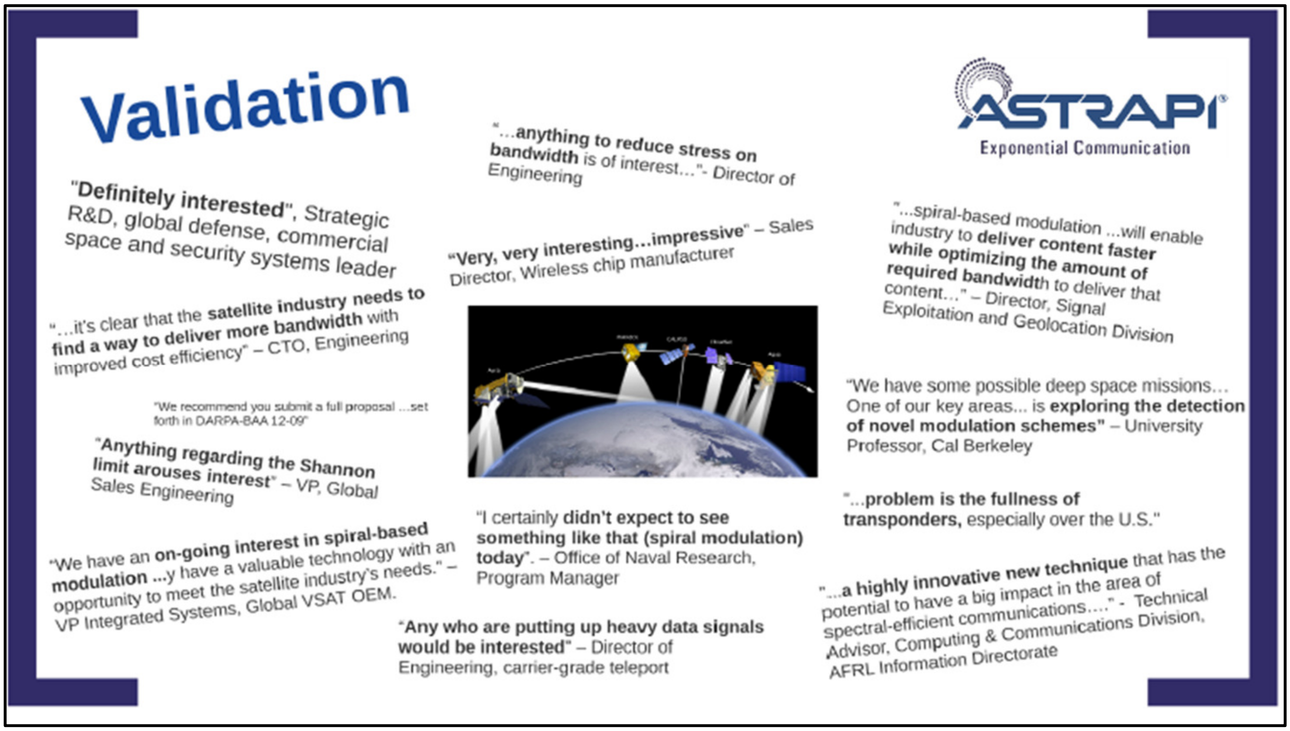
ASTRAPI®

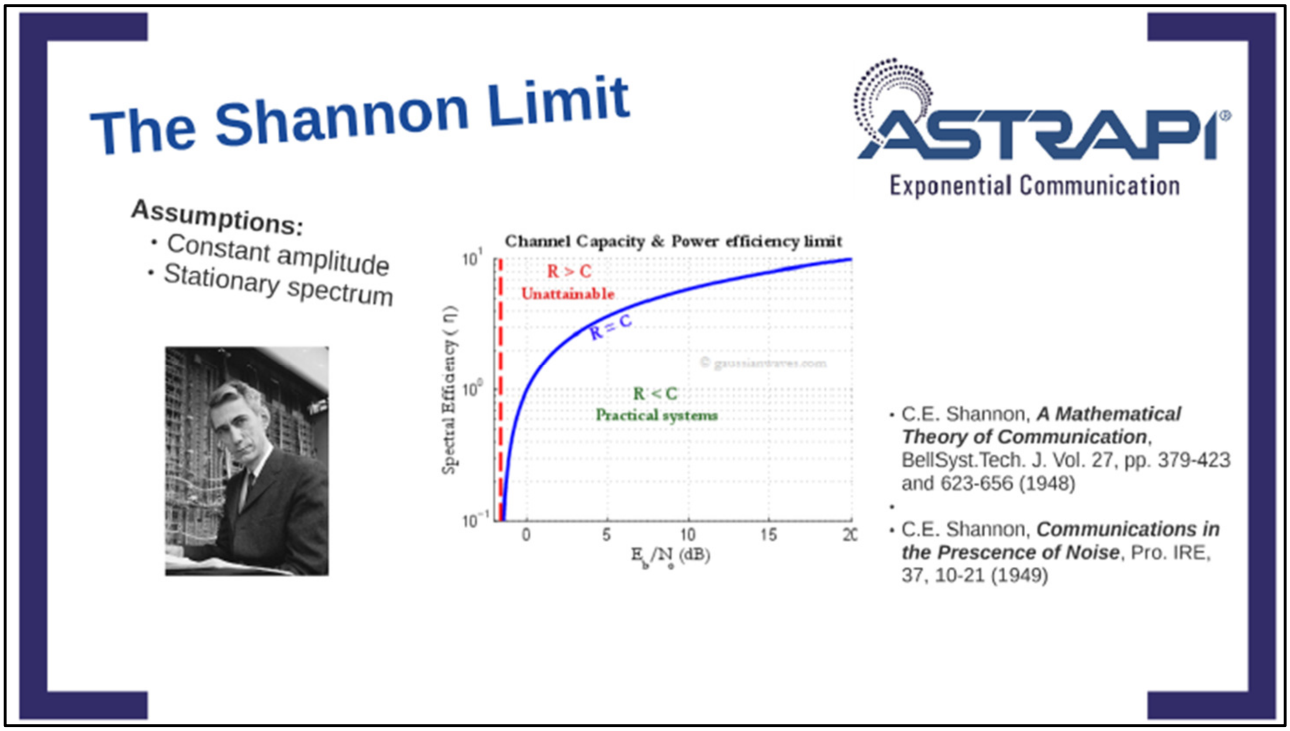
Exponential Communication

Astrapi (ΑΣΤΡΑΠΗ) translates to "lightning" in Greek.

Astrapi defines and controls an entirely new field – spiral modulation. Spiral modulation addresses an acute problem - the spectrum crisis. The spectrum crisis impacts four massive market opportunities for Astrapi – satellite, both near-earth and deep space, terrestrial wireless, including 5G+, defense and IoT.



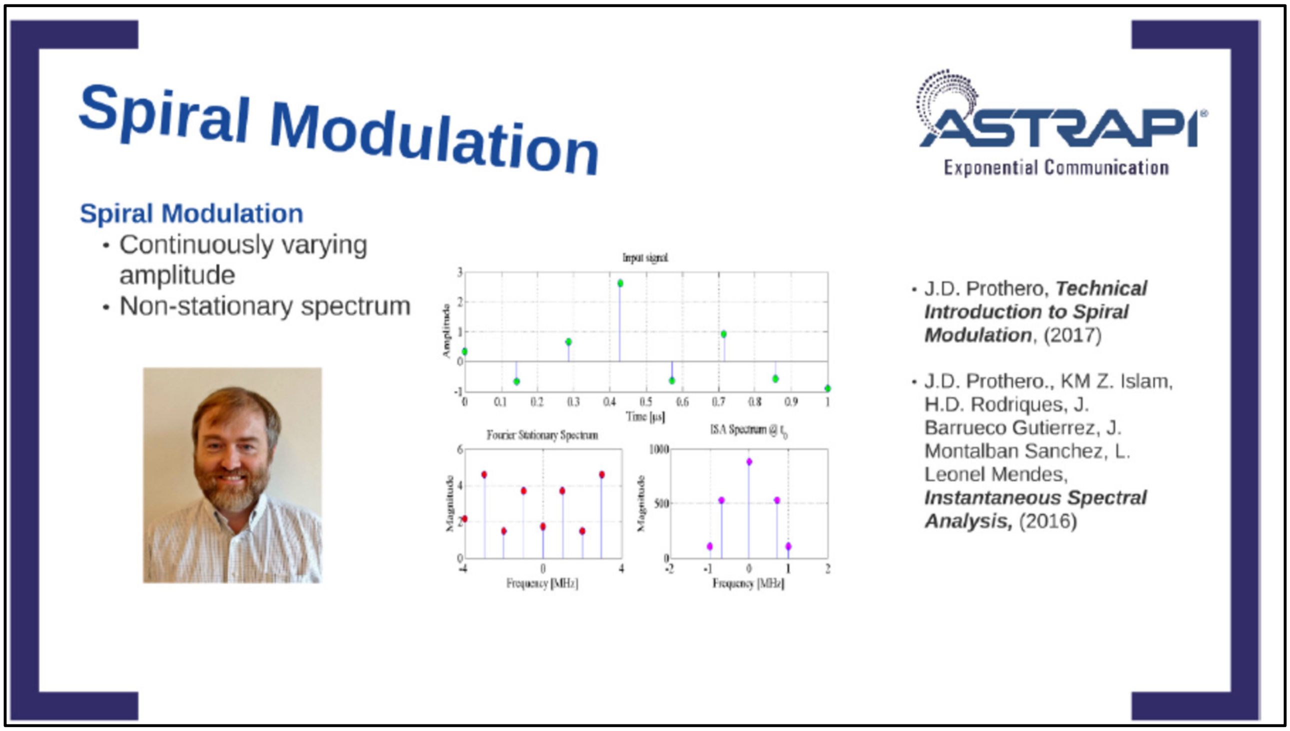
We all know that the amount of spectrum is finite and that the demand for it is not. That's why network operators spent over $44 billion at the AWS auction which was 2.5X more than what analysts predicted. That's why they spent over $15 billion at the recent 600 MHz auction. And that is why Astrapi was organized – to alleviate network congestion licensing our spiral modulation. Existing signals are constructed using sine waves with constant amplitude. Astrapi, for the first time, uses spiral modulation with continuously-varying amplitude, continuously-varying amplitude. That's never been done before. There is no prior art here.



Let's do a quick refresh. In the late 1940's, Dr. Claude Shannon, the father of information theory, published "A Mathematical Theory of Communications" and "Communications in the Presence of Noise" the seminal papers that established the capacity of communication channels.

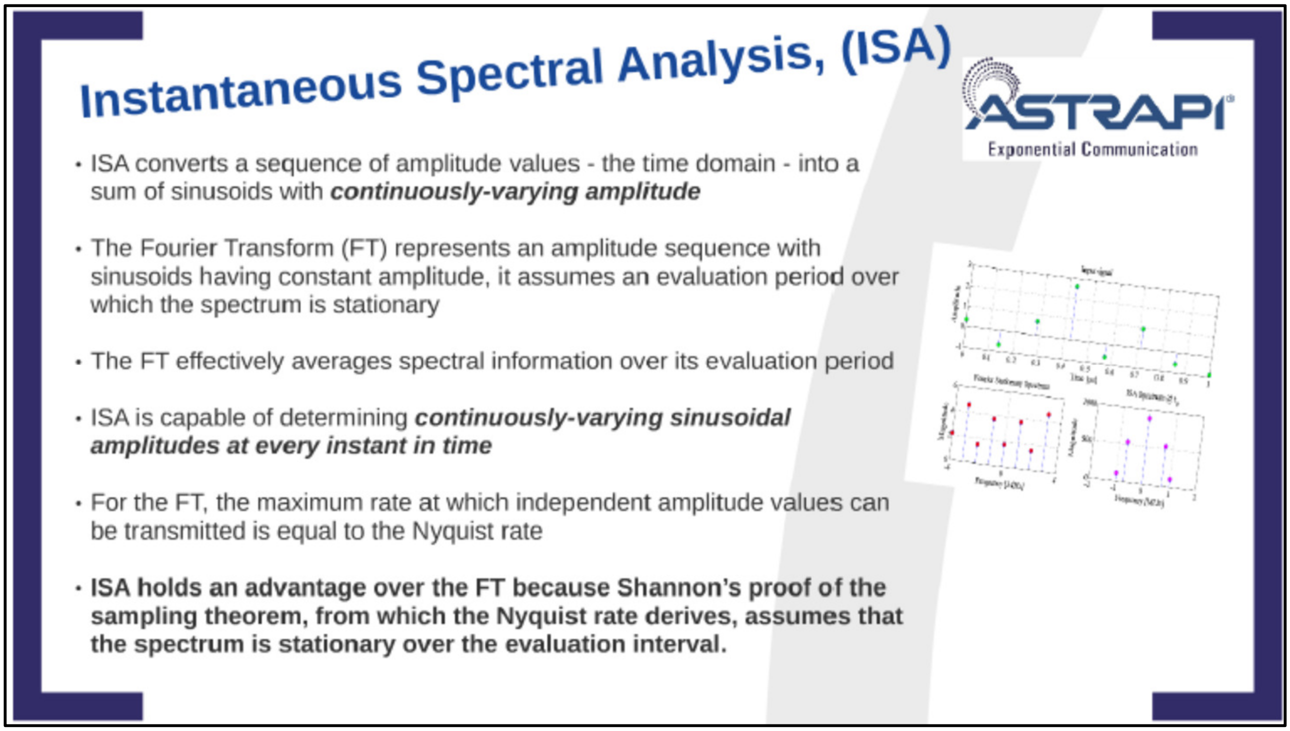
Dr. Shannon's proof uses a Fourier transform, which constructs a signal from sinusoids with constant amplitude over symbol time. The implicit assumption is that the spectrum is stationary.

The mathematical model uses complex circles based upon Euler's formula using Fourier analysis. There is a sharp upper bound on spectral efficiency that we've reached. The upper bound is dependent upon the Nyquist rate which is dependent upon the Shannon-Hartley limit. All based upon the assumption that spectrum is stationary and that constant amplitude is used.



Dr. Jerrold Prothero is the Co-founder and CEO of Astrapi. Dr. Prothero invented spiral modulation while exploring Euler's formula, the foundational math of the entirety of communications. Jerrold was not looking to solve the bandwidth crisis. He was not trying to solve a communications problem. He was exploring the elegance of the math which led to the invention of spiral modulation and the related tools.

Unlike Shannon's assumption of stationary spectrum with constant amplitude, Astrapi enables us to exceed channel capacity, beyond Shannon's law, by introducing spiral modulation using continuously variable amplitude with non-stationary spectrum.

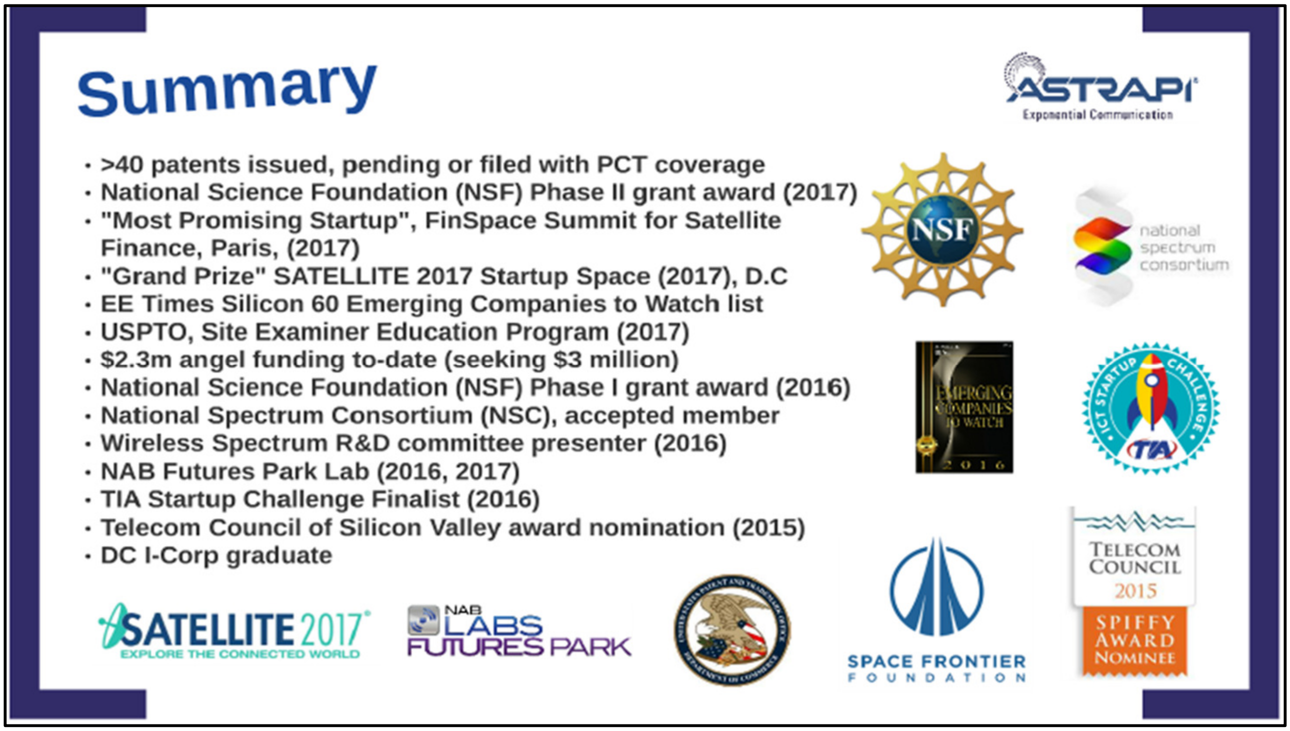


Instantaneous Spectral Analysis (ISA) converts a sequence of amplitude values - the time domain - into a sum of sinusoids with continuously-varying amplitude. This is in contrast to the Fourier Transform, which converts the time domain into a sum of sinusoids with constant amplitude.

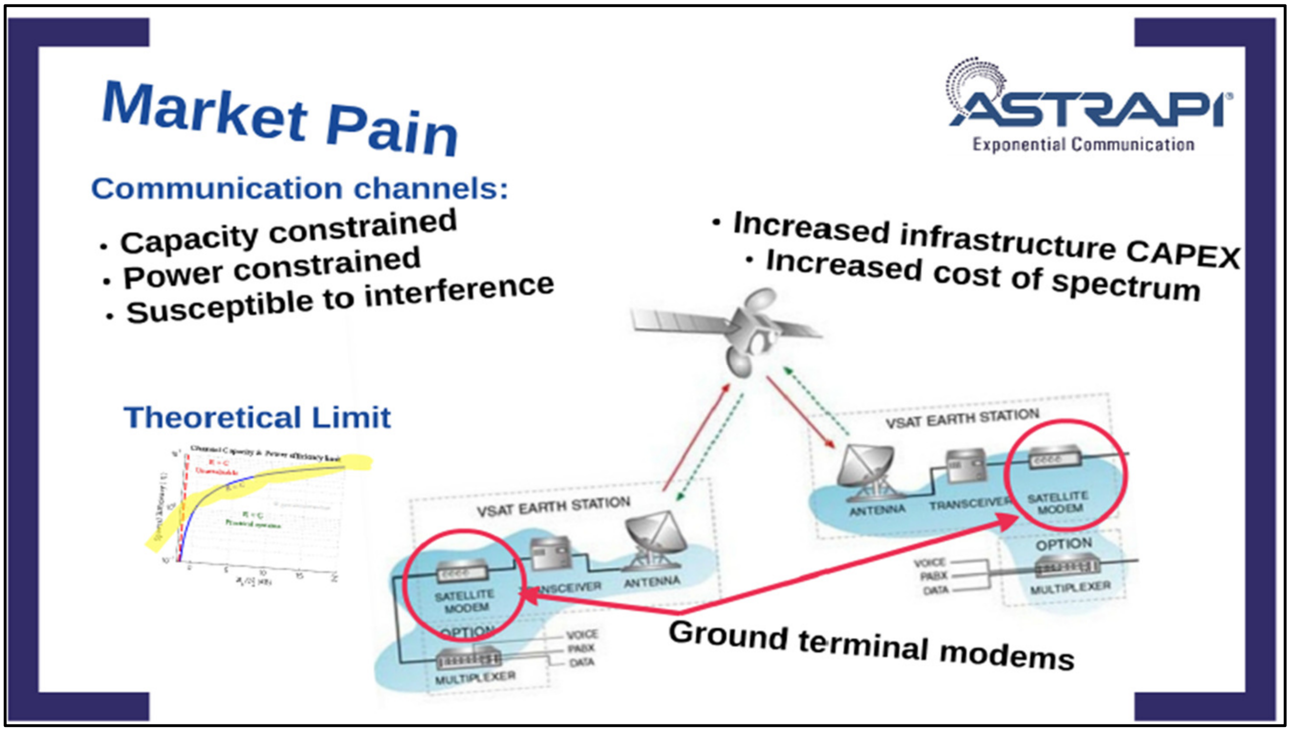
Since the FT represents an amplitude sequence with a basis set of sinusoids having constant amplitude, it assumes an evaluation period over which the spectrum is stationary; that is, over which the power assigned to particular frequencies is constant.

The FT effectively averages spectral information over its evaluation period to produce constant sinusoidal amplitudes. ISA is capable of determining continuously-varying sinusoidal amplitudes at every instant in time.

For the FT, the maximum rate at which independent amplitude values can be transmitted is equal to the Nyquist rate. For ISA, there is no inherent upper bound in terms of on the rate at which independent amplitude values can be transmitted. ISA holds this advantage over the FT because Shannon's proof of the sampling theorem, from which the Nyquist rate derives, assumes that the spectrum is stationary over the evaluation interval.



We now have over forty patents issued and pending among ten patent families. We are covered in over a dozen countries. We've closed over $2.3 million in funding and were awarded two National Science Foundation grants totaling over $923,000. The EE Times recently named us to their Silicon 60 list of emerging companies to watch. We won the inaugural Grand Prize at the Startup Space Pitch at SATELLITE 2017 this past March. In September we were named one of five "Most Promising Startup" at FinSpace, the Summit for Satellite Finance in Paris. And we're a member of the National Spectrum Consortium. They have a billion two-fifty budgeted to optimize defense spectrum and we are well positioned to capture some of that funding.



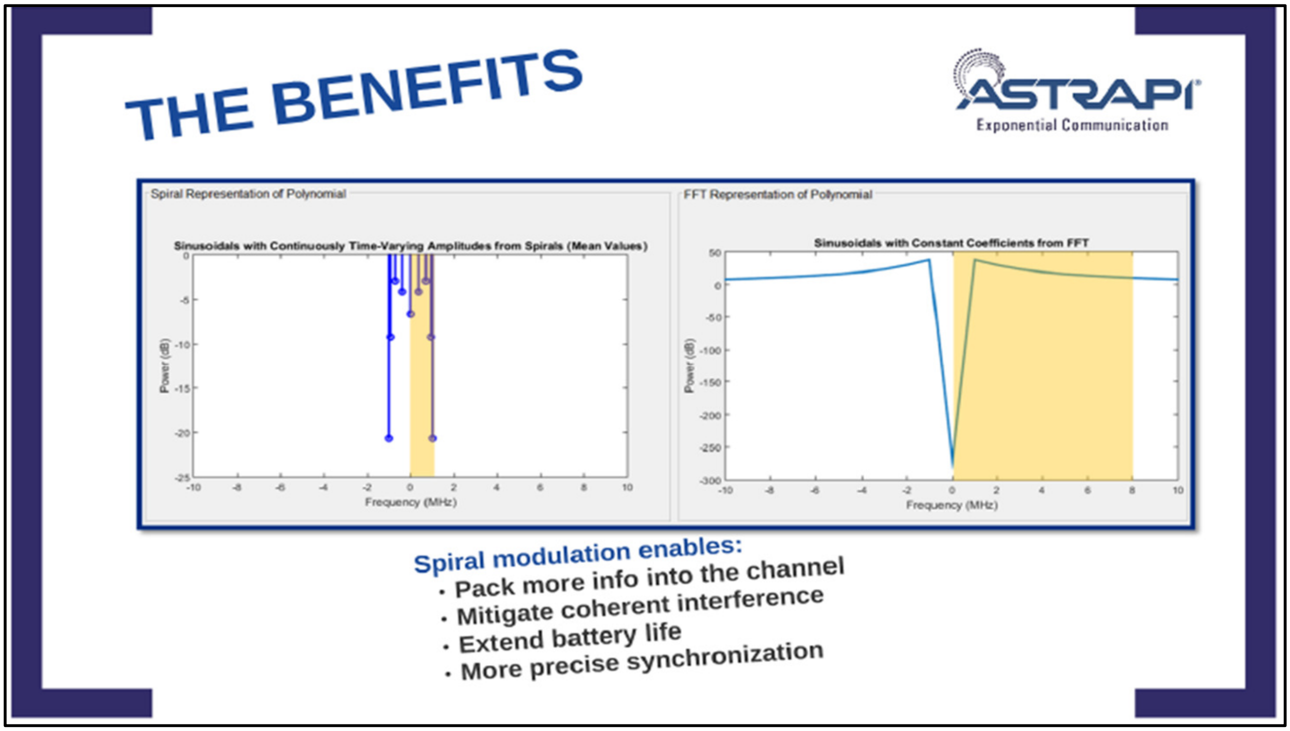
Communication networks and especially satellite networks are increasingly capacity and power constrained, and susceptible to increasing amounts of signal interference. Yet their customers are demanding more. Satellite networks operators, the smart device manufacturers and the modem manufacturers all have a big problem. The modulation approaches they have available have reached the theoretical limit. That's why the operators have to spend billions at the complete opposite end of the value chain to acquire spectrum rights or significantly increase CAPEX on infrastructure to meet this crazy growth in demand.

Well, Astrapi unleashes economic value back down in the physical layer. We compete directly with those existing modulation approaches like Quadrature Amplitude Modulation or QAM, Phase Shift Keying or PSK, and their derivatives.

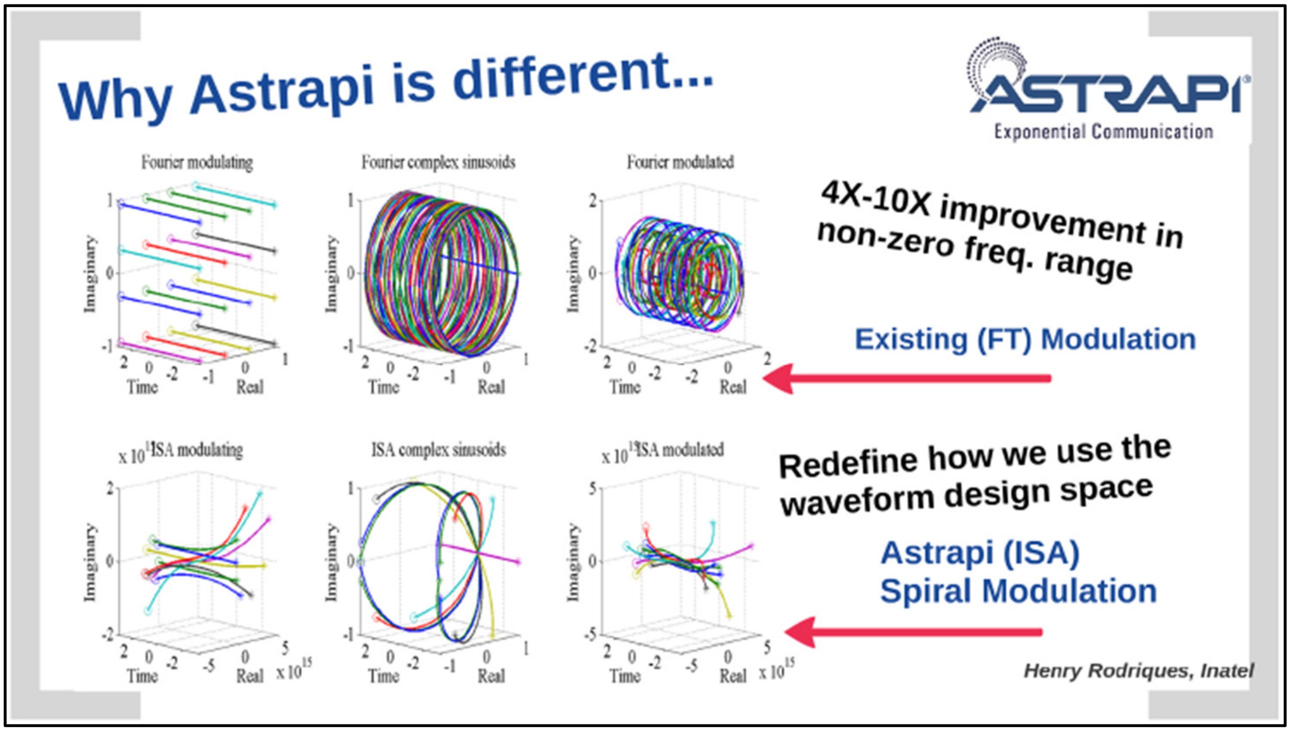
We compete indirectly with alternative infrastructure investment like High Throughput Satellite systems, new cell towers, small cell networks and the repurposing of existing spectrum.

And, of course, there are other emerging approaches. The Microwave Journal recently published an article stating that spiral modulation and full duplex are the two “next frontier” technologies to address spectral efficiency.

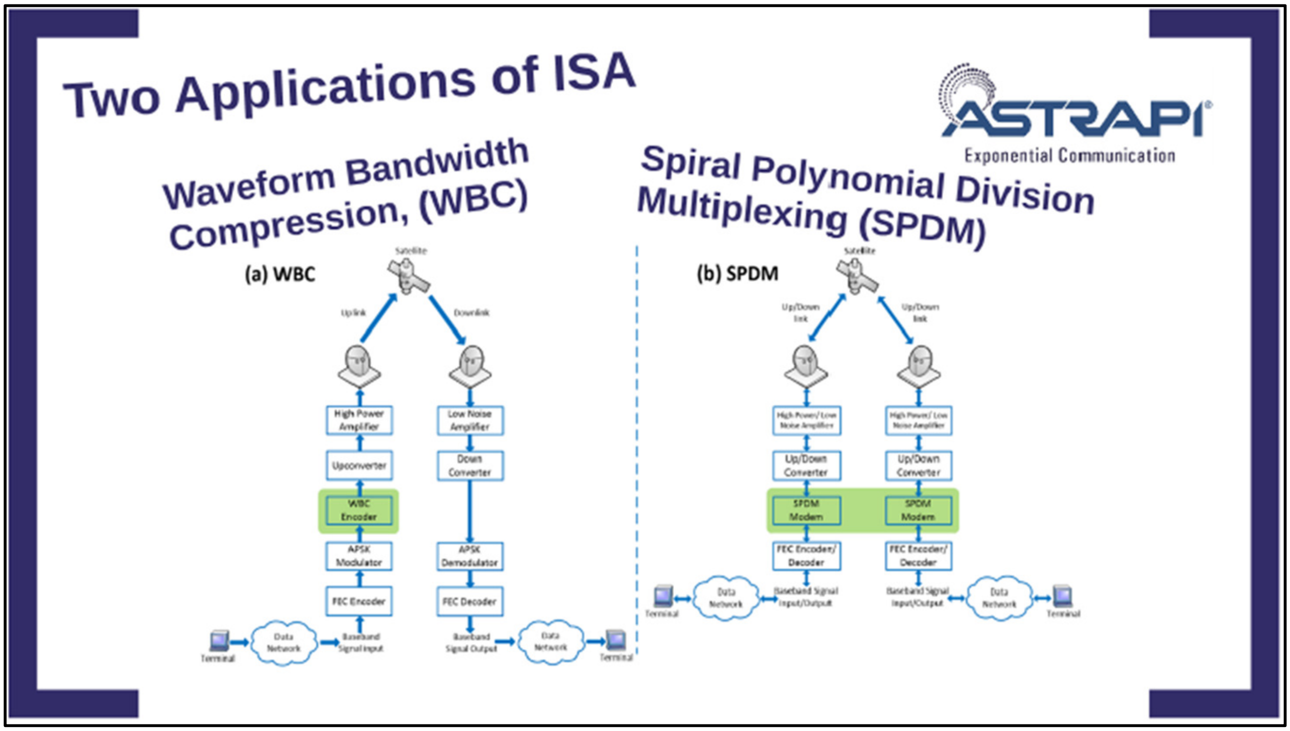
We invented and own spiral modulation. Interestingly we were invited to participate in a full duplex defense project with a major prime contractor for a full duplex project. The modulation portion was cut, in fact I’m not sure any of it was funded. The larger point is that Astrapi owns one frontier technology and may be deployed in the second.



So modulation is all about spectral efficiency first. So what does that mean? If you consider the graphic on the right you will see a traditional modulation example that require 8 MHz to transmit 16 amplitude values per one microsecond of symbol time Our spiral modulation, on the left, only needs 1MHz. 1MHz to transmit the same 16 amplitude values. Traditional communications theory says this cannot be done.



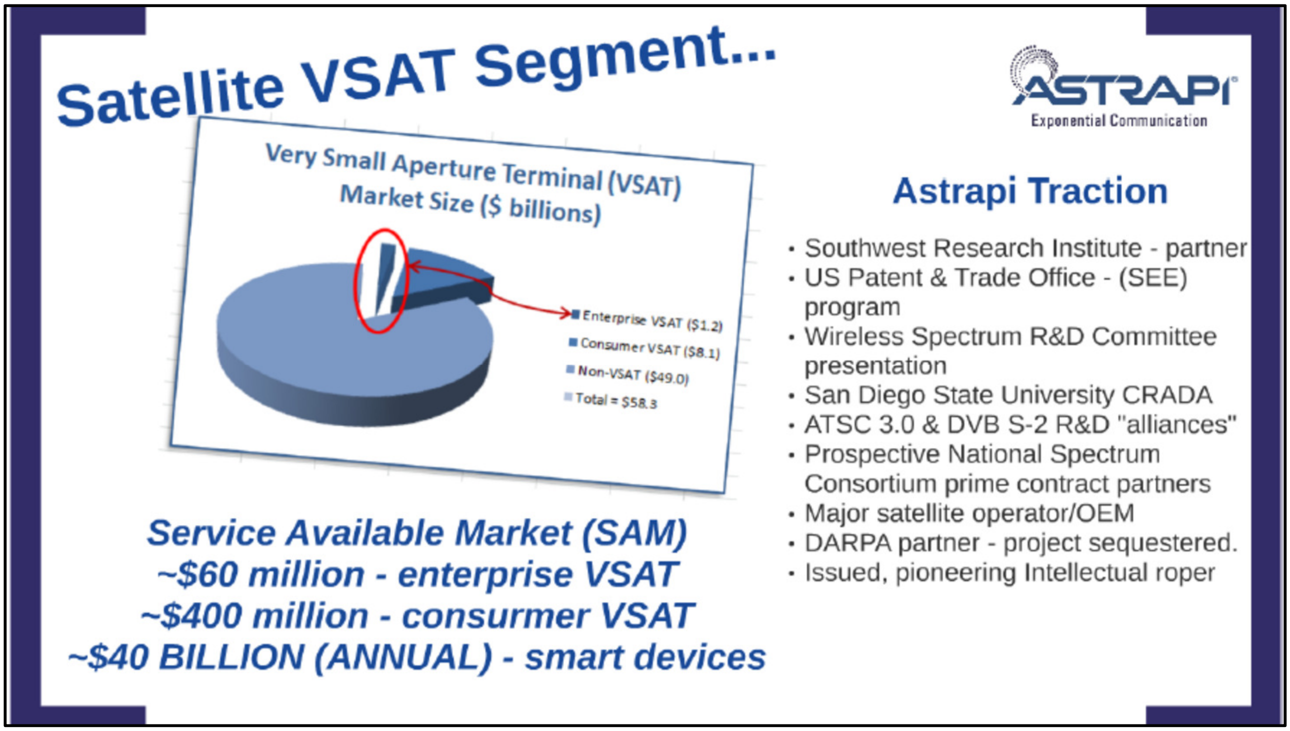
So it's spectral efficiency first, but spiral modulation is much more than that. This graphic was generated by one of our friends in Brazil, Inatel. If you compare the lower horizontal graphics to the upper ones you will see that spiral modulation completely redefines how you use the waveform design space and improve the trade-offs among: bandwidth, signal power, data throughput, and error rate.



There are two applications of ISA

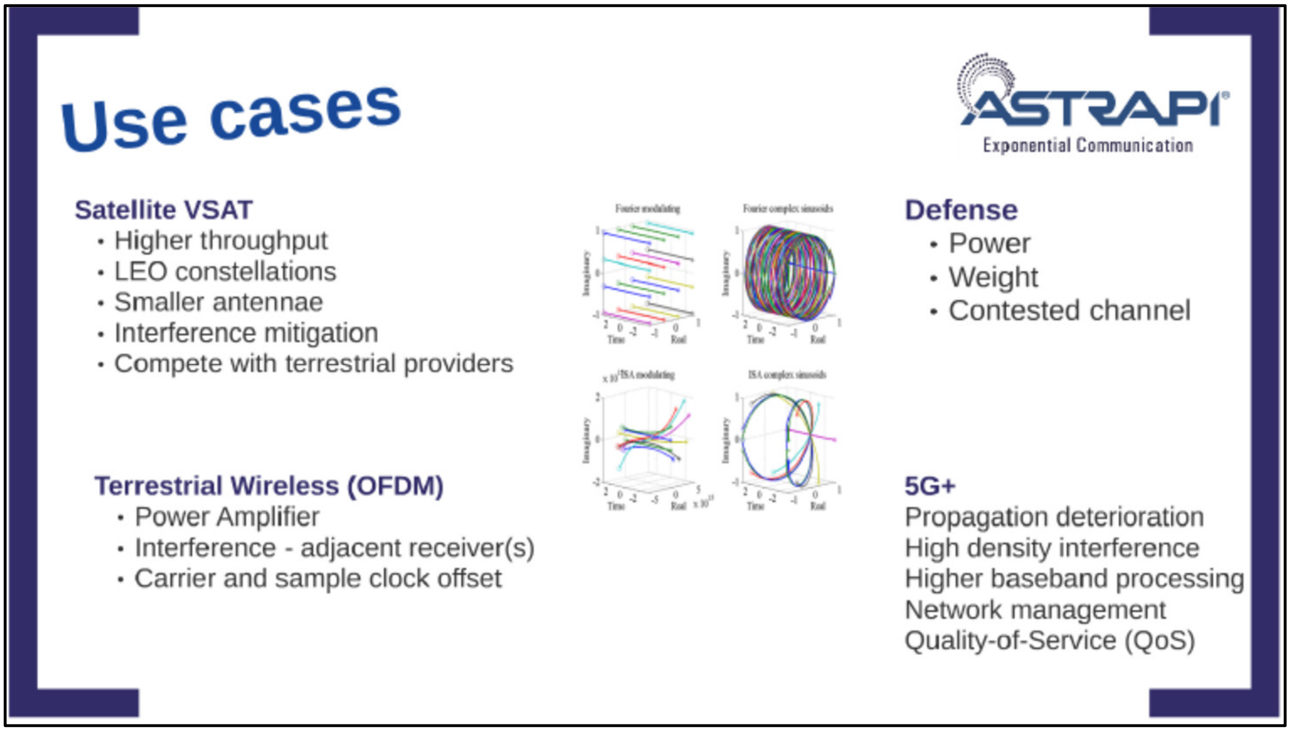
Waveform Bandwidth Compression (WBC) arises from asking the question: “What is the simplest way to obtain benefits from ISA while changing existing radio architecture as little as possible?” ISA then makes it possible express the data-carrying amplitude values into a much smaller range of frequencies with nonzero amplitude than would be necessary using traditional methods. This has the effect of compressing the waveform bandwidth. In principle, the receiver design is not affected by WBC because the expected sequence of amplitude values arrives, although expressed differently in terms of sinusoidal sums. The diagram on the left shows, at a high level, that we deploy WBC into existing hardware by embedding it before the digital to analog conversion. We don’t think there are any other changes required to network architecture. And we have a couple of operators interested in our approach.

Our National Science Foundation funding is built on the broader deployment of our Spiral Polynomial Division Multiplexing (SPDM). The SPDM model of communication consists of transmitting polynomials. Since general polynomials have much more waveform distinguishability than the sinusoids used by traditional signal modulation methods, they are more resistant to noise, and therefore may have much better Bit Error Rate (BER) performance. SPDM is the combination of representing symbol waveforms as polynomials with ISA for bandwidth-efficient signal transmission.



Our recent National Science Foundation work demonstrated we can reduce the Bit-Error-Rate equivalent and the number of symbols required for standard satellite DVB-S2 framing techniques. In one test we showed about a 5-6 dB performance improvement.

We plan to transition those types of performance gains into the $58 billion satellite VSAT segment first. The enterprise segment represents a $60 million opportunity for Astrapi. The consumer VSAT segment represents a $400 million opportunity. We scale from there. To be clear, we intend to embed spiral modulation into the 2.2 billion smart devices projected to ship annually. That represents a $40 billion annual, a $40 billion annual Service Available Market opportunity for Astrapi.



Satellite VSAT- Goal is to deploy more high-throughput systems, Low Earth Orbit constellations with improved ground station equipment to enable spot beams with reduced antennae size/cost resistant to interference. More transponder capacity, therefore fewer satellites, better interference mitigation improve Quality of Service and reduce guard band requirements, reduce cost and CAPEX to compete with terrestrial high-throughput offerings.

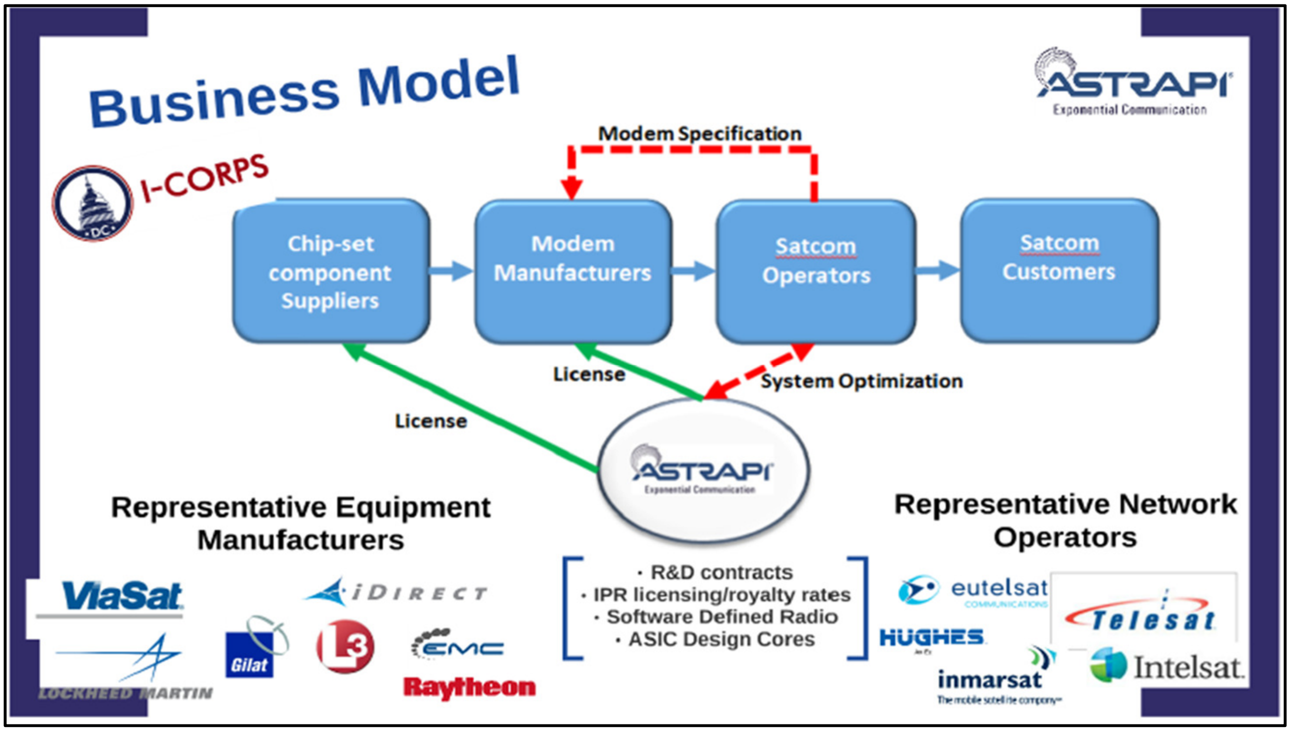
Terrestrial Wireless – OFDM, carrier frequency and sample clock offset, interference due to adjacent transmitters due to high channel blocker at the receiver create demodulation and noise performance issues. High Peak-to-Average Power (PAPR) for OFDM signal requires a Power Amplifier that must be oversized in terms of average power which limits applications for laptops, tablets, etc. – it's the battery. A higher degree of accuracy in synchronization with less power enables the SPDM modem to reduce overhead in synchronization signaling. SPMD provides the ability to reduce PAPR of the power amplifier. Aided by SPDM, lower power requirements should enable OEMs to dramatically lower their total cost to manufacture. SPMD minimizes coherent interference performance loss by exploiting dramatically increased waveform design flexibility.

Defense – Rifleman Radio, NET Warrior – power/weight/extension of mission, anti-jamming…Same throughput using less power, requires fewer batteries, lessens the load on the soldier, extends the mission life and the novel waveform is hard to find, and through over-sampling resistant to jamming effort. Rogue actors won't know what they are looking. Cognitive radios with AI functionality for defense spectrum sharing applications.

5G or 5G+ – propagation deterioration at higher frequencies, fat pipe 60 GHz CAPEX real estate challenges, interference due to density, MIMO beamforming needs increased baseband processing capacity all leading to network management quality of service issues…We think spiral modulation is an enabling technology, though we are focused on other uses now.

So our pathway is broadly defined by channels that are capacity and power constrained and susceptible to increasing interference. That's about all of them really. So we do not want to get mired in standards committee meetings…yet.

That leads us to point-to-point implementations where one entity controls both ends of the channel. Satellite makes sense because they use fewer symbols and the industry is moving to High Throughput Systems to compete with terrestrial competitors. The move to higher throughput requires more power which generates more interference, already an industry problem. We address those challenges. So enterprise satellite makes sense first.



The diversity of satellite networks creates multiple opportunities for Astrapi and is a good market entry point. The diversity of satellite channel requirements enables the modem manufacturers the opportunity to embed spiral modulation into their modems to meet their customer's, the operators, diverse and unique challenges.

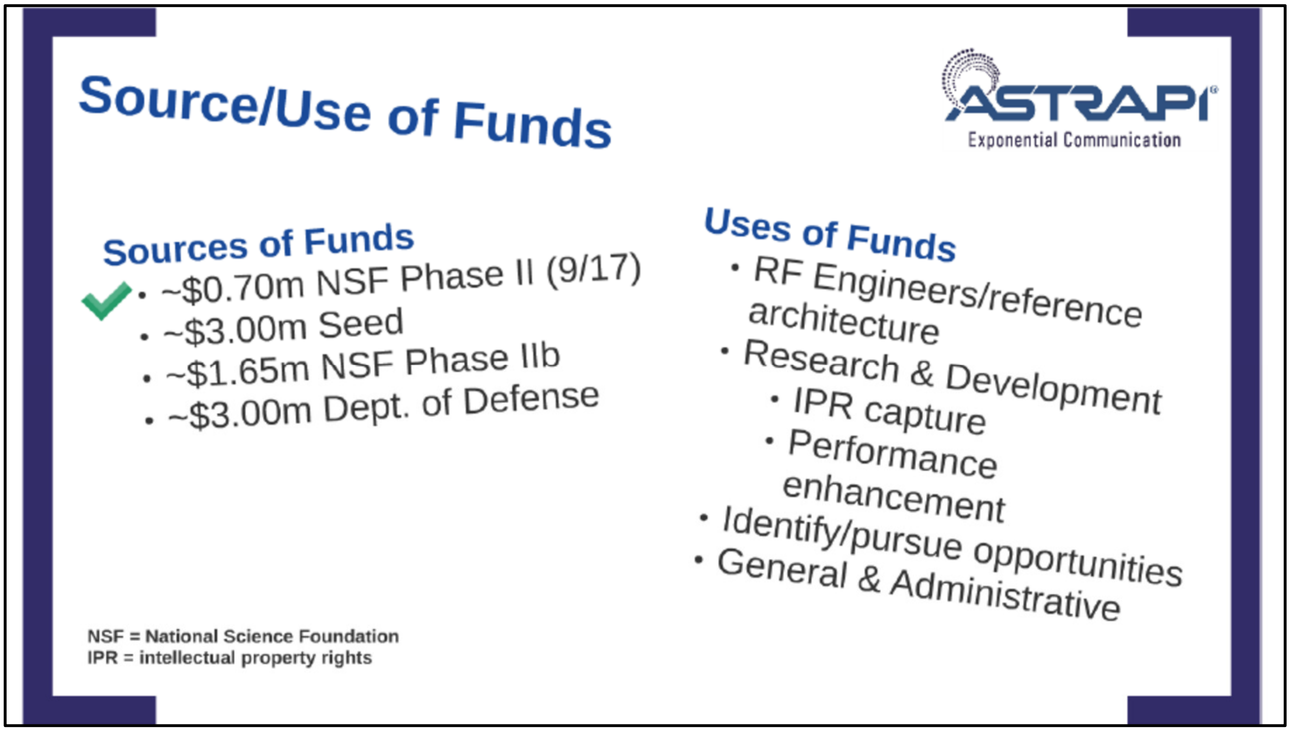
So our path to market is to license spiral modulation to the modem manufacturers first. We deploy spiral modulation into Software Defined Radios first. So spiral modulation is a software upgrade first. We scale from there.

Astrapi has traction. We have keen support and interest from a variety of satellite manufacturers and network service providers. We have support from backhaul companies and major defense contractors. We have interest academics, private labs and Defense labs.

We are led by Dr. Jerrold Prothero. Jerrold has a background in physics and computer science with honors, as well as an interdisciplinary Ph.D. from the University of Washington. As mentioned he he invented spiral modulation while exploring the foundational math. Dennis Ahearn was the former Chief intellectual property and licensing counsel for Comsat which was acquired by ViaSat and in a similar role with Lockheed Martin. Dennis will tell you we have the strongest IP he has ever seen in his thirty-five year career. Dr. Tanay Bhatt has joined the team and is with us today. He has his Ph.D. in EE and has taught graduate level courses at SMU, UTD, and Arkansas.

We have a strong team in place with a deep bench of advisors. We have deeply talented people who now want to work for us. We now have five global research institutions working with us including the Southwest Research Institute, a $500 million per year non-profit research center in San Antonio, Dr. fred harris a noted DSP expert out of San Diego State, and Morgan State who is helping us with some machine learning work to ascertain the optimal polynomials to use.

And both the TSR research lab in Spain and Inatel, the national lab of Brazil are helping. We met both at the National Association of Broadcasters show. They are involved in the DVB-S2 and other standards related to video broadcasting.



Significantly most of the funds we have sourced will be used to open, staff and support lab in North Texas and capture the intellectual property that falls out of those efforts.

Each problem we solve, each challenge address will likely have an entire patent family fall out of those efforts. Again, there is no prior art here and spiral modulation represents an IP green field.

However, the point here is the value of Astrapi today, tomorrow and twenty years from now resides in our pioneering patent portfolio.

Is there value in IP? Qualcomm generates over $8 billion annually from their licensing program. Of course Broadcom was trying to buy Qualcomm for over $100 billion, largely based upon the value of their IP.

ARM Holdings was recently acquired by Softbank for $32 billion based upon the value of their IP.

Kumu networks, a full duplex, pre-product company has raised over $45 million and Austin's GenX Communications has secured over $7 million in funding for their full duplex efforts.

Eight of the ten largest strategic investors, and many, many others, are aligned with our value proposition. So our likely exit is an M&A event based upon the value of our IP.

Thank you, I am happy to take questions.