton/year ARC separations facility. Its estimate for a demonstration plant to be available by 2020, would cost $3.2 billion over a 10-year period. This is an extremely safe concept, with proven reactor materials and equipment, and it could be a most reasonable and practical method to dispose of the tremendous spent fuel inventory now stored at U.S. reactor sites. The ARC concept is a patented, electrometallurgical process—but it needs to be demonstrated and verified.

We have adequate uranium available for fuel for the foreseeable future. A pound of uranium, as found in nature, has an energy equivalent of about 7,500 barrels (bbl) of oil, or 1,500 tons (3,000,000 pounds) of coal. Uranium in nature is 0.7 percent U-235 (fissionable), and 99.3 percent U-238. Commercial reactor nuclear fuel is normally enriched to about 4-6 percent U-235.

We now store the 40- to 50-year spent fuel inventory of our commercial nuclear power plants at the power plant sites, because we have no fuel reprocessing plants operable. Jimmy Carter came along as President and said "I do not want to reprocess fuels," because of proliferation concerns. Spent fuel represents a wealth of energy, and basically money, that is sitting there idle. We only use about 1 percent of that fuel in a once-through cycle. So you have 95-plus percent of that spent fuel that can be used to fuel another reactor, *if you reprocess*.

Why would we want to process this spent fuel? The spent fuel of a 1,000-MWe plant over a 40-year lifetime, contains the equivalent energy of 5 billion gallons of oil, or 37 million tons of coal. And we have the equivalent of 60 to 80 of these plants in the United States.

HTGR—High Temperature Gas Cooled Reactor. The concept is not well tested in the United States. Two reactors, Peach Bottom (100 megawatts-thermal) and Fort St. Vrain (330 megawatts-electric) operated successfully, between 1967 and 1989. Both have been shut down. Their high temperature operation of 700 degrees C made for efficient electrical production, probably in the 50 percent range. Both concepts

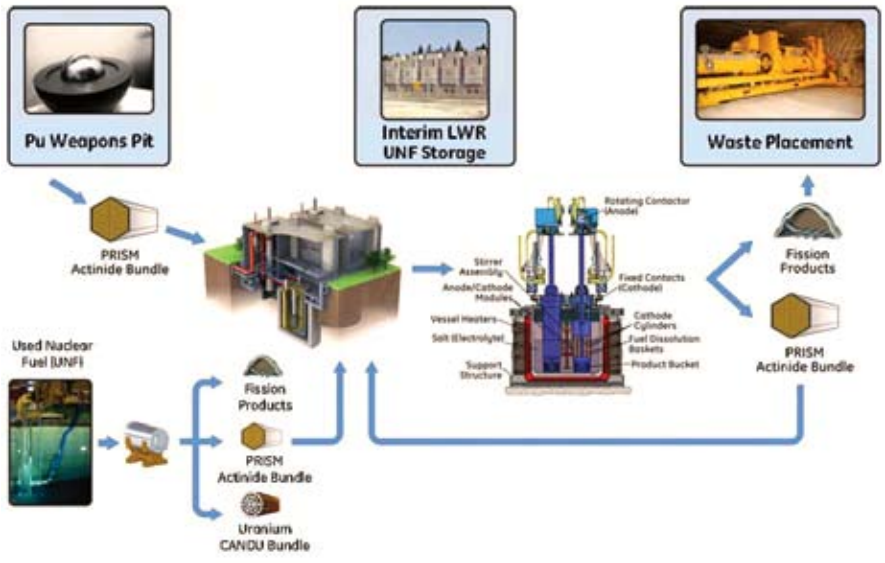


Figure 8
ARC—ADVANCED RECYCLING CENTER
The GE-Hitachi ARC is designed to recycle spent fuel, and also to process used weapons-grade nuclear materials to be used as new fuel for the PRISM or other reactors.

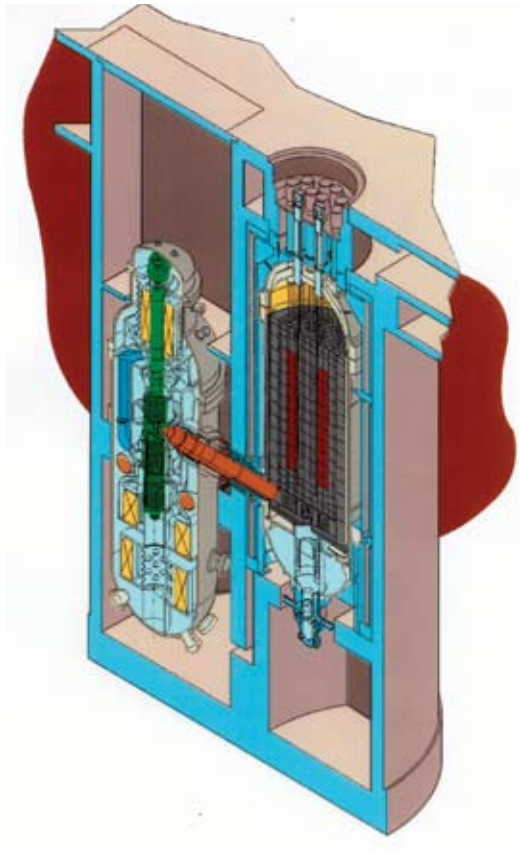


Figure 9
HIGH TEMPERATURE GAS-COOLED REACTOR
Cutaway view of General Atomics' modular GT-MHR power plant, showing the reactor vessel (right) and power conversion vessel. The helium gas is used both as a coolant and to directly drive a gas turbine generator, which gives the reactor nearly a 50 percent increase in efficiency. Both modules are located below-ground.

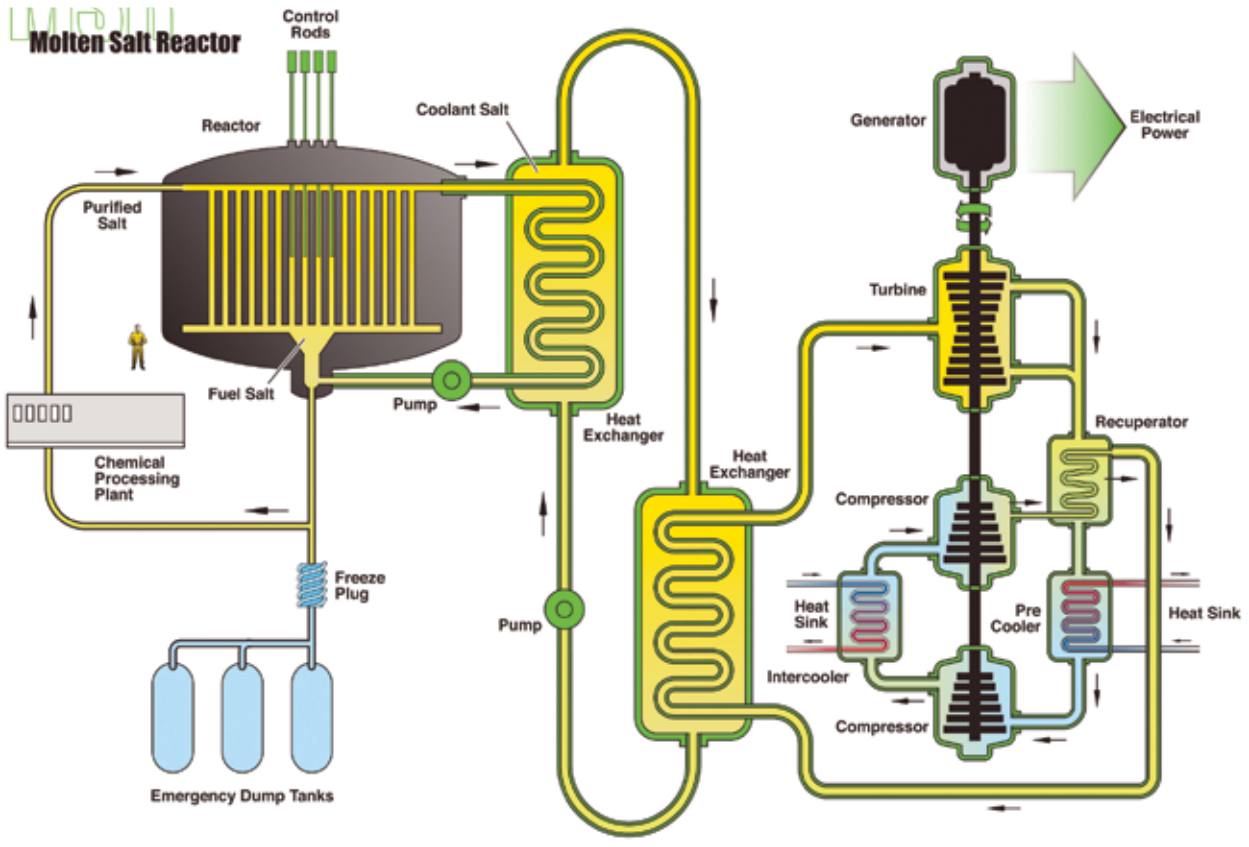


Figure 10
MOLTEN SALT REACTOR

The Molten Salt Reactor, which was researched at Oak Ridge National Laboratory in the 1960s and 1970s, uses a molten salt mixture as coolant, which can operate at high temperatures and low pressure. The molten salt mixture is less reactive than a liquid sodium coolant. The Liquid Fluoride Thorium Reactor (LFTR) is one promising type of MSR design. The thorium fluoride fuel is dissolved in the molten salt.

were helium-cooled and graphite moderated. Their design of a "dilute" core made for enhanced, safe operations.

The United Kingdom has many gas-cooled reactors operating, while the United States currently has none. It is anticipated that the operating and capital costs would be similar to that of the BWR and PWR. Licensing approval is probably not much different from the existing light water reactors' process.

MSR—Molten Salt Reactor. This concept circulates nuclear fuel in a molten salt, without any external coolant in the core. The primary circuit runs through a heat exchanger, which transfers the heat from fission to a secondary salt circuit for subsequent steam generation. It was studied in depth in the I960s at Oak Ridge National Laboratory, but nothing has occurred beyond the laboratory stage.

CANDU Reactor. This is Canada's preferred pressurized reactor concept, fueled with natu-

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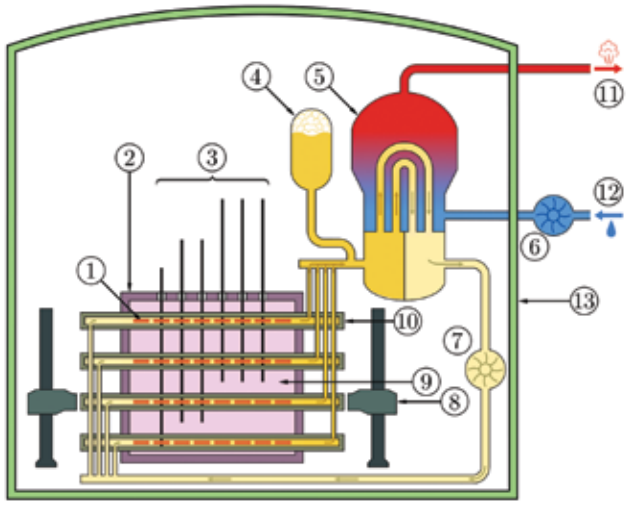
Canada has exported several CANDU reactors. These two 728-MWe Candu-6 reactors are operated by the Third Nuclear Power Company, Ltd., at Qinshan, China.

Figure 11
SCHEMATIC OF THE CANDU REACTOR

The CANDU (CANada Deuterium Uranium reactor) uses natural uranium as fuel and heavy water as a moderator. The primary heavy-water loop is in yellow and orange, the secondary light-water loop in blue and red. The heavy water moderator in the calandria (reactor vessel) is pink.

CANDU reactors can also use thorium and processed spent fuel.



Key
1. Fuel bundle
2. Calandria
3. Adjuster rods
4. Heavy water pressure reservoir
5. Steam generator
6. Light water pumps
7. Heavy water pump
8. Fueling machines
9. Heavy water moderator
10. Pressure tube
11. Steam going to turbine
12. Cold water returning from turbine
13. Containment building of reinforced concrete

ral uranium, and moderated and cooled with heavy water. The CANDU design allows for on-line refueling, thus minimizing downtime for improved operating efficiency. Since the spent fuel is never reprocessed, and only natural uranium is used, proliferation is not a concern. The heavy water coolant and moderator would allow the production of an insignificant plutonium by-product.

Canada has used this concept for the past 40 years. The CANDU spent fuel can be buried and/or stored with little or no economic penalty. Since some of the NAWAPA power requirements exist in Canadian provinces, Canada may prefer the CANDU reactor because of their construction, operating, and licensing experiences. Operation of these reactors is very safe, based on considerable experience with 10 or so reactors.

SAVANNAH RIVER NATIONAL LABORATORY/ HYPERION POWER GENERATION, INC. Savannah River and Hyperion recently proposed the development of a "mini" nuclear power reactor, referred to as the Hyperion Power Module (HPM). As NAWAPA will most probably have requirements for some small modular nuclear plants to be used in the numerous proposed pumping stations, I will describe the plant design, as discussed by Hyperion.

The proposed HPM would produce 70 megawatts-thermal energy, and 25 megawatts-electric when connected to an electricity-generating system

According to Hyperion, "The reactor features uniquely stable uranium nitride fuel, an environmentally secure lead bismuth eutectic coolant, and robust HT-9 stainless steel construction. Scientists on the HPM project believe they have selected the safest combination of materials studied over decades of the nu-

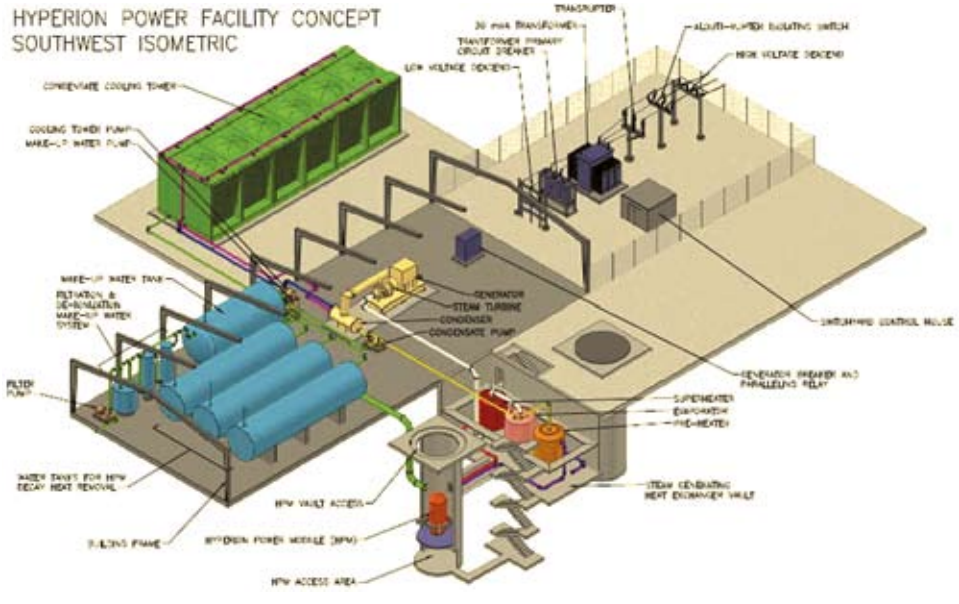
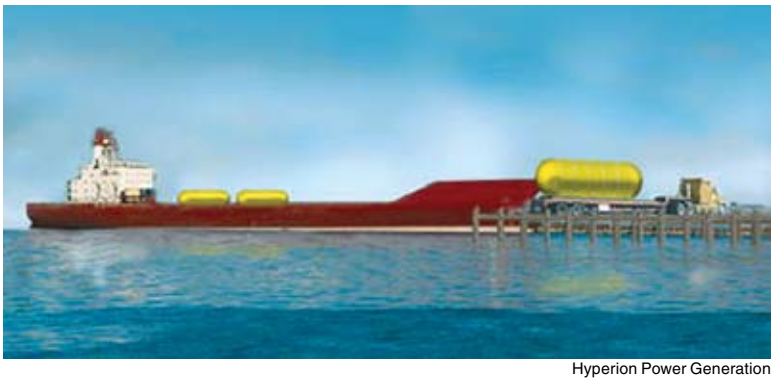


Figure 12
HYPERION'S MINI REACTOR LAYOUT

The Hyperion Power Module is a 25-megawatt-electric modular reactor design, which has been proposed for development at the Savannah River National Laboratory. The design would use uranium nitride as fuel with a lead bismuth coolant, and the whole module would be located underground.



Hyperion Power Generation

Its small size makes the Hyperion reactor easily transportable and suitable for remote locations.

clear age to create the most proliferation-resistant designed reactor thus far.

"The reactor vessel itself is about the size of a refrigerator and buried below grade for an extra measure of security. The complete plant, including the electrical generation system, takes up less than an acre. Transportable, permanently-sealed small reactors providing localized distributed power can be ideal for isolated locations that require an uninterruptible source of power, but they also have the potential to give utilities greater flexibility to add generation in a way that's comparatively inexpensive."

Future plans include testing and evaluation "to show how and where it can work," under the management of Savannah River Nuclear Solutions, LCC, a Fluor-Daniel Partnership, comprised of Fluor, Northrop Grumman, and Honeywell, which are responsible for the management and operation of the Savannah River Site.

Obviously, the HPM, if successfully developed, could be viable for NAWAPA. Development needs to proceed soon to demonstrate the concept.

Thorium-232 and Uranium-233 Cycle Reactors. In concepts discussed above, uranium and plutonium are the primary nuclear fuels. Thorium exists worldwide and is used extensively in India, where it is plentiful. The United States has done minor testing of thorium fuels in the Peach Bottom HTGR, the Fort St. Vrain HTGR, and at Shippingport, and India has had extensive experience with thorium.

Thorium oxide absorbs neutrons to produce U-233, which is fissionable. Some advantages of thorium-oxide are: The fuel has 10-15 percent better thermal conductivity than uranium dioxide and a melting point of 500 degrees C higher than uranium dioxide, thus giving an additional safety margin. The U-233 produced gives a higher neutron yield per fission than U-235 and/or Pu-239—and thus is more efficient in a fissioning and/or breeding cycle.

Based on the design of the reactor core, heavy water or light water can be used as the coolant. High temperature gas, probably helium, is also a coolant option.

"The difficulties in developing the thorium fuel cycle include the high cost of fuel fabrication," according to critics of the cycle, who cite the high radioactivity of U-233 and its contamination with traces of U-232, and contamination of Th-232 with highly radioactive Th-228. Also cited is the "weapons proliferation" risk of separated U-233.

Natural Gas, Hydro, and Electricity Transmission

The water for the NAWAPA project will need to flow continuously, requiring reservoirs, pumping stations, and the necessary back-up power and equipment. An engineering analysis will be required to determine where power is needed, including the hydropower available and the specific locations. Hydropower and gas-fired electrical plants seem logical for remote locations, because the strong technical workforce required for nuclear plants might limit available and willing personnel in the numbers required.

What's needed is an energy analysis that would evaluate the power requirements and the hydropower potential, to determine whether small modular plants with minimal transmission lines, or large nuclear plants with an extensive transmission connection would be most cost efficient, appropriate, reliable, and environmentally acceptable.

In establishing the overall energy made available along the NAWAPA water route, advanced planning should consider resource development power requirements. The Canadian Tar Sands are currently being developed. The current oil extraction from the tar sands requires an estimated 400,000,000 cubic feet of natural gas per day to heat the water needed to accomplish this oil separation. Nuclear power could provide the energy for

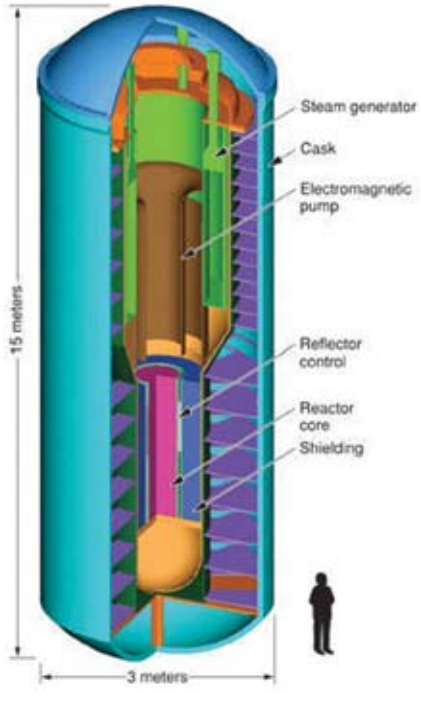


Figure 13
THE SSTAR THORIUM REACTOR

There are many nuclear reactor designs for using thorium fuel. India, which has large thorium reserves, has considerable experience with thorium, and is working on a thorium-fueled Advanced Heavy Water Reactor and an Advanced Thorium Breeder Reactor.

Shown here is the SSTAR (small, sealed, transportable, autonomous reactor), under design by the Lawrence Livermore, Los Alamos, and Argonne national laboratories. The reactor is here enclosed in a transportation cask.

heat requirements, saving the natural gas for purposes unique to natural gas, such as home heating, fertilizers, and so on.

It is also possible that oil shale development in the Western United States could be enhanced with the separation energy requirements provided by nuclear power.

Powering Lift Pumps

BWRs and PWRs have demonstrated operating experience with considerable industrial capacity in the United States. The fabrication capability of the large pressure vessels required may need to be re-established domestically. The Westinghouse PWRs, generally, are a loop-type design, with two, three, or four loops of 300 megawatts-electric each, thus allowing individual sizing to meet the requirements of a specific power site.

Other PWRs and BWRs are of a single rating of about 1,200 megawatts-electric. Economy of size is important for nuclear plant construction and operation.

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NAWAPA's power requirements will need both conventional nuclear plants, which can be built quickly, and advanced reactor designs, which must first be built as demonstration models. Here, the Bruce Power Plant in Canada.

In my opinion, these plants could be built on today's well proven experience. No demonstration plant is required. The newer, safer plants are not dissimilar to the existing 100 nuclear commercial plants operating in the United States. Reprocessing, waste disposal, and some plutonium proliferation issues remain. If one had to choose today for a plant(s) to be operable in a 10- to 12-year period, without further developmental costs, the BWR and PWR concepts would suffice.

If we look to advance the U.S. nuclear program beyond the existing water reactors, liquid metal (primarily sodium) fast reactors should be considered, because they can breed new fuel, they have much higher power density per unit volume of core, and their fuel can be processed on-site, which significantly reduces proliferation concerns.

One concept, PRISM, as proposed (and discussed above), would use a dissolving and electroplating concept to reprocess spent stored fuel.

The three advanced concepts that I would consider for the pumping requirement are the PRISM, the IFR, and the LMFBR. These concepts each have pluses and minuses. Many concerns would be addressed via a vigorous demonstration plant program. A demonstration plant of intermediate size, 300 to 500 megawatts-electric would be in order.

Reflecting on the above sodium-cooled concepts, I offer the following personal views for further review and discussion.

Argonne National Laboratory (ANL) has extensive reactor design experience of a pool type, sodium-cooled, and metal (uranium and plutonium) fueled cores, attached to a hot cell fabricating facility; that is, the EBR-II facility. Metal fuel was chosen for the core for testing a high density fuel, high power density, high fast flux, and breeding capability. Metal fuels originally had a problem with swelling, thus limiting their core lifetime and affecting costs. To my best knowledge, the swelling issues have been made manageable by fuel alloying and fuel element design. However, I am not currently aware of the tested and verified maximum burn-up achievable with metal fuels.

Industry and utilities, initially, did not embrace the sodium-cooled metal fuel concept because of their extensive experience with uranium dioxide fuel and water-cooled reactors. The design and maintenance of equipment and water-cooled reactor operation was perceived as a better proven concept than the sodium-cooled concept.

ANL designed and operated EBR-II. Westinghouse designed and operated the FFTF, because it was the operator of the Hanford facility when the FFTF was constructed. General Electric was a prime contractor to the government for testing mixed-oxide fuels in a sodium-cooled reactor environment. This occurred during a 20-30 year period commencing in the 1960s. GE also has extensive experience with uranium dioxide-fueled water-cooled reactor concepts for the next generation of water-cooled thermal reactors.

It, therefore, is of significant note that GE is proposing as an advanced reactor concept a sodium-cooled metal-fueled fast reactor with an attached reprocessing hot cell. This PRISM concept addresses both proliferation and spent fuel reprocessing issues. Also, it implies that a major industrial vendor is endorsing a metal-fueled, sodium-cooled fast reactor. The GE choice, with its significant experience and resources, should be a major factor in the selection of an advanced reactor design.

ANL still exists to assist (if required) in the design of equipment and components of a sodium pool-type reactor, where most fuel handling is accomplished in a non-transparent sodium pool with argon, an inert gas.

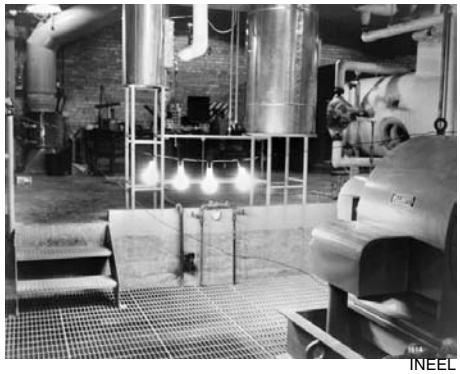
In my view, the PRISM concept, with GE's formidable technical experience and resources, may be a preferred concept for NAWAPA to advance the U.S. nuclear program. As proposed, the PRISM concept with its Advanced Recycle Center is probably the most complex of the concepts considered above. Without an ARC, the PRISM is similar to the IFR, but the ability to reprocess spent stored fuel is lost.

Spent Nuclear Fuel Is An Abundant Source of Energy

by Dale E. Klein, Ph.D.

INL

Spent nuclear fuel casks in dry storage at the Idaho National Laboratory.



INEEL

The Experimental Breeder Reactor No. 1 located at the National Reactor Testing Station near Arco, Idaho, produces the first electric power from a nuclear reactor, December 1951.

ANL

President Lyndon Johnson, with nuclear scientist Glenn Seaborg, at the 1966 ceremony making the EBR1 a National Historic Monument. Johnson is holding one of the original four light bulbs.

The world today is moving to the "closed fuel cycle" by recycling spent nuclear fuel. France, Japan, the United Kingdom, Russia, India, and China reprocess spent fuel. There are two reasons. First, reprocessing recovers significant energy value from spent fuel that contributes to energy security. Second, reprocessing substantially reduces the volume and radiotoxicity of high-level nuclear waste.

These distinct advantages are currently driving international research efforts and likely will influence national decisions on the establishment of domestic and regional nuclear waste repositories.

U.S. leadership in this area has been lost, and the underlying

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Visitors at the EBR1 today.

technological capability and intellectual capital needed to compete internationally have diminished to near irrelevance.

Establishing domestic infrastructure to recycle nuclear fuel will require a public-private partnership that operates outside normal appropriations and has a charter to manage the fuel over a period of decades.

Energy from Spent Fuel: 60 Years Ago

Later this year, the United States will celebrate the 60th anniversary of a major accomplishment in the history of science and technology: the production of electricity using nuclear power. On Dec. 20, 1951, in a remote part of eastern Idaho, scientists and engineers from Argonne National Laboratory started a small electrical power generator attached to an experimental reactor that created enough energy to power four 200-watt electrical bulbs.

The next day, they were able to increase the power to illuminate the whole building. It was one of the great demonstrations of the peaceful use of nuclear energy, and it gave birth to today's global commercial nuclear power industry. But what is often lost in the history of this event, is the simple fact that the first nuclear-powered electricity was produced using reprocessed plutonium.

What Is in Spent Fuel?

The news media often refer to spent nuclear fuel, which includes a small amount of plutonium, as "waste." It is not waste. Rather, our failure to reprocess, or recycle (the two terms are used interchangeably) spent fuel is a waste of an extremely valuable resource.

How much uranium comes out of a nuclear reactor? Let's start with a typical fuel reactor fuel that has been enriched to contain 4 percent U-235, and the rest 96 percent U-238. While in the reactor, the U-235 is consumed and plutonium is both created and consumed. In the end, the typical used fuel bundle will have about 5 percent mixed fission products and a mixture of about 93 percent U-238, and 1 percent each of U-235 and mixed plutonium isotopes. Basically, this means that 95 percent of the uranium and plutonium, and therefore 95 percent of the potential energy value of the used fuel remains.

Ninety-five percent is an astonishing figure when you consider that the current practice in the United States is to use the fuel once and then store it at the reactor for eventual disposal in a geologic repository. Idaho Rep. Mike Simpson captures the illogic of failing to recycle spent fuel. He says it is like mining gold and throwing nine pounds out of every ten back in the ground.

The energy density of uranium is remarkable when compared to other fuel types. Table 1 gives a few comparisons among fuel types for a 1,000-megawatt-electric power plant.

The once-through nuclear fuel cycle, which is our practice in the United States, is an enormous waste of potential energy. The math is straightforward, and certainly this is the reason why so many advanced nuclear countries are developing the technology and infrastructure to capture that energy.

Proliferation Concerns

To get to the energy value contained in that used fuel requires reprocessing. President Jimmy Carter stopped spent fuel reprocessing during his administration on the grounds that it would lead to the risk of proliferation of weapons-grade plutonium. However, other nuclear nations did not follow his path.

Table 1
FUEL NEEDED FOR A 1,000-MW ELECTRICAL POWER PLANT

Fuel	Quantity (Metric tonnes)	Volume
Coal	2.6×10^6	2,000 train cars
Oil	2.0×10^6	10 supertankers
Uranium	30	1 reactor core

Table 2
WORLD COMMERCIAL SPENT FUEL REPROCESSING CAPACITY

Reactor Fuel Type	Facility	Processing Capacity
	France - La Hague	1,700
LWR	U.K. Sellafield (THORP)	900
	U.K. Sellafield (Magnox)	1,500
	Japan - (Rokkasho)	800*
	Russia - Ozersk (Mayak)	400
PHWR	India (4 plants)	330
	Total all fuel types	5,630

* Japan's facility is expected to start operations in 2012

Now, more than three decades later, six nations have major commitments to reprocessing their spent fuel. The arguments against reprocessing as a proliferation concern are not compelling and obviously, other nations interested in extracting the energy value from their spent fuel do not align with U.S. policy.

A typical commercial nuclear power reactor will generate about 20 tonnes of spent fuel every year. Contained in that spent fuel is about 200 kilograms of reactor-grade plutonium. Often misunderstood, or misrepresented by opponents to recycling, the isotopic mixture of reactor-grade plutonium makes it unsuitable for nuclear weapons.

Weapons-grade plutonium is approximately 95 percent Pu-239, whereas reactor-grade is only about 50 percent Pu-239. The cost and complexity of the technologies required to purify reactor grade to weapons grade makes it impractical for use in nuclear weapons.

In fact, we know of, or strongly believe, that nine nations have developed nuclear weapons. Looking historically at the origins of the fissile materials used to develop those weapons, we know that the sources were either through enrichment of uranium or with the use of graphite or heavy-water-

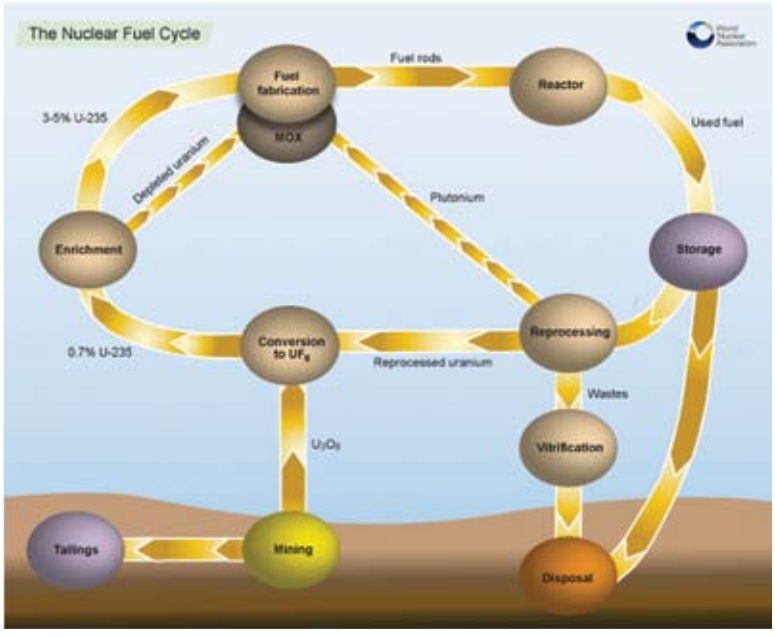


Figure 1
CLOSED NUCLEAR FUEL CYCLE

moderated production reactors, but not commercial reactors.

Israel, India, Pakistan, and North Korea are believed to have produced weapons-grade plutonium from the diversion of their heavy water research reactors to irradiate target materials. No nation has ever tried to produce nuclear weapons from the type of spent fuel discharged by commercial power reactors.

Global Reprocessing Capacity

In total, the current global capacity for reprocessing spent nuclear fuel is about 5,600 metric tonnes (Table 2), or almost three times the current annual production of spent fuel from U.S. reactors. That fact alone demonstrates the failure of the Carter policy.

In the next two decades, the World Nuclear Association estimates that 400,000 tonnes of used fuel will be generated by operating commercial reactors worldwide. This number could change, based on the number of new reactors built, and some decommissioned, but one fact is known: The inventory will increase over time, as more nations look to nuclear power to meet their energy demands and obligations to reduce greenhouse gases. With 95 percent of the total energy still remaining in spent fuel, energy-starved nations are already beginning to look at this as an asset, not a "waste."

Converting Waste to Energy

There are two basic paths to converting spent fuel to energy. The first, and most common is to use reprocessed material to make fuels for existing light- or heavy-water reactors. The second, and more efficient method, is to use fast reactors, as we did 60 years ago, to produce the first electricity from a nuclear reactor.

Mixed Oxide Fuel. The simplest way to obtain energy value from spent fuel is to extract the reactor-grade plutonium through reprocessing, re-blend it with uranium, and use it in fabricating fresh fuel assemblies. Otherwise known as a mixed oxide fuel or MOX, a typical MOX fuel is composed of about 93 percent U-238, and 7 percent reactor-grade plutonium.

MOX fuels assemblies are used to replace typical enriched uranium fuel in light water reactors. Currently, about 30 reactors in Europe (Belgium, France, Germany, and Switzerland) are using MOX, and Japan expects to use MOX in about 20 of its reactors. No U.S. nuclear plants use MOX fuel, although there is some growing interest in doing so, particularly as the price of uranium increases.

Advanced Fast Reactors. According to the IAEA, there are five operating fast reactors and three under construction, for a total of about 2 gigawatts-electric when fully operational. The distinct advantage of fast reactors over today's light water reac-

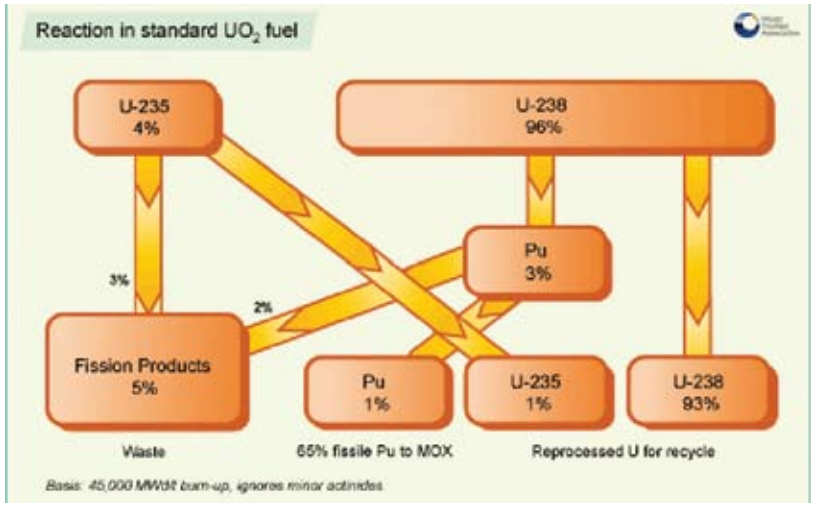


Figure 2
NUCLEAR REACTION IN URANIUM OXIDE FUEL

tors is that they can convert both plutonium and uranium to energy.

In a fast reactor, plutonium can be produced and fissioned to produce more energy and make new fuel at the same time. Fast reactors are often designed to be "breeder" reactors, and can convert U-238 to additional fuel. Fast reactors can also be "burner" reactors, and can utilize as fuel, or transmute, many of the long-lived actinides that cannot be fissioned in a commercial light water reactor. This gives the fast reactor the advantage of being capable of destroying the major source of long-lived radiotoxicity in spent fuel, while also making new fuel and producing energy.

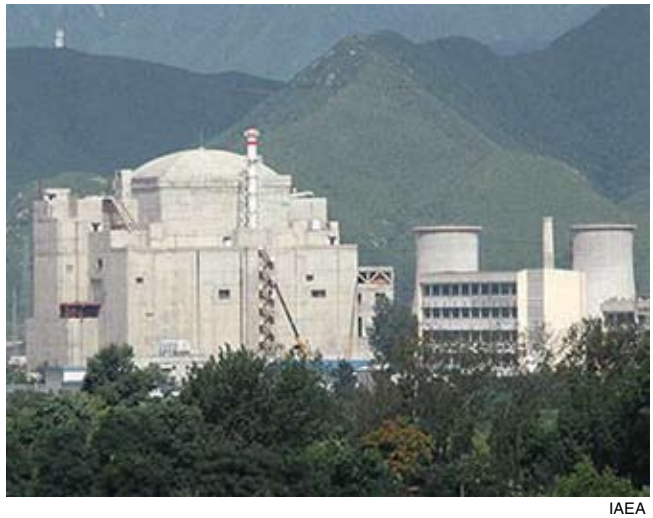
The existing U.S. inventory of used fuel from commercial reactors (more than 60,000 tonnes), if reprocessed for use in fast reactors, would be more than sufficient to supply the nation's energy needs for several hundred years.

A cutaway model of Russia's BN-600 fast reactor.

It is very clear that several nations are rapidly moving forward to develop commercial fast reactors. For example, Russia has been working on fast reactors for several decades. The Russian concept of plutonium management (both civil and weapons) is based on the principle of a closed fuel cycle to enhance fuel efficiency, and decrease the radioactivity of disposed long-lived wastes. Their BN-600 reactor had its first criticality in 1986 using MOX fuel and they are in the process of finishing their BN-800 reactor, which will be fueled using excess weapons-grade plutonium.

Russia's BN-800 fast reactor in construction.

India, too, is in the process of finalizing construction of its 500-MWe prototype fast reactor, which it has stated it expects to have deployed extensively by mid-century. France, China, Japan, and Korea are all actively engaged in developing fast reactor designs.



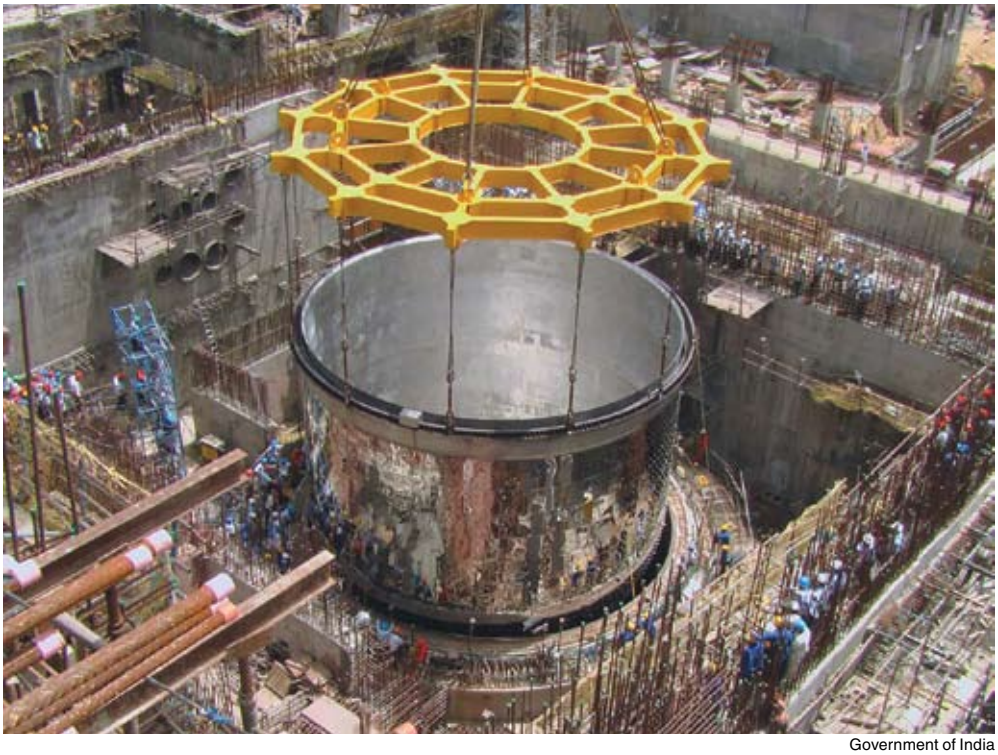
IAEA

China's experimental fast breeder reactor.

Barriers to Reprocessing

There is no broad agreement that re-starting spent fuel reprocessing in the United States is the right way to go. The nuclear industry itself has been ambivalent, and the low cost of uranium fuel has not warranted the investment in the infrastructure need to reprocess.

Recent efforts by the Department of Energy (DOE) to revive interest in reprocessing were perhaps overly ambitious, given that the United States has only recently re-started building



Government of India

The huge main vessel of India's indigenously designed 500-MW fast reactor, being lowered into place at the Kalpakham nuclear site.

new nuclear power plants after a 20-year hiatus. The DOE's Global Nuclear Energy Partnership (GNEP) proposed to build a three-part system composed of spent fuel recycling, advanced fuel fabrication, and fast reactors. While technically feasible, the challenge for GNEP was funding and, perhaps more important, it failed to make the case for an integrated spent fuel policy. Unlike other advanced nuclear nations, the United States has never linked or required reprocessing as a means of managing spent fuel and treating it prior to disposal.

There were also objections from sources that had significant influence in Washington. In 2007, the National Academy of Sciences reported to Congress, relative to the GNEP program, that, in its view, R&D for spent fuel reprocessing should be stopped altogether. Instead, the academy said, R&D funding should be redirected to develop new reactor designs in a Department of Energy program called "Generation IV."

In 2010, the Massachusetts Institute of Technology updated its interdisciplinary study of the future of nuclear energy. It found that uranium supplies will not limit the expansion of nuclear power in the United States or around the world for the foreseeable future. The new study suggests an alternative to fast reactors. The authors of the study cited their preference for this approach because it also addresses their concerns about proliferation of nuclear materials.

While I respect the findings in the reports from these groups, I think circumstances are changing that will lead to new interest in reprocessing.

The Value of MOX and Reliable Fuel Services

Nations with commitments to nuclear energy recognize the value in recovering the energy value in commercial spent fuel. In fact, some nations may even compete for it in the future.

For instance, both Turkey and South Africa have told reactor vendors bidding on new projects that they want to see a portion of the revenue stream come from the recycled fuel. These demands in planned contracts for new reactor projects clearly illustrate the case for reprocessing spent fuel, which are energy value and energy security.

In effect, these countries will lease the fuel from suppliers. They will receive some relief on price because the supplier will recover uranium and plutonium from the spent fuel to make MOX fuel and sell it to other customers.

Countries building new reactors will want guarantees of reliable fuel supplies, without having to make their own. This approach lifts the financial and environmental burdens of building local uranium enrichment and fuel reprocessing plants. The United Arab Emirates adopted this model in its award in December 2009 of a $20 billion contract to South Korea for four new 1,400-megawatt reactors.

We are beginning to address the recycling issue here. The

Areva

The MOX fuel facility under construction in at the Savannah River Site (SRS) near Aiken, South Carolina. The plant design is based on AREVA's MOX facilities in France. The French have used MOX technology for almost two decades and currently supply MOX fuel to over 30 reactors worldwide.

The U.S. facility will be able to turn 3.5 metric tons of weapon-grade plutonium into MOX fuel assemblies annually.

DOE

Brent Scowcroft, co-chair of the Blue Ribbon Commission on American's Nuclear Future, at a full commission meeting in Augusta, Georgia, in January 2011.

United States is building a $4.5 billion MOX fuel plant in South Carolina, which will convert 34 tons of weapons-grade plutonium into MOX fuel and is expected to be operational by 2016. While no U.S. utilities are currently using MOX fuel, it is expected that when this new plant becomes operational, there will be a growing interest in using MOX to supplement fuel supplies.

Blue Ribbon Commission to Address Reprocessing?

The likelihood that the United States will build a commercial reprocessing plant in the next decade depends on many political factors. But perhaps one of the most important factor will be the recommendations of the Blue Ribbon Commission on America's Nuclear Future. Chartered by the Department of Energy, the Commission was created to fill the policy vacuum created when the Administration, for political reasons, abandoned the Yucca Mountain project and the mandates of the Nuclear Waste Policy Act.

The 15-member Commission is chaired by former Congressman Lee Hamilton of Indiana and former national security advisor Brent Scowcroft. Its goal is to make recommendations for the safe, long-term management of spent fuel. Its draft report is due this Summer, with a final report to be completed in January 2012.

Many in the industry have hopes that the Commission will chart a reasoned path for spent fuel management which will include reprocessing. Equally important, there are high hopes that the Commission will recommend that the United States develop a public-private partnership, a quasi-governmental agency formed with industry, to take over management of spent fuel from the DOE and de-politicize the process.

The Case for Institution Building

What is needed is a long-term political commitment and the institution building to carry it out. Last Summer, then-Senator George Voinovitch (R-Ohio) proposed legislation to create a Federal corporation like the Tennessee Valley Authority (TVA) to manage spent nuclear fuel and to build facilities to reprocess it. Here's a brief outline of what it would look like.

- As a Federally chartered corporation, like the TVA, it would be self-governed by a Congressionally appointed board that focusses on long-range strategy that looks far beyond the needs of the next election cycle.
- It would have the authority to manage spent fuel, recycle it, and bury the remaining high-level waste.
- It would use the money in the nuclear waste fund, which would not be subject to annual appropriations.
- It would implement U.S. nonproliferation policies as part of its management of spent fuel.
- It would be subject to environmental regulations issued by Federal agencies, including the Environmental Protection Agency and the Nuclear Regulatory Commission.

The concepts in the bill have support from the Nuclear Energy Institute, which is the main trade association of the nation's nuclear utilities. For instance, on May 25, 2010, the Institute's CEO, Marvin Fertel, told the Commission, "The Federal government's used nuclear fuel program should be transferred to an entity with a management and financing structure that is able to function in the presence of inevitable political and policy uncertainty."

Opponents of nuclear energy have used the lack of a comprehensive solution for spent fuel as a cork to bottle up future development of new nuclear reactors. A three-decade ban on construction of new nuclear reactors in several states is based on this concept.

Senator Voinovitch said in 2010 that the passage of his bill would resolve that issue and create thousands of jobs not only for the new reactors that the nation needs, but also to manage the spent fuel. The difference would be management based on science as a prevailing paradigm rather than politics as usual.

In summary, reprocessing of spent nuclear fuel should be on the agenda in the United States because of the energy value it contains and the security of energy supply it provides, relative to future needs for uranium, and becuse it significantly reduces the volume of material to be disposed as high level waste. By adopting a path to reprocessing spent fuel, we will remove uncertainties in these critical areas and set our nation on a sustainable path to cleaner energy futures.

An Afterword on Fukushima

The nuclear community continues to analyze the tragic events of the earthquake and tsunami that crippled the reactors at Fukushima Japan. Many lessons will be learned from this unprecedented event that will further improve the safety of nuclear power.

While it is too early to say how this event might affect the global expansion of nuclear power, one issue brought to the world's attention was the storage of used fuel at reactors. Several governing bodies have now called for decreasing the amounts of used fuel stored in reactor cooling pools by transferring it to interim storage or recycling facilities. Fukushima has clearly brought attention to the need for robust international and domestic used fuel management programs.

—Dale Klein

USMA

West Point was organized on the model of the École Polytechique in France, with the mission of becoming a great scientific and technological school that would spread the benefits of its education through the population. The Corps of Engineers was stationed here in 1802, by an Act signed by President Jefferson.

THE SCIENCE THAT BUILT THE NATION

West Point and the Tradition Of the Army Corps of Engineers

by Pamela Lowry

Sylvanus Thayer, known as the Father of the Military Academy, devoted his term as Superintendent to developing the educational system at West Point, which included small classes, daily recitation at the blackboard, the study of military and civil engineering, and the famous honor system. Thayer transformed a small, isolated military academy into a first-rate scientific school, as well as the first engineering school in the nation. He is portrayed here by Robert Weir, a Hudson River School artist who painted many West Point faculty and scenes.

"We must get up early, for we have a large territory; we have to cut down the forests, dig canals, and make rail roads all over the country."

—A West Point cadet to a foreign visitor, 1854

All the military guests at the glittering banquet in the Hotel Robert in Paris wore side arms, and many of the civilians had pistols hidden in their formal clothing. The headquarters of Lord Hill's British Grenadier Corps loomed directly across the street, and it was possible that there would be some kind of trouble. It was Jan. 8, 1816, and a group of Americans, joined by their French, Prussian, Austrian, and Russian supporters, were about to defy the British occupation force in Paris.

Following on the heels of the final defeat of Napoleon at Waterloo, the Allied Powers of Europe had occupied Paris and reinstated the Bourbon Monarchy. The crowned heads of Europe breathed a sigh of relief that so much of the pro-American faction in Europe had been destroyed or silenced by the French Terror and the Napoleonic Wars. The British officers, flushed with victory, had been insolent in their disdain for the conquered French. The Duke of Wellington had gone so far as to commandeer the box reserved for the French King at the Paris opera, but was forced to retreat amidst a hailstorm of boos and catcalls.

British scorn was also applied to the Americans, with whom they had just finished fighting the War of 1812, Britain's unsuccessful attempt to reconquer its lost colonies. To salve their wounded pride, the regiments that had been with the defeated Ross and Cockburn at Bladensburg, Maryland, in 1814, held a banquet in Paris on Aug. 24, 1815, to celebrate the first anniversary of the burning of Washington.

Colonel Winfield Scott, who had fought heroically on the northern frontier during the war, countered this insult by scheduling the banquet at the Hotel Robert, attended by many of Britain's erstwhile allies in the fight against Napoleon, to commemorate the American victory at the Battle of New Orleans.

There were two young American Army officers at that banquet, both veterans of the War of 1812, who were in Paris on a mission crucial to the future of the Unit-

Library of Congress

A depiction of Benjamin Franklin in France. His research on electricity, from 1745 on, led to many contacts with French scientists, and Franklin himself was elected to membership in the French Academy of Sciences. While he was the American Commissioner to France during the American Revolution, Franklin's expanding network of French republicans, many of them leading scientists, became known as the "American Party." Later, many members of that network attempted to install a republican government in France.

ed States. They were Sylvanus Thayer and William McRee, and they had been sent to rescue the science and technology which had been developed by France's republican faction, and to bring it back to America. It would be desperately needed to develop the country, now that the British Empire could turn its attention away from Napoleon and towards another attempt to ruin independent America.

In fact, immediately after the war's end, Britain began dumping its manufactures in America at cost, in order to strangle the development of new American industries. This policy was merely a continuation of what Americans had faced during the colonial era, when they were forbidden to build iron foundries or any other manufactories that would compete with Mother Britain.

What America needed to develop its productive capacity—both industrial and agricultural—was transportation infrastructure, but the new nation had only a few self-taught engineers. No American school existed which could teach the scientific and technical skills required for a massive internal improvements program.

And the world's premier engineering school, the École Polytechnique of Paris, which had been founded by French republicans in 1794, had already suffered cuts under Napoleon and now faced destruction of its core curriculum under the conquering British-allied regime. If its textbooks, construction models, and even some of its graduates and faculty could be rescued from under the very noses of the occupying army, and brought to the new military academy at West Point, then America would have a chance against the feudalist, anti-development opposition now arrayed against it.

The Invaluable École Polytechnique

Thayer and McRee had been dispatched to France by President James Madison and Secretary of War James Monroe. Thayer carried a letter of introduction to General Lafayette, who had become Monroe's close friend during the American Revolution. When Monroe later became American Minister to France, he and his wife helped save Lafayette's wife, Adrienne, from being guillotined during the Terror, and then nursed her back to health. In 1802, Monroe returned to France to participate in the negotiations with Napoleon for the Louisiana Purchase. He was therefore familiar with the École Polytechnique and with Benjamin Franklin's circles in France, which were known as the "American Party." The remaining pro-American forces in France were under heavy attack. When Lafayette considered running for the new House of

Mathematical Association of America

French physicist and mathematician Gaspard Monge also served the early revolutionary government of France as Minister of Marine. One of the founders of the École Polytechnique, Monge's researches laid the foundation of modern descriptive geometry. He taught at the famous military engineering school at Mézières and then became the guiding spirit of the École. His 1799 Géométrie Descriptive *was written to enable his students to represent three-dimensional objects on a two-dimensional plane.*

The École Polytechnique was founded in Paris in 1794, after the Jacobin Terror had shut down all schools that were deemed to be aristocratic and/or scientific. Lazare Carnot, trained as a military engineer, had become a member first of the Legislative Assembly and then of the Committee of Public Safety. He and Gaspard Monge established the École as an institution where French science could once again flourish after its near-destruction by the Jacobins.

Deputies, the Electoral College was informed by the victorious Allied Nations that if such an event were to occur, 20,000 additional Prussian troops would be quartered in Lafayette's district.

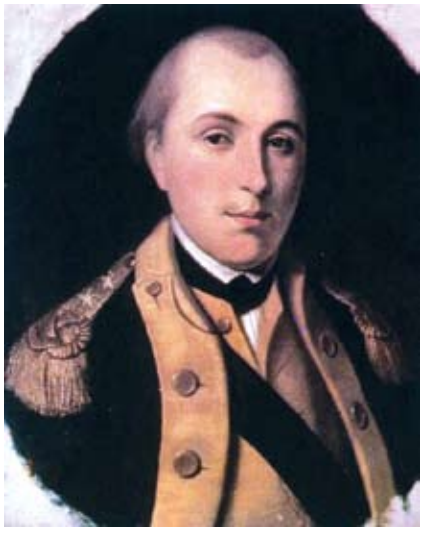
The beleaguered American Party had run an earlier rescue operation, which culminated in the founding of the École Polytechnique. When Lafayette and Franklin's circles began the French Revolution and attempted to establish a constitutional monarchy, the British reacted with desperate fury. The British Empire was determined that no American-style republic, monarchist or not, would ever exist on the continent of Europe. Therefore, British agents Danton and Marat were instructed to wreck the Revolution, and their chosen instrument, the Jacobin Terror, wiped out much of the French officer corps that had served in the American Revolution, including those who had contributed so heavily to the American victory at Yorktown. But that was not enough.

In 1793, the French Committee on Public Instruction ordered all academies suppressed, including the world-renowned Academy of Science, which had been founded in 1666 by Jean-Baptiste Colbert. Marat followed up by attacking Benjamin Franklin' s theory of electricity and the "aristocracy of knowledge" which had produced it. The "Law of the Suspects," also passed in 1793, proclaimed that the scientific aristocracy was to be prosecuted in the same manner as the aristocracy of birth. The guillotine then claimed much of Franklin's scientific circle, including Paris Mayor and Lafayette co-adjutator Jean Bailly; Franklin's former secretary, the Duke de La Rochefoucault; and chemist Antoine Lavoisier.

As soon as the 1794 Thermidorean reaction against the Reign of Terror had been accomplished, surviving American Party members Lazare Carnot and Gaspard Monge took control of the Committee of Public Safety and founded the École Polytechnique. The school was founded to train engineers, to spread republican values throughout the population, and to arouse talents which could advance science. Monge, who became the heart and soul of the École, based the structure and curriculum of the school on his training by the great humanist Oratorian Order, and on scientific schools which had been directly founded by Benjamin Franklin and his colleagues, while Franklin was the American representative in Paris.

The students at the École were divided into small sections, and more advanced students were able to test and widen their knowledge by teaching the younger students as assistants to the professors. The most important subject at the school was geometry. Monge taught this not as a fixed set of axioms, but as a means to educate the students' minds by showing them the coherence of the physical universe with the way their own minds worked. It gave them the capacity, therefore, to think well about any scientific or technological problem.

Monge wrote a textbook on descriptive geometry for his students, which enabled them to represent three-dimensional objects on a two-dimensional plane. It was a tool to achieve higher



The Marquis de Lafayette, a hero of the American Revolution, had been unable to stem the tide of the Jacobin Terror in France, and was forced to flee for his life. He then suffered years of imprisonment in the fortress of Olmutz, a captivity dictated by British orders to the Austrian Emperor. When he was released and returned to France, Lafayette aided Thayer and McRee with introductions to the French scientists who had survived the Terror.

Jean Sylvain Bailly was a French astronomer whose work on the satellites of Jupiter brought him membership in the French Academy of Sciences. During the early phases of the French Revolution, he worked closely with Lafayette as a member of the States-General and then as President of the National Assembly. As Mayor of Paris, Bailly attempted to curtail the excesses of the Jacobins, and for this he was guillotined in 1793.

technological levels of development, and Monge wrote in his treatise on the subject that

> it was a language necessary to the man of genius who conceives a project, to those who must direct its realization, and finally, to the craftsmen who must themselves complete its specific aspects.

By the 1820s, the Americans were applying this principle to the problem of producing interchangeable parts for armaments and machines.

A Treasure-Trove for West Point

Despite the fact that the École had been shut down by the time they reached Paris, Thayer and McRee were able to speak with many of its faculty members, using their letters of introduction to the remnants of the pro-American networks. It is possible that they were able to speak with Carnot before he was exiled to Switzerland, and to Monge, who was still in Paris. Their journals show that they consulted with an unnamed professor who taught descriptive geometry, and that he obtained architectural models for them. Thayer bought more than a thousand books for the West Point library, including many of those used at the École. He also obtained topographical maps and models of fortifications. Most important, École graduate Simon Bernard was recruited to head the construction of U.S. coastal fortifications, and École Professor Claudius Crozet agreed to teach engineering and descriptive geometry at West Point.

Virginia Military Institute

Claudius Crozet, a graduate of the École Polytechnique who served as a Captain under Napoleon, was recruited to become a member of the West Point faculty. By 1817, he had become head of the Department of Engineering, where he introduced the study of descriptive geometry, the first time it had been taught in an American college. Crozet wrote the first American textbook on the subject, titled A Treatise of Descriptive Geometry for the Use of the Cadets of the United States Military Academy, 1821. *Later in life, Crozet became the State Engineer of Virginia, and modelled the new Virginia Military Institute on West Point.*

While Sylvanus Thayer was still in Paris, he was selected to become the new Superintendent of West Point. Thayer had been an early graduate of the academy, and had experienced the frustrations felt by its faculty and students alike at its lack of funding for textbooks and scientific apparatus, and its inconsistency of requirements for its students. Thayer resolved to completely reorganize West Point on the model of the École, and to transform it into a great scientific and technological school which would disperse the benefits of its education into the general population.

This outlook corresponded to that of the Founding Fathers, who had pressed Congress for the establishment of a military academy, including the study of science and technology. George Washington, Henry Knox, Alexander Hamilton, and John Adams had all envisaged such an academy, but the funding from Congress was not forthcoming. Finally, in 1802, President Jefferson signed the Military Peace Establishment Act, creating a Corps of Engineers to be "stationed at West Point," which was ordered to "constitute a military academy."

Jefferson had reversed his original opposition to the plan, and appointed Jonathan Williams, the grandnephew of Benjamin Franklin, as head of the Corps of Engineers and Superintendent of West Point. Williams, a scientist in his own right, had worked with Franklin's ally, Caron de Beaumarchais, to conduit French supplies from his base in Nantes, France, to the Continental Army during the American Revolution. Once at West Point, Williams stocked the academy's library with the books he had inherited from Franklin.

Williams added geometry to the West Point curriculum, but his requisition for 12 inexpensive drawing instruments took months to fill. The War Department turned down his request for more and newer textbooks, on the grounds that scientific knowledge was changing so quickly that the books would be out of date before they arrived. Despite these frustrations, Williams told one of his officers to never

> lose sight of our leading star, which is not a little mathematical school, but a great national establishment to turn out characters which in the course of time shall equal any in Europe.

When Thayer returned from France, he was determined to carry out this mission, whatever it might cost him personally. He set up requirements for admission to West Point, drew up an honor code of conduct, and evaluated cadets only on their merits. As one West Pointer of the time remarked:

> West Point constitutes the only society of human beings that I have known in which the standing of an individual is dependent wholly upon his own merits so far as they can be ascertained without extraneous influence.

The curriculum was completely overhauled to correspond as much as possible to that of the École Polytechnique. French was taught from the first year, since the École texts had not yet been translated into English. Mathematics, including descriptive geometry, was considered to be the basis for an engineering degree. Classes were small and used cadet instructors from the older classes to supplement the faculty.

When Claudius Crozet arrived from France and attempted to teach engineering, he received a shock. One of his students wrote that "The surprise of the French engineer instructed in the

USMA

A West Point engineering class. Under Sylvanus Thayer's reforms, West Point became a great scientific school. The cadets studied their subjects in small sections, divided by ability, and every student was required to recite in class every day. The curriculum included mathematics, French, drawing, analytical geometry, physics, chemistry, mineralogy, rhetoric, moral and political science, and then, in the final year, engineering, with an emphasis on civil engineering. Every engineering school founded in the United States in the 19th Century copied the West Point curriculum, used West Point books, and recruited graduates of the Academy to serve as their faculty.

Polytechnique may well be imagined when he commenced giving his classes certain problems and instructions, which not one of them could comprehend or perform." Many of the cadets had only a very rudimentary background in simple arithmetic, and therefore Thayer instituted a mathematics curriculum which led from algebra, geometry, and trigonometry to calculus and engineering.

In the cadets' senior year, Crozet, using a blackboard and sometimes a student translator of French terms, taught field fortification, permanent fortification, the science of artillery, grand tactics, and civil and military architecture. In the architecture section of his class, he taught the construction of buildings, the design of arches, canals, and bridges, and the machines used to build them. He also made sure that his students learned the amount of materials, labor, and time that it took to build the structures they studied. By 1826, the engineering course included roads, tunneling, inland navigation, railroad construction, and artificial harbors.

The West Point curriculum also included chemistry, and Thayer procured enough equipment to allow the physics course to cover hydrostatics, hydrodynamics, hydraulics, pneumatics, machinery, optics, and astronomy. The four-year course also included mineralogy, rhetoric, moral and political science, and an emphasis on both topographical and classical drawing.

In addition to teaching, the professors soon began to translate the French textbooks, and to write texts of their own. These were used in many other American colleges. By 1821, Claudius Crozet had published his "Treatise on Descriptive Geometry," and exhibited for the first time, in English, Pascal's Theorem. Cadet William Frazer wrote proudly to his brother:

> We have just finished our course for this year and are now reviewing; we went as far as Spherical Projections in Descriptive Geometry, it is a study which is studied no other place but here.

To inform the nation of what was going on at isolated West Point, Thayer encouraged the War Department to establish a Board of Visitors, composed of distinguished men from across the country, who would oversee the oral examinations of the cadets and report on the progress of the school. He also formed a West Point band, and during the summer the smartly uniformed cadets would march through cities and towns, demonstrating their precise maneuvers to great applause.

On one of these trips in 1821, they visited the aging John Adams at his home in Quincy, Massachusetts, and heard this early supporter of a military academy tell them:

> I congratulate you on the great advantages you possess for attaining eminence in letters and science as well as arms.... These advantages are a precious deposit for which you are responsible to your country.

Building the Nation

The cadets who graduated early-on in Thayer's superintendency were generally deployed as officers in charge of the construction of coastal forts or the dredging of harbors. But Thayer and his fellow officers did not see the cadets' function as purely military. In 1823, Thayer wrote to General Alexander Macomb suggesting that if at any point some of the graduates were not needed for military service, "they might be usefully employed as Civil Engineers either in the service of the General Government or of the States." And in 1824, Congressional legislation would establish a military-civilian partnership for developing the nation.

In that year, the Supreme Court ruled in *Gibbons v. Ogden* that the Federal Government asserted authority over interstate commerce, which included river navigation. Following that decision,

The "West Point" was the third steam locomotive built in the United States, and the first featuring a horizontal locomotive-style boiler. Its name is appropriate, because the West Point graduates who entered the Corps of Engineers were involved in surveying, designing, or supervising the construction of most of America's early railroads.

A further association of locomotives with West Point began in 1818, when Gouverneur Kemble built the West Point Foundry at Cold Spring, across the Hudson from the Academy. Although manufacturing at the Foundry began with cannon, it soon progressed to designing and building railroad locomotives. Members of the West Point faculty visited the Foundry regularly.

Congress passed two pieces of legislation that enabled the Corps of Engineers to participate in planning and building civil infrastructure. The first was the General Survey Act, which authorized the President to order surveys of routes for roads and canals "of national importance, in a commercial or military point of view, or necessary for the transportation of public mail." President James Monroe assigned the survey task to the Corps of Engineers. Second, Congress appropriated $75,000 to improve navigation on the Ohio and Mississippi Rivers by removing sandbars, snags, and other obstacles. Later, the act was amended to include other major rivers such as the Missouri. This task, too, was given to the Corps of Engineers.

In 1825, John Quincy Adams was inaugurated as President, and the American System of Political Economy came into its own. Both large and small infrastructure projects were undertaken in every area of the country, forging a system of national communication and improving the transportation of finished and unfinished products. These engineering projects for improving the general welfare also brought the realization that the nation as a whole benefited from improvements that were made in any area of the country.

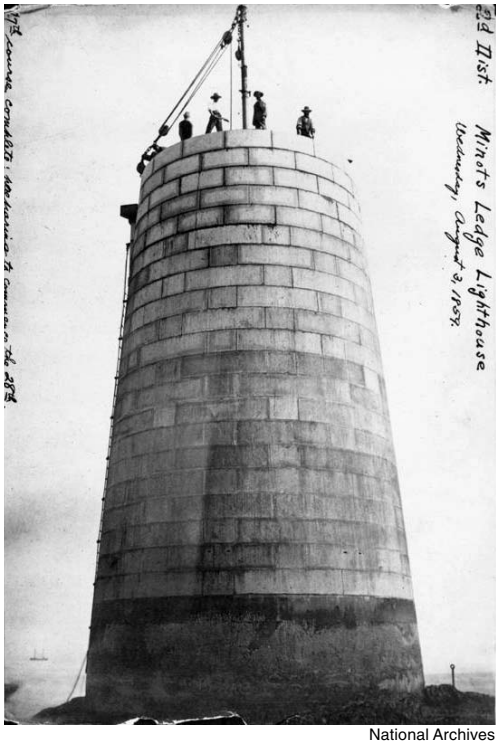
New legislation in 1826 authorized the President to have surveys made to clean out and deepen selected waterways and to make other river and harbor improvements. This led to major Corps of Engineers projects to build locks and dams along hundreds of miles of river, and to the development of floating machines to remove giant snags, or log-jams, from rivers. These were known as "Uncle Sam's tooth pullers."

Members of the Corps also built almost every canal in America, with the exception of the Erie and the Middlesex. Two very large-scale hydraulic surveys were also mounted; one of the Great Lakes and the other of the Mississippi Delta. On land, the Corps was given responsibility for taking over construction of the National Road, which stretched from Chesapeake Bay to Illinois. As railroads began to be built in the late-1820s, members of the Corps surveyed railroad routes, and the War Department often loaned engineers to the railroad companies once construction began. Thus, Captain William McNeill supervised the survey for the Baltimore and Ohio Railroad, and Lieutenant George Whistler was in charge of laying the track.

By 1830, many engineer officers were granted furloughs to work on the railroads. This burst of internal improvements, leading to the forging of a strong national identity and a strong economy, did not go unnoticed by America's inveterate enemies, who encouraged the growth of a kind of populism known as "Jacksonian Democracy," which had an eerie resemblance to the Jacobin attacks on the École Polytechnique. When Andrew Jackson was elected President in 1828, West Point began to be the target of coordinated attacks. It began with speeches and articles stating that the local militia companies were all the country really needed to defend itself, not those high-tone cadets at the military academy. Congressman Davy Crockett, who had ridden Jackson's coattails to victory, proposed in Congress that West Point be eliminated. Other attacks took the form of proposals for "local control" of internal improvements, which would eliminate

The cornerstone of the Baltimore & Ohio Railroad, one of the earliest and longest railroads, was laid on July 4, 1828 by Charles Carroll of Carrollton, the only surviving signer of the Declaration of Independence. The history of the building of the B&O is closely tied to West Point's Corps of Engineers, for members of the Corps ran the survey for the railroad. Because the early construction of the railroad coincided with the Administration of President John Quincy Adams, who supported what was then called "internal improvements," officers of the Corps of Engineers were allowed to take leave from the Army in order to supervise the building of the railroad.

This painting of the cornerstone is displayed at the B&O Railroad Museum in Baltimore.



National Archives

The Minot Ledge Lighthouse, shown here in construction in August 1859, is considered a triumph of engineering and is an American Society of Civil Engineering Landmark. The Atlantic Ocean off Cohasset, Massachusetts, had seen many shipwrecks, because of rocky ledges lurking beneath the surface. In 1850, an iron structure containing a warning light was built on Minot Ledge, but the next year it was destroyed by a storm that killed its two assistant lightkeepers.

General Joseph Totten, a West Point graduate, designed the replacement lighthouse, and Barton Alexander of the Corps of Engineers supervised the construction. The large, interlocking granite blocks were cut and preassembled on the shore, and then transported to the ledge on calm days. The base of the tower could only be built when Minot Ledge was visible at low tide. Because the force of wind and waves serves to strengthen the dovetailing of the granite blocks, the lighthouse has stood for 150 years.

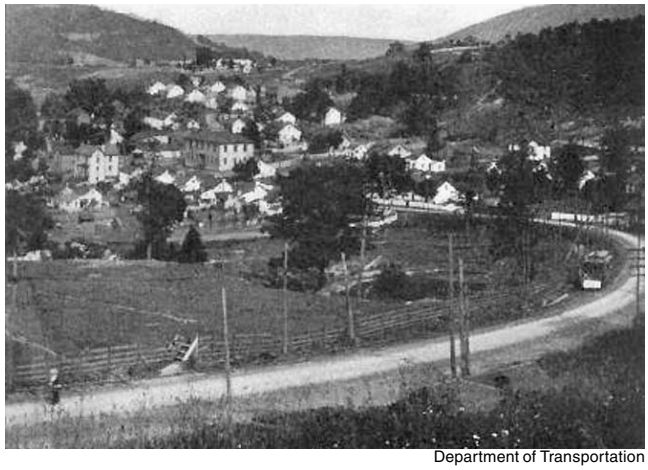
the national planning focus of the Corps.

Future President Martin Van Buren fought John Quincy Adams tooth and nail on the question of the Federal role in internal improvements, and proposed a constitutional amendment in 1825, which would have prevented Federally sponsored public works. The rationale was that development legislation was "unequal and unjust" because money from one state was being used to benefit other states.

The populist rhetoric had gained such momentum by the mid-1830s that many states withheld the Federal treasury surplus which they normally gave to their private colleges, even though there was a tradition of state support for these institutions. The United States fell upon hard times economically in the Panic of 1837, largely because President Jackson had refused to recharter the Bank of the United States, and had fired Treasury Secretary McLane when he refused to transfer the funds to Jackson's "pet banks" on the state level. Jackson found a more pliant Treasury Secretary by appointing Roger Taney to do the dirty work, moving him over from the Attorney General's slot. The U.S. Senate was so furious at this action that it refused to ratify Taney's nomination as an Associate Justice of the Supreme Court in 1835. But the membership of the Senate had changed enough

Army Corps of Engineers

Improvements to America's waterways (shown here is work on the Mississippi River), has been a mission of the Corps of Engineers. Early steamboats energized commerce and helped tie the nation together, but travel on the major rivers was dangerous. Currents undermined the banks of the rivers, causing thousands of trees to fall into the water, where they pierced or ripped the hulls of the steamboats. Engineer officers supervised the double-hulled boats called "Uncle Sam's Tooth-Pullers," which pulled up the snags, cut them up in a powered sawmill on deck, and used them as fuel. By 1832, not a single boat was lost to a snag on the Ohio or Mississippi Rivers.



Department of Transportation

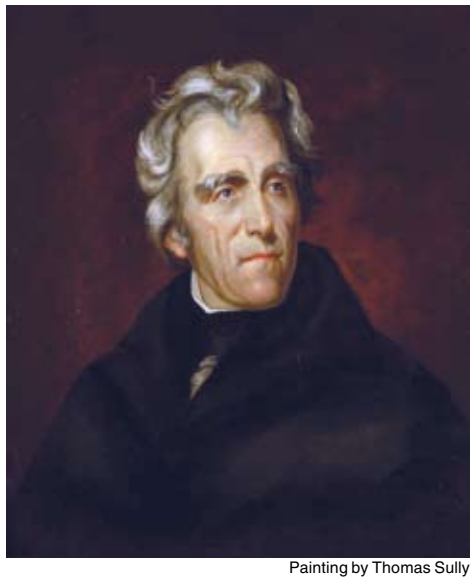
The U.S. Constitution gives the government the power to "establish post-offices and post-roads," and when Ohio became a state in 1804, the need for transportation to and from the new state led to legislation authorizing construction of a National Road. By 1818, the road stretched from Cumberland, Maryland, to Wheeling, West Virginia, on the Ohio River. Gradually, the road was extended through Columbus, Indianapolis, and on to Vandalia, the early capital of Illinois. During the first phases of construction, the road was built by private contractors with Federal money, but, later, the Corps of Engineers was given the job of surveying and maintaining the National Road. Shown here is a section of the road in Eckhart, Md.

by the next year to allow Taney to be appointed as Chief Justice.

Jackson also vetoed the Maysville Road Bill, on the grounds that the road lay completely within Kentucky and therefore could not qualify as a national project. On the role of the Corps of Engineers, Jackson was more cautious, as internal improvements were popular, and Jackson himself had stated that West Point was a good school and two of his nephews graduated from it. But he defied Superintendent Thayer again and again, by reinstating cadets who had been dismissed from the academy for code infractions or academic problems.

Thayer refused to be baited, and said, "This course may in the end occasion my removal, but in the meantime I shall have done some good and performed my duty." Finally, the challenge to his authority as Superintendent became so severe that he sent Captain Ethan Allen Hitchcock, his commandant of cadets, to the White House to see what could be done. President Jackson shouted at Hitchcock: "Sylvanus Thayer is a tyrant! The autocrat of the Russians couldn't exercise more power."

Painting by J. Boze



Painting by Thomas Sully

Jean Paul Marat (left) and Andrew Jackson shared an anti-science ideology. Marat, a leader of the Jacobins, concluded that the revolution had no need of scientists. Just as the British Empire did when Benjamin Franklin became a leader of the American Revolution, Marat also attacked Franklin's scientific reputation and his experiments in electricity. These scientific findings from colonial Philadelphia supposedly sprang from an "aristocracy of knowledge," and therefore all scientists were prosecuted as if they were members of the aristocracy. The 1793 "Law of the Suspects" succeeded in wiping out a large proportion of Franklin's scientific collaborators.

President Andrew Jackson, not so openly sanguinary, destroyed the National Bank which financed America's internal improvements by putting its funds into the "pet banks" of his like-minded cronies. The clearing of snags from America's rivers came to an abrupt halt. Next, Jackson attacked Superintendent Thayer's methods at West Point, calling the cadets an "aristocracy" that the militia could easily replace, and accusing Thayer of being a "tyrant." President Jackson consistently undermined Thayer's authority at West Point by reinstating cadets that Thayer had dismissed, until finally Thayer was forced to resign to save the Academy from Jackson's wrath.

Spreading the Army Corps Tradition

On Jan. 19, 1833, Thayer resigned as the Superintendent, in order to save the institution from Jackson's further wrath. It was only a matter of time, before the Survey Act was withdrawn (it happened in 1838), and Congress passed legislation that prohibited Army officers from being granted leave to work with private companies such as railroads.

However, the foundation which Thayer had built for the Corps of Engineers endured. Many engineering officers resigned from the Army and continued to work on developing America's infrastructure, especially its railroads. Others, still members of the Corps, completed projects on America's coasts, rivers, and lakes. Still others built railroads in countries like Russia and Egypt, or in the growing republics of Central and South America. Before the Civil War, the four alternate routes for the Trans-Continental Railroad were surveyed by members of the Corps.

Other engineering schools were founded, including the one endowed by Thayer at Dartmouth, and many of them used West Point texts and West Point professors. Secretary of War Porter stated in 1828,

> The Military Academy is scattering the fruits of its science … not merely to the rest of the army, but to the youth of our country generally, and the interchange of the theoretic science of this national school with the practical skill and judgment of our civilian engineers, which is now going on throughout the United States, will soon furnish every part of the country with the most accomplished professors in every branch of civil engineering.

As the American Civil War approached, pushed by the forces that wanted to destroy internal improvements and national sovereignty by any means possible, it was still the case that almost every infrastructural project had been planned or executed by a West Point-trained engineer. A Congressional committee declared, after enumerating some of these benefits:

> These are some of the enduring memorials of the usefulness of the Military Academy, and of the returns it has made for the care, and time, and money which have been bestowed upon it.

This article initially appeared in the Executive Intelligence Review, *Sept. 9, 2005.)*

INTERVIEW: DR. YUANXI WAN

China's Ambitious Path to Fusion Power

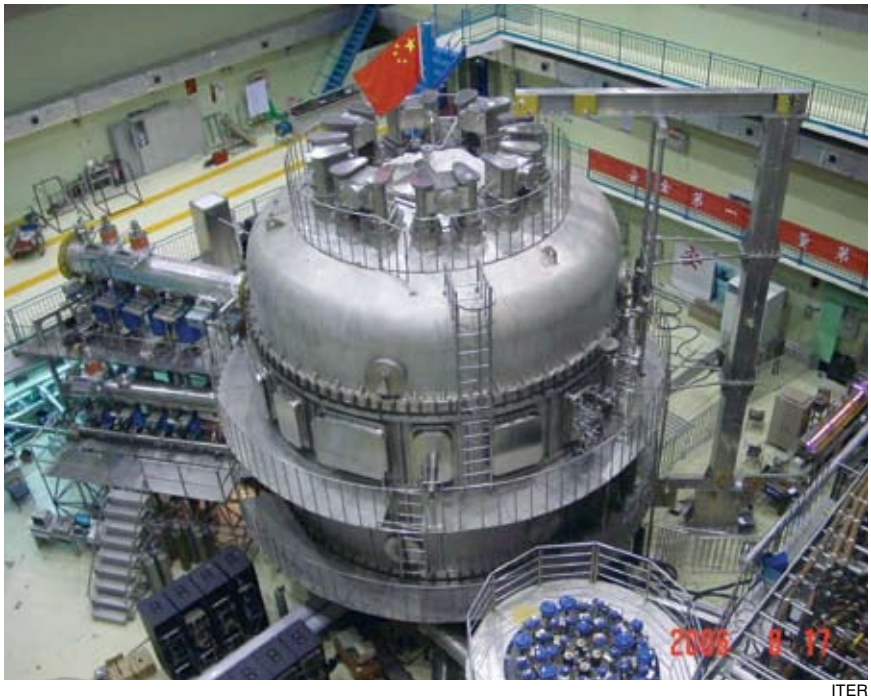
Question: Could you tell us a little bit about yourself?

Wan: My generation is a little different than the younger generation. We suffered when I was a university student. When the so-called Cultural Revolution happened, I was at Beijing University, the highest quality university in China. But fortunately, before I graduated from the university, the Cultural Revolution stopped, and we returned to a normal situation.

Question: What were you studying at the university?

Wan: Physics. When I graduated, I became a graduate student, also at Beijing University, but unfortunately, I was some kind of a "dangerous person," as part of the intelligentsia, because if you have independent ideas, you can see things and make judgments, by yourself. So, at that time, I "got a chance" to go to the big mountain area, near Tibet, in the underdeveloped area. And my wife, also from Beijing University, went to this mountain area. I became a worker, a farmer, and it lasted more than three years.

When the Cultural Revolution ended, the government realized that the intelligent person is very important, very useful. I had many classmates in Beijing, in the Chinese Academy of Sciences, and working in some institutes. Immediately, they, these classmates, introduced the fact that Dr. Wan is still in the big mountain area as a worker. When the Chinese Academy Sinica wanted to promote fusion research, immediately they sent an invitation to me, asking me to come to the Chinese Academy Sinica.



ITER

China's Experimental Advanced Superconducting Tokamak (EAST) was the first fully superconducting tokamak in the world. Mastering superconducting magnet technology is crucial for the success of the international ITER project.

Question: What year was that, that you went to Beijing?

Wan: In 1973. I went to the capital city of Anhui Province, Hefei, not Beijing. At that time, in Beijing City, it was very difficult to get rights as a citizen, because the government controlled the level of population. The Chinese Academy Sinica wanted to promote fusion research, but they could not set up a new institute in Beijing. So the Beijing Institute of Physics

Dr. Yuanxi Wan is the Dean of the School of Nuclear Science and Technology at the University of Science and Technology in Hefei, Anhui Province, People's Republic of China. He is an Academician of the Chinese Academy of Sciences at its Institute of Plasma Physics in Hefei, where he has worked for more than 35 years. A pioneer in China's thermonuclear fusion program, Dr. Wan is described as the "mastermind" behind China's Experimental Advanced Superconducting Tokamak (EAST), the first fully superconducting tokamak in the world. On Jan. 9, 2009, on behalf of the EAST team, he received China's State Top Scientific and Technological Award from Premier Wen Jiabao.

Dr. Wan was appointed the chair of the ITER Science and Technology Advisory Committee in May 2010. He brings decades of experience, and an engaging sense of humor, to the international fusion development effort.

He was interviewed by Associate Editor Marsha Freeman on Dec. 1, 2010, during the annual meeting in Washington, D.C., of Fusion Power Associates. A version of the interview appeared in Executive Intelligence Review, *March 11, 2011.*

The Institute of Plasma Physics of the Chinese Academy of Sciences (IPPCAS) in Hefei, where Dr. Wan has worked for more than 35 years. China plans to train 2,000 skilled experimenters to carry out research and development in magnetic confinement fusion, according to a recent report in China Daily.

The TEXT tokamak at the Texas Fusion Research Center in Austin, where Dr. Wan worked for two years.

took the responsibility to found a new division in the city of Hefei. In 1973, I came back from the big mountain area, to the city of Hefei.

Question: And you are still there?

Wan: Yes, until now. For almost 40 years, I was fortunate to work on magnetic fusion research.

Opening the Door to China

Question: At that time, it must have started as a very small program.

Wan: In 1973, this was a new institute. I had the opportunity to join this special group, to set up a new institute. We learned a lot of things from Russia, from the United States, from other countries. At the beginning, I did not know what a tokamak was! I also didn't know what a plasma is. Because, when I was a graduate student, there was no plasma, just a theory. I majored in nuclear theory, and there was no special study of plasma for fusion.

The Chinese Academy Sinica's tradition is more open than the Academy of Sciences. It gives people more freedom, in this environment. Other organizations are sometimes more conservative, because they emphasize the political situation, and so on. But the Chinese Academy Sinica emphasizes doing scientific research. And worldwide, without international exchange and knowing other scientists, you cannot promote scientific research and accomplish a more rapid development.

My personal opinion is that former Chairman Deng Xiaoping, the chairman of our government, made the very important decision to open the door of China.

Question: How did this new policy affect the fusion program, and your research?

Wan: The whole of China changed. After I worked at the Institute of Plasma Physics in Hefei, I had the chance to visit other countries. First, I visited Germany. In 1983, I had the chance to visit the United States, in Austin, Texas, at the Fusion Research Center, to do experiments on the Texas Tokamak machine, TEXT. I worked in Austin for more than two years. This was an opportunity for me to learn a lot of things. At that time, there was a big difference between China and the United States, and between China and Europe.

Question: At that time, did China have any experimental fusion facilities?

Wan: Yes, a small tokamak, in Beijing. We had the CT-6—China Tokamak-6—at the Beijing Institute of Physics. A special group worked on this. The people in our Institute in Hefei learned a lot from this Institute. We grew very quickly, and that special group in our Institute became much larger than the group in Beijing. Also, we designed and built a small tokamak, that we called HT-6; and then, the HT-6B, and HT-6F, two small tokamaks. We did it ourselves: designing, fabricating, and assembling this tokamak.

So, from the time that China opened the door, our Institute had the chance to communicate and exchange information with other institutes abroad.

Compared to the young generation, I am unlucky. Compared with the old generation, I'm lucky.

Question: Why is that?

Wan: Because the young generation right now, doesn't need to go to the countryside; they never suffered the Cultural Revolution. I am lucky, compared to the older generation, when some people could *not* do scientific research during the Cultural Revolution. And after the Cultural Revolution, time passed, and they were older, and some died. So many people.

Question: How did fusion research in China progress?

Wan: Our Institute grew very quickly; also, fusion research, overall, in China. From the small project, developed a medium-sized program. Then, China was able to join the ITER, International Thermonuclear Experimental Reactor project in 2003.

Question: Your frontier fusion project now is the Experimental Advanced Superconducting Tokamak, or EAST. It is my understanding that this was the world's first fully superconducting tokamak. In 2009, I visited the KSTAR superconducting tokamak in South Korea, which is newer, but yours was first.

Physics.ucla.edu

EFDA, JET

Inside the General Atomics Doublet III (above) and the Joint European Torus (JET). Both reactors made significant progress toward a burning plasma condition. The JET is shown both before and during (at right) operation.

Wan: Thank you. You remember! We collaborate, exchange, support, and compete with each other.

Toward a Superconducting Tokamak

Question: What was your reason for building EAST? What were your goals?

Wan: Our Institute developed very openly. We learned a lot from the United States, and also from Russia. We realized that for the tokamak, this device, the final goal must be fusion energy. At that time, fusion research on tokamaks had already made significant progress. For example, on the DIII-D, JET (Joint European Torus), TFTR (Tokamak Fusion Test Reactor). But still the tokamak, even with this significant progress, still is not a real fusion energy device, because although the tokamak has gotten to the burning plasma condition for fusion power, it is temporary, for only very short time.

For example, on the JET, even though it made significant progress, we say this is a scientific demonstration. Just three shots using hydrogen and deuterium fuel were used to produce the fusion reaction, to get a maximum of fusion power, of about 16 megawatts. But only with a few shots, and each shot lasts only a few seconds. This is not real fusion energy. But it is significant progress, because it got to the real fusion reaction, but it was only temporary.

If you want to go to real fusion energy, you must prolong this discharge even more, and go to a steady state. If the tokamak can go to the burning state in a steady-state condition, then you can produce a lot of fusion energy. Our Institute said we must make a contribution to this final purpose. What kind of technical path can we take to a superconducting tokamak?

At that time, we had already imported, shipped, the first superconducting tokamak, the T-7, from the Kurchatov Institute in Russia to our Institute.

Question: You brought the Russian tokamak to China?

Wan: Yes, because the T-7 was the first superconducting tokamak in the world. But it is not fully superconducting—just a part of the magnet was made of superconducting material. It was the toroidal magnet that was superconducting, but the others are normal. It was the first tokamak to demonstrate that superconducting technology can be used on the tokamak magnetic-confinement device. This was very useful. But this machine in Russia was used just for engineering testing, just to gain experience on how to use superconducting magnets on the tokamak.

Question: They were not concerned with producing fusion energy? It was just for testing?

Wan: It is a small machine. Even for physics experiments, its capability is poor. When the Russian situation changed quickly, when the Soviet Union collapsed, everything was stopped, including some fusion research. This machine was in the garbage. So we discussed this with the Kurchatov Institute, and we shipped this machine to our Institute, be-

cause in China, there was not enough of a budget to support fusion research.

China did not have enough money to support fusion research, but we were able to use the used equipment from France and Russia, and we shipped this used equipment to our Institute and worked on it. It was maintained, reassembled, and so on. It was made up of a huge number of components, and was very dirty! It was totally unusable. This was a way of training for us. Even though the quality of the equipment was very poor, in our workshop, the scientists and technicians worked together, and we cleaned every component. We reassembled all of the equipment. We learned a lot about the tokamak.

It was a difficult time, because it was very difficult for our Institute to get budget support for fusion research. So we used our good relationship with foreign countries, and fusion laboratories, to get used equipment.

Question: When was this?

Wan: We shipped the Russian tokamak in 1992, and, in 1994, reassembled it ourselves in our workshop, and we started experiments. So the first fully superconducting tokamak today is the HT-7, which had originally been the T-7 in the Kurchatov Institute.

Question: Why did you rename it the Hefei tokamak?

Wan: We modified the vacuum chamber, and modified other components, and just kept the superconducting toroidal field magnet. We did a lot of experiments on this machine. At the same time, significant progress had been achieved on other machines, and we realized that a superconducting tokamak should make more of a contribution for a fusion reactor. Because to go to a real steady-state operation of a tokamak, you must get to full superconducting operation, which means including the poloidal magnet. So we decided to design a full superconducting tokamak.

Question: When did the government approve the EAST project?

Wan: In 1997. Once they made the decision, we decided to design an advanced configuration in the full superconducting tokamak. This means that the plasma cross-section is elongated, in a "D" shape. The TFTR and JT-60 have a plasma cross-section which is a circle, but the JET is elongated, and is more advanced. This design is very similar to ITER. We made these decisions: one, for the superconducting tokamak, and second, with an advanced configuration.

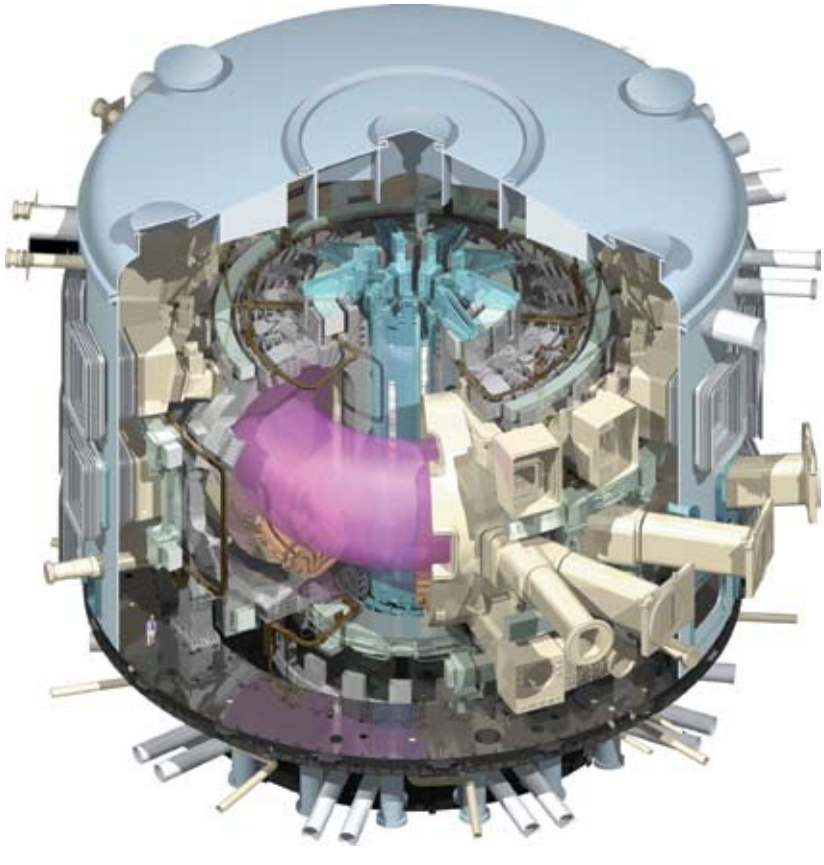
Freedom to Collaborate

Question: So your design did not depend upon the final design of ITER. You felt that, in any case, this was the pathway to follow?

Wan: Yes. But we learned a lot of things from the Princeton Plasma Physics Lab TPX (Tokamak Physics Experiment) work. George Neilson was the manager of that superconducting tokamak.

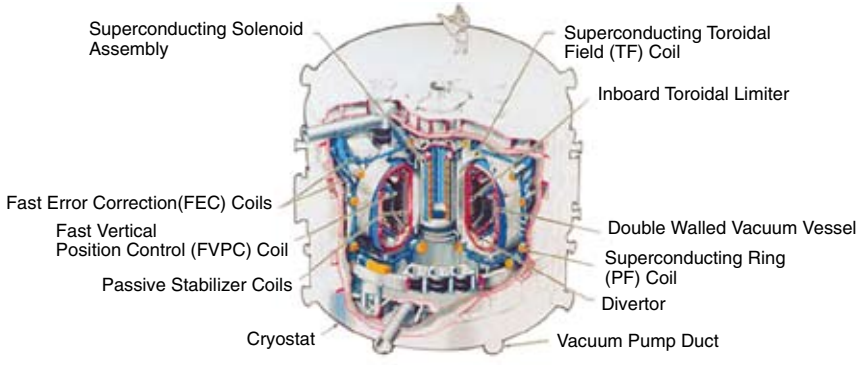
IPPCAS

The HT-7 tokamak at IPPCAS, which was shipped from the Kurchatov Institute in Russia in 1992, and reassembled and modified at IPPCAS.



ITER

Cutaway illustration of the 8-story-tall, 30-meter-diameter ITER, with a burning plasma depicted. Now in construction, ITER will be built over the next decade with contributions from Russia, the United States, Europe, Japan, South Korea, India, and China.



PPPL

The TPX (Tokamak Physics Experiment) at Princeton Plasma Physics Laboratory was designed as a follow-on reactor to the successful TFTR (Tokamak Fusion Test Reactor). But the TPX, a long-pulse machine, was killed in the engineering stage.

Unfortunately, the United States spent some money for a few years, and then stopped. Also, people from the Kurchatov Institute, about 100, came to work at our Institute, engineers and scientists. We all worked at our lab, together. It was totally international. Fortunately, because magnetic fusion is a totally peaceful project, there is a lot of freedom for the exchange of ideas and ability to communicate with each other. It is very open, which promotes the research, which can then move forward quickly.

When we proposed our EAST project to the central government, there was competition with other projects. So we improved our design, and argued many points to improve our design. Finally, the experts committee voted, and supported our project as a national project. We got special budget support, for construction of the EAST machine. I also visited PPPL (Princeton Plasma Physics Laboratory), General Atomics, and the Tore Supra, which is another superconducting tokamak of the French. The government realized that the superconducting tokamak, worldwide, had very strong support, and has a good foundation for development.

Even though I say there was full support for our EAST project, in fact, our budget is only about U.S.$30 million, in total. But, more than 15 years ago, this was a quite large budget compared to others.

Question: South Korea, your neighbor, is also pursuing fusion research developing superconducting magnet technology. Do you compete?

Wan: South Korea's fusion budget is more than 20 times higher than ours. The funding was short for us, so I made the decision that everything would be designed and fabricated by ourselves. All of the superconducting conductor was made by ourselves, in our workshop; all of the magnets, we made ourselves. And even the cryogenic systems, which you can buy on the world market, we fabricated ourselves. We assembled this tokamak by ourselves.

We had to seriously control the quality, during the manufacturing process, for the superconducting magnets. This will also be the case for ITER. When you finish manufacturing one piece of the superconducting magnet for ITER, you will cool it down to test it. But when you assemble all of the sections of the magnet together, you cannot test it at the low temperature. So, at room temperature, you are assembling all of the magnet together. You manufacture some joints, and so on, at room temperature. There is no way to cool down these parts to test whether the quality is good or not, beforehand. So, you must seriously control the quality another way.

Question: I understand that one of the proposals that has been put forward to cut down the cost of ITER is to test parts of the coils, but not the whole magnet, and to cool it down to liquid nitrogen temperature, not liquid hydrogen, which

CEA, Cadarache

France's Tore Supra superconducting tokamak.

www.defenceforumofIndia

India's Steady State Superconducting Tokamak, SST-1, in development at the Institute for Plasma Research. IPR is involved in research in various aspects of plasma science including basic plasma physics, research on magnetically confined hot plasmas, and plasma technologies for industrial applications.

EAST researchers celebrate the first plasma discharge in September 2006.

ITER

The sixth ITER council meeting, which took place in Suzhou, China, in 2010. Below, the ribbon cutting ceremony at the meeting.

ITER

EAST is a national project, supported by the central government. Here, He Guoqiang, secretary of the Central Commission for Discipline Inspection, visits EAST along with other government officials.

is what it will require. Is that very risky?

Wan: With the superconducting tokamak, you always take a high risk, because there is no way you can test the whole magnet. For our EAST machine, as you said, this was a risk. So I made the decision that each piece of the magnet would be cooled down and tested separately. The whole magnet is too large. As each segment is cooling down, you check for leakage. You can only cool it down, piece by piece. You join them together at room temperature in the final assembly stage.

Question: So, the first time that the whole magnet will be cooled down to become superconducting, is when it is in the tokamak?

Wan: Yes. You have to pump down the cryostat which covers the vacuum vessel and magnets. If you had to take it apart to fix the leak, it is a more complicated process than the initial assembly.

India is facing this kind of problem. They made the announcement that they had finished the final assembly of their device, and would test it. But when they cooled down the magnets, they had a leak. There is no way you find the leak or fix it. You can only disassemble it totally. This is the risk.

Question: That's why Dr. G.S. Lee was nervous when we were visiting the KSTAR superconducting tokamak in South Korea, because they were cooling down the magnets for the first time, and he was calling the laboratory in the middle of the night, worried about a leak.

Wan: Me too! for the week of the cooling down. With some materials, if you cool down to liquid nitrogen (77°K), there is no leak. But sometimes, when you cool down to liquid helium (4°K), there is a leak. When it turns warm again, the leak goes away, and you cannot find it.

For example, in Germany, the W7X, the Wendelstein stellarator, suffered this kind of leakage, and they still don't know where it is. You cannot go to low superconducting temperature because you do not have a good enough vacuum, because of the leak. For ITER, we emphasize, especially for the magnet, during the fabrication process, quality control is more important than anything else. The final assembly will take several years, so it is very important. ITER is so large. I think Dr. Lee is right. He said during the fabrication process of the magnet, quality control is the most important.

For our EAST, I cooled down and tested all of the magnets. I did not find any problem, fortunately. So up to now, we have done 14,000 discharges, a few hundred per day, of electromagnetic pulses on the components. The tokamak itself has not had any problems, just the facing components, facing the very high-temperature plasma. But this is no big problem, because you can look through the win-

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Technicians at the Institute of Plasma Physics in Hefei with a model of ITER's superconducting correction coils.

©Peter Ginter/ITER

Scientists at the Institute of Plasma Physics in Hefei work on the jacketing of superconducting cable for ITER.

dow into the vacuum chamber, and maintain and change these components.

The Materials Question

Question: Do you have to do this maintenance using remote handling?

Wan: Remote handling is only needed for a burning plasma when you use deuterium (D) and slightly radioactive tritium (T). For EAST we just use helium and deuterium, so there is no radioactivity and no problem. This is an experimental device. Inside the vacuum chamber, all of the components can be changed through the window directly after you do experiments. For ITER, we are still arguing about this. The design of some ITER components, still right now, is not totally solved.

For example, what kind of material will be used for the first wall? This is still under development. Should we use CFC (carbon fiber composite) material, tungsten, or some other material? This is under investigation. First we must use a CFC. But before the D-T (deuterium-tritium) charge, we have to change to tungsten. I hope this is not too specialized. Many plasma physicists don't understand this!

Question: Materials have been a challenge for operating in a fusion plasma environment.

Wan: I agree with you. Outside the fusion community, some people will say: "You have not resolved the materials problem for a tokamak, to be able to go to a reactor." And it is true. But I divide the materials question into two different problems.

One, is the first-wall material. It directly faces the high-temperature plasma. So, when the plasma's energetic particles are pumped and go to the first wall, which has a high heat flux, heat load, it can damage some components. Even though the plasma is magnetically confined, the high-temperature ions still create a high heat flux for the first-wall material. We have to choose the material which can suffer a high-density heat load, so, even if it erodes, and the first wall material can enter the core of the plasma, it cannot be allowed to influence the core plasma. This would cause an impurity, which will decrease the temperature, and cause a disruption. You cannot sustain fusion reactions with a dirty plasma (i.e., with impurities).

Another material problem is, that, even if the first-wall material can suffer the high temperature, the fast neutrons will penetrate the first-wall blanket. The material for the blanket is inside some very complicated structural material. The neutrons are at a very high flux. We do not have any evidence that any material can survive this. We have developed materials to survive the first wall heat flux. They are not good enough, but we can use it temporarily. But for the high neutron flux, up to now, there is no experimental data on what kind of material can be used, because we don't have a neutron source for testing new materials.

That is why, when the international fusion community made the decision to construct the ITER project, some scientists

ITER

Members of ITER's Magnet Division spent a week at the Institute of Plasma Physics in Hefei, where work is ongoing on the design of the magnet feeders. Here team members look at the first bending and insulation trials on conductor dummy lengths, which will be used in the electrical connections to the magnets around the tokamak. These provide flexibility for thermal contraction as the magnets are cooled to liquid helium temperatures.

made the proposal to construct another test facility, IFMIF, the International Fusion Materials Irradiation Facility. It is an accelerator. It would be a very huge and expensive facility. It would use an accelerator to produce neutrons to get the experimental data, and see what kind of material can suffer a neutron environment. This is the second-most serious problem.

But fortunately, all of this blanket and first-wall material is changeable. You can change the blanket and maintain it through the windows. The lifetime may be 20 years, I suppose, if you can develop a new material. If you cannot, then, in three or five years, you can change it. It is a serious problem, but it is not impossible. The question is just the lifetime of the components. We should develop materials, and do many kinds of tests to get a high quality of material. Then we can increase the lifetime of these components, which means decreasing the price of fusion energy. Otherwise it will be very expensive, in competition with other energy resources.

ITER

Ultrasonic inspection for cracks of 30 prototype low carbon central solenoid jacket sections for ITER, produced by Baosteel in Shanghai, under an ITER contract. The sections will undergo compaction at the jacketing line in Kyushu, Japan, and then be sent to Oak Ridge National Laboratory for preliminary winding trials.

Nuclear Power in China

Question: While developing fusion technology, China is carrying out a very ambitious nuclear energy development program, unlike the United States or western Europe.

Wan: China right now is only 1 or 2 percent nuclear. You can use solar, and wind, hydropower, but that is only part of global energy. So nuclear power is the solution, because if you really think CO_2 causes the "greenhouse effect," and you must control this, nuclear power stations are good.

Of course, safety has been a problem. In Russia they had a big accident. In the United States. after an accident, it stopped. But now, the safety has improved a lot. An airplane looks terrible in terms of safety, but the airplane is safer than riding a bicycle in China. So, finally, people are realizing that nuclear power stations are safer and cleaner.

So I think more and more countries are changing their ideas.

Question: Although you are starting from a relatively small nuclear energy base, the projected rate of growth is impressive. And you are looking toward the next 20 or 30 years. Can you talk about the fission-fusion hybrid project that you have proposed be developed, as the bridge between fission and fusion?

Wan: China must develop fission power stations as rapidly as possible. Otherwise we have a big pollution situation, not just domestically, but internationally. Right now, about 70 percent of our energy comes from coal. It is terrible. It is the highest percentage in the world. If you consider that the population is so large, the absolute amount of coal China uses each year is very huge. So China must decrease this, and fission power is a good way to decrease the primary energy resources from coal. The government and the public support the rapid development of nuclear power stations.

In a nuclear power station, you can only use about 1 percent of the uranium, so, very quickly, there will be a shortage of uranium—in less than 100 years. So this is one problem. The second problem is the waste, which is increasing very quickly, year by year. This is also very dangerous.

So, how do you deal with these kinds of problems—the shortage of material and the waste? Of course, you can develop a fast breeder, which needs time. Also, the efficiency is quite low.

If the tokamak fusion reactor is successful, you can use the fusion neutrons to irradiate uranium-238 into plutonium-239 for fission fuel. Also, you can use the neutron source to transmute the waste, which is safer. To do this, you don't need a pure fusion power reactor, which still has the materials problem. If you use the hybrid concept, you can use a little pure fusion in a cold plasma, which means that the neutron flux is much lower than in the pure fusion power station. But you can use the fusion reaction in the blanket to amplify the output of energy. You can breed fission material, and treat the fission waste.

This is a benefit for both sides: for fusion, you can promote the development of fusion technology, of materials development, so you can get an early application for fusion, and, at the same time, benefit fission. This is the best idea.

Twenty years ago, many Europeans and Americans didn't support this idea, because, coming from the political point of view, they thought you will produce a lot of plutonium for nuclear bombs. I say that the energy problem is more dangerous than the nuclear bomb. The next generation, and several after, will face a serious problem [without nuclear energy].

In South Korea, India, Russia—I heard, even in the U.S.—more and more people

support this fission-fusion hybrid concept.

Question: The hybrid concept was put forward in the United States 30 years ago. Dr. Edward Teller strongly promoted it, as a bridge between fission and fusion. But it was never developed here.

Wan: The first director general of ITER, the Frenchman Paul Henri Rebut, talked with me about it one day, in China: that the hybrid is the best way to use nuclear energy, combining fission and fusion. Right now, it looks like everyone agrees on the concept of a hybrid. So China would like to do this. But first, the tokamak reactor has to be a success.

So right now, in the meantime, we will use an accelerator to produce the neutrons, not a fusion reactor, for breeding nuclear fuel and to transmute the waste, and so on.

Question: But you're not going to wait to see if the ITER tokamak reactor is a success before going ahead with your own program?

Wan: I think that the tokamak program has already made significant progress, on JET, TFTR, on JT-60. The tokamak can really go to a burning plasma. Some scientists in China say, ITER is not clearly a success. Why do you want to construct another machine?

The tokamak has a very strong basis, which comes from all of the experiments that have been done. We summarized all of the experiments that were done, to get the scaling law from the previous experiments, and then extrapolated. So we have very strong confidence that ITER will be a success. I think there is no problem for ITER to go to the 400 megawatts of burning plasma.

I use this argument with others: China should prepare before ITER is fully successful. We should design and do some R&D, and maybe construct our hybrid test reactor. We have already made this kind of proposal to the government. But many projects compete, and they criticize each other! So we will continue to do this. Our Institute is in competition with others, who continue to criticize.

Question: When you look at China's nuclear program, you see that the government does understand that the country needs an adequate supply of energy, and takes responsibility for infrastructure. That has not been true here in the United States.

Wan: Twenty years ago, being in the United States was a big surprise for me, but now, for Chinese people who go to the United States, it is no big surprise, because the highways in China are also developing, especially around the big cities.

Question: And the United States has been going dramatically in the wrong direction. I am sure you are aware, for example, of the housing crisis; we have people who have lost their homes, and are living in their cars.

Wan: People in China are following the situation in the United States.

Question: People are living in their cars?

Wan: Yes. In Beijing, rush hour is terrible, more terrible than in New York!

China should learn some things from other countries, but also not to make some mistakes.

Looking to the Future

Question: The political leadership of China has said it is not going to do what was done in Russia after the fall of the Soviet Union, with the privatization of that nation's economy and national patrimony. It is a disaster.

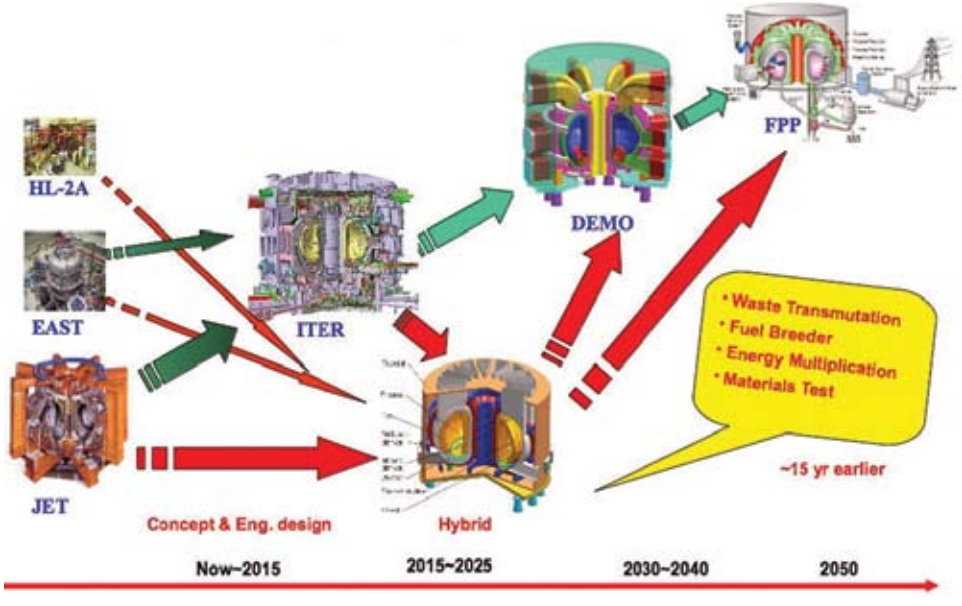
Wan: I was in Moscow in 1992, to get the T-7 tokamak shipped. Moscow was terrible. There was a food shortage, and there were no products for sale.

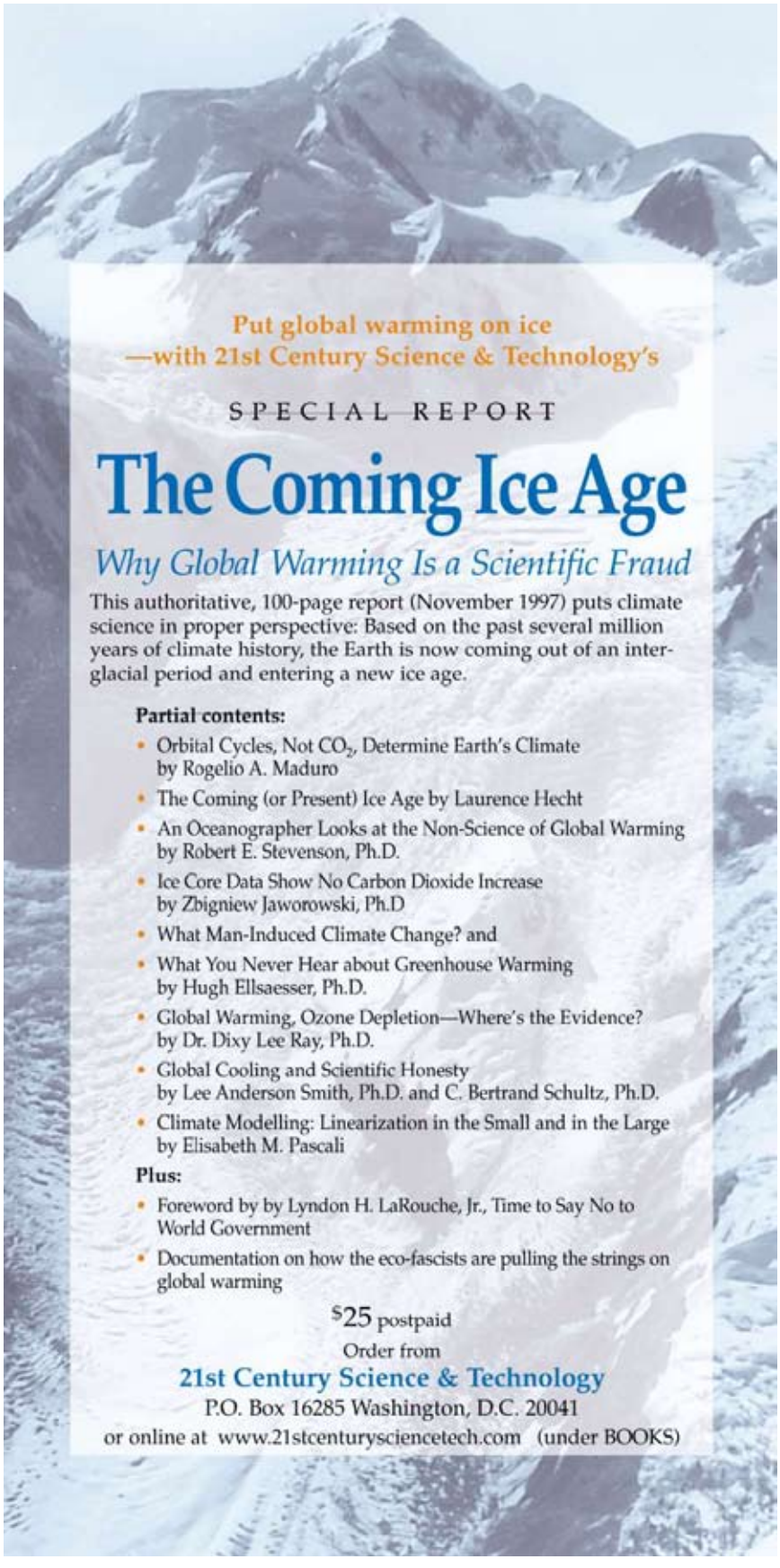
To come back to the hybrid: after I made the presentation, several people invited me to join in a workshop in the United States, and one in Italy. More and more people realize this could be a good choice.

I don't know if the Chinese government will make an early decision to build the hybrid, or not. The big problem for

POSSIBLE FUSION ROAD MAP TO DEMO IN CHINA

The next step proposed for China's fusion program is a fusion-fission hybrid, to be built while ITER is under construction. The fusion neutrons would be used to breed fuel for, and burn waste from, China's fission reactors, while tackling the technological challenges of fusion.





our magnetic fusion community is this: Most experts in China say "Your magnetic fusion community has already gotten a huge budget to support ITER. You are so rich! So please wait for 10 years, until you are fully successful with ITER, or with EAST. Then, maybe, the government will give you more support."

But I think time is very important. We should overlap the projects. This is long-term research, to solve the big problem of energy in China. So we must make the decision in advance. People always ask, "What is your schedule?" I say, my personal opinion is, that to make the decision is most important. Otherwise, there is delay, delay, delay. In fact, the schedule is not determined by the design, construction, assembly, and so on. It is determined by the decision.

For example, for ITER, the beginning was more than 20 years ago. They finally made a decision to build it, but after 20 years! Twenty years, just to make the decision! But the construction will be only 10 years. This is not reasonable.

For our EAST machine, we took only about five years to finish the design and fabrication of the components and assembly, and finally, we got the first plasma, in 2006; about a year and a half before KSTAR. I think making the decision as soon as possible is very important.

Question: You also need to keep momentum, if you want to bring in young people. How long will you be doing experiments on EAST? Will they continue until ITER is operational?

Wan: I think we can continue experiments on EAST for 10 years. Before ITER is in operation, both EAST and KSTAR can make different kinds of contributions to ITER, so we should use them both as much as possible to get technology development and support. ITER is an experimental reactor, so it is necessary to make broad investigations in many technologies—how to control the plasma to go to steady-state operation, how to profile the plasma, and so on. It is a very sensitive and very complicated technology. How to heat it and keep the plasma current is also a very complicated situation. If you do the research in depth, in the future, the tokamak reactor can be simpler.

So we will continue to do these kinds of experiments.

ALEXANDER VON HUMBOLDT

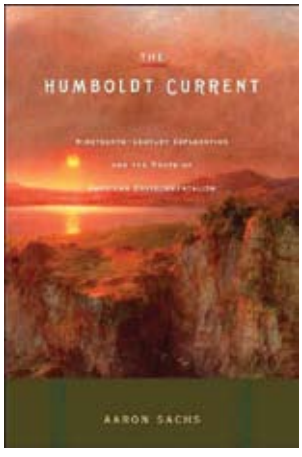
Beacon of American Science And Forerunner of NAWAPA

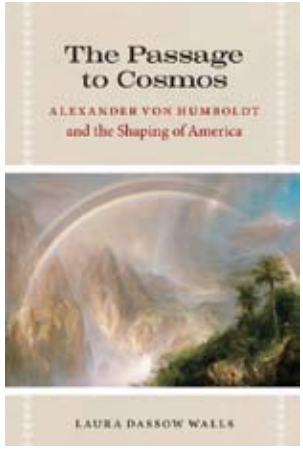
by Timothy Rush

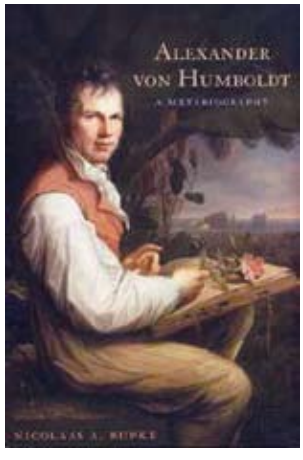
The Passage to Cosmos: Alexander von Humboldt and the Shaping of America
Laura Dassow Walls
Chicago: University of Chicago Press, 2009
Hardcover, 404 pp., $35.00

The Humboldt Current: Nineteenth-Century Exploration and the Roots of American Environmentalism
Aaron Sachs
New York: Viking Press, 2006
Hardcover, 496 pp., $25.95

Alexander von Humboldt: A Metabiography
Nicolaas A. Rupke
Chicago: University of Chicago Press, 2008
Paperback, 316 pp., $21.00







Both Aaron Sachs and Laura Walls make significant contributions to a long-overdue subject for Americans: Humboldt's devotion to the success of the American republican ideals, what Lincoln would later term man's "last, best, hope on Earth," and the fecundity of Humboldt's scientific, cultural, and aesthetic influence on the nascent republic, throughout the 19th Century. Both exclaim over the startling vanishing of Humboldt from the American intellectual landscape in the 20th Century, and seek to remedy that amnesia in the 21st.

Although they overlook a crucial vector of Humboldt's formative investigations and travel in the international networks of Benjamin Franklin (see this author's "Alexander von Humboldt: A Republican Scientist in the Tradition of Franklin," *21st Century,* Spring 2002), they fill out considerably the subsequent phases of Humboldt's influence in America.

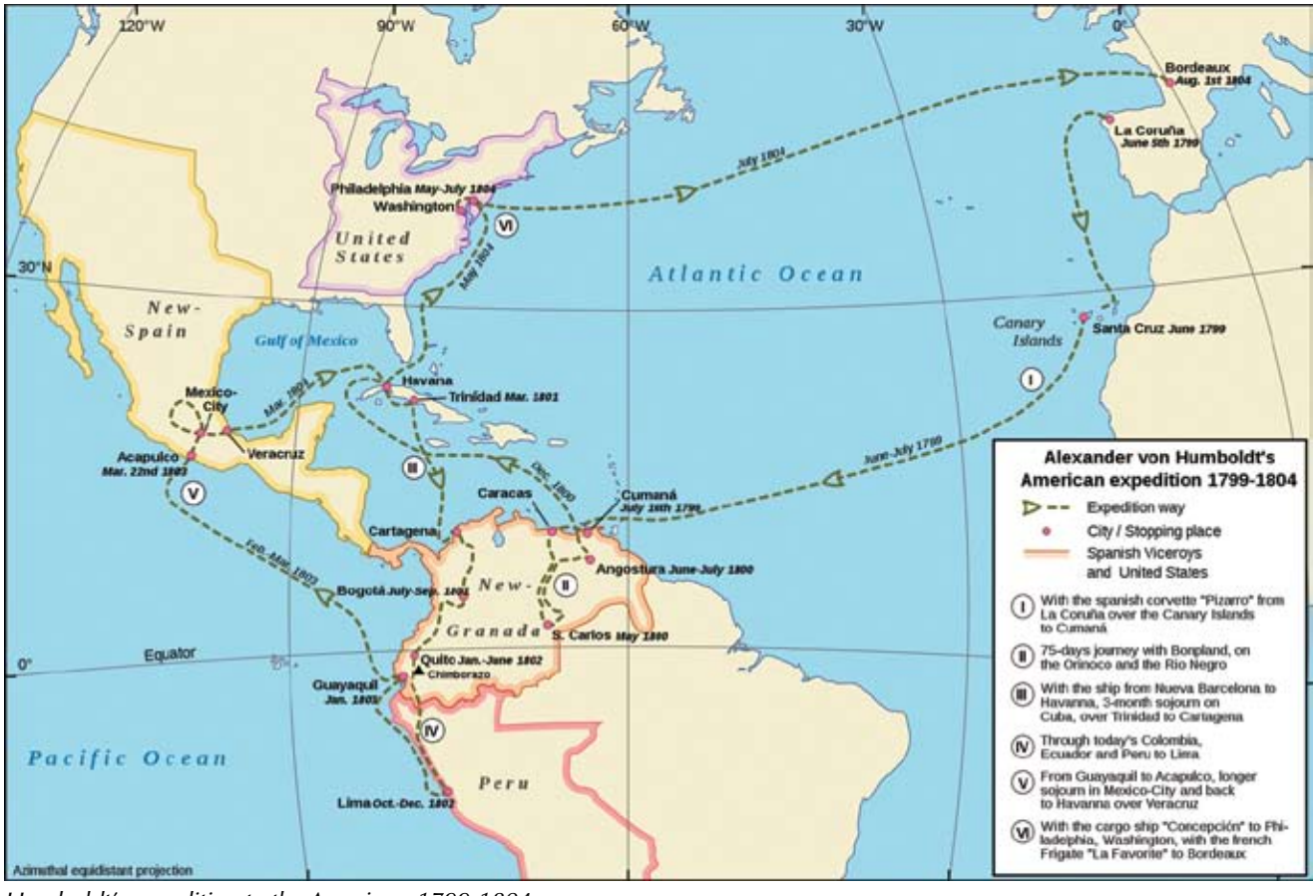
Nicolaas A. Rupke has authored what he terms a "metabiography." Rather than write a biography of Humboldt directly, Rupke exhaustively chronicles the changes in biographical treatments of Humboldt over the succeeding historical periods. His chapter titles by themselves show not only the absorbing and startling shifts in portrayal of Humboldt and his influence, but also something of the immense richness and complexity of that life itself: "Liberal Democrat before the Empire Period," "The Wilhelmian and Weimar Kultur Chauvinist," "The Aryan Supremacist of National Socialism Nazification," "East Germany's Antislavery Marxist," "West Germany's Cosmopolitan Friend of the Jews," and "Today's Pioneer of Globalization." The latest raft of new books would undoubtedly prompt Rupke to add a further chapter, "Forerunner of Environmentalism," although this would be an utterly false characterization, as shown below.

The first 110-odd pages of Sachs's treatment, focussing on Humboldt and his U.S. connections per se, is first-rate material, which brings out, in particular, the enormous affinity between Humboldt's outlook and the Whig political establishment, founded around Henry Clay's and John Quincy Adams's revival of the country's founding Hamiltonian economics. "The mutual understanding between Humboldt and America's Whig intellectuals in the 1840's was remarkable," peaking with "the appearance of the English translation of the second volume of *Cosmos* [Humboldt's magnum opus of his last decades] in 1848," Sachs correctly emphasizes.

However, the bulk of Sachs's book is dedicated to turning points in the careers, travels, writings, and aesthetics of four individuals whom Sachs sees as exemplary "Humboldtians": J.N. Reynolds (1799-1858), Clarence King (1842-1901), George Wallace Melville (1841-1912), and John Muir (1838-1914). These sections all have some interest, but are not fundamental to understanding Humboldt's thinking and direct influence.

A Treat

Laura Walls's 400-page study is accurately conveyed in its title, *The Passage to Cosmos: Alexander von Humboldt and the Shaping of America*. The book is, in



Humboldt's expedition to the Americas, 1799-1804.

many respects, a treat. Of particular value is the summary of the formative currents in what became known as "physical geography"; the devastating losses of key Humboldt collaborators in Ibero-America's Wars of Independence; the direct collaboration of Humboldt and John Quincy Adams in promoting the American cause at the 1814 negotiations to end the War of 1812; and the extended treatment of Humboldt's role in battling the pseudo-scientific rise of "physiological proofs" of the inferiority of darker skinned peoples, which emerged in the 1840s in the United States to buttress the continuance of slavery.

Along the way, Walls drops comments of much more suggestive insight than she herself is aware: "Although the British geographical tradition excluded human beings, the Germans did not," for one. Another: the Humboldt brothers, Wilhelm and Alexander, shared a suspicion "of the Enlightenment attempt to reduce the world to abstract principles along Newtonian lines."

The Green Pest

What is infuriating about the Sachs and Walls books is the axiomatic acceptance of modern environmentalist dogmas, as if they were in agreement with Humboldt's method and outlook, when evidence available in the books themselves, shows such an assertion to be absurd. Admittedly, both authors refute an even more extreme misrepresentation of

Alexander von Humboldt (1769-1859) spent a year in Mexico, studying its physical geography and economy. His detailed map of the country, from which this is taken, was published in 1811 in his Political Essay on the Kingdom of New Spain. *The Essay also includes his proposals for major geo-engineering projects to develop the country.*

Humboldt's importance to Mexican science is acknowledged in the inscription on this statue, which is located in the Alameda Central (central park) of Mexico City: "From the Mexican Nation to Alejandro de Humboldt—Deserving the thanks of the country 1799-1999." The statue celebrated the 200th anniversary of the beginning of Humboldt's great travels.

Humboldt's role, that of Mary Louise Pratt in a 1992 essay "Humboldt and the Reinvention of America."

Walls summarizes Pratts's argument: "Humboldt invented America as 'primal' nature, emptied of human history in order, in the classic imperialist mode, to repopulate it with white European systems and goals," and decries that Pratt's travesty "has become canonical in postcolonial studies . . . the single most often cited treatment of Humboldt by a U.S. American."

But both Sachs and Walls have their own absurdities to deal with, as they try to shove Humboldt into an environmentalist straitjacket. The solitary item from the immensity of Humboldt's 30 major works based on his research and travels, (as well as five volumes of his crowning *Cosmos*), which both authors choose to highlight, is Humboldt's analysis of falling water levels in the Tacarigua Lake near Valencia, in today's Venezuela.

The local inhabitants thought the drop in water level was caused by underground seepage. Humboldt convincingly demonstrated that diversion of the water for indigo crops, and deforestation of the surrounding hills, were the primary culprits. "Humboldt explained that the surrounding soils, once deprived of the trees' root systems, had a greatly diminished capacity for water retention, so they could no longer recharge the springs that fed the lake," Sachs writes.

Humboldt generalized the case in the following words: "By felling the trees which cover the tops and sides of mountains, men in every climate prepare at once two calamities for future generations: want of fuel and scarcity of water."

No one, greenie friend or foe, could take exception to Humboldt's insight and admonition. But such an example hardly supports Sachs's repeated interjections that "watching Humboldt at work, we train our own eyes to see the truth—especially about our own smallness, our humble place in nature."

And Walls somehow darts from the lake in Valencia to the wild assertion that Humboldt's "work on climate change marks the beginning of awareness of global warming." She expands on the theme later, decrying how "... so many of us live in virtual worlds, while the real one, the one we didn't construct, tips into a cascade of climate change that we ourselves . . . caused, that we cannot control, and whose consequences we can only dimly foresee."

Contrast this insidious cultural pessimism to the magnificent conclusion of the first volume of Humboldt's *Cosmos*. After citing a quote from his brother Wilhelm, that "the unrestrained development of the physical powers" is "the ultimate and highest aim of society, identical with the direction implanted by nature in the mind of man toward the indefinite extension of his existence," Humboldt concludes:

"From the remotest nebulae and from the revolving double stars, we have descended to the minutest organisms of animal creation. . .; and here we have been able to arrange these phenomena according to partially known laws; but other laws of a more mysterious nature rule the higher spheres of the organic world, in which is comprised the human species in all its varied conformation, its creative intellectual power, and the languages to which it has given existence. A physical delineation of nature terminates at the point where the sphere of intellect begins, and a new world of mind is opened to our view."

Humboldt and NAWAPA

In sum, Sachs and Walls paint Humboldt as a proto-greenie ready to do battle to reduce man's "footprint" on the globe, a many-faceted impresario of Earth sciences who had an exquisite aesthetic appreciation of nature and a corresponding sense of the "smallness and nearsightedness" of Man, as one of the authors puts it. The authors would surely enlist Humboldt as an authority in denouncing the vast transformation of the West of the North American continent—something 40 times greater than the TVA—envisioned in the North American Water and Power Alliance (NAWAPA).

Ironically, the reason Humboldt's name graces the major river, mountain chain, and inland sink of northern Nevada—bestowed on these features in the mid-1840s, in an area never visited by Humboldt and some 40 years after his one and only, brief stay in the United States—is that Humboldt was seen by several generations of America's frontline explorers, geographers, and geologists, as the guiding spirit of America's development of these parched areas.

Today, Humboldt, an ardent promoter of technological progress in general and great engineering enterprises in specific, would be an emphatic partisan of NAWAPA. In fact, there is no stretch in calling him a father of NAWAPA. Here is the evidence of his paternity:

Three vast human geo-engineering projects for the Americas stand out in Humboldt's panoply of initiatives.

The first proposal was made after he personally verified that the Orinoco River of Venezuela was connected to headwaters of the Rio Negro (a tributary of the Amazon) by a singular, natural canal-like

watercourse called the Casiquiare. Humboldt proposed that the interior of South America be developed by linking all three of the great river basins of the continent—the Orinoco, the Amazon, and the Rio de la Plata—into a 4,000-mile vast inland transport and development network.

Put forward two generations before the building of the transcontinental railroad in the United States, Humboldt's conception shared much of the railroad's function in opening the interior of a continent to systematic development, and thus breaking the patterns of coast-based enclaves of colonial economy. Humboldt's vision is still not built today—although it is much discussed and studied.

The second and third of his hallmark geo-engineering projects are contained in his extraordinary *Political Essay on the Kingdom of New Spain*. This lengthy work, the fruit of his roughly one year (1803-1804) spent in New Spain (what is today Mexico), was translated into English the very year of its original publication in French, 1811. (Fortunately, this John Black translation has been reprinted in its complete four volumes in 1966 by AMS Press in New York (available online). Otherwise, modern readers would be stuck with an abridged Borzoi version published in the 1950s by Alfred A. Knopf which "eliminated with regret" exactly these two defining projects!)

Humboldt observed that the Orinoco River in Venezuela (shown here) was connected to a tributary of the Amazon, and proposed a great project to develop the interior of South America by linking the three great river basins of the continent—the Orinoco, the Amazon, and the Rio de la Plata—into a 4,000-mile vast inland transport and development network.

Connecting the Oceans

The first of these projects, contained in Book I, Chapter II, pp. 16-45, is an astonishing survey of nine routes for connecting the Atlantic and Pacific coasts of the Western Hemisphere, including with canals. (See illustration, p. 62) As he writes: "We must confine ourselves here to the *problem of the communication between the two seas,* in all the generality of which it is susceptible. We shall present in one view nine points . . . and all offer a greater or less probability either of canals or interior river communications" (italics in original).

The first of these points is an examination of possible connections between the Columbia River and Canadian Arctic rivers, including the Mackenzie. Geographical knowledge of the region at the time Humboldt was writing was too sketchy for him to come to any conclusion on the point. In fact, the river systems are not naturally connected: That will be accomplished with NAWAPA.

The third route identified by Humboldt is the Tehuantepec Isthmus in Mexico. The fourth, involves a crossing at Nicaragua, utilizing the San Juan River and the Lake of Nicaragua. Humboldt finds this the most viable (as did the extended U.S. surveys of 1870-1875), but says many more studies and surveys are needed.

The fifth location is the crossing at Panama. Humboldt devotes more space to this possibility than any other, and with extraordinary prescience observes that because of the difficulties of the terrain, the notion of a sea-level canal "ought to be completely abandoned." Would that the French effort under Ferdinand de Lesseps 70 years later had had such acumen!

Humboldt then proceeds to point six, the Atrato-Truandó route through the Colombian side of the Darien Isthmus. He concludes with point nine, a speculation that there might be a potential crossing of Patagonia, 7 degrees north of the Strait of Magellan (later proven not feasible).

Wherever the interoceanic canal would be determined to be most viable, Humboldt writes in summary, it would be "an undertaking calculated to immortalize a government occupied with the true interests of humanity."

Defeating Tropical Disease

Tellingly, Humboldt recognizes that defeating the vectors of tropical disease will be a prerequisite for such gigantic undertakings. He devotes 70 pages to an exhaustive survey of the extant literature in Europe, the United States, and Spanish America, regarding yellow fever, known in the tropics as *"vómito negro"* for the typical gushing of darkened blood from the mouth in its final stage. To this he adds extensive personal field notes accumulated in his travels, along with tables of incidence of the disease correlated with weather readings gleaned from health records in notorious fever-ridden ports such as Veracruz, Acapulco, and Panama City.

Humboldt does not hit upon the *Aedes aegypti* mosquito vector (that would wait for the work of Carlos Finley, Walter Reed, and William C. Gorgas at the end of the 19th Century), but he shows a *method* of assembling and cross-referencing all data in all variables which eventually would yield the breakthrough. It would not come in time to save the doomed French phase of the Panama Canal enterprise; but the discovery was an indispensable compo-

The East Humboldt range in Nevada looking northwest from Spruce Mountain. Many American locations bear Humboldt's name, not because he was there in person, but because generations of America's explorers and scientists saw him as the guiding spirit of America's development of its Western lands.

The Humboldt River, running east to west in northern Nevada, was named by explorer John Charles Fremont in 1846, and became the strategic route by which the California Trail and the Transcontinental Railroad united the country.

nent of the successful U.S. effort 10 years later.

The Mexico Basin

The second great project outlined by Humboldt in the *Political Essay on the Kingdom of New Spain* is a solution to the hydrographic challenges of the basin of Mexico City. He devotes no less than 85 pages to the nature and history of the problem, which bedevils Mexico City to this day. His treatment became legendary, and modern studies continue to refer to his summary of the efforts to deal with the difficulties as a landmark.

The problem was clear even at the time of the Spanish Conquest. The basin of Mexico City has no natural drainage. The Aztecs built their capital city, Tenochtitlán, as an island city in the middle of one of the large lakes of the basin, connected to surrounding higher ground by causeways. Even so, they suffered periodic floods.

When the Spaniards arrived, they attempted to drain the surrounding lake, (one of four lakes in the broader basin), but likewise faced recurrent devastating floods. The years 1629-1634 were one uninterrupted period of flooding! Over a period of 200 years, up to the very time of Humboldt's visit, a series of large-scale hydraulic works were initiated, which Humboldt called "undoubtedly one of the most gigantic hydraulical operations ever executed by man."

These included a tunnel at Nochistongo (also designated by the name of the nearby town Huehuetoca), to drain the upper lakes at the lowest point in the surrounding hills and mountains. The tunnel collapsed—because, Humboldt noted, the designer failed to use *elliptical* curvature, of the kind Humboldt, trained as a mining engineer, knew to work for similar conditions in shoring up mine tunnels.

The viceroys then ordered that the rock above the collapsed tunnel be excavated (at times using 15,000 native Indian laborers), to make the passage an open-air cut. But as Humboldt demonstrates, the cut was too narrow for the nature of the surrounding rock, and the passage was routinely blocked by rockfalls for long periods of time. Humboldt prepared a cutaway schematic (see illustration, p. 62) of the levels of the water courses to aid the conceptualization of a more enduring solution.

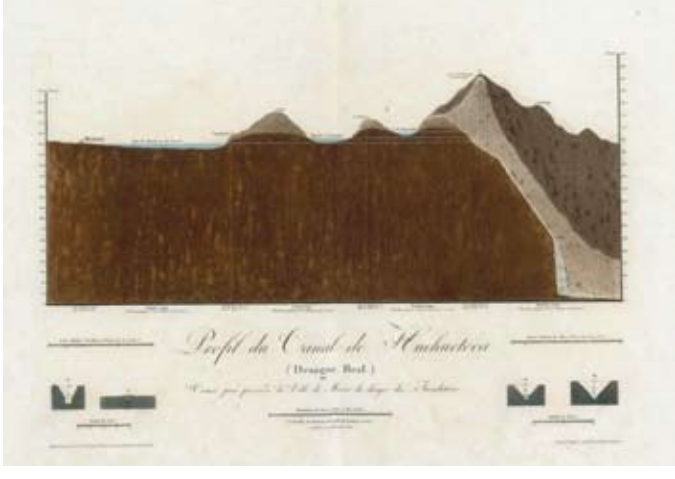
Photo by William Henry Jackson, ca. 1880s; Brigham Young University

Rock falls at Nochistongo. Humboldt observed that when it was decided to cut the tunnel, the slope was inaccurately engineered, leading to constant rock falls and re-excavations.

Humboldt notes with interest a proposal just being conceived at the time of his visit, of digging a deep drainage tunnel at a different point in the valley, leading out to the Tequizquiac River. This was indeed the major advance undertaken 150 years later, in the mid-20th Century! He also emphasizes that the brute force work conditions of the Indian laborers had aroused "the most bitter hatred against the desague [drainage cut] of Huehuetoca," and that "a hydraulical operation is looked upon by them in the light of a public calamity, not only because

From Humboldt's *Political Essay on the Kingdom of New Spain*, 1811

Humboldt's map of eight of the nine potential canal and river transport connections he identified, to link the Atlantic and Pacific Oceans. Map VII (center bottom) shows the site that was eventually chosen for the Panama Canal.



Humboldt's cutaway schematic showing water levels around the failed tunnel at Huehuetoca, which was intended to guide the construction of a successful project at the same point. As a mining engineer, Humboldt understood the elliptical curvature that would be needed for a stable tunnel.

a great number of individuals have perished … but especially because then were compelled to labour to the neglect of their own domestic affairs, so that they fell into the greatest indigence while the desiccation was going on."

It was clear that Humboldt recognized that major technological advances were required to avoid this appalling human toll.

But the most interesting observation from Humboldt, of special relevance to the interacting features of the NAWAPA project, is his passionate attack on those who obstinately defined the problem of the Mexico City basin solely as how to get the water out.

"In all the hydraulical operations of the valley of Mexico, water has been always regarded as an enemy, against which it was necessary to be defended either by dykes or drains. We have already proved that this mode of proceeding, especially the European method of artificial desiccation, has destroyed the germ of fertility in a great part of the plain of Tenochtitlán. Efflorescences of carbonate of soda have increased in proportion as the masses of running water have diminished. Fine savannas have gradually assumed the appearance of arid steppes. For great spaces the soil of the valley appears merely a crust of hardened clay, destitute of vegetation, and cracked by contact with the air."

Modern-day residents of Mexico City, afflicted with frequent dust storms and consequent breathing difficulties during the dry seasons, arising from the desiccated expanses of dried lake-beds and denuded landscape, will heartily assent to Humboldt's admonition.

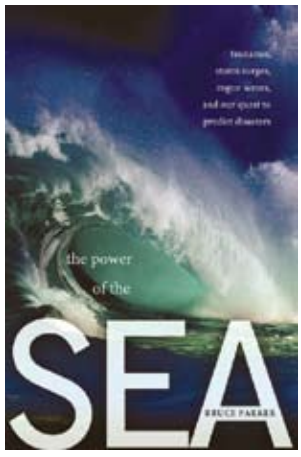
But the real fun is Humboldt's sketch of a solution: "It would have been easy, however, to profit by the natural advantages of the ground, in applying the same canals for the drawing of water from the lakes for watering of the arid plains, and for interior navigation. Large basins of water ranged as it were in stages above one another facilitate the execution of canals of irrigation."

That is, a human makeover of the entirety of the basin, in a comprehensive application of man's creative powers.

Humboldt was a builder!

The Sea Around Moses, Napoleon, and Atlantis

by Rick Sanders



The Power of the Sea
Bruce Parker
New York: Palgrave Macmillan, 2010
Hardcover, 292 pp., $28.00

Have you ever wondered how Moses got the children of Israel across the Red Sea, without magic—and what this had to do with the (Passover) full Moon? Can you resist a story about Napoleon almost meeting the same fate as the Pharaoh at the hands of the Red Sea, 3,000 years later? Or how about cracking the mystery of the date of the destruction of Atlantis, looking at the 1755 Lisbon earthquake and tsunami?

That is why I recommend this book, even though the author, the former chief scientist of the National Ocean Service at NOAA, tries to sneak in some unconvincing global warming propaganda.

First, the story of Moses. There are some clues relating to Moses' experience and his genius as a leader. After killing the Egyptian overseer, Moses had fled to the land of Midian, in the southern part of the Sinai peninsula, near the Red Sea, which has substantial tides, perhaps 5 to 6 feet, and sometimes more, depending on the wind.

Furthermore, it seems that the tide in the Red Sea comes in very fast, because of the shape of the sea floor. Now, you will remember that the Jewish Passover and Christian Easter are both dated by the first full Moon after Spring equinox (with different particulars). Pharaoh, unlike Moses, not having lived near the Red Sea, but near the tideless Mediterranean, might not have suspected what was going to hit him. Moses, being a great leader, must have had it all planned.

When the Moon is new or full, the "Spring tides" are higher, lower, and longer than usual, the which gave the children of Israel the time to get across to the other side. Furthermore, something Moses could not have counted on, but which would have helped, was that "the LORD caused the sea to go back by a strong east wind all that night, and made the sea dry land, and the waters were divided" (*Exodus* 14, 21). This would have kept the ground bare longer, for the Israelites to pass over.

Then the tide rushed in, faster and higher than usual, washing over the heavy Egyptian chariots enmired in the sand, and as the song says, "Pharaoh's army got drownded."

3,000 Years Later

This same Red Sea tide nearly drowned Napoleon. Unlike the Pharaoh, Napoleon did know about tides: Off the French Atlantic coasts there are tides which have drowned many an unwary fisherman, rising 45 feet in 6 1/4 hours. The locals living along the coast describe the incoming tide as like galloping horses.

Parker tells the story about how, nonetheless, Napoleon nearly got caught by the Red Sea. During his invasion of Egypt, Napoleon wanted to visit a place called the Wells of Moses, which required leaving Suez and crossing a mile-long expanse of sea bottom that was exposed at low tide.

"Late in the afternoon he and his men left and began their return trip to Suez. The sun had set by the time Napoleon and his soldiers reached the seashore. The tide seemed to be out far enough for them to begin crossing the exposed sea bottom but the sea bottom did not stay exposed for long. Suddenly the tide began rushing in at them, seemingly from all directions surrounded by rapidly rising water, and with darkness adding to their confusion, they were thrown into disorder and panic. As the tide rose, the water quickly became deeper and threatened to engulf them. Their only chance was to find a shoal where the water might still be shallow enough to walk on.

"Napoleon called his men and ordered them to form concentric circles around him each horseman facing outward as part of several straight lines pointing in different directions like the spokes of a wheel. He then ordered each line of horsemen to advance outward. When the lead horse of a line reached deeper water

One of many contemporary depictions of the earthquake and tsunami that leveled the city of Lisbon on Nov. 1, 1755.

and had to begin desperately swimming, that column drew back and followed one of the columns still walking on the sea bottom. Eventually each of the columns lost their footing until only one remained, which everyone followed to an ultimate escape from the Red Sea."

Lucky for Napoleon, it was a only a neap tide (the twice monthly lowest level of high tide).

Parker tells a number of other fascinating, and little-told stories, including the Allied landing preparations for avoiding the obstacles that the Nazis had put underwater off the Normandy coast during World War II, and the difficult weather and tide predictions required for the landing in Africa.

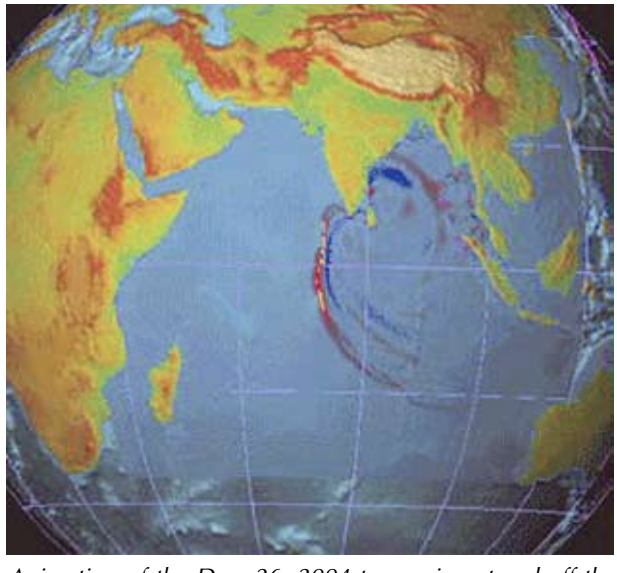
He also tells the lesser-known story of the treacherous storm surges, less notorious than tsunamis but much more frequent, which have killed many more people—including in the middle of what appears to be local good weather! For example, in Bengal on Oct. 4, 1864, the day was beautiful, sunny, and dry after nearly five months of torrential downpours. But within an hour or so, a cyclone-created storm surge killed at least 80,000 people and 100,000 cattle.

Ruins of Lisbon's Convento do Carmo, which was gutted by the 1755 earthquake. More than 85 percent of Lisbon's buildings were destroyed by the earthquake and fires.

The Killer Tsunamis

Parker does give the tsunami its due, with a fascinating and horrifying minute-by-minute description of the 2004 tsunami, which killed 300,000 people within the first two hours. At one place, the tsunami came in as two waves, the second one 115 feet high—as high as a 10-story building. We will come back to this one.

But first, let's look at the earthquake and tsunami that destroyed Atlantis, and how this was discovered by indirection. Parker gives a detailed description of the Nov. 1, 1755 earthquake on All Saints Day, when Lisbon, Portugal was full of churchgoers. The ground began to tremble around 9:30 a.m. People who escaped the collapsing buildings ran in panic to the riverbank, where there were no high buildings. Ninety minutes after the first earthquake shock, the water of the Tagus river began rising, ships rocking wildly, although there was no wind. In the distance, a large body of water, rising as it were like a mountain, came foaming and roaring towards the shore.



Animation of the Dec. 26, 2004 tsunami centered off the coast of Sumatra, Indonesia, that killed more than 230,000 in several countries. http://en.wikipedia.org/wiki/File:2004_Indonesia_Tsunami_Complete.gif

The first wave was 40 feet high and swept away thousands; the massive quay was flipped over like a toy. When the wave subsided, many people were inexorably dragged into the river. The second wave came 10 minutes later, charging even farther up the shore, followed by a third one.

Tsunamis wiped out entire cities to the south, along the coast of southern Portugal, Spain, and Morocco, and on Madeira, an island 600 miles southwest of Lisbon.

On the island of Antigua, in the Caribbean, the water rose 12 feet several times, and then subsided.

Now here's the punch line: Modern marine geologists have examined the sediment in the coastal area around Lisbon, and have found that eight large tsunamis hit there in the last 12,000 years, roughly one huge tsunami every 1,500 years. The 1755 tsunami, one of the largest in human history, pales in comparison with a tsunami of 12,050 years ago whose sediment layer, the deepest of the eight, was five times larger than the 1755 layer. And that date, 12,050 years ago, is the date Plato gives for the destruction of Atlantis, west of the Strait of Gibraltar!

Tsunami Ironies

The 2004 tsunami brought out certain ironies, one of them being that certain modern people who fancy themselves educated, perished because they were too illiterate to "read" the warning signs, while some so-called primitive people, who had an oral tradition about tsunamis, headed for the hills and survived.

However, if Western tourists on the beach had not been cut off from their own traditions, and had studied the *History of the Peloponnesian War*—where Thucydides attributes the 425 B.C. tsunami that washed away an Athenian fort, to an earthquake, saying that the shock drives the sea back, and then it recoils with redoubled force causing an inundation—they might have saved themselves.

Some tourists were just lucky: At one tourist spot, eight elephants, tourists onboard and

all, took off for the jungle-covered hills behind the resort as soon as the tremors began. At one rural location in Thailand, water buffalo all suddenly lifted their heads, pricked up their ears, looked out to sea, and stampeded up the hill with the confused villagers chasing after them, thus saving their lives.

The Power of the Noösphere

However, we beg to differ with Parker on the title of the book: *The Power of the Sea*. Agreed, he has given abundant evidence of the power of the ocean. Yet, as we more and more master the noösphere and through it, the biosphere, the number of deaths from "natural disasters" ought to decrease dramatically. Besides, some of these disasters are not so "natural": People should not be living in tin shacks on the coast, for example.

What can't we do thanks to satellite observation and GPS (thanks to JFK's space program), combined with sea walls, earthquake-proofed buildings, warning systems, and the like? We landed on the Moon, 60 short years after the Wright brothers' first flight—despite two world wars, the Depression, and some lousy Presidents. That is "the power of the noösphere."

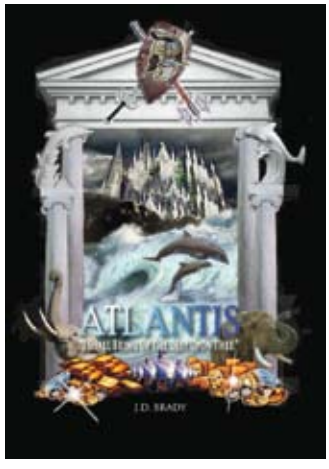
If we do things right in greening Africa, we might tame and eventually wipe out the hurricanes (which, as NASA has shown recently, are born in East Africa, and from there make their way to terrorize the southeast of the United States). We will domesticate the Earth, and turn it into a garden.

But that's only the beginning. The real moral of the story should be, that we must not be victims of accidents, but rather develop our creative powers, taking responsibility for what does and does not happen in our Solar System and beyond. Shall we just wait for such cataclysms as the Sun's going supernova, which it likely will when most of its hydrogen has burned up? Or shall we colonize a large number of new "Solar Systems" within our galaxy, and eventually beyond to other galaxies, to ensure mankind's eternal existence.

A Flawed Account of Atlantis

by Charles E. Hughes

Atlantis: 'I Shall Bring Up the Deep Upon Thee'
J.D. Brady
Bloomington, Ind.: Ex Libris, 2010
Paperback, 268 pp., $19.99



The burden of evidence indicates that the civilization of Atlantis, so-called, actually existed somewhere in the Atlantic Ocean, north of the equator, at the end of the last ice age, or circa 10,000 B.C. This was a culture of sea people, who had sailing ships and the capabilities to cross oceans.

Author J.D. Brady, however, would have us believe that Atlantis was in the eastern Mediterranean Sea, near the entrance to the Black Sea, in the more recent period of the historical Bronze Age. I strongly doubt this.

The ancient philosopher Plato (427-347 B.C.) left us the most extensive account of Atlantis in his two dialogues *Timaeus* and *Critias*. Unfortunately, the Black Sea did not even exist in the time period when Atlantis actually existed—10,000 B.C.

In Brady's account, the Atlantis civilization was connected to the cities of Troy and the Etruscans. It seems that Brady is trying to propitiate mainstream opinion on these matters of archaeology. The book has abundant material on Troy and the Etruscans, save that Brady denies Professor Barry Fell's decipherment of Etruscan, and instead claims that the language is still a mystery. Epigrapher Fell stated that the Etruscan language had obvious Hittite word roots, and found 500 word roots with close similarity with respect to sound and meaning in the Hittite language, which is well known by philologists. (See "Barry Fell's Revolution in Deciphering Old World Scripts," *21st Century,* Summer 2001).

If any investigator is serious about finding a lost city, he should look in the Atlantic Ocean off the Spanish coast, near the city of Cadiz, an area of undersea ruins reported by many divers. Prof. Maxine Ascher's book *The Atlantis Expedition* (1975), describes this, including an account of how the Spanish government cancelled her permits, after she had located ruins underwater. Ascher was then a teacher at Pepperdine College in California.

In his *Atlantis,* Brady makes the evidence fit the established paradigm, which is an act of disrespect to Plato and the sea people of the Atlantis island, our ancestors.

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Krafft Ehricke's
Extraterrestrial Imperative
by Marsha Freeman
ISBN 978-1-894959-91-9,
Apogee Books, 2009,
302pp, $27.95

From this new book the reader will gain an insight into one of the most creative minds in the history of space exploration.

Krafft Ehricke's contribution to space exploration encompasses details of new, innovative ideas, but also how to think about the importance and value of space exploration for society.

The reader will gain an understanding of the early history of the space pioneers, what they have helped accomplish, and how Ehricke's vision of where we should be going can shape the future.

At this time, when there are questions about the path of the space program for the next decades, Krafft Ehricke has laid out the philosophical framework for why space exploration must be pursued, through his concept of the "Extraterrestial Imperative," and the fight that he waged, over many years, for a long-range vision for the program.

Readers will find it a very imaginative work, and a very up-lifting story.

Krafft Ehricke's Extraterrestrial Imperative is the summation of his work on encouraging the exploration and development of space. The book contains all of his reasons why we need to get off the planet and explore space.

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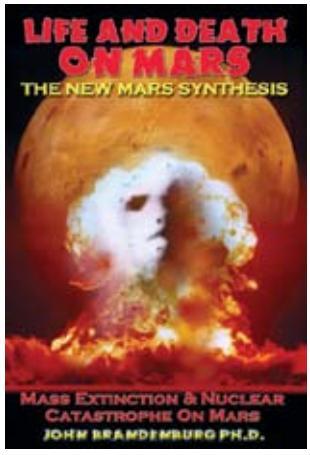
Mars: Some Optimism at Last!

by Charles E. Hughes

The Life and Death of Mars: The New Mars Synthesis
John Brandenburg, Ph.D
Kempton, Ill.: Adventures Unlimited Press, 2011
Paperback, 275 pp., $19.95



This book is well worth reading, because the author, who has a background in planetary science, is an advocate of manned exploration of the Solar System, and Mars in particular.

Brandenburg shows how the space science community has been split, since the Mars probes began in the 1970s, between those who believe that Mars was once Earthlike, and may still contain life, and those who believe that Mars is Moon-like, and never had life. Before the time of unmanned probes of Mars, in the 19th Century, the prevailing outlook concerning Mars was that it possibly harbored advanced life, or at least, vegetation.

The author presents us not only with some history of Mars, but with some startling aspects of conditions on Mars at the present time. As some readers of *21st Century* may already know, Mars shows evidence of emitting methane gas. This is a crucial indicator of life processes occurring right now.

It is revealed in *Life and Death of Mars* that this methane is not a trace, but hundreds of tons per year—a fact that the pessimists would not like to be well known!

Another crucial point: Mars is known as the red planet, not a reference to the planet's political preference, but the fact that its entire surface is covered with various oxides of iron. A stupendous amount of oxygen would be required to reduce the surface iron to this oxide; *ergo*, oxygen was very prevalent on Mars in its past. As far as we know, oxygen is a result of life processes, such as plants metabolizing carbon dioxide and emiting oxygen as a waste product.

Another indicator: Large deposits of hematite, a form of iron oxide, have been detected by Mars orbiters, and also by the two rovers on the Mars surface. On Earth, iron oxide is produced in oceans with the aid of bacteria and simple plants. Oceans of water were once on Mars, and water may still be there, most probably frozen. Most of the northern hemisphere of Mars seems to have been ocean basin.

Brandenburg's chapter on meteorites, states that dozens of specimens of meteorites have been found on the glaciers of Antarctica, particularly near the Japanese scientific base. Some of these are believed to have come from Mars, and they show a unique oxygen isotope analysis, in agreement with rock samples examined by the Mars rovers.

The Life and Death of Mars is well illustrated with black and white and color plates. One such plate is labeled "Sunset on Mars, please note blue skies"—a jab at some NASA color photos which show bilious red skies, either a mistake or an effort to discourage colonization.

This is a book, at last, which shows the scientific optimism essential for our future exploration of this planet and beyond. I highly recommend it.

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