



Envisioning the Future of Software Engineering

Featuring Anita Carleton and Forrest Shull

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Forrest Shull: Welcome, everybody, to the SEI Podcast Series. My name is [Forrest Shull](#), and I am the lead for Defense Software Acquisition Policy Research here at the Software Engineering Institute. Today I am pleased to welcome and be here with [Anita Carleton](#), director of the Software Solutions Division at SEI. We are today to talk about the new study, [Architecting the Future of Software Engineering: A National Agenda for Software Engineering Research & Development](#). This is a major report that we here at the SEI just recently completed to re-envision software engineering and create a roadmap for future research and investment. So welcome, Anita. I suppose I should say too before we get started, I was part of the team that worked on this study, so I'm familiar with this, but hopefully I'll be able to have a conversation with Anita and bring out some points that everyone else might not know just yet. But anyway, great that you could be here today, Anita.

Anita Carleton: Thanks so much, Forrest. I am looking forward to the conversation.

Forrest: Great. Just by way of introduction, Anita, why don't you give folks a little bit about yourself, your background. Actually, I will say, what is the best part of your job here at SEI?

Anita: OK. Well, sure. It's hard to believe it, Forrest, but I recently celebrated 33 years at SEI, which I am incredibly proud of. I have held various technical and senior leadership roles here at the SEI. My current role, as you said, is leading the software engineering portfolio at SEI. But I will say this, being at the SEI 33 years means that I have seen the software engineering field evolve and advance quite a bit. The original and ongoing mission of SEI is to provide leadership in advancing the state of software engineering practice. But delivering on that mission called first for the SEI to contribute to establishing a discipline for software engineering. I will say that I have been really fortunate to have had the opportunity to contribute to establishing this discipline for software engineering by developing, applying, transitioning models and analysis techniques for software lifecycle approaches that were designed to yield high-quality software and high-performance teams through some of the early [Capability Maturity Model](#) work and some of the [Team Software Process](#) and [Personal Software Process](#) initiatives.



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The other big area of research interest for me has been leading the [software measurement](#) body of work. And, in our earlier years, our foundational work then was in defining the SEI core measures, establishing measurement definitions, and a whole measurement program for the Department of Defense to facilitate data-driven decision-making. And I know that is something near and dear to your heart as well. But as a consequence of our earlier foundational work, the SEI established tenets for modern software engineering practice in [software architecture](#), [assurance](#), formal analysis, virtual integration, [DevOps](#), automated code analysis and testing, as well as the measurement and analysis work. And so while the software ecosystem continues to continuously evolve through these new technologies, I think the SEI's mission remains the same, to lead and continue working closely with the software engineering community worldwide to continue to invent, build, evolve, and advance these software engineering tenets.

Something else that you asked me then is, What's the best part of my job? That is easy, Forrest. Two major things: it's the people and the mission. So let me just say something about that. You don't stay somewhere for 33 years unless you love the people that you work with and you love the mission that you are working for. But I'll tell you, I am really blessed to work with extremely talented and diverse colleagues, not only at SEI and CMU, but across the global software engineering community, through my involvement with [IEEE Software](#), and the [IEEE Computer Society](#). The other really exciting part I think of what I do is that opportunity to work with that broad software engineering research community to help set the research direction for software engineering. That mission is incredibly bold and inspiring to me.

Forrest: Great. Wonderful answer. I think we will come back in a little bit and talk a little bit more about that larger community that you mentioned, because I think that was an integral part of this study. But before we do that, I was going to say, we did have a core team that pulled all this together and I think a lot of really talented people and a lot of energy really went into it, I know. But it seemed to me at least that the original idea of this study and a lot of the effort that it took to get it off the ground and rolling along was really yours, Anita. So I wondered if you could give us a little bit of a sense of, what was the thinking behind it? Why did you think this was so important to do and to get started?

Anita: You know, Forrest, nothing is ever sort of one person's thought. Yes, I am passionate about this, but when I look at our whole team, we have all been excited, I think, to think big and broad and think about the future of software engineering. But the premise of the study is that the stakes for software are elevated now more than ever. You know the Dunkin' Donuts commercial, I think it says something like, The world runs on Dunkin'. Well, the world really runs on software. It is the connective tissue to everything we do. Software engineering affects everything because software is everywhere. We hear a lot about infrastructure—it is in our nation's infrastructure: defense systems, financial systems, education and healthcare systems, to name just a few. But it is this ever-growing dependence on these software systems that makes it really imperative to maintain our nation's leadership and strategic advantage in software engineering. In addition to devising a research roadmap for the future of software engineering, I think another really key objective that we had was to raise the visibility of software engineering to the point where it receives that sustained recognition and investment that is commensurate with its importance to national security. Not unlike the strategic investments that we are seeing that the U.S. has made in [AI \[artificial intelligence\]](#) or domestic chip manufacturing, and then even the more recent discussions that we



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are hearing in the news about hypersonics. So that is really the premise for the study and the premise for Why now?

Forrest: Good. I was going to say, too, I think that really matches a lot of what I am seeing in my own work that I do within the Department. Certainly, a lot of senior leaders are recognizing more than ever, I think, that software is really an integral part of this. There is a focus nowadays on trying to get capability out more quickly but still high quality. I think everyone recognizes that software is really the cost-efficient way to do that. And it goes all the way up to the congressional level now, too, because I think we have seen some of the congressional interest in making sure that these technologies move along and get adopted in ways that really do, like you said, serve a national interest. So great.

Anita: Perfect.

Forrest: So coming back, you mentioned the importance of the community, the larger software engineering community, both within the country and then globally, too. I wonder, in terms of that focus, why did you think it was so important to bring the community together? Let's start there, and then we'll go a little bit further.

Anita: Yes. Sure. The focus of the study is that new types of systems are going to continue to push beyond the bounds of what current software engineering theories and tools and practices can support. So as we think about future systems and these fundamental shifts that we're seeing, they are going to require new research focus areas in smart automation, the idea of reassuring these continuously evolving systems, and understanding how to compose these large-scale software systems and of course new system types. We are going to need to think about all the different kinds of application areas and these new system types: [AI-enabled systems](#), these societal scale kinds of systems and [quantum multicore](#) kinds of systems.

But to be able to think about that kind of focus, the study really had to include sort of a future vision, think about research focus areas, a research roadmap, what the key findings and recommendations were going to be. All of those things, we took a lot of time and thought to think about how we were going to derive these ideas and thoughts. And you are going to remember this. We looked at the state of software engineering practice. We looked at the new trends and emerging technologies that were going to be needed to advance the state of software engineering practice. And this is where the community part comes in Forrest that you asked me about. We held a number of workshops with the software engineering research communities. We did a literature survey. We interviewed a number of experts. And we pulled together just the most incredible advisory board. But the idea here was to think big and bold and future. And get really diverse perspectives from across our software engineering community. The researchers, the practitioners, research labs, defense-industrial-base organizations, tech organizations, the Department of Defense, and so on. So to really think big and bold about the future, we really, really had to and wanted to work with the really broad software engineering community.

Forrest: Great. Just out of curiosity, I wonder, I mean, since we had so many of these community conversations, I mean, how would you characterize the tone of the conversation, I wonder? In terms of what I've seen through the Computer Society, for example, has been a lot of anxiety around these things, as well as a lot of excitement about what the technologies can do. So I wonder, was it both? Did it come



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one way or the other in terms of optimism versus pessimism, or how would you characterize the tone do you think?

Anita: I think we heard and saw both, optimism and concern, I guess. Concern that we are not moving fast enough. But optimism in that, as we think about how we are going to create and build the systems of the future, there's all different parts of the community that can weigh in to bring the best ideas. And so as we think about a research roadmap, as we think about future visions, as we think about future scenarios, they are really grounded in so many different perspectives. I think bringing that to the table made this really exciting.

Forrest: OK. And, then, since we've talked a lot now about the future of software too, I think it's important for the listeners... What is the timeframe that we're talking about there from all these conversations?

Anita: Yes, I think that's a really good question. Technology is moving so fast, I mean, we're all living in that, right? New iPhones are coming out, we can't keep up with how fast the new iPhones are coming out, right? But as we think about the future, we're thinking about now. So we're not looking at something like, Oh, gosh, we're thinking about something 10 to 15 years out, but we're thinking about now to five years, to 10 years, to 15 years out. I mean, we're on a lot of these trajectories. But the idea is how do we accelerate moving to these future visions.

Forrest: Okay. So you mentioned a number of times now that one of the key things that came out of the study was the roadmap, which really tried to bring all this information and all the different sources of info together. I wonder if you could talk a little bit about that process? First how the roadmap came to be. You mentioned a lot of these different sources, the workshops, the literature review. Do you want to talk about how you went from that to the actual roadmap itself?

Anita: Well, I think first the process of assembling the study and assembling this report was interesting and not at all what we had, I think, originally planned. Forrest, you have been a part of our team from the very beginning, but COVID-19 really disrupted our original plans. And our plans were originally to convene different cross-sections of the software engineering community at major software engineering conferences and workshops worldwide to elicit thoughts on the future of software engineering. But because of COVID, the entire study was done virtually. So all five of the workshops that we held were done virtually. We held four or five advisory board meetings, they were all done virtually. And of course the writing team, and our own writing team was not just all in Pittsburgh. You are in the D.C. area, and we had [Doug Schmidt](#) in Tennessee. Our writing team was dispersed. So all of that was done through two million Zoom calls. We should have kept metrics on how many Zoom calls it took to compose the final report. I think that the process was really pretty remarkable.

First I wanted to mention the really incredible advisory board that we had the pleasure of working with, the whole collaboration team, from the advisory board to all the people that came to the different workshops, to our author team. I mean, the whole collaboration team was remarkable. Dr. [Deb Frincke](#) was the chair of our advisory board. She is the associate lab director for national security sciences at [Oak Ridge National Lab](#). But we had someone of her caliber that was the chair. We had people like [Sarah](#)



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[Manning Dawson](#), she's one of the CTOs at [Microsoft Research](#). We had Jeff Dexter from [SpaceX](#), who's the senior director of flight software and cybersecurity. We had [Yolanda Gil](#). And Yolanda Gil had put together a similar study, looking at AI and the future of AI technologies just a few years before, so we were lucky to have Yolanda helping and guiding us and sharing what she learned. We had icons like [Vint Cerf](#), and he calls himself the chief internet evangelist at Google. I mean, it was awesome to have Vint. Then we had folks from the defense-industrial-base organizations, from Lockheed and from Boeing, Penny Compton and [Nancy Pendleton](#). We had someone from [Zoic Labs](#). We had [Michael McQuade](#), our VPR [vice president for research] at CMU. We had Tim Dare, who at the time was overseeing the National Defense Authorization Act, Section 255 study, a DoD study, to also think a little bit about the future of software engineering. And then of course we had [Bill Scherlis](#), another software engineering visionary and icon who is at DARPA [Defense Advanced Research Projects Agency]. So that team was remarkable. And then we had researchers from the software engineering community, from CMU, from various research labs. We had Department of Defense senior leaders. We had the opportunity to work with people that looked at how to devise future scenarios. Someone like Keith Webster, who helped us to think about future scenarios to ground our study in. So that was really exciting.

And we also had the opportunity at one of our workshops to partner with DARPA. And Forrest, you know, you were the lead of that workshop, but it was amazing to partner with DARPA, to have keynotes from NSF [National Science Foundation], Dr. Sol Greenspan and others, to also think about software engineering's grand challenges. What were our grand challenges, and how were we going to as a software engineering research community address what these grand challenges were? So those were some of the ways that we brought in different parts of the community to bring innovation and new thinking to the future of software engineering.

Forrest: Great. Until you reminded me, I had forgotten actually that the entire study was done virtually, which I think, you talk about rapid change through software or the pace of change throughout the software world. I think that's one that we all lived. Right? I mean, the ability to go from an in-person world to a virtual one, all built on top of software-enabled technologies. Then to have such a good experience with it that I forget that I never met these people in person is something that is still kind of shocking to me actually.

Anita: Well, it's funny. It really became very seamless. We didn't think about it. It would have been great to build those in-person relationships because we really did meet with so many people over the year. But on the other hand, this has just come out, the study just came out a few weeks ago. I don't even think about how we put that together and that it was all done virtually. It really was so seamless how it all came together. That is a part of our vision for the future, right, Forrest?

Forrest: Absolutely. So that was the process, and we talked about the community and all that involvement, and then it really all boiled down to the roadmap. I am still kind of amazed, actually, in my own head that with all that breadth of perspective and all that breadth of expertise, that we managed to articulate I think a reasonably good storyline where it all comes together to one kind of vision in the future. I wonder if you could say a little bit about what that future vision was and then kind of back up to talk about the roadmap and how that supports it?



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Anita: Yes. That is great. I guess before I dive into the research roadmap or the research focus areas, I think it is important to mention the guiding vision that we had assembled. Because you are right, five workshops, lots of ideas, lots of input, energized by this incredible advisory board, and then further energized by our whole writing team, it was a lot of different things to bring together. Right?

Forrest: Yes.

Anita: And so the guiding vision that we assembled was that the current notion of the software-development pipeline as we think about it, as we know it, will be replaced by one where humans and software, humans and AI, are trustworthy collaborators that rapidly evolve systems based on program or intent. While it may sound eloquent to say that vision, it took us awhile, Forrest, to get there. How do we see that vision? This is how we currently build systems, but what's going to be different about how we build systems in the future? To achieve this vision, we anticipated the need for new development paradigms. That is, creating software in ways we haven't already. And architectural paradigms, the idea that innovation and advances would require interdisciplinary thinking. For example, software engineering at the intersection of AI systems. Software engineering at the intersection of societal scale systems. And, just one example of other computing paradigms, but software engineering at the intersection of quantum systems. That is the way we tried to organize the research roadmap, to think about new development paradigms and new architectural paradigms.

There are a lot of different ways we could have gone, but we said, Hey, we're going to put a stake in the ground in six research focus areas. The way that we thought about these, as we think about this notion of a software-engineering pipeline, we see that it's changing and changing rapidly. We are trying to accelerate the production of code and the ability to deploy software at high velocities. So we need to outpace our competitors' ability to rapidly deploy new computing capability that provably works. So that vision that I talked about in this mindset, this is how we crafted these six major areas.

So, the first one, as systems get more complex, we need to think about smart automation of every aspect of the software pipeline. And so one of our areas is called AI-augmented software development. Another area of research, scale motivates the need for safe and resilient software composition. And what I mean by that is, combining components to create large software systems. So we have got a whole area that talks about software composability and being able to put together the rules of software composability. Another area, we talked about the fact that software is ubiquitous. There is an ongoing and increasing need for software to continuously evolve to incorporate new capability. So we, therefore, need to understand how to continuously reassure software-reliant systems efficiently without doing harm to existing capabilities. For the idea of continuously assuring software systems, elevating the importance of assurance evidence and assurance arguments will be key in that body of research.

We have talked a little bit about AI playing a very big role. So the development and sustainment of AI systems shares many parallels with building, deploying, and sustaining software systems. So we will need to understand how to engineer systems that have AI components and how to apply AI across the whole software engineering lifecycle. So AI is a part of a new development paradigm, but it is also a part of an advanced architectural paradigm. It is going to play important roles in both of those.



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Then there is a whole architectural paradigm on designing societal scale software systems like social-media systems. But the thinking there is that there are new quality attributes that we will need to think about, such as data privacy, such as trust, and ethics. That all of these are going to mean new design considerations for these new societal scale software systems.

Then the last sort of major thinking is that we need to think about how we architect and engineer for new computational models. And I've talked about some of these already, systems that have AI, systems that have people, such as the social-media kinds of systems, and then maybe systems like quantum systems, [multicore systems](#), and so on. So we've got six major areas and they comprise these new development models or new development paradigms and new architectural paradigms.

Forrest: Great. I think that that really does make it, like you said, a huge body of expertise and in perspectives and we got much more practical and understandable, to see how this all fits together. I always particularly liked the idea of how AI plays into that. Because as you said, and I think it's something that the community is doing more of these days anyway, is looking at how we engineer AI systems. I think that's something that we are all used to thinking about. But seeing how AI can come back into that process and now support the software development and make some of these other issues that we've been I think maybe aiming for for a long time as a community, like trusted composability, more tractable as we go forward is exciting too. And that was a neat part for me at least.

Anita: Perfect.

Forrest: Let's go from there. So you talked about this overall vision: AI coming in as a trusted partner now and that enables us to scale up and do a lot of these things at speed with confidence. What kind of steps do you see being taken now to help us get from here to there?

Anita: That is a great question. If you would have asked me a few months ago about where the hard work was for us I think I would have said, *Well, the hard work was taking all of these ideas and putting together the vision, and the research focus areas, and designing the whole research roadmap.* But now that the study's out, I'm realizing, Forrest, the real work is just starting, when we talk about implementation and enactment of the roadmap. I think that is where we are now is to think a little bit about how do we go forward and implement this vision and implement all the research focus areas? How do we take this and move forward?

I think that we have given thought to the fact that convening and enabling intercommunity discussions. We started that last year with the DARPA SEI workshop. It was great to partner with DARPA, to host the Software Engineering Grand Challenges Workshop. But this year, what is so exciting to see is that the Department of Energy, the U.S. Department of Energy, is hosting a workshop actually mid-December, bringing the scientific software engineering community together. So it's great.

I think that every so often it makes a lot of sense to step back and look at the future of our field in a very strategic way. I think that is what we were able to do, Forrest, is day in and day out, like the whole rest of the world, you're faced with the challenges that occupy your thinking. Today's worries, today's challenges. But I think what the study helped us to do is to think a little bit bigger and broader. And



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bringing different parts of the community together, I don't think we want that to stop. So convening and enabling inter-community discussions I think is going to be key. Thinking about investment, influencing common investment, so to figure out the right set of partners that can come together and commonly invest on specific research focus areas, I think is going to be something that can move the needle forward as well. Then maybe government can focus or invest dollars where industry isn't investing. Maybe that is a way to think about how we move to the future vision.

The other one of the things that I think SEI is wanting to do is, we had an advisory board, but I think makes a lot of sense to put together an enactment team and work with different parts of the community to assemble projects along the different research focus areas for collaboration. And so I think that's something that we will be doing as well.

Forrest: Great. It struck me too, you mentioned that need to step back from the day to day, because the technology does move so fast, and kind of take that more reflective look. One of the things that always stuck with me was that one of our participants, Sol Greenspan, I think from the National Science Foundation, mentioned how we as a field have this kind of habit of doing it every 10 years or so. This one comes in right on time as it were. And just looking at some of those earlier studies, it struck me how in 2001 people were talking about, oh, all the complexity of dealing with systems of like 100,00 lines of code, and then 2010 it was tens and millions of lines of code. Now I think we don't even talk about lines of code anymore, because we're in such a dynamic ecosystem that that is really not a way to measure the size or sophistication of these things. But just the sheer speed-up or scale-up, the increase in sophistication, as well as what are in the general sense, what our expectations are for the software to do. I think it only goes up from here, you know? I think the challenges only ever go up.

Anita: No, I think you're exactly right. I thought Sol Greenspan's talk was really, really very interesting last December, because when you look at the field in those 10-year chunks, you see the evolution. He talked about what we talked about in 2000 and then 2010, and now here we are at 2020. Last year was 2020, and the topics that we talked about you really do see that evolution.

I think the other remarkable thing is you see different parts of the community coming together to really work on what some of these key challenges are. I think that for us, for example, DARPA puts out some of these grand challenges, and that is something that we had talked about last December is partnering with DARPA to host a Software Engineering Grand Challenge Problem area and bring different parts of the community together to work on a software engineering grand challenge. So these are all different things that I think we want to think about.

The other thing, Forrest, is, something that I think we have been thinking about is influencing the influencers. So, for example, a couple weeks ago when we announced that the study was released, we heard from, oh my gosh, there was so much excitement about the study and the research roadmap and the different perspectives that we were able to bring together. But, for example, we heard from different parts of the research community saying, *You know what, we want to take some of these research focus areas and have those be a part of our Ph.D. programs.* We want our researchers to undertake some of these areas of study. The future of software engineering and this idea of a research roadmap seems to really



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have a lot of people excited and charged up and wanting to work with different parts of the community, all the objectives that we had for this.

Forrest: Great. That is wonderful. What you talked about there was exactly that vision, of the community finding something in there of interest and then taking it on themselves to continue to build and develop in this area. That is the larger community. And I just wondered, as we end up the podcast here, I wondered if I could just ask, what do you think is next for us, for SEI, as a part of this?

Anita: I think I had mentioned this idea of an enactment team, and I think that is definitely something that we are going to do. Not only was the research roadmap to step back and think about the future of software engineering, but it was also something I think we are energized by. It informs our research priorities as well. So I think for us there are some very specific areas that we want to pursue. Of course looking at [AI and how we engineer AI components into the software lifecycle](#), but also what are the engineering artifacts that we have to think about as we engineer for AI. So that's going to be an area of research focus for us.

The idea of reassurance or assured composability, it's combining a couple of these research areas. That's definitely a research area that we want to pursue. And I know we want to collaborate with [Carnegie Mellon University Institute for Software Research](#) because they have a really strong program in societal scale software engineering. And so that's an area we see ourselves collaborating with them. But I also see us moving forward and reestablishing and working with the community, working with DARPA on a Software Engineering Grand Challenge. I think, Forrest, both you and I are really excited about working with the Department of Energy on the scientific software engineering challenges and moving forward and working with the community at large there. And I think, Forrest, you play such an important role with the IEEE Computer Society as president. But even working with different parts of our global software engineering community, to think about the research ramifications of the roadmap to the global software engineering community and how they may enact this. So I think that is another important connection that we want to make too.

Forrest: Great. So Anita, thank you so much for talking with us about this work today. I know that part of the intent here is to reach out and continue that important dialogue with the community. So I wondered if you had some final thoughts or about how they can continue to be part of the discussion as it goes forward?

Anita: Thank you so much, Forrest. Yes, absolutely. We really do want to continue the engagement that we have had with the whole software engineering community. Please, give us your reactions. Give us your thoughts. And as you enact and implement some of the research focus areas, give us your feedback. Our thought is that in a few years we want to do an update to the study. So getting your feedback, getting your input, getting your ideas, we would really, really love that. So let us know and give us your feedback. Thank you.

Forrest: Great. So for our audience, if you want to give us the feedback, as Anita suggested, we can easily accept that via email. If you send an email to info@sei.cmu.edu, we will make sure we get the



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message and include that in the conversation going forward. Thank you in advance for your time and your thoughts on being part of this as well.

Anita, thank you again for talking with us today about this work.

For our audience, we will include links in the transcript to resources mentioned during this podcast, so you will have a chance to see some of this firsthand. If you would like to download a copy of the report, please go to sei.cmu.edu and type “Future of Software” in the search field at the top of the page. We also have blog posts and an upcoming webcast on this topic. Again, those links will be included in the transcript as well. Thanks again for joining us everybody.

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