

SmallCatSat Symposium: Unofficial Notes:



February 7th – 9th, 2023, in Mountainview, California



Financial, Valuation, and Industry Consulting

NOTICE: These notes were taken live at the 2023 SmallSat Symposium in Mountainview, California, September 7 - 9, 2023. They are a good-faith representation of our impressions of the events and what was said by participants. However, we cannot guarantee the accuracy of any specific comment. These notes are not endorsed by Sat News in any way. This document is not a recommendation to buy or sell any security. Please consult with appropriate professional advisors before making significant business decisions. Comments and corrections are welcome.

Executive Summary

SatNews' 2023 SmallSat Symposium was the largest ever, with 901 in-person attendees. However, the mood was somewhat subdued. The realization that financing will be tighter, and an inevitable winnowing of competitors is starting to sink in. Ambitious early-stage companies with significant funding needs before breakeven will likely be hit hardest. Key themes included:

- Artificial Intelligence (“AI”)/ Machine Learning (“ML”) was a hot topic with significant implications for flight operations and orbital debris avoidance, computer programming, and other areas.
- Vertical Integration. Companies across the spectrum discussed the advantages and, in many cases, the need for significant vertical integration. The most common reason given for vertical integration was that supply chains are well-developed or otherwise unreliable. In some cases, this is due to companies having unique business plans and needing supplies commonly produced to the required specifications. In other cases, vertical integration was justified based on supply chain issues. Supply chain shortages threatened to leave companies exposed to shortages of critical components if they did not take on the task of building those components internally.
- On-orbit processing was another significant theme. The consensus seems to be moving away from “dumb” bent-pipe satellites to ones with significantly enhanced onboard processing. Justifications range from reducing the amount of data downloaded from space (e.g., don't download the remote sensing images that are 100% cloud cover) to reducing the environmental impact of terrestrial data centers. [AM Comment: In the past, bent-pipe architecture was preferred as processing power rapidly evolves. Shorter NGSO lifespans, however, may change this calculation]
- Standardization, something the satellite industry has long avoided in practice, is an idea whose time appears to have come. Speakers stressed the importance of standardization for reducing costs to unlock new customer markets across the sectors of the industry.
- Space Debris concerns continued to amplify, with Viasat's Mark Dankberg giving an interesting perspective (See the summary of Session P on page 33).

Elon Musk was the elephant in the room. None of Musk's companies presented. However, Musk's presence was felt. It is unclear how many of the new launch companies intend to compete with SpaceX, how the broadband constellations intend to compete with Starlink, or how the ground equipment companies can compete with his low-cost user terminals. Several companies stressed the importance of a diverse ecosystem, but few ideas on how to get there.

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[AM comment: The conference went through mid-day on January 9th. I did not attend the final half-day but took notes from the web replay]

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DAY ONE: TUESDAY, FEBRUARY 7, 2023

A. THE 2023 SMALLSAT MARKET: SIZE, VALUE, AND GROWTH SECTORS

- MODERATOR: Janna Lewis, Senior Corporate Counsel - BAE Systems
- Shalini Bhatia, Principal - Deloitte Consulting
- Fletcher Franklin, Senior Program Manager – BryceTech
- Dr. Ward Hanson, Lecturer in Economics - Stanford University
- Sita Sonty, Partner and Associate Director - Boston Consulting Group (BCG)
- Dr. Abhishek Tripathi, Director of Mission Operations - Space Sciences Lab University of California, Berkeley

PANEL DISCUSSION

- Dr. Ward Hanson, Stanford Lecturer
 - Space industry has mostly been B2b, but now moving to consumer markets
 - Takes longer for consumers to adopt technology than you think, but it usually goes further than expected
 - Starship may not charge competitively because they have a monopoly
 - Can have all kinds of complicated contracts to price discriminate to stop competition
 - Will the government come in and require SpaceX to sell starship as opposed to just leasing it?
 - VC questions – how are you taking advantage of machine learning? – we need to have an answer as it's the most active area in venture funding. It can substantially increase efficiency in software creation
 - Mobileye is the largest provider of sensors for cars – can potentially be added to the space industry – there are other spillover technologies
 - #1 question for econ graduate students choosing grad programs is how many GPUs the department has access to? Training in ML is a high compute effort and skillset that will spill over to other areas including earth observation
 - SmallSat market will grow in 2023
- Sita Sonty, Boston Consulting Group
 - Increased scrutiny on transactions – not only financial but also heritage (flight, supply chain, talent)
 - Market is interested in earth observation, esp. high resolution, as well as in edge computing
 - Expect some consolidation in the market
 - Government is both civil application and national security components

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- Some market fundamentals, such as conflict and earthquakes won't go away – these will drive satcom in the long-run
 - Capital markets are excited about space technologies and applications for other industries. But if producers of technology don't know how to sell it, it won't sell
 - Industry needs to develop refined revenue generation and sales acumen. If it's not addressed soon, it won't permit winners – need additional talent development
 - Government probably won't interfere too much with Starlink, but the industry may try to impact pricing dynamics
 - Lots of consolidation of small launch providers is not going away, but it creates opportunities for SmallSat companies to combine on rideshares to get more leverage on launch
 - Fewer people are talking about vertical integration this year
 - PE is moving from space infrastructure to space services
 - Investment declined from 2021 to 2022: ~\$47.1 billion to ~\$20.1 billion
 - SmallSat market will grow in 2023
- Shalini Bhatia, Deloitte
 - Satcom, IoT, and earth observation market will grow over time
 - Driven by manufacturing and launch capacity and government regulation
 - Broadband is the biggest use case
 - Many industries benefit from ubiquitous security, processing at the edge, AI and ML
 - Industries that don't think they are an active participant in the space industry actually are (e.g., sat imagery benefits the insurance industry by processing claims faster)
 - Access to capital markets only make this happen faster
 - Private money going into space has increased 10x over the last decade – over 600 funding events in 2021, 2022 was a weird year
 - Rideshare model will increase
 - As the ecosystem grows, more people will want to outsource some elements and have less vertical integration
 - Strong industry fundamentals for capital markets
 - VC is looking for innovation and scale
 - PE firms are looking for value creation
 - Several players are ripe for private equity and have the opportunity to grow – and lots of dry powder to invest
 - ML is better than Eyeballs for reviewing remote sensing
 - SmallSat market will grow in 2023

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- Abishek Triathi, Berkley
 - Will see some tightening in 2023
 - Need to differentiate beyond the hardware
 - Customer may want more of a turnkey solution
 - Starship is a big woolly mammoth – the market can probably support only one or two SmallSat launchers – rideshare is the wave of the future, and SmallSat manufacturers will need to learn to integrate with them
 - Want to vertically integrate if there are no other options or quality/availability is a problem - but vertical integration is hard and takes time – takes a wealthy backer
 - Most people vertically integrate when they need to but won't if there is a reliable provider
 - Do satellite operators want to own the whole value chain or focus their energy?
 - SmallSat market will grow in 2023
- Dr. Rich Leshner, BryceTech
 - Bryce SmallSat “by the numbers” report is out
 - SmallSat were 95% of all spacecraft launched, 50% of all up mass, and 60% of all launches – about 80% of SmallSats were for communications
 - This year, there were lots of SmallSat launches, but only a 1% increasing SmallSats being launched by SmallSat launchers. Small launchers will continue for a few years – starting to see some standardization of form factors and other issues to allow changes in launch providers
 - SmallSat growth is somewhat dependent on government programs putting in large amounts of money – don't see large unlocking of commercial customers in 2023
 - Remote sensing is likely to have the first failures – many providers not on-orbit yet
 - Lack of investor funding and failed use cases will be a limiting factor – supply chain problems may delay the time needed to prove the market
 - SmallSat market will grow in 2023 in terms of numbers

B. ORBITAL DEBRIS REMOVAL AND MITIGATION: SITUATIONAL AWARENESS MOBILITY, PROPULSION, AND TUGS

MODERATOR: President and Founder - Northern Sky Research - NSR
Dr. Dan Ceperley, Founder and CEO - LeoLabs
David Henri, CEO & Founder - Exotrail

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Dr. Clare Martin, Executive Vice President - Astroscale
Charlie McGillis, VP of Partnerships - Slingshot Aerospace
Toku Sakai, COO - Pale Blue

PANEL DISCUSSION

- Dan Caperly, LeoLabs
 - Operators are now willing to invest in space debris mitigation
 - Dept of Commerce will take over space traffic management in the US, formerly done by the department of defense
 - Transparency will hopefully allow avoiding a tipping point into geopolitical problems
 - Active satellites are highly coordinated, but debris removal is not coordinated
 - Working with the insurance industry to develop things like LEO tools and identify the dominant areas of risk
 - Lots of debris clouds at 800 – 900 km
 - Need to understand life cycle risk
 - The industry is now already starting to take debris seriously – we have already hit the inflection point

- Dr. Clare Martin, Astroscale
 - Some commercial operators are actively engaged in improving debris mitigation
 - Government conversation has improved a lot in the past year or so
 - No one tipping point; it all depends on the mission
 - Industry needs to acknowledge there is an issue and incorporate the risks in the design of the satellite missions
 - Motivation for debris removal – a 1 cm piece can destroy a satellite
 - Inspection as an on-orbit service that is important to insurance
 - UK and a few other countries require 3rd party liability insurance before launching
 - Technology, policy, and economics will all need to come together to solve the problem

- Toku Sakai, Pale Blue
 - Pale Blue develops water-based propulsion technologies
 - Significant commercial self-interest in satellites that can avoid collision and deorbit, but at a reasonable cost
 - Water-based system reduces cost and have
 - From a defense or security point of view, will countries want the capability to take countries' satellites?
 - Are we just one major collision or accident away from space being inhospitable, or is there enough room?
 - Insuring systems in space is tricky

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- Need to be able to identify and quantify damages from debris
- Charlie McGillis, Slingshot Aerospace
 - Focused on all orbits, can bring significant amount of data in and produce results for customers
 - Many questions about debris rules and what should be required
 - ISS gets constant pinging of debris hitting it
 - Industry can get close to no accidents with autonomous capability
 - Dream that there are multiple space stations – human element as well. Don't want to put people in space without dealing with debris removal eventually.
 - Insurance companies are large users of their database
 - Will likely need to have some regulation, such as an insurance requirement
- David Henri, CPO Exotrail
 - Raised \$58 million series B – announced this morning
 - Move things around in space
 - French has law the spacecraft must deorbit within 25 years – only one
 - ASAT requires a sane political environment that does not exist between the US and China
 - Need automation and innovation for customers to coordinate around debris
 - Most new satellites have some collision avoidance, not due to regulation, but due to risks to the business case
 - First priority is mission design to prevent debris; Second is to optimize the number of satellites down to reduce risk; Third is to deorbit. Fourth is to look to ADR –
 - In the last month, we have seen interest in moving away from crowded orbits to reduce the probability of insurance
 - Need the incentive to avoid crowded orbits, such as lower insurance rates
 - It will take a high-profile accident for things to change to take debris seriously

C. MARKET BRIEF: THE DAWN OF CIVILIAN SMALLSAT INTELLIGENCE

- Dr. Paul Streaker, CEO Arrasar Partners
 - Satellites have enabled more complex warfare
 - Maxar, SpaceX, etc. have been helpful in Ukraine
 - Most were cobbled together by Ukrainians in months – very quickly
 - It can decide to fire in an hour. In the US and other countries, it would take an hour to avoid friendly fire accidents

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- Starlink had barely started with the Ukraine war started
 - Ukrainian communications were targeted, but 10,000 Starlink terminals provided the backbone
 - Starlink has withstood attempts to jam – a major unsung issue
 - Starlink now has permission for 7,500 gen-2 satellites
 - Until a few years ago, only a major government could field a widescale communications network
 - Eyes in the Sky – big word in imaging is hyperspectral
 - Being able to scan in 2-dimensions can get a better look at things, especially at different wavelengths like infrared
 - Due to cloud cover, you need more than imaging
 - Business plans of remote sensing companies changed to more to military applications
 - Synthetic Aperture Radar
 - Nanosecond/ft – by the time you get the reflection, you’ve moved 0.9 KM, so you have an antenna the size of three football fields
 - Can use differential SAR to get accurate pictures of where things are at all time
 - Capella space and ICE EYE are both in X-band – down to 0.3 meters
 - Only difference between an imaging satellite and a balloon is altitude
 - Balloon is at 100,000 ft, so you can get down to cm level detail
- If SARS satellites are adjusted, you can get all kinds of information about the locations of important assets
- In just one year, an intelligence system has been put together (Starlink).

D. DIRECT TO DEVICE: WHAT ARE THE KEY ENABLERS BETWEEN SATELLITE AND CONSUMER TERRESTRIAL

MODERATOR: Noel Rimalovski, Managing Director - GH Partners

Coral Faradjian: Director, Legal, and Regulatory - Iridium Communications

George Giagtzolou, Vice President, Strategy - Omnispace

Munira Jaffar, Director of Spectrum and Standards - EchoStar Corporation

Jaume Sanpera., Founder and CEO - Sateliot

Tyghe Speidel, Co-Founder and CTO - Lynk Global

PANEL DISCUSSION

- Coral Faradjian, Iridium
 - Iridium will be active in the direct-to-devices market
 - Need to satisfy the consumer’s need

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- SOS is the beginning, but it is not the business plan of Iridium or others on the panel
 - Hopes for regulation depend on where you are in the development cycle
 - Do you need spectrum or want to optimize existing service?
 - Looking for dual-use spectrum
 - Lots of regulatory work on interference issues
 - Satellite industry needs to keep it simple
 - Will be hard to start from scratch, and those who are ahead will be hard to compete with
 - Satellite industry may need to collaborate as many of the terrestrial alliances (Apple, Qualcomm, etc.) have been set
 - Want to solve known common problems - power, debris, serving underserved areas, etc.
- George Giagtzolu, Omnispace
 - Looking at technology to bring satellite technology into the consumer here including into pocket devices and IOT
 - Business model is based on people paying the same for satellite coverage when they are out of terrestrial range – needs to be a seamless experience for the customers
 - Capacity is important to be able to provide enough capacity in rural areas – governments will need to subsidize
 - Expect that over time, there will be an evolution of satellite to handset to 5G standards
 - Near-time opportunity is real
 - Rural areas with 2G are an opportunity
 - There is an area 4 miles from the White House without wireless coverage
 - Looking at conventional and non-conventional vendors but not making our own satellites
 - Satellite also needs common standards to develop mainstream solutions
- Munira Jaffar, EchoStar
 - Will leverage what we have available
 - Working to put S-band and L-band in 5G PPP standard, so it can work similar to a terrestrial phone.
 - Don't need spectrum from MNOs – not clear if the satellite can use terrestrial spectrum
 - Want to have a single device to be compatible with 5G
 - Standardized solutions with technology commonality will help pricing and allow the industry to better address mass markets

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- Jaume Sanpera, Sateliot
 - The US is one of the wealthiest countries in the world, but people elsewhere probably won't pay as much for satellite capacity
 - In developing countries, the market is for small messaging - \$1 or \$2 per month
 - Regulators are open to allowing satellite users to use terrestrial spectrum
 - Don't want to build our own satellites
 - Launched five satellites recently, going to go to 64 satellites
 - Can do store and forward IOT for non-time sensitive with current five satellites – no pressure to go to real-time if there is no business there
 - Launch availability has not needed an issue

- Tyghe Speidel, Lynk
 - User experience is important.
 - Having to point satellites is a pain
 - In-building coverage is harder but somewhat possible
 - Handsets are the missing piece for other providers. We are backward compatible with existing phones
 - Want to use existing phones, MNOs have lots of spectrum, so that's the place to go
 - Not our spectrum, but it is our customers' spectrum to deploy as they see fit
 - New standards will come on board, and we are looking at S-band and others
 - Existing satellite spectrum may be added to handsets
 - Not having our own spectrum is not a disadvantage
 - Will address the other three billion
 - Satellite use of terrestrial spectrum is not approved, but I don't think it will be a big issue
 - Did interference analysis work with the FCC and overcame the hurdle
 - We are vertically integrated because the technology ecosystem was not there
 - Need to keep the price low
 - Would like SpaceX to have more share rides per year, but the standby service is not too bad – only modestly impacted by supply chain issues.

- Live Audience Poll
 - Most people won't pay extra for SOS messaging but would for more advanced services

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E. KEYNOTE SPEECH BY DR. MICHAEL MORGAN

Dr. Michael Morgan, Assistant Secretary of Commerce for Environmental Observation and Prediction - NOAA - National Oceanic & Atmospheric Administration

- NOAA reaches from the sun to the bottom of the ocean, and about 1/3 of the US GDP
 - Formerly a professor of atmospheric science at the University of Wisconsin, Madison
- Department includes the Department of Space Commerce and coordinates with the department of commerce
 - NOAA is engaging in work to forward US leadership in Space
 - Office of Space Commerce has a space coordination committee
- From 1997-2002 – Five \$1 billion+ disasters per year, now growing to 17 per year in the last five years
 - Need to prepare so the US is “climate ready” to reduce the impact of climate change
 - Need to make sure everyone has access to data
 - Help communities meet their local needs
- Observation satellites are fundamental to the value chain
 - GOES-R, JPSS satellite, and others
 - Evolutions of various satellites – very expensive and inflexible
- Looking to use more innovative satellite technology
 - Opening data for more data purchases
 - Quicksounder satellite will use existing technology
 - Pathfinding NOAA’s ability to buy small satellites from commercial sources
 - Will do more of this if Quicksounder is successful
- NOAA collaborates with Taiwan on Cosmic-2 LEO satellites
- Average temperature in the troposphere has increased by 0.5 deg/decade, but the lower stratosphere has decreased by the same amount
- The agency is slowly moving towards incorporating more commercial data and technology
 - This is saving money and provides options for different distribution rights (with Spire)
 - Free data sharing with others is part of the agency
 - Need to have different distribution rights from no distribution to complete

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- distribution
 - Not using the highest level of data distribution so everyone can get it
- Working on new contracts based on the prior experiences
 - Looking at other data needs and placing some orders for Ionosphere data
 - May lead to sustained orders
- Recent contract with Tomorrow IO
- Much of recent progress is based on policy change from a decade ago that emphasized using commercial sources when possible
- Office of Space Commerce was upgraded and, in 2018, was given responsibility for dealing with space debris tracking
- US entities with sensors must get NOAA authorization – but ones used for mission assurances, won't need licenses. Many of the others are simple.
- US regulations need to provide certainty and clarity to the commercial sector
 - Space authorizations are critical to advancing US commercial leadership while protecting US public interest
- Satellites need SSA capabilities, particularly in low-earth orbit
 - Gov't SSA was designed for military satellites, not to help commercial operators – now moving to the commerce department, which is better suited to serve the commercial sector
 - Need to provide some basic services but don't want to compete with advanced commercial offerings

F. THE FUTURE BATTLEGROUND – WHAT ARE NON-GEOSTATIONARY ORBIT SYSTEMS DOING FOR SPECTRUM?

MODERATOR; Randy Segal, Partner - Hogan Lovells

Dr. Tim Farrar, President - TMF Associates

George John, Senior Associate - Hogan Lovells

Karl Kensinger, Deputy Chief of the Satellite Division - FCC - Federal Communications Commission

Dr. Whitney Lohmeyer, Faculty Member - Franklin W. Olin College of Engineering

Ahsun Murad, President and CEO - Optimal Satcom

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PANEL DISCUSSION

- Tim Farrar, TMF Associates
 - Much of S-band and L-band has not been used intensively, so people are likely to go after it.
 - Processing rounds work better with one or two applicants. With eight players, it's hard for all to survive
 - Recent auction to provide satellite service in Saudi Arabia
 - Price not released, but likely higher than expected
 - If satellite spectrum is auctioned, people are likely to expect more with respect to flexibility and exclusion of others
 - The biggest issue is that several businesses have been funded, but now things have changed
 - The new environment benefits those [billionaires] with deep pockets

- George John, Hogan Lovells
 - Application fee lower from \$475,000 to \$15,000
 - Big help for some smaller applicants
 - Lots of L-band with only one or two users that can potentially be shared
 - Are there alternatives to processing? Not really – auctions, beauty contests, or first-in-time are all worse
 - Some applications for other bands have small footprints, so processing rounds are not needed

- Karl Kensinger, FCC
 - Different NGSO systems have different spectrum requirements
 - Spectrum needs will increasingly be met with spectrum that is already in use
 - Compatibility with existing use will be increasingly important
 - Proceeding open for potential more spectrum in the 17 GHz range for NGSO
 - Still processing requests for V and W band for MSS and FSS applications
 - Requests for lunar and beyond earth missions
 - Companies that come to the processing round are at various stages of development, and companies may need to rush into applying
 - Question about how changes are handled
 - NGSO is a multi-user environment, and work needs to start early

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- Dr. Whitney Lohmeyer, Olin College of Engineering
 - Significant GSO and NGSO sharing is possible
 - The Processing Round regime was established in 2003, in a time when only one or two systems at most were expected to launch. Now the FCC has inherited these rules and is trying to handle the inherent challenges
 - When a Processing Round is announced, entities have four months to file, which leads to a scramble for companies to file if they value spectrum priority. Companies are at various stages of design, and some aren't able to submit full interference analysis and debris mitigation plans, leading to further delays.
 - Processing Rounds also incentivize overfilling due to the nature in which applications can be modified (interference must not increase between modification). This in turn has created an environment where systems submit applications for tens of thousands of satellites, and uncertainty around aggregate interference.
 - On the whole, if only one or two systems come to fruition, first to file makes sense. If more than two to five systems come to fruition, knowing priority based on processing rounds could be beneficial.
 - Processing rounds help establish priority but also have some challenges
 - Entities have four months to file once the processing round is announced
 - Significant of scrambling to get the application done if in pilot stages (e.g., interference analysis and debris mitigation)
In the end, they are probably better to keep
 - Causes overfilling because applicant can't be modified to increase interference, so applicants file for as many satellites as possible
 - Keeping first to file in bands with less demand makes sense for now
- Ahsum Muran, Optimal SatCom
 - Major need for communication between satellites
 - 60 GHz is great for space as oxygen on earth will insulate from interference
 - Smart ways of using spectrum are bringing additional efficiencies, including forms of dynamical spectrum allocation and beamforming

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G. TECH BRIEF: STRUCTURAL ENGINEERING: BACKBONE OF THE SPACE REVOLUTION

Nathaniel Rogers, Principal Aerospace Engineer - SC Solutions

- Many important things are related to structural engineering in space
 - From initial proposal through launch and often beyond
- Need to deal with initial competing requirements
 - Material selection, thermal stability, etc.
 - Can't have much motion. Relative motion must cancel each other out, so there is no net movement
 - Some satellites cannot even support their own weight on earth
 - Need to have satellites that barely work to keep weight down
 - Mass = money
 - Falcon 9 skin in $\frac{3}{4}$ the thickness of a can of coke
- Cross-disciplinary coordination is critical to make the optimal solution
- Better performance requires good structural engineers
- Structural engineers make good payload engineer or their best friends
- There is a lack of standards for space structural engineers
- Structural engineering is often overlooked

H. EARTH OBSERVATION: PROVIDER INNOVATIONS AND CUSTOMER BENEFITS

MODERATOR: Dr. James Crawford, Chairman and CTO - Orbital Insight

Viktor Danchev, CTO - EnduroSat

Dr. Marco Esposito, Managing Director - cosine Remote Sensing

Dr. Burke Greer, Director of Product - Edgybees

Nina Soleng, Head of Communications - KSAT - KONGSBERG SATELLITE SERVICES

Dr. Ignacio Zuleta, VP Product Imagery Platform – Satellogic

PANEL DISCUSSION

- James Crawford – Monitoring
 - Onboard processing can recognize useless images and not download them
 - Can reduce the need for communication and also reduce latency for time-

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sensitive alerts

- GPU has fixed architecture, soft FPGA can be reconfigured on orbit
- Constellations are not coordinated – which makes them hard to use together
- Some potential customers need something like ten contracts to get the information they need

- Vikto Danchev, EndurSat
 - Known as a hardware provider, but now building their own satellites to offer as a service (infrastructure as a service)
 - In-orbit processing is becoming a commodity
 - Clients don't want to wait hours for data on the earth
 - Machine learning in-orbit will be a big differentiator – moving from demonstration to actual usable applications
 - Almost all customers are moving from GPU to soft cores and FPGAs that can be adjusted
 - Profile of what customers are asking for is emerging
 - Space data is now becoming more accessible to non-space people
 - Still definitely a need for aggregation – lots of potential to add analytics on top of data
 - Want harmonization and ease of use so customers can deal with it easier without needing government-level resources
 - Machine learning is a necessity due to the amount of information

- Dr. Marco Esposito, cosine Remote Sensing
 - Dutch company dealing with optical payloads (25 years old)
 - Focus on how to make information available in the payload itself - in orbit
 - Space ecosystem is moving faster than in the past – up, down, and mid-stream
 - Several companies are putting effort to find ways to make faster insights onboard
 - Customer needs are also changing quickly and need to be able to adapt – need to provide insights
 - Companies are providing platforms with on-board processing to make fast decisions
 - Driven by climate change, geopolitical developments, and other

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events

- New devices can offer power-efficient GPUs and other ways to do calculations – this is where we need to look, as we can't make bigger and bigger platforms to support GPUs
- Non-space people are increasingly getting into using remote sensing – need for an aggregation provider to simplify the market for users – but potential to fuse data into images and make data interoperable
 - Big companies are putting energy into platforms – Microsoft, Amazon, Google – users may not need to deal with data, but information
- Need to migrate from demonstrations to real applications customers adopt
 - Next 3-5 years will be about machine learning and AI to help enable this
- Dr. Burke Greer, Edgybees
 - Work on software for data pipelines, quality, and harmonization
 - Lots of mapmaking, data science experience, and working to address hurdles for data access
 - Three ways to use data
 - Feed into things happening immediately
 - Use for planning purposes
 - Looking historically and building models to advise the future
 - Excited about machine learning on edge, but only some users actually need it
 - Now, we are reducing the time from data collection to client solution and providing a unique picture that was not available before
 - Uncoordinated satellite data providers are an opportunity to combine and deal with them – new pictures are available from multiple sources
 - Next ten years will be about taking something that works for a customer to scale it into a bigger reliable product for more customers
 - Need to make products more usable by those who are not geospatial experts
 - AI and ML will make stacks of data usable
 - No code and simple ways to run models without deep geospatial expertise will expand the market
- Nina Soleng, KSAT
 - Known as a ground station provider through a global network – also do value-

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added data services

- Monitor most of Europe's waters for maritime safety and border control and sell data to a portfolio of clients
- Use many satellites in combination to meet customers' clients – SARS, optical, and other sources
- Requests for faster revisit, additional satellites, also new sensors such as greenhouse gas sensors – today, it's not a big issue to get data down quickly
- Can do a lot more now with processing power, and machine learning allows you to look at a lot of data quickly
 - Need a sweet spot between quality and speed – when do you want to put the human in the loop? Want to avoid technology for technology
- Hoping to see additional greenhouse gas sensors with greater capability – methane and co2 – can perhaps monitor carbon capture and storage
- Some gaps in maritime as well – need sensors to be better coordinated. New sensors and missions optimized for maritime being developed in Norway will help
- Others are challenging the satellite industry to be able to provide data in a format that more people can use – the end user may be confused now
 - Need to unlock the B2B market [AM Comment: I have heard this for 25 years!]
 - Customers' top issues are delivery time, greater coverage, lower price, etc.
 - Latency starts from need, not from image acquisition
- Satellite has a role in sustainability – an object from observation from space and provides the transparency we need (e.g., deforestation project Airbus & Planet Labs for Norwegian govt – can be expanded to other areas such as fishing)
- Dr. Ignacio Zuleta, Satellogic
 - Earth observation company in Argentina and Spain – focusing on providing imagery, constellations, and space systems as a service – higher resolution and revisit so you can do object inventory
 - Move to machine learning will impact how we look at data as it can be combined
 - Hardware for edge computing has been flying for a few years, but the business proposition for using it has not been there other than for security – technology is

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- ahead of the value – can always process in space
- Some consumers that can control the food change (big countries) want localization of technology – buy their own satellites
- Also, the amount of hi-res imagery is increasing the expectation that the data can be combinable [from different satellites]
 - Can only do the needed geometry in a fully integrated way - need to be able to do a 3D reconstruction of scenes. Need to be done by machine in an automated way
- Customers want data they can use
 - Most is ground data with a little bit of satellite data (in money, time, and effort)
 - They are used to using ground data already
 - Tasking issue an artifact we [the industry] created – customer should not even need to know about it but be able to order data already available

I. FUNDING SMALLSAT ENDEAVORS FROM CONCEPTION THROUGH MATURITY

MODERATOR: Dara A. Panahy, Partner - Milbank LLP

James Bruegger, CIO & Managing Partner - Seraphim Space

Francois Chopard, Founder and CEO - Starburst Accelerator – Late due to plane delay

Mike Collett, Founder and Managing Partner - Promus Ventures

Tyler Letarte, Vice President - AE Industrial Partners

Dr. Xiaoming Yin, Senior Investment Manager - Lockheed Martin Ventures

PANEL DISCUSSION

- MODERATOR: Dara Panahy, Milbank
 - 2022 is now the year of rationalization in the space sector
 - Massive pullback - \$20 billion invested vs. over \$40 billion in 2021
 - Lowest since 2015
 - Space infrastructure was \$6.3 billion a 57% decline
 - But a 63% pickup in the 4th quarter
 - SpaceX raised \$2 billion
 - US was ~50%, but China was about 1/3rd

- James Bruegger, Seraphim

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- 2022 was down, but earlier stage deals had record volume
 - We measure overall deals as down only 25%
 - Bifurcation in the market between later-stage businesses and initial stages
 - Later stages are hard and mostly done with existing investors
- Extremely limited appetite for anything “growth” – the satellite industry does not seem to be unfairly targeted
- It’s hard to value a space company, but there are similar challenges in other areas of the technology sector
- Proof of science often needs government support and companies need to be disciplined about how to engage with government – can’t avoid it.
 - But dangerous to build things exactly to government specs
- Opportunity
 - Space is critical, and the climate crisis is an opportunity (all data, insurance, etc.)
 - In-space economy – hundreds of companies – just published a map [AM Comment: Try to get]
- Excited about most areas of the industry

- Mike Collett, Promus
 - Market has changed dramatically
 - Involved with many sY. pace companies
 - Macro looks bad
 - Launched Space Index – to see trading multiple
 - Private market is catching up with public markets
 - Great ideas will still get funded
 - Plenty of clever ideas out there
 - The Exploration Company in France just raised a \$44 million Series A
 - Raising money will take longer and less credit for LOI – need to show real revenue
 - The faster you can bring revenue, the faster the market will notice
 - Space is more important to the government today, so now that private money is harder to get, government money is playing a larger role

- Tyler Letarte, AE Industrial Partners

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- Dosage of reality trickling through the market
- People are raising capital but at lower valuations – smarter, more patient, and skeptical investors – need to show business model, market, customers, cash flow, etc. [AM Comment: Remarkable this needed to be said]
- There will be many opportunities in the sector – need to be patient
 - Downturn, but lots of revenue from the government
 - [Satellite] Technology is meeting launch industry capabilities
 - LEO is being commercialized
 - Need to differentiate between incumbents and new space
- Earlier stage investments will get smaller checks to hit milestones
 - May need to raise additional capital more often until further along
 - If raising a large amount of capital early, then will be stuck with low valuation and dilution – it's a big risk
 - How do you build room for a supplier six months late?
- Communications between spacecraft -- hardware and processing to handle this data needed to do this. Still a gap between payloads being built and where they are going to go
- Some ideas are marked for failure but are 10-15 years away from success and waiting for bridge technologies. It is worth investing in the bridge technologies
- Over next eight years, there will be revolutionary technologies
- Dr. Xiaoming Yin, Lockheed Martin
 - Reduction is growth stage investment
 - People are getting creative at bringing in cash
 - LMT is looking to deploy additional capital in the sector
 - With double size fund and the team here to deploy money
 - Looking to collaborate startups (invested in Terran Orbital)
 - Companies who have a clear observation about government timetables have better luck with government revenues, as do those partnering with primes (such as LMT) are also more successful
 - Exciting
 - Short term – platforms that democratize access to data
 - Mid-term – in space infrastructure
 - Long-term – space exploration

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- In the short run, there are some corrections, but good long-term outlook

J. MARKET BRIEF: SUPPLY CHAIN ISSUES AFFECTING SATELLITE CONSTELLATIONS

Dr. Ane Aanesland, Founder & CEO – ThrustMe

- Small satellites are frequently done as prototypes, now becoming industrialized to produce volumes
- How to make satellites in the thousands while keeping innovation
 - New tool is the “digital twin” – a digital replica of a physical object
 - Make physical measurements and digitize – with twin, you can “test” and upgrade digitally
 - Design for manufacturing to reduce design to manufacturing time frame
 - Need sub-system manufacturing strategy
 - So, if one part is delayed, it won’t impact the lead time
- 2020-2021, there was a lack of containers which delayed delivery
 - Predator or Prey Oscillations (from physics)
 - Need to balance supply vs. demand
 - Happening within months as opposed to years, formerly including changes in raw material prices
- War in Ukraine
 - Ukraine is the largest supplier of noble gasses
 - Important for steel, but also semi-conductors – cause of delays in electronics
 - Noble gasses are also used for propulsion including Xenon
 - Prices increased by a factor of 20 in the US and 10 in Europe and Asia
- Significant number of satellites now requires greater thinking about sustainability
 - Sustainable solutions need to be economical from the beginning of production to use cases, including full supply chain
 - At ThrustMe, we are not using a full clean room, but keep products clean, but not the people. Use recycled water for cooling

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K. ACHIEVING OPTIMAL AFFORDABILITY IN SMALLSAT LAUNCH MISSIONS

MODERATOR: Chris Stott, Executive Chair - Mansat

Dan Hart, President and CEO - Virgin Orbit

Dr. Marino Fragnito, Senior Vice President and Head of Vega Business Unit - Arianespace

Dr. Giulio Ranzo, CEO - Avio

Adam Spice, CFO - Rocket Lab

Bill Weber, CEO - Firefly Aerospace

PANEL DISCUSSION

- Dan Hart, Virgin Orbit
 - Marry launch vehicle with a 747 airplane
 - Have had four launches, including one failure in the UK on January 9th in Cornwall
 - It is in an investigation now, but can't discuss yet – but points to a filter that was dislodged (a \$100 part)
 - It is important to be available when needed – an important part of the service
 - The idea of how to get capabilities for national security is changing –
 - Now, if something happens anywhere, the government wants a satellite there ASAP – the launch industry needs to respond
 - Countries and regions want their own capability
 - Commercial companies are growing increasingly mature
 - It will be a slow process for China to enter the western market

- Dr. Marino Fragnito, Arianespace
 - Launchers are getting smaller and smaller
 - Dedicated to Vega C and Ariane 6
 - Everyone wants to make money, except one [AM Comment: Reference to SpaceX?]
 - Trying to grow launch size as there is a sweet spot for the launch provider
 - Ours in 1.0 to 1.5 metric tons – that is where you can make a profit
 - That is where there is government business
 - 50 kg or 100 kg satellites are hard to make money due to low reference price
 - 40 years ago, the market was entirely GEO
 - Have been waiting for a long time for the large constellations, it has

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- arrived
 - Now, there is a launch vehicle shortage
 - Don't see China coming as a competitor in the launch sector unless there is a large political change. Previously thought, India could be a strong competitor, but don't see them much as a competitor, sometimes as a partner (e.g., with OneWeb). Russia is withdrawing from the market
 - Optimistic that the launch market is booming, have never seen so much business in my 30 years – more positive than before that additional companies will survive because there is large demand
- Dr. Giulio Ranzo, Avio
 - European company makes Vega
 - Also has Vega C
 - Uses solid propulsion but has flexible reignition capability to deliver payloads to different orbital plans in the same launch
 - Financed for a capacity of 5-6 per year – enough for local capacity [AM Comment: Seriously?]
 - Launch is hard and takes money – affordability needs to take tradeoffs into account
 - No easy solution to lower price launch service [AM Comment: Sounds like he is having challenges]
 - Sector has skin in the game – but it is a difficult job to reduce costs
 - Airline industry has managed increased traffic, and launch fields will likely do the same and get more efficient
 - Will need to adjust to different requirements, but will likely still be around when SpaceX starship arrives
 - Vega-C investigation is to be released soon
 - The former version of the rocket (Vega) is not affected by the accident
 - Expect Verga-C to be back in 2023
 - Have \$1 billion in public money to improve technology and production capacity
- Adam Spice, Rocket Lab
 - 2/3 of revenue is from non-launch activities

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- Acquired four companies in recent years
 - Developing a medium-lift launch vehicle (13 tons)
 - Made inroads in complex areas including NASA, Globalstar, and others
 - Learning the actual costs of running a launch service – higher than expected
 - Many failures with small launch companies
 - SpaceX has suppressed small launch market prices – need to build a base of ongoing business from the government
 - Will be fewer players in the market in a few years
 - The reduction depends on how difficult the business is
 - We are at the beginning of the bloodletting of aspirational launch companies
 - Capital is needed to grow, and this is a major constraint on small providers
- Bill Weber, Firefly Aerospace
 - End-to-end space transportation company
 - Working on 1 ½ ton Alpha launch vehicle –
 - Intends to launch every two months
 - Medium launch vehicle to launch in 2024
 - Lunar lander to launch in later 2024
 - More demand in upcoming years esp., with government missions, commercial demand following, and their manifests and multi-launch agreements
 - We don't differentiate between them – all want prompt, predictable, and reliable launch services
 - Still launch slots in US launch ranges
 - There will be a time when US launch ranges will be booked
 - Blueprint launch companies need to line up available US launch ranges, but not constrained today
 - Lots of diversified missions and applications that we can all address
 - See market ramping and additional countries involved in launch
 - Have launched Alpha 5x (including once as a test) and headed to do it every two months
 - Market is asking us to step up and excited about 2023

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L. DAY TWO: WEDNESDAY, FEBRUARY 8, 2023

M. GROUND SERVICES ENABLING SMALLSAT CONSTELLATIONS

Chris Stott, Executive Chairman - ManSat Group

Dan Adams, CEO (USA), Kongsberg Satellite Services - (KSAT)

Jai Dialani, Managing Director - Leaf Space USA

Pam Lugos - VP, Business Development Satcom Products - CPI - Communications & Power Industries

Chris Richins, Founder and CEO - RBC Signals

Tony Wilkey, Executive Vice President - AvL Technologies

[AM Comment: Chris Stott substituted for Katherine Gizinski as moderator]

PANEL DISCUSSION

- Tony Wilkey, AvL Technologies
 - Trying to develop the most flexible “Swiss Army Knife” for the industry as possible, especially for the military
 - Q and V-band represent challenges due to the need for near perfection with dish accuracy and maintaining pointing
 - Took an order for a Q-band antenna recently
 - Q-band has been around for a long time
 - Cybersecurity is tough for a small company like us (with ~200 people)
 - Security compliance work has gone up 2-3x in the past few years

- Pam Lugos, Power Industries
 - Amplifiers, radomes, antennas, composite structures, terminals, etc., for the satellite industry for 40 years
 - A significant number of LEO applications are very price sensitive
 - Important to understand requirements upfront and be open to different waveforms, etc.
 - See demand going to Q and V-band - have a 250-Watt Q-band amplified now
 - Ground station capabilities need to increase with inter-satellite links as there will be fewer of them
 - Cybersecurity is primarily with internal operations and products

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- Dan Adams, KSAT
 - 250 antennae in 2022 and over 1 million passes in 2022
 - More than 100k passes/month in 2023
 - Getting to scale
 - Q and V-band are not operational on the ground side – only now starting to have operational Ka-band
 - Doing work in Antarctica
 - Geography is tough, but fiber is not an option – will always be a satellite use case in Antarctica
 - Optical is not yet profitable, but it has a future
 - Especially for lunar and deep space missions
 - Cybersecurity is table stakes for the industry
 - Satellite breakdown could lower 30-40% of US industry, including food production
 - We want to explore how ground [equipment] can add value to other parts of the value chain such as using data sets, processing, etc. – as opposed to being just a conduit

- Chris Richens, RBC Signals
 - With LEO constellations, after launch, until satellites are distributed into final orbits, it is harder, and having lots of locations is helpful
 - Closed network limits the equipment you can use and makes things harder, and increase costs
 - Encourages NGSO operators to think about modulation and encoding schemes to make sure they are compatible – it will save money
 - Optical is just another higher-frequency band
 - Significant government money is going into it
 - Encourage customers to license multiple ground stations to make sure they can move demand or back-up
 - Education is key with customers, especially with new entrants
 - ITU does not give you landing rights or earth station rights
 - Cybersecurity is a lifestyle – use NISH 800-171 standard
 - It's an ongoing focus

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- Looking at cost trade-off of leasing dedicated flat rate antennas and then adding more on a per pass or another method
- Jai Dalian, Leaf Space
 - 9,000 passes/month
 - Want to have software defined implementation as it will save money in the long term
 - A lot is already standardized
 - Using other options for remote earth stations where there is no fiber, including LEO
 - intersatellite links will use the same ground stations we currently use, but optical is a challenge with localization
 - Encourage customers to keep on top of regulations at the same time as dealing with orbital rights to make sure ground stations can go where needed
 - Don't wait until the last minute, as it takes time
 - Put ground stations in filings
 - Major upcoming missions require high security
 - We are based on zero trust

N. GOVERNMENT POLICIES AND FUNDING OF SMALLSAT ECOSYSTEMS

MODERATOR: Phil Carrai, President - Kratos Space, Training and Cybersecurity
Dr. Nicholas Estep, LtCol, Program Manager: Defense Innovation Unit - DIU
Jim A. Faist, Advisory Board Member - Aitech Defense Systems
Tom Gillespie, Managing Partner - In-Q-Tel
Christine Jenkins, Director, Civil Programs - Stellar Solutions
Michael Maughan, VP of Resilient Space Missions: Viasat Government Systems

PANEL DISCUSSION

- Dr. Nicholas Estep, Defense Innovation Unit
 - Mission is to accelerate the adoption of commercial technology in DoD
 - Usually look for private investment that is leading the way
 - Government likes to build things but need to leverage overlap between commercial and government sector as there is a lot of overlap now

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- Can reduce R&D etc.
 - Investors need to have a clear framework/regulatory regime to make investments
 - See some signals this is happening, but there is a natural latency for this to manifest itself with government contracts
 - Latency from government strategy clarity can be multi-year
 - Bespoke government capabilities are not as good for international cooperation
 - Coalitions will usually rely on commercial non-classified technologies, etc.
 - The more the company develops the IP, the less the government needs to have government purpose rights
 - It would be a shame if the government stood back and did not have input into a major commercial architecture, esp. with transport, and could not leverage it
 - Space is moving faster than the government's ability to regulate
 - A key priority to rectify in the future
 - SmallSats have proven themselves which is why there is greater government support, and the sector has expanded – also showing commercial viability
 - Need PPBE (“planning, programming, budgeting, and execution”) reform is needed, so the commercial sector does not need to wait so long between steps – this is starting to happen. Also, govt is to risk-averse and intolerant of failure
- Jim Faist, Aitech Defense Systems
 - Aitech is a leader in space electronics
 - Moore's law can now be implemented in LEO and add new, improved tech in layers/tranches over time
 - All is supported by microelectronics – how you implement is the gamechanger
 - Move to PLEO is disruptive to the government – changes the way satellites are procured and controlled – move to lasercom reduces ground infrastructure
 - It is imperative to get there with architecture many providers can plug into – physical interoperability
 - Commercial providers are more efficient at controlling satellites – policy change is needed to allow them to take over DoD satellites
 - In some areas, the government needs to own the network, and in other areas, they don't
 - Hard to sell information if the government gives it away for free

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- Lengthy process to get to revenue based on how the government is structured
- Need interoperability on the physical layer for better cooperation with allies – should use allies on PLEO projects
- IP ownership on government projects is unclear and impacts investment
- Capabilities on satellites have gone up at least ~100x in terms of bits/watt in the last ten years
 - Much greater mission capability on small satellites, and this will only increase – physical layer issues are getting solved
- Big DoD acquisitions should be reformed to better allow outside investment

- Tom Gillespie, In-Q-Tel
 - Strategic investor works with the national security agency
 - Invest for the government in commercially focused venture capital like start-ups
 - Have a market map to look for opportunities in the ecosystem and invest across areas
 - The greater clarity investors have the more attractive; the regulatory portion are important for clarity
 - Some countries try to attract companies by offering fewer regulatory restrictions
 - In some areas, there is less clarity on regulation
 - IP is an issue when working with the government
 - We turn down deals if there is not enough regulatory clarity
 - Many SmallSats have proven themselves to the government, and the government has come a long way in understanding how to leverage them

- Christine Jenkins, Stellar Solutions
 - Work in the civil sector – also have defense, intelligence, international, and DoD sectors
 - One component is debris, and we need to be able to manage this
 - Industry needs to work together – SmallSats need time and space to avoid collisions
 - Investors/market needs to be assured that regulations won't prevent planned services from being sold
 - Government is good at supporting proof of concept

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- Many barriers are not technical, but regulatory – ITAR has changed little in 20 years – the government needs to get more efficient at updating regulations in pace with technological development
- It's still the “wild west” with interoperability, standards, and guidelines
- Challenge-based acquisition can save a lot of money – should be encouraged

- Michael Maughan, Viasat Govt. Solns
 - Mostly work in non-GEO projects within Viasat
 - Focused on delivering payloads and mission services for US and international governments
 - Also looking to leverage GEO, including Viasat-3 and other GEO assets, to offer space-based services - e.g., potentially providing bi-directional communication for LEO operators using Viasat-3
 - Viasat is focused on providing end-to-end services and wants to apply to LEO
 - Broad government recognition of the value of proliferated LEO (“PLEO”)
 - Some new policies are needed
 - Role of government is in exquisite capabilities that the commercial sector won't fund
 - Government is becoming a smart buyer
 - Government needs to set demand signals to stimulate a market for services that might be needed in the future
 - Some examples of this already
 - US should incentivize broader international cooperation and partner with allies – it's a force multiplier
 - Not enough standards on satellite links yet for next-generation systems
 - Now is a land grab – it's nine a “commanding height” [AM Comment: see the book by Daniel Yergin by the same name]

O. MARKET BRIEF: THE ECONOMIC/GLOBAL SITUATION AND HOW IT IMPACTS SMALLSATS

Brooke Stokes, Partner - McKinsey & Company

- Stated expectations vs. reality

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- Ambitions are not materializing are expected
 - But winners are starting to emerge and can raise money even in this environment
- Stocks
 - Space startup stocks are down
 - Satellite constellation operators are doing better
- Adoption of SmallSat tailored technologies
 - Took Starlink out of analysis
 - Small launchers are coming down the cost curve
- Is space a net attractor of talent?
 - Yes – the new space industry has attracted 2x the talent lost to other industries
 - Including old space and primes, it would be 1.5x
 - Job openings are above pre-covid levels
- Raising Capital
 - Rounds are taking longer to close
 - 2022 was second largest year in terms of private capital raised (excludes defense and only SmallSat)
 - \$8 billion (this is different from other analysis showing close to \$20 billion for space as a whole)
 - SpaceX is a substantial chunk
 - Also increased globalization
- Government adoption of commercial technology
 - It is happening in pockets
 - Pressure on the government for speed will force hybrid models

P. CHALLENGES OF SMALLSAT MANUFACTURING AT SCALE

MODERATOR: Dr. Eric Anderson, President - And One Technologies

Debra Facktor, Head of AIRBUS U.S. Space Systems - Airbus US Space Systems

Mike Kaplan, VP of Business Development - LeoStella

Casey Kelby, Business Development Manager - Kongsberg NanoAvionics

Michael Pavloff, VP of Strategic Solutions - Terran Orbital

Al Tadros, Chief Technology Officer – Redwire

PANEL DISCUSSION

- Debra Faktor, AIRBUS
 - Working with OneWeb was a strategic decision to get into LEO manufacturing at

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- scale
 - Now have a larger bus, the Nano 450
 - Already at scale and moving to a larger scale
 - Working with the supply chain to ensure it arrives working and push down testing to the lowest level necessary
 - Trying to keep processes repeatable – put sensors into handheld tools to make it impossible to make mistakes (e.g., torque sensor)
 - Use technology to help people reduce human error
 - Culturally, AIRBUS is known for having good relationships with its supply chain
 - Want to take advantage of the expertise of partners
 - The more frequently you build of the same thing, the better
 - Some reasons to tweak, but choose wisely as there are cost and schedule risks – even a small contractual change takes time
 - Need to predict what you will need, so you hire a step ahead
 - Ukraine war has driven up the price of Xeon, and people are potentially considering other options
 - Scaling most with people is most critical
- Mike Kaplan, LeoStella
 - JV between Thales and BlackSky
 - Satellites models but share common systems
 - Most difference is in power
 - Scaling was designed from the start
 - Scale for us is dozens of satellites per year per customer
 - Rarely are satellites identical
 - Customers see how a satellite works and then want tweaks on future ones as they see performance
 - We have efficient processes
 - Modularity and standardization do not mean making the identical satellite over and over
 - We outsource a lot and push vetting down to the lowest level
 - We vertically integrate subsystems
 - Keep our finger on the pulse of our supply chain
 - No one size fits all solution with respect to vertical integration and

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- outsourcing
 - We benefit from bringing new people into the industry
 - Software is critical – we don't have a single piece of paper in the factory!
 - All is tracked electronically
 - Most of the cost of things is software
 - People are the most critical issue
- Casey Kelby, Kongsberg NanoAvionics
 - Scale is something we are tracking
 - Looking to diversify customer base
 - Opened a new facility in Lithuania
 - Interested in smaller projects as well as mega-constellations and also looking for attractive launch options
 - Big part of our business is vertical integration
 - Helps with cost and schedule – don't want to be waiting a long time for a part
 - Keep close with important suppliers, so they feel like part of the organization
 - When ramping-up quantity, it requires ramping-up quality processes
 - Quality assurance team is up to about 30 people
 - Software has been important to optimize production
 - Hiring people is the most critical issue
- Michael Pavloff, Terran Orbital
 - Scaling in a class of vehicle and also in serial production of launch vehicles
 - Now up to 1 to 1.5-kilowatt satellites
 - Have capacity of male 250 vehicles per year
 - Training and repeatable process are important
 - Using augmented reality to train
 - Our designs are modular
 - But some customers have unique requirements, and we need to do one-off
 - Often need to be vertically integrated to get what we need
 - People coming from other industries help satellites sector as they bring new skills

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- Working hard to bring “new blood” into the company
 - Vehicle automation is the most important issue
- Al Tadros, Redwire
 - Formed three years ago to acquire and integrate companies that are established with the challenge of scaling and helping them
 - Have made nine acquisitions to date
 - Mega constellations are part of the story
 - Have a step function in complexity when working for a constellation
 - Many overlook the ability of supply chain to work with the prime
 - Problems are different when you go to scale
 - Quality needs to be baked in from the beginning to catch mistakes early
 - It’s a different process at scale
 - Industry has diversity of locations that helps with attracting talent
 - Software is particularly important in the end product
 - Hiring is the biggest priority, as well as facilities and supply chain

Q. KEYNOTE SPEECH BY MARK DANKBERG

Mark Dankberg, Chairman of the Board, Chief Executive Officer, and Co-Founder - Viasat

- Started company in his house doing ground segment and networks and slowly grew it
 - Decided there was an opportunity for GEO broadband for a new entrant, like Viasat, that was not well-capitalized
- Regulatory environment may prevent this kind of start-up going forward
 - Flagging rules of nations is important
- When we started Exede, we needed to commit \$1 billion
 - Needed confidence that the access to orbit and spectrum would still be there when we launched
- It’s becoming evident that access to space will be very valuable
 - Potential value of asteroids, lunar rights, etc.
- Regulations have a lot of national self-interest
 - Every country will pay attention to their national self-interest
 - Differences between policies and rules are also often not clear

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- New regulations invert the golden rule into “Due unto others before the due unto you” and “The one with the gold makes the rules.”
 - Recognition of the value of the heavy lift, but there is less focus on the high end
 - Major industry focus is on basic entry [AM Comment: Perhaps because this is technically easier. Small launchers seem to be gradually moving to towards larger platforms, but so far, admittedly mid-sized rather than heavy?]
 - But going forward, scale will be important for the heavy-lift market
- Have been rounds of consolidation before Viasat entered space
 - There was a shift in the dimension of value – Viasat-1 had 50x the capacity of other satellites
 - Previously, spectrum could have gone to a small number of players, and we would not have had new entrants
 - Direct to device will have a considerable influence, good and bad, on the industry
 - Some countries will not want watches connecting to space, and this will impact access to orbit and access to spectrum
- Two largest constellations in the world come from the two companies with the heavy lift vehicles
 - Formerly, space costs were fixed, now they are mostly variable costs that dominate
 - The way to be successful is to get large amounts of mass into space
- Smallsats used to be 150 kg, now Telesat at 700-800 kg, and next generation Starlink will be 2,000 kg range
 - Regulators initially dismissed concerns about total mass in space and cross-sectional risk but are now looking a bit closer (only approved 7,500 of 30,000 SpaceX satellites initially)
 - Concern metric was “100 object years,” now it is changing to “100 object mass years”
 - Instead of 25-year post-mission disposal, the rule is now down to 5 years
 - SpaceX will burn in 5 years up to about 550km
 - Implication is that lower orbits will be increasingly valuable as they don’t need to worry about decommissioning as much
 - Regulatory now allowing great orbital altitude tolerances
 - Effectively, nothing between ~375km and ~575km that is not occupied

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- Satellites are required to have propulsion, but this encourages larger satellite design
 - A large propulsive satellite that fails is more dangerous than a smaller one designed to be non-propulsive from the start
- One important regulation in NGSO will be around in-line events – what is the definition of an in-line event and how does that restrict operators from using their satellites, and where do they rank priority wise
 - Power flux densities are also important standards that are underappreciated
- Competition among countries to have companies use them
 - Some countries, such as France, are concerned that rules are not favorable to them
 - French regulator sees rules being exploited as ways non-favorable to France
 - Also happening in the UK and Canada
 - France is now considering using landing rights to assert their views of safe anti-competitive policies (launch insurance, etc.)
- Lots of people working on risks for too much mass, cross sectional area, etc.
 - If there is not enough room in space, how should it be allocated
 - If everyone has a common view, the decisions are reproducible
 - Industry is doing work on situational awareness
 - But it is not clear that collisions between movable objects will be dominant space accidents
- Interest in open standards to improve scale
 - Don't need very large satellites to do space missions
 - We [Viasat] think we can go to 10,000 gigabits (10 terabits) using roughly the same size satellite [as Viasat-3]
 - Demand drivers that apply to broadband will apply to connected devices
 - Interested in standards to make sure bandwidth is used efficiently
- Can't disrupt distributed LEO satellites by harming one satellite, but plans are floated to destroy the whole constellation – that could destroy access to space [presumably with Kessler syndrome or similar]
 - The closer we are to a complex choreographed LEO system, the easier it is to destroy, intentionally or unintentionally – so are think a more moderate approach makes sense

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- Bought Inmarsat to become global – one reason we are sensitive to the self-interest of nations and the implications
 - Working with China on in-flight connectivity, as there are many international flights to give seamless connectivity
 - Flights between Europe and SE Asia take hours longer due to the need to avoid Russian airspace
 - Need harmonized system between orbits
- Viasat 3 launch date is April 8 for 1st and September for 2nd
- Computational load in space is extremely high, so the amount of power that can be devoted to transmission is smaller – this is one reason SmallSats are growing [in mass]
 - We are trying to move computations to ground-based data centers

R. SMALLSAT M&A: FROM PRIMES TO NEW ENTRANTS

MODERATOR: Alexis Sáinz, Partner – Hogan Lovells

Phil Ingle, Managing Director - Morgan Stanley

J. Armand Musey, Financial and Valuation Consultant - Summit Ridge Group

Sunil Nagaraj, Founder and Managing Partner - Ubiquity Ventures

Karl Schmidt, Managing Director - KippsDeSanto & Co

Pawel Skonieczka, Director - Technology, Media, Telecom Investment Banking - Deutsche Bank

PANEL DISCUSSION

- Phil Ingle, Morgan Stanley
 - MD in Morgan Stanley industrial group that includes space – involved in Maxar deal and MDA IPO and SPACs such as Rocket Labs and Planet Labs
 - Big aerospace & defense deals were space-related
 - Veritas buying CAES Space
 - Advent buying Maxar
 - L3 buying Aerojet
 - M&A likely to be up in 2023 – hope the capital markets are more open
 - Budgets in DoD focused on space are growing faster, so primes have an appetite for space acquisitions
 - Some of the primes have stood-up venture arms
 - With Maxar, the outsiders saw a lot greater value than the public markets

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- Smaller start-up remote sensing companies should take note that a sophisticated investors may see greater value
- Looking at space broadly, successful companies usually have a lot of government business
- Seeing some “green shoots” in the market. Will have IPOs this year and some tech companies will be brought to market that aren’t profitable – but profits need to be soon
- About a dozen space SPACs, but some will be gone in the next year or so
- Now launch is an excess demand market
- Tech investing dominated by AI

- Armand Musey, Summit Ridge Group [AM Comment: This is me 😊]
 - Valuation and industry analysis in telecom, media, and satellite
 - Valuation for due diligence, litigation support when deals go bad, and restructuring when things go really bad
 - Space industry has been impacted differently depending on the part of the sector
 - Hard on companies that need to raise money
 - Things are good if they have significant government revenue
 - M&A values will follow trends in public markets
 - SmallSat is dominated by companies that need money – not that many “quality” companies that will have an easy time raising money
 - Viasat’s acquisition of Inmarsat shows value of distribution, particularly global distribution
 - Infrastructure technology, e.g., launch, is rapidly changing, increasing risk
 - Expect activity in software, ground equipment, and launch due to a shortage of launch capacity despite the capx requirements
 - Greater emphasis on AI now – the industry is getting serious

- Sunil Nagaraj, Ubiquity Ventures
 - Provide money and coaching to very early entrepreneurs – the personal focus is making software ubiquitous in the physical world. Work with 35 software companies that take software off computers in cars, spaces, a cow, etc.
 - Previously helped run space investment at Bessemer Trust

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- Historically, investors saw infrastructure as less risky and having larger upside if the sector grows
- Recent activity is not of the disruptive kind that drew Silicon Valley investors to look at space in the past
- Large multi-billion-dollar platform acquisitions are often decoupled from DCF and IRR calculations, as are they are intended to give buyers a capability to move them where they want to be one day. May bring in new players to the sector [AM Comment: Interesting – a deal can be big enough that valuation may not be important]
- Some SPACs may have overcorrected and become attractive targets
- Good idea for companies to weave AI into their taglines
- May need a major incident before movement happens with orbital debris
- Karl Schmidt, KippsDeSanto & Co.
 - M&A in middle market aerospace and defense and some capital raising
 - Cautiously optimistic about 2023 – macroeconomic headwinds are offset tailwinds
 - Easier for top companies with cash flow, harder for those at the bottom
 - Tech and Aerospace & Defense have been very different
 - Defense has benefited from Ukraine war
 - Strong space companies involved in national defense have been doing well
 - For middle market, many deals won't be reported, and companies can pay more without needing to explain it [AM Comment: They can overpay because no one will know?]
 - Slingshot's Numerica acquisition was a function of the culture of the business and the parties wanting to work together – smaller private deals, you can't overestimate the importance of culture. Similar to LMI's acquisition of Synapttech – cultural fit for the seller was important
 - Can't rescue bad companies and bad models with M&A
 - No one wants to buy companies with major capx requirements
 - SPAC valuations were hard to understand – space SPACs were down ~90%
 - Expect activity in areas related to software – may have some ground equipment deals coming out

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- Pawel Skonieczka, Deutsche Bank
 - Focused on the space sector from launch to manufacturing to service to earth observation to data analytics
 - Full service: M&A, debt & equity capital raising, structured products including export credit agency financing, project financing, etc.
 - Involved in Rocklab, Astra, and AST space
 - Flight to quality – companies with revenue and with EBITDA or close are doing much better raising money – this is likely to continue in 2023
 - Valuation reflects risks of underlying cash flow – those with stable cash flow have had greater stability. Early-stage space companies have higher risk, and valuations have fallen
 - Primes are acquiring but also making strategic investments, such as L3Harris making a minority investment in laser coms company [Mynaric]
 - Intelsat/SES would need to combine over 100 satellites. With smaller satellites, there is an opportunity for additional consolidation
 - AEI[ndustrial Partners] is a financial investor going after critical assets (“picks and shovels”) that enable other companies to take advantage of space
 - Many companies are in cash conservation mode – those who need money are often looking at flat or down valuations

S. AFTER THE ANTENNA: EARTH STATION TERMINAL DESIGN AT CONSTELLATION SCALE

MODERATOR: Tom Stroup, President - SIA - Satellite Industry Association
Brad Bode, Chief Technology Officer & Co-Founder - ATLAS Space Operations
Aaron Hawkins, Director Viasat - Real-Time Earth Ground Service – Viasat
Steve Richeson, VP Sales & Marketing - Mission Microwave
Dr. Vagan Shakhgildian, President - Comtech Satellite Network Technologies
Tim Shroyer, Chief Technology Officer – CPI

PANEL DISCUSSION

- Tim Shoyer, CPI
 - Constellations require you to be able to ramp-up to quantity – also prototype is not for one of many
 - If you don't design ground hardware needs at the same time, it can make it hard

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- to get the data
- It can make sense to combine frequency bands in antennas, but it's not the cheapest way to do it
- Doing Q and V-band now; going to Ka-band is a slam dunk
 - May take longer with LEO and MEO until infrastructure costs come down
- Brad Bode, ATLAS
 - Constellations have hardware problems
 - Need access to space
 - Need to be able to expand network without changing software
 - Want to reduce friction to get to your data, move it to the cloud and make available
 - We de-risk this for our customers
 - Ground equipment needs to be set-up early, and reserve capacity needed
 - Not going to be able to build a terminal that does everything, so you need to have a collection of hardware with seamless swapping
 - If you crosslink in space, data may never need to come down or come down in one place
- Dr. Vagan Shakhgildian, Comtech
 - Constellations mean change in scale in ways previously unheard of
 - Need capabilities for design and manufacturing at a reasonable point
 - Want to futureproof, so looking at things like software-defined devices
 - Standardization is important and can't be overlooked
 - Some virtualized waveforms can't be supported with existing equipment – standardization is needed
 - Industry is getting more complex – both satellite and ground segment need to be designed hand in hand
- Aaron Hawkins, Viasat
 - Need to productize to evolve with customer
 - Can use multiple customers per antenna, or customer can have dedicated hardware or can just host for customer
 - Bandwidth economics is important on a \$ per gb down – need to increase the

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- downlink rate with higher bandwidth
 - Smart constellation plans include lots of ground equipment and locations as possible – no cost to add sight they won't use, but adding a new one is a bigger issue
 - Lack of integration between ground radio and space, radio people
 - Looking for areas where they can be more flexible by optimizing across multiple schedulers
 - Push to higher frequencies; ka-band is here – may be able to reduce pass time by 50%
- Steve Richeson, Mission Microwave
 - Need to look at missions to see how constellations will scale
 - Formerly, ground equipment was designed at the end, but the industry is getting better, but there is still plenty of room to improve
 - Getting a terminal to do everything will cause problems
 - ,E.g., if the terminal is certified for the military, you can't change it at all
 - Often best to keep applications separate

T. OPTICAL COMMS FOR INTER-SATELLITE AND SATELLITE-GROUND OPERATIONS

MODERATOR: Natalia Larrea Brito, Director of US Operations - Euroconsult

Tina Ghataore, Chief Commercial Officer - Mynaric

Campbell Marshall, Chief Operating Officer - Skyloom

Dr. Jean-Francois Morizur, CEO - Cailabs

Dave Pechner, Vice President Technology - SA Photonics, A CACI International Inc. Company

Sven Rettig, Chief Commercial Officer– Tesat Spacecom

PANEL DISCUSSION

- Tina Ghataore, Mynaric
 - Mynaric has been around for over a decade and has been involved in getting optical com technology into scalable products and deployed in various market segments (space, air, and ground) and has products on several missions currently.
 - Optical is a global technology that needs to be deployed
 - Need pioneers to bring technology to market – US government is facilitating this

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and enforcing a standard [AM Comment: This might happen in other areas as well]

- Need other parts of the spacecraft tech stack to need to keep up with optical capabilities
- Not just a government-focused tech - commercial applications in addition to government, including Starlink
 - Interoperability is critical for the terminals – can't get the efficiency gains with bespoke equipment
- At least three people on the panel will deliver a few hundred terminals this year – it will be a big year for all of us
- Government data needs today may not need optical ground terminals, but they provide options
 - Optical is complementary to RF
 - Can use geographic diversity to manage clouds
 - To go from 2.5 Gbps (current govt requirement) to 10 Gbps is just a card swap in a box – we have plans to go to 100 Gbps
 - Hopes government stays out of regulating optical
- Scaling to affordability and managing the supply chain are the big challenges
- Campbell Marshall, Skyloom
 - Standalone US-based company (moving from Oakland, CA to Colorado), but moving to Colorado
 - Fashion ourselves as the 1st space-based telecom company
 - Space is moving to space-based optics
 - Announced a partnership with SpaceCompas to launch 1st optical data relay satellite over Asia Pacifica
 - Partnered with Honeywell adds knowhow
 - Pushing the envelope beyond the current SDA standard now
 - Technology is evolutionary, so physical issues are not as large a challenge
 - Working with govt on 10 Gbps terminals
 - Meeting standards and interoperability and the like are a challenge as they will require some thought leadership in the group – need to engage with customers to evolve together
 - Will be a requirement for standards (customers will demand it), especially as we

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- move to triple-digit speed, but may be diverse ways to get there
- Optical changes the paradigm, including increased security
- Optical can be reused and avoids many of the justifications for regulation, such as interference
 - Government ground users see LPI/LPD (hides information into the noise, improving security) as a game changer
- Over the next five years, different architecture will drive us to find out which speeds work at different distances or modulations and innovate on these capabilities
- Architectures are now driven by military use, but if a major geopolitical event happens, what does that mean to the supply chain? We will be prepared for this difficulty, having dealt with covid
- Dr. Jean-Francois Morizur, Cailabs
 - VC-backed French startup (70 people, raised \$42 million) – focused on the ground level only
 - Can deal with turbulence which makes ground stations special
 - Have the support of French DoD and contracts with others, including the Swedish Space Corp
 - In 2007, pioneered optical communications in space
 - Seeing new demand cases that don't necessarily require a constellation
 - Few hundred units a month
 - Complementary to RF
 - Given the direction of data rates, optical will be needed to bring data down
 - It's likely that there will be some optical regulation, but likely to be lighter
 - Governments will want to regulate ground equipment
 - Manufacturing of optical in space is not as mature as on the ground and also needs interoperability
 - Our technology has been validated to 100 Gbps
 - Likely to find plenty of new use cases over the next five years
- Dave Pechner, SA Photonics, A CACI International Inc. Company
 - SA Photonics was purchased by CACI last year
 - A handful of locations in the US

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- Working on space, airborne, and ground parts of the system
 - Main system is “Crossbeam,” which supports some government programs
 - Have done crosslink and space-to-ground experiments
- Going from 10 Gbps to 100 Gbps will be much harder
- Using the optical link to calculate position and time may be as important as the communication link for the government
- Optical industry needs to plan for higher data rates
- When you get to 100 Gbps, modulation schemes change, and interoperability may be harder
- Will have optical constellations in space in 5 years, and likely more after that
- Sven Rettig, Tesat Spacecom
 - Tsat Spacecom is based in Germany with about 1,200 people with over 300 million euros in revenue
 - Active in everything about space communications
 - Equipment, product, subsystems, small payloads in RF domain, amplifiers, downlink, TT&C systems
 - In 2007, we pioneered optical communications in LEO
 - Working on cross-links
 - Launched on a satellite 18 months ago
 - We connect in space in all areas
 - Challenge is to fill client needs at a low price
 - Optical will be needed for newer high speeds, but RF and fiber will still be needed
 - Optical allows new applications
 - Higher data rates will require optical
 - We have 10 Gbps capability, and others can often upgrade optical via software
 - There is much talk about communication with the moon, but it is not a big market yet – perhaps one day
 - What happens on earth will happen in space

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U. TECH BRIEF: THE ROLE OF SMALLSATS IN EARTH SCIENCES

Negar Feher, Chief Revenue Officer – Space Ryde

- Review of how SmallSats have impacted the earth
- Atmosphere – 99% of what comes to us
 - Air quality monitoring is now coming from small sat
- Lithosphere - maps of rocks on earth and plate movement come from SmallSats
 - Constellations can give better
- Hydrosphere
 - Includes all of the water
 - Precipitation, flood prediction, etc.
- Biosphere
 - Living features on earth
 - Data gathered for crops, etc., is largely coming from SmallSats
- Some limitations on SmallSats due to power, etc.
- Monitoring oil spills, early warning for disasters, ecosystem monitoring,
- Emerging smallsat technology is radar (formerly only on larger satellites)
 - Example Lunasond – MRI matting of the earth 2 km below the surface
 - Tomorrow.io – uses radar weather analysis for B2B customers
- Challenges
 - SmallSats are often on rideshare and may not be in an orbit they need
 - This may require additional propulsion
 - Calibration problem with multiple satellites is harder
 - , E.g., One satellite might be facing the sun and be hotter
 - Benefits
 - Can do many small satellites and new system architectures, gap fillers, etc., for the same budget
 - Disruption Opportunities
 - Data downlink is a problem
 - Edge computing on the satellites to reduce the amount of data that is downlink
 - Can have data centers in space, but this is probably 10-15 years away – probably when more lunar missions start

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V. CRAFTING ADVANCED SOFTWARE AND HARDWARE THROUGH SIMULATION AND AI

MODERATOR: Lori W. Gordon, Systems Director - The Aerospace Corporation

Kameron Baumgardner, CTO - RS21

Jeromy Grimmett, Founder & CEO - Rouge Space Systems

Even Rogers, CEO and Co-Founder, True Anomaly

Alvaro Alonso Ruiz, Co-founder & CCO – Leanspace

PANEL DISCUSSION

- Jeromy Grimmett, Rouge Space Systems
 - Data solutions using AO
 - AI is central to what we do, such as machine learning
 - It will be interesting to apply AI analysis to financially engineer the space domain
 - Currently, there are specific missions
 - To unlock demand, we need to do it at scale and make it financially viable
 - Now, mindset is starting to change such that there are space battle domains and need to be addressed
 - To train our staff, you need to have something in space to train against
 - Chatbot has been quite effective if questions are specific, but has a little way to go – humans will be needed for a while
 - Eventually, we'd like to see self-driven, goal-based AI
 - China is likely ahead of the US in space AI
- Even Rogers, True Anomaly
 - VC-backed defense and sustainability company
 - Lots of simulation activities and use AI to train satellite operators
 - Looking for the right moment for people to intervene in the process
 - Contemporary conflict is multi-domain
 - AI is about the ability to get confidence that the AI answer is verifiable
 - It will be interesting in areas where there is a surprise
 - We rely on analogy a lot for training due to the nascence of the sector
- Alvaro Alonso Ruiz, Leanspace
 - French software/cloud system for space missions

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- Connect software tools and data across the mission – get data from the simulation into tools
- A significant number of space companies don't know how to apply AI
- One thing to run simulations and another to actually implement it to deliver actionable information
- Develop technologies to defend if satellites are attacked
- Want data from satellite operations to train AI algorithms
 - Need good data for simulations
- On software, we are well behind other industries
 - Much of the software does not flow from one tool to the next
 - Holds back scalability need to connect as with banks and automotive
 - Space sees software as isolated bubbles
- In 5-10 years, satellites need to manage avoidance maneuvers
 - Still done manually, but this will be impossible with new mega-constellations – need to digitalize the processes
- Mega constellations are the first application for AI
 - It will be hard to do this without AI as the satellite flying needs to be continuously optimized
- Kameron Baumgardner, RS21
 - Using machine learning to train models for predicting satellite failures
 - Have seen a decent amount of initial adoption and now need to answer a lot of questions other industries with more AI experience have addressed
 - Need to figure out UX for user intervention as well as limitations
 - Can't train satellite like ChatGBT – need real data to start
 - Should we remove humans for decisions? Not if there are issues that are hard to recover from
 - Looking for RAD-hardened chips in space

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W. SPONSORED SESSION – TURNING CONSTELLATIONS INTO NETWORKS

MODERATOR: Dr. Tim Farrar, President - TMF Associates
Michael Abad-Santos, Chief Executive Officer - BridgeComm
Randall Barney, Director of Certification and Membership - World Teleport Association
Dr. Clemens Kaiser, Chief Program Officer - Rivada Space Networks
Larry Paul, VP Corporate Business Development - Inmarsat
Ronald van der Breggen, Chief Commercial Officer - Rivada Space Networks

PANEL DISCUSSION

- MODERATOR: Dr. Tim Farrar, TMF Associates
 - Success of Starlink is hanging over the industry

- Michael Abad-Santos, BridgeComm
 - On component side, we see increased demand for mesh networking and interconnecting ability
 - Seeing a convergence between satellite and terrestrial capabilities
 - Can space drive the cost down to make it completely seamless
 - This is the ultimate goal
 - Verticalization of SpaceX and Kuiper is good, as prime integrators have not adapted much
 - New space economy is adapting faster than established primes
 - We have the technology to take advantage of scale using COTS equipment
 - From an optics perspective, teleports are important
 - The scale of production is changing now
 - Hard to make the modem/antenna that works for everything because everyone wants a closed system to keep revenues
 - 2023 is a big year for BridgeComm as we have orders to complete

- Randall Barney, World Teleport Association
 - Teleports as established robust systems and good places to co-locate
 - Teleports are sustainable but may need to do more collaboration with companies like Amazon moving in
 - To support new constellations and increased pace of development teleports need to partner with new constellations (e.g., Speedcast is working with Starlink), and

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this will happen more

- Dr. Clemens Kaiser, Rivada Space Networks
 - Only ten days apart in the ITU filing database
 - But addressing a different market – only 600 satellites
 - Allows a different design on the ground and space
 - Will need a phased array antenna on the ground
 - Options from existing products or those under development
 - High vertical integration from Amazon and Starlink will still allow us to have an open system
 - Our real added value is running the network
 - Don't intend to be another manufacturer
 - Customer may not even see what kind of system they are using
 - Is there enough bandwidth in space to do what we want to do?
 - We have a high filing priority, so maybe it will work
 - May eventually need to move to another medium (optical) eventually
 - Need to apply for US access, but have not does this yet – maybe the next round will be soon

- Larry Paul, Inmarsat
 - Starlink has turned the industry on its head
 - 27 terabits of capacity in space, doubling every 18 months
 - Starlink thought about the terminal first and the user experience first
 - Customers (mostly US govt) are asking for multi-frequency multi-orbit satellite proliferated solutions
 - Not all companies have a 15-year time horizon (like Kuiper and Starlink). We will use partners and buy things
 - Orchestra will stitch together other LEO systems and make them work
 - We provide a lot of gateway services to the US Government
 - It instills a lot of confidence if you can transfer from satellite to satellite and terminate on customers' premises
 - We can do a lot at the switch level, but a multi-operational antenna would be great
 - Still doing plenty of GEO, but customers also demand some LEO. We don't have

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the balance sheet to do it ourselves, so we are partnering with others – also, prices are dropping

- In 2023, we need to make more progress on pulling the network together
- Waiting for the UK competition bureau as well as EU and US approval for Inmarsat/Viasat merger

- Ronald van der Breggen, Rivada Space Networks
 - Money will come from customers ultimately
 - The industry seems to be chasing the last mile to ensure connectivity where there is none to connect people
 - But this is expensive, makes sense to keep data in the system longer
 - Example Colt Telecom – in the last 90s, if you wanted to terminate in London, they have developed company to carry customers the whole way
 - Same with satellite – to carry customers’ traffic and take it the whole way
 - Satellite market, is satellites are configured better, is much larger
 - Address people with problems with cybersecurity, latency, etc. & budgets
 - Going from an operator of antennas to managing a network will mean an opportunity for teleports to be part of a new satellite systems
 - Have security, resiliency, and other advantages in addition to latency
 - Bent pipe constellation will be in the last mile – a price-sensitive market
 - From \$3,000 to under \$100 (per Mbps/month)
 - SD-WAN is of critical importance with antennas from rooftops of companies
 - Have started to manufacture satellites already – working on the rest of the supply chain

DAY THREE: THURSDAY, FEBRUARY 9

X. ARCHITECTURAL AND TECHNICAL CONSIDERATIONS IN SMALLSAT CONSTELLATIONS

MODERATOR: Dr. Ioana Cozmuta, CEO - G-Space
Julian Fernandez Barcellona, CEO and Co-Founder - Fossa-Systems
Andrew Haslehurst, Chief Technology Officer - Surrey Satellite Technology - SSTL

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Brian Holz, CEO - Mangata Networks
Talbot Jaeger, Founder and Chief Technologist - NovaWurks
Rob Schwarz, Chief Technology Officer – Momentus

PANEL DISCUSSION

- Julian Fernandez Barcellona, Fossa-Systems
 - Start-up from Spain – founded in 2020 – have 13 satellite in orbit
 - Expect worldwide IOT by 2024
 - Most of our customers are looking for a solution and don't have a space-specific need – different from others
 - Many opportunities to work with terrestrial, but in the short-term, space won't replace terrestrial as things in space cost more, and consumers will need to pay a premium in rural areas
 - Need to focus on space debris in LEO where passive deorbiting is possible with the correct design
 - Try to build satellites in a standardized manner
 - It's a long time, perhaps a century, before true manufacturing in space, but perhaps in-orbit assembly is possible
 - We are interoperable with LORA devices – compatible with licensed IMT spectrum for uplink

- Andrew Haslehurst, Surrey Satellite Technology – SSTL
 - Around for 40 years, pioneering SmallSat
 - Use architectural building blocks that can be replicated
 - Need to understand
 - With a large constellation, there is a challenge to bring data down. Additional needs to address on board or to a larger space ecosystem
 - Several missions are going to the moon, and more will be needed there, including connectivity to build an economy on the moon – Surry's Lunar Pathfinder will help, but it's a small step into a new frontier

- Brian Holz, Mangata Networks
 - Constellation geared to enterprise to bridge to intelligent computing
 - Constellation design is about coverage and finding performance and economic drivers to optimize

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- OneWeb about 4G waveform, Mangata is looking at enterprise VPN – a different project
 - We don't want a uniform coverage model
 - We put a lot of computing at the edge
- Satellite won't compete with terrestrial capability but can mesh with it
 - Starting to see advances in on-board processing with beamforming, you can make satellites perform closer to terrestrial technology and reduce the cost per bit
 - Most LEO satellites are not generating any revenue at any given time
 - Add terminal distribution, landing costs, etc. it is a challenge
 - Need to focus on critical issues related to capital deployment
 - With 4k satellites, they [SpaceX?] can service 11-12 million people – won't make a dent in the 4 billion people with poor connectivity
- Direct to Home is hard for satellites is hard – we think it's better to run as hybrid and part of a network
- Ongoing disruption of cloud with 5G and 6G and smaller cells – Also, AI will disrupt cloud search
 - Creates opportunity for how to connect people – we are just seeing this start
 - Things won't be in just one place; they will be distributed
 - Satellites are just now getting to the point they can be developed and launched fast enough to be closer to terrestrial technology development
- Talbot Jaeger, NovaWurks
 - Trying to provide enabling tools for space, including building blocks
 - Need to think differently – can we enable more so we can easily service, fuel, and maintain satellites
 - Can we develop an architecture to sustain and supports the space economy? There is a larger architecture we are missing
 - Key is service areas where there is not good communication infrastructure
 - Can do storage in space, put labs in space, etc.
 - Now focused on dedicated space missions, not changing the system – there is a lot there in terms of possibilities

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- We can build communities in space, including large constellations, with the right tools
- Moving down the path to creating a different basis for space – how do we enable this?

- Rob Schwarz, Momentus
 - In-space transportation – are now in space
 - Support infrastructure in space, including in-orbit service, movement, de-orbit, and space debris removal
 - Want to help fleet management of large constellations
 - Customer requirements dictate a lot – often end up designing constellations around the rocket as usually launching a plane at a time
 - There is a need for in-space computing and data management. Lots of data and little amount of information
 - Uses spectrum better to allow more processing in space and then only download a small amount of it
 - Need to integrate space and terrestrial
 - Starlink is great in some places – such as where I live in Santa Cruz
 - Not as good in urban areas
 - A plane with ten satellite will have perhaps 35% running at the end of it – will have a lot of dead cells, and constellation management will get complicated
 - Will drive manpower and fuel to avoid collisions

Y. NEXT-GENERATION CYBER THREATS – LOOKING OVER THE HORIZON

MODERATOR: Preston C. Dunlap, CEO - Arkenstone Ventures
David Andaleon, Manager, Business Development & Technology - Innoflight
Matthew Erickson, VP Solutions - SpiderOak
Declan Ganley, Chairman and CEO - Rivada Networks
Daniel Holtzman, Authorizing Official - Chief Digital and Artificial Intelligence Office - Department of Defense
Mike Vinter, Executive Vice President - International Space Brokers

PANEL DISCUSSION

- MODERATOR: Preston C. Dunlap, Arkenstone Ventures

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- NISR recently released framework for satellite ground system
- David Andaleon, Innoflight
 - Build avionics for LEO and National Security and NSA Crypto
 - If you perceive your foe has something you don't, you need to address it
 - Several attack layers in space – software, hardware, uplink, etc.
 - Encryption protects the black [public] side of the network, but not the red [internal] side of the network – need to address all levels
 - Worry about attacks we aren't aware of, including the unauthorized movement of data exfil)
 - CNSA – Commercial National Security Algorithms
 - Provides at a technical level where the government is thinking about cybersecurity
 - Space ISAC (“Information Sharing Analysis and Collaboration”) – a useful resource for cyber security and other things
- Matthew Erickson, SpiderOak
 - Provides space-based cyber security solutions
 - Cyber is the future of war – China has an integrated peace and war activity
 - No such thing as a fully secure data center in space – it can be touched at any moment
 - There will always be seams in systems that you want to minimize – this is where attackers get in
 - Need to think about how to make systems safer (e.g., why have numbers on a credit cards?)
 - No matter the technology, assume insider threat always and be vigilant
 - Cannot assume everything is safe if it is on a red network
 - Government procurement needs to catch up with cybersecurity – typically, it just says something like “conform to NIST”
 - Need some flexibility to address concerns of flexibility
- Ronald van der Breggen, Rivada
 - Cyber security is super important
 - Architecture is important to protect information – main area it is addressed

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- Space creates opportunities for cybersecurity
 - When you can keep data on one network you can keep it secure at the lowest necessary hardware level [AM Comment: Rivada's System]
 - Space has an opportunity for this
- Space between space – LEO constellations are very different than GEO due to the number of moving satellites and difficulty knowing which one is carrying the data and only seeing it for a few moments
- With laser link constellation, you might be able to access one satellite and then get access to all of them – each node on the network
 - Operator has greater cyber control if they can see all of their assets at once
- Some big announcements from Rivada later this month
- Daniel Holtzman, Department of Defense
 - Person to blame when something goes wrong in cyber
 - It's all about data – focus on the goal of the system and how to protect it
 - Can't call emergency service is there is a problem in space, so this creates a unique risk that needs to be addressed upfront
 - We don't understand the technologies enough – move to zero trust and assume it is always compromised
 - Our thought process causes most of the issues
 - Encryption itself can be a denial of service – it is really time component protection
 - Need to work from the perspective that nothing is safe – can't have a single solution answer
 - Diversity is a huge advantage – if you can do things differently, you can escape some of the attacks
 - Passive collection is part of the threat, even if another size if watching the data and learning. Also, need to be aware of what information we might be giving away be the way data is protected
 - Need the flexibility to look at the intent of government policies as opposed to the strict text
 - Analytics of data and constructs around it is where we need to focus in the world of AI – we want to keep data secure but also to share it –but it needs to be

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appropriately tagged – especially if it can be correlated with other data

- Mike Vinter, International Space Brokers
 - Provide insurance to the space industry
 - Space insurance used to be vague with respect to cyber – not they have specific exclusions for cyber
 - No coverage if your satellite is hacked and you lose control over it
 - If the industry is expected to broaden coverage, there will need to be an education process about how the security will work
 - There is a cyber market for space companies – that covers consequential loss but not the satellites themselves – business interruption, liability, extortion, etc.
 - But the underwriting and application process is complex
 - Aon’s space insurance market report is being finalized

Z. FIRESIDE CHAT

Jason Kim, Chief Executive Officer - Millennium Space Systems
Ryan Reid, President - Boeing Satellite Systems International

- Jason Kim, Millennium Space Systems
 - 2022 was busy – unveiled SmallSat factory
 - High-rate production programs
 - Three spacecraft to GEO
 - Resurgence of a Silicon Valley mentality in SmallSat
 - Agile development, etc.
 - Vertical integration is something we have invested in
 - We still look at other suppliers – what makes sense for the mission?
 - Our high-speed production supports both commercial and government markets
 - Launched 1st SmallSat in 2017 – new additive manufacturing significantly reduces the number of components
 - Handful of programs that neither Boeing nor Millennium would have won by themselves but won together – now it is about execution
 - Huge emphasis on onboard processors – good for JADC2 work
 - Vertical integration also allows for better interoperability and can adapt quickly for JADC2

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- Move to constellations and multi-orbit is good for resiliency and economies of scale with common parts
- Tries to show employees their purpose – also, there is a lot the team learns from Boeing and people get responsibility quickly. People can also work in other areas of the company
- Ryan Reid, Boeing Satellite Systems International
 - 2022 was an interesting as 1st satellite launched for a few years
 - Ended with O3B mPower – 1st software defined phased array satellites
 - Viasat-3 Americas is near completion
 - Viaaat-3 EMA later in 2023
 - In 2022, the importance of commercial satcom in military applications became clearer – resiliency, troop morale, etc. Interoperable capabilities are useful
 - Technology developments for MEO are designed to scale up to GEO or down to other NGSO applications
 - Additive manufacturing (e.g., 3D printing) gets very efficient and moves the needle
 - We were able to move to be a rapid development company, partially with Millennium’s expertise
 - Commercial market is transitioning to NGSO as it is now becoming more economically viable
 - Greater flexibility allows greater opportunity
 - Need skilled labor and recognize that how we design is important so we can have production ready to go [AM Comment: Reading between the lines, I think he is saying they design the satellites, so they don’t need such deep talent to manufacture them]
 - We are pulling talent from a wider pool than aerospace engineering – RF engineering, etc. - but competition talent is tough

AA. CLOUD COMPUTING IN SMALLSAT ARCHITECTURES: STORAGE, PROCESSING, AND DISSEMINATION

MODERATOR: Chris Quilty, President - Quilty Analytics

Dennis Gatens, CEO & Founder - LEOcloud

Dr. Miguel Roman, Chief Scientist and Tech Fellow - Leidos

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Pratish Shah, General Manager - Aitech Defense Systems

Eric Truitt, CSO - MapLarge

Buffy Wajvoda, Global Leader for Aerospace Solutions Architecture - Amazon Web Services - AWS

PANEL DISCUSSION

- Dennis Gatens, LEOcloud
 - Building 1st infrastructure as a service in space – to allow multi-cloud infrastructure to be extended to space – the next frontier for edge computing
 - More data in space that can be downloaded to earth without significant delay
 - Going up the value chain allows satellite operator to deliver information as opposed to data – can reduce latency for actionable insight by doing computing in space
 - Software can make decisions about on-orbit processing vs. downloading to earth, depending on the situation
 - Expect one day to have a certain level of processing on satellite, a next level at a space station, and then deliver to end uses
 - We have seamless internet architecture in the US – this is what drove the market
 - The same will likely happen in space
 - Interoperability will create redundancy, reduce latency, and reduce transport costs
 - You can reduce your carbon footprint on earth by putting data centers in space
 - Costs more, but it's all about the total cost of ownership – it will be a positive business case for hardened space-based hardware as it won't need (or allow for) servicing
 - Value of IP is mostly in the software, so we want to have basic containerized hardware that can support new software
 - Terrestrial infrastructure is interoperability, and space needs to go in that direction
 - The ability to be as nimble as possible helps react to cyber attacks
- Dr. Miguel Roman, Leidos
 - Company focused on intel and defense data processing and algorithms for many govt agencies
 - SAR and Hyperspectral remote sensing are major drivers of demand

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- Move to deliver near real time results
 - Provide data quickly to politicians to change policies, such as in floods in Puerto Rico
 - Government will increasingly rely on commercial solutions and seeing the need for monitoring (e.g., seeing methane leaks from space)
 - Improving smallsat architecture will enhance IoT and its integration with earth observation capabilities
- Pratih Shah, Aitech Defense Systems
 - Sells hardware systems for cloud computing in space – computers, storage devices, etc.
 - Amount of growth and demand over the last few years is similar to ground, especially in storage devices and processing needs – want to do more with smaller size
 - Cloud computing in space is one of the demand drivers – at an inflection point
 - As technology and use cases evolve, the services will evolve – optical is emerging, but still has work needed – Weight, Power, and Bandwidth need to be traded off, and pendulum will swing as needs evolve
 - Space is a harsh environment for electronic parts but we need to put reliable solutions in space as it is in the cloud. Not there today, but going down this path
 - Radiation-hardened device premiums have gone down
 - COTS technology is happening rapidly in the industry
 - Smallsat architecture will enable ubiquitous communication over the next several years
- Eric Truitt, MapLarge
 - Software platform for enterprises to deploy critical custom applications – now deploying on-board processing LEO
 - Disaster response and geo-political use cases often drive urgency for solutions but don't investment
 - Governments are starting to realize the need for investment – for example, to monitor vegetation near power infrastructure – also commercial needs (e.g., Suez Canal blockage and need to reroute supply

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chain)

- On-board processing works across multiple parts of a satellite and is coming to the forefront of platform design
 - Developers often think in a bespoke mindset and not about the benefits of interoperability – this will change
 - Expect more regulatory changes to ensure satellite platforms are better protected
 - See seamless connectivity coming via space, and other things will build on top of that
- Buffy Wajvoda, Amazon Web Services – AWS
 - Runs Aerospace Solutions group for AWS
 - Increased demand for edge computing in space. The ability to do AIML in space will be a game changer
 - But also, more data processing on the ground
 - Will see additional flexibility and convergence in space – enhanced connectivity and network convergence
 - Satellites used to be bespoke but now are getting standardized and economies of scale are emerging. Standardized platforms will also enable computability
 - As space becomes increasingly ubiquitous, government standards are somewhat inevitable, but much of it will be driven by industry
 - Security is a top priority at Amazon, with over 300 security services available for customers
 - As the world becomes increasingly interconnected, there will be greater vulnerability to traditional cyber-attacks – need to use traditional detection, protection, and mitigation methods

BB. BEYOND IMAGERY: EO SENSORS ENABLING RADIO FREQUENCY ANALYSIS, METHANE DETECTION, WEATHER ETC.

MODERATOR: Drew Svor, Partner - Sheppard Mullin
Andy Bowyer, Co-Founder/CSO - Kleos Space
Bryn Davis, Technical Advisory Group Chair - MethaneSAT
Dr. Alex Saltman, Chief Operating Officer - GeoOptics
Dr. Robert Sproles, VP of Constellation Planning and Operations - Spire Global

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Kaitlin Zimmerman, Chief Data Scientist - Hawkeye 360

PANEL DISCUSSION

- Andy Bowyer, Kleos Space
 - Collect RF data from space to produce actionable data, especially for defense
 - Need to focus on getting data from collect to users' hands is where we are aiming to push
 - Massive capacity constraint in sensing environment
 - Frequently need to educate newer users – put data in the hands of researchers who can try to develop niche applications we can't develop
 - We are ITAR-free, but we must consider where our data is sold, so we remain responsible
 - Regulatory obstacles have not impacted commercial model much – does not impact technology
 - Only a handful of customers can take raw data and get value from it
 - Need to be able to explain the data to customers
 - No customer wants to be the only customer – even the US Govt
 - Customers want to see that we have a broader market to survive
 - RF is very accurate, but optical is good for validating the date and providing context – the end user wants a complete picture

- Bryn Davis, MethaneSAT
 - Project on building hyperspectral sensing satellite for methane emissions – controlled by the Environmental Defense Fund (“EDF”) measurement with a unique combination of ground resolution and coverage range
 - Reduction of cost and complexity of launching a satellite is why something like MethaneSat is possible
 - Manufacturers we buy from the need to serve government customers and different commercial customers at the same time
 - Imposes costs and complexities for them
 - Need to come to grips with data processing and dissemination
 - Many places the data needs to do not have the telecom infrastructure to received it
 - We inject lots of data – it would be great if government-provided weather data were enhanced

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- Dr. Alex Saltman, GeoOptics
 - Observation, radar, and gravity measurements from their satellites
 - Things we want to do in space were not in mass quantified until recently, particularly RF processing and the ability to push the analog to digital conversion as close as possible to the antenna
 - Seen an explosion in the last year – piggybacking on technology for cell towers, etc.
 - We don't have much that is ITAR covered, but it is still a pain as we need to deal with ITAR with international partners, etc.
 - New technologies are coming in, and regulators are looking at new ways to regulate them
 - We often license spectrum outside the US because it is easier
 - If I were starting a new company, I would not want to do it in the US – other countries have more friendly regulatory environments
 - Regulatory obstacles required us to make non-optimal downlink and uplink decisions – we now know how to work the system – but feel bad for small startups
 - We are analyzing to expand the customer base to grow
 - Can't grow the way we want with only government customers
 - Talking to customers gives us insight into what customers might want and incorporate it into the next generation of satellites
 - Most customers are 1st world countries that know how to use the data
 - Have not run into problematic customers, but it is a concern
 - Need growth both in terms of developing an end product, but also partnering with additional companies who have customer solutions
 - It's not easy for the government to give up additional data from microwave sounding, etc.,

- Dr. Robert Sproles, Spire Global
 - Space-based data company
 - Larger amount of processing is being pushed to the satellite - machine learning is being pushed to the satellite – one of the more exciting things happening in the industry

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- Need to fuse data from different sources across a wider picture than this a narrow vertical
- Government licenses often make it hard to change service offerings to meet customer requests, even if the hardware itself does not change
- Our customers want different things – this is one of the challenges – providing so many different packages
- Need optics and RF to provide a full solution for customers – can't just use one

- Kaitlin Zimmerman, Hawkeye 360
 - Operate satellite constellation collecting RF data
 - Just launched 6th cluster of satellites
 - Will have nine by the end of the year
 - New capabilities, including new frequencies and faster, revisit time, are being added
 - As we add customers and capabilities, the ground segment needs to do more, as there are additional signal types and capabilities for customers
 - Have seen a large variation in customer familiarity with RF data
 - Government customers are very familiar with the data and do their own analysis of data
 - Other customers are less familiar with and want us to do analytics for them
 - How can we do this efficiently for them
 - Significant work is needed with regulatory agencies to make them comfortable that data won't be used irresponsibly, or illegally as new products develop
 - Also have problems with scale given the custom demands from the customer
 - Data infrastructure needs to be optimized to able more easily customize analysis for customers
 - Some partners have the trust of end customers which adds value
 - We work with partners who can help us
 - Would like to see enhanced capabilities to get additional processing in space, such as in-orbit data centers

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CC. ADVANCES IN ON-ORBIT SOFTWARE DESIGN, DEVELOPMENT, AND DEPLOYMENT

MODERATOR: Professor Andrew Kwas, NG Fellow - Northrop Grumman
Tom Barton, Co-founder and CEO - Antaris
Dr. Trevor Bennett, Co-founder - Starfish Space
Thomas Jensen, CEO - Gatehouse Satcom
Avi Shabtai, CEO - Ramon Space
Jake Teufert, Chief Technology Officer - Benchmark Space Systems

PANEL DISCUSSION

- MODERATOR: Professor Andrew Kwas, Northrop Grumman
 - Northrup is now the #1 space company – largely due to software – an intangible
 - Do much own coding, but also rely on products – not trying to do it all is an advantage over some competitors

- Tom Barton, Antaris
 - We are purely a software company – building software suite for design, simulation, and operation of satellites
 - Can use software to build a virtual satellite and then add hardware when ready
 - Creates a “sandbox” to try changes before pushing them to live satellite system
 - Upcoming launch of the satellite using software is going on SSLV2 today
[AM Comment: Confirmed the launch was successful]
 - We don't care what hardware we run on and can tailor to customers' requirements
 - Architecture can support AIML, but we do not write some of that code
 - Make sure all of the processes can communicate with the bus etc., using standard terrestrial solution best practices
 - To an extent, you can isolate issues, so you don't need to change everything – use microservices to change small portions of code
 - Starlink in Ukraine was able to send small patch updates
 - With the right predictive computing, you can have self-healing software
 - No difference between LEO and GEO software – same computing architecture
 - But new classes of software are needed to make the network work
 - We believe that an open standard of software ecosystems for satellites will

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- emerge – similar to computer operating systems and cell phones
 - Pressure is especially hard on LEO costs, so standardization is particularly important
- Working in a fun industry helps us hire people – being able to operate virtually also helps
- Dr. Trevor Bennett, Starfish Space
 - One of the co-founders – building the Otter satellite service vehicle for on-orbit services, including GEO servicing, debris removal
 - Autonomy is the future – space can benefit from what is happening in space – things can come together in a modular way – move complexity from hardware to software
 - Want to be 2nd life extension after Northrup Grumman – need to be good at flight software
 - How much control can we cede to the spacecraft
 - Need to distinguish between sensor data and decision making
 - Software upgrades in space allow you to tune/adjust some of the physical assets and resolve hardware issues
 - You can never know that you have tested everything
 - Need to get a stable base and then upgrade if you need – but needs systems that are serviceable and upgradable
 - Focused purely on modular software systems – can fly on multiple satellites – need to have open standards that are hardware independent to lower costs – key to scaling
 - Interest from DoD in standards
 -
- Thomas Jensen, Gatehouse Satcom
 - Incorporated in 1992 – software company that developed software protocols for EUs and base stations and test tools – doing this for over 20 years
 - Key partner for Inmarsat – worked on Inmarsat GAN and BGAN – about 50k active terminals
 - Technology has gotten more developed and advanced – the body of 3GPPP is starting to look at space and bringing the space domain into the standards

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- In 2019 started, 5G narrowband IoT protocols – now can be deployed for Geostationary systems – will be ready for LEO in a year or so
 - This standardization will change how we use communications systems
 - Make most of the software ourselves – good for government programs and security
 - Testing is a big part of the software and needs to be continuously done
 - When putting hardware in space, you need to handle latency, etc., which can be different for LEO and GEO
 - Continuous connection to upgrade LEO is more complex
 - Have lots of telecom engineers that we work with and employ
 - Space sector is interesting and can attract people
 - In future, you won't notice if you are communicating from space or earth
- Avi Shabtai, Ramon Space
 - Building space-resilient infrastructure
 - Can process, store, or move data – this is the infrastructure we build
 - Want to run the software the way we do in space with data centers and edge computing
 - Want to update in orbit and allow customers not to need to consider the space environment when building software
 - Space is moving towards machine learning and AI – need to start running analytics in orbit – both with earth orbits and in deep space
 - Hardware for space is qualified; software also needs to be tested – but it's also important to test that the software can be updated in space in a reliable way
 - In GEO, we usually speak about one satellite – a constellation is different from updating when they are working as a network – much more complicated than upgrading a single GEO entity
 - Whole new economy of applications and service is possible if hardware can run multiple software services – need to decouple hardware and software
 - We look for employees who want to do something different and are excited about space and see it as something different
 - Joined the space industry three years ago because it looked exciting
 - In the future, satellites will be huge computing machines

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- Jake Teufert, Benchmark Space Systems
 - Benchmark is an on-orbit mobility company – propulsion enhanced by A C and G software layer – interested in how propulsion can be a true plug & play system – want to use software to abstract propulsion away and handle lower-level control to make it easier to integrate and standardized
 - Want to build capability autonomous on-orbit mobility for high traffic space environment without having a human on the ground
 - Want to abstract propulsion away to make it easier to integrate
 - Building hardware that is strongly software enabled so it is easier to integrate
 - Collision avoidance is an obvious area for AI
 - Testing is vital with AI – especially when decision processes are a bit of a black box
 - Do a lot of model-based testing and move toward physical realism
 - Need a “bulletproof” core that is recoverable and then able to add upgrades/patches if needed
 - The industry is going to standardization and modularization to abstract from the hardware
 - Hire by being open to adopting technologies from other industries – this opens the talent pool
 - In the future tens of thousands of satellites will be performing properly without many people on the ground operating them

DD. TECH BRIEF: CISLUNAR, MARS, ASTEROIDS, AND DEEP SPACE

Ben Reed, CTO and co-founder - Quantum Space

- Cislunar, Mars, and Deep Space
- GEO – 36,000 km; Distance to moon is 10x; La Grange Point is 500,000 km
- Our mission is to advance the state of humanists by advancing the human journey to the stars
- Why Explore Space
 - Moon is a time capsule for the solar system as there is no erosions
 - Finding evidence of life in space drives our passion

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- National prestige drives space budgets
- Resource extraction is another reason to go to space
- Tourism – Denis Tito went to space as first tourism in 2001
- National security also drives as national security follows commerce
 - Bad actors may try to hide on the moon (“Lunar code of shame”)
- Artemis 1 has a 70% unsuccessful rate for CubeSats that were released
 - Much harder to do SmallSat on Lunar or deep space as infrastructure is not there
 - Collision avoidance maneuver was needed by the Indian program in 2021
 - No drag on orbital debris on the moon – it will star there forever
 - No one is tracking space debris
 - Communications relay is not in that region of space
- Companies are working on services to meet these needs
- Without the infrastructure, there are still 250 lunar missions planned!
 - Will be a lot more with the proper infrastructure in place

EE. LAUNCH SERVICE MISSION MANAGEMENT

MODERATOR: Gary Hatch, CTO New Media
Curt Blake, President and CEO - Spaceflight
Tom Choi, CEO and Founder - Saturn Satellite Networks
John Conafay, Co-Founder + CEO - Integrate Space
Kier Fortier, Managing Director of Exolaunch USA - Exolaunch
Raul Verdu, Co-Founder and COO - PLD Space

PANEL DISCUSSION

- Curt Blake, Spaceflight
 - Launch integration and OTV company – 50 missions and over 450 satellites
 - Did the first GEO cislunar rideshare
 - Mission management is the backbone of what makes the industry tick
 - We have three orbital transfer vehicles
 - Stepping down as CEO
 - Start customers with questionnaire about their needs and then try to find the most appropriate vehicle for them
 - Have a mission control about what information is needed
 - Both regulators and launch providers look to launch integration folks or the satellite customer as an auditor of what information is required and if

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various licenses are needed

- Every process is different depending on the launch vehicle – some need information eight months in advance, and others can be closer to two months
- A healthy launch market and diversity of options is healthy – not options are a bit thin – more demand than supply
- Industry needs more regulatory standardization, including a space traffic control system, something like air traffic control in aviation – will take international cooperation that brings everyone along
 - Talent is difficult, and salary expectations, until recently, have been difficult
- Tom Choi, Saturn Satellite Networks
 - Satellite developer – not making technology, but working with customers, investors, and technology to make low-cost bandwidth from GEO – called Space Broadband Networks – going GEO on one rocketed ~ \$500 million
 - Have 40% and will get an EXIM bank guarantee for the balance
 - Have shown end-user commitment for \$1 billion and have converted this into over \$300 million of contracts
 - ten years ago, the minimum GEO satellite was \$60 million minimum launch
 - Electric propulsion reduced the cost per satellite down to \$30 million (2 on a satellite)
 - Now under \$15 million if launched as a cluster
 - May offer a direct GEO ride to small satellites if we have room
 - For GEO mission will be working with Arianespace and MHI – they can go to direct to GSO
 - Also looking at others with “kickers” that can boost GSO and others that can reduce cost of getting to GEO
 - LEO is the flavor of the day – demand at LEO only 10% of what is at GEO
 - Always GEO demand because the terminals are cheap (under \$300) and use little power – need this for mass market
 - LEO projections growing from \$3-\$4 billion to \$30-\$50 billion in next ten years – not enough launch vehicles to meet this demand
 - Encourage people who are working on launch vehicles to continue

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development – having a reliable low-cost rocket, even 500 kg to low earth orbit, is sufficient

- New systems are able to get to GEO and beyond
- LEO market will explode [AM Comment: Is he changing his tune on LEO?]
 - Even cows will have IoT, new earth observation satellites, satellite to handset, etc.
- If the business plan is good enough, there is significant interest in investing in space
 - Regulatory is the largest challenge – LEO does not have enough spectrum to bring data down
 - If satellites increase by a factor of 10, what frequencies can they use to bring data to earth?
 - Optical frequency will be regulated – no regulator will allow you to have communications access outside the country without a license or regulating it.
 - Need to get more spectrum new LEO applications and get optical regulations defined
- John Conafay, Integrate Space
 - Building a software platform for mission management – the backbone of space
 - It's an unrecognized team that has to get a lot of information together to run the processes
 - Trying to digitize the process to make it better streamlined
 - Do integration and software for mission management – don't do mission management itself – but try to streamline the process
 - From Bus Dev to mission management, there are over 150 things that need to happen – we have software to manage this process
 - Launch is constrained now
 - It's challenging to fill a launch vehicle with lots of satellites, and operators don't want to operate at a loss
 - We need diversity in launch providers for constellations to thrive
 - As rideshare and multiple launches per year develop, the complexity increases exponentially – not linearly, and the mindset is totally different

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- Optimistic about the future, standardization, and cooperation between organizations and nations, and other stakeholders is a must – additional standardization can be done across the board
 - 60% of data is useful, and 40% is not value added – need to distill requirements we really care about

- Kier Fortier, Exolaunch
 - We provide turn-key launch service solutions as well as customizable solutions
 - Have had 18 launches for 265 customers over the last two years
 - It can be hard to get to the launch site – numerous challenges
 - Many constellation customers are in LEO. Others are looking at more exotic orbits
 - SpaceX rideshare program has been a game changer for the industry with a predictable schedule and good reliability
 - But also working with new launch vehicle companies, including Isar and maiden Ariane 6 and unannounced others
 - Exolaunch can provide a separation system, Exopod, for CubeSats and carbonics for microsats
 - Still optimistic about investment – companies need to hit targets, and part of that is getting to orbit (we are also developing a small tug to get to the last mile)

- Raul Verdu, PLD Space
 - Most promising European micro launch company in 2011 started – 550 kilos to SSO orbit and developing demonstrator
 - Manufacture everything in house
 - Raising \$60 million investment – targeting to close first binding contracts to launch a small satellite using Mira-5
 - Customers are happy to fly out of French Guyana – the most experienced base, and customers know it well
 - RFP mainly for SSO. Some niche markets use micro launches (e.g., 150 kg)
 - Can do small, dedicated missions – a small launch market is hard
 - Need to make long-term decisions, not to be 1st at something
 - Champaign is when you deliver a satellite in proper orbit
 - Make the rocket simple

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- We are a premium company that spends a lot on quality assurance
 - Need to understand well what the customer is looking for
- Launch providers need time to ramp up – its takes experience to get to 20 launches per year
 - Micro launcher is a niche market
 - We complement other launch provider to cover specific hot spots
- See an optimistic future – the aviation industry grew during the financial crisis, and we believe our industry will be found during current challenges

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