

Unofficial Notes:

Satellite 2017 Conference

March 6th – 9th, 2017
Washington, DC



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Executive Summary

Satellite 2017 made clear the industry is in the midst of massive change. Vertical integration, massively falling prices, reusable launch vehicles, digital satellite payloads, cheaper customer equipment, IoT, and 5G dominated discussions. While some of these had been discussed previously, it's clear they have now descended upon the industry. Recent new events are likely drove the increased attention on data security issues.

There should be no more question about whether satellite pricing was stabilizing. Discussions abounded about how to lower pricing was needed in consumer markets to grow demand. There was widespread acknowledgement that satellite bandwidth price is falling more generally. Almost as if to drive in the point, Hughes ended any doubts by unveiling its new Jupiter service that halved pricing per unit of capacity.

In satellite manufacturing cost per unit of throughput is falling – new benchmark metric for new systems is \$1 million per Gbps of throughput. Manufactures are scrambling meet increase customer expectations with software defined payloads, streamlined manufacturing processes etc. Debate about optimal HTS satellite life in the face of rapid evolution came to the forefront. Concerns that others in the value chain, including launch providers and ground equipment manufacturers, are not matching this level of cost/performance improvement.

Pressure to lower prices across the value chain may lead to increased vertical integration as the investments one area, particularly user terminals, disproportionately benefit service providers. Indeed, the two leaders in consumer broadband, ViaSat and Hughes are both vertically integrated. Other announcements including the Hughes/Thales InFlyt/SES joint venture in aviation and the Intelsat investment in Kymeta were additional examples of vertical integration. This is marked change from the Euroconsult conference this fall. At that time, the notion of investment in customer applications and hardware as being necessary to stimulate demand to fill HTS capacity was only barely breached. Now it has spilled into the open.

Speaking of Intelsat, no one seems to understand how OneWeb benefits from the Intelsat match except that it helps SoftBank that has significant direct and indirect control over OneWeb. Support on the regulatory front does not make sense. But the Intelsat/OneWeb merger was not an isolated deal. Telesat is also moving towards launching a LEO constellation and SES has already deployed its O3B system. In general, the synergies between GEO and LEO operators are not clear. Should FSS operators become more vertically integrated with their distribution partners, this could change. Perhaps it's only a matter of time?

Longtime Satellite conference co-chair and fixture in the industry, Scott Chase, announced his retirement after over three decades. We wish him a long, happy and healthy retirement.

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DAY ONE – Monday, March 6, 2017

Armand's takeaways from Day 1

- Lots of change in the industry at the same time
 - Satellite cost/performance, ground equipment etc.
- Global distribution remains a challenge
- 45% of ARPU for HTS satellite is in 1st four years, 10% in last four years
- Delays are expensive
- Value of extended life is marginal
- Quote of the day: "The LEO business plan is to invest \$5 billion, go bankrupt and then start over at \$25 million" Dave Hershberg, CEO of STS Global

A. Monday Opening Session: CTOs and Tech Leaders on Adapting Group Technology for the Future Space Segment

- Denis Curtin, Moderator
- Marco Brancati, Telespazio
- Stuart Daughtbridge, Kratos
- Wayne Haubner, iDirect
- Adrian Moris, Hughes

- Wayne Hubner
 - Risk calculation is different with short life and cheap launch
 - Want to be able to leverage cellular technology to leverage data through multiple portals
 - Need to be able to provision a VPN in minutes, not weeks or months

- Adrian Moris
 - VSAT performance driven by
 - Wave form X2X wave form.
 - Has broad and dynamic range – VSAT can adjust for weather and service changes
 - Wideband single string
 - 500 MHz+ string
 - High Performance
 - Need good processors need 200 MHz PCB
 - High level of integration
 - Want common set of building blocks
 - Want to be able to scale

- Marco Brancati
 - What is needed to improve depends on the service and the price points
 - Consumer vs. enterprise
 - How to connect to data revolution?

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- You don't start with the data, but the question you want data to answer
 - Drones can be content creators
 - Lots of things a car can do and lots of potential subscribers to manage
- Satellite industry needs greater voice in spectrum allocation over next several years
- Need to be able to fix so that satellite can work with 5G
- Aeronautical industry wants to switch between networks
 - Need for multiple hardware sets is problematic
 - But Aero market is small relative to cell phones, so it won't get much attention
- Don't want to stifle innovation by forcing interoperability
 - Technology moves quickly
- Some issues with frequency reuse – need to spread out gateways to be able to have the necessary capacity
 - Need to move feeder links to higher frequencies (V and Q-bands) to better utilize user segment spectrum
- Expect integration of service providers so customers can get more seamless coverage
- No silver bullet and look across whole network to optimize system
- How much security is enough – can always spend more
- Many HTS terminals are near cell towers and causing some interference issues that are hard to find (often to other users)

B. Finance Forum Opening Remarks

- Christopher Baugh, President, NSR
- Andrew Spinola, Equity Research, Wells Fargo
- Expects slight video decline in developed markets, but increase in developing markets
- Will take time for new applications to take off and offset declines in data revenue
 - Consumer broadband is growing
- Debt investors are comfortable with LT cash flows etc, took 2016 in stride
- Equity investors are much less comfortable and really spooked by 2016
 - More discussions about shorting than going long
- HTS brought more supply for same amount of capX
- Intelsat was biggest spender last year – ViaSat will be largest spender over next two years
- Industry has low barriers to entry - lots of new entrants
 - Anyone can access manufacturers technology
 - Lots of new entrants
 - [Armand's comment: this was an interesting point, especially given the new quasi government entrants]
- ROI
 - Has been falling – history of industry is not good
 - Too many players in the sector

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- Need to consolidate as airlines have done
- EchoStar is the only one in position to do acquisitions, but it's hard to figure out what they want to do
- Consumer Broadband
 - Over 5 million people have less than 3 million people
 - Aviation ARPU per plane is likely to be stable
- HTS
 - 45% of ARPU in 1st 4 years, 10% in last 4 years
 - Global distribution is a problem/challenge

C. Comparing the Financials: What Does the Data Say?

- Blaine Currico, NSR (Moderator)
- Justin Cadman, SVP – Investment Banking, Raymond James
- Bruno Fromont, SVP – Strategy and Asset Management, Intelsat
- Jean-Hubert Lenotte – Chief Strategy and Strategic Marketing Officer, Eutelsat
- Giles Thome – IT Hardware & Infrastructure, Equity Research, Jeffries Group

- Giles Thome
 - Constructive on video
- Justin Cadman
 - Big more to OTT
 - Cable is losing 1% a year
 - This pressure will more to satellite operators
 - Opportunity is in emerging markets
 - Opportunity for OTT via satellite

- Bruno Fromont
 - Video is becoming more interactive
 - Video will grow in emerging markets
 - May jump straight to wireless for video which could create opportunities for satellite
 - See growth in video
 - OTT growth is incremental to linear tv
 - Cost is too high to move all traffic from satellite to OTT (5x to 10x the cost)
 - Need to keep independent network (satellite) that is separate from telcom
 - Want to push services to that satellite can look like OTT [Armand's comment: does he mean via caching?]
 - Eutelsat grows in broadband a
 - Has JV with ViaSat (51%/49%) for infrastructure
 - Also, a ground segment JV with reverse

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- Justin Cadman
 - Satellite operators have traditionally been infrastructure providers
 - Look at other industries (towers etc)
 - Nothing inherently means lower margins
 - But now looking like service providers and this transition will depress margins

- Bruno
 - Wants to grow EBITDA margins in absolute terms
 - Necessary ecosystem does not always exist and may need to make some investment and go down the value chain
 - These ecosystem investments may create barriers to entry
 - If OneWeb merger does not happen, Intelsat would just move forward
 - Not sure if high value for old satellite (SES sale to GoGo) is a trend
 - Need service providers to focus on selling

- Giles
 - ROIC is more important than EBITDA
 - SES is looking at that metric
 - Intelsat deal depends on how strategic SoftBank sees the deal and wants to sweeten the deal

- Panel consensus
 - GEE satellite deal is not likely to become standard
 - Was a one-off deal

- Need to link HTS capacity to price elasticity for certain applications
 - HTS may allow industry to benefit from demand elasticity
 - Low cost ground terminals will make or break HTS model

- Historically reasons satellite had small market share are changing
 - Lower costs capacity
 - Better distribution
 - Cheaper ground equipment

- Bruno
 - Best places to spend additional CapX are where it makes a difference at the retail level

- Jean-Hubert
 - Best to spend CapX – keep cost of video low and cautiously on broadband where it makes sense
 - Ka-Sat is not a flexible satellite – can't move capacity
 - New satellites are much better

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- Giles
 - Not sure CapX will go down
 - Satellite can address mass market with data and this will create new capx opportunities
- Justin
 - 4 billion people without Internet – only need a small portion to be successful
 - Hughes and ViaSat have a lock on distribution

D. Emerging Space & Satellite: Where to Invest Next

- Carolyn Belle, Senior Analyst, NSR (Moderator)
- Chris Quilty – President, Quilty Analytics
- Ryan Lewis - VP & Deputy Director, In-Q-Tel CosmIQ Works
- John Seafinini – CEO, HawkEye 360, Allied Minds
- Mark Boggett – Managing Director, Seraphim Capital

- Chris Quilty
 - Finally, a lot of changes in the various parts of the industry that is causing significant change
 - Lower launch costs
 - HTS
 - Cheaper ground terminal etc.
 - The industry will look a lot different in 5 years

- Ryan Lewis
 - Lots of new things, like new launch services will be tested this year
 - Previous money raised, now ready to show product
 - New wave of startups are behind them
 - Ecosystem approach to looking at investment, particularly with imagery makes sense
 - Still a very nascent field
 - Need to avoid major implosion as it can sour investment appetite
 - Need to find a “soft landing” that sorts out the winners from the losers

- John Seafinini
 - Only build companies from scratch – no established companies
 - Long investment horizon 7-10 years
 - Hawkeye is an example
 - Bridgesat is another
 - Optimizes optical communication with LEOs

- Mark Boggett
 - Has a space fund for doing A rounds and also an Angel fund
 - Want to identify first movers in the satellite market

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- 1st investment is Spire for weather
 - Barrier to entry is being the 1st mover
 - Lack of successful exits has hampered early investment
- Ryan
 - Collects a unique set of data
 - This becomes a barrier to entry
 - Space hardware is not the same as software
 - Need to really understand the capital and time needed for the business case to validate itself
 - Many new firms are able to work with open source software to put things together faster – reduces risk
 - Looking to raise next round in smaller steps so they can show progress
- Mark
 - Remote sensing sector will need consolidation
 - Planet Labs almost crashed
 - [Armand's comment: hasn't it already consolidated? Or is there more to go?]
- Chris
 - There is a bubble on the investment side
 - Companies and activities will continue, but lots of people will lose money over the next 5 years
 - Public markets need to be more receptive to the sector if the industry is to move to the next step
 - Need public markets for exit from private investment
 - Some large private companies have active markets for their shares – did not exist 10 years ago
 - [Armand's comment: This makes sense, but public equity markets are not positive on the sector now – even with high current market levels]
- Role of government? Will they continue to be a key player
 - Mark – very important
 - John – US Gov't is a big help for sector – esp. in LEO under Trump
 - Ryan – remote sensing companies need a strong anchor tenant
 - Govt fills this role
 - Chris – Gov't is everyone's friend. Lots of budget cuts coming, but moves to privatize things may present opportunities
- Mark
 - See insurance applications as being significant
- Chris, John
 - See weather as a potential critical application

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E. Lunch Presentation – Will Porteous, General Partner & COO, RRE Ventures

- Lots of early stage investments in the satellite sector
 - Spire etc.
- Bringing venture mentality to satellite sector
 - Need to take risks – smart tradeoff's – not absolute focus on technical perfection
 - Hardware becomes a commodity
 - Open architecture and small groups can be tremendously effective
- Access to launch is hard to predict
 - Being secondary payload gives lots of uncertainty
- Most vendors are unreliable and need to do more in-house
- Need to be able to fix in space via software patches
- Predictions
 - 2017 will see small private companies generate significant revenues
 - Windows to funding new companies in some sectors are closed
 - Other such as synthetic aperture terminal will get funded
 - Launch companies are not truly disrupting
 - Pace of consolidation accelerating among remote sensing
 - Access to capital is a key differentiating factor
 - Longer-term financing will be done in bits – need to show some success
 - Open standards are coming to small satellites
 - Also, sharing ground stations assets
 - Ability to build small satellites fast (like Henry Ford) will be a strategic advantage
- Industry will rise and fall together – need to cooperate

F. Impact of Technology Changes on the Satellite Investment Case

- J. Armand Musey – President/Founder, Summit Ridge Group, LLC (Moderator)
- Rich Currier – SVP, Business Development, SSL
- Chris Kunstadter - SVP and Global Underwriting Manager, Space, XL Catlin
- Joshua Benegal Marks - EVP Aviation Connectivity, Global Eagle Entertainment
- Clay Mowry – Sales, Marketing and Customer Experience, Blue Origin

- Rich Currier
 - Doing lots of things to reduce cost/improve performance
 - Exploring in-orbit service
 - Satellites might be upgraded like you can upgrade the RAM in your computer
 - Looking at shorter life HTS satellites with faster cycle times
 - Customers are expecting faster build-cycle times
 - Video remains the single largest driver of satellite demand.
 - HTS is driving growth to meet the needs of ever increasing IP traffic.

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- Manufacturers are looking at standardization to reduce production time and lower costs.
 - Making satellites more flexible with digital payloads and other advanced technologies.
- Chris Kunstadter
 - Satellite insurance industry has lots of new technologies to evaluate
 - New types of launch vehicles
 - New manufacturing processes
 - Increased pressure for faster cycle times and many more
- We can do this and will bill according to risk
 - Insurance industry can accept new risks created by industry change, but will just need to price accordingly
- Evaluating insurance for launch delays
 - An area of concern as current launch vehicles are delayed, new launch vehicles are proposed, and large constellations are attempting to be deployed.
- Joshua Marks
 - We might be ready to invest in take or pay contracts as appropriate to help finance new satellite technology
 - Need to evaluate carefully
 - Want satellites that are cheap, built fast, and have all the latest technology
 - [Armand's comment: usually you only get two of the three: fast, cheap and good. But may this it's buyer's market?]
- Clay Mowry
 - Reusable launch vehicles will dramatically bring down price
 - Will be able to meet schedule for OneWeb of a launch every 21 days
 - Excited about in-orbit servicing

G. Small Sats: Will They Generate Large Returns?

- Carolyn Belle – Senior Analyst, NSR
- Chad Anderson - CEO, Space Angels Network
- Jason Andrews - CEO, Spaceflight Industries
- Chris Boshuizen - Entrepreneur in Residence, Data Collective
- Craig Clark - CEO, Clyde Space LTD

[Armand's comment: I missed part of the session]

- Chris Boschuzen
 - Big Opportunity around leveraging small sats
- Chad Anderson
- Jason Andrews
 - Launch delays are expensive

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- Need to get past the first few to build capacity
- Conclusions
 - Small sat will generate returns, but losses on the way
 - Markets outside of earth observation are speculation

H. Finance Forum - Pricing Roundtable

- Christopher Baugh – President, NSR (Moderator)
- Blaine Curcio – Senior Analyst, NSR (Moderator)
- Pierre-Jean Boylier - CEO Speedcast
- David Bruner – VP Global Communications Services, Panasonic Avionics Corporation
- Thomas Choi – CEO, Asia Broadcast Satellite
- Mark Rigolle – CEO, LeoSat Enterprises
- James Trevelyn – Head of Sales, Arquiva Satellite & Media

- Tom Choi
 - Pricing on Point-to-point connectivity, pricing has a lot further to fall
 - New technology will send it down
 - Market will absorb at low prices
 - Video neighborhoods will hold-up better
 - Old c-band at \$2,000/MHz, now 75-80% lower
 - Will see HTS pricing below \$200/MHz
 - Video contracts down – want to lock-in deals
 - US Gov't only signs 1-year deal but get 5 renewal
 - Those providing VSAT usually want to match contract lengths
 - Probably won't see another deal like SES
 - It is rare outside of N. America that someone would lease satellite with slot for low rate
 - May be hard to sell satellite capacity after 5G
 - May lose Ku and Ka-band spectrum for wireless industry
 - Will lower cost of delivering broadband to rural areas terrestrially
 - Selling lots of capacity to cellular operators doing backhaul, but they will be able to buildout those networks with more spectrum
 - Have not pushed into HTS area because it believes the video business will last longer
 - If you don't have broadband, you aren't going to get OTT
 - Lots of people with no TV or broadband
 - Satellite will be the only way to serve them
 - Market will be protected for decades
 - Can gain 1x-2x EBITDA turns in valuation, but keeping costs down
- James Trevelyn
 - Pricing will decline in video as well

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- Outside video, where orbital slot is not as important and there are new entrants pricing will aggressively fall to allow them to sell capacity
- Falling prices does drive some demand with backhaul
 - Normally M&Os in the UK don't like satellite, but might be tempted with lower prices
- Satellite video is fairly insulated from prices

- Pierre-Jean
 - Have 8500 MHz of capacity under contract
 - Prices are coming down
 - Now we are a larger customer and prices are falling
 - Price decline is not consistent across regions or frequencies
 - As prices will continuously decline, so no long-term capacity deals
 - Some resellers are going to making capital expenditures to lower price per bit – this is not a plan at Speedcast
 - FSS operator and service provider is a different business
 - Different DNA – need to buy and keep separate
 - Bandwidth often less than 1/2 of total customer price: labor, equipment etc.
 - Satellite service providers will likely continue to consolidate
 - Satellite Operators are also likely to consolidate

- David Bruner
 - Prices come down 4-5x fold but demand increases by as much so operators get the same amount of money
 - Can't keep up with demand for capacity
 - Hard to forecast needs and if come-up short, then need to get short term deal
 - Flat panel antennas are still not quite ready right now
 - Not ready for prime time – no clear winners now
 - Some markets are not growing because the antennas are not ready
 - Small marine
 - The antennas, when ready, will open the market
 - Might buy a satellite, but not certain
 - Likely to see many types of combinations in the marketplace

- Mark Rigolle
 - Lack of differentiation causes focus on price
 - If your service is unique, price is a different discussion
 - Same at 1990s to much over-building non-differentiated capacity
 - Can't solve overcapacity by doing down the value chain
 - Linear video minutes are still growing
 - No watershed moment for the bottom falling out from satellite video
 - Electronically steerable antennas will be upside to LeoSat's business plan
 - Needed for specific niche markets
 - Most customers are happy with sufficiency of parabolic antennas

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I. Closing General Session: Cultivating New Market Opportunities on the Ground

- Denis Curtin – Principle, Communication Satellite Consultants
- Dave Heshberg – CEO & Chairman of the Board, STS Global
- Ron Levin – VP, Global Accounts, Gilat Satellite Networks
- William Milroy – Chairman & CTO, Thinkom Solutions, Inc.
- Paul Sheridan – Vice President, Optus Satellite
- Bart Van Poucke – Vice President, Product Management, NewTech

- Dave Hershberg
 - Can only get complete security if you can get the traffic off the Internet
 - 20-30 organizations trying to keep networks safe
 - Critical infrastructure needs to be off Internet
 - Creates opportunity for satellite
 - LEO business plan is to invest \$5 billion, go bankrupt and then start over at \$25 million
 - LEOs take a lot of gateways
 - Lots of hardware to maintain
 - Hughes ground set-up costs \$200-\$250 with a \$60 antenna – LEO is likely to cost a lot more
 - Need to look a few years ahead to see what might be needed to be competitive

- Ron Levin
 - Working on techniques to mitigate effects of latency on user with 4G and 5G
 - Everyone agrees capacity prices will continue to drop
 - With enough users, you can use over subscription to get even more efficient
 - Gilat can achieve good results with 4G over satellite
 - Takes satellite from last alternative to become more mainstream
 - In rural broadband, GEO satellite is a simple solution
 - Facebook is deploying a satellite – based solution in Africa
 - Inter-satellite links also increased the sophistication of the modem
 - Latency is 600ms in GEO and 120ms in MEO
 - Industry has been dealing with it and is continuously evaluating how to mitigate it and improve user experience

- William Milroy
 - Using larger satellite antennas
 - Moving from 36 MHz to 125 MHz to 500 MHz
 - Antenna is first line of defense against interference
 - Regulatory focus is on the transmit side
 - Need to bring the highest efficiency on the forward link
 - NGSO coordination is not a reality

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- Especially challenging with polar orbits
- May have joint LEO/MEO/GEO antennas
 - It's amazing what economies of scale can do
 - OneWeb probably needs to be in the cell phone/wi-fi range as that is what it is competing against
- Paul Sheridan
 - Need government support to get communications in remote Australia
 - Have "check-in" spots in remote areas where drivers can stop and connect
 - NBN is national initiative for rural connectivity for last 3% of the populated areas
 - Two Ka-band satellites
 - Also, infills in more dense areas that have pockets without connection
 - Optus fly satellites for NBN, but is not involved in their business plans
 - Really need government support in rural areas – just not cost effective
- Bart Van Poucke
 - Connectivity on airplane is good, but price is not good
 - Finding ways to have small antennas that are efficient
 - Only use spreading when needed so as to not allocate a large amount of capacity
 - Land and maritime based systems can benefit from this as well
 - HTS needs to target multiple applications and verticals
 - 5G base stations may be cheaper than 4G, but the business case does not work
 - Even wi-fi hot spots don't work without external funding
 - It's a challenge for modem providers to deal with complexity and keep costs down without standards
 - Will be hard to get satellite ground ecosystem standardized like mobile phone as the market is
 - Not as large a market and complexity is getting larger

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DAY TWO – Tuesday, March 7, 2017

Armand's Takeaways from Day 2

- Massive debate about the viability of LEO constellations
- All the FSS operators, even the regional ones, are looking at LEO systems
- Apparently, they don't want to be left out
- Notion that coverage of rural areas may be paid for by company seeking advertising as opposed to via subscription
- **Quote of the day: "People need to spend more time on the earth (desert, jungle etc.) to know what's going on. Everything looks good from space." Tom Choi – CEO ABS**

A. Keynote – Interview with Jeff Bezos (Interviewed by Jeffrey Hill)

- Slow is smooth and smooth is fast
- Reusability needs to be defined
- Needs to be true operational reusability
 - Like an airplane – don't want to disassemble, test, reassemble, test etc.
 - Fuel for large launch vehicle is under \$1m
 - In addition to reusability, need practice to reduce cost
 - New Sheppard has been relaunched with less than \$10k of maintenance between launches
 - Likes vertical landing – inverted pendulum issue gets easier with larger vehicles
 - New Sheppard technology leads to orbital vehicle
 - Informs all orbital vehicle and processes
- Entertainment industry can be a driver of new technology
 - New Sheppard's tourism will drive new technology
- New Glenn (in two different sizes)
 - Heavy booster - even larger than Delta IV Heavy, but smaller than Saturn V
 - Can take 13 metric tons to GEO and 45 to GEO
 - Engine designed for 100 flight lifetime
 - Can land the booster in lots of weather conditions
 - Don't need to do an in-space deceleration burn
 - Exhaust Plume is blue as it uses liquefied natural gas
- Eutelsat is new customer – Eutelsat CEO Rudolph enters stage
 - Eutelsat see part of their role in industry as stimulating competition
 - Were approached a few months ago
- Goal is to dramatically lower launch costs
 - Will grow the industry and new equilibrium
 - More technology risks on satellites
 - Shorter satellite life cycles

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B. CEO Panel

- Mark Dankberg – CEO, ViaSat
- Dan Goldberg – CEO, Telesat
- Steve Spengler – CEO, Intelsat
- Rupert Pierce – CEO, Inmarsat
- Rudolphe Belmer – CEO, Eutelsat

- Mark Dankberg
 - Broadband is great opportunity
 - ViaSat has worked with every LEO system ever build
 - 95% of people live on 5% of earth
 - Need to focus on where the people and economic activity is
 - Lots of opportunities for services on planes and ships
 - Demand for bandwidth exists – people want more bandwidth for same price
 - People don't need to be convinced to use bandwidth on planes or in rural areas – just need to make it available
 - No shortage of demand for bandwidth
 - With cheap bandwidth, you can use smaller antennas on cars
 - Targeting 3" and "6 antennas on cars
 - Need to look at whole system to transform the industry
 - Can't happen by a stand alone manufacturer
 - Can't look any optimization with existing modularization
 - ViaSat-1 generates \$600m revenue a year
 - A month delay (\$50m) dwarfs cost savings by new launch vehicles

- Dan Goldberg
 - LEO - All comes down to bandwidth economics
 - Thinks LEO has gotten to the point where it has an edge
 - Prototypes will be launched later this year
 - Want to be in-orbit/in-service by 2021
 - Some in polar orbit, some in inclined orbit
 - Takes fewer satellites – a few hundred and then can modularly add capacity
 - Challenge is that satellite assets last so long and development cycle is so long that you need to anticipate technology change
 - Addressable market for LEO will get larger and larger
 - But GEO will be around for a long time
 - LEO customers are the same ones as today, but want more
 - Need user terminals to come way down in price
 - Agrees w/ Dankberg that whole ecosystem needs to work together
 - Agree there is not yet a lot of cord-cutting with video
 - But people leaving DTH are moving to platforms that are more two-way
 - Satellite needs to find way to support VOD
 - Can't get complacent about lack of cord cutting
 - Near-term industry challenge is that revenues are flat to down

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- Longer-term is technology change in that industry ecosystem is not coordinated
- Steve Spengler
 - Hopes to simplify satellite ground installation
 - Services will make differences
 - Need to reduce terminal costs to get to connected cars etc.
 - Need to have smaller antennas to get into cars and be built into production line
 - Both LEO and GEO capability for cars is important
 - Need to look at all sources of innovation and there are lots of them
 - Kymeta, Qualcomm etc
 - Think there should be open modular systems with standards that can be leveraged
 - Don't see geopolitical risk as slowing regulatory approval and hurting industry growth and returns – demand is too strong for regulators to ignore
- Rupert Pierce
 - Agrees there is demand for lots of bandwidth – much more than currently available
 - Connectivity is becoming an increasingly important ingredient for efficient enterprise management
 - Don't have to make the ROI argument as much now
 - Connectivity is becoming a “human right” like clean water [Armand's comment – I don't think people without clean water are worried about connectivity]
 - Edge of coverage and coverage holes are no longer acceptable
 - Challenge is not dealing with customers, but the consequences of our success [Armand's comment: That success does not seem to be reflected in Inmarsat's stock price over the past year.]
 - Can deliver to cars at 1/3 the price of 5G
 - Increasing cost of fixing software bugs on cars favors satellite
 - Looking at other areas for satellite – connected cities, agriculture etc.
 - Once you connect things, it needs to be maintained etc and more data is involved – opportunity for satellite
 - Broadcast delivery to the edge will become increasingly important
 - Important for industry to invest in one another, but doesn't believe it is modular – not “plug and play” yet
 - JV R&D with iDirect and Cobham
 - All components of telecom stack need to work together to move the ball forward
 - Our CapX is actually going up. No CapX holiday going forward for Inmarsat – that's because there are so many opportunities [Armand's comment: not sure investors will see this so positively.]
 - Reliable launch vehicles that are available is the biggest problem in the industry

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- Risk is that people want to use bandwidth more, but don't want to pay enough for industry to develop a good return
- Industry is complex for investors to understand
- Rudolph Belmer
 - Connectivity is becoming universal
 - O3B was meant to serve other three billion, but ended-up doing something totally different
 - Want satellite to be perceived as legitimate technology to complement telcos
 - Need to deliver quality performance at low cost with terminals that are adapted to mass market
 - There are not facts to support the notion that linear broadcast is going away
 - Linear video is still 5 hours per day per home
 - OTT have little impact on linear video [Armand's comment: I am not sure I believe this – at some point OTT people will likely “cut the cord” as they did with wireline telcos when wireless adoption reached critical mass]
 - Want to look at specific areas to decide where to invest in capx, some will go up and others will go down
 - Investment has not yet impacted top-level growth [Armand's comment: I did not understand this explanation]
 - Impact of new OTT players on video landscape is overstated. Average time in front of TV is growing globally, flat in Europe and slightly declining in the US

C. Impact of Spectrum Frontiers on Future Connectivity

- Kalpak Gude – President, Dynamic Spectrum Alliance (Moderator)
- Éric Fournier – Director, Spectrum Planning & International Affairs, Agence National des Fréquences (ANFR)
- Agostino Linhares – Manager of Spectrum, Orbit & Broadcasting, ANATEL
- Erin McGrath – Legal Advisor, Wireless Public Safety & International, FCC
- Dr. Veena Rawat – Senior Spectrum Advisor, Group Speciale Mobile Association (GSMA)
- Suzanne Malloy – VP, Regulatory Affairs, O3B Networks
- Veena Rawat
 - 5G revolution has started
 - Need spectrum in all frequency ranges
 - Industry dialog is necessary
 - What will systems look like?
 - What will spectrum sharing look like?
 - Harmonization is not dead – it is a prerequisite for economies of scale
 - It's hard because of incumbents in certain who would need to move
 - 700 MHz started in 2009 and still continues
 - Timing of priorities is important

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- Have meeting only once every four years
 - C-band started in 2007
 - Countries have sovereign right to implement when they want
 - Need to look at sharing in higher frequency bands where neither satellite and terrestrial systems know what their systems will look like
 - Need to develop realistic parameters
 - Even if only a few countries sign up to a footnote, it can begin the process for broader harmonization
- [Armand's comment: given advances in spectrum aggregation technology, has the value of harmonized spectrum declined somewhat?]
- Erin McGrath
 - Next generation systems will take different types of spectrum for different purposes
 - Need low, middle and high band
 - Finishing Broadcast Incentive Auction (low band)
 - Working on 3.5 GHz (mid band)
 - Working on millimeter wave etc. (high band)
 - Harmonization is also important for convenience of users who travel
 - Protecting incumbents requires lots of interference studies etc.
 - Studies were blocked for 28 GHz
 - How will sharing be permitted
- Suzanne Malloy
 - Satellite networks are going same direction as wireless networks including 5G
 - How will they fit together? What is satellite's role?
 - Want coverage needs with and integration into 5G infrastructure
 - Lots of innovation in satellites and spectrum sharing, but lots of investments have already been made in satellites
 - Hard to apply new sharing technologies on existing satellite fleet
 - Still relying on global harmonization to continue build-out
- Agosto Linhares
 - Satellite and wireless is important part of Brazil's economy
 - One of the largest and diverse countries in the world
 - Use C-band in the rain forests
 - Want to support economies of scale etc.
 - Respect countries autonomy to now follow ITU, but doesn't think it's good for the industry
 - ITU identification is a signal to industries that they will likely be implementing the technology
 - Need to have harmonization of both identification and allocation for IMT
 - Agree that some positions in ITU are trying to "over-protect" certain uses

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- 600 MHz is hard to share, especially around borders, due to long distances it travels (10s of kilometers)
- Éric Fournier
 - ITU has flexible framework
 - Respect their consensus, inc. 28 GHz
 - Making regulation to facilitate moving earth stations
 - Including GSO, NGSO etc.
 - What spectrum above 24 GHz could be harmonized?
 - Selected 26 GHz
 - Harmonization process has started
 - Need to promote sharing everywhere possible, but it is not a magic bullet
 - To implement sharing, you need coordination – hard with multiple organizations
 - 5G and satellite on 28 GHzs will be harder
 - Exhausted review of spectrum below 60 GHz for ITU
- [Armand's comment: I left panel early to go to the HNS presentation summarized below]

D. HNS Press/Analyst Event

- Mike Cook Presents
 - Demo of Jupiter-2
 - Showed 99.57 Mbps down and 16.6 Mbps up
 - Apparently went even faster in other demos
 - New terminals will all support 200 Mbps
 - New plans have about twice the data for the same money.
 - Implies a cut in \$/GB/Month of about 50%
 - Now \$2.50 to \$3.50 per GB/Month – much less than LTE
 - [Armand's comment: Impressive demo. But surprised HNS is dropping the price so quickly as opposed to maintaining prior pricing for a longer time. May imply intense industry price competition and/or a concern about the size of the market at current price levels]
 - With EchoStar XIX, EchoStar XVI and HNS payload on Eutelsat 65W it is called the “Jupiter System.” 400 Gbps total throughput
 - In Brazil offering entry plan at \$40/month compared to \$49.99 in the US
 - Suggest HTS pricing internationally will need to be somewhat lower than in the US
 - Launch of Telstar 19V with Hughes payload will expand S. American coverage
 - Now have technology to offer security (Link Level 256 AES), VPN and other features for the enterprise market
 - Expect to market it as cheaper than 4G for backup
 - May allow Jupiter to compete head-to-head with so-called “open architecture” FSS Systems such as Intelsat's EPIC.

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E. Service Provider Decision: Acquire, Sell or Partner for Growth

- Maury Mechanic, Independent consultant and Former Counsel, White and Case LLP
- Francis Rolland - Executive Vice President, Satellite & Network, Globecast UK
- Jorge Villarreal – CEO, Elara Comunicaciones
- Alan Young – COO, Crystal

[Armand's comment: Limited summary as I only saw a portion of this panel]

- Alan Young
 - Merging involves changes and departures in the leadership team
 - Very risky especially when done in the middle of change
 - Need to consider the culture
 - Changing accounting systems and the like can also be risky
 - Always room for entrepreneurial spirit
- Francis Rolland
 - It is difficult for an established company to move into new markets
 - It can be done, but it's hard
- Jorge Villarreal
 - Technology evolves and allows for specific niches that a small entrepreneur can enter

F. The Certified Teleport: Competing on Quality

- Roger Franklin – CEO, Crystal - Moderator
- Michael L. Smith – SVP, Enterprise Technologies, Kratos
- Alan Afrasiab – CEO, Talia International, Inc.
- José Sánchez Ruiz – Director of Service Operations, Eutelsat
 - Angus Blackwood – Managing Director, HawkCX
 - Roger Franklin
 - Move to certifying teleports
 - Move to having levels of quality you can specify when ordering services
 - Angus Blackwood
 - Runs consultancy to improve teleport quality
 - Is an auditor with WTA
 - Robust infrastructure needed
 - Backup electrical, AC, fire suppression etc
 - Some room for variance based on customer needs
 - Many teleports need improvement in operational approach
 - Need processes documented etc.
 - José Sánchez Ruiz

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- Whole process of certification
 - Bring in an auditor etc.
- Looking to certify 3rd party vendor teleports
- ISO is applicable to any company
 - Fix your own quality level and check to make sure you can meet it
- WTA sets a specific quality level for a teleport
 - Redundancy, infrastructure, organization etc.
- Some say aspects are confidential – too confidential for WTA
- WTA board trying to bring certification to public's attention
 - Started certification a year ago

- Alan Afrasiab
 - A lot like ISO certification
 - Includes follow-up checking
 - Don't need to tell details of operations as much as what the procedures are

- Michael Smith
 - How is the problem fixed?
 - What is the ongoing monitoring approach?
 - What is the monthly review to update the monitoring approach?
 - Should be a trusted advisor who can show stuff under NDA to check processes

- [Armand's comment: finally - a rational industry move to create customer friendly differentiated service in a response to competitive pressures – bravo!]

G. IoT & the Uber-Connected Society

- Paul Febvre – CTO, Satellite Catapult (Moderator)
- Mike Mulica – CEO, Actility
- Jassem Nasser – Chief Strategy Officer, Thuraya Telecommunications Co.
- Greg Curtis, Vodaphone IoT
- Dave Goldstein, Honeywell Aerospace
- Fabien Jordan, Astrocast

- Jassem Nasser
 - IoT is small part of Thuraya, but one they are looking to grow
 - IoT technologies are not very specific
 - 70% low bandwidth applications
 - 5% high bandwidth
 - 50 billion devices connected by 2020
 - Also, has a deal with Inmarsat
 - Many customers want to keep connectivity full-time

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- Mike Mulica
 - Sells software to service providers so they can put IoT connection on front-end
 - Helps with a platform to have a customer-facing portal so they can get IoT solutions
 - Desperate need for innovation in developing countries
 - Smart cities, tankers etc.
 - LoRaWAN
 - Can put sensors on things and monitor data using batteries that last as long as a decade
 - Uses Inmarsat as a partner
 - Costs are now lower and this is opening the market
 - SCADA is standardizing the market
 - Unlicensed spectrum is the way to go
 - LTE is too expensive
 - This (IOT) is more like the Internet than the telecom sector
 - Can develop anywhere and implement worldwide
 - Automating the whole stack from developer to buyer's selections process must happen
 - If there are a lot of professional services in the mix, it will be too expensive
 - 70% of IoT is low data rate with long-life batteries
 - Want to keep the cost of the battery low, so use best
 - Lower prices will drive IoT, but we are not there yet
 - Developing countries will be first as they need it to exist
 - It's not like a mobile network, but it's a private network
 - More like Wi-Fi
 - Spread spectrum will allow more base stations to increase performance
- Greg Curtis
 - Licensed spectrum is important to guarantee quality of service
 - Some mission critical things should not go over the Internet
 - Only Small percentage of [customer] sites can't get cellular connectivity
 - Satellite is a pain in the neck to implement and integrate
 - Brought Inmarsat as a roaming partner on their SIMs
 - Have large technical salesforce and leader in IoT
 - Demand for UAV to do things like update "no fly" zones
- David Goldstein
 - Strong dividing line between what the cockpit can do and the applications for the passenger
 - Need to be very careful with open source etc with cockpit communication
 - Need isolation for critical components
 - Cars has economies of scale that airplanes can't touch
 - Millions vs thousands
 - Economies of scale will help with UAVs

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- It's all about bandwidth to move as much data as possible
- Fabien Jordan
 - It's all about economies of scale and standardization
 - Companies are looking for more than just automation, but also abilities to do new things
- [Armand's comment: Seems IoT has a way to go before it is a meaningful user of satellite bandwidth. The sector continues to say that low cost will drive deployment, but IoT does not seem to be deployed even in areas where potential returns are potentially high at today's prices]

H. Closing General Session

- Khalid Balkeyhour, Arabsat
- Eric Beranger, OneWeb
- Thomas Choi, Asia Broadcast Satellite
- Carlos Espinos Gomez, Hispasat
- Pradman Kaul, Hughes Network Services
- Masood M. Sharif Mahmood, Yahsat

- Thomas Choi
 - Did a \$400m recapitalization to repay ExIm Bank
 - Lead by Goldman and HSBC
 - Looking at new ABS-8
 - Old ABS-8 would have not been efficient
 - Need to get to \$1 million per gigabit
 - New satellite will be better than that
 - LEOs don't make sense
 - 1/3 of time in Arctic and Antarctic regions
 - 70% of the rest of the time it is over the ocean
 - Only lasts 5 years
 - Net, it is 30x more expensive
 - Mobility is an important market (planes and ships)
 - But this requires global coverage so better for global operators
 - Connecting people in rural areas is also important
 - Hard to serve as they are poor and have little access to electricity
 - This segment will be open for a long time
 - Connected cars lots of competition, such as 5G
 - 5G towers will be connected by ka-band (28 GHz)
 - May make Ka-band satellite obsolete [Armand's comment: seems a bit extreme given the limited areas 28 GHz is usable terrestrially]
 - Don't want to repeat mistake of Iridium, Globalstar, ICO by ignoring what the terrestrial wireless industry wants
 - May not be any demand in urban or suburban areas

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- In consumer market, you need to know where you are focused as mobile sector will go into Ka-band
 - People need to spend more time on the earth (desert, jungle etc.) to know what's going on. Everything looks good from space. [Armand's comment: hilarious]
 - Need to temper excitement and see where you can focus and be competitive
- Five years from now 5G smartphone will be 100 Mbps
 - [OneWeb] Can only have four units in a beam
 - No matter how well you market that, you can't be competitive
- Carlos Gomes
 - Looking for cheaper satellites and user equipment
 - Considering various options for the future
 - [Armand's comment: sounds like they might be for sale, but I have no information to support that]
 - We need to change what we have been doing is past years
 - Must be more efficient
 - Need to focus where this are not other terrestrial option
- Eric Beranger
 - 4 billion people have little or no access to the Internet
 - Goal is to bridge the digital divide
 - We have good partners
 - Intelsat gives [OneWeb] access to salesforce and regulatory people
 - Only a 1st step
 - We are in a different time than 20 years ago
 - Smartphones, etc
 - OneWeb will be core element of worldwide connectivity
 - When we unleash capability of everyone, human creativity will create things we can't imagine today
 - It's important to think about applications, but need to an enabler
 - People should be able to forget they are using a satellite
 - Need to make it simple to use satellites
 - In process of deploying 5G and in discussions with mobile operators
 - Opportunities in suburban areas for cellular backhaul
 - Can be more economical
 - First OneWeb launch in 2018 (10 pilot satellites) then production satellite
 - Will introduce services step by step
 - First have good coverage at poles and the can reduce latitude where service can be offered
 - Have demand in some of those high latitude areas
 - Not served by many people
 - Can't relax customer experience – needs to be as good or better than cellular service

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- Pradman Kaul
 - Have 400 Gbps in the Americas now
 - More than anyone else
 - 1m subscribers - \$60-70/month average ARPU
 - Launched Brazil 6 months ago
 - 40k subs and growth is accelerating
 - Can repeat US economics in Brazil and then others as it makes sense
 - Likely the rest of South America and Mexico
 - Maybe India eventually
 - Invested in OneWeb
 - Have agreement to use OneWeb capacity in other areas
 - \$3B on balance sheet to invest in other things
 - Don't expect to compete in 5G, but to find holes and serve those people
 - This will be enough for a good business

- Khalid Balkeyhour
 - Covers all of Africa and Europe with Hellisat
 - Have other satellites on order
 - Looking at LEO as investment and/or partnership
 - LEO's have a future and will take some market share
 - Don't want to miss the boat
 - Will make a strategic decision by yearend
 - Arabsat has worked on getting closer to the customer
 - No disagreement for need of data
 - People are hungry for data
 - But different kinds of ways to meet that need
 - Need to be careful with what we invest in
 - New dynamic – richest in the world are companies that want to connect other 4 billion (Facebook etc) and don't need a return via ARPU
 - This changes the dynamic [Armand's comment: Interesting, but sounds a bit like the initial internet bubble logic around 2000. Then revenue didn't matter, just "clicks" and everyone assumed revenue would somehow emerge from some undefined place – but it didn't]

- Masood M Sharif Mahmood
 - Focus on IP-based traffic
 - IP-based traffic is rapidly growing
 - Focused on GEO for now, but not excluding LEO possibility
 - Have 2 satellites
 - Third satellite will provide coverage of 95% of Africa and Brazil
 - Go into niche markets and make sure they can establish marketing etc.
 - Need to have flexible technology to serve customers
 - Can't make a gut call on LEO
 - Need to look hard at the data

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- Need to look at how to make a return
- Don't want to be like telcos that treat themselves like an infrastructure play
 - Need to perfect the art of managing the customer
- It's not GEO or LEO, but distribution and the value-added services so they are on the minds of customers

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DAY THREE - Wednesday March 9th, 2017

Armand's Takeaway from Day Three

- Aviation revenue to satellite operators may not increase at nearly the rate of bandwidth usage
- Massive price competition is on the way
- HTS satellite systems (LEO and GEO) are becoming more gateway intensive
- Optimizing gateways and adding them incrementally can reduce capx
- Increase industry emphasis of cyber security
- **Quote of the day: "You can't get great at something you do only 12x a year. You can great if you do it 50-100x a year." Rob Meyerson - President Blue Origin, on the value of increase launch rates.**

A. Opening General Session: Satellite Manufacturers Panel

- Carolyn Belle – Senior Analyst, Northern Sky Research
 - Nicholas Chamussy – Executive Vice President, Space Systems, Airbus Defense and Space
 - Frank Cubbertson – President, Space Systems Group, Orbital ATK, Inc.
 - Paul Etsey – Executive Vice President, Engineering, Manufacturing, and Test Operations, SSL
 - Martin Van Schaik – Senior Vice President, Thales Alenia Space
 - Mark Spiwak – President, Boeing Systems International, Inc.
- [Armand's comment: Due to a client meeting, I unfortunately missed this session.]

B. Cyber-Security and Interference Forum Welcome & Introduction

- Pat Rareman – Director, Space & National ISR, Semper Fortis Solutions
 - Dawn Murphy - SVP Global Regulatory, Inmarsat
 - Andrew Tomaszewski – Chief Information Officer, iDirect
 - David Henning – Director, Security Operations Team, HNS
 - Craig Miller – CTO, Gov't Services, ViaSat
 - Chris Hill – co-founder and CTO, ITC Global
- Pat Rareman
 - No static "steady state" defenses
 - Need continuous review, creating challenges for service providers
 - Dawn Murphy
 - Collaborate with customers on security
 - More integration needs create more vulnerabilities
 - More work to do to maintain network resiliency
 - Work closely with partner to create tools etc as well as training
 - Some hardware was not initially designed with the sophistication needed to support robust security processes

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- Andrew Tomaszewski
 - Industry is now getting on the same page on security issues across the value chain
 - Everyone is targeted by nation state actors
 - Also, need info from law enforcement agencies
 - Use outside testers for data and networks

- David Henning
 - Offers satellite sector customer lots of security services/support
 - Don't see anything in security sectors that should be help back
 - Security is based on gov't standards
 - No reason not to be shared

- Craig Miller
 - Holistic approach to enable rapid response
 - Customers include Air Force One to consumers
 - Leads to wide range of potential threats
 - ViaSat is a highly integrated company
 - Can make trades across and see threat across the network
 - Can be more agile in terms of response
 - Built-in coordination between elements of the network
 - Threat response must operationalized into company
 - Can't allow customers to simply protect themselves
 - Attacks can also degrade network performance

- Chris Hill
 - Skillset needed has evolved to include IP
 - Why is important traffic on the internet?
 - Should be kept private
 - In-depth topology
 - Need to assume each layer will be compromised at some time
 - Including client equipment
 - Need to get notification of potential compromises
 - Need to trust data in pipe to eliminate viruses etc.
 - Don't want to be sending IP addresses to remote sites via satellite
 - Don't want modems on public networks with default passwords
 - Turla Malware
 - Turns hardware on itself
 - Good reason to not make IP addresses public
 - Can't just rely on client's firewall

- Discussion
 - Can't allow customers to simply protect themselves
 - Attacks can also degrade network performance

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C. In-Flight Connectivity Focus: Service Providers and Airlines – Who Picks-up the Tab?

- Sima Fishman – Managing Director, Euroconsult (Moderator)
- David Bruner, Panasonic Avionics
- Don Buchman, ViaSat
- William-Huolt Marchand, Thales InFlyt Experience

[Armand's comment/caution: Some panelist comments may be misattributed. From my position, it was often hard to identify which panelist made which comment. They are included because, in my judgment, they were useful contributions to industry discussion, regardless of who made them]

- Sima Fishman
 - Aviation is a large growth market for aviation by planes
 - N. America - 7% CAGR by connected aircraft
 - Asia Pacific – 33% CAGO by connected aircraft
 - In terms of capacity
 - Growth is even higher
 - Similarly, with air to ground systems
 - Areas in aviation
 - Passenger/Cabin Crew
 - Cockpit Cres
 - Aircraft Data
- David Bruner, Panasonic
 - Has been in aviation communication since the start
 - Most growth now is passenger revenues
 - Hard to take advantage of aircraft management data until it is fleet-wide
 - Hard to capture
 - Need to justify training everyone etc.
 - Need for it to be ubiquitous
 - Expect to have 86% of word covered with HTS by yearend
 - 95% covered by satellite
 - Offer ability for airlines to decide what level of service to provide
 - Antennas and other ground equipment has not fallen as fast as bandwidth
 - Lots of RF capability
 - Cost of retrofitting varies dramatically across the world
 - Pricing vary
 - South Pacific is very capacity constrained
 - N. America has low prices
 - Need to drop price 20%/year
 - Consumers don't want to pay more

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- Also, offer GSM phone service on planes on own phone and complementary broadcast television on planes – offer 9 channels globally (fastest growing)
 - Expect more broadcast channels in N. America from Panasonic
 - 16 Channels including some HD
- Agrees that space segment is area for improvement but better modems etc. are worth looking at
 - Network design is a place to differentiate
- No real impact from management change at Panasonic
 - Strategy remains in place
- Don Buchman, ViaSat
 - Started with Ku-band aviation
 - Now getting consumer viasat-1 experience in aviation market
 - Expectations in airplane should not be different than in the home
 - ViaSat keeps increase size of satellites to reduce price with each generation
 - Internet is a proxy for entertainment
 - Need to get more and more useful bandwidth out of the same investment
 - What is purpose of Wi-Fi on plane?
 - See a shift in that it is part of brand
 - Starting seeing free Wi-Fi
 - Biggest bang for the buck is lowering the cost of satellite bandwidth
 - Other things like more efficient modems and antennas aren't as significant
 - Not just offering Wi-Fi
 - Looking to how it is scaled?
 - How can demand be handled?
 - Need to match 4G on trains and offer similar experience on planes
 - Think that the ViaSat-3 is the approach for the rest of the world
 - Need to deliver the most capacity at the lowest price
- William-Huot Marchand, Thales InFlyt
 - Passenger demand continues to grow
 - Announced new partnership with SES and Hughes
 - Includes EchoStar 17 and 19 and SES 17
 - We are still in the early states of aircraft connectivity
 - In the Americas, the streaming market is strong
 - As much as a Tbps
 - 30-40 Mbps is not enough
 - See increase of 40-45% annual increase in demand per passenger
 - Need to do it at a low cost
 - Volume goes up as price comes down
 - Some competition is immature and won't stand the test of time

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- Jet Blue has free service including streaming
 - Need to offer an experience that is scalable
- Price of connectivity is high and airlines are looking at it on a holistic basis to include cockpit data
 - Want to be able to charge customers and have good information for the pilot
- People now watch less TV than before and are connected more [Armand's comment: makes sense to me, but others in satellite industry disagree about decline in television viewing]
- Many aircraft are equipped with connectivity but are not competitive with what will be available over the next 12 months
- US market is more mature in usage than the rest of the world
 - Reason for US offering
 - US experience will form strategy for future in other areas
- [Armand's comment: surprise to see all discussion focused on bandwidth cost and no discussion of installation costs. Offline discussion with a panelist suggested that all-in installation costs may total \$500k/plane or a few thousand USD per seat. Aggressiveness of HNS's new pricing and alignment with Thales Inflight suggests competition in aviation market has not peaked]

D. Satellite Executive of the Year Lunch

- Ariannespace CEO Stéphane Israël
- [Armand's comment: Curious choice. Mr. Israël is obviously a talented executive whose genuine accomplishments are quite laudable. But it's hard to see Ariannespace as having the most notable achievements in the launch industry over the past year, let alone the whole satellite sector.]

E. Do New Constellations Have to Cost Billions (Next-Gen Connectivity with a Better Business Model)

- Mark Brady – Partner, Clark Belt 2.0
- Yoel Gat – CEO, Satixfy
- David Lewis – Managing Partner, Clark Belt 2.0
- Neil MacKay – Managing Director, Mile Marker 1.0
- Robert Schmidt – CEO, Great American Broadband LLC
- Talbot Jaeger – Chief Technologist, Novaworks

- Robert Schmitt
 - Clark Belt 2.0 can get price to per MB down to a penny
- Neil MacKay
 - Antennas don't have economies of scale
 - Flat panels don't go to horizon

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- Need to be rotated and/or tilted
 - Elliptical orbital allows flat panels to work
 - Also, get more power and bandwidth due to being closer to the earth
- David Lewis
 - 98% of people live on 13% of the globe
 - 95% of people live on under 5% of the world
- How can you close a business case when it costs \$5B, covers 95% of the world where there are no people?
 - Need to be able to add capacity – can't with GEO
- Clark Belt 2.0 can add capacity
 - Can drive order of magnitude improvements
 - Can triple number of orbital slots
- HiSat
 - Can use building blocks to add capacity
 - Mass produced items
 - Reduces capacity but order of magnitude
 - System is on space station
- Yoel Gat
 - Benefits of integration by reducing cost/bit
 - Beam hopping over satellite
 - Drive traffic to user
 - On-board processing
 - Software-defined radio
 - Electronically steerable/beam forming antenna
 - Multiple beams from a single array
 - Building satellite to take advantage of these , one can dramatically increase capacity of satellite
 - More capacity
 - Drive capacity more efficiently

[Armand's comment: Likely a sponsored panel to promote a highly elliptical orbit approach to satellite broadband. I don't think this approach gets as much attention as it should from mainstream satellite industry participants]

F. Very High-Throughput Satellites (VHTS): Myth or Reality

- [Armand's comment: This was a very informative presentation]
- Bernard Jacque, Advances Space Telecommunication Solutions, Thales Alenia Space
 - Key market trends
 - Total demand is increasing from GB to TB
 - In the context of global traffic, this is not a lot
 - Total is a zettabyte
 - Demand can increase a lot
 - Also, need to consider data rates available to users

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- Demand is, in many cases, for mobility
 - Must handle both mobile and fixed
 - Potential move from linear TV to streaming
- Challenges
 - Need to provide data in wider areas
 - Cut CapX/Gbps and OpEx
 - Ground CapX is starting to rival satellite CapX
 - May need 100s of gateways
 - Working on progressive deployment to scale CapX as system is deployed
 - Need to learn from 1st generation of HTS
 - Lots of capacity but lack of flexibility
 - Implement Cyber-Secured end-to-end solutions
 - Can have 1000s of attacks a month
 - Need Cyber security with connected cars
 - About two folds of additional capacity each generation
 - Add capacity for Aeronautical service
 - Can be enabled by
 - Technology breakthroughs including full digitalization
 - Digital allows flexibility
 - Design as end-to-end system – including ground solution
 - Versatile architecture to allow diverse network designed
 - Need to have an attractive customer offer in a fiber world
 - Adaptive products & solutions to face business uncertainties
 - Currently the industry has
 - More powerful processing and sampling technologies for satellites
 - Photonics and optics will be available in a few years
 - Will soon have a 1 Tbps processor that can be fully flexible
 - Usage of Q/V Band can reduce the number of gateways to 1/3
 - But very sensitive to atmospheric interference
 - Need to be able to reconfigure with diversity (to move to other gateways)
 - Fast switching solutions
 - Satellites are getting larger and larger
 - Don't want to outsize the launchers
 - Like beam hopping
 - In past, each beam is allocated part of spectrum
 - Can't use all spectrum in a give beam
 - Beam hopping allows use of all spectrum in same beam with time division separation
 - Can put capacity at right location at the right time
 - Change duration of beams in certain areas

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- Larger and higher capacity satellites
- Dynamic resource management
 - Need to take full benefit of new solutions
- Greater Network Resilience
 - Need to re-route traffic if gateway is out
- Interference management with in-flight spectrum dynamic allocation
- Scalable ground infrastructure & progressive deployment
 - So you don't need all gateways at day 0
 - Can defer until system need increase and time delay means lower costs
- Adaptive architecture and all types and mix of services
 - Operational diversity to manage uncertainty
- Effective dynamic management due to software intense products
- Conclusion: VHTS is a reality
 - Will have some interesting offering by 2020

G. Commercial Launch Service Executive General Session: Leading the Charge

- Patrick Boyle - Senior Consultant, Sage Communications (Moderator)
- Stéphane Israël – Chairman and COO, Arianespace
- Rob Meyerson – President, Blue Origin
- Dr. Ko Osagawara – VP and Director, Integrated Defense & Space Systems, Mitsubishi Heavy Industries, Ltd
- Kirk Pysher – President, International Launch Services
- Gwynne Shotwell – President and COO, SpaceX
- Steve Skladanek – President, Lockheed Martin Commercial Launch Services
- Where will the industry be in five years?
 - Stéphane Israël
 - Two additional launchers
 - More cost competitiveness
 - Constellations and connectivity will be important for the whole business
 - Rob Meyerson
 - Will have new launchers in business
 - LEO and GEO – including Blue Moon to return to the Moon
 - Operational reuse to lower costs
 - Delivering engines to ULA as well
 - Ko Osagawara (hard to understand – heavy accent and bad acoustics)
 - New launch vehicle
 - Kurt Pysher
 - Launch market customer needs will be very diverse
 - GEO, MEO and LEO
 - Introduced Proton launch variants, 5-meter faring
 - Will be available next year
 - Will help with heavy HTS satellites and LEO aggregators

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- Glynn Shotwell
 - Exciting time in industry
 - Full Falcon 9 manifest
 - New heavy coming on line
 - Some follow-on technology
 - Including a vehicle to take 100 people to Mars
 - Moonshot announced – lots of people have expressed interest
 - 2022 is aggressive for trip to Mars, but expect lots of progress
- Steve Skladnek
 - Government launches stable
 - Civil satellites (weather satellites etc)
 - Atlas does most of them
 - Commercial
 - Large GEO is not a growth market
 - Struggling with their own economic models
 - Will continue unrelenting pursuit of reliability
 - Won't do anything to back away from that esp for govt customers
 - Making progress on the price side
 - Streamlining production
 - 3D printing
 - Shortening testing cycles
 - New Rocket – Vulcan
 - Starts with a clean sheet of paper to address customer issues
- How do you get more out of production to cut prices?
 - Kirk
 - We manage things better and make variants of rockets
 - Eliminate things that are unnecessary for non-defense customers
 - Reduce insurance by self-insurance
 - Gwenn
 - Lower cost via reusability
 - Requires the right inspection techniques etc
 - Reusability should help with reliability as you can inspect vehicle and see stress zones etc.
 - Stephan
 - Want to reduce cost by 40% vs Ariane 5 [Armand's comment: that's significant esp. w/o reusability]
 - Work with government
 - Increase cadence as Ariane 6 will be used for wider range
 - Will have commonalities with another vehicle
 - Use technologies to improve design processes etc.
 - Europe has decided to develop a new engine that is 10x cheaper than

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- current engine
 - Arianne 6 is the start of the process of continuous improvement
 - Reusability depends on the market
 - Rob
 - Great to be able to get a rocket back and inspect
 - Want to have inspections automated eventually
 - Practice is also important
 - Can't get great at something you do only 12x a year
 - Can get great if you do it 50-100x a year
 - Ko
 - Unclear is H3 may eventually be reusable
 - Cooperation with Mitsubishi automotive parts to help production
 - Steve
 - Reusability of what?
 - Makes sense to reuse the most expensive parts of the launcher – 1st stage engine
 - Rest of a dump tank – no need to recover
 - Maybe 2nd stage can stay in orbit and be refueled
 - Essentially a “space tug”
 - Could revolutionize launching
 - Who are you worried about that aren't here?
 - Gwenn
 - Need to be aware of competition
 - Chinese are extraordinary launch providers – launch more than anyone than them
 - Stephane
 - Indian Space Program has two launch vehicles
 - Will have great access to space and may enter commercial market (assume for 3rd party launches)
 - About 50 firms who want to launch small sats. Is this where you want to be?
 - Rob
 - New Glenn is the smallest we will do
 - Kirk
 - Developing some new launch vehicles
 - Developing processes for aggregation and 2ndary payloads
 - Gwenn
 - Entered in the small satellite market
 - Time might be better now
 - Serving now as an aggregator and as 2ndary payloads
 - Need to be aware of new launch entrants
 - Stephane
 - Aggregation is the cheapest way to launch small sats
 - Some of the new entrants will probably survive

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- Where does the technology stand with the dispensers? What is the maximum number you can launch?
 - Gwenn
 - Have flown a cubesat, Iridium, Orbcomm etc.
 - Not sure if technology on dispenser is a driver
 - Need to be responsible
 - Steve
 - Have looked at dispensers that can handle 100+ satellites
 - Not sure how to prevent them from crashing into themselves
 - Will continue to look at new things
- What is the long-term business case for new large vehicles?
 - Gwenn
 - Market for larger vehicles will evolve will emerge as we push further into the solar system and beyond
 - Need a big ship to go to Mars
- Which of your competitors do you admire most?
 - Kirk
 - I admire the group achievements we all need too support each other
 - Gwen
 - Soyuz is the most successful vehicle
 - Lots of respect for the Chinese
 - Ko
 - Atlas, it is hard to launch and they do it well
 - Rob
 - Admire ULA as you can't argue with their record
 - Stephane
 - Admire everyone
 - There are different ways of being successful
 - Success and reliability will always be important factors
 - Lots happening in Silicon Valley
- Time delays cost \$50M/month (Dankberg), what is the ability to compress turnaround time and other misc. questions:
 - Gwenn
 - I see a lot of launches in the future
 - No more than 2 months between launches (very soon)
 - Want to be able to re-fly in 24 hours
 - We'll get to the point of eliminating delays
 - Will have stand-by back-up in less than five years
 - Industry used to be more cooperative with providing back-up
 - We will catch-up by yearend
 - Trying to launch every two weeks

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- Expect to have 6 reuses this years
 - Won't say how much it costs for moon trip
 - Rob
 - Need to meet customer demand for a launch on time
 - 1st launch in 2020 – want to be sure we can deliver
 - Still determining how to bring New Glenn online
 - Won't be like New Sheppard
 - No update on working with NASA on Moon service
 - Kirk
 - Having incident/failure that requires an investigation makes some delays inevitable
 - Need to be responsible with manifesting to make sure there is not overbooking
 - Need to work together to provide back-up opportunities
 - Angora 5 needs a new launch site for commercial use
 - Won't be available until 2025
 - Given current market, Proton will go well past 2025
 - Angora 5 will support federal programs
 - Next launch end of April/early May
 - Proton manifest is 7 launches
 - Proton quality test has a problem with a piece of sodder
 - Steve
 - We are on time – average of 1 ½ weeks delay
 - Will keep flying Atlas for a while until Vulcan is proven
 - Probably a 5 –year overlap
 - Struggling to find customers for Athena
 - Not actively marketing it, but can restart if customer emerges
 - Stephan
 - Need to let customer know if you have a delay and work to find creative solutions
 - Need to be transparent and cooperative with the customer, but this is not easy
- What do you worry most about?
 - Steve
 - Heritage workforce is leaving
 - Not sure we are doing enough to transfer the knowledge
 - Gwen
 - Launches are stressful and keep me awake
 - Kirk
 - Keeping commitment to customers
 - Ko
 - Pressure to launch rapidly after a delay/failure
 - Rob

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- Advanced manufacturing processes coming on line over the last few years
- Lots of changes happening quickly
- Stephane
 - Reliability must be maintained
 - Need to deliver Ariane 6 on time
 - How will connectivity change the market?

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Day 4: Thursday March 9th, 2017 (1/2 Day)

Armand's Takeaway from Day 4

- Expect more industry consolidation
- Ground equipment is becoming a more important element to industry success
- Quote of the day: In 5-10 years, we can reduce [satellite] production times to 6 months in you go all solid state." Vern Smith, Vice President of Communication Satellites and New Ventures, Lockheed Martin Space Systems.

A. Opening Keynote: A Global Sensing Revolution

- Robbie Schingler – Co-founder and Chief Strategy Officer, Planet
 - Satellites are about sensors – we take in signals to live on the planet
 - Trends changing space architecture
 - Lots of proliferation of space sensors
 - Due to improvements in sensors and access to space so they are no economically viable
 - Want to make global change visible and actionable
 - Collect 50 million sq kilometers of earth's surface every day (about 1/3)
 - Stitch it together so see monthly changes
 - Agriculture is largest customer – have been doing precision agriculture for 25 years
 - Sensors on combines etc.
 - Many countries have never had remote sensing capability for industry
 - [Armand's comment: he went through lots examples of images that change over time to monitory construction type projects – many of them military related]
 - Building a platform to allow value added services
 - Lots of this analysis is done by computers to allow near real-time information
 - Can more toward anticipatory analytics
 - Predict an avalanche etc.
 - Coral reef changes
 - Ice flow in rivers
 - Can see mine impacting a forest, displaced people
 - Need to get form factors down to have 100 satellite constellations
 - Does a line scan of the earth
 - Provides full image of the earth every day
 - Uses special sun synchronous polar orbit
 - Have sent two demo satellites from ISS
 - Now need to redesign telescope
 - Pulled in-house
 - Can build 20 satellites in a week
 - Long-lead items is telescope (4 months)
 - Other items are about a month
 - One week to build

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- Now on build 13
 - Lots more data and wider view
- Deployed 88 satellites in 700 seconds by Indian launch
- Moving to better than daily update for the full plant
- Definitive agreement to joint with Terrabella
 - Some regulatory issues, but it is on track

B. Visions of the Future Satellite Industry: Business Beyond Satellite 2017

- Scot Chase – Co-chairman, Satellite 2017 (Co-Moderator)
- Mark Holmes – Editorial Director, Aerospace, *Via Satellite* (Co-moderator)
- Thomas Choi – CEO, Asia Broadcast Satellite (ABS)
- Kalpak Gude – President, Dynamic Spectrum Alliance
- David Harrower – Vice President of Business Development, iDirect
- Dr. Jean-Yves Le Gall – President, Centre National d’Etudes Spatiales (CNES)
- Vern Smith – Vice President of Communication Satellites and New Ventures, Lockheed Martin Space Systems
- Andre - RSCC

- Jean-Yves
 - Looking at reusability
 - Now lots of launch vehicle project that say they will be reusable
 - Lots of technical changes over the past few years
 - If reusability works, it will be a game changer
 - Things are moving faster and faster
 - Launch vehicles used to take 10-years minimum
 - Now Blue Origin says 3 years – impossible to say previously
 - How much work needs to be done between reuse will have consequences on business model

- What trends are you seeing that impacts the future? [Asked to Tom Choi]
 - Traditional FSS operators are opening to NGSO systems
 - Intelsat, SES, Telesat etc.
 - Regional operators are open as well
 - Seems like a herd mentality to larger and larger HTS satellites without understanding how the capacity will be sold or where the customers will come from
 - Need to think about the #1 thing – the customer
 - Can’t understand why networks are being designed the way they are
 - If I want to serve people, I would put capacity where people are
 - With OneWeb, 90% of capacity won’t be usable – what problem is that trying to solve?
 - Want to keep cost low and efficiency high to provide return to customer
 - In 1990s people also rushed into constellations and they failed as people ignored what was happening on the ground

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- Private equity investors made money on Intelsat, but they are so debt laden they can't innovate
 - SoftBank investment is good, but should not have been necessary
- Demand for large satellites? [Asked to Vern Smith]
 - People are looking at larger and larger satellites
 - Hard to sell all the capacity unless you are vertically integrated like ViaSat and HNS
 - People are also looking at smaller satellites that match demand better
 - Solid state design etc.
 - Next big change is in the production line
 - Need to productize across multiple platforms
 - See an acceleration and amplification
 - In 10 years, satellites will be nearly fully solid state that are faster to build, cheaper and more flexible
 - In 5 years, can reduce production times to 6 months if you go all solid state!
- How does ground segment respond to demand for higher demand at lower costs? Are they keeping-up? Will get to price-points for cars etc? [Asked to David]
 - Ground infrastructure is getting more expensive part of the network
 - Need to move to telco model of high volume
 - Maybe GSM architecture and other standards
 - Flat panels etc.
 - Softbank is more interested in GSM compatibility
 - See convergence in wave forms – need to have that standardization
 - Starting to see demand for interoperability
 - Sitting down with manufacturers to try to have an integrated solution
 - Largest project is to keep-up with demand
 - Cruise ships looking for 500 Mbps vs 10 Mbps 10 years ago
 - Requests for 1 Gbps duplex modems
 - Need to have new architectures for this to work
 - The manufacturers will need to get to consumer price antennas
 - Need to be reliable, scalable, available etc.
 - Need to get to \$100 range
 - Won't work otherwise – can't get to new markets otherwise
- What's the role of space agencies in the 21st century? [Asked to Jean-Yves]
 - Agencies need to consider both space systems and ground segment
 - With old LEOs huge effort was made to launch the system
 - But was not customer friendly – that's the problem
 - Support development of commercial sector
- Where is the spectrum debate going [Asked to Kalpak]
 - Demands of spectrum are growing, but not equally everywhere

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- Hard to reconcile different regions with different demands
 - Makes things difficult at WRC
- Satellite industry really needs harmonization based on its use method
 - Where can satellite industry get new spectrum?
 - No new spectrum in years
- Need to address in a dynamic method and use opportunistic
 - Allows underutilized spectrum to be unlocked
- Much of satellite industry is locked in “old school” mentality of defending spectrum
 - Need to take new approach to dynamic sharing
 - Best way for satellite to keep and expand spectrum is to embrace dynamic usage
 - Old school approach favors incumbent’s rights
- Satellite industry needs to make peace and align with terrestrial ecosystem
 - 5G really is IOT – see European paper
 - Satellite is important for IoT
 - Starting to see an opening of minds in satellite industry
- Terrestrial wireless industry is also starting to open-up to spectrum sharing
 - Historically build around exclusive access – but this is harder to come by
 - Sharing is much more important
 - GSMA is starting to think about sharing as well
- What markets have dynamic growth? [Asked to Andre]
 - Lots of areas where telecom networks don’t work
 - Trends
 - Lots of consolidation
 - Hughes/Gilat joint antennas
 - Former massive rivals
 - Globalstar and Inmarsat
 - Are days of GEO ending?
 - GEOs are trying to play in NGSO
 - Wall Street shows great interest in NGSO every 15 years
 - Some improvement and changes this time around
 - Manufacturers are building much quicker for LEOs
 - RSCC strategy is GEO + highly elliptical orbit w/ apogee over N. Hemisphere
 - Want to provide service above 80 deg latitude in artic regions
 - Need better elevation angle for mobility customers
 - At least one LEO is likely to be built, but the question is whether it can be profitable
 - Need ground system development to accelerate
 - Need under \$100 for flat panel antennas
 - Cost of bringing ka-band antenna to Russia is 100% charge for taxed etc.
 - Hard to build locally

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- Need to be able to ship a highly precise production line to low-income areas
- Outside growing DTH markets and mobility, what is new business opportunity for ABS [Asked to Tom Choi]
 - 4 billion people without TV or broadband
 - Also, have limited money and electricity
 - How are we going to solve this issue?
 - Terminal costs need to be very low
 - Flat panel antennas won't go to \$20-\$30
 - Can get a high-gain ka-band antenna for \$60 in Taiwan
 - Need to get the modem down so there is a \$100 kit
 - Add wi-fi and can be used in poor area and share with 10 neighbors and it might make sense
 - Need smaller satellite to bring lots of capacity to people who need it on a targeted basis in areas where we know culture, distribution etc. and can execute
 - Virtuous cycle to increase connectivity, income etc and then their demand increases
 - Looking at SubSaharan Africa and SE Asia
 - Lots of people with growing GDP and little infrastructure
 - Examples: Indonesia, Papua New Guinea, DRC
 - Look for customers, not for some penguin in Antarctica to buy service
 - Kalpak
 - 5G is more about connecting things and satellite can provide a role
 - Requires capacity where there may not be people
 - Demand from people who aren't connected
 - Mostly from mobile devices not desktop
 - Terrestrial wireless industry has failed in those rural areas do to costs
 - LEO can be useful for IOT in areas where GEO is harder
 - Andre
 - IOT devices is now, in many cases under \$10 using ORBCOMM and Inmarsat
 - Not sure why we need a new system for this
 - In-orbit debris status [Jean-Yves]
 - Everyone who launches today is aware of orbital debris
 - Fewer explosive devices to separate stages
 - Enough power to de-orbit
 - Now working on LEO end of life issues
 - Need to be sure the new large constellations won't turn into debris

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- Tom Choi
 - A \$400k satellite won't have the quality of a \$400M satellite
 - Governments that allow them to be launched, they better take responsibility
 - Can get a series of collisions that could end LEO access
 - It is a threat to humanity! [Armand's comment: Seems rather dramatic!]
 - Need to be sure they are built carefully
 - Can't see how that can be done at the prices they plan
 - Any short to mid-term killer app that global ubiquitous coverage would unleash
 - The amount of capacity you can deliver might go so high and the cost so low you can offer a free broadband service and make money on advertising
 - Want to be able to offer a free but profitable broadband service
- David
 - Need to have a silicon-based solution for ground equipment and integration into GSM device – only way to get price down
 - Power is a major challenge, even solar
- Kalpak
 - IoT is the killer app
 - Airlines engine companies sell thrust as opposed to engines and monitor it all the way along
 - Can take this model down the industrial complex but it requires lots of connectivity
- Vern
 - Operators are getting squeezed by service providers
 - Terminal manufacturers are also getting squeezed
 - Question is how to you share value along the value chain
 - This is driving some of the consolidation
 - Need to align on a regional and global basis
- Kalpak
 - Government's and regulators believe there is a spectrum shortage and looking for solutions
 - Advances in sharing technology and willingness to share go hand in hand – chicken and egg
- Jean-Yves – final comments
 - Satellites are key to global connection
 - Satellites are important for monitor climate change
 - Important for human survival
 - Important factors for industry growth

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- Most of industry has been built on public-private partnership
 - Innovation and entrepreneurship is growing
 - International cooperation is also needed

C. A Cost-Effective, Permanent Solution to LEO Debris

- Marshall Kaplan – Principal, Launchspace Technologies Corp
 - Can get to “Gridlock” in LEO where you can’t use LEO any more
 - Kessler Syndrome
 - Possibly as early as 5 years, but unclear
 - 25K things larger than 10cm
 - Can’t track smaller than that
 - About 100 billion pieces total
 - So far only one satellite-satellite collision (Iridium-Cosmos satellite)
 - Rest are debris
 - See debris on space station
 - Don’t need to take out the large debris – can avoid it
 - Most debris removal tries to remove large items, one at a time
 - Even if we stop launching now, it is not enough
 - No serious proposals until now to remove small debris
 - Thousands of small satellite launches proposed
 - Debris field is unfortunately in same zone as satellites
 - Lots of debris at high inclinations 60-75 deg to 105 deg and 600 to 800 km altitude
 - Altitude is only distinguisher
 - Can have collisions on different planes even if altitude is the same
 - Sun synchronous orbit is very popular
 - Below 600km is “self-cleaning” – presumably from burning and re-entry
 - **Solution**
 - Constellation of collection device in path of debris
 - Maneuverable to avoid satellites and large debris
 - Can be serviced
 - Target “high-density” debris zones
 - Can provide as a service to constellation owners
 - Charge a monthly or annual fee
 - Have a patent for the collection device
 - May have the government agency launch it
 - May raise money and do it commercially and get a launch license
 - Collectors will be a few hundred square meters each
 - Would hope to refurbish and service
 - [Armand’s comment: This would need to be carefully done as it could cause a lot of damage if it fails and starts to trap operational satellites]

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