“With the launch of Intelsat 29e in early 2016 we embarked in a new era of satellite operations. The staff members of the Network Operations team want to share the technical capabilities of the new Intelsat EpicNG satellite and explain how the new satellite operates, the biggest differences compared to “traditional” satellites, and how customers will benefit from the new features in the new EpicNG satellites.”

Ruben Marentes, Director RF Operations Center
Introduction

Business globalization and increasing broadband requirements are expected to continue in the foreseeable future. This global bandwidth demand, including regions previously underserved by traditional means, requires a new method of delivery. While satellite networks have been an integral part of global communications for decades they are not capable of handling many of the increasing data requirements of telecommunication providers, maritime, aeronautical and government sectors. This gap between demand and the service abilities of traditional satellites requires a new approach to satisfy the growing needs of an ever diversifying customer base. It is with these needs in mind that Intelsat designed the EpicNG satellite platform; the next evolution in satellite technology engineered to deliver higher throughput and efficiency while providing enterprise grade, next-generation capabilities for new and existing networks.

What’s So Epic about Intelsat EpicNG?
The Intelsat EpicNG generation of satellites introduces Intelsat’s first high throughput satellite (HTS). HTS spacecraft are capable of many times the throughput of traditional fixed satellite services (FSS). There are three major technical features introduced with the EpicNG spacecraft (specifically IS-29e): The first one is related to the multi-spot beam design. The second is the use of the Analog to Digital converters (ADC) and the last one is the use of the Digital payload. In the next few sections we will explain all of them.

Multi-spot Beam Design
EpicNG spot beam footprints are shaped by standard multi-array antennas aboard the spacecraft. These beams range in bandwidth between 62.5 – 500MHz. Beam polarization is regulated by the orientation of the beams’ feeds, and frequency ranges are isolated by uplink and downlink beam filters. The benefit of the more focused, concentrated beam is high forward and return gains, less power to transmit an RF signal and ability to utilize a smaller antenna to close the links. Also, a more asymmetric nature of the traffic is changing the way we operate. Lately we are seeing customers asking for 4-to-1 or a 6-to-1 ratio. With the new G/T and EIRP performance it means that we can now push more megabits and be more efficient, not merely meeting but exceeding expectations.
Introducing Channelized Capacity

For a multi-spot payload to be flexible, it is essential to be able to interconnect each and every spot beam. Accordingly, Intelsat EpicNG satellites are complimented with a transparent digital switch matrix. Typically referred to as the digital payload, this component is situated between uplink and downlink paths on the satellite, as pictured in Figure 2 below.

![Figure 2: EpicNG Digital Payload](image)

The Digital Payload provides any beam to any beam connectivity on all EpicNG signals by provide routing and gain control on all incoming signals. It receives the down-converted RF spectrum at L-band frequencies (1.4 – 1.9GHz). Every spot beam connects to a receive port on the input of the digital payload. Connectivity and routing of RF spectrum is performed at increments of 2.6MHz. These segments are referred to as sub-channels:

- There are 192 sub-channels per receive and transmit port. Individual or contiguous blocks of sub-channels are combined to accommodate transmission of services larger than 2.6MHz.
- The usable bandwidth of any beam is determined by the number sub-channels which have been allocated on the digital payload. This usable bandwidth is therefore defined by physical hardware and is identified as a sub-beam.
- When a connection of one or more sub-channels are established from an uplink sub-beam and downlink sub-beam and EpicNG connectivity is established.

The Digital Payload can establish four different kinds of connectivity (routes) between beams. The standard route consists of a single or group of sub-channels routed for downlink transmission. The digital payload can also perform a “fan-out” which duplicates an uplink sub-channel on one or more downlink sub-channels. Conversely, one or more uplink sub-channels can be combined on a single downlink sub-channel to create a “fan-in” route. Lastly, a combination of fan-out and fan-in connectivity can be established to
produce the order wire route. Before exiting the digital payload, signals are converted back to analog for transmission on the desired downlink beam (See Figure 3). Combined with multi-spot coverage beams, Epic\textsuperscript{NG} digital payloads introduce a number of new approaches and challenges to space and ground segment operations. This includes impacts to traffic planning and analysis software such as OFPS and STRIP7, network monitoring philosophy and procedures, and even ground control operations.

**Figure 3: Connectivity Types**

### Difference between Epic\textsuperscript{NG} Digital Payloads and Traditional Satellites

<table>
<thead>
<tr>
<th>No.</th>
<th>Traditional Transponder Satellite</th>
<th>Epic\textsuperscript{NG} Digital Payload</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Typically 500MHz allocated per coverage</td>
<td>Typically 62.5 – 250MHz allocated per coverage</td>
</tr>
<tr>
<td>2</td>
<td>Large geographical coverage per beam</td>
<td>Small, focused beam</td>
</tr>
<tr>
<td>3</td>
<td>Transponder represents the up to down beam connectivity for a specified frequency range in a beam</td>
<td>A sub-channel (2.6MHz) or group of sub-channels in an uplink beam can be connected to any sub-channels in any downlink beam</td>
</tr>
<tr>
<td>4</td>
<td>Up to Down beam connectivity planned at a satellite level to provide coverage to support commercial plan</td>
<td>Up to Down beam connectivity planned at a service level to provide coverage to support a specific contract opportunity</td>
</tr>
<tr>
<td>5</td>
<td>Downlink amplifier services a single downlink beam</td>
<td>Downlink amplifier may service one or more downlink beams</td>
</tr>
<tr>
<td>6</td>
<td>Downlink amplifier services a single transponder</td>
<td>Downlink amplifier may service one or more downlink beams</td>
</tr>
<tr>
<td>7</td>
<td>Transponders sized by the power available on the downlink beam (Typically 36, 54 or 72MHz)</td>
<td>Up/Down sub-channel connectivity sized by a multiple of sub-channel bandwidth (2.6MHz)</td>
</tr>
<tr>
<td>8</td>
<td>Downlink translation frequency fixed for a transponder</td>
<td>Downlink translation frequencies determined when a sub-channel connectivity occurs. A single sub-channel can Fan-Out to multiple downlink sub-channels with differing translation frequencies</td>
</tr>
<tr>
<td>9</td>
<td>Up to Down beam connectivity switched at C-Band or L-Band</td>
<td>Up to Down beam connectivity converted from analog to digital and switched via digital payload</td>
</tr>
<tr>
<td>10</td>
<td>Automatic Level Control (ALC) and Gain control available at the transponder</td>
<td>Automatic Level Control (ALC) and Gain control available at the sub-channel level inside the digital payload</td>
</tr>
<tr>
<td>11</td>
<td>Ground based power monitoring or telemetry on satellite</td>
<td>Power measurements available at input to and output from digital payload at sub-channel and beam level</td>
</tr>
</tbody>
</table>


**Throughput & Efficiency**

In order to get higher throughput from a specific orbital slot, you have to reuse the frequency band that you’re assigned in that slot more times so that you can get more bits through the spacecraft. Frequency reuse is not new to Intelsat. Many are already familiar with the Intelsat 9 series spacecraft which delivers six-fold the frequency reuse at C-band achieved via hemispheric and regional coverage zones, resulting in 4Gbps throughput (See Figure 4).

![IS904 Coverages](#)

![IS33e Coverages](#)

*Figure 4: IS-904 vs. IS-33e (3rd Qtr 2016)*

“The true benefit of Epic\textsuperscript{NG} capabilities is realized by the end user. Epic\textsuperscript{NG} spacecraft greatly increases the amount of bandwidth while increasing overall efficiency per MHz of spectrum, ultimately reducing customer cost. Epic\textsuperscript{NG} enables greater service flexibility for our customers.”

*Mike DeMarco*

*Senior Vice President, Intelsat Network Operations*
By dividing the available spectrum into geographically distributed segments that are using small, multi-spot uplink and downlink beams, one is able to effectively re-use the spectrum even more than with traditional spacecraft. We emphasize this idea by illustrating the distribution of frequency segments in both 4-color (typical HTS) and 8-color (used on EpicNG) re-use schemes. Intelsat EpicNG satellites achieve a predicted throughput of 25 - 60GBps or 10 times that of a traditional spacecraft (See Figure 5).

![Figure 5: 4-color (typical HTS) and 8-color (used on EpicNG) re-use schemes](image)

“The use of smaller beams also means lower noise temperature and higher EIRP over a comparable geographic region than traditional spacecraft. This end is result is significantly better performance and higher throughput.”

Knut Tjonneland  
Director Satellite Engineering
**Epic\textsuperscript{NG} Spectrum Monitoring**

Applying traditional downlink monitoring methodology on Epic\textsuperscript{NG} spacecraft would be inherently difficult and costly. Could you imagine installing a monitoring facility at all 45 Ku-band downlink beams on IS-29e? How would you monitor the beams which cover the Gulf of Mexico & Atlantic Ocean regions? As a satellite operator, we face the challenge of ensuring we provide the same quality of service which means there should be no gaps in spectrum visibility. Fortunately, the Epic\textsuperscript{NG} spacecraft packs some additional capabilities that not only overcome these challenges, but provides even more detail about a particular service, channel, or monitoring point aboard the spacecraft. Epic\textsuperscript{NG} monitoring will, in fact, entail many different methods of monitoring which will provide varying degrees of detail for any particular type of application. Monitoring for Epic\textsuperscript{NG} is significantly different than traditional satellites for good reason: if you look at the coverages for IS-29e, there are multiple beams serving the Atlantic ocean. It would be very difficult to deploy monitoring stations in every beam in the middle of the Atlantic. The Digital Payload eliminates the need for every-beam monitoring stations, and we have more accurate and frequent data for measurement. The following data points are included in our monitoring solution: Sub-channel power telemetry, the Spectrum Monitoring System (SMS) and the Sync Receiver Monitoring System (SRMS) for uplink spectrum monitoring, and then we have the capability to make fan-out measurements for downlink spectrum monitoring.

<table>
<thead>
<tr>
<th></th>
<th>Traditional</th>
<th>Telemetry</th>
<th>SRMS</th>
<th>MFO</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Commanding Time</strong></td>
<td>None</td>
<td>None</td>
<td>None</td>
<td>10 Min</td>
</tr>
<tr>
<td><strong>Update Time</strong></td>
<td>&gt;= 2 seconds*</td>
<td>10 Seconds</td>
<td>50 seconds</td>
<td>&gt;= 2 seconds*</td>
</tr>
<tr>
<td><strong>Historical Data</strong></td>
<td>“If Monitor Plan is Defined”</td>
<td>Full</td>
<td>Full</td>
<td>None</td>
</tr>
<tr>
<td><strong>Measurement Reference</strong></td>
<td>D/L EIRP</td>
<td>Flux Density &amp; D/L EIRP</td>
<td>Channelizer Input</td>
<td>Relative Measurement</td>
</tr>
<tr>
<td>“Available for Calibration for FD, EIRP”</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td><strong>Measurement Span</strong></td>
<td>Only routed BW</td>
<td>All Rx &amp; Tx Bandwidth</td>
<td>All Rx Bandwidth</td>
<td>Only routed BW</td>
</tr>
<tr>
<td><strong>Resolution BW</strong></td>
<td>On Demand</td>
<td>2.6MHz Fixed</td>
<td>10KHz Fixed</td>
<td>On Demand</td>
</tr>
<tr>
<td><strong>Sweep Time</strong></td>
<td>On Demand</td>
<td>10 Seconds</td>
<td>Fixed &lt; 200mS</td>
<td>On Demand</td>
</tr>
<tr>
<td><strong>Instrument Control</strong></td>
<td>Full</td>
<td>No</td>
<td>No</td>
<td>Full</td>
</tr>
<tr>
<td><strong>Application</strong></td>
<td>Measurement</td>
<td>Alarm Monitoring</td>
<td>Spectrum History Measurement</td>
<td>Measurement</td>
</tr>
<tr>
<td></td>
<td>Alarm Monitoring</td>
<td>Performance Trending</td>
<td>U/L C+N/No Performance Trending</td>
<td>Antenna Alignment Signal Characterization</td>
</tr>
<tr>
<td></td>
<td>Antenna Alignment</td>
<td>Signal Characterization</td>
<td></td>
<td>Signal Characterization</td>
</tr>
</tbody>
</table>

* NetOps may need to move antenna to monitor spectrum
Sub-Channel Power Telemetry

With sub-channel power telemetry the satellite sends to us power measurements for each of the 9,216 up-link and downlink sub-channels. We also receive port aggregate power measurements for each of the 48 uplink and downlink ports. It takes about 9.6 seconds to receive the data for every sub-channel.

We use this data to monitor the operating point of the ADC (Analog to Digital Converter) and the DAC (Digital to Analog Converter) in addition to cross-referencing with the SRMS power measurements while monitoring individual carriers. Our monitoring system retrieves and overlays the sub-channel power telemetry in a graph across the measured spectrum of an individual port. This allows us to easily relate the telemetry data with the measured spectrum data. This graph is comparable to a spectrum analyzer set to a resolution bandwidth of 2.6 MHz with a 500 MHz span and a 9.6 second sweep time.

This is a very powerful tool to troubleshoot link issues. It's important to have all of these data points as it allows us to create a single view that includes the input back-off to the tube, the downlink EIRP, the flux density, and operating points of the ADC and DAC. This combined view can show us how we perform according to the spot we are supposed to be, at all of these points throughout the payload.

“The amount of telemetry that comes down in this in-band carrier is about 50 times more than a traditional spacecraft. This provides unprecedented coverage.”

Knut Tjonneland
Director Satellite Engineering

Spectrum Monitoring System

The Spectrum Monitoring System (SMS) is a digital payload process which provides spectrum monitoring directly from the satellite. This is achieved with the creation of synchronized dynamic fan-out routes. This is a dedicated process which fans out groups of 24 sub-channels at a time which equates to 62.5 MHz of bandwidth. Dwelling on each segment for approximately 200 milliseconds, the process cycles through all receive ports of the digital payload approximately once per minute. The fan-out routes are downlinked via the digital payload over a specified beam to be received and processed by a special synch channel receiver at the ground station, the SRMS. For IS-29e, the SRMS is implemented at the Mountainside Teleport.

As the sampled 62.5 MHz segments are downlinked, the SRMS re-con structs calibrated uplink and downlink spectrum for all beams and ports providing calibrated power measurements for planned carriers. The measurements provided by the SMS/SRMS are calibrated to the input of the digital payload. We have additional calibration data that will allow us to take the measurement of the input power to the digital payload and bring it to four additional reference points. We can include in our measurements flux density, digital payload input and output power, TWTA IBO and downlink EIRP from this single measurement.
Monitoring Fan-Out (MFO)
The digital payload also allows us to utilize traditional RMS based monitoring by creating a Monitor Fan-Out (MFO). What this means is that we can send a copy of any sub-channel or group of sub-channels on the spacecraft through the digital payload to reserved bandwidth in the Gateway beam over Mountainside, or to any other site where we have the down-link monitor capability. This allows us to utilize our test equipment for real-time continuous monitoring, which is helpful in troubleshooting bursting RFI, performing signal characterization, and performing peak and pols. This option allows the ROC to set up real-time monitoring of any capacity on the spacecraft.

Troubleshooting Interference on Multi-Spot Channelized Payloads
The Epic\(^{NG}\) payload has several target operating points for each service. This could be the input of the digital payload, the output of a digital payload and even the HPA backoff. One or many of them can be used for the isolation of RFI events.

- The sub-channel power is a numerical calculation of the RF signal, and it’s very accurate. The accuracy of the sub-channel power measurement is leveraged to provide a precise pilot tone to the SMS/SRMS, thereby fully calibrating this measuring type.
- The SMS is a dynamic fan-out that covers the entire receive spectrum. We will get a constant snapshot of the complete spectrum, and we know that this is going to be used to provide a very proactive and not reactive response.
- Epic\(^{NG}\) provides via In-band or Auxiliary Telemetry more data points now than we have ever had on any other spacecraft. Depending on the circumstances or the problems that we are troubleshooting, we can apply these data points along with our spectrum monitoring to obtain a broader view of the performance of the service.

Epic\(^{NG}\) Service Restoral & Carrier Relocation
Epic\(^{NG}\) allows new restoral and relocation options previously unavailable to Intelsat Operations. For example, we now have gain control over individual connectivities and sub-channels where as in the past we could only rely on transponder pad changes, which is not always possible when multiple customers use the same transponder. Additionally, if a customer is experiencing RFI on a frequency where remote sites are operating then the ROC (RF Operations Center) staff can command the digital payload to be adjusted and the carrier can then move to a different frequency range away from the interference without the uplinker making any changes on their end.
About the Intelsat RF Operations Center (ROC)

The Intelsat ROC is not only the direct point of contact for customers when it comes to RF service activation, operation and troubleshooting, but it also provides vital information and feedback to virtually all other departments within Intelsat. The ROC is divided into 3 groups:

- ROC1: Conducts all activation and initial troubleshooting on Intelsat's traditional spacecraft.
- ROC2: Is the primary escalation point for trouble tickets and handles hot-list customers. ROC2 is also initially handling all EpicNG events for IS-29e. The EpicNG task force is going to be leading the training for the NetOps group. It is going to get us there to support any complex issues. They are also going to be spearheading the on-boarding task, and we are going to be supporting the migration and the activation on these services. They are helping us grow the tools, and this goes back all the way from setting up the requirements, working with the coders, working with the staff on the ops center, making sure they resolve any issues, and they are providing the training needed in order to use them efficiently.
- ROC3: Is the escalation point for any issues that either cannot be corrected by ROC2 or are of an intensely complicated or sensitive nature.
Conclusions

Intelsat EpicNG satellites offer customers and Intelsat operations multiple benefits previously unavailable through traditional satellites. However, with new benefits come new challenges that must be overcome to continue providing world-class service and support to Intelsat customers far into the future. As we become more familiar with EpicNG satellites and the new tools associated with them, we must adapt to the new environment and anticipate changes as what is new today will be the standard tomorrow. If there are ever any questions regarding EpicNG abilities or operations, please contact the ROC.

The true benefit of Intelsat EpicNG capabilities is realized by the end user. EpicNG spacecraft greatly increases the amount of bandwidth while increasing overall efficiency per MHz of spectrum, ultimately reducing customer cost. EpicNG provides users with the best service flexibility in the industry.
About Intelsat

Intelsat operates the world’s first Globalized Network, delivering high-quality, cost-effective video and broadband services anywhere in the world. Intelsat’s Globalized Network combines the world’s largest satellite backbone with terrestrial infrastructure, managed services and an open, interoperable architecture to enable customers to drive revenue and reach through a new generation of network services.

Thousands of organizations serving billions of people worldwide rely on Intelsat to provide ubiquitous broadband connectivity, multi-format video broadcasting, secure satellite communications and seamless mobility services. The end result is an entirely new world, one that allows us to envision the impossible, connect without boundaries and transform the ways in which we live.

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