...enabling the adaptive potential of systems of systems, defining how humans will add value in the second machine age, and wrestling with complexity and its implications at the interface of social, technological and economic systems...

I’m John Paschkewitz, and I joined DSO in April 2015. In my industrial work before starting at the agency, I enjoyed—and struggled with—problems in modeling and designing systems involving mechanical, fluidic, electrical and optical elements with severe cost and performance goals. Using mathematics and modeling to help make the difficult design choices about where to put risk, performance, and cost in systems is what I am passionate about.

Like many engineers I’ve spent a lot of time playing “whack a mole” addressing unintended interactions and consequences of seemingly simple design choices. The existing approaches to addressing these design problems in the systems engineering community simply do not work from a designer’s perspective. Systems of systems—which are integral to how the Department of Defense is attempting to address similar problems in trading off cost and performance—have taken this problem to an extreme. I want to attack these problems in the design of complex systems, like an F-35, and systems of systems, such as a hospital, which requires the composition of power, water, supplies and people, in a fundamental way in my time at DARPA.

My CASCADE program, which kicks off this summer, is focused on maturing and exercising a new set of mathematical tools to rethink how we design for change and changeability. What makes disaggregation—the idea of breaking up a currently monolithic platform like an F-35 into a set of smaller, cheaper platforms that work together to realize the same function—so powerful is that operators can mix-and-match capabilities at mission time to address unexpected problems and needs that are only apparent in the field. Unfortunately, mixing and matching capabilities also breaks the current tool chain for systems design, which assumes static environments, small perturbations from reference architectures, and predefined operational “playbooks.” If successful, CASCADE will allow the definition of functions—say, search and rescue—and allow simultaneous exploration of system designs, operational concepts, and changing environments that will fundamentally change how we think about system definition and adaptability.

I’m currently interested in two areas for new program concepts.

The first is rethinking how we design human-machine systems. One of my colleagues described the state of the art for human-machine system design as akin to steam engine design in the early 1800’s: a purely empirical endeavor with heuristics for why certain elements work. Is there an equivalent of the powerful abstractions of thermodynamics that enabled a principled and rigorous design of steam engines in the late 1800’s—using concepts such as Gibbs free energy, entropy, and enthalpy—that would enable quantitative, general purpose human-machine system design? How would we test and validate the generality of such models across a range of experimental platforms ranging from crowdsourced science to command and control to cybersecurity? I am particularly interested in ways to think about and design teams of multiple people and machines—which have rich capabilities and interactions, abilities exceeding those of either humans or machines, and increased potential for adaptability to “unknown unknowns,” the true surprises.

The second is exploring the intersection of complexity, physical and social systems, and mathematics to catalyze a renaissance in the science of system design. With appropriate tools, could we reframe and
make progress on problems that currently seem too difficult or even impossible to make meaningful progress on. For example, are there alternative ways to think about design for change and changeability that transcend the limits of modular thinking in complex physical systems? Are there effective ways to understand and model socio-economic impacts on our logistics supply chains and distribution networks? Or are there ways to address the threats of financial or economic or other unconventional means of warfare? The state of the art today is a lot of descriptive and ultimately not very useful discussion on so-called complex adaptive systems. Can we make practical, predictive insight possible by rethinking the mathematical and conceptual foundations for these problems?

I look forward to meeting and discussing ideas in these areas with you today.