EMD Uranium (Nuclear & REE) Committee

2018 EMD Uranium (Nuclear Minerals and REE) Committee Annual Report

May 5, 2018

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Executive Vice President and Chief Geologist (Mining) / Chief Hydrogeologist (Environmental)
I2M Associates, LLC, Houston, TX
Founding Member of EMD in 1977, and Past President of EMD: 2010-2011
Fellow SEG; Fellow GSA; Fellow AIG; Fellow and Chartered Geologist GSL; EurGeol; and RM SME
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May 5, 2018

Presented Summary by Chair to EMD Annual Meeting, Salt Lake City, Utah by Teleconference
Report Updated: Version 1.6
(To Check for Updates, Note Version and Click (here)

Vice-Chairs:

- **Henry M. Wise, P.G., C.P.G., (Vice-Chair: Industry),** SWS Environmental Services, La Porte, TX (Founding Member of EMD in 1977)
- **Steven S. Sibray, P.G., C.P.G., (Vice-Chair: University),** University of Nebraska, Lincoln, NE
- **Robert W. Gregory, P.G., (Vice-Chair: Government),** Wyoming State Geological Survey, Laramie, WY

Advisory Group:

- **Kevin T. Biddle, Ph.D.,** V.P., ExxonMobil Exploration (retired), Houston, TX (Founding Member EMD in 1977)
- **James L. Conca, Ph.D., P.G.,** Senior Scientist, UFA Ventures, Inc., Richland, WA
- **Gerard Fries, Ph.D.,** Areva Mines, KATCO JV, LLP, Almaty, Kazakhstan
- **Michael A. Jacobs, P.G.,** Pioneer Natural Resources, (Founding Member of EMD in 1977), ex-Tenneco Uranium Inc., Midland, TX
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- **Karl S. Osvald, P.G.,** U.S. BLM, Wyoming State Office Reservoir Management Group, Casper, WY
- **Mark S. Pelizza P.G.,** M. S. Pelizza & Associates, LLC, Plano, TX
- **Arthur R. Renfro, P.G.,** Sr. Geological Consultant, Cheyenne, WY (Founding Member of EMD in 1977)
- **Samuel B. Romberger, Ph.D.,** Sr. Geological Consultant, Golden, CO
- **David Rowlands, Ph.D., P.G.,** Rowlands Geosciences, Houston, TX

Special Consultants to the Uranium (Nuclear and Rare Earths) Committee:

- **Ruffin I. Rackley**, Senior Geological Consultant, Anacortes, WA, Ex-Teton Exploration, Casper, WY (Founding Member of EMD in 1977, Secretary-Treasurer: 1977-1979, and President: 1982-1983).
- **Bruce Rubin**, Senior Geological Consultant, Millers Mills, NY (Founding Member of EMD in 1977), Ex-Teton Exploration.
- **M. David Campbell, P.G.**, Vice President and Senior Project Manager, I2M Associates, LLC, Houston, TX.
- **Robert A. Arrington**, VP, Exploration, Texas Eastern Nuclear, Inc. (retired), College Station, TX (Founding Member of EMD in 1977).
- **Jay H. Lehr, Ph. D.,** Science Director, Heartland Institute, Chicago (on Nuclear Power)

UCOM COMMITTEE ACTIVITIES

The AAPG Energy Minerals Division's Uranium (Nuclear and Rare Earths) Committee (UCOM) monitors the uranium industry and the production of electricity within the nuclear power industry because that drives uranium exploration and development in the United States and overseas.

Input for this Annual Report has been provided by:

Henry M. Wise, P.G., C.P.G. (Vice-Chair: Industry) on industry activities in uranium, thorium, and rare-earth exploration and mining;

Steven Sibray, P.G., C.P.G., Vice Chair (University) on university activities in uranium, thorium, and rare-earth research; and

Robert Gregory, P.G., Vice Chair (Government) on governmental (State and Federal) activities in uranium, thorium, and rare-earth research.

Special input and reviews are also provided by members of the Advisory Group.

In this report, we also provide summary information on current thorium and rare-earth exploration and mining, and associated geopolitical activities as part of the UCOM monitoring of "nuclear minerals," thorium and rare-earth elements (REE) activities (a function approved by the UCOM in 2011). Uranium and thorium include REE minerals in deposits in the U.S. and around the world (more).

UCOM is also pleased to remind the reader as a regular feature of the UCOM reports that the *JayMcMurray Memorial Grant* is awarded annually to a deserving student(s) whose research involves uranium or nuclear fuel energy. This grant is made available through the AAPG Grants-In-Aid Program, and is endowed by the AAPG Foundation with contributions from his wife, Katherine McMurray, and several colleagues and friends.

Those students having an interest in applying for the grant should contact the UCOM Chair for further information and guidance. The biography of Mr. McMurray's outstanding contributions to the uranium industry in the U.S. and overseas is presented (AAPG Foundation, 2015).

We are pleased to announce that Justin Drummond of Queens University, Kingston, Ontario, Canada was awarded the McMurray Memorial Grant in 2016 (more). Other recipients of the Grant since 2009 are presented in the following Table 1.

Table 1

Recipients of the Jay M. McMurray Memorial Grant from AAPG

2009	FORMATION OF PRECURSOR CALCIUM PHOSPHATE PHASES DURING CRYSTAL GROWTH OF APATITE AND THEIR ROLE ON THE UPTAKE OF HEAVY METALS AND RADIONUCLIDES	Olaf Borkiewicz	Miami University
2010	PRECIPITATION KINETICS OF AUTUNITE MINERALS: IMPLICATIONS FOR URANIUM IMMOBILIZATION	Denise Levitan	Virginia Tech University
2011	THE FORMATION MECHANISMS OF UNCONFORMITY- RELATED URANIUM DEPOSITS: INSIGHTS FROM NUMERICAL MODELING	Tao Cui	University of Windsor
2012	NOVEL NANOSEISMIC SURVEY TECHNIQUES IN TUNNELS AND MINES	Chiara Mazzoni	University of Strathclyde
2013	(U-TH)/HE AND U-PB DOUBLE DATING CONSTRAINTS ON THE INTERPLAY BETWEEN THRUST DEFORMATION AND BASIN DEVELOPMENT, SEVIERFORELAND BASIN, UTAH	Edgardo Pujols	University of Texas at Austin
2014	ANTHROPOGENICALLY ENHANCED MOBILIZATION OF NATURALLY OCCURRING URANIUM LEADING TO GROUNDWATER CONTAMINATION	Jason Nolan	University of Nebraska - Lincoln
2015	GEOCHEMISTRY AND DIAGENESIS OF GROUNDWATER CALCRETES: IMPLICATIONS FOR CALCRETE-HOSTED URANIUM MINERALIZATION,WESTERN AUSTRALIA	Justin Drummond	Queen's University
2016	GEOCHEMISTRY AND DIAGENESIS OF GROUNDWATER CALCRETES, WESTERN AUSTRALIA: IMPLICATIONS FOR CALCRETE-HOSTED URANIUM MINERALIZATION	Justin Drummond	Queen's University
2017	RECONSTRUCTION OF CRETACEOUS PROVENANCES OFABEOKUTA GROUP OF THE EASTERN DAHOMEY BASIN SOUTHWESTERN NIGERIA BASED ON THE FIRST URANIUM-LEAD DETRITAL ZIRCON GEOCHRONOLOGY	Fadehan Tolulope Abosede	University of Lagos

UCOM PUBLICATIONS AND NUCLEAR OUTREACH

The EMD co-sponsored Journal: *Natural Resources Research* has published the bi-annual *Unconventional Energy Resources: 2015 Review* in Volume 24, Issue 4, December, 2015 (more). The UCOM 2015 contribution begins on page 450 and is titled: *Energy Competition in the Uranium, Thorium, and Rare Earth Industries in the U.S. and the World: 2015*. Earlier versions include: the 2013 version (here); 2011 (here); 2009 (here); and 2007 (here) and all (here). The Unconventional Energy Resources: 2017 Review will be available soon from JNRR.

The AAPG-EMD Memoir 101: *Energy Resources for Human Settlement in the Solar System and Earth's Future in Space* was released in mid-2013 (more).

The EMD's Uranium (Nuclear and REE Minerals) Committee and members of I2M Associates, LLC, contributed the final Chapter entitled: *Nuclear Power and Associated Environmental Issues in the Transition of Exploration and Mining on Earth to the Development of Off-World Natural Resources in the 21st Century* (more). *Forbes.com* has highlighted Memoir 101 emphasizing the coverage of Chapters 8 and 9 (more). James Conca, Ph.D., a member of the UCOM Advisory Group, continues to contribute popular articles to Forbes.com on many nuclear and associated energy topics. To review the chronological list of Dr. Conca's Forbes' contributions to date, see (here).

In 2015, we modified the format of the UCOM report to provide greater coverage and more timely information in a more concise format. To accomplish this, the UCOM members examine certain topics as we have in the past, such as the issues behind the current uranium mining industry conditions and activities, and their driving forces, e.g., yellowcake prices, nuclear power plant construction, uranium reserves and world-wide exploration, especially new uranium discoveries.

To support this coverage, the I2M Web Portal has just been upgraded and improved, both in response speed and layout, plus it now allows multi-word searches, whereas the previous version only permitted one-word searches (more). The UCOM can now focus on particular issues covered by the I2M Web Portal by conducting and presenting search-results that are automatically updated even after we have published the two UCOM reports each year.

We draw on the I2M Web Portal database, which now contains almost 7,500 abstracts and links to current technical reports and media articles from sources in the U.S. and around the world, (see the Index to all commodity fields covered in the I2M Web Portal (here)). The primary emphasis of the I2M Web Portal also reflects interests and objectives of UCOM (more).

The UCOM focus is on: a) uranium exploration (more); b) mining and processing (more), and marketing, as well as on topics related to: c) uranium recovery technology (more); d) nuclear-power economics (more), reactor designs (more), and operational aspects that drive uranium prices (more); and e) related environmental and societal issues involved in such current topics as energy resource selection and climate change (more). The latter have direct and indirect impact on the costs, mining, and utilization of uranium, thorium, and rare-earth fields.

Our coverage also includes summaries of reviews of the current developments in research on thorium (more), helium-3 (more), and fusion research (more), and environmental and societal issues related to nuclear waste storage and handling (more). Current research developments in the rare-earth commodities are also summarized (more).

The nature and impact of radiation, perceived and real, are receiving coverage from a variety of mining and nuclear power adversaries. In response, we have been addressing these important issues since the beginning in 2004) reporting within the UCOM (e.g., 2005) while continuing to address the issues surrounding human-health issues in greater detail over the past few years (more) and (more). We have updated the section in our reports titled: *Ambient Radiation in the Atmosphere,* near the end of this report. Because radiation is difficult to understand, we place radiation in context with our environment, on Earth, in the atmosphere, in the orbital reaches, and in deep space.

Also, the I2M conditions of specific interest to geoscientists working under field conditions or others who manage the Web Portal includes the Alerts Program. I2M personnel monitors and reports on potentially hazardous such operations. This ranges throughout the various geological hazards, earthquakes, meteorological, and others (Field Alerts: more).

There are other on-going monitoring programs underway at I2M Associates, LLC via the I2M Web Portal. These include Security Alerts: (more), which covers computer hacking warning events and cyber security issues, and media bias monitoring (more).

The AIPG Texas Section has invited UCOM members and members of EMD to join them in sponsoring and participating in a field trip to visit the in-situ uranium mining and processing projects located in the south Texas when production has resumed (circa 2019-2020). For further information, see the AIPG announcements (more).

OBJECTIVES OF UCOM REPORTS

One of the principal objectives of our Annual (Spring) and Mid-Year (Year-End Summary) reports is to provide a summary of the important developments in uranium exploration and production of yellowcake (U_3O_8) for the benefit of the members of the Energy Minerals Division, AAPG and for the general public interested in the use of energy to generate electricity in the U.S. and overseas.

These activities are driven by nuclear-plant demand for fuel for the 99 reactors (and for those under construction/planned for use in the future). Plants also must plan for the storage of their waste products in the U.S., especially because the U.S. federal government failed to provide the national storage facility mandated by law while still charging nuclear plants billions of dollars to build Yucca Mountain Facility (without success) and to manage the plants' radioactive waste, when alternatives were available, e.g., the WIPP project in New Mexico.

We also include and assess the status of thorium and rare-earth exploration (and development) because both are often encountered in some types of hard-rock uranium deposits and the presence of both impact the economics of recovering uranium and rare earths, often with revenue credit for thorium concentrates.

EXECUTIVE SUMMARY

- The two primary objectives of this report are:

    1. to alert the members of the Energy Minerals Division, of AAPG and the general public on the supply side regarding current activities within the uranium, thorium, and rare-earth industries in terms of prices, exploration, and environmental issues, and

    2. to assess the impact of uranium production cuts in Canada and Kazakhstan and the role Russian-owned companies have in the U.S. uranium mining industry and now in supplying uranium to U.S. utilities.

- Some 99 Nuclear power plants in the U.S. remain in operation, a few are scheduled for retirement, two new reactors are being completed in Georgia.

- The U.S. is the world's largest producer of nuclear power, accounting for more than 30% of worldwide nuclear generation of electricity.

- The U.S. produced about 4,015 billion (kWh) of electricity at utility-scale facilities in the U.S.

- Currently, about 63% of the U.S. electricity generation is from fossil fuels (coal, natural gas, petroleum, and other gases). About 20% was from nuclear energy, and about 17% was from renewable energy sources, including hydroelectric power palnts.

- Following a 30-year period in which few new reactors were built in the U.S., it is expected that two more new units will come online soon after 2020; others resulting from 16 license applications made since mid-2007 are proposing to build 24 new nuclear reactors, most of which are of the new SMR design.

- The first zero-emission credit programs have commenced, in New York and Illinois.

- The years 2015 and 2016 exhibited the highest annual growth in nuclear plant capacity in 25 years,

- Significant uranium production cuts were made in 2017 from world’s largest uranium producers,

- Uncovered utility demand reaches ~24% by 2021 and 62% by 2025,

- Sustained low-price of uranium indicate that few new sources of supply are on-line, but a number of mines are either on stand-by or are available for development,
- Uranium holdings could be of strategic interest in the event of uranium supply interruption,
- U.S. utilities looking for risk-free ways to acquire significant supplies for future (likely Canada),
- Implied current yellowcake value is lower than many mine's cost of production,
- Most of the uranium purchased by utilities is contracted (based on the long-term price: currently \$31.00/lb U_3O_8),
- Saudi Arabia plans to build 16 reactors by 2030 with first reactor to come online in 2022;
- South Korea currently operates 25 reactors providing 33% of South Korea's power, and is building reactors on budget and on time for UAE.
- Japan is upgrading and re-starting most of its fleet of nuclear power plants after Fukushima.
- China plans to build 99 reactors by 2030, with government investment of over \$100 billion. Current position: 38 reactors in operation, 20 under construction, 39 planned/proposed for 240 total reactors on the horizon.
- China is rapidly building some 25 new plants and hundreds more are planned along with financially underwriting the construction of more than 40 projects in joint ventures with other countries.
- Russia currently has seven reactors under construction at home; An average of one large reactor per year is due to come on line through 2028,
- Russia is testing a "fast breeder" design that consumes most waste. Russia also is building nuclear plants in other countries as well, and providing financing.
- Russia is considering banning uranium sales to U.S. utilities because of the sanctions and tariffs applied by the U.S.
- Russia also is building a floating nuclear power plant for use along the coast of Siberia and for Sudan.
- India has turned to nuclear power to ramp up electricity production to match population growth rates and is also working on "fast breeder" designs.
- India plans to be 25% nuclear-energy-powered by 2050.

- ❖ Many other countries are also building nuclear plants funded by a variety of sources.
- ❖ There have been numerous discoveries of high-grade uranium deposits in Canada and new low-grade deposits reported to be under development in Argentina and Peru.
- ❖ Senior U.S. uranium industry personnel indicate that mining in Texas might not be re-initiated for a number of years because of the low uranium prices.
- ❖ Many uranium companies drilling new and established properties to establish an in place resource base in preparation for development sometime in the future.
- ❖ With hundreds of new nuclear power plants under construction in the world, it is only a matter of time until additional uranium supplies will be required, which will have to put pressure on the uranium price to increase substantially after 2020 and beyond.
- ❖ New data from ISS indicate that based on studies of astronauts, genes in humans are "turned on" in space, and remain on after returning to Earth while others return to "normal".

Introduction

The uranium price of the fuel for the nuclear power industry is obviously affected by the economic health of the nuclear power industry in the U.S., at least. The more plants, the higher the demand for fuel from China, India, and other countries. As new uranium supplies from new mines have come on-line but demand has not yet increased as expected, a condition of oversupply continues to persist creating depressed prices, which now shows some potential increase as production has been limited by some large producers, i.e., Kazakhstan (more). The principal impact on current prices is the overhang of uranium supplies remaining in the market (from a lack of consumption) resulting from the slow recovery of nuclear operations in Japan (more) in the period between before the impact of new requirements from China and India, etc. (more). As indicated above, other impacts on the uranium price include the U.S. government, which has been dumping some of their back-up yellowcake supply into the U.S. market (more).

The U.S. government sales are more than double the expected uranium production in 2017 in the U.S. However, proceeds from the sale of federal uranium inventory were used to fund the cleanup of legacy federal government nuclear facilities, such as the Paducah and Portsmouth uranium enrichment plant sites. This is an example of the government attempting to pay by bartering for its own activities albeit at the expense of the uranium industry (more).

The current uranium production growth has already been built into the supply chain that has come on-line with ramping up production and this creates an increased amount of uranium to be sold on the basis of the spot price into a weak market, which has been keeping prices low (more). As of late March, 2017, the price remains around $25.00 to $30.00 as a result of long-term uranium oversupply, although with the Japanese re-starts, combined with Chinese and other new reactor start-ups, this will serve to diminish the oversupply and serve as a catalyst for rising uranium spot prices along with increasing utility contract prices over the long term. Figure 2 illustrates the "chart" view that shows the bottom (and turnaround) of the uranium price has just begun.

Figure 2
Historical Spot Price of Uranium: 1988 to 2018 (\$/U_3O_8)
From (UXC)

However, even with the current low prices, many mining companies are moving forward with uranium exploration and mine-development projects hoping to capitalize on the eventual rebound in prices expected in 2018 or later. The recent uranium spot-price increases involve the perception of supply consumption, which ultimately drives an eventual uranium price bull market, but with early minor price volatility.

The actual fuel price (after conversion of yellow cake (U_3O_8) and refinement into UF6), the precursor is made into the fuel pellets that are assembled in racks during refueling a reactor. The cost of refining the mine-produced yellowcake to the fuel precursor (UF_6) ranges from 2.7 times that of yellowcake during high prices to about 3.0 times during the current low prices of mine-produced yellowcake (more) (see Figure 3).

Even at the current low prices, only 6% of the 57 million pounds U_3O_8 delivered in 2015 was U.S.-origin uranium at a weighted-average contract price of $43.86 per pound (committed to individual utilities). Foreign-origin uranium accounted for the remaining 94% of U.S.-contracted deliveries at a weighted-average contract price of $44.14 per pound U_3O_8. Uranium originating in Kazakhstan, Russia, and Uzbekistan accounted for 37% of the 57 million pounds.

Figure 3
2004 - 2018 UF_6 Fuel Spot Prices ($/kgU)
From (UXC) (for Conversions see (more)

However, the prices have fallen further during the latter part of 2017 with a spot price around $20.00 /pound U_3O_8 and long-term contract prices around $30.00 /pound U_3O_8. Campbell, et al., (2017) discussed the reliance of U.S. uranium fuel needs on foreign sources. More recently, Richards (2018) reports on an appeal by Wyoming uranium producers to the Federal government to limit foreign importing of uranium. In response, Russia is moving to ban trade with U.S. nuclear power plants in response to the new administration's tariff announcements (more).

Industry Response to Current Uranium Prices

During early 2018, the spot price of uranium continued to be relatively stable near the bottom of the cycle (See Figure 2). Significant production cuts have been announced in Canada, the United States, Kazakhstan and Africa. The production cuts came after a period of prolonged depressed uranium prices, which, according to UxC, were below the all-in production costs of most of the world's sources of primary uranium supply and coincident with the expected expiration of higher priced supply contracts signed during the utility contracting cycle in the mid-to-late 2000's.

Volatility returned to uranium prices late in the third fiscal quarter of 2017 because of the announcement of further substantial cuts to global production in November 2017 – beginning with Cameco Corporation ("Cameco") announcing a minimum ten month shutdown of the McArthur River Mine/Key Lake Mill complex in Saskatchewan, Canada. Cameco's McArthur River/Key Lake operations represent the largest and highest-grade uranium mine in the world, with a designed production rate of approximately 18 million pounds of U_3O_8 annually. Following Cameco's announcement, National Atomic Company Kazatomprom ("Kazatomprom") made a further announcement regarding production restraint – outlining that production through 2020 would represent a 20% reduction in planned output from its operations in Kazakhstan. Following these announcements, the spot price of U_3O_8 increased again, reaching a high of US$26.50 per pound U_3O_8 in December 2017, before retreating to US$21.25 per pound U_3O_8 by the end of fiscal 2018.

Although the Cameco and Kazatomprom supply curtailments have had an impact on the spot price, it has not been sustained. The impact of the curtailments from a global production standpoint, however, is quite significant. According to UxC data, global production peaked in calendar 2016 at 162 million pounds of U_3O_8, then fell in calendar 2017 to 154 million pounds U_3O_8, and this trend is expected to continue in calendar 2018 with the latest forecasts of total production dropping to 141 million U_3O_8. To put this in perspective, UxC expects annual uranium reactor requirements (UxC's Requirement's Model "URM" Base Demand) in calendar 2018 to be in the range of 194 million pounds U_3O_8 (more).

The rationalization on the supply side was long needed, however, higher priced long-term supply contracts were protecting much of the higher cost mine production from exposure to spot price levels in the US$20 per pound U_3O_8 range. As many of these legacy contracts are now expiring, the rate and degree of production cutbacks has finally accelerated, and these curtailments are expected to result in the drawdown of excess uranium supplies in the market, and ultimately an accelerated rebalancing of uranium market fundamentals.

A recent market development that could be preventing the U.S. utilities from entering into a new cycle of significant uranium contracting, is the Section 232 Trade petition recently filed by two U.S. uranium producers before the U.S. Department of Commerce. This provision of the U.S. Trade Act of 1962 was successfully pursued by U.S. producers of aluminum and steel in response to levels of foreign imports that were viewed to be negatively impacting U.S. national security. The New Administration has imposed tariffs on the import of both commodities, although some nations (including Canada and Mexico) have been provided exemptions. It is still too early to predict how the U.S. Department of Commerce will respond to the uranium Section 232 trade petition, and what (if any) remedies would be applied in the case of uranium imports. For context, U.S. domestically mined uranium accounted for approximately 5% of U.S. uranium requirements in calendar 2017, and it is expected that U.S. production will decline further in 2018. However, as discussed above, with the announcement that Russia could cease trade with American utilities, this action might stimulate American production, but U.S. utilities will likely turn to Canadian uranium sources to meet demand and Russia might be offering their uranium to the Chinese (more).

On the demand side of the uranium market, fundamentals continue to trend positive. Many nations today, particularly in the emerging markets, struggle with the need to deliver reliable and affordable electricity to their growing populations, without compounding climate change and air pollution challenges. As such, nuclear energy, with its reliability and clean air benefits, is filling an important role in the supply of baseload power around the world. Measured in new nuclear capacity connected to the grid, the calendar years 2015 and 2016 were the best two years in decades.

Reactor start-ups in calendar 2017 declined slightly from those levels, however the trend of increasing nuclear capacity appears to be continuing. For example, the Chinese government recently announced that in calendar 2018 it would be connecting an additional five reactors to the grid, and that construction will commence on six to eight additional units. In addition, the Kingdom of Saudi Arabia is advancing its nuclear energy plans, having commenced reactor procurement discussions with supplier countries, and the United Arab Emirates is rapidly nearing the completion of their four reactor construction program, with the first unit expected to be connected to the grid in calendar 2018 (more).

The recovery of the Japanese nuclear energy industry post-Fukushima continued to gain momentum in calendar 2017 with seven reactors in operation and a further two more likely to restart in calendar 2018. This is in line with recently re-elected Japanese Prime Minister Abe's stated goal to utilize nuclear power to supply between 20% and 22% of electricity needs going forward (more).

In the U.S., with the closure of six nuclear power plants in recent years, there has been a growing recognition of the value of the 24/7 baseload, carbon-free energy source. Three states, New York, Illinois and Connecticut, are preserving their nuclear-power generating capacity by passing legislation to level the playing field for nuclear, and three additional states, Pennsylvania, Ohio, and New Jersey, are considering similar legislative action. The U.S. federal government also continues to stress the negative impact on the reliability and resilience of the country's national grid from the potential loss of additional nuclear capacity. A recent Department of Energy Grid Reliability Study and the Federal Energy Regulatory Commission have both pointed to the need for changes to current market structures. With respect to new reactor construction in the U.S., the two Vogtle units in Georgia have resumed construction following the Westinghouse bankruptcy restructuring, and construction of the two Summer units in South Carolina remain suspended (more).

As of March 2018, the World Nuclear Association ("WNA") reported 448 reactors operable worldwide with 57 new reactors under construction, 158 reactors planned or on order, and another 351 proposed. These numbers are, incidentally, higher than those existing prior to

Fukushima. Translated into uranium demand, UxC projects their URM Base Demand to range from 174 to 210 million pounds annually over the period from 2018 to 2035 (more).

Of the many uranium companies affected by the uranium price is the Uranium Participation Corporation (UPC), a unique publically traded corporation. UPC is not an ETF* or closed or open-end fund as their activities are directed by an independent Board of Directors. Denison Mines Inc. serves as the Company's Manager, under a management services agreement, and takes direction from the UPC Board of Directors. Denison purchases and sells uranium holdings at Board's discretion, which allows UPC the ability to manage assets for premium/discount to repurchase of shares, if trading at a discount, and to issue equity if trading at a premium. UPC operates as standard corporate reporting on and managing fiduciary responsibilities.

The primary objectives of UPC include:

- Achieve appreciation in the value of its uranium holdings through increases in uranium price;
- Maintain an investment strategy to buy and hold physical uranium inventories for long-term appreciation;
- No active speculation on uranium prices;
- Offer an investor profile to be commodity focused or generalist to investors looking for direct exposure to uranium prices;
- Holds physical uranium in inventory;
- No exposure of mineral resource to project risks;
- No mine or processing operating risks;
- At least 85% of the net proceeds of equity offerings are to be invested, or held for investment in uranium holdings.

Global Drivers for Uranium Price Increases

The long awaited price increase now has much support; the stage for a meaningful turnaround is based on the following:

❖ The years 2015 & 2016 exhibited the highest annual growth in nuclear plant capacity in 25 years,

❖ Significant production cuts were made in 2017 from the world's largest uranium producers,

- ❖ Uncovered utility demand reaches ~24% by 2021 and 62% by 2025,
- ❖ Sustained low-price indicates few new sources of supply, but available for development,
- ❖ Uranium holdings could be of strategic interest,
- ❖ Utilities looking for risk-free way to acquire significant supplies for future (likely Canada),
- ❖ Implied current yellowcake value is lower than many mines' costs of production, and
- ❖ Most of the uranium purchased by utilities is contracted (based on the long-term price: currently US$31.00/lb U_3O_8), while UPC's net average value (NAV) is reported based on the spot price.
- ❖ China plans to build 99 reactors by 2030, with government investment of over $100 Billion, Current position: 38 reactors in operation, 20 under construction, 39 planned/proposed for 240 total reactors on the horizon.
- ❖ India plans to be 25% nuclear-energy-powered by 2050,
- ❖ Russia currently has seven reactors under construction; An average of one large reactor per year is due to come on line to 2028,
- ❖ Saudi Arabia plans to build 16 reactors by 2030 with first reactor to come online in 2022;
- ❖ South Korea currently operates 25 reactors providing 33% of South Korea's power, and building reactors on budget and on time for UAE.

Global Drivers for Uranium Production by Mining Company

Russia's Kazatomprom – 2017 Announced 20% reduction from permitted production levels for a period of three years commencing January 2018; estimated to represent 7.5% of annual global uranium production (estimated for 2018) in each of the next three years, keeping ~10 million lbs U_3O_8 out of the market in each of 2018, 2019 and 2020. However, the recent issues with the U.S. and the potential Russian ban of sales to U.S. utilities because of sanctions and tariff issues, this will likely alter Russian uranium production cut-backs in order to support an already weak Russian economy.

Cameco – 2017: McArthur/Key Lake to be suspended for 10 months beginning in January, 2018; Resulting in an estimated 14-15 million lbs U_3O_8 to be curtailed. These cuts might be reversed if the Russian threat of banning sales to U.S. materializes in order meet U.S. utility requirements.

AREVA – 2017: At NEI WNFC (Toronto) announced 2017 guidance would be between 13% and 16% lower at Somair and Cominak mines, with various news outlets suggesting further cuts can be expected. These cuts might be reversed if the Russian threat of banning sales to U.S. materializes in order meet U.S. utility requirements.

Cameco – 2016: Rabbit Lake Mine, suspended operations (4 million lbs U_30_8 /yr); McArthur River Mine reduction (2 million lbs U_3O_8 /yr); U.S. Operations, suspending operations (2.5 million lbs U_3O_8 /yr). These cuts could be reversed if Russian threats of banning sales to U.S. materializes in order meet U.S. utility requirements.

THE IMPACT OF JAPAN NUCLEAR Re-START-UPS

The Japanese fleet of 43 nuclear reactors, with a total installed capacity of about 42,000 MW, has been largely idled since September 2013, when the country adopted stricter nuclear safety requirements in the wake of the Fukushima tsunamis that damaged a few power plants along the coast of Japan (more). Reactors have now for the most part received safety-review approvals from the Nuclear Regulation Authority, some of which still must secure permissions from local towns and prefectures, and final NRA approval of preoperational tests before it can load nuclear fuel and resume operations.

Twenty-four of the 43 reactors have applied to NRA for safety review; it is unclear how many of the remaining units will apply in the future. In addition, Japan Electric Power Development Co. has applied for NRA safety review of its Ohma nuclear unit, which is under construction and could come online by the end of 2021 (more).

Progress continues in Japan in restarting their idle nuclear power plants, but not without some academic criticism (more). Even more detailed surveys of health issues report that the thyroid cancers identified so far are unlikely to be from radiation exposure, and are more likely to be the result of screening using highly sophisticated ultrasound techniques. However, long-term screening is continuing to evaluate whether the risk of childhood and adolescent thyroid cancer is caused by radiation exposure increases or not (more).

URANIUM PRODUCTION IN THE U.S.

4th Quarter, 2017

U.S. production of uranium concentrate in the fourth quarter 2017 was 622,987 pounds U_3O_8, down 3% from the third quarter 2017 and down 14% from the fourth quarter 2016. During the fourth quarter 2017, U.S. uranium was produced at seven U.S. uranium facilities, the same number as in the third quarter 2017.

U.S. uranium mill in production:

1. White Mesa Mill (Utah)

U.S. uranium in-situ leach plants in production/standby:

1. Crow Butte Operation (Nebraska)
2. Lost Creek Project (Wyoming)
3. Nichols Ranch ISR Project (Wyoming)
4. Ross CPP (Wyoming)
5. Smith Ranch-Highland Operation (Wyoming)
6. Willow Creek Project (Wyoming)

Total 2017 U.S. Production

Total preliminary U.S. uranium concentrate production totaled 2,442,789 pounds U_3O_8 in 2017. This amount was 16% lower than the 2,916,558 pounds produced in 2016 and the lowest annual U.S. production since 2,282,406 pounds were produced in 2004. Production reflects primary source uranium from the six operating in-situ leach facilities as well as primary, alternate and recycled feed at the White Mesa Mill in Utah. Much of the recycled uranium feed has already been counted at some point in previous production totals and in 2017, this contribution comprises a significant portion of the total uranium production (see Figure 4 and Table 2).

The owner of the White Mesa Mill, Energy Fuels Inc., provides additional information on the mill's operations in its financial filings, including the amount of U_3O_8 produced from alternative feeds. The company's financial filings are, at this writing, are available (here).

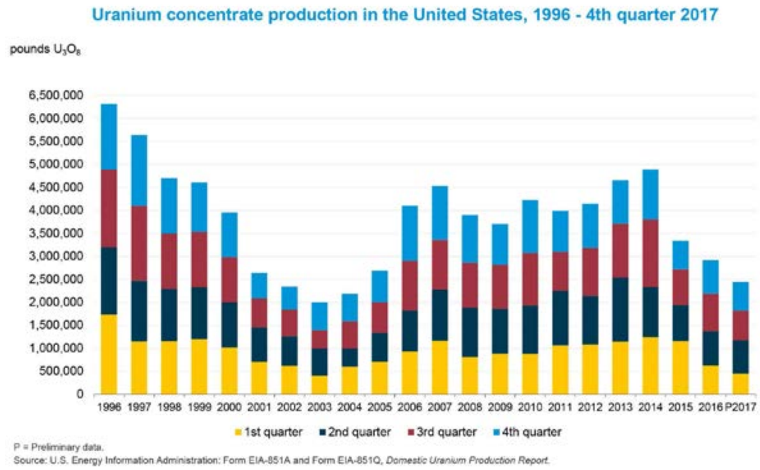


Figure 4
(EIA-2017)

Table 2
(EIA-2017)

Total production of uranium concentrate in the United States, 1996 - 4th quarter 2017

pounds U_3O_8

Calendar-year quarter	1st quarter	2nd quarter	3rd quarter	4th quarter	Calendar-year total
1996	1,734,427	1,460,058	1,691,796	1,434,425	**6,320,706**
1997	1,149,050	1,321,079	1,631,384	1,541,052	**5,642,565**
1998	1,151,587	1,143,942	1,203,042	1,206,003	**4,704,574**
1999	1,196,225	1,132,566	1,204,984	1,076,897	**4,610,672**
2000	1,018,683	983,330	981,948	973,585	**3,975,545**
2001	709,177	748,298	628,720	553,060	**2,639,256**
2002	620,952	643,432	579,723	E500,000	**E2,344,107**
2003	E400,000	E600,000	E400,000	E600,000	**E2,000,000**
2004	E600,000	E400,000	588,738	E600,000	**2,282,406**
2005	709,600	630,053	663,068	686,456	**2,689,178**
2006	931,065	894,268	1,083,808	1,196,485	**4,105,626**
2007	1,162,737	1,119,536	1,075,460	1,175,845	**4,533,578**
2008	810,189	1,073,315	980,933	1,037,946	**3,902,383**
2009	880,036	982,760	956,657	888,905	**3,708,358**
2010	876,084	1,055,102	1,150,725	1,146,281	**4,228,192**
2011	1,063,047	1,189,083	846,624	892,013	**3,990,767**
2012	1,078,404	1,061,289	1,048,018	957,936	**4,145,647**
2013	1,147,031	1,394,232	1,171,278	946,301	**4,658,842**
2014	1,242,179	1,095,011	1,468,608	1,085,534	**4,891,332**
2015	1,154,408	789,980	774,541	624,278	**3,343,207**
2016	626,522	745,306	818,783	725,947	**2,916,558**
P2017	450,215	726,375	643,212	622,987	**2,442,789**

E = Estimated data. P = Preliminary data. NA = Not available. -- = Not applicable.

Notes: The reported 4th quarter 2002 production amount was adjusted by rounding to the nearest 100,000 pounds to avoid disclosure of individual company data. This also affects the 2002 annual production. The reported 2003 and 1st, 2nd, and 4th quarter 2004 production amounts were adjusted by rounding to the nearest 200,000 pounds to avoid disclosure of individual company data. The reported 2004 total is the actual production for 2004. Totals may not equal sum of components because of independent rounding.

Source: U.S. Energy Information Administration: Form EIA-851A and Form EIA-851Q, *Domestic Uranium Production Report*.

The status of the in-situ recovery plants in the U.S. are presented in Table 3. Notice that there are 19 such facilities in various states of readiness.

Table 3

(EIA-2017)

U.S. uranium in-situ-leach plants by owner, location, capacity, and operating status

In-situ-leach plant owner	In-situ-leach plant name	County, state (existing and *planned* locations)	Production capacity (pounds U_3O_8 per year)	2016	1st quarter 2017	2nd quarter 2017	3rd quarter 2017	4th quarter 2017
				Operating status at end of				
AUC LLC	Reno Creek	*Campbell, Wyoming*	2,000,000	Partially Permitted And Licensed	Partially Permitted And Licensed	Partially Permitted And Licensed	Partially Permitted And Licensed	Partially Permitted And Licensed
Azarga Uranium Corp	Dewey Burdock Project	*Fall River and Custer, South Dakota*	1,000,000	Partially Permitted And Licensed	Partially Permitted And Licensed	Partially Permitted And Licensed	Partially Permitted And Licensed	Partially Permitted And Licensed
Cameco	Crow Butte Operation	Dawes, Nebraska	1,000,000	Operating	Operating	Operating	Operating	Operating
Hydro Resources, Inc.	Church Rock	*McKinley, New Mexico*	1,000,000	Partially Permitted And Licensed	Partially Permitted And Licensed	Partially Permitted And Licensed	Partially Permitted And Licensed	Partially Permitted And Licensed
Hydro Resources, Inc.	Crownpoint	*McKinley, New Mexico*	1,000,000	Partially Permitted And Licensed	Partially Permitted And Licensed	Partially Permitted And Licensed	Partially Permitted And Licensed	Partially Permitted And Licensed
Lost Creek ISR LLC	Lost Creek Project	Sweetwater, Wyoming	2,000,000	Operating	Operating	Operating	Operating	Operating
Mestena Uranium LLC	Alta Mesa Project	Brooks, Texas	1,500,000	Standby	Standby	Standby	Standby	Standby
Power Resources, Inc. dba Cameco Resources	Smith Ranch-Highland Operation	Converse, Wyoming	5,500,000	Operating	Operating	Operating	Operating	Operating
South Texas Mining Venture	Hobson ISR Plant	Karnes, Texas	1,000,000	Standby	Standby	Standby	Standby	Standby
South Texas Mining Venture	La Palangana	Duval, Texas	1,000,000	Standby	Standby	Standby	Standby	Standby
Strata Energy Inc	Ross CPP	Crook, Wyoming	375,000	Operating	Operating	Operating	Operating	Operating
Uranerz Energy Corporation (An Energy Fuels company)	Nichols Ranch ISR Project	Johnson and Campbell, Wyoming	2,000,000	Operating	Operating	Operating	Operating	Operating
Uranium Energy Corp.	Goliad ISR Uranium Project	*Goliad, Texas*	1,000,000	Permitted And Licensed	Permitted And Licensed	Permitted And Licensed	Permitted And Licensed	Permitted And Licensed
Uranium One Americas, Inc.	Jab and Antelope	*Sweetwater, Wyoming*	2,000,000	Developing	Developing	Developing	Developing	Developing
Uranium One Americas, Inc.	Moore Ranch	*Campbell, Wyoming*	500,000	Permitted And Licensed	Permitted And Licensed	Permitted And Licensed	Permitted And Licensed	Permitted And Licensed
Uranium One USA, Inc.	Willow Creek Project (Christensen Ranch and Irigaray)	Campbell and Johnson, Wyoming	1,300,000	Operating	Operating	Operating	Operating	Operating
Total Production Capacity:			**24,175,000**					

Notes: Production capacity for 4th Quarter 2017. An operating status of "Operating" indicates the in-situ-leach plant usually was producing uranium concentrate at the end of the period. Hobson ISR Plant processed uranium concentrate that came from La Palangana. Hobson and La Palangana are part of the same project. ISR stands for in-situ recovery. Christensen Ranch and Irigaray are part of the Willow Creek Project. Uranerz Energy has a tolling arrangement with Cameco Resources. Uranium is first processed at the Nichols Ranch plant and then transported to the Smith Ranch-Highland Operation plant for final processing into Uranerz's uranium concentrate. CPP stands for central processing plant.

Source: U.S. Energy Information Administration: Form EIA-851A and Form EIA-851Q, "Domestic Uranium Production Report."

Uranium Exploration

The nuclear fuel cycle starts with exploration for uranium and the development of mines to extract the uranium ore, usually produced as U_3O_8, which is only slightly radioactive. A variety of techniques are used to locate uranium, such as airborne radiometric surveys, hydrochemical sampling of groundwater and geochemical sampling of soils, and exploratory drilling to understand the underlying geology (see Campbell and Biddle (1977)). Once uranium ore deposits are located, the mine company usually follows up with more closely spaced *in fill,* or development drilling, to determine how much uranium is available and what it might cost to recover it (see Dickinson and Duval (1977)).

Uranium Mining

When ore deposits that are economically feasible to recover are located, the next step in the fuel cycle is to mine the ore using one of the following techniques (see Figure 5):

- underground mining
- open pit mining
- in-place (in-situ) solution mining/recovery
- heap leaching (not common in U.S.)

Before 1980, most U.S. uranium was produced using open pit and underground mining techniques (Hunkin, 1977). Today, most U.S. uranium is produced using a solution mining technique commonly called in-situ-recovery (ISR). This process extracts uranium that coats the sand and gravel particles of groundwater reservoirs. The sand and gravel particles are exposed to a solution with a pH that has been elevated slightly by using oxygen. The uranium dissolves in the groundwater, which is then pumped out of the aquifer and processed at the uranium mill (for more, see Campbell, et al., (2007)(2009)).

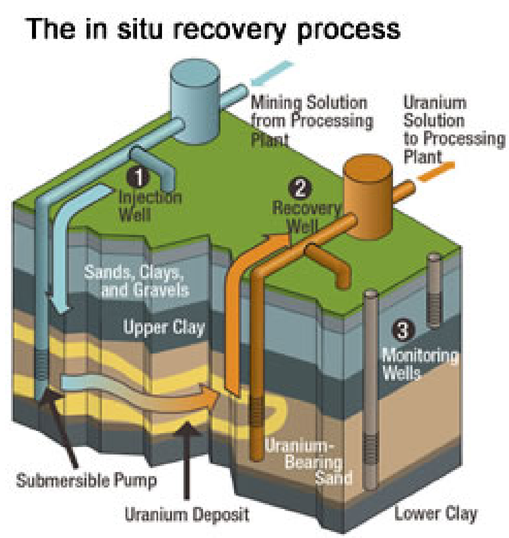


Figure 6

Source: United States Nuclear Regulatory Commission

The details regarding uranium milling, uranium conversion into UF_6 gas by enrichment, reconversion and nuclear fuel fabrication were discussed in the 2017 UCOM Mid-Year (Year End) report (more).

Interim Waste Storage and Final Storage

After use in the reactor, fuel assemblies become highly radioactive and must be removed and stored at the reactor under water in a spent fuel pool for several years. Even though the fission reaction has stopped, the spent fuel continues to give off heat from the decay of radioactive daughter products that were created when the uranium atoms were split apart. The water in the pool serves to both cool the fuel and block the release of radiation. From 1968 through June 2013, about 241,500 fuel assemblies had been discharged and stored at 118 commercial nuclear reactors site either shuttered or still operating in the United States.

Within a few years, the spent fuel cools in the pool and are often moved to a dry cask storage container for storage at the power plant site. An increasing number of reactor operators now store their older spent fuel in these special outdoor concrete or steel containers with air cooling.

The final step in the nuclear fuel cycle is the collection of spent fuel assemblies from the interim storage sites for final disposition in a underground storage repository. The United States currently has no permanent underground repository for high-level nuclear waste. For additional information, (see Nuclear Waste Storage: later in this report).

U.S. Nuclear Power Plant Activities: Electricity Generation

The World Nuclear Association (WNA) reviewed the conditions within the U.S. as of February, 2018 and concluded that:

- The U.S. is the world's largest producer of nuclear power, accounting for more than 30% of worldwide nuclear generation of electricity.

- The country's 99 nuclear reactors produced 805 billion kWh in 2016, almost 20% of total electrical output. There are two reactors under construction.

- Following a 30-year period in which few new reactors were built, it is expected that two more new units will come online soon after 2020, these resulting from 16 license applications made since mid-2007 to build 24 new nuclear reactors.

- Government policy changes since the late 1990s have helped pave the way for significant growth in nuclear capacity.

- Some states have liberalized wholesale electricity markets, which makes the financing of capital-intensive power projects difficult, and, coupled with lower gas prices since 2009, have put the economic viability of some existing nuclear power plants and proposed projects in doubt.

- The first zero-emission credit programs have commenced, in New York and Illinois.

In 2016, the U.S. electricity generation was 4,079 TWh (billion kWh) net with:

- 1,380 TWh (34%) of it from natural gas,
- 1,240 TWh (30%) from coal,
- 805 TWh (20%) nuclear power,
- 266 TWh (7%) from hydroelectric,
- 226 TWh (6%) from wind, and
- 117 TWh (3%) from other renewables, including solar (EIA data).

In 2017, about 4,015 billion kilowatthours (kWh) (or 4.01 trillion kWh) of electricity were generated at utility-scale facilities in the U.S., with:

1. about 63% of this electricity generation was from fossil fuels (coal, natural gas, petroleum, and other gases), and
2. about 20% was from nuclear energy, and about 17% was from renewable energy sources, including hydropower (more). For a detailed break-out, see Table 4.

Table 4

(2018 EIA)

U.S. Electricity Generation by Source, Amount, and Share of Total in 2017 - Note [1]		
Energy source	**Billion kWh**	**Share of total**
Total - All Energy Sources	4,015	
Fossil Fuels (Total), including:	2,495	62.7%
3. Natural gas	1,273	31.7%
4. Coal	1,208	30.1%
5. Petroleum (Total), including:	22	0.5%
a. Petroleum liquids	13	0.3%
b. Petroleum coke	9	0.2%
6. Other Gases	14	0.4%
Nuclear Energy	805	20.0%

Renewables (Total), including:	687	17.1%
1. Hydropower	300	7.5%
2. Wind	254	6.3%
3. Biomass (Total)	64	1.6%
4. Wood	43	1.1%
5. Landfill gas	11	0.3%
6. Municipal Solid Waste (Biogenic)	7	0.2%
a. Other Biomass Waste	3	0.1%
7. Solar (total)	53	1.3%
a. Photovoltaic [2 and 4]	50	1.2%
b. Solar thermal	3	0.1%
8. Geothermal Energy	16	0.4%
Pumped Storage Hydropower [3]	-6	-0.2%
Other sources	13	0.3%

[1] Preliminary data for 2017. Includes utility-scale electricity generation, which is electricity generation from power plants with at least one megawatt (or 1,000 kilowatts) of total electricity generating capacity.
[2] Small-scale solar photovoltaic systems are electricity generators with less than one megawatt of electricity generating capacity that are usually at or near the location where the electricity is consumed. Most small-scale solar photovoltaic systems are installed on building rooftops.
[3] Pumped storage hydroelectricity generation is negative because most pumped storage electricity generation facilities use more electricity than they produce on an annual basis.
[4] The U.S. Energy Information Administration estimates that an additional 24 billion kWh of electricity generation was from small-scale solar photovoltaic systems in 2017.

Electricity Demand

Annual electricity demand is projected to increase to 5,000 billion kWh by 2030, though in the short term it is depressed and has not exceeded the 2007 level. Annual per capita electricity consumption in 2013 was 11,955 kWh. Total net summer capacity was about 1,060 GWe.(2018 EIA).

Nuclear power plays a major role in generating electricity over the past 50 years. The U.S. currently has 99 nuclear power reactors in 30 states, operated by 30 different power companies, and in 2016 they produced 805 TWh. The average capacity factor has risen from 50% in the early 1970s, to 70% in 1991, and it passed 90% in 2002, remaining at around this level since. In 2016, it was a record 92.5%, compared with wind 34.7% (based on 2018 EIA data).

Since 2001, these plants have achieved an average capacity factor of over 90%, generating up to 807 TWh per year and accounting for about 20% of total electricity generated by nuclear power. The industry invests about $7.5 billion per year in maintenance and upgrades of the nuclear plants. Average nuclear generation costs have come down from $40/MWh in 2012 to $34/MWh in 2016. Few records are available on the actual O&M costs of wind and solar systems presently in operation (more).

There are 65 pressurized water reactors (PWRs) with combined capacity of about 64 GWe and 34 boiling water reactors (BWRs) with combined capacity of about 35 GWe – for a total capacity of 99,062 MWe (see Nuclear Power in the U.S. Appendix 1: U.S. Operating Nuclear Reactors). Almost all the US nuclear generating capacity comes from reactors built between 1967 and 1990. Until 2013 there had been no new construction starts since 1977, largely because for a number of years when gas generation was considered more economically attractive and because construction schedules during the 1970s and 1980s had frequently been extended by opposition, compounded by misguided safety fears from the movie China Syndrome that ingrained falsehoods about nuclear radiation before and following the Three Mile Island accident in 1979 (more).

Another PWR (Watts Bar 2) started up in 2016 following Tennessee Valley Authority's (TVA's) decision in 2007 to complete the construction of the unit (more).

Despite a near halt in new construction of more than 30 years, U.S. reliance on nuclear power has grown (more). In 1980, nuclear plants produced 251 billion kWh, accounting for 11% of the country's electricity generation. In 2008, that output had risen to 809 billion kWh and nearly 20% of electricity, providing more than 30% of the electricity generated from nuclear power worldwide. Much of the increase came from the 47 reactors, all approved for construction before 1977, that came on-line in the late 1970s and 1980s, more than doubling U.S. nuclear generation capacity. The U.S. nuclear industry has also achieved remarkable gains in power plant utilization through improved refueling, maintenance and safety systems at existing plants. Average generating cost in 2014 was $36.27 per MWh ($44.14 at single-unit sites and $33.76 at multi-unit sites), including fuel and capital, and average operating cost was $21/MWh. There are plans for a number of new reactors; two more new units will come online by 2021.

Since about 2010, the prospect of low natural gas prices continuing for several years has dampened plans for new nuclear capacity. In May 2016 the Energy Information Administration (EIA) said that nearly 19 GWe of new gas-fired generation capacity was expected online by 2019, mostly using shale gas. It later reported that 9 GWe of gas capacity had come online in

2016, along with 8.7 GWe wind and 7.7 GWe solar. There was a net capacity gain in 2016 of 15 GWe after about 12 GWe retirements.

The two AP1000 reactors under construction at Vogtle are eligible for subsidies similar to but significantly less than those allowed for wind power generation. Under the Energy Policy Act (EPA) 2005, up to 6,000 MWe of new nuclear is eligible for production tax credits (PTCs). PTCs are divided pro-rata among those applicants which had filed combined construction and operating license (COL) applications by the end of 2008, commenced construction of advanced plants by 2014, and will enter service by 2021. At the start of 2018, an extension to the PTC was passed by the U.S. Senate and Congress. This was critical for the Vogtle plant, where Reactor 3 is not expected to enter operation until 2021, with Reactor 4 a year later. The level of the PTC is 1.8 cents per kWh, for eight years, and cannot be claimed until an asset is producing electricity. There is an annual payment limit of $125 million for each 1,000 MWe of capacity (more).

In addition to granting an extension, the new act just passed in February, 2018 and allows non-profit and municipal owners of the new Vogtle units to trade their credits to a profitmaking company involved in the construction of the reactors. (Non-profit and municipal power companies do not pay taxes and therefore could not benefit from the credits.) The largest owners of each project are for-profit utilities, Georgia Power for Vogtle and South Carolina Electric & Gas for Summer (more). Allowing the municipal and non-profit owners to transfer their tax credits to a company involved in the ownership or construction of the units will save ratepayers money and would “correct a disparity of current law.” For more information, see section on financial incentives below.

In February 2013, Duke Energy's 860 MWe Crystal River PWR in Florida was decommissioned from damage to the containment structure sustained when new steam generators were fitted in 2009-10, under previous owner, Progress Energy. Its 40-year operating license was due to expire in 2016. Some $835 million in insurance was claimed. Dominion Energy's 566 MWe Kewaunee PWR in Wisconsin was decommissioned in May 2013, after 39 years operation (more).

Then, in June 2013, the two 30-year old PWR reactors (1,070 and 1,080 MWe) at San Onofre nuclear plant in California were retired permanently owing to regulatory delay and uncertainty following damage in the steam generators of one unit. An economic study claimed that Californian generating costs rose by $350 million in the following year and carbon emissions by 9 million tonnes per year as a result (more), In August 2013, Entergy announced that its 635 MWe Vermont Yankee reactor would be closed down at the end of 2014 as it had become uneconomic, and decommissioning is now underway (more).

Ten other nuclear plants (13 reactors) were considered (at the start of 2014) to be at risk of closure, all but one of these in the northeast of the country, are in deregulated states. The factors giving rise to uncertainty are high costs with low power prices, regulatory issues, and local concerns with safety and reliability. The Nuclear Energy Institute (NEI) said in December 2015 that "total electric generating costs at US nuclear plants have increased 28% – to an industry average $36.27 per MWh – over the past 12 years," including fuel, capital and operation and maintenance costs. It announced an initiative coordinated with the Nuclear Regulatory Commission (NRC) to cut electricity production costs by 30% by 2018.

Coal is projected to retain the largest share of the electricity generation mix to 2035 unless something interrupts the projection (like increased nuclear power (SMRs and AP1,000 models prevail), and about 20 GWe of coal-fired capacity was added. More than 53 GWe of older coal plants were retired according to the EIA, due to environmental constraints and low efficiency, coupled with a continued drop in the fuel price of gas relative to coal, and tax policies favoring renewables. A further decrease up to 2020 is expected, because most operating coal-fired plants are older than 35 years and not climate friendly.

The EIA projects 13 GWe of new gas-fired capacity, mostly CCGT, were to come online in 2017, adding to the existing 431 GWe, but with 2 GWe to be retired. This trend is expected to continue to about 2020. The predominance of CCGT is driven by low gas prices, strict regulation of coal-fired plants, though the need to back up intermittent renewables (wind and soalr) input favors less-efficient OCGT. Natural gas prices from 2015 to March 2017 ranged from $1.50 to $3.80/million BTU (more).

Given that nuclear plants generate nearly 20% of the nation’s electricity overall and 63% of its carbon-free electricity, even a modest increase in electricity demand would require significant new nuclear capacity by 2025 in addition to the two nuclear reactors currently under construction in order to maintain this share (more). If current nuclear plants retire after 60 years of operation, 22 GWe of new nuclear capacity would be needed by 2030, and 55 GWe by 2035 to maintain a 20% nuclear share. The new SMRs could play an important role over the next few years (more) to make up this gap (more).

About half of U.S. generating capacity is over 30 years old, and major investment is also required in transmission infrastructure. This creates an energy investment crisis which was recognized in Washington, D.C. along with an increasing bipartisan consensus on the strategic importance and clean air benefits of nuclear power in the energy mix, but Liberal opposition (and wind and solar proponents) stand in the way of maintaining the power grid.

Low natural gas prices continue to depress the prospects for commitment to further nuclear power plant construction (more). Today, the importance of nuclear power in the U.S. is geopolitical as much as economic, but continues to be reducing dependency on oil and gas. The operational cost of nuclear power in existing plants is very competitive with alternatives (wind and solar). In 2012, nuclear cost was 2.4 ¢/kWh, compared with gas 3.4 ¢/kWh and coal 3.3 ¢/kWh. But plans for new nuclear capacity are starting to take account of opportunities for small reactors (SMRs) as well as the typical large capacity plants currently in operation (more).

From 1992 to 2005, some 270,000 MWe of new gas-fired plants was built, but only 14,000 MWe of new nuclear and coal-fired capacity came on line. Coal and nuclear supply almost 70% of U.S. electricity and provide price stability, relative to the natural gas prices. When investment in these two technologies almost disappeared, unsustainable demands were placed on gas supplies and prices quadrupled, impacting large industrial users of natural gas offshore and pushing gas-fired electricity costs towards 10 ¢/kWh. As of early 2108, with the appearance of shale gas, such costs are now much lower, albeit not likely sustainable for any length of time.

The reason for investment being predominantly in gas-fired plants was that it offered the lowest near-term investment risk. Several uncertainties inhibited investment in capital-intensive new coal and nuclear technologies considering that natural gas prices need to recover to $8/GJ or /MMBtu before there is renewed confidence in deregulated states. In regulated states, a longer-term outlook is possible. SMRs provide possible relief from major upfront finance burdens, and these will soon have design certification from the NRC.

There are three regulatory initiatives which in recent years have enhanced the prospects of building new nuclear power plants. First is the design certification process, second is provision for early site permits (ESPs) and third is the combined construction and operating license (COL) process (‘Part 52’) as an alternative to the ‘Part 50’ two-step process of construction permit followed by operating license (more). All have some costs shared by the DOE.

U.S. Nuclear Power Plants Under Construction

Of the above, for the first four AP1000 units, construction is well underway at Vogtle, Georgia, with about $4 billion invested in the project before it was technically 'under construction'. Construction was also well underway at Summer, South Carolina, but has been put on hold. In addition to sites listed above, Southern Company is evaluating several possible sites, including existing plants and greenfield locations, for additional AP1000 reactors (more). However the economic outlook since 2013-14 indicates that merchant plants are not economically viable, and that some kind of assured market is necessary to underwrite the high-capital costs of nuclear plants (more).

Design Certification

As part of the effort to increase U.S. generating capacity, government and industry have worked closely on design certification for advanced Generation III reactors. Design certification by the Nuclear Regulatory Commission (NRC) means that, after a thorough examination of compliance with safety requirements, a generic type of reactor (say, a Westinghouse AP1000) can be built anywhere in the U.S., only having to go through site-specific licensing procedures and obtaining a combined construction and operating license before construction can begin. Design certification needs to be renewed after 15 years.

Designs now have U.S. design certification and are being actively marketed:

- The GE Hitachi advanced boiling water reactor (ABWR) of 1300-1500 MWe. Several ABWRs are now in operation in Japan, with more under construction there and in Taiwan. Some of these have had Toshiba involved in the construction, and more recently it has been Toshiba that promoted the design most strongly in the U.S. (more). Both the Toshiba and the GE Hitachi versions need to have their design certification renewed from 2012, but NRC shows both as "applicant delayed, not scheduled". Toshiba withdrew its design certification renewal application in mid-2016.
- The Westinghouse AP1000 is the first Generation III+ reactor to receive certification (see notes (more)). It is a scaled-up version of the Westinghouse AP600 which was certified earlier. It has a modular design to reduce construction time to 36 months. The first four of many are being built in China, and four more in USA.
- GE Hitachi's Economic Simplified BWR (ESBWR) of 1,600 MWe gross, developed from the ABWR. The ESBWR has passive safety features and is currently included in the COL applications of two companies in USA. GE Hitachi submitted the application in August 2005, design approval was provided in March 2011, and design certification was provided in September 2014. The first COL with it was approved in May 2015.

Reactor designs undergoing U.S. design certification or expected to do so are:

- The Korean APR1400 reactor, which ha operated in South Korea since 2016 and is under construction in the UAE. Following 11 pre-application meetings, Korea Hydro & Nuclear Power submitted a design certification application to the NRC in October

2013. However, further detail was requested, and the revised submission was accepted by the NRC in March 2015. The final safety report is expected late in 2018.

- The Mitsubishi US-APWR reactor, a 1700 MWe design developed from that for a 1538 MWe reactor planned for Tsuruga in Japan. The application was submitted in 2007 and certification was expected to be completed in 2016, but Mitsubishi delayed the NRC schedule for "several years". European certification for the almost identical EU-APWR was granted in October 2014. Two US-APWR reactors were proposed in the Luminant-Mitsubishi application for Comanche Peak, but Mitsubishi has withdrawn from this project. Luminant is closing coal plants and integrating their energy mix by adding wind and solar systems combined with a series of acquisitions (more).

- The Russian VVER-1200 reactor which is operating at Novovoronezh II and being built at Leningrad II could be submitted for U.S. design certification through Rosatom Overseas, according to Rosatom before the development of recent political issues with the U.S.

A reactor design formerly undergoing U.S. design certification was the U.S. Evolutionary Power Reactor (U.S. EPR), an adaptation of Areva's EPR to make the European design consistent with U.S. electricity frequencies. The main development of the type was to be through UniStar Nuclear Energy, but other U.S. proposals also involved it. The application was submitted in December 2007 and the design certification rule was expected after mid-2015, with delays resulting from the complexity of digital instrumentation and control systems. Areva then delayed the NRC schedule and in 2015 indefinitely suspended the application. The 1600 MWe EPR is being built in Finland, France, and Guangdong in China, and is planned for U.K.

U.S. Small Modular Reactors (SMRs)

New reactor designs are being certified but not yet marketed in the U.S., and also on small modular reactors, which appear to be on a fast-track for certification and marketing in the U.S., UK, Middle East, China and elsewhere (more).

In addition, several designs of small modular reactors (SMRs) are proceeding towards NRC design certification application or the alternative two-step route of a construction permit then operating license:

- A demonstration unit of the 160 MWe Holtec SMR-160 PWR (with external steam generator) is proposed at Savannah River Plant with DOE support, and a construction permit application is likely, or a similar application in Canada. In September 2016 Mitsubishi Electric Power Products and its Japanese parent became a partner in the project, to undertake the I&C design and help with licensing. In 2017, SNC-Lavalin joined the project. South Carolina and NuHub also backed the proposal and it should move forward.

- A demonstration unit of the NuScale multi-application small reactor, a 50 MWe integral PWR is planned for the Idaho National Laboratory. Subsequent deployment of 12-module power plants in western states is envisaged under the Western Initiative for Nuclear. The NRC accepted NuScale's design certification application in 2017 and a COL application is planned early in 2018. Nuscale had spent some $170 million on licensing to mid-2015, and expects the NRC review to take 40 months, with the first unit operating in the mid-2020s. In 2013 NuScale secured up to $226 million DOE support for the design, and applied for the second part of its loan guarantee in September 2017. Further details under the section on UAMPS below.

- SCEG is evaluating the potential of X-energy's Xe-100 pebble-bed SMR (50 MWe, a high temperature gas-cooled reactor) to replace coal-fired plants, in 200 MWe 'four-pack' installations.

- In August 2015, Russia's AKME-Engineering received a US patent for its modular SVBR -100 lead-bismuth cooled integral fast reactor. The company said that it wants to protect its intellectual property as it prepares for the construction of a prototype SVBR-100 unit at Dimitrovgrad. No plans for the U.S. have been announced.

In 2014, the NRC said that its most optimistic scenario for awarding design certification for small reactors such as SMRs was 41 months, assuming they were light water types (PWR or BWR). Since then, however, as indicated above, SMR development seems to be picking up momentum in the U.S. and U.K. (more).

Nuclear Waste Storage

The debate continues in the U.S. on when and where to store the nuclear waste material generated by 99 nuclear power plants in the U.S. (more). The new administration was pressing for the Yucca Mountain facility to be completed after spending billions of dollars on its development to date. However, alternatives are also being considered. Conca (2018) reports that the U.S. Nuclear Regulatory Commission has accepted Holtec International's license application for its proposed consolidated interim storage facility for spent nuclear fuel (more), called HI-STORE CIS.

To be located in southeastern New Mexico near Carlsbad, the facility would store spent nuclear fuel, (which is referred to as slightly used nuclear fuel), until a final storage facility is built or until new fast reactors are available that will burn it, or recycle it into new fuel.

Reactor fuel usually spends five years in the reactor, after which about 5% of the energy in the fuel is used. However, fission by-products of the reactions have built-up to the point where the fuel must be replaced. After leaving the reactor, the spent fuel usually spends about 5 years in spent fuel pools of water, until heat and radiation have decreased sufficiently to allow the fuel to be passively cooled in a dry cask. These systems are indeed a temporary interim measure. The stainless-steel canisters are easily retrievable and ready for transport to whatever permanent solution is chosen, such as deep geologic disposal or burning in fast reactors. The canisters are designed, qualified, and tested to survive for centuries and prevent the release of radioactive material under the most adverse accident scenarios postulated by NRC regulations for both storage and transportation.

As an add-on, Holtec is also seeking approval from NRC to use the heat generated by the waste, from just sitting on the pad, to make clean drinking water from dirty water contained in industrial processes like drilling. New Mexico generates a lot of water contaminated with organics and salts, especially in the region where the interim storage facility will be located, and use of their patented process-heat design would be quite a boon to this arid region (more).

Even though the 'store in place" plan is viable, the nuclear power plants have been paying for decades, as mandated by law, for a secure place to store (not dispose) the nuclear waste generated by the nation's nuclear power plants (more). This distinction has been made on the basis that the material could be useful at some point in the future for reprocessing.

The activities of the growing support and the opposition against opening the Yucca Mountain facility is being continuously monitored by the I2M Web Portal (more). In all, billions of dollars have been collected by the federal government to manage the nuclear waste, but the completion of the Yucca Mountain Facility has been blocked by anti-nuclear opponents (and congressmen), including a few senators (more), so other sites are now being considered (more). Conca (2018) suggests that a new site near Carlsbad might be feasible.

Australia has also begun to evaluate the feasibility of offering nuclear waste storage to the world (more).

INTERNATIONAL URANIUM EXPLORATION AND DEVELOPMENT

Beyond the exploration and mining projects in the U.S., drilling in Canada is likely to be at record levels, primarily because of the world-class discoveries that are being developed in the Athabasca Basin over the past few years. UCOM reports over the past few years have discussed these in some depth (more). Drilling is also very active in Kazakhstan, in Africa, and South America, China, and Australia. Although the latter has substantial uranium potential, it is still suffering from political fatigue in all uranium states (Western Australia, Northern Territory, Queensland, and even South Australia).

In response to the expansion in plant construction throughout the world, new discoveries of uranium deposits in Canada and elsewhere have increased in number over the past decade even under conditions of low market prices for U_3O_8. This continuing activity has occurred no doubt as a result of increasing confidence that nuclear power will continue to expand worldwide (and U.S.) to support the future demand for uranium.

As indicated above, exploration in Canada has produced numerous discoveries, many of which are of world class deposits located around the periphery of the Athabasca Basin of Saskatchewan (more). Specifically, NexGen is drilling up huge reserves with high uranium grades at depth (more), while Fission has made another major discovery in the Patterson Lake area (more), and UEX continues to expand its reserve base at Christie Lake with a wide zone averaging 20% uranium mineralization (more). The top 10 mines are located in: Canada (more than 1 mine), Kazakhstan (5 mines), Australia (1 mine and others), Niger (1 mine and others), Russia (1 mine and others), and Nambia (1 mine and others).

INTERNATIONAL URANIUM PRODUCTION

As indicated previously, the U.S. consumes a significant portion of the world's uranium supplies for use as fuel to create electricity by nuclear power (fission), yet it produces only a few million pounds of this raw material to make fuel inside the U.S. (2016). As the U.S. makes an effort to focus on energy independence, there will likely be a push to potentially subsidize production of uranium by U.S uranium companies (or production by a U.S. or Canadian companies operating outside the U.S., e.g., the URI (now Westwater Resources) Temrezli Uranium Project in Turkey, the UEC Oviedo Uranium Project in Paraguay, Macusani in Peru, etc.) in order to avoid reliance on importing uranium to supply power plants by unreliable foreign-owned uranium mining companies. If that situation were to occur, a number of projects in the U.S. that are currently not economically viable would be brought on-line for immediate evaluation and preparation for mining.

With more than 450 nuclear power plants in current operation worldwide, they require some 23 million pounds of yellowcake to be available for processing to fuel pellets to meet the various 3-5 year cycles of the plants. As each new plant construction is announced, an additional 50,000 pounds will be needed 5-10 years in the future to fuel the new plant and then the same every 3 to 5 years hence. This would stimulate new mine production or an expansion of existing mines, should the mines have such capabilities.

Some mines in Canada, Australia, and perhaps Kazakhstan, and other areas have been shown to have such expansion capabilities, e.g., Cigar Lake, McArthur River in Canada. But new, large deposits (some very high grade) have been discovered nearby around the rim of the Athabasca Basin of Saskatchewan and Manitoba, Canada, breccia pipe deposits in Arizona (more), and roll-front deposits elsewhere in the world (i.e., Peru, Uruguay and Paraguay, India, Iran, and Tanzania.

So, there will be no shortage of producing mines over the next few decades at least (more). But, this might even create market conditions that will keep the price below \$75.00 per pound (U_3O_8). As indicated to date, 35 countries account for about 5 million tonnes of U_3O_8 in the ground (equivalent to about 10 billion pounds U_3O_8), which would provide utilities with fuel for some 80 years based on a worldwide consumption rate of 50 million pounds U_3O_8/year over a 3-year fuel cycle for 450 reactors (more). Based on recent discoveries in Canada, its percent of acknowledged world reserves will increase considerably. One condition that could develop is a long-term over supply of uranium from a plethora of high- and low-grade deposits that would keep prices even below \$50.00/ pound, below that required for the typical in situ mines in the U.S.

The second condition created by the development of very high grade, large reserves of uranium present around the periphery of the Athabasca Basin of Canada (where new discoveries have been made in the past few years) that could be produced at prices lower than most other uranium mining projects. Some grades are so high that the beginning of robotics mining could well be in the offing. This could raise the cost to mine and transport such high-grade ore in the beginning but would decrease as the technology settles in (more).

Substantial investment money is coming into the new Canadian discoveries to support the development of these high-grade deposits (more), including Chinese (more) and Russian funding (more). But what will the demand be in the foreseeable future to fuel the expanding fleet of nuclear power plants in the U.S. and worldwide? If Chinese and Indian projection come to pass, fuel needs will rise significantly over the next 10 years and beyond (See Figure 6).

Timing is all important in mining and in providing uranium for processing into fuel. It is also important for management to estimate when prices will be high enough for their projects to make reasonable profits. They have to set operations into motion well before reality arrives, which often results in some companies making the right moves in exploration and permitting, as others having been too aggressive will have to wait, or have been too slow and will have to catch up with the market, losing premium dollars from higher prices.

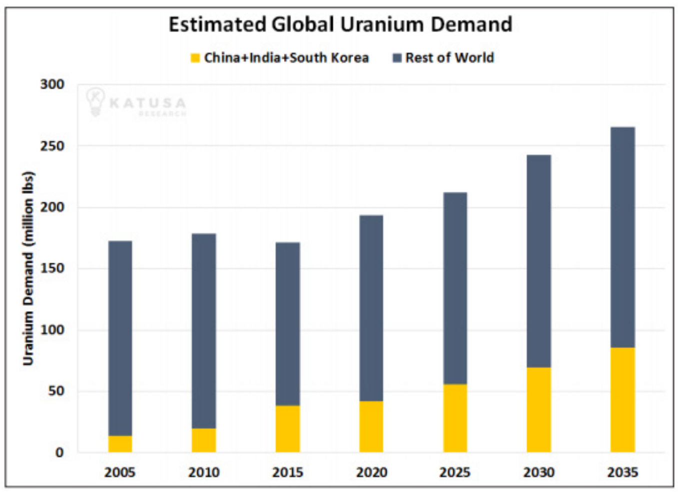


Figure 6

(Shaw,2017)

Drilling within uranium prospects is very active in Africa, and South America, in China, and in Australia and Asia; although the latter has substantial uranium potential, it is still suffering from political fatigue in all uranium states (Western Australia, Northern Territory, Queensland, and even South Australia).

Exploration in Canada has produced numerous uranium discoveries and with continued development drilling, revealing world-class deposits located around the periphery of the Athabasca Basin of Saskatchewan (more). As a result of the success of these program, substantial investment money is coming into the uranium companies making these new Canadian discoveries.

OVERALL PERSPECTIVE Based on the Focus of the I2M Web Portal

1. Coal vs. Nuclear Power and Natural Gas (here)
2. Renewable Energy vs. Nuclear Power (here)
3. Industry Bias: Google Search Results: (here)
4. Academic Bias: Google Search Results: (here)

Thorium Activities Summary

Thorium-Based Reactors continue development in the U.S., but especially in China and India (more). The WNA presents a 2017 status review of thorium reactor development to date (more).

1. I2M Web Portal: Search Results: Thorium (more)
2. University Research: Google Search: Thorium (more)
3. Industry Research: Google Search: Thorium (more)

Rare Earth Activities Summary

1. I2M Web Portal: Search Results “Rare Earth” REE (more)
2. University Research: Google Search Results (more)
3. Industry Research: Google Search Results (more)

PROPONENTS and ADVERSARIES to URANIUM MINING & NUCLEAR POWER

1. Industry Media Bias (more)
2. Academic Bias (more)

URANIUM & RARE EARTH UNIVERSITY RESEARCH

By Steven S. Sibray, P.G., C.P.G., (Vice-Chair: University), University of Nebraska, Lincoln, NE

Interest in uranium research has decreased since the Fukushima Daiichi nuclear accident in 2011 with very few grants and new sources for funding. Interest in Rare Earth Elements [REE] research has also decreased from weak market conditions but the recent discovery of deep sea-floor rare earths and other metals continue to be investigated for their economic and environmental feasibility (more). The deposits are located near the island of Minami-

Torishima, about 1,900 km southeast of Tokyo. The research team, led by Yutaro Takaya, an instructor at Waseda University and Professor Yasuhiro Kato of the University of Tokyo, published detailed findings on the size of the deposits for the first time in *Scientific Reports*, a U.K. online scientific journal. They also said they had come up with the technology to allow the resources to be extracted efficiently even from such great depths and with minimal environmental disturbance. The researchers plan to work with private companies to recover the rare earths (more)..

The Society of Economic Geologists Foundation (SEGF) and the SEG Canada Foundation (SEGCF) recently announced the Student Research Grant awards for 2017. Of the 56 grants awarded, four awards were for uranium related research and four awards were for research on REE or carbonatite deposits. Two uranium research project will concentrate on the uranium rich Iron Oxide-Copper-Gold [IOCG] Olympic Dam deposit in Australia. The Olympic Dam copper/ gold deposit is also the largest uranium deposit in the world where uranium is produced as a byproduct. One uranium research project will study pre-ore enrichment of pyrite in Cameco's McArthur River mine and another uranium project will look at predictive modeling of surficial uranium systems.

SEGF - SEGCF – 2017 Scholarship Recipients

The SEGF-Hugh E. McKinstry Fund supports "study, research and teaching of the science of economic geology or for related projects," with preference given to field and related laboratory research by graduate students. The SEGCF grant program is similar to the SEGF scholarship program. The Hugo T. Dummett Fund promotes applied economic geology research and the development of new exploration techniques.

SEGF-Hugh E. McKinstry Fund.

Matt Ferguson	US$3,500	University of Tasmania (Australia)	Ph.D.	Intermediate-felsic rocks in the Olympic Dam district and Gawler Ranges: genesis, modification, and role in IOCG mineralizing processes
Yan Hei Li	US$2,300	University of Hong Kong (Hong Kong)	Ph.D.	Genesis of the ion adsorption type REE deposits in South China
Shang Liu	US$3,750	Institute of Geology and Geochemistry, CAS (China)	Ph.D.	Fluorine alteration and its implication for the REE mineralization in the giant Bayan Obo REE-Nb-Fe deposits, China
Gephen Sadove	US$4,000	University of Michigan (USA)	Ph.D.	The Philips Mine iron oxide-apatite deposit, Adirondack Mtns, NY State: a potential domestic source for REE
Yanlu Xing	US$3,400	Monash University (Australia)	Ph.D.	Role of F on metal mobilization in hydrothermal fluids and its implications on the formation of the Olympic Dam deposits.

Hugo T. Dummett Fund

Bijal Chudasama	US$3,500	IIT Bombay (India)	Ph.D.	Predictive modeling of surficial uranium mineral systems
John DeDecker	US$1,700	Colorado School of Mines (USA)	Ph.D.	Pre-Ore Pyrite Enrichment of the P2 Fault at McArthur River Uranium

Canada Foundation SEGCF

Dylan Langille	US$2,400	Western University (Canada)	M.Sc.	The Mineralogical Characterization of Peralkaline Granites hosting HREE-rich Pegmatites, Lac Brisson, Quebec

At the Colorado School of Mines, John DeDecker is working on unconformity-related uranium deposits in the Athabasca Basin and has published the following two abstracts with Dr. T. Monecke:

DeDecker, J., Monecke, T., 2017, Chlorite alteration of pre-ore pyrite at the McArthur River uranium deposit, Athabasca Basin: Possible implications to ore deposition. Geological Society of America, Seattle, Washington (October 22-15, 2017). Electronic Abstracts, paper 2-9.

DeDecker, J., Monecke, T., 2017, Chlorite alteration of pre-ore pyrite at the McArthur River uranium mine, Athabasca basin: Possible implications to ore deposition. Goldschmidt, Paris, France (August 13-18, 2017), Goldschmidt Abstracts, p. 867. New Mexico Institute of Mining and Technology, published a special issue of NM Geology on uranium. It was a continuation of the special issue started in 2016.

In New Mexico, McLemore, V.T. and Wilton, T., 2017, Uranium in New Mexico: A special issue of New Mexico Geology: New Mexico Geology, v. 39, no. 1, p. iii. (Vol.38) (Vol.39).

McLemore, V.T. and Chenoweth, W.C., 2017, Uranium resources; *in* McLemore, V.T., Timmons, S., and Wilks, M., eds., Energy and Mineral deposits in New Mexico: New Mexico Bureau of Geology and Mineral Resources Memoir 50 and New Mexico Geological Society Special Publication 13, 80 p.

McLemore, V.T., 2017, Heavy mineral, beach-placer sandstone deposits at Apache Mesa, Jicarilla Apache Reservation, Rio Arriba County, New Mexico; *in* The Geology of the Ouray-Silverton Area, Karlstrom, K.E., Gonzales, D.A., Zimmerer, M.J., Heizler, M., and Ulmer-Scholle, D.S.: New Mexico Geological Society 68th Annual Fall Field Conference Guidebook, p.. 123-132

McLemore, V.T., 2018, Rare Earth Elements (REE) Deposits Associated with Great Plain Margin Deposits (Alkaline-Related), Southwestern United States and Eastern Mexico: *Resources* 2018, *7*(1), 8; 44 p., doi: (more)

Asafo-Akowuah and McLemore at New Mexico Institute of Mining and Technology also published a poster on abandoned uranium mines in New Mexico**:**

> Asafo-Akowuah, J. and V. T. McLemore, V.T., 2017, The Characterization of Abandoned Uranium Mines (AUM) in New Mexico: Society for Mining, Metallurgy, and Exploration, 2017 Annual meeting abstract (more)

URANIUM & RARE EARTH GOVERNMENT RESEARCH

By Robert W. Gregory, P.G., (Vice-Chair: Government), Wyoming State Geological Survey, Laramie, WY

The Wyoming Legislature has funded several studies during the last few years conducted by the Wyoming State Geological Survey (WSGS) including rare earth elements (REE), lithium, iron, and zeolite resources. The WSGS released a report in June, 2013 which examined known and potential REE occurrences and deposits. Report of Investigations 65 (RI-65) covers reconnaissance surveys statewide and highlights areas of anomalous concentrations over five times the average crustal abundance.

In June, 2016, the WSGS released a follow-up study to RI-65, A Comprehensive Report on Rare Earth Elements in Wyoming (RI-71). RI-71 is focused on expanding the investigation of REE in areas not reached in the RI-65 timeframe and as a follow-up sampling in areas with anomalous REE concentrations, including an examination of select REE occurrences and their association with uranium deposits.

Also released in 2016 were reports on the iron, lithium, and zeolite resources, all are available on WSGS's website. This included a public information circular (PIC 46), which is a general reference on the geology of uranium and its use. This publication is intended for the general reader and includes explanations of the nature and origination of uranium, physical and chemical properties, mining history in Wyoming, and descriptions of the various steps of the nuclear fuel cycle.

The U.S. Geological Survey (USGS), in cooperation with the Texas Bureau of Economic Geology, released an assessment last year that highlights an estimated 200 million pounds of estimated (eU_3O_8) resources in the south Texas Gulf Region. The study also reports an estimated

60 million pounds of identified uranium resources in the ground. They point out that that is roughly equal to five years' worth of uranium requirements for the U.S. (more).

The USGS also released in late 2015 their findings from a study conducted on core samples from an in-situ (ISR) recovery operation in the Powder River Basin, Wyoming. They examined the nature of distribution and concentration of uranium (in both +4 and +6 oxidation states) in the ground following mining operations. They noted links between higher concentrations of uranium and precursor minerals in layers of lower permeability, as well as slightly elevated uranium levels associated with organic matter and the clay/silica matrix. Examinations of microbial communities in the ore zone indicated a variety of co-existing microenvironments in the samples observed. Their findings could have important implications on groundwater restoration processes and methods (more).

For information on current and older research projects at the USGS, visit their website (more). Additional uranium research subjects investigated by the U. S. Geological Survey and other state and overseas geological surveys are available for review via the I2M Web Portal (more). Additional rare-earth research subjects investigated by the U. S. Geological Survey and other State and National Surveys are available for review (more).

Ambient Radiation in the Atmosphere

On the basis that the impact of radiation can be harmful both in the short-term and long-term exposure to humans, information regarding the minimum safe radiation (or hazardous) exposure to humans has over the years been debated widely (Conca, 2014). This matter has also been treated in some detail earlier by the UCOM committee (Campbell, et al., 2013, pp. 171-177), and others (I2M, 2018k).

Conca and others (2017) report that, aside from exposure to the Sun causing skin cancers and to radon causing lung cancer to underground mining personnel, especially those who smoke, it is very rare for anyone to be damaged by any dose of radiation. Contrary to the hype and fear pandering by the media on Fukushima (UNSCEAR, 2014), and even Chernobyl (I2M, 2018l), the observable radiation health effects from both accidents were small. In the case of Fukushima, it was near zero (Kant, 2017; and Karam, 2016).

In the case of Chernobyl, although significant, it was much lower than originally assumed (WNA, 2016) and WHO, 2005). The reason for this is that almost all radiation professionals have been using the wrong model to predict health effects from radiation at these levels, and only recently have the global health, nuclear and radiation agencies realized that error and are moving to correct this matter. However, as with most science, this change has been slow. And, the matter is also very political as it involves extensive investments over many years, time will be required to reset the records and widespread viewpoints.

But the heavily entrenched views are often suspicious of industry activities involving radioactivity particularly. Once the views are adjusted in the scientific and technical literature, however, the implications for removing artificial barriers and unnecessary regulations are enormous, especially in the nuclear power industry regulations.

But new information on humans in the exploration and development during recent off-world activities indicate that changes do occur, especially in how the human body reacts to weightlessness is a much more pressing matter to prepare for than radiation in examining duration rather than exposure. Information just released by NASA concerning the "twins study" is not good news (Specktor, 2018). The genetic code and some of the physical characteristics of the twin in space changed significantly beyond those typically experienced on Earth. Interestingly, Scott Kelly has since shrunk back down to his initial pre-spaceflight height and suggests that the physical and mental stresses of Scott Kelly's year in orbit could have activated hundreds of "space genes" that altered the astronaut's immune system, bone formation, eyesight and other bodily processes. Although most of the genetic changes reverted back to normal following Scott Kelly's return to Earth, about 7 percent of the astronaut's genetic code remained altered, and it may stay that way permanently.

More than 200 researchers in 30 states are helping to analyze the Kelly brothers' various off-world test results, looking for space-induced changes in Scott Kelly's cognition, metabolism, microbiome and many other physiological processes. NASA will publish the comprehensive findings of these tests in a single study later in 2018.

Concerning the impact of radiation on earth, one scientific society has made it clear that the model applied over the years should not apply to humans on earth. They are the most qualified, independent group to understand this issue are known as the *Health Physics Society*. This is the scientific society that includes radiation protection scientists, and they recently put out a revised position statement in *Radiation Risk In Perspective* (HPS-2018). In it, they advise against estimating health risks for people from exposures to ionizing radiation that are anywhere near natural background levels because statistical uncertainties at these low levels are great. In other words, claims of possible adverse health effects resulting from radiation doses below 10,000 mrem (100 mSv) are not defensible.

Background radiation across the Earth varies from 3 mrem/yr (0.03 mSv/yr) over the oceans to 10,000 mrem/yr (100 mSv/yr) in areas of high elevation made up of granitic rocks on the surface. Thus, it is not surprising that populations subjected to radiation levels of 10,000 mrem (100 mSv) or below, show radiation effects that are not statistically different from zero.

Cancer can develop naturally with no contribution from radiation. If a large population is exposed to radiation levels ten times their normal radiation levels, 40,000 ± 1,600 will develop cancer over their lives (NIH, 2018). Of course, there could be a few dozen cases hiding in that huge error bar number, that plus or minus 1,600 is within the margin of error, but by definition, those will be statistically insignificant and should not be any cause for concern. They are too few to ever be measured. The concern should be for the 40,000 natural cancers, the direct causes of these are the subject of ongoing, intensive medical research (i.e., Jaworowski, 2010), and others (I2M, 2018m).

The reasons for this 60-year reliance on the incorrect model, called the Linear No-Threshold dose hypothesis, have been examined in some detail (Kathren, 2002). LNT has been used in radiation protection to quantify radiation exposure and set regulatory limits. First put forward after WWII, LNT assumes that the long term, biological damage caused by ionizing radiation (primarily the cancer risk) is directly proportional to the dose … increase the dose, increase the risk, increase the cancers, increase the deaths.

But this model just sums exposure to all radiation, without taking into account dose levels or dose rates, or the fact that healthy organisms have immune systems that are very effective at repairing cellular damage from normal, natural doses of radiation. Conca (2016) provides additional compelling evidence regarding the "low dose" impact. He emphasized that this model was used incorrectly to estimate public health effects.

Hundreds of thousands of people were unnecessarily evacuated because of the overestimation of adverse health effects by radiation exposure as predicted by the LNT, incurring a much larger risk from the perils of the evacuation. As a result, many thousands of deaths occurred, not from radiation, but from panic, depression and alcoholism. This applies to all of the incidents at Three-Mile Island (in 1979), at Chernobyl (in 1986), and at Fukushima (in 2011), all created by a fear-pandering media and ignorant public service support systems.

The damage at the Fukushima Daiichi Power Plant following the devastating tsunami in Japan has proven costly in many ways, politically, economically and emotionally. But the feared radiation-induced cancers and deaths are not occurring, as claimed by many adversaries. According to UNSCEAR (cited above), no radiological health effects have resulted from the

Fukushima incident in the public, neither cancers, deaths nor radiation sickness. No one received enough dose, even the 20,000 workers who have worked tirelessly to recover from this event.

Cuttler and Welsh (2015) in the *Journal of Leukemia* pointed to two important aspects of the radiation issue. UNSCEAR unequivocally reported that "Radiation exposure has never been demonstrated to cause hereditary effects in human populations," a finding supported by recent research UNSCEAR (2001), and the health data from Hiroshima on about 96,800 humans show that there is an acute radiation threshold at about 50 rem (500 mSv) for excess leukemia incidence. This is consistent with the conservative threshold dose of 10 rem (100 mSv) for all cancers.

The large numbers of cancers and deaths predicted for Chernobyl and for Fukushima that have flooded the media were all generated by applying this incorrectly-applied model. It is now up to the scientific community, which generally avoids political controversy, to weigh in on this subject and decide whether being conservative is worth the pain and suffering it will cause the public if (or when) another incident occurs.

Radiation Perspectives

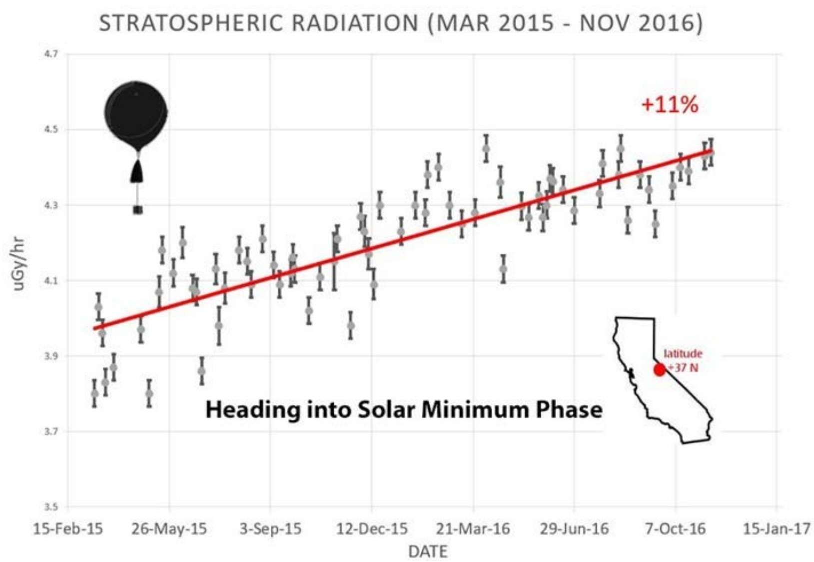
Of particular importance is the knowledge that since the large earthquake and tsunami causing the nuclear reactor meltdown in Japan during and after March 11, 2011, there have been no deaths directly caused by the radiation leak from the nuclear plant in Fukushima.

The latest update (in April) by the World Nuclear Association on the Fukushima disaster states that there have been no deaths or cases of radiation sickness caused by that nuclear accident (WNA, 2017).

Sources of Radiation

Our Sun, at present, is in its Solar Minimum phase. As sunspots vanish, the extreme ultraviolet output of the sun decreases. This causes the upper atmosphere of Earth to cool and collapse, decreasing orbital resistance. Space junk remains in orbit longer. Also during Solar Minimum, the heliosphere shrinks, bringing interstellar space closer to Earth. Galactic cosmic rays penetrate the inner solar system with relative ease. Indeed, a cosmic ray surge is already underway as indicated in Figure 7 (Philipps, 2018).

Figure 7
(Spaceweather.com)

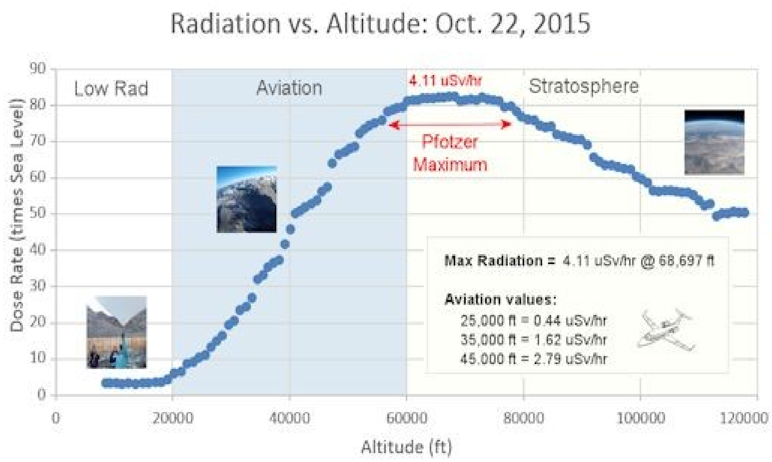


As indicated in previous UCOM reports, radiation (from cosmic rays) measurements are being recorded on regular flights of space-weather balloons. Approximately once a week, the students of *Earth to Sky Calculus* fly space weather balloons into the stratosphere over California, the data from which are presented on *Spaceweather.com* and elsewhere (more). These balloons are equipped with radiation sensors that detect cosmic rays, a form of space weather.

Cosmic rays can seed clouds (CERN, 2018), trigger lightning (Moskvitch, 2013), and penetrate commercial airplanes (Phillips, 2018). The measurements show that a person flying back and forth across the continental U.S., just once, can absorb as much ionizing radiation as 2 to 5 dental X-rays. As a guide, Figure 11 is the plot neutron flux from the October 22, 2015 flight. The plot below shows the data recorded for increasing altitude vs. radiation dose rate during the balloon flight, which reaches a maximum altitude of 120,000 feet above sea level. Figure 8 also shows the aviation range of radiation exposure.

Figure 8

(**[Spaceweather.com]**)



Radiation levels peak at the entrance to the stratosphere in a broad region called the "Pfotzer Maximum." This peak is named after physicist George Pfotzer who discovered it using balloons and Geiger tubes in the 1930s. Radiation levels there are more than 80 times those at sea level and then decreases to 50 times. The reason for this decrease is likely related to the differing position of the Earth's geomagnetic field over California, New Hampshire, Oregon, and now Kansas, see Figures 9 through 15:

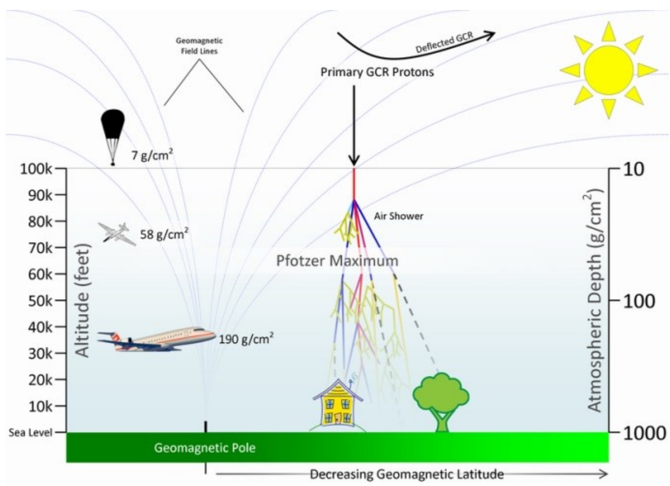


Figure 9

Location of the Pfotzer Maximum Radiation

(**[Spaceweather.com]**)

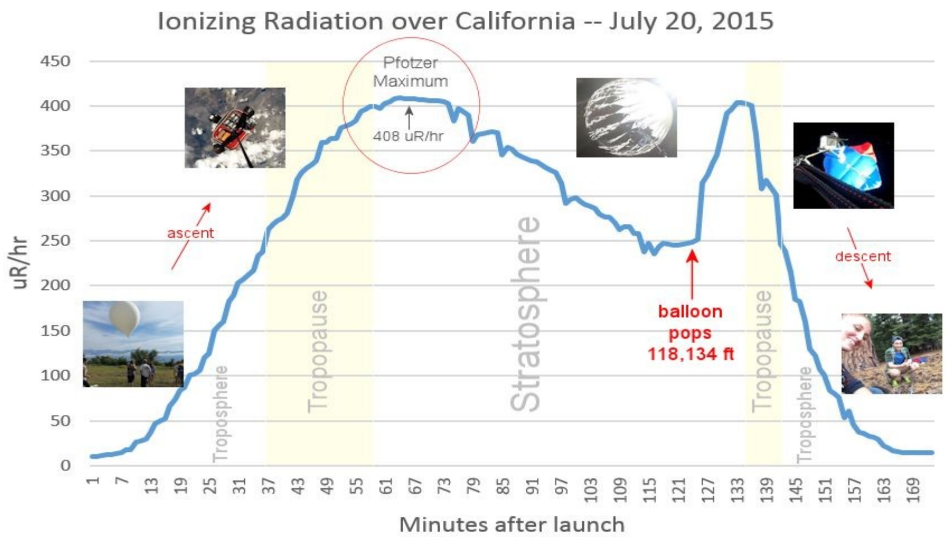


Figure 10
Activities During a Balloon Launch
(Spaceweather.com)

Figure 11 also includes radiation reporting as gamma rays and neutrons.

Figure 11

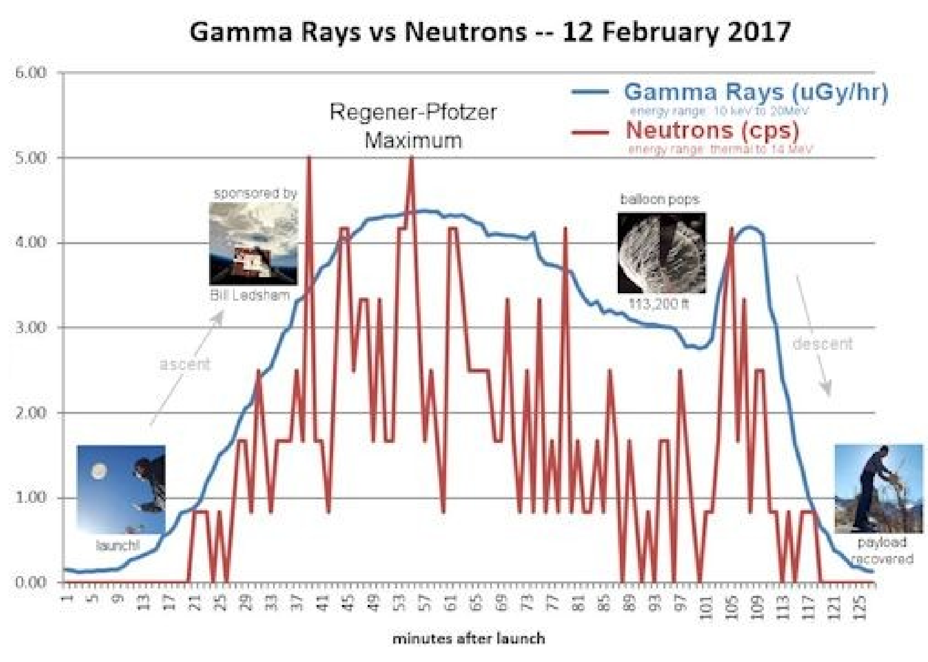


Figure 12
Difference in Maximum Radiation
(Spaceweather.com)

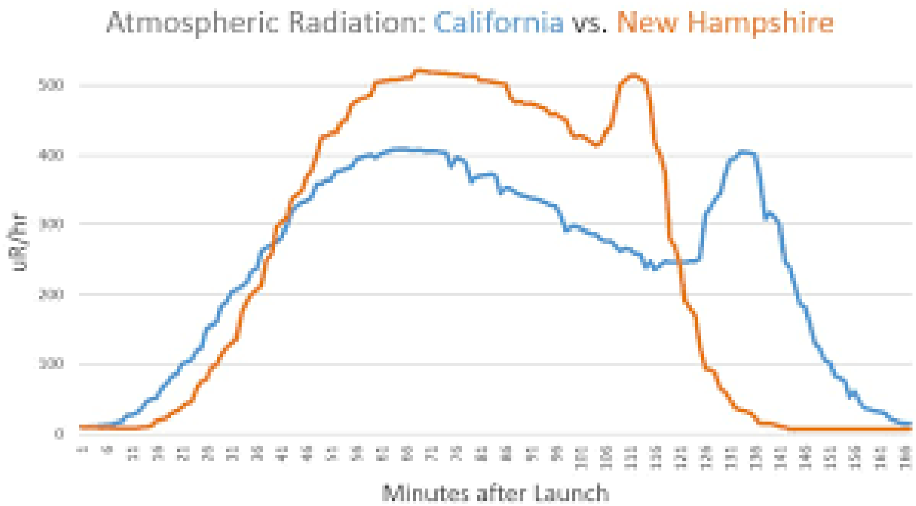
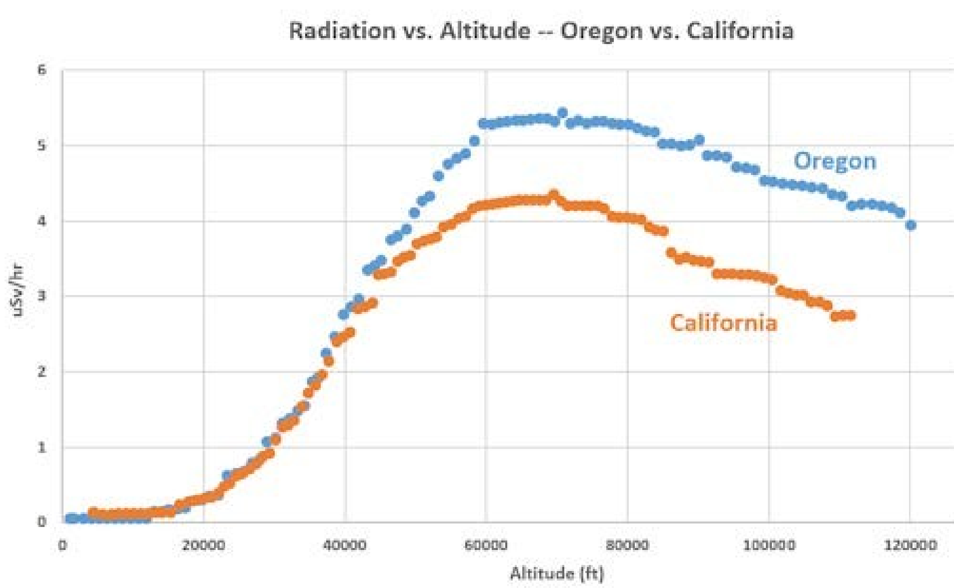


Figure 13
Difference in Maximum Radiation



(Spaceweather.com)

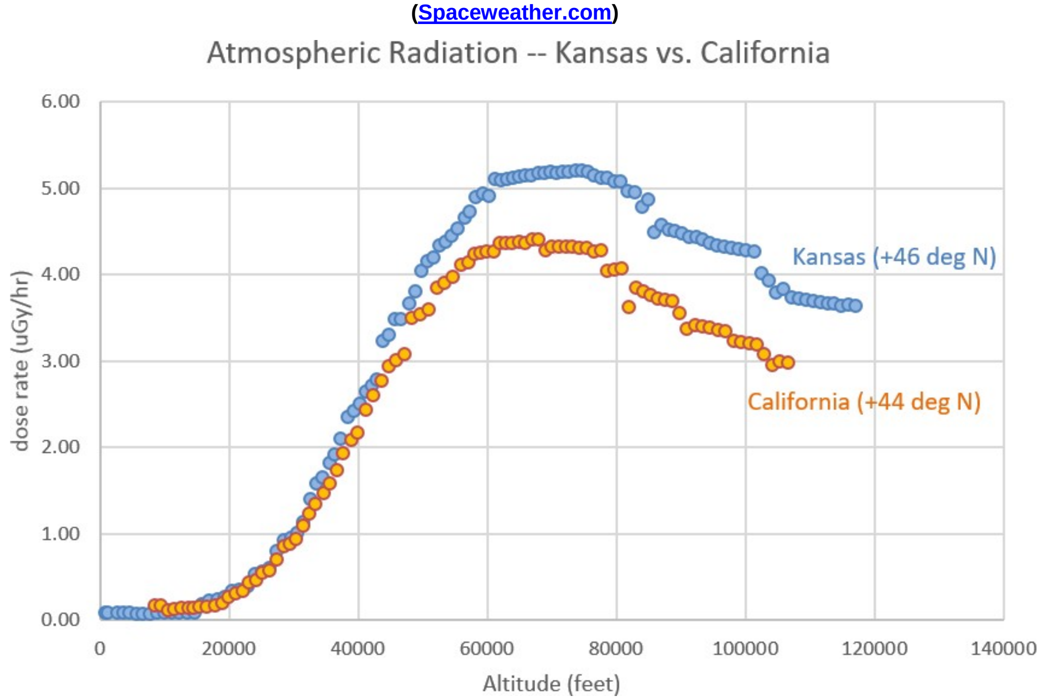
From ground level to 40,000 feet, the two curves are similar. In terms of radiation, California and Oregon are much the same at altitudes where planes fly. Above 40,000 feet, however, the curves diverge. Peak radiation levels detected in the stratosphere over Oregon were more than 25% higher than California. The reason for this difference is, again, likely related to the Earth's magnetic field.

The students of the Earth to Sky Calculus have found something somewhat surprising in the November, 2016 balloon reporting data (more). X-ray and gamma radiation in the atmosphere over Kansas is stronger than expected. Figure 14 compares dose rates vs. altitude for Kansas and their regular launch site in central California. Although the two sites are at nearly the same magnetic latitude, their radiation levels are quite different, although similar to the Oregon data in Figure 16.

The Pfotzer Maximum (PM) extends from about 55,000 feet to 75,000 feet in altitude and is monitored to evaluate its response to solar storms. Most airplanes fly below it; satellites orbit high above it. Energy releases during large thunderstorms that recently have been identified are known as Jets, Sprites and Elves appear to be in the middle and above the Pfotzer Maximum zone but they also could contribute energy to the Earth's geomagnetic system in some way (see Figure 15).

But note in Figure 9 that the bottom of the Pfotzer Maximum is near 60,000 ft. This indicates that some high-flying aircraft are not far from the zone of maximum radiation (PM). Indeed, according to the 2017 measurements, a plane flying at 45,000 feet is exposed to 2.79 uSv/hr. At that rate, a passenger would absorb about one dental X-ray's worth of radiation in about five hours. For context of such radiation; see Radiation Dose Chart (Munroe, 2014).

Figure 14
Difference in Maximum Radiation
(Spaceweather.com)



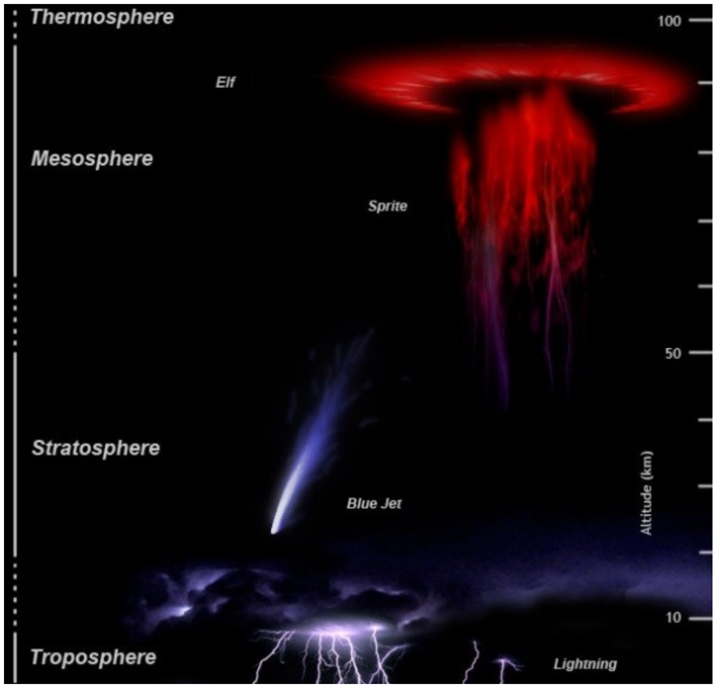


Figure 15

Sprites and Jet "Lightning" above Large Thunderstorms

(HAARP)(Red Sprites)

The radiation sensors onboard the helium balloons detect X-rays and gamma-rays in the energy range 10 keV to 20 MeV. As indicated, these energies span the range of medical X-ray machines and airport security scanners (see Wikipedia, 2018). High levels of ionizing radiation are dangerous to human health, but the levels discussed in this section are not, except for the altitude range of the PM. More research on the impact at these altitudes will be forthcoming in the near future as humans plan to spend more time passing through these altitudes on their way to orbital stations and beyond.

Such research is available by NASA showing that there is no peak in the dose equivalent rate at the Pfotzer-Regener maximum as previously inferred. Instead, the dose equivalent rate keeps increasing with altitude as the influence of dose from primary cosmic rays becomes increasingly important. This result has implications for high altitude aviation, space tourism and, owing to its thinner atmosphere, the surface radiation environment on Mars (Hands, et al., 2016).

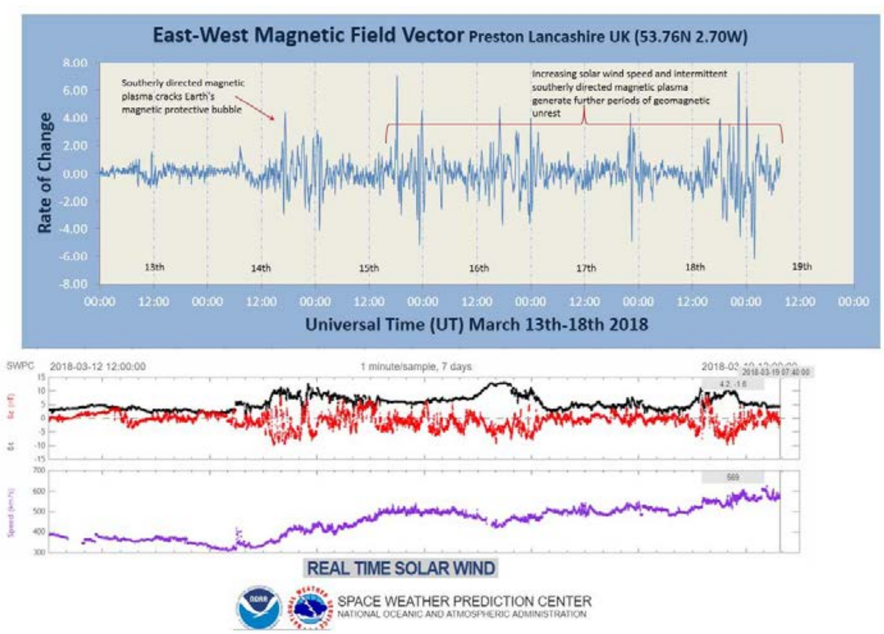
Recent Flux in Magnetic Field

Recently, magnetometers around the globe are registering geomagnetic unrest as Earth continues to feel the effects of a recent stream of fast flowing solar wind emanating from a large coronal mass ejection from an opening in the Sun's atmosphere (NOAA/SWPC, 2018). However, it's not only the speed of the solar wind that is important, it is also the direction of the magnetic field embedded in the plasma that determines the severity of the geomagnetic response by Earth, as illustrated with reference to the NOAA data accompanying Green's magnetometer chart (see Figure 16).

Much of the unrest correlates with negative Bz, when the approaching field turns south (Green, 2018). The Bz parameter represents the z–component of the sun's magnetic field. When Bz goes negative, the solar wind strongly couples to the Earth's magnetosphere. The Bz component allows transfer of significant amounts of energy. The more negative Bz, the more energy can be transferred, resulting in more geomagnetic activity. Related parameters involved are the density and the solar-wind velocity; these determine just how much energy is transferred when Bz is negative.

Because the role of the changing magnetic field around the Earth centers mostly on its ability to deflect the solar wind and solar mass ejections, the impact of the anticipated magnetic pole reversals on humans and wildlife in general are unknown except that our vulnerability to rising radiation will be increased (Dovey, 2015).

Figure 16



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