Commercial Communications for the ISS: System Considerations

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Agenda

- **Purpose**
- **Data Requirements**
- **Orbital Connectivity**
- **Conclusions**
- **Recommendations**

NASA's Objective

"…NASA will seek to privatize or commercialize its space communications operations"

- Reduce costs
- Free resources for science & technology

White House National Space Policy
Civil Space Guidelines
Commercial Space Guidelines
September 19, 1996

Purpose

- **Make the International Space Station an asset for mankind through a *robust communication system***
- **Transfer research data and video to deliver discoveries in medical, environmental, and materials research to earth**
- **Create a telepresence or "Virtual Experiment Bay"**
  - **thus creating a user friendly environment**

Robust Communications is an Enabler

What is the Commercial Satellite Environment?

- **Orbits**
  - **LEO, MEO, GEO**
- **Constellation Size**
  - **Few to hundreds**
- **Frequencies**
  - **L band through V band**
  - **Optical**

Next Generation Constellations

Representative Systems

System	Skybridge	GS-2	Teledesic	Spaceway NGSO	Spaceway EXP	Astrolink	CyberStar
Orbit	64 LEO	64 LEO/ 4 GEO	288 LEO	20 MEO	8 GEO	9 GEO	1 GEO
Intersatellite Links	No	RF 60 GHZ	RF 60 GHz	Optical	Optical	Optical	--
Frequency Up/Down	Ku	S/C/Ku	30/20 GHz	30/20 GHz	30/20 GHz	30/20 GHz	30/20 GHz
Bandwdth	1.05 GHz	40/100/200 MHz	500 MHZ	500 MHZ	1.5 GHz	500 MHZ	1.25 GHz
User Data Rate	16 Kbps to 60 Mbps	Up to 144 Kbps	Up to 64 Mbps	2 to 155 Mbps	1.544 to 155 Mbps	Up to 10.4 Mbps	3.088 Mbps
Aggregate Data Rate (per satellite)	2.25 Gbps		10 Gbps	7.2 Gbps	60 Gbps	6 Gbps	3.7 Gbps
Filed By	Skybridge (Alcatel)	Globalstar (Loral/ Qualcomm)	Teledesic	Hughes	Hughes	Lockheed Martin	Loral

1) Above systems represent FCC filings, not necessarily systems in work.
2) Data compiled from FCC Filings and Network Computing Web Site

The Next Generation Commercial Systems Will Provide High Data Rate and Global Coverage

Current Filings Will Expand Commercial Satellite Communication Capability

Representative V-Band Systems

System	M-Star	OrbLink	StarLynx	Global EHF Satellite Network (GESN)	Global Q/V-band Satellite System	CyberPath	Expressway
Orbit	72 LEO	7 MEO	4 GEO/ 20 MEO	4 GEO/ 15 MEO	9 GEO	10 GEO	14 GEO
Intersatellite Links	RF 60 GHz	RF 68 GHz	Optical	Optical	Optical	RF 60 GHz	Optical
Frequency Up/Down	50/40 GHz	50/40 GHz	50/40 GHz	50/40 GHz	50/40 GHz	50/40 GHz	50/40 GHz & Ku bands
Bandwdth	3 GHz	1 GHZ	1.1 GHz	3 GHz	3 GHZ	1 GHz	3 GHz (V) 500 MHz (Ku)
User Data Rate	2.048 to 51.84 Mbps	10 Mbps to 1.244 Gbps	4 Kbps to 8 Mbps	155 Mbps to 3 Gbps	Up to 155 Mbps	16 Kbps to 90 Mbps	1.544 to 155 Mbps
Aggregate Data Rate (per satellite)	7 Gbps	29 Gbps		75 Gbps-NGSO 50 Gbps-GSO	4.6 Gbps	17.9 Gbps	64.8 Gbps
Filed By	Motorola	Orbital Sciences	Hughes	TRW	Lockheed Martin	Loral	Hughes

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2) Data compiled from FCC Filings, Network Computing Web Site, & “V-Band Expansion of the Spectrum Frontier” by Robert Nelson published in Via Satellite 2/1/98

Future High Frequency Broadband Commercial Systems Will Provide Even Higher Data Rate Capability

How Much Comm?

- **ISS Baseline - 50 Mbps**
- **ISS Growth Model - 150 Mbps**

But It Could Easily Be Much Greater

From ISS Familiarization Manual dated July 31, 1998
Published by Mission Operations Directorate Space Flight Training Division
NASA Johnson Space Center

Space Station Major Payload Facilities

- **US Lab (13 exp)**
- **Facility Class Payloads**
  - **Human Research Facility (1 exp, 5 data sources)**
  - **Advanced Human Support Technology (1 exp, 1source)**
  - **Materials Science Research Facility (1 exp)**
  - **Microgravity Science Glovebox (1 exp)**
  - **Fluids and Combustion Facility (2 exp)**
  - **Biotechnology Facility (7 exp)**
  - **Window Observational Research Facility (1 exp)**
  - **X-ray Crystallography Facility (1 exp)**
- **Laboratory Support Equipment (variable)**
- **Attached Payloads (6 sites)**
- **Centrifuge Accommodation Module (~ 7 exp)**
- **Japanese Experiment Module (10 exp)**
- **Columbus Orbital Facility (10 exp)**
- **Russian Research Modules (unknown)**

From ISS Familiarization Manual dated July 31, 1998
Published by Mission Operations Directorate Space Flight Training Division
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Estimated Downlink Data Rates to Accommodate Projected Requirements

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Assume there is a desire to create a telepresence or "Virtual Experiment Bay" on the Earth for the researchers

<u>Then For Example</u>

- **Number of significant payload components: 8**
- **Total number of experiments/sites: 61**
- **Assume one HDTV channel down per significant payload component:**
  - **8 * 20 Mbps = 160 Mbps**
- **Assume one NTSC channel per significant payload component:**
  - **8 * 8 Mbps = 64 Mbps**
- **Assume each experiment wants T1 of data down**
  - **61 * 1.5 Mbps = 91.5 Mbps**
- **Total down: ~ 316 Mbps (Next standard rate OC-12: 622 Mbps)**
- **Comments:**
  - **Compression technology likely to drive application data rates down, reducing total throughput needs**
  - **User demands likely to drive number of applications up, increasing throughput needs**

Even ISS Growth Model (150 Mbps) May Be Too Conservative

Coverage Comparison

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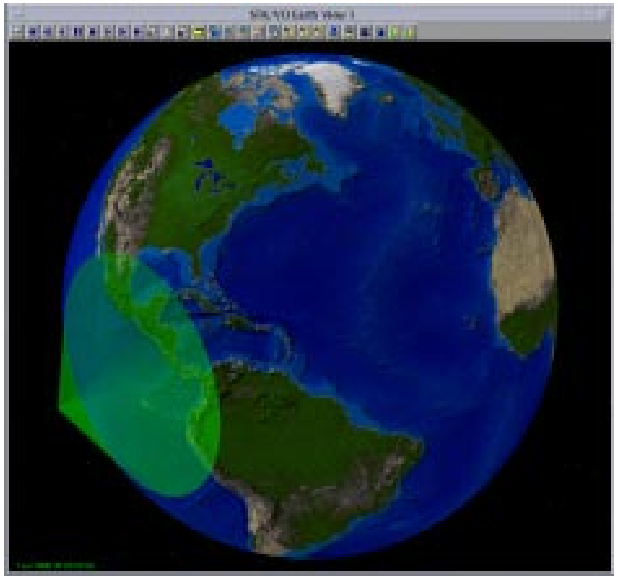
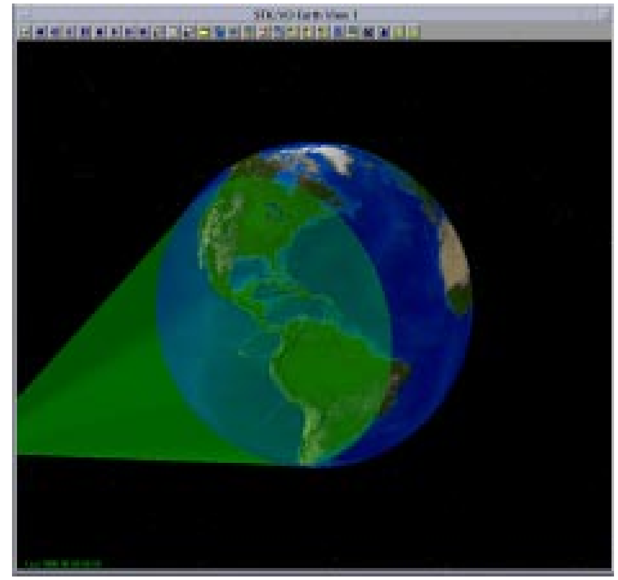
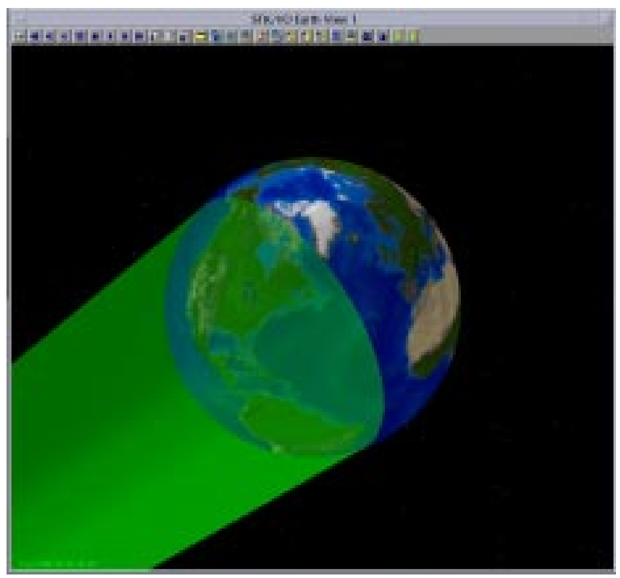
LEO



MEO



GEO



<u>Based on</u>
10° minimum elevation angle

<u>altitude</u>
ISS: 400 km

LEO: ISS + 1000 km

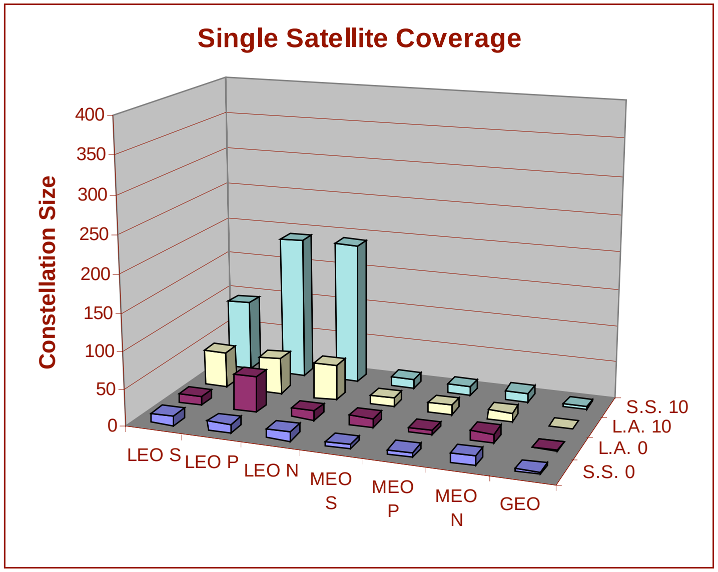
MEO: ISS + 10000 km

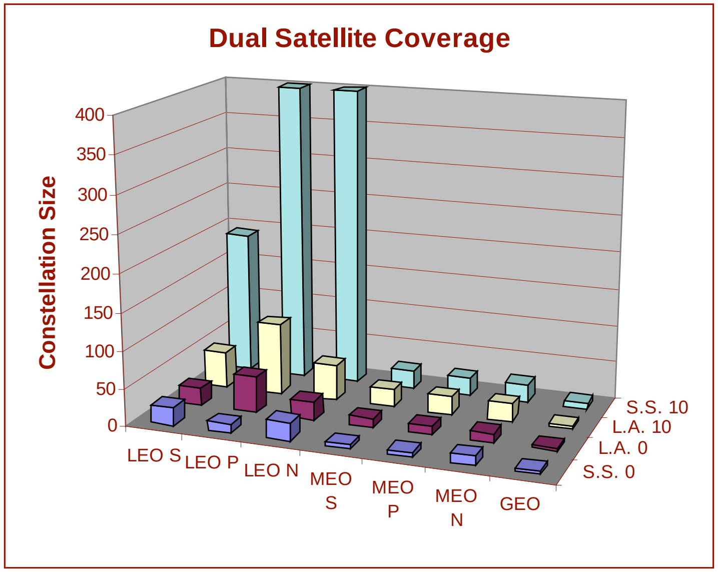
GEO: 35786 km

Satellite Tool Kit (STK)® by Analytical Graphics Inc. (AGI) used to generate data.

Constellation Complexity

- **LEO**
  - **Requires many satellites**
  - **Must crosslink or have many ground stations**
- **GEO**
  - **Fewest satellites**
  - **Requires minimal number of ground stations**





Legend

LEO (MEO) S = inclination same as ISS

LEO (MEO) P = inclination 89°

LEO (MEO) N = inclination normal to ISS

LA (SS) 0 = min. elevation angle = 0°

LA (SS) 10 = min. elevation angle = 10°

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Velocity Issues

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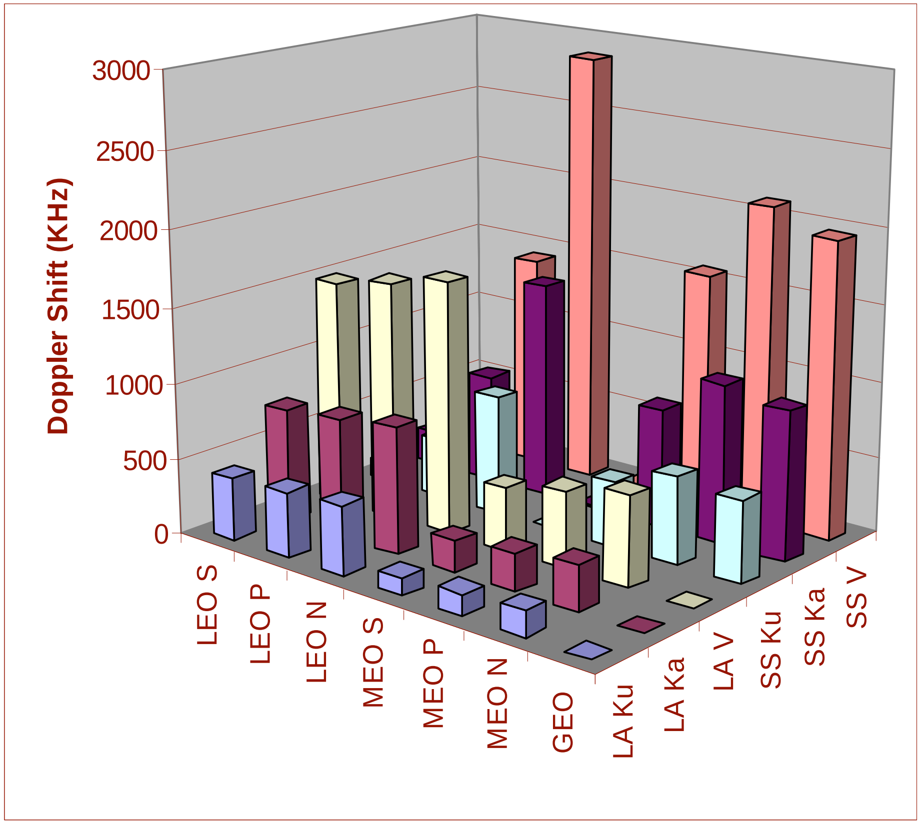
- Doppler shifts wrt ground sites are higher for LEOs
- Doppler shifts wrt ISS are a strong function of inclination for LEOs
- Doppler shifts wrt ISS are higher for GEOs than coplanar LEOs
- Slew rates are higher for LEOs
- All Doppler values small percentage of carrier frequency
- Slew rates can be accommodated



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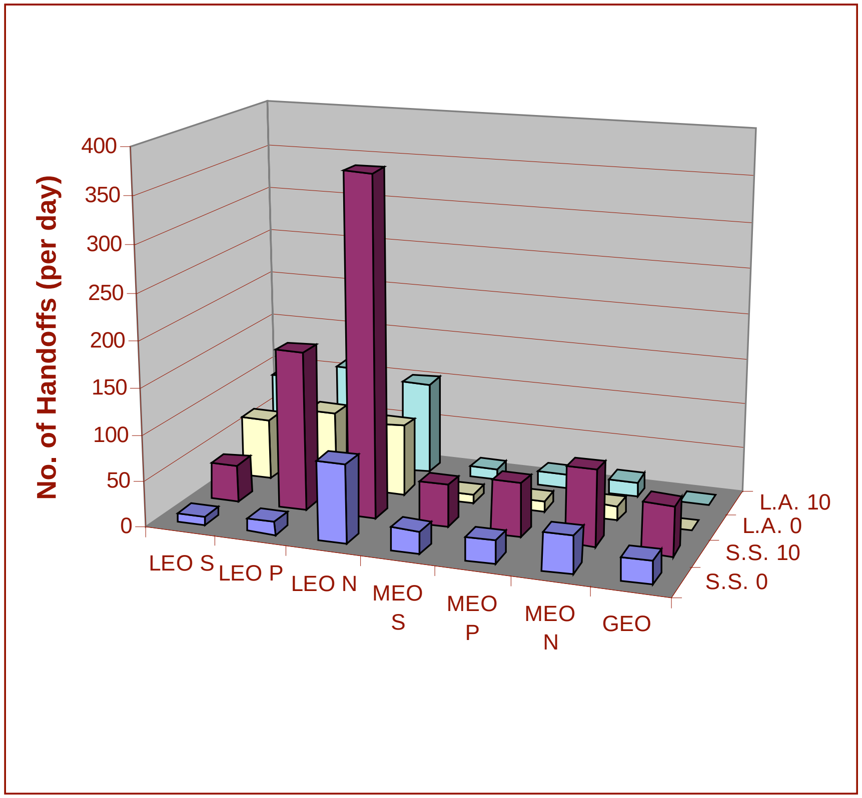
Expected Number of Handoffs

- **Frequent handoffs**
  - **requires make before break**
  - **two transmitters/receivers**
- **Lower number of handoffs**
  - **use of scheduling to avoid outages**
  - **one trasmitter/receiver**
- **LEO inclination is a key parameter**
- **ISS field of regard a consideration**



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Latency Issues

- **Latency is a network management issue rather than an orbital regime issue**
- **Many applications are insensitive to GEO propagation delay contributions**
- **Delays over today's internet can be an order of magnitude greater than GEO propagation delay**
- **Good network system engineering allows partitioning of traffic based on latency sensitivity**

Technology and Systems Will Be Available to Accommodate ISS Needs

- **Representative commercial constellations (filings) provide data rates commensurate with projected needs**

- **Technologies to realize those rates are here or in work**
  - **link budgets consistent with realizable hardware**

- **ISS transition from a dedicated comm system to a commercially based one appears feasible**

NASA Must Be Proactive to Assure ISS Needs Satisfied With Commercial Systems

Conclusions

- **Wide variety of proposed commercial satellite systems appear viable for ISS communication service**
- **Potential solutions exist for Ku, Ka, and V-band**
- **Potential solutions exist for LEO, MEO, and GEO constellations**
- **ISS data rate growth model (150 Mbps) may be too conservative**

Recommendations

- **Be visionary in defining data rate**
- **Be proactive with satellite system & service providers to assure ISS requirements satisfied**
- **Be timely in defining ISS requirements/trade space**
  - **Comm system prime power and weight**
  - **Line of sight blockage**
  - **Comm aperture size, mounting locations, and dynamics**
  - **Level and Quality of Service**
  - **Ground infrastructure**

Robust Communications Will Enable ISS to Succeed in its Mission to Bring Enduring Benefits For Life on Earth and In Space