LPPFusion Report
September 12, 2019

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Sen. Pennachio Introduces NJ Fusion Energy Bills

Sen. Joe Pennachio (R-26) introduced into the NJ State Senate on Aug. 26 three bills to promote fusion energy research. The first bill, the Fusion Technology Industry Promotion Act, S4074, would mandate the NJ Economic Development Authority to invest in fusion technology development companies in NJ, matching dollar for dollar private investments in the companies. This was an idea raised by LPPFusion's President Eric J. Lerner at the Fusion Symposium in May organized by Sen. Pennachio's office. A second bill, S4073, would make fusion energy companies eligible for any state renewable energy or emerging technologies economic incentive programs. The third bill, S4075, would establish the NJ Fusion Technology Industry Commission which would oversee the fusion energy program for the state of NJ. In addition, Sen. Pennachio introduced a resolution, SR-146, urging the US Congress to increase funding for fusion energy research.

"It's wholly apparent that some prudent moves by the State to support this industry in its infancy could yield massive dividends for our residents and New Jersey's future" Sen. Pennachio said in a press release. "Just as California has its Silicon Valley, New Jersey could have its Fusion Epicenter if we play our cards right."

"Fusion is one of the world's most promising sources of energy, with the potential to supply our world's growing electricity needs without further polluting the atmosphere or producing long-term radioactive waste," Pennacchio added. "This is something that New Jersey and the world desperately need."

We at LPPFusion believe that the introduction of these bills into the NJ Senate is a great step forward. We hope that the Legislature and Governor Murphy will rapidly enact this legislation, which can serve as a model for fusion development in other states. **We ask everyone to please send emails to Sen. Pennachio at SenPennacchio@njleg.org expressing support for these bills. Of course, if you live in NJ, or especially in the 26th Legislative district, mention that. But emails from all over are helpful.**

Tracking Down FF-2B's Problematic Oscillations

LPPFusion's research team continued to track down the causes of the asymmetric *gas-to-plasma breakdown* (start of the electrical current flow) and the associated, problematic, early current oscillations in FF-2B's pulses. We've made progress in isolating the causes of these early oscillations. This is now the main focus of our research and it will probably take a while to complete a solution. Getting a symmetrical breakdown at the start of the pulse is a necessary step to getting the higher densities and fusion yields that will result from a strong compression at the end of the pulse. Thus, these early oscillations are preventing the expected higher fusion yields.

Experiments in early August showed that the oscillations persisted even when we used nitrogen rather than neon as the mixing gas with our deuterium fuel. Nitrogen allowed a stronger preionization current to smooth the way for the main current, but we still did not get a swift, even breakdown. Instead the pulses got off to a slow and unsteady start.

LPPFusion Chief Scientist Eric Lerner noticed that the oscillations in current from different shots looked almost identical (see Figure 1.) This was a big clue that the oscillations were caused by something unchanging in the device, not a random process. Was this some asymmetry in the device that we could fix?

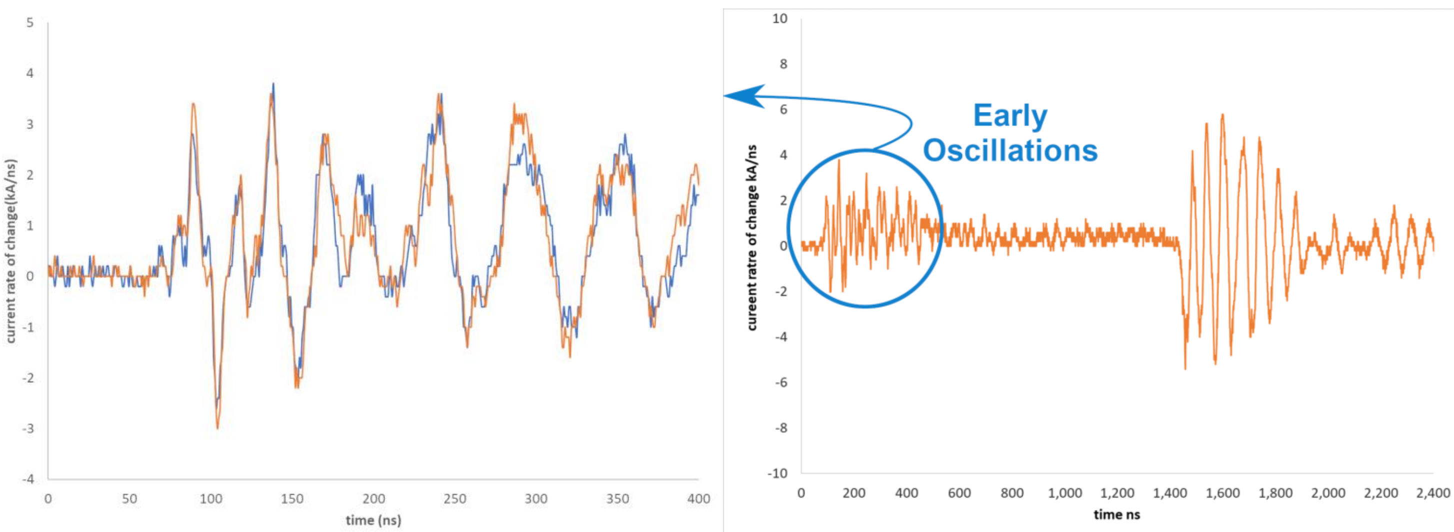


Figure 1. (a, left) The Main Rogowski Coil (MRC) signals for shot 1 (blue) and shot 2 (orange) of August 9, 2019 measuring the rate of change of the current, are nearly identical in the first 400 ns at the start of the pulse. This shows that whatever is causing these big oscillations is not random. (b, right) The MRC signal for the whole of shot 5, July 9 shows the early oscillations dying down, but then a poor pinch at 1500 ns, indicated by a relatively small downward spike in the signal. A small spike (a good one would go down to -10 kA/ns) indicates poor compression and low fusion yield, confirmed by neutron measurements.

To take a closer look we decided to take photos of the gas-to-plasma breakdown from a window below the electrodes, so we could look for a cause of asymmetry in the current sheath formation. The only way we could do this with an ordinary camera (instead of our complex ICCD camera) was by using a trigger pulse instead of the main, mega-amp current pulse. The trigger pulse is used to trigger the switches when the capacitors are charged. But even if the capacitors are uncharged, the trigger pulse by itself can create a breakdown very similar to the start of the main current pulse. The advantage is that the trigger pulse is too small to damage a camera the way the main pulse could by excessive light, X-rays and radio waves.

The photos we obtained in this way (Fig. 2) show the anomalous speck formations on the anode, near the insulator (presumably bits of melted beryllium) were indeed causing an uneven, asymmetric gas-to-plasma breakdown. To remove these pesky specks without opening the chamber, we fired the main bank several times, using a heavy mix of nitrogen with the deuterium. This, we calculated, would cause the current to linger longer on the bright-white specks, vaporizing them. After each shot, we checked with the trigger photos (Fig. 2) to see if the specks were gone. After four shots, we saw the specks were first swept down the anode and then away altogether. This is an important step, as it shows we can clean up these specks if they form again without the time-consuming opening of the chamber.

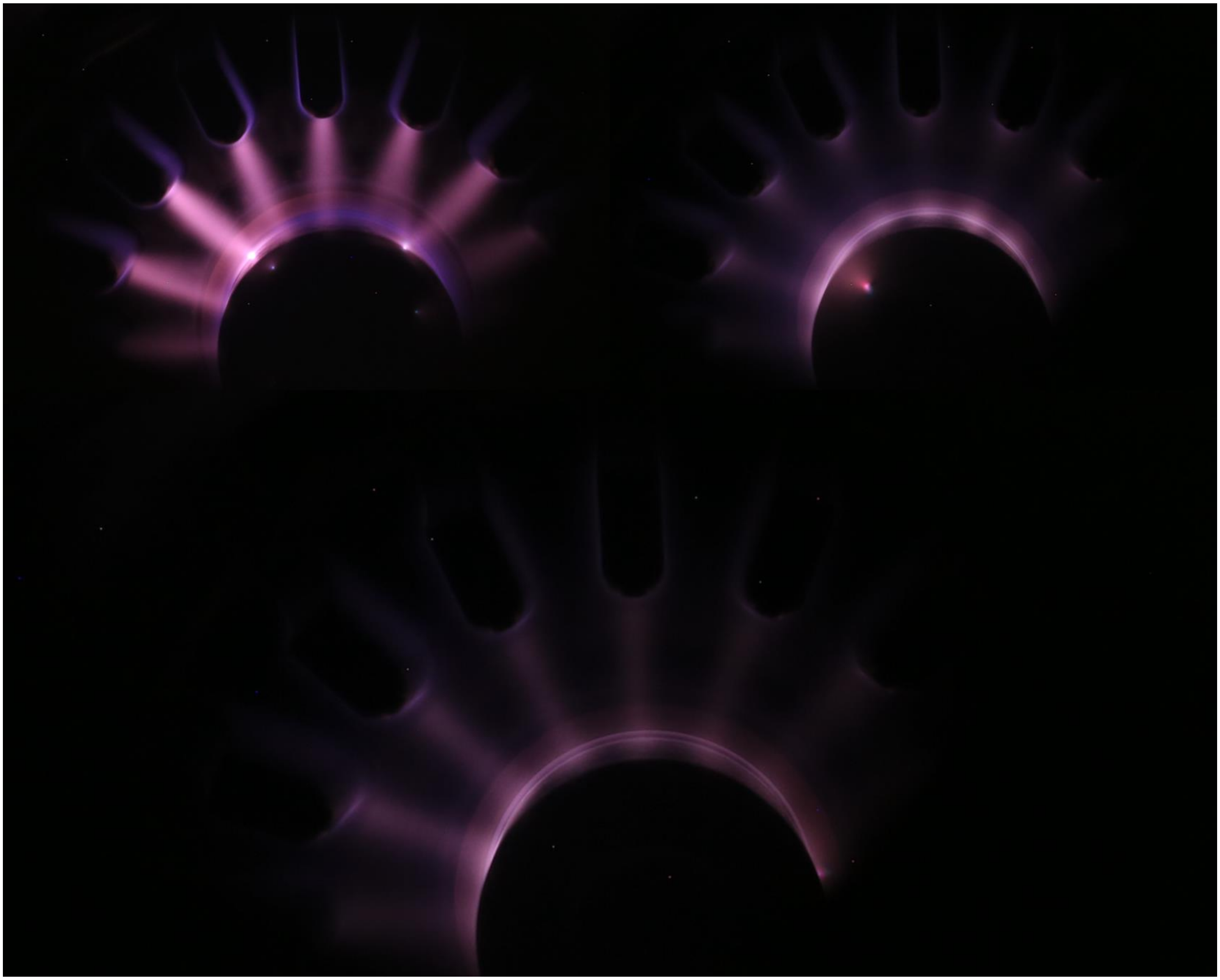


Figure 2. Trigger photo images taken from the window below the electrodes show the start of a pulse with the trigger as the source of the current. The images were taken after "cleaning" shots with the main capacitor bank. After shot 2 on Aug. 27 (upper left) current is concentrated on two specks (bright spots) sitting on the anode near the end of the insulator (brighter ring). After shot 4 (upper right) the spots near the insulator disappeared, but one spot appeared near the end of the anode (in dark area). After shot 5 (bottom) the spots had disappeared and the breakdown appeared symmetric in these long-exposure photos. The dark outer objects touching the purple rays are the cathode vanes.

However, the early current oscillations only decreased by about 25%, so it turned out that the specks were not the biggest problem. We then looked at the frequency spectra of the oscillations (Fig. 3). These oscillations spectra show clearly that the oscillation at 16 MHz was larger in the 2019 shots (orange line) than in the shots in previous years (blue line, 2016). We know that these 16 MHz oscillations are caused by some current sloshing back and forth between the switches and the electrodes. But the spectra also showed a relatively narrow peak at 40 MHz. Such a narrow peak—like a pure note in music—is probably produced by some resonance of the current in the external circuit. Once we find out where this resonance is, we should be able to fix it by either eliminating the resonance, or increasing the energy absorption (*damping*) of the circuit or both. A well-damped circuit will not oscillate at all.

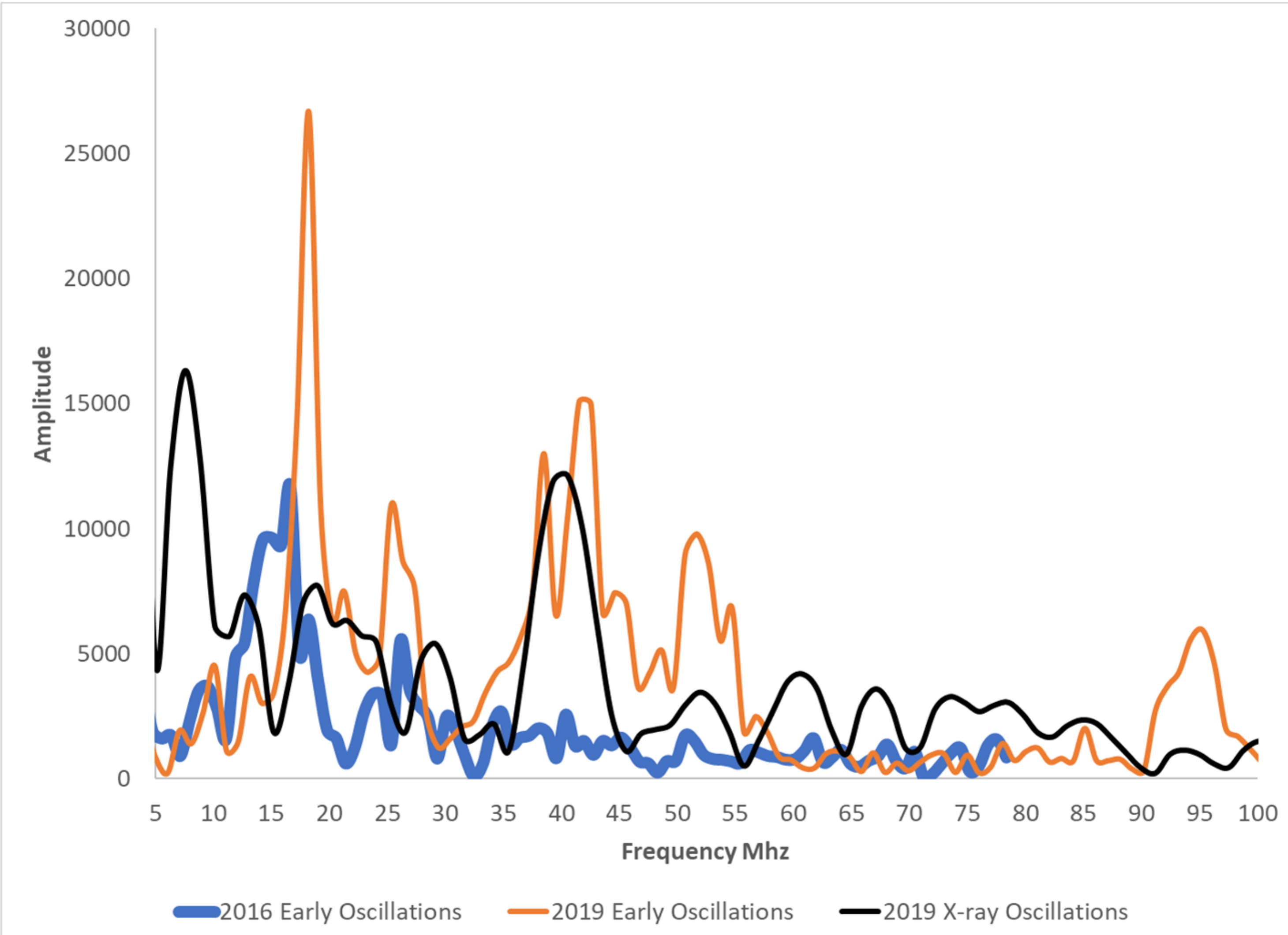


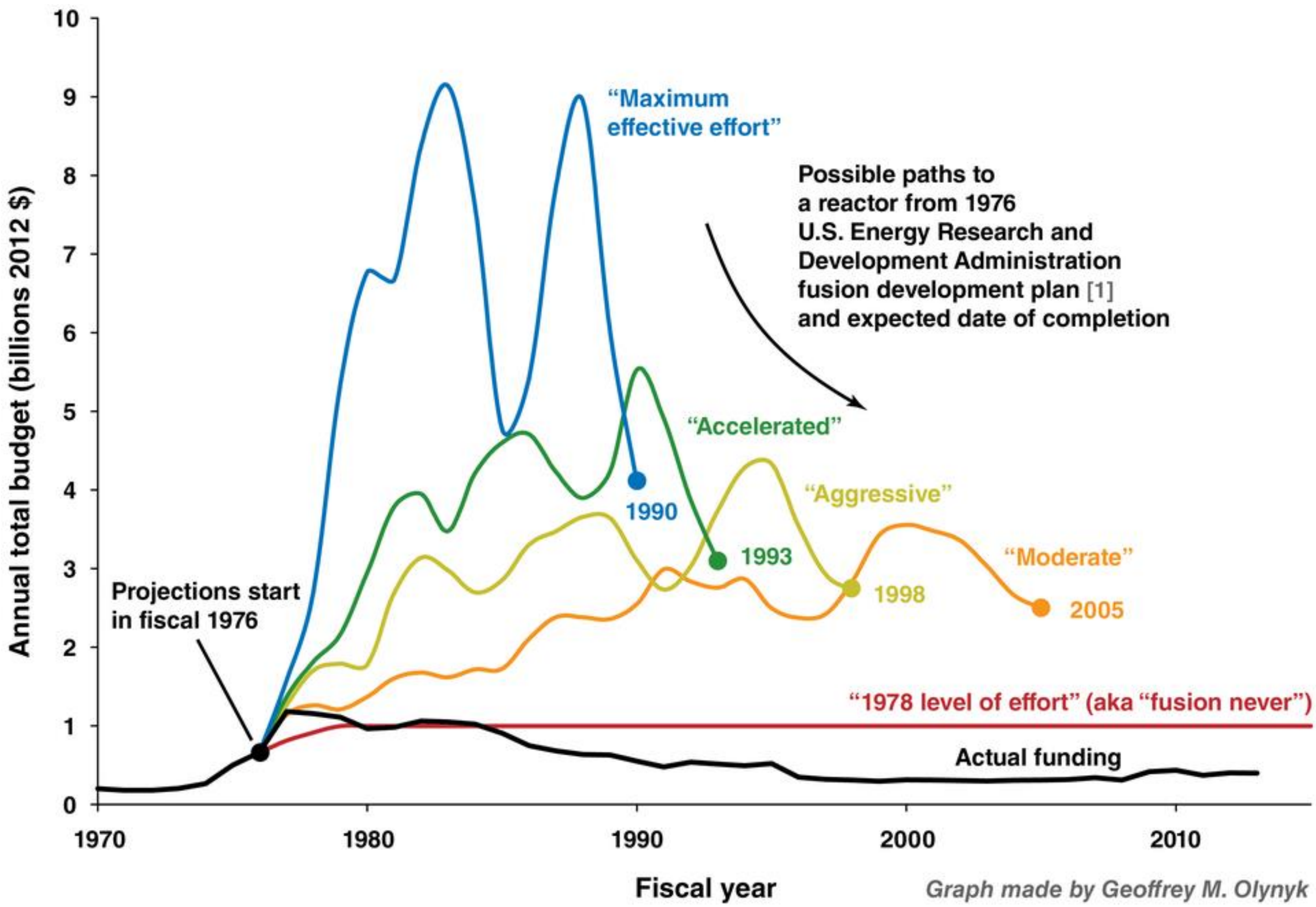
Figure 3. Frequency spectra of the early current oscillations shows that in a typical recent shot (July 9, shot 5, orange line) the peak at the 40 MHz frequency mark also appears in the oscillations of X-ray power during the pinch of the same July 9 shot (black line). This indicates that at least the oscillations at this frequency have an effect on the entire current pulse. By comparison, in a typical shot from 2016 (June 6, shot 5, blue line) the 40 MHz peak is entirely absent and the peaks at 16 MHz and 26 MHz are much smaller. The tall, narrow spikes in the spectra of the 2019 shots indicate resonances in the external circuit of FF-2B. We are researching this issue. The 7 MHz peak in the X-ray plot just shows the width of the X-ray pulse and is not of concern.

While we are hunting down the source of the early oscillations, we are finalizing our designs for the new switches that will increase current in the device. We are also installing the remote controls of the trigger and charging circuits that will allow us to experiment with our proton-boron fuel.

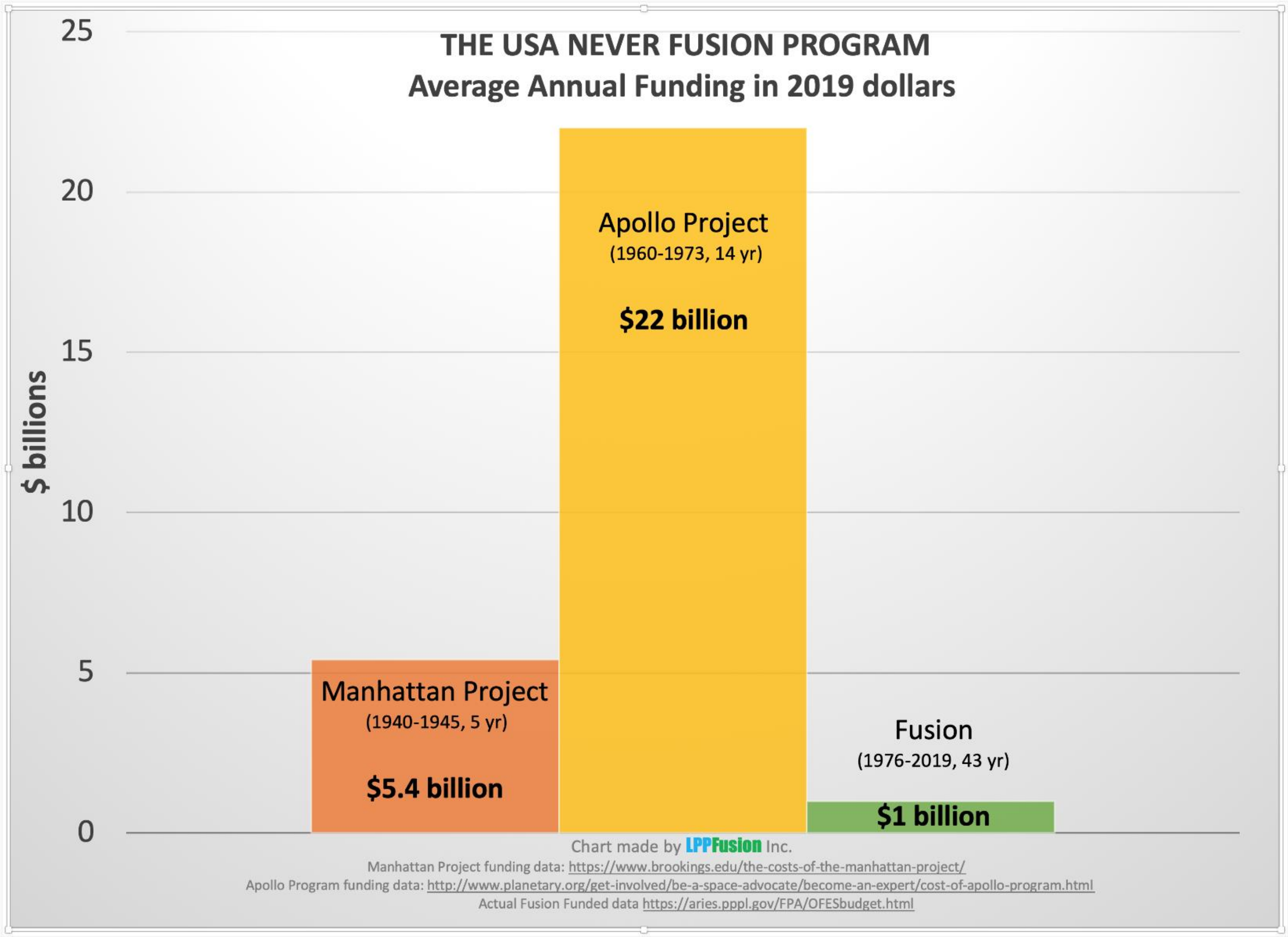
Subscription Drive Starts, We Need to Sell More Bikes!

The reason your home is not powered by fusion energy today is that the 1976 Fusion Crash Program was never implemented since it was never funded—not even at the minimum level required.

The US government spent, in 2019 dollars, $5.4 billion a year on the Manhattan Project, $22 billion a year on the Apollo Program, and only $1 billion a year on Fusion R&D for the past 40 years. LPPFusion wants less than $0.001 billion a year to research the fastest and most promising route to fusion.



[1] U.S. Energy Research and Development Administration, 1976. "Fusion power by magnetic confinement: Program plan" ERDA report ERDA-76/110. Also published as S.O. Dean (1998), *J. Fus. Energy* **17**(4), 263–287, doi:10.1023/A:1021815909065



Last month, we started building our "bicycle store"—a source of steady income from subscribers, as the Wright Brothers used their actual bike store to finance their research. This will, in part, supplement unpredictable private investments until we get our X-Scan tech off the ground. So far, we have subscriptions from 24 generous fusion supporters, for a total of $400 a month. Thank you very much, supporters! Our goal is $30,000 a month.

We want to spend the time either doing the research or telling you all about it on Facebook and Twitter, so if you want faster progress in the lab, and more frequent updates **subscribe now** and help us get more followers and subscribers!

Fusion Poem and New Song Contest

A while back we asked focus fusion fans to send in songs and poetry about our project. We got some submissions, but well, we were really, really busy, and somehow, we did not get around to announcing the winner of our contest. Whoops—very sorry! But better late than never so here is the winner, a limerick by Gregory N. Ranky.

There once was a researcher for fusion,
Who was told his plans were a delusion.
But with tight plasma arcs,
He ignored those remarks,
And achieved a worldwide solution.

Congratulations, Gregory!

To make up for our lapse in memory we are announcing a new contest and we will be sure to announce the winner on time! This contest, to conclude Nov. 1, is a song parody contest. A song parody takes a popular song (from any epoch) and alters the lyrics for a new purpose—in this case something relevant to fusion.

Send your submission to fusionfan@lppfusion.com. Use "Contest" as the subject of the e-mail so we can easily find it.