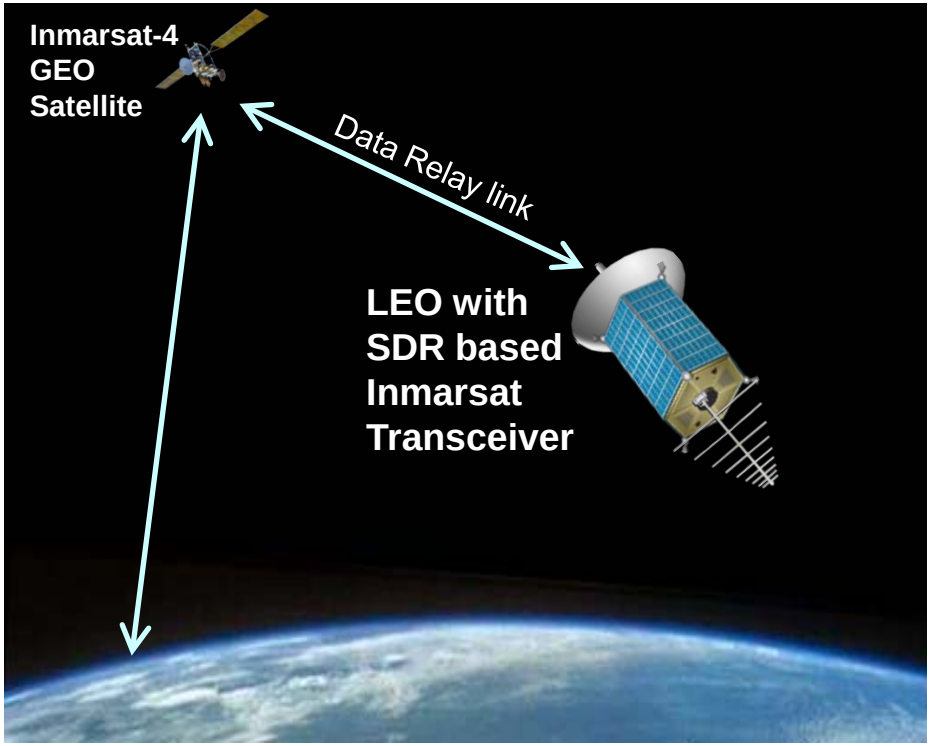
# The Inmarsat Roadmap for SDR in Its Future Mobile Satellite Terminals




***Proceedings of The SDR09 Technical Conference and Product Exposition***

***SATCOM-SIG Workshop***

***December 3rd, 2009***
***Crystal City Virginia, USA***

***Presenting:***
***Eyal Trachtman***





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# About Inmarsat

- Leading Provider of Global Mobile Satellite Communications Services
  - Established in 1979 as an international co-operative and privatised in April 1999
  - Voice and high speed data for maritime, aeronautical and land mobile users
  - Delivers its communication solutions through a worldwide network of over 450 distributors and other service providers in over 80 countries to end users in the maritime, land and aeronautical sectors
- Global Provider of Safety Services
  - Maritime and Aeronautical GMDSS
- Satellite System Procurement & Operations
  - More than 24 year of experience in designing, implementing and operating satellite networks
  - Global coverage with ten in-orbit satellites.
- Space Segment Provider for SBAS Systems
  - Dedicated transponders for EGNOS (WAAS and GAGAN in the past)

# Our markets

## Maritime

- Around 148,000 vessels use Inmarsat
- Unrivalled combination of global reach and service choice
- Only provider of global safety services

## Land

- BGAN service unique in the market
- Global broadband data and voice
- Around 22,000 BGAN terminals in use
- Used in 190+ countries

## Aeronautical

- Around 10,000 aircraft use Inmarsat
- First operator to provide ICAO-compliant safety services
- In-flight connectivity for both cockpit and cabin

# Inmarsat-4 Satellites in orbit

I4-F1 Atlas V
Mar 11 2005

Spacecraft Power : 12 kW
L-band EIRP : 67dBW
Launch Mass : 6 Tons
Solar Array Span : 48 m

I4-F2 Sea Launch: Nov 08 2005

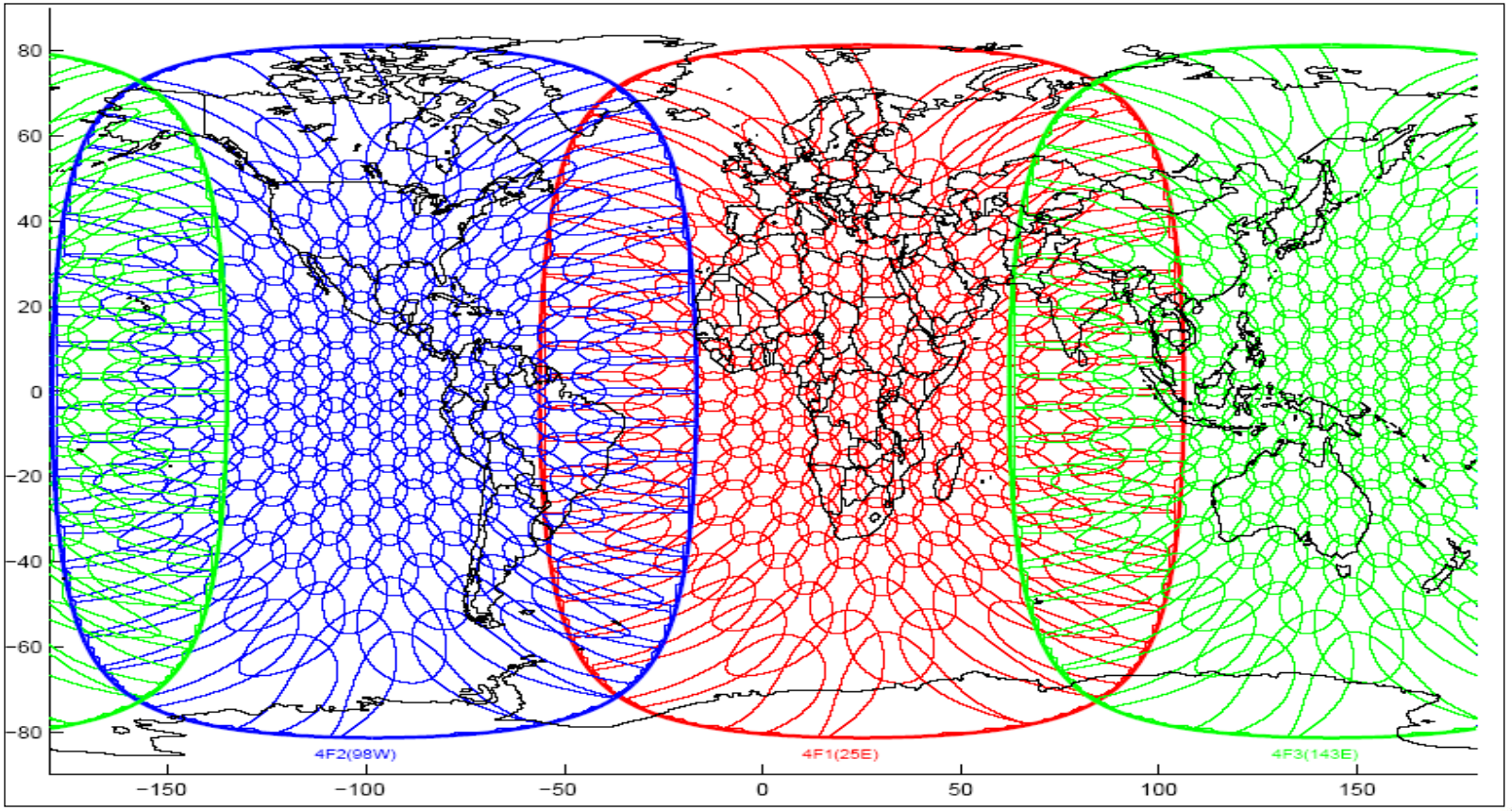
I4-F3 Proton Breeze M
August 18 2008

# I-4/BGAN Worldwide Coverage

F3 Launch
18 Aug 2008
98° W

F2 Launch
08 Nov 2005
25° E

F1 Launch
11 March 2005
143.5° E

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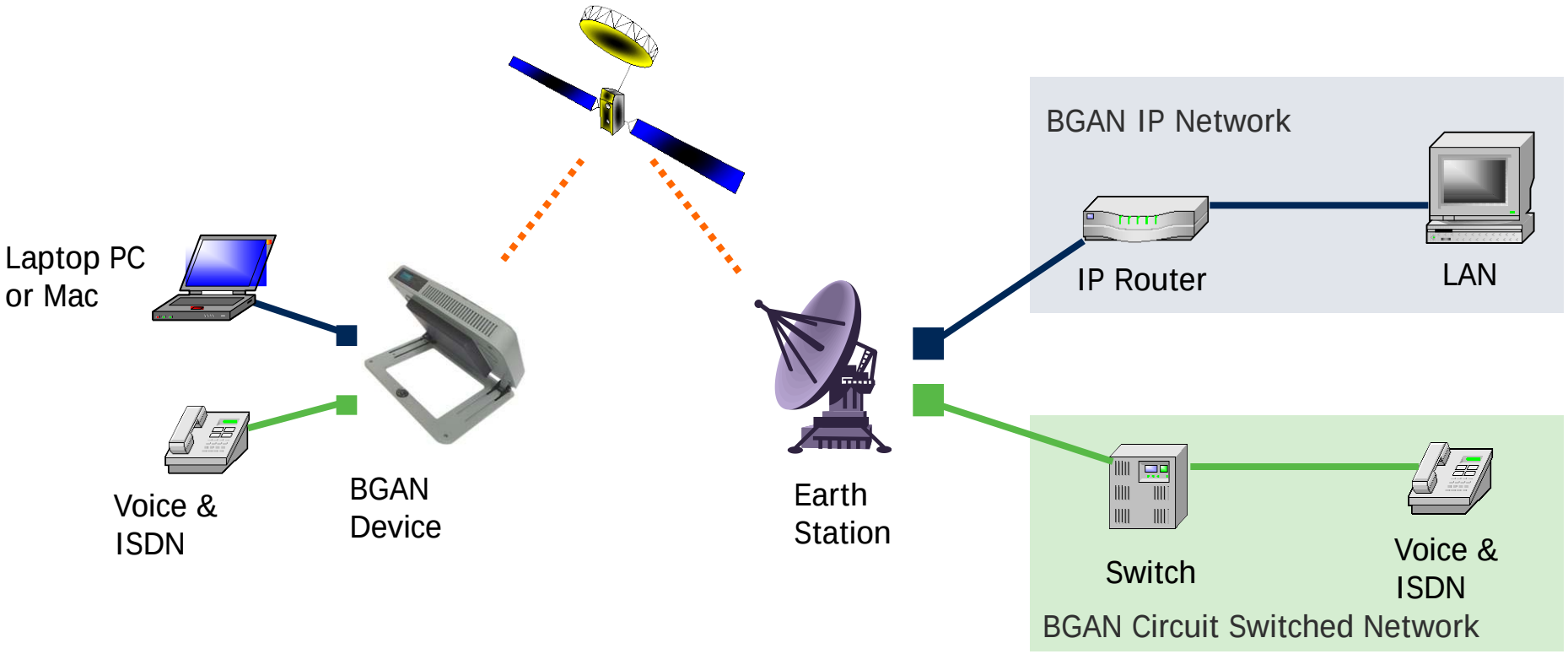
# An introduction to BGAN

## Broadband for a mobile planet™

# BGAN – Broadband Global Area Network

## *One Device, Two Networks*



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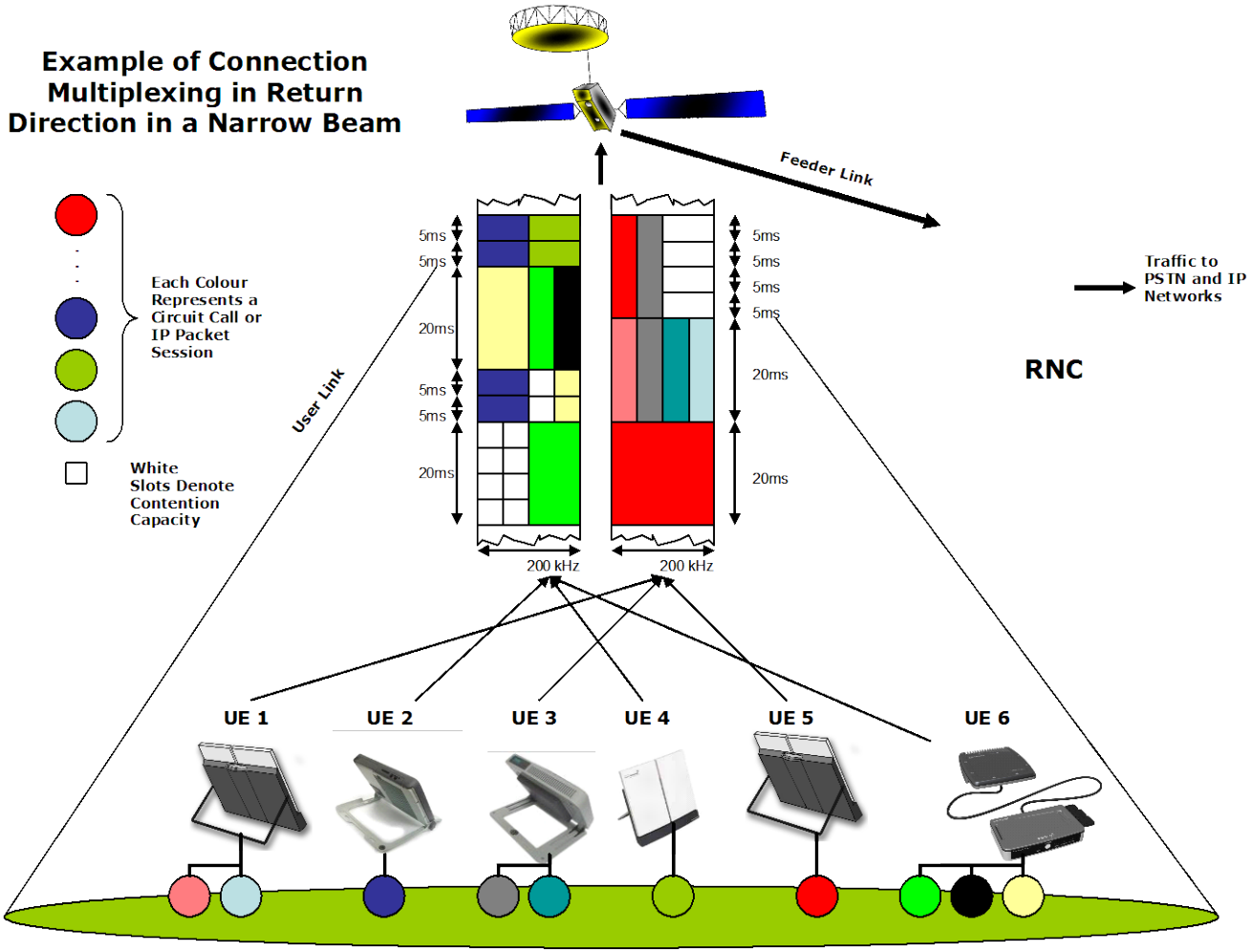
# The BGAN Waveform

## *Example: From-Mobile TDMA*



# BGAN New Mobile Terminal Classes

## BGAN Baseline

### Portable

Class 1


Class 2

Class 3

## BGAN Extension

### Aeronautical

Class 6

Class 7

### Maritime

Class 8

Class 9

Class 12

### Land-vehicular

Class 10

Class 11

# Our SDR Strategy
## Applied to
## Inmarsat Future User Terminals

- Strategic drivers
- Potential applications
- Roadmap into the next gen of Inmarsat satellites

# How Can SDR Benefit Our BGAN SATCOM Terminals

- Flexibility
  - Allows for different standards to be supported through the same hardware platform, by loading the appropriate software.
  - Provides an effective way to future proof the system, as new standards can be supported by developing and loading new software.
  - Simplifies the production of multi-mode multi-frequency terminals.
- Cost Reduction
  - Generic hardware platform → higher aggregate volumes





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# How Can SDR Benefit Our BGAN SATCOM Terminals (cont')

- Potential benefits for Inmarsat
  - A common platform for current and future Inmarsat Waveforms:
    - **Multi-mode** → BGAN classes 1 to 12, GSPS, Future L-band services
    - **Multi-band** → Paves the way for future Inmarsat services to be provided over multi-band satellites (L, S, Ku, and Ka band)
  - Lower "entry barrier" for new terminal developers → a wider manufacturer basis
  - Support high-end programmes that stand to benefit from porting of our SATCOM Waveform onto a "special application" Hardware





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# The Envisioned SATCOM SDR Solution

- A complete SCA compliant waveform, certified by the Joint Programme Executive Office (JPEO) and type approved by Inmarsat.
- A natural path into Joint Tactical Radio System (JTRS), to be offered to:
  - Terminal manufacturers, to allow them to offer BGAN SATCOM capability.
  - Government/ Defence/ Military end users wishing to add BGAN SATCOM capability
- Use SDR to address Gov/ Defence/ Military, commercial, and special application customer needs with future Inmarsat SATCOM Waveforms





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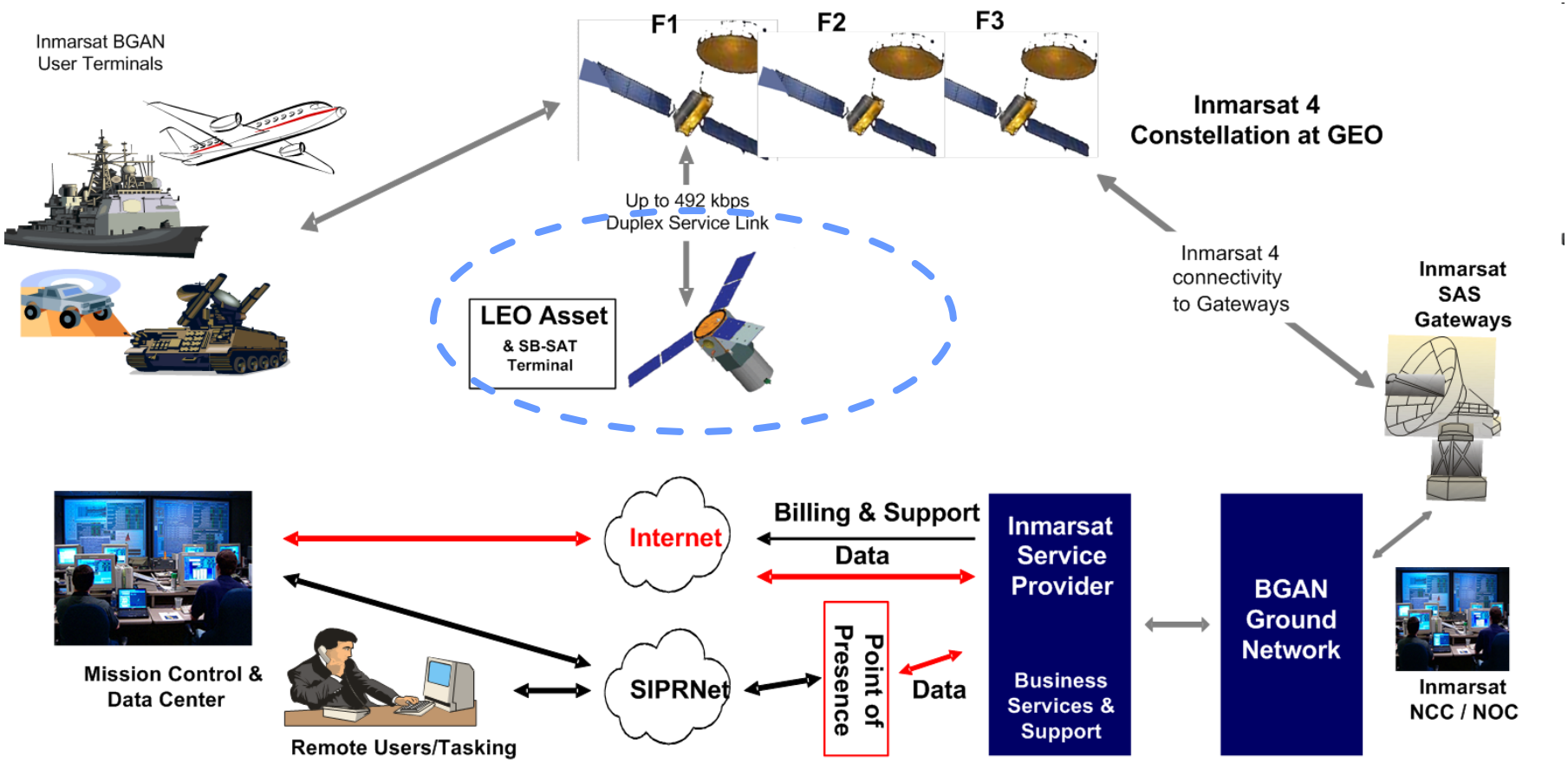
# SB-SAT

## An Example of BGAN SDR Application for Space Platforms

# SB-SAT Network Architecture



# SB-SAT Benefits to the LEO Operator

- **Eliminates need for expensive global ground infrastructure and service**
  - Mission data and T&C are delivered end-to-end as an IP service, via the reliable and mature BGAN system & global network
  - **Competitive pricing compared to ground based alternatives, even before considering the benefits of an on-demand real-time service**
- **Near real time and up to 24/7 relay service for T&C and Mission Data**
  - **Real-time T&C Benefits**: Significant risk reduction to satellite asset, as it allows real-time detection of anomalies, followed with immediate resolution measures
  - **Real-time Mission Data and Tasking Benefits**: Allows relaying mission data **key-holing** (sending real-time low resolution data samples) , and **tasking** information in real-time
- **A new "Disruptive" Technology in data relay servicing LEO Sats**
  - Support smaller and cheaper LEO missions that require frequent data relays, previously not economically viable, or available, due to cost or availability of existing data relay services





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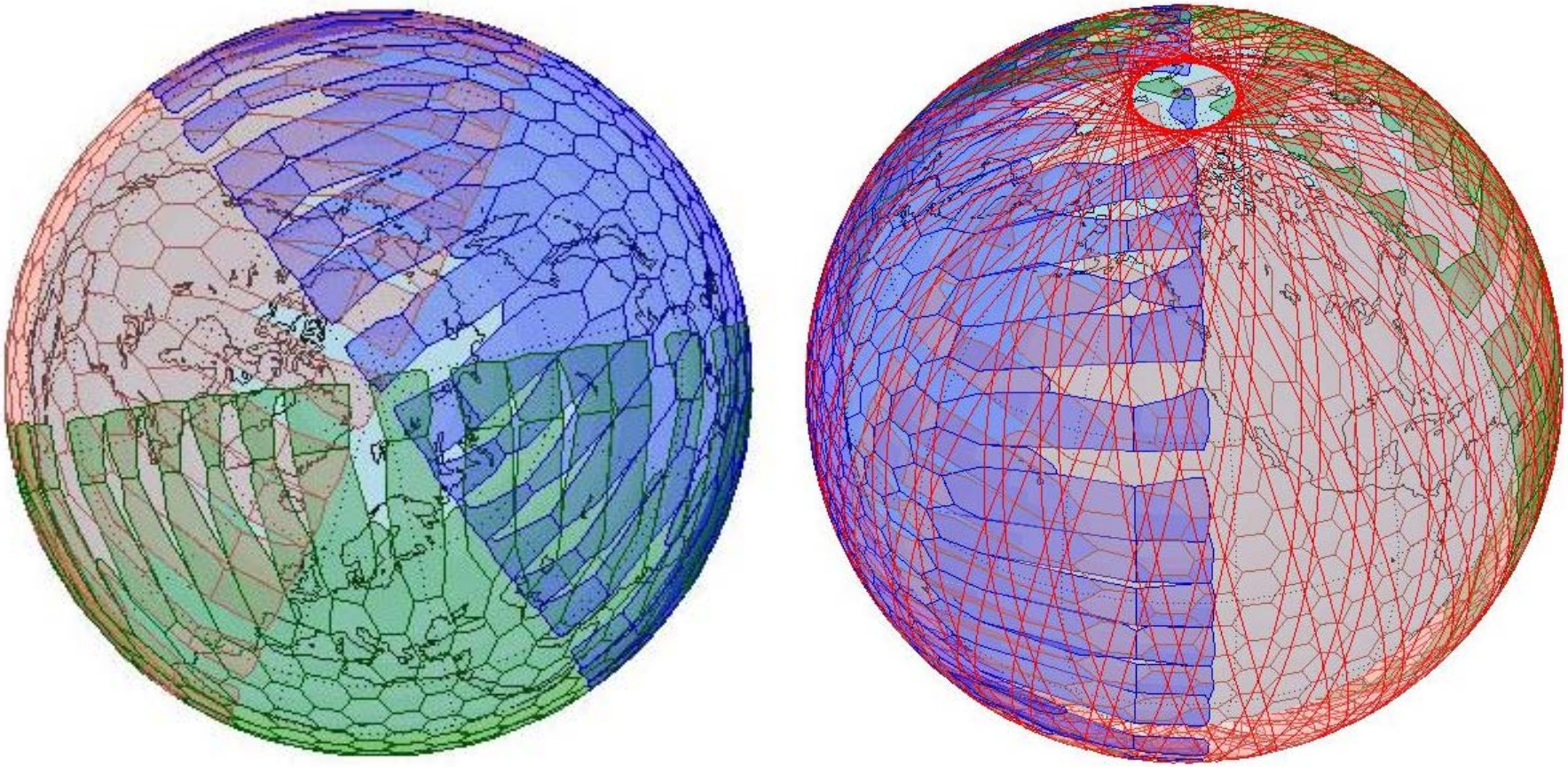
# SB-SAT Service Coverage



400 km coverage, polar view (left); 700 km coverage with 98° inclination orbit (right)

# SB-SAT Service Capabilities

## Quality of Service

- Standard IP
  - Capacity shared based on local (spot) traffic load.
  - Latency varies between 500ms and 1500ms
  - Normal mode of operation - satisfy majority of LEO traffic profiles, which would tolerate reduced capacity for a few minutes duration (passage through a “hot spot”)
- Streaming IP
  - Required fixed bit rate allocated based on local (spot) available capacity.
  - Latency typically less than 500ms
  - Required in exceptional cases where the customer needs real-time video and /or voice over IP
- Assured IP (from 3Q-2011)
  - Premier service, to be required in exceptional cases where the customer needs immediate access to capacity regardless of the local traffic load
- Up to 11 IP sessions may be supported in parallel

## Connection Availability

- IP session continuity during spot beam handovers
- Connection availability corresponds with service coverage for the specific LEO orbit
- Interruption expected in satellite handovers (additional 1.5% of non-availability)





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# SB-SAT Service Capabilities (cont')

| Coverage | Case | RTN | FWD |
|---|---|---|---|
| Nominal | Best case (center of beam) | 475 kb/s | 464 kb/s |
| | Worst case (edge of beam) | 332 kb/s | 300 kb/s |
| Extended | Worst case (edge of extended beam) | 258 kb/s | 200 kb/s |

***Supported throughput (SB-SAT class 6)***

The data rates in the above tables were obtained under the following assumptions:

1) Short data-rate variations during spot beam handovers were not considered
2) Interruptions during satellite handovers were not considered (<40 sec / handover)
3) Reduced data-rate due to congested spots or due to sharing BGAN channel with other users is not considered (assumes highest level of service priority)
4) Throughput and volumes include BGAN signalling overhead of typically 10% and in some cases up to 15%





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# SDR Based BGAN Transceiver for Space

- **Unique challenges**
  - High Doppler due to on-orbit dynamics
  - Fast beam transitions
  - Unique fading requirements
  - Sometimes complex antenna needs
  - GPS on orbit requirement – tight coupling of GPS and BGAN Radio
  - Power, Mass, Volume limitations
  - Harsh thermal & radiation environment
  - Not serviceable on-orbit
  - Very high reliability requirements
  - 5 to 15 Year lifetime
  - Limited hardware availability for space applications
  - Costly relative to commercial/ground/military terminals

# SDR Based BGAN Transceiver for Space

- **Enabling Technologies are now Available**
  - Radiation hard PowerPC 440 CPU from Broad Reach Engineering
  - Radiation tolerant TI DSP
  - Space proven GPS from Broad Reach Engineering
  - Sufficiently large radiation tolerant FPGAs from Actel and XILINX
  - RF Front-End designed for space by COMDEV

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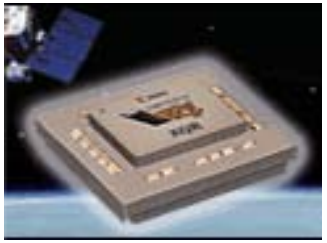


**BRE440 PowerPC SOC**
- BGAN Protocols
- Interfaces
- GPS

**TI 6701 DSP**
- Baseband Processing
- Waveforms

**XILINX Virtex 4QV Series**
- DDC/DUC
- HW Decoders/Encoders

# Extending BGAN in Space with SDR

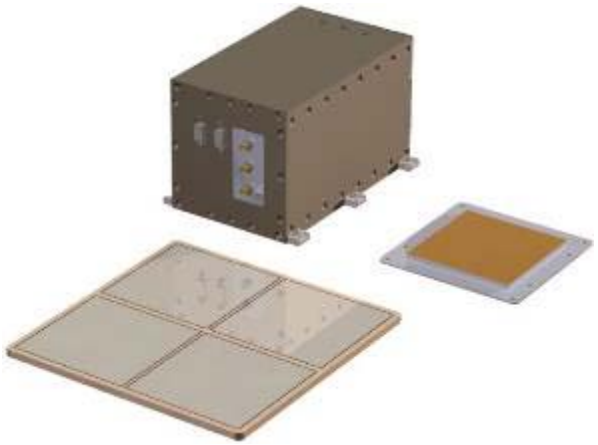
- **Re-programing on Orbit**
  - Allows for system modifications despite “far” deployment
  - Allows forward compatibility (within the realms of RF front-end)

- **On Orbit Extension**
  - With some forethought, can be extended
    - Multi-Mode radio to include TDRSS Capability
    - Multi-Mode radio to include L/S-Band standard downlink at higher rates for mixed system use on-orbit
    - BGAN → Alphasat upgrades
    - I5 System compatibility

- **SDR reduce risk by allowing on-orbit tuning & improvements**

# Typical SB-SAT Systems

## Low Rate Version



*Common Features:*

- Single String Design
- Built-In GPS
- Standard Interfaces
- Single Channel BGAN
- Designed for 5-7 Year life
- Rad-hard technologies

## High Rate Version

- Low to medium data rates (100-200kbps)
- Lower power (2-4W RF)
- Fixed antenna
- Lower mass

- Highest rates (up to 492kbps)
- Higher power (6-8W RF)
- Mechanically / electronically steered antenna
- Built-in steering controllers

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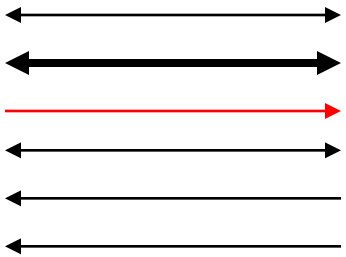
*Standard Interfaces*

*Optional Interfaces*

Command & Telemetry over RS-422 UART
Data Communications RMII (Eth) over LVDS
Switched 28VDC
MCU-100 Interface over RS-422
1PPS via RS-422
GPS PVT @ 1Hz/10Hz via RS-422



Terminal, APM, Antenna





COM DEV

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# Inmarsat SDR Strategy - Summary

- **SDR is a revolutionary technology that is now made possible by developments in processors and other ancillary components.**
- **In the near term it is more appropriate for our high value BGAN User Terminals, but over time could become attractive even for low cost terminals.**
- **We (and our Gov, Defence, military, commercial and special application customers) stand to benefit from commercial SDR HW products that are already available in the market.**
- **The SDR solution offers Inmarsat:**
  - **A fast-track to the development of a BGAN SATCOM SDR solution;**
  - **Support for multiple SATCOM Waveforms in a single terminal;**
  - **A platform for future multi-band satellites.**
  - **Porting the BGAN waveform to multiple Hardware platforms (e.g. space hardened)**