

Numberphile Podcast Transcript
Episode: The Klein Bottle Guy - with Cliff Stoll
Episode Released January 8 2019

Computer hackers, Klein bottles and searching for a lost teacher - Cliff Stoll is a man with stories to tell.

[Cliff's Klein bottle website](#)

[The man with 1000 Klein bottles under this house](#)

[Cliff Stoll videos on Numberphile](#)

[The Cuckoo's Egg by Cliff Stoll](#)

[Silicon Snake Oil by Cliff Stoll](#)

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Brady Haran [BH]: Cliff is currently hanging the microphone from a piece of string from the ceiling.

Cliff Stoll [CS]: Not string! Twine.

BH: Twine. 'Cause he wants to be able to use his hands.

CS: C'mon!

BH: [laugh]

[intro music fades in]

CS: And Brady meanwhile thinks that he can sort of capture me on a microphone that is...

BH: That's a bit a low isn't it?

CS: It's a bit low. Let's hoist it up a little bit higher.

BH: It depends where you're sitting.

[gentle piano music]

BH: I'm Brady Haran and the guest on today's Numberphile podcast, if we ever get the set-up, is Cliff Stoll. Now people who watch Numberphile videos might recognize Cliff as this guy.

[Numberphile video clip of Cliff]: If you think math is about numbers you probably think that Shakespeare is all about words.

BH: You know? The Klein Bottle Guy.

[music continues]

CS: What I'm interested in is a little section of topology called Non-orientable Manifolds. More specifically I'm interested in Klein Bottles.

BH: The man with thousands of mathematical glass sculptures stored in the crawl space under his house in Oakland.

[music continues]

CS: Under my house is my little forklift robot.

BH: And you might even remember seeing this. He retrieves them with a remarkable home-made remote controlled forklift.

[electronic and mechanical noises of robot]

BH: Complete with a little camera on the front so he can see where he's going.

[mechanical noise continues]

[music continues]

BH: But as you're about to learn, there's more to Cliff than the wild haired super enthusiastic guy than you've seen on Youtube. It's a story of KGB funded computer hackers, a long lost school teacher and some predictions about the future of the internet which ended up being... well maybe a little bit embarrassing. But let's start at the beginning.

[music fades out]

CS: Okay I'm born in 1950. Apply your retro rockets inside your brain to somebody who's educated in Buffalo, New York. Which is a pretty gritty steel city on the East coast of the United States and with two sisters, two brothers and folks who are at best making minimum wage. Blue collar neighborhood, you don't have a lot. My dad worked at a hotel as a bartender. My mom, bless her heart, used the GI Bill to go to college. Her idea was if she could become an

English teacher in the public schools, man, that's a job. Oh, little did she know what it meant, but eventually she did. Along the way the two of them fired five shots into the impending baby boom and two of my older sisters are BLIP! Up and away, my two younger brothers are out and about and the world is probably a better place for the bunch of us.

BH: Were you brainy? Like were you clever at school? Would I have said, oh he's gonna be an astronomer or mathematician or engineer one day, that guy?

CS: I wish somebody had said that. Boy I wish I had said, oh he's the brainy one in the neighborhood! Rather I felt here's my chance, going to school to figure out and learn about what's going on around me. The first... five, six, seven, years of education was strictly public school elementary school, grammar school [grunts] public school number sixty-one. And I got a blue star for good attendance.

BH: Right.

CS: I mean, wow that is good stuff! And then I started in 7th grade at Millard Fillmore Junior High School. I mean their can't be two schools in North America named after Millard Fillmore.

BH: Who was Millard Fillmore?

CS: Who was Millard Fillmore? Millard Fillmore was a dough faced president around 1850...

BH: Yeah.

CS: Whose claim to fame was that he brought a bathtub to the White House.

BH: Okay.

CS: In fact there... he wasn't the first to bring a bathtub there, but that's the main thing that's he's known for today.

BH: Is he the most forgettable president then is he?

CS: He's a very forgettable mediocrity.

BH: Alright.

CS: And every now and then in Western New York there are bathtub races where people put wheels on bathtubs to just do Millard Fillmore races, but that's beside the point. Alright so I'm in 7th Grade at this cool new Junior High School and it's 1964. Our math teacher is going to teach the New Math. Now the New Math is not like that old boring arithmetic and pre-algebra that kids are learning. No, the New Math is all about sets! Set Theory and combinations and my folks have never heard of it, I'd never heard of it. I'm sitting in and my teacher Ms. Forenz* starts talking about what is a set and what are certain rules. The commutative law, the associative law, the distributive law, and what happens when you have a Venn diagram and you make circle and these things. And I'm sitting there, 7th, 8th grade, boy this stuff is squeaky obvious.

*[Ed Note: Best guess based on pronunciation compared against surnames found in Buffalo NY]

BH: Do you mean you were finding it too easy?

CS: Oh yeah, it was way easy.

BH: Yeah.

CS: Just way easy. And this is going on through 8th grade and Ms. Forenz bit

by bit by bit and I'm having a great time because I'm learning really new novel stuff that I've never thought about and one spring day sitting in English class and English teacher says, you know some greek philosophers pointed out that there's no rule so general, so universal, that it does not admit to at least one exception. I'm sitting there in English and twenty minutes later find myself in Ms. Forenz' math class and she's talking about the commutative law. You know, $A \text{ times } B$ [gibberish] equals $B \text{ times } A$. Up goes my hand, Ms. Forenz, Ms. Forenz! Mr. Lama down the hallway he said [gibberish] there's no universal [gibberish] except. And she says, you're right, the commutative law has an exception. And I'm thinking, oh this is cool. And she says it's hard to describe what it is but I'm going to assume that you're asking a real question. Namely, what's the exception to the commutative law of algebra. And so she begins by saying, a matrix looks like this and draws a matrix of two by three matrix on the chalk board. She says, right now this matrix doesn't look like it's useful but I can make another matrix next to it and I can multiply the two together. Matrix A times Matrix B and I can get Matrix C, she points out just how you do matrix manipulation. How you do matrix multiplication. And she says, I'm not telling you this for any test at all, I'm telling you this because you asked a good question. $3 \text{ times } 7$ is the same as $7 \text{ times } 3$ by the commutative law. Matrix A times Matrix B does not equal Matrix B times Matrix A. The commutative law doesn't apply! And I'm sitting there listening and this stuff is just soaking into me. I'm sponging it all up and I'm thinking where would you use a matrix? What is it? What's it for? Bless her heart she continues, she describes places where you'd use it, you know, you could measure temperatures on different days and multiply them by something. And so I stash it in the back of my mind. Continue on junior highschool, get to high school, sure enough the end of high school taking a calculus class and teacher starts talking about linear algebra and mentions and oh in blah blah blah matrix blah blah, I hear this ping in the back of my mind. This neuron fires! It says, oh I've heard of these matrices before. They don't commute. And I raised my hand and I say, oh they don't commute, do they?! And my high school math teacher says, wow, you know about this, don't you? And I say no not really, I just know... I remember how they multiply. So get

to college, up comes linear algebra again, up comes these matrixes all over the place in physics. I get to grad school, boy they're all over the place in physics and every time I see one of these matrices I remember this day in 8th Grade where Ms. Forenz introduced this absolutely weird and wonderful concept to me. So I'm finishing up in grad school and my dissertation is of all things to define the scattering matrix for the cloud particles in Jupiter's upper atmosphere. In other words when sunlight falls on Jupiter, the clouds in Jupiter's atmosphere scatter the light in different directions. What direction does it preferentially scatter into and if I can understand... suppose a lot of the light get's forward scatter, I might be able to say something how big and what shape are the particles in the clouds of Jupiter. I might be able to say, oh is it ammonia crystal, is it a methane crystal, can I separate the two by looking the scattering matrix. And these matrices all over the place! And I'm foolin' with these matrix and I keep thinking, thank you Ms. Forenz, thank you to my 8th grade math teacher who went out on a limb and spent all of fifteen minutes of class time to introduce me, this little pipsqueak in the front row, to matrix algebra. So I finished this and I think to myself, you know, I need to thank her. I want to go back and say thanks to this woman. So I go back, try to look her up, Ms. Forenz, where are you? She's in no phone book. She's not listed anyplace in Buffalo. Eventually, oh ten, fifteen, twenty years later a new century comes about. Matrices, they're no longer this cool new thing that shows up in physics, they're my old friends. They're friends that are helpin' me figure things out! I can't look at an Excel spreadsheet without thinking about matrices. And I'm thinking to myself, I owe this woman a deep thank you for going way beyond the call of duty.

BH: Cliff, did you find her?

CS: In 2014 I said, okay, I've actually put in sometime looking for Ms. Forenz. I'm gonna find out where she is. Put my spade into the dirt, going through county paper records. Finally early 2015, it's now what... fifty years since I took this class. Yeah fifty years since I last saw her, I find, oh I think there is a condominium in Florida that has her married name attached to it.

BH: Right?

CS: Called the condominium manager who says, oh yeah that was sold [gibberish], you might want to call so and so in Minnesota. So I start calling everybody with this particular last name in Minnesota. Thirteen, fourteen phone calls later I call up this guy and say, I'm looking for Ms. Forenz. The guy says, huh? You wanna talk to my wife. Thirty seconds later this very very familiar voice gets on the phone and say, hello? I'm looking Ms. Forenz who used to live Buffalo and taught mathematics and I hear over the phone, yes, this is she. I say you don't remember me. You don't have any idea who I am, my name is Cliff Stoll, fifty some years ago you taught me the New Math, more than that, you taught me the commutative law and deeper than that you showed me what a matrix was. And she says, oh my god, I have followed you career across the decades. I saw you chase down this computer hacker. I read your books. I always wondered whether you were the same kid that was in my 8th grade math class. I wondered if you were the same clever interesting kid that I taught so long ago. But I never knew how to reach and I mail a Klein Bottle to her because of all people she'll appreciate a Klein Bottle. Back comes a letter. [Shuffling papers] Back comes a letter postmarked Lake City, Minnesota.

BH: You've got it there.

CS: And it says, Dear Cliff, this letterhead Buffalo Academy of the Sacred Heart, is where I went to High School.

BH: What does she say in the letter, like what's the gist of it?

CS: So at the very end thanks again for looking me up and giving life one more interesting twist. I'm really enjoying it. Take care, signed Mary her first name in parenthesis Ms. Forenz. I know of course she hasn't used that name in fifty-two, fifty-three years and in this letter she says I now have credibility with

my grandkids because they can see you on Youtube. You did a TED talk, you wrote these books, and they're impressed with me because I was your 8th grade math teacher. What's cool about it isn't, oh yeah, I learned about matrices, no, everyone in math and science and physics and chemistry, biology knows about it. My feeling deep inside is that I have a responsibility to sort of like to extrapolate we have a responsibilities in general to pass along our appreciate to those people who have done good things for us.

[gentle chime music]

CS: Suppose for a minute that you're in 7th grade in Buffalo, New York at Fillmore Junior High School over on Appenheimer Street, okay, hypothetically further suppose that you're in a science class taught by Ms. Coen, who's teaching. And meanwhile you have a curiosity about the sky and you say I'm gonna make a telescope and your folks don't have any money, you don't have any money, so you have to make your own telescope which means grinding a mirror and polishing the mirror yourself and mounting it in a tube and figuring how to bend pipes so that you can point it at the sky and one day I say, hey I'm looking at the sky with this homemade telescope, well there's this object I see, wow there's a couple stars right next to it. I wonder if that's the planet Jupiter, with the Galilean Moons around it? I'm what thirteen, fourteen years old had this homemade not very good telescope. Next morning I run into school, go up to my 7th grade teacher and Ms. Coen! Ms. Coen! I made a telescope and she says, oh that's interesting put your homework over here and sit down, third row. I say, no, no, no, you don't understand I made a telescope and I was looking at the sky last night and looking at things. And she says, very nice, very nice, put your homework here and sit down, class is about to begin. I think I saw the planet Jupiter and it had stars next to it! Very nice young Clifford, please hand in your homework and sit down over in row number three in your chair, now. I walked over sit down thinking this probably is the way life is and I go home mention it to my mom and my mom says that doesn't sound right. Let's see if we can find somebody who might know something more about astronomy, she sure

didn't. The whole idea of science in my neighborhood was [scoffs] it was a class you had to get through. So we went over to the Buffalo Museum of Science. I go up to the 3rd floor. There's a door that has gold letters on it, Curator of Astronomy, knock on the door, voice comes out says, come on in! By now I'm completely, you know, after what happened in my 7th grade science class [laughs] what to do, so I say, excuse me sir I'm thinking about how I got shut down in my science class in 7th grade.

BH: Were you doing the talking Cliff or was your mum doing it? Or were you...

CS: No, my mom just said, you go... you walk in there and you tell 'em what you did! And obviously she's not gonna do it for me.

BH: Yep.

CS: So I walk in and explain to this guy who's sittin' there, smoking a cigarette...

BH: [laughs]

CS: And I say I made a telescope. And this guy looks up and says, oh really? What kind? Reflector, refractor, what did you make it with lenses? I said no it uses a mirror. He says, you ground it yourself? I said, yeah, you know, carborundum grit and I polished it using this stuff and he said, what'd you mount it on? I said, well I don't have much so I used some cardboard and couple pieces of wood and a tube and pipes, some plumbing pipes to make sort of a mount.

BH: So this was like a homemade telescope? You hadn't bought a kit?

CS: Oh no, no, this is not a kit, this home-brew.

BH: [laughs]

CS: Homemade. You know, you have to go back to 1962, '63 when money was scarce. My family is living off my father's minimum wage job.

BH: Yeah?

CS: There's five kids. When somebody would tip the bartender heavy, we would have hamburger the next day. When nobody was tipping well the next day it would be beans and rice for us. That's my life.

BH: This astronomer must have been so impressed by this kid that had just...

CS: This astronomer, this guy says oh well what have you observed? And I reached in my pocket and pull out a little spiral pocket notebook and I say well here's what I saw the other day. Open up and show him that oh it looks like a bright star with some little stars next to it. He says, I wonder if it's the planet Jupiter. And I'm thinking I hope so, I hope so, I hope so! And so he reaches up on the shelf pulls out this thick gignondo book called In Ephemeris and it has all sorts of numbers in and a graph showing where the moons of Jupiter are. He matches my cruddy notes with his wonderful book and he says, oh yeah over here, you saw the planet Jupiter, here's Io, that's the one that you got over close here. Ganymede's over here. Callisto, yep. It must have happened on Tuesday night at about 7:30 dot dot dot and he looks up and says this is good work. What's your name? I say it's Cliff... and he says what's your last name? Cliff Stoll. He says okay from now on and he reaches over to the shelf, pulls out a notebook. He says from now on every time you make an observation I want to see that name in ink at the top of every page. Here's your notebook. You'll notice it's not spiral bound. It's not three ring bound. It's a sewn in notebook. Every observation you make at the top of the page I want your name, where you are and the date. Don't forget the year. And this'll be your log book. And by the way, next Thursday it's public

night, come on up. I'll show you the sky through real eight inch refractor telescope.

BH: What did that make you feel?

CS: It made me feel wonderful. As if somebody actually valued what I'd done. What you've done is interesting. It matches observations that have been predicted in this American Ephemeris. He's not saying, oh, hand your homework in and sit over there and pay attention and fold your hands and be quiet. He's actually treating me as if my time is worth something. Well, I showed up for public night and halfway through he invites me to tell people about the moons of Jupiter of which I don't even know their names and the public night after that I do my homework in advance and I'm able to talk about Jupiter a little bit more. And a year goes by. I start taking classes in astronomy at the museum. A couple more years go by and this guy says, oh you know, I'm thinking of starting a summer program in astronomy. Summer program astronomy is five or six high school kids from around Western New York, a couple of whom have made their own telescopes. Several of whom... hey they're just interested in astronomy. We're up every day using a solar telescope. Figuring out how sunspots evolve and this guy is telling me, hey, there's this journal that comes in, called the Astrophysical Journal, read a couple articles in it. I open this book. It's filled, just crammed filled with snake-like mathematics that I can't understand. I say... go up to him and say I can't understand it. He says, find the ones you can, read those. And by the way read this book on how sunspots come about. It's called Bray and Loughhead Sunspots. Start reading it, pretty easy and he says pretty soon it starts talking about physics, magnetism, electricity and dynamos and boy it's hard going. He says read this book over here by Secchi, great Jesuit astronomer, about what's happening in the sun. Read that one, that's a hundred years old that's real easy to read and I'm picking up all of this. By the end of the summer, the whole crew of us head over to a place in Michigan, near Pontiac, Michigan. McMath-Hulbert Solar Observatory. We meet real solar astronomers. They're showing us there spectroheliographs and hydrogen-alpha filters and I

know what they're talking about. I'm not afraid of a spectroheliograph. Hey, I use a little spectroheliograph at the museum. I understand what a solar flare is. I sort of can see why prominences have the shape they're in. I'm sixteen, seventeen years old and I'm realizing I can actually understand what real astronomers are talking about. They're not talking down to me. When they talk to each other I can pick up some of the words they're saying and understand just what kind of projections they're doing, and Brady, it was like every now and then I'd bump into somebody who's idea of a kid was not, oh kid go over there in the third row. Sit down fold your hands be quiet I'm about to start class. Every now and then I'd meet somebody who gave a damn that I could learn. Who cared that I could become somebody much more than who I was now. And over there on the wall.

BH: There's a picture of him.

CS: There's a picture of Ernst Both. I knew him for forty-eight years. Not a month went by for forty-eight years that we didn't write a letter. Didn't call each other. Along the way I've realized, oh yeah he has a Masters degree, no PhD, the depth knew astronomy, wasn't that deep, he was really a mycologist. He was an expert at studying mushrooms.

BH: [laughs]

CS: Because in World War II when he was thirteen years old he was starving and his folks were driven across Eastern Europe, they had nothing to live on but mushrooms.

BH: So your astronomy mentor was a mushroom expert? [chuckles]

CS: Yes, yes and he's got a flock of mushrooms named after him because he was such a researcher, the important thing was he understood what research meant.

BH: Why was he the curator of astronomy, if he was a mushroom expert? That was just the job that was going?

CS: Like many other people, he was over qualified for this job, but it wasn't open so he said yeah I can do astronomy and my first book that I wrote, Cuckoo's Egg, I dedicated to him, simply because he was the one guy who cared... who wasn't interested in just teaching. He cared that I grew into a real human.

BH: Looking back now with the hindsight, like you know, the wisdom of being an adult who tries to mentor young people yourself, what do you think he saw in that boy who came into his room? What did he say that made him say, I'm gonna give this young lad more of my time?

CS: Wow. Wow. Surely he saw a guy who was curious. Who wanted to fool around. I hope he saw someone who didn't give a damn about, oh I need a job, or I want a letter of recommendation. I hope he saw somebody who was embarrassed that his mom had taken him there. It's a difficult challenge to find the thing that resonates in a kid and feed it enough energy at just the right frequency so it keeps on vibrating and vibrates louder and louder inside of you.

[gentle bell music]

BH: How did becoming a professional astronomer, now you're working as an astronomer, having done all your studies, how did that compare to what you imagined it would be when you were like a kid looking at Galilean moons, like, was the reality of being a working astronomer more amazing? Less amazing? Surpass expectations? What was it like?

CS: How I wish that the joy of going out in your backyard and seeing a lunar eclipse. Moon gets dark and the excitement of looking forward to oh I'm gonna travel to see a solar eclipse someday. How I wish that were reflected in graduate

school. How I wish that that were well reflected in professional astronomy. It saddened me to finish grad school and start doing postdocs and realizing that oh yeah, what people want me to do is to write three papers a year and get published at least one paper that's good enough that it'll show up on... be reviewed in the annual reviews of blah blah blah, what a let down that so much of what preparation for astronomy led into was writing grant proposals, reviewing telescope proposals for others, figuring out you know how do we get funding for this, that and the other. I found it so sad. Something that was once so new, so true, so hypnotically addictive as looking at the sky and looking for the Messier Number... looking for double stars. Trying to see if I could resolve divisions in Saturn's rings and then finding that well, having done this it's now time to write grant proposals. Oh Okay! So I was doing a postdoc in Baltimore at Space Telescope Institute and there's three or four of us walking down the street in Baltimore and of course Central Baltimore the sky's pretty bright and we're walking along I look up and say, oh I can see Venus over there. Astronomer, no kidding? PhD astronomer looks at me and says, how do you know that's Venus? Oh c'mon, c'mon. He says, no, no really how do you know that's Venus over there? I said look, we're an hour or so after sunset, we're walking west, it's a bright star in the... c'mon you're kidding me aren't you? When I realized that they're are astronomers who don't look at the sky. [Groans] The thing that was such a joy to me, lying on my back looking at the sky. Looking for meteors and going over near a bog swatting mosquitos, listening to frogs, looking at the sky and I'm dreaming and imaging. There are people for whom that's not a part of their life.

[Gentle chimes ring]

CS: I beeped for Professor Elizabeth Roemer. It's my first year in grad school at the Lunar and Planetary Labs, Department of Planetary Sciences at University of Arizona. And there's phenomenal professor, Elizabeth Roemer who's famous for doing astrometry, precision measuring of star positions, but especially comet and asteroid positions. Turns out to be really important because a lot of comets

and asteroids are so faint that you can see 'em once, if you don't keep following 'em you lose me. Well, this is 1974, September, October of '74 and I'm taking a class with her. I'm taking a class under the world's most important astrometrist and comet specialist, there's only two or three other people in the class. A month or so in she says, I'm going observing up on Mt. Bigelow, anybody wanna come along? It's one point six meter telescope. This is a big telescope and I have a chance to go observing with her. Well, I immediately raised my hand, I say sure and two, three people in the class look at me like I'm a Martian. You wanna go observing? So Friday night, go up in the hill, go to Mt. Bigelow, just outside of Tucson and it's cold up there. It's up [laughs] a thousand or so meters and it's hot in Tucson but it's cold up there so I dress warm and get there. It turns out that in order to figure out the position of an asteroid you have to let the light from the asteroid fall on a glass plate. But the asteroid's moving and it might be like a 19th, 20th, magnitude object which is so dim that you can't even see it. So, how do you take a picture of a really dim asteroid? Well, you have to let all the fall on one point on the photographic plate, but the asteroid's moving so while the telescope is following the stars you have to carefully move the glass plate, the film, to follow the asteroid. Okay so the frame of reference is the motion of the stars, and I have to slowly offset a glass ten by ten inch plate to follow the motion of the asteroid. Ahead of time you've spent a week doing linear algebra to figure out just how much to turn it. So, Professor Roemer is there behind the telescope, brings out this hyper sensitized nitrogen baked plate, mounts it in the telescope, opens the shutter and she will for the next eight hours very carefully offset guide this telescope with crosshairs following a dim star and very carefully manipulating the telescope so this star is exactly on the crosshair. Meanwhile, every forty-three seconds she has to turn a knob on the side of the plate holder that turns a lead screw that causes the plate to move a fraction of a millimeter to follow the motion of the asteroid. Yep, Brady, my job was every forty-three seconds to say, beep!

BH: What, you had a stop watch and you were just like just saying, beep every forty-three seconds?

CS: I was watching the the sweep second hand of a clock in the observatory every forty-three seconds from 8:30 at night until five o'clock in the morning. Every. Forty-three. Seconds. Beep. That was my introduction to professional astronomy.

BH: Do you tell that story to make me think, oh the drudgery, or was that a thrill for you because you were helping this celebrity astronomer?

CS: Imagine how you would feel if you'd come all this way and you meet this person who's essentially your hero and you spend a full night counting off forty-three second intervals... I mean a Kodak darkroom timer could do a better job than I was. I mean it was 1974 but I could have built an electronic gizmo to turn this damned knob a half turn every forty-three seconds. I didn't need Arduino to do that. This is... a simple RC circuit could do it. I'm realizing that wait a second, it's the surgeon having a medical student here doing the scut work just so that you realize, oh yeah, [raspberry] you got a long way to come kid. It wasn't six months later that a radio station calls up the Lunar and Planetary Lab and says, we hear that there's a meteor shower that's gonna happen tomorrow night, and what should we do? And nobody's around so I answer and say oh the best thing to do is go out in the desert, bring a sleeping bag, pillow, bring your sweetheart, lay on the back, watch the sky and look for meteors. Next morning Professor Elizabeth Roemer is threatening to kick me out of grad school for speaking to the public something that only a professor should do. Again a real introduction to professional astronomy. And it hearkened back to, yeah, put your homework over here, sit in the third row, fold your hands and pay attention. Yeah. There's a lot of that in the world.

[bell chimes]

BH: Now in 1986 something happened that would change Cliff's life and it was the start of something which would actually change the way everyone used

the internet. At this point working at the Lawrence Berkeley National Lab, Cliff's supervisor asked him to investigate a minor accounting error, just nine seconds of computer time, that hadn't been paid for, and turns out this was the key to finding a hacker, but this was really before the days when any knew anything about hacking. Computer security just, well, it wasn't really a thing. Cliff launched his own investigation. He set traps. He monitored the mysterious intruder. Eventually tracking him down to West Germany. It turns out this guy was stealing and selling American military secrets to the KGB. Cliff's adventures brought him into contact with people at the FBI, CIA, NSA... but even these people didn't really always appreciate what a big deal it was. But eventually Cliff won the day. The hacker was arrested and put on trial and when the story broke, Cliff was famous. He's still kind of famous for this, and he wrote a best selling book about the whole caper, it's called, *The Cuckoo's Egg*.

CS: Who wants to be a celebrity? Not me, certainly not you, I don't give a damn about celebrity. I do care about getting the word out. I don't wanna be known as, oh you're the guy that caught [gibberish] but I do care people realize oh we have insecure computers. I do care that this new thing called the Arpanet, the internet, allows computers not only to link with one another but allow security holes in one computer to cause problems for someone else. It's not, oh wow you're a celebrity, you're famous! No! No! No! No! No! No! That's not what I want, it's one of the few things that I learned in grad school was if something happens write it down. If you don't write it down, it might as well not have happened. But, beyond that, publish what you've learned. If you don't tell people about it'll happen again but it'll happen to somebody else in a worse way, or better way. So I felt, yeah, caught this hacker, I had no idea that there were such things as computer security problems. There were no books on computer security and I figured well I'll write a scientific paper about it. Wrote a refereed article in the *Communications of the ACM*. What is it? The Association for Computer Machinery called, *Stalking the Wiley Hacker*, [laughs] friend of mine [laughs] Richard Mueller up at the Lawrence Berkeley Labs, Richard says to me Cliff you oughta write a book. You know, I say dunno how to write a book, I

don't know how to write. I would't know what to do. He says it's real easy to write a book. What you do is you write an outline. For every chapter of your book, make a paragraph then write a complete one full chapter. Not the first one, not the last one, some middle chapter, write a biography of yourself then mail it to this guy in New York. John Brockman, he's a book agent. So I just caught this computer hacker, it's 1987 or so.

BH: It hadn't been in the newspapers yet or anything?

CS: Hadn't been in the newspapers. You know, the FBI kept calling me up saying don't say anything. The NSA said oh don't say anything! The CIA said don't say anything! My boss says don't say anything. So I'm good at keeping my mouth shut... except around you, Brady. [chuckles]

BH: [chuckles] Yeah of course.

CS: So I start writing this book proposal and I figure I wanna write a book called Fundamentals of Computer Security in a Networked Environment.

BH: Right... not catchy but alright.

CS: And chapter one, you know, what's a computer, what's a register stack, what's a disk drive, you know, what's boolean logic. Chapter two, what's a program, what's a compiler, what's an operating system. Chapter three, what's a network, what's the internet protocol, what's the Arpanet. Chapter four, what's security, what's coding, what's cryptography, one way trapdoor functions. So I just write this outline... twenty-three chapters and send it to this guy John Brockman, he's a book agent. Three days later I get phone-call, no kidding, looking for Cliff Stoll. This is Cliff. Brockman here, got your book proposal, can't sell it, you don't know how to write. And he hangs up.

BH: Right?

CS: And I say, welp, perfectly fine and I go back to doing astronomy and physics at Lawrence Berkeley Labs and a week, a month, two three months goes by and somebody in Germany, well all this stuff's been kept hush hush, secret. Somebody in Germany leaks the story to somebody who leaks the story to the New York Times. One Monday morning, it's Monday morning, and front page of the New York Times, above the fold, Berkeley Astronomer Cracks Computer Spy Ring.

BH: Had they not spoken to you? Did you not know that was coming? Had they not interviewed you?

CS: No! My logbook at had been leaked in Germany. Front page of the New York Times, above the fold, it's four o'clock over here in Berkeley. My phone rings, oh I'm looking for Cliff. This is Cliff. Brockman here! Lemme sell your book! Lemme sell your book!

BH: [laughs]

CS: Huh? [big breath] Lemme sell your book! You're famous! You're Hot! Front page of the New York Times [gibberish] Berkeley Astronomer!

BH: [laughs]

CS: huh? [pause] Yeah! Lemme sell your book! Lemme sell your book proposal! John I can't write any better today than I could three months ago. I don't care you're hot today! [gibberish]

BH: Tell me you didn't give him the deal? You didn't give him the book deal?

CS: I say... yeah go ahead just leave me alone, let me go back to sleep.

BH: [laughs]

CS: Eight hours later, this guy calls back, he sold this book proposal that three months ago he wouldn't blink an eye at. He sells it for forty thousand bucks! And this is twice my salary.

BH: But you didn't write the book in that dry method that you just aligned a moment ago, did you?

CS: I sure did.

BH: Did you?

CS: I got out the outline, you know, he calls back eight hours later. Sold your book, forty thousand bucks!

BH: But Cuckoo's Egg the book is not... has got a bit more narrative to it, doesn't? It's a bit more exciting than this is what a computer is. [laughs]

CS: So I start writing. chapter one, what's hardware, what's a register stack. chapter two, you know, disk drives and all stuff and get through four or five chapters, friend of mine Guy Consolmagno comes by, we've known each other since grad school, we're in the Lunar Planetary Labs together. We've known each other for ten, fifteen, twenty years. He comes by, he says he's joining the Jesuits. Oh! Brilliant astronomer, wonderful friend, and so you know, so I say well I'm gonna become a published author. Guy looks at me and says, wow that's absolutely cool, what are you gonna do? How are you gonna do it? And I say well, you know, like this, he wants to see my manuscript. So I show him the five chapters and he starts paging through it and he gets through four or five chapters, he says, looks up at me and he says, Cliff, this is terrible. You don't know how to write. And I say, I don't care, they're gonna pay me forty thousand bucks! They bought this book proposal. And Guy looks at me and says, Double

Day's gonna sell six hundred, maybe seven hundred copies to every computer jock in the world. And I say, perfectly fine by me. Guy says, Double Day doesn't wanna sell four hundred or five hundred, they want sell four thousand! Five thousand if they can! You know, I say well all I can do is write what's in the proposal and Guy says, no no no no no no no no no no, there's a problem with your proposal is it's all about computers. And I said, that's the whole thing, I chased down these computer security problems. Guy says no no no no, it's not about computers, it's about people. And I said no, no it's not about people, it's about problems in this software, in this UNIX system. Guy says, no it isn't! It's about these hackers. It's about these Stasi agents in East Germany. It's about these fools who are leaning on you in the government. It's about these people at the NSA, it's about these CIA spooks, it's about this FBI agent who won't help you. It's about these people in Berkeley who are skateboarding on Quaaludes! It's about this bunch of people you're living with. It's about the little commune, it's, you know, about Berkeley life. It's about astronomers that you know. It's about you. And I say... not it isn't. It's about register stacks, it's about disk drives. So Guy and I, we would walk around Berkeley, and spend a day and he says you know, I can't help you. Go find a book on how to write. So we go over to a bookstore, find a book, How To Write, and Guy points to it and says look, what does it say? And this book by a guy named Bill Stott, something about write to the point or something like this. And it says, whenever you write a paragraph, use the magic words. Well, what are the magic words? He, She, They, Them, Us, We, but most importantly I. Don't let a paragraph or a page get by without talking about people. It goes on, says, you know what do you do when you can't figure out what to say? You ask a question. And you spend the rest of the page or the rest of the paragraph answering the question. When you come to a stopping point, oh figure out what's cool, what's interesting, or who's doing what. Well, all that stuff's easy to do, 'cause, hey I'm a physicist, I keep a good notebook, so I just started telling stories about what was happening meanwhile, whenever I got tired of it, I'd go back to writing a book about computer security, writing a book about how we caught this hacker and how you did it Berkeley. And so, thanks to Brother Guy [laughs], I finished a book... [laughs] I would have

never guessed it.

BH: How did you like the moments of fame where you were on the road and meeting VIPs and telling your story to big crowds? Like it must have been a really interesting experience, it must have given you opportunities you would never have had otherwise?

CS: [sighs]

BH: No?

CS: No. But Guy... a physicist friend, comes up to me and says you know, fame is a lot like a kiss. You know when it's coming. You know, you could just feel that a kiss is coming. And while it's happening, boy it takes your brain away from you and all you can think about is this kiss. But you know yourself that when it's over with you're gonna have to live with yourself. You're going to have to be a person that hopefully has integrity. Hopefully has a sense of where they're going and where they've been and you can't [snaps fingers] call upon the genie to make this experience happen again. This guy, be very careful of that. Figure out in advance who you want to be because these experiences are transformative and it's real easy to get rock star disease. You actually think that you're important because, oh, momentarily all these TV cameras are pointing at me. But you know, in a few months or a year, those TV cameras are going to be pointing at somebody else. Realize that you can't, you shouldn't, try to extend that. No, use that, put it behind you, become who you wish to be. Work hard to become more of who you are. And in a phenomenally indirect way that's given me the license, of all things, to fool around in mathematics. Topology. To make Klein Bottles. I've done a lotta things! How should I put it? [pauses] I don't wanna give 'em a standing target. You know, people are throwing tomatoes at me and I wanna make sure they mostly miss. I want to keep exploring the universe around me.

[bell music chimes]

BH: Why Klein bottles? Why has that become your thing? What is it about them?

CS: It's not my thing. I enjoy mathematics and topology. I'm... tickled and delighted to supply math fanatics with one-sided surfaces. I'm not a mathematical researcher. To me the joy of it is, it's a chance to meet smart mathematicians and learn from 'em. It's a chance for me to go and read books about these things and say oh, now I sort of understand what homeomorphic really means. Or, no I got that one wrong. I gotta think about what a contractile system around a point is. It's a chance to learn and do something that I haven't done before. And like practically every other field its arbitrarily wide, arbitrarily deep and high. There's huge amounts to learn and that I have learned. Why Klein bottles? Oh, years and years... forty, fifty years ago, I tried making a Klein bottle in high school, in the chem lab, broke a lotta glass, cut myself, burnt myself tryin' to bend pyrex tubing and you know, said oh this doesn't work, and then later on as an undergraduate, made a couple Klein bottles that were more or less, mostly less, successful and you know '72, '73, I actually wrote a silly paper about doing this and then later on in grad school asked a bong maker to make Klein bottle for me, it was an absolute disaster. [scoffs] Guy took my twenty dollar bill and hadn't occurred to me that... bong makers oftentimes were bong users. Twenty dollars went up his nose probably and I made some other Klein bottles of various materials when I was a postdoc but then after this thing with the hacker died down, I realized you know, I can fool around and make a few of these.

BH: Are you a business man? Are you entrepreneurial? Like you've got so many of them and you sell all these different variations and you got a really fun website, but it is a little business....

CS: It's fun! It's business in the extent that yeah, money exchanges hands and... Brady, you understand this. Of all people you understand this, you're not

doing this, oh for money! You're doing it because it's a gas when a fourteen year old kid starts talking to you about topology and they're smarter than you are and they know more! And you're learning from them, or someone's giving a Klein bottle as a wedding gift to a couple and say you know may your lives intertwine like this, be one-sided... it just gives me nice nice feelings. It's a chance to meet fascinatingly wonderful people. Not to mention to do a little bit of artistry in glass. A little bit of burning my fingers and not a week and a half ago somebody comes over here and you know, wants a Klein bottle, so we spend fifteen, twenty minutes, I show her a bunch of Klein bottles, and ask her what she's doing [gibberish] then pretty soon she's teaching me about the Cantor Set. Well, I knew something about the Cantor Set and Cantor Dust. And she says, oh but you don't know about the Fat Cantor Set, and I hadn't realize there was such a thing. And it's the ingredients of thinking in the middle of the night. You'd wake up in the middle of the night instead of thinking err this thought that thought, I'd start thinking what does it mean to have zero measure. What does it mean to have a set that when you add up an infinite number of points you still have nothing? It's just good stuff like this.

BH: Tell me about being a Youtube star, how do you like doing Youtube videos?

CS: Oh how do I like doing them? Well, Brady, you're there for all of 'em.

BH: I am.

CS: It's fun. What I think others are unaware of is... not all... but many of the things that you come by and I start talking about, it's a chance for me to learn math. It's a chance for me to make a mistake and have people call me up and say hey, you got that wrong, Cliff! And I say, oh, you know, I didn't know that part. I did something or other on curvature of pizza and guy comes over and we're talking and he says oh yeah you mostly understand what Gaussian curvature is but what you don't understand is [gibberish]! And I hadn't... I didn't have it all

wrong but I had a couple things wrong and wow it was so neat to have a better understanding. Being a star, that goes no where. It's like going back a little bit, the people that I'd like to [pauses] impress... no that's the wrong word. The people that I would like to show these Youtube videos to and say, look what you've done, are my teachers. Ms. Forenz. Ernst Both. Jerry Nelson. The people who have left their finger prints all over me. For me the joy of being known online, or elsewhere, isn't, oh look at me! Look at me! But rather, hey teacher of mine, your work wasn't in vain. One of the seeds that you planted turned into [whispers] this guy that makes Klein bottles.

[gentle bell chimes]

BH: Let's jump forward to the mid 1990s now and Cliff, still famed for catching a hacker, writes another book called Silicon Snake Oil. He's skeptical about the internet. He also writes a short essay on the topic and that gets published in Newsweek. It's this essay about ten years later which is dredged up by bloggers on the website BoingBoing. They poke fun at Cliff's misguided predictions. Although, I've gotta say another thirteen years have since passed and some of Cliff's other predictions ended up being somewhat prescient. Anyway, I'm not gonna read the whole essay now, but I am gonna read a few chunks of it. I've included parts that are gonna well... [laughs] maybe slightly embarrass Cliff, but in fairness I've also included some of his predictions which, when you consider they're nearly twenty-four years old now, well I think some of them are rather insightful.

[gentle piano music]

BH: The truth is no online database well replace your daily newspaper. No CD-ROM can take the place of a competent teacher and no computer network will change the way government works. Consider today's online world, the Usenet, a world-wide bulletin board, allows anyone to post messages across the nation. Your word gets out, leapfrogging editors and publishers, every voice can

be heard cheaply and instantly. The result? Every voice is heard, the cacophony more closely resembles citizens band radio, complete with handles, harassment and anonymous threats. When most every shouts, few listen. How about electronic publishing? Try reading a book on disk, at best it's an unpleasant chore, the myopic glow of a clunky computer replaces the friendly pages of a book and you can't tote that laptop to the beach. Yet Nicholas Negroponte, director of MIT media lab, predicts that we'll soon buy books and newspapers straight over the internet. Uh... sure. What the internet hucksters won't tell you is that the internet is one big ocean of unedited data, without any pretense of completeness. Lacking editors, reviewers or critics the internet has become a wasteland of unfiltered data. You won't know what to ignore and what's worth reading. We're told that multimedia will make school work easy and fun. Students will happily learn from animated characters while taught by expectedly tailored software. Who needs teachers when you've got computer aided education? Bah! These expensive toys are difficult to use in classrooms and require extensive teacher training. Then there's cyber-business, where promised instant catalog shopping, just point and click for great deals, we'll order airline tickets over the network, make restaurant reservations and negotiate sales contracts. Stores will become obsolete. So... how come my local mall does more business in an afternoon than the entire internet handles in a month? Even if there were a trust-worthy way to send money over the internet, which there isn't, the network is missing a most essential ingredient of capitalism. Sales-people. What's missing from this electronic wonderland? Human contact. Discount the fawning technobabble about virtual communities. Computers and networks isolate us from one another and network chatline is a limp substitute for meeting friends over coffee.

[gentle piano music]

CS: In the mid 90s my wife and I had two children and I found raising kids to be so much more interesting than anything that was online, meanwhile there was an enormous amount of hyperbole about our world will be transformed for the

better by the wonders of computers and networks and I was skeptical as I am skeptical of lots of things and I made some pretty stupid rash statements, many of which were absolutely phenomenally wrong. Some of which I'm very sad to say were correct. I'm not disturbed at all by being wrong. You know, I hope I'm wrong often. Probably I'm wrong at this very moment, nor do I preen myself oh I was right about that look I did that... said that right! No, no, no, no neither of these mean anything to me. The sadness comes from seeing people who have such phenomenal potential, so much to contribute, spending huge amounts of time playing video games. Checking in on social networks. And instead of making wonderful cool things, instead of developing things and changing the world, instead they find, oh I can escape from reality into this virtual online or offline world. It's not, oh I'm against computer games, nor is it that I'm against fooling around with systems, rather I really love the idea of people reading new things that will change our world for the better and [sighs and laughs] how can I say that's the direction that I want to see. It's not like oh I'm upset that this is the world that's developed this way or that. No, I'm... the most precious thing I have, the most precious thing you have, Brady, time. It's so easy to waste. It's so easy to spend it on things that don't have meaning or importance. I can't judge for you, you can't judge for somebody else, I can judge in my own life though. I know when I'm wasting time and I know when I'm doing something that's interesting to me. Might be uninteresting to everybody else, I know when I'm making something new or I'm coming up with an understanding of the Poincaré Disk and how things work in hyperbolic space. I'm not saying I'm pushing back the boundaries of human endeavor, no. Poincaré's work's been around for 120 years. Instead I'm saying work to become. Spend your time not trying to acquire. Spend your time trying to become someone more than who you've been.

BH: Cliff anyone who spends time with you or sits in your office like I am now can tell that you're a guy who does a lot of stuff and makes a lot of stuff. I have to know though, how does Cliff Stoll waste time? What's your vice? What's your time waster?

CS: I haven't written an astronomy paper, a physics paper... in a couple decades. I haven't written a mathematics paper... ever! I don't think... my whole life is wasted, I'm not doing anything... I mean I'm constantly building things but will they leave a lasting impression? Nah. [scoffs]

BH: But do you see that as a waste of your time? You don't surely?

CS: I don't know.

BH: You know the tiling you've done in your bathroom was surely not a waste of time, it was beautiful.

CS: It's fun.

BH: What's the thing you do and you kick yourself and go aww that was a waste of time, I probably shouldn't have watched that TV show or...

CS: I probably shouldn't have gone to grad school, huh?

BH: [laughs]

CS: Yeah I would have been a whole lot happier if I hadn't. I'd still be in love with the sky. So, we all look back and say oh yeah... the seventeen craziest things I've done, who can say? Every time you open a door you hear the sound of a thousand other doors slamming nearby.

BH: When you come to the end, like, the end of your time...

CS: Yeah and there's an epitaph...

BH: What should I call you... like would you say...

CS: Well don't call me on the cellphone... the batteries will be dead.

BH: [laughs] No. But will I say, Cliff Stoll was an astronomer, Cliff Stoll was an engineer. Like I would describe myself as a journalist, maybe, or a video creator. What's your like description, what do I call you? If someone say aww, I'm seeing my friend Cliff.

CS: My dream in high school was I wanna get my HAM radio license. Got it.

BH: You got it?

CS: Yeah. WB2PSX* and later on K7TA extra class ticket, the whole thing, learned morse code to the point where I could send and receive 20 words a minute. Got my radio license. Was licensed to work at an FM radio... what am I talking about? FM means Fine Music and Consistently Fine Music is found at 88.7 on your FM dial, WBFO, the student voice of the State University of New York at Buffalo. Number One now! Number One then, January 15th 1802 this song was number one one one one one... yeah my dream then was I wanted to do radio. Somehow or another I ended up doing radio. I was hanging out with the people who started National Public Radio, and then I decided, no I'm not going to go to Washington, I'm gonna head over to Tucson and go to grad school. I'm gonna become an astronomer! Became when, then became a, computer security jock, became a writer, wrote a book then became a topology entrepreneur, along the way became a dad, a husband, someone who helped put speed bumps on the streets in Oakland, California.

[Ed. Note: American Radio Relay League records show his first callsign as WN2PSX.]

BH: [laughs] but above HAM radio operator?

CS: My wife says, [gentle music fades in] oh on her grave stone carve the

words, The Jury is Still Out. I like that. Uh-huh. Well, I like her too.

BH: I like that. Let's go with that. Cliff Stoll, the jury's still out.

[music swells and fades]

BH: I'll include a few links to bits and pieces, including Cliff's Klein Bottle Business, which is a very entertaining website in itself, in the notes that accompany this episode. I'd like to thank the Mathematical Sciences Research Institute for its support of Numberphile. And this episode was made possible by Meyer Sound, the audio engineering company based not far from where Cliff is in the Bay Area. Meyer Sound aren't here to sell anything, but they're always doing some pretty cool research and projects and you can go read about them anytime on their website, meyersound.com. Again, I'll include a link. Lastly and hopefully not least, you can find out more about Numberphile, maybe even support us on Patreon, by going to Numberphile.com. Thank you so much for listening, and hope to... well speak to you all again pretty soon.

[Music swells again and fades out.]