Advancements in SATCOM for Airborne C2 and ISR Networks

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Hughes Company Overview
Satellite Communications Leadership (Revenue > $1.8B)

- Now under EchoStar ownership, 4th largest satellite operator in the world
- World Leader in Global Managed Services for Ground and Airborne Networks
- End to end systems for data transport (consumer, enterprise, government)
Why BLOS for Airborne C2 & ISR?

- Typical air to ground links limited by range - ~150 miles
- Typical air to ground links are line of sight (LOS)
  - Issue in Mountainous regions such as Afghanistan
- Certain flight patterns and operations can result in longer stand off ranges and lower altitudes
  - LOS blockage becomes more likely
  - Requirement for Mission ISR directly to US COmmand
- BLOS currently in use on higher flying and longer range UAS
- BLOS demand increasing for many other ISR platforms including rotary wing and smaller UAVs.
Satellite capacity continues to increase

**SPACEWAY 3 (2008)**
- First with Onboard Switching/Routing
- Dynamic Coverage Allocation
- Dynamic Capacity Density Allocation
- Smallest Beam Size, Flexible Capacity Density
- 800 Mbps VSAT Receiver
- Bandwidth-On-Demand

**EchoStar XVII JUPITER Technology (2012)**
- 100+ Gbps capacity
- High capacity multi-Gbps gateways
- Beyond DVB-S2/ACM with AIS
- Fastest VSATs

**JUPITER 2 EchoStar XIX (2016)**
- 200+ Gbps
  - More capacity
- 100+ beams
  - More coverage
- Higher VSAT throughput
  - More users
- Advanced networking
  - More services
Ka: Inmarsat I5 Constellation

Look Angle Limits (Degrees): 5 / 10 / 15 / 20 / 25
KU: Intelsat Epic\textsuperscript{NG} Constellation
X-band Coverage – Skynet Constellation – Airbus/UK MOD
OneWeb - New LEOs are on the way

- The OneWeb GEN-1 LEO is using 18 orbit planes with up to 49 satellites per plane, total 882 satellites
- Altitude 1200 km
- User link is Ku-band
- Gateway feederlink is Ka-band
- Total User link bandwidth is 2 GHz
- Capacity per satellite is 7.2 Gb/s (FWD)
- 10 Pilot satellites launch in 2018
- Production launches start in 2019
- Total Launched Capacity of 6.4 Tb/s
- Effective Useable Capacity 1.4 Tb/s (FWD)
Ground and Terminal Segment Advances

Mbps Throughput (UDP)

- PES
- DW2000
- DW7000
- HN7000S
- HT1000
- HT2000
- Next Gen


Higher Performance
Advances in Hub Technology

Hughes Gateway Technology
8 Gbps with a Single Rack (Ka, Ku, C)

Hughes high capacity Gateways with small footprint for ease of deployment and efficient operations

Gateway Advances

2016
8 Gbps Per Rack

2013
2 Gbps Per Rack

2010
.25 Gbps Per Rack

Hughes Technology
• High Capacity Modems
• L-Band Switch Matrix
• GPS Timing

Gateway Scalability
• Supports up to 100,000 Subscribers
• Spans 6 to 8 GHz Spectrum
• Throughput 10+ Gbps

COTS Equipment
• Cloud Data Center Class Computing
• 10GigE fiber optic connectivity
• Deep packet Inspection for QoS

Technology - Combines Hughes Modem Technology with COTS Equipment
Special Consideration for Airborne

- Video Compression – H.264 moving to H.265
- Doppler Compensation – up to Mach 1
- Certifications and Spreading – small apertures...
- Beam and Satellite Switching – signal continuity...
- Latency issues and “double hops”
- Antenna Considerations – keyhole and skew issues
- Rotary Wing and small UAV applications – SWAP is key

Given the 44,000 mile round trip distance and the use of a satellite for relay the problem becomes more complex than typical LOS links
**Approaches to Airborne ISR**

- **TDM/MF-TDMA**
  - Used for enRoute/C2 Comms vs ISR
  - Numerous planes in the air at one time - >20
  - More data into plane than out
  - Bursty, IP traffic
  - Higher cost/capacity ground station
  - ASIC based air modem
  - Typically a global coverage network

- **Managed SCPC w/DAMA**
  - Used for ISR vs enRoute/C2 Comms
  - Few planes in the air at one time - <20
  - More data out of plane than into plane
  - Streaming traffic – video, SIGINT, ELINT
  - Lower cost/capacity ground station – build up as you need
  - FPGA/SDM based air modem – allows for specialized waveforms
  - Can be a global or regional network
Typical TDM/MF-TDMA System

- Wideband DVB-S2X outroute
- High Speed Inroute channels with AIS
- Highly secure and efficient IP data transport
- High performance remote terminals
- Highly scalable system
ASIC/SoC Technology Drives down SWAP and Cost

- Highly integrated Jupiter System on Chip (SoC)
- High user data throughput > 200Mbps
- IPv4 and IPv6 (dual stack)
- Jupiter Wideband Waveform
  - DVB-S2X Wideband TDM Forward Channel
  - High Speed Return Channel
    - 256k to 12Msps
    - OQPSK/8PSK/16APSK Modulation
    - LDPC FEC Coding
    - Adaptive Inroute Selection (AIS)
- Advanced Protocol Acceleration Features
- Network-layer IP, Routing and QoS Features
- Link-layer AES Security (hardware based)
- Web Based GUI for Status and Configuration
New aero system including:

- Ku/Ka dual band antenna
- Modem and baseband chassis (ARINC compatible)
- High performance
  - Delivers up to 400 Mbps to each aircraft
- Aero-enabled on entire Jupiter 2 footprint
- Will operate on other Ku and Ka networks
- DO-160 Certified
Aero Broadband Network Architecture

- Supports both Ka and Ku managed services (Mbps)
- Supports both HTS (spot beams) and conventional satellites
- Supports handover between multiple gateways and multiple satellites
- Centralized NMS
- Works well for large fleets
Typical Commercial Aero Footprint – Ku/Ka

750+ Aircraft in service
9 Teleports, 12 Satellites
Significant expansion underway
Aero May Drive Interoperability
DoD Pilot Study - Satellite and Ground Diversity

Resilient Terminal
- Tracking Antenna RF
- Multi-Modem Adapter
  - Modem 1
  - Modem 2
  - Modem M

Intermittent

Satellite Resource Bandwidth (BW) Pools

User Network

HTS
WGS
LEO/MEO Constellation

Management Interfaces
- Resource Management
- Network Management
- Service Management
- SLA Management
- Situational Awareness

Policy Based Management
- Satellite Selection
- Protection
- Cybersecurity

GWOC
Terrestrial Network Manager
SLA
SA
Mission Management System
SATCOM for ISR Architecture - Optimized for HD Video-

**Airborne System Characteristics**

- Software Defined Modem
- Often SCPC with DAMA NMS
- BLOS Transmission of video, SIGINT, other sensor data
- SWAP Critical
- Higher Speed Returns
- Open Antenna Interface
- Ku, Ka or X commercial or MIL satellites
- Managed Service to teleport (Mbps) or customer ground system (MHz)
- Type 1 crypto or AES
- Video Compression
- Requires advanced waveforms
ISR: Advanced Microsat Waveform

- With low rate codes, may operate under the noise floor
- Variable code rates, modulation, and spreading factors allow trades between throughput, bandwidth vs. power and LPI/LPD
- Rapid Synchronization allows for adverse noise/blockage
- Independent code-block by code-block acquisition lends itself for enhancements in the upper layer
  - Upper Layer Protocol Enhancement (ULPE) protection against pulse jamming and other disruptions
Multiple Access and Interference Immunity

- Interference cancellation enables a large number of terminals to access the same frequency at the same time, randomly, without coordination between transmitter and receiver.

- Hughes SCMA Waveform is about 2x more efficient than CDMA:
  - Less bandwidth for smaller networks
  - More efficient for ‘bursty’ traffic with terminals sending data autonomously without hub coord
  - Much lower FEC and interference cancellation providing greater power and bandwidth efficiency
Advantages of Active Cancellation

Out-Route Cancellation Module (OCM) Function

10 dB at Input of Transponder

Before Cancellation

9 dB

After Cancellation
SCMA and Special Communications

In-Route Over Out-Route Scenario

- Shannon Remotes
- Hub Ant
- OCM
- Return Channel Demod
- TURBO DECODERS
Improved BLOS for Certified Predator

- **Uses software defined modem**
  - Runs advanced waveforms
- **Modem will operate X, Ku, Ka**
  - GD X band antenna – improved tracking
- **WGS and SkyNET certified**
- **Open AMIP Interface to antenna**
- **Improved SWAP**
- **Improved throughput to 45 Mbps**
- **Rapid Blockage Recovery**
- **Interference Mitigation**
- **Bandwidth efficient**
- **Lightning protection on composite platform**
UAS: UK MOD PROTECTOR Program

- £332M FMS Program to replace aging Predator MQ-9 UAVs
- Awarded to GA-ASI using their Certifiable Predator B “Sky Guardian” UAV
- Will operate in X Band over Airbus/UK MoD SkyNET 5 Satellite
- Numerous airframe and comms/sensor system advances
- BLOS advances in SWAP, throughput, efficiency, reliability
Diverse Mission Applications with Helicopter BLOS Satellite Communications
BLOS for Helicopters is Platform Independent

- **KMAX**
  - Demonstrated ability to transmit BLOS video data through a *dual blades* counter rotating systems

- **V-22**
  - Demonstrated ability to transmit BLOS SATCOM data through the blades on a MV-22
  - Demonstrated HD Video
  - Phased array antenna

- **North Star Aviation 407 MRH**
  - Flight demonstration of HD video through the January 2017
  - Demonstrated 360 degree coverage with two antenna’s (diversity)
  - Integrated into EO-IR Camera
  - Incorporating Voice over IP (VOIP)
Hughes BLOS Rotary Wing
SATCOM Overview

- Rotary Wing Beyond Line of Sight (BLOS) SATCOM is a **flight proven capability** with the lowest SWaP
- Hughes advanced waveform is the **key technology** behind the BLOS success and has been tested and validated
  - Transmits real time HD video (FLIR Data) through the rotor blades (off of the aircraft)
  - Provides a command and control link via satellite to platform (MTS-A EO/IR camera) to include voice (both directions)
  - System components are tailored to the customer’s requirements, platform and satellite parameters

- **OPEN Architecture** and use of Commercial Off the Shelf (COTS) hardware and affordable based SATCOM solution

- **Reduction in Size, Weight, and Power (SWAP)** is critical on airborne platforms and meeting customer requirements
Advanced SATCOM for BLOS on Rotary Wing
Understanding Blade Interference Is a Critical Parameter in SATCOM on Helicopters

Counter Rotating Blades

Transmission through the blades

Four Blades
Ex. DataPath CCT200 Ground Terminal

<table>
<thead>
<tr>
<th></th>
<th>X Band</th>
<th>Ku Band</th>
<th>Ka Band</th>
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<tbody>
<tr>
<td></td>
<td>Automatic positioning through GPS, electronic compass and inclinometer</td>
<td>2.0 x 1.4 m Elliptical Antenna with Gregorian offset feed</td>
<td>58.1 dBW P_max_lin</td>
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<tr>
<td></td>
<td>61.9 dBW P1 dB</td>
<td>61.8 dBW P_max_lin</td>
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<tr>
<td></td>
<td>20.7 dB/K @ 7.5 GHz</td>
<td>23.6 dB/K @ 11.8 GHz</td>
<td>26.2 dB/K @ 20.7 GHz</td>
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<tr>
<td>Circular, Reversible</td>
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<td>2</td>
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<tr>
<td>335°</td>
<td>10° - 90°</td>
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<tr>
<td>7.79 - 8.4 (Tx)</td>
<td>13.75 - 14.50 (Tx)</td>
<td>30.0 - 31.0 (Tx)</td>
<td></td>
</tr>
<tr>
<td>7.9 - 8.4 (Rx)</td>
<td>10.70 - 12.75 (Rx)</td>
<td>20.2 - 21.2 (Rx)</td>
<td></td>
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Intelsat, Eutelsat, WGS and FCC compliant
Helo Video using HM 200 Series Modem
BLOS SATCOM for Rotary Wing Platforms Summary

- A Beyond Line-of-Site (BLOS) satellite capability for Rotary Wing Platforms adds an advanced situational awareness capability
  - Transmission of critical ISR EO/IR camera data real-time to GHQ
  - Presents to ground commander real time situational awareness

- A BLOS SATCOM systems can utilize the Global network of Ku or Ka operated by around the world

- A BLOS system could easily be installed as a “mission specific” capability without major modification to the helicopter

- A BLOS systems can have an immediate positive impact on operations
Challenges for smaller Class 3 UAS

- Extremely SWAP Critical
  - Credit card sized modem
  - Small, steerable antenna
- 1-2 Mbps Return Speeds
  - Requires H.265 (MPEG 5) video compression
Conclusions

- Global aero HTS networks and systems rapidly being built-out
  - Hughes, Intelsat, Inmarsat, Airbus, Yahsat, SES, Eutelsat
- MF-TDMA hardware speeds are increasing rapidly
  - Rapid take-up by commercial airlines and enRoute C2
- SWAP reduction involves modem, antenna, waveform and satellite advancements – *systems integration approach*
  - ISR: Robust waveforms, improved efficiency, open systems
  - Class 3 BLOS
  - Rotary Wing BLOS
- Near term LPI/LPD capabilities are available as we work towards longer term USAF SMC PTS solutions
- Interoperability between networks (GEO, LEO, Terrestrial) is solved with advanced network management techniques
  - USAF WGS AoA Pilot Study Programs driving innovations
Thank you!
Booth 034

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