Hello,

- This presentation takes a look at the rapidly developing NewSpace industry
- Focussing on new developments in satellites

It’s exactly 60 years this October (2017) since Sputnik I, the world’s first artificial satellite, was launched.

But it’s only in recent years that developments in launch and smallSat technologies have changed the rules of the game.

**Some of the major changes in the industry have been in the reduction of mission cost, and the management of risk.**

And to manage risk we must test.
Over the next 45 minutes:
- we will cover some background on the changes that have been occurring in the industry
- We’ll then look at how cost of test is an important factor in the development of any space mission
- Before looking at a specific example in the test of wideband RF systems
- We’ll then draw our conclusions
Space involves three vital parts:
- The Components - satellite payload, terrestrial receivers, etc.
  - data will be bi-directionally transmitted between the satellite and earth station(s). This data may be telemetry, measured data, imagery or communications signals.
- The Launch vehicle/launch site
  - This is the most visually active area of development, and there has been great development here.
  - COST of launch is being reduced by a factor 10, which enables new approaches to business.
- The Operations / Maintenance
  - These will have to evolve with the developing applications and emerging Space businesses.

Any Business plan for a Space mission must include the costs and revenues from all three components.

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Satellite Data:
For communications this process typically uses a transponder, which receives signals over a range of uplink frequencies and retransmits them on a different set of downlink frequencies. A transceiver can also be thought of as a "re-transmitter" or regenerative. The frequencies used for communications might be low frequency (amateur radio ~3 MHz) if the data bandwidth requirements is not great (9.6 kbps). If the data needs are greater, higher frequency is required. Frequencies up to Ka band (26.5 to 40 GHz) are increasingly being used to access unallocated bandwidth.

Imaging applications, though not transceivers will generate a lot of data on the downlink to the operation control – these are aiming to provide real-time imaging for military/disaster situations and frequent daily weekly monthly updates for industries and agriculture.

Launch Cost:
the general rule of thumb NASA Space shuttle was that it would cost $10,000/lb ($22,000/kg) to launch a satellite into low earth orbit. SpaceX are quoting 1/10th of these prices for launches in 2018 with $1,230/lb ($2,700/kg) when launching up to 22,800 kg using the Falcon 9 launch vehicle, and down to $750/lb ($1,650/kg) when...
launching up to 54,400 kg using the Falcon Heavy — Others have been less public on their pricing strategy.
In recent years you may have heard the term “NewSpace”. This really refers to recent changes in approaches to the SPACE business which have been quite revolutionary.

1. With the reduction of launch costs the doors have been opened for multiple new business ventures.
2. There are huge opportunities for such ventures, and the barrier to entry has been drastically lowered - (see examples on right)
3. The approach of these businesses to space is to balance risk, cost and time-to-market and rather than eliminate risk completely, manage risk as a cost

- The evolution of the space industry is affecting everyone, not just these new groups – traditional players are having to change their business plans to compete

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**Satellites:**
Low earth orbit is an orbit around the earth with altitudes of 160 km (99 miles) to 2000 km (1200 miles) with orbital periods of about 88 minutes to 127 minutes respectively. Satellites in LEO are travelling over 7 km/s. All manned space stations as well as the majority of satellites are in LEO. The majority of satellites are or are being planned for observation missions, both examining the earth and space. These systems promise to revolutionize the quality and amount of data available to commercial, government and academia for many purposes. There are also communication systems envisioned that could provide the level of profound change similar to personal computers, wireless telephony and the internet.

**Funding:**
There are new sources of funding for NewSpace: Venture capital//Crowd funding//Angel investors//Personal fortunes//Contests//SBIR

**Risk:**
Note that many are no longer using rad-hard components as the expense and performance of such devices is offset against the ability of commercial components to withstand space over a short time-scale before being replaced and updated with newer technology – technology refresh
NewSpace:
Established providers, driven to compete by the changes in market forces can also benefit and grow within the new economy with cheaper access to space. Ariannespace have developed the Vega launcher specifically for the launch of such SmallSat technologies. Similarly the dimensions of the SmallSats lend themselves to “Piggybacking” on the launch of other payloads. Suched hosted payloads help to participate the cost of launch whilst maximizing the efficiency of each launch. In February 2017 Planet launched 88 of its Dove Satellites in a single launch by a PSLV rocket from the Satish Dhawan Space Centre in Sriharikota, India, sharing the launch with an Earth Observation mission from the Indian Space Agency.
So there are some MAJOR trends going on that changed the dynamic of the space industry

1. Huge reduction in launch cost that opened the door to new commercial business ventures
   1. Launch cost divided by 10
   2. SmallSat complexity growing – relatively "cheap and easy" to launch satellite networks
   3. More Competition

2. As Consumers, we have grown more dependent on higher data throughput – mobile data, global imaging
   1. Use of our mobile devices, and the emergence of IoT means that there is a lot of wireless data that could be offloaded to satellites
   2. New applications like global imaging will generate continuous streams of high resolution video images requiring large data down links.

3. RF frequencies are occupied little availability pushing us to higher frequencies and use of steered antenna arrays to minimize cross-talk
   1. Oxygen absorption is not an issue between satellites in space, but focusing our RF beams can help combat losses.
   2. As we look to 5G networks in the future it’s entirely possible that there will be a mix of base stations, pico cells and satellite communications that will allow seamless transfer between data sources.

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Lowering the barrier to entry - access to space has opened the doors for many new players and **New Competition**.

It allows the use of satellites for applications that were not economically viable in the past, and changes the economics of the established market.

But in aiming to manage risk, we accept a *certain* failure rate, and compensate with designed redundancy. We can also benefit by accepting that we will refresh these technologies, using lower cost **non-Rad-Hard** commercial components (Careful COTS).

These approaches are not mutually exclusive: but both require test, and an approach to test that may be novel for many established companies. (MTBF, and building and testing assemblies rather than the individual components, buying components in production lots, etc.)

Overall the calculation of Revenue vs cost has become much more complex. And within that cost, **test is an important aspect**.

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Though the trends show us that the total non-materials costs in manufacturing have decreased dramatically over the last 20 years, the cost of test has overall remained fairly constant. As a result, the cost of test has become a highly visible contributor to overall program cost, and there is a constant pressure to drive down the cost of test. Let’s take a look at what comprises the cost of test and discuss ways that it can be reduced. Then we will discuss how traceability is the key concept that connects it all together.
In an ideal world, we would eliminate testing completely. Unfortunately, the final manufactured product never matches exactly with the intent of our design, though it can be improved with better simulation.

Given that test is necessary, we will look at what it takes to reduce the cost of test.

Let's begin by breaking down the cost of test into a simple model. This will help us determine how a given change in one element of the equation will affect the total cost.

The cost of test can essentially be broken down into four distinct categories, as shown here. The elements underneath each category will vary based upon the stage of the product lifecycle that you are in, from design and validation to manufacturing and acceptance testing.

So now, by looking at one of the variables in this diagram, we can start to see how it plays into the big picture of the total cost.
Test Step Cost
• Number of test stations, fixtures per station, and DUT’s per fixture
• Total test time, including loading, setup, measurement time, unloading and removal
• Cost of consumables within the test stations, such as cabling
• System downtime

Diagnostics and Repair, (or redesign if in the design and verification stages)
• Yield – which is the amount of devices that pass vs. fail, keeping in mind false passes and false failures
• Time to diagnose, repair, or redesign
These categories are sometimes left out but should be considered
• Depreciation of the diagnose and repair
• Cost of disposable materials and scrap

Overhead and constant costs – the ones listed here try to capture the essence of costs – this is more to examine how different factors affect the cost rather than an exhaustive, quantitative exercise to determine all constant costs.
Taking an average of these costs usually suffices
• Total time the test stations are running
• Number of maintenance and support engineers and labor costs
• Lump cost for all device materials
• Upfront capital costs
• Non-recurring engineering cost to get the system up and running

Product Waiting, which is related to the cost incurred while components or systems are waiting to be tested
This consists of the average number of units waiting for test, diagnostics, and repair or redesign
What will produce the greatest return on investment in terms of reduced cost of test? Increase measurement speed? Pay more money upfront for a test instrument with better specifications?

The cost of test model can help determine this. However, this does not address the main issue with the current approach for reducing cost of test: that by defining the test system at each stage of the lifecycle, you are very limited by how much you can do to reduce the cost of test.

Test systems are designed by the team working on the individual stage of the product lifecycle – example is the manufacturing team designs the manufacturing test systems. As a result, most of the variables in the cost of test model are fixed. Only small changes can be made, such as buying an instrument with faster speed for a given measurement.

Two ways to reduce the cost of test the most
• Define the test systems during the requirements definition stage
• Take a program perspective

What does the total program perspective look like?
• Reduce the total program schedule (significant reduction in cost)
• Improve consistency in results across all stages of the lifecycle (spend less
time and money repeating tests and troubleshooting inconsistencies)
• Improve system level performance (no more over-design of components)

So, taking a program level approach, where can you start?

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One common challenge is trying to determine where to focus energy in order to get the greatest reduction in cost of test. For example, is it best to focus on streamlining test code to reduce test time by multiple seconds? Or would it be more beneficial to reduce the upfront capital spend by $10,000?

Clearly, there are many relationships between the various contributors to cost of test, complicating this question. A model like the one we have just defined can help make it possible to answer the question.

The current widespread belief is that changing the individual variables will have the greatest impact on reducing cost of test. In the current approach each team that is working at a different stage in the lifecycle designs their own test systems, trying to reduce the cost for their particular step in the process. An example of this would be to buy an instrument with faster speed for a given measurement.

The problem with this approach is that once the design requirements and specs for the product have been determined, the test system requirements become fixed. This severely limits the number of variables in the cost of test model that can be changed.

The solution consists of two parts. First, define the test system during the requirements definition stage. Second, take a program level perspective when using the cost of test model to reduce overall costs.

For example, instead of trying to reduce test time for an individual measurement, consider how to reduce your program schedule as a whole. Instead of looking at the test results of an individual measurement or test plan, consider the consistency of your results, which guarantees an optimal pass rate during acceptance testing. And finally, instead of just buying an instrument with better specifications, consider the system level performance.

So, taking a program level approach, where can you start?
Program lifecycle costs determined versus costs actually spent. Though most of the cost is spent during final design through production, the costs are already determined upfront. Why is this? The reason is that the tests are designed around the design requirements, rather than being both being defined together.

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To start, we will take a look at the documented program costs throughout the program schedule. The blue line is where the costs are determined, based upon the system requirements and other factors. The yellow bars represent the actual dollars that have been spent. As you can see, there is a very big discrepancy between them. During the requirements definition stage, 80-90% of the costs for the entire program have been defined, though only 10% of the dollars have actually been spent.

What this shows is that the requirements of the program set the costs for everything, including the test system. If a new test system is designed separately at each stage of the process, it is very difficult to optimize for cost of test- the program requirements have already defined what is required. On
the other hand, if the test systems for each stage of the lifecycle are designed as the program requirements are set, then the requirements for the product can be defined within the scope and performance of the test system. This frees up the variables in the cost of test model and opens up great potential for reducing the total cost of test, and therefore total program cost.

Source: GAO 2003 report
Now let’s talk about how practically we can take a program perspective to reduce the cost of test. Improving system level performance reduces cost of test, saves on program schedule, and improves confidence in the consistency of test results.

Accuracy is extremely important in space because once there, the payload cannot easily be accessed or modified. This puts tight requirements on each component in the system to ensure that it works the first time.

Link budget determines the minimum required performance for the payload system and its components.

Another way to look at it is acceptable margin, which is limited by the link budget. Each component contributes to the margin as well as the overall performance of the test system. If the test system uncertainty is high, then the margin of each of the components must be set tighter in order to meet minimum design requirements and pass functional acceptance testing.

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Now let’s talk about how practically we can take a program perspective to
reduce the cost of test.

Improving system level performance reduces cost of test, saves on program schedule, and improves confidence in the consistency of test results.

First, consider the case of why accuracy is extremely important in space. Once a payload is transported to space, it cannot be easily accessed or modified. This puts a lot of pressure on the final product to behave as close to the design as possible. If the requirements for each component in the design are too relaxed, the overall system uncertainty will be too great, at best reducing the yield during final testing and at worst causing the satellite to fail.

Here is a look at the definition of the satellite link budget: it represents the minimum power received by the payload such that the resulting bit error rate meets system requirements. As you can see, it is affected by factors including distance and atmospheric effects like rain- this is especially important at mmWave frequencies. The key point, however, is that the performance of the payload is a significant portion of the link budget, and therefore, we can use the link budget to set the minimum performance for the payload system and relative components.

Another way to look at it is the acceptable margin. This is essentially a relative comparison between working performance and design requirements. In order to ensure accurate, working components, traditionally, tolerances are set very narrow. If the system level uncertainty is large, the acceptable margin of the components must be set much tighter in order to ensure that the design passes final acceptance testing. This increases cost due to tighter design specification requirements.
How does system level performance affect cost of test, program schedule, and thus total program cost?

- As we mentioned previously, the more accurate the test results, the less time spent over designing components to account for system level performance (i.e. margin)
- The more accurate the test results, the less risk of needing to re-design at later stages in the lifecycle
- The more accurate the test results, the less time spent re-working parts in production
- The more accurate the test system, the more confidence that results are consistent at each step in the design, verification, and manufacturing process
- Better accuracy across test systems ensures confidence in consistency between systems and repeatability from one day to the next, as well as minimizes uncertainty between systems. This is a key gap in today’s approaches

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We have just talked about how poor system performance can negatively impact the program schedule and cost test. What are the current ways to mitigate the issue of poor system performance and accuracy?

The current approach:
1. Increase margins to add headroom for system performance
2. Use a golden DUT to characterize systems

Consequences of this approach:
- Tighter component requirements, which add unnecessary cost to the program schedule
- Test fixturing is ignored and performance is determined at the instrument level- this is usually ok when dealing with lower frequency, narrowband signals. However, trends are pushing to wideband, mmW signals, where the contribution of the fixturing cannot be ignored any longer
  - Connector care: mmWave cables and connectors are very fragile and can easily be damaged. The small size of the contacts can make them hard to see
  - Using a fixed uncertainty introduces the potential for non-repeatable test results
- Golden devices are useful for verifying the repeatability of a system. However, it is always a relative comparison. This widens the limits within which devices pass performance tests, causing more "bad" devices to pass
We have talked about how poor system performance can negatively impact the program schedule and cost test. What are the current ways to mitigate the issue of poor system performance and accuracy?

The current approach to managing system level uncertainty consists of two parts:

• First, to account for the system level performance, larger headroom is introduced to the device system and component requirements. Either a rough estimation of the worst case uncertainty is calculated and margins are adjusted, or the margins are simply adjusted by an approximated value.

• Second, to account system level variability, every system is characterized with a “golden device,” which is one whose performance has been extensively measured and is expected to pass all tests.

What are the consequences of this approach?

• For complex systems, the large amount of headroom added when using these methods forces tight requirements on component design, increasing the cost of test.

• For simpler systems, usually earlier in the program cycle, the effects of the signal routing and conditioning elements, such as the cables and adapters, are often assumed to have a negligible effect on system performance. While this works when testing narrowband, RF and low frequency microwave signals, the contributions to the signal from these elements cannot be ignored at the wider bandwidths and higher microwave and mmWave frequencies that are and will be used.

  • An example of this is regarding connector care- at mmWave frequencies, connectors are much more susceptible to damage due to the small parts. Be sure to accurately inspect all connectors, as damaged ones can greatly contribute to result variability and system uncertainty.

• Using an unverified uncertainty introduces the potential for non-repeatable test results on a day-to-day basis and when moving from one stage of the product lifecycle to the next.

With regards to the “golden device” approach, this method does allow for verification of individual system repeatability. However, there is no way to tell how accurate the system is relative to accepted national standards of units. The system could be repeatedly measuring an inaccurate result. This widens the limits within which devices will pass the test, even though their performance may not be actually within passing limits. Therefore, more devices that should fail will actually pass the system test, which increases the
failure rate of devices during assurance testing, requires more device rework, and strains the budget and schedule.
Traceability means that the instrument or system used to test the device has been calibrated by another instrument or standard with known uncertainties that can be traced directly back to a national metrology lab. This ensures the accuracy of a measurement system within a statistically known value of uncertainty.

Traceability is the solution to the challenge of managing system level performance and variation among systems. Use a calibrated instrument or standard with known uncertainties to verify the system performance and correct for systematic errors. For example, a traceable calibration standard, in the form of a comb calibrator, can be used to correct for wideband system performance.

Define the system level performance parameters, such as insertion loss, power level accuracy, and frequency accuracy. Regular testing for these system parameters ensures that the system has not drifted and will produce repeatable results from design through final product shipment. This also makes it possible to see the effects of making a change to the instruments within the system, perhaps to achieve wider bandwidth, higher frequency, or better performance.

These system performance parameters should be defined upfront with the product level requirements. As we discussed, this will enable the best test
system performance that complements the product design, and will enable significant savings during the later stages of the program.

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Traceability means that the instrument or system used to test the device has been calibrated by another instrument with known uncertainties that can be traced directly back to a national metrology laboratory. The great advantage of traceability is that it ensures a measurement result is exactly what is reported within a known, derived uncertainty.

Traceability is the key to ensuring system performance and managing variation among systems. This is done using traceable transfer standards, in the form of instruments, to verify system parameters like insertion loss and frequency accuracy. Wideband calibration techniques improve the system level accuracy by removing linear degradations to wideband performance. A traceable calibration standard, such as a comb calibrator that has been fully calibrated, can be used to make this possible.

It is important to define system level performance parameters that are of interest, and determine their associated uncertainties. Doing so will enable the use of the transfer standards to calibrate the system, reducing required margins. If it is assumed that the phase of the reflected waves between each element in the signal path is random, the uncertainties for each element can be combined using the root sum of squares technique. This definition must be done upfront, when program requirements are being defined, in order to ensure that the device requirements are complementary to the limits of test system performance, within acceptable limits of final yield and costs.

Another advantage of using traceable transfer standards to verify performance is that the test systems can be designed around the measurements rather than an individual device or program. This improves leveragability and reuse.

Using an external, traceable instrument to measure and verify performance ensures that from business concept through final acceptance testing, the results will be consistent. This reduces cost of test, and, combined with upfront definition and planning, enables significant savings in total program cost and schedule.
Now we have looked at traceable test and the cost of test. Let’s look at how we can extend these traceable methods all the way through the test fixture to our device under test or “DUT”.
The test fixture takes our DUT, which could be a component or assembly, and provides connections so that the proper functionality and performance can be tested.

It provides power to the device, and access to specific ports to allow testing. It will include switches, attenuators and other components that may be needed to allow accurate measurements on the device.

Typical measurements for a satellite assembly might include:
- Power consumption, using a power analyzer
- Signal transmission, using the network analyzer
- And Wideband distortion using a vector source and wideband receiver.

In addition, if we are looking at devices that will be in orbit, the entire test fixture may be sitting in a Thermal Vacuum Chamber for extreme testing.

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- **Satellites in LEO (Low Earth Orbit) orbit the earth every 88 to 127mins – part of that journey is in the shadow of the earth**
  - When nanosatellites are on the dark side of the earth they have to rely on battery power to perform all of their functions.
  - Small current drains can accumulate and potentially cause the satellite to power down before it is able to reach the sunlit side of the earth

- **This slide shows an example of a current waveform measured in both active and sleep modes.**
  - The upper yellow trace shows the waveform on a 200 mA scale and the lower green trace shows the waveform on a 2 mA scale.
  - **The lower trace clearly shows that some activity is occurring even when the upper trace indicates that the device is inactive.**

Test instrumentation with wide dynamic range and bandwidth is necessary to fully characterize satellite performance

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It is crucial to understand nanosatellite power consumption when solar power is not available. Tiny current draws during “sleep” mode can add up and drain battery reserves, resulting in satellite down time.

Even if the satellite is in non-active mode, small current drains can accumulate and potentially cause the satellite to power down before it is able to reach the sunlit side of the earth. This slide shows an example of a current waveform measured in both active and sleep modes. The upper yellow trace shows the waveform on a 200 mA scale and the lower green trace shows the waveform on a 2 mA scale. As you can see, the lower trace clearly shows that some activity is occurring even when the upper trace indicates that the device is inactive. For this reason, fully optimizing nanosatellite designs
requires the ability to capture sleep mode, active mode and everything in between --- in one measurement. It is therefore important to capture these sorts of dynamic current waveforms in sufficient detail so that you can find and fix these elusive problems that eat away at product performance.
This is a block diagram of a wideband signal source. When testing a DUT we plan to apply a particular waveform at the DUT input.

But …

There are several considerations that must be taken before we are confident our measurements are accurate.

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The primary question we must answer in this slide is: **Do we have a good signal at the DUT input?**

We have a block diagram of a wideband signal source. When testing a DUT we plan to apply a particular waveform at the DUT input.

But …

There are several considerations that must be taken before we are confident our measurements are accurate.
From the generator to the DUT input, there are several sources of error, and we can never be sure if our signal which reaches our DUT is perfect.
We calculate the waveform that we want to apply to the DUT and send that data to the DAC in our signal generator.

**But *EVERYTHING* between the output of our DAC and the input of the DUT is a source of distortion in our signal.** This includes the mixers and rf circuits in the instrument itself as well as the interfaces to the test fixture, and whatever components and circuits are implemented in the test fixture to apply our signal to the DUT.

Similarly after the DUT to the analysis we may have other circuits and distortion before our analysis.

**IF we want to measure our DUT to a traceable standard – we must characterize any distortion before and after the DUT measurement plane.**

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The signal coming out the signal generator will be of good quality, but after it travels through various components (adapter, filter, amplifiers) which may be part of the up converter, the response of the signal will likely no longer be ‘flat’.
A good example of the sorts of distortions that can be introduced can be seen if we look at the instruments themselves:

Even though we assume that our signal analyzers and generators are perfect, they themselves have sources of error which need to be accounted for.

In the diagrams above we can see how potential sources of distortion can affect our measurements.

This is just in the signal analyzer are signal source, there are several other components within the test system that can cause significant issues.
Here is a more complete list of the system errors which one might find when trying to measure mmWave systems.

First we must look at test equipment issues, these can range from VSWR mismatches, due to test setup, Group delay due to extensive switching, and attenuation as well.

There are source IQ modulator errors, phase noise (for OFDM), SNR, and the amplitude flatness and phase linearity of the system

Obviously some of these issues are due to the equipment, however many of us fail to account for test equipment issues as places where you can correct out the distortions within our systems.
There are few issues which can be resolved for manually, however when resolving these issues manually, we are usually not able to control every portion of the equation.

Above we have two examples, Gain Imbalance and Phase Imbalance. Usually in a non-calibrated environment both of these issues would be present to a certain degree.

Manually, we can adjust for Gain Imbalance and Phase Imbalance, but these manual adjustments do not correct out issues for a wide range of frequencies or they are not stable across the frequency range.

Keeping track of these manual adjustments for traceability purposes is also not feasible.

And remember as we are going into a higher frequency range, these distortions become un-avoidable for better measurement results.
The Signal Optimizer calibration can calibrate to the DUT input plane and DUT output plane separately.

In most DUT setups have all the issues which were described in the previous slides we have test fixtures, adapters and cables as part of the setup along with our signal generator, and analyser. These fixtures degrade our measurement capabilities. To solve all of these issues, signal optimizer enables calibration to the DUT input plane and the DUT output plane, which allowing for accurate measurements to be made.

First we use the Comb generator to calibrate the signal generator since the comb generator has in-built phase and amplitude information.

Next the Signal generator will send a special test signal from the generator to analyzer so the analyzer can be properly calibrated as well.

Signal Optimizer can generate and analyze wideband and custom waveforms within the same software, so it’s really simple but powerful story that Keysight can provide the essential wideband signal solution with this software and calibration schemes.
As we move to the higher bandwidth signals demanded by the application it becomes harder to avoid the distortions introduced in the RF path, reducing the ability to make calibrated measurements. To reduce the uncertainties introduced we must be able to measure the distortion in our paths to and from the DUT and mathematically remove them from our measurements.

We want to ensure the DUT is characterized to as great of an extent as possible. In most DUT setups not only do we have all the issues which were described in the previous slides, but we have test fixtures, adapters and cables as part of the setup.

We would like the signal delivered to the DUT input to be the ideal signal, but in practice the signal path will be imperfect and the delivered signal will be distorted as a result. We cannot know in advance what these imperfections will be because they are entirely dependent on the specific hardware, the test fixture and its configuration. We can, however, measure the test setup to determine its channel response and vector modulation impairments, then use that information to develop a filter that will pre-compensate the waveform data so that the delivered signal is as near to the ideal signal as possible.

The channel imperfections are estimated by transmitting a specially designed test signal, which is then acquired by a calibration receiver at the point in the diagram labelled as the measurement plane. This should be as close to the
DUT input as possible because this is the point where the signal will be nominally ideal after calibration.
The ability to move our reference plane up to the input and output ports of the DUT, gives us a tremendous advantage to change our DUT without it affecting the entire system setup.

We are able to more confidently test our system, and this system also allows us to have significantly more stability of our test system setup.

Furthermore, the pre-distortion filters can be saved locally for the various test settings in a test plan and can be applied as needed.

Having a full optimized setup is paramount for traceable measurement results.
And now we must draw our conclusions…
What we have presented today is a brief look at the complexities facing the NewSpace Industries, and how costs can be reduced through proper design and test.

It’s an exciting market with many opportunities. But without careful consideration, and planning, for test from an early design stage operational costs may be higher than needed.

We have shown you:
- How using such a method ensures that from business concept through final acceptance testing, the performance results will be consistent.
- And a specific example showing wideband correction that will allow the traceable measurement of a Device on a test fixture, inside a TVAC chamber.

THANK YOU
Questions?