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About This Publication

In April 2016, NASA, DOT&E, and IDA collaborated on a workshop designed to strengthen the community around statistical approaches to test and evaluation in defense and aerospace. The workshop brought practitioners, analysts, technical leadership, and statistical academics together for a three-day exchange of information with opportunities to attend world-renowned short courses, share common challenges, and learn new skill sets from a variety of tutorials. A highlight of the workshop was the Tuesday afternoon technical leadership panel chaired by Dr. Catherine Warner, Science Advisor, DOT&E. This article summarizes core themes discussed during the panel session.

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Panel Session Summary

Summarized by Laura Freeman, IDA

In April 2016, NASA, DOT&E, and IDA collaborated on a workshop designed to strengthen the community around statistical approaches to test and evaluation in defense and aerospace. The workshop brought practitioners, analysts, technical leadership, and statistical academics together for a three-day exchange of information with opportunities to attend world-renowned short courses, share common challenges, and learn new skill sets from a variety of tutorials.

A highlight of the workshop was the Tuesday afternoon technical leadership panel chaired by Dr. Catherine Warner, Science Advisor, DOT&E. Panelists shared stories illustrating the lessons they had learned over the years in technical leadership roles. The panelists' remarks reflected a few core themes, including the importance of clear communication about statistical methods and an emphasis on making sure that you are answering the right question. As one panelist, Mr. Roberts, eloquently noted, "You can greatly increase value and impact by doing simple analysis and answering the right question, as opposed to doing very sophisticated analysis and answering the wrong question." It also was observed that solving problems using statistical methods is really a "team sport" and that clear communication and asking the right questions are the first steps in getting all stakeholders involved in the process to ensure a successful outcome. Finally, the panelists touched on the challenges they had seen in successfully implementing "leading edge" statistical methods in organizational processes.

The panel consisted of representatives from across the Department of Defense (DoD) Test and Evaluation (T&E) communities and senior technical leadership from NASA. The panel participants were:

- Mr. Paul Roberts, NASA Engineering and Safety Center Chief Engineer at Langley
- Mr. Frank Peri, Deputy Director of the Langley Engineering Directorate, NASA
- Mr. Paul Johnson, Scientific Advisor, Marine Corps Operational Test and Evaluation Activity (MCOTEA)
- CAPT Peter Matisoo, Technical Director, Commander Operational Test Force (COTF)
- Jeff Olinger, Technical Director, Air Force Operational Test and Evaluation Command (AFOTEC)

Dr. Warner started the conversation by reflecting on the large number of participants at the workshop, contrasted their numbers and enthusiasm with the situation in 2010 when she first became the DOT&E Science Advisor, and many in the DoD were openly hostile towards using statistical approaches for operational test and evaluation. Dr. Warner noted that the success stories being related throughout the workshop highlighted how people were using "regression and other kinds of modern statistical techniques to solve the complex problems that face our national defense and aerospace industries."

Clear Communication

All of the panelists discussed the importance of clear communication in the successful implementation of statistical methods in their experiences. Mr. Johnson recounted his experience explaining to senior leadership why the Marine Corps needed experimental data to support decisions on incorporating women in ground combat roles. His unconventional approach to discussing statistics with senior leaders involved using weighted dice and live demonstrations of statistical hypothesis testing. Mr. Johnson shared stories of rolling the dice with leaders at the highest levels of the Marine Corps to explain the importance of experimental designs and statistical thinking!

"A four-star general has enormous decisions on his plate. He does not have the time to come and meet me half way in the explanation and understanding process. I assume it is my responsibility to go 100 percent in his direction, to learn his vernacular, and carry my message across so that he gets it."

His story of convincing leadership that this was the right direction to move in resonated with the audience. Mr. Johnson emphasized to the technical audience:

"It's incumbent upon us to make sure that our message - the statistical designs - the robustness - the reason why we're doing what we're doing – is accessible to the decision-makers."

The panelists noted the importance of communication in the DoD testing, which requires involvement from many organizations. Mr. Olinger and CAPT Matisoo noted that it was important to have strong working groups that communicated clearly and frequently across organizational lines, including the requirements experts, system operators, and oversight organizations, and that all stakeholders be involved in the test planning process. The panelists were especially reflective of communication with DOT&E oversight (their panel moderator!), Mr. Olinger noted:

"We work with DOT&E, we don't work for them. A lot of people talked about close communication being a key piece. Per DOD instruction, DOT&E approves our plan adequacy, and so we're working very closely on the plan that we go execute."

Finally, CAPT Matisoo, noted the importance of communication in "turning the data into information," highlighting that communication is important in both planning a test and reporting the results. He noted that you need the system operators (the customers) in the room when discussing and presenting analysis to ensure that the analysis is meaningful and the operational implications are clear,

"Get those operators back in the room, sit down with the operators and say let's talk about what we're seeing from the experiment."

Answer the Right Question

Closely related to the need for clear communication is the need to make sure that you are trying to answer the right question. Mr. Roberts related a story about a valve failure they were investigating on the shuttle program. He noted that the original question posed was "*the probability of a catastrophic failure due to another poppet valve failure."* The answer to the question was critical for future determination of flight readiness. An interdisciplinary team was established and set off to answer the question,

"We tested for a few weeks, generating data, did a lot of sophisticated statistical analysis on it, walked that preliminary analysis back to the program office and said this is the type of information we're going to be able to give you and they looked at it and said I can't make a decision from that, that doesn't do me any good. So we were answering the question that they asked, but it wasn't the right question. We went back and we began to get a heavy dose of statistical engineering, what we should have done right up front. We started asking questions, talking to all kinds of people, trying to find out what knowledge they were really looking for. Now we eventually found the right question and that was, what is the velocity that causes a certain depth of dent due to a projectile hitting in various orientations? From the answer to that question, they could tie it with structural analysis and come up with a critical velocity of the flow, and as long as we kept everything under that critical velocity, the probability of having a catastrophic event due to a poppet failure would be very very low. …

What I want you to take away from that particular little story is, if you apply the proper statistical engineering methods, you can greatly increase the value and the impact by doing simple analysis and answering the right question, as opposed to doing very sophisticated analysis and answering the wrong question."

From the operational test perspective CAPT Matisoo reflected similarly on the need to understand the question the operational test is trying to answer:

"One of the key lessons that I could give you is sitting down with whoever your operators are, in our case it's folks who are in warfighting uniforms, but sitting down with the customer or the operator and really understand what the question you're trying to answer is."

Mr. Olinger addressed the same concern of getting the right question from another perspective; he noted that in operational testing we have to balance test needs with test complexity.

"Another challenge is level of test. We need to figure out the balance between testing at a campaign level - can we win the war - which requires a large, complex test - to how did the system do in the limited environment that it was in a smaller test?"

Mr. Olinger highlighted that the two different questions drive different approaches to test design, and each can have different impacts on cost and the capabilities required to execute the test.

Statistics is a Team Sport

All of the technical leaders emphasized the need for an interdisciplinary team for determining the best approach for answering the questions of interest. Mr. Olinger described the AFOTEC initial test design process:

"We bring in all the stakeholders, … the program officers, the contractor, we bring in DOT&E, we bring in intelligence. You name it, if anyone's got a stake in it we bring them into the meeting. Yesterday in Dr. Montgomery's talk, the first three steps of any experiment design if you will, he said is a team sport. So you really need to make sure you have all the people involved."

From a different perspective, Mr. Peri also noted the importance of fully integrating statistical engineers and statistical engineering into existing team and project structures. He related this message through a story about how NASA is moving towards composite materials and the need to incorporate statistical thinking in that process:

"We're making investments in composite technologies for fuel tanks with pressurized hydrogen and oxygen. And one of the benefits would perhaps be a reduction in weight, right? Getting mass out of lower earth orbit is the biggest problem, and the lighter you can make the vehicles the better chance you have of carrying more payload into orbit. So you make the vehicle lighter and use composites. Well as it turns out, the engineers, being as conservative as we are as an agency putting humans in space, were designing our prototype composite structures to the same standards that we we're doing for aluminum lithium. So part of the culture that we have to overcome is, let's change our standards. Let's come up with different ways to approach engineering processes that don't use and rely on 50 plus years of conservative engineering design."

Mr. Peri noted that statistical methods for quantifying risk are essential for thinking about design standards differently.

Implementing Statistical Thinking in Organizations

Dr. Warner started the panel session talking about the changes in the DoD test and evaluation workforce in terms of the attitudes and widespread implementation of statistical methods. The dramatic change has been made possible by strong organization leadership, changes to standard

processes, and the hiring of analysts with statistical backgrounds, all of which are challenges for organizations.

Additionally, these methods are not as widespread in the DoD developmental test and evaluation community, as CAPT Matisoo noted:

"Coming from a developmental test background like myself, that's where you fly at the precise altitude and precise air speed and you can control all those conditions, that's great for system characterization with DOE, … but I think we have yet to convince developmental test activities the value of design of experiments"

He emphasized that *"design of experiments actually is a tremendous benefit to understanding the system performance,"* and that the developmental community will start using these methods once the operational community shows them the benefits.

Mr. Peri noted the difficulties that NASA has seen in incorporating the relatively new discipline of statistical engineering into their processes:

"When we try to look at some of these new disciplines, it's very challenging for us to adopt that into our engineering methodologies in a wholehearted way because we don't have a lot of different projects going on. As a research organization [NASA Langley Research Center], it's a little bit easier for us because we do have some flexibility, and I'm sure you know Peter Parker's work [Statistical Engineering Group] is kind of at the leading edge of the kind of work we've been trying to do within the center, but taking that and scaling that to a broader engineering discipline has been very challenging for us."

Mr. Olinger noted the challenges with manpower:

"We really have a challenge from an Air Force perspective to get enough analysts and engineers on our teams. Our ideal preference is that we have one on each team, but sometimes that one is also designated on two other teams so they're really spread thin, so trying to get that test design, that analytical input into our test can really be a challenge simply because of manpower."

Relating organizational change to clear communication, Mr. Peri also noted that it is, *"really important for the senior managers to understand the benefits and try to fold those into our mainline activities."*

Concluding Thoughts

The overarching comments from the panelists provided a lot of material for an engaged question-and-answer session with the analytical audience. The panel emphasized the importance of such cross-organizational dialogues to share lessons learns, training resources, and motivating examples of why incorporating statistical thinking into organizational processes is critical for the future of our organizations.