Noshir Contractor (00:15):

Greetings to all of you members of the IllinoisX Space Technologies Academy. My name is Noshir Contractor, and I'm going to share with you some research that my collaborators and I have been doing in this particular presentation that is titled, Missions to Mars: Understanding and Preparing Teams for the Future. Thank you very much for joining me. I also want to thank in addition to Leslie DeChurch, who's listed on this cover, my other collaborators, which include the names that are listed on this. Obviously, it's a very large team of individuals who are working on it, and I'm very lucky to be a part of this team.

Noshir Contractor (00:51):

As you all know, humans are on the verge of becoming an interplanetary species, and NASA has made a commitment to make a journey to Mars in the next few decades. As we think about going to Mars, we realize that in addition to the risks that space research has known in terms of radiation, in terms of low Earth gravity, as we begin to go on longer missions that go into space for longer durations of time, we begin to also have to consider the risks associated with human psychosocial behavior. This psychosocial behavior risk, which was considered as something that was accepted with monitoring for lower Earth orbit or for travel to even the moon, now becomes a big challenge as we plan, not just to make a short trip to the moon, but habit habitating on the moon or taking a trip to Mars, which is going to be much longer.

Noshir Contractor (01:43):

And as you can see, this is something that is considered a high risk and therefore requires some kind of mitigation. This is where our research comes in. We were invited by NASA to help them understand what are the risks associated with people working in teams for a long duration space exploration mission, and what are the ways in which we can help reduce the risks associated with the risk reduction strategy for human space exploration. For example, by current propulsion standards, it's likely to take 259 days for a whole trip to Mars. It takes a long time to get there, about a year to get there. You have to stay on Mars for a long period of time before the orbits align so that you can make a quick sling back, back from Mars, back to Earth. And then again, it's going to take about a year to get back.

Noshir Contractor (02:34):

And so, because of these issues associated with this, we also have to take into account that this distance between Earth and Mars is phenomenal. The international space station that is orbiting above the earth right now and has been doing so with human habitation for over 20 consecutive years now, is only 250 miles above the Earth. The moon is 250,000 miles above the Earth, and Mars is 250 million miles. That's a thousand times farther than the moon. And along with this distance, comes another issue, and that is it takes about 25 minutes, it can take up to 21 or 22 minutes for a signal to travel from Earth to Mars, and then back again, which means that essentially the crew has to operate with a great deal of autonomy. They can't be relying on mission control to tell them exactly what to do. In the past, Apollo missions, the astronauts were able to say things like "Houston, we had a problem."

Noshir Contractor (03:31):

That's no longer going to be something that they can rely on mission control to do. Because of this, it's going to be a very big challenge for them to work as a team autonomously over long durations. A Russian Cosmonaut said, "All the conditions necessary for murder are met if you shut two men in a cabin measuring 18 by 20, and then leave them there together for two months." That's not what we expect to

see when we go to Mars. And so, we are asking the question, what happens to teamwork under extended periods of isolation and confinement? And we say, wouldn't it be nice to have a human Petri dish where we could be testing individuals and putting them into some kind of an isolation where we could manipulate their sensory depression, their sleep habits, give them complex and boring tasks, monitor them 24/7 physiologically, psychologically, record them?

Noshir Contractor (04:24):

Wouldn't that be a great way for us to understand and prepare for a mission to Mars? And of course, most people who know anything about psychological experiments today on the planet will know that that's not going to be allowed by any institutional review board. But wait, that is in fact exactly what we are doing. And the reason we are doing it is because NASA itself has facilities such as the ones you see on the slide that says, "NASA's human exploration research space analog." And places like this at NASA are kept where they put people in there for up to 45 days at a time, and we get to research them. We get to study them. We get to observe them. We get to ask them questions and make them do certain boring activities and see how they get along with each other. We get to understand what happens when they go through sleep deprivation.

Noshir Contractor (05:15):

We need to understand what happens when they're put into a communication delay where their communication with people outside that space analog is delayed by several minutes, and we want to see how that affects their coordination, etcetera. We are not the only ones doing this. The Chinese have something called the Chinese Luna palace, which is also very similar to this in terms of what it is trying to accomplish, and of course, the Russians have a facility called NEK, where we are actually collecting data. NASA is collaborating closely with the Russians. This is a facility where we have collected data where they've six people in there for 120 days, and later this year, they're going to put six people in there for 240 days, same sort of strategy. The Japanese have a chamber called the isolation chamber and the European Space Agency have many simulated martian services in different places around the world.

Noshir Contractor (06:05):

Even private foundations have gotten into this. So now that we have a Petri dish, what happens to teamwork under extended periods of isolation and confinement? We have a lot of work that has been done on teams on Earth that we can rely on. We know that team performance on Earth is affected by team cognition, that is the extent to which they have shared mental model, the extent to which they like each other, what is called a team affect. The extent to which they have good leadership in the team and the extent to which they have good team processes, that is, they engage in activities together as a team, that are constructive, both in terms of socio-emotional issues, as well as in terms of coordinating on the tasks associated with them. These factors that affect team performance are in turn affected by a variety of team work interventions that compete to you.

Noshir Contractor (06:53):

One we are focusing on is crew composition. How do we choose that dream team, that when you put them together, they have the best chance of having high team cognition, affect leadership and team processes, which we know then will lead to good team performance? You go back in the history of crew selection. One of the first examples, comes from people who were going on expeditions to go to Antarctica. And this particular classified ad appeared when Ernest Shackleton was trying to recruit a crew to go with him to the South Hall, to Antarctica. His ad said, "Men wanted for hazardous journey.

Small wages, bitter cold, long months of complete danger, constant danger, darkness, safe return doubtful, honor and recognition in the event of success."

Noshir Contractor (07:39):

You could see that this did not attract some of the most savvy, socially skilled people. In fact, what it did was it got people who were socially inept, people who were like, "What have I got to lose? I might as well. I don't have much of a life here in Europe, in the West. I might as well get on this boat and go to Antarctica, and if no one sees from me again, no one will miss me. If we succeed, then it'll be great."

Noshir Contractor (08:03):

So there was a certain kind of person that was more likely to be interested in having these kinds of long distance, hard explorations into isolated confined and extreme environments.

Noshir Contractor (08:17):

Of course, things changed by the time you got to crew selection for space, as opposed to Antarctica. In 1959, when NASA announced the first seven astronauts that were referred to as the Mercury Seven, they were chosen for a different criteria. They were chosen because they were jet pilots. They liked to go at supersonic speeds. These were people who were very rugged, bold, and literally, they had to be realized that what was happening was they were being put into a cannon and shot like a bullet in the space, because in a sense, that's what the Mercury capsule was. And so these were people who were basically recruited because of their grit and their courage. But that's why when Tom Wolf wrote the book, he said, "That's what the right stuff was." They had the grit and the courage to be solo, successful astronauts in space.

Noshir Contractor (09:02):

That changed again. Today, we have teams that are going into space, starting with the Gemini missions that had two, the Apollo that had three. And then after that, Skylab and space shuttle, and today on the international space station, we have large numbers of team members working together. Here is an entry from one of the astronauts in the international space station, as told to Jack Stuster, a space researcher. In the diary, the astronaut is talking about his commander and says, "He's brilliant at knowing the perfect balance of fun with professionalism." Now, as we begin to go beyond the space station and have the Artemis mission, that's going to take us back to the moon, and then on from there to Mars, we need to start thinking about what are the kinds of people that we could work on, just to get the best team that's going to do well.

Noshir Contractor (09:50):

What I'm going to share with you now is some of the work we are doing as part of two projects with NASA, one called Project CREW, which stands for crew recommender for effective work in space. And more recently, a more application grant that we have just received in the last month, called project TEAMSTAR, which is focusing on taking the science that we learned from crews and applying it to create a real dashboard, to help NASA help identify and project and forecast what would happen if the 4, 5, 6 people that they are planning to send back into space, how well will they get along, and what can we do to help fix problems if we see it? That's what I'm going to share with you, a little bit of that basic research. Now, the first step is the conceptual model. There's a lot of social science research that has told us what are the kinds of factors that impact team performance.

Noshir Contractor (10:41):

And so, if you think about crew performance, a lot of that is mediated by how the crew members get along. But, how crew members get along depends on personality factors of individuals, the fit between personality factors, two people getting along well with each other because they have similar or different personalities, the social network connections that they have, their prior connections, the amount. And then on the external side, how much a workload do they have? They have a high workload, that's going to stress them out. They're not going to get along well. How long are these tasks going to take? And then finally, these, what we call is isolated confined and controlled conditions, contextual conditions. That is, are they going through a communication delay during a period of time? Have they been put into a situation where they've been deprived of sleep for two days? Has the cumulative workload just gotten really high?

Noshir Contractor (11:31):

How long has it been since they got into this chamber? Has it been the first 10 days, 20 days, or is it the 44th or the 45th day when they finally come out of this chamber? So we were able to collect data from 12 of these four member crews, and we collected data from them between eight and 12 time points over the course of 30 day missions initially, and now more recently, 45 day missions. We asked them questions such as the one you see, with whom do you work effectively? And they would tell us who they worked effectively with. This is what we call as a social network question. And you can see from the top here, that the people in general, there were lots of green arrows, many of them going both ways, which basically said they all work really well effectively. But when we ask the question who makes tasks difficult to complete, we see something interesting.

Noshir Contractor (12:19):

We see this astronaut here at the bottom, who very quickly is seen as a hindrance by the rest of the crew. Everyone is pointing arrows to this person, and that stays for the rest of the mission. But this astronaut doesn't see others as a hindrance necessarily. So what you begin to ask the question is, could we have predicted before the crew left on this mission, that this astronaut would be seen as a hindrance by everyone else? If so, could we have done something to either avoid it or to help repair those kinds of relationships? Let's see how we went about doing that. We collected all the data and we built what is called as a computational model.

Noshir Contractor (12:59):

We took the data that we had collected and we saw, how could we use this now to build essentially a weather forecast model, but not for weather, but instead for the climate, if you may, of the team, how well they got along with each other. We used an agent based modeling platform that's called net logo that actually is developed right here at Northwestern University, and is a very simple way of being able to model the kinds of relationships that you see amongst individuals.

Noshir Contractor (13:25):

We got results from this that told us exactly how important each factor was, both in terms of task affect, that is the extent to which people got along with each other, and who hindered one another. These are live results. Let's, for the sake of simplicity, just focus on a couple. For example, we found that those individuals who were very high on a personality trait called self monitoring, who were very good at monitoring themselves, they were very good at figuring out when other people were upset with them, how other people were reacting to them. That's called self monitoring. Those who were good at self

monitoring were generally liked by other people, other people enjoyed working with them, and were very unlikely to be seen as a hindrance.

Noshir Contractor (14:08):

Now we know exactly the kinds of ways in which we can predict what's going to happen in team dynamics between people. Let's take another one. This tells us that as the cumulative workload of a person increased, as a particular person was being completely overwhelmed with work, they were less likely to enjoy working with other people, and they were more likely to be seen as a hindrance by other people. Again, these are just examples of these results, for the model, as you saw, was very complex, lots of factors go into it. Once we estimated this model and we got all these numbers that how much impact each factor has, the next question we ask ourself is, well, how good is this model? Is it really predicting what's going to happen?

Noshir Contractor (14:51):

And then basically we did a bunch of training and testing models, and we found that our performance of our data was actually quite good, that we were ready to... Our accuracy was in the 70%, our precision and recall, for those who may be familiar with that, was also very high. And so we were doing better with predicting who gets along with one another. We were not doing as well in terms of predicting who makes tasks difficult. Here are our scores, our percentage scores were a little lower, but overall we were doing quite well. And we thought it was time to uncork the champagne and say, "We've accomplished what we wanted to do. It's time to be able to move on." But this is exactly where NASA came back to us and said, "Congratulations, but you've only told us who is and isn't going to get along well with one another 30 days or 45 days into a trip. What are we going to do about it? It's not enough to know that two people are not going to get along. We now have to figure out how we can fix that problem."

Noshir Contractor (15:49):

And so we took this as the analogy of saying, when you are forecasting the weather, all you're asked to do is forecast when there'll be a hurricane or when there will be a tornado, or when there will be a snow blizzard, but we are not just weather forecasters. For us, it's not enough to predict. We have to prescribe. We have to fix the problem that we are anticipating. And that's where we move to the next stage of our project. The final was application. How can we leverage our model to improve crew functioning or at the very least, to mitigate or to reduce our problem with crew functioning? In other words, how could we pair up individuals on the most interdependent tasks that they had, so that if we saw a problem coming, we could avoid the problem?

Noshir Contractor (16:33):

We could take two people who are not likely to get along well, and over a period of time, tell them that either see that they don't work with each other, or that they work with each other on tasks that they both enjoy doing, because that's going to make them excited, or pair them up with a third person who they both enjoy working with, and maybe that person will fix it. So what we did was exactly that. We did the models of the crew that was going into the mission and we figured out who was not going to get along with them, and we said, "On day 24, we think this A and B are not going to get along." Now, what we had to do is to say, "Okay, how can we change the schedule of who's going to be working with whom when, during the course of the mission to avoid this problem?"

Noshir Contractor (17:19):

But of course, in order to test whether our model was making the right predictions, we actually had to put people together who we thought were going to do really well and see if they continue to do well. We had to put together those who we thought were going to do really badly and make them work, just to prove to us that their relationship was in fact going to get worse. That was the only way we were going to know whether our repairing was really going to be successful. And so we set up a really complicated design to be able to compare which people were going to be working with which other people, and we tried this on two very interdependent tasks that they were asked to do. One was two crew members who were simulating a Rover task, and the second was two crew members who were simulating the geological sampling of an asteroid.

Noshir Contractor (18:08):

So these were the tasks that they were given. We chose these tasks because we wanted to make sure we had some really interdependence. They had to work closely together. Our goal was to maximize the number of days the crews worked, enjoyed working together and minimize the number of days they found each other difficult to work with each other. The Phobos sampling, this was the one where they did the geological sampling. As I mentioned, it was chosen because it had a very high percentile in terms of the NASA workload index, and it required a very high level of interdependence. The two had to work together, so if they don't like each other, there's going to be a problem. We had the second task, which was the Rover task. Here again, they had to work very closely with each other. These tasks also had a high degree of interdependence and a high workload.

Noshir Contractor (18:52):

They had to work very well together. They had to work closely together. It was an intense task that they had to do together. When we modeled the relationships, we found that the different pairings, whether it was the commander with the flight engineer or the commander with the mission specialist one, or the commander with the mission specialist two, there was a lot of fluctuation in who was going to get along with one another and who was not going to get along with one another. This was what we wanted to see. We wanted to see changes so that then, we could go in and say, "Let's try to see if we could fix the problems where people didn't get along with each other." So, because we had these data, both for the, who got along with each other and who didn't get along with each other, we then came up with this very inelegant design where we intentionally paired who we thought was the best configuration to work together, and the worst configuration worked together, across four missions.

Noshir Contractor (19:42):

Each of these missions lasted 45 days, and you see the missions, campaign five mission 1, 2, 3, and four. And this was mission day one to 11, 12 to 22, 23 to 34 and 35 to 45. So, what did we find? We found that when we predicted two people would work well together, they, in fact, we asked them the question with whom did you enjoy working with? And the ones that we predicted would do better, got higher scores, .99, as compared to those we predicted would not do so well. Those, when we came to who makes tasks difficult to complete, exactly as we predicted, those who we thought were the worst partners reported that other people made tasks difficult to complete .08, almost significantly higher than 0.03. The same thing was true in both the Phobos and the Rover condition.

Noshir Contractor (20:33):

Let's look at the Phobos. In the case of the Phobos, in three out of the four quarters... In three out of the four missions, I should say, mission one, mission, two mission three, mission four, three out of the four

missions, the pairings that we predicted were the best scored significantly higher than the pairings that we predicted would do the worst. When it came to, my partner made it difficult to complete the tasks, the pairings that we predicted to do the worst in three of the four missions did in fact report doing worse than those that we predicted would do well. We asked the question, working with my partner on the Phobos was a positive experience. Here again, the pairings that we thought would do better, did better in three out of the four missions, and those that we thought were going to do worse, did worse in three out of the four missions.

Noshir Contractor (21:21):

Clearly you can see that our ability was there, not only to predict who was going to work well together, but when we moved people around and we repaired them and predicted which was going to get better and worse, we were successful in doing that. So again, we got the same results in the case of the Rover task pairing as we did in the case of the Phobos, I'm not going to go through these in detail. Essentially, what I want to leave you with is that we now have ways of taking computational models, social science theories, building really advanced models, to help NASA figure out if they're deciding to send four people on a mission, or six people for that matter, on a mission, we now have the ability to give them a forecast of who's going to get along with whom, and who's not going to get along with whom, on every single day during that mission.

Noshir Contractor (22:07):

And, we have the ability to then not only make that prediction, but prescribe repairing who can work with whom, in order to be able to improve task and relationship satisfaction. If you want to learn more about the work we are doing, I'll encourage you to take a look at an interview we did with NASA's podcast called Houston, We Have a Podcast, and it's a podcast that is run by them, and in this episode 175, my colleagues and I discuss team composition research at NASA, and the role teams play in human flight and space exploration. You can also learn more about what we do in a science magazine podcast that I did just about a month ago, and in this, we talk about crew conflict on long space, and in this episode, I talked to Sarah Krespy about a session that we did at the American Association for the Advancement of Science, and keeping humans in harmony during long space missions, and how marked missions on Earth are being applied to plans for recruit mission to Mars.

Noshir Contractor (23:10):

Well, I hope you've enjoyed this little preview about the work we've been doing to help NASA. Again, I want to end by acknowledging our own team out here that is helping us study teams to go to Mars, and of course, that team also includes our collaborators at NASA who have been very generous with their time and their expertise. Thank you again very much.