# A Terabyte per Month to the Car

By Tom Freeman – Senior Vice President Land Mobile Kymeta Corporation

Figure 1: The Kymeta/Toyota concept car as introduced in NAIAS January 2016.

Kymeta® and Toyota® are embarking on a journey together to traverse an overpass from where we are today—a world of technical limitations, low capacity, and difficult business models with current cellular technology—to a world that delivers to the connected car completely unprecedented capacity—first world service to every Toyota car no matter where it is and state of the art security, and all for a fraction of the cost of today's cellular systems.

This overpass is built on the four pillars of capacity, service coverage, security, and cost. This crossing will be complete when we have connected the Toyota fleet of incredible cars to today's **and** tomorrow's satellite constellations. Together we are leading a consortium of content and space segment suppliers to cross this bridge to next generation connectivity and service. Please forgive the obvious literary device of the automotive overpass, but I deploy it because like its physical world equivalent, it by-passes congestion, inconvenience, and the delays of today.

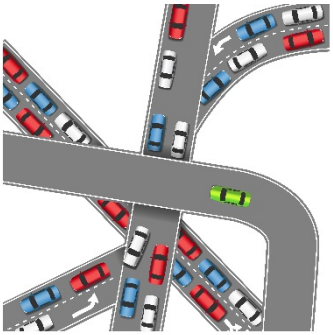

Figure 2: By-passing today's LTE traffic jam

## About Kymeta

I'd like to start by giving you a brief introduction to Kymeta. I'll tell you where we come from, how we started and why we have created a commercialized version of one of the coolest satellite antennas you'll never actually see. And then I'll tell you why you won't care about our antenna—you'll care about the technology and services it unlocks by bringing incredible amounts of data to and from your car.

Figure 3: The thin, powerful, strong and nearly invisible heart of the Kymeta antenna compared to a familiar consumer electronics device.

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Dr. Nathan Kundtz is an inventor and innovator in the field of metamaterials and microwave devices and is the CEO and founder of Kymeta. Nathan's research and work at Duke University on metamaterials is highly cited as it focuses on the development of novel design techniques, such as transformation optics, to meet real-world needs. The success of his work ultimately led to the formation of Kymeta Corporation in 2012 in Redmond, Washington, and we have been making incredible technological leaps for the past four years. Our principal tool set is in the field of metamaterials. By combining what we've learned with established liquid crystal display manufacturers, we have developed a flat antenna that requires very low power, can be fabricated inexpensively, is incredibly strong, and disappears into the existing form factor of your car's roof.

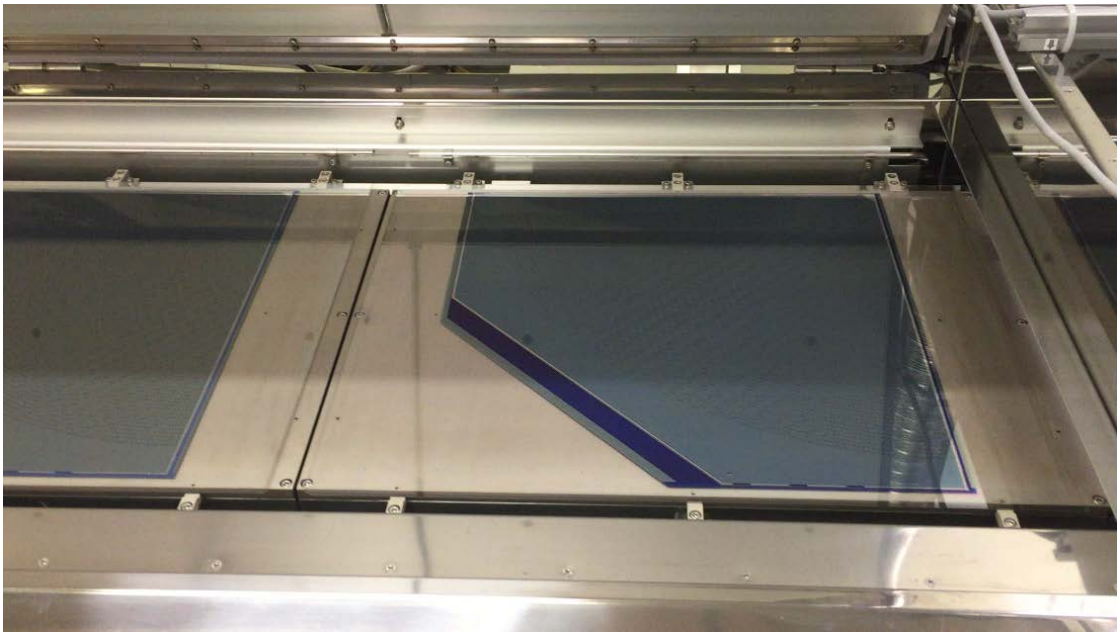

Figure 4: By leveraging previous consumer electronic manufacturing investment, the Kymeta antenna delivers solutions to today's and tomorrow's automotive issues.

But don't think of Kymeta as an antenna company—think of us as a solutions company. What problem do we solve? To answer that and what's happening in the space segment and what it means for your car, we have to look back at the trends of data consumption.

## The Challenge

The world we live in today is not the world we'll live in tomorrow. The need for more data is a trend that will continue into the foreseeable future where content will be richer and more immersive.

The world we live in today is not the world of yesterday. In years past, when we thought about connecting to the Internet we heard this familiar sound:

*Queue 9600 baud modem connection sound – you know the sound; you are hearing it in your head right now!*

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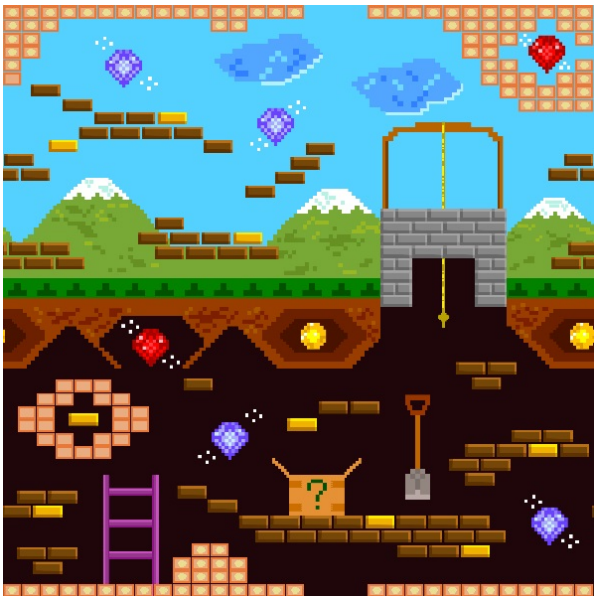
Twenty years ago, if you used a 9600 baud modem to email your friend a selfie taken with today's typical smartphone, it would have taken 40 minutes to upload. Today, the average connection speed in the United States is about 12 Mbps. That's **twelve hundred** times faster. That same picture uploads in **one second**. And for those that have to have the best, you can find service that's even a hundred times faster than that to your home.



**The entire Super Mario Bros.® game was only 40 kilobytes.**

**This screenshot is 283 kilobytes.**

Figure 5: There is a hard and fast relationship between richness and the number of lines of code.

As illustrated in the simple Super Mario Bros. screenshot above, there is a hard and fast relationship between the richness and immersiveness of a media experience and number of lines of code it takes to build it.

Thus, in tomorrow's world, the customer will just expect complete access to data, media richness, and all that entails.

So, why is it that today you can get such fast speeds in your house or apartment but not to your car? It's because your house is in a fixed place, connected by wires and fiber optic cables. And for the most part, your house does not move. And if the past is any guide to the future, your need for faster speeds, richer data, and more bandwidth will only grow.

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But our challenge and the reason we are teamed with Toyota is that we're talking about connecting a car. It's obvious you can't connect it with wires. (I had originally titled this piece *Fiber to the Car* because I liked the metaphor, but more literal minds prevailed.) But what isn't always obvious is that the current technology and wireless spectrum available will not meet the projected demand. Some believe that the current cell tower infrastructure approach can meet the demand for data to your car. We believe that is not true. The simple physics behind the problem with the current infrastructure do not support the cell tower solution. We believe we can achieve a much-better-than-home experience in the car using spectrum and satellite. As illustrated by the picture of the frustrated consumer, cell technology is **not** a mission critical technology.

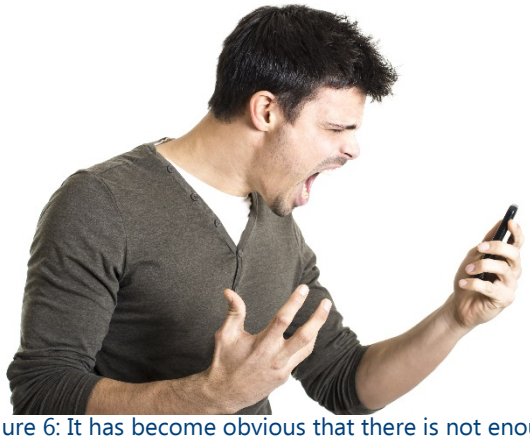

Figure 6: It has become obvious that there is not enough wireless spectrum available to meet the projected demand at a price people have come to expect, for today's or tomorrow's applications.

## Spectrum

Our technology—the one you don't care about and don't see when it's embedded in your car—will give you and your automobile access to data that exceeds data going into your home today.

This is possible because of a particular natural resource which is highly limited on the ground but widely available by satellite. That resource is called frequency spectrum or just spectrum. Massive amounts of data can be delivered with this spectrum.

As illustrated in Figure 7 there is a huge amount of spectrum available in the areas designated as fixed satellite spectrum. So here is the heart of the Kymeta/Toyota story: What if you could make the fixed satellite spectrum mobile?

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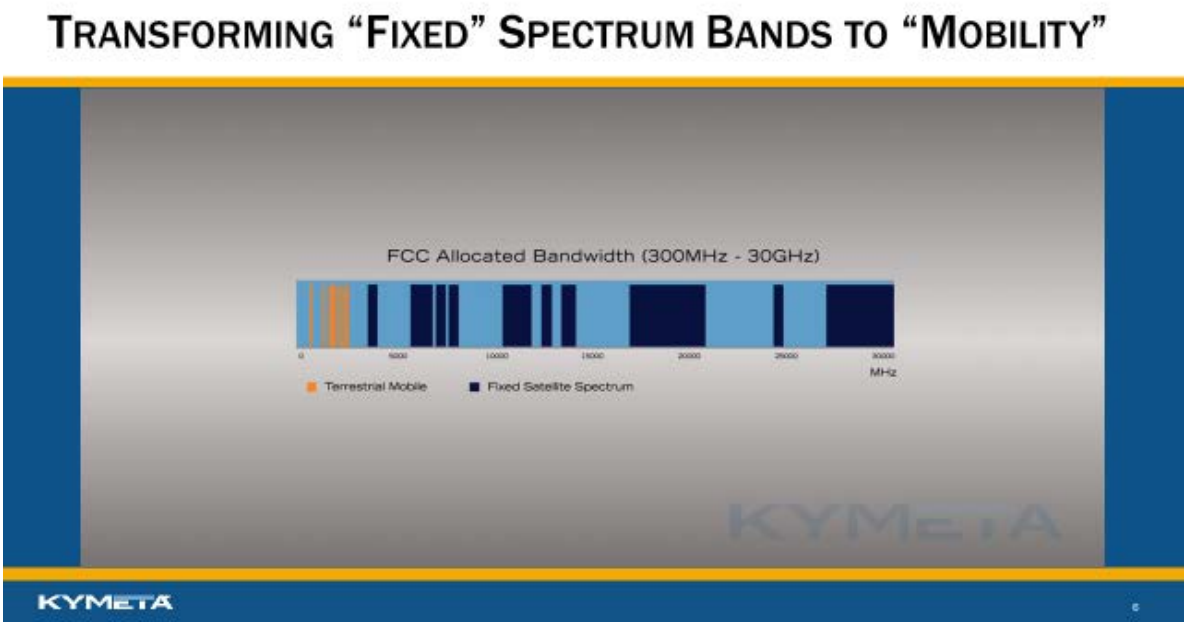


Figure 7: The heart of the Kymeta/Toyota story: What if you could make the "Fixed Satellite Spectrum" mobile?

If you could transform fixed spectrum bands into mobility, you would have sixteen times the amount of spectrum available, and until now, you would have needed to mount a dish to your car to get access this spectrum.

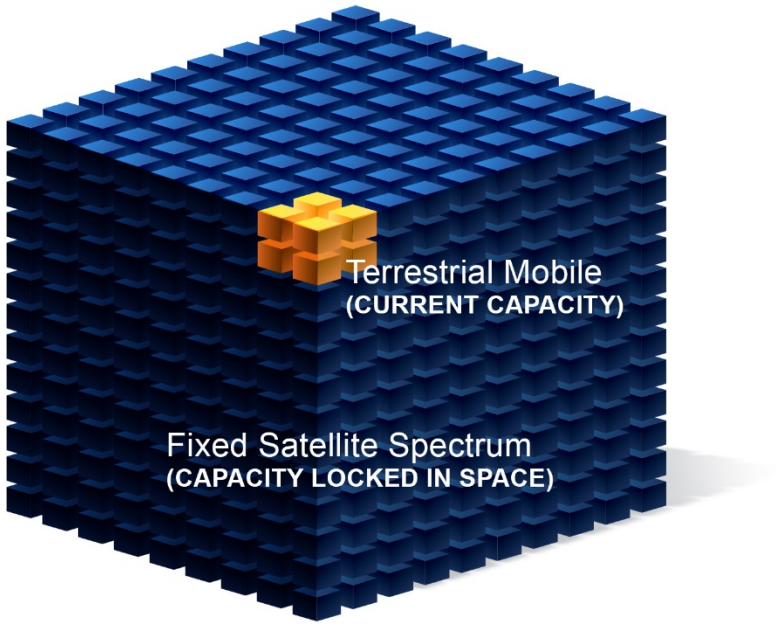


Figure 8: 16 times more spectrum that can be delivered at significantly faster data rates.

But keep in mind, not only is there more spectrum, the spectrum that is at these frequencies is more efficient at carrying data.

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The proposition is even better. A dumb smart phone can only see one cell tower at any given time, but a smart space antenna can see up to 300 satellites, in various orbits, on the same frequency sending different or redundant content.

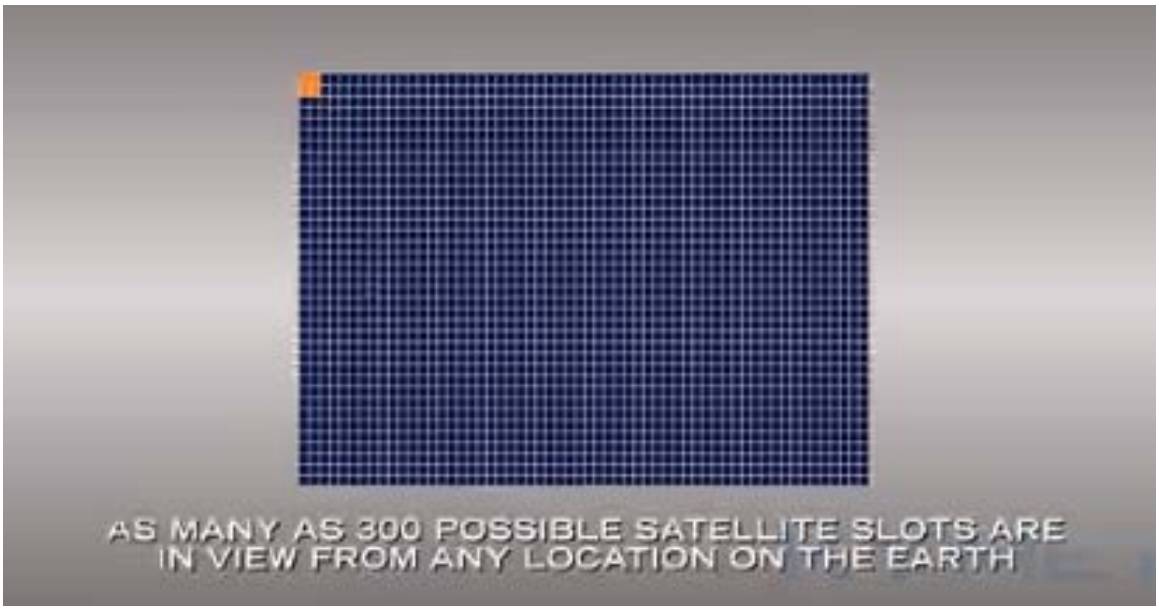


Figure 9: A smart antenna system would allow your car to see up to 300 satellites at once delivering 4800 times the spectrum.

This is how Dr. Kundtz's invention turns an antenna company into a solutions company: by opening the spectrum capacity that previously could go only to those aesthetically challenged dishes hanging off houses or planted on roofs and making that fixed spectrum capacity mobile, nimble, and invisible.

A smart antenna system would allow your car to see up to 300 satellites at once delivering 4800 times the usable spectrum.

**This is the capacity that helps complete the overpass metaphor of a congested cell system world. Spectrum is the first pillar of that overpass.**

The Kymeta/Toyota concept system is targeting a terabyte of data per month per car. This is actually a modest goal based on a driving time of ½ hour in the morning and of ½ hour in the evening, leaving plenty of data capacity for infotainment, telematics, software updates, and autonomous driving. This goal is based on the geosynchronous satellite configurations of today.

The space segment is on fire with capacity expansion with the introduction of high throughput systems (HTS) and the introduction of low earth orbit (LEO) satellite constellations. What is just game changing today will be a completely different sport tomorrow.

The beauty of a software driven antenna is that cars with Kymeta antennas will be compatible with these new satellite systems and constellations that deliver huge increases in data to the car before they are even off the drawing board. This is a significant point: it's like saying that GPRS phone you bought in 2006 was completely compatible with and would support the throughput of the 4G system in 2016. As a

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professional, I am not going to suggest that those who are contemplating 5G[1] today do not have as their highest priority making sure that today's systems are completely compatible with 5G.

## Just-in-Time Capacity

The flip side of space capacity is vehicle capacity. With Kymeta tiling technology, antenna numbers and sizes can be mixed and matched to meet regional, market, and price-point requirements. Just-in-time capacity means that one system can deliver maximum manufacturing flexibility to meet different market conditions.

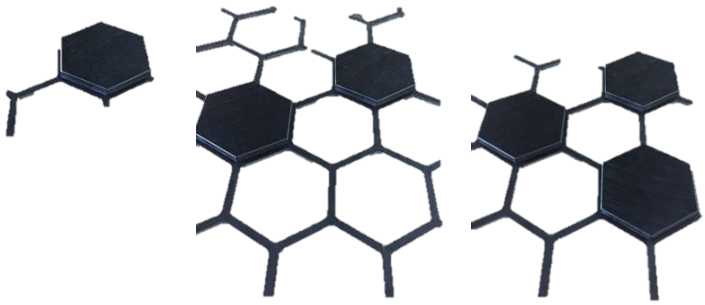

Figure 10: Just-in-Time capacity - multiple small antennas for the right capacity

Think of the Kymeta system like LEGO® bricks—if more capacity is needed, more LEGO blocks can be added: more solar panels for more transmission power, one solar panel for receive only. One 15.24 cm antenna for cars with minimal receive only capabilities, multiple antennas for higher gain.

Figure 11: One 15.24 cm with 4 visible solar panels for powering transmit and receive from the car at NAIAS on Kymeta/Toyota Mirai concept car January 2016.

[1] While the effort to define 5G is still in its early stages, there have been definitions that would include frequencies that are advantaged by Kymeta antennas and include space segment distribution and back haul.

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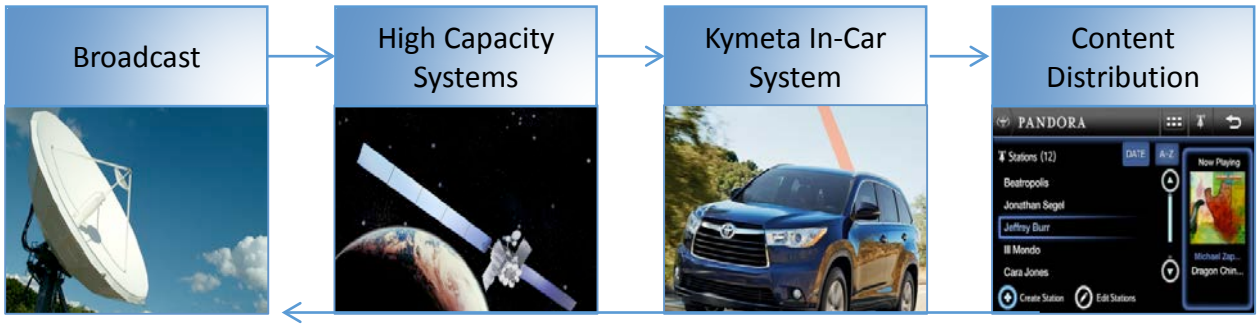


Figure 12: A consortium of partners

## The Connected Car Service

**Broadcast centers**

Kymeta is leading a consortium of content and space segment suppliers to cross the bridge to next generation connectivity and service, supplying a worldwide network of global and regional content. The broadcast centers aggregate and condition content (observing the regional business rules and rights management for that content), encrypt the content, provide the account and subscription management, manage the work and release flow of the content, and then process the acknowledgements for that content. These broadcast centers then release the content by way of a secure private network to ground stations around the world for uplink to the appropriate high-capacity satellite systems. This is all done within state of the art security protocols.

**High-capacity systems**

High-throughput satellite (HTS) is a classification for communications satellites that provide at least twice, though usually by a factor of 20 or more, the total throughput of a classic fixed service satellites for the same amount of allocated orbital spectrum thus significantly reducing cost-per-bit. Some suppliers do provide more than 100 Gbps of capacity with their constellations, which is more than 100 times the capacity offered by a conventional Ku-band satellite. By way of example of the changes in the space segment, one HTS satellite, at the time of its launch in October 2011, had more capacity (140 Gbps) than all other commercial communications satellites over North America combined. The space segment is on fire with growth.

Low Earth orbiting satellites (LEOs) are being deployed in new satellite constellations because a single LEO satellite covers a small, moving area extremely well as the satellite travels at the high angular velocity needed to maintain its orbit. Many LEO satellites are needed to maintain continuous coverage over an area. The advantage for automobile applications is that the look angle for any particular satellite is

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almost directly overhead, providing easy line-of-sight service to drives in London, Moscow, and Anchorage. There are numerous LEO systems in various stages of deployment.

**Kymeta in-car system**

Kymeta In-Car System

Once the data is received by the Kymeta antenna, the Kymeta in-car system handles the data. The data is stored in the KyVault™ cache and proxy server and is then used by various systems in the car as required. KyVault cache and proxy server safely and securely manages incoming information, tracks, deploys, acknowledges (by terrestrial and satellite return paths), certifies, and archives messages. KyVault cache and proxy server is the "keeper of the keys" as it performs the job of tracking, authenticating and releasing in vehicle bound software updates to various systems throughout car. KyVault cache and proxy server is also a cable-box in the car. It is the source of stored and current content of all kinds—games, movies, radio, audio books, and points of interest. It acts as the source for the various types of monetization. The KyVault cache and proxy server is a standard part that incorporates functions from various legacy parts.

**Content distribution in the car**

Content Distribution

Coverage areas are interesting things. Our partners at Toyota have really radical ideas about who deserves to have access to this kind of data. They have told us that they care just as much about their customers in New York City as those in Sub-Saharan Africa. Whether they are delivering movies or software updates, they believe that every one of their customers should have access to these services.

It is not unfair to characterize cars as mobile software devices. Vehicles are comprised of many systems, and systems, almost by definition, have a large software component. From telematics to security, from infotainment to CAFE performance, from steering to emissions, from ride and comfort to airbag deployment—all can be thought of as a software system with an interface to a physical standard part.

Recalls are the perfect storm of negative business. They are extremely expensive. The consumer feels disappointed, inconvenienced, and betrayed. The brand takes a horrible hit. And to make matters worse, most consumers never actually return their cars without sustained bribing, cajoling, and threats. It has been estimated that the root cause of over 80% of all recalls is software related.

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Figure 13: Kymeta/Toyota concept Mirai with High Density maps and real time weather at the North American International Auto Show (NAIAS) along with multiple movie and infotainment offerings.

Some cars today have over 100 computing processors—just twenty years ago there weren't any. Today's high end automobiles reportedly have over 100 million lines of code. Tomorrow, the data pipe we'll need will be even bigger, and it can only exist from space. The Kymeta antenna delivers that pipe on an unprecedented scale. The equation is simple: cars with updated software equal safer cars.

**Satellite return path**

Figure 14: The satellite return path for confirmation, acknowledgement telematics information, airbag, and e911

The return path for telematics confirmation, for map tiles reception acknowledgement, for airbag deployment, for e911 calls, for software update acknowledgements, and for monetization are controlled by the KyVault cache and proxy server. One major security advantage of direct to satellite acknowledgement is there can be no middleman attaches because there are no systems in the middle. Acknowledgements of software updates or airbag deployment go directly to the satellite and then directly to the appropriate authority.

**This is the second pillar of our overpass: service coverage. The consumer in rural Kansas, or East Asia, or in the Yukon deserves the safest and most up-to-date vehicle possible.**

## Security

Security will continue to grow in importance. A key advantage you'll have with connectivity from space is the security of the channel. The White House uses satellite connectivity for secure transmissions for this reason. To create a secure system, many elements are required, among them:

- Attack surface reduction
- Authentication/certification

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- Configuration management
- Source system integrity
- Application security
- Rapid, global, and complete reaction to attacks

Terrestrial systems can match the security levels of satellite systems in authentication/certification, configuration management, source system integrity, and application security because the level of security deals with the integrity of the data inside the delivery system. However, there are two areas where satellite systems are vastly superior to terrestrial: reducing external attaches and reacting fast and fixing data inside the delivery system if it is ever compromised.

- Attack surface reduction
- React to attacks fast, globally, completely

The nature of this security stems from the point-to-point architecture of the transmission. There can never be middleman attack because there never is a middleman. There are fewer points of entry into this channel, and if there is any kind of security breach, the point of attack can easily be discovered and patched. The fix can then be broadcasted to all regions on the planet simultaneously. No fix has to be dumbed down to support a slow network. No one is left behind.

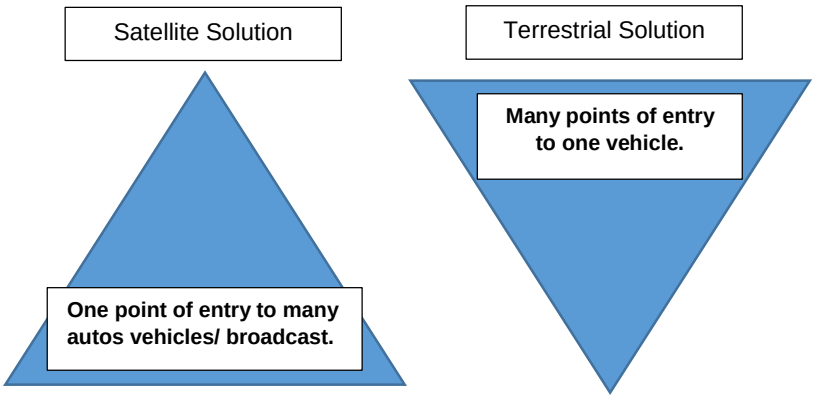

Figure 15: Satellite advantages: attack surface reduction and fast, complete global response.

**This is our third pillar: security. Satellite is the securest method of mass electronic distribution of data.**

## Cost

And what about cost? This is an excellent question. Cost comes in a three components. What does the Kymeta system cost? What does it cost to get that data to the car? And what does it cost to use the content?

**What does the Kymeta system cost?**

This wonderful system that does so many good things does no one any good if it cannot be a standard part on every car made. This is the version of the airbag issue: is it only for the rich? But keep in mind, auto manufacturers are under tremendous pressure to reduce cost.

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The good news here is that Kymeta has teamed with Sharp Corporation to produce this antenna. Three years of intensive collaboration with Sharp Corporation have led Kymeta to a product design that can be manufactured using Sharp Corporation's existing liquid crystal production capabilities. This is an important factor for Kymeta and Toyota. By using a production technology that is already widely deployed in consumer devices, with over $250 billion of industry-wide investment in infrastructure and R&D, we are able to mass-produce antennas on a scale previously unattainable. This means that functionality that previously costs tens of thousands of dollars and more is now available at a consumer price point. As a standard part, the consumer will never notice the cost.

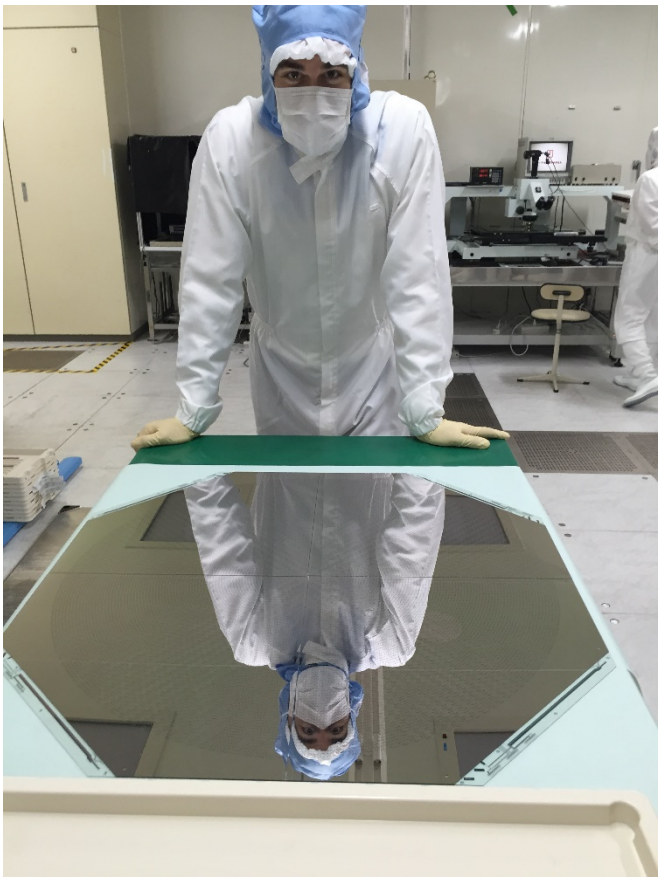

Figure 16: Manufacturing antennas as if they are TV displays.

**What does it cost to deliver the data?**

The best way to think about this problem is to use a very analogous sister industry: satellite TV. Satellite TV charges a subscription. Some large percent of that subscription goes to pay for content and a very, very, very small percentage of that subscription goes to getting the bits to the roof of our consumer's house. We're interested in what those bits cost. Imagine you have a satellite sitting over the western half of the United States and it costs you $100,000.00 (completely made up number for illustrative purposes only) to get all your channels to one house. If you had two subscribers it would cost you $50,000 per house. And if you had a 100,000 subscribers it would cost you $1 per house, if you had 1,000,000 subscribers…etc. The Kymeta system has a huge pipe that sends the same data to all the KyVault servers in all the cars where each KyVault server either accepts or rejects data based on its unique ID and then stores it. If you make 10 million cars per year and cars last for 10 years, the cost per car may not be worth the effort to figure out.

**What does it cost for the content?**

The car owner would not likely be charged for standard software improvements or other data that is critical to the car. The auto company wins because there is no actual recall, the customer is happy because he or she was not inconvenienced, and the CFO of the auto company is happy because this all costs less then bringing a car back. Infotainment content sent to the KyVault server will remain dormant and un-charged-for until and only if the consumer decides to use it. Like other applications on the internet, content can be paid for by watching ads, taking actions, or paying currency.

**Cost is the fourth pillar. This solution is the least expensive way of moving content to the car.**

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Figure 17: The Mirai – Kymeta/Toyota Concept car as shown at the North American International Auto Show January 2016 includes all four pillars of the over pass, receiving over 50 Mbps in the car.

Now. Think back to this sound:

*9600 baud modem connection sound – you can still hear it…*

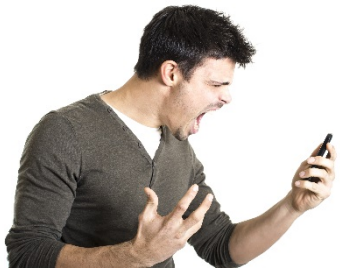

Figure 18: An abysmal experience for all

That was only twenty years ago. Think of your car today as if it is connecting with that thin noisy thread of data, only now it's not only slow but also limited in capacity. Think about your connectivity at a trade show or a stadium. More people contending for spectrum equals a more abysmal experience by all.

Our technology puts a gigabit per second and a terabyte per month firmly within reach. That's over 100 times what your monthly cell plan gives you today.

So what kind of data will tomorrow's car need? Software- and firmware-over-the-air updates, telematics, high definition and 3D mapping and infotainment, vehicle diagnostics, interactive and augmented reality, owner's manuals, and usage based insurance.

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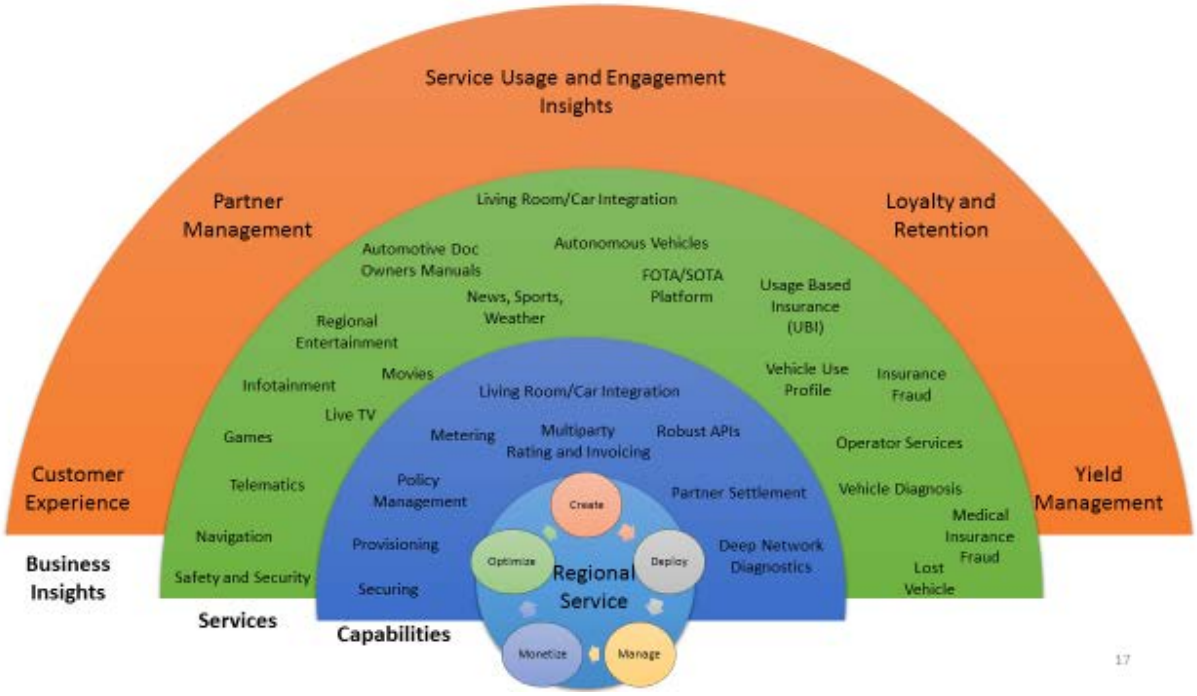


Figure 19: The car of today and tomorrow will have ever increasing data requirements.

Car owners will no longer have to come in to a dealership and plug into a couple of laptops to get the latest software—it will be a fleet-wide multicast that the car receives. High density weather maps will warn drivers to pull over to avoid a flash flood half a mile up the road. Kids will have on-demand gaming in back while parents preview the best sushi shops in a five-mile radius.

Cars will be safer because they will be current. Cars will be more fun with games, living room/car integration, news, sports, weather, regional entertainment and live sports, live TV, movies, short form video and interactive POIs, and yet un-dreamt of applications.

**But I want to Skype and email from my car, no matter what! Better yet, I want to broadcast HD video from my car. I need guaranteed connectivity anywhere, anytime!**

Kymeta is working, in parallel, on what we call VIP cars. These cars, also known as diplomatic and security services cars and civilian armored vehicles, serve a market that value reliable, secure, high capacity communications on the move. The requirements of these car are for a huge **bi-directional** TCP/IP pipe for bringing the internet to a mobile vehicle in such a manner that does not to draw attention to itself.

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Figure 20: The Kymeta prototype VIP car with powerful transmit and receive capabilities as shown on an exclusive basis at NAIAS and introduced at Satellite 2016.

**Travel Across America**

A 20,000 mile trip

- This market requires power. Our solution has the ability to receive 50+ Mbps down and 10+ Mbps up with various satellite systems today and gigabits per second tomorrow.
- This market requires antennas subsystems in the car be inconspicuous. Our solution fits between headliner and roof < 3 cm in depth
- This market requires the antennas to be invisible from the outside: the Kymeta zero-profile solution to satellite communications
- This market requires secure communications. Satellites provide the securest global communication by reducing 1) attack surfaces and providing 2) the fastest cure in the event of a breach.

Kymeta alpha units will be available in mid-2016. Eventually what Kymeta learns from the VIP market will be incorporated into the standard OEM product offering.

## Conclusion

If you believe consumption for data will continue to climb and if you believe the car will follow the same data consumption trend as the home, then the only practical way to deliver access to the required bandwidth is from space. This is precisely what Dr. Kundtz's antenna solution does: unlimited, inexpensive data from space without wires. Without cell towers. Without poor coverage areas.

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