Constellations

Episode 220 – Intelligence, Automation and Turn Signals

Speaker: Dr. Siamak Hesar, Co-Founder and CEO, Kayhan Space – 29 minutes

John Gilroy:

Welcome to Constellations, a podcast from Kratos. My name is John Gilroy and I'll be your moderator. In today's episode, we are joined by Dr. Siamak Hesar, CEO of Kayhan Space, a company focused on space flight intelligence, automating space safety and collision avoidance. Today we will discuss how building a safer orbital environment depends on shared data, intelligent automation, and global cooperation to prevent collisions and ensure space remains sustainable for the next generation of missions. You ready to go? Okay.

Siamak Hesar:

Let's do it.

John Gilroy:

Dr. Hesar, you have emphasized the limits of siloed operational data in collision prediction. So what is meant by siloed operational data and how can it be addressed?

Siamak Hesar:

Thanks, John, for the question. And first of all, yeah, thanks so much for having me. This is fun.

So yeah, let's look at the problem first. As the number of satellites that are being launched into Earth's orbit increase, so do the number and the variety of the operators that operate those satellites. And by variety, what I mean is the sophistication of those satellite operators that actually operate their missions. So on one end of the spectrum, you have companies with very sophisticated systems, automated systems, such as Starlink, that they are operating 8000-plus satellites in our orbital environment seamlessly. On the other side of the spectrum, you have operators that don't even have a flight dynamics engineer onboard, on the staff to ensure that their satellites are safe or they're not posing risks to other people.

So what has happened in the past decade-and-a-half or two decades is that we have obviously, the commercial space industry has grown tremendously and we are all fond of that. However, we have gotten to a point that we have a lot of the smaller and medium-sized operator, that they have information about their satellites that are necessary for the safety of the overall space environment, however those are not being shared with other operators. So that is really what I mean by siloed data ecosystem and I can go into details of that if you are interested.

John Gilroy:

Yeah, I'm just interested in the gaps here. So what gap do you see in how operators manage collision risks?

Siamak Hesar:

Yeah. One of the big gaps when it comes to space flight safety and coordination is the fact that, and it's very simple, and that is that the operators do not share their planned maneuvers with each other by and large. Again, I'd like to go ... And I'm going to be referring to Starlink throughout this podcast quite a bit because in my opinion, they are obviously the largest operator in orbit, but also they are doing a lot of the processes well, so in a way they are a model.

But when operators don't share their planned maneuvers ... In other words, my best analogy is imagine you're driving on the road and you want to turn left into traffic and you don't turn on your turn signal and you just turn. So that turn signal is sharing planned future maneuver plans that is going to result in changing your trajectory in a future time. And no one else in the world other than that particular operator that is planning to perform that maneuver or change of trajectory knows about the existence of that plan. Even the US government doesn't know it because they are tracking as things happen.

So you can have cases that there could be a conjunction event that we predict. And by the way, when we say conjunction, it's a potential collision. It's a probabilistic event, that's why we call it conjunction. So when there could be a potential conjunction that we are tracking, but because we are not aware that one of the operators is going to perform maneuver, that might not be there. The other side of the coin is even more worrying because if we are not tracking a conjunction and suddenly an operator performs a maneuver that no one is aware of it, last minute there's a conjunction. So that is one significant step that every operator can take, to share their planned ephemeris and maneuver to make sure people around them know basically which direction they're going to turn.

John Gilroy:

You've talked a lot about the importance of ephemeris sharing as orbital traffic increases. First, please explain to our listeners what ephemeris is, and then maybe discuss some of the barriers to sharing high fidelity ephemerides among operators and how they can be overcome.

Siamak Hesar:

Sure. So when we say ephemeris in the space world, what we mean is basically a time series of position and velocity of a satellite that is flying in space in its orbit. And obviously, there are a lot of different standards. The most widely used standards is the CCSDS consultative community in space data systems, if I remember that correctly. CCSDS is standards that we have OEM, OCM, OPM standards that a lot of satellite operators are familiar with these. But at the end of the day, what we mean by ephemeris or ephemerides is that they are a time series of position and velocity, it's also called a state where satellite that is in orbit, and also the prediction of the operator about their spacecraft. That it's going to be in the next few hours, in the next day, in the next three days, this is the orbit that I'm going to fly. And you can immediately see how important that is.

John Gilroy:

I guess it's a table of celestial position so you can have an idea of where something's going to be?

Siamak Hesar:

Absolutely, absolutely. And it is one of the most important things, data types that when we talk about space traffic coordination because if you don't know where something is going to be, then you cannot coordinate. And by definition, space traffic coordination happens in the future because we want to coordinate our actions in the future time. And we do want to ensure that operators do share their ephemeris with each other.

And going back to earlier question, the most important piece of information in those ephemeris files is the planned maneuvers that is included in those ephemeris files. That tells everyone else, "Hey, I'm planning to perform this orbit raising maneuver and I'm going to be higher altitude than what you see now." And as a result, everybody be aware of it.

John Gilroy:

Dr. Hesar, I think there's a lot of sources of data out there. It seems that data fusion is at the heart of situation awareness. So how do you bring together orbital data from different sources, government, commercial sensors, and operator telemetry, to create this unified operating picture?

Siamak Hesar:

Very good question. Yeah, and we have heard a lot about data fusion. I guess there's a lot of literature on this, there's a lot of research. But I guess for the purpose of this conversation, I'd rather focus on what we are doing at Kayhan Space. And in that, what I see the role of Kayhan Space is a data aggregator in the space industry. And as such, we have basically are working very hard and coordinating with different sources of data to ensure that we are able to pull data from different sources to have a better picture of what is happening in space and space environment, compared to the case that if those data sources are siloed as we talked about.

So that data source can be tracking data that the US Space Command, the US government is doing through 18 Space Defense Squadron and the Space Surveillance Network. That is one source of data. The other source of data is GPS-based tracking data from our own customer satellite operators, as well as other operators that do share their GPS-based ephemeris, both as they have flown, but also their predicted ephemeris even more importantly with the public. As well as there are a lot of commercially available data sets, or commercial companies that track objects in space, and we work with them to pull their data.

And I think that is, as the space becomes more congested and the number of objects increase, for us being able to track objects using different types and phenomenologies of data sources is very important because certain things might not be very visible with one particular type of data.

John Gilroy:

Dr. Hesar, earlier in our conversation, you used the word conjunction. Let's bring that up again here. AI and ML are increasingly applied in conjunction and anomaly detection. Could you explain how AI is used to sift through fused data and improve collision prediction accuracy?

Siamak Hesar:

Very good question, yeah. Obviously, we are in the AI world these days and there has been, especially in the past few years, it's been mind-boggling for me personally to see the significant amount of growth and improvement in artificial intelligence side. And specifically, when we talk about large language models. A lot of people, when they talk about AI, we also combine them, AI-ML, but obviously there's a big difference between machine learning algorithms, the statistical-based machine learning algorithms, versus these large language models that are the next level of artificial intelligence. And I definitely am in favor of utilizing LLMs in space applications, however that application needs to be used in the correct way.

And what I mean by that is a lot of the things we do in the space environment and the work that we do with flight operations, with space traffic coordination, with conjunction assessment, those are all very nuanced physics-based models. That we have very accurate models about it, we have very accurate models about the governing forces that act on an object in space and how it is going to evolve and how it's going to move in its orbit. So it's like you don't want to ask AI or LLM to tell you what's 2+2. The answer might come back as 4.1. So in cases like that, that's a very simple example I guess. But in cases like that when we are talking about equations, the motion and physics, and physical forces that act on objects, there's not really a place for AI or LLM to add any value.

However, when we now deal with a system-level or a mega system, system of system level process where there are very complex constraints. Let's say we have a constellation, we want to make an optimization of that constellation for whatever purpose, there are all these real world constraints around how to achieve that optimal goal. Then in those complex environment, obviously using LLMs is very useful.

You mentioned in your question anomaly detection. That's a very good use case for LLMs to teach them about what is the, quote-unquote, "normal" behavior of an object for purpose of national security or even commercial purposes. And then if there is certain anomalous action from that object, then the LLM can quickly detect that.

John Gilroy:

If you were at a trade show and listen to a panel of AI experts, they'd inevitably be talking about your phrase, using it in the correct way, and this leads to privacy. Privacy or proprietary concerns often inhibit data sharing. So are there privacy techniques that can help, especially when operators may not want to reveal their orbital details? That's where it gets difficult, isn't it?

Siamak Hesar:

Absolutely. And this is not something we should take it lightly. We are always talk about data sharing, the importance of it, and how people need to cooperate. But there are certain areas, for example national security reasons or in the regions of war zones, and not just government assets, but also commercial assets that are providing certain important data sets for government and national security purposes. They are definitely serious concerns in terms of sharing their precise ephemeris, where they are, where they are going to be, and how they're going to change their trajectory.

So let's put that aside for a second. That is obviously common sense, national security reasons, that's something that I don't think should be shared widely. But I would say the vast majority of concerns from commercial and purely commercial satellite operators about sharing their ephemeris and maneuver plans and such is not well-founded. The reason I'm saying is that because at the end of the day, I talked about commercial data providers. That there are a lot of companies that they have radars, telescopes that they track objects in LEO and GEO and MEO environment. And at the end of the day, we all see these objects, we know where they are, we know what they are doing. So by not sharing your ephemeris, you're not really hiding anything. And again, I'm only focusing on purely commercial activities.

And the downside however is bigger, which is that it is by not sharing that information and those data sets, we are putting everyone at risk. So definitely there is concern. And when it comes to conjunction assessment and space flight safety, a lot of people don't realize that the amount of data that we require to make an informed decision about a conjunction and avoid a potential collision is very minimal actually.

For instance, when I am talking about sharing maneuver plans, I want to be very clear. I'm not talking about, hey, go ahead and share your propulsion technology, I don't know, what is your power system, how you maintain your attitude, all that stuff. None of that. What I'm saying is that basically the thrust vector in which that you are going to perform that maneuver that is going to result in changing of the trajectory. So the amount of data that we can share for a space flight safety reason is very minimal and there are definitely ways that we can keep them secret for the purpose of making sure that people are comfortable with sharing those.

John Gilroy:

Earlier, you facetiously mentioned that AI would tell you 2 + 2 is 4.1. Everyone knows it's 4.2.

Siamak Hesar:

Yes.

John Gilroy:

But the problem is that, it's AI and regular intelligence, too. When combining data from multiple sources, differences in data calculations occur. How do you manage uncertainty and ensure operators do not receive conflicting information?

Siamak Hesar:

This is a very good question and it is at the heart of data fusion. When people talk about data fusion, what really people mean is that what is the best way of combining different sources of data and different types of data to get the best information out of those data sets. So you are correct, there are different sets, they're in different types. Not every data is generated the same. There's going to be large uncertainties on some of them. Some are going to be more precise than the others. For example, GPS data is very precise compared to ground tracking optical systems or radar systems. However, as long as the data set is accompanied by information about their precision level, or the other side of the coin of the precision is obviously uncertainty, or lack of precision or uncertainty.

As long as it comes with that information or information about the biases on the sensors, that enough information for the system to be able to process that data properly. There's a lot of different systems, they are known mostly as orbit determination filtering systems. Basically, they collect different sources of data based on the information they receive. They are able to estimate and utilize different sources of data commensurately to their accompanying uncertainty. And even if those information are not supplied, we can still figure out the level of uncertainty or biases and such by using what's called calibration satellites. That, in fact, we do this work, we support US government in evaluating a lot of data sets for them because we don't own sensors, so we are a third party unbiased source of truth, if you will. And we use, quote-unquote, "truth trajectories," or calibration satellite trajectories to calibrate the data sets that might not come with that type of information.

John Gilroy:

When you talk about AI and data, the topic of scale always comes up. And if we look at projections of satellites in the next few years, I guess we talk about scale and scale is important for a lot of things. So as constellations scale into tens of thousands of satellites, collision management I guess has to scale, too. So could you walk us through the challenge of handling realtime operations and potentially hundreds or thousands of conjunction events simultaneously? How many can you juggle, Doctor? A lot.

Siamak Hesar:

Yeah, yeah, yeah. It turns out, people can actually juggle a lot because, again, I want to go back to Starlink. So that's a very good real world example of a constellation that really, in the matter of few months, from having zero satellites, they became the largest satellite operator in the world. And today, if I'm not mistaken, that they have on the order of more than 8000 operational satellites, the Starlink constellation. And how was that done? Through automation. That there's absolutely obviously no way to be able to manually operate all those satellites, so automation is key.

But actually, I want to change the focus of question a little bit and talk about the fact that the number of objects, we always talk about the number of objects and satellites going to space and increasing, and congestion is increasing. Obviously, that is a problem. But the bigger problem, and again Starlink is a good example, is not that we don't have the capability of operating a large number of satellites. Clearly, we do. Starlink is doing it every single day. The problem again comes back to lack of communication. So for instance, what Starlink cannot do is if another operator that is in their vicinity or in their neighborhood, if they do something that is not communicated with Starlink ... Again, if they perform a maneuver that is not communicated and they suddenly show up in front of one of their satellites, then that is something that Starlink cannot control.

Again, I guess at the crux of all this, when you go to the root of this, yes, there are technology solution is, rather I don't want to say it is trivial, but it is doable. Automation is doable. That the human factor and the factor that there are all these different companies, operators that we need to get them on the same page. That, "Hey, you need to all share this type of information with each other." That is the part that concerns me. And when we talk about problems with scaling, those are the things that really come to my mind that we need to resolve those issues.

John Gilroy:

A lot of startup companies talk about innovation and really it has to be applied somewhere, so let's talk about maybe applying innovation here. So how do you see commercial innovation helping shape future norms for orbital operations?

Siamak Hesar:

Yeah. We have come a very long way in a very short amount of time. Every day when I look at different ideas and the companies that are starting a space venture and they are pursuing different ideas that I've never thought about before, that's always interesting. The innovation is always great fuel for moving forward in the industry. And again, space is a vast topic, industry, it has a lot of different verticals. My expertise is in when it comes to space is about space operations, satellite tracking, and space flight safety. And in that area, there are many specific parts that innovation can really help us. And in that, better sensors, better tracking. That is something that we can all get great advantage of. Tracking of smaller objects because we are only tracking 40,000 objects or so consistently and there's in the order of a million debris objects in the space around the Earth.

John Gilroy:

Wow.

Siamak Hesar:

So we are not even tracking a very small percentage of it. Actually, there is a lot of innovation in build more resilient satellites. So in other words, putting bumpers if you will in your car. That in case you hit a piece of debris ... Some objects are large enough, there's no protection against them. But you can actually make your satellite more resilient against some of these smaller pieces of debris that we are never going to be able to see so that your satellite doesn't disintegrate, for instance. Or doesn't break apart, so it creates more debris on its own.

Maneuverability is another big topic and it can be controversial. Obviously, it is more expensive for operators to have a maneuverable satellite. But to me, from my perspective, that is someone that's concerned about the space flight safety. If you are building a satellite that is not maneuverable and you're launching it into space, you're basically adding another debris. Yes, you can communicate with that satellite, but it's not going to be able to change its course in case there is a conjunction with another piece of debris, let's say.

Now, I want to be clear. Some satellites and satellite operators, in fact we have also demonstrated this, that you can change your attitude profile and basically perform what's called differential drag, so using force of drag to change your trajectory. So to me, that's a maneuverability capability. And yeah, the automation and the correct use of large language models I think is going to be another big breakthrough in space industry in the coming years.

John Gilroy:

I've been taking notes this conversation. I got thousands of satellites, millions of pieces of debris. So let's try to project what's going to happen in the future. So looking ahead, what is your vision for AI-driven orbital management? Is it possible to see a world where maybe even autonomous satellite coordination becomes routine?

Siamak Hesar:

I actually don't think we have any other choice. Again, when we are talking about thousands of satellites whizzing by each other and coordinating. Again, I like analogies, and my best analogy again is autonomous cars, autonomous driving. And the first thing when you drive as a human driver or an autonomous driver is that informing other drivers around you, informing the traffic about what you are going to do. So that's why we have turn signals, that's why we have brake lights, to inform other drivers around you what are your intentions. So obviously, with autonomous cars, a lot of these communication could happen through sensors, through connections between different cars, and the same can happen in space. In a way, you can ...

The way I think about the space problem, it's a large node. It's a large network. And if you think of all these operators as a node of this network, now you thousands of these nodes. So for each one of these node to now start having a connection with another node, suddenly you're going to have a very complex system and it's almost not doable. And that's how I see the role of Kayhan, is that as an arbiter in between all these operators, a platform, and that is why we build Satcat. It actually has a lot of free for public capabilities that everybody can enjoy, satcat.com. But we have several, basically more than 30 satellite operators on Satcat that are coordinating each other. And we have in fact, we have been able to enable autonomous coordination between different satellite operators via that platform. So having a central through which different operators talk to each other, I think that's how this process can scale and scale properly.

John Gilroy:

No, that's fascinating. I think you have given our listeners a better understanding or sharing data, automation, and AI. I'd like to thank our guest, Dr. Siamak Hesar, from Kayhan Space CEO. Thank you.

Siamak Hesar:

Thank you so much. Appreciate the time.