Developments in Advanced SATCOM Networking from Hughes

Presented by: Dan Losada
Sr. Director – Defense Systems
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Agenda

- Technology trends in Satcom
  - New developments in protected satcom waveforms and systems
  - Global Airborne BLOS C4ISR networks
  - Smaller, lighter terminals for quick deployments
- Overview of HM System
- Overview of Jupiter System
Hughes Company Overview

- Now under Echostar ownership, 5th largest satellite operator in the world

- World Leader in Global Managed Services for Ground and Airborne Networks

- End to end systems and solutions for data transport
The Hughes Solution – Complete Defense Satcom Network Interoperability

- **Strategic/Enterprise Network**
- **Intelligence Surveillance and Reconnaissance**
- **Tactical SATCOM**
- **Affordable Protected Satcom**
NEW DEVELOPMENTS IN PROTECTED SATCOM WAVEFORMS AND SYSTEMS
Military Protected SATCOM Challenges

- Future contested warfighting environment
  - Anti-Access/Area Denial (A2/AD) scenarios present a challenge for combat forces command and control (C2)

- Ever-increasing demand for mobile SATCOM users
  - Intelligence, Surveillance and Reconnaissance (ISR) data is integral for warfighting effectiveness

- Ground and Airborne platforms require small antennas supporting high data rate requirements
  - Comm-on-the-move (COTM) vehicles and remotely piloted aircraft (RPAs) require asymmetric SATCOM links

Defense Forces want Affordability and Resiliency
Resilient Communications

Affordable Resiliency
- Multiple Waveforms
- Digital RF Interfaces
- COTS Technologies
- Networking Standards
- Management Systems

Unified Management
- Situational Awareness (RF, Cyber)
- Dynamic Resource Allocation
- Ground Diversity
- Space Segment Diversity
- Mission-Specific QoS Assurance

Space Segment
- WGS
- Commercial SATCOM
- Small Satellites
- Hosted Payloads
- HTS

Packet Network Devices
- IPS
- IDS
- AES-256
- COTS

Resilient Comms

Advanced Protected Waveforms
- R2CP
- Multipath Routing
- FAST

Ground Infrastructure
- IPS
- IDS
- AES-256
- COTS
# US DoD SATCOM Roadmap for Affordable A2/AD Ops

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# USAF Protected Tactical Service Program Background and need

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<tr>
<th>DoD Capability</th>
<th>System</th>
<th>Issues</th>
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<tr>
<td>Protected Strategic SATCOM</td>
<td>AEHF</td>
<td>• Too expensive for defense-wide rollout</td>
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<td></td>
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<td>• Inadequate capacity for tactical communications</td>
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<td>Wideband SATCOM</td>
<td>WGS</td>
<td>• Non-protected Satellites</td>
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<td>• Relatively Low bandwidth compared to HTS</td>
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<td>Commercial Mil-SATCOM</td>
<td>Satellite Bandwidth</td>
<td>• Satellite bandwidth lease expensive based on current contracting models</td>
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<td>• Not protected</td>
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### Summary

**USAF SMC**
- **Affordable Protected Tactical Service**
  - Jam-Resistant Communications
  - Advanced Waveform
  - Tactical Users in non-linear Battlefield
  - Commercial and WGS Satellites
  - Commercial Crypto (Coalition Partners)
  - Future PTS Satellites and Payloads

**US DoD Programs of Record (PoR)**
- Protected SATCOM

**US Army CERDEC**
- RFI

**US Navy**
- Protected Program

**NATO, UK MoD**
- Protected SATCOM

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**Affordable Anti Jam Modems key for future MILSATCOM system and segments**
Team Hughes PTS Solution
Affordability and Compatibility

- Based on DoD Developed PTW Waveform
- Terminal modem hardware
  - High Speed processing hardware and interfaces
  - Integration with legacy Navy, Army and Air Force terminals using common platform design
- Software development
  - State-of-the-art FPGA for programmable logic – future proof
  - SDR platform also runs EBEM and other protected waveforms
- Future Ground System roll-out leveraging NMS and UMS
- Low cost alternative to AEHF
- Designed to operate over WGS or commercial satellites.
GLOBAL AIRBORNE BLOS C4ISR NETWORKS
UAS/Airborne Architecture Concept

Airborne System Elements

• Aero Terminal
  – Modem
  – Antenna including Positioner and RF
  – Radome

• Satellite Air Interface
  – Wideband Channels
  – Standards based
  – Multiple Access capable

• Mobility Gateway(s)
  – Multiple GWs depending on HTS Satellite Beam Mapping/Coverage
  – Baseband Equipment includes satellite modulator/demodulator and protocol processing
  – Common Networking Equipment to support terrestrial communication
  – RFT

• Network Management System (NMS)
  – Centralized NMS controls multiple Mobility GWs
  – Supports Multi-beam and Multi-satellite
Today’s Airborne SATCOM Requirements

- Sufficient uplink bandwidth to transmit Full Motion Video and more
- Global coverage with seamless regional transition
- Provide TRANSEC and COMSEC capability
- End-to-end QoS across global network – Bandwidth Efficiency
- Low jitter and latency for VTC, VoIP and Video
- Minimal impact of equipment to aircraft flight dynamics. Requires low profile and ultra small aperture antennas
- Interoperability with Land and Maritime Systems in and outside the same AOR

Today’s COTS Satcom Solutions meet many of these requirements
Unified SATCOM Management
Global Network Operations – OV-1

Remote management to support global network operations over multiple satellites and SATCOM modem families – resiliency and efficiency
Hughes/GEE Network Coverage (Ku)
SMALLER, LIGHTER TERMINALS FOR QUICK DEPLOYMENTS
User Requirement for Portable Tactical Broadband

❖ Information Exchange Requirement:
  – Tactical Beyond Line of Site (BLoS)
  – Support for small teams or staff section, liaison officer; 2-5 personnel
  – Asymmetric links for broadcast/multicast receive, med rate transmit
    ❖ Up to 1 Mbps symmetric data
    ❖ <384 Kbps upload
  – Services including email, VoIP, FTP, low-rate video
  – Alternate bearer for larger nodes

❖ Patrol Man-pack
  – Truly man-packable – field pack, briefcase
  – Short duration deployment
  – Tactical Security
    ❖ Antenna footprint
    ❖ Low probability of detection

❖ Mobility Applications
  – Flexible and tactical antennas for platform integration
  – Maritime – patrol boats; minor warfare vessels; coast guard
  – Airborne – rotary wing; fast-jets; light surveillance aircraft
  – Land – troop mobility/C2 vehicles; armored vehicles; logistic tracking
HM SYSTEM
EFFICIENT AND AGILE
SATCOM FOR FIXED,
MOBILE AND PORTABLE
APPLICATIONS
HM Product System Applications

- **Applications**
  - **Airborne**
    - Rotary-wing aircraft
    - Fixed-wing aircraft
    - Manned/unmanned (UAV)
  - **Ground/sea**
    - Mobile
      - Vehicle/boat mounted
    - Fixed/transportable
- **Suitable environments**
  - BLOS/ISR Missions
  - Special Forces
  - Rapid response/reaction
  - Customs/Border Patrol
  - Broadcast aviation
  - Search and rescue
  - Disaster response
  - A2/AD Environments
HM System Waveform Overview

- Waveform Based on Hughes newly developed Scrambled Code Multiple Access (SCMA) technology
- Innovative waveform based on very low-rate coding and new multiple access techniques
- Efficient sharing of the same bandwidth by using specific scramblers to separate timeslots
- Enables small antenna users, supporting COTM, RPAs, and other Intel and SOF users
- Independent of frequency band used (Ku-, Ka-, X-band, etc)
SCMA utilizes low rate LDPC codes with moderate length and then scrambled by a sequence

- Spreading sequence may be clocked at symbol rate, if no spreading needed

Information is encoded by a low rate k/n LDPC code, typically, n = 9, k = 1, 2, 3, 4

Each LDPC code block starts with a unique word (UW), allowing independent acquisition should the previous code block not be received successfully

Optional pilot symbols are inserted once per m symbols for synchronization purposes, typically, m > 10, to minimize overhead

For time multiplexing from different terminals, a guard interval is added at the beginning of the UW.
SCMA Salient Features

- SCMA operates under the noise floor, not visible by spectral analysis
- Provides an affordable protected satcom solution
- Variable code rates, modulation, and spreading factors allow trades between throughput, bandwidth vs. power and anti-jamming capabilities
- Synchronization is designed to support reliable operation in the most adverse noise/interference environment
- Independent code block by code block acquisition lends itself for upper layer capabilities
  - Frequency hopping to wider bandwidth
  - Upper Layer Protocol Enhancement (ULPE) protection against pulse jamming and other disruptions
  - Other enhancements for Low Probability of Detection (LPD)
- Inherent Low Probability of Intercept/Detect (LPI/LPD) and Anti-Jam (AJ) characteristics
Hughes Core Software Defined Modem Technology

- The Software Defined Modem (SDM) is the Core Technology for our COTM, Airborne and HUB products
  - Microsat Waveform Properties
  - Integrated Product Solutions
  - Production Hardware
  - Versatile Applications

- The SDM was designed and developed at Hughes
- Allows for customer specified waveforms
- Porting of MSS and FSS waveforms
HM100 Rack-Mounted Hub Modem

- Universal HUB
  - Airborne
  - COTM
  - Maritime
- Utilizes Core SDM Technology
- Transportable
- Light Weight
- High-throughput capabilities
- SCPC
- Protection
HM 300
XEBRA SERVICE
Announcing Airbus XEBRA Service (HM300 Terminal)
Terminal Specification
Form Factor
- W: 247.9mm  L: 236.9mm  H: 84.3mm
- Weight: 5.4kg

Other Details
- Interfaces: 1x RJ45
- Pointing: Manual
- IPv4/IPv6 agnostic

Environmental Data
- Operational Temperature: -20 to +55°C
- Storage Temperature: -30 to +80°C
- Operational Altitude: up to 10000ft
- Waterproofness: IP65
- Relative Humidity: 95%
- Shock: Mil-Std-810G Method 514.6
- Vibration: Mil-Std-810G Method 516.6

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XEBRA Network Setup

**IP to IP Connectivity:**

- Service interface is before Customer Furnished Crypto and Baseband
- Connection to XeBRA Hub in UK SGS via Skynet 5
- Traffic delivered to and from customer JOM
- Crypto and Baseband Solutions to suit customer requirements

**HUB Locations**
- Oakhanger, UK
- Colerne, UK
- Adelaide, Australia
XEBRA Sample Deployment
HM200 Ruggedized COTM Modem

- High-throughput COTM BLOS capabilities
- Operates on HM System Waveform
- Low power-level requirements
- COTS ruggedized chassis, mounting tray
- MIL-SPEC connectors
- Internal power supply
- GUI for management and control
- Separate data and M&C ports
- Airborne Installs at +40000 ft
HM200 Rotary Wing applications
JUPITER HIGH THROUGHPUT TDMA PRODUCT LINE OVERVIEW
KEY Features:

- Based on High Throughput Satellite
- Open Standards based: TIA1008B, ETSI
- High density gateways minimize teleport footprint
- High throughput terminals
- Spot beam architecture support
- High Data Rates: >1 Gbps Outroute, >50 Mbps Inroute
- SCPC Return Option
- COTM Support
- Native IPv6 support
- Highest level security features
- WGS Certification
- Exceeds all JP2008 5B1 Advanced Waveform Performance requirements
### JUPITER System Deployments

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<th>Date</th>
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| In-Service 2012 | EchoStar® 17  
• 100+ Gbps capacity  
• 16 Gateways (5+ Gbps each)  
• 1 millions remote terminals shipped |
| In-Service 2013 | Telefonica Media Networks Latin America  
• Amazonas 3 Ka-Band  
• 2 Gateways |
| Installation Now | Russian Satellite Company  
• AM5 Ka-Band  
• 1 Gateway |
| Over-air     | Pegaso – SCT Broadband  
• Ku-Band |
| Over-air     | TS Global – Malaysia Schools  
• C-Band |
| Preparing for Shipment | Turksat  
• Turksat 4B Ka-Band  
• 1 Gateway |
| 2016         | EchoStar® 19  
• Launch scheduled for 2016  
• 150+ Gbps capacity |
| 2016         | 65W  
• Launch scheduled for 2016  
• Consumer services for Brazil |
## JUPITER Service Platform

### Highlights

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<th>Benefit</th>
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| Wideband DVB-S2 ACM 200+ Msps                                         | • Increased bandwidth Efficiency  
                        • Better suited for higher service plans |
| 32APSK outroute 5% roll off                                           | • Increased Efficiency, Throughput                                      |
| JUPITER SoC                                                            | • High performance (100 Mbps) yet cost effective terminals            |
| Advanced Highly Scalable and Reliable Gateway Architecture            | • Lower Total Cost of Ownership (TCO)  
                        • Lights out operation for low Opex                                  |
| Native IPv6 transport                                                 | • Future proof                                                        |
| Hardware 256 AES encryption/TRANSEC                                   | • Security with performance                                            |
| WGS Certification                                                     | • Use by Coalition partners                                           |
| QPSK, 8-PSK and 16-APSK inroutes                                      | • High efficiency return channels for high gain spot beams            |

**Plus:**  
- **Powerful HNO/VNO**  
- **Strong QoS capabilities**  
- **Advanced IP routing features**  
- **Flexible Service Plans and FAP**  
- **Full Featured NMS**  
- **Rich API**
JUPITER System Efficiencies

Bidirectional

- Advanced Web acceleration (WAS)
- IP header compression
- IP payload compression
- Byte level compression

Outroute

- GSE encapsulation
- 200+ Msps
- DVB-S2/ACM
- 32APSK modulation
- Rate 8/9 coding
- 5 or 10% roll-off

Inroute

- IPoS TDMA
- 256 Ksps – 6 Msps
- LDPC coding
- QPSK/8PSK modulation
- Rate 9/10 coding
- 90% efficiency

The result is significant reduction of “satellite bits” vs “router bits”
JUPITER Traffic Classification

Classes are arranged according to:
- Latency
- Jitter
- Packet loss
- Throughput requirements

Standards based classification approach

Priority 1 (highest)
- Optimized for two-way voice
- Tolerant to errors
- Require low latency
- Low throughput requirements

Priority 2
- Optimized for applications like Web browsing, credit card transactions
- Low tolerance to errors
- Require low latency
- Medium throughput requirements

Priority 3
- Optimized for streaming video
- Tolerant to errors
- Medium latency requirements
- High throughput

Priority 4
- Optimized for bulk file transfers
- Low tolerance to bit errors
- Insensitive to transfer delays
- High throughput requirement
Multifield Classification

MF Classifier Rules

Priority Q1 - Conversational
Priority Q2 - Interactive
Priority Q3 - Streaming
Priority Q4
Priority Q5** - Bulk (Background)

Layer 3 Packet Classification and Queuing

Queue Servicing

Terminal or IPGW
IP Features

- Dual IPv4/IPv6 stack
- Dynamic IPv4 and IPv6 addressing
- Static IPv4 addressing
- Per-flow QoS assignment using configurable traffic classifier (source/destination IP, port, protocol, DSCP)
- Outroute traffic prioritization based on QoS
- Inroute traffic prioritization based on QoS
- Outroute FAP – daily, weekly, or monthly volume quota
  - FAP by QoS, including the ability to not FAP particular classes
  - Separate daytime and off-peak FAP buckets with configurable times
- Outroute fast track (flow control bypass) for conversational class
- Inroute CBR (e.g., for conversational class VoIP or other)
- Inroute CBR virtual framing for VoIP
- VSAT SIP proxy and on-demand streaming
- Terminal DHCP server
- IPv4 NAT via COTS NAT router at gateway
Enterprise Services and Security

- Enterprise routing protocols and services
  - BGP IPv4 and BGP IPv6
  - RIPv2
  - Default route advertisement via BGP
  - BGP communities support
  - Authenticating BGP connections with MD5
  - VLAN tagging
  - VLAN template configuration
  - Policy-based routing at the IPGW and terminal
  - Access Control List (ACL) at the terminal
  - Fenced Internet access
  - End-to-end DSCP

- Security functions and configurations
  - AES256 link layer encryption – inroute and outroute
  - Hitless terminal AES key changes
Advanced Web Acceleration

- HTTP acceleration for both static and dynamic content
  - Embedded object prefetch
  - Caching of objects in VSAT
- Highly efficient
  - Byte Level Caching and V44 combine to provide high compression ratios on HTTP traffic
- Separation of Streaming and non-streaming HTTP traffic

We tested 100 Web pages in total

![Graph showing nearly 50% reduction in response time]

Average response time in seconds
JUPITER System On A Chip (SoC)

Industry First ASIC To Support Wideband

- Megagate high-speed CMOS SoC
- 1-200+ Msps wideband receiver
- 32APSK demodulation at all symbol rates
- OQPSK/8PSK modulation
- Multicore processor with rich suite of interfaces
- Hardware-based AES engine
- Network-layer IP functions

More processing  
Improved modem performance  ➔  Higher speeds  
Higher capacity
JUPITER (HT) Enterprise Modems

HT1400

HT1460

HT MODMAN
Gateway System Architecture

- High-availability/reliability architecture
- State-of-the-art, high-density baseband
- Optimized end-to-end IP solution
- Flexible VNO model configurations
- Integrated lights-out management
- Centralized network management
Network Management Overview

- Hierarchal management scalable to large number of gateways and millions of terminals
- Centralized high availability redundant database
- Distributed local management functions at each gateway
- Comprehensive fault and performance management using ScienceLogic EM7 solution
- Single unified interface to BSS based on RESTful API standard
Virtual Network Overview

- **Satellite Operator (SO)**
  - Owns Satellite
  - Responsible for maintaining, managing, deploying and operating the satellite
  - Sells Satellite capacity to one or more HNOs

- **Host Network Operator (HNO)**
  - Controls own capacity, owns at least one Gateway and NMS/NOC
  - Configures time/frequency plan
  - Divides the DVB/IPOS network into one or more Operator Virtual Network (OVN) and distribute own resources among them

- **Operator Virtual Network**
  - The base of contract between HNO & VNOs

- **Virtual Network Operator (VNO)**
  - Assigned to an OVN with either Mbps or MHz bandwidth
  - Owns and manages its terminals that form the virtual network
  - Restricted client mode access to NMS
JUPITER API Support

- Programmatic interface to external OSS/BSS for all service-related configuration or actions
- Support asynchronous notification to customer BSS after service-related changes (activation, deactivation, swap, move, suspension)
- API architecture
  - RESTful (Representational State Transfer)
    - Requires less dependency between client and server
    - API itself is exposed in a human-understandable manner (using verbs/nouns for URIs)
    - Works over a standardized protocol (uses HTTP and corresponding actions – GET/PUT/POST/DELETE)
    - Supports OAuth authentication and security models
    - Can easily scale across multiple clients
    - Input/Output parameters are in JSON format

Most APIs available to VNOs
- Service Plan Management
- Throughput Monitoring
- Terminal Management
JUPITER Gateway Rack

- JUPITER configuration optimized for conventional satellites
  - C-, X, Ku-, or Ka-band
  - Can also be used as a starter configuration for HTS systems
- Integrated 4IF distribution
  - Multiple transponders/beams/satellites
- Up to five networks within a single rack
  - Starter rack configured with one network
  - 1:N redundancy
- Highly scalable
  - Expansion to support 1 Gbps per rack
  - Expansion is achieved through combination of hardware and licensing

4IF distribution
1:1 LAN switch
NMS firewall
intelligent power

Up to 6
JUPITER-TCS

Up to 6
JUPITER-IPAS

1:1 redundant
JUPITER-NMS
JUPITER-Transmission Control Server

- Advanced multicore server with Modulator Demodulator Chassis
- MDC is a PCI chassis equipped with single OMM and single IDM
  Outroute processing
  - Outroute can scale from 1 to 200+ Msp s
- Inroute processing
  - Up to 24 Msp s (based on licensing)
- IP processing for outroute capacity
  - Additional IP processing achieved through expansion servers
  - Licensing required for IP expansion

OMM – Outroute modulator
IDM – Inroute TDMA demod
Fully Configured JUPITER-SRS

JPTR-SRS with
- 6:4 IF distribution
- Quantity of 6 JPTR-TCS-MDC
- Quantity of 6 JPTR-EXP-SRVR
- 1:1 redundant NMS

An Operational Scenario

Servers run IPGW and WAS functionality
One rack meets all capacity requirements for SGS-E or SGS-W per JP2008 5B1 Program
JUPITER Enhanced Management System
Available

JUPITER is integrated EM7 management system
Hughes Aero Solutions and Services

**Hughes Powers In-Flight Connectivity**

- Hughes Equipment Platform with Comprehensive Mobility Support
  - Doppler
  - Spreading
  - Multiple Beam and Satellite Operation
  - Multiple GWs/NOCs
  - NMSS
  - Modem
  - Jupiter Technology Based Aero Solution (in development)

- Wholesale Services
  - Space Segment
  - Teleport and Uplinking
  - GW/NOC Operations and Maintenance
  - Backhaul, Internet Access and Rack Hosting
  - Engineering services
Customers current fleet of satellite-connected aircraft: 600+

Southwest

Transaero

Norwegian

Nok Air

Mango

Air China

Icelandair
Jupiter Aero System Concept

Aero System Elements

- Aero Terminal
  - Modem
  - Antenna including Positioner and RF
  - Radome

- Satellite Air Interface
  - Wideband Forward Channel
  - MF-TDMA Return Channel

- Mobility Gateway(s)
  - Multiple GWs depending on HTS Satellite Beam Mapping/Coverage
  - Baseband Equipment includes satellite modulator/demodulator and protocol processing
  - Common Networking Equipment to support terrestrial communication
  - RFT

- Network Management System (NMS)
  - Centralized NMS controls multiple Mobility GWs
  - Supports Multi-beam and Multi-satellite
Jupiter Aero System

Next Generation Aero System Based on Jupiter Technology Platform

• Complete transport solution:
  - Ground segment
  - ARINC 600 DO-160 certified aeronautical terminal
  - Ka-band aero antenna and radome
  ... All working in conjunction with customer furnished IFE, service management, and in-cabin distribution systems

• Designed for commercial aviation operation on high-throughput Ka satellites

• Enhanced beam switching supports multiple satellites, each with large numbers of spot beams and overlapping coverage

• System spanning multiple satellites and many gateways managed by a single NMS
Jupiter Aero System Architecture

Key Elements:

- Multiple transport gateways each supporting multiple beams
- Common mobility network access point provides single point of entry to Internet and therefore consistent IP address
- Single NMS manages entire system
- Uses proven Jupiter Technology air interface
Jupiter Aero Terminal

- ARINC 600 compatible MODem MANager (MODMAN) chassis with up to 2 Jupiter modems and Intel Quad-Core coprocessor board
- Doppler correction
- Mobility power control with link adaptation
- Maximum Power Spectral Density management through dynamic spreading
- Rapid beam, gateway, and satellite handovers minimize traffic delays and maintain end-to-end TCP connectivity
- Support for large aircraft with many users
  - 100+ Mbps terminal throughput (as permitted by link budget)
  - Traffic shaping provides fairness amongst cabin users
- Real time mobility terminal tracking in NMS
- Low profile antenna and radome
Aero Terminal Main Interfaces

• Satcom Modem
  – Standard Jupiter IPOS Interface
  – Wideband Forward Channel
  – MF-TDMA Return Channel
  – Optional Dual Modem Configuration

• Communications Interfaces
  – 5x Gigabit Ethernet Ports for in cabin/WiFi
  – 4G Cellular Interface

• Antenna Interface
  – L-Band IF Interfaces for Tx (950-2200) and Rx (950 – 2150MHz)
  – 50MHz Reference Signal Multiplexed on Tx Interface (10MHz option)
  – ARINC 791 AMIP Interface for Antenna Control (10/100 BaseT Ethernet)

• Aircraft Interface
  – ARINC 429 Rx Interface for Navigation Data
  – Discrete I/O (weight on wheels, Tx Mute, etc.)
  – 115VAC 360-400Hz with 200msec Hold-up

• ARINC 600 4-MCU Chassis

• DO-160 Qualification Tested
THANK YOU

QUESTIONS?
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