Rashmi Mohan: This is ACM Bytecast, a podcast series from the Association for Computing Machinery, the world's largest education and scientific computing society. We talk to researchers, practitioners, and innovators who are at the intersection of computing research and practice. They share their experiences, the lessons they've learned, and their visions for the future of computing. I'm your host, Rashmi Mohan. If you think about the underpinning of every secure transaction on the internet today, the answer most likely to come to mind is cryptography. From keyless entry into our cars to every credit card swipe, we rely on and rest easy with secure communication, thanks to the pioneering work by our next guests, the 2015 ACM Turing Award winners, Whitfield Diffie and Martin Hellman.

As the joint creators of the Diffie-Hellman Key Exchange, they introduced the world to the transformative new idea of public key cryptography. Whit has spent a large portion of his career as a security practitioner and has been conferred the fellowship of the Royal Society, is a Marconi fellow, and a recipient of numerous other awards in computing. He's currently a consulting scholar at the Center for International Security and Cooperation at Stanford University. Martin is a professor emeritus of electrical engineering at Stanford University. He's also a published author and a recipient of the RSA Lifetime Achievement Award, inducted into the National Cybersecurity Hall of Fame amongst many other accolades. Whit and Martin, welcome to ACM Bytecast. I'd like to lead with a simple question that I ask all my guests. If you could please introduce yourself and talk about what you currently do and give us some insight into what drew you into the field of computer science. Whit, would you like to go first?

Whitfield Diffie...: Sure. What do I currently do? My interest is in history of cryptography and my work such as it is, is as an advisor to various companies. What brought me into computer science? I wasn't really good enough as a mathematician and I was trying to dodge the draft. So I took a job programming.

Rashmi Mohan: That was very, very succinct. I'm definitely going to dive into that a little bit more, but Martin, I'd love to hear from you as well.

Martin Hellman: Sure. What I do now is best summarized by the subtitle of a book my wife and I wrote six years ago. We are creating true love at home and peace on the planet. I'm also involved with Stanford Center for International Security and Cooperation where Whit is associated. The war in Ukraine is obviously occupying my thoughts right now, working on trying to reduce the risk of a nuclear war and thanking my wife every day for moving me in this direction. How did I get into computer science? I started in information theory, which was my PhD and then there are several missing links that I'll leave out for now. But when I was teaching at MIT in the EE department, 1969 to 1971, Peter Elias, one of the original contributors to information theory, gave me a copy of Claude Shannon's paper connecting Information Theory and Cryptography. And that's

when I realized maybe I could do work in cryptography. And so that's how I ended up here.

Rashmi Mohan: Great. Thank you for sharing that.

Whitfield Diffie: You see, so he skipped over your first question into your second question, and the reason is he only got into computer science because they came to call what we did computer science.

Martin Hellman: Well, the other thing I left out is that when I was at Bronx High School of Science, they had 1620 computers before most colleges had it. This was 1959 to 62, and I assiduously stayed away from that computer because I thought you had to be some weird math genius, which I didn't think of myself as being in those days to program a computer. When I was forced to take a two unit FORTRAN programming course in about 1964, I was shocked to find out how simple it was.

Rashmi Mohan: Oh, thank you. It's amazing how both of you talk about yourself as not being great mathematicians and yet have had such amazing and successful careers in computer science. Whit, I'd like to go back to what you said previously about not being good at math. Also, because I was listening to a bunch of your previous interviews and you talking about not being great at academics. A lot of young students typically feel like a lot of doors close for them because they're not getting the grades that they should to choose a career of their choice. What would your advice be to them? How did you navigate that?

Whitfield Diffie: My advice is to have good luck. I've had incredibly good luck. I don't know how to teach that, but there were two entirely different things. I'm not a very good student. That's very different from not being any good as a mathematician. And yes, of course, I know more mathematics than 99% of the human race. What impresses me is that the best mathematicians I know, and for example my college roommate could solve in a minute problems that took me a day will be counted as nothing in the pantheon of 20th century mathematics. So I say it's a long way up and long way down. Another way of putting it is that I never learned very much about what the activity of mathematics was. So I had read Eric Temple Bell's Men of Mathematics, and thereby had learned to be a mathematics professor of the 19th century and I didn't succeed at doing that. So I had to go into computer science instead.

Martin Hellman: The thing that I would add that people should remember is Albert Einstein had trouble in school. So school isn't designed for everybody.

Whitfield Diffie: There are mixed claims about that. Pais claims he was quite a good student. So I'm not clear what's true about that.

Rashmi Mohan: How did both of you meet? You've obviously collaborated and you've probably brought very unique traits to the table. You've done some amazing work

together. What brought you both together and what did you feel worked as a team? How did you collaborate?

Martin Hellman: Why don't you tell that story, Whit? Because Alan Konheim figures prominently and you were there.

Whitfield Diffie: We were introduced by Alan Konheim. In 1970, my very brief biography in this matter is I got seriously interested in cryptography. I got interested in cryptography for the last time in my life. It was about the second or third time I got interested. It was the time it stuck in the fall of 1972, so it's been 50 years ago and in the spring of 73, I left the artificial intelligence laboratory at Stanford and began driving around the country. The first discovery I made was my wife, without whom I believe I wouldn't have discovered anything else, and she and I began traveling around together. And the summer of 1974, we visited the IBM laboratory at Yorktown Heights, which was the only significant non-government cryptographic group in the country at the time. And the head of the mathematics department, which was what was doing cryptography there was Alan Konheim and he said, I can't tell you anything. We're under a secrecy order here, but when you get to Stanford you should look up my old friend Marty Hellman.

He subsequently wished he never said that because we became a great nuisance to him. But when I got back to Stanford, I called Marty from Oakland where I was living with Leslie Lamport as in this is a small world, and Marty, as I recall, graciously granted me half an hour of his time on what I think of as a Wednesday afternoon, though I'm not certain of that. And Mary and I drove down to Stanford and she took the car and went off and she knew better than a half an hour. So at six she called and Marty invited us over to dinner. And as families we got along very well, and Marty and I worked together for the next four years, I became a graduate student because it was the cheapest way of supporting me. And in four years I took four courses and wrote four papers and I've forgotten what the courses were, but I've been making a living off the papers for the last 50 years or so.

Martin Hellman: I've described Whit as being ABC. Most people don't get a PhD because they're ABD, all but dissertation. Whit was all but courses because he did great research, but as he said, he had difficulty with courses when homework assignments were assigned, he would get under his Datsun and work for hours to avoid doing what anybody had told him to do. He's very independent.

Rashmi Mohan: That's great. That's great to hear. And it's amazing to hear what he talks about in terms of saying, Hey, the research work that I did has really taken the direction of my life. So Marty, in your thoughts, I've heard so often from entrepreneurs and from others that finding the right partner in order to be able to solve a great problem is the most key thing and the most difficult thing. In your case, you both found each other. Is this a problem in terms of the world of cryptography? Is that something that you had already envisioned as something

you wanted to solve or as you both got together the problem started to define itself

Martin Hellman: More the latter. I wasn't looking for anybody. All my colleagues told me I was crazy to work in cryptography. In fact, I have a talk on the wisdom of foolishness. It turns out most of the great breakthroughs are seen as foolish apiary. I was honored to address the annual meeting of Nobel Laureates three and a half years ago, and I asked five of them before my talk whether the work that won them their Nobel prizes had been encouraged or discouraged as crazy, four to five crazy. So when Rich showed up, just like Alan Konheim said he should see me. So I set up this half hour meeting, but it was clear, almost immediately, that there was a real meeting of the mines. Whit was interested in the same things I was, I was interested in some different things, which is why we ended up going to 11 o'clock that night. There's no question that finding Whit was a key part of my life and my contribution, although I didn't know it at the time.

Whitfield Diffie: My description of it is that each of us found the other one, the best informed person willing to talk about cryptography that he had encountered.

Martin Hellman: Yes, I think that's a good summary.

Rashmi Mohan: That's great. Marty, also, I know in one of your interviews you had spoken about the fact that you were keen on fighting for the rights of research to be done in a more democratic way in this area for papers to be published in this space and not necessarily have governance over it. Would you care to talk a little bit more about that, why that was important to you and what you were hoping to do with it?

Martin Hellman: Yeah, well, I fell into it, as did Whit I think, originally I didn't think there would be a problem, but then as problems surfaced and the government started to make noises even threatening to throw us in jail if we continued publishing our papers. I grew up in the Bronx and I wasn't a very good street fighter. This wasn't a bad neighborhood, but still I got beat up a lot. And so I became a street fighter with my mouth and my mind and I think that was what the government didn't realize. And I think Whit has a similar personality, so we would just wouldn't back down. we had a choice of either backing down or continuing and it was just obvious that you don't back down. Especially this was right after Watergate. And so trusting the government was not something that people were prone to do.

Whitfield Diffie: Marty, you should read a book called Haunch, Paunch and Jowl. An unsentimental memoir of the Lower East Side. I don't remember who wrote it, but you can find it. It's about somebody who had the same response that you did, applied his brain to becoming tough and grew up from being a gang member to being a crooked lawyer and a corrupt judge.

Martin Hellman: Well, in my case, I never was a gang member, but as I look back on it, no wonder the other kids beat me up because I remember one argument I was having with another kid in the neighborhood, is two is not, is two is not. I'll bet you a dollar I'll bet you a hundred dollars. I'll bet my house against yours. And then I said, You don't even own your house. We lived in a two family house and he lived in an apartment. No wonder he wanted to beat me up.

Rashmi Mohan: Okay. I would love to understand, did either of you have... While you were working on this problem together, do you have an aha moment where you're like, Oh my gosh, this is exactly what we were trying to get to when you got to solving the, or coming upon the concept of public key cryptography?

Martin Hellman: Yeah, I think there were two. Whit had one and I had one. Why don't you tell yours first, Whit?

Whitfield Diffie: So I had been working on two problems. One for five years and one for 10 years. And in modern description, the 10 year one, we would now call key management. I hadn't been devoting much time. I didn't think of myself as working in cryptography. I just had become aware that the problem of negotiating keys, I know how to do it. And then five years after that I became aware of the problem we would now call signatures. And then in 1975 I set out to try to confine the virtues of Unix login with the virtues of what's called identification friend or foe in between radars and aircraft and came up with digital signature. And a few days later I realized if you turned my approach to that around you would solve the key negotiation problem. And at that moment I understood that I had discovered something.

Martin Hellman: So basically Whit came up with the concept of a public key crypto system but didn't have a workable system for either key exchange or digital signatures. And we, along with Ron Rivest, I didn't know Shamir and Adleman and were also working on it with him, and Ralph Merkle independently at Berkeley was working on this as well. And my aha moment was in May of 1976 when by this time we were all talking with one another via snail mail. We did not have email in 1976. I came up one night at this, I think it's this very desk where I'm sitting now with what's now called Diffie-Hellman Key Exchange. I was playing with discreet algorithms. John Gill had suggested them to me. [inaudible 00:14:51] Manuel Blum students at Berkeley and he was a colleague of mine here at Stanford and Assistant Professor of electrical engineering. And I was playing with [inaudible 00:15:00] to the X trying to turn it into a public key crypto system. And well and behold, I came out with a Merkel public key distribution system instead, which is now called Diffie-Hellman Key Exchange.

Rashmi Mohan: That's incredible. Did you imagine the absolute widespread use of your work when you first came up with this idea?

Martin Hellman: Well, Whit came up with the first sentence of our paper, new directions in cryptography. We stand today on the brink of a revolution in cryptography, and

that was 1976 that we wrote that. We thought that within five or 10 years, commercial cryptography would take off. It took more like 10 or 20. In fact, the internet in the mid-nineties really is what catapulted it. Today, public e-cryptography protects over 6 trillion a day in foreign exchange transactions alone. Plus our piddling banking transactions and digital signatures are essential to software updates, trusted authentication, things like that.

Whitfield Diffie: Internet commerce in general.

Martin Hellman: Oh yes. E-commerce in general would not be possible without public e-cryptography.

Rashmi Mohan: Have you both been involved in the evolution of the algorithm that you first came up with and continuing to see how it's evolved and especially in the use cases that we currently encounter? How have you stayed engaged?

Martin Hellman: Well, Whit's been more engaged in it than I have. Remember this was 1976, 1980, my wife and I got married in 67. Whit screwed our relationship up pretty well. She was ready to leave me, although I didn't know it, and she decided not to and was instead looking for catalysts. And she got involved with a group called Creative Initiative that morphed into a group called Beyond War in which we worked starting in the 80s. I really shifted my interest starting around 80, 81. I was just involved in the early days of it intensively, whereas Whit has stayed more deeply involved.

Rashmi Mohan: Okay. I would love to touch upon that as well, Marty, but Whit did you have more to add in terms of how you found yourself continuing to stay engaged in the world of cryptography? What did you feel, how it was evolving?

Whitfield Diffie: Well, yes. The one very big thing that happened over these last 30 years is that it turned out, although RSA, the crypto system Rivest, Shamir and Adleman developed has continued to be tremendously important. Diffie-Hellman is so to speak, more flexible and there was a transformation that Diffie-Hellman is less done these days over the finite field we imagined and done using what's called elliptic curve cryptography, but the protocols were all the same. What I did over my career was work on... I morphed into an cybersecurity person because I had the same job at two different places. I was the quote manager of secure systems research for the Canadian telephone System, and then I was Chief Security Officer for Sun Microsystems. And both of those are a matter of applying cryptography and other security techniques to solving real problems.

Rashmi Mohan: Right. Yeah. No, absolutely. I was reading about you being in that Chief Security position. Did that ever morph into building algorithms beyond just the organization and thinking about security from the organization's perspective, how did your research evolve?

Whitfield Diffie: I actually did design a cryptographic device one time. Northern Telecom manufactured it.

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So Marty, maybe going back to your own thoughts around, I know that you've been doing a lot of thought around rethinking national security. I was reading a little bit about your work and your interest in that field. I'm wondering if you could talk more about it. I know there's a personal journey associated with it, but you're also thinking about it at a much more global level.

Martin Hellman: Well, the two really go together in the book we wrote and people can download a free PDF from my Stanford website. One of the sound bites is Get Curious, Not Furious. And so when Dorothy, my wife, used to do things that seemed crazy to me, I treated her like she was crazy in the old days, which drove her crazy, which convinced me I was right that she was crazy and it was a feedback loop. Now I go to her and I ask questions. I say, I can't get over feeling that what you're doing is crazy, but I know you're not. What am I missing? Every time she has a different way of looking at it, just a [inaudible 00:19:58] view.

And the same is true internationally. And so we need to ask more questions. And the evidence that the societal method of managing marriages or international relations is not working, there's a 50% divorce rate that shows that at the marital level, if you look at the wars that the United States has been involved in over the last 40 years, every single one of them, I believe, has been needless and has hurt our national security rather than helped it. And yet we don't learn from our mistakes. We really need to rethink national security. And I'm very honored that a former Secretary of Defense, a former Director of NSA who wanted to throw us in jail 45 years ago, now a good friend, Admiral Bobby Inman and a former Chairman of the National Intelligence Council have all signed on to a statement of support for rethinking national security.

Basically in this age of nuclear weapons, pandemic, cyber attacks, terrorism, global environmental crises, we ask is it possible that national security is becoming inseparable from global security of all nations? And if so, how do our current policies need to change? We're convinced that in fact the question has the affirmative answer, but we ask it as a question because that's where we had to start.

Rashmi Mohan: Understood. How do you think this applies to a lay person, right? There's of course been, we're talking about policies, definitely one of the biggest ways that we can influence that is to vote and vote into what we believe is the right causes. But how else do you think an individual can get involved?

Martin Hellman: Actually the best way to get involved is the way I started, which is not trying to make the world a better place. I was standard on that, said I cared, but I didn't really. It was when I was in pain in my marriage. And so the best thing a person can do is to start getting curious, not furious in his or her interpersonal relationships, carrying that over to the international, asking more questions like, what do we really know about the war in Ukraine? What do we really know about Putin? What do we really know about Zelensky? And it turns out many of the things we think we know turn out not to be true. Some of them are, but not all of them.

Being more inquiring, especially before we go killing people, we need to really think things through. We have not done that as a nation, and it's not that the United States is uniquely damaged that way, every nation behaves that way. But as an American, I try to change my own nation because that's where I have some hope of doing it. And I think everybody has that opportunity. Everybody has the chance not only to write to their congressman or congresswoman, but to meet with that member of Congress. On my rethinking national security page on my Stanford webpage, there's a link to what you can do and the last item is to meet with your member of Congress and it explains how you might bring that about and that can really make a difference.

Rashmi Mohan: Got it. Yeah, we'll definitely share the resources, but that's very insightful information. Seeking the answers, making sure that you fully understand them before you can act upon them. Great advice.

Martin Hellman: And just one thing to add, I've been very amazed that when I talk to people who are part of the national security establishment, a number of them have told me that reading my report on rethinking national security, which examines, I think a dozen assumptions that masquerade is self-evident truth, one man told me that his brain was clicking the whole time. It's things that he hadn't really thought about and whether we need to think about

Rashmi Mohan: That is amazing and I'm really looking forward to all of the resources that you're going to share.

Martin Hellman: There's a connection back to public key cryptography. It's questioning assumptions. There was an assumption in cryptography that you couldn't have a public key. In fact, when I talked to Horst Feistel, who was one of the key IBM people in the area, I only had 10 minutes with him before we had Diffie-Hellman Key Exchange. He said, you can't do that. And that's because there was a general rule in cryptography that all security must reside in the secrecy of the key. So how can you have a public key? Well, you also have a secret key, but that's the thing that people miss. And so many of the great ideas both technical and otherwise come about as a result of questioning the conventional wisdom.

Rashmi Mohan: Absolutely. Yeah, questioning assumptions. I think that's excellent advice. Thank you for sharing. Whit, I'd love to pivot back to you in terms of, I know that you

spend time working with startups or advising entrepreneurs. What has been your experience? What have you enjoyed most about that journey?

Whitfield Diffie: Going to be a standard answer. I get to talk to lots of interesting people working on lots of interesting things.

Rashmi Mohan: You're obviously advising them from a business perspective. Do you do a lot of technical advising as well? Because one of the things that I know we've already spoken about is a lot of startups don't always have the wherewithal to have a large research team, but pairing with maybe academic researchers might be immensely beneficial for them to really further the technology journey that they're on.

Whitfield Diffie: I think my virtue in this field is length and breadth rather than depth. That is to say, I've been watching it personally for 50 years and I have studied its history in a good deal of detail. So I can teach people not just about technology, but about projects and policies and people and so forth. And so I think I bring cryptographic culture with me.

Martin Hellman: I also think one of your greatest strengths is the fact that you question conventional wisdom. You did that continually. You're a rebel.

Whitfield Diffie: Okay. Right. That's why I make snide remarks about my client's work.

Rashmi Mohan: Them inviting you in, they see great value in it.

I'd like to pivot the conversation to ask you, Whit, to comment on what you think might be the effect of quantum computing on the field of cryptography. There are some very dire scenarios that are floating around. I wonder what's your perspective on that?

Whitfield Diffie: If quantum computing comes through the way the physicists are process are promising, and IBM certainly put on a very moving demonstration and discussion at its summit in New York a month ago, it will destroy Diffie-Hellman and RSA, the public key crypto systems that have been the workhorses over the last 40 years. But there is a whole set of new mathematical approaches to these problems, particularly what are called lattice-based crypto systems that are being proposed now as standards to replace the systems we designed.

Rashmi Mohan: Do you think that those are ready for primetime? Not to say that quantum computing is ready for primetime, but what do you feel in terms of how ready they are, how well tested they are to be used in the field?

Whitfield Diffie: I can't report that I've evaluated them and liked them or anything like that. If you look at our experience and this would be the third experience roughly of its kind, that is to say it took our systems one or two decades to be generally accepted. It took elliptic curve cryptography approximately the same amount of

time. So it might take these the same amount of time. I can't tell you, I don't know anything about whether any individual one is going to be successful or not.

Martin Hellman: Something important is even if quantum computing becomes a threat 50 years from now, things that are protected today should still... Many things should still be secret 50 years from now, like your medical records. So I think we really should be paying much more attention to this. Plus we need to be looking not only at quantum computing, but at possible breakthroughs in factoring and discrete algorithms. I've proposed as a theoretician, I can do this, that we should use two key exchange methods, Diffie-Hellman for one, your key distribution centers, which is a classical approach, which has a lot of problems with it, but then you're exclusive or the two keys together, and if either system stays secure, you're secure. And of course this increases the cost, but that doesn't bother me as a theoretician. Then the same way I think digital signatures should use a public key digital signature as well as a Merkle tree signature. You sign a message twice and if either signature stays secure, you're secure. And so I think we ought to be doing things like that as well.

Whitfield Diffie: And Merkle tree signatures have the virtue of not requiring secrets. If you have a secret, you have a vulnerability. Anything that uses secrets has problems.

Martin Hellman: Yes. Tree signatures only rely on one-way functions.

Rashmi Mohan: Got it. Thank you. Thank you for sharing that. So there's a lot of talk around popular messaging platforms introducing end-to-end encryption. What are your thoughts on this topic or any sort of governance in this area?

Whitfield Diffie: Government has undergrown a growth over the couple last few centuries, rather analogous to the growth of the God of the Jews who was once the God of the Jews. And then they eventually decided it was the God of everybody. And government was just one element of society and now thinks it is the essence of society. And so it thinks that what government doesn't want or would make some of its work inconvenient it shouldn't have. And I think that individual rights, privacy, autonomy are what government exists to assist in and are not things that should ever be compromised toward government's convenience.

Rashmi Mohan: Marty, do you have more thoughts around the end-to-end encryption as well?

Martin Hellman: Let's talk about what are usually thought of as back doors and phones and things like that. It's interesting that 20 years ago, 30 years ago, both NSA and the FBI wanted weak encryption or wanted this back door, I would call it a front door, since everyone knows that it's there. Whereas more recently, it's been only the FBI that's been asking for it, and former Directors of NSA have actually said that they're wrong to want that. And I think there was a report by a number of cryptographers, including Ron Rivest called Keys Under Doormats. And I think that describes it well. I don't see any way you can build in this back door, front

door to a phone without creating keys under doormats, basically, it's a very dangerous thing to do.

And the other thing I would say is that when the FBI says, all they want to do is go back to the good old days, when they got a warrant to wiretap, they could wiretap, well, today maybe half the stuff they intercept is encrypted, but they're also getting a hundred times more information than they got in the old days. They have automated license plate readers, they've got the security cameras that record. They're probably getting a hundred times as much raw information, half of which is unavailable to them, which of course frustrates them. And I wish there was a way to give it to them, but there isn't. They're still getting 50 times more information than they did in the good old days under that simplistic assumption.

Rashmi Mohan: That's a fair point. Yeah. I know an interest of time, Whit, do you have any thoughts for our final bite? What are you most excited about in the field of technologies over the next five years?

Whitfield Diffie: Field of technology is a bit too broad. Having seen the first moon launch since my relative childhood the other day is incredibly exciting. I frankly think biotechnology will transform the world in a way that nothing we previously have done holds a candle. I don't think human beings are going to be running the world at the end of the century. And I think all sorts of other questions like should we have man space flight or unmanned space flight will dissolve into a doubt about what's a person or what isn't. I'm not so current with contemporary artificial intelligence, but it seems to me clear that computers are going to outthink people in the near future in quite a number of different ways. And so all sorts of things are exciting.

Rashmi Mohan: Marty, what about you? What are you most excited about over the next five years?

Martin Hellman: The thing that excites me the most about technology is how it's forcing us to grow up. The real problem is not nuclear weapons. They're a symptom of a underlying problem, which I'll get to in a second. Similarly with cyber-attacks, global warming, which has a tremendous public concern, all of those are symptoms of a deeper underlying problem. Technology has given human beings what has traditionally been thought of as God-like physical power. In the Bible, only God was supposed to be able to destroy Sodom and Gomorrah with thunderbolts, we call them nuclear weapons. Only God was supposed to be able to create a flood that would necessitate Noah building an arc.

I'm not saying these stories are true, but taking the biblical stories. Whereas technology, climate change is threatening flooding on that level. And so the real problem is not nuclear weapons or climate change or any of the cyber-attacks, it's the chasm between our God-like physical power through technology and our best irresponsible adolescent behavior as a species. And I sometimes liken

humanity to a 16 year old kid with a new driver's license who somehow gets his hands on a 500 horsepower Ferrari. We're either going to grow up really fast or we're going to kill ourselves, and I'm working to make sure that we survive and we grow up really fast rather than killing ourselves. So that's what excites me.

Rashmi Mohan: That's a wonderful analogy. Thank you so much for sharing that, and this has been an amazing conversation. Thank you both for taking the time to speak with us at ACM Bytecast.

Martin Hellman: Well, you're welcome. And thank you for pulling together your questions. You obviously did a lot of research on us.

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