

California Water and Infrastructure Report

Formerly, the “California Drought (and Flood) Update”



For August 30, 2018

by Patrick Ruckert

Published weekly since July, 2014

An archive of all these weekly reports can be found at both links below:

<http://www.californiadroughtupdate.org>

<https://www.facebook.com/CaliforniaDroughtUpdate>

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The development of high-density and very-high density sources of power, the process of increasing the rate of flow of fresh, clean water through the world's national economies, a progressive revolution in the practice and principles of public health, very large-scale mass-transportation of passengers and freight emphasizing magnetic levitation, the development of new conceptions of raw materials and their processing, and increased emphasis on exploration of nearby space for scientific purposes, will lead the list of undertakings.

These types of great undertakings will be the drivers which define the direction of organization of all leading phases of production. These great projects will then define the base-line of capital factors underlying all significant other economic activity in the economies within and among nations of the world as a whole.

A Note To Readers

As drought, fire, water and other related news this week is very light, or very silly, this report will be heavily focused on more fundamental ideas and principles. And, of course, it is only from the standpoint of fundamental principles that more local tasks can really be addressed more seriously--like California's water and infrastructure.

The above quotation is from a 10-year old report by Lyndon LaRouche, written at the outbreak of the 2008 crash of the U.S. and western world banking and financial system. Remember the one in which 8 million people lost their jobs and upwards of 6 million lost their homes? Well, then, and even more so today, the urgency of ending the 47 years of financial speculation, gambling and looting of the real

physical economy is what must be the policy of the United States. For, as I reported last week, August 15, 1971, when President Nixon ended the post-WWII “Bretton Woods” fixed-exchange-rate monetary system, that set off the process of banking and financial deregulation that has destroyed so much.

The article, “New Bretton Woods: Russia’s Role in a Recovery,” can be found here:

https://larouchepub.com/eiw/public/2008/eirv35n35-20080905/eirv35n35-20080905_004-new_bretton_woods_russias_role_i-lar.pdf

So, it is time to return to that Franklin D. Roosevelt designed Bretton Woods system, with a New Bretton Woods. Below is the link to a petition to Presidents Trump, Putin and Xi, and Prime Minister Modi of India to put together a summit of those four major nations to do just that:

The Leaders of the United States, Russia, China and India Must Take Action!

We, the undersigned, appeal to President Trump, President Putin, President Xi Jinping and Prime Minister Modi, to convoke an emergency summit in order to create a New Bretton Woods global monetary system. https://schillerinstitute.nationbuilder.com/nbw_petition

The last item in this week's report, “*The most beautiful demonstration of the unity of art and science.*” is an excellent illustration that the fundamental principle of economics is the creative power of the human mind in the discovery of new physical and classical artistic principles-- new principles that drive forward the application of new technologies of production, uplifting to a new, higher platform of productivity the entire economy and the labor force. The report is on the near 600 year-old Florence Cathedral, and its unique, unsupported by buttresses, dome that still marvels architects and engineers around the world, and how the most advanced nuclear science is being used to discover the secrets of Brunelleschi's Dome.

In This Week's Report

We begin, as is our usual practice with the U.S. Drought Monitor for California, followed by a short item on the most intense drought ever that now grips British Columbia.

Then comes our fire report. With no new major fires igniting in the past two weeks, some may wish to relax, but that could be a very serious mistake this early in the fire season.

Then, for entertainment purposes only, is the new apocalyptic report by the state of California that foresees, if you are alive 80 years from now, you will be roasted, starved and die of thirst. Jerry is very happy to present this forecast to the people of the state during his final months as governor.

The Oroville Dam Update this week just has one construction progress video.

Then we are back to the “California Water Wars.” Most developments in this never ending “war” are merely a linear extension of what has been reported here over the past few weeks. So, there are just a couple of items included. Led by this, “Western water honchos secretly huddle on tunnels, fish.”

Two articles, one on the decline of life-expectancy in the U.S. and Europe and the second on the fact that more than one-half of the children in the U.S. must rely on some form of government assistance, demonstrates the failure of the post-JFK economic policy.

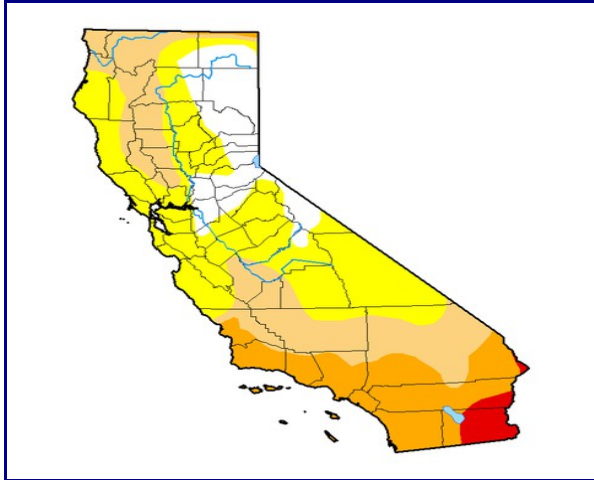
Under the title, “We Have Seen This Nonsense Before,” I review an article on a United Nations sponsored study, with the weird title, “Scientists Warn the UN of Capitalism's Imminent Demise.” The study is a combination of a re-run of the 1972 book "Limits to Growth," and the post-industrial fantasies of that same era.

Then, finally, the Feature on Filippo Brunelleschi's famous dome of the cathedral of Florence, Italy.

U.S. Drought Monitor - California

As of August 28, 2018






Author: Jessica Blunden, NCEI/NOAA



Drought Conditions (Percent Area)

Week	None	D0-D4	D1-D4	D2-D4	D3-D4	D4
Current 8/28/2018	13.78%	86.22%	47.58%	21.05%	2.77%	0.00%
Last Week 8/21/2018	13.78%	86.22%	47.19%	20.75%	2.77%	0.00%
Three Months Ago 5/29/2018	30.49%	69.51%	37.08%	20.75%	2.78%	0.00%
Start of Calendar Year 1/02/2018	55.70%	44.30%	12.69%	0.00%	0.00%	0.00%
One Year Ago 8/29/2017	77.88%	22.12%	8.24%	0.04%	0.00%	0.00%

Drought Intensities

- None: No Drought
-  D0: Abnormally Dry
-  D1: Moderate Drought
-  D2: Severe Drought
-  D3: Extreme Drought
-  D4: Exceptional Drought

Drought worsens as fires continue to burn throughout B.C.

This weekend's rain was not enough to extinguish fires or replenish streams and rivers

Amy O'Brian · CBC News · Posted: Aug 27, 2018

<https://www.cbc.ca/news/canada/british-columbia/drought-worsens-as-fires-continue-to-burn->

[throughout-b-c-1.4800686](#)

Nearly one-quarter of B.C.'s regions are now at the highest drought rating, with no significant rain in the forecast.

And while those fighting the province's more than 500 wildfires have welcomed the recent rain and cooler temperatures, a spokesperson for the B.C. wildfire service says the fires will continue to burn for weeks.



The Capilano Reservoir in summer 2015, when a Level 4 drought was announced for the Metro Vancouver region. (CBC)

The same conditions that are creating B.C.'s drought have also created the devastating wildfire season, which is nowhere close to over, with 536 fires still burning as of Monday morning.

Fires

California fires set to exceed 2017

By [Adam Brinklow](#) Aug 27, 2018, 1:10pm PDT

<https://sf.curbed.com/2018/8/27/17788182/california-fires-million-acres-quadruple>



Photo by [mikeledray](#)

California's ongoing, seemingly [never ending firestorm](#) has hit the closest possible thing to a lull in recent weeks, with many of the largest and most destructive blazes curtailed or entirely contained.

But that's about the end of the good news, as Cal Fire's most recent [statewide stats update](#) provides a stark and startling view of the state's continued anti-fire crusade: So far in 2018, Cal Fire has recorded

over 876,400 acres burned.

That's more than four times the total at the same time last year, which was just over 228,800 acres. Which itself was an alarming spike from the previous five year average of 156,700-plus for the first eight months of the year.

Altogether, 2018 has seen nearly 5.6 times as much fire activity as usual, and more than 3.8 times as much fire damage just year over year.

It's worth noting that the worst of 2017's fires didn't start until later in the year, so the "year so far" statistics do not yet reflect how 2018 compares to the worst fire-related disasters in the past 12 month period.

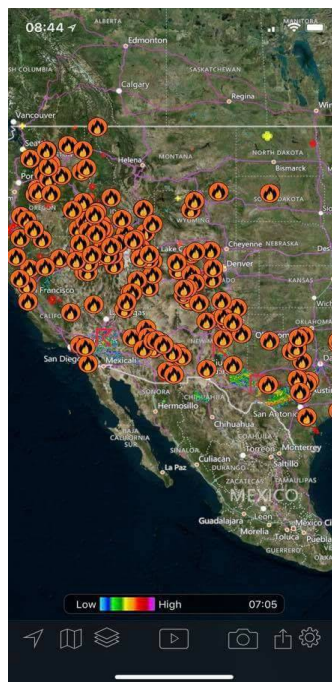
However, when US Forest Service statistics are added to Cal Fire's, 2018's burn total to date comes out to 1,227,473 acres burned. For [all of 2017](#), the Cal Fire and Forest Service totals were just barely more: 1,248,606 acres.

So even if a repeat of last year's apocalyptic late year scene mercifully does not occur, 2018 is already on the verge of exceeding the previous year's tragic total.

Overall, the state recorded 9,133 fires in 2017. So far in 2018 the figure is 5,319. And thus far the 2018 fire breakout hasn't been as damaging in terms of cost to human infrastructure, with last year's Tubbs Fire still [the most destructive](#) in state history, burning over 5,300 acres.

As of Monday morning, Cal Fire is still trying to tame the [ongoing Ranch Fire](#), which at 402,468 acres is the largest in California history. The blaze is an estimated 67 percent contained.

Western States Fire Map from early this week



Governor Brown's Legacy: An Apocalyptic Vision of the Future

California Climate Change Report Shows Rise in Wildfires, Sea Levels and Snow Drought

By [Mark Matthews](#)

August 27, 2018

<https://www.nbclosangeles.com/news/local/California-Climate-Change-Report-Shows-Rise-in-Wildfires-Sea-Levels-and-Snow-Drought-491847441.html>

Bigger fires, dirtier air and more flooding. That's the crux of the stark warning in the latest University of California climate change report released Monday by the governor's office.

The report projects a 300 percent increase in wildfires over the next 30 to 50 years, a trend that seemingly already has started with record-breaking wildfire numbers in the past two years.

So far this year, 1 million acres have been charred, three times the five-year average, and scientists predict that will increase 77 percent by 2100.

Flooding from rising sea levels also is expected to have a big impact on Bay Area transportation. BART stations and San Francisco International Airport are among those transportation hubs threatened by rising seas. In fact, the report's authors say the water level could reach as high as three meters above current levels, and 31 to 67 percent of Southern California beaches may wash away.

California Releases New Climate Science, Planning Tools to Prepare for Climate Change Impacts

August 27, 2018

From the California Natural Resources Agency:

"Warning that two-thirds of Southern California's beaches could completely disappear and the average area burned by wildfires could nearly double by 2100, the State of California today released [California's Fourth Climate Change Assessment](#), which details new science on the devastating impacts of climate change and provides planning tools to support the state's response.

"In California, facts and science still matter," said Governor Edmund G. Brown Jr. "These findings are profoundly serious and will continue to guide us as we confront the apocalyptic threat of irreversible climate change."

The Fourth Assessment suggests these events will worsen in the future. Among the key findings:

- **Wildfire:** *Climate change will make forests more susceptible to extreme wildfires. By the year 2100, if greenhouse gas emissions continue to rise, one study found that the average area burned by wildfires would increase 77 percent and the frequency of extreme wildfires burning more than 25,000 acres would increase by nearly 50 percent. In the areas that have the highest fire risk, the cost of wildfire insurance is estimated to rise by 18 percent by 2055. Additionally, the percentage of property insured in California would decrease.*

- **Sea-Level Rise:** *Under mid to high sea-level rise scenarios, up to 67 percent of Southern California beaches may completely erode by 2100 without large-scale human interventions. Statewide damages could reach nearly \$17.9 billion from inundation of residential and commercial buildings if sea-level rise reaches 20 inches, which is within range of mid-century projections. A 100-year coastal flood, on top of this level of sea-level rise, would almost double the cost of damages. Updated modeling can help local planners analyze vulnerabilities in their area.*
- **Energy:** *Higher temperatures will increase annual electricity demand for homes, primarily for use of air conditioning units. High demand is projected in inland regions and Southern California. More moderate increases are projected in cooler coastal areas. Increases in peak hourly demand during the hot months of the year could be more pronounced. This is a critical finding for California's electric system, because generating capacity must match peak electricity demand.*
- **Extreme Heat Events and Impacts on Public Health:** *Heat-related illnesses and deaths are projected to worsen drastically throughout the state. By mid-century, the Central Valley is projected to experience heat waves that average two weeks longer than those today, and the hot spells could occur four to 10 times more often in the Northern Sierra region. A new California Heat Assessment Tool (CHAT) could support public health departments as they work to reduce heat-related deaths and illnesses.*

Oroville Dam Update

Just one video for this week

Oroville Spillways Phase 2 Update August 24, 2018

[California DWR](#)

Published on Aug 30, 2018

<https://www.youtube.com/watch?v=shtNiqfT6ms>

Crews clean the rock foundation of the Lake Oroville emergency spillway in preparation for the placement of more roller-compacted concrete (RCC). In the middle chute, cranes fly in structural rebar and forms for walls, which are then set and followed by the placement of concrete. Crews continue to place curing blankets on recently placed concrete slabs. Meanwhile, at the dentates at the bottom of the main spillway, crews mechanically demo the concrete surface in preparation for anchor and rebar placement.

California Water Wars

One must enjoy the irony that San Francisco, the home of the “save the fish” hysterics, in order to save the fish, will have to ration its own water if the Water Board has it way. Otherwise, is it a conspiracy that the “Western water honchos secretly huddle on tunnels, fish?”

Western water honchos secretly huddle on tunnels, fish

Jeremy P. Jacobs and Michael Doyle, E&E News reporters

Greenwire: Friday, August 24, 2018

<https://www.eenews.net/stories/1060095217>

California's biggest water players quietly gathered on the shores of Lake Tahoe this week, hoping to reconcile some long-standing differences involving tunnels, fish, rivers and more.

In an unpublicized summit that convened Monday, Bureau of Reclamation Commissioner Brenda Burman met with representatives from Democratic Gov. Jerry Brown's administration as well as officials from the state's major rural and urban water districts. And though the get-together was largely kept under wraps, some interested parties described it as an effort to reach a "global solution" to problems that until now have defied resolution.

Among the topics discussed: Brown's \$17 billion plan to build twin tunnels under the Sacramento-San Joaquin River Delta, the coordinated operation of state and federal projects that shuttle water from the wet north to farms and cities in the arid south, and California's controversial proposal to reduce water deliveries to farmers from the San Joaquin River to benefit fish.



An aerial view of the Sacramento-San Joaquin River Delta. formulanone/Flickr

The meeting, held at a resort and conference center on Lake Tahoe's North Shore, comes as the Trump administration has ramped up pressure on California. Last weekend, Interior Secretary Ryan Zinke issued a memo asking for his staff to come up with recommendations within two weeks to increase deliveries to California farmers ([Greenwire](#), Aug. 21).

Zinke's memo empowered Deputy Secretary David Bernhardt to provide the "final recommendation for action." Bernhardt is a former lawyer for the Westlands Water District, the state's largest agricultural water district.

In a letter dated the same day, Aug. 17, Reclamation formally called for renegotiating a 1986 compromise with the state concerning the operation of the state and federal projects.

The complicated coordinated operation agreement focuses in large part on the Sacramento-San Joaquin River Delta. At its core, it lays out requirements for how much water state reservoirs and federal reservoirs must release to flow into the delta for ecological and water quality purposes. Most of

that water flows through the San Francisco Bay and out to the ocean; it does not enter the projects' conveyance system to farms and cities in the south.

Under the agreement, the federal Central Valley Project reservoirs are required to release much more of that water, up to three-quarters of it.

Reclamation agreed to that in 1986 for two main reasons: It operates most of the large reservoirs in California — so it had more water available — and it needed to use the state's more powerful pumps south of the delta to effectively move water.

Conditions have changed since 1986, though, including federal Central Valley Project contractors wanting more of that water. The bureau and the state have long sought to update the 1986 agreement but have failed to do so.

The [letter](#) is the first time the agency has officially issued a "notice of negotiation" for a new agreement, and it set a one-year deadline for talks.

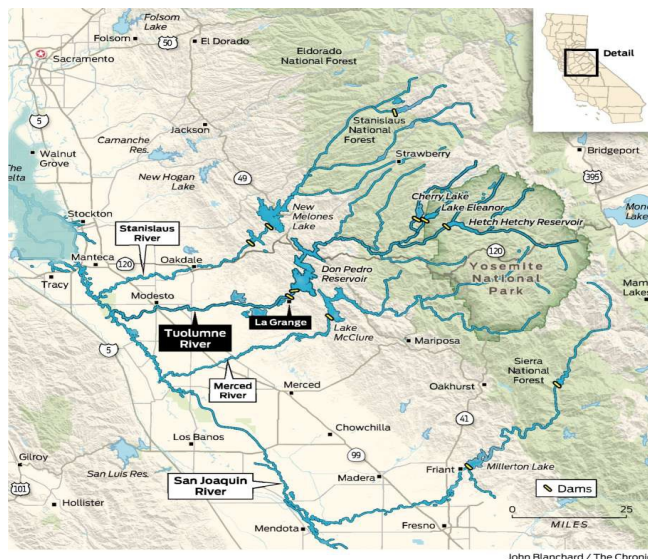
If the bureau comes out ahead, it could have a major impact on contractors who get water from the California State Water Project, including the Metropolitan Water District of Southern California — the country's largest water seller.

California water wars: State plans to cut SF's Sierra supply to save delta

[Kurtis Alexander](#) Aug. 19, 2018

<https://www.sfchronicle.com/science/article/California-water-wars-State-plans-to-cut-SF-s-13166078.php>

LA GRANGE, Stanislaus County — The cold, rushing water of the Tuolumne River, piped from the high peaks of Yosemite to the taps of Bay Area residents, is not only among the nation's most pristine municipal water sources but extraordinarily plentiful.



This point of pride for San Francisco, which has maintained rights to the cherished Sierra supply since the early 1900s, is being threatened, however. Under a far-reaching state plan to bump up flows in California's rivers, the city would be forced to limit its draws from the Tuolumne for the first time in recent memory.

City leaders call the restrictions unthinkable. They fear unprecedented water cutbacks for Bay Area residents and even businesses, and they've forged a strange marriage with farm communities which

worry the plan will leave crops with insufficient water. Together, they have asked the state to scale back its initiative, but the state hasn't budged, and another front in California's enduring water wars has opened.

The intent of the California Water Resources Control Board is to rescue the Sacramento-San Joaquin River Delta. The West Coast's largest estuary and a vital water source for much of the state has become short on water and wildlife as thirsty cities and farms have squeezed the rivers that nourish the delta. The Tuolumne is one of those rivers.

The central question of debate is whether the state's push for the environment has gone too far, threatening commerce not only in California's farm belt, but also in its urban centers where the growth of tech, housing and retail is on the line.

Between 7 and 23 percent less river water on average would be available for human consumption, and sometimes more, according to state estimates.

While the plan would have little bearing on how much water Bay Area communities get during wet years when there's plenty to go around, periods of drought would force the utility's customers to go beyond making cuts to landscape irrigation. It would cause them to sacrifice water use in their homes and offices, Ritchie said.

A Little Longer Excerpt From the LaRouche Article

AUGUST 20, 2008

New Bretton Woods: Russia's Role in a Recovery

by Lyndon H. LaRouche, Jr.

https://larouche.pub.com/eiw/public/2008/eirv35n35-20080905/eirv35n35-20080905_004-new_bretton_woods_russias_role_i-lar.pdf

If we assume, as I do for the purposes of this report, that we are at a point of desperately hopeful opportunity for all mankind. We are, thus, on the verge of establishing the form of long-ranging cooperation in development among sovereign nation-states which I have prescribed, such that the greatest increases in categories of production globally will occur in very large-scale capital improvements typified by great projects in basic infrastructure. These will be, to a very large degree, international projects of cooperation among sovereign nation-states, including projects whose initial development and turnover will span several or more generations.

The development of high-density and very-high density sources of power, the process of increasing the rate of flow of fresh, clean water through the world's national economies, a progressive revolution in the practice and principles of public health, very large-scale mass-transportation of passengers and freight emphasizing magnetic levitation, the development of new conceptions of raw materials and their processing, and increased emphasis on exploration of nearby space for scientific purposes, will lead the list of undertakings.

These types of great undertakings will be the drivers which define the direction of organization of all leading phases of production. These great projects will then define the base-line of capital factors underlying all significant other economic activity in the economies within and among nations of the world as a whole.

From this point of departure, we shall obtain the base-line of costs and values which will underlie and permeate all phases of production, trade, and consumption throughout the world. That base-line, tied to

a fixed-exchange-rate system shared in common by respectively sovereign nation-states, will then define the base-line to be referenced in determining suitable levels of pricing and related cost-estimations among the cooperating national economies of the world.

Within that framework, individual freedom to innovate will be promoted, and will be actively present in precisely the degree that the potential scientific and relative creativity of the individual person is promoted.

The Very Real Destruction by Austerity

New Indicators in Sharp Decline in Trans-Atlantic Potential Relative Population-Density

Aug. 24 (EIRNS)—Two new demographic studies of 18 developed Western nations show that life expectancy declined in 12 of those countries in 2015, according to an Aug. 22 report in Reuters. “This hasn’t occurred in decades, and the size of these most recent declines were larger than prior declines,” said study co-author Jessica Ho of the University of Southern California in Los Angeles. The studies were published in *The BMJ* (formerly *British Medical Journal*), described as one of the world’s oldest medical journals published by the British Medical Association.

EIR has reported on previous studies pointing to the ongoing demographic collapse in the United States. In the new studies, the trend is shown to apply across the board in the trans-Atlantic sector. “This is the first time in recent decades that so many high-income countries simultaneously experienced declines in life expectancy for both men and women,” Reuters wrote. “Most of these countries reversed their life-expectancy decline in the 2015-2016 period, but in the U.S. and the U.K., the declines continued, the [studies’] authors note.”

Reuters pointed to the opioid crisis and drug overdose deaths as a leading culprit. But they also quote lead study author Dr. Steven H. Woolf of Virginia Commonwealth University in Richmond saying: “A leading cause is fatal drug overdoses—fueled by the opioid epidemic—but we make a mistake if we focus only on the drug problem, which is just the tip of the iceberg. Deaths from alcoholism and suicides have also increased, what some call deaths of despair.” Woolf further commented that there are rising midlife death rates from dozens of diseases of the heart, lungs, digestive systems and other organs. It even found rising death rates during pregnancy and early childhood, Woolf said. “Something far-reaching is affecting the health of Americans in the prime of their lives,” Woolf said.

That “something” is caused by what Lyndon LaRouche scientifically defined as allowing a society’s potential relative population-density to drop below its actual population. Willy-nilly, the result of that will be some combination of demographic collapse, life expectancy reduction, waves of forced migration, wars, drug and other epidemics, soaring poverty, and cultural decay.

Over Half of Americans Under 18 Live in Poor Households Needing Government Assistance

Aug. 24 (EIRNS)—According to the latest statistics published by the U.S. Census Bureau, and reported by CNSNews.com on Aug. 22, in 2016 some 52.1% of all American youth under the age of 18 lived in households that were receiving “means-tested government assistance,” i.e., their level of income/poverty justified participation in aid program such as food stamps or free school lunches.

This is a sharp rise over the last two decades, under the British Empire-run Bush and Obama Administrations. In 1998, some 36.9% of children under 18 years of age lived in such households; by 2008, that had risen to 40%; in 2013 it broke 50% for the first time; and it rose steadily for the next four years, to stand at 52.1% in 2016. In absolute numbers, this meant that 38.4 million out of the 73.6 million people under 18 in the U.S., lived in households receiving such means-tested government assistance.

The demographic breakdown indicates that the problem is even worse: The higher percentages of those receiving benefits are in the younger age cohorts. For example, the national average for all ages in 2016 was 35.9% living in such households; in the 18- to 24-year cohort, it was 40.1%; and in the under-18 group, it was 52.1%. In other words, there is an inverted pyramid, in which poverty requiring such federal assistance is disproportionately affecting the young.

We Have Seen This Nonsense Before

Scientists Warn the UN of Capitalism's Imminent Demise

by [Nafeez Ahmed](#)

Aug 27 2018, 8:40am

https://motherboard.vice.com/en_us/article/43pek3/scientists-warn-the-un-of-capitalisms-imminent-demise

The paper is a combination of a re-run of the 1972 book "Limits to Growth," and the post-industrial fantasies of that same era.

Since the paper completely ignores the fastest growing large economy (and non-capitalist, by the way) in the world-- China and its Belt and Road Initiative-- its perspective is a fraud from the start. Secondly, it, like the Limits to Growth book, studiously ignores in its discussion of energy not only nuclear power (which it mentions once), but also the really not too distant in the future development of fusion, the incompetence and ideological prejudices of the authors should leap out at any somewhat intelligent reader.

Then in using the phrase, "industrial overconsumption," the study further demonstrates the roots of the study, or the authors own roots, in once again the insanity of the Malthusian "Limits to Growth" ideology.

They should travel to Africa and see the evidence of the fraud of such a phrase. By the way, it is China's Belt and Road Initiative now that is actually bringing infrastructure and industry to Africa, already resulting in both a decline in poverty in many nations and a rising life expectancy. I am sure the authors would be very upset that the fastest growing economy in the world today is Ethiopia, with over a 10% real growth for the last few years.

Finally, since the fundamental problem in the Western economies is not what the author and the study purport to show-- real production-- but a financial system that has virtually destroyed the real economy of infrastructure, industry and an aggressive science and technology development policy, over the past near 50 years of turning the US and much of Europe into financial speculative gambling casinos, the real solution lies in returning to the regulated financial system of the Bretton Woods and Glass-Steagall. Then the US (and Europe) can really join with China and Russia for real economic development and progress. Oops, I used the word that is not really politically correct anymore-- progress. Well we should make that word the standard once again.

Feature: The most beautiful demonstration of the unity of art and science

Maybe not having much to do with water and infrastructure, but the following report is a demonstration of the fundamental principle of economics being the creative power of the human mind in the discovery of new physical and classical artistic principles. New principles that drive forward the application of new technologies of production, uplifting to a new, higher platform of productivity the entire economy and the labor force. That is the Fourth Law of Lyndon LaRouche's Four Laws.

Below, the report of the near 600 year-old Florence Cathedral, whose unique and largest unsupported dome still marvels architects and engineers around the world, and the most advanced nuclear science now being used to discover the secrets of Brunelleschi's Dome.

Italy's famous dome is cracking, and cosmic rays could help save it

Filippo Brunelleschi left no detailed blueprints for how he built his famous structure.

[Jennifer Ouellette](#) - 8/21/2018, 3:49 PM

<https://arstechnica.com/science/2018/08/cosmic-rays-could-help-unlock-the-secrets-of-brunelleschis-dome/>



Florence's famed Il Duomo has been plagued by cracks for centuries. Muon imaging could help preservationists figure out how to fix it. [CAHKT/Getty Images](#)

The soaring dome atop the Cathedral of St. Mary of the Flower justly dominates the Florence skyline and has stood for centuries, ever since Filippo Brunelleschi designed it in the early 15th century. But scholars aren't quite sure how this goldsmith with [no formal architectural training](#) managed to construct it. Brunelleschi built a wooden and brick model of his plan but deliberately left out crucial details and left no comprehensive blueprints so his rivals could not steal his secrets.

Elena Guardincerri, a physicist at Los Alamos National Laboratory who grew up in a nearby town in Italy, thinks she can help [resolve part of the mystery](#) with the aid of a subatomic particle called a muon.

Inverted tension

Brunelleschi found inspiration for his design in the inverted catenary shape of the Pantheon, which is an ideal shape for domes because the innate physical forces can support the structure with no need for buttressing. Robert Hooke phrased it best in the 17th century: "As hangs the flexible chain, so but inverted stands the rigid arch." A chain suspended between two points will naturally come to rest in a

state of pure tension; inverting that catenary shape into an arch reverses it into a shape of pure compression. Standard building materials like masonry and concrete would break fairly easily under tension, but they can withstand large compressive forces.

The Pantheon's circular dome has a single concrete shell. Brunelleschi's design called for an octagonal dome spanning 150 feet and soaring nearly 300 feet in height with no flying buttresses for support. He used two shells: a very thick inner shell and a much thinner outer shell. Historians believe he used three pairs of large stone chains (which are still part of the structure) to act a bit like barrel hoops, applying sufficient pressure to hold the bricks in place while the mortar set.

The final dome is a spectacular achievement. Almost immediately, however, cracks began to appear in the structure, albeit very slow-moving cracks. "Nobody is expecting it to fall down any time soon," said Guardincerri. But a botched restoration effort in the 1980s exacerbated the problem, adding a greater sense of urgency to the quest to preserve the dome, which is one of Florence's chief tourist attractions. However, the lack of detailed information about the internal structure remains a stumbling block.

Preservationists have employed many different methods over the years to try to fill in their gaps in knowledge. In 1987, 300 different devices were hooked up to the dome, prompting *The New York Times* [to declare it](#) "the world's most carefully monitored structure." But the inner shell is so thick, most conventional methods can't penetrate it. Specifically, it would be nice to know whether the stone chains used to stabilize the dome were reinforced with iron bars, clamps, or more chains to fortify its structural integrity. That's where muon imaging should be able to help.



Tourists climb up the exterior of Il Duomo's inner shell. [Brad Coy/Flickr](#)

The magical muon

There is a long history of [using muons](#) to [image archaeological structures](#), a process made easier by the fact that cosmic rays provide a steady supply of these particles. An engineer named E.P. George used them to make measurements of an Australian tunnel in the 1950s. But Nobel-prize-winning physicist Luis Alvarez really put muon imaging on the map when he teamed up with Egyptian archaeologists to use the technique to search for hidden chambers in the Pyramid of Khafre at Giza. Although it worked in principle, they didn't find any hidden chambers. Just last year, however, [scientists used](#) muon imaging [to detect a mysterious void](#) in the Great Pyramid of Giza, which could be evidence of a hidden chamber.

There are many variations of muon imaging, but they all typically involve gas-filled chambers. As muons zip through the gas, they collide with the gas particles and emit a telltale flash of light, which is recorded by the detector so scientists can calculate the particle's energy and trajectory. It's similar to X-ray imaging or ground-penetrating radar, except with naturally occurring high-energy muons rather

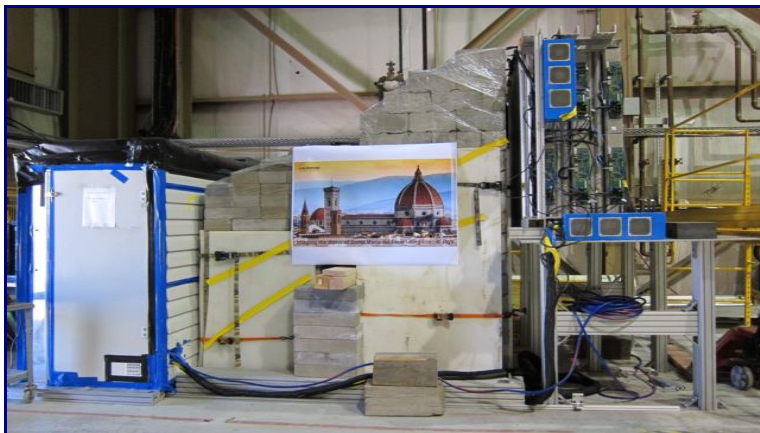
than X-rays or radio waves. That higher energy makes it possible to image very thick, dense substances, like the stones used to build pyramids or Il Duomo's seven-foot-thick inner shell. The denser the object being imaged, the more muons are blocked, casting a telltale shadow. Hidden chambers in a pyramid would show up in the final image because they blocked fewer particles. And if Brunelleschi used iron bars to fortify his dome, they would show up as darker patches.

The Los Alamos muon tracking technique was first developed in the early 2000s when Guardincerri was still a graduate student. She originally built her muon detectors to prevent the pesky particles from interfering with her attempts to study ghostly neutrinos. When a host of experts on the Florence Cathedral came to a workshop at the lab in 2013, she realized the same technique could be used to learn more about the materials used to build the dome—except she would need to build two smaller, portable detectors.

It takes two

A single muon detector works well for scanning large objects like pyramids or mountains, but there is so much scattering of the muons that you get lower resolution and blurry images. Sandwiching the object of interest between two muon detectors gives you higher resolution, but it limits the field of view to whatever part of the object is between them. That's an acceptable tradeoff for imaging Il Duomo.

Over the summer in 2015, Guardincerri and her students built a mock-up of the dome's thick inner shell out of radiation-shielding concrete bricks, which have similar properties to the clay bricks used to build the original, and embedded iron bars of varying thickness within it. They placed the muon trackers on either side of the six-foot-thick mock-up wall and took data for 35 days. After just 17 days, all three iron bars were clearly visible in the resulting image. When she reported her findings to the cathedral's guild members, she quickly gained approval to develop a set of muon-tracking modules to install on site.



Los Alamos scientists built a mockup wall to test the double-detector concept.
E. Guardincerri/Los Alamos National Laboratory

The two detectors are completed, and Guardincerri is now waiting on collaborators at the University of Pennsylvania to finish testing the custom-made electronics for analyzing the data, based on technology used in the ATLAS experiment at CERN's Large Hadron Collider in Switzerland. Once that's done, both detectors will be shipped to other collaborators at the University of Florence, who will retest them to ensure nothing was damaged during transit.

Then the detectors will be mounted in the dome itself: one will press against the inside wall, and the second will rest between the two shells, also against the inner wall. The Florence scientists will collect

data for a month in that position and then move the detectors two meters higher for another month of data collection, and so on, until the entire dome has been imaged. And then we may know once and for all whether there are any iron reinforcements in the dome. That would be welcome news to preservationists as they ponder how to address the cracking problem.

Muons in the Cathedral

[Los Alamos National Lab](#)

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<https://www.youtube.com/watch?v=-LTucISqRYQ>

Muon-imaging technology — far better at penetrating materials than x-rays — makes it ideal for peering into thick, dense objects. While muon-imaging technology was developed for national security purposes, such as searching cargo shipments for nuclear materials, it could also be useful for determining what is inside any structure. Now, scientists at Los Alamos are using muons to look inside a nearly 600-year-old Italian church in hopes of preserving it for centuries to come.