Introduction to the Mission Thread Workshop
featuring Michael Gagliardi as Interviewed by Suzanne Miller

Suzanne Miller: Quality attributes, also known as *–ilities* play, a driving role in the architectures of both systems and systems of systems, which are also known as SoS. In this episode we will discuss The Mission Thread Workshop, which aims to help program managers identify architecturally significant systems of systems challenges, which are derived from architecture, engineering, and capability issues derived from an analysis of mission threads.

Welcome to the SEI Podcast Series, a production of the Carnegie Mellon University Software Engineering Institute. The SEI is a federally funded research and development center sponsored by the U.S. Department of Defense and operated by Carnegie Mellon University. A transcript of today's podcast is posted on the SEI website at sei.cmu.edu/podcasts.

My name is Suzanne Miller. I am a principle researcher here at the SEI. Today, I am very pleased to introduce you to Michael Gagliardi, a principal engineer here at the SEI also. In today's podcast, we are going to be discussing the Mission Thread Workshop, which uses existing systems-of-systems end-to-end mission threads, and accompanying SoS architecture plans, and augments the mission threads with quality attribute, engineering, and capability considerations with inputs from the SoS stakeholders. OK, that is a mouthful.

First, a little bit about our guest. Mike's research focuses on systems of systems, system, and software architecture specification, development and evaluation as well as acquisition. He has over 25 years of experience in mission-critical software system and SOS development, especially in the areas of real-time and fault tolerance. Mike has been responsible for the development of the SoS and system architecture practices to address quality attributes based on the SEI's software architecture methods. Thanks for being here with us today, Mike.

Mike Gagliardi: Thank you, Suzanne, for letting me have the opportunity to talk about this.

Suzanne: It is good stuff. So, let's start off by having you explain for us what is a mission thread and why does it matter, especially to the Department of Defense (DoD)?

Mike: Mission threads are really just expressions of end-to-end SoS capabilities. They are used to drive architecture capability, acquisition analysis activities, and decisions further down the road. An SoS typically supports many mission areas in the DoD, specifically (for example), ballistic missile defense, undersea warfare, mobility, sustainment, just to name a few of the important mission areas. Each mission area is supported by a set of end-to-end mission threads. Now, most SoS programs that we deal with have a good initial set of mission threads early in their lifecycle. However, these mission threads typically include very little information about the non-functional requirements or, as you mentioned earlier, the quality attributes, such as availability, performance, securities, scalability. The list goes on and on. There is a lot of *-ilities* that are important to each specific SoS. Now, these quality attribute considerations really are critical architecture drivers in these architectures just as they are in the system and software architectures.

We are coming from a position of, *Due diligence must be paid to the quality attributes early in the lifecycle*. If not, there are significant integration and operational issues later on down the line, which almost always requires some amount of extensive architecture rework. The mission thread workshop was developed to address this by eliciting the quality attribute considerations for the mission threads from the SoS stakeholders.

Suzanne Miller: One of the interesting things about quality attributes that may not be obvious to people that haven't dealt with them before is that quality attributes are not all complementary, right? Some of them conflict. So, often security and usability are two quality attributes that conflict. If you don't deal with that early on and recognize some of those conflicts, then you could compromise the ability to execute the mission. Correct?

Mike: That is very correct. When you get right down to it, there is only so many ways to skin the cat, architecturally, when it comes to specific quality attributes, for example performance, availability, security. But all those approaches—their tentacles reach far beyond their initial swim lane and throughout the whole architecture, whether it is system, software, or SoS. These behavioral implications really play off each other, and that has to be understood. It's not enough to just say, *I have a capability mismatch between these constituent systems*. What we are really looking for are the architectural mismatches that sometimes get overlooked.

Suzanne: Sure. So, mission thread workshops are one of the ways to discover some of those mismatches and a way to help people to at least make them clear what is the mismatch and then decide how to deal with it.

Mike: Yes. So, then you are on the same technical footing when you are looking for capability gaps. Now, we are looking for architectural gaps early in the lifecycle, so we can do something about it.

Suzanne: What are some of the different types of mission threads that you would run into that you would address in these kinds of workshops?

Mike: That is a very good question. We initially started out looking just at operational mission threads, since that is the kind of the bread and butter of most SoS capabilities, *What are the operational capabilities*? Then, we also realized that there are a couple of others. One is in the area of sustainment mission threads and developmental mission threads. We realized after the first few mission thread workshops, you shouldn't really combine those together. There is a whole different set of stakeholders for operational than there are for developmental. We really want to make efficient use of the stakeholders' time. So, we kind of bin these into three major categories of threads.

Suzanne: OK. So, when you are talking about developmental mission threads, you are talking about things that affect the ability of the stakeholders who are developing the system to actually meet the goals of the system, and the same thing with sustainment. With operational, you are looking at the end user in terms of their thing. So, those are different stakeholder groups that have to be accounted for.

Mike: Yes. There are very different stakeholder groups, and we just...

Suzanne: They don't talk about the same things the same way do they?

Mike: No. And, they are also looking at different aspects of the architecture. One is looking at the constructional aspects of the architecture. One is more of the operational behavioral aspects.

Suzanne: OK, excellent. So, give us some ideas about what a mission thread workshop is, and what does it actually produce. What is a scenario that you would use in conducting a mission thread workshop?

Mike: To give a brief overview, the mission thread workshop is really a facilitated, stakeholder-centric method. We are there to illicit and refine end-to-end quality attribute, capability, and engineering considerations for SoS architectures. The starting point is existing SoS mission threads and whatever accompanying SoS architecture plans you have and usually a pretty good idea of what the constituent legacy systems are that are going to be cooperating to create this SOS capability. We fully acknowledge that no one is going to begin and embark on a new SOS capability endeavor from a greenfield perspective. So, it is basically looking a lot of constituent legacy systems—not only what the capability gaps are, but as we've been discussing, what are the quality attributes and architecture gaps.

Suzann: Because some legacy systems were built with one thing in mind. Say one constituent may be very secure and focused on that. Another one may be very high-reliability focused.

Mike: That is correct.

Suzanne: So, those kinds of things when you compose that new system of systems, you have got to account for all that.

Mike: That is exactly correct, and even if you have two or three that are supposedly high availability, for example, they do it differently. They have different behaviors. When you put them together in an SoS context, this emergent behavior comes out that may be a little bit unexpected or not satisfying what the SoS capability really needs. That kind of ties in what the quality attribute expectations at the SoS level are with what is being realized at the legacy constituent system level.

Suzanne: So, part of what you are trying to do with the mission thread workshop is avoid some of those surprises. You want those to become clear early, so that you can make adjustments. So, if you have got too-high availability constituents that have very different interactions, let's say, with their sub-systems, you may have to re-architect elements of that, so that they can interact consistently across the whole space.

Mike: Yes, the whole point is getting that visibility and getting that technical information early, so that you can reason about where the tradeoffs should be made…

Suzanne: And, where the costs are.

Mike: Right. Sometimes you will find a constituent system that has all the capability you really want, but architecturally it is a big mismatch versus one that is just the opposite. You want to be able to let the SoS architects be able to reason about, *Where do I make these accommodations*?

Suzanne: *Where do I make the tradeoffs*?

Mike: Right. *Maybe I do something at the SoS level, or maybe I go and contract with the legacy systems and make a couple tweaks in their architecture, so that they are consistent.*

Suzanne: This has always been important for single systems, but one of the things that I would expect you to support is the statement that this is really critical in a system-of-systems to have this level of understanding. If you don't do something like a mission thread workshop, there are not many ways to get that understanding.

Mike: Yes, that is correct. When you start looking at the different architecture views that are typically supported in a DoD SOS architectures they fall in the DoDAF [DoD Architecture Framework] 2.0 views, and they are a very good set of views.

Suzanne: DoDAF is an architecture framework that the DoD uses to express different aspects of architectural knowledge.

Mike: That is correct, but it doesn't really do a great job—none of the views really do a great job—of talking about the cross-cutting quality attribute requirements and the architectural support there. Also, a lot of SoS folks will start getting into system-use cases. System-use cases are a great idea, it's a great thing that you want to use but it doesn't give you that end-to-end perspective.

Suzanne Miller: It doesn't cross.

Mike: Yes. So, that is when we took some of the good ideas from the software architecture work that was here at the SEI with quality attributes and we scaled it up to the SoS level. We did not use the actual scenario that the SEI does at the software level. That is why we said, *Well, the end-to-end mission thread is the SOS scenario, so...*

Suzanne: Figuring out what that should be, so that we can touch everything in the system of systems is one of the things that you are actually looking for as an output from the mission thread workshop.

Mike: Right. Yes, so we want to really basically augment a set of end-end mission threads with quality attribute considerations, not only from an overarching SoS perspective, but also each step of the mission thread we look at, and we investigate with the stakeholders, *What are the issues here and what are some of the break points?* Some things that come out of there are a really nice set of architecture challenges.

So, when we go through the process of the mission thread workshop, we are going to augment each step along the way: *What are the quality attribute considerations*? A lot of good information is gleaned from the stakeholders that we document as part of the augmented mission thread. From there we do some analysis on that to find out, *What are the real architecture challenges here?*

It was very surprising when we first did these, the first few. We didn't really set out to look at the engineering and capability aspects. We just want to get to the architecture part. A lot of times it is the first time a group of SoS stakeholders get together to actually look at the whole SoS from an end-to-end perspective. Lo and behold, a bunch of engineering and capability issues started popping out as well. So, that is now a part of what we look for in a mission thread workshop, not only architecture mismatches but engineering and capability gaps that can only be seen from an end-end perspective…

Suzanne: That feeds that development side of things. You find some things out in the operational mission thread workshops that then can feed the, certainly, the developmental and depending on the particular stakeholder group, the sustainment as well. Why don't you give our listeners an example of a mission thread, just a short description of what might be a mission thread that you would use to elicit some of this information in one of the workshops.

Mike: The mission threads come with two parts. One is kind of an overall description and then there is the step-by-step articulation of what has to happen in the mission thread. An overview description of a mission thread that we have used before goes like this:

> *You have two ships, we'll call them Alpha and Beta. They are assigned to air defense to protect the fleet containing two high-value assets. You have a surveillance aircraft, and four [UAVs](#) in two pairs are assigned to the fleet and controlled by the two ships. A pair of the UAVs flying as a constellation can provide fire control quality tracks directly to the two ships. While that is going on, a two-prong attack occurs on the fleet. The first one is five aircraft-launched missiles from the southeast, for example. Then a few minutes later, you get seven submarine-launched missiles from the southwest. The upshot of all of this is the fleet is protected with no battle damage.*

So, that is the overall description. It is something we call a *vignette*, actually.

Suzanne: It has got some complexity to it. It has got enough complexity to it, so that you can exercise different elements of the system. But, it is also simple enough to understand. Basically we have got a constellation, it gets attacked, and we have to protect it. So, it is easy enough to understand, but then it breaks out into things that give you sometimes surprising kinds of insights into what has to happen to make all this stuff work.

Mike: The end-to-end mission thread that supports that overall description or vignette, as I called it, has about 20 steps. I'm not going to go into all 20 steps…

Suzanne: And those are in your [technical report](#)?

Mike: Yes. This one is actually in [the technical report](#).

Suzanne: So, you will have that available to people to read for this vignette.

Mike: That's correct. The first step is going to be something along the lines of one of the ships develops an air defense plan and rules of engagement sends that over to the other ship. They start exchanging plans, initially…

Suzanne: Just that element alone, you start thinking about communications. You start thinking about mission planning and what is the scope of the plan. So, just that one element of the thread, and there are 19 more. So, this doesn't take just two hours, does it?

Mike: No, not at all. You can actually envision another thread right before this where they actually have a whole bunch of mission plans, contingency plans. This is outside the scope. You can imagine in any missionar area there is a whole bunch of threads.

Suzanne: Do you do more than one thread in a workshop or do you typically stay with a single thread per workshop?

Mike: The way it goes is we like to do these in two-day, facilitated workshops with all the stakeholders present. We typically can get through three complete thread augmentations in one mission thread workshop session. The first one that is very interesting is much like an ATAM [Architecture Tradeoff Analysis Method] or Quality Attribute Workshop [QAW] at the software level. We find a lot of issues in the first thread, for each of these steps and for the overarching aspects as well. Then, when we get to the second thread, because there are going to be kind of similar mission area threads, you don't always have to revisit what you found in the first step, because if you find that degraded modes of operation is a big problem, hasn't been thought out, there is no CONOPS [concept of operations] will be true for the next.

Suzanne: So you can say same as number one.

Mike: Yes. We backward reference. So, the first one takes…something like this would take a good four to five hours to get through and there is a lot of information we capture. It is a great dialog between the stakeholders, because even they are surprised at what they were unaware of at the time. Then, the second and third threads usually take two or three hours. You can get three threads done in a two-day workshop.

Suzanne: But, that is a lot of work for everyone…

Mike: All the feedback we get…Like we say, it is the first time they have actually looked at it from this perspective, and it drives a lot of analysis further on. There is a lot of follow-on activity that this drives.

Suzanne: Basically, as soon as you have identified what the systems of system is meant to be and what its goal is, that is probably a good time for doing this. The longer you wait, the more you are going to have decisions that have been made that constrain what you can do, right?

Mike: Or, they are going to require you to go back and revisit and re-architect, which is not what we want. We have been in a situation where we have been invited to system-of-system architecture efforts that were much farther along down the path, but we actually were able to go

back and say, *You've got to update your CONOPS in these areas. You still have time to do that, perhaps*. The earlier the better.

Suzanne: The longer you wait, the more work it is.

Mike: That is right. Always.

Suzanne Miller: How many of these have you conducted, and what are some of the trends and challenges you have seen system-of-systems programs encounter so far because of this insight?

Mike: Over the last three or so years, we have conducted probably a little bit over 20 different mission thread workshops on a variety of SoS architectures. As I said earlier, we typically augment three mission threads per workshop. So, I think in our catalog, we probably have 60 to 70 augmented mission threads and accompanying challenges and issues that come out of it. At the end of each mission thread workshop, we roll up the challenge areas, and then we vet those with the principles after each one.

Suzanne: So, a lot of different insights that have come out of this. Have you been able to share these and translate some of the insights outside of DoD systems? I mean, in my own mind, early response (first responders) would be a natural fit for some of this. I don't know what other kinds of areas you have looked at so far.

Mike: Yes, we have applied this a couple times in some commercial enterprise architectures, and we have had the same very good results come out of those. The basic mission thread workshop machinery is pretty much unchanged. The inputs will change when you look at an enterprise architecture versus a DoD-SoS architecture, but for the most part we found the same good results, same good outputs coming out of...

Suzanne Miller: And, in commercial you are using business threads.

Mike: We use business threads. We just basically change the name and a little bit of the format changes, but it is basically end-to-end business processes. What is nice about the commercial application is they have a broad set of business processes pretty well detailed. So, we are good to go.

Suzanne: When you think about finance kinds of systems—insurance, health care—all of those have many of the same challenges of systems. They are themselves systems of systems, even though they don't necessarily use that terminology that frequently because they have got to interact with lots of different stakeholders to get their business accomplished.

Mike: Yes. When you get right down to it, what the actual specifics of the quality attributes are are kind of different between a DoD mission-critical system and enterprise. But, there is a very

similar set of quality attributes, they just are expressed [differently] and their expectations are different. But, that is what we try to capture.

Suzanne: Yes. So, in commercial, you have got a big emphasis on a PII, private information. That really has a strong analog of security kinds of concerns that you have in the DoD. But, it is a quality attribute that has complementary and contradictory effects on other attributes as well.

Mike: Right. They both have pretty serious availability and throughput versus different types of performance issues but, when you get right down to it, it is really eliciting those things from the stakeholder so that the architects themselves can make the best decisions early as possible.

Suzanne: So, they are visible. The idea here with all of this, whether it is commercial or DoD, is to make these things visible, so that you can deal with them and make them tractable.

Mike: Right. So, to back up one question about the trends and challenges we have seen is that over a variety of these mission thread workshops we are starting to notice a commonality or a pattern of challenges. You can almost point out that you are going to run into these things pretty early in the mission thread workshops.

For example, degraded modes of operation and all the architecture support that is needed, not only at the SoS level but at the constituent system and software levels, is something that we always run into. It is a tough nut to crack, but it is something that is foundational to the architecture, and it is foundational to the constituent architectures. And, you have got to get that right, or you are not going to get the behavior you want.

One surprise that I wasn't expecting was some of the training issues, that each component system comes with its own training CONOPS and associated tools. When you start looking at this SoS capability from end-to-end thing, you realize the training is not holding together right. So, you have got to go back and revisit the training. That was a little surprise.

Usability, a lot of the *–ilities*, you will see common patterns, if you are looking for that common look and feel from usability perspective how much automation. When you start putting in these end-to-end capabilities, some of the systems have a good amount of automation and some are very manual. You can't live in that world where you are jumping back and forth to manual and automation. Those are some of the big challenges we see, and it is a common set of challenges.

Suzanne: Now, you have published work on the topic of mission threads itself, but have you published about the sort of common challenges? Have you been able to make some of that work available to people so they can sort of bring that into their own awareness?

Mike: We have. I've given some presentations—I think one was at NDIA, a couple of SEI Saturn conferences, that we start just uncovering the challenges we found. Here are some of the

recommendations but, you know, when you get right down to it, it's very specific when you are in it's hard to always generalize …

Suzanne Miller: It's hard to genericize…

Mike: It really comes down to specifics. When we do a mission thread workshop and we find challenges, we come up with specific recommendations.

Suzanne: I'm thinking more of things like how do we teach architects to pay attention to some of these things.

Mike: I would love to go further into that research.

Suzanne Miller: Well, Mike I really have enjoyed following your work in this area. I think there are some more things that are going to be coming ahead for you. I thank you very much for joining us today.

For our listeners to view a technical report that Mike coauthored on this topic that provides a deeper dive into this research, please visit our SEI digital library at http://resources.sei.cmu.edu/library. In the search field, enter the name of the technical report, which is Introduction to the Mission Thread Workshop to view all related resources on this topic. I also encourage you to search on quality attributes for lots of information about that aspect of this.

This podcast is available on the SEI website at sei.cmu.edu/podcasts and on Carnegie Mellon University's iTunes U site. As always, if you have any questions, please don't hesitate to email us at info@sei.cmu.edu. Thank you.