



**2017 Halifax International Security Forum
Plenary 6 Transcript
Satellite Armies: The Race in Space**

SPEAKERS:

Ms. Theresa Hitchens, Senior Research Scholar, Center for International and Security Studies at Maryland, University of Maryland

General John E. Hyten, Commander, United States Strategic Command

Ms. Julie Perkins, Chief Engineer, In-Space Vehicle Propulsion Systems & Associate Technical Fellow, Boeing

Dr. Rajeswari Rajagopalan, Senior Fellow and Head, Nuclear and Space Policy Initiative, Observer Research Foundation

MODERATOR:

Ms. Jeanne Meserve, Member, Aspen Institute Homeland Security Group

Jeanne Meserve: Good afternoon. I'm Jeanne Meserve, a member of the Aspen Institute of Homeland Security Advisory Group, great to be here with you. Whether you are trying to find the closest Starbucks to buy a caramel macchiato or you are trying to guide a missile to its target you're reliant on satellites.

As Steve Merkel pointed out in his excellent film we're reliant on satellites for commerce, communications, transportation, surveillance and there is no sector more reliant on satellites than the military which is why so many people say in future conflicts the ultimate high ground may well be space.

That's what we're here to discuss today with this excellent panel. Let me introduce to you starting at the far end we have with us Theresa Hitchens. Theresa is a Senior Research Associate at the Center for International and Security Studies at the University of Maryland. Sitting next to her is Dr. Rajeswari Rajagopalan who is a Senior Fellow and Head, Nuclear and Space Policy Initiative at India's Observer Research Foundation.

Making an encore performance because he was so great this morning is General John Hyten, Commander of U.S. Strategic Command and sitting next to me is

Julie Perkins. Julie is Chief Engineer of In-Space Vehicle Propulsion Systems at the Boeing Corporation.

Let me say first of all I was a little concerned that we had a general here and three women who have great depth of knowledge but did not have a military title or an official rank. General Hyten kindly agreed to let me throw protocol out the window. I'm going to be calling you John while we're here today.

General John Hyten: I like that name. Nobody calls me that anymore.

(Laughter)

Jeanne Meserve: We will call you that here Sir. I want to start out by talking about whether or not this issue has been hyped. Some people say it has been, that we have exaggerated this because it's kind of sexy to talk about. I'd like to do a quick round robin of the panel and get your sense of how great is the threat here, let's say Theresa on a scale of 1 to 10, where would you put it.

Theresa Hitchens: About an 8.

Jeanne Meserve: 8 for you? Raje?

Dr. Rajeswari Rajagopalan: Somewhere around 8, 9.

General John Hyten: I'd say about 5 now, moving to 10 in a hurry.

Jeanne Meserve: 10 in a hurry, okay.

Julie Perkins: I'd put it about 7.

Jeanne Meserve: So, uniformity of opinion here. This is a subject that some people in the room may not have great depth of knowledge of so I want to talk about exactly what we're facing in terms of technology and space. The Chinese have tested an anti-satellite weapon. They aren't the only ones with such weaponry are they Theresa? Who else has it?

Theresa Hitchens: I wouldn't say with such weaponry. I think you have to be very careful about your terms. The Chinese have tested an anti-satellite weapon in 2007.

Jeanne Meserve: Successfully.

Theresa Hitchens: Successfully. But in the 1980's the United States and Russia tested such weapons as well. You also have to remember that almost

every technology that you would use in space for a beneficial purpose also could be used as a weapon.

Jeanne Meserve: For instance, the Chinese have a satellite with a robotic arm, correct? Raje, tell us about that. It looks like it could clean up space debris but

--

Dr. Rajeswari Rajagopalan: It can also be used for a number of other purposes and it is by and large looking at the maneuvers it has undertaken so far it does appear as a space weapon. Let me go back to the anti-satellite weapon that we talked about. There were a lot of anti-satellites done by both Soviet Union and the US in the late 1980's but it was completely stopped for about 2 or 3 decades but now with China's anti-satellite test in January 2007 there is a new spurt to the whole issue.

Countries like even India are beginning to think about how we need to respond to this. Do we need to build up deterrence measures and so on, so that's giving way to new issues, new dynamics it's created.

Jeanne Meserve: I want to talk a lot more about India and what it's doing. Kamikaze Russian satellites up there?

General John Hyten: The Russians have satellites that can maneuver. If you maneuver a satellite into somebody else and kill them you can put any name on it you want. Kamikaze would be a fair name.

Jeanne Meserve: They can also eavesdrop by getting close up, correct?

General John Hyten: Everybody knows we use satellites overhead for intelligence purposes.

Jeanne Meserve: One satellite can eavesdrop on another?

General John Hyten: Satellites can basically eavesdrop on anything if they just open their ears and listen.

Jeanne Meserve: What about blinding? I've heard about lasers from the ground being shot up into space. Are satellites vulnerable to that?

Julie Perkins: They're definitely vulnerable to that. You can also if you want park another satellite in front of a satellite and blind it that way. You don't have to just do it from the ground.

Jeanne Meserve: General Hyten, I've heard the US has developed a space drone and some people are saying that's going to be a space fighter. Are they right?

General John Hyten: All I can say about the X37 is it does really cool things. I've said that before and I'll say it again.

(Laughter)

It does really cool things. It's an amazing piece of equipment. We continue to explore what it does. That's pretty much all I'll say.

Jeanne Meserve: You see the threat moving from a 5 to a 10 quickly. Why?

General John Hyten: Because I watch what our adversaries do. As a military officer I don't get to vote what I'd like space to be. For the record I liked the music this afternoon but my view of space comes from when I was a kid. I want space to be available for everybody to use forever but as a military officer I have a primary job and that's to defend the nation and defend our allies.

When I see adversaries moving quickly into the weapons domain and they are moving quickly, moving very, very fast and I see our country not moving fast, that causes me concern. That's why I say it's fast moving to 10 because we have a huge capacity in space right now that pretty much overwhelms anybody. When the adversaries are building up significant capabilities that can threaten that, I have to figure out how to respond to that.

Jeanne Meserve: The principal adversaries Russia and China but Raje as you alluded to, many other actors are entering the stage.

Dr. Rajeswari Rajagopalan: Many actors around the world are just beginning to recognize, appreciate the need for space assets for a number of different functions, countries whether they're in Latin America, Africa and in Asia but in Asia I think there's a big difference. Countries are beginning to use outer space assets for a number of national security related missions, whether it's intelligence gathering, surveillance, reconnaissance, military communications.

A number of national security dominated functions are beginning to appear in Asia and I think that's also a reflection of the changing balance of power both at the global level but also the changing Asian military equations. I think this is not going to go away. Unfortunately this is going to be dominating the Asian scenario for some time to come. That's going to pick up the pace now.

Theresa Hitchens: I want to say that I do see both Russia and China are experimenting with what's called counter space capability, the ability to harm

another satellite and I think that's true. I also though want to caution that the technologies they are demonstrating are technologies that have already been demonstrated or deployed by the United States, maneuverable satellites.

We have two satellites in geosynchronous orbit high up that are maneuverable or the geostationary space situational awareness program satellites, GSSAPS, and those satellites can move close to other satellites. We say they are for inspecting other satellites and keeping an eye on moving debris, things like that which is a very good thing to have.

On the other hand if you're sitting in Moscow and Beijing I'm pretty sure you suspect those things have been weaponized. We have to be careful about our words. We have to make sure we don't hype the threat, that we don't pretend to be behind in some kind of space arms race. I do not want to see rhetoric that sounds like the famous missile gap of the 60's. That is not the case. We need to be careful about how we talk about this.

General John Hyten: I have to look at what our adversaries say and then I have to look at the intelligence that either support or contradict what our adversaries are doing. When I put those things together what I see is I see a very aggressive action to build a fore structure that would counter our entire space capabilities. That's what you see.

As a military officer I don't get to choose whether I want to respond to that or not. I have to. The rhetoric in Russia and China if you read what the Russian дума is saying, what military officers are saying, if you read what China has been saying in public without any intelligence related to it, it is very aggressive. If that is the case then we have to be able to respond. For the record we have four GSSAP satellites now.

Dr. Rajeswari Rajagopalan: I think this is exactly the situation so if you look when there are no multilateral negotiations and where countries are going and there is a huge trust gap among the major powers, major established space players, this is how it's going to play. The deterrence game is going to come into play.

Deterrence in outer space, so far none of the states have established deterrence as a gain when it comes to space at least in the stated policies of states but the fact is it is beginning to figure. If a state, one state deterrence is an important game then others are going to follow that game and it's going to have, deterrence will have cascading effects and it's negative for all. We need to be careful about how we are going to play ourselves in this game.

Jeanne Meserve: I want to talk a bit more about how crowded the space is up there. Commercial items are up there as well. This isn't just nation states putting satellites up there.

Julie Perkins: No and the trend now is going towards constellation so instead of just launching one spacecraft people are looking at constellations of eight or in some cases hundreds of satellites. It's going to continue.

Jeanne Meserve: There's a certain danger in just the space being too congested isn't there?

Julie Perkins: Yes. If one operator loses control of his satellite and can't properly dispose of it then it becomes a danger to everything else that's near it.

Jeanne Meserve: Theresa, you had some amazing numbers on how many satellites we're likely to see.

Theresa Hitchens: Currently we have about 1,700 operational satellites. That's not counting the population of space junk which is already huge and problematic. We have 1,700 operational satellites and if you look at the plans around the world by various companies to create these constellations to do new missions such as earth observation but also providing internet across the globe to places that can't get it currently, again all good things.

You're talking about more than 10,000 satellites in space in the next five years. That is huge, a huge problem when a lot of those satellites will all have to cross over the poles in their orbit. There's going to be a giant traffic jam at the polar level.

Jeanne Meserve: And a really serious one.

General John Hyten: It's interesting because my job and all the missions that I have, nukes, space, cyber, missile defence, all those missions are there to defend the United States but I have a different mission when it comes to space because I feel in space I also have a job to defend the environment.

If we don't defend the environment all those capabilities that Theresa just described are impossible to do if you have a debris cloud that circles over the poles all the time, you'll never be able to fly over the poles. If you have a debris cloud that's moving geo all the time it threatens everything we have to do. It's critically important to us at Stratcom, it's important to the country that we always work to defend the environment as well.

Jeanne Meserve: Does that make it less likely in your view that we see some sort of kinetic attack than some sort of jamming effort because whoever attacks is going to be hurt by this debris as much as anyone?

General John Hyten: I was on the F15 satellite program in 1985 when we shot down a US weather satellite. Interesting, the Chinese shot down a Chinese weather satellite. Ours was much lower than the Chinese satellite so their debris is going to be up there a lot longer than ours was but nonetheless, the debris we created lasted for over a decade before it came down.

It was something we had to work on to avoid all the time. The Chinese debris, we maneuver the space station two, three times a year to avoid Chinese debris. We have to be able to watch and categorize and characterize that. We provide warning now to the Chinese and Russians from the air force.

Why do we do that? We do that because we want to make sure we don't have another accident in space. We had one in 2009, the Ridding Cosmos collision that created as much debris as the Chinese A Sat. Each one of those events is as problematic as a kinetic event in war.

Jeanne Meserve: How good is our visibility up there?

General John Hyten: The visibility right now we see about 23,000 objects we can track. The estimates there's somewhere between 250,000 and 500,000 objects which means we can't see a lot of those but we're going to deploy a capability in 2019 that's called a space fence that will see probably upwards of 250,000 plus objects we see, mostly in lower orbit now which is kind of where we have a tough time understanding and characterizing the orbit. We'll be able to do a much better job in 2019.

Jeanne Meserve: Julie, as the engineer here, tell us how vulnerable satellites are. Some of them are very old.

Julie Perkins: Yes, some of them are very old and quite honestly commercial satellites aren't designed for warfare. They're designed to survive the sun and micro meteoroids and such but they're not designed to take on adversaries. They're there so we can pay our gas at the pump.

Jeanne Meserve: Are they being built to be more robust than in the past or is that impossible because that would add too much weight?

Julie Perkins: It would add a lot of weight. It also would add a lot of cost which everybody is striving for faster and cheaper at this point.

Jeanne Meserve: What's our resilience capability? If some of our satellites are taken out either by debris or by attack, what happens? Will everything shut down as some have predicted?

General John Hyten: You can call me John by the way. Our space constellations in the military are not nearly as resilient as they need to be. We built them for a benign environment. They're designed to operate like the commercial side in a benign environment. That's a mistake.

The requirements now that are coming out of strategic command is that I don't want to buy any more fragile undefendable satellites but everybody thinks that means I want a Battlestar Galactica that can defend itself. Like Julie said, you can't build that. You can't afford to do that.

You can't put all the weight in space that would do that. That means we have to build capabilities to defend ourselves in space just like we do every other domain. It's just a military problem. It's a military problem that we solved in the air. We've solved it on the ground. We've solved it at sea. We just need to solve it in space.

Jeanne Meserve: What are the capabilities? How do we defend ourselves in space?

General John Hyten: With really cool stuff.

(Laughter)

Jeanne Meserve: A little more specific maybe, a little more granularity please.

General John Hyten: I will say that how we defend ourselves in space will be a mix of maneuver capability, of off board defensive capability, of on board defensive capability and for anybody in here that's ever flown an airplane, in the military what does that sound like to you?

That sounds like a defensive structure that you have in the air on the airplane. The one thing we won't have is chaff (ph). Deploying chaff in space is not a good idea. But we will have significant defensive capabilities in the future and we have to build it that way and think about how to defend ourselves so we don't make ourselves easy targets for an adversary.

Theresa Hitchens: I totally agree with that. I think resiliency needs to be the focus and we failed ourselves in our strategic thinking by failing to provide that up to now, allowing space to become what engineers call a single point failure. We shouldn't have designed the system like that in the first place but that's aside.

My other point is besides defending ourselves and besides deterrence which people often think about deterrence as I need a weapon to deter their weapon. It's a point counterpoint kind of thing. That is not the only form of deterrence. There are other forms. Resiliency is one. That's called deterrence by denial but another one is called deterrence by assurance or positive deterrence.

That means trying to make it worthwhile for other people not to attack your stuff. In other words they get benefit from doing the right thing, from following the right rules. One of the big problems right now is we don't have agreed rules of the road in space for military operations even for best practices. We need to remember that diplomacy and rules of the road are ways to prevent the war that the general doesn't want in the first place. We don't start with attack and defend. We should be starting with prevention.

Jeanne Meserve: Is there interest in creating rules of the road? By all parties?

Theresa Hitchens: Yes. There's ongoing effort. There was what's called a UN group of governmental experts that finished a report in 2013 which was approved by the UN.

Jeanne Meserve: Here we are four years later.

Theresa Hitchens: It has a whole bunch of recommendations. Unfortunately I haven't seen a lot of uptick even in the United States who is a key player for implementing those things. There's an ongoing process in Vienna right now, a very similar UN process. Part of the problem with the diplomatic efforts is the major countries have not put the political muscle into that that they have into aggressive rhetoric and trying to scare each other.

Jeanne Meserve: Given the geopolitical situation now General is this feasible that we're going to meet agreement on rules of the road?

General John Hyten: Some people find it surprising that I'm one of the biggest supporters of developing rules of the road in the country. I think it's essential for our future security to have that. In what domain don't we have rules of the road and norms of behaviour?

When you look at space, when the operators in the air force and the army and navy go to work and they are operating in space they're flying satellites in space, what rules of engagement do I give them of what to do in case something happens? They have none. They're the only operators in the entire military that go to work without rules of engagement. Why do they do that? Because we don't have any international norms of behaviour to build around.

We need to agree on norms of behaviour, at least the basic norms of behaviour then we can develop rules of engagement for our soldiers, sailors, airmen that operate space craft to work in. Without that we're problematic. Guess what we're doing right now?

We're making up our own rules of engagement because we're not going to send young people to work in a contested environment without some kind of rules of engagement.

But that's a bad answer. We should do that in some kind of international norms so it's agreed to internationally and we're not making it up as a single nation.

Dr. Rajeswari Rajagopalan: Clearly I think rules of engagement, rules of responsible behaviour, these need to be put into place and I think at individual levels when you speak to countries they all agree on the need to develop responsible behaviour, (unintelligible) confidence building measures, engaged through measures like the UN GGE but at the end of the day we have several recommendations in the GGE report that came out last in 2013 but how many of those recommendations have been converted for instance through UN Security Council resolutions?

Have they been converted into more actionable initiatives? We haven't done that and I think that's one of the bigger problems because otherwise the UN GGE comes out with a very doable recommendation but unless we are able to convert them into practical proposals within a large set up like the UN Security Council, UN GGE are not going to go very far. In the meantime we need to make progress with confidence building measures, norms of responsible behaviour.

These are achievable goals but it is still hindered by the process that we don't have political consensus. The lack of consensus among the major powers today have come to be the biggest hurdles in making and developing an effective space regime. We need to move past some of the political motives that have been in the way but under the current political climate it's going to be extremely challenging. The challenges in space security are securing outer space for a safe, secure, sustainable access to outer space, we need rules of the road. We need rules of engagement.

Jeanne Meserve: Julie, I'm wondering if you have any thoughts about the fact that the private sector has become such a player up there. We have Space X and others launching and more and more private industries becoming a player, more and more countries becoming players. Does it become more complicated to set rules of the road that everybody is going to abide by in this very complex environment?

Julie Perkins: I think on the commercial side it's more organized. We have the ITU at least for the geo-belt you have to apply for a licence, make sure you're operating in the right spot. I think the question for me is everyone going to abide by the rules because if you get the major players you might be able to get them to abide by the rules but we see on the ground now people who are no longer playing by the rules. What are we going to do about that?

Jeanne Meserve: Julie, one other thing that I wanted to probe with you was jamming and the susceptibility of satellites to interference in that regard. Would it be hard to hack into a satellite?

Julie Perkins: It depends on the age of the satellite and how secure it is. Some of them are fairly secure with their communications. For your standard communications satellite not super hard to be able to interfere with it.

Jeanne Meserve: Could a non-state actor do it?

Julie Perkins: Quite possibly.

Jeanne Meserve: Quite possibly? Great. (Laughs) Do we have any indication by the way that any non-state actors are exploring this space and trying to gather this expertise?

General John Hyten: Jammers are cheap to buy. What you should really be worried about is that I could build a jammer. I'm old. I used to be an engineer. I've become not very skilled but I could still go to Radio Shack today, buy the parts I need to build a jammer.

If I wanted to I could just go onto the European market and buy a GPS jammer. It's about 10 to 15 Euros. I haven't looked in the last few months, to buy a GPS jammer you can put in your car and it will work. They're illegal in the United States by the way. You can't buy those.

Nonetheless they're not hard to do. It's a very weak signal. We're looking at ways to increase the power, increase the protection, increase resilience using other domains by the way, not just the space domain because we have to be able to defend the mission, not necessarily the place.

There's no such thing as war in space. There's just war and it might extend into space someday and when it does extend into space we have to figure out what to do about it. By the way, deterrence, I like Theresa's description but we need to think about that broadly. The deterrent population is not about the domain. It's about an adversary. What do you do about the adversary? The actions may not be in space in order to effectively deter.

Jeanne Meserve: Any regrets that (unintelligible) was allowed to languish, wasn't updated, because that would be your backup to GPS.

General John Hyten: There's limitations to (unintelligible) but I've advocated in the PNT position navigation time executive committee of our nation for (unintelligible), enhanced (unintelligible) capability which is basically a ground base but it's really focused on ports. It's really focused on limited locations but nonetheless it doesn't provide resilience in that constellation.

The army is working on what I think is the best model right now. The army model has a four chip set of navigation and timing system. First chip is GPS, this gold standard. Second chip is Galileo. Third chip is an INS and the fourth chip is a truth chip to see what's being jammed. You put those together and you figure it out. It's really not that hard to get a capability. It's not all about the satellite. It's about the user equipment. It's about the ground system. It's about the infrastructure. The key is the mission, not the spacecraft.

Jeanne Meserve: Theresa, did you want to weigh in there? Oh, I thought you were ready to jump in. We've talked about rules of the road. What about a space arms control treaty? Is there any prospect of that? No, no, no.

Dr. Rajeswari Rajagopalan: Exactly. I think legal options are legally binding, verifiable measures. Are they possibly ideal options? I think again to go back to the current political environment you won't get any of the major powers to sign on to legally binding measures.

Even as Russia and China have proposed the draft treaty of the prevention of the placement of weapons in outer space which is called PPW in short, they are not serious about it because they understand that no other country is going to sign onto it. Legally binding options even as it's the most ideal option they are not going to be feasible in the near future.

Therefore given the number of challenges and by the way space arms race I think comes third in the whole list of space security challenges. First may be the space debris which is already a huge problem. In fact Ecuador just launched one satellite. They lost it to space debris back in 2013. That's a threat which is already pretty significant.

The second is the renewed frequency interference which is not as serious today but it's going to become a very big issue in the coming years. Third is potentially the arms race that is building up strength at this point in time. Given the number of security challenges we have we do need certain rules of the road because at the end of the day if you do not have some basic rules to guide the traffic management in outer space that's going to be a serious problem. But legally binding options are not going to happen in the near future.

Theresa Hitchens: I agree with you about that, particularly because the big three powers are not talking seriously. You can't get to any kind of treaty if you're not talking seriously but I want to note one of the ways you get legally binding measures is you start with norms of behaviour that are internalized into national laws.

That has happened with the space debris mitigation guidelines that the UN came up with some years ago. They've been integrated into the licensing processes in the US and in France. Not all countries have done that but this is a way to overcome national disinterest in signing treaties that seems to be pervasive at this time.

Jeanne Meserve: How extensive is our cooperation with Russia in space? I know we're on the international space station together but apart from that.

General John Hyten: We're on the international space station. We still buy our used Russian rocket engines on the bottom of the Atlas Five.

Jeanne Meserve: Yeah, we're still reliant on the Russians.

General John Hyten: For getting to space, therefore we have a partnership with (unintelligible) to make sure we can if we have a problem we have to have engineering support from the Russians and those kinds of things. That's actually a useful arrangement but I don't like having a Russian engine on the bottom of an American rocket.

I really don't like that. I want to get off that but when we have these arrangements with the Russians there's always goodness that comes out of talking. Similar to what I said this morning, I always think it's better when you have an adversary if you're talking to them. It's a better place to be than not talking.

Jeanne Meserve: Are there limits on cooperation in space with the Chinese?

General John Hyten: There's limits from a military perspective on how to engage the Chinese.

Jeanne Meserve: Isn't Congress also putting limits on that?

General John Hyten: They have and so we're working through that. I continue to put requests in. I'd like to start small. I think the best way, if you watch the video that everybody watched a while ago, anybody think going to watch a rocket launch is not cool? I've used that word three times now but it really is.

Let's have the Chinese come over and watch one of ours and we'll go over and watch one of theirs. It's just a place to get started, to have a conversation.

Jeanne Meserve: Julie, how much longer are we going to be reliant on those Russian engines?

Julie Perkins: We do have a lot of other players coming into the market now. Of course there's Space X and a lot of our commercial market is being launched on those. We also use Aerion (ph) quite often so for the commercial side we're not as dependent on the Russian rockets.

Jeanne Meserve: General, excuse me John, the national defence authorization act says the US has a broken national security space enterprise. It points out that the decision making is fragmented across more than 60 offices in the US government. How do you respond to that criticism?

General John Hyten: I would say almost every element of our enterprise in the military responds to about 60 offices in the Pentagon.

Jeanne Meserve: Is it the right way to do things?

General John Hyten: No, it's not. If you read the problem statement that was written by Congress, the House of Representatives in particular, read that problem statement. They describe the problem statement exactly right. If you get the problem statement exactly right and say how do we solve that, that's a great step forward.

I would like to apply some of those lessons in the MVA that came out to the broader government because my biggest fear is not about the Russians or Chinese. My biggest fear is that our country seems to have lost the ability to go fast and our adversaries are going fast. If we don't fix that we won't stay ahead of them. That's my biggest fear.

Jeanne Meserve: Do we need a space corps?

General John Hyten: No, we don't need a space corps. I don't think we need a space corps. I had a boss one time told me you don't need a space corps until you have twin fighters. That's about the timing I think you would need when you get to the need for a space corps. It just adds more bureaucracy.

If you read the MDAA it's actually pretty good right now because it eliminates bureaucracy. When was the last time you saw a law passed by our Congress that eliminates broad swathes of bureaucracy within the government? That's an amazing statement. They haven't said what's going to replace it.

That's left to the department. That's a good thing too because now we can figure out what we have to do but the whole goal was to eliminate some of the bureaucracy that was keeping us from going fast and say alright, the air force, you have a big role, air force space command.

You're in charge. Now we have to figure out the Pentagon side of the house. They basically cleaned the floor of everything in the Pentagon and say now figure out the way to go fast.

Jeanne Meserve: I'd love to start taking some audience questions here.

Question: Thank you so much. Scotty Greenwood with Canadian American Business Council. Terrific discussion. I heard all of you talk about space debris as being a major threat and that's a light bulb moment for me. I hadn't thought about that. What I haven't heard and I'd like to ask is, is there anybody working on a space junkyard that you could gather it all and send it way far away?

I don't know what the solutions are but is there a serious approach because I take the point that getting international agreements is quite challenging at any time. We haven't ratified the Law of the Sea. We've pulled away from trade agreements. Is there a serious effort whether it's private sector or through government or NGO's to collect the debris and do something with it to reduce the threat?

Theresa Hitchens: Debris removal is a topic of great interest right now for a number of countries and a number of commercial entities as well are exploring technologies. Up to this point we have no such thing as a space hoover I'm afraid, a space vacuum cleaner. We haven't perfected the technology yet.

There's also a legal problem. Under the Outer Space Treaty you own your stuff that you put in space. If I'm company X in Luxembourg and I wish to go up and remove a piece of space debris it has to be Luxembourg's debris. If it's India's debris I have to go to India and get permission. Unfortunately a lot of that debris is ancient and we don't really know who it belongs to. That's a problem as well.

It's technologically challenging but there are discussions internationally at UN venues such as in Vienna at the committee for the peaceful uses of outer space about how to approach this. One last thing, we also have to be very careful about this because any technology that could go up and remove space debris could also remove your satellite, your active satellite. There has to be international discussion about how we do this.

Jeanne Meserve: Julie is it right that a very tiny piece of debris could do huge damage because of the velocity at which things are moving?

Julie Perkins: Oh yeah, if it hits the wrong thing, if it were to hit a propellant line or take out a significant portion of a solar ray, you could severely degrade the capabilities of a space craft.

Jeanne Meserve: How small a piece of debris can do that kind of damage?

Julie Perkins: It doesn't take something very big, it's surprising. You can take something that's even that big and go in at the right speed hitting the right place can do significant damage.

Question: General I wanted to follow up on your comment about going fast. You said you're worried that the space innovation is not moving fast enough or at least fast enough to keep up with the enemy. We've heard this a lot. The director of (unintelligible) Technology Office last week talked about this as DOD continues to buy exquisite systems, fewer number of expensive systems that take a long time.

There doesn't seem to be movement in the direction you're talking about. What changes would you recommend at this point or how would you change the mindset so things can start moving faster?

General John Hyten: The US Air Force and the National Reconnaissance Office have together built what they call the space enterprise vision. In that vision there's a mix of capabilities that we need to operate differently and defend ourselves. In that vision you won't find any of those big exquisite long-term satellites.

You'll find more resilient capabilities, more distributed capabilities. I made a call at US Strategic Command that we will embrace that as the vision of the future because I think it's correct and we will drive our requirements because they're combat and command requirements to require the services to build those satellites and I won't support as the combatant commander the development of any further large, big, fat juicy targets. I just won't support that.

We're going to go down a different path. We have to go down that path quickly. Not everybody in the country, not everybody in Washington believes that's the right path but I think you hear from all of us, the most important thing is to be able to defend ourselves. If you build a capability you can't defend, what are you doing? We have to go a different direction.

Question: I have a question to General Hyten and to Theresa. General you were referencing the visibility issues in space. If there is increasing ability to undertake kinetic activities in space, to move around but there is also a lot of debris, how confident are you in your ability to distinguish an accident from

hostile malignant activity? What (unintelligible) communication lines do you have in place to prevent a catastrophic escalation of such a situation?

General John Hyten: The first thing we have to do is we go into this new future is we have to improve our space situational awareness capabilities. The first and most important thing is to be able to understand what is happening and be able to attribute bad behaviour if something happens in space.

Right now we have a very good capability to track stuff. We don't have a very good capability to attribute behaviour. A lot of the new capabilities that we'll have that are in the budget will allow us to see and understand. That's one of the reasons the system that Theresa mentioned a while ago, the geosynchronous space situational awareness program is in existence.

When we announced it in 2014 it was announced as a neighbourhood watch program because we wanted everybody to understand that whatever happened in geosynchronous orbit we would see and be able to attribute that behaviour. It was important to the United States that we announce that to the world that we would be able to see everything.

As far as measures to communicate with our adversaries we have very little. We have the Russian nuclear exchange issue from Washington. That's the only means we have to communicate right now. There is an interesting story about that. When we started providing collision warning messages to commercial operators, international operators we decided we would do it for Russia and China as well.

We first sent messages into the foreign ministry of China and then had to filter down and it was only a couple of years later when we got a message from China saying instead of sending it to the foreign ministry how about sending it to this address in Beijing because it would get to us a lot faster. In many cases the timing is very important so we started doing that. There are ways to walk into this. There are certain things we have in common. We don't want debris in space because pretty soon we won't be able to fly and operate.

Dr. Rajeswari Rajagopalan: Talking about the space situational awareness I think that's an important aspect of how we deal with a whole range of accidental and other issues. I think so far the US has the largest network of sensors and radar but I think the coverage is not all that much and followed by the US you have the Russians and then the Europeans.

I think this is one area where we need to strengthen the collaboration. The US and India have been talking to each other about space collaboration. India and Japan have been talking so I think this is one area where this is a fairly non-

controversial area that should be expanded to a number of different countries in order to expand the scope of visibility and so on.

Theresa Hitchens: Because everyone has to see. The US military is very good about sharing the information they have. We are the only country that shares that on a routine basis. However we don't share all the data. We don't have all the data, we need more data. We need ways to share the data better. We need more people providing data, more observations and we need to do this in the civil domain not just the military domain.

Question: I am (unintelligible) Japan's national graduate institute for policy studies. I'd like to ask one question about North Korea's capability. Although we don't know whether North Koreans have re-entry capability to their missiles, there is a possibility that they conduct high altitude nuclear detonation. Some time ago in this year North Korea suggested they will do so.

There are some people who say that the high altitude nuclear detonations have a serious effect but some people say no. I was wondering how do you calculate the effect of such nuclear detonations in outer space.

General John Hyten: I don't want to go into a physics lesson. I'll just say since we've been operating nuclear weapons in the United States for a long time we have an exquisite understanding of high altitude nuclear detonations and the effect is an electromagnetic pulse.

If you have an electromagnetic pulse that goes off high enough, you create basically electromagnetic charges that will destroy any non-hardened electrical system which is any digital computer, any digital capability on the ground within a line of sight basically. It is a significant issue for a high altitude nuclear explosion that has to go over an area that will be threatened.

Over the ocean the concerns are is there any airplanes or shipping underneath that? Nonetheless that could be significant but you have to be worried about anybody who would deem the explosion of a nuclear weapon in space as a good thing. We've done that way back in the beginning of time and it basically will destroy any non-hardened satellite within line of sight of that which is about a third of the constellation of most constellations. That would be a disaster for our nation and for the world. We have to get away from that. If you talk about norms of behaviour that should be significant on the list of something to never do.

Question: Robert Baines, President of the NATO Association of Canada. I'm interested about space weather and our resiliency from space weather. Obviously a lot of our defence systems here on the ground rely on all the

communications that are necessary. How threatening is the spectre of space weather?

Julie Perkins: Luckily we've been learning a lot about it over the years. We do plan for it. We have something called the solar cycle and we know what the spacecraft have to be able to survive over the years and we design all of our electronics and solar rays to be able to handle that.

We do get surprises every once in a while. The sun sometimes can get a little angry, throw off a bunch of stuff all at once and it can damage some spacecraft, particularly older spacecraft when we hadn't learned all our lessons yet. I think at this point we've got a pretty decent handle on it.

Question: Mustafa Barghouti from Palestine. Since there is so much effort today in the world to prevent dissemination of nuclear weapons is it unimaginable to think of a treaty that would guarantee that space is free from weapons and from military capabilities?

Jeanne Meserve: I think we heard there's a lot of doubt that that's possible, correct?

General John Hyten: One thing I'll add. I think they answered that question beautifully but one thing I'll ask you as you think about that is define what a space weapon is. Nobody has ever been able to define that correctly to me because any satellite that you take and drive into something else, it's a satellite but if it drives into it, it becomes a weapon. Are we legislating against satellites? That's the difficult part and I don't know how. What you want to do is what Theresa said and that's focus on normative behaviour.

Question: What you might do to defend yourself might sound to others as an act of aggression and so they would respond to the same reaction and it will become inevitable that we have another race.

General John Hyten: That's why you want to have the norms because you can work the norms and that's how things start settling out. When you don't have norms – a lot of people have criticized me for saying I support norms of behaviour because they think that ties our hands in our ability to react to a bad event.

When I say ties our hands is not having norms of behaviour because when you don't have norms of behaviour if something bad happens the airman on the floor at Truman air force base in Colorado does. He says something bad happened so he calls his boss who calls his boss who calls his boss who eventually gets to me and then I call the Secretary of Defence and is that any way to conduct a military operation? No.

That's why I support that kind of construct and it also has the added benefit of starting to stabilize the environment. That will be a significant point of discussion for the next number of years until we get to that point but we have to get to that point. We got to that point in every other. It took us a long time to get to the Law of the Sea where we understood norms of behaviour on the sea. It will take us a long time in space but we have to go down that path.

Theresa Hitchens: I think you do have to worry about trying to set up legal constraints on technology and what the General said is true. Space technology is by and large dual purpose. You can use it a number of different ways. What you can legislate or make legal treaties about is behaviour.

For example, if I ruled the world I would have a legally binding treaty that banned the testing and use of kinetic energy weapons against a satellite because that would prevent people from using those types of anti-satellite weapons that create space debris and put the rest of us in danger. You could do that without getting into limiting missile defence although personally I have a huge problem with missile defence especially if people are now talking about space based missile defence.

I think that's not only technically insane, it is geopolitically poison. It will make everything unstable. You could do that. You could start to think about legal prohibitions on certain types of activities rather than the technology itself. We're not there yet. We have to start the baseline conversations. You can't simply impose a legal weapon when you don't have a dialogue. You need to have the dialogue first.

Dr. Rajeswari Rajagopalan: I would add to that. I think space assets should not be compared to nuclear weapons because nuclear is far too dangerous and very different. We need to compare given the dualist nature of outer space assets we need to compare it more to chemical weapons or biological and so forth.

Therefore the kind of global mechanism you would think about is along the lines of the Chemical Weapons Convention or Biological Weapons Convention because of the dualist applications of space assets but a legally binding about certain activities I agree with Theresa but not necessarily a legally binding mechanism to -- even if you're talking about a code of conduct for instance, it may be a non-binding mechanism at the global level but it does dictate certain national laws and national liabilities at the domestic level.

It doesn't matter if you have a completely non-binding voluntary mechanism at the global level as long as it translates to more binding measures and regulations at the national level which is what you need and also the need to

involve the multi stakeholder approach in a sense. You have to bring in the technician, the scientific bureaucracy. You also need to bring in the lawyers as well as the political leadership because otherwise we are not going to make any headway with any mechanism.

Question: I'm Leila Alieva. I'm interested in democratic control. We didn't mention that aspect at all because I think satellites make the issue of monitoring the citizens much easier especially in the countries with the lower level of democracy. I also am concerned with this issue because I'm coming from the country where the government is also interested in satellites and we know the dangers coming out of it.

My question is do you think that the issue of democratic control over space industry is more important than with the other aspects of the military? How do you think – what should be done to make it more pronounced and also I'm interested in how do you see the PR of this industry particularly as reflected in the film industry and games. What is the interaction between – what kind of influence does it have on popular perception?

Jeanne Meserve: Anybody want to tackle that one? I think you stumped the panel.

General John Hyten: I'm a military guy. I'm not going to go into the policy realm of who uses what satellite for what but I'll tell you one of the fascinating things as you watch the commercial side that Julie talked about start to develop and you go from 1,700 satellites to 10,000 and 20,000 and even more how ubiquitous the capability is going to become to the world, not just to the developed nations but the developing nations as well. That will bring the internet. That will bring different things which will allow the more seamless sharing of information across the globe. I can't see that as anything but a good thing.

Jeanne Meserve: John, I'm curious as to whether you have Jeff Bezos or Elon Musk or Richard Branson on speed dial.

General John Hyten: I used to. I don't anymore. Not Richard Branson but I talked to Elon Musk a lot and I talked to Jeff Bezos a lot. They're great partners. They have a great vision of the future. They're changing the way – talk about going fast. They're going fast and it's always awesome to see companies that embrace a different vision of the future, invest and go fast. I loved working with them in my last job. My current job is about war fighting and they're not big into war fighting so I don't call them very much.

Question: My name is Yamaguchi. I'm teaching at International University of Japan, former army aviator. My question is to the General about the Chinese

anti-satellite weapon 2007 which was done at an altitude of 800 km or 850 and causing thousands of debris. Some of them might have caused danger to Chinese own satellites. My question is how do you think Chinese (unintelligible) that kind of danger?

General John Hyten: I haven't talked to the Chinese so I don't know the specific answer to the question but I can share my personal experience. I came into the F15 ASET program right on the time of the intercept of the American weather satellite in 1985 and we were unbelievably surprised at the debris that we created.

We did not understand the physics of that event when it happened and one of the lessons we learned from that is creating debris is bad. That's one of the reasons that program was cancelled because – then the army got the next program and tried to figure out how to do the same thing without creating debris. It was a giant fly swatter in space. That didn't work out very well.

Then we took a hiatus from that but it was a little bit surprising to me that the Chinese would not have learned from that event in 1985 that the international outcry of dismay and actual anger in many cases about the Chinese creating debris in an environment where the space station operates, where other things operate has had a significant impact.

How do I know that? Because it's been ten years since and there hasn't been another event like that. When the international community does come together and make a statement it does have an impact. They are continuing to pursue that technology though so as a military officer I have to be worried about it.

Question: General, can you give us some examples of behavioural norms that you would like to have?

General John Hyten: I can. Theresa gave you one just a while ago and that is you shouldn't take any intentional action that creates debris in space. That's it, no intentional action that creates debris in space. That's a norm of behaviour and if you see anybody create debris in space they have now crossed an international line and now you can do something about it. But right now there's no norm so that's a bad thing. I think there should be.

Jeanne Meserve: Unfortunately we have to leave it there. I want to ask all of you to say in place because we have another chat coming up with Jonathan Teperman. Theresa, Raje, John and Julie thank you so much for joining us for this great conversation.

(Applause)

