[SQUEAKING]

[RUSTLING]

[CLICKING]

DAVID KAISER: OK. So for today, it's kind of fortuitous given, again, all the sources of let's just say swirling uncertainty in the wider world. Maybe it's a lucky timing that the lecture for today is on maybe a little bit lighter material. So we can wrap up our unit on physics, and the state, and the bomb, but ending in a very different place than some of the pretty heavy material we were looking at only a few class sessions ago with Nazis, and nuclear weapons, and wartime, and huge Cold War drama after the war.

So today, we're going to be talking about a longer tale, some of the unanticipated shifts in the field coming about a quarter century after the end of the Second World War, when this Cold War system that we looked at now for a few classes in a row was really going through some pretty significant changes. And that will set us up then to launch in, in earnest, on next week, for a week from today, the last main section for the course, where we start looking at post-war developments in high energy physics, astrophysics, and cosmology.

So for today, we're going to wrap up this middle unit for the class on, as I say, a bit of a, I think, more fun or more lighthearted set of themes, perfect for the timing. So what we're going to be talking about is under the general topic of counterculture and physics. And for this talk, for this lecture I have some more colorful than average sets of slides.

The material is drawn mostly from a book I wrote a few years ago called*How the Hippies Saved Physics,* and then worked on with some friends and colleagues expanding upon that in this book called *Groovy Science.* And one of the readings for today was by a different colleague of mine, Cyrus Mody from this more recent collection.

And so today, as usual, we have three main topics, three main sections for the discussion. We're going to look at some of the shifting topics. What counted as relevant topics to study by whom, and where, and to what ends in physics? And then how was this newer work being supported?

So we've seen a lot, especially in the previous class session, on some of these quintessential Cold War formats for supporting research in the physical sciences-- huge emphasis on military funding, on a huge expansion of the university system for training young physicists. Today, we're going to look at some of the ways that system came in for a readjustment during the 1970s-- late '60s, early '70s.

And then lastly, for the third part, we're going to be looking at what were some of the ideas that wound up having a longer than expected legacy-- some of them reaching really literally right up to today-- that came from this moment of real uncertainty in the way that some people were approaching the study of physics and particularly questions within it. So that's our path for today.

So I began working on this project that became that book that I mentioned by trying to understand how we've all come to live in a world in which really exciting, very significant new topics were bubbling up all over the place in a field that's now often called quantum information science or QIS.

And that includes topics you probably have heard about-- maybe you've been taking courses in by now-- topics like quantum encryption, quantum computing, and then related areas, and basically putting some of the strange features of quantum theory that we have looked at together, even if briefly over this semester-- putting those to work in real world engineering scenarios and not only thinking about strange features of quantum theory in the abstract.

And some of the most dramatic examples of that are already being rolled out in real world implementations, not only on chalkboards or planning. I think the furthest ahead among this collection of topics is quantum encryption, or quantum cryptography. Already now 16 years ago-- it's quite a long way-- there were already these real world beta tests being conducted in many parts of the world.

So I have these headlines here, press releases. One of them, from Vienna in April 2004, was the first successful use of quantum encryption to conduct basically a wire transfer, a money transfer in the city of Vienna. And what they did is both the mayor of the city and one of the leading banks collaborated with local physicists, led by Anton Zeilinger and his group, to use this new form of encryption to protect the electronic message going between City Hall and the bank to wire some money from one to the other.

And the signal was encrypted not in the way most of our signals even to this day are encrypted, by using fancy algorithms to manipulate very large numbers that are much easier to multiply than to factorize. So our ordinary computers take a long time to break these secret codes.

Instead, this the quantum encryption, or quantum cryptography, exploits features of quantum theory-- of quantum theory itself, including, most principally, things like quantum entanglement to create signals that should be protected by the very laws of physics. These are signals that aren't protected by the practicalities of current day computing algorithms, but actually by very fundamental laws like quantum entanglement, like the uncertainty principle, and so on.

And this was demonstrated in a real world test with fiber optic cables strung through the sewers, the underground sewers of Vienna. I always joke that's why you actually need graduate students, to get under the ground and sling this stuff through the muck. And it was a highly successful test.

Right around the same time, a few months later, there was a similar demonstration of the same basic kind of technology in Geneva, in Switzerland in this case, to protect electronic voting. So there were regional or cantonal elections throughout Switzerland.

And to transmit the results of those local elections, again, government officials worked closely with a different team of quantum physicists, Nicolas Gisin and his group, to demonstrate that the electronic signal could be transmitted successfully and encrypted with encryption protected by the very laws of physics. So very exciting. These are already now quite old examples.

What I wanted to figure out, when I was launching into this project, is how do we get into a world like that, where bankers and politicians entrust their most sensitive information to quantum physicists, where quantum physicists could be harnessing some what appear to be basic laws of nature in these increasingly practical engineering contexts.

And so as I dug in a bit more, it took me back to this plot that we looked at together in the previous class session, how that new field-- this now flourishing multi-billion-dollar field, which is being pursued in earnest by physicists and engineers in many, many parts of the world, both in universities, and in private sectors, and in government labs-- to understand how we got there we collectively got there.

We come back to this plot with this really dramatic series of changes coming out of the Second World War, a second immediate Cold War response around the time of the launch of Sputnik by the Soviet Union, and then this really precipitous collapse. And we looked a little bit at this collapse, the downward turn in the previous class as well, this constellation of forces that really shook what had come to seem like a very straightforward Cold War response in the years after the Second World War.

And we captured that in these really extraordinary job placement statistics so that by the early 1970s-- pardon me, early 1970s, there were 20 times more young physicists applying for jobs than jobs available. If you look at this entry from 1971, the gap had widened to just an extraordinary degree.

And that counts not just academic positions, but positions advertised for PhD physicists in industrial labs and in government labs as well, just a complete collapse of the kind of job market or employment path for young physicists in this country, very similar trends in many other parts of the world.

And so last time we saw this is like a speculative bubble. It's like a stock market crash. You have this remarkably rapid exponential rise that is self-evidently not sustainable, that can't keep rising forever. And there's an equally sudden, equally dramatic adjustment. Rather than noodling around some equilibrium, you have this unstable rise and fall.

And it turns out that transition in the field, in the realities of trying to become a young physicist in the United States and in many other parts of the world-- that really is critical to help us understand what would become this now flourishing field of quantum information science.

And so to dig in, to try to understand what was it like to try to become a young physicist during that moment of pretty dramatic shifts in the expectations for career paths or job opportunities in the field-- to make sense of those shifts, I wound up looking at this group that called themselves the Fundamental Fysiks Group.

I always joke that, then as now, physicists don't know how to spell. They spelled physics with an F. They're actually just being very playful. It was a group founded in Berkeley, California in 1975. It had roughly 10 core members. And then they would hold weekly informal discussion sessions, some of which would swell to have 40 or 50 members for a given session. Other times, it would be more of the 10 to 12 or 15 core members.

The people who founded the group, who really kept it going for several years throughout the '70s, had almost all of them had earned their PhDs in physics already. Some were still grad students at the time. But they were being trained in some of the most elite physics programs in the country. They'd earned PhDs from places like Columbia, and Stanford, and UCLA, and University of Illinois, Urbana-Champaign, and so on.

They were exceptionally well-trained. They had entered the field during that post-Sputnik boom when fellowships were plentiful, when it looked like the sky was the limit, during that extraordinary ramp up in the field that we did look at again a bit more directly at last time, when the enrollments were really booming.

They entered their graduate study in the years after Sputnik. And then their main miscalculation was completing their PhDs just when the bottom fell out, which, of course, no one really saw coming. So they were entering very elite programs, doing very well, publishing articles in mainstream journals. And then unfortunately for them, by the time they were going on the job market, there were hardly any jobs available. So they were caught right up in that boom and bust cycle.

One of the founders is this person here, Elizabeth Rauscher. She was at the time still pursuing her PhD at Berkeley. This is a photograph of her in the control room for one of those huge particle accelerators. I think it was the Bevatron, one of the huge accelerators at the laboratory.

So folks like Elizabeth, and like the others who joined her in forming this group, they were trained in that era of what we looked at last time, the so-called shut up and calculate, where the emphasis had phonon away very abruptly from the philosophical, or interpretive, or open-ended investigation of, say, the mysteries of quantum theory, the meaning of quantum theory.

And instead, they were taught during this period of exponential growth in the enrollments and a kind of narrowing of what counted as pedagogically of ways to deal with quantum theory. They were taught how to calculate, but not really to entertain these bigger questions of the sort that kept people up the generation or two before, the kinds of debates about Schrodinger's cat, about superposition, about entanglement or EPR.

Those things that had really bothered people like Albert Einstein, and Niels Bohr, and the young Werner Heisenberg, for this generation trained after the war, those questions were deemed really just on the sideline and really not relevant. We saw that shift in the pedagogic materials. We talked a bit about that last time.

So this group that wound up forming the Fundamental Fysiks group, they had entered the field because they were really enchanted by these big what does it all mean questions. And yet, in their formal training during that period of the exponential growth of enrollments, that was really not what their training was focusing them on.

And so Elizabeth said, many years later when I wound up talking with her about it, what was her motivation for joining this-- for founding this informal discussion group? She said, it would be easy to learn about all this material, which was not being covered in the textbooks or problem sets by that time, if we got together for informal discussions and lectures. And that's what they set out to do.

So Elizabeth was still a full-time grad student. She was entitled to reserve space, to just reserve a room on Friday afternoons at the Lawrence Berkeley Laboratory, where she was doing a bunch of her research. And so she basically signed up a room that was available. And she and her friends began putting out flyers and saying, open to anyone, come, let's discuss the big questions in quantum theory, and modern physics more generally, Friday afternoons.

And it began in 1975. And it ran virtually every week for about four years, a long stretch of time. We have records of the topics that they talked about informally virtually every week. We have pretty good paperwork from that time. And we can see then that the one topic that totally dominated their discussions was something we looked at together in this class a few sessions ago, quantum entanglement, as crystallized by that work by John Bell.

So you may remember, Bell published this work that we now call Bell's theorem, related to Bell's inequality. We had some optional lecture notes on this. We had we looked a bit at this some class sessions ago. Bell's really famous paper was published in 1964. This group was getting together just a little over a decade after that.

So they were really, really just mesmerized by Bell's inequality and what Einstein had called, as we saw, spooky action at a distance. As a cartoon reminder, entanglement concerns systems where there's some source that emits pairs of particles. Their properties are correlated because of the nature of how the pair of particles were produced.

And then we can subject each particle separately to measurement. We can choose to measure various properties of one particle or the other. And then as Bell demonstrated they must-- according to quantum theory, the outcomes of those measurements are more strongly correlated than anything like an Einstein-like explanation would ever allow or could ever account for.

So you could really say that entanglement truly is the case in which the whole system-- the system particles A plus B-- is literally more-- in fact, it's infinitely more than the sum of its parts. Knowing everything we could about this system A and B is completely insufficient to tell us anything definite about particle A on its own and vice versa.

So there's this really strange quintessentially quantum mechanical behavior of these entangled systems. And the Fundamental Fysiks Group thought this was just extraordinary and the kind of thing they wanted to spend Friday afternoons talking about together because it was not being emphasized in their main coursework, even in grad school.

So today, Bell's theorem, that 1964 article, is literally renowned. Renowned is a technical term to high-energy physicists. Some of you might know this. Physicists relentlessly count our citations. My wife is a psychologist. She has all kinds of theories of why we're so obsessed with this form of measurement.

Anyway, for a long, long time, it's been routine to count up the number of citations in the scientific literature that a given article receives and use that, fairly or unfairly, appropriately or otherwise, as a kind of proxy for influence or importance. There's all kinds of caveats to be had there. People are a bit more sophisticated now about that citation counting than we used to be. Nonetheless, we have this machinery for counting up citations.

So if you do that exercise, then today, that 1964 article by John Bell is among the most cited articles in all of physics in the history of the universe-- not just in 20th century physics, not just in quantum physics. Take any subfield and go back to the time of Isaac Newton or Aristotle if you'd like, and it's very, very hard to find a single article that has been cited more often in the scientific literature than Bell's 1964 article.

It is literally renowned, which is the highest category, the label for the most cited papers when physicists do this kind of chopping up exercise of citation counts. So this is really, really today recognized as an extraordinarily well-known and influential article. And yet, it took a long time to get there.

So if we look at the citation counts to Bell's 1964 paper over the first 15 or so years after it was published-- not the half century or more since then, but in the first period of more than a decade, it was really, really not lighting the field on fire at all. It was published in 1964, very late in 1964. There were no other citations to it in that year. There were no citation to it in all of 1965 in the worldwide literature.

There was one citation to the article in 1966 that was actually a self-citation. It was a follow-up article by John Bell himself. We might take that one away. So it was really only in the mid-1970s, mid to late-1970s that we see anything like a kind of sustained attention, at least by this proxy measure, by citation counts, anything like any kind of sustained if still rather modest attention to a topic that today is considered literally renowned.

If you do a little more careful looking-- don't just count things, but see who is writing the articles that were doing that citing, who was actually engaging with Bell's theorem and quantum entanglement during this period-- it turns out that about almost 3/4 of all the articles that make up this blue area under the curve-- of all those that were written by physicists based in the US, which was already itself the largest fraction of these, 3/4 of that US-based body of work that was citing Bell's theorem came from members of this very strange little ragtag study group called the Fundamental Fysiks Group, the group that was founded by Elizabeth Rauscher at Berkeley in '75.

So that helps us at least make sense of why citations aren't picking up around here. This is the period when that group itself was founded and reinforcing this topic as really interesting. Meanwhile, if you don't just look at the authorship but actually read the articles, which is kind of fun, you can see that actually the proportion rises to be almost 90%, about 86% of that US-based proportion here, if you include people who either wrote the articles or thanked members of that first group, the Fundamental Fysiks group, in the acknowledgments.

This group was really what we would call the early adopters, these people who mostly got their PhDs, graduated from graduate school, couldn't get a typical job in the field because of these larger scale shifts later in the Cold War. They met each week to talk about quantum entanglement. And they were just mesmerized by Bell's inequality. And they were really helping to get at least some sustained attention to this topic at a time when it was still otherwise quite marginal.

They weren't only talking about it. A core member of the group shown here, John Clauser in his lab at Berkeley-- at this point, he was a postdoc at the Berkeley Laboratory. And he and then graduate student Stuart Freedman conducted the world's first laboratory test of Bell's inequality. This was the first laboratory test to try to confirm or to check whether the measurements on these pairs of entangled particles really show this spooky correlation beyond what an Einstein-like theory could ever account for.

This was published in *Physical Review Letters* in 1972. The next year, Clauser was told by multiple department heads where he'd applied for jobs that he not only would not be hired, but that several department heads wrote in to say they didn't think this was actually real physics.

So he and Stuart Freedman had conducted the world's first laboratory test of Bell's inequality, found results squarely in keeping with the predictions from quantum theory, squarely in conflict with Einstein's own careful view about how the world should work. And he was told that this was literally not even proper physics. He actually never was offered an academic position, though that had been his ambition, certainly for that stage of his career.

So this work was really, really still marginal. And yet, this little study group, the Fundamental Fysiks Group, included people like Clauser who were at the world's cutting edge for trying to explore the topic experimentally. So it turns out this study group had some broad-ranging interests.

So the members, not all-- some members of the group some of the core founding members of the group were really curious about quantum theory and, it turns out, a wider range of topics. And for some members, the stew of curious topics bled together.

So some of the members of the group actually hoped they could use quantum mechanics, especially quantum entanglement or so-called nonlocality, to make sense of other strange features of the world. And they were especially interested in something called parapsychology or psi phenomena.

So it's very convenient. As we know, in quantum physics, we use the Greek letter psi to represent Schrodinger's wave function. And the field, or the pseudo-field of parapsychology, its own practitioners often referred to it as psi phenomena, the same letter.

So what's parapsychology? You might know it by other terms. It includes things like mind reading. Let's say alleged mind reading, or ESP, extrasensory perception, telepathy, precognition, which is a fancy word for saying having visions of the future like clairvoyance, remote viewing, a particular kind of telepathy we'll talk about in a moment-- again, alleged telepathy-- psychokinesis-- could you move matter with the power of your mind alone?

Pretty out there sounding stuff. So this is where the fact that this group was getting together in the San Francisco Bay area in the mid 1970s matters a great deal. These are hardly typical phenomena studied in academic settings today, though there are some exceptions. And yet, this group was kind of on the margins. And some members, not all, were especially eager to explore all kinds of questions that were marginal.

Bell's inequality was very marginal compared to mainstream physics at the time, as were some of these questions about basically mind reading or ESP. They were especially excited when this gentleman shown here, Uri Geller, came to visit the San Francisco area, again, in around 1972, '73, just before the group really started meeting more formally.

Geller was originally Israeli, from Tel Aviv. He had made an early career as a stage magician. He literally said, I am a magician. I can do sleight of hand tricks. And then somewhere along the way, he started proclaiming that he could actually perform not just clever sleight of hand, but actual ESP. He claimed he had paranormal abilities, not only exceptionally good kind of magic trick skills.

He was whisked to the United States, subjected to hours and hours of seemingly controlled scientific study at this place called the Stanford Research Institute, or SRI. SRI was, until that time, a defense-oriented laboratory affiliated with Stanford University, very much like Draper Lab or Lincoln Lab at MIT. The lab was funded, through the late '60s, almost exclusively by military contracts.

But as we saw, there was this collapse in the physics bubble right around 1970. And the Stanford Research Institute was spun off as its own independent institute separate from Stanford, in part over Vietnam War protests. And then they were under-capacity because, like most of physics, they were not getting the kind of grants that they had once done.

So some laser physicists, very well-trained laser physicists Harold Puthoff and Russell Targ, wondered if they could spend some of their free time studying basically things like ESP. They wound up doing hours and hours, dozens of hours of filmed seemingly laboratory control tests on Geller himself at the laboratory. They were able to publish their findings in journals like *Nature,* a peer reviewed journal among the most elite scientific journals on the planet.

Likewise in the proceedings of the IEEE for the electric engineers, they were finding what they considered scientifically sound, robust, statistically significant evidence that Geller seemed to have ESP-like abilities. Now, this wasn't uniformly accepted, as you might expect. There were some efforts at debate or rebuttal.

Among the most entertaining were actually done by a real magician named James Randy. He went by The Amazing Randy. In fact, he just passed away in his 90s or near age 100 just a few weeks ago. So James Randy would then find ways to give more conventional explanations based on his own quite extraordinary sleight of hand skill. He said, well, Geller might have been able to do this or that. But I could reproduce the same effects. And I'll tell you I don't have ESP. Randy would say, I just am a skilled magician. So this went on and on and on, a circus of back and forth.

The point is this was happening in the San Francisco area and getting a ton of attention in the newspapers, and magazines, and television. Geller went on to become enormously famous and well-known. And this was the earliest stages, literally right in the backyard for this Fundamental Fysiks Group.

Some members of the group were then hired at Stanford Research Institute, at the SRI, to serve as in-house consultants, to be house theorists to make sense of these and related studies in ESP, and to try to puzzle through, could these strange phenomena, like quantum entanglement, maybe make sense of or account for what seemed to be magical effects otherwise?

And so one core member of the Fundamental Fysiks Group named Jack Sarfatti began releasing these press releases downstream from Geller's original visit saying things like this top quote, "The ambiguity in the interpretation of quantum mechanics leaves ample room for the possibility of psychokinetic and telepathic effects."

Basically, Bell's inequalities start sounding like telepathy already. That's why Einstein thought it was so, so strange. He called it spooky. "If the events could remain correlated across arbitrary distance," so they began to argue, "maybe there's some correlation between a quantum particle that lodges in Geller's mind, or brain, and some correlated particle that lodges somewhere else. Is that at least consistent with this kind of action at a distance?"

Jack goes on to write a follow-up press release. "My personal professional judgment as a PhD physicist," which we now all have to reevaluate what that's good for-- "my professional judgment is that Uri Geller demonstrated genuine psychoenergetic ability.

Now, cast your minds back to mid-1970s San Francisco Bay Area or imagine it if you can. And if you have a bunch of PhD physicists working with seemingly a very upstanding scientific research institute finding what looked to be robust evidence of mind reading and ESP, that's going to be pretty exciting news.

So here's a picture of some of the core members of that Fundamental Fysiks Group. This one here in the saffron robe is Jack Sarfatti, who just gave those press releases I quoted from. Here is Saul-Paul Sirag. I would literally kill for that hair. Look at that. That is just fantastic. Nick Herbert and Fred Alan Wolf. So they were just clowning around. They were having a lot of fun mostly, because they were out of work.

Nick Herbert had finished his PhD in physics at Stanford and at this point was on welfare. He was literally on public assistance because he couldn't get a job. That's how bad the system had contracted. So these young, highly trained physicists were having an awfully good time wondering about deep quantum mysteries and beyond.

And so they were highlighted in San Francisco area magazines. There was a big photo spread on the group in a local magazine in '75, which highlighted these folks were going into trances, working at telepathy, and dipping into their subconscious and experiments towards psychic mobility, which is literally groovy man. I mean, this was like totally in-step with the times. And they became really just multimedia darlings.

And it wasn't only San Francisco. There were similar stories picked up by the news wires, by the *Associated Press,* and *United Press International.* There was a cover article in *Time Magazine.* It was covered in other publications like *Oui Magazine,* which I always say was not a publication of the French embassy. It's actually a porno mag. *Oui Magazine* was *Playboy's* answer to *Penthouse.*

In 1979, if you wanted to read a detailed article about quantum entanglement, you could find actually a very competent popular science treatment in *Oui Magazine,* because it was deemed so interesting, but not in many other venues. So the group starts getting lots and lots of attention because there was this strange coagulation of well-trained physicists not just dabbling with strange topics, but claiming they could actually explain it, that quantum mechanics might unlock the power of mind.

OK. Let me pause there for some questions. And then we'll move on to the next part. Any questions on that? So Alex asks, how much LSD were these people using? That's actually, literally a fair question. One thing to keep in mind-- I write about this in the book a little bit-- LSD, until right around this time, was actually not considered illegal.

It was reclassified first as use of it was a misdemeanor and later made, of course, a more serious felony charge, but only a bit later. In fact, LSD was considered a very interesting research substance on which there was a lot of research being done at the time at Stanford Medical School, at many university hospitals, and biology departments, and psychology departments.

And so it does seem that not all members of the group, but some members claimed at least they were having a lot of fun with recreational drugs. Others said they never touched the stuff. It wasn't the whole group. But what's interesting is that the associations around such psychedelic drug use were quite different than what would become more common later on.

And so Alex also asked about MKULTRA. That's right. So that was, at the time, still quite top secret. That was a program subsidized at least in part by the US Central Intelligence Agency, top secret at the time, to see if psychedelic drugs like LSD might have some role as a kind of truth serum. Could these have a role in national security or national defense? The results for which seem to be-- let's just say inconclusive.

But it did lead to some pretty sensational experiments that were revealed only years later when the secrecy was broken. So these folks weren't directly involved in it. But that's another indication of the time. It's still a relevant topic because many people-- research psychologists, defense experts, and others-- thought that these psychedelics might unlock the true meaning and role of consciousness and so on.

It, later on, was come to be seen as more dangerous or illicit with corresponding criminal charges against it. But one of the men I mentioned, Nick Herbert, remembers participating in a Stanford University study where he was a willing subject. He was asked to participate in a psychology experiment, took several doses of LSD under close supervision, and was asked to describe the experience. It was still seen as an on-campus thing through the early and mid-60s. Any other questions about the setup here-- the group, the times, anything like that?

OK. Well, if questions come to you, we'll have another chance to discuss them. But let me press on a bit. So I wanted to let us know about what were some of the topics these folks were focusing on. Let's ask, how are they doing it? Remember, this was a time when the conventional career paths for many, many physicists in the United States had really been interrupted.

So they weren't just getting positions as assistant professors at universities, though that was what most of them had been aiming for. So how do they support their work? How did they conduct research? How did they share their findings and so on if they weren't in a typical research environment that had at least come to seem typical for the generation before?

So again, we start asking questions much like we asked about in the previous class. Who's paying for the work? Who's supporting it? What's the kind of funding structure? And what are the institutions in which the work will be pursued? Let's ask about money first. Let's talk about funding.

So on the one hand, there was actually a kind of continuity with the Cold War stuff we looked at in the previous session. A fair amount of the work-- of the funding to support this work actually came from the US federal government in the part of both the CIA, that I mentioned briefly, and also something called the DIA, the Defense Intelligence Agency, which is, as its name implies, a kind of CIA, but within the Pentagon. So they're actually separate agencies, though they have similar kind of roles to play.

Here's an example of one of their reports that was later declassified. It was originally a classified report. Now, you can download it on the internet. It was declassified in response to a Freedom of Information Act request. Originally finished in July of 1972, it has this kind of innocuous sounding title called "Controlled Offensive Behavior USSR."

What it's really about was an investigation into whether the Soviet Union was how-- put it this way, how far ahead the Soviet Union was in basically weaponizing mind reading and mind control. Think about if you've ever heard of the movie *The Manchurian Candidate* or so-called brainwashing.

The concern from the Pentagon Intelligence Agency here, the Defense Intelligence Agency, was that the Soviets weren't just pursuing advanced efforts in mind reading and mind control, but were actually excelling at it. And therefore, the United States faced, so they estimated, a gap, much as there had purportedly been a so-called scientific manpower gap that we looked at last time, or a so-called missile gap, which also turns out wasn't actually there. So this was a concern that the Soviets were way ahead in a kind of parapsychology program.

And so that unleashed lots of funding, or at least some surprisingly generous funding, within US settings to try to catch up to the supposed Soviet advances in things like parapsychology. So between the CIA and the Defense Intelligence Agency, funding began for what came to be called ESPionage, which is using ESP to conduct espionage.

Wouldn't it be great if it were possible to spy on the Soviet Union from the comfort of Langley, or CIA headquarters, or some Air Force base in California? So if minds could become entangled, which it seemed people like Uri Geller seemed to suggest could be happening, then could that be harnessed to protect the nation?

And both the CIA and the Defense Intelligence Agency said, well, if so, we'd better find out. So they began funding research at places like the Stanford Research Institute, that spin-off defense lab I mentioned in the Bay area and at defense labs actually around the country, a fair amount spent at Aberdeen Proving Grounds in Maryland. And many other of these once highly classified replication studies were being conducted.

And again, with the help of Freedom of Information Act, one can begin to learn how much of this kind of dark money was channeled to these once highly classified defense efforts to basically try to figure out mind reading and maybe even mind control. Some of you might have seen the movie called *The Men Who Stare at Goats.* It was originally a bestselling paperback, and then made into a movie a number of years ago with George Clooney and others. That's actually based on the true story of some of these military efforts to figure out ESP.

Other investigative journalists, and historians, and others have pieced together at least some of the spending, which was once highly classified. This was discretionary spending. It wasn't disclosed to Congress directly. But later Freedom of Information Act requests revealed that often millions, sometimes many millions of per year being invested in these efforts. The program was supposedly canceled in 1995. Some people say maybe we started again after 9/11. I've seen no evidence of that.

Anyway, this is one way to perpetuate research in parapsychology, was you convince the US federal government that the Soviets were doing it. And that unleashes lots of money because there was a Cold War rivalry. It was still a Cold War rivalry. I find that pretty astonishing.

So several members of that Fundamental Fysiks Group, including Elizabeth Rauscher and George Weissmann-- together, they had founded the group-- Jack Sarfatti I showed you, Saul-Paul Sirag-- he was one of the great hair-- they actually began conducting their own unclassified replication efforts as well, some of it partly underwritten by some of this defense money.

So they would do the following. They actually published in the open literature, in the open parapsychology literature. So it wasn't classified. It also wasn't in mainstream journals. So they would do things like this, is what became known as so-called remote viewing.

They would try to find people who seemed to be particularly sensitive to these shared sensations, like Uri Geller seemed to be. And they found others who seemed to have comparable abilities, at least to their estimation. And they would basically have that person sit in a dark room with very few external stimuli-- no bright lights, no loud music-- have them sit there while someone else traveled to a randomly selected location in the San Francisco area.

There would be a series of targets. But they wouldn't know which target. They would try to shield the information from the sensitive person back at home base. And that person who's outside would just go to some landmark location and stare at it very, very hard, like places on Stanford's campus, or Berkeley's campus, or Golden Gate park, and so on.

And then the person who's trying to receive these seemingly entangled signals would just start either sketching or verbally speaking what they seemed to-- the pictures that would form in their minds. And the argument was, as Rauscher, and Weissmann, Sarfatti, and Sirag eventually concluded, was that there was actually no better than chance in matching between the descriptions and the targets statistically. It was about even.

However, there was what they considered remarkable precognitive effects. So in fact, what the sensitive people seemed to be doing was sketching the next target in line. Or if you relaxed the criteria for matching, they found lots of matches afterwards. So naturally, we leave it up to you about how robust that effect seemed to be.

The point is that's the kind of thing they spent a fair amount of time trying to pursue. Turns out again, as we know from Freedom of Information Act declassifications, there were very significant efforts at this at multiple defense laboratories across the country, some of which claimed success, although independent audits usually came down to statistical chance.

Anyway, that's one thing. That was one way this work was supported. Basically, go back to the Defense Department and say the Soviets are doing it. We should do it, too. The folks I was focusing on got even more creative, a little more entrepreneurial in how to support their work. And that was not only to appeal to the Defense Department, but also to some of these quintessential California self-made millionaires in what came to be called the California Human Potential Movement.

It was very, very much in the rage, starting in the late '60s throughout over the 1970s and beyond. There are a number of these folks who became really nationwide or even international celebrities for, again, either claiming to have unlock the secrets of human consciousness and therefore human potential or at least investing heavily in the efforts to do so.

One of them was named-- took on the name Werner Erhard. He was actually born Jack Rosenberg and grew up in Philadelphia. But through a whole series of events, he wound up moving to the West Coast, adopting this assumed name. He called himself Werner, not "Verner."

Although, he borrowed the name from Werner Heisenberg because, as a kid, he'd been very interested in modern physics and used to read some of Heisenberg's popular books. So he thought "Verner" or Werner would be kind of a serious sounding name. So he adopted this pseudonym, Werner Erhard.

Erhard introduced something that came to be called Erhard Seminars Training or EST. And if you ask your parents, they will almost certainly have heard of this, at least if they grew up in the United States or even many parts of Europe. It became really an international sensation-- EST, E-S-T, for Erhard Seminars Training.

This was in the mainstream news regularly, relentlessly over the course of the 1970s. The EST movement could eventually claim devotees among gold medal-winning Olympic athletes, among people pretty close to political leaders-- sons, daughters, cousins of presidents and senators-- that kind of thing, media stars. It became really, very, very pervasive.

I think they claimed something like 800,000 paying alumni had gone through these intense-- hotel ballroom intense kind of sessions. So Erhard met up with-- he was, by this point, based in San Francisco. He met up by chance with members of that Fundamental Fysiks Group in a way that I talk about the book.

And he basically was convinced that this quantum entanglement stuff really would be the key to unlock powers of consciousness. So he actually helped-- his lawyers help set up a not-for-profit corporation, a way that they could actually collect and spend money, much of it coming from Erhard's own generosity. They call themselves the Physics Consciousness Research Group that actually filed for incorporation in the state of California.

And this was, again, a kind of structure to enable the group to raise funds from private donors and to spend funds. And Erhard was among the most generous early donors to get that started. Erhard went on to become quite controversial. E-S-T, or EST, also kind of eventually faded from view. There was a huge series of very high profile scandals and counter-scandals and claims and counterclaims, again, that tails off through the '80s and into the '90s.

For some time, Erhard was outside the country. Then he actually wound up winning a bunch of cases that had been brought against him. So he is back in the country, and so on. Anyway, it became a big, big to-do. But over the '70s, Erhard was a kind of almost household name and one of the earliest supporters of this work. So now, you have the group not only getting some support from the CIA and the Defense Department, but also from some of these self-made California gurus of this counterculture scene, like Werner Erhard.

It turns out before we say, oh Erhard, that stuff sounds a little flaky. At almost the exact same time, Erhard was also starting up another series in physics that ran for 13 years and was run by one of my own colleagues here at MIT, Roman Jackiw, and my physics PhD advisor, one of my advisors Sidney Coleman. And their meetings attracted people like Stephen Hawking, and John Wheeler, and a number of Nobel Laureates. Gerard 't Hooft's in this photograph somewhere.

So at the same time that-- or basically around the same time that Erhard was funding this Physics Consciousness Research Group from the Fundamental Physics Group and digging into things like ESP and quantum entanglement, other physicists at leading institutions, who had pursued more typical careers in the field, academic careers, were also getting support from that same source and hosting what turned out to be a pretty successful series of informal conferences held often in Erhard's personal house-- a big, huge mansion that he bought in San Francisco.

So the source of patronage was not a kind of one way or the other. I take that as a further sign of just how much that Cold War set of assumptions had really been disrupted by the early and mid-1970s, where even Harvard, MIT physicists, even Nobel Laureates, were at least sometimes in need of this untraditional patronage because the usual sources were really in short supply.

OK. So it wasn't only Werner Erhard. The group, the Fundamental Fysiks Group, also got considerable support from another kind of California counterculture maven named Michael Murphy. Murphy, much like Werner Erhard, had been really enamored by quantum physics as a younger person. He actually studied physics briefly at Stanford before he switched his major. But he was really fascinated by this.

And then soon after graduating, he founded this place called the Esalen Institute in Big Sur, California, down the coast about 150 miles South of San Francisco, nestled, as you can see, in this extraordinary location on the Pacific Coast. So Esalen became, over the '60s and '70s, ground zero for the hippie world, for the counterculture world.

This is where people would go to talk about things like vegetarianism, which once seemed incredibly strange in the United States. It's where they would go to explore psychedelic drugs, both before and even a bit after they'd become illegal, where people would explore this newer set of ideas about human consciousness and human potential and, it turns out, where they would go to explore quantum entanglement.

So as I mentioned, Murphy himself was fascinated by quantum physics. He invited this group, this Berkeley-based group, to come down and host a month long workshop underwritten entirely by Murphy-- host a month long workshop at Esalen for a bunch of their friends and colleagues. And then other people could pay a modest entrance fee to attend the workshop and have naked hot spring baths, massages, and all the rest.

So they advertised this workshop that perhaps a new kind of inspired physicist experienced in the yogic modes of perception must emerge to comprehend the further reaches of matter, space, and time. And when it came to yogic modes of perception, Esalen had the market cornered. That's literally what they became known for.

Some of you might have heard of the book *The Dancing Wu Li Masters.* It actually won the National Book Award-- excuse me, the American Book Award. It's sold something like 20 million copies worldwide, many, many translations. It became a publishing sensation. The author of the book, Gary Zuka, was, at the time, the roommate of Jack Sarfatti, one of those members I mentioned before, the one who'd been in that saffron robe.

So Jack invited his friend Gary to come along. And the whole book is basically trying to capture the nature of these discussions at this month-long quantum physics workshop at Esalen in January of 1976. In fact, the very first chapter is called Big Thoughts in Big Sur, named for Big Sur, California. So you have this kind of broader circulation of some of these ideas well beyond the Pacific Coast itself.

And in fact, much like those Erhard-funded workshops, there wasn't only a one-off. There were 13 years worth of annual, week-long sessions that were follows-up after the month-long one that became known as the Bell's Theorem Study Group held every year at Esalen with members of the Fundamental Physics Group, like Henry Stapp shown here coming down the coast for the week-long retreats every week.

And in fact, it became the longest running-- longest running workshop in Esalen's history. So Esalen is known for hippie counterculture stuff-- psychedelics, nature consciousness, vegetarianism, Eastern mysticism and spiritualism. And yet, the longest running workshop, the longest continuously running workshop was actually on quantum entanglement. So you can see the group's getting funds and also something like a kind of institutional base from which to try to pursue their work.

So how do you spread the word beyond just the hot spring baths or the conference room at the Berkeley Laboratory? That actually was not so straightforward. It turns out, at the time, the long-running editor of the *Physical Review* actually banned articles on the philosophy or interpretation of quantum mechanics.

In fact, he even went so far as to draw up a special sheet of instructions for referees. And the instructions were, if this summation to the journal, to the mainstream research journal, looks like it's only on the so-called philosophy or interpretation of quantum theory, then don't bother reviewing it. Just check this box. And we'll automatically reject it. It was really a high barrier in the US journal scene.

So high, in fact, that a number of follow-up articles by John Bell himself on Bell's theorem wound up appearing in these very strange out of the way places. So some of John Bell's own work was shunted out of the mainstream journals like the *Physical Review* and into these hand-typed mimeographed newsletters from, in this case, a little group in, I think, Geneva or somewhere in Switzerland and circulated as a kind of clubhouse newsletter.

So it wasn't peer reviewed. It wasn't sent to libraries. It was basically you sent in a postcard saying, please send me the next month installment. And so this was a kind of underground newsletter called *Epistemological Letters.* And literally, some of the work that would later come to be recognized as remarkably important for understanding things like quantum entanglement, this follow-up work, was shunted into these non-traditional circulation mechanisms.

Even more untraditional was the following. It became to be known as The Unicorn-- A Unicorn Preprint Service. The Unicorn was a little joke based on the last name of this gentleman, Ira Einhorn. So as you might know, in German, Einhorn means one horn, a unicorn.

Einhorn had also been enamored of physics as a younger person. He actually briefly did a double-- he briefly pursued a double major in physics and English as an undergraduate. He dropped physics and just was an English major in the end. And then he got really swept up with some of these pretty big dramatic changes in the US by the late '60s.

He became an anti-war activist and even something of a kind of anti-war, iconic leader, showing up at a lot of the famous protests with people like Abby Hoffman and Jerry Rubin. He actually helped to emcee the nation's first Earth Day Raleigh in his native Philadelphia in 1970.

At around that same time, he became an unusual kind of management consultant to the Pennsylvania branch of Bell Telephone. So Bell Telephone executives, based in Philadelphia where Einhorn was from, were worried that they were kind of falling behind with what the youth culture was all about, which was almost certainly correct.

So a bunch of the executive types in Pennsylvania Bell wanted to get a sense for what the young people of the day, the hippie counterculture scene, was all about. So they hired Einhorn, who at this point had become really well-known in Philadelphia, to come and be their channel to what the youth of the day were into.

Einhorn refused any traditional payment. But instead of being paid in cash for his consulting services, he made a deal with the executives at Pennsylvania Bell that he would send to them regularly-- sometimes once a week, sometimes every two weeks-- a big stack of materials-- newspapers clippings, unpublished physics preprints, just a mash of stuff. This is, remember, well before the internet.

And so the executives at Bell would have their administrative assistants Xerox for free all these things, make 300 copies of these packets, and then pay the postage to mail it to 300 hand-picked recipients on Einhorn's list. And the recipients were really international, some of them even behind the so-called Iron Curtain in the Soviet Union or at least Soviet-aligned countries in Eastern Europe.

It was also, even within the United States, a mixture of people that included renowned physicists like Freeman Dyson and John Wheeler, Gerald Feinberg, at the time, was the physics department head at Columbia University. So these really very prestigious physicists in the US and abroad, as well as people like the handler of Uri Geller, Andrija Puharich, other people who were well-known at the same time for being really into the ESP parapsychology scene. Here's Nick Herbert, remember, of the Fundamental Fysiks group.

So Einhorn would concatenate, would collect stuff that he thought these 300 people just had to have, things that he thought were especially interesting. And it was usually about quantum theory and the nature of consciousness. And so he was really instrumental in circulating unpublished or barely published versions of these latest physics investigations by the Fundamental Fysiks Group, including, for example, this preprint by Jack Sarfatti and Fred Alan Wolf that was sent to Ira and then from Ira sent, thanks to Bell Telephone, literally around the world.

So they're doing an end run around the ordinary peer review journals, like the*Physical Review.* This worked really, really effectively until the very end of 1979. He was doing this for about a decade. What happened in 1979 is that while Einhorn was actually at Harvard as a short-term invited scholar at Harvard, at I think the Kennedy School, to talk about leadership, the rotting remains of his, it turns out, murdered girlfriend were found in a trunk in his apartment.

He was suspected of having been foul play when his girlfriend Holly Maddux disappeared. And yet, Einhorn, this peace-loving hippie favorite person of Philadelphia, was never seriously investigated for 18 months until finally retired FBI agent hired by Holly's family followed the clues that indeed led investigators to Holly.

Einhorn was charged with murder. He was eventually convicted. It's a whole long story. Anyway, as you can imagine, as soon as he was charged, the Bell Telephone folks stopped their circulation service. So this Einhorn *Unicorn Preprint Service* worked remarkably effectively for nearly 10 years, until it stopped one day with no warning when the situation had changed so dramatically.

Long before the arrest, long before Holly Maddux had disappeared, Einhorn had had a second career as a free-form literary agent. He was actually connecting some of these new authors, many from the Fundamental Fysiks Group, to big commercial publishing houses in New York City, which, again, were really eager to tap into this youth hippie counterculture market.

And so a second way that the group got their word out, rather than publishing in the*Physical Review,* was actually in some genuinely commercially successful, very widely circulating popular books, books like *The Dancing Wu Li masters* that I mentioned and, in fact, a number of related or knockoff books, some of which became really quite well known in their day, many of which were kind of shepherded into print thanks to Einhorn and his connections.

So one of the books that came out of that was the topic of the other reading you had for today, my short little piece on Fritjof Copra's book, *The Tao of Physics.* Copra was, again, one of the founding members of this Fundamental Fysiks Group. He was originally from Vienna, as you read, but had come over to California as a postdoc, and then went back to London when his visa expired and so on. But he stayed in touch. He came back, once again, to California after that.

So he wrote this book originally to try to write a textbook on modern physics. He thought this would help him get an academic teaching job, which is the kind of position he'd been longing for. He was sharing drafts of particular chapters with renowned physicists like Vicki Weisskopf and John Wheeler and getting advice how to sharpen his discussions and so on, and then finally was told that you're not going to get a job.

You're not going to get rich to support yourself on the royalties of a textbook. Why don't you combine these two interests that he'd been otherwise enamored of, modern physics and Eastern spirituality? And so he rewrote the drafts to become what became known as *The Tao of Physics,* became an international bestseller.

Now, it turns out this book was not only popular with the new age counterculture set. It got really quite warm and enthusiastic reviews in places like *Physics Today.* A reviewer, a Cornell astrophysicist, reviewed the book for *Physics Today* and said, the physics is basically right. After all, Copra had done a PhD, and two postdocs, and had really, really senior physicists reading over drafts. It was reasonable, accessible discussion of things like the uncertainty principle.

Moreover, the reviewer emphasized, it couches this physics in, quote, "the immediate feeling-oriented vision of the Mystics so attractive to many of our best students." Again, this was a time when the enrollments had crashed, when physics classrooms were emptying out faster than any other field.

And this was seen as a vehicle to try to recapture the invagination of some of the disaffected young college students who were no longer flocking to physics classrooms. It was seen as reasonable in the physics and a great kind of PR tool if nothing else.

Meanwhile, there broke out almost like a Cold War competition in another very prominent journal, the*American Journal of Physics,* which, as you probably know, is devoted-- has been devoted since its founding to improving the teaching of physics. So it's not really a research journal, per se. But it's research on how to improve the teaching of physics from high school level through undergraduate and beyond.

And so you can trace through, in the pages of the*American Journal of Physics,* again this kind of playful gamesmanship not whether physicists should use books like *The Tao of Physics* in their classrooms, but how best to. They all agreed you should because it was pretty clear on the physics and also seemed to have this special appeal to the youth culture of the day.

And so you have these dueling lesson plans and whole semester-long courses being paraded through the *American Journal of Physics* because it looked like this book was too good to pass up. And it turns out other books by members of the Fundamental Fysiks Group played a similar role a few years later. They were published a little bit downstream from Capra's book. And they also were picked up as quasi-textbooks, as well as often best selling paperbacks.

Let me pause there. So that unit was really on this question about institutions, funding, how do you get the word out, how do you get a stable platform on which to pursue this work if the folks were not going to be pursuing university-type careers. Any questions on that?

Einhorn was often credited, even while he was in jail, with having invented the idea of the internet before the internet. You can see this preprint service was like a kind of-- not quite Reddit, but some kind of likeminded group, where you go there and find out an eclectic group of people from all over the world who might share some niche interests that can find each other and communicate.

And that's the kind of connectivity model that Einhorn was trying to build with Xerox machines and postage stamps. It was technologically quite old school. But the notion of trying to get niche communities to be able to communicate that was maybe a little bit ahead of its time.

Any questions on that? You're stunned into silence? That's OK. Is it worth reading some of these books? That's a good question. Let me put it this way. When I was a grad student at Harvard some many, many years ago, I was a teaching assistant for a physics course. And we still listed Nick Herbert's book, *Quantum Reality,* on the syllabus as a worthwhile supplemental reading.

And I still think it's a good book, Nick's book. I personally read*The Tau of Physics* as a high school student. It was still widely in circulation. And I just stumbled on it, like in a used bookstore. And my personal assessment is that I found the physics parts really well-described and really fun for me as a high school kid who was taking physics but not yet in college.

And the descriptions of Eastern kind of spiritualism just didn't really do it for me. But that was just me. Those books, I think, were more careful with the physics than others like *The Dancing Wu Li Masters,* which I will say without hesitation is not very good on the physics. The author had no training in physics himself. And it was rushed into print and sold more copies than many of the others put together.

So not all these books are worth reading. I mean, maybe I should make that clear. But I think that Nick's book reflects the earnest efforts to make sense of these strange quantum entanglement phenomena. And it's a popular book with no equations. But it's a well-received example of the genre.

And *The Tau of Physics,* for me, runs hot and cold. But that's because it's doing two different missions at once, whereas Nick Herbert's book is maybe a more straightforward physics popularization. It's like, let me try to explain some cool physics ideas and just march forward.

And I think other books that maybe do that better have come out since then. But that book came out in like 1985. It was pretty early in the genre. And I think it was a pretty admirable job in its time. And again, it's not just me. I remember there were books, physics textbooks, aimed at both undergraduates and even graduate level textbooks on quantum mechanics before topics like Bell's inequality had really percolated into the mainstream textbooks.

It was a long delay until they entered the main textbooks in the '90s. So in the '80s, one could still find published textbooks recommending both Nick Herbert's book and some of them recommending the physics as helpful supplemental reading. So you don't have to take my word for it. We all have our tastes. And they can rightly vary.

But these were seen as serious enough to be helpful supplements. And I think that's a fair-- I think that's a fair assessment. They really were showing up on syllabi and in textbooks really across the US and Canada for a long time. I think there are some better books out now. But that's true of any popular science topic. I mean, a lot's changed since the '70s and '80s. But in their day, I think they were quite reasonable, careful descriptions.

So Alex says, like what books? So I mean, maybe I'll talk more about that later. I have my own personal set of favorites. And a bunch of my friends have written them by now. But I think, as I say, for the earlier period when this was not yet such a common thing for other scientists to do, I think these were quite successful and respectable efforts.

Let me press on. I've got one more section here for today's class. And then I'd be glad to come back for more chatting here. Let's look briefly at that third part for today, which is why am I telling you about all this crazy stuff. Why on Earth are we hearing about this Fundamental Fysiks Group today?

And that's because, again, what I stumbled on without knowing about it ahead of time was some pretty surprising connections, one might even say entanglements, between this very strange Wu Li tie-dyed counterculture scene and some recent developments like quantum cryptography today, which is now really, really considered pretty serious stuff.

So what were some of the ideas and legacies that this group helped really nurse and put forward? As I mentioned, they were totally obsessed or fascinated by quantum entanglement. And they really wanted to push on it. One of the things they wanted to do was see, could you use quantum entanglement to basically break relativity? Are they headed for a showdown? Which is a pretty significant question to ask.

These are the two main pillars of modern physics. And it looks, on the face of it, like they're not compatible. That's what upset Einstein so much. That's what Einstein called it spooky action at a distance because Einstein was convinced that anything like entanglement seemed to violate a kind of local causes yield only local effects. And that question with the same kind of intellectual stakes really drove a lot of this Fundamental Fysiks Group's discussions as well.

So one very clever idea came from Jack Sarfatti, that same guy from the saffron robes. He actually filed for a patent disclosure, the first step toward trying to retain a patent-- and again, you can see he sent it to Ira Einhorn, which is partly why it wound up in the archival collections of many physicists back in the spring of '78.

The idea was to use the exact same source of entangled photons that his fellow Fundamental Fysiks Group member, John Clauser, had literally been using in the laboratory, using the exact same source-- they were getting tours of John's lab at the time-- a certain down conversion in excited calcium atoms.

You emit these entangled photons, send them both towards double slits. So now, we get to think about the double slit experiment, as well as collecting screens in the back, and have this variable efficiency slit detector. That's pretty clever actually. You'd have a kind of potentiometer on here, a little dial, where you could tune this to either always determine exactly which slit a given photon went through or never and have a continuous range in between.

So you could adjust the accuracy with which this slit detector could determine through which slit a given photon passed. So you have a varying sharpness of the resulting interference pattern. This goes back to that wave particle duality we looked at in class some time ago.

The idea was then the varying interference pattern here, as you tune up or down the sharpness with which you can tell which slit information, that, Jack argued, should then be instantaneously correlated with a varying sharpness of an interference pattern over here. Then he says, hook it up to a speaker.

So now, you could basically be encoding like voice messages instantaneously across arbitrary distance. That can be pretty handy to be able to do. So you harness the variable sharpness of an interference pattern from double slit, and then harness the instantaneous connectedness from quantum entanglement. And now, you should be able to send varying interference patterns instantly across arbitrary distances. That was at least the claim, which was the basis for this patent disclosure.

He goes on to say, this isn't just cool. We could really use it. Remember the discussions he's immersed in. He says, "The device could give instant communication between an intelligence agent, a spy, and his headquarters. In this case, we would use correlated psychoactive molecules, such as LSD, affecting neurotransmitter chemistry."

Let me just back up and say, what he's proposing here is this will really work if you get both the CIA field agent and the CIA Handler hopped up on LSD, send the field agent into, say, Novosibirsk in the Soviet Union. And then the field agent's brainwaves would be instantly connected to those of the handler. The patent was not granted.

Part of the reason the patent wasn't granted was actually because it fell apart because of fully local discussion. So around the same discussion table in Berkeley was another core member of the group, Felipe Eberhard, who was originally a European scientist. But he spent his career as a staff scientist at the Berkeley Lab.

And he also had the taste for these fundamental questions in quantum theory. And he introduced what has become the textbook reason why we all now know with some confidence that entanglement cannot be used to send signals faster than light. We know that because these people debated it around a conference table every Friday afternoon in the '70s.

So Eberhard got wind of Jack's cool idea because they were talking about it every week. And Eberhard said, that shouldn't work. And it was actually Eberhard who cracked it, [INAUDIBLE]. And it goes like this, if you only have access to one side of a measuring device, one side of a Bell-type test, then all you have access to is the series of measurements that you perform, that you measure, say, polarization in orientation 1 or 2. Remember, we get to choose that.

And the outcomes-- was it spin up? In which case, the green light flashes or spin down, in which case, the red light flashes. We know detector settings and measurement outcomes from one box only, if we only have access to a local information. If you only have access to this side, then you don't know that the red and green flashes actually were correlated with what happened all the way over there.

We only recognize the correlations inherent in Bell's inequality when we can bring information from both detectors together and compare the log books. When we can compare the sequence of detector settings and measurement outcomes from both sides, then we can go through the data and say, oh look, there were these remarkable correlations in the outcomes.

If you only have access to one box, all you see is what looks to be a thoroughly random series of plus 1's and minus 1's, green flashes and red flashes. And I actually put that in the very end of the optional lecture notes from a few class sessions ago on Bell's inequality.

So that's easy to summarize now. Now, we can all say, oh, of course, of course. No one knew that. John Bell didn't realize that in 1964. In fact, Bell himself thought that entanglement was on a collision course with relativity. This was pretty subtle stuff. And we all know that as a community, in part because it was being debated over in a very friendly, very kind of fun, ongoing debate by members of the Fundamental Fysiks Group in Berkeley, California in the late '70s.

This became the standard response that was packaged up with another one of these very lovely, widely circulating popular books by another person on Ira Einhorn's distribution list, Heinz Pagels. That's also a lovely book, by the way. I recommend that one.

And Eberhard's own proof-- you see, he had to publish it in one of the Italian journals, not in the *Physical Review* because of that kind of ban. And he says and the conclusions that, "Don't be discouraged. Just because this argument fails doesn't mean we should stop asking that question." So he says, "Don't discourage the work being performed by groups like the Fundamental Fysiks Group because these are really important questions that are not getting sufficient attention."

So Jack's main patent effort did not go anywhere. But that only upped the ante for another core member, named Nick Herbert, who then introduced the following a few years later. There's again a kind of cat and mouse game on unspooling here with the discussions in Berkeley.

So Nick Herbert introduced something he called FLASH, which was a playful acronym that stood for first laser-amplified superluminal hookup. He also writes physics limericks. He's very playful. So the idea was the following. He considered, again, a system that would emit pairs of entangled photons, just like his friend John Clauser was really doing in a laboratory at Berkeley.

And he put in a little extra machinery here. Let's go through this one step at a time. Both for classical Maxwellian waves, for regular light waves, and even for individual quantum photons, we can characterize the polarization in several different ways, several equivalent ways.

If we choose to measure the so-called circular polarization using a certain combination of wave plates, then we can measure the photon as either being right-handed, right circular-polarized, or left-handed. It has to do with the orientation of the spinning electric and magnetic fields with respect to its direction of the photons trapped.

So we have a complete basis for polarization called circular right/left. If we choose to measure polarization actually with a linear filter-- think about the usual kind of picket fence picture of a polarization filter-- then we have one of two opposite outcomes. It's either going to be horizontal or vertical with respect to some orientation in space.

So we have two complete bases with which we can characterize light's polarization. In fact, we can do any linear combination-- half/whole elliptically polarized states. But it's enough to consider circular right/left and plane polarization horizontal/vertical. And in fact, at the quantum mechanical level, people long ago long since worked out that you can write one state as a superposition position of the other. They're two complete bases. We can always rewrite one in terms of the other.

So at a quantum mechanical level, the quantum state of right circularly-polarized photon could be written as an equal superposition with a particular phase between horizontal and vertical. Left is a different superposition and vice versa. So now, Nick says, well, from this source, prepare exactly the entangled states that John Clauser and Stuart Freedman really were.

Prepare these maximally entangled states where if we choose to measure photon A in the horizontal basis-- excuse me, in the linear, in the plane polarization basis, we have a 50/50 chance of finding photon A to be either horizontal or vertical. If we find photon A in horizontal, then photon B must be in vertical. If we find photon A in vertical, photon B must be in horizontal. These maximally entangled. If one is basically the equivalent of spin up, the other must be spin down-- spin down, spin up.

That exact same entanglement implies that if we happen to have measured photon A in a circular basis-- let's say we happen to find right-handed-- then photon B must be found to be left-handed when measured in circular basis and vice versa. That's actually just an exact rewriting because these two bases are so easily relatable.

So now, Nick gets a little more creative. We subject photon A to some measurement. And again, as usual the physicist over here gets to choose, can choose at the last moment, well after they're emitted, which basis to choose for her measurement. She can choose to measure either in the HV basis or in the RL basis, by choosing by choosing whether or not to put in a waveplate. She makes that choice.

Whatever choice she makes, she finds a particular outcome with 50/50 odds. Let's say she happens to measure plane polarization and happens to get a horizontal photon. Then photon B, at that moment, gets put into the quantum state V. It must be in the matching pair, the correlated state.

So after its state is determined but long before it gets to its detector station, it enters this magical thing called a laser gain tube, which, at that point, was about 20 years old. There really were working lasers by then. A laser gain tube makes lots and lots of copies of the signal that enters it.

So Nick says, well, we'll just send photon B into a laser gain tube, which emits many, many copies of the incoming photon. If the incoming photon was put into quantum state V, then now you have a bunch of copies of photon V coming out, photons in the state vertical polarization.

Send those to a beam splitter. So now, half of the output goes to station 1. Half the output goes to station 2. Measure those in the distinct bases. One station is measured in circular, right or left. The other station is measured in plane, horizontal/vertical. And now, you have a series of possibilities.

If you chose to measure photon A in the circular basis, you have a 50/50 chance of finding right or left. Let's say you find left. Then photon B must have been put into state right, right-handed. Then you magnify. You amplify. You make lots and lots of copies.

So if the detector station is only measuring circular, you should find them all in the right detector, right-handed detector. And they should be equally split because of this property here, equally split in the other station between horizontal and vertical. If physicist A happened to measure photon A in the horizontal/vertical basis, they should get the opposite set of outcomes. All of photon B copies that are measured in that same basis should go to vertical. If A was H, B had to be V.

Meanwhile, you should have a 50/50 split at the other station. So now, you can signal instantaneously, or arbitrarily quickly, by choosing here-- it's like you can make Morse code by whether you choose a detector station A to measure in circular or plane polarization. That's pretty awesome, right?

Nick wrote it up in a preprint that was circulated in part thanks to Ira Einhorn. This is what the cover looked like because he was really into Eastern mysticism at the time. This was released by the Notional Science Foundation. That's not a typo. He had no support. He was on welfare. This was his joke for like consciousness studies, as opposed to the National Science Foundation. And he worked out of a post office box.

This was submitted to another out of the way journal that had only recently been founded called *Foundations of Physics,* not the *Physical Review.* I was able to track down many of the referee reports. The referees were mostly split and stumped. They said, this shouldn't be able to work. It seems to violate relativity. And yet, they couldn't find the loophole.

The paper begins-- the preprint begins an even wider journey. So it's sent by the journal to be refereed by Giancarlo Ghirardi in Italy. He writes back right away saying, reject it and here's why. He wrote a one paragraph referee report, which Giancarlo shared with me. In the meantime, unbeknownst to Giancarlo, the preprint was also circulating due to the remnants of that Einhorn network.

And it gets to people like John Wheeler. And Wheeler passes it on to his students, including Wojciech Zurek, who then gave me copies of his notebook to look at. They're grappling with this challenge. And then independently of each other, both Wheeler's students-- Bill Wootters and Zurek, and then separately Dennis Dieks in the Netherlands, who'd gotten the paper again through the underground network-- all find the reason why this won't work.

It turns out the same reason that Girardi had found a year and a 1/2 earlier, but had never published, that Nick Herbert had missed something very subtle, as had most of the referees. Yes, we can write the right-handed circular photon as an equal parts superposition. But what the laser does is it doesn't make n copies of a single particle state. That would violate the linear behavior, the linear nature of the Schrodinger equation.

You can't go from one to many because Schrodinger's equation is a linear equation. What happens in the laser gain tube is that you make one multi-particle state, instead of many single particle states. That's really subtle. If that went too fast, you're in exceptionally good company. Wojciech Zurek told me that he stumped Richard Feynman with this, which I believe. This was really hard to puzzle through. This was not at all obvious. Now, we can take it for granted.

This became known as the no cloning theorem, which is to say you can't make arbitrary many copies of an unknown quantum state because that would violate linearity. This is as central as the uncertainty principle today. It's in the opening pages of most of our textbooks on quantum information science. We, as a community, know this because people were beating their heads against this really clever challenge from a member of the Fundamental Fysiks Group.

That last bit, the fact that you can't make copies of an unknown quantum state, is what was the last missing piece needed for quantum encryption. That's why encryption systems can work. If any eavesdropper tried to grab onto one member of an entangled pair and make many copies of it to then do exactly what Nick Herbert had in mind to reverse engineer that secret signal, it will destroy the entanglement so that neither the eavesdropper nor the intended recipients will get the intended information.

So encryption works because you can't make copies of a quantum state without basically breaking the encryption and destroying the original state. That's what leads, with very rapid order, to the very first protocol for quantum encryption, as I wrote about more in the book and I could say more.

So let me wrap up. We're almost done. So the Nobel Laureate Roy Glauber gave credit to Nick Herbert for really pushing on this seemingly weak joint between quantum theory and relativity. He said, yes, it was wrong. But it was remarkably productive. We had to learn through that mistake as a community. And that was a worthwhile exercise.

So he's not saying Nick Herbert was right. We all know why Nick Herbert wasn't right now. But he's saying, we learned that because of the process, because some people took the question seriously. Very similarly, Asher Peres, another leader in the field who just passed away a few years ago, actually turned out to have been one of the referees of the paper who admitted many years later he couldn't crack it and therefore urged the journal to publish it because he said, this must be wrong. But I can't figure out why. We need to crowdsource this, so we all learn, because this is pointing to something very, very deep.

So I find that a productive mistake. So let me close here. This very unusual sounding group, called the Fundamental Fysiks Group, actually left their mark in modern physics in ways that can be a little surprising or counterintuitive. Members like John Clauser conducted the world's first experimental test of Bell's inequality. It was through these really playful, but earnest efforts to understand things like faster than light communication devices that the entire community learned just exactly how to keep quantum theory compatible with relativity.

It led to new understanding of how amplifiers work at the quantum mechanical level, which had never been clarified before. A huge area of quantum optics begins to get a boost from that. These are the first kind of publications that are bringing pretty grounded information about quantum entanglement even into classrooms and whole lesson plans being built around that for undergraduate instruction in physics.

So this work with all of its clear successes, which are things otherwise I personally don't endorse or believe in, nonetheless was active in a very unusual time to bring some of these really important topics, topics that we all now, I think, can agree are really important, like entanglement and relativity, back into US classrooms.

So I'll stop there. Again, I apologize for running a bit long. If people have questions, I'd be glad to stay on longer. But of course, I know if people have to head off, please don't be shy. Any questions about that? Stay well, everyone. Remember, no class Wednesday. See you next week.